# A STUDY IN THE DEVELOPMENT OF PRIMITIVE AND MODERN TIDE TABLES

PAUL HUGHES

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ABSTRACT

Tide tables predict the times and elevations of high and low water. This thesis is a history of such tide tables. The object is to show how prediction was undertaken in the past, and how they continue to be made today. The study spans the period from the 8$^{th}$ century AD to the present, but pays particular attention to two 19$^{th}$ century developments. This account presents material drawn from original sources located across the world.

For over a thousand years, lunar position was man's gauge for the tides. This concept, first expressed in primitive form, later became the *Establishment of the Port*. By the fourteenth century, prediction on a daily basis was gathered together geographically. As clocks became more refined, the temporal part then changed its presentation to ordinary solar time.

From factors of secrecy, emergent hydrography and the dissemination of theory: a systematic examination of tides was in the public domain by 1828. This led to the Admiralty Tide Tables of 1833, containing daily predictions of high water times for four ports. With the addition of tidal heights and low water times, within decades the annual serial covered all Britain. The *synthetic* method is an empirical assessment of long records.

With the synthetic method found not to work universally, a *harmonic* method, considering different parts of the tide, derived from French physics during the 1860's. The large computing needs of this theoretical method promoted the development of a mechanical computer. Indian geodesy funded a research programme for proving this rigorous method. Emulating the 1880 *Tide Tables for the Indian Ports*, research programmes sprung up across the world; with America rising to a world-wide portfolio by 1896. WWI induced Britain to undertake a new research programme, leading to its improved global portfolio of 1921.

Among the subsidiary findings of this research are: an eighth century manuscript is now established as the world's oldest tide table, and a supposed early thirteenth century table shown to be of lesser antiquity; a sixteenth century diagram is now completely explained; and a document of importance to Newton's *Principia Mathematica* now located. I present a bibliography of the first tidal computer's scientific work and establish the question of who devised the predicter. The research catalogues two thousand 19$^{th}$ century documents relating to this most crucial period.

TABLE OF CONTENTS

**CHAPTER 1 INTRODUCTION** 1
1.1 TIDAL TERMS 1
1.2 THE THESIS AIM 3
1.3 PREDICTION METHODS 4
1.4 NARRATIVE STRUCTURE 7
1.5 SUMMARY 8
**CHAPTER 2 LITERATURE REVIEW** 11
2.1 INTRODUCTION 11
2.2 MEDIEVAL PREDICTION 11
2.3 MODERN PREDICTION 15
**CHAPTER 3 NETWORKS OF CORRESPONDENCE** 27
3.1 INTRODUCTION 27
3.2 METHODOLOGY 28
3.3 THE CORRESPONDENCE DOCUMENTS 32
3.4 INVESTIGATION METHODS 34
3.4.1 The main tidal scientists 34
3.4.2 The archive of the harmonic network 35
3.4.3 The archive of the synthetic network 38
3.4.4 Institutions and deficiencies 40
3.4.5 Foray into the American archive 43
3.5 INTERNATIONAL CORRESPONDENTS 44
**CHAPTER 4 CAROLINGIAN DATA** 48
4.1 INTRODUCTION 48
4.2 BEDAN MANUSCRIPTS 48
4.3 THE TIDAL FOLIOS 50
4.4 *COMPUTUS* AND BEDE 58
4.5 EXPLICIT FUNCTION 61
4.6 COMMENTARY, WINDS & MAP 63
4.7 THE IMPLICIT MESSAGE 66
4.8 CONCLUSION 72
**CHAPTER 5 THROUGH LORE TO THEORY** 80
5.1 INTRODUCTION 80
5.2 DAILY RETARDATION & THE WALLINGFORD TABLE 80
5.3 THE FLYE OF 1569 85
5.4 PRIMING & LAGGING 90
5.5 THEORY AND PHENOMENA 94
5.6 CONCLUSION 98
**CHAPTER 6 THE 1678 TONKIN REPORT** 101
6.1 INTRODUCTION 101
6.2 FRANCIS DAVENPORT 102
6.3 THE FACTORY JOURNALS 104
6.4 SAILING DIRECTIONS 108
6.5 A ONCE A DAY TIDE 112
6.6 CONCLUSION 115
**CHAPTER 7 THE DESSIOU HYDROGRAPHY** 117
7.1 INTRODUCTION 117
7.2 THE DESSIOU FAMILY 117
7.3 OUTLINE OF DESSIOU'S CAREER 119
7.4 DESSIOU'S PERSONAL HISTORY 121
7.5 THREE JOSEPH DESSIOUS 125
7.5.1 The hydrographic work of Joseph Foss Dessiou 1769-1853 126
7.5.2 The body of contested authorship 129
7.5.3 The hydrographic work of Joseph Dessiou 1743-1822 132

7.5.4 Cartographer Joseph Foss Dessiou 1792-1818 ... 133
7.6 HYDROGRAPHIC CONTENT ... 133
7.7 DESSIOU AT THE HYDROGRAPHIC OFFICE ... 139
7.8 CONCLUSION ... 141
**CHAPTER 8 ADMIRALTY TIDE TABLES 1833** ... 144
8.1 INTRODUCTION ... 144
8.2 EARLY PROGNOSTICATION ... 145
8.3 A PUBLISHED METHOD ... 148
8.4 THE ADMIRALTY INVOLVEMENT ... 150
8.5 COMPARISON OF LONDON TIDES ... 153
8.6 OBSERVATION & PREDICTION ... 155
8.7 DISCUSSION ... 162
8.8 1836 HEIGHT COMPARISON ... 163
8.9 CONCLUSION ... 167
**CHAPTER 9 TABLES FOR THE INDIAN PORTS** ... 169
9.1 INTRODUCTION ... 169
9.2 GATHERING OBSERVATIONS ... 170
9.3 EARLY PREDICTIONS ... 172
9.4 THE SURVEY OF INDIA ... 176
9.5 HARMONIC ANALYSIS ... 177
9.6 HARMONIC PREDICTIONS ... 182
9.7 THE PREDICTER ... 186
9.8 THE PREDICTER'S ORIGINS ... 190
9.9 TABLES FOR THE INDIAN PORTS ... 195
9.10 INTERNATIONAL DEVELOPMENT ... 198
9.11 AFTER EFFECTS ... 200
9.12 CONCLUSION ... 203
**CHAPTER 10 MECHANICAL COMPUTING AIDS** ... 205
10.1 INTRODUCTION ... 205
10.2 THE CONSTANTS OF A PORT ... 206
10.3 THE ANALYSER ... 209
10.5 THE ARITHMOMETER AND ABACUS ... 215
10.6 CONCLUSION ... 219
**CHAPTER 11 WORLD WIDE PREDICTION 1896 – TODAY** ... 221
11.1 INTRODUCTION ... 221
11.2 SYNTHETIC & HARMONIC COMPARISON ... 223
11.3 FRENCH CONTRIBUTION ... 224
11.4 THE FIRST WORLD WIDE TIDE TABLE ... 226
11.5 TABLE PROLIFERATION ... 231
11.6 BATTLE OF HELIGOLAND BIGHT ... 235
11.7 THE 1921 ADMIRALTY TABLE ... 240
11.8 CONCLUSION ... 242
**CHAPTER 12 SUMMARY** ... 245
12.1 INTRODUCTION ... 245
12.2 STATISTICAL ANALYSIS ... 245
12.3 A RETROSPECTIVE OF PREDICTION ... 246
12.4 DEFICIENCIES ... 249
12.5 FUTURE RESEARCH ... 250
12.6 CONCLUSIONS ... 252
**BIBLIOGRAPHY** ... 257
**APPENDIX 1** CATALOGUE OF CORRESPONDENCE ... 272
**APPENDIX 2** LIST OF CORRESPONDENTS ... 322
**APPENDIX 3** TONKIN SAILING DIRECTIONS ... 329
**APPENDIX 4** THE DESSIOU BIBLIOGRAPHY ... 336

TABLE OF FIGURES

Figure 1 The Nineteenth Century Tidal Correspondence ........ 33
Figure 2 The Harmonic Network 1867-1903 ........ 37
Figure 3 The Synthetic Network 1828-1851 ........ 39
Figure 4 The early correspondence of the American Network ........ 44
Figure 5 The rota A ........ 52
Figure 6 A schematic representation of a complete tidal rota, comparable to those found in manuscripts A and B. ........ 54
Figure 7 Tidal table F. ........ 57
Figure 8 Hervagen's 1563 rota ........ 60
Figure 9 The Chinese bore. ........ 72
Figure 10 The rota B. ........ 76
Figure 11 The list C ........ 77
Figure 12 The rota D. ........ 78
Figure 13 The rota E ........ 79
Figure 14 The St. Albans tide table ........ 82
Figure 15 The Bagford Fragment ........ 84
Figure 16 Beating of the two tidal components ........ 91
Figure 17 Brisbane's tabulation for lunar distance ........ 93
Figure 18 The creation of semi-diurnal tides ........ 95
Figure 19 Tyger's point from the SW ........ 109
Figure 20 The Do Son Peninsula ........ 110
Figure 21 St. Petrox, Dartmouth, from the Kingswear shore ........ 118
Figure 22 London Docks ........ 120
Figure 23 The church in which Dessiou worshipped ........ 124
Figure 24 A cartouche with signature Joseph Foss Dessiou ........ 128
Figure 25 A cartouche with signature Joseph Dessiou ........ 131
Figure 26 The Dessiou output of both charts & sailing directions ........ 136
Figure 27 Total United Kingdom and Dessiou production of sailing directions ........ 136
Figure 28 Biannual comparison of UK trade with hydrographic productions ........ 137
Figure 29 Bernoulli's second table ........ 146
Figure 30 John W. Lubbock (1803-1865) ........ 148
Figure 31 Plymouth 1833: Comparison between contemporary and modern calculations ........ 158
Figure 32 Sheerness 1833: Comparison between contemporary and modern HW calculations. ........ 159
Figure 33 Adjusted Portsmouth 1833: Comparison between contemporary and modern HW calculations. ........ 161
Figure 34 Sheerness 1836: Comparison between contemporary and modern HW time calculation. ........ 165
Figure 35 Sheerness 1836: Comparison between contemporary and modern HW height calculation. ........ 166
Figure 36 Bombay's nineteenth century observation sites, the first south, second north ........ 175
Figure 37 Edward Roberts (1845-1933) ........ 179
Figure 38 The 10-component predicter ........ 185
Figure 39 Thomson's 8-component tide predicter ........ 187
Figure 40 Roberts' 20-component predicter ........ 188
Figure 41 The wooden model ........ 191
Figure 42 The 2-component model ........ 192
Figure 43 Bashforth's 1892 rendition of a 4-component diagram of 1845 ........ 194
Figure 44 The U.S. tide-predicting machine No.2. ........ 208
Figure 45 Thomson's 5-component model analyser. ........ 209
Figure 46 Thomson's 11-component analyser ........ 210
Figure 47 Side view of Thomson's analyser ........ 211
Figure 48 The Ferrel predicter ........ 214

Figure 49 The arithmometer ..... 216
Figure 50 The tidal abacus ..... 217
Figure 51 HW predictions at London Bridge by two contemporary methods ..... 224
Figure 52 Inglis's first predicter ..... 233
Figure 53 Rauschelbach's first predicter. ..... 239
Figure 54 Rauschelbach's second predicter. ..... 243

## TABLES

Table 1 Summary of the contributors, of the main papers ..... 19
Table 2 The expansion of the ATT with *home* and *foreign* ports ..... 24
Table 3 The geographic expansion of the Indian tide-tables ..... 25
Table 4 National tide tables held in the Proudman Oceanographic Laboratory ..... 26
Table 5 Correspondence produced by search subject ..... 29
Table 6 Summary of the main tidal scientist's correspondence ..... 31
Table 7 The eighty international reporters ..... 45
Table 8 Extract of stream table ..... 87
Table 9 Summary of the publisher, author and type of publication of the Dessiou work ..... 126
Table 10 Plymouth data analysis. ..... 158
Table 11 Sheerness data analysis. ..... 159
Table 12 Portsmouth data analysis. ..... 161
Table 13 Sheerness 1836 time data analysis. ..... 165
Table 14 Sheerness 1836 height data analysis. ..... 166

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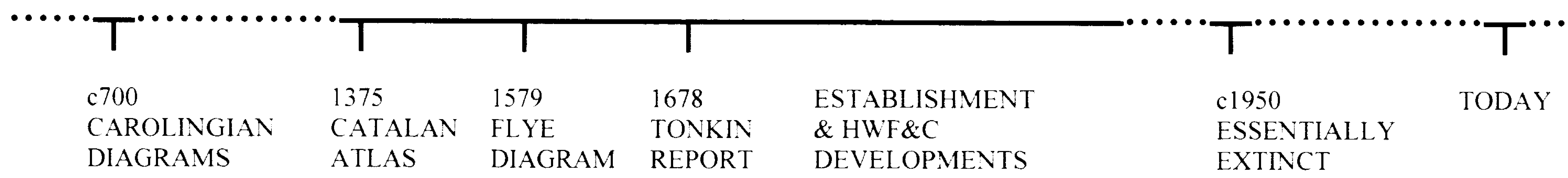
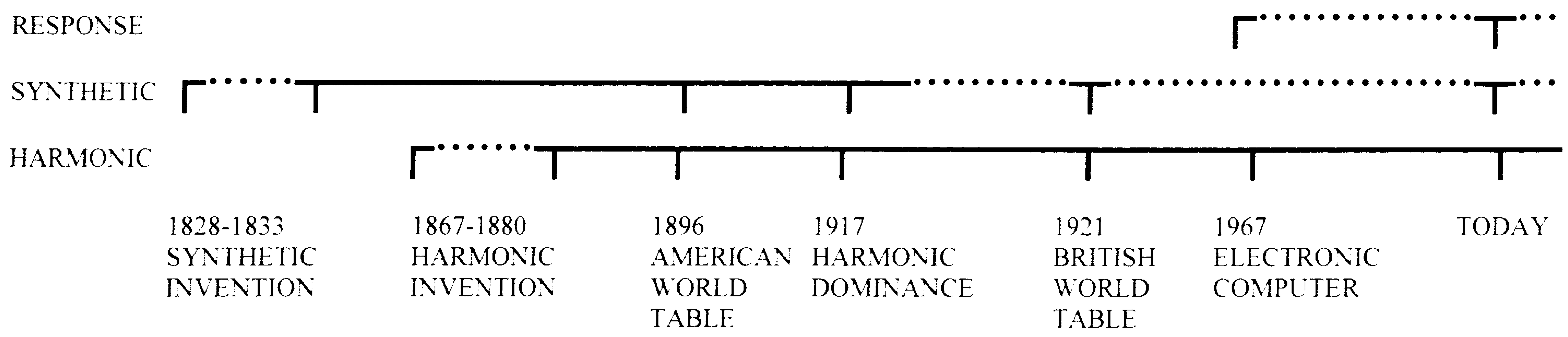
Paul Hughes, Airmyn, March 2005.

TIMELINE OF PRIMITIVE METHOD




# TIDAL PREDICTION

TIMELINE OF MODERN METHODS



# CHAPTER 1 INTRODUCTION

## 1.1 TIDAL TERMS

After *time*, the English noun *tide*, when it refers to the sea, is the second meaning of that originally Teutonic word. While the first meaning traces back to the eighth century, the second appears in 1340.[1] It is the predicted time, at which the tide begins to flood and ebb, which is the subject of this thesis. Ultimately, that concern is with both the time and height of the tide's slackwater. Slack is the water's state which occurs near every high and low water, when the flow changes direction. The initial Carolingian (8th – 9th century) concern was with low water. Then a millennium passed before prognostication returned to that consideration. During the intervening years, tabulation devolved mainly on the high water event. This thesis is not a textual source of tidal theory or prediction methods, sources of which are available at both the student and professional levels.[2]

Tides are caused by gravity – that of the moon and sun – disturbing the ocean. The disturbing force varies with latitude, but is uniform in longitude, and very small compared to normal gravity (g). This small force, acting on the whole ocean mass, causes the tides so clearly visible in many places, though tides are not equally visible everywhere. The Mediterranean is often said to be tideless, yet there are parts of that sea with dramatic tides. The Baltic might be a better example of a near-tideless sea. Close to oceanic islands, such as Hawaii, Mauritius and Madeira, the tides range less than one metre vertically. Conversely, when the tide encroaches onto the continental shelf, its effects can become much magnified. Some Atlantic shores throw up very large tides, ranging to as much as thirteen metres in the Bay of Fundy and twelve in the Bristol Channel.

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[1] *The compact Oxford Dictionary*, second edition, (Oxford, 1989).

[2] The lower level is catered for in the Open University publication and in the Canadian Tidal Manual available on the website of the Proudman Oceanographic Laboratory. The higher level is catered for in the Admiralty Manual of Tides and the two more modern books by David T. Pugh.

Tides form a scientifically complex phenomenon, which, after extensive observation have become largely predictable. I enter into none of the astronomical theory, needed for even a modest understanding of prediction. To appreciate tide table construction history, only a basic understanding of the solar system is required. Tides are complicated because their main ingredients have complex components. The moon dominates most tidal patterns; and 'the moon', Newton said, 'made his head hurt'.[3] Another complex part is how a particular region, perhaps the North Sea, responds to its influencing ocean, the North Atlantic. Technically these are boundary conditions of the deep ocean. In addition to the dependence of the coastal basin's dynamical response to the tidal potential, there are also other factors. These include the basin's shape and bathymetry, its latitude (the strength of the Coriolis acceleration due to the earth's rotation) and bottom friction. Solar tides, typically forty percent the size of lunar tides, tend to have similar spatial characteristics to the lunar. Tides due to the planets are negligible.

The moon moves more slowly across the sky than the sun. This results in the moon appearing in the sky fifty minutes later each day. Similarly, having the same daily retardation, tides appear approximately fifty minutes later each day. Most tidal ports, but not all, have two tides a day (here loosely meaning high water). Because of the daily delay, such places only have one tide on one particular day each fortnight.

The North Atlantic has two tides per day (semi-diurnal), particularly around Britain. However, parts of the world have a tide which shows itself once a day (diurnal). The diurnal tide is manifest around parts of Australia, the Pacific and especially in the Southern Ocean. In the Indian Ocean, particularly around India itself, there is a mixture of tidal types: called mixed, or irregular, because of a large diurnal component. This thesis treats British and

[3] Alan Cook, *The motion of the moon*, (Bristol, 1998) p5.

Indian tides, particularly the formation of tables predicting the tides of their adjoining waters.

## 1.2 THE THESIS AIM

While researching in the 1990s, I identified a body of tidal manuscripts at Cambridge.[4] At first, the manuscripts seemed to provide material suitable as the basis for a biography of Lord Kelvin. However, as Kelvin had an array of interests beyond tides, and with a monograph on him appearing as recently as 1989, I soon rejected this idea. In fact the manuscripts form a more suitable source for Sir George Howard Darwin's biography, a man much more focussed on tides than Kelvin. However, as a Darwin biography would require a sound knowledge of astronomy I also dropped that idea.

By then, it had become apparent that the corpus of published tidal literature was incomplete. Available texts were either highly mathematical or, if in prose, stopped short with use of incomplete, outdated theory. The manuscript investigation continued with an idea of forming a history of tidal theory. The preliminary investigation allowed progress in three ways. The first way was to begin transcribing manuscripts – the basic data for this thesis. The second way was to begin a systematic literature search. The third and concurrent way, was to approach this institution with a thesis application, with the finally crystallised aim of researching tide table construction history.

This thesis presents the results of that research by describing *how* the tide tables were made. I concentrate on shewing that they were primarily devised in Britain and India. An aim is to explain that *why* the tide tables were funded and produced was as an indirect consequence of other activities, such as trading and banking. *When* the principal prediction methods were established, is fixed to periods between 1828 and 1880. I elaborate on the identities of the

[4] Paul Hughes, *Staiths (the early river jetties of York, Hull and Howden)*, Yorkshire Archaeological Journal, Vol 71, 1999, 155-184.

group of people *who* actually made the tide tables. Key workers included not only famous scientists but also a group of largely unknown figures, whose contribution is here highlighted for the first time.[5] All together, these people number about two dozen; although they are referred to in chapter three, on the investigation method, their proper introduction appears in the narrative, from chapter four onwards.

The thesis addresses the practical issue of how the tide tables were devised. This is not an issue of science alone; it is also one of history. The thesis constitutes a history of science on a particular subject – the tide tables. I will show that the research has been successful on several fronts. These include: the treatment of the subject, at this length and depth for the first time; in addition, much of the material upon which the study is built had previously been inaccessible. The research succeeds in providing a number of new insights; and also, in locating a particular document, long sought in vain by others interested in tides.

## 1.3 PREDICTION METHODS

The narrative covers three periods. On the preceding page x, a time-line sketches out the periods, and the methods' points of introduction. The rule-of-thumb method of prediction prevailed throughout the medieval era. Then the modern period produced consecutively, two systematic investigations into predicting tides. The synthetic method, invented in the early nineteenth century, flourished until after the 1914-18 war. Similarly, the harmonic method, created in the late nineteenth century, did not generally supplant the synthetic method until after the 1939-45 war.

The medieval method is set out in the chapter section 8.1. Fittingly, early tidal lore was set out as 'to know what moon makes high water'. The horizontal direction of the moon acts as a useful clock. This is particularly so during the Full Moon, when it illuminates at least one

[5] Paul Hughes, *Joseph Foss Dessiou 1769-1853*, Dictionary of Nineteenth-Century British Scientists, (Bristol, 2004).

of that day's tides. The method was prior knowledge of a constant for a particular place. The constant is the Full Moon's azimuth at High Water. From simple observation, the knowledge, sometimes called the rule of thumb method, is lore rather than science.

Leaning on its earlier French terminology, the rule-of-thumb became the 'establishment of the port' by 1831. In that guise it had become the time interval, between lunar meridian passage at new or full moon, and the next high water.

The investigators of the early nineteenth century did not give any special title to their method. However it was an advanced method, giving daily predictions and adaptable for many places. Then after the harmonic method development, the earlier method was at first referred to as the old method, or Lubbock's method. The harmonic method was the first to receive a generic title, and it did so from the start. During the Great War there was a desperate resort to hybrid methods. After the war, those investigators then began to refer to Lubbock's method as the non-harmonic method. The *Admiralty Manual* refers to it in that way. Lubbock's non-harmonic method attracted the generic term, synthetic, only in the late twentieth century.[6] (See the time-line on page x.) Darwin had also used that description, however unwitting it may have been.[7]

The synthetic method of tidal prediction is one of parameterisation, relating the time of high water to the time of lunar transit. Then a number of small variations are added; these are to allow for the effects of declination, parallax, the time of year and the stage in the fortnightly tidal cycle. It is a method sufficiently robust to remain viable, and its simplicity over the harmonic method enables its continued use in a limited way. This was valid on the coasts of

[6] David E. Cartwright, *Tides a scientific history*, (Cambridge, 1999), p 91.
[7] George H. Darwin, *Third report of the committee ... for the harmonic analysis of tidal observations*, British Association for the Advancement of Science Report 1885, 35-60.

Britain[8] in 2002; and in Germany[9], Holland and France in 1996. (From colleagues at the Proudman Oceanographic Laboratory, I understand more recently that most European agencies now use varieties of harmonic analysis.) However the synthetic method is only effective with strongly diurnal or semi-diurnal tides; it does not function as well with mixed tides. In addition the analysis and prediction is limited to the extrema, to high and low waters. At least a year of observations is needed to predict times, and ideally nineteen years are needed with which to predict heights to an acceptable accuracy (see chapter 8).

There is a most significant difference between the synthetic and harmonic methods. The harmonic uses elevation information throughout the whole tidal cycle. In contrast, the synthetic employs only the extrema (the 'turning points') of high and low water. Consequently, the harmonic method can deduce much more about the structure of the tide as a function of time. The harmonic method views the wave of a real tide, as the sum of several harmonic component tides. Each constituent tide has its own frequency, amplitude and phase. Useful predictions can be made from only a month of observations; from a year's, most of the constituents can be drawn. Harmonic prediction gives the height for any moment in the future, or retrospectively for the past. Conversely it also offers the time of a future or past height. In the interests of economy, tide tables in book form, derived from the harmonic method, generally restrict themselves to extrema. However, the software that produces such tables is equally capable of providing predictions of tidal elevations (heights) for any point in the cycle.

Monk and Cartwright invented another method, the response method of analysis and prediction, in the 1960s. Oceanographic researchers use it frequently, particularly with regard to the study of short records from tide gauges and current meters. As yet, it has only a marginal role with regard to production of the familiar tide tables. In the response method,

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[8] *Admiralty Tide Tables Volume 1 2002 United Kingdom and Ireland (including European Channel Ports*, United Kingdom Hydrographic Office, 2001 page xxxviii.

the ocean can be regarded as a 'black box', the input to which is the tidal potential and meteorological forcing. The output is then expressed in terms of the input as a frequency-dependent 'admittance function', from which a description of the tide can be inferred and predictions produced.[10] The response description is more complete than a finite harmonic analysis. As the response method has a relatively very small role in the history of tide table production, I have not dwelt on it at length in this thesis.

## 1.4 NARRATIVE STRUCTURE

Chapter 4 and 5.2 address the rule-of-thumb method of tidal prediction. With parts 7.8 and 8.1 they combine to show the three different phases, that this most primitive method underwent. Several tidal diagrams have come down from the Carolingian period – from the age of Charlemagne scholars. This section contains what appears to be the earliest known tide table. The work of the Carolingian scholars then developed into those exclusively for tidal prognostication. The first summit of this approach is then represented in the beautiful sixteenth century Flye (chapter 5.2), where they used the horizontal direction of the moon as the tidal gnomon. The second pinnacle related the tide more conveniently to the time of the clock. The growing body of hydrographic material, flowering in the early modern period (chapter 7, particularly 7.8), partly documents this second ascent. There is then some reference to the transition to the first of the modern methods in that on the Admiralty tables (chapter 8).

The sections on Tonkin tides and Hydrographer Dessiou, (chapters 6 & 7), might appear to be somewhat diversionary topics, but to the discerning it will be seen that the modern methods actually stand upon the material contained within these chapters. The Tonkin text contained crucial information integral to emergent tidal theory, and upon which both of the modern methods stand. The Dessiou chapter is essentially a description of the work of the

[9] Pugh, *Tides surges and mean sea-level*, 98.

first truly complete hydrographer. Without his breadth of knowledge it is difficult to imagine how the synthetic method could have been developed, let alone done so well. Yet he is a figure that has remained largely unknown.

Chapters 8 & 9, on the Admiralty and Indian tables respectively, contain the creation and ascent stories of the synthetic and harmonic methods. The transition between the two methods is related a little in the Indian chapter, with more of the difficulty encountered related later, in that on global tide tables (chapter 11).

I provide only an outline of the tidal science, as the main aim of this thesis is to relate development of the tide tables. The different prediction methods are outlined above. Parts 5.3 & 5.4 provide statements on tidal theory within the ascent of the early lore: because expressions of a first glimmering of the processes involved came in that period. The elementary, mechanical computing part of harmonic prediction begins with the Indian tables (particularly parts 9.7 & 9.8). Chapter 10 describes the computing at greater depth, with a very simple explanation to harmonic analysis and prediction in parts 9.5, 9.6 & particularly 10.2.

The fight for the synthetic method contains statistical studies of 1833 and 1836 (chapter 8). Part 11.1 gives a further comparison, of the harmonic and synthetic methods for 1883.

## 1.5 SUMMARY

There is evidence in China, Arabia and Europe of tidal lore of great antiquity. Modern tide tables owe a little to that past, with the lore usefully retained today, among workers out on the tideway. However, the modern tide tables rest much more upon that knowledge gained from Newton onwards. The nineteenth century produced two prediction methods. The

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[10] W. H. Munk and David E. Cartwright, *Tidal spectroscopy and prediction*, Philosophical Transactions of the Royal Society of London, **A259**, (1966), 533-81.

culmination of this thesis is the description of the world-wide tide table series' construction from those methods.

As will be shown, tidal information was widely distributed in the early middle ages. Its gathering into one geographical compilation indicates its importance to seamen. By the seventeenth century tidal data, actively sought to promote development of a universal understanding of tidal phenomena, led to an increase in regional knowledge. The systematic investigations undertaken in the early nineteenth century enabled the Admiralty to begin presenting tidal information in the familiar format. Tide tables are now highly standardised and essential shipboard items.

The thesis places the aim in a context of the whole epoch of tidal study. I shed light on the tidal lore of three medieval texts: one for the first time and two in augmentation. Aspects of the Flye diagram, which had evaded earlier commentators, are set down. Several mathematical expositions reinforce the Victorian narrative.

I include both the successful and unsuccessful philosophy. As explained in the literature review, other authors already delineate some of the success. This investigation adds much to that historical progress. The difficulties, or contrary philosophy, could not have been told without this investigation (particularly chapters 5, 6, 8, 9, 10 & 11). These contributions came from the transcription of over two thousand documents, mostly correspondence. Ninety-nine percent of this source remains unpublished. The catalogue of the correspondence forms Appendix 1. The catalogue and list of correspondents (Appendix 2) form an integral result of this investigation, and together they constitute important finding aids for further research.

A strong element of the thirteen hundred years of tidal consideration is that of the personages involved. The Venerable Bede, Francis Davenport, Joseph Foss Dessiou and

Edward Roberts are the names of people already known of in the tidal pantheon. Here, I emphasise their contribution. This review of their worth is particularly set out for Dessiou (in chapters 7 & 8) and Roberts (in parts 9.4-9.9).

It was the British who produced the methods from two independent research programmes, with the higher data gathered and analysed in India. Other programmes emerged among the continental Europeans, but Australians and Americans made more significant early achievements. Australian scientists were among the first to envisage global tidal tabulations. Yet it was the Americans, explicitly designing their tidal work upon the global principles of Alexander von Humboldt (1769-1859), who compiled the first world wide tide table.

The contributory work of individuals and the width of the researchers' geographic spread have so far not been properly acknowledged. This thesis addresses that knowledge gap.

# CHAPTER 2 LITERATURE REVIEW

## 2.1 INTRODUCTION

The review is in two parts. The thesis considers both primitive and modern prediction. As their methods are not contiguous, I treat the periods separately.

The early tidal texts that have survived are rare and partly repetitious, and consequently have attracted little dedicated study. In the modern period there is a superficial repetitive pattern to their layout, but a difference in intrinsic detail caused their systematic investigation. The later, profuse material has therefore attracted somewhat more study than the earlier period. While I confine this study to that literature available in the English language, a bibliography compiled for the International Hydrographic Bureau indicates sparseness in other languages.

## 2.2 MEDIEVAL PREDICTION

After the exuberance of the success of early modern tide tables the old rule of thumb method for predicting tides was largely set aside. The old rule survives in the form of diagrams, largely unaccompanied by text. However, knowledge of the existence of early tidal diagrams has developed in recent decades. In 1971 Margaret Deacon placed some of the diagrams in a context with the more familiar tide tables of today.[11] Within the context of ocean science, she is one of the first to point to the diagrams, offering a Latin text of a contemporary commentary.

Several of those who have worked directly on Bedan tidal scholarship were American; they include Jones, Lipp, Eckenrode, Smyth and Wallis. The main body of early diagrams are those identified by Charles W. Jones in 1943.[12] Jones, of course, was concerned with a

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[11] Margaret Deacon, *Scientists and the Sea 1650-1900*, (London, 1971, rpt. 1997).
[12] Charles W. Jones, *Bedae Opera de Temporibus*, (Cambridge MA, 1943).

scholarly edition of the Venerable Bede's (672/3-735) scientific work. He achieved his aim with the texts, but did not produce anything similar with the associated diagrams. Thereby he left a gap in the scholarship. His student, Frances Lipp, was fortunate to have sighted images of some of the diagrams.[13] Lipp's 1961 thesis was on that scientific work of Bede's which came earlier than that contributing to tides. Nine years later, sight of the manuscript diagrams is something that Thomas Eckenrode patently did not achieve.[14] Lipp identified further contextual diagrams. Eckenrode's scientific exploration, supplemented by subsequent articles, collated various isolated comments from antiquity.

Two later studies address Bede's work directly from the history of science viewpoint. That of Wesley Stevens skirts around tides and does not contribute on this issue. In contrast, that of Marina Smyth is highly relevant.[15] However, neither Stevens nor Smyth cite either of the manuscript or published diagrams; though profuse citation of the diagrams' surrounding text indicate Smyth's likely knowledge of those published. Indeed she elaborates on that part of the Isidorean diagrams formulated a little earlier than Bede's writing.

The diagrams themselves generally stand alone, without a direct interpretative text. The associative text is Bede's. This is what Eckenrode had leaned upon in his interpretation of Bedan tidal lore. Smyth had gone further in her interpretation of Carolingian tidal lore; she offers translation of numerous extracts. Only in 1999, did Faith Wallis achieve the first complete textual translation.[16] The latest scholarship, that of David Cartwright, is from a

[13] Frances R. Lipp, *The Carolingian Commentaries on Bede's De Natura Rerum*, (Ph.D. dissertation, Yale University, 1961).
[14] Thomas R. Eckenrode, *Original Aspects in Venerable Bede's Tidal Theories with relation to Prior Tidal Observations*, (PhD thesis, St. Louis, 1970).
[15] Wesley M. Stevens, *Bede's Scientific Achievement*, (Newcastle, 1985); Wesley M. Stevens, *Bede, the schools and the 'computus'*, (Aldershot, 1994); Marina Smyth, *Understanding the Universe in Seventh-Century Ireland*, (Woodbridge, 1996).
[16] Faith Wallis, *Bede the reckoning of time*, (Liverpool, 1999).

tidal scientist, but it does not conflict with any of the previously cited studies from among the humanities.[17] Nor, again, did he utilise the diagrams.

Therefore it can be seen that an undue primacy has so far been given to textual considerations alone. As I will show in the narrative (chapter 4), when the manuscript diagrams were first published in the sixteenth century they were corruptly interpreted. A century ago Jean-Paul Migne made the diagrams accessible to more general study, but inexplicably he did not correct them then. This thesis reviews the originals; it is the first concerted study of the diagrams. No doubt students with wider language skills will bring further light to bear.

The parts of this thesis covering diagrams are concerned primarily with their predictive use.[18] This is what the other commentators have either missed or ignored. I have built upon the textual basis of Jones, and shown that the diagrams are only implicitly for an exact place, not explicitly. This is in slight contradiction of Jones who gave a defined place. Secondarily, the meanings of technical words require greater rigour in their definition. Latham & Howlett, producing a medieval dictionary in stages, still have their work in hand.[19] I have shown that tidal etymology needs greater attention. Over the connection of old wordings to modern words, I also encountered a small disagreement in this area with Smyth.

Scholarship on the later medieval diagrams is scarcer than that on the earlier body of work. This is probably because of a combination of their separateness, or isolated nature, and the particular or limited information that they convey. Grosjean's study of the 1375 Catalan

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[17] Cartwright, *Tides a scientific history*; David E. Cartwright. *On the origins of knowledge of the sea tides from antiquity to the thirteenth century*, Earth Sciences History, Volume 20 number 2, 2001, 105-126.
[18] Paul Hughes, *Implicit Carolingian tidal data*, Early Science and Medicine, Vol.VIII No.1 (2003) 1-24.
[19] Latham, R. E. & Howlett D. R., *Dictionary of Medieval Latin from British sources*, (London, 1975-).

Atlas is essentially that of a critical text without any interpretation.[20] Because of the original, intact 1569 Flye being hidden for a long time, an article on it, with a copy of the diagram, is now an invaluable contribution.[21] However, Taylor began their interpretation in 1956, with Waters making significant additions two years later.[22] Then Taylor produced a magnificent critical text to accompany some of the diagrams in 1963.[23] Howse then built on the earlier work and provided a mathematical survey of most of the rule-of-thumb diagrams.[24]

The purpose of these later diagrams is generally an expression of the ancient prediction method. When Howse produced his survey he confirmed what Waters had also been unable to decipher, about the Flye. This thesis interprets the symbols concerned. The symbols show the direction of flood, and that is the primary purpose of this particular diagram.

The undoubted scientific success of the first one hundred and thirty five years of the *Philosophical Transactions* led to their reissue in 1809.[25] These made their earlier contents much more widely accessible, and prove invaluable to the emergent university colleges of that new century. However, this edition was in an abridged form of the original. In the abridgement, the editor castigated a letter by a Francis Davenport as tedious, rendering publication unnecessary. The abridgement, cutting out thefamous letter on the tides of Tonkin, has masked access to it over the intervening years. Fortunately the letter's content (if there ever was such a form) is in the original publication.[26] Obvious errors in that publication, led to searches for the manuscript. As all the searches remained in vain, the

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[20] Grosjean, G., *The Catalan Atlas of the Year 1375* (Zurich, 1978).
[21] Bosanquet, Eustace F., *The flye*, The Library, Fourth series XVIII, 1938, 194-200.
[22] Eva Germaine Rimmington Taylor, *The haven-finding art*, (London, 1956); David W. Waters, *The art of navigation in England in Elizabethan and early Stuart times*, (London, 1958).
[23] Eva Germaine Rimmington Taylor, *A regiment for the sea and other writings on navigation by William Bourne of Gravesend a gunner*, (Cambridge, 1963).
[24] Derek Howse, *Some early tidal diagrams*, Revista da Universidade de Coimbra, **33** 1985 365-85.
[25] Charles Hutton, George Shaw & Richard Pearson, *The philosophical transactions of the Royal Society of London from their commencement in 1665 to the year 1800 abridged with notes and biographic illustrations*, Volume III, (London, 1809).
[26] Francis Davenport & Edmund Halley, *An account of the course of the tides at Tonqueen in a letter from Mr. Francis Davenport July 15. 1678. with the theory of them, at the Barr of Tonqueen, by the*

emergence of any substantial literature explicitly about the letter, also stood in a state of omission.[27] I succeeded in locating the original text (in the form of part of a journal), and give a critical edition among the appendices.

## 2.3 MODERN PREDICTION

David Cartwright demonstrated the increasingly saturated level of tidal literature in 1999.[28] Among that literature, the dominant concern is with theory; though it is not only high theory that interests people. A range of sciences have a need for the more mundane feat of accurate prediction. In the nineteenth century, devising those predictions became a glorious triumph of international scientific co-operation. Consequently, the twentieth century saw several nations publish tide tables covering the globe. Now, in the twenty-first century there is some reduction, as there are only two sets of world-wide tables remaining: the British and the American.

Predictions are the end product of theory and observation. While tide tables are simply useful, the publication of world-wide editions in a wide number of maritime languages is now gone. This was partly due to web publication, and partly to the economics of global marketing to a largely English-fluent maritime population. Generally, the tide tables are only available to those afloat in hard-copy form; to those ashore the quantity of tidal information, however ephemeral, in daily newspapers and on television, keeps increasing. In addition there is web and e-mail dissemination but this is, as yet, barely available to the mariner. This thesis displays the struggles involved in the tide tables' book-form construction.

Tides derive from astronomy, and in causing part of the lunar acceleration, they return an effect to astronomy. That acceleration is as far as astronomers, in general, tend in their

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*learned Edmund Halley Fellow of the Royal Society*. Philosophical Transactions of the Royal Society of London. (1684). **13**, 677-688.

[27] Private communication from David Cartwright FRS, 14th October 2001.

[28] Cartwright, *Tides: a scientific history*.

interest in tides. After astronomy, a wider context involving tides is cartography. Seymour's *A History of the Ordnance Survey* claimed to be a comprehensive survey in 1980.[29] It gives the barest mention of tides, only doing so with reference to Ordnance Datum Newlyn. This is not too surprising, as sea level is the literal basis of survey and geodesy, where the tides are of interest only as correction terms, as in hydrography.

Perhaps the widest field of greatest interest with tides is oceanography. This encompasses tidal elevations, currents, tidal mixing, effects on sediment transport, and biology. Margaret Deacon's history of oceanography and both of David Pugh's engineering handbooks admirably cover these wider aspects.

Hydrography is a subset of both cartography and oceanography, and hence constitutes a narrower context in which tides might be considered. G. S. Ritchie, a former Admiralty Hydrographer, revised his autobiography in 1995, but still produced what appears to be more of a tale than a history.[30] Archibald Day, an earlier Hydrographer, had produced a history for a more fulsome period in 1967.[31] It has been particularly useful for its later period, supplying facts not otherwise accessible. Each work has a popular style, without referencing.

Jordan Kellman has shown how the French bridged the gap between Dutch and British hydrography. This dissertation was useful for a description of the setting up of the *Dépôt des cartes et plans.* While widening the study to France, nevertheless it concentrated on the eighteenth century.[32] Ursula Lamb then gave an indirect view into Spanish hydrography;

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[29] W. A. Seymour, *A history of the Ordnance Survey*, (London, 1980).
[30] George Stephen Ritchie, *No day too long, an hydrographer's tale*, (Edinburgh, 1992); George Stephen Ritchie, *The Admiralty chart, British naval hydrography in the nineteenth century*, (Edinburgh, 1995), second edition.
[31] Archibald Day, *The Admiralty Hydrographic Service 1795-1919*, (London, 1967).
[32] Jordan Kellman, *Discovery and enlightenment at sea: maritime exploration and observation in the 19th-century French scientific community*, (PhD dissertation, Princeton, 1998).

both were particularly useful for access across the language barrier.[33] One other study, by Hugh Slotten in 1994, is of a most discerning and perceptive quality.[34] Slotten investigated the historiography and epistemology of the early United States Coast Survey. He has lit a path for other studies to follow. Together, Kellman, Lamb and Slotten throw light upon wider, international hydrography. They, with Ritchie and Day, give very little indication of any history of tidal study. With little on tidal study in general, there is even less material available on tidal prediction.

It was the British who began a vigorous and systematic investigation of tides. This started in the late Hanoverian period. They then ascended to prediction by an openly known method. The investigation began with North-West European places and advanced to the Indian Ocean's northern shore. Until a successful method established itself in India, the Americans never really got to grips with prediction. They then followed this later method. However it was the Americans, who first raised the endeavour to a global dimension.

The Admiralty publishes the definitive British tide tables, four volumes in 2004. As the American set differs very little, I have studied the tables' history with the more accessible Admiralty set as the basic model. For any particular ocean, the ATT acronym is what they are increasingly now known as.[35] Each volume lists the *Admiralty Manual of Tides* as a miscellaneous publication.[36] Arthur Doodson and Harold Warburg jointly published the manual in the middle of the 1939-45 war.[37] While considering tidal theory, it is primarily a manual: describing how to observe tides, analyse the observations, and construe predictions

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[33] Ursula Lamb, *The London years of Felipe Bauza,* Cosmographers and pilots of the Spanish maritime empire, 1995 Volume 499, 319-340.
[34] Hugh Richard Slotten, *Patronage, practice, and the culture of American science Alexander Dallas Bache and the U.S. Coast Survey,* (Cambridge, 1994).
[35] For example: *Admiralty tide tables volume 1 2002 United Kingdom and Ireland (including European Channel ports),* (Taunton, 2001); *Admiralty tide tables vol 2 2002 Europe (excluding United Kingdom and Ireland), Mediterranean Sea and Atlantic Ocean,* (Taunton, 2001); *Admiralty tide tables vol 3 Indian Ocean and South China Sea (including tidal stream tables),* (Taunton, 2001); *Admiralty tide tables vol 4 Pacific Ocean (including tidal stream tables)* (Taunton, 2001).
[36] Arthur T. Doodson and H. D. Warburg, *Admiralty manual of tides,* (London, 1941 (reprinted 1980)).

from the analysis. The manual also gives skeletal details of who, where and when two tidal methods were devised. Whilst they produced the manual under war-time tribulation, they published at a time by when the British had also achieved a world tidal portfolio.

Doodson & Warburg's manual of 1941 still remains current, though David Pugh supplanted parts of it in 1987.[38] His is sufficiently the set-text to keep in continuous print; and he added a further edition in 2004.[39] Pugh brings tidal prognostication up to current pitch, placing historical facts in a modern perspective. However it remains a text-book, not a history.

The two investigations, the synthetic and harmonic, both followed similar publication patterns. The primary investigators published their results in several papers and reports (Table 1). While the leading papers are in the *Philosophical Transactions of the Royal Society*, the cutting edge reports were those to the *British Association for the Advancement of Science*. Three American journals also published a considerable number of papers.[40] More are found in French journals and a few in reports of the *Australasian Association for the Advancement of Science*. The accounts concentrate on the tidal regime of an individual port, or of a few ports. They are primarily concerned with the establishment of a general theory of the tides. They also give as non-primary information, how predictions were formulated in a particular locality.

[37] Doodson and Warburg, *Admiralty manual of tides*.
[38] Pugh, *Tides surges and mean sea-level*.
[39] David T. Pugh, *Changing sea levels, effects of tides, weather and climate*, (Cambridge, 2004).
[40] American Journal of Science and Arts, Proceedings of the American Association for the Advancement of Science & United States Coast Survey Reports.

Table 1 Summary of the contributors, of the main papers

| Author | No. | Period | Area |
|---|---|---|---|
| Lubbock JW | 17 | 1830-1839 | Synthetic |
| Whewell W | 19 | 1833-1854 | Synthetic |
| Chazallon B | 8 | 1842-1856 | French |
| Airy GB | 8 | 1842-1877 | Synthetic |
| Bache AD | 33 | 1850-1858 | American |
| Haughton S | 12 | 1854-1879 | ---- |
| Mitchell H | 8 | 1856-1877 | American |
| Ferrel W | 12 | 1856-1884 | American |
| Thomson W | 15 | 1863-1881 | Harmonic |
| Roberts E | 8 | 1868-1881 | Harmonic |
| Borgen C | 5 | 1876-1884 | German |
| Pearson J | 6 | 1877-1883 | ---- |
| Darwin GH | 21 | 1878-1906 | Harmonic |
| Rysselberghe | 5 | 1880-1884 | Belgian |

During the nineteenth century both John Lubbock and George Darwin introduced their work with its place in history, each fully aware of what they were building. George Airy appeared not to appreciate that a portfolio was in the making, he had not risen to the larger area concept. However, by 1870 William Thomson vividly saw what was at stake; as an inducement, he offered the allure that he might bring Indian prediction to the same pitch as in England.[41] None of the academics were directly concerned with the mundane build up of the tabulations port by port; they left that to their associate workers. Equally germane, with the exception of Thomson's public row of 1879, concentrating on success, they omitted reference to their contemporary difficulties.

[41] William Thomson, *Committee for the purpose of promoting the extension improvement and harmonic analysis of tidal observations*, Report of the British Association for the Advancement of Science, 1870 p151. However, Thomson was merely publicising William Parkes view, expressed four years earlier (Royal Geographical Society, MG706a).

Further students will find a full bibliography of papers on tidal science for the period 1665-1969.[42] Cartwright dealt with the ensuing years. He also indicated the ongoing need for scientific supervision of the tide tables.

There are in existence a hand-full of monographs on tidal history, but all are in some way insufficient with regard to tide tables. At the beginning of the twentieth century, the American, Rollin Harris, produced a lengthy chronology of the theoretical ascent.[43] Then by mid-century, Eric Aiton synthesised a history of tidal theory concentrating upon the inequalities.[44] Later, addressing a school-teacher audience, he wrote several papers which are useful in their clarity of exposition of those inequalities. Eckenrode had gone deeper into the philosophy, yet only considered the ancients.[45] Deacon, interested in the broader sweep of oceanography, produced by far the fullest account.[46] The deficiency is that, while each ascends in philosophical purpose, they nevertheless do relate what are chronologies. In addition, as they are secondary works, they fall into the area of only telling success stories and not that of the difficulty encountered; the main story is in the problems and pitfalls along the way.

Deacon was the first to have described how the tide tables were made. There was a problem with the tide table at what was the world's busiest port, London. Importantly she identified some of the roots of that problem. This thesis adds to Deacon's considerable body of work.

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[42] International Association for the Physical Sciences of the Oceans, No. 15., *Bibliography on tides 1665-1939*, (1955); International Association for the Physical Sciences of the Oceans, No. 17., *Bibliography on tides 1940-1954*, (1957); International Association for the Physical Sciences of the Oceans, No. 29., *Bibliography on mean sea level 1959-1969 and bibliography on tides 1955-1969*, (1971).
[43] Rollin A. Harris, *Manual of tides appendices to reports of the United States coast and geodetic survey*, (Washington, 1897-1907).
[44] Eric J. Aiton, *The development of the theory of the tides*, (unpublished University of London M.Sc. Dissertation, 1953).
[45] Thomas R. Eckenrode, *Original Aspects in Venerable Bede's Tidal Theories with relation to Prior Tidal Observations*, (PhD thesis, St. Louis, 1970).
[46] Deacon, *Scientists and the sea 1650-1900*.

Cartwright concentrated on published sources in a similar way but he spoke from the advantage of a highly specialised scientist.[47] He was also intent upon the development of tidal theory. Nevertheless he included description of difficulty and failure. For example, he cited William Whewell and what was for the time an overly ambitious idea of co-tidal maps. However, a mathematical appreciation is necessary to gain the full benefit of Cartwright's scientific history.

Michael Reidy took the converse approach and deliberately excluded formulae.[48] He extensively concentrated on the epoch of when the Admiralty first took up tidal prediction. He is among the first to have delved into primary tidal sources, and extolled Whewell's work. Doing so, he fails to stress that it was not he, but Lubbock, who published the more worthwhile tidal work. As an historian, Reidy was not interested in the tables of prediction, though he did successfully engage with the methodology and epistemology involved.

For the epoch involved, Reidy extensively adds to Deacon's work. Reidy, from Lamb and Secord, then developed the idea of the early tidal investigators corresponding with one another in the form of a network. I have built upon his early exposition, and show how networking properly extends to each research programme; and that several parts of tidal knowledge derived from correspondence networks.

Nor did the important work of Sheesley extend the history of tide table development either.[49] He concentrated on a similar period to Reidy and again employed primary sources. Instead he produced a dissertation on tidal mapping within a Humboldtian framework of global

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[47] Cartwright, *Tides a scientific history*.
[48] Michael S. Reidy, *The flux and reflux of science the study of the tides and the organization of early Victorian science*, (PhD thesis, University of Minnesota, 2000).
[49] Sheesley, Benjamin C., *A Humboldtian Science Framework for William Whewell's Tidal Maps*, (MSc thesis, University of Wisconsin, 2002).

science. Sheesley's acclaimed work identified causes of the mapping's early failure and later success.[50]

**Four** papers have been located which deal explicitly with historical tide table production. The published bibliography, together with personal contact to several tidal historians, result in my belief that no other significant papers exist.

**1.** At the end of the nineteenth century, J. Eccles touched on the part of tide-table development that had taken place in India.[51] As his sub-title indicates, he gave details of the observations made there between 1873 and 1892. The paper is a description of the methods of reduction. It is also an early general account of the whole work, but considers each port separately, without attempting to look at the whole of India.

**2.** Despite the advantage of his location at the International Hydrographic Bureau between the wars, H. Bencker lamented upon the difficulty of obtaining tables from its constituent national members.[52] He stated how it had been impossible to consult all of the original sources, and called for further help from the membership. However, his was a study of tide tables across the world. He made a small-scale study of their accuracy, comparing prediction with observation, but presents the result inadequately. Apart from typographical errors it is plainly erroneous. While Bencker's is the seminal study, I have significantly improved upon it.

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[50] Washington Map Society, Walter W. Ristow Prize 2003.

[51] J. Eccles, *Account of the operation of the great trigonometrical survey of India Volume XVI*, (Dehra Dun, 1901).

[52] H. Bencker, *A study of the tide tables published by the different nations*, The Hydrographical Review, 1929, volume 6 part 1, 125-150.

**3.** It was Steacy Hicks who, in 1967, gave the third witting tide table history.[53] His paper is brief, but invaluable. His primary source it the manuscript of an earlier writer, and helps to set the scene in America. Because of its brevity, and that there has been subsequent change, together with being several decades old, this present study readily adds to that formative contribution. It is evident that his source manuscript draws heavily from primary sources – as does this study.

**4.** Having been the very first geographic set, the Admiralty table retains a leading role in the tidal field. J. Rossiter's 1972 sketch was probably the first for the Admiralty tables' history. While taken purely from published sources it is a good outlining attempt.[54] The sketch contains a few errors and ignores the different prediction methods. It also confuses the role that development of the Indian tables had with those of the Admiralty.

The tide tables themselves are an unwitting form of literature from which to consider their own development. Having said that, they are an exceptionally scarce resource. Their consideration is not simply that of straight forward geographical areas. The tables in the nineteenth century were in an embryonic stage. It was a stage when they evolved from national areas, to ones encompassing the interests of economic reach. It was also a stage before they grew to a proper global portfolio. The principal areas are: the British Isles and near continent, India, and North America.

Of the Admiralty tide table, only one complete set from 1833 is known to exist – that in the Hydrographic Office at Taunton. The second best set of the serial, missing the first edition and other later years, is in the British Library. Both the serial itself, and the *Admiralty Tidal Manual*, provide a simple skeleton of the table's geographic expansion. Table 2 has been

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[53] Stacey D. Hicks, *The tide prediction centenary of the United States Coast and Geodetic Survey*, International Hydrographic Review, 1967 Volume 44 part 2 121-131.
[54] Jack R. Rossiter, *The history of tidal predictions in the United Kingdom before the twentieth century*, Proceedings of the Royal Society of Edinburgh Section B (Biology), Volume 73 1972 13-24.

collated from most, if not the whole, of the Admiralty serial; this covered the period, from inception, to during the 1939-1945 war. By then, the expansion of the number of ports in the tables, and its geographic range, had stabilised to that resembling today's composition.

Table 2 The expansion of the ATT with *home* and *foreign* ports

| Year | Editor | Home | Foreign | Price |
|---|---|---|---|---|
| 1833 | Dessiou | 4 | 0 | 6d |
| 1834 | Dessiou | 5 | 0 | 6d |
| 1835 | Dessiou | 9 | 1 | 6d |
| 1836 | Dessiou | 10 | 1 | 1/- |
| 1849 | Burdwood | 20 | 1 | 1/6d |
| 1856 | Burdwood | 23 | 1 | 1/6d |
| 1910 | Purey-Cust | 26 | 6 | 2/- |
| 1911 | Purey-Cust | 26 | 14 | 1/- |
| 1912 | Purey-Cust | 26 | 28 | 1/6d |
| 1915 | Parry | 28 | 30 | 1/6d |
| 1919 | Parry | 29 | 30 | 2/- |
| 1920 | Warburg | 29 | 34 | 2/- |
| 1921 | Learmonth | 28 | 43 | 2/6d |
| 1922 | Learmonth | 28 | 45 | 3/6d |
| 1923 | Learmonth | 28 | 47 | 3/- |
| 1924 | Learmonth | 28 | 54 | 3/- |
| 1925 | Learmonth | 27 | 69 | 3/6d |
| 1926 | Douglas | 28 | 75 | 3/6d |
| 1928 | Douglas | 29 | 81 | 4/0 |
| 1929 | Douglas | 29 | 90 | 4/0 |
| 1930 | Douglas | 29 | 89 | 4/0 |
| 1931 | Douglas | 30 | 92 | 5/0 |
| 1932 | Douglas | 30 | 94 | 6/0 |
| 1933 | Douglas | 31 | 95 | 6/0 |
| 1935 | Edgell | 31 | 96 | 6/0 |
| 1937 | Edgell | 31 | 97 | 6/0 |
| 1938 | Edgell | 29 | 100 | 5/0 |
| 1940 | Edgell | 29 | 103 | 5/0 |

Within the tables, are bare facts of chronology, but with later ones also containing the observation period leading to the predictions. They also contain information, or imply it, upon which ports were predicted by which method. Further discussion of the contents of Table 2 is contained in the narrative and the final conclusion of this thesis.

*Tide-Tables for the Indian Ports* are also a scarce commodity. It can not be determined if any have survived in the Indian sub-continent. Whilst all were in vain, I have made several searches in this endeavour. The larger of the two sets in the British Library ranges from 1880 to 1957; another set exists in the Proudman Oceanographic Laboratory for the period 1913-1988. For its first four decades, the annual was printed in London. Similarly to the Admiralty set, it also contains an outline of its geographic expansion. Here, the consideration of its expansion is perhaps best in coastal miles, rather than port number, as given in Table 3.

Table 3 The geographic expansion of the Indian tide-tables

| Year | Price | Vols. | Publication | Ports | Area | Mileage |
|---|---|---|---|---|---|---|
| 1860 | | 1 | | 1 | Karachi | - |
| 1880 | | 2 | London | 2 | Karachi-Bombay | 483 |
| 1881 | 2 rupees | 1 | London | 8 | Aden-Vizagapatam | 3740 |
| 1882 | 2 rupees | 1 | London | 16 | Aden-Moulmein | 4873 |
| 1883 | 2 rupees | 1 | London | 18 | Aden-Moulmein | 4873 |
| 1884 | 2 rupees | 1 | London | 20 | Aden-Moulmein | 4873 |
| 1886 | 2 rupees | 1 | London | 23 | Aden-Moulmein | 4873 |
| 1889 | 2 rupees | 2 | London | 29 | Aden-Mergui | 5253 |
| 1892 | 2 rupees | 2 | London | 31 | Aden-Mergui | 5253 |
| 1905 | 2 rupees | 2 | London | 39 | Suez-Mergui | 6558 |
| 1923 | 8 rupees | 2 | Dehra Dun | 40 | plus Persian Gulf | 7468 |
| 1925 | 8 rupees | 1 | Dehra Dun | 19 | Suez-Rangoon | 7265 |
| 1931 | 3 rupees | 1 | Dehra Dun | 68 | England-Japan | 14815 |

I discuss the above content more fully later. It is however important to state at this stage what is meant by *India*. The area under consideration is that which pertained to the politics current in the late nineteenth and early twentieth centuries. The geographic area is the northern coast of the Indian Ocean, that stretching between Aden and Rangoon. Its area of interest included the Persian Gulf, as well as the French and Portuguese controlled areas.

The British Library is far from being the best resource for tide tables made in other countries. Some difficulty with terminology exists in knowing what to look for; the English phrase *tide table* is *gezeitentafeln* in German, and *annuaire des marées* in French. The best resource, in Britain, would appear to be the Proudman Oceanographic Laboratory, from which Table 4 is compiled.

Table 4 National tide tables held in the Proudman Oceanographic Laboratory

| | | |
|---|---|---|
| Argentina | 1963-1979 | local |
| Australia | 1978-1997 | local |
| Canada | 1907-2000 | local |
| France | 1947-2004 | world |
| Germany | 1926-1995 | world |
| Great Britain | 1919-2004 | world |
| India | 1913-2003 | hemisphere |
| Japan | 1925-1997 | local |
| Netherlands | 1931-1998 | local |
| USA | 1901-1989 | world |

Not all of the sets described as local confine themselves to ports within their nominative national boundary. However, as can be seen from the above, the tables are largely of either a local nature or have discontinued. This Proudman Laboratory archive is the result of past preservation choices, many other countries with a tidal littoral do actually publish tables.

The literature search has made plain which national set of tables were developed but have not survived. This study ultimately concerns itself with the world-wide tide table portfolios. The British and Americans each publish on paper, the French and Germans publish on the world-wide-web.

# CHAPTER 3 NETWORKS OF CORRESPONDENCE

## 3.1 INTRODUCTION

The research reveals the development of tidal ideas and the exchange of information in each epoch. In each period the workers developed *networks of correspondence*; the thesis defines those networks, particularly between the 1678 Tonkin Report (chapter 6) and the 1914-1918 war (part 11.5).

The information for the earliest rule-of-thumb method, that obtained by the Venerable Bede, was garnered from a network of correspondents. The ecclesiastical network, primarily concerned with dating Easter, produced a powerful statement useful to tidal prediction.

The Tonkin report is also the product of a correspondence network. The efficiency of the East India Company's business network produced three tidal reports. Their result led to a theoretical contribution, eventually enrolled into tidal prediction.

The Admiralty then became the principal conduit for the network that grew around the synthetic method. This first tidal network had its origins in hydrography. It had further focuses at Cambridge University and the private home of the principal investigator. Eventually, when the network had run its course, the Hydrographic Office then conducted further business for the ongoing method.

A second tidal network of correspondents grew up around the investigations conducted around the United States. Created in the middle of the nineteenth century, this persisted into the early decades of the twentieth. This network, centred on Washington, coalesced explicitly to investigate tides.

Cambridge University became the main focus of the tidal network that formed around the harmonic method. Other centres of the correspondence were Glasgow University, the Nautical Almanac Office and the Survey of India. Although this network formed to investigate tides, it prospered only because of the Survey's needs. After this, the former busyness subsided and no other investigative networks have become apparent.

The networks of Bede and the East India Company both produced tidal contributions. However, each network was for a purpose other than tides; the former ecclesiastical the latter commercial. The main tidal developments then grew out of the needs of mapping. I therefore show that the investigators' involvement in tides came about somewhat inadvertently. Except in America, no network members were exclusively employed in tidal work; although two British individuals (Dessiou and Roberts) did become deeply involved in tides.

The main networks were those of the nineteenth century. After their initial investigations, their residuary institutions then evolved to become exclusively for tides and their prediction.

## 3.2 METHODOLOGY

I have identified over two thousand letters, mostly nineteenth century, concerning tidal prediction methods. As in Table 5 they are mainly located in a dozen repositories, spread across seven towns, on two continents.

The investigating methods which follow, details the way they were located.

Almost from the start, I saw the necessity of cataloguing the correspondence, and initially wanted to emulate the catalogue of the Kelvin & Stokes correspondence, made by David

Wilson.[55] A gratuitous event brought a halt to that ambition. This then led to building up a superior database in Microsoft Access.

Table 5 Correspondence produced by search subject

| Repository | Search subject | Letters |
|---|---|---|
| | **Personal** | |
| Glasgow University Library | Thomson | 54 |
| Cambridge University Library | Thomson | 95 |
| Cambridge University Library | Darwin | 428 |
| Cambridge University Library | Airy | 250 |
| Cambridge University Library | Stokes | 44 |
| St. John's College, Cambridge | Adams | 86 |
| Trinity College, Cambridge | Whewell | 410 |
| Hydrographic Office, Taunton | Beaufort | 165 |
| Royal Society of London | Lubbock | 244 |
| Royal Society of London | Herschel | 20 |
| St. Andrews University Library | Forbes | 3 |
| Whitby Museum | Scoresby | 1 |
| Bristol Merchant Venturers | Bunt | 4 |
| | | |
| | **Institutional** | |
| Liverpool Record Office | Lyceum | 1 |
| Bristol Archive Office | Bristol Institute | 7 |
| Bodleian Library, Oxford | BAAS | 4 |
| University College London | SDUK | 29 |
| Cambridge University Library | B. of Longitude | 33 |
| Royal Society of London | Royal Society | 17 |
| | | |
| National Archives, Washington | USCS | 148 |

Appendix 1 gives a paper version of the catalogue. The catalogue gives a unique identity to each document, with letters and numbers making up the identifier. The first three letters give each document's repository; then follow the repository's own document record. A small legend, found in the appendix, interprets this label. The catalogue is a list of all the nineteenth century tidal correspondence. It is a significant contribution to tidal studies.

Not every manuscript is in a personal letter form, some are circulars and some *letters to the editor*. Three records in the catalogue contain no more information than their identity. No date is borne by 190 records, 12 remain anonymous and 23 have no known addressee. All

[55] David B. Wilson, *Catalogue of Stokes and Kelvin Collections*, (Cambridge, 1976).

other records have their four fields complete; in addition to their identity they are dated, they have the name of who wrote the letter, and also to whom it was addressed.

The electronic database is superior to the paper catalogue, because any of its four fields can marshal the data. The four fields are: *date*, *from*, *to* and *document*. The *date* field can take either an ascending or descending order. The *from* and *to* orderings are alike, and group the letters together, in correspondent order. The *document* ordering groups the correspondence together by repository. Some repositories, most notably Cambridge University Library, hold more than one relevant collection.

Appendix 2 contains a list of the four hundred correspondents. The list of correspondents is alphabetic; with the number of letters they sent, followed by the number of letters received. The correspondent list, combined with the catalogue, enables the location of documents that relate to a particular person. Table 6 of the most prolific correspondents, constitutes extractions from that appendix.

One other way in which the electronic database has been more effective than a paper catalogue, is in hyper-linking each record direct to its actual transcribed letter. So successful was this simple strategy for accessing the data, that I abandoned another attempted analytical process. That process was an electronic index, one similar to a book index, and abandoned because it became much too large and cumbersome. With the successful strategy then established, a constant check was maintained on the large amount of material. This facilitated the drawing out of the narratives. A defect of the strategy employed is that it relied, to some extent, on fallible human memory of each letter's contents. The counter to the defect was the added labour of more searching; in turn, this induced greater rigour and vigilance.

Table 6 Summary of the main tidal scientist's correspondence

| Correspondent | From | To | Total | Status | Network | Epoch |
|---|---|---|---|---|---|---|
| Darwin GH | 97 | 442 | **539** | Academic | Harmonic | 1845-1912 |
| Whewell W | 100 | 391 | **491** | Academic | Synthetic | 1794-1866 |
| Lubbock JW | 80 | 254 | **334** | Academic | Synthetic | 1803-1865 |
| Airy GB | 164 | 112 | **276** | Academic | Synthetic | 1801-1892 |
| Beaufort F | 94 | 133 | **227** | Academic | Synthetic | 1774-1857 |
| Thomson W | 91 | 92 | **183** | Academic | Harmonic | 1824-1907 |
| Roberts E | 117 | 8 | **125** | Worker | Harmonic | 1845-1933 |
| Bunt TG | 104 | 7 | **111** | Worker | Synthetic | 1794-1872 |
| Adams JC | 25 | 82 | **107** | Academic | Harmonic | 1819-1892 |
| Baird AW | 71 | 9 | **80** | Worker | Harmonic | 1842-1908 |
| Bache AD | 33 | 44 | **77** | Academic | American | 1806-1867 |
| Dessiou JF | 66 | 8 | **74** | Worker | Synthetic | 1769-1853 |
| Pourtales LF | 45 | 26 | **71** | Worker | American | 1823-1880 |
| Ross D | 55 | 3 | **58** | Worker | Synthetic | 1812-1854 |
| Stratford WS | 42 | 8 | **50** | Academic | Synthetic | 1791-1853 |
| Gordon WW | 20 | 29 | **49** | Worker | American | fl.1848-1855 |

During the early part of the research, stemming from the advice of Margaret Deacon, I created a website (www.airmynyorks.co.uk). The website, an extension to the catalogue database, serves several functions. One is in attracting queries from a variety of other students; this interaction has been most productive. Another is the exhibition of the contents of appendices 1 & 2, for the benefit of other researchers. Its primary function however, was to build up biographical information about the tidal investigators. In this respect it has been modestly successful, allowing much fuller life stories of three key workers: Francis Davenport of Tonkin, Joseph Foss Dessiou of the Hydrographic Office, and Edward Roberts of the Nautical Almanac Office.

I made the transcriptions as useful readings, rather than at the scholarly level, necessary for publication.[56] Despite that, I made numerous visits to the repositories in order to check transcription accuracy. I photocopied a few, often because they contained data, a formula or a sketch. Where a manuscript contained large amounts of irrelevant data, I generally deployed ellipsis rather than make a complete transcription. Several letters covered more

[56] R. F. Hunnisett, *Editing Records for Publication*, (London, 1977).

than one scientific subject, some contained inconsequential personal details. Where the data was strictly mathematical, I again usually omitted its transcription, leaving appropriate notes for each ellipsis. These notes were found very useful later, when more precise detail was needed.

The above, pragmatic approach, brought in a full collection of British material. With constraints of time and money, it also enabled a useful collection of American material.

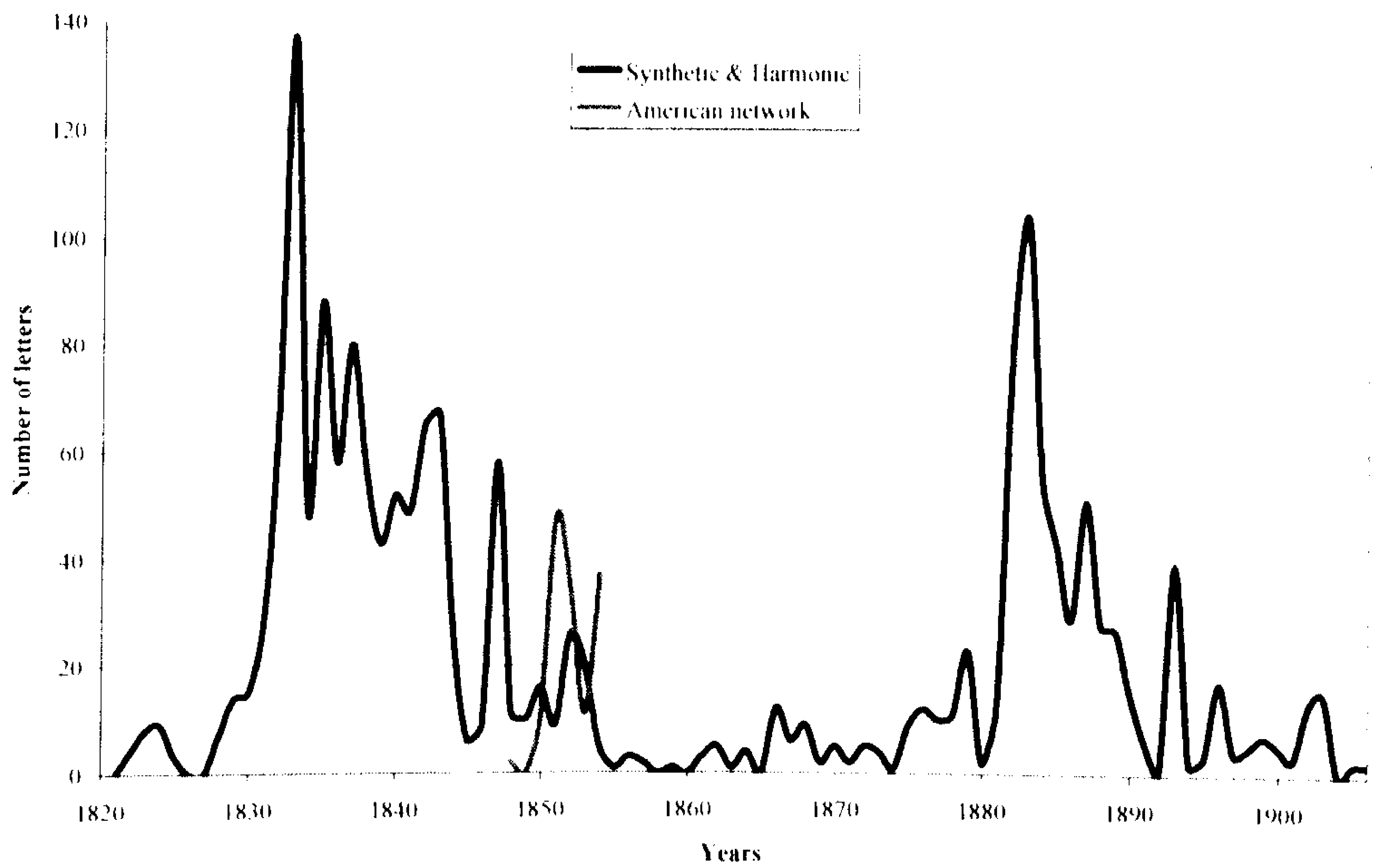
## 3.3 THE CORRESPONDENCE DOCUMENTS

The nineteenth century correspondence was between people who formed three discrete networks. Other types of networking activity was also undertaken, such as discussions at the Admiralty and learned society soirées; and they are at least partly published in memos and proceedings. This thesis largely confined to unpublished manuscripts, essentially measures only one network activity.

The early network, involved with the synthetic method of prediction, effectively operated between 1828 and 1851. In 1866, Airy considered that the early investigation had come to a close. While the later, harmonic method can trace its origin to 1861, its network was most active from 1867 to 1903.

Figure 1 shows the flow of network correspondence. The graph shows the American network as an overlay, because it was a network operating separately to those in Britain. I also show it separately because the transcription, of its correspondence, has been artificially curtailed (owing to research cost constraints).

Figure 1 The Nineteenth Century Tidal Correspondence




The main line of the graph is that of the numbers of letters of the synthetic and harmonic networks. It is not split, in the way that the American has, because of overlapping interests. For example, the Astronomer Royal of the first period appointed the main computer of the second period. Another example is in the correspondence between the Hydrographer in the second period and the inventor of the harmonic method; the hydrographer espoused the earlier, synthetic method. The overlap is small and the two hiatuses are sufficiently far apart to not necessitate splitting.

Omitted from the graph are the 190 pieces of correspondence which bore no date.

The main line shows how two networks focussed: on the work of Whewell in the first half-century, and on the work of Darwin in the second half. Before its closure in 1828, the Board of Longitude was a source of money to the ingenious. The first bump of the line, in the 1820's, is as a result of gold diggers applying to the residual Board. The dramatic first rise is around Lubbock's efforts. The peaks then, on into the 1840's, represent the activity of

Whewell's geographic experiments. Airy's investigations sustain the mid decades. Why the correspondence numbers did not rise throughout the 1870s is because, while they had a new method, funds for a research programme had yet to come. The dip of 1880 is clearly owing to Thomson's decline in regard for Roberts. As they wound down the Survey of India by about 1890, the then curtailment of funds is also evident.

## 3.4 INVESTIGATION METHODS

The method of investigating the activity of the tidal prediction networks has mostly been through their surviving manuscripts; but is heavily supplemented by the wealth of contemporary material available on the internet, such as the content of library catalogues.

### 3.4.1 The main tidal scientists

In turn, I pursued the investigation through manuscripts in two ways. One was in categorising people and another was through places, or institutions. But they intermingle a little.

A limited, but invaluable, source guide to the papers of British scientists aided the search.[57] The investigation then extended from the initial manuscripts' content. The whole collection makes clear that the greatest part in making the tide tables was the work undertaken by about sixteen people (Table 6). The papers of the *Philosophical Transactions* and the reports of the *British Association* unwittingly hide that point. This thesis extols the hitherto inadequately recognised contribution made by the non-academic workers, particularly Joseph Dessiou and Edward Roberts.

[57] The Royal Commission on Historical Manuscripts, *The manuscript papers of British scientists 1600-1940*, (London, 1982).

Table 6 is only of the main correspondents. Arranged in descending order of magnitude, it is of their surviving tidal archive. It adequately represents each correspondent's importance in their respective network. The listed numbers do not, in any way, represent the actual numbers that must have existed. Phrases in the surviving correspondence, such as: 'In reply to yours of the 26$^{th}$ ...' provide ample proof of absent, non-surviving, correspondence.[58] This absence is also true for Appendix 2, which lists the whole of the correspondents in alphabetical order.

The above status classification is entirely arbitrary. However the status does show up a deficit of letters sent to the workers. Edward Roberts and Andrew Baird must have received more letters than have survived, or have been located. George Darwin and John Adams, academics of the harmonic network, must have sent more. Similarly, of the synthetic network, Thomas Bunt, Joseph Dessiou and Daniel Ross must have received more, and John Lubbock and William Whewell sent more. It is likely that the number of a workers' in-and-out letters would have been somewhat in balance. In contrast, the academics attracted many letters – many boastful, and several displaying a highly eccentric nature.

### 3.4.2 The archive of the harmonic network

Knighted in 1866 and raised to the peerage in 1892, William Thomson generally attracts his simple title, Kelvin. However, as his interest in tidal work traces to 1861 and that he had ceased being active in tides by the time of his elevation, I therefore refer to him by his family name. For that, and further reasoning related in the narrative, 1861 then forms a suitable beginning of the harmonic network.

My initial interest in Thomson, led to investigating two of his archives. The Cambridge and Glasgow catalogues list merely correspondent and date. At first, most of the correspondents' names were meaningless. This left the bulk of the archives inaccessible.

[58] Cambridge University Library (CUL), Additional 5750 3.

One of Thomson's correspondents was George Darwin; the *Admiralty Tidal Manual* names him. Darwin's name in the Cambridge card index, led to a particular file of correspondence. The file is an artificial collection, put together sometime in the past for an unknown reason; the file, however, is all about tides. The 120 letters are between 24 different correspondents. The file identified three of Darwin's principal correspondents: Adams, Baird and Roberts.

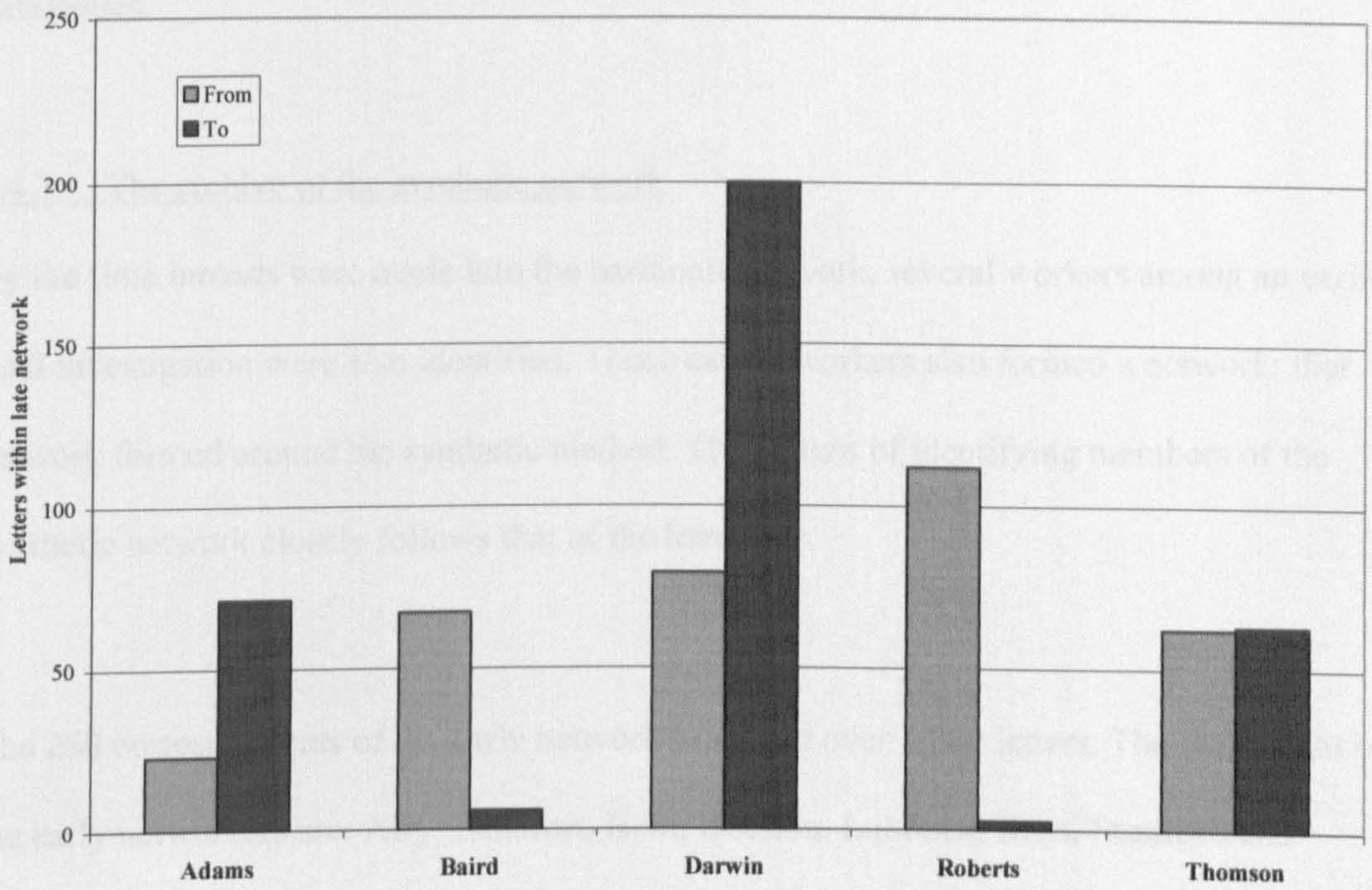
Adams completes the available main archive source of this late network. The five networkers were Adams, Baird, Darwin, Roberts and Thomson. All except Roberts feature in the *Oxford Dictionary of National Biography*.

By then, the search had identified many of the key networkers. Their identity enabled a systematic penetration of the previously inaccessible archives. From possession of a correspondent name, many tidal letters came forth.

Initially, the search obtained only letters from the period concurrent with those in the file of 120 letters. So at first, the mistake was made of cutting off correspondence considered too early, or too late. As a larger picture emerged, this pursuit policy was later changed. The transcription then expanded to that of all known tidal letters. As the known network expanded, the searches were re-iterated several times. Consequently, it is highly likely that a few tidal letters will still lie buried in the archive. However I believe that my extraction constitutes the bulk.

There were about 108 correspondents in the network. Together, they produced at least 565 letters. However, the five people in Figure 2 drove the network.

Figure 2 The Harmonic Network 1867-1903




The network really got going in 1867 (by Adams, Thomson and Roberts) when they set up a committee for the harmonic investigation. They knew Baird by 1872 and Darwin joined the network in 1876. When Thomson snubbed Roberts in 1879, (explained in Chapter 9) the correspondence between the two halted. Yet Roberts remained most active with the other participants. As Baird left tidal work in 1888, his correspondence then dwindled. Adams, active to the very end, died in 1892. The network, continuing through the turn of the century, finally petered out with a letter from Roberts to Darwin in 1903, but with the harmonic method then thoroughly established.

Published in 1976, Wilson's is the final catalogue of Thomson's papers. At the start of the transcription work, there was no catalogue for either of Adams' or Darwin's papers. Interim catalogues were eventually made available after this thesis began.[59] The latter two catalogues remain unpublished, but they are computerised and hence searchable. This thesis has the advantage of having obtained consultation with all three compilers of those electronic catalogues.

### 3.4.3 The archive of the synthetic network

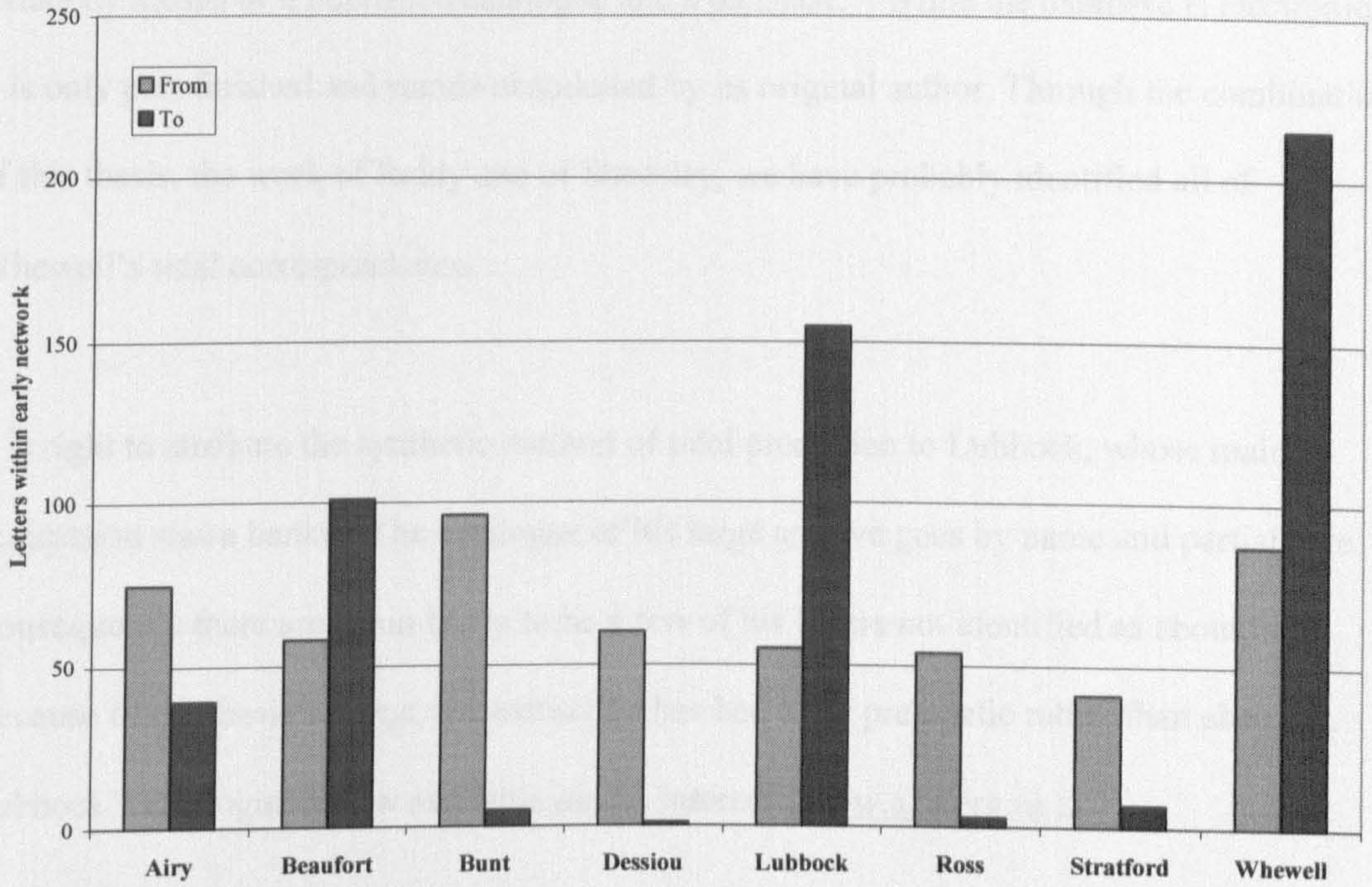
By the time inroads were made into the harmonic network, several workers among an earlier tidal investigation were also identified. Those earlier workers also formed a network; that network formed around the synthetic method. The pattern of identifying members of the synthetic network closely follows that of the harmonic.

The 250 correspondents of the early network produced over 1,200 letters. The main eight of the early networkers are: Airy, Beaufort, Bunt, Dessiou, Lubbock, Ross, Stratford and Whewell. The *Oxford Dictionary of National Biography* lists the five academics. The *Dictionary of Nineteenth Century British Scientists* list Dessiou - because of this research, and Bunt. Dessiou became the first editor of the Admiralty tide tables, and Chapters 7, 8 and Appendix 4 graph much of his life. *Memoirs of Hydrography* list Ross, Dessiou's assistant.[60] The whole eight of Figure 3 drove this early network.

Lubbock got this network going in 1828. It really took off when Dessiou, Whewell and Francis Beaufort joined the correspondence the following year. William Stratford and Airy joined in, before the Admiralty tide tables emerged in 1833. When Dessiou wrote his last to Lubbock in 1851, a begging letter, the network had run its course.

[59] They are respectively available in St. John's College, Cambridge and Cambridge University Library.
[60] Ross is not to be confused with a contemporary Captain Daniel Ross, cartographer to the East India Company.

Figure 3 The Synthetic Network 1828-1851




The early network, while large, was intensively active for a shorter period than the later network. Two of its components, Airy and Bunt, interacted with the late network and sat on the tidal committee on harmonic analysis, convened in 1867. From that standpoint it is intriguing, that while they worked on tides through most of the early period, neither had any direct input into devising the Admiralty tide table.

Airy enjoyed a long tenure as Astronomer Royal. He left his papers at the Royal Greenwich Observatory in meticulous order; he also made wet copies of his outgoing letters. Happily, both sides of his correspondence have often survived. Whilst the Observatory archive is institutional, the Airy section takes on a highly personal nature.

Whewell, teaching at Cambridge, was Airy's contemporary. Whewell was also not directly involved in the Admiralty tide table developments, but he did himself investigate tides. This was partly as a result of the investigation begun by Lubbock. R. Ward had previously extracted a large number of letters from Whewell's main archive. The selections listed by him in 1967, have tides as their main subject; but beyond that, the particular reason for his research is not known.[61] Supplemented with a list of correspondents, the search located more letters by means of a published catalogue and a database.[62] While the database is electronic, it is only part finished and stands abandoned by its original author. Through the combination of this thesis, the work of Reidy and of Sheesley, we have probably identified all of Whewell's tidal correspondence.

It is right to attribute the synthetic method of tidal prediction to Lubbock, whose main occupation was a banker. The catalogue of his large archive goes by name and partial date. Consequently there are again likely to be a few of his letters not identified as about tides. Because of the thesis's scope, the extraction has had to be pragmatic rather than absolute. Lubbock's catalogue is now available on the internet (www.a2a.org.uk).

At the time, the man in charge of the Hydrographic Office was Beaufort, but Dessiou edited the Admiralty table. Both men were professional hydrographers, with Beaufort as the Admiralty Hydrographer. Dessiou, with a whole portfolio of publications to his personal accreditation, was much the more considerably complete hydrographer. The records of the Office are only part accessible; this accessibility applies mainly to the period before 1857. In counterbalance, the in-letters are indexed by both person and subject. It is inevitable that the proceeding catalogue of that office will reveal more tidal records. The Hydrographic Office resource is clearly of an institutional nature rather than personal. Ross augmented Dessiou there as director of the tide table.

3.4.4 Institutions and deficiencies

Each of the academics wittingly left archives. Any archives that their associated workers may have left have not come to light. Of the early network: Airy, Beaufort, Lubbock and Whewell left archives; as did Darwin, Thomson and Adams from the later network. Baird

[61] Trinity College, Cambridge, manuscript index to Whewell papers R.6.20.

extracted various papers from out of his office in India.[63] Nothing else is known of what Bunt, Dessiou, Ross and Roberts may have left. Stratford's papers appear to have suffered misfortune.

Stratford was the first Superintendent of the Nautical Almanac Office, the same office where Roberts later worked. With the repository damaged twice by fire, no nineteenth century Almanac records have survived. This thesis therefore forms seminal commentary on that important office. The commentary is a thematic cohesion derived from the letters that it sent out; and which are now scattered around diverse repositories.

It is not clear why so few of the letters from Lubbock and Whewell, to Dessiou and Ross, have survived. The latter two worked very much on a personal basis for the former two, mostly using their professional HO address. Before the penny post of 1840, use of the office address would have been highly suitable to both Dessiou and Ross; it would also have saved them the not inconsequential postage costs. Dessiou died a pauper, and Ross a cripple.

Bunt was an independent, successful surveyor. I contacted his descendents, as well as those of Dessiou, but no papers of either emerged.

Roberts and Baird were computers. They conducted their correspondence from a mixture of official and private addresses. While Roberts was wholly London based, Baird worked in India and furloughed in Europe. I again made contact with descendants, but none of either of their papers have been located.

Despite Baird's paper removal, I made an unsuccessful attempt to access the Survey of India records, in Delhi. The records were said to exist in the National Archives of India. The

[62] Patricia Bradford, *A catalogue of the Whewell manuscripts at Trinity College Cambridge*, (London, 1973).

officials originally gave written permission to see the records; but in the actuality, in Delhi, they unfortunately denied access. This denial of access was for no explained reason.

The main strategy, used to penetrate the archives, has been that of identifying the people involved. The strategy, identifying four hundred people, and producing over two thousand correspondence pieces, has been successful. Table 5 displays the result.

It can be argued that the personal search for Beaufort material was really an institutional search of the Hydrographic Office. However the Beaufort search started in a personal way. I searched that part of his papers, at the Huntington Library, in California, before those in Taunton. The Beaufort papers in California are largely of a personal nature whereas those in Somerset are professional papers.

The records held in the Hydrographic Office and the Royal Society are far from being dead archives. This is particularly so for the former and to a lesser extent for the latter; the old hydrographic records are still used in present day map making and sailing directions. The Royal Society has been one of the few institutions to produce material from an institution led search. A similar search in the Royal Astronomical Society produced nothing.

The results obtained from institutions were generally achieved by searching in a likely place, rather than being the product of a systematic approach. I had to do the ferreting in situ, using hand lists and card indexes. A significant failure to find anything has been among the records of the Ordnance Survey, now held at the Public Record Office. Conversely, it is clear from Table 5 that Cambridge University, as an institution, has been a most productive place to search.

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[63] CUL DAR 251/3786.

The internet has been the most useful tool for locating the relatively few manuscripts by subject. In particular, the internet has enabled several useful documents to be located in the India Office. The internet has also been very useful for checking, raising accuracy in the project. It has also enabled a wide geographic search: I have searched the British repositories well, in addition to several in both North America and Europe. The internet has also been a powerful tool for genealogical aspects.

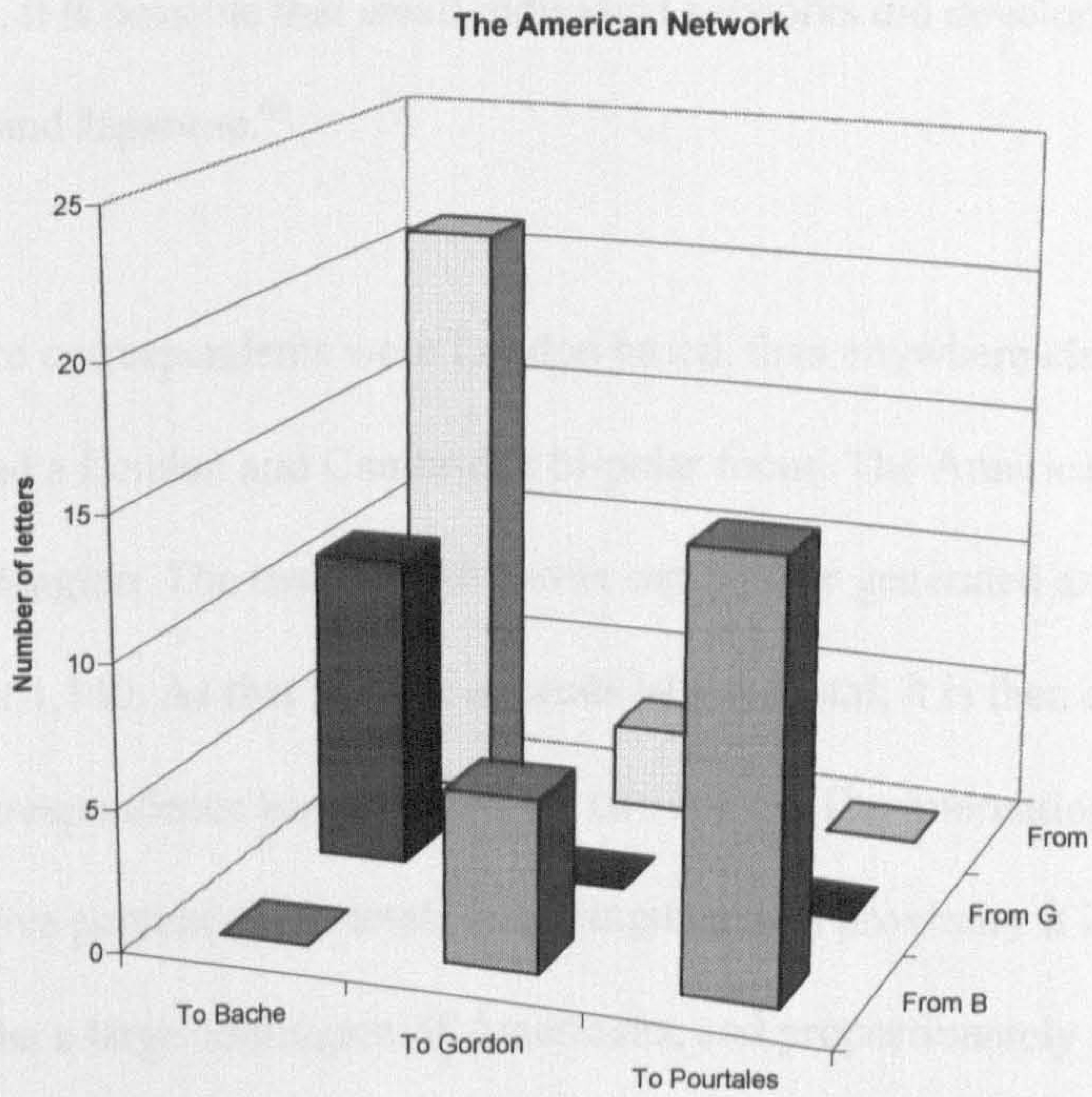
### 3.4.5 Foray into the American archive

From first encounter with *The Admiralty Manual,* the existence of contributory tidal work in America was plain. However it was not until researching the synthetic network that I saw a network of investigators existed in America.

The manuscripts transcribed from the National Archives, in Washington, are only the first few of a much larger number. The tidal archive of the United States Coast Survey runs from the 1850's on into the first decades of the twentieth century. It contains many more records than have been transcribed.

The 46 correspondents of the early American tidal network produced 148 pieces. The network got going in 1849. Because of cost constraints, the diligent search terminated at 1855. However, a few searches were made in vain among the later records, particularly where there was known to have been correspondence with Europeans. Figure 4 shows the three principal correspondents of that part of the network. The search in America was among the foundation papers of their respective institutions. However, I unwittingly curtailed the search before the date, 1867, from which the American tide table began.

Figure 4 The early correspondence of the American Network




The extracted records are purely of an institutional nature. As they are merely a snapshot of what exists, they serve in order to put flesh on the bones of the personality of Alexander Bache. Bache, as head of the Coast Survey, might also be considered an academic.

The Americans were active participants in both networks that developed among the British. From its start, Bache contributed to the synthetic network, as did Bowditch, Davis and Everett later. The harmonic network had Abbe, Ferrel and Hilgard joining in from the United States, Johnson from Canada and Chapman from Australia.

## 3.5 INTERNATIONAL CORRESPONDENTS

The Dutch, French and Portuguese contributed to the early network. In addition, to French and Dutch-Indonesian effort in the later network, there were then Danish, German, Italian, Japanese and Portuguese contributions. No other network, or major body of tidal correspondence, has been identified which did not involve those in Britain and the United States. In view of the number and nature of foreign correspondence, few other networks could have developed – they would have been so isolated. However, reflecting their few published papers, it is possible that small individual networks did develop among the Dutch, German, French and Japanese.[64]

Significantly more correspondents were London based, than anywhere else. Each of the two main networks had a London and Cambridge bi-polar focus. The American network focussed on Washington. The two English towns captured or generated an equal number of letters each, about 1,140. As that number exceeds half the total, it is then clear that quite a volume of the correspondence was between the two towns. The international correspondents constituted only five percent of the total. With language and proximity it is not surprising that there should be a large contingent of Americans, and proportionately so of Dutch. Appendices 1 & 2 combine with Table 7 to form a larger image of the global tidal workers. The international list forms a reversal to the bulk of the home based networkers; the harmonic investigators dominate it. This, of course, I should have anticipated, because it was the harmonic method which was much more applicable to world tides.

Table 7 The eighty international reporters

| Correspondent | Nationality | Network | Location |
|---|---|---|---|
| *Bache AD* | *American* | *Synthetic* | *Washington, DC* |
| *Bowditch NL* | *American* | *Synthetic* | *Berlin* |
| *Chamberlin TC* | *American* | *Synthetic* | *Beloit, Wisconsin* |
| *Davis CH* | *American* | *Synthetic* | *Cambridge, MA* |
| *Everett E* | *American* | *Synthetic* | *Cambridge, MA* |
| *Ferrel W* | *American* | *Harmonic* | *Washington, DC* |
| *Gairdner M* | *American* | *Synthetic* | *Vancouver, Oregon* |
| *Graham JD* | *American* | *Synthetic* | *Washington, DC* |
| *Hilgard JE* | *American* | *Harmonic* | *Washington, DC* |
| *Holden ES* | *American* | *Synthetic* | *Washurn, Wisconsin* |
| *Lowrie WH* | *American* | *Synthetic* | *Pittsburgh, Penn.* |
| *N.Y.D.M.* | *American* | *Synthetic* | *New York, NY* |

[64] Association d'Oceanographie Physique (IAPO-IUGG), *Pub. Scientifique no.15*: Bibliography on Tides 1665-1939, Bergen, 1955. Followed by *Pub. Sci. no.17*, (1840-1954), Göteborg, 1957; and *Pub. Sci. no. 29*, (1955-1969), (Birkenhead, 1971).

| | | | |
|---|---|---|---|
| *Thompson P* | *American* | *Synthetic* | *London* |
| *Vaughen D* | *American* | *Harmonic* | *Cincinnati, Ohio* |
| *Wilkes C* | *American* | *Synthetic* | *New York, NY* |
| Chapman RW | Australian | Harmonic | Adelaide |
| Darby J | Australian | Harmonic | Adelaide |
| Friend MC | Australian | Synthetic | Van Diemans Land |
| Pasco C | Australian | Harmonic | Melbourne, Aust. |
| *Van de Wayer S* | *Belgium* | *Synthetic* | *Belgium* |
| Baird AW | British | Harmonic | Poona, India |
| Ballingell | British | Synthetic | Bermuda |
| Barnden | British | Synthetic | Pago Pago, Tort. |
| Bax HB | British | Synthetic | Texel, Holland |
| Blunt W | British | Synthetic | Fort William, India |
| Braby EE | British | Harmonic | Hong Kong |
| Cabert F | British | Harmonic | Hong Kong |
| Chadwick O | British | Harmonic | Granada, W.I. |
| Connor EJ | British | Harmonic | Poona, India |
| Curwin C | British | Synthetic | Bombay, India |
| Doberck W | British | Harmonic | Hong Kong |
| Eccles J | British | Harmonic | Dehra Dun, India |
| Franklin J | British | Synthetic | Van Diemans Land |
| Govt of India | British | Harmonic | Calcutta, India |
| Greenlaw CB | British | Synthetic | Calcutta, India |
| Hennessey JBN | British | Harmonic | Calcutta, India |
| Hill J | British | Harmonic | Poona, India |
| Hillier HM | British | Harmonic | Hong Kong |
| Ibbetson R | British | Synthetic | Singapore |
| Kyd J | British | Synthetic | Kiddapore, India |
| Maclear T | British | Synthetic | Capetown, S.Africa |
| Morice CCD | British | Harmonic | Poona, India |
| Murchison R | British | Synthetic | Singapore |
| Neison E | British | Harmonic | Durban, S.Africa |
| Parker H | British | Synthetic | Fort William, India |
| Reid W | British | Synthetic | Bermuda |
| Roberts W | British | Harmonic | Hong Kong |
| Robinson W | British | Harmonic | Hong Kong |
| Royeal MW | British | Harmonic | Poona, India |
| Stanley O | British | Synthetic | Brisbane, Aust. |
| Strahan G | British | Harmonic | Dehra Dun, India |
| Taylor PG | British | Synthetic | India |
| Thuillier HR | British | Harmonic | Poona, India |
| Wright CWH | British | Synthetic | India |
| Young AE | British | Harmonic | Perak, S.S. |
| *Bayfield HW* | *Canadian* | *Synthetic* | *Prince Edward I.* |

| | | | |
|---|---|---|---|
| *Chevallier E* | *Canadian* | *Synthetic* | *Halifax, N.S.* |
| *Dawson WB* | *Canadian* | *Harmonic* | *Ottawa* |
| *Denison FN* | *Canadian* | *Harmonic* | *Victoria, B.C.* |
| *Endor AR* | *Canadian* | *Harmonic* | *Pictou, N.S.* |
| *Gordon AR* | *Canadian* | *Harmonic* | *Halifax, N.S.* |
| *Jarrad FW* | *Canadian* | *Harmonic* | *Prince Edward I.* |
| *Johnson A* | *Canadian* | *Harmonic* | *Montreal* |
| *Mcarthy D* | *Canadian* | *Harmonic* | *Toronto* |
| Crone C | Danish | Harmonic | Copenhagen |
| Ryder CH | Danish | Harmonic | Copenhagen |
| Bahhuge I | Dutch | Harmonic | Leiden |
| *Beyland C dew* | *Dutch* | *Harmonic* | *London* |
| *Braaksma H* | *Dutch* | *Synthetic* | *London* |
| *Moll G* | *Dutch* | *Synthetic* | *Utrecht* |
| *Stok JP van der* | *Dutch* | *Harmonic* | *Batavia, E.Indies* |
| Beautemps-Beupre | French | Synthetic | Paris |
| Chazallon AR | French | Synthetic | Paris |
| Daussy P | French | Synthetic | Paris |
| Dubois E | French | Harmonic | Brest |
| *Borgen AC* | *German* | *Harmonic* | *Wilhelmshaven* |
| Plana M | Italian | Synthetic | Turin |
| *Horoyama S* | *Japanese* | *Harmonic* | *London* |
| Cerquero J | Portuguese | Synthetic | London |
| DaCunha | Portuguese | Harmonic | Madeira |

The above nationality status is somewhat notional. America, within the duration of the synthetic network, was still adding the lands to the west, from where many of the reports were coming in. Australia federated in 1901; Canada came about in 1861. At the beginning of the period Belgium was a new concept, as the harmonic period closed Italy and Germany had barely been put together.

# CHAPTER 4 CAROLINGIAN DATA

## 4.1 INTRODUCTION

The British Library possesses a thirteenth-century tide-table for London Bridge.[65] In China there is a tide-table of about that period, but based on one much older.[66] Yang, Emery and Xui have recently thrown more light on this Chinese table.[67] However, in 1943, Charles W. Jones identified several ninth-century tidal diagrams.[68] Given the recent increase in interest in tidal history, those folios deserve particular consideration.[69] I will show that one of the folios serves the office of a very early tide table. The importance of this table has been completely overlooked. Schematically, it leads to the well known tidal diagram of the Catalan atlas and especially to the subject of chapter 5.

In *Scientists and the Sea*, Margaret Deacon traces the history of oceanography. The study she achieved goes from oceanography's beginning to its establishment as a science. When speaking of the tidal science of the Middle Ages, Deacon cites Jones and Migne, but not the sources themselves.[70] In contrast, I use the actual sources to provide a critical text edition – neither established by Migne nor of primary interest to Jones. As for more recent work: David E. Cartwright's scientific history of the tides omits the Carolingian data, while Michael S. Reidy's dissertation focuses on Victorian tidology.[71]

## 4.2 BEDAN MANUSCRIPTS

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[65] British Library, MS Cotton Julius DVII, folio 45b.

[66] A. C. Moule, *The Bore on the Ch'ien-T'ang River in China*, T'oung Pao, 2nd series (Leiden, 1923), 135-188. Moule gives as its date 14th September 1056.

[67] Joseph Needham, *Science and Civilisation in China*, vol. 3 (Cambridge, 1959); Z. Yang, K. O. Emery and Y. Xui, *Historical Development and Use of Thousand-Year-Old Tide-Prediction Tables*, Limnology and Oceanography, 34 (1989), 953-957. This table is based on an earlier one, which had been carved in stone and was printed in about 1252 with moveable type – two centuries before the Gutenberg Bible. The article's abstract states that the tables of 1056 are still extant.

[68] Charles W. Jones, *Bedae Opera de Temporibus* (Cambridge MA, 1943), 126 and 365.

[69] Deacon, *Scientists and the Sea 1650-1900*.

[70] Deacon, *Scientists and the Sea*, 24 and 34.

Jones' 1943 edition of the *Opera de temporibus* by the Venerable Bede (672/3-735) lists ten tidal diagrams. The MSS containing these diagrams are presently located at:

| | | |
|---|---|---|
| London, The British Library, Harley 3017, f.135r | *A* | rota |
| Berlin, Preussischer Kulturbesitz, 138, f.35r, Phillips 1833 | *B* | rota |
| London, The British Library, Cotton Vespasian BVI, f.103r | *C* | list |
| St. Gall, Stiftsbibliothek, 248, p. 61 | *D* | rota |
| Rome, Biblioteca Apostolica Vaticana, Regin.Lat.123, f.83v | *E* | rota + table |
| Berlin, Preussischer Kulturbesitz, Lat. 128, f.123r, Phillips 1831 | *F* | table |
| Paris, Bibliothèque nationale de France, Lat. 4860, f.141r | *G* | table |
| London, The British Library, Harley 3017 f.113 | *H* | table |
| Besançon, Bibliothèque Municipale, 186, f.162v-163r | *I* | table |
| Rome, Biblioteca Apostolica Vaticana, Pal. Lat. 1448, f.69v | *J* | table |

The above list emends Jones' foliation in some minor ways.[72] To facilitate discussion, sigla refer to folio pages that contain either a tidal rota, or a list or table. The manuscripts fall into groups: *A* to *E* and *F* to *J*, according to the way they present the tidal information.

Jones largely provides the date and provenance of the MSS.[73] The tenth-century MSS, including *B*, belonged to the French scholar Abbo Floriacensis (c. 945-1004). Abbo had been in charge of studies at Ramsey from 985 to 987; after which he became Abbot of the Benedictine abbey of Fleury-sur-Loire, near Orleans; which housed one of the largest libraries in Europe. Abbo, who belonged to the vanguard of astronomy and *computus*, had used Macrobius'*Commentary on Cicero*. This was the text which formed the cornerstone of

[71] Cartwright, *Tides: A Scientific History*; Reidy, *The Flux and Reflux of Science*.
[72] Jones' foliation is as follows (with the necessary emendations italicised): Paris, Lat.4860, *fol. 141v*; London, Harl.3017, fol.113r; Vatican, Pal.lat.1448, *fol. 70v*; London, Cotton Vesp.B VI, fol.103r; Besançon, 186, *fol.162v*; Berlin, Lat.128, fol.123r; St. Gall, 248, p.61; Vatican, Regin.Lat.123, *fol.83*; Berlin, 138, *fol.35iv*; London, Harley 3017, fol.135r.

scientific instruction in Carolingian schools. His own *computus*, in turn, provided the starting point for the *Enchiridion* of Byrhtferth (c. 969-1020).[74]

Nearly all computistical MSS written after Abbo show the influence of the Fleury tradition.[75] *A* and *H*, which are taken from another example of a Fleury *computi* from Northern France, have been dated 861-864.[76] *C* is the last folio of a MS of Bede's *De Temporibus Ratione* (*DTR*); the whole MS is a patch-work of a number of different hurried hands, probably written near Auxerre in 848.[77] *D* was first ascribed to the early ninth century; although it has been established that the folios surrounding *D* belong to the eleventh-century portion of the MS.[78] The monk, Oliva of Ripoll, probably composed the codex with *E*, in 1056. He had access to French MSS and to a collection of Bede's letters.[79] *F*, found between folios stemming from Verona and Metz, is dated 810-818. G is among 167 tenth-century folios from Mainz.[80] The two adjacent folios that make up the table of *I*, situated at the end of a ninth-century MS, is traceable to Britain.[81] *J*, from Treves or Mainz, is among folios dated 779-797.[82]

## 4.3 THE TIDAL FOLIOS

Figure 5 reproduces *A*. The construction of the diagram appears to have started with the careful drawing of the concentric circles. The complex process of matching the internal data

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[73] Charles W. Jones, *Bedae Pseudepigrapha: Scientific Works Falsely Attributed to Bede* (Ithaca & London, 1939), 84-140.
[74] See Peter S. Baker and Michael Lapidge, *Byrhtferth's Enchiridion*, (Oxford, 1995).
[75] Jones, *Bedae Pseudepigrapha*, 60.
[76] Baker & Lapidge, *Byrhtferth's Enchiridion*, xlii.
[77] Wesley M. Stevens, *Bede's Scientific Achievement*, Cycles of Time and Scientific Learning in Medieval Europe, (London, 1995), 57.
[78] Jones, *Bedae Opera de Temporibus*, 126; Stevens, *Bede's Scientific Achievement*, 58, dates the manuscript to the second half of the ninth century, while Jones, *Bedae Opera de Temporibus*, 365, draws attention to the eleventh-century environment of p. 61 of the St. Gall MS.
[79] Jones, *Bedae Pseudepigrapha*, 136.
[80] Jones, *Bedae Pseudepigrapha*, 128; Stevens, *Bede's Scientific Achievement*, 57, dates the preceding folios to the second half of the ninth century.
[81] Charles W. Jones, *The 'Lost' Sirmond Manuscript of Bede's 'Computus'*, English Historical Review, 52 (London, 1937), 204-213, at 209.
[82] Jones, *Bedae Pseudepigrapha*, 135; Stevens, *Bede's Scientific Achievement*, 56, dates the succeeding folios to the first half of the ninth century.

resulted in four drafting mistakes. It omits the day in which the moon has aged twenty-two days. Another omission is the third minim of numeral *III*, in alignment with where the moon has aged fifteen days. Marks to the upper two medallions, correct the other two mistakes. This is in order to locate them tidally at the twenty-eighth and fifth days. The regularity of the central T-O map, suggests that it provided the starting point for the data. The data inscribed into the three outer rings, appear to have begun with the first *malina* day, when the moon is twenty-eight days old. Initially the segment spacing is generous, but then quickly closes and finally opens up to complete the circuit. The winds are set quite badly, with each skewed a little clockwise so as to match the lunar age; they are also twisted towards the T-O map orientation. Gold illuminates *Favonius*, the west wind, and the *ledon* medallion of the moon's last quarter. *Auster*, the south wind, and the *malina* (*mallina*) medallion of the new moon are viridian. *Subsolanus*, the east wind, and the *ledon* medallion of the first quarter are blue/brown. *Boreas*, the north wind, and the *malina* medallion of the full moon are illuminated madder. (I will return to the question of how to translate *ledon* and *malina* below). The tint of these last two shades of brown are not as clearly contrasted as the gold and viridian are. The rota itself and the data inscribed in it were drawn monochrome.

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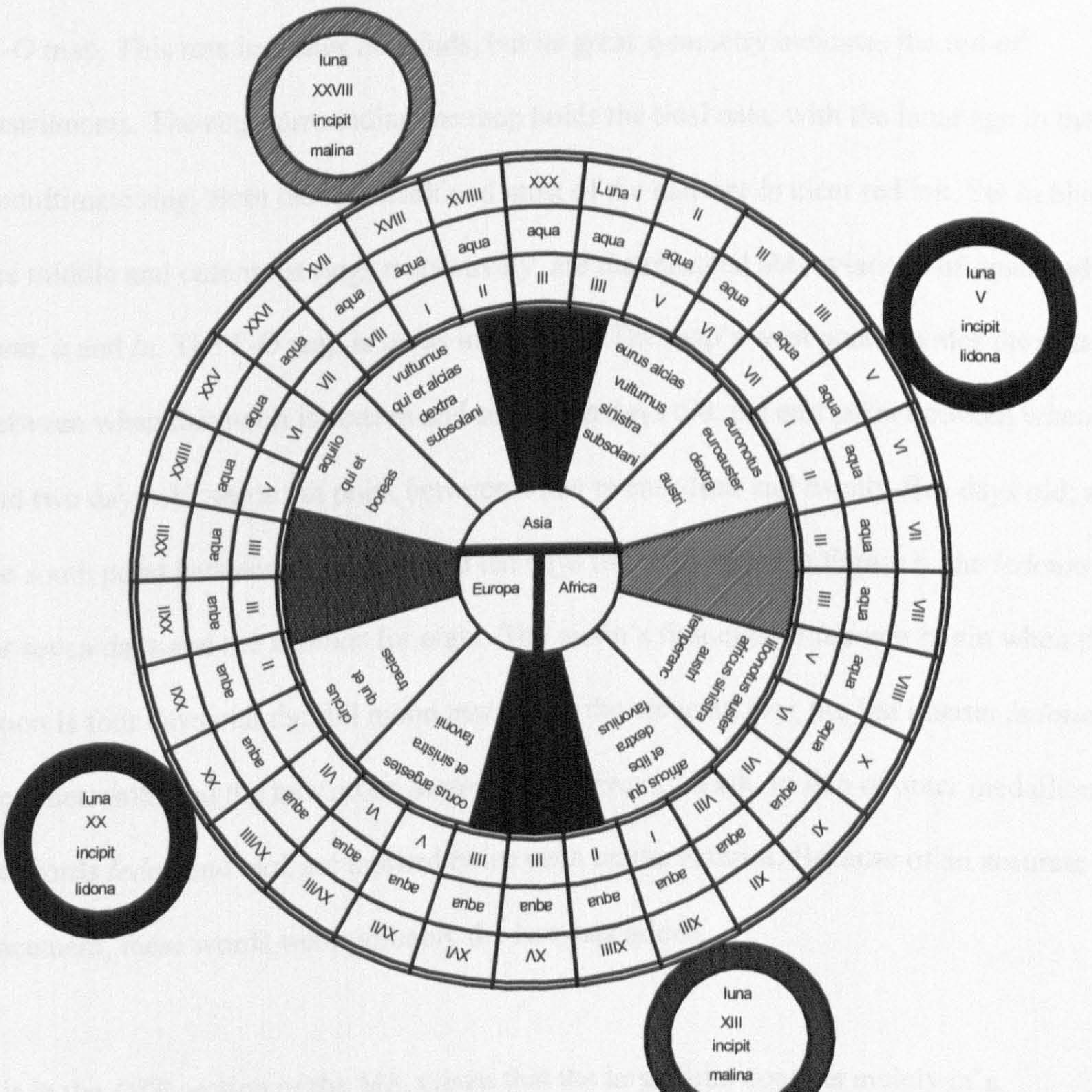
*A* shows elements of precision drawing, notably in its framework, but the data are inscribed free-hand. Two other elements also raise the quality of *A* above that of other folios. Although thoughtfully corrected, the *rota* is left as it is. This is probably due, not just to vellum and labour costs, but also to the exasperation involved in reproducing such a complex diagram. The element best defining *A* is its matching, illuminated cardinal points and medallions. The coloured medallions give a particular orientation, to use like a star chart, with west on the right and east on the left. The orientation in *A* is with the new moon in the south-east – or point of winter sunrise – and implicitly at the moment of *dodrans*, or first-of-flood. This moment of the tidal cycle concurs with the phenomenon current in Jarrow and Monkwearmouth during 2003, as is evidenced by the *Admiralty Tide Tables*. Whilst all ten folios concern Bedan knowledge, none refer tidally to a place. Importantly, however, folio *A* fulfils the office of a tide-table for an unspecified place. As I shall explain in greater detail below, the orientation, together with the Bedan context implies that the tide-table was actually drawn up for Jarrow.

I reproduce *B* in Figure 10. This rota is similar to both that in Figure 5 and the schematic representation of Figure 6. *B*, drawn with care, and probably with instruments, contains no obvious mistake. The winds take their name according to the patrological tradition. The ring indicating the lunar age has the uppermost division between the first and second days, and the lowermost between the sixteenth and seventeenth. The medallions are located tidally at the fifth, thirteenth, twentieth and twenty-eighth days of the moon's age. There is a tension between the medallions' symmetry and the disportment of the days indicating lunar age: the medallions are symmetrical with respect to the inter-cardinal points; but in order to achieve this, the days are out of place within their circuit. The words *malina* and *ledo* are illuminated green. *B* has been drawn with a mixture of red and black ink and bears the title *Concordia Maris et Lunae*. The folio containing *B* bears two other computistical *rotae* and part of the *Vetus Commentarius*. As for the *Vetus Commentarius*, it suffers from a lack of unity, because it represents the combined effort of several teachers who worked at Auxerre in the late ninth and early tenth centuries.[83]

**Figure 6 A schematic representation of a complete tidal rota, comparable to those found in manuscripts A and B.**




*C* is reproduced below, in Figure 11. *C* provides a list of the data contained in the three outer rings of the modern representation (Figure 6). The list runs from the first to the thirtieth day of the lunar cycle. *Lidona incipit* is inserted where the moon has aged five days, a + mark followed by *incipit ma lina* is inserted where the moon has aged thirteen days, a + mark

[83] Peter S. Baker, *The Old English Canon of Bryhtferth of Ramsey*, Speculum, 55 (1980), 22-37.

followed by *ledona incipit* where the moon has aged twenty days, and a + mark followed by *ma lina augmentum capit* where the moon has aged twenty-eight days.

*D* is also reproduced below, in Figure 12. *D* is a rota of some accuracy. It also contains the data in the three outer rings of Figure 6. The data is arranged in five rings around the central T-O map. This rota indicates no winds, but its great symmetry indicates the use of instruments. The ring surrounding the map holds the tidal data, with the lunar age in the penultimate ring. Both the rota itself and most of the data are in clear red ink. Set in black, in the middle and outermost rings respectively, are the repeated abbreviations of *aqua* and *luna*, *a* and *lu*. The T-O map is set as in Figure 6. The map's west point divides the data between when the moon is sixteen and seventeen days old; the east point between when one and two days old; the north point between when twenty-four and twenty-five days old; and the south point between when nine and ten days old. In contrast to Figure 6, the *ledones* run for seven days and the *malinas* for eight. The moon's first quarter *ledones* begin when the moon is four days old; the full moon *malinas* at the eleventh day; the last quarter *ledones* at the nineteenth; and the new moon *malinas* at the twenty-sixth. In lieu of outer medallions, the words *ledon* and *mal.* are marked twice each on the exterior. Because of an accurate placement, these words were probably the last data added.

*D* is in the *DTR* section of the MS. Given that the large folio consists mainly of a computistical text in Carolingian minuscule, the *rota* forms only a small portion of it, though it belongs to the older part of the folio.

Again, *E* is reproduced below, in Figure 13. All of folio *E* concerns tides. At its bottom, there is a *rota*, in the middle a table and at the top an extract from Isidore. The *rota* differs from the foregoing. It shows five concentric rings of data. The rings, beginning with the innermost, contain: 1, *mare-lune*; 2, repetitions of *a*; 3, repetitions of *m* & *l*; 4, lunar age; and

5, hours of tidal flow. A ring of pigment surrounds each data ring: dark madder, light madder, indigo, brown, and brown again; the hours and *malina-ledon* data is slightly smeared madder. In the centre is an upright cross transfixed diagonally by the words *lune* and *mare*. The left arm of the cross divides the ring of lunar age between one and two. Lunar age runs only to twenty-nine days. The first quarter *ledones* run for seven days from when the moon is five days old; the eight *malinas* of full moon begin with the twelfth day; the seven *ledones* of the last quarter run from the twentieth day; and the seven *malinas* of new moon run from the twenty-seventh. Set around the outer ring are five phrases: *III horas ledo, III horas mall., VI horas dimidia mall., VIII ho. ledo, VIIII ho. mall.* The table below the *rota* is of *malinas, ledones* and lunar age as in Figure 7. However, the order in which the *malinas* and *ledones* of this table are formatted is in concord with the information of *A-E*. The table has a thirtieth day added.

All of the folio descriptions given so far refer to Figure 6. It is a rectified *rota* of five concentric rings, with clockwise running data, surrounded by four medallions. The innermost ring contains a T-O map, centred on Jerusalem. It has three segments: representing Asia, Europe and Africa; and lines: for the Black Sea, Nile, and Mediterranean.[84] Surrounding the map is a ring of twelve segments. The cardinal point segments are illuminated. The remainder bear wind names. The next ring is of four series of numerals. These are the number of days of *malina* and *ledon* tides which begin at *I*, and run alternately to *VII* or *VIII*. The next ring has thirty repetitions of the word *aqua*. The outermost ring is the age of the moon. The surrounding four medallions are colour-coded with respect to the cardinal points. Their alignment is with their respective lunar age and with the *incipit* of each set of tides. I based Figure 6 on *A*, because of both the illumination and the correcting annotations. The medallions are placed asymmetrically, following *D*, because that is their natural place, whereas the symmetry of *A* and *B* is contrived.

Folio *F* includes the tidal table of Figure 7. Folios *F-J*, which all carry the title *concordia maris et lunae*, tabulate four paired columns of data: lunar age and *malina* and *ledon* tides. Each column is headed *luna* and *aqua*. Each folio has the paired headings badly set out. The tidal meaning is the reverse to that in *A-E*. That is to say, in *F-J*, the eight *malinas* relate to the fifth to the twelfth day and to the twentieth to the twenty-seventh day of the lunar cycle. The seven *ledones* refer to days thirteen to nineteen and twenty-eight to four. However, there are some variations. *F* and *J* set out eight *ledones*, but no corresponding lunar age. *G* does the same and writes V instead of VIII in the *malina* column by day twelve. *H* duplicates day twenty, producing three sets of eight. It omits the corresponding V on day two, and finishes with an eighth *ledon* but no lunar age. *I* also sets out eight *ledones*. This is without a

[84] Cf. John T. Wright; *Geographical Lore of the Time of the Crusades*, American Geographical Society Research Series No 15, (New York, 1925), 259.

corresponding day twenty but with a duplicated day five. Each folio of *F-J* has a list of *loca embolismorum*, that is, of those months that have an intercalated day.

Jones was unable to cite a manuscript source for Johannes Hervagen, the first publisher. Because of a distinct continuous line left of *subsolanus* and *luna I*, together with the almost completely faithful wording, one must conclude that the *rotae* in Hervagen resemble *B*. However *B* sets the four medallions squarely, which is in contradistinction to Figure 6. The *orbis terrarum* is upright in each of *A*, *B* and *D*, but with a tilt in the published *rotae*.[85] The previously published *rota* is unacceptable because it reproduces the one without the other. That is to say, the segment of new moon, skewed too much to the left, tilts the earth. The tilt is not a Carolingian representation of the inclination of earth's axis, and the *cardines* are out of line with earth. It is very difficult with the best of twenty-first century tools to make a flaw-free reproduction of the manuscript *rota*. Hervagen's woodcuts may be a paper saving compromise; equally they could be an early Copernican acceptance, depicting the tilted earth. The twentieth-century CD-rom editions of Migne in fact exclude the *rota* altogether. *A* and *B* are *rotae* of sufficient similarity for either, or both, to have been the model for Hervagen.[86]

The *rotae* in Migne are identical to Hervagen's, reproduced in Figure 8. The tilt of twelve degrees is probably in mere coincidence with the zodiac width. Hervagen published the *rotae* in 1563 at Basle, only twenty years after Joannes Petreius first published the heliocentric tract in Nurnberg.

## 4.4 *COMPUTUS* AND BEDE

[85] Migne, *Patrologia Latina*, vol. 90: 259-60, 277- 78, 385-86, 423-24. All four of these *rotae* are identical. It is not apparent why the diagram should have been reproduced an extra three times without variation, although it is what Hervagen had also done.
[86] I. Heruagium, *Opera Bedæ Venerabilis ... omnia ... Addito rerum & verborum indice copiosissimo*, (Basileæ 1563) p39, 97, 117, 118.

Whilst *B* & *E* are each associated with someone known, most *computus* are anonymous.[87] *Rotae* are an integral part of Isidore's *DNR* and Jones says that the tidal *rotae* were apparently invented in or near Fleury.[88] However, this inland genesis of the concept seems highly improbable. The tidal tables, *F-J*, arose after Bede, with the Irish transmitting *I*.[89] It has not been established which individuals devised the tidal *rotae* and tables.

A *computus* is a set of tables, notes and diagrams for calculating moveable dates.[90] The calendar was the most necessary book after the Bible. It defined the solar year and the lunar months according to the Julian calendar, and marked the Christian feasts over a period. It also had to take account of the Hebrew calendar, as the Hebrew month *Nisan* was important for the dating of Easter.[91] The Nicene Council of 325 A.D. set the computed equinox on March 21st; there they recognised that the scholars of the Alexandrian Church were the leading computists of the time.[92] The council embraced the Pachomian doctrine of celebrating Easter after the equinox.[93]

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87 Jones, *Bedae Opera de Temporibus*, 75

88 Charles W. Jones, *Bedae Venerabilis Opera Pars 6 Opera Didascalica*, (Brepols 1975) p186. Jones, *Bedae Opera de Temporibus*, 365.

89 Jones, *Bedae Opera de Temporibus*, 112 & 126.

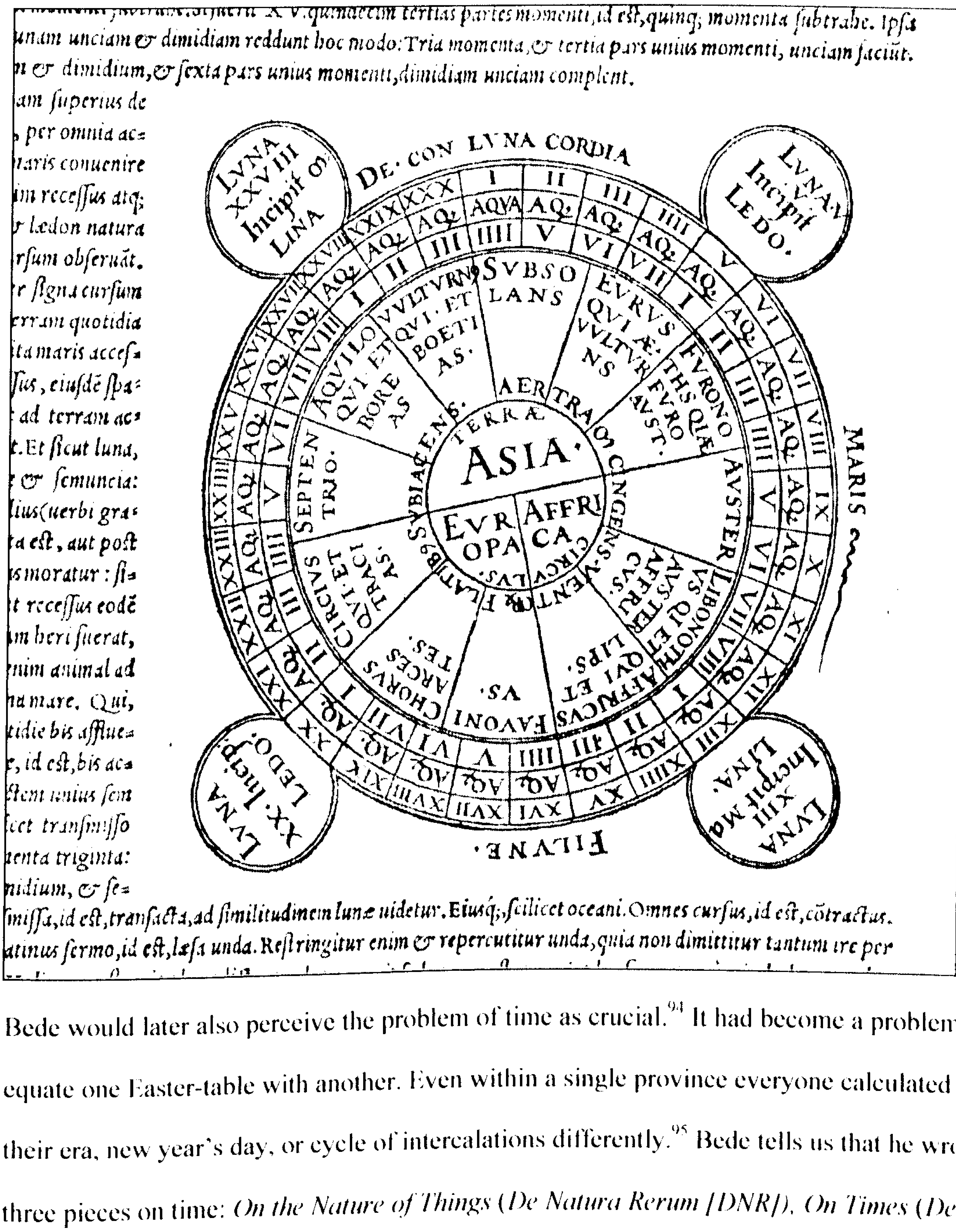
90 J. Murray: *The Compact Oxford English Dictionary*, (Oxford, 1992), 305. Cf. Peter S. Baker, *Byrhtferth's Enchiridion and the Computus in Oxford St. John's College 17*, Anglo-Saxon England, 10 (1982), 123-142, 124.

91 Charles W. Jones, *Polemius Silvius, Bede and the Names of the Months*, Speculum, 9 (1934), 50-56, 53.

92 Charles W. Jones, *The Victorian and Dionysiac Paschal Tables in the West*, Speculum, 9 (1934), 408-421, 408.

93 Charles W. Jones, *A Legend of St Pachomius*, Speculum 18 (1943), 198-210 , 209.

Figure 8 Hervagen's 1563 rota



unam unciam & dimidiam reddunt hoc modo: Tria momenta, & tertia pars unius momenti, unciam faciūt.
n & dimidium, & sexta pars unius momenti, dimidiam unciam complent.

am superius de
, per omnia ac-
iaris conuenire
im recessus atq;
r Laedon natura
rsum obseruāt.
r signa cursum
rram quotidia
ta maris acces-
sus, eiusdē spa-
ad terram ac-
t. Et sicut luna,
& semuncia:
lius (uerbi gra-
a est, aut post
s moratur: si-
t recessus eodē
m heri fuerat,
nim animal ad
a mare. Qui,
idie bis afflue-
, id est, bis ac-
tent unius sem
ect transmisso
enta triginta:
idium, & se-
missa, id est, transfacta, ad similitudinem lunae uidetur. Eiusq; scilicet oceani. Omnes cursus, id est, cōtractus.
atinus sermo, id est, laesa unda. Restringitur enim & repercutitur unda, quia non dimittitur tantum ire per



Bede would later also perceive the problem of time as crucial.[94] It had become a problem to equate one Easter-table with another. Even within a single province everyone calculated their era, new year's day, or cycle of intercalations differently.[95] Bede tells us that he wrote three pieces on time: *On the Nature of Things* (*De Natura Rerum [DNR]*), *On Times* (*De Temporibus*) and also *One Larger Book On Times* (*De Temporibus Ratione [DTR]*). Hervagen invented the last title in 1563, to distinguish it from the shorter *De Temporibus*.[96]

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[94] Charles W. Jones, *Some Introductory Remarks on Bede's Commentary on Genesis*, Sacris Erudiri, 19 (1969/70), 115-198, 115.
[95] Charles W. Jones, *Bede as Early Mediaeval Historian*, Medievalia et Humanistica, 4 (1946), 26-36, 28.
[96] Bede, *A History of the English Church and People*, ed. Leo Sherley-Price (rev. ed., London, 1968), 338. On the title of *DTR*, see Charles W. Jones, *The Byrhtferth Glosses*, Medium Aevum, 7 (1938), 81-97, 87.

Bede treated tides in *DNR*, repeating what Strabo and Pliny had previously set out, and then in a more original fashion in *DTR*.

In Ireland and Britain, the seventh-century Paschal controversy propelled computistic knowledge to a higher level, than had so far obtained on the Continent. Bede did more than popularise the Dionysiac table, developed in 532. Besides describing the Dionysiac tables, in his *DTR* of 725, offers an extended commentary on Easter-tables and calculation. He intended this larger work on chronology to clear up the confusion existing on both sides of the Irish Sea once and for all. As his primary sources, Bede used extant *computi* resembling the Carolingian Berlin MS 128 and St. Gall MS 248.[97] *DTR* was a textbook at European higher schools for centuries to come. When Johannes Noviomagus published Bede's work in 1537, it was for their practical value.[98] Bede and Dionysius Exegius stood in the same relation to computistical science, as Euclid stood to geometry.[99]

## 4.5 EXPLICIT FUNCTION

The *rotae* depict the moon, circling a world encompassed by an ocean. The moon waxes and wanes, as it traverses continents beset by tides. *Rotae* make the cyclical nature of time and tide more evident than tables do. Yet the list in *C* constitutes an interesting compromise. There, the author sets out how a month divides into four parts according to tidal action, as in Bede:

> In alternating periods of seven or eight days, they divide up the month among themselves in their fourfold diversity of change. Sometimes by equal shares both fill up their course in 7 1/2 days; sometimes they will arrive earlier or later, ..., with the result that sometimes their order is upset, and the *malina* tide claims more in this month, and less in the next.[100]

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[97] Jones, *The 'Lost' Sirmond Manuscript*, 207.
[98] Joannes Bronchorst, *Bedae Opuscula complura de temporum ratione diligenter castigata: atque illustrata veteribus quibusdam annotationibus una cum scholiis in obscuriores aliquot locos*, (Cologne, 1537).
[99] Jones, *Bedae Pseudepigrapha*, 2.
[100] Quoted from Faith Wallis, *Bede: The Reckoning of Time* (Liverpool, 1999), 84.

Tides, used in *computus* as a metaphor, explain how days, months and years fit into a calendar. The diurnal, menstrual and annual time units are not absolutely reconcilable; tides also show this variance. The proximity of an embolismic table to the tables in *F-J* strengthens this argument. In his manual, for the unlettered clerks who were destined to serve in parishes, Byrhtferth had to take recourse to the vernacular and a simple syllabus.[101] This may offer a possible explanation for the contradiction found between the simple *F-J* and the complex *A-E*.

Knowledge of the semi-menstrual tide existed at the latest by Pliny's time.[102] But the *rotae*, list and tables go further than that; because they correlate tidal activity to four defined parts of a month. They do this on a daily basis. They also add a tidal nomenclature. The basic lunisolar tidal response is to the synodic month of about 29 ½ days. The *rota* employs 30 segments. It puts the new moon in the top segment, as in Figure 6, at the 30th day.[103] The age of the moon then counts out clockwise, being one day old in the segment *Luna 1*. From Pachomius and the Nicene Council, came the determination that Christ arose during the fourteenth moon, on or after the day when the moon has aged fifteen days.[104] The tidal diagrams count out the age of the moon. The third-century Roman author Augustalis introduced the epact, the age of the moon at the start of the calendar year.[105] Whilst the author of the Paschal Chronicle of 630-641 receives credit for invention of the *rota*, they are probably of a classical origin.[106]

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[101] C. Hart, *Byrhtferth and his Manual*, Medium Aevum, Vol 41 no 2, (1972), 95-107, 96.
[102] Pliny, Natural History, Books I-II, ed. and tr. Harris Rackham (Loeb Classical Library 352)(rev. ed., Cambridge, MA, 1991), 345.
[103] Frances R. Lipp, *The Carolingian Commentaries on Bede's De Natura Rerum*, (Ph.D. dissertation, Yale University, 1961), 6.
[104] Jones, *A Legend of St Pachomius*, 208.
[105] E.G. Richards, *Mapping Time* (Oxford, 1998), 349.
[106] Jones, *Bedae Pseudepigrapha*, 61.

## 4.6 COMMENTARY, WINDS & MAP

Bede expanded *De Temporibus* into *DTR* and never rewrote his *DNR*; *t*he task of explaining which, true to the Benedictine tradition, fell to later commentators. Although the intellectual ferment of the Benedictine reform produced outstanding scholars, Byrhtferth's was a lesser mind than that of Bede.[107] Byrhtferth's manual and other types of *computus* appeared after the bloom of the Carolingian period.[108] However, the utility of *computus* ensured their continuance into the early printing period.

Jones describes that edition of Bede's work on time, which came from the Basle presses of Johannes Sichardus in 1529, as the *editio princeps*.[109] Johannes Noviomagus followed in 1537 with an edition, which included a simplified *rota*.[110] This *rota* featured an interior Europa uppermost, accompanying *DNR*, and a *scholium* to explain the *rota*. Traditionally, the Johannes Hervagen edition of 1563 supplies the body of Bede's scientific works, but it is corrupt.[111] Hervagen added to Bede the *Vetus Commentarius* and Noviomagus' *scholia*, which he described as *Bridferti Ramesiensis Glossae*.[112] The commentary accompanies a *rota*, repeated twice in an identical form. The *rota* is tilted twelve degrees; the tilt may have been in order to save space but this publication was twenty years after the death of Copernicus. This is the *rota* reproduced in Migne's *Patrologia*.[113]

In *B*, the passage in the *Vetus Commentarius* that relates to the *rota B* reads as follows:

> The next wheel pertains to the harmony of the sea and the moon, if they agree, which is greatest, as Bede teaches in (his) book *On Times*. For the flood and ebb of the ocean are brought twice daily to come and return again, that is to say on the rising and setting of the moon. And these risings are divided into *ledonas* and

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[107] Hart, *Byrhtferth and his Manual*, 104.
[108] See for example: British Library, Regius 13 AXI, f137r, Egerton 3088, f19r, Cotton Tiberius EIV f71r; Cambridge, St. John's 221, 15.1, pp. 3, 71, 72.
[109] Jones, *The Byrhtferth Glosses*, 82.
[110] Bronchorst, *Bedae Opuscula*, f.17v-18r.
[111] Jones, *Bedae Pseudepigrapha*, 14.
[112] Jones, *Bedae Pseudepigrapha*, 14.
[113] Jean-Paul Migne, *Patrologia Latina*, vol. 90 (Paris, 1904), cols. 259-260, 277-278, 385-386, 423-424.

> *malinas*, that is into lesser and greater tides. The *malina*, it is clear, is from the greater moon, and the *ledona* flows as if one spoke of a loss. These flows, when they begin or for what time they last, are noted in the diagram. And the inside wheel has the names of the three parts of the world. The space which is outside this stands for the air surrounding the earth on all sides and has the names of the winds blown by the air. And thus the outer wheel has the ages of the moon from the first to the thirtieth. Beneath this, which is the short line containing letters in red, it signifies the water of the ocean which surrounds the world. And below this the drawn line contains the number of days by which the aforesaid tides advance and recede, whereby against the first number is always denoted on the outside at what age of the moon should it begin to arise, whether those flows be *maline* or *ledone*.[114]

Although the above was probably composed near the year 900, its author remains anonymous; Abbo left us a Latin text of it. The text associates the regular patterns of the sea and the moon, with the wind direction and place. It offers a description of the concord between sea and moon; so much so, that it becomes more a discussion of the tides than of computing. This commentary is the only known description of the Carolingian *rotae*, which is roughly contemporary to them. The description of tidal flow simply covers *rota B*, joining somewhat abruptly to that of the pointing devices. Without illumination, the medallions of folio *B* lack orientation.

*A* does not name the four cardinal points, on which the world hinges. As Strabo said, there are really only two directions, the poles – *βορέαν* and *νότον*.[115] However, it is not without import that the four cardinal points can be contrived into spelling out the name Adam: *ανατολή, δύσις, αρκτος, μεσημβρία*; east, west, north, south.[116] This list is drawn from a Latin

[114] "Sequens rota pertinet ad concordiam maris et lune si concordat que maxima est ut Beda docet in libro de temporibus. Nam aestus oceani cotidie bis venire et remeare perhibetur in ortu scili[c]et et occasu lune. Accensus autem ipsi in ledonas ac malinas dividuntur id est in minores ac maiores æstus. Malina patet a maiore luna et ledona quasi lesa dicitur. Qui accessus quando incipiant vel quantum temporis teneant signatum est in figura. Nam interior rotula trium partium mundi habet nomina. Spatium quod extra hanc est æris terram undique cingentis tipum gestat unde et ventorum per ærem flantium nomina habet. Exterior sane rota ætatis lune habet a prima usque ad xxx^mam^. Subtus hanc que est linea brevis ex minio continens litteras aquam significat oceani qui totum orbem circuit. At infra hanc ducta linea numerum continet dierum quibus accedunt vel recedunt prefati æstus. Unde semper contra primum numerum est de foris signatum quota luna incipiat quisque eorundem accessuum ad maline vel ledone exortum." Note that there are some small variations between B and Migne's *Patrology*. A readily accessible extract of the *Patrology* is found also in Deacon, *Scientists and the Sea*, 34. I am grateful to M. C. O'Regan, of Leeds, for both the translation and transcription.
[115] H.L. Jones, *The Geography of Strabo*, (Cambridge, MA, 1989), 105, referring to Strabo, *Geography*, 1.2.21.
[116] Marina Smyth, *Understanding the Universe in Seventh-Century Ireland*, (Woodbridge, 1996), 282.

translation and does not conform to the order in the original Greek. The order would have been familiar to the seventh-century Irish, reflecting the ancient Indo-European view of direction, where one stands facing the rising sun. *A*'s cardinal bilaterals extend this concept further, with *dextra subsolani* and *sinistra subsolani*, replicated for *austri* and *favoni*, but not for *boreas*. As winds, these twelve directions were named by Aristotle, set into a rose by Seneca and carried into the Middle Ages by Isidore. In Greek antiquity, the division of the wind-rose by eight points had for some time replaced an earlier form, of twelve divisions. It was Pliny who reintroduced the twelve points.[117] The deficiency of the twelve-point rose, which is not subject to simple halving, was shown by Bede. In the absence of an inter-cardinal he had to employ a circumlocution. This was to express that the first-of-flood comes when the Moon is "at about the Winter Sunrise."[118] This inter-cardinal, or solstitial, is south-east at Jarrow. Two other wind roses, one exhibiting twenty-four points and the other sixteen points, are adapted as compasses.[119]

The central T-O maps in *A*, *B* and *D* are of the *oikoumene* – the known, inhabited world.[120] The earliest extant diagrams hail from the seventh-century and are found in the *De Natura Rerum* of Isidore, who in turn drew from Aeschylus (525-456 BC).[121] Their divisions are those of Macrobius and also correspond to what St. Augustine had in mind in *De civitate Dei*.[122] These maps became commonplace in the eighth century with some showing Africa and Europe in a reverse position.[123]

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[117] Lipp, *Carolingian Commentaries*, 28.
[118] Wallis, *Bede*, 85.
[119] For the 24-point wind-rose, see Paris, Bibliothèque nationale de France, N.A. 1615, f128r-f135r. For the sixteen-point wind-rose, see Rome, Biblioteca Apostolica Vaticana, Regin.Lat. 1260, f1r-7v. For their adaptation to the use of compasses, see Lipp, *Carolingian Commentaries*, 4.
[120] Wesley M. Stevens, *The Figure of the Earth in Isidore's De Natura Rerum*, *Isis* 71 (1980), 268-277, 268.
[121] Leo Bagrow and R.A. Skelton, *History of Cartography*, (London, 1964), 45.

## 4.7 THE IMPLICIT MESSAGE

The words *aqua*, *malina* and *ledon* are employed in their tidal meaning, as can be seen from the following. *B* and *E* are accompanied by a short text on tides. *B*, *F*, *G*, *H*, *I*, and *J* each bear the title *Concordia maris et luna*. That is the chapter 29 title of Bede's *DTR*, "The harmony between sea and moon," – which is a treatise on tides. The MS folios preceding and following *A* are not contiguous with it. The verso shows that *A* is set within a text on navigation and the *aquilo* wind.

*Aqua* is evidently used in its narrow sense of 'tide.'[124] *Malina* and *ledon* have, at times, been translated as 'spring' and 'neap' respectively.[125] As we have already alluded to, they do carry that meaning in *A-E* but have the opposite meaning in *F-J*. Let us accept the following definitions, "Neap tides are: tides of small range which occur twice a month, when the moon is in quadrature; Spring tides are: semidiurnal tides of large range which occur twice a month, when the moon is new or full."[126] Note that at Jarrow, by Bede's monastery, springs occur 2 days after syzygy (the actual moments of new or full moon).[127]

*A-E* show the four parts of the monthly lunar phase, where *malina* tides alternate with *ledon* tides. This is in explicit correlation with springs and neaps. The middle of each set coincides with a point two days after syzygy and quadrature. The reverse correlation, first of the *ledon* and then of the *malina* sets relating to springs and neaps, is found in *F-J*. The main testimony, from which this contradiction stems, gives a further source of confusion. Bede said:

> When the tides are increasing, they are called *malinae*, and when they are decreasing, *ledones*. .... Hence we have ascertained that the *malina* often begins

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[122] Smyth, *Understanding the Universe*, 27.
[123] Cf. e.g., Cambridge, St. John's, MS 221, 15.1 3; Stevens, *The Figure of the Earth*, 275.
[124] For the sub-meanings of *aqua*, see D. P. Simpson, *Cassell's Latin-English Dictionary*, (London, 1997).
[125] R. E. Latham, *Revised Medieval Latin Word-List* (Oxford, 1994), x and *s.v.*
[126] Pugh, *Tides, Surges and Mean Sea-Level*, 460-2.
[127] The Hydrographer of the Navy: *Admiralty Tide Tables*, 1 (Somerset, 1998), 94.

> about five days before the new or full moon, and the *ledones* the same number of days before the half moon.[128]

In the language of Bede, the smallest neaps occur about five days before new and full moon, and then increase; the largest springs occur about five days before each half moon, and then decrease. Bede refers to the set of tides which are changing their state, that the set is either increasing or decreasing, rather than to the set which is of large or small magnitude. In the same tract, Bede adds to the confusion when considering the inequality of the semi-diurnal tides on his own shore:

> Indeed, when an evening tide occurs at the full or new moon, it will be a *malina*, and for the next seven days this same *malina* tide will be greater and stronger than the morning tide.[129]

The statement adds extra contradiction by saying that the *malinae* are the tides of the first and third quarters, that is from syzygy to the quadrature following. The result is four possible meanings. According to the OED, *ledon* is originally a Greek expression. Neither *malina* nor *ledon* appear in classical Latin, as their earliest known use is by Marcellus Empiricus (fl. *ca.* 475). The *Dictionary of Medieval Latin from British Sources* defines *ledon* as meaning both ebb and flood.[130]

Smyth had noticed the Bedan contradiction in 1996.[131] Bede had been called upon to refute the Irish in the Paschal dispute, which he did in his *Epistola ad Wichendam*.[132] In the process, he brought himself into the most vibrant contact with Irish scholarship. That tradition relied on whatever it could gather of the tidal lore of antiquity, adding to it the results of their own observations. After all, Ireland is situated amidst the most dominant tides of the world to the extent that it was known at the time. The Irish works show a

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[128] Quoted from Wallis, *Bede*, 84-5.
[129] Wallis, *Bede*, 84.
[130] R.E. Latham and D.R. Howlett, *Dictionary of Medieval Latin from British Sources*, Fascicle 5 (London, 1975), 1577-8.
[131] Smyth, *Understanding the Universe*, 256n.
[132] Jones, *Polemius Silvius*, 51.

distinctly classical flavour and a great knowledge of secular scientific works. This knowledge was obtained through the intermediary works of grammarians, who had very little understanding of what was involved, and hence only provided rudimentary outlines of the technical sources.[133] In *De Genesi ad Litteram*, St. Augustine (354-430) had written on tides, as had Philippus Presbyter of Sidetes (d. 455/6), in his *Commentarii in librum Iob*.[134] Cited by Bede, the latter commentary is a treatise that underlies early medieval Irish knowledge of tides.[135] The Irish tidal texts are *De Mirabilibus Sacrae Scripturae (DMSS)* by Augustine, dated to 654 or 655, and the *Liber de Ordine Creaturarum (LDOC)*. The latter, previously ascribed to Bishop Isidore of Seville (560-636), is nowadays understood to be of Irish origin; it was written after 655 but before 700, that is, before Bede's *DNR*.[136] These sources attempt to explain miraculous events rationally. Their information was taken from observation and makes direct reference to the physical world; it was used to extend both Christian sources and physical theories, inherited from such secular sources as Pliny.[137]

Both *DMSS* and *LDOC* contain explicit descriptions of tidal patterns. But Marina Smyth, in her *Understanding the Universe in Seventh-Century Ireland*, does not think that this is the case.[138] The texts indicate a *malina* flood of five hours and ebb of seven hours for some unspecified place. *DMSS* sets the *ledon* tides at six hours each, of both flood and ebb, and specifies that they alternate weekly with *malinae;* and states that their alternating inception is at three and a half days prior to quadrature and syzygy. This difference in the tidal descriptions is part of the normal variation within tides; it could have its origins in the different practices of exactly where, in relation to the solstice and equinox, a season was taken to begin or end. The Irish defined them in the middle and the Greeks at the start.[139] Springs or *malina* tides are merely big tides, neaps or *ledon* tides are merely small tides. Big

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[133] Smyth, *Understanding the Universe*, 20-1.
[134] Migne, *Patrologia Latina*, vol. 26 (Paris, 1904), 752D.
[135] Smyth, *Understanding the Universe*, 27 and 137.
[136] *Ibid.*, 11-3.
[137] *Ibid.*, 27.
[138] *Ibid.*, 11. Note that the interpretation on page 11 contradicts the translation on page 252.

and small are only relative terms. On the other hand, *LDOC* is more specific than *DMSS*, it attempts the more exacting terms later to be used by Bede in *DTR*.

> And the *malina* is observed to have such great agreement with the moon, that the moon is always born in the middle of it; and diligent investigation shows it to last for seven days and twelve hours and the fourth part of a day.[140]

This omits the drag between syzygy and top springs, of one or two days. But, as both Pierre Duhem and Smyth argue, it depicts the medieval "desire to show the wonderful orderliness of the universe."[141] *Malinae* and *ledones* can be identified with modern springs and neaps, because they are entire sets, as Bede's *rotae* and tables indicate. This result is in disagreement with Smyth, who takes the springs and neaps to designate only the few *maxima* and *minima*.[142]

Posidonius, in the first century before Christ, Strabo and Pliny, and the Christian writers Basil, Ambrose and Augustine all reported that soft substances could wax and wane with the moon. St. Augustine had written on the two possible causes of lunar phase.[143] The fifth-century Marcellus Empiricus refers to the phases of the moon when herbs are best gathered. This constitutes that first usage of the terms *malina* and *ledon*, that has been mentioned earlier.[144] Isidore of Seville subsequently associated the words with tides. The late seventh-century *Hisperica Famina* also describes a *malina*, and in such a way that it fits the meaning of a 'top spring' superbly.[145] As it was the Irish who eventually applied *malina* and *ledon* to a technical analysis of the behaviour of the tides, these two word's derivation is possibly from the Celtic language. It seems to have been the Irish who had recognised a relationship between lunar age and a repeated alternation of two tidal types. Isidore also used the Greek

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[139] *Ibid.*, 153n.
[140] *Ibid.*, 257.
[141] *Ibid.*, 258.
[142] *Ibid.*, 253.
[143] *Ibid.*, 24.
[144] Latham, *Revised Medieval Latin Word-List*, x.
[145] Smyth, *Understanding the Universe*, 255.

term *rheuma* to describe flow in a medical sense; whereas, using the fourth century Vegetius as his source, it was Bede who applied the word to tidal flow.[146]

*Rotae* also provide witting testimony to the prevailing pre-Copernican geocentricity. The computists, or at least the best of them like Bede, were intimately engaged in the study of the actual universe. The *Vetus Commentarius* in fact contains an unusual assertion, of the inferior planets circling the Sun. Martianus Capella had stated this earlier in 439.[147] The commentary refers to Pliny more than once, whereas Bede often concealed his sources if their orthodoxy seemed questionable.[148] Generally, the science of the Carolingian masters was contained in a book if it was original, and in glosses if unoriginal.[149] Whilst the Irish recognised the relationship between tidal magnitude and lunar phase, neither they nor Philippus directly related the delayed tides to the delayed moon. Clear awareness, of the course of the moon around a spherical earth, is necessary to recognise the full pattern in the correspondence.[150] Bede unequivocally espoused the round earth.[151] He knew a commentary probably transmitting the idea that Venus has a two-year cycle.[152]

Bede also corrected the commentators on Philippus regarding the *dodrans* – or the daily tidal retardation. [153] This term, which stands at the heart of an understanding of early medieval tidal data, has stirred the interest of both Jones and Wallis.[154] The tidal *dodrans* (three-quarters) of Philippus was of an equinoctial hour and equates with forty-five minutes. Much

[146] Charles W. Jones; *Bede and Vegetius*, The Classical Review, XLVI (Oxford, 1932,) 248.
[147] Jones, *Bedae Pseudepigrapha*, 31; William H. Stahl, *Martianus Capella and the Seven Liberal Arts*, vol. II, (New York, 1977), 333. For a discussion see: Bruce Eastwood, *The Astronomies of Pliny, Martianus Capella and Isidore of Seville in the Carolingian World*, in P. L. Butzer and D. Lohrmann, *Science in Western and Eastern Civilization in Carolingian Times*, (Basle, 1993), 161-180.
[148] Jones, *Bede and Vegetius*, 248.
[149] C. W. Jones; *Bede's Place in Medieval Schools*, in Famulus Christi. Essays in Commemoration of the Thirteenth Centenary of the Birth of the Venerable Bede, ed. G. Bonner (London, 1976), 272.
[150] Smyth, *Understanding the Universe*, 251.
[151] Thomas R. Eckenrode, *The Growth of a Scientific Mind: Bede's Early and Late Scientific Writings*, The Downside Review, 94 (1976), 197-212, 205.
[152] Smyth, *Understanding the Universe*, 27.
[153] A.K. Brown, *Bede: A Hisperic Etymology and Early Sea Poetry*, Medieval Studies, 37 (1975), 419-432, 419.

earlier Pliny, when speaking about the moon, had spoken of *dodrantes semiuncias* (one twenty-fourth), amounting to forty-seven and a half minutes.[155] Bede had utilised these in his *DNR*. Later, in his *DTR*, he moved beyond the term *dodrantes* and improved the retardation to four *puncti* (four-fifths), which amounted to forty-eight minutes. He continued in *DTR* to raise the accuracy of his descriptions, by stating that in fifty-nine days there are fifty-seven lunar meridian passes, and double that number of tides. This ratio, of the sun to both moon and tide, amounts to a retardation of about fifty minutes; it is the closest ratio to what is measured today. Clear in description and exact in calculations, Bede separated *dodrantes* from retardation.

As for those places where bores occur, the more an expected flood is delayed the greater is the likelihood of a bore being created. In commenting on Job 38:16, Philippus uses the term *dodrans* to mean that raging first-of-flood that evidences itself as a bore or eagre. This usage is shared by the author of *Hisperica Famina*, Columbanus and Aldhelm.[156] Springs or the *malina*, do cause wrack to be dumped up on the foreshore. The insular *dodrans* raging *trans delfinum dorsa*, has been translated as "over the backs of sea monsters."[157] This is rather romantic when compared to the ordinary dolphins of a staith[158] – *steaðweallas*. When *dodrans* is glossed into Old English, it is rendered *egor;* the spelling of which is so similar to eagre, and bores are created in springs. At that time the word is added to *malina*.

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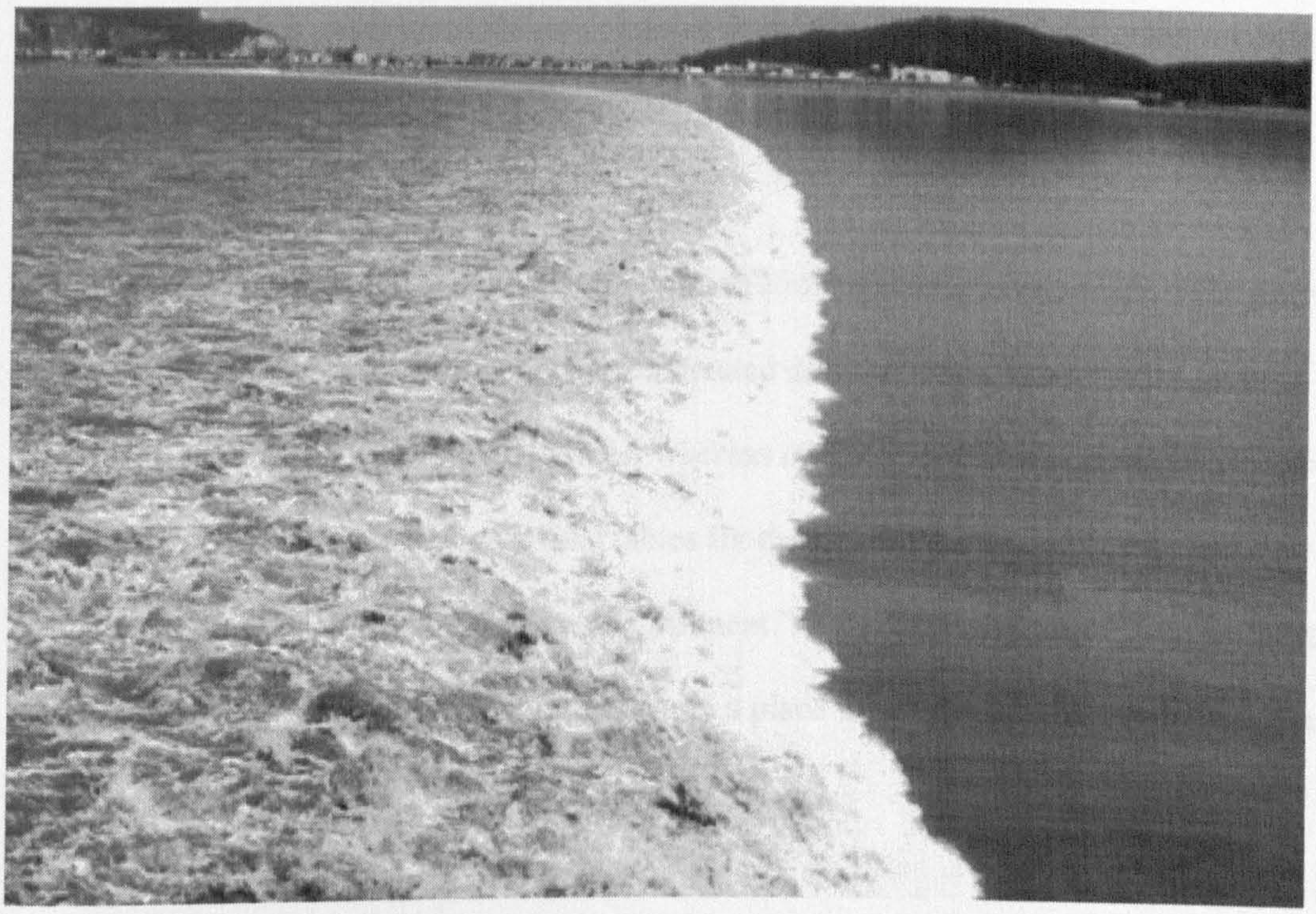
[154] Jones, *Bedae Opera de Temporibus*, 303-5; Wallis, *Bede*, 18 n31.
[155] Pliny, *Natural History*, ed. Rackham, 206 (Pliny, *Hist. Nat.* 2.11.58).
[156] Brown, *Bede*, 419-32.
[157] *Ibid.*
[158] Paul Hughes, *Staiths, the Early River Jetties of York, Hull and Howden*, Yorkshire Archaeological Journal, 71 (1999), 155-184.

Figure 9 The Chinese bore.



Note that the first-of-flood bore described by Philippus, is second only in quality to Alexander's description from the Indus.[159] Incidentally, the Chinese table, referred to in this introduction, is about the very same bore phenomenon (Figure 9).

## 4.8 CONCLUSION

In 1939, Jones described these tables with the adjective "tidal."[160] George Darwin, the nineteenth-century tidologist, had been deliberate in his definition: "The word 'tidal' should, I think, only be used when we are referring to regular and persistent alternations of rise and fall of sea-level."[161] It was the flow that was of concern from Bede to Robert Grosseteste and beyond.[162] The Irish "Augustine" had characterised the tides by the duration of flow; Philippus had clearly specified a particular regime of hours, though without citing a place. Without a place, little can be said concerning the utility of the hours indicated in *E*.

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159 Quintus Curtius Rufus, *History of Alexander*, tr. John Carew Rolfe, 2 vols. (*Loeb Classical Library* 368/9) (Cambridge, MA, and London, 1946), 445.
160 Jones, *Bedae Pseudepigrapha*, 69.
161 George H. Darwin, *The Tides,* (London, 1898), 1.

However, flow duration, strength and the vertical amplitude of a tide are bound together. Bede had explicitly understood the two types of flow, the astronomical and meteorological - such as the Nile flood. One of his sources being Vegetius' *Epitoma rei militaris*.[163]

The phrase "tide-table" for the data in all of these folios would be inappropriate; for since the late eighteenth-century, that phrase has indicated daily *extrema*. The Chinese and London tables are nominatively tide-tables; whereas most of the ones under discussion are adjectively tidal. Jones referred to: "tidal tables for the North Sea, copied without change at St. Gall and other inland Scriptoria on the Continent." Two points within that statement still puzzle. The ten manuscripts he lists do not name a place to which the tables refer; and some do have clerical changes (as indicated above).

The diagrams were used by computists to count incommensurable time periods by the moon and tide relationship. The apparent reversal of this relationship in *F-J* with respect to Bede's doctrine and the labelling in *A-E* does not disturb the calendar illustration. Whether *malina* is a spring tide or a neap tide is not pertinent to the division of the month. What is pertinent, is that there are four divisions, two pairs of *malina* and *ledon* tides.

Cosmography was among the source material available to Bede.[164] Bede had relied on pseudo-Isidore for his early belief that syzygy marked the middle of the *malinas*.[165] In his *DNR*, he talks of the "five circles of the earth" which are clearly represented in the coloured bold rings of *E*. With *DNR* being unoriginal, Bede subsequently wrote *DTR* at the behest of his students. In *DTR* he discussed the divisions of time within the natural year. He reconciled the Roman calendar with the Hebrew calendar to facilitate Easter calculation.[166] This was by

[162] Richard C. Dales, *The Text of Robert Grosseteste's* Questio de fluxu et refluxu maris *with an English Translation*, Isis, 57 (1966), 455-474.
[163] Eckenrode, *Growth of a Scientific Mind*, 200.
[164] Eckenrode, *Growth of a Scientific Mind*, 210.
[165] *Ibid.*, 198.
[166] *Ibid.*, 202.

bringing into use an established concept, that of nineteen solar years being identical to two hundred and thirty-five lunar months. The embolisms involved, just as in the embolisms in *F-J*, found a metaphor in tides.

Bede had a conservative Latin style.[167] *Incipit malina* and *incipit ledon*, used as variants in each of *A*, *B*, and *C*, indicate either the beginning of springs and neaps, or the beginning of the group of increasing and decreasing tides. At the time, it was commonly, but erroneously, maintained that springs at new moon are bigger than at full moon. Because of the addition of *augmentum* in *C*, in the set leading towards new moon, a simpler meaning of the big tides beginning becomes more acceptable than the inception of increasing tides.

After Bede, knowledge of the *computus* was lacking in England due to effects of disruption caused by Viking invasion, so that the Archbishops entreated Abbo to visit.[168] In 976 Abbo wrote a simple compendium to introduce young scholars to computistical science. This was based on Helperic of Auxerre's *Liber de Computus* of 903.[169] Obviously, Latin directly influenced the formation of Old-English sea terms. Aelfric's *De Temporibus* is an OE translation of parts of Bede's *DTR*.[170] Byrhtferth, too, composed his manual in the vernacular.

As already mentioned, the origins of *malina* and *ledon* are remote.[171] When employed by medieval writers such as Bede, their meanings were obscured by several differing explanations, but *ledon* was mostly taken for neaps and *malina* for springs.[172] William of

[167] Brown, *Bede*, 421.
[168] Hart, *Byrhtferth*, 95.
[169] *Ibid.*, 99.
[170] *Ibid.*, 98.
[171] See also: Migne, *Patrologia Latina*, vol. 122, (Prooemium XXVIII Auctor Incertus); Charles Du Fresne Du Cange, *Glossarium ad scriptores mediae Graecitatis* (rpt., Graz, 1958), Appendix 128 and 244.
[172] Migne, *Patrologia Latina*, vol. 89 (Willibaldus, Vita S. Boniface, 0632).

Malmesbury (d. 1143) and Roger Hoveden (d. 1201) appear to be among the latest users to directly analogue *malina* with springs.[173]

When the tides culminate, an observer of tidal waters in cloudy conditions can be certain that moon has been in syzygy. All ten diagrams provide that information. Bede reversed the message. He observed, that when a new or full moon coincides with the point of sun's winter rising, then the first-of-flood sets in at Jarrow. This happens to be the same rule as the one given in the Chinese tide-table. In a different guise, that observation was widespread by the late fourteenth century. By then, various texts were concerned with what bearing of the moon makes a full sea.[174]

There is very strong similarity of design between early tidal *rotae* and late medieval tide tables. In between these, about 1011, Bede continued to be known for his tidal learning.[175] For the scribes, the tidal phenomenon was invoked to explain how the calendar was driven by the heavenly rotations. Although it is obvious, that at inland scriptoria, few scribes would have had any familiarity with the tidal phenomenon itself.

The lists, *rotae* and tables stand out from the texts because they are diagrams. In *computus*, there tend to be few diagrams compared to the mass of texts. This renders the diagrams even more powerful. The *rotae* shown in this chapter should be compared to the one shown in the next. The circular diagram in the following chapter is not called a *rota,* it is one of what are called tidal diagrams

The simple power of this first capability in tidal prediction, is that it lasted for a thousand years.

[173] Migne, *Patrologia Latina*, vol. 179 (*Gesta Regum Anglorum*, 1153); Jones, *Opera de Temporibus*, 364.

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## CHAPTER 5 THROUGH LORE TO THEORY

### 5.1 INTRODUCTION

In the previous chapter it has been established that at least one Carolingian diagram can lay good claim to being the world's oldest tide table. This chapter begins with that early table of St. Albans, which is attributed to one of two monks from Wallingford. However, this table, previously considered to be from the early thirteenth century and Europe's oldest, under re-examination would now appear to be several decades younger.

Then, between 1375 and 1569 tidal diagrams became numerous, although few survive. The Flye diagram represents a high point of the Carolingian understanding already described. The state of tidal knowledge possessed by seamen, as it existed at the time of Newton, is then set out. This leads to an outline of some of the theoretical route that the subsequent research programme took to create a daily prediction method. The chapter introduces specific tidal nomenclature.

### 5.2 DAILY RETARDATION & THE WALLINGFORD TABLE

The Venerable Bede was among the earliest of tidal prognosticators. He treated tides in general and cited the tide in his locality. He also referred to the tide beyond his visible horizon, a viewpoint necessary to tidal understanding. The inland tide of his vicinity is derived from a distant ocean, and that ocean's tidal forcing is derived from the far away moon and sun.

Bede's exposition is complex and contains what appear to be contradictions. The confusion within his treatise was carried beyond the Middle Ages into the twentieth century.[176] Bede

[176] Thomas R. Eckenrode, *Original aspects in Venerable Bede's tidal theories with relation to prior tidal observations*, (PhD dissertation, Saint Louis University, 1970) p271.

spoke about the quantity of time by which the moon appears later each day. He said that in fifty-nine days there are fifty-seven passes of the moon. This can be re-phrased into the moon being retarded by fifty minutes per day. It is an accurate figure; and the tides, two per day, flex in concord with the moon. Therefore those semi-diurnal tides arrive at a mean fifty minutes later each day.

The Carolingian diagrams are divided into thirty segments, marking out the age of the moon. This amount of division is also found in the Brouscon almanac of 1546; with each counting out the age clock wise.[177] Thirty segments would allow counting of the tides and lunar age, to elapse at the rate of forty-eight minutes per day. Stemming from about the thirteenth century, this particular rate had been used at St. Albans.[178] Generally though, this division into thirty parts and an explicit usage of forty-eight minutes was not always given. As late as 1842, even Airy, the then Astronomer Royal, could refer to a highly distorted figure of forty minutes without attracting opprobrium.[179]

Catalonia, in Spain, was only ever briefly under the Moors before becoming part of the late Carolingian empire. The 1375 Catalan atlas is associated with the, by then, independent ruler. The atlas contains both a tidal diagram and a partial explanatory text. The diagram is divided into sixteen winds or compass points, although it does allow for a full thirty-two point compass rose. Thirty-two divisions could lead to an idea of the retardation being forty-five minutes per day but there is little evidence that this ever happened.[180]

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[177] H. Derek Howse, *Some early tidal diagrams*, Revista da Universidade de Coimbra, **33** 1985 365-85.
[178] Tony Dyson, *A thirteenth-century Thames tide table*, Ships of the port of London, volume 5, 1996, 216.
[179] George B. Airy, *Tides and Waves*, Encyclopaedia Metropolitana, (London, 1842) p241.
[180] c.f. Taylor, *The haven finding art*, 134; but see Greenvile Collins, *Great Britain's Coasting Pilot*, London, [1693].

The ascription of the Figure 14 tide table, to John of Wallingford, who died an abbot in 1258, may have been due to John Lubbock.[181] Lubbock's preoccupations were that of directing a bank and involvement in science. He had been informed of the table's existence by James Yates, the British Museum librarian. In conveying that information, Yates had merely indicated that the text lay among John's productions.[182] Lubbock unwittingly fixed it

[181] John W. Lubbock, *On the tides*. Philosophical Transactions of the Royal Society of London, **127**, 97-104, 1837.
[182] Royal Society of London (RSL), Lubbock papers, LUB Y.2.

to John. Recently, when the antiquity of the text attracted scholarly interest, its date was asserted to be accurate.[183]

As can clearly be seen, the tide table exhibits four influences: Latin, English, Arabic and Scandinavian.[184] Thirteenth century numerals were normally Roman; the Wallingford list uses Arabic. In the list, the numerals for four and seven resemble forms more prevalent in later centuries. Zeroes are represented by a mixture of both a simple circle, and the o symbol derived from the Scandinavian letter 'o'. Because Latin language does not explicitly accommodate tidal activity, the scribe had to resort to a vernacular phrase in the title. This discontinuity has the appearance of English as opposed to Anglo-Saxon. As English phrases only appear from the late fourteenth century, the formal dating of the list has to be called into question.

The list is of theoretical tide times. They age regularly each day, rather than irregularly as observations do. This theoretical approach, together with choice of numeral, may indicate an Arabic information supply. A slightly later abbot of St. Albans was Richard of Wallingford (1292-1336). As a clockmaker, he was much more overtly scientific than John. Altogether, Richard rather than John, looks to be the likelier author or scribe.

The Arabic science, represented in the list, had entered western minds by the twelfth century. Robert Grosseteste (d. 1253), studied at Paris and then taught at Oxford; by 1225 he based his tidal treatise on that ninth century science.[185]

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[183] Tony Dyson, *A thirteenth-century Thames tide table*, Ships of the Port of London, 1996, Volume 5 p216.

[184] British Library, Cotton Julius DVII folio 45b.

[185] Richard C. Dales, *The Text of Robert Grosseteste's* Questio de fluxu et refluxu maris *with an English Translation*, Isis 57 (1966), 455-474.

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## 5.3 THE FLYE OF 1569

Perhaps the most sophisticated tidal diagram of all, exhibiting full thirty-two points, is Philip Moore's *Flye*, of 1569. The diagram, held in private hands in 1937, then dissapeared from the view of several writers. While, the surviving fragment of Figure 15 was known about, I have only succeeded at the very conclusion of this thesis in locating the intact *Flye* at the British Library.[186] There, the *Flye*, catalogued by its unhelpfull incipit combining with an absence of the author's name, would account for its location difficulty across the intervening decades.[187]

Philip Moore, a Suffolk doctor, is thought to have obtained the substance of the diagram from the Dutch. Moore's *Flye* is a beautiful diagram of tidal information for North West Europe. The diagram is complex, and requires an interpretation as to its usage; beyond the title, it is without any accompanying text. In the same year, William Bourne (fl. 1565-88) published *A Regiment for the Sea*.[188] Bourne sets out some of the same material as Moore, and indicates how the diagram might be used; importantly he showed how to calculate the moon's age.

The number of divisions in the *Flye* matches the modern thirty-two point compass, with those divisions being explicitly to indicate a compass point. The *Flye* therefore is significantly different from all the earlier diagrams, by counting out neither lunar age nor daily tidal retardation but offering more. However all of this counting is encountered in the contemporary Bourne text. The text and diagram, together advanced tidal knowledge by their collation of a whole area.

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186 British Library, Harley 5937 f.9.
187 Eustace F. Bosanquet, *The flye*, The Library, Fourth series XVIII, 1938, 194-200.
188 Taylor, *A regiment for the sea*.

Both diagram and text deal with the direction of the syzygy moon to predict high water. The syzygy moon is when it is either new or full. The mariner had to consider a notional or mean moon. The direction of the syzygy moon was used to indicate the moment of high water; this could also be expressed in time, as well as with the reciprocal direction. Thus: at the Lizard, high water will come when the full moon bears west; notionally this will be at six in the evening; it will also be high water when bearing east, at six in the morning. The diagram unusually sets out the direction of the moon in the quarters.

The title of the *Flye* indicates that the tabulation was called by some mariners – the flye. The *Flye* does not give an actual rectangular table. What it does give, is a diagram of concentric circles. Tidal information is then contained within segments of the diagram. The word *Flye* was contemporaneously used to indicate a compass card.[189] The diagram does not have an explicit, direct orientation; although it is set north-up. It also sets out the tides around a rose of thirty-two points. The places are superficially set around the rose in geographic order; but closer inspection reveals they are in an order that actually represents tidal advancement along the coasts. The three coasts are: the English east coast from north to south, the corner of France from Belle Isle around Ushant, and the English south coast from west to east. Clockwise, they represent the conventional progress of the flood, and anti-clockwise the ebb. Therefore, the diagram basically considers the tidal stream. The diagram also gives symbols requiring further interpretation.

Table 8 comprises: an implied direction; the place[190], symbol and time from Moore; and three instantaneous states of the stream.[191] The list, taken from a circular presentation, begins with Berwick because that is how the table begins in Bourne.

[189] Leonard Digges, *Panometria*, (1571); S.T.C. 6858.
[190] The places named in the *Flye* which are no longer current have been substituted with suitable places extracted from the present day Admiralty tide table.
[191] Basil D'Oliveira, *The Macmillan Reeds Nautical Almanac*, (2002).

Table 8 Extract of stream table

| Dir. | Place | Sym. | Est. | -1 hr. | HW | +1 hr. |
|---|---|---|---|---|---|---|
| NNE | Berwick | | id | Ebb | Ebb | Flood |
| NExN | Holy Island | | ii | Ebb | Ebb | Slack |
| NE | R. Tyne | | iii | Ebb | Ebb | Slack |
| NExE | R. Tees | | iiii | Ebb | Ebb | Slack |
| ENE | Bridlington | | iiiid | Ebb | Ebb | Ebb |
| ExN | Spurn Head | | iiiid | Ebb | Ebb | Ebb |
| E | Blakeney | | vi | Slack | Ebb | Ebb |
| ExS | Cromer | | vii | Slack | Ebb | Ebb |
| ESE | Winterton | | viid | Flood | Slack | Ebb |
| SExE | Yarmouth | | viii | Flood | Slack | Ebb |
| SE | Lowestoft | | ix | Flood | Slack | Ebb |
| SExS | Orford Ness | | x | Flood | Slack | Ebb |
| SSE | Walton Naze | | xd | Flood | Flood | Slack |
| SxE | Sunk Head | | xi | Flood | Flood | Slack |
| S | Southend | | xii | Flood | Flood | Slack |
| SxW | Shivering Sand | | i | Flood | Flood | Slack |
| SSW | Harwich | | iii | Flood | Flood | Slack |
| SWxS | Belle Isle | | iii | Flood | Flood | Flood |
| SW | Pen March | | iii | Flood | Flood | Flood |
| SWxW | Fountness | | iii | Flood | Flood | Flood |
| WSW | St. Mathieu | | iiiid | Slack | Flood | Flood |
| WxS | Portsall | | iiiid | Slack | Slack | Slack |
| W | Lizard Point | | vi | Ebb | Ebb | Ebb |
| WxN | Start Point | | vi | Flood | Ebb | Ebb |
| WNW | Portland | | vi | Flood | Ebb | Ebb |
| NWxW | Bembridge | | x | Flood | Ebb | Ebb |
| NW | Eastbourne | | x | Flood | Flood | Ebb |
| NWxN | Rye | | x | Flood | Flood | Flood |
| NNW | Folkestone | | xd | Flood | Flood | Flood |
| NxW | Herne Bay | | xi | Flood | Flood | Slack |
| N | Faversham | | xii | Flood | Flood | Slack |
| NxE | Sheerness | | i | Flood | Flood | Slack |

The *Flye's* explicit purpose, as stated in the title, was to give the ebb and flood. The state of slack water is always a difficult thing to determine. Only recently has there been any real facility in making tidal measurements in the offing. At any given instant, the moment of slack water is a rare event. Therefore the fewest symbols, the six bisected ovals, may represent slack – or high water. This is borne out by there then being an equal thirteen representations each, of either flood or ebb, with the other two symbols. The plain oval represents flood, the trisected oval ebb.

The purpose of the diagram was also to give the time, at which the state of the stream was in. An almanac, slightly earlier than the *Flye*, set out tidal information in repetitive sheets for each compass point. A modern and much used extension of this concept is in a tidal stream atlas, a series of pictures, of the coast under consideration, related to each tidal hour at a control point – such as Dover.[192] I have used a modern version of these atlases, to extract the streams represented in the above list. There is a good fit for the streams when the coasts are at the moment of high water Dover.

Previous interpreters have given the purpose of the *Flye* as for the establishment of each port. That is not its primary purpose. The symbols lie in a higher order of importance to the establishment. Earlier commentators were unable to come to an interpretation of the symbols.[193] The explicit establishments are in lower case Roman numerals, with a δ for dimidia, or half-hour. Whilst, on each coast, the establishments are contiguous, they do not run onwards from the first numeral. Clearly Harwich and Shivering Sand are out of sequence in the above list. Their change of sequence would appear contrived, in order to maintain the time continuity. Further contrivance is that the French coast, with times of iii and iiiδ, comes between Harwich and the Lizard, at iii and vi respectively.

The only published reproduction, Bosanquet's of 1938, of the representative sheet of the *Flye* has its extent heavily curtailed. On the left, out of alignment with the west point is a small mark; on the right, in line with the east point is a cut off word. At the bottom, in line with the south point, is the inverted word *South*. It could suggest that the diagram expresses

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[192] See: Anonymous, *Brown's Tidal streams in twelve charts*, 17th edition (Glasgow, 1972).
[193] See: David W. Waters, *The art of navigation in England in Elizabethan and early Stuart times*, 1958, p129 & H. Derek Howse, *Some early tidal diagrams*, Revista da Universidade de Coimbra, **33** 1985, p380.

a state of the stream. Implicitly it would have to be for some control point, such as Dover. More probably, as the above list terminates in the Nore (Sheerness), that would have been the point. There may then have been other similar sheets; each of which would have had the symbols slightly shifted for each of the remaining tidal hours.

The *Flye*, clearly written in English, was for the use of English seamen. The dominance of eastern rather than southern ports would suggest a greater interest in the east. That it presents information skirting Ushant indicates its use to access Biscay. The omission of other French information in the Narrow Seas, combined with the presence of some southern English data, suggests the route adopted.

On the other hand it is easy to see the value of the information that the diagram provides. On a power driven ship, the mariner still navigates with a stream atlas open on the chart table. The information conveyed, would have been even more vital on a ship under sail. At its crudest, the *Flye* tells the mariner if the tide will push him shoreward. It also tells him when he most risks the strand.

Whichever interpretation one takes, the *Flye* holds a bird's eye view extending across several hundred miles of ocean. Whilst the basic tidal cycle runs for a mean twelve hours and twenty-five minutes, its ordinary variance is from twelve to thirteen hours. There is also a difference of longitude engaged with; this covers a local time difference of half an hour. At that time the globe was without the modern definition, but the diagram succeeds well in coping with the world. The *Flye* appears to have represented a more advanced state of hydrographic knowledge than has so far been expressed.

The following small mnemonic is anonymous, yet it holds the once essential lore displayed in the *Flye*.

Half flood at London Bridge
High water Swin.
Half ebb at Yarmouth Roads
Low water Lynn.[194]

## 5.4 PRIMING & LAGGING

The concept of adding a fixed period of time, as the moon aged, to the establishment for the change day, persisted into the nineteenth century. In the interim, Flamsteed took the empirical approach in 1683 and observed that part of the phenomena, later entitled priming and lagging. This is where the tide is only a little later each day at springs, and considerably later during neaps. John Flamsteed was a great astronomer, but an earlier notion of this concept had appeared in an account by Bourne – a gunner of Gravesend.[195] Bourne's humble account remains without scientific acknowledgment, but in between, Henry Philips had raised the concept with the Royal Society in 1668.[196]

For the Paris Academy prize of 1740, Daniel Bernoulli considered the matter from basic astronomy and decisively influenced tidal predicting for the better.[197] Bernoulli distrusted Isaac Newton's estimate of the ratio of the tidal potential, between the sun and moon. Bernoulli was concerned with the mean time intervals between high waters on successive days.[198]

The two largest tidal components, $M_2$ and $S_2$, attracted that particular notation in the nineteenth century. That notation is because $M_2$ is the semi-diurnal component emanating from the moon, and $S_2$ similarly from the sun. If the magnitude of $M_2$ is taken as unity then that of the sun is a little less than half, at 0.4652.

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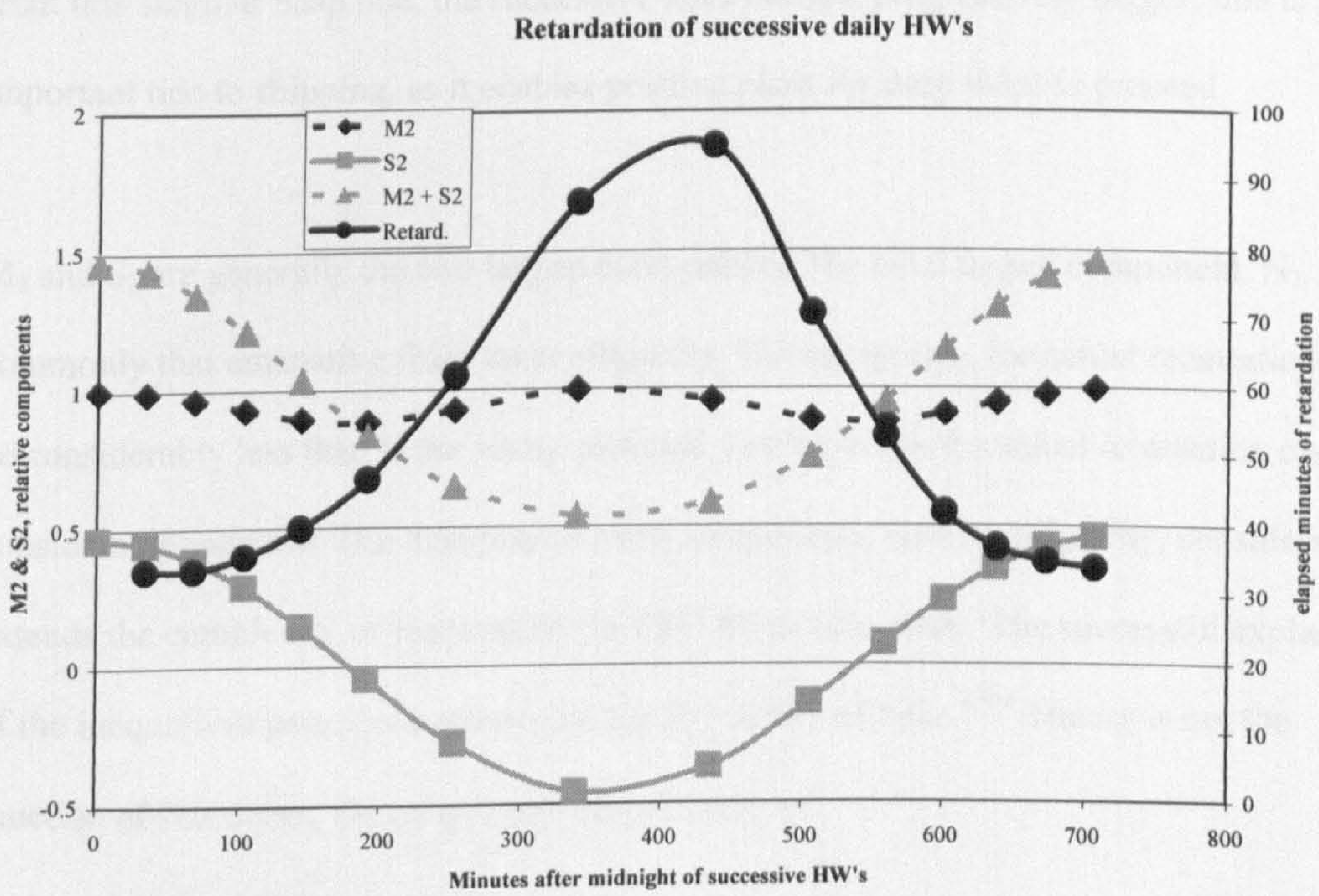
[194] Anonymous, Mariner's Mirror, 1913 **3(2)** 287.
[195] Taylor, *A regiment for the sea,* 67.
[196] Henry Philips, Philosophical Transactions of the Royal Society, 1668 **2,** 656-659.
[197] Daniel Bernoulli, *Traité sur le flux et reflux de la mer,* Principia Mathematica, 4 vols (Geneva, 1739-1741), volume 3.
[198] Cartwright, *Tides a scientific history,* p48.

The tides of NW Europe are strongly semi-diurnal and resemble characteristics found in the equilibrium tide. In that theoretical tide the moon is the main cause of HW. Over the cycle of springs and neaps the sun augments or diminishes this main cause. When $M_2$ and $S_2$ are beating in phase, they cause the spring tides; in anti-phase they cause the neaps. So the time of springs is when those components are largely in phase, the time of neaps when generally out of phase.

Figure 16 Beating of the two tidal components




Because the tide is retarded, the time of HW becomes progressively later each day. The difference shown on a 12-hour clock, between HW on two successive days, expresses this retardation. The retardation is also smallest when the two components are in phase. The difference is largest when they are in anti-phase. The beating (Figure 16) is a consideration of the two components of the equilibrium tide.

In Figure 16: the one x-axis applies to all four curves; the left hand y-axis applies to the $M_2$, $S_2$ and $M_2 + S_2$ curves; and the right hand y-axis applies to the retardation.

Spring tides are those tides which achieve a high level at high water; neaps are those which achieve a low level at high water. Mariners refer to the tide with the lowest level of neap high water as bottom neaps. The typical values are for the daily retardation to be 34 minutes during top springs, and to achieve a peak retardation of 95 minutes well after bottom neaps. There are several spring tides with successive HW's close together; priming is an arcane term for this clustering together. In contrast there is one neap tide with the largest lag between two successive daily HW's; this is when that one tide is the most retarded. At, or from this singular neap tide, the successive tides become progressively bigger; this is an important tide to shipping, as it enables positive plans for deep ships to proceed.

$M_2$ and $S_2$ are generally the two largest components. The third largest component, $N_2$, is commonly that emanating from lunar ellipticity. During springs, the actual retardation can be considerably less than in the above exercise. During neaps the actual retardation can considerably increase. The interplay of extra components, such as ellipticity, considerably extends the complexity of explanation. In 1955 Eric Aiton said, "The successful explanation of the inequalities provides a severe test for any theory of tides."[199] Theory is not the function of this thesis, but certain aspects are included.

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[199] Eric J. Aiton, *The contributions of Newton, Bernoulli, and Euler to the theory of the tides*, Annals of Science 1955 ii, 213.

Figure 17 Brisbane's tabulation for lunar distance

Sir Thomas Brisbane *on the Computation of High Water.* 55

| Moon's passage over Merid. Hours. | Moon's passage over Merid. Minutes. | Moon in Perigee. | Moon in her mean Distance. | Moon in Apogee. | Moon's passage over Merid. Hours. | Moon's passage over Merid. Minutes. | Moon's passage over Merid. Hours. | Moon's passage over Merid. Minutes. | Moon in Perigee. | Moon in her mean Distance. | Moon in Apogee. | Moon's passage over Merid. Hours. | Moon's passage over Merid. Minutes. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ′ | ′ | ′ | | | | | ′ | h ′ | h ′ | | |
| 0 | 0 | − 4.0 | 0.0 | + 5.5 | 12 | 0 | 6 | 0 | − 55.5 | − 1.2.5 | − 1.12.5 | 18 | 0 |
| | 10 | − 6.1 | − 2.6 | + 2.1 | | 10 | | 10 | − 52.4 | − 0.58.6 | − 1. 7.6 | | 10 |
| | 20 | − 8.2 | − 5.2 | − 1.2 | | 20 | | 20 | − 49.3 | − 54.8 | − 1. 2.8 | | 20 |
| | 30 | − 10.3 | − 7.8 | − 4.6 | | 30 | | 30 | − 46.1 | − 50.9 | − 0.57.9 | | 30 |
| | 40 | − 12.5 | − 10.5 | − 8.0 | | 40 | | 40 | − 43.0 | − 47.0 | − 53.0 | | 40 |
| | 50 | − 14.8 | − 13.3 | − 11.5 | | 50 | | 50 | − 37.7 | − 40.7 | − 45.3 | | 50 |
| 1 | 0 | − 17.2 | − 16.2 | − 15.0 | 13 | 0 | 7 | 0 | − 32.5 | − 34.5 | − 37.5 | 19 | 0 |
| | 10 | − 19.6 | − 19.1 | − 18.5 | | 10 | | 10 | − 27.3 | − 28.2 | − 29.7 | | 10 |
| | 20 | − 22.0 | − 22.0 | − 22.0 | | 20 | | 20 | − 22.0 | − 22.0 | − 22.0 | | 20 |
| | 30 | − 24.3 | − 24.8 | − 25.5 | | 30 | | 30 | − 16.7 | − 15.7 | − 14.3 | | 30 |
| | 40 | − 26.7 | − 27.7 | − 29.0 | | 40 | | 40 | − 11.5 | − 9.5 | − 6.5 | | 40 |
| | 50 | − 29.1 | − 30.6 | − 32.5 | | 50 | | 50 | − 6.3 | − 3.3 | + 1.3 | | 50 |
| 2 | 0 | − 31.5 | − 33.5 | − 36.0 | 14 | 0 | 8 | 0 | − 1.0 | + 3.0 | + 9.0 | 20 | 0 |
| | 10 | − 33.6 | − 36.1 | − 39.4 | | 10 | | 10 | + 2.1 | + 6.9 | + 13.9 | | 10 |
| | 20 | − 35.7 | − 38.7 | − 42.7 | | 20 | | 20 | + 5.2 | + 10.7 | + 18.7 | | 20 |
| | 30 | − 37.8 | − 41.3 | − 46.1 | | 30 | | 30 | + 8.3 | + 14.6 | + 23.6 | | 30 |
| | 40 | − 40.0 | − 44.0 | − 49.5 | | 40 | | 40 | + 11.5 | + 18.5 | + 28.5 | | 40 |
| | 50 | − 42.0 | − 46.3 | − 52.0 | | 50 | | 50 | + 12.7 | + 20.0 | + 30.3 | | 50 |
| 3 | 0 | − 44.0 | − 48.7 | − 55.0 | 15 | 0 | 9 | 0 | + 14.0 | + 21.5 | + 32.3 | 21 | 0 |
| | 10 | − 46.0 | − 51.1 | − 58.0 | | 10 | | 10 | + 15.2 | + 23.0 | + 34.1 | | 10 |
| | 20 | − 48.0 | − 93.5 | − 1.1.5 | | 20 | | 20 | + 16.5 | + 24.5 | + 36.0 | | 20 |
| | 30 | − 49.7 | − 55.6 | − 1.4.1 | | 30 | | 30 | + 16.2 | + 24.1 | + 35.5 | | 30 |
| | 40 | − 51.5 | − 57.7 | − 1.6.7 | | 40 | | 40 | + 16.0 | + 23.8 | + 35.0 | | 40 |
| | 50 | − 52.2 | − 59.8 | − 1.9.3 | | 50 | | 50 | + 15.7 | + 23.4 | + 34.5 | | 50 |
| 4 | 0 | − 55.0 | −1.2.0 | −1.12.0 | 16 | 0 | 10 | 0 | + 15.5 | + 23.0 | + 34.0 | 22 | 0 |
| | 10 | − 56.1 | −1.3.5 | −1.13.5 | | 10 | | 10 | + 14.4 | + 21.7 | + 32.5 | | 10 |
| | 20 | − 57.2 | −1.5.0 | −1.15.0 | | 20 | | 20 | + 13.3 | + 20.5 | + 31.0 | | 20 |
| | 30 | − 58.3 | −1.6.5 | −1.16.5 | | 30 | | 30 | + 12.1 | + 19.3 | + 29.5 | | 30 |
| | 40 | − 59.5 | −1.7.0 | −1.18.0 | | 40 | | 40 | + 11.0 | + 18.0 | + 28.0 | | 40 |
| | 50 | − 59.7 | −1.7.3 | −1.18.5 | | 50 | | 50 | + 9.2 | + 15.9 | + 25.4 | | 50 |
| 5 | 0 | −1.0.0 | −1.7.7 | −1.19.0 | 17 | 0 | 11 | 0 | + 7.5 | + 13.8 | + 22.8 | 23 | 0 |
| | 10 | −1.0.2 | −1.8.3 | −1.19.5 | | 10 | | 10 | + 5.7 | + 11.6 | + 20.1 | | 10 |
| | 20 | −1.0.5 | −1.8.5 | −1.20.0 | | 20 | | 20 | + 4.0 | + 9.5 | + 17.5 | | 20 |
| | 30 | −0.59.2 | −1.7.0 | −1.18.1 | | 30 | | 30 | + 2.0 | + 7.1 | + 14.5 | | 30 |
| | 40 | − 58.0 | −1.5.5 | −1.16.3 | | 40 | | 40 | 0.0 | + 4.8 | + 11.5 | | 40 |
| | 50 | − 55.7 | −1.4.0 | −1.14.4 | | 50 | | 50 | − 2.0 | + 2.4 | + 8.5 | | 50 |
| 6 | 0 | 55.5 | 1.2.5 | 1.12.5 | 18 | 0 | 12 | 0 | 4.0 | 0.0 | 5.5 | 24 | 0 |

*Method of Using the Table.*

EXAMPLE I.—Required the Time of High Water at Cork on the 21st October 1830, the Moon being in Perigee * ?

| | |
|---|---|
| Time of the Moon's passing the meridian, - - | 12ʰ 13′ |
| Correction in the Table corresponding to 12ʰ 13′, - - | — 7 |
| Time of the Greatest Action of the Sun and Moon, - | 12ʰ 6′ |
| Time of High Water at Full and Change, - - - | 4 54 |
| Time of High Water required, viz. at 5 in the morning, | 17ʰ 0 |

* The moon's horizontal parallax in the Nautical Almanack will determine whether the Moon is in her perigee, mean distance, or in apogee.

Childrey had described the effect of lunar ellipticity on the tides in 1670. His source appears to have been seamen's lore, and originated from about 1652.[200] Daniel Bernoulli's significant contribution to predicting tides, appearing in 1740, gave two tabulations of these inequalities. One is reproduced by Cartwright and the second is reproduced in chapter 8 (Figure 29). Both Aiton and Cartwright showed that the general corrective tables, which Lubbock published in 1836, descend from Bernoulli's earlier treatment. But that attribution is to ignore a highly detailed, interim tabulation (Figure 17). Sir Thomas Brisbane (1773-1860) gave this in 1821, only six years before Lubbock's interest awakened. In turn, the explanation to the table attributes much of the calculation to Pierre-Simon Laplace (1749-1827).[201]

## 5.5 THEORY AND PHENOMENA

For their intrinsic interest, tides have attracted systematic study for at least four hundred years. During which, many new terms have arisen, and with those terms overtaken by new ideas, they are then forgotten. Priming and lagging are such terms now, the concept perhaps only of interest to a few estuarial workers. Bernoulli's tables of priming and lagging derive from a theoretical basis. After that from St. Albans, Bernoulli's tables were the second set. However, arriving within the period of enlightenment science Bernoulli's were decidedly influential.

Tidal theory, teaching how tides form, retains a difficulty in explanation. Popular expositions rarely convince; and authoritative attempts by distinguished scientists have attracted the accusation of failure.[202] Yet even critics can contribute, as does the diagram from O & Kapp in Figure 18. As a graph, it stands between prose and a mathematical explanation; it succeeds with a simple but possibly misleading idea of the cause of semi-diurnal tides. Herein can be seen some of the difficulty of explanation, because 'it is the

[200] Eric J. Aiton, *Galileo's theory of the tides*, Annals of Science, 1954 x, 44-57.
[201] Thomas Brisbane, *Table for determing accurately the Time of High Water at any given Port*, The Edinburgh Philosophical Journal, 1821 volume iv, 54-56.
[202] Reginald O. and John G. Kapp, *On teaching how the tides are produced*, The School Science Review, volume 41 1960, 281-290.

horizontal and not the vertical component of the disturbing forces that are effective in the formation of tides'.[203]

Figure 18 The creation of semi-diurnal tides

THE SCHOOL SCIENCE REVIEW

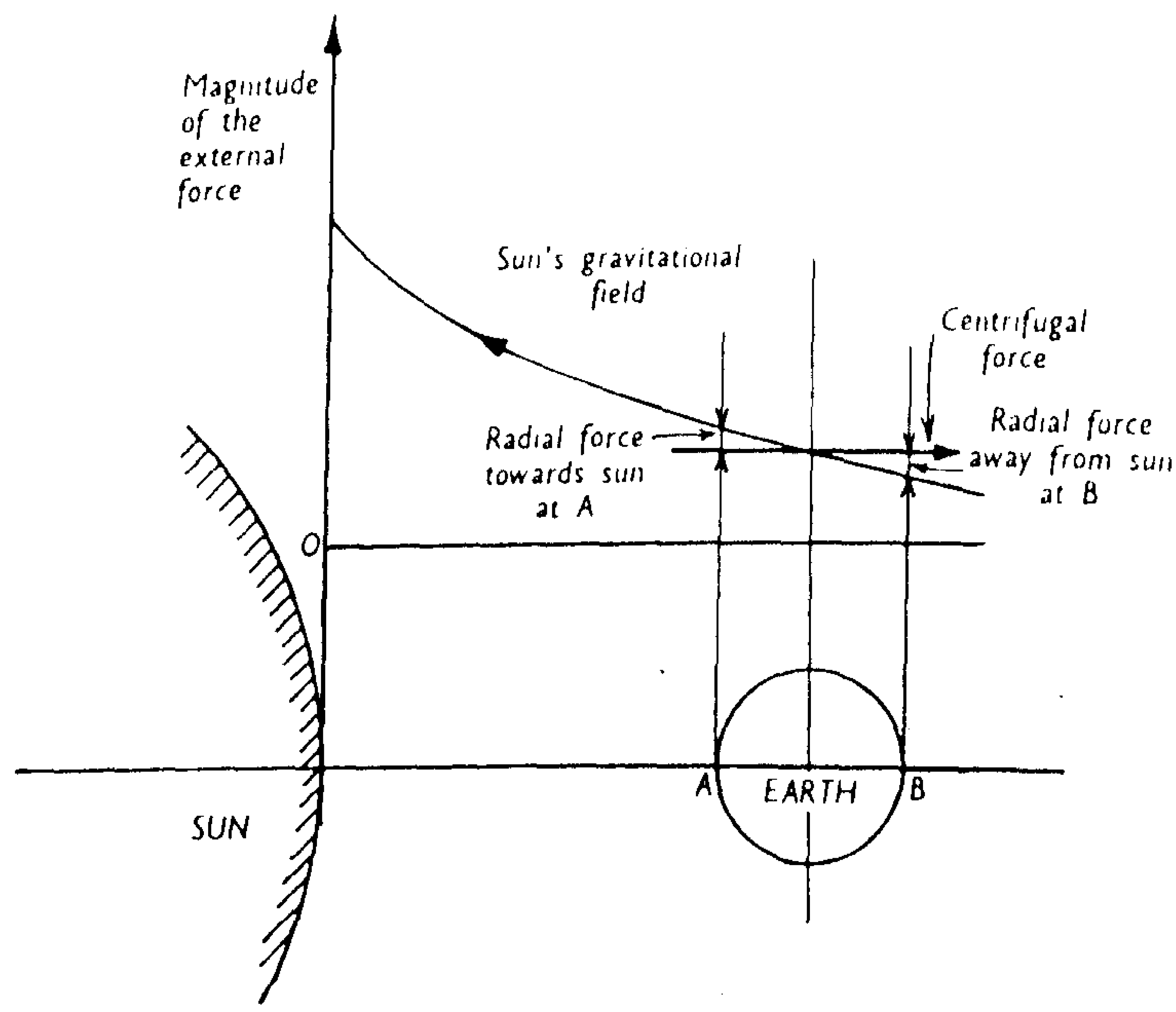


FIG. 1.—External forces on the earth.

With the body, either the sun or moon, in either the zenith or the nadir, the direction of the influence is wholly vertical. The influence then is only a variation in g, the gravity of earth; it has no sensible effect on the oceanic level. Forty-five degrees away, the influence is then between the vertical and horizontal. It is the horizontal component of this which provides the tractive force.

In the equilibrium tide, the lunar component mostly determines the height of HW. As the moon waxes and wanes, this lunar component contributes to HW at differing times of the day. The lunar component of the equilibrium tidal height is maximised at both the twelfth and sixth hour. Though still the most significant component, it is the lunar part of HW height which diminishes a little, at about the third and ninth hour.

[203] Eric J. Aiton, *The formation of tides*, The School Science Review, volume 42 1961, 380-388.

The clock rigidly fixes the solar component of HW, $S_2$; it does not change. The clock simply measures the sun. However, within the month, the time of the solar contribution moves around the clock as the lunar phase changes. With a relative lunar movement, the magnitude of the solar contribution varies considerably. Therefore, the solar augments the prime, lunar cause of equilibrium HW height at the twelfth hour, and diminishes at the sixth. The equilibrium tide developed by Newton is highly theoretical, meaning it accounts for the time of springs at twelve o'clock only.

In addition to the tables developed by Bernoulli, he gave formulae to calculate the effect of declination. It is from these, that Lubbock based his material tables, published in 1836.

Bernoulli and other mathematicians, notably Euler and Laplace, developed the dynamic theory of tides. This accounts for the ocean's depth causing its tide to delay behind the moon's daily progress, as the earth rotates. Euler was a joint winner with Bernoulli in the essay prize. His chief contribution was recognition of the horizontal component, of the tide generating force, as the effective part. Laplace first treated the theory of the motion of fluids in 1774, and which he elaborated in his later *Mécanique Céleste.*[204] Both the vertical and horizontal components of the tide generating force are of the same magnitude order. Compared to Earth's gravity the vertical component is small and has negligible effect. The effect of the horizontal component is to cause movement in the ocean, known as the tractive force.

During the nineteenth century, the configuration of ocean basins and the Coriolis force then attracted greater attention. Whewell, working in the southern North Sea, identified a place around which the tides rotate. At this amphidromic point, the water level remains steady. In the amphidromic system, a wave of HW crest circulates once each tidal period.[205] In the

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[204] Pierre-Simon de Laplace, *Traité de mécanique céleste*, (Paris, 1878).
[205] Open University, *Waves, tides and shallow-water processes*, (Milton Keynes, 1989).

system, the height of HW increases the further from the amphidromic point. Thomson then developed the Kelvin wave where the system is confined. The American, Rollin A. Harris, further developed resonance and standing wave systems in the decade from 1897.

Both the dynamic theory and the amphidromic system allow for the basic cycle of springs and neaps to appear at different localities at any hour.

The height of a tide leads to a multitude of local curiosities. Southampton is noted for its double HW. In Holland a double LW is known as the agger. The tide in Tonking varying directly with lunar declination, rather than phase, is what once attracted Newton's attention. Rivers strongly attenuate the tides' duration of flood and extend that of the ebb. When this bias becomes particularly severe a bore forms. Famous ones occur on the Amazon, Hooghly, Seine, Severn, and Tsientang.[206]

Sometimes a curiosity is more of a man-made contrivance than that of nature. One now defunct fact, remarked on every year in the Admiralty tide tables for the first half of the twentieth century, was that the tide at Hull laid exactly on the sixteen feet mark at three hours either side of HW.

At Hull, they had systematically observed the tides since the beginning of the nineteenth century.[207] The oddity was reported to William Whewell early in the century, and then in 1850 came a new dock.[208] Showing heights above the sill, the dock wall had numerals etched into the stonework; this allowed a better and more useful place of observation. Within a

[206] Photographic imagery of bores exist: William H. Wheeler, *The aeger in the rivers Trent and Ouse*, Nature, No 1880 volume 73, November 9 1905, 29-30; Royal Geographical Society, CO59/005332-5 The tidal bore at Haining Chou.
[207] T. Saunderson, *The Hull tide table calculated astronomically and corrected by careful observation during the last thirty years*, (Hull, 1833).
[208] Trinity College, Cambridge, Whewell papers R.6.20[18](hereafter Whewell).

year, following supply of records to the Admiralty from an automatic gauge,[209] the British Association for the Advancement of Science heard a report of the apparent phenomenon, in 1861.[210] As was their way, they appointed a committee to investigate the curiosity. Nevertheless, the committee were zealous in their endeavours, and furnished a short report to the Association in 1864; it was complete with numerous observations but was without a conclusion on cause.[211] The earliest report, that to Whewell, had attributed its likely cause to the speed of the ebb. Here, it is the ebb which is stronger than the flood lower down the estuary, at Immingham.

While the tide reached that height, at that time, at Hull, it was really more of a coincidence of datum. The contrivance lies in that it was a whole number of a linear scale at a whole number of hours above an arbitrary datum. More than a century on, the scale has been changed from imperial units to metric. In addition, the whole dock wall with its etched numerals appears to have subsided a little. This means that the imperial sixteen feet mark is irrelevant; and that the water ordinarily no longer laps the mark at three hours off HW.

## 5.6 CONCLUSION

Several late-medieval tidal diagrams strongly resemble the diagrams accompanying Bedan texts. The earliest is from about 1375 and others are sixteenth century. No matter how strong the schematic resemblance is, no evidence of direct idea transmission exists. The Carolingian world used a geocentric consideration of the cosmos. The Carolingian diagrams concern time and lunar motion, the later diagrams concern tide and solar motion. Yet the St. Albans table sits in between.

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[209] Taunton, United Kingdom Hydrographic Office (UKHO), Original MS 26.6.12.
[210] James Oldham, *Report of tidal observations on the Humber*, Report of the British Association for the Advancement of Science, 1862, 101-3.
[211] James Oldham, *Report of tidal observations on the Humber*, Report of the British Association for the Advancement of Science, 1864, 129-188.

With details of tidal flow, the *Flye* takes Bedan lore to its ultimate extent. After the time of the *Flye*, clocks were significantly improved; they became reliable and common in public places. This enabled one further uplift to establishments, as shown in the diagram. That was, to give the establishment in a more precise time. It may well have been a pious effort, being dubiously pedantic. However, the simple but crude type of tidal knowledge given in the diagram is what those at the water-side still find useful today.

The *Flye* diagram displays the tide at individual places over a large geographic area. The *Flye* and Bourne's account collate the type of information found in the St. Albans table, which was for only one place. The *Flye* is a discrete view of hydrography over an entire area, recently considered a Humboldtian concept.[212] It was Humboldt's intention to create a new science of the globe; he hoped to achieve this by a deep analysis of the interconnectedness of all phenomena. As such, the *Flye* considerably pre-empts Humboldt. Although perhaps arcane, another view of this representation of a whole area of tidal activity has received the adjective *kludonometric* – a graph of the wave.[213]

Bede's observation developed into the rule of thumb method no later than the time of the St. Albans table. This concept then evolved into a list of tidal establishments. The *Flye* holds two-dimensional tidal information. In the early nineteenth century Whewell adapted the establishment lists to two-dimensional co-tidal charts. At much the same time as Whewell, Lubbock and Dessiou were to engage in a systematic investigation, which was to open tidal prediction to the known. The predictions came in a much more collated form; as this form was geographic the volumes were therefore tables of information. As will be shown, Dessiou, already well versed and adept at simple tidal lists, proved to be particularly as competent at elaborating tide tables.

[212] Susan Faye Cannon, *Science in culture*, (New York, 1978), 104-5.

[213] W. Nelson Greenwood, *Kludonometric tide tables*, (1886-1890).

# CHAPTER 6 THE 1678 TONKIN REPORT

## 6.1 INTRODUCTION

The seventeenth century Kingdom of Tonkin was in what is now Vietnam.[214] Tonkin produced goods attractive to the East India Company, and the Kingdom agreed to the establishment of a factory there. Returns from the early factory journals remarked about a particular tidal phenomenon, of a tide so very different to anything known of in Europe at the time. The reports were of a diurnal tide, which acted in concord with lunar declination. This action was different to the then well known semi-diurnal tide, in concord with lunar phase.

Published in 1684, the best of three reports had a direct input to Newton's equilibrium theory of tides. This research has located the long sought manuscript printing source of that report, and found that the source and printed texts differ significantly in presentation. Consequently, I present a critical text in Appendix 3. Made in 1678, the report is part of a remarkable set of sailing directions for entering the Cua Cam River. Those extant directions, with details of the East, form an early example in a European language.

Nothing exists in the literature of the provenance of this informative report, nor directly of its compiler; this article addresses that gap by placing them both into a context. A recent revisitation to the Tonkin tides drew attention to the site of the original observations; I identify that site.[215]

[214] The following orthograpic counts are from the British Library catalogue: Tonkin 339, Tongking 86, Tonquin 46, Tongkin 19, Tunquin 18, Tunkin 15, Tonking 14, Tungking 7, Tonqueen 5, and Tunking 1.

## 6.2 FRANCIS DAVENPORT

Although Francis Davenport (fl. 1670-94), authored the successful report, no other facts were known about him until this research.

In 1670, Davenport, the educated son of a Boston captain, sailed away from New England as a young man, and probably never returned.[216] After surreptitiously taking over a ship in the West Indies, he fled eastwards across the Atlantic. Then, he sailed still further east, from England itself, on the *Hopewell*. He only entered the Company's employ when he had got out to India. Then the frigate *Zant* took Davenport and the factory establishment on to Tonkin.[217] The ship, leaving Portsmouth in November 1671 and in Bantam, on Java, during the May following, made a quick passage. A frigate of 180 tons, the *Zant* provided several weeks of refuge to the adventurers, before it continued on to Macao.

The *Zant* arrived at Tonkin on a Tuesday, about noon.[218] Her arrival, watched by four pilots, were respectively nationals of Holland, Portugal, France and China. The adventurers navigated the ship over the bar of the river, 'with much hazard and danger; but (blessed be God) in safety, onely lost a boate and an anchor'. Yet, the Chinese pilot almost despaired for the safety of the newcomers. Nevertheless, brought-up inside the river mouth, the *Zant* successfully anchored near the town of Batsha.[219] Crossing the bar was a hazard; and it is as part of written advice for how to accomplish it without any loss, that Davenport made the tidal report.

[215] David E. Cartwright, *The Tonkin Tides Revisited*, Notes and Records of the Royal Society of London, **57** (2) (2003), 135-142.
[216] George White, *Reflections on a scandalous paper entituled the answer of the East-India-Company to two printed papers of Mr Samuel White: together with the true character of Francis Davenport the said Company's historyographer*, (London, 1689).
[217] Anthony Farrington, *Catalogue of East India Company Ship's Journal and Logs 1600-1834*, (London, 1999).
[218] British Library (BL), Sloane 998.
[219] Batsha is sometimes called Battshaw, Backshaw and Batsham.

By the summer of 1673 Henry Baker had written entries into the factory journal. A subsequent entry, notes how several necessary papers were then despatched on a Portuguese ship going back to Bantam, the main centre of operations for the various national East India Companies. The last and eighth of those papers was, 'Mr Baker's observations of the tides at Battshaw, as alsoe his letter to the Commander of our ship that shall come next before this barr'. This first notification of an unusual Tonkin tide to reach London, supplemented the more directly commercial report for crossing the bar.

Baker composed his tidal observations sometime between 1672 and 1676. For Davenport wrote in the second factory journal that he made his account of the tides, 'in compliance with your orders to that purpose of 29th May last.'[220] Davenport's wording implies the year of 1677. The *Eagle* probably brought out those orders, for it records making its departure from Tonkin during the eleventh month of that same year.[221] Davenport completed his highly detailed tidal account in the second journal, in July 1678. The result of information garnered from natives and his own observations, he supplemented it with measurements taken over several months. With the report complete, a factory meeting of 23rd September 1678 resolved that Davenport should return westwards. This was to be via Bantam, on the *Formosa Frigate*.

More than a year onwards, in London, the Court of Committees, referred to Davenport in the past tense as the 'late mariner'.[222] It was a premature death notice. The *Formosa* had various ports of call to make; when it got down to Bantam, Davenport therefore transferred to a ship going direct to England.[223] Unfortunately for him, the ship he then took, the *Johannah*, had a

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[220] BL, IOR/G/12/17 225-251.
[221] This could be either November 1677 or January 1678.
[222] Hosea M. Morse, *The chronicles of the East India Company trading to China 1635-1834*, (Oxford, 1926); Ethel Bruce Sainsbury, *A calendar of the Court Minutes etc of the East India Company', with introductions and notes by William Foster and William Thomas Ottewill*, (Oxford, 1938); BL, IOR/B/35 East India Company, Court Minute Book, 154.
[223] BL, IOR/B/36 East India Company, Court Minute Book 1680-1682, p15, 15th July 1680.

difficult voyage and he became marooned.[224] This resulted in the prosecution of his career then continuing within Asia, on the shores of the Bay of Bengal.

Davenport had at one time enjoyed some social standing. Despite that, during an interim voyage from Tonkin, he took the boatswain's job on the *Flying Eagle*; and then when finally leaving Tonkin in the *Formosa*, he secured a place as gunner down to Bantam.[225] He also employed phrases of self effacement in his Tonkin sailing directions, and again in another set of 1694. After having been a pilot on the Hooghly and having become a qualified navigator, Davenport then rose to achieve a chart of the Ganges.[226] Unusually for the time he eschewed drink. Therefore he would seem to have been an ideal scientific observer. In contrast, in several depositions, made in 1689 to the House of Commons, where the Company was attracting much criticism for its Jacobite monopoly, Davenport stood accused of bigamy, piracy, and murder.[227]

## 6.3 THE FACTORY JOURNALS

The first Tonkin journal now resides inexplicably separated from the main Company archive.[228] That journal, kept by its compilers from their first arrival in Tonkin on the 25th June 1672, runs on to 1677. By then the book was nearly full. The journal, written in a series of similar hands, supplies us with the factory accounts. Additions at the end of each account, are the names of numerous people, in the way of witnesses. Although not the chief factor, Davenport autographs the opening account. It begins with, 'Tonqueen anno 1672, A Journall Register of all the transactions in the first settlement there, & the negotiation of Merchantile affaires for the honourable English East India Company ...' The nature of the account

[224] Maurice Collis, *Siamese White*, (London, 1936).
[225] John Anderson, *English intercourse with Siam in the seventeenth century*, (London, 1890).
[226] The chart and sailing directions are those cited in the Hakluyt Society volume edited by Richard Carnac Temple. The originals, held at Horse Guards with reference Z 30/43, were copied by Temple in 1904. While those originals have not been located, the copies are in the India Office collection: IOR/X/9121/1-2.
[227] *Journals of the House of Commons*, volume 10, 92+216+413+472+502.
[228] BL, Sloane 998.

suggests that it may well have been the actual working journal that was kept in Tonkin, rather than a later fair copy made up in London.

Despite Davenport's marooning, a copy of his sailing directions still resided in Tonkin, safe among the factory records. Fortunately for the sake of science, that account was carried back to London successfully on another ship. The second Tonkin journal contains the directions.

This second journal, written up in one, early modern hand, has its explicit numbering on the front cover.[229] With introductions, such as that on folio 16 of, 'we likewise received the following account', they show that the document is, in contrast to the former, a fair copy of various reports sent back to London. The journal is for the accounting period 1678/9. It consists of 26 folded foolscap pages which possess three different sets of numbering. The original pagination runs from the title folio, followed by folios 1-51; there is then superimposed another manuscript part pagination, of odd numbers only, from the title page plus 449-499; and then a third foliation has been stamped on, of 225-251. This latter is the catalogued foliation. During 2002, the document was in the process of being rebound. That rebinding gave a superb opportunity, enabling me to read  the text lying around the page folds, words which the binding material normally obscures.

The second journal, laid out before the Court on 15th September 1680, concluded the previous year. There were then two tidal reports available in London: the first Baker's, the second Davenport's. Those reports, of once-daily tides in the Gulf of Tonkin, seemed to be so remarkable to the directors, that a third report was called for. Robert Knox accomplished that eventual third account, during the second half of 1682. It arrived in London, on the *Tonquin Merchant*, in September 1683.

[229] BL, IOR/G/12/17 225-251.

It was very unusual for the Company to have any direct input into the navigational aspect of the prosecution of a voyage.[230] Therefore it is noteworthy that the court ordered even the second report. Beyond the scientific remarkableness of the tides, that Davenport appeared to have been a refugee from justice, may partly account for the even more remarkable calling of the third report. The other likely partial reason is that the scientific content of the early reports had caught more than the directors' attention. Members of the Royal Society were attracted to the report's content; sceptical, they sought corroboration.[231] One of the Company's adventurers, Edmund Halley, was also a member of the Society.

Neither of the first nor third accounts, those by Baker and Knox, have survived or come to light. Knox's account went into the hands of the Earl of Clarendon, so that it was available for consultation while Knox was away at sea, in the April of 1684.[232] That Baker's account required augmentation, and that no apparent use was made of the account by Knox, it would therefore seem that the second account – Davenport's – was the best available to Halley and the Fellows. The Royal Society registered Davenport's account on April 16th 1684. The register included Robert Hooke's remark on the declination's paradoxical effect on the tides.[233] Someone then published Davenport's simple account next to Halley's analytical paper.[234]

There is also the possibility of there having been an intervening publication source, beyond that of the manuscript which has survived. This is because there is a little conflict in the evidence between that manuscript and the printing. The heading of the manuscript is, 'An

[230] Andrew Stanley Cook, *Alexander Dalrymple (1737-1808), hydrographer to the East India Company and to the Admiralty, as Publisher: a catalogue of Books and Charts*, (unpublished PhD thesis, University of St. Andrews, September 1992), 43-0110.
[231] RSL, Journal Copy Book VI 1682-6, April 16th 1684 p142.
[232] CUL Additional 1.110.
[233] RSL Journal Copy Book VI 1682-6, April 16th 1684 p142.
[234] Francis Davenport and Edmund Halley, *An account of the course of the tides at Tonqueen in a letter from Mr. Francis Davenport July 15, 1678 with the theory of them, at the Barr of Tonqueen, by the learned Edmund Halley Fellow of the Royal Society*, Philosophical Transactions of the Royal Society of London, **13**, (1684), 677-688. Davenport's account runs from page 677 to page 684 and

account of the bar and course of the tides at Batsha'. This phrase, so similar to that in the 1684 publication, is on the intermediate folio 16, rather than either the title page or folio 24. These pages are the beginnings of the journal and the tidal piece respectively, suggesting that the manuscript is the source. Stronger evidence is the published latitude of '20.50.'; this appears as a *nota bene*. The note is to be found exactly so in folio 19, which precedes the tidal section. Conversely the published longitude 'is about 110 degrees'. This conflicts with that in the manuscript of, '117$^{d}$:30'. Both longitudes are explicitly east of London (Bridge), rather than from the observatory being built at Greenwich. The published date of the account is July 15$^{th}$ 1678. In the manuscript, the account is twice dated on the 12$^{th}$; although it was completed before the 16$^{th}$, the date of the entry following. However, because of the publication date, it seems unlikely that the possible source could have been Davenport's sea journal; for he appears to have been writing into that at later dates, during his Bay of Bengal sojourn[235].

The published account's title incorporates the work of Davenport and Halley together. Davenport's published text, extracted from out of its larger manuscript context, is also a rearrangement. The larger context is that of the sailing directions. The new composition and deliberate placement next to Halley's tidal theory, changes the nature of Davenport's text to one of being purely a tidal report. A possible contending author of the rearrangement is Robert Plot, as he was editor of the *Philosophical Transactions*. However, the published arrangement of Davenport's account is more likely to be Halley's composition, as he was the natural philosopher (scientist) who developed its significance.

The manuscript account is arranged in order of: '1 Concerning the choice of time in respect of the tides, for comeing over the Barr', '2 Concerning the different soundings on the Barr in certaine months', '3 Concerning the course of the tides', 'For Example', and 'To prevent

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Halley's, with a subsequent title, *A theory of the tides at the Bar of Tunking*, from page 685 to page 688.

mistakes in the Accompt of the Moones'. There are a few minor phrases in the manuscript which are extra to the publication; the publication also contains some calendar dates not found in the manuscript.

## 6.4 SAILING DIRECTIONS

The way to Tonkin should have been available to English navigators via a French chart of about 1650.[236] The Dutch also had a chart available by 1661. That gives a longitude of 131$^{0}$20' measured from the Canaries; although another Dutch atlas gives a longitude of 148$^{0}$.[237] When the English caught up with a wayguide in 1675, it could have been of little direct use to the factory. By then they had already found their own way there. However that pilot did give a general set of sailing directions from Bantam to Japan and provided a good map of the Gulf of Tonkin. While it is without longitude, it lists the Tygers Point below Batsha.[238]

The factory's first account, of their arrival at Tonkin and consequent loss of Company property – the boat and anchor – provides sufficient reason for compiling proper sailing directions. The directions focussed attention on an excuse, and nature provided one in the peculiar tide. Davenport is explicit about why he compiled his second set of directions. He considered that it only needed a modest amount of knowledge and advice, to enable the proper bringing of ships to within the harbour. Consequently, he wrote that the compilation was gainful employment of his time. That part of the journal exclusively written by Davenport begins with folio 16; it concludes with his initials, FD, at the bottom of folio 30.

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[235] BL IOR/G/12/17 folio 29; Maurice Collis, *Siamese White*, (London, 1936).
[236] BL Maps 58505.(1), *Royaume d'Annan comprenant les Royaume de Tonkin et de la Cocinchine, etc.*, [1650?].
[237] UKHO Va13, Peter van Alphen, *A new Sea Atlas or Waterworld Discovering all the known Sea-coasts on the whole world*, (Rotterdam, 1661); Vb19, *Atlas DeWit*.
[238] UKHOVe 24, John Seller, *The English Pilot, Describing the Sea Coast, Capes, Headlands etc in the Oriental Navigation*, 1675 (no pagination). A chart of the Eastern part of the East Indies and China.

whole part comprises the essential advice of sailing directions. The sailing directions are of a high order of excellence, as exhibited in the view (Figure 19).

The simple sketch, of the type still used, is an early example of a navigational view. As in the modern chart, he identifies rocks with a small cross. The view identifies *Alcoran* on the left, the *rice pot* in the middle, the *pitch of the Hook* to the right, and *Pearle Island* on the extreme right. The modern chart identifies *Alcoran* as *Great Mirador*, and the *pitch of the Hook* as *Little Mirador* (Figure 20). The *rice pot* appears to be the hill which is 223 feet high.

The sailing directions indicate his witting intent. He provided ordinary compass bearings and soundings around Tygers Hooke. That quantitative information interweaves with a description of what coastal features upon which to align, to gain entrance to the harbour. His purpose was so that a ship's Master would be able to enter, independent of any pilot. The directions, of how to sail and come to an anchor under the lee of Tygers Hook, are in three parts. The first direction is how to go between Pearle Island and the Hook, then how to go without the Island, followed by directions for coming over the bar. Tygers Hook is a very apt description of the thin, seaward-pointing, curved Do-Son peninsula; again, the modern chart clearly identifies Pearle Island as Hon Dau (Figure 20). The quality of the sailing direction is then enhanced over folios 22 and 23. He gives the best state of tide and wind for crossing the bar; it includes the amount of water to expect, and enables one to tell when one is exactly approaching the bar, and then when one is clear of it.

Davenport concludes with how he had done his best to comply with every particular of the orders. He said that the recompense for his endeavours was self satisfaction.

The sailing directions Davenport gave, for crossing the bar to enter the Cua Cam, are highly detailed and precise. He was a modern navigator, using the New Style date and familiar with the azimuth-compass. The directions are also perfectly understandable to a twenty-first century navigator. An E. Walsh surveyed 'Tonqueen Bar' nearly a century later. That map is of the bar west of Batsha, with which to enter the Song Ca, or Red River up to Hanoi.[239] That charting, of a distinctly modern nature, also provides a profile of the Do-Son peninsula. The profile is from Alcoran through Tygers Point and out to Pearl Island. Original to Davenport, those place-names have since disappeared from use. The Walsh profile is as seen from south-west of the peninsula, and it is in a true perspective. Davenport's profile is the view from the same direction but closer in, with detailing of the pine clad hills. Perhaps unwittingly, Davenport exaggerates the vertical dimensions. Davenport's purpose was to assist on first arrival at the outer open anchorage, before crossing the bar to gain the protection of the small inner harbour of Batsha.

An anonymous map of 1791 retains the early naming.[240] Extending along one hundred miles of the river, it locates the first English factory site precisely. By then it had moved; but the map shows its original site had been on the left bank, half way up the river, towards the capital. The chart (

[239] Alexander Dalrymple, *A Collection of Plans of Ports in the East Indies*, (London, 1775), plate 40. E. Walsh, 'Tonqueen Bar', London, 1st October 1774.

Figure 20) derives from nineteenth century information and is itself no longer current. By then, siltation had wrought considerable hydrographical changes. Davenport made his tidal observations at Batsha. The site of which has now been identified from a chart of 1774.[241] It was on the creek to the west of the sandalwood groves of the Do-Son peninsula, and lay NW of the hill Great Mirador in the chart. This identification supersedes another recent identification, because more information has since come to light. The qualification therein, derived from William Dampier, that the site was at the mouth of a river remains valid the Tonkin river outlets via a changing delta.[242]

## 6.5 A ONCE A DAY TIDE

The tidal report is one of the most famous items in the tidal pantheon. It is a good example of the complexity of tidal phenomenon.

At Tonkin the tide is not semi-diurnal in character, as in much of the world, but diurnal, as in several other parts of the Pacific and Southern Oceans. This diurnal tide is a response to the declination of the moon (the angle of the moon above or below the equator), and when the moon has little declination there is little tide. As the declination of the moon increases, it produces a more positive diurnal tide in Tonkin. The declination cycle, between being fully north and then fully south of the equator, produces a period of large diurnal tide every fortnight, one of a three metre amplitude. As the declination changes, then the time of the tide changes between mornings and evenings; the time of year further modify these changes. Because of tidal unpredictability during periods of intermission, Davenport warned of the danger involved while crossing the bar then. He advocated waiting a few days, to enable a ship to lift over the bar at high water.

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[240] Anonymous, *Plan of Tonquin River from Cacho to the sea,* ([London], 1791).
[241] Alexander Dalrymple, *A Collection of Plans of Ports in the East Indies*, (London, 1775), plate 40. E. Walsh, 'Tonqueen Bar', London, 1st October 1774.
[242] Cartwright, *The Tonkin Tides Revisited.*

Davenport had himself been made aware of the irregular tides. This had been at a time when he was engaged somewhere else, other than Batsha. The two likely positions of where he then was: are at Hien (Hanoi), where the factory eventually based itself; or it may have been at some point before he ever arrived in Tonkin. In the latter case, news of the tide could have passed to him as shipboard gossip, or gleaned from foreign seamen. The Dutch had a hydrographic office in Bantam. In the former case, Henry Baker, when compiling his own observations, or even later, when orders came through from London for more information, could have attracted Davenport's notice to the phenomenon. Under those orders, Davenport was down in Batsha for the *Eagle's* sailing. On that occasion, he made additional notes about the tide, in the end of his sea-journal. While extracts of the sea-journal were later published, it itself has not been traced. Speculating, before he was actively noting the tides, he thought it possible that the irregularity could be due to geography or the monsoons. Then, when he started observing their course, orderliness and constancy, he admitted to being baffled as to their metaphysical cause.

After the Company had responded to the first report, a full six years elapsed before the third report was available for consideration. During that time, the Company had most royally treated Halley during his sojourn to St. Helena. When Knox finally returned, Halley was already involved in discussing tides: with John Flamsteed, William Molyneux and Isaac Newton.[243] It is not surprising therefore that Halley was interested in the account of Tonkin's most unusual tides.

After publication, there was plenty of informed speculation about the report. Robert Hooke received correspondence about it from Bristol.[244] In his *Principia*, Newton is of course clearly referring to the published account; he called for further observations in support of his tidal hypothesis of the combination of two waves. Halley, while presenting a special edition

[243] Colin A. Ronan, *Edmund Halley genius in eclipse*, (London, 1970), 122-3.
[244] Whewell O.11.a.[25].

of the *Principia* to James II, composed an equally special explanation for the King.[245] Euler gave further useful consideration to Tonkin tides in 1740 and again in 1781. However, not all of the references were scientific in nature; one was fictional another satirical. Displacing continents in 1719, Daniel Defoe devised Robinson Crusoe to have careened his ship at Tonkin. Thereby he allowed the Asian tiger's early acquaintance to the Americas. Jonathan Swift also utilised the Tonkin account, referring to tides and other phenomena, when he ridiculed the *Philosophical Transactions* in Gulliver's Travels of 1726.[246]

Within only a few years of the report, the Company withdrew from Siam. By the time of Tonkin's subsequent abandonment, the French were beginning to accept a Newtonian cosmography. However, Indo-China, the part of the world containing the phenomenon, was already succumbing to the French. Despite both Newton's and Euler's call for more observations, none were made until the nineteenth century, when Gabriel Héraud contributed two papers on the tides of what had become Cochin-China.[247] Héraud, enjoying the advances in tidal theory of Laplace and later tidal scientists, was the first to return to observing Tonkin tides. However, those tides as reported by Davenport continue to excite interest into the twenty-first century.[248] David Cartwright has had the most recent word. He gives both an easily understood explanation of the special phenomenon and a mathematical model, explaining Halley's interpretation; Cartwright also shows that neither of Newton's nor Euler's hypotheses was needed at Batsha.

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[245] BL Sloane 1030 ff97-108.
[246] Paul Turner, *Jonathan Swift Gulliver's Travels*, (Oxford, 1999), 138, 143-4, 161.
[247] G. Héraud, *Marees de la basse Cochinchine*, Annales Hydrographique, **35**, (Paris, 1872) 346-414; G. Héraud, *Onde diurne des marées observées en Cochinchine et au Tonkin*, Congrès. internat. Sci. Géogr., **1**, (Paris, 1877), 111-116.
[248] J. D. Mollon, *The origins of the concept of interference*, Philosophical Transactions A, **360** (2002), 807-819; Steffen Ducheyne, *Newton's Notion and Practice of Unification*, Studies In History and Philosophy of Science (Part A), forthcoming October 2004.

## 6.6 CONCLUSION

The tide at Tonkin did not fit into a tidal context as understood in the seventeenth century. Tidal literature then denominated a relationship in accordance with the moon's extreme phase. Not only is there only one tide a day at Tonkin, but it fluxes according to the moon's declination. So that news of the Tonkin tide considerably extended the then lexicon of tidal pattern, and continued to defy total understanding for three centuries.

The published edition is a rearrangement of the tidal part of the sailing directions. That rearrangement emphasises the scientific aspect of the information, at the expense of the navigational utility. The edition uses punctuation where none exists in the manuscript, altering the emphasis of the prose. I have identified the place where the original observations were made.

This chapter sets out the convoluted route by which the unusual tidal information was garnered, and offers a number of corroborations about long-ago Batsha. The chapter identifies an original source of data integral to the *Principia*. Tidal historians in particular and science historians in general have long sought that source. The document therefore remains a piece exploited contemporaneously by Halley, the scientist. This paper brings it to the attention of modern historians.

The chapter shows that the initial interest in the tide arose out of the loss of property, and then the peculiar Tonkin tide attracted a direct interest. I now identify the reporter beyond his mere name, and associate him with several tracts which omit that cross identity.[249] Only good fortune preserved that reporter's text. Davenport's observation directly contributed to useful tidal hypotheses. As chapter eight will show, these uplifted into contributory

[249] In addition to those already cited there are about six other connected publications. They may conveniently be located in IOR/Eur.D300. However, this collected volume is more easily referenced as IOR/J762.

theoretical tide tables by Bernoulli and Brisbane. Taken together, these resulted in the late eighteenth century in improved predictions in Europe.

However the substantial and practical uplift was the devising of a published method. As has already been said, Deacon and Reidy describe that achievement. The part of the contribution made by the human computer involved in that achievement has gone largely unremarked; it begins in the narrative now following.

# CHAPTER 7 THE DESSIOU HYDROGRAPHY

## 7.1 INTRODUCTION

The family name of Dessiou is associated with over a hundred different pieces of hydrographic work. Covering a period from 1770 to 1851, they are the product of more than one author. Within this chapter's narrative and the bibliographic appendix I clarify the complex authorship of that work.

The main author, Joseph Foss Dessiou, was the early nineteenth-century's most prolific hydrographer, but whose pivotal contribution has been virtually left out of previous accounts. The following biography outlines his work; it included the production of charts, sailing directions, light lists and the first tide table from a published method. In the process, he formed early hydrographic serials, and became the first director of the Admiralty tide tables. Towards his period end, the work, being official publication, was largely anonymous. This paper establishes Dessiou as the most complete hydrographer of the era, and identifies a unique contribution to hydrography.

Contemporary manuscript correspondence and published papers helped to reconstruct this previously much neglected life. The narrative includes details of his origin and family, together with facts added from Registry and Navy records.

## 7.2 THE DESSIOU FAMILY

The church of St. Petrox (Figure 21) still stands, down by the narrow mouth of Dartmouth Harbour, Devon. There, the mariner Peter Dessiou (1708-1793) married Mary Foss on 3 il 1738.[250] Their eldest child became the second Mary Dessiou and they christened their

Joseph, there on 2 May 1743.

on 17 April 1766, at the church of St. John Baptist, in Paignton, Devon. They christened all of their eleven children in Paignton, between 1767 and 1787.[251] At the time there was much infant mortality, and the Dessious resorted to repeating Christian names. While they gave two of their children the names Joseph Foss, it was the second who grew to maturity and old age.

The education of **Joseph Foss Dessiou** (1769-1853), Master RN, has not been determined. His wife, also called Grace, was born in May 1772 at Hallsands, Devon, and became the

250 International Genealogical Index.
[251] Joseph Foss I, Joseph Foss II, Peter II, Samuel Foss I, Mary III, Grace II, Grace III, Samuel Foss II, Richard Goodridge, Grace IV and Jacob. For clarity, dynastic sigla have been added to the names.

fifth Grace Dessiou. Although married in St. John's, Newfoundland on 23 August 1791,[252] they christened their two children at Paignton.

One of those children also became **Joseph Foss Dessiou** (1792-1818), Second Master RN. During this lifetime, the Dessiou family contained three Josephs; each of whom rose to become a cartographer. To avoid confusion, I refer to these three Josephs as the father, Dessiou and the son.

## 7.3 OUTLINE OF DESSIOU'S CAREER

Dessiou entered the Royal Navy; becoming a warrant officer his name survives in the records of four ships. He got his first appointment as Master on the *Camilla*, in 1794.[253] Of the 6th rate, she was active in the Channel and off the Low Countries.[254] In 1795, he became Master of the *Albion*, a 22 gunner.[255] Two years later he transferred directly to the *Warrior*, a 3rd rate 74 gunner. After a month's leave in 1800, he became Master of a new building: the *Dreadnought*, a 2nd rate, 98 gunned, three decker. There was something hurried about the appointment; he joined her underway, while she was leaving Portsmouth dockyard. From Spithead, they sailed immediately for Finesterre, Cape St. Vincent and Cadiz.[256] Dessiou eventually paid off on 15 July 1802, in Portsmouth.[257] The report of him being physically unfit for further service afloat probably indicates an injury. However, Dessiou's Superannuation from the Navy was not until 24 August 1805.[258]

No matter what his physical condition was after leaving the Navy, Dessiou settled in London and succeeded in several occupations – all related to hydrography. His merit was recognised

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[252] London, The National Archives (TNA), PMG 19/43 – 94.
[253] *The Navy List*, (London, 1833), 121 [no more bibliography].
[254] TNA ADM 29/1 Service record.
[255] TNA ADM 51/1117, ADM 52/2892.
[256] TNA ADM 51/1434, ADM 52/2949.
[257] TNA ADM 29/1 p54; David Lyon, *The Sailing Navy List*, Conway, (London, 1993).
[258] L. S. Dawson, *Memoirs of Hydrography*, (Eastbourne, [1882]); *The Navy List*, (1829), 37.

only once during his lifetime; Trinity House elected him a Younger Brother, in 1811.[259] At that time he was Captain of a merchant packet in the Newfoundland trade, the *Naples*.

Before 1809, he was living in the parish of St. George in the East.[260] Professor E. G. R. Taylor has shown that he lived at two addresses in Albion Street, just north of London Dock, before the Commercial Road.[261] When insuring the property of 14 Cannon Street, Ratcliffe in 1818, he had broadened his occupations to that of artist and bookseller; which was in addition to proclaiming himself a hydrographer; the street is that immediately west of St. George's (Figure 22).[262] By 1832 he had moved across the river, to 30 White Hart Street,

[259] London, Guildhall Library, Trinity House MS 30004 Vol 16 257.
[260] Trinity House MS 30004 Vol 16 p357; Joseph Dessiou, *The seaman's complete daily assistant*, The sixth edition, (London, 1809), iv.
[261] Eva Germaine Rimmington Taylor, *The mathematical practitioners of Hanoverian England*, (Cambridge, 1966), 335; Joseph Wisdom, *The A to Z of Regency London*, (London, 1985), 24.
[262] London, Guildhall Library, Sun Fire Office MS 11936/472/940316.

Kennington.[263] That house, situated on the site of the present Elephant & Castle station gave him a two mile walk, across Westminster Bridge, to his office on Whitehall.

In 1819 he had an interim position, teaching navigation and nautical astronomy. By then, Dessiou may no longer have been an active seaman. It would have been convenient for him to practise that shore-side calling from Albion Street, close to the Pool of London. It was also only a mile from Faden's publishing premises in Charing Cross; producing nautical publications was the part of Dessiou's career which has left an attributed legacy. Then Dessiou, at fifty-nine, was no longer a young man when he entered into his final capacity, directing the annual tide tables. He continued this work for twenty years, only retiring in the summer that he became seventy-nine.

Dessiou also took freelance work, computing astronomical tables for the Society for the Diffusion of Useful Knowledge, in 1828. For two decades after that, he computed tides with John William Lubbock.

During his life, Dessiou's occupations ranged from: Master RN, merchant navy captain, cartographer, teacher, Younger Brother, computer and Admiralty hydrographer.

## 7.4 DESSIOU'S PERSONAL HISTORY

Reference to a troublesome wound in later years, would explain Dessiou paid off unfit for service in 1802.[264] Dessiou had chronic gout also. From his appointment to the Hydrographic Office in 1828 and onwards he suffered from gout. This was severe enough for his colleagues to make reference to his absence from work in such terms, and gout figured on his death certificate.

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[263] RSL LUB.D.129.
[264] RSL LUB.D.167.

The strain of age began to tell on Dessiou during his final career in tides. He worked full-time in the Hydrographic Office and part-time for Lubbock and the Society. The two parts were in supplement of each other. Lubbock was concerned at the demands upon rest that the extra-mural work was having upon Dessiou. The day work even stretched into Dessiou's free time.[265] Dessiou was so ill in 1832 that he took a costly coach in to the Office one morning. Then at a crucial moment in November 1833, Dessiou fell seriously ill and Lubbock, with his Cambridge colleague, William Whewell, considered replacing him.[266] However they wanted to keep him for the tidal discussion, for the sake of uniformity. He was so ill Lubbock feared Dessiou might die and they would lose their astute computer.[267] Fortunately Dessiou creaked on for a number of years.

Dessiou was always anxious for work. Resiliently he expressed to Lubbock, "Calculating the Tides for the office is office work; and I am sorry that you have nothing for me to do at home." Dessiou became eager for the work and its payment. In early 1837 he again wrote to Lubbock, "I have been in expectation of having some employment on the Tides to occupy my leisure hours." Later that year Lubbock granted Dessiou's wish, as he was recalculating the London tides for him with which to make new tables.

In addition to debilitating health Dessiou was frequently distressed financially. He chided Lubbock in April 1838 because the Society had not completed a payment. As a consequence Dessiou pleaded that he was being threatened with arrest for himself having not kept up a regular instalment.[268] Dessiou explained his financial position that month; he needed the tidal work to maintain himself. He had given up all other outside employment and prospects in order to just do tides. In early January 1839, his leg wound confined Dessiou at home.[269]

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[265] Whewell R.6.20[223].
[266] UKHO Original MS 23.6.1.
[267] Whewell R.6.20[224].
[268] RSL LUB.D.164, 18th April 1838.

After Dessiou retired he suffered a marked decline. Then, aged eighty-two, he wrote a begging letter to Lubbock.[270]

> It is with great reluctance that I now address you, to acquaint you with the distressed state that I am in, owing to my very ill health, and almost continued confinement during the last sixteen months, and also my wife's ill health several months, causing very heavy expenses, which together with some considerable losses, have reduced me to my present state. I am in arrears for rent, and my landlord threatens me with an execution next week. ... If you can ... favor me £10, it will save my furniture.

Notably, during this time of straightened circumstance he issued two more charts - his last.[271]

That one reference, to his wife, is the only note of anything like a familial nature in the whole bundle of Dessiou correspondence. Only the facts from official sources provide any information about his family. Made out on 15 April 1847, his will was in favour of Grace.[272] Although 78 year old Grace had been ill several months at the time of the 1851 census, she outlived him. When his death came, on 16 February 1853, after fourteen days of gout and caused by the decay of nature, he was on reserved half-pay.

Subsequently she obtained a naval widow's pension of £50 per annum. Until her death in 1860, Grace Dessiou then lived with relatives at Gloucester.

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[269] RSL LUB.D.167, 11th January 1839.
[270] RSL LUB.D.170.
[271] Appendix JFD45, 46.
[272] TNA PROB 11/2170.

Despite being in arrears for rent and threatened with an execution (eviction), Dessiou died in residence at number thirty. In keeping with the times, Mr. and Mrs. Dessiou were able to afford a resident house servant. Perhaps they were not so badly off, after all.

Dessiou was of Huguenot stock and he worked among other Huguenots. However, he married in an Anglican church and christened his children there. Shortly after he had made his will out, he published a religious tract. Being the words of a medium, the book is somewhat removed from the traditions of French and English Protestantism. *Divine and* *spiritual communications through Thomas Dowland to Elias Carpenter* was available at the House of God in 1848. Situated along Amelia Street, the *House of God* (Figure 23) was only a short walk from his home. The building had an association with the famous medium Joanna Southcott (1750-1818). He had, in 1838, been using prophetic almanacs and star charts. Taken together this would suggest a drift away from established religion and towards astrology.[273]

## 7.5 THREE JOSEPH DESSIOUS

Hydrography, surveying the sea, was already an established science when William Cunningham spoke of the 'old Hydrographers', in 1559.[274] Within a century, appointments followed of *Hydrographer to the King*, before the creation of such an explicit governmental department. Therefore hydrography was a most pertinent word during the time of Joseph Foss Dessiou's careers, and has remained so since.

Over one hundred and sixty copies of hydrographic work, bearing the Dessiou family name as author, can be located in main repositories. The pertinent repositories are mainly British, with a few more in the New World. Two works survive in more than six copies.[275] Thirty-four appear to survive in as few as one copy. On the web, a sale catalogue records a singular copy passing into private hands. As other private ownership is also likely to exist, the checklist of the appendix may consequently deserve addition.

Among the copies there are seventy different pieces of work. The Dessiou family production forms a considerable body of work; although the overwhelming bulk is by Dessiou, that which his father added is part of the context. The work falls into two classes: the anonymous and the attributed. That class without a named author is related later. This chapter is

[273] RSL LUB.D.166
[274] *The compact Oxford English Dictionary*, (Oxford, 1992).
[275] Appendix JFD7, 28.

primarily concerned with that class clearly with an author. All of the items in this class are by either Dessiou or his father.

Table 9 Summary of the publisher, author and type of publication of the Dessiou work

| Publisher | No. | | Author | No. |
|---|---|---|---|---|
| Faden | 36 | | JD | 4 |
| L & W | 9 | | JD → JFD | 20 |
| Moore | 9 | | JFD | 46 |
| Manuscript | 7 | | Dessiou | 70 |
| Heather | 2 | | | |
| Steel | 2 | | Type | No. |
| Wyld | 2 | | Chart | 54 |
| Dessiou | 2 | | SD | 15 |
| Norie | 1 | | Tract | 1 |

The above summary requires interpretation. Four works are unequivocally attributed to Dessiou's father – Joseph Dessiou; forty-six works are also unequivocally attributed to Joseph Foss Dessiou himself. Another twenty works bear a short name, without the middle Foss. After discussing the work of Dessiou, I then show that we should attribute this twenty to him also.

### 7.5.1 The hydrographic work of Joseph Foss Dessiou 1769-1853

Captain James Cook gained his surveying tutelage from DesBarres, and DesBarres had in turn received his schooling from Bernoulli. Dessiou therefore found himself in the very fortunate position of improving upon James Cook's cartography. Cook's *Coast of America* of 1759 included Newfoundland and the Gulf of St. Lawrence.[276] Michael Lane continued with Cook's survey in 1768, which went on until 1785. After Cook the systematisation of charting was encouraged, with an *Essay on Marine Surveying* appearing in 1771. The first definitive and complete textbook on *Maritime Survey* was Murdoch Mackenzie's of 1794. He based his work on the methods of the land surveyor – triangulation. For shipboard surveying Mackenzie introduced the station-pointer.[277] Dessiou became the beneficiary of these technological advances, with chronometers appearing earlier, on the surveying ships on which he served, than in ships of the line. Though, as has been noted, station pointers remained a rare item into 1806.[278]

Until creation of the Hydrographical Office in 1795, hydrography was exclusively the business of private enterprise. With the Office's remit evolving over the early decades, it took five years to bring out the first chart, and for a while they restricted issue to the navy. The firm of William Faden (1749-1836) had supplied the Ordnance Survey with map plates; it was these that the Admiralty originally adapted for their charts. It was not until 1821 that the Admiralty offered their own charts for sale to the public. When Faden retired in 1823, the Admiralty acquired his chart plates.

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[276] G. M. Badger, *Captain Cook navigator and scientist*, (London, 1970), 34.
[277] E. G. R. Taylor, *The mathematical practitioners of Hanoverian England*, (Cambridge, 1966), 71.
[278] Susanna Fisher, *Captain Thomas Hurd's Survey*, Mariner's Mirror, LXXIX No.3 (1993), 293-304.

Faden's was one of the six leading commercial publishers. However the quality of his publications, together with appointment as 'Geographer to the King', raised him above that competition. Faden had taken new premises at 5 Charing Cross in 1801, from where he brought out the first Ordnance Survey map. Initially the Admiralty had bought-in a hundred charts from the private publishers for its own use, half of which were from Faden. Dessiou sold most of his output to Faden.

Dessiou's publications appear from 1802, the year in which the Royal Navy deemed him unable to serve in a post afloat. It had previously been his duty, as it was that of all RN Masters, to provide his own maps and books of navigation. As his superannuation did not come until 1805, he needed a means of supporting his family of four. As well as commanding a merchantman, he produced many charts and sailing directions up to about 1819. By then, shortly after his elder son's death, he had come ashore. His personal mapping, of much of the Atlantic seaboards, enabled him to supply work for publication, to the cartographic firms (see Table 9). This activity, of assembling minute data from a large geographic area for a long period, has been described as Humboldtian science.

Dessiou's Gibraltar chart for Faden was only one of many, 'Approved by the Chart Committee of the Admiralty.' Dessiou produced at least thirty-seven works for Faden. When Faden retired, the business went to his former apprentice James Wyld (1790-1836). It was the younger James Wyld (1812-1887) who introduced the art of lithography into Britain. Dessiou's work remained of value into mid-century, when Wyld republished his earlier work as steamship editions.[279] Dessiou supplied William Heather (1765-1812) who founded the famous firm of Norie's. Sussana Fisher has recently told the story of how the leading chart firms became linked. Two manuscript charts and individual charts for each of Steel, Norie and Moore are also identifiable as Dessiou's.

### 7.5.2 The body of contested authorship

The private chart publishers, of the late eighteenth and early nineteenth centuries, relied upon 'nautical friends' for much of their information.[280] They were the blueback makers and both Dessiou and his father were their friends. Four cartographic pieces are the father's because of their early period. Forty-six pieces are very clearly Dessiou's because of inclusion of his middle name - Foss. In addition, most of them have his style, *Master of the Royal Navy*, given as a selling point. Similarly, three times he added his Trinity House fellowship; once invoking an association with the famous Peter Heywood, and another with William Bligh, and once his teaching status. Their authorship is exact.

[279] Appendix JFD46.
[280] Sussanna Fisher, *The makers of the blueback charts*, (St. Ives, 2001), 6.

The twenty pieces which bear the short signature rather than the long one, date from 1802 to 1819. It is exactly the period of when Dessiou flourished, from his thirty-third to fiftieth year. It is also the period between when his father, then aged fifty-nine, left the *Sincerity* - on towards his death. The needy Dessiou was London based, while his richer father was remote in Devon. One of these pieces bears the appellation *Captain;* it could legitimately apply to either man. Another piece bears *Master Mariner;* whilst an imprecise title, it would have been inappropriate for the father; conversely, it would have been highly appropriate to the then Trinity House applicant.

One piece, made at the time of that application, bears the name G. F. Ryves (1758-1826). It was Ryves who had borne Dessiou's sponsorship to the House. Another bears Dessiou's street address in London.

The twenty pieces were scattered across four publishing houses, as though they were a resort for a different style. One includes the earliest for Faden; the longer style was not resorted to at other houses until after the flourish. The twenty are for a haphazard geography. The Dessiou pieces are co-ordinated in time and place, particularly so for Canada and the English Channel – which form two consecutive coast serials. It is as though the twenty are for Dessiou's pocket-money, hand-me-downs from the superior Faden directed serials.

John Hamilton Moore (1738-1807) published nautical textbooks.[281] One ran to at least twenty five editions and may derive from plagiarism; it was in turn plagiarised in America, right down to 2002.[282] Immediately Moore died it was significantly corrected, enlarged and improved; then the short style name was added. Later, when Dessiou engaged with the

[281] R. A. Skelton, *Copywright and Piracy in Eighteenth-century chart publication*, Mariner's Mirror, XLVI, No.3 (1960), 207-212.
[282] Harold L. Burstyn, *Copywright, Piracy, and the Practical Navigators: three notes*, Mariners's Mirror, XLVII No.3 (1961) 223-5.

Society for the Diffusion of Useful Knowledge, as editor, he inserted his full name into the volume.

It would appear that all of the twenty pieces are by Joseph Foss Dessiou, and that they are not by his father, Joseph Dessiou. The evidence is circumstantial rather than absolute. The higher quality work is also an indicator in this direction. These twenty are all of a similar style to the forty-six bearing the name Foss: all of which lean upon the surveying he encountered while in the navy. The cartography in the twenty is much superior technically, to the four explicitly by his father.

### 7.5.3 The hydrographic work of Joseph Dessiou 1743-1822

The father drew two manuscript charts and published two more; all four were of Dartmouth.

He dedicated the 1770 manuscript to Viscount Howe, Rear Admiral of the Blue, as his servant.[283] The dedication is a puzzle, as Howe only achieved that rank twelve years later. In that year, he also dedicated a second manuscript to the local MP and Governor of the Garrison. He then dedicated a chart, very similar to the first, to Trinity House in 1790, but published by John Hamilton Moore.[284] Three years later, acting independently of Moore, he published on his own account – with Moore only the seller. This was a set sailing directions for Dartmouth harbour and a chart for the Graving-Dock.[285] I have not traced the sailing directions. The Graving-Dock chart had been 'published as the act directs.' This act of 1777, 'for more effectually securing the Property of Prints to Inventors and Engravers', eventually proved highly troublesome to Moore.

The Dartmouth charts bear charming depictions of St. Petrox church but the intention is not simple decoration. The charts are large scale and the church, in its visible height, forms a stable and navigationally relevant landmark. As a device, it survives from the earliest of English charts and sailing directions, and remains highly practical.

Sussana Fisher reports the name, Joseph Dessiou, appearing in this period, as an example among a set of ship's accounts, devised by Moore for instructional purposes.[286]

From 1793 through to 1801 the father captained the seventy ton sloop *Sincerity*, a regular packet between Dartmouth and London.[287] With earnings of up to £1,000 per annum, the

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[283] Appendix JD1.
[284] Appendix JD3.
[285] Appendix JD4.
[286] Fisher, *The makers of the blueback charts*, 26.
[287] *The Register of Shipping 1764-1833*, Lloyds Register of British and Foreign Shipping, reprinted 1964.

packet trade at the time was highly lucrative.[288] Registered to pay land tax and regarded as a gentleman, he died possessing several properties. The significant burial vault, for himself and his family, he furnished with an engraved memorial stone.

### 7.5.4 Cartographer Joseph Foss Dessiou 1792-1818

By 1817 the son had served as a West Indiaman's Chief Mate and on the Weymouth Store Ship. As his father had taught him, Dessiou in turn taught his son cartography and navigation. With patronage, the son gained an acting post as Second Master on HM sloop *Aid*, intended for a scientific voyage. Renamed *Adventure* they encountered enemy action in the Mediterranean. On 9th September 1818, the *Adventure's* Muster Book records that Joseph Foss Dessiou drowned at sea.[289]

This Joseph Foss had gained the patronage explicitly because of his cartographic skills, yet he died during the height of Dessiou publishing, to which he did not contribute.

## 7.6 HYDROGRAPHIC CONTENT

The navigation, by lunars and with time-keepers, which Dessiou taught his son, was of the leading-edge variety.[290] It was with a time-keeper that Dessiou explicitly fixed the longitudes of his 1808 West Indies chart. Therefore it is highly likely that, from during his early career, he had his own chronometer – a not altogether uncommon practice. His father was wealthy enough to have provided him with such a valuable instrument.

All of the charts and sailing directions are for the Atlantic seaboards. Before foundation of the Nautical Magazine in 1831, no method of promulgating small revisions to any nautical publication existed. Consequently, republishing was the only way to modernise. This republication is evident in the several Dessiou editions of the West Indies chart. Whilst there

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[288] Ronald Hope, *A new history of British shipping*, (London, 1990), 247.
[289] TNA ADM 37/6154.

were an assortment of Dessiou publications for the Atlantic and Mediterranean, those for the Channel and Newfoundland exist in the form of overlapping chart and sailing direction serials. The serialisation is evident in the Channel charts bearing county titles, as in the early Ordnance Survey style; and that they are at similar scales

The serialisation is strikingly evident in Dessiou's publications for Faden; particularly those emboldened *Master of the Royal Navy*. Four Newfoundland pilots match with charts, published by Faden over several earlier decades; the match in their title is exact. This relationship marks the descent of English hydrography from Des Barres, through James Cook and Michael Lane to Dessiou. Dessiou was not a particular innovator; his contribution is the solid work of filling in the map based on sound cartography. He was the first to apply a chronometer to Newfoundland and other coast surveys. He rose to write original directions to his own original North Sea charts. In turn at least two others wrote directions explicitly to accompany Dessiou's charts; Heywood being one and Vicenzo di Luccio's *Treatise on the Currents in the Gulf of Venice* another.

The majority of Dessiou's charts have an identical overall appearance. He used foreign and Ordnance Survey maps for his landwork whenever possible; several charts in the channel series clearly exhibit the triangulation involved. Then, in 1813, he explicitly stated taking his outline from Mudge's recent Trigonometrical Survey. The 1805 chart of the Downs and Margate Roads is large scale and oriented west-up; initially a plan without either scale or graticule, the second edition of 1812 rectified the deficiencies. The 1808 Dover Straits chart explicitly states the proposal by Dessiou, of forming a contiguous series. He built up the channel series over twelve years, running to about fifteen charts and directions.

The county titling did not prevail. The coordinated sailing directions for Newfoundland and the North Sea, adopted titling by coastal features. The example: 'from Cape Charles to

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[290] UKHO, Letter Book 1 124, 28th February 1817.

Sandwich Bay' – is as in current practise. An interesting aberration is in the Adriatic chart of 1806, with its orientation diagonal to the graticule. This was so as to fit the Adriatic on one piece of paper, at the largest possible scale. The device produces a roughly north-east-up orientation. Another device to accommodate available paper size survives in the North Sea Chart. There, the main, southern part of the North Sea builds up from four pieces of paper. Those four pieces, when pasted together, form a whole chart with one integral graticule surrounding it. The northern North Sea, again in parts, is a subsidiary chart; here the clear intention is that one should paste these pieces on also, over the northern graticule of the former; this was to then form a larger and new, six pieced map, of the whole North Sea.

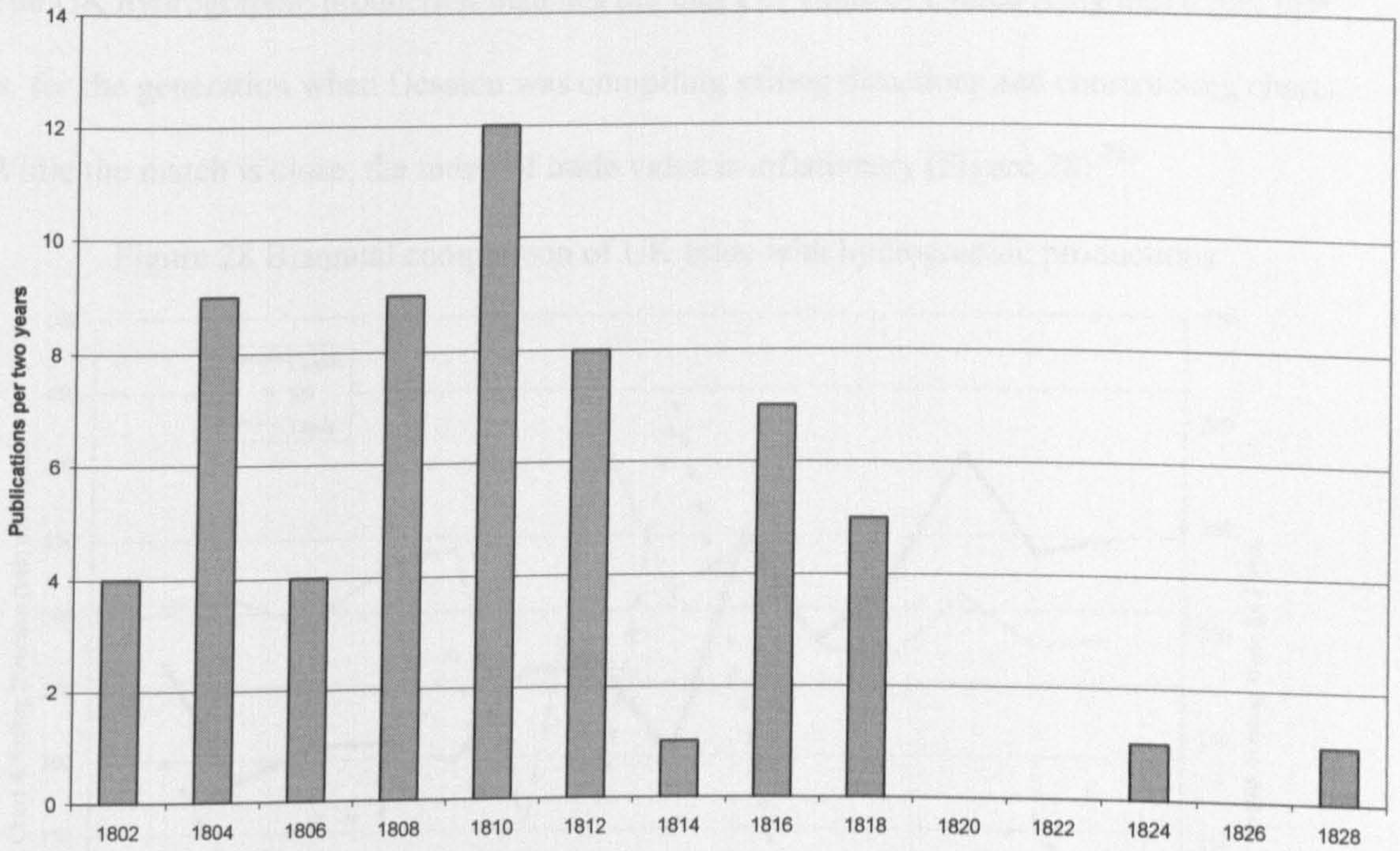
At a Court of the House in 1812 an examining committee reported that they found 'Mr. Dessiou's chart of the North Sea very accurate'. So impressed were they that they bought twenty-one copies.[291] Dessiou continued presenting ingenious chart schemes to the House through to 1814.[292]

There are a total of six dedications to Trinity House and one to Thomas Jefferson, president of Congress. Another was dedicated to the Merchants and Underwriters Assembling at Lloyd's Coffee House. It clearly helped to appeal direct to a market and use the names of famous people, as twice with Lord Nelson; it lent authority and boosted sales. Heywood and Bligh are associated with the infamous *Bounty* incident. Another, from Robert Fitzroy, in an 1810 set of Newfoundland directions, is merely a signature prior to fame.

The total Dessiou output (Figure 26) shows publication lulls in line with Trafalgar, Waterloo and during the time he was teaching.

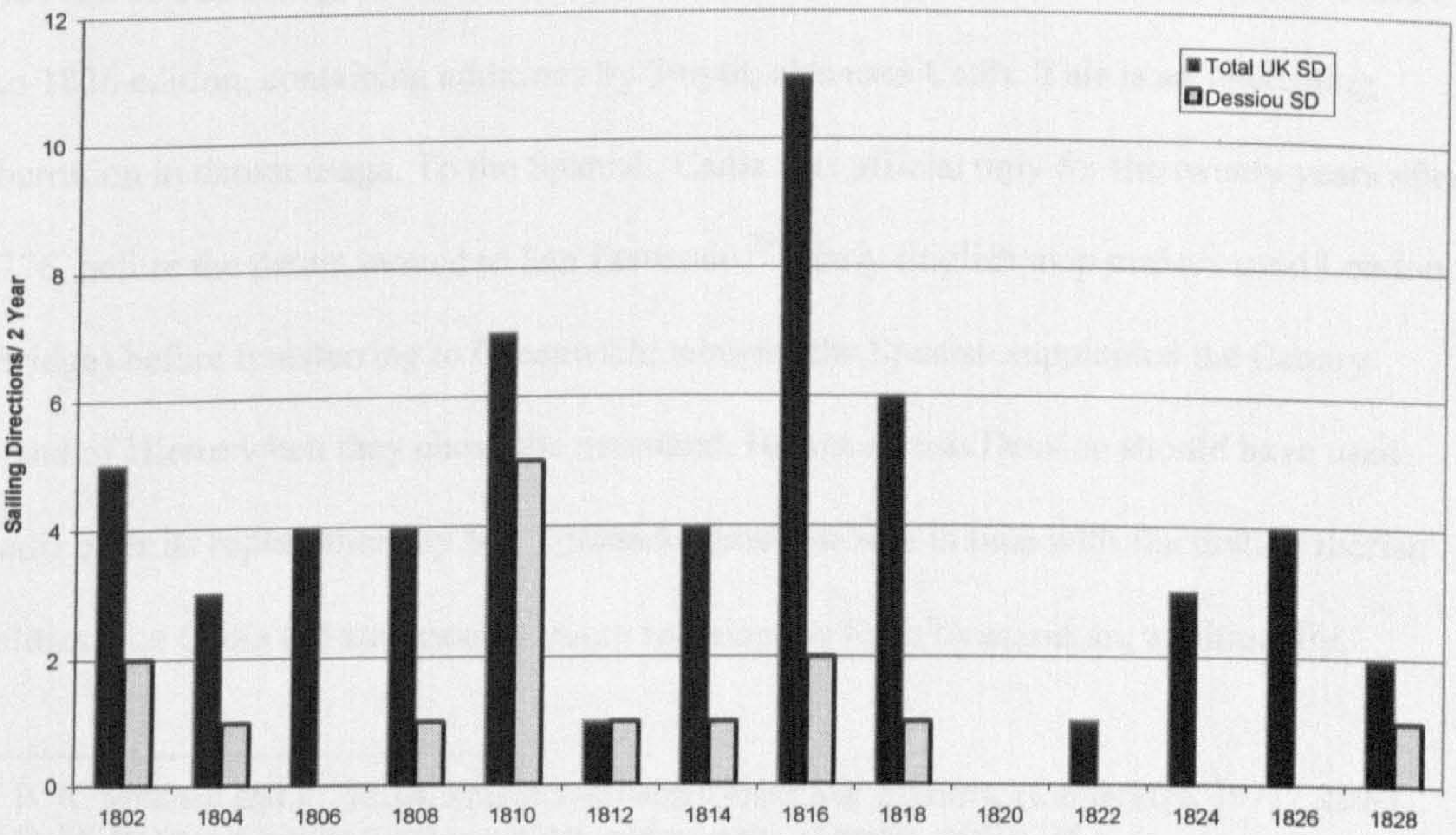
[291] Trinity House MS 30004 Vol 16 281, 3rd September 1812.
[292] Trinity House MS 30004 Vol 16 337, 6th January 1814.

Figure 26 The Dessiou output of both charts & sailing directions



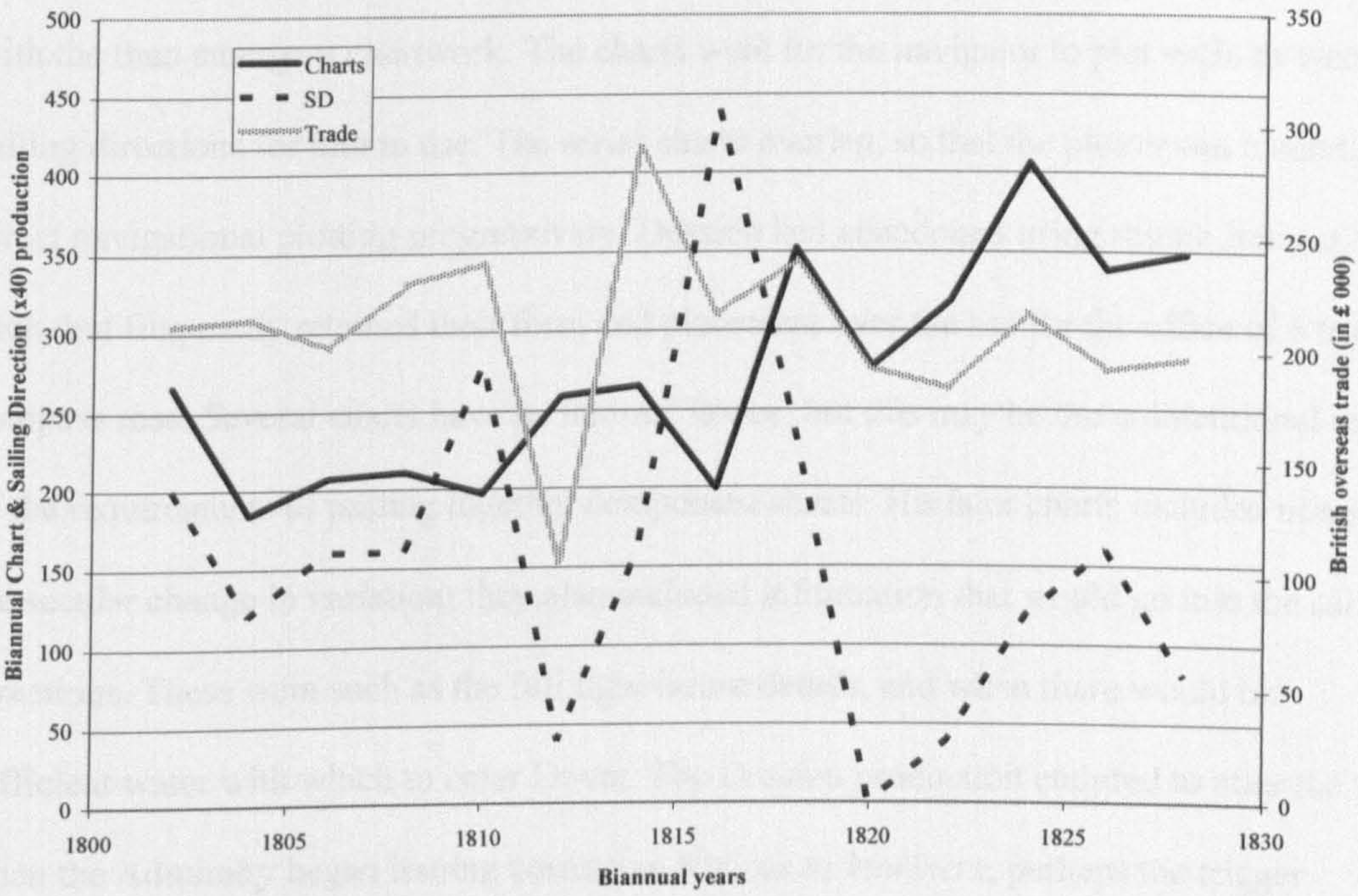

His output of sailing directions (Figure 27) amounted to the bulk of the whole United Kingdom production in some years. (That is assuming, that what resides in the British Library is a reflection of past production.)

Figure 27 Total United Kingdom and Dessiou production of sailing directions



The UK hydrographic production matches the index of value of United Kingdom trade; that is, for the generation when Dessiou was compiling sailing directions and constructing charts. While the match is close, the index of trade value is inflationary (Figure 28).[293]

Figure 28 Biannual comparison of UK trade with hydrographic productions




Longitude is co-ordinated from an artificial datum; and some charts have had Greenwich as that datum since 1738.[294] In 1806, Dessiou oddly took Cadiz's longitude for Prime Meridian. This use of Cadiz might be an indication of the chart being destined for the Spanish market. An 1826 edition, containing additions by Smyth, also uses Cadiz. This is an interesting aberration in datum usage. To the Spanish, Cadiz was official only for the twenty years after 1776, before the datum moved to San Fernando.[295] Early English map makers used London (Bridge) before transferring to Greenwich; whereas the Spanish supplanted the Canary island of Hierro when they chose the mainland. However, that Dessiou should have used Cadiz after its replacement by San Fernando shows he was in tune with fluctuating Iberian politics. For Cadiz did temporarily return to being the Spanish meridian; additionally,

[293] B. R. Mitchell and P. Deane, *Abstract of British historical statistics,* (Cambridge, 1971), 280-3.
[294] G. M. Badger, *Captain Cook navigator and scientist*, (London, 1970), 38.
[295] Arturo Pérez-Reverte, *The nautical chart,* (London, 2002), 174.

Dessiou had the advantage of knowledge gained from Felipe Bauza during his exile in London.[296] Cadiz had also been the last place Dessiou visited, whilst active in the Royal Navy.

The land arrangements, large scope and large scale of many examples went hand in hand with the then emergent chartwork. The charts were for the navigator to plot with, as were the sailing directions for him to use. The serial charts overlap, so that the plotter can extend his direct navigational plotting progressively. Dessiou had abandoned using rhumb lines as such, but frequently retained their form and placement over the sea for the office of a true compass rose. Several charts have an internal lattice, but this may be the unintentional result of the requirements of pasting together component sheets. His later charts included notes on the secular change in variation; they also included information that would go into the sailing directions. These were such as the full light-house details, and when there would be sufficient water with which to enter Dover. The Dessiou production endured to after the time when the Admiralty began issuing corrective *Notices to Mariners*, perhaps the trigger enabling their own portfolio to dominate.

In addition to charts and sailing directions having been originally devised by private individuals, so too were tide-tables. From the beginning, Dessiou had compiled lists of tidal establishments, and he had inserted tidal flow information on charts. His output was knowledge accumulated from both his father and his own voyages. While the charts were limited in their global scope, reflecting personal experience, the tidal lists cover the world. It was part of general habit, to describe the lists of establishments as tide-tables. When sorted alphabetically, the list of establishments are merely a list of facts. Though when sorted geographically, then the information becomes a true, two-dimensional table of data. A tidal establishment is the relationship between the time of High Water and passage of the Full

[296] UKHO Letter Book 4 326; Urlsula Lamb, *The London years of Felipe Bauza*, Cosmographers and Pilots of the Spanish maritime empire, 1995 volume 499, 319-340.

Moon. However crude a measure, it is durable information, highly suitable for publication in texts. Day by day tidal predictions are rare before 1770.

Dessiou's father had included tidal data on his charts and Dessiou continued the tradition on all he produced. With tidal establishments inserted as Roman numerals, his 1804 chart of the Channel echoes Edmund Halley's of 1701. The French Coasting Pilot of 1805 gives a list of tidal establishments for eighty places, together with both neap and spring rise in French feet. By 1810 the list in the *New Practical Navigator* extended to approximately 1,250 places. There, Dessiou introduced a table for calculating high water times with the assistance of the Nautical Almanac. Several Dessiou charts bear early examples of the tidal acronym, HWF&C. It represents High Water Full and Change, and set to be a standard chart feature until the end of the twentieth century.

Dessiou intended his text books for the instruction of navigation and nautical astronomy. Whilst he certainly taught these subjects, few records of this activity survive, allowing only a limited reconstruction of his life. With only two more acknowledged publications coming forth, he largely disappeared from view at about the time of his son's death. He re-emerged ten years later, producing astronomical tables for the Society for the Diffusion of Useful Knowledge. Fittingly for Dessiou, one of the deliberate aims of the emergent society was to provide authoritative maps and texts.

## 7.7 DESSIOU AT THE HYDROGRAPHIC OFFICE

When Dessiou paid off the *Dreadnought*, at thirty-three years of age he had about twenty years service in. After that, he appeared in the Navy List as a superannuated Master. It remains uncertain whether the status of the Hydrographic Office naval assistants, was one where they were actually in the Navy or not. The census, of 1841 listing Dessiou as in the Navy, and of 1851 as a Royal Navy pensioner, probably reflects a modest vanity.

It was a starting point, for all of those entering the Hydrographic Office that they had been involved with surveying and had constructed a chart. But few, like Dessiou, had compiled so many charts or even sold them commercially. Even fewer published successful sailing directions. None exhibit an involvement in tide prediction before Dessiou. His fellow Huguenot, Francis Beaufort (1874-1857), and his colleague Becher both became titular Admirals; he remained Mr. Dessiou. This was perhaps a reflection of his entry into the Office as a warrant officer, rather than from a commissioned rank. The records show by 1838 though, with the Admiralty tidal project the main contribution of the Office to hydrography under Beaufort, that it was clearly Dessiou who was driving the project; and that his influence endured beyond retirement.[297]

Dessiou took up his appointment to the Office in order to begin their series of sailing directions, in February 1828. This he did, though his task there was changed at Lubbock's behest and became that of computing tides, directing the first Admiralty tidal programme.[298] The 1825 Chart Catalogue credits only one of his early charts to him. Then the 1830 catalogue credits his directions for the North Sea to him, but the four of Newfoundland are not; it cites them as by Michael Lane. Explicitly, the sailing direction set, believed to be by Dessiou, is attributed to the Admiralty. Thereafter, this attribution in the catalogues increasingly becomes the most common authorship given.

There are other publications known to have been by him; the best being the new annual tidal tabulations; others are less clearly attributable. He was closely involved in three series of tide tables. These begin with that which he computed from 1829, for the *British Almanac*. Then they continue in a different format with the *Nautical Magazine;* this ran from February 1833. His work reaches its peak in the Admiralty Tide Tables, first given as a supplement to

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[297] UKHO Letters-In D.70, June 11th 1849.
[298] Paul Hughes and Alan D. Wall, *The Admiralty Tidal Predictions of 1833: Their Comparison with Contemporary Observation and with a Modern Synthesis*, The Journal of Navigation, LVII, (2004), 1-12.

the *Nautical Almanac*. The 1833 supplement for the whole year included January, but there was a considerable delay before it was published; and it then came out after the February *Nautical Magazine*. Dessiou continued to compile these annual tabulations through to his retirement in 1847.

The first Hydrographic Office sailing direction Dessiou wrote, is *West India volume I*.[299] The ensuing information is sporadic, but his output includes: in 1834 sailing directions for the *Bristol Channel*,[300] in 1838 Star charts,[301] in 1838-9 unspecified sailing directions, in 1842 sailing directions for *Ireland*,[302] and in 1845 Light Lists for the Western Atlantic shores, which were presumably Nova Scotia.[303] The number of works without an explicit author or editor, for which evidence exists that they were by Dessiou, totals about forty.

In addition, Dessiou very clearly wrote one published paper. However, Lubbock presented it before the Royal Society and, normal for the time, has been credited with its contents ever since.[304]

## 7.8 CONCLUSION

As a Master expected to supply his own charts, Dessiou had been active in hydrography since at least 1794; that was a full year before the creation of the Hydrographic Office in Britain. However, the French Hydrographic Office, *Le Dépôt des Cartes et Plans de la Marine*, had been created in 1720, and his father monumentally accentuated their French descent. A number of Dessiou's charts had been bought-in by the Admiralty under their second hydrographer, Thomas Hurd (1757-1823). It was Hurd who in 1817 had cited Dessiou as 'a perfect mapmaker' and had persuaded the Admiralty to make the charts

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[299] UKHO typescript notes by Commander J. S. Pryor of 1983 iv.
[300] Whewell R.6.20[169], 14[th] October 1834.
[301] RSL LUB.D.166, 20[th] July 1838.
[302] Whewell R.6.20[173], 6[th] August 1838; RSL LUB.D.168, 23[rd] January 1839.
[303] UKHO Letters-In D.147, 15[th] October 1845.

prepared in the Office accessible to the public.[305] By then Dessiou had also come to style himself Hydrographer.

The absence of Dessiou in his father's will is curious. It includes his sister and brother, with the son added in a codicil.[306] The omission may be in connection with the twenty pieces of cross-authorship, due to a rift between them over the use of name without the middle Foss.

His real brother, Samuel Foss, also followed Dessiou into Trinity House. As part of the Younger Brethren, they had both gained standing in the maritime establishment, but Samuel did not enter into publication. The officers of the house thought highly of Joseph Foss Dessiou's work and commended it. He also worked with two of the acknowledged leading cartographers of the period: Graeme Spence and G. F. Ryves.

Bound into an atlas, a number of the currently available charts survive in a good condition; but many of those held in a loose state are torn and crumpled. Some, indicated by their protective edging, may have been subject to navigational use. Yet of those available, almost none show the tell-tale residual marks of a pencilled course. The early depredation of the printings can be partly accounted by contemporary practice. Admiralty instructions were: that a ship, upon receipt of replacement editions, should destroy old editions. Twentieth century loss can not so easily be accounted for, as a small number of examples, featured in current catalogues, are euphemistically said to be 'not found'; those apparent losses have not been listed. Collating a list of early nineteenth century charts, many of multiple editions scattered across numerous locations, is not without its difficulty. The Admiralty chart numbering system did not begin until during Dessiou's time at the Office. In counter balance, the World Wide Web exhibits about four Dessiou charts.

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[304] John William Lubbock, *Discussion on Tide Observations made at Liverpool*, Philosophical Transaction of the Royal Society of London, Part 1, (1835), 275-99.
[305] UKHO Lettter Book 1 123, 17th March 1817.
[306] TNA PROB 11/1666, 5th February 1823.

The preferment given to his son had come from Hurd. One may perhaps guess that Dessiou must have continued producing useful work in the intervening years because of the patronage he subsequently enjoyed. The Duke of Clarence appointed him to the Hydrographic Office. There he came to work with more notable gentlemen beyond Beaufort, Lubbock and Whewell. They include the Astronomer Royal, George Biddell Airy (1801-1892), and the foreign scientists Dominique Arago (1786-1853) and Gerritt Moll (1785-1838). These associations set him aside from the other naval assistants.

Joseph Foss Dessiou, in the second quarter of the nineteenth century, became the world's premier tidal computer. The United Kingdom Hydrographic Office has the only known complete set of his tide tables. Dessiou was responsible there for not just tide tables, but for much other, unacknowledged work. Involved in all of the Admiralty output – light lists, sailing directions, charts, tide tables – he must also have had some input into what was initially only for its own internal organisation – The Chart Catalogue. Dessiou was the Office's most significant producer.

The whole Dessiou work combines to make him a considerable hydrographer, one whose contribution has largely gone unrewarded. This chapter shows how particularly fitting the choice of this hydrographer was, for the development of the first published tidal prediction method. The chapter also highlights the qualities for which he was chosen and which contributed so much to the value of the ensuing Admiralty tide tables.

# CHAPTER 8 ADMIRALTY TIDE TABLES 1833

## 8.1 INTRODUCTION

Predicting high-water times at London and three naval dockyards, the Admiralty Tide Table came out in early 1833.[307] With most of the tables stemming from observations made at the dockyards, it is fortunate that those observations have very recently come to light.[308] This chapter reveals the circumstance of the tables' construction; and also analyses part of the later observation series. The analysis is a comparison of the difference between observation and contemporary prediction, and to tides synthesised from the modern method. The Almanac only admitted the tables into production after comparing the new tables to its competitors. Those early comparisons were for London alone and a recent study also concentrates on that one area. This present study extends comparison to the remaining three-quarters of the early Admiralty table: viz. to Sheerness, Portsmouth and Plymouth.

Until well into the nineteenth century, seamen, and others, predicted tides by a method elaborated by the Venerable Bede more than a millennium earlier. That method is knowledge from simple observation, of the time of a place's High Water (HW) when the moon is in either of her extreme phases. The extreme phases are when the moon is full and when it is new. New moon and the change of the moon mean the same thing. Among seamen, this led to the once essential, but now arcane, acronym for the time of HW at Full & Change (HWF&C). The needs of the period were satisfied that the time of HW at full moon corresponds with the time at new moon. To know the time of a particular tide, on a day that intervenes with either day of extreme phase, one had to count out an allowance for how much later per day, the moon, and hence roughly the tide, would pass the observer's

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[307] Whewell R.6.20[165a].

[308] Anonymous, *Observations of the tides communicated to the Royal Society by the Admiralty and printed by order of the President and Council*, London, 1833. The existence of two copies are known,

meridian. Despite Bede having indicated how to make an allowance that amounted to 50', tidal prognostication employed an allowance of at best 48' and often only 45'. The method was a rule of thumb, adequate to contemporary commercial requirements and to time measured by sundial.

## 8.2 EARLY PROGNOSTICATION

Daniel Bernoulli jointly won the Paris Academy of Sciences competition of 1740, with an essay on tidal causes. In it, he gave an equation and crude semi-diurnal general tide table, giving a seminal idea for the better prediction of tides.[309] The British, coming some years after the French, first produced their own Nautical Almanac in 1767. After that, several people appear to have taken up the tidal idea; Bulpit, Epp, Gregory, Holden, Innes and White all evidently published a calendar year of daily high water times. Some also added height predictions. Holden's predictions for Liverpool, date from 1770. They continued into the twentieth century, and were a lucrative form of income at 1/- each. Because of the income which they fetched, the Holden generations throughout the eighteenth and nineteenth centuries would not divulge their method. But lately, Philip Woodworth has shown that it was descended from Bernoulli's method. George Innes, a watchmaker and astronomical calculator, published predictions for Aberdeen and the adjacent coast. Doing this from 1820 onwards, he grew to deplore the secrecy of other prognosticators. Innes founded his tables upon a method published in Dr. Andrew MacKay's *Complete Navigator*. Although he used French tabulations and ephemeris, Innes declared he was unaware of what Bernoulli had devised.[310] Gregory published for Leith and the others for London, mostly by methods unknown. As Harrison won the Longitude Prize in 1765, timepieces were then substantially improved, and use could properly be had of an improvement in predicted HW times. The new contemporary tabulations gave time to the accuracy of a minute.

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both in Cambridge; one is at the Institute of Astronomy, with shelfmark Rc.606; the other is in Trinity College.

[309] Philip L. Woodworth, *Three Georges and one Richard Holden: the Liverpool tide table makers*, Transactions of the historic society of Lancashire and Cheshire, **151**, (2002), 19-51.

Figure 29 Bernoulli's second table

*TABLE PLUS GENERALE ET CORRIGE'E pour trouver les Hauteurs des Marées.*

| *Distances entre les Luminaires.* | *HAUTEURS des Marées au Perigée de la Lune.* | *Hauteurs des Marées aux Distances moyennes de la Lune à la Terre.* | *HAUTEURS des Marées à l'Apogée de la Lune.* |
|---|---|---|---|
| 0 Deg. | 0,995A+0,149B | 0,883A+0,117B | 0,795A+0,082B |
| 10 | 1,104A+0,038B | 0,970A+0,030B | 0,874A+0,021B |
| 20 | 1,138A+0,000B | 1,000A+0,000B | 0,901A+0,000B |
| 30 | 1,104A+0,038B | 0,970A+0,030B | 0,874A+0,021B |
| 40 | 0,995A+0,149B | 0,883A+0,117B | 0,795A+0,082B |
| 50 | 0,853A+0,319B | 0,750A+0,250B | 0,676A+0,176B |
| 60 | 0,668A+0,527B | 0,587A+0,413B | 0,529A+0,290B |
| 70 | 0,460A+0,749B | 0,413A+0,587B | 0,372A+0,412B |
| 80 | 0,284A+0,958B | 0,250A+0,750B | 0,225A+0,527B |
| 90 | 0,133A+1,127B | 0,117A+0,883B | 0,105A+0,621B |
| 100 | 0,034A+1,238B | 0,030A+0,970B | 0,027A+0,682B |
| 110 | 0,000A+1,277B | 0,000A+1,000B | 0,000A+0,703B |
| 120 | 0,034A+1,238B | 0,030A+0,970B | 0,027A+0,682B |
| 130 | 0,133A+1,127B | 0,117A+0,883B | 0,105A+0,621B |
| 140 | 0,284A+0,958B | 0,250A+0,750B | 0,225A+0,527B |
| 150 | 0,460A+0,749B | 0,413A+0,587B | 0,372A+0,412B |
| 160 | 0,668A+0,527B | 0,587A+0,413B | 0,529A+0,290B |
| 170 | 0,853A+0,319B | 0,750A+0,250B | 0,676A+0,176B |
| 180 | 0,995A+0,149B | 0,883A+0,117B | 0,795A+0,082B |

The Holden tide tables, in their initial accuracy, fulfilled a commercial need at Liverpool Docks; then their commercial success enabled the tables' revision, improving their utility still further. William Vaughan, one of the directors of the London Dock Company, inspired by the Liverpool tidal record from which their predictions were devised, instituted similar records at the site of London Docks, stating that they 'would some time or other be useful'.[311] The directors of London Dock began to record tides in August 1801, four years before their dock opened. Vaughan wanted their records put to good use, as at Liverpool.

[310] RSL LUB.I.8.

With extractions of the first year or two used by a Mr Bulpit to calculate some London tidal predictions, this did come about. Bulpit styled these predictions on tables of the hydrographer, Joseph Huddart FRS.[312]

The eighteenth century lassitude of the Royal Society enabled a reshaping of science to take place in Britain at the start of the second quarter of the nineteenth century.[313] This involved the Society for the Diffusion of Useful Knowledge, the *Nautical Almanac*, the British Association for the Advancement of Science, and the rejuvenated Royal Society itself. The Society for the Diffusion of Useful Knowledge got under way in1826, and published a *British Almanac* annually, from 1828 onwards. That almanac, included a tide table for London, which also followed MacKay's method. Although the precise authorship of this tide-table's first computer remains unknown.

The *British Almanac*'s tide table was specifically for London Bridge; but in the late 1820's that bridge was not in a proper state of existence. John Rennie began a new bridge in 1825, about thirty yards upstream of the old bridge, eventually completing it on August 1st 1831.[314] With three fewer arches, the new bridge offered less resistance to tidal flow than the old. With London Bridge a peripatetic focus for the tide table, the accuracy of the newly published table was immediately called into question. The Admiralty Hydrographer asked the Warden of Trinity House what their Elder Brethren considered should be HWF&C at London Bridge. The quantified reply, in January 1829, added that it was based upon an earlier determination of Huddart's.[315] However, in total the new almanac was a resounding success; so that the Society co-opted the mathematician John Lubbock to direct a sustainable computation of the tide table part.

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[311] RSL LUB.P.121.
[312] RSL LUB.P.119.
[313] RSL LUB.A.96.
[314] Smiles, Samuel, *Lives of the engineers harbours lighthouses bridges Smeaton and Rennie*, (London, 1891), p370.
[315] UKHO Letters in before 1857 H.517.

## 8.3 A PUBLISHED METHOD

The Lubbock family business was banking. The bank, as a shareholder, became involved in the building of the St. Katherine's Dock Company. Squeezed in between London Dock and the Tower, St. Katherine's Dock had space and construction problems. Concurrently Lubbock had been interested in the affairs of the new scientific Society since 1827.[316] By October of the following year, he was considering tidal data from the dock in which his family held an interest.[317] Therefore, when the Society's committee resolved to improve their tide table, they had Lubbock to resort to for help.

[316] The Dictionary of National Biography.
[317] The Dictionary of National Biography; RSL LUB.K.2.

He tried to see what information, about the method employed, he could get from established sources. Neither Bulpit, nor any of the other London tide table makers, would divulge to Lubbock the method whereby they were able to predict tides; as they sold their predictions for a living, the method was their remunerative trade secret. However, by late spring of 1829 Lubbock had located the long London Dock records, and in their abundance, realised that additional help was needed, with which to make an analysis of them. The Society was particularly lucky in obtaining, in June 1829, the services of Joseph Foss Dessiou as their computer, to work on the London Dock series.[318] The Astronomer Royal, John Pond, commended Dessiou to the Society. The combination, of Dessiou and his father, had been involved in marine cartography and tidal information since at least 1770.

The First Lord of the Admiralty had appointed Joseph Foss Dessiou to the Hydrographic Office, in February 1828. As shown in the previous chapter, Dessiou originally worked as a naval assistant to compile sailing directions; but increasingly he became wrapped up in tidal work. From the summer of 1829 he was working on tides, both in the office during the day as his official duty, and at home during the night for pocket money. At first this pocket-money came from the Society. With creation of the British Association in September 1831, it then took the cost of discussing tides under its wing. This was before some of the burden eventually passed, not without opposition, to the office of the Nautical Almanac. Also at first, discussion of London Dock tides was an acceptable part of Dessiou's office duties. This was because both the then Astronomer Royal, whilst he still had the scientific almanac under him, and the Admiralty Hydrographer, Francis Beaufort, simply wanted reliable tidal predictions available. They wanted a set of tables derived by a published method, not by something akin to astrology. So there was a straightforward reason for Dessiou to discuss the London data, with which to make predictions, for the new commercial almanac; and for the method, from whence they came, published in the *Companion* to that almanac. When

[318] University College, London, Society for the Diffusion of Useful Knowledge, LUB.24.

Dessiou had completed the first discussion for the 1830 almanac, they then decided to revise immediately for the 1831 edition.

The tide-table which Bernoulli had formed in 1740 resulted from a consideration of the change in the mean time intervals between High Waters on successive days.[319] This is essentially the product of beating together the two most influential tide generating forces. Because of its prominence, it is also inconceivable that Lubbock could have been unaware of a particular tidal paper of Thomas Brisbane's, in 1821. His paper dealt with the third largest influence in detail, that of the lunar elliptical, and included a second tidal-table.[320] These two tables were theoretical general considerations, with the second one descended from the *Mecanique Céleste* of La Place. Lubbock published a translation of Bernoulli's essay and improved his own original table.[321]

Initially just for London, the method developed by Lubbock was for the particular, rather than the general. The method examined tidal extrema as functions of lunar age, parallax, declination and the time of year.[322] In principle, while the method demands the use of data covering a full nineteen year lunar cycle to produce HW heights, a year suffices for HW times. Notable, the later harmonic analysis of the whole tide, has not entirely supplanted this pioneering non-harmonic method.

## 8.4 THE ADMIRALTY INVOLVEMENT

The Admiralty was the effective science research department of the Hanoverian government.[323] The changing arrangements of the department at the time were a little

[319] Cartwright, *Tides a scientific history*, p48.
[320] I am grateful to Steve Hutcheon for bringing the following paper to my attention: Thomas Brisbane, *Table for determining accurately the Time of High Water at any given Port*, The Edinburgh Philosophical Journal, volume iv 1821 54-56.
[321] John W. Lubbock, *Account of The "Traité sur le Flux et Réflux de la Mer", of Daniel Bernoulli*, (London, 1830).
[322] Cartwright, *Tides a scientific history*, p91.
[323] Reidy, *The Flux and Reflux of Science*.

Byzantine. Its work done, Parliament dissolved the Board of Longitude in 1828, and passed residual responsibilities to the Admiralty. That important residual work, administered by the Astronomer Royal based in Greenwich, was publication of the Nautical Almanac, based in London. At the Board's dissolution, it had published the almanac down to 1831. At first, under the new arrangement, the Admiralty kept the almanac under the Astronomer Royal. Then later in the 1830s, their Lordships relieved the Astronomer Royal of the almanac, creating an actual Superintendent of the Nautical Almanac Office. Even then, overall control remained with the Hydrographer. Equally Byzantine was the infighting among the scientific men, right at the very heart of the developing Empire.

The success of Dessiou and Lubbock's effort at first producing, and then improving, tidal predictions by a published method, was noted among the growing network of scientific society committees and their officers. The Astronomical Society (later the Royal AS), at the invitation of the Admiralty, recommended various changes and improvements to the Nautical Almanac; among those recommendations was one that the almanac should contain a supplementary tide table. William Samuel Stratford gained the appointment to superintend those changes in April 1831. Lubbock had also desired the appointment. Despite that, it at first seems bizarre that Stratford should have as vigorously opposed the inclusion of a supplementary tide table as he did – but there were reasons for his opposition.

The opposition involved reasons of control of cost and inspection of the discussion. They also had to maintain a balance between ideal science and the pragmatic needs of the highly commercial Port of London. The work, begun by Dessiou and Lubbock on London Dock tides for the Society, and allowed to overflow into office work at Lubbock's request, became Superintendent Stratford's responsibility, by the time his office published the first Admiralty table. The modern title, the *Admiralty Tide Tables*, did not emerge until 1917. However that volume is in direct descent, by incremental addition and improvement, from that with the title *Tide Tables for Plymouth, Portsmouth, Sheerness and London, for the year 1833*, and published by the Admiralty.

The Admiralty had had tides recorded at their Sheerness dockyard for some time. Then at the suggestion of the Royal Society, the Admiralty set in train additional observations of the tide, which included those from late 1831at their Plymouth and Portsmouth dockyards as part of the same series. The following year, the discussion, originally just for London, then grew to include the observations of these three additional ports.

The discussion, the actual computation of the tides, did not take place at 3 Verulam Buildings, the home of the Nautical Almanac Office. Dessiou continued performing the labour much as he had before Stratford's appearance. He worked principally in the hydrographic office; this lay on the top floor, at the back of the newly built Admiralty in Whitehall. He also worked at night, at his home in Lambeth.

Lubbock's and Dessiou's responsibility manifested itself as to who they were to present accounts to, to Stratford rather than to Beaufort. This had the effect of curtailing some disbursements to Dessiou. The responsibility also meant that it was Stratford who regulated the amount of Admiralty computing power applied to the discussions. The arrangements were tortuous. Stratford did not have the main computer, Dessiou, under his direct supervision. In contrast, Dessiou enjoyed immense patronage and became the effective director of the Admiralty table from its inception until his retirement in 1847. He also had additional workers directly under him. This effective directorship strengthened, particularly as Lubbock's interest waned in the mid 1830s, once the initial work was complete.

The proposal was wholesale adoption by the Nautical Almanac Office, of the material tables produced by Lubbock and Dessiou, for London predictions. Stratford had a simple scientific objection to the proposal. He wanted it demonstrated that their predictions were superior, or at least as good, to those already produced. Stratford remarked that predictions were available so relatively cheaply, from Bulpit, White and the others. The fact that those latter productions were secret did not weigh at all with Stratford, he wanted a comparison done. Lubbock read Stratford's comparison before the Royal Society on June 25th 1832, together with a comparison made by Dessiou.[324] Irrespective of both objection and the comparisons, to include predictions in any forthcoming publication Stratford had to either adopt the method of Lubbock and Dessiou already on offer, or devise a method himself. Beaufort eventually instructed Stratford to accept Lubbock's offer, and to be grateful for it. The other main advantage, of taking the method and material tables already constructed, was that by then they were considered to be adaptable for the other ports. The method, initially for London, Lubbock and Dessiou extended to Sheerness, Portsmouth and Plymouth.

The Portsmouth and Plymouth observations, were made manually from October 1831, and carried through to May 1833, when manual recording gave way to automation. With part of the Sheerness series added, from January 1832 through to April 1833, the whole were then printed.[325] That those observations carried through into the first few months of 1833, the year of the first Admiralty predictions, enabled making this present comparison for those three ports.

## 8.5 COMPARISON OF LONDON TIDES

The thirteenth century tide table, drawn up for London Bridge, is also the place where John Flamsteed made tidal predictions for, four centuries later. The bridge marks the furthest upstream point of the Pool of London, where English cartographers first measured their longitude from. Thus, London Bridge was once rather a special place in the surveying world, because of its coincidence of the separate datum's of two dimensions, one vertical and the

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[324] John W. Lubbock, *Note on the tides in the port of London*, Philosophical Transactions of the Royal Society, Part I 1833, 595-599. NB there is a typographical error on page 595 which states Deacon instead of Dessiou.
[325] RSL LUB.R.114.

other horizontal. The coincidence did not last, as Greenwich began functioning as a Prime Meridian from 1738.[326] Nor did the tidal datum of London Bridge ever gain any ascendancy except that, for a place remote from present commercial need, the present-day volume surprisingly still retains it. Thereby it forms a long continuous link to one of Europe's older tidal records.

Along the Thames, in the early nineteenth century, there was a profusion of places where tidal observations were gathered. Sheerness was the lowest point: where Nevile Maskelyne's old transit clock measured the tides. Higher up, towards the various dock systems, were first the East India Docks. Next, Mitchell had erected a gauge at Greenwich. Above Greenwich were the East Country Docks. Then beyond Limehouse Reach came Eastern London Docks, the Shadwell entrance where they situated London Dock tide gauge. Lastly, close by the older, upriver Wapping entrance to London Docks was St Katherine's Dock, effectively marking the lower limit of the Pool of London.

Based upon Dessiou's work on the London Dock observations from 1808 to 1826, Lubbock presented the first comparison paper to the Royal Society, in June 1831. The subsequent paper was for the short period of the first quarter of 1832. That comparison, between observation and prediction, contains some confusion about where some of the figures were for. The paper read by Lubbock, contained notes by Stratford. Lubbock presented it at a time of utmost friction between the two, so communications might not have been of the best of order. Stratford appears to be the misleading party, which, as he was only concerned with management rather than any hands-on data gathering, might have been due to his lack of knowledge of the geography involved. The paper states that Bulpit's tables were for the entrance to East India Docks, not the eastern entrance to London Docks. William Pierce, the observer at London Docks, was of the opinion that Bulpit had made the tables for his (Pierce's) dock, and that is what Lubbock had expressed. Nevertheless, Stratford reduced all

[326] G. M. Badger, *Captain Cook navigator and scientist*, (London, 1970), p38.

the data to London Docks; adding twenty minutes to Bulpit's times for the ostensible East India Docks and deducting ten minutes to the times of White and the British Almanac for London Bridge. Consequently the validity of the comparison is somewhat compromised.

Lubbock presented more of Dessiou's comparative work, concerning London observation and prediction, to the Royal Society on June 18th 1835. Whilst this comparison was of the first six months of an unspecified year, inspection of the tabulations from the British Almanac indicate that year to have been 1835.[327] Amin again used data from that paper only recently, showing that there have been large changes in the phase of the tide, due to secular trends and man-made alterations.[328]

## 8.6 OBSERVATION & PREDICTION

During the whole of the nineteenth century, London was the world's premier port. As it was a port with a sufficiently significant tidal regime, no English tidal study could ignore it, because of its commercial significance. However London presented a problem of extrapolation. The data gathered in at one place, London Docks, they used for predictions for another place, London Bridge. That particular problem did not exist among the non-commercial military ports to which the Admiralty first extended the wider study to. This extension of the concerted study of several places over a large geographic area – from the Thames to the Western Approaches – is the second element of this endeavour of Lubbock and Dessiou, which marks the work out as special. The emerging global nature of which has been described as Humboldtian science.[329]

[327] John W. Lubbock, *Discussion of tide observations made at Liverpool*, Philosophical Transactions of the Royal Society, **125**, 1835, 275-299.
[328] Mohamed Amin, *On perturbations of harmonic constants in the Thames Estuary*, Geophysical Journal of the Royal Astronomical Society, **73** 1983, 587-603.
[329] Susan Faye Cannon, *Science in culture*, (New York, 1978), 104-5.

The basic data of the observations is of time and extreme height at each location. Attached to the published record of the observations are notes that state that the *time* is *mean time*, and respectively that:

at Plymouth time is,

> observed by the Dock-yard clock, which is regulated by a person of the town employed for that purpose. The Height of the Tide is ascertained by a self-registering Tide-gauge, made to range between the lowest and highest limits, from zero to 20 feet: zero being 2 feet above the lower Sill of the Gates of the North New Dock;

at Portsmouth time is,

> obtained through the Royal Naval College; and the Dock-yard Clock, which is used for ascertaining the *Times* of High and Low Water, is regulated thereby, by Mr. Smithers, Clockmaker, Portsea. The Height of the Tide is ascertained by Lloyd's Tide-gauge. The Line from which the Heights are measured, is the Sill of the North Dock Gates;

at Sheerness time is,

> as shown by a clock in the Tide-gauge House, adjusted by the Dock-yard clock, which clock is regulated by a sun-dial and the Equation of Time. The height of High and Low Water is registered above the entrance of the basin, or from a fixed line 31 feet below Lloyd's standard mark + XXXI. on the Quay. For a description of the Tide-Gauge, see the *Nautical Magazine* for October 1832.

The published observed times and the published contemporary predictions are taken to be *local* mean time. The modern calculations, synthesising past predictions, are in Time Zone UT (GMT), like true predictions themselves. Consequently I have also reduced the observations and contemporary predictions to UT, so as to have them both on the same basis as the modern calculations, and so that the comparison is simple and straightforward.

The London records used for predictions extended back over many years. For the dockyards there was at least one full year, part of 1831 and the whole of 1832, from which to make time predictions for 1833.

The observations used for computing the Admiralty table, originated from two source types: a privately owned commercial dock in London and three government owned military dockyards. At the London Docks they noted the tides specifically for the commercial convenience of the Docks.[330] In contrast, the dockyard observations were specifically for the purpose of making tidal predictions. The different natures of the observations' origin explain why the recently located record is only of the military tidal stations, that it does not include the private records made at the tidal station on London docks. The Sheerness record, complete from January 1832, exists because of the observations made there for the great levelling which was carried out on the Thames, in the late 1820s, by John Augustus Lloyd.

The published observations were once analysed by George Airy, the Astronomer Royal, in 1840, who had considered that they contained anomalies which he wanted to investigate.[331] However his manuscript papers contain nothing relevant in this direction.

An automatic tide gauge made all the Sheerness records. The precise month of installation of the automatic gauge at Plymouth remains uncertain but seems to have been some time in 1832. At Portsmouth, the intended installation of an automatic gauge appears not to have been undertaken before May 1833, when the records cease.

The Proudman Oceanographic Laboratory has supplied the modern calculations for the three ports. Amin in 1983 subtracted 'tides synthesised by modern constituents' from the corresponding observed time of high water. I have derived the following data for HW times for the three ports in the same way, deducting the contemporary predictions from the observations, to produce time intervals in minutes. Similarly, from the observations the modern synthesis is subtracted, producing further time differences. This gave a negative or positive interval of difference, in whole minutes. The frequency, the numbers of semi-diurnal observations of each same time difference then plots out the whole four or five months in histogram form.

[330] CUL RGO/6/499/82.
[331] CUL RGO/6/499/16.

There are two comparisons to be made of the data. The first comparison is between the observed tide at a particular port and the calculated tide; with the calculations being both contemporary and from a modern synthesis. The second comparison is between the three ports. The contemporary predictions are those published in the beginning of 1833, from the data preceding that year. The Proudman base the modern calculations on twentieth century tidal knowledge.

Figure 31 Plymouth 1833: Comparison between contemporary and modern calculations.

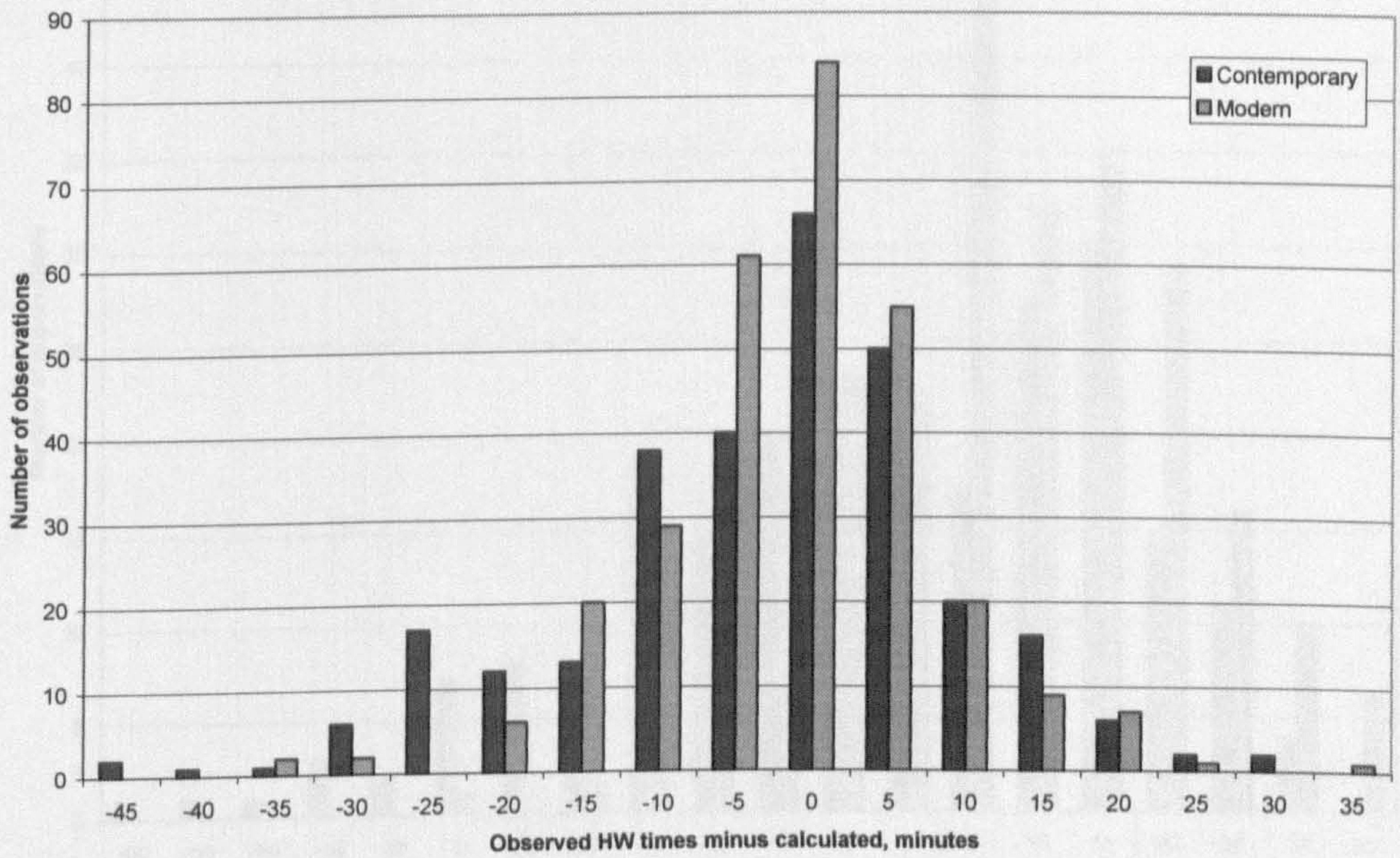


Table 10 Plymouth data analysis.

| Data | Contemporary | Modern |
|---|---|---|
| Mean | -1 | 1 |
| Median | 0 | 1 |
| Standard Deviation | 12 | 9 |
| Range | 78 | 71 |
| No. of observations | 292 | 292 |

At Plymouth the values for the contemporary and modern are about the same. This suggests that there has been little change in tidal characteristics at Plymouth, as expected for a deep water port, and that the cruder prediction methods for the contemporary are almost as good as for the modern. The modern histogram skews less than the contemporary one.

The histograms for both Plymouth and Portsmouth are from 292 observations of HW made over five months.

Figure 32 Sheerness 1833: Comparison between contemporary and modern HW calculations.

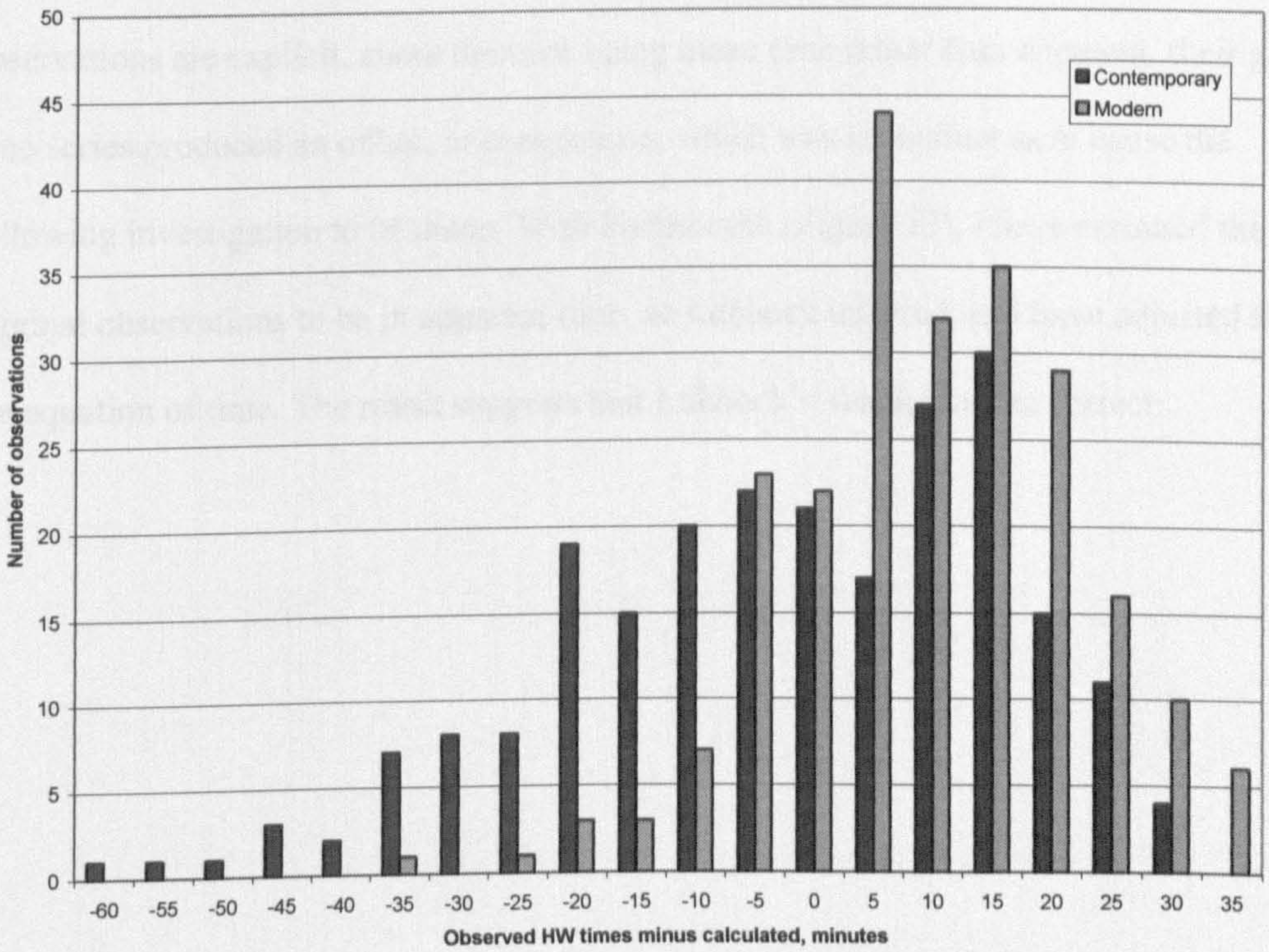


Table 11 Sheerness data analysis.

| Data | Contemporary | Mean |
|---|---|---|
| Mean | 0 | 11 |
| Median | 2 | 12 |
| Standard Deviation | 18 | 12 |
| Range | 89 | 72 |
| No. of observations | 232 | 232 |

At Sheerness, the outcome is decidedly mixed. The mean is not improved in the modern, but both the standard deviation and range are reduced. At this port, the published data only ran into four months of 1833, giving 232 observations. The time series gave large monthly signals in the contemporary predictions; the limitation of the data set prevents their understanding.

In the early autumn of 1832 Lubbock had reminded Beaufort, of how vitally necessary it was to have the observations annotated with precise details of the time, height, manner of recording, and the observer.[332] Sheerness supplied most of the facts as wanted, but not Portsmouth or Plymouth. By the end of that season, it was Lubbock's inference, that what Portsmouth was supplying was actually in apparent time.[333] Whilst the published observations are explicit, about the time being mean time rather than apparent, their graphed time series produced an offset, in comparison, which was so distinct as to cause the following investigation to be made. With Portsmouth (Figure 33), I have assumed the original observations to be in apparent time, as Lubbock inferred, and have adjusted them by the equation of time. The result suggests that Lubbock's suspicion was correct.

[332] RSL Letter Book 425.231.
[333] RSL Letter Book 425.273.

Figure 33 Adjusted Portsmouth 1833: Comparison between contemporary and modern HW calculations.

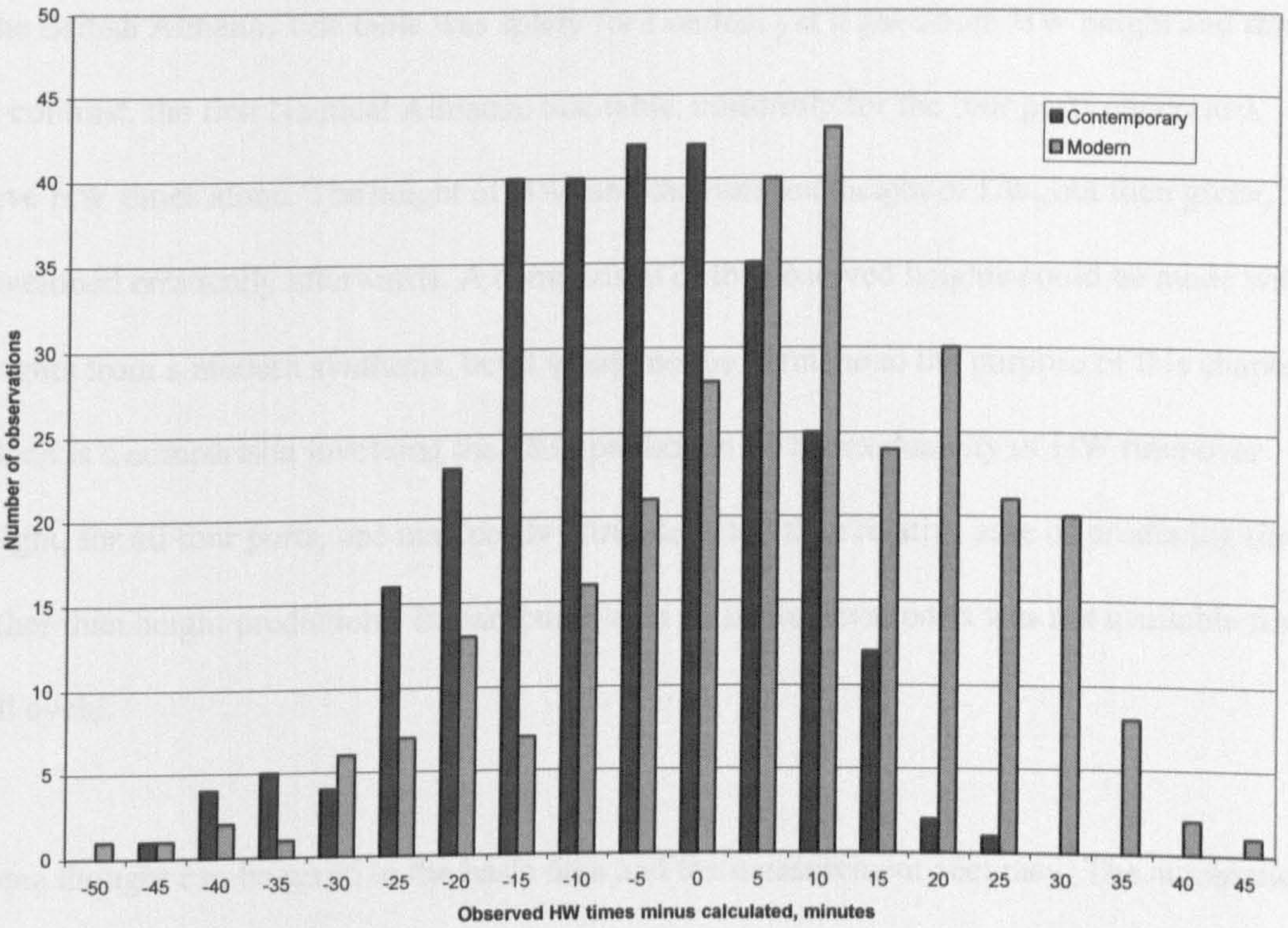


Table 12 Portsmouth data analysis.

| Data | Contemporary | Modern |
|---|---|---|
| Mean | -4 | 9 |
| Median | -3 | 10 |
| Standard Deviation | 13 | 17 |
| Range | 72 | 93 |
| No. of observations | 292 | 292 |

Were the observations for Portsmouth available for a full twelve months, then this study could definitely state whether the assumed application of the equation of time has been valid or not. With only four months available it can only be guessed at.

The spread in the distributions could be due to measurement errors, or to errors in manually made predictions. Most importantly, some spread is likely to be due to the effect of storms causing small changes in HW times, and which no normal tidal prediction method can include.

## 8.7 DISCUSSION

The British Almanac tide table was solely for London, yet it gave both HW height and time. In contrast, the first Nautical Almanac tide table, uniformly for the four ports concerned, gave HW times alone. The height of HW, and the time and height of LW, not then given, developed erratically afterwards. A comparison of the observed heights could be made with heights from a modern synthesis, but it would not be germane to the purpose of this chapter, which is a comparison involving the 1833 predictions. This exclusivity of HW time over height, for all four ports, one may partly attribute to the then relative ease of producing time rather than height predictions. In particular, data from the naval ports was not available for a full cycle.

Some thought can be given to the basic data and the measurement accuracy. The automatic devices were then new inventions and hence untested, nevertheless, as simple clockwork devices they were uncomplicated. The automatically-made record is of a superior quality to the man-made one, because it is a continuous record of the actuality; whereas that manually-made is a reactionary record of extrema alone. Whilst the times are recorded to the minute, this discrimination is acceptable from the automatic gauges using stilling wells. On the other hand, it is a matter of coarse judgement in the case of manual recording, as the tide takes several minutes to make any discernible height change. This is particularly so where the level is observed in the open dock yard. A further complication with manual recording, is how to secure illumination of the water surface at night.

Shifts in the range of time differences are of the same order at all three ports. In summary, both contemporary and modern methods show remarkably similar distributions when plotted against observed times of HW. At all three places, the mean and median are both negligible for the contemporary method. However, the modern method has mixed results with a negligible mean and median for Plymouth, but values over 10 minutes for Portsmouth and Sheerness.

Note that the manual recorders took heights to the half-an-inch, but that it is the magnitude of the vertical range which helps in measuring the **time** of high water. Fortunately, all three ports exhibit good spring ranges, with Plymouth and Sheerness both being about 18 feet, and Portsmouth a little less at 14 feet.

They carried the observations on in a second series up to 1838, after which Airy considered that there were certain anomalies in the time; despite his doubt, they do appear to be of good standard.[334] This is justified by the contemporary predictions, appearing to be as good a match to the observed value (if not better), than the modern predictions. The distributions of differences show that the contemporary method was generally as good as the modern method for one port, but was looking superior for the other two ports. Thus two ports show a bias error. However, one should not interpret this, as showing that the modern method is actually less accurate, but is more probably because of one or all of the following causes.

Physical change can occur in the underwater landscape in a port and its approaches. This could have particularly affected Sheerness which is above the shifting banks and estuarial shoals of the Thames mouth. The relative deep water approaches to Plymouth would be clear of sedimentary factors. Portsmouth is somewhere within the middle of the other two type of port landscapes, and subject to some of the complex tidal influences peculiar to the inner Isle of Wight area. Of the three ports, it is in Portsmouth, where the period of high water is extensive, that extra difficulty exists in deciding which is the particular minute of HW.

## 8.8 1836 HEIGHT COMPARISON

Within the meteorological archive of the Royal Society of London there are a number of tidal records from across the world. They include two volumes titled *London-Dock Tide*

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[334] CUL RGO/6/499/147.

*Computations.*[335] They purport to hold a tidal record for 1836, which was the year in which the Admiralty tables included heights. W. E. Russell made the computations, with funding from the British Association, under the direction of John Lubbock. Covering the period 1801 to 1836, the record is set out somewhat curiously.

The data is set out according to the hour of moon's transit, with the observed time and height of high water then inserted. In order to make present day use of the tidal observations, a copy was rearranged in the order of ordinary solar time, rather than that of the moon. A few data points are missing, but the number of omissions was not significant enough to prevent an attempt at comparing tidal observations with predictions. There were erratic or observational omissions. What did prevent that comparison, was a regular but odd omission of data.

When there is only one tide in a day, it is natural that there should be only one piece of data on that day. With semi-diurnal tides, it is normally the day when the tide is near midnight or noon. However, the extant London record preserves an omission in the fourth hour, that between three and four o'clock. The omission is regular and also alternates between AM and PM; yet it remains unaccounted for.

I attempted to look further into the data by putting the observations and predictions alongside each other. It could be seen that the heights of the two sets were a little out of sequence, but from the heights it was apparent that the Royal Society data was actually for London – as the title said so. A plain semi-diurnal tidal characteristic was also evident. Beyond that, the structure of the data has yet to receive an explanation and hence remains unusable.

[335] RSL MA 195.

The Admiralty predictions for 1836 had grown to include the high water time for eleven ports. For seven of the places, heights were also included. The fullest set of observations available, relative to those early tide tables, is that for Sheerness.[336] This is a complete record of the time and height of high and low water; begun by John Mitchell in 1832, it runs onward for several decades. It appears to be the only set of surviving observational data for 1836, the year when the tables first included height prediction.

Figure 34 Sheerness 1836: Comparison between contemporary and modern HW time calculation.

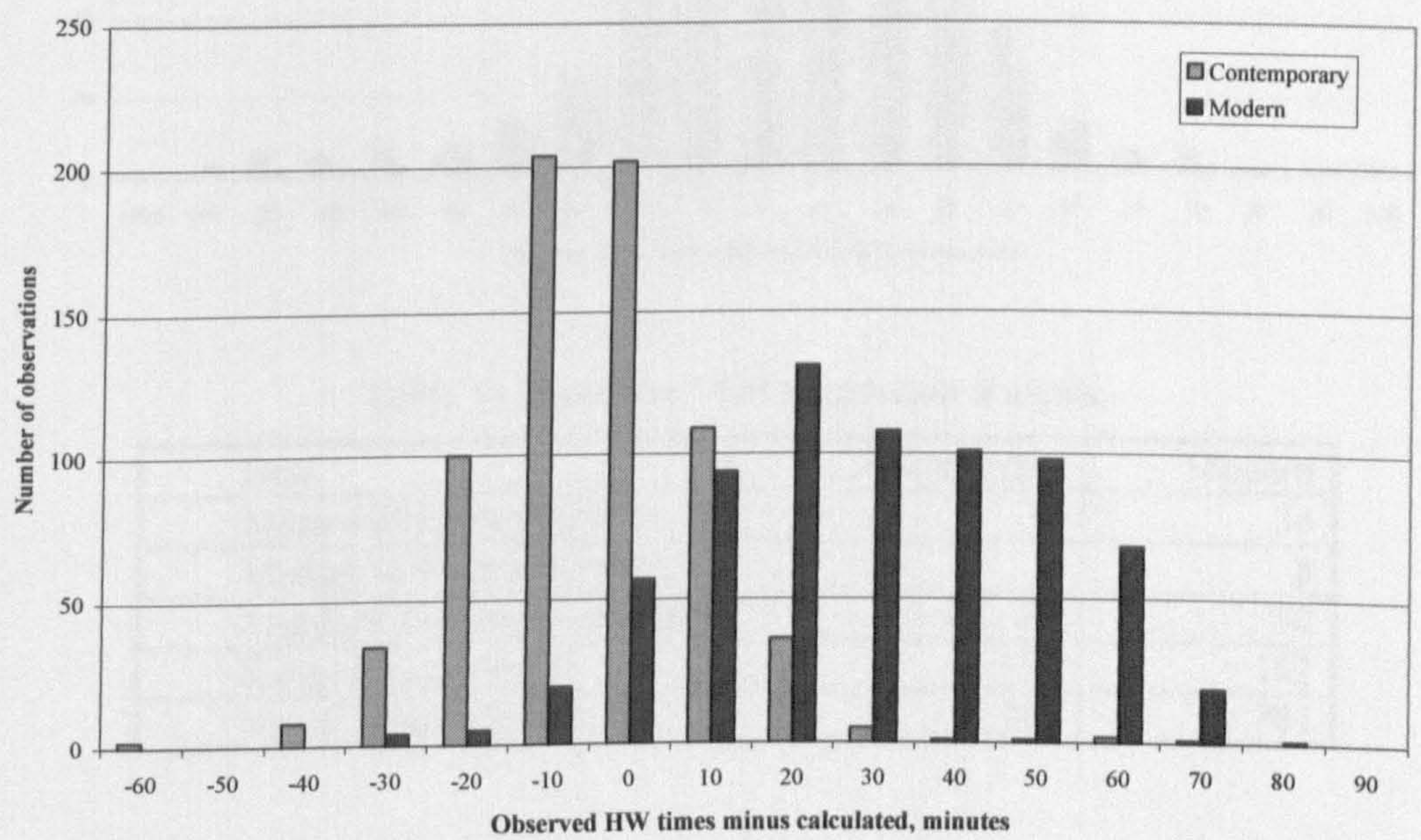


Table 13 Sheerness 1836 time data analysis.

| Data | Contemporary | Modern |
|---|---|---|
| Mean difference (Mins.) | 44 | 44 |
| Median difference (Mins.) | 4 | 20 |
| Standard Deviation (Mins.) | 71 | 48 |
| Range (Minutes) | 204 | 131 |
| No. of observations | 705 | 706 |

336 Liverpool, Proudman Oceanographic Laboratory, Sheerness tidal record.

Figure 35 Sheerness 1836: Comparison between contemporary and modern HW height calculation.

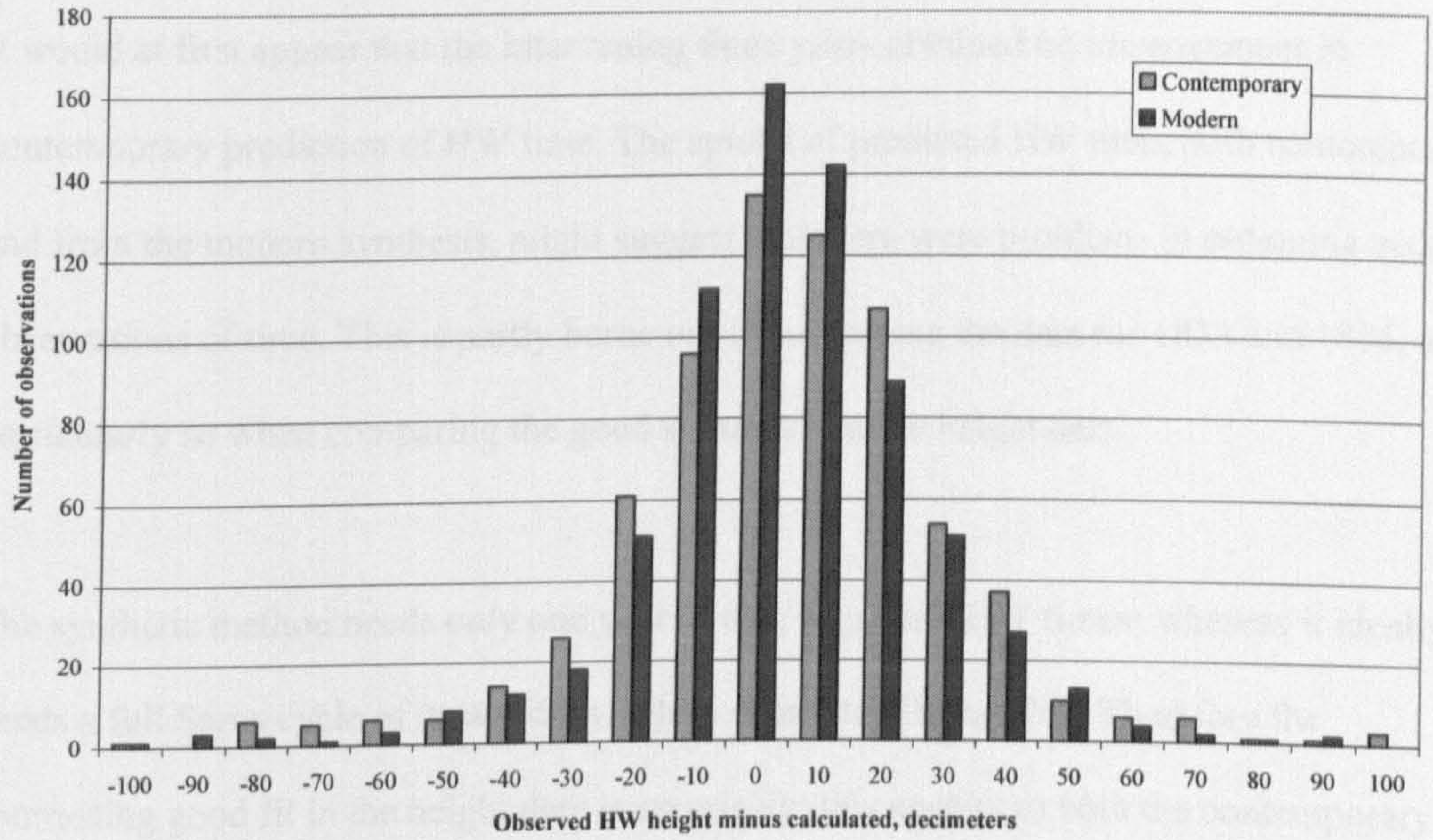


Table 14 Sheerness 1836 height data analysis.

| Data | Contemporary | Modern |
|---|---|---|
| Mean difference (Decim.) | 33 | 34 |
| Median difference (Decm.) | 6 | 8 |
| Standard Deviation (Decim.) | 45 | 50 |
| Range (Decimetres) | 135 | 162 |
| No. of observations | 706 | 704 |

The set of Sheerness data, for the earlier analysis, was a different source to this analysis of 1836. The earlier data was that taken from published observations of the three naval dockyards. The 1836 data is from Mitchell's manuscript record. More than one tide recording gauge was in use at Sheerness in the early 1830's; therefore it is possible that the two sets of data may have been from different gauges.

A full year of 1836 data has been employed for this comparison, of times and heights, in the year that heights were added to the tables. In contrast only a season of 1833 data was available for the earlier analysis of HW time alone. I could have taken a longer set of data, including the period subsequent to 1836. It was not, because only a simple comparison was wanted, for which one year was deemed sufficient.

It would at first appear that the intervening three years obtained no improvement in contemporary prediction of HW time. The spread of predicted HW time, both contemporary and from the modern synthesis, might suggest that there were problems in obtaining accurate observations of time. This is partly borne out in comparing the data for 1833 and 1836, and particularly so when comparing the good symmetry in the height data.

The synthetic method needs only one year of data to predict HW times; whereas it ideally needs a full Saros cycle of data with which to compute HW heights. Therefore the contrasting good fit in the height data is surprising; this applies to both the contemporary and modern synthesised predictions. Knowledge is not available of how long a Sheerness record of tidal data was available for the contemporary computing. While Mitchell's record dates from January 1832 there is likely to have been more data available. This is because John Augustine Lloyd had presented his paper on the general Thames levelling down to Sheerness, in 1831.

With heights, the more difficult factor emanating at Sheerness, it is only an extrapolation that improvement in time predictions should follow.

## 8.9 CONCLUSION

The tide prediction method developed in the early nineteenth century remained the Admiralty method for a century; its generic title is the non-harmonic or synthetic method. Although developed in the second part of the nineteenth century, the Admiralty eventually adopted the harmonic method by the 1920s. While the harmonic method remains in use throughout the world, some tides in parts of the eastern North Sea remain suitable for prediction by the synthetic method. As I have demonstrated, from the first, the non-harmonic method produced very acceptable HW times compared to a modern synthesis.

With Portsmouth, Plymouth and Sheerness being directly open to their respective influencing sea, at none of those places can changes be significantly attributable to man-made alterations; as was the case with the examination undertaken in the Thames. For London Bridge, Amin ascribed some of his differences to changes in the secular trends in tidal harmonics. Effectively we have now extended the study to four ports. As there is conflicting evidence, for the three relatively close military places, and that two of the four ports are on the Thames, then it cannot be said that there is one common time-development in the phase of the tide, within the English south coast area.

At least three comparisons have been made in total over the years, of the intrinsic use of the published prediction method used for the first Admiralty table. Although they were each for merely one of those four ports, that made up that tide table, London. This study extends judgment, and justification, for the original publication being brought into existence, to the authority of the modern harmonic method and the advantage of electronic computation.

This chapter is the direct product of the collection of tidal correspondence. After the development of the synthetic method was established, the correspondence between the various scientists involved continued, but it naturally declined in quantity. I show some of that activity among those correspondents in the early part of the next chapter. The chapter following, describes the development of a prediction method, that competed with the synthetic for four decades, before gaining dominance.

# CHAPTER 9 TABLES FOR THE INDIAN PORTS

## 9.1 INTRODUCTION

Asia offers much to tidal studies. For a thousand years a stone tide table has warned of a Chinese bore; and Newton discussed observations from the Gulf of Tonkin in his *Principia* (chapter 6). This chapter shows how the investigation for Indian ports, turned the subject of tides from a closed area study (as in chapter 8), into a method suitable for the globe. In addition, it was for making Indian tide tables that an early computer was developed. It was also workers within Asia who reduced observations by both methods and computed tides; with their harmonic practices having now become universal. It is also shown how much, mere diligence contributed to tidal science.

In the early nineteenth century there were many tide prediction sheets available for sale. All of the prediction methods that they used remain an unpublished secret. Then in 1829, John Lubbock, set out a method in the *Companion to the British Almanac*. Lubbock was the first to publish a method; it was for a specific place but was then adapted for prediction at other places. The method initiated by Lubbock became the Admiralty method, whose method's dominance endured for well over a century.

Successful prediction relies upon the analysis of past observations, and so it was with tides. As there were so few past observations readily available, the Admiralty set about making a series of observations. From the autumn of 1831 onward, observers began recording tides for this purpose at several places in Britain. By the end of 1832, with a full cycle of observations to hand, their analysis could begin and predictions be induced from them. The British Isles' predictions, first out in 1833, were attracting the title of the Admiralty Tide Tables by 1857.[337]

## 9.2 GATHERING OBSERVATIONS

As the investigation widened, so did the number of workers and agencies widen. Whilst at Cambridge, Lubbock had studied under William Whewell. Although Whewell was involved with Lubbock's investigation from the start, it was not until January 1831 that he himself had woken to an interest in tides. Whewell coined the word 'cotidal' and borrowed 'tydology', from the Frenchman Sade, along the way.[338] It appears to have been Lubbock who, sometime during 1831, instigated the Royal Society's involvement in global observations.[339] However, it was Whewell who utilised those that came in from Africa and America; and would later bring about a separate tidal survey, (conducted by the Coast Guard), around the whole coast of Great Britain in 1832.[340]

In January 1831, Whewell read up on tides of the world, in the *Philosophical Transactions*. He noted that the investigators ought to resort to the East India Company's Hydrographer, James Horsburgh, for full information[341]. It was then, when Whewell made clear to Lubbock, his intention to seek a systematic observation of tides around the whole globe.

It took time for the different bodies to act; not until November 1832 did the Admiralty convey what the Royal Society had in mind, to the Company directors[342]. They sought observations throughout the colonies. The Royal Society laid down at which specific places they wanted the tides measuring, such as Bombay and Singapore. In addition, they

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[337] UKHO Letters In Before 1857, B.596; an earlier, less definite, citation was made in 1850 UKHO Letters In R.708; a later, authoritative, citation appeared in the 1868 British Association Report, 510.
[338] RSL LUB.W.255.
[339] RSL LUB.R.114.
[340] Trinity College, Cambridge, Additional MSS a.206[60].
[341] RSL LUB.W.255.
[342] BL IOR/F/4/1474/57936.

commanded the East India Company to make observations at other places, 'that the Court may think conducive to the important object of forming a general theory of the tides'.

With some forethought to uniformity, the Royal Society had designed a form for the undertaking, and it was widely distributed. Through 1833 and into 1834, the Company gathered observations in from a number of places within their domains. Several of the records obtained were simply of high and low waters, but at least some included the continuous record from a float gauge. When Horsburgh collected the station reports he also compiled a memorandum.[343] The stations were temporary affairs, as he then expressed concern at the expense of a proposed building.

Horsburgh's memorandum, of September 1834, tells us how they measured tide time, using a compass for the meridian line and checking their obviously poor watches against it. He proposed the superior method of using equal altitudes, but did not consider that sending out sundials from England was necessary. Shortly before Horsburgh's death his colleague, the Admiralty Hydrographer, showed Whewell the reports from India.[344] Whewell sought more Indian short observation series in 1835, wanting them prior to the installation of any automatic tide-gauges there.

The Governor-General of India himself promised help. In late 1835, Lord Auckland, previously First Lord of the Admiralty, accepted the appointment of Governor-General. He had a great personal interest in scientific research, and volunteered his aid in procuring an extension of tidal and meteorological observations.[345] By 1838, Lubbock's interest had waned, and Joseph Foss Dessiou had become the director of the Admiralty tidal

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[343] BL IOR/F/4/1474/57936.
[344] UKHO Letters In W.543.
[345] UKHO Letters In H.566.

programme.[346] Despite the interest from on high, Dessiou informed Whewell he was in receipt of several incomplete records. They were insufficient, and therefore could not be worked into predictions, in the same way as those for the Admiralty were.[347] However, Whewell considered that the scraps of information were worthy of being the content of an 'eleventh serial', to his researches on the tides.[348] Whewell cited that Daniel Ross, Dessiou's assistant, gave assistance to him. In fact Ross wrote most of Whewell's paper.[349] The words, in a letter dated October 1838 from Ross to Whewell, were subsequently published as the latter's.

## 9.3 EARLY PREDICTIONS

Auckland retained his direct interest and, in February 1840, two automatic tide gauges were despatched to India.[350] Thomas Gamlen Bunt, of Bristol, built them and then despatched them to Major Thomas B. Jervis of the Bombay Engineers.[351] Jervis had the general superintendence of the Indian tidal investigation. That association of the Engineers and tides was to last until the end of the century; it was eventually to lead to one of their number elected a Fellow of the Royal Society.

The tides were in the hands of the Engineers, probably because it was they who were undertaking the Survey of India. However the Bombay Marine, which formed the initial Indian Navy, also distinguished itself as a school of surveyors. The Marine were constantly reputed to be jealous of the Engineers having the tides. This begun to show in 1847 when Sir

[346] Paul Hughes and Alan D. Wall, *The Admiralty Tidal Predictions of 1833: Their Comparison with Contemporary Observation and with a Modern Synthesis*, The Journal of Navigation, LVII, (2004), 1-12.
[347] Whewell R.6.20[173].
[348] William Whewell, *On certain Tide Observations made in the Indian Seas*, Philosophical Transactions, CXXIX, (1839), 163-6.
[349] Whewell R.6.20[264].
[350] UKHO Letters In B.643.
[351] Whewell R.6.20[248].

Charles Malcolm, after reading the *Bombay Times*, wrote to Whewell: he urged Whewell that more should be done on observations in Western India.[352]

Malcolm's associate, Professor A. B. Orlebar, had been the superintendent in Bombay after Jervis. Because the site was unfavourable, Orlebar had done away with the original tide house, the one which they had used during 1833-4.[353] During his temporary absence, and despite favouring Malabar Point, he had a permanent building constructed at the Observatory in 1842. Fortunately the self-registering gauge was still usable, and Orlebar began his observation series in December 1845. Although he departed from India in February 1847, his successor continued the series down to the end of 1848. Earlier, in 1845, the Government also directed Orlebar to commence observations at Karachi, among other places. He told Whewell how little was then presently being achieved, because of a lack of co-ordination, and that the various records were likely to end up lost.

As it turned out, Orlebar's series were not lost; William Parkes, in his Karachi harbour engineering work of 1857-8, used them.[354] Parkes made several series of observations, formed two prediction sets, and conducted three separate tidal discussions. Discussion is the term, used by the tidal investigators since 1828, for the mathematical treatment of the observations. The first series, at Karachi, were from a season's observations up to March 1858; from which he predicted eighteen months up to December 1860.[355] Subsequent to the first discussion, Parkes obtained Orlebar's 1846-8 Bombay observations and took them for his second tidal discussion. As he found that the self-acting machine recording the Bombay tides poorly adjusted, he then hoped to have those observations superseded by a better record. With an 1865 half-year series of Karachi observations also in existence, the

[352] Whewell R.6.20[245].
[353] Whewell R.6.20[251].
[354] William Parkes, *On the Tides of Bombay and Kurrachee*, Philosophical Transactions, CLVIII, (1868), 685-96.
[355] William Parkes, *Tide Tables for the Port of Kurrachee From July 1859 to December 1860*, (London, 1859). (These tide tables are presently located in the British Library at IOR/V/19).

following year, the Secretary of State for India instructed Parkes to predict the tides of Bombay and Karachi, for 1867. Parkes calculated the predictions from his third discussion. Then he had the wit and presence to check his predictions against observation; enabling him to revise the remaining half year of his 1867 predictions.

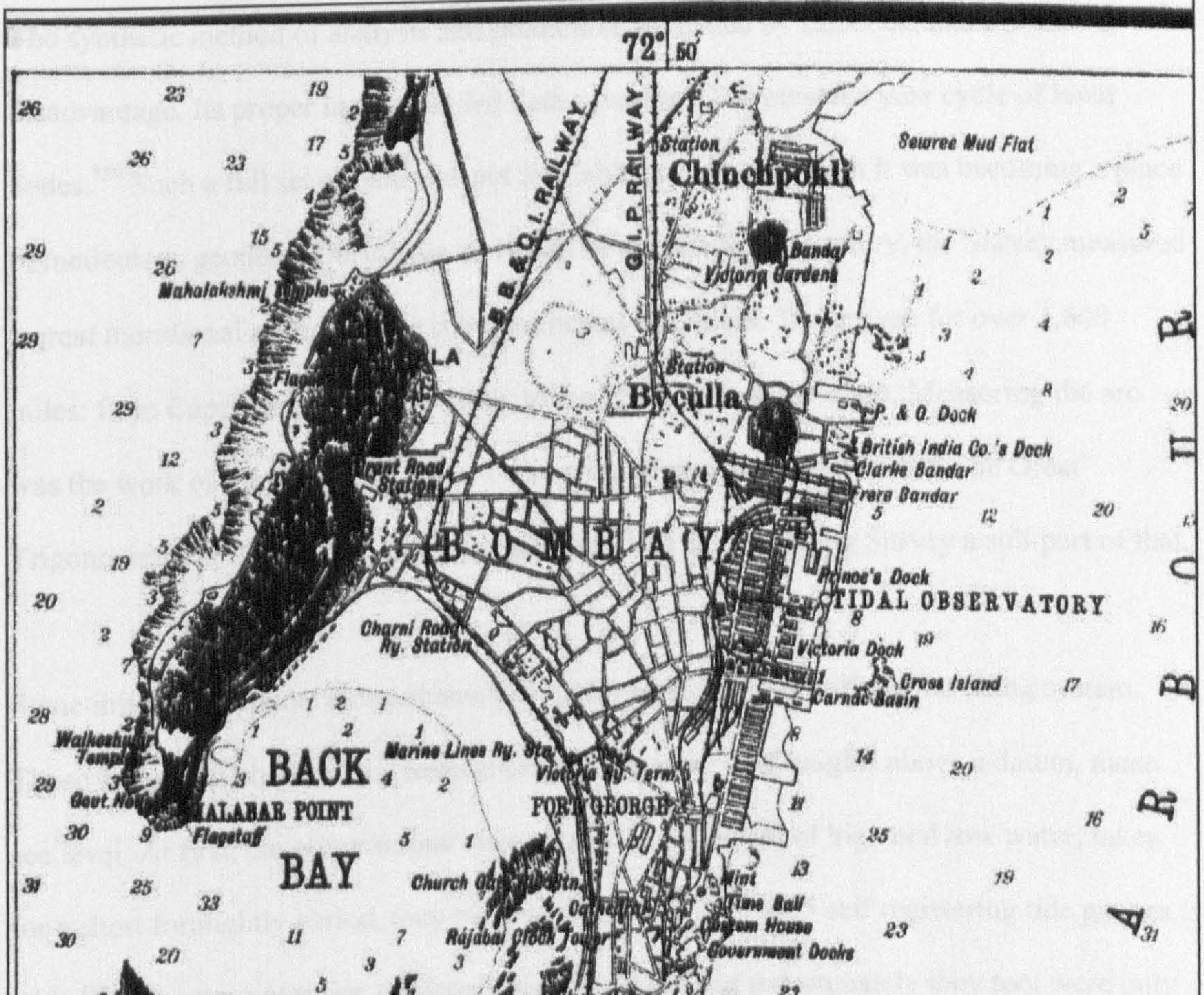
The first predictions made by Parkes were on principles set out by George Airy, the Astronomer Royal. Parkes thought, from comparing the tables for the English ports with the actual tides, that the difference should be tolerable. He found that that was not the case in India: 'The tides on the coasts of India present a marked difference from those on our own coasts in the large amount of diurnal inequality to which they are subject.' Despite the deficiency Parkes formed an annual set of tables in 1867; they were for both Bombay and Karachi and ran on to 1874.[356] The observations, put in train by Parkes, were continued. They were then available to a process that produced a sustainable Indian tidal serial. However, that production was to require two further ingredients: a suitable prediction method, and computing power.

Despite the deficiencies, the harmonic investigators properly lauded Parkes as the first to achieve any sort of success with Indian tides.[357] Parkes was among the first to undertake the whole process whilst in India: that is, the observation, discussion and prediction.

[356] The British Library citation for them is IOR/X/2868, but repeated requests for them in 2004 produced the response that they were not available.

[357] Edward Roberts, *Tide-Tables for the Port of Bombay for the year 1880*, (London, 1879); Edward Roberts, *Tide-Tables for the Port of Kurrachee for the year 1880*, (London 1879).

Figure 36 Bombay's nineteenth century observation sites, the first south, second north[358]




358 J. Eccles, *Account of the operations of the Great Trigonometrical Survey of India Volume XVI*, (Dehra Dun, 1901), Part II facing page 30.

## 9.4 THE SURVEY OF INDIA

The synthetic method of analysis and prediction, perfected by Lubbock, had a practical disadvantage. Its proper use demanded data covering a full nineteen year cycle of lunar nodes.[359] Such a full set of data was not available in India, although it was becoming a place of meticulous geodesy. During the early part of the nineteenth century, the Survey measured a great meridional arc across the sub-continental land mass. The arc ran for over 1,600 miles: from Cape Comorin in the south, to the Himalayas in the north. Measuring the arc was the work of the Survey of India. There were several parts to this: with the Great Trigonometrical Survey the main part, and the Tidal and Levelling Survey a sub-part of that.

Some initial Indian tidal measurements were for establishing a national levelling system. Those early tidal observations were in order to measure land heights above a datum, mean sea level. At first, the observations were merely of the height of high and low water; taken for a short fortnightly period, they recorded no times. The 1855 self registering tide gauges added for the same purpose, obviously included time, but unfortunately they too, were only for short periods.[360] The synthetic method of the Admiralty tables, required a year's observations to produce tide times alone; in addition, Parkes had shown that that method could not deal with the large diurnal inequality of Indian tides.

By mid century, geologists believed the relative levels of land and sea to be changing in the sub-continent. That concept required a more exact determination of sea-level than had previously been made. To that end in 1863, the Great Trigonometrical Survey of India sought to place one of their personnel as an undergraduate at Cambridge.[361] The area of main concern was the coast of the Gulf of Cutch. John Thomas Walker, the General

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[359] Cartwright, *Tides a scientific history*.
[360] Andrew Wilson Baird, *A Manual for Tidal Observations and their reduction by the method of Harmonic Analysis*, (London, 1886).
[361] St. John's College, Cambridge, Adams papers 15.10.1 (hereafter Adams).

superintending the Survey in 1872, then adopted the recommendations of a new tidal committee of the British Association for the Advancement of Science.

The Survey's need was the native catalyst, eventually resulting in the Indian tidal serial.

## 9.5 HARMONIC ANALYSIS

The British Association had been involved with tides from its very foundation. Their new tidal committee coming together in 1867, included Airy and Bunt.[362] Bunt had contributed a paper to the Royal Society only the previous year; in his report, Airy said that it was a good winding-up of the series of tidal investigations, which had formerly occupied so much of the Society's attention.[363] Another member of the committee, fresh from Atlantic cable-laying, was Sir William Thomson.[364] When Thomson asked about the precise purpose of the committee, Airy told him that their stated object was unclear.[365]

However the function of the committee was to promote a new tidal study. The new method needed records superior to those of the synthetic method. The old method only needed records of extreme height and its time; the new method wanted accurate records of the height at every hour. With forty years of concerted tidal study behind them, even by then, good quality records were still in short supply.

Thomson's theoretical interest in tides goes back to when he was thoroughly embroiled in thermodynamics and the *age of the earth* question.[366] Fourier's *Théorie analytique de la chaleur* had appeared in 1822; which Thomson studied, when in Paris in 1840, and mastered

[362] The full committee was: Thomson, Adams, Airy, Bateman, Belcher, Bunt, Burdwood, De La Rue, Fischer, Gassiot, Haughton, Hind, Kelland, Moriarty, Oldham, Parkes, Price, Prichard, Rankine, Richards, Robinson, Sabine, Sissons, Stokes, Webster, Fuller & Iselin. William Thomson, *British Association for the Advancement of Science Report*, (London, 1868), 489.
[363] RSL RR.6.34.
[364] Glasgow University Library, Kelvin M.54 (hereafter Kelvin).
[365] Kelvin A.3.

in a fortnight.[367] Then, in the autumn of 1861, he was the first to successfully realise the potential of adapting Fourier's methods to tides.[368] In 1867, with Tait, he published how they might make the adaptation.[369] So powerful was his insight that, at Norfolk, the meeting of the British Association decided to act upon his idea immediately. That December, three months after querying Airy, Thomson had drawn up a statement of explanation to the Committee on Tidal Observations.[370] At that point, Thomson then became the new light in tidal science.

Supplementing Thomson's statement was a report by Edward Roberts of the Nautical Almanac Office.[371] Roberts had been Airy's best supernumerary; but being such an asset did not stop Airy commending him to the Almanac as a computer, and to Thomson also.

> 'He is the sharpest fellow that we have had for a long time. He is not an educated astronomer, but speedily educated himself to my special work, soon acquired the mastery of tables etc. He is perfectly familiar with all our work. He is the best for hunting out an error by irregular examination that we have ever had.'[372]

Roberts, among all of the harmonic investigators, grew to have the longest association with the work. Roberts also impressed Thomson immediately,

> 'He enters into the principle of the calculation in such a way as to give much more value to his work than if he were a mere calculator'.[373]

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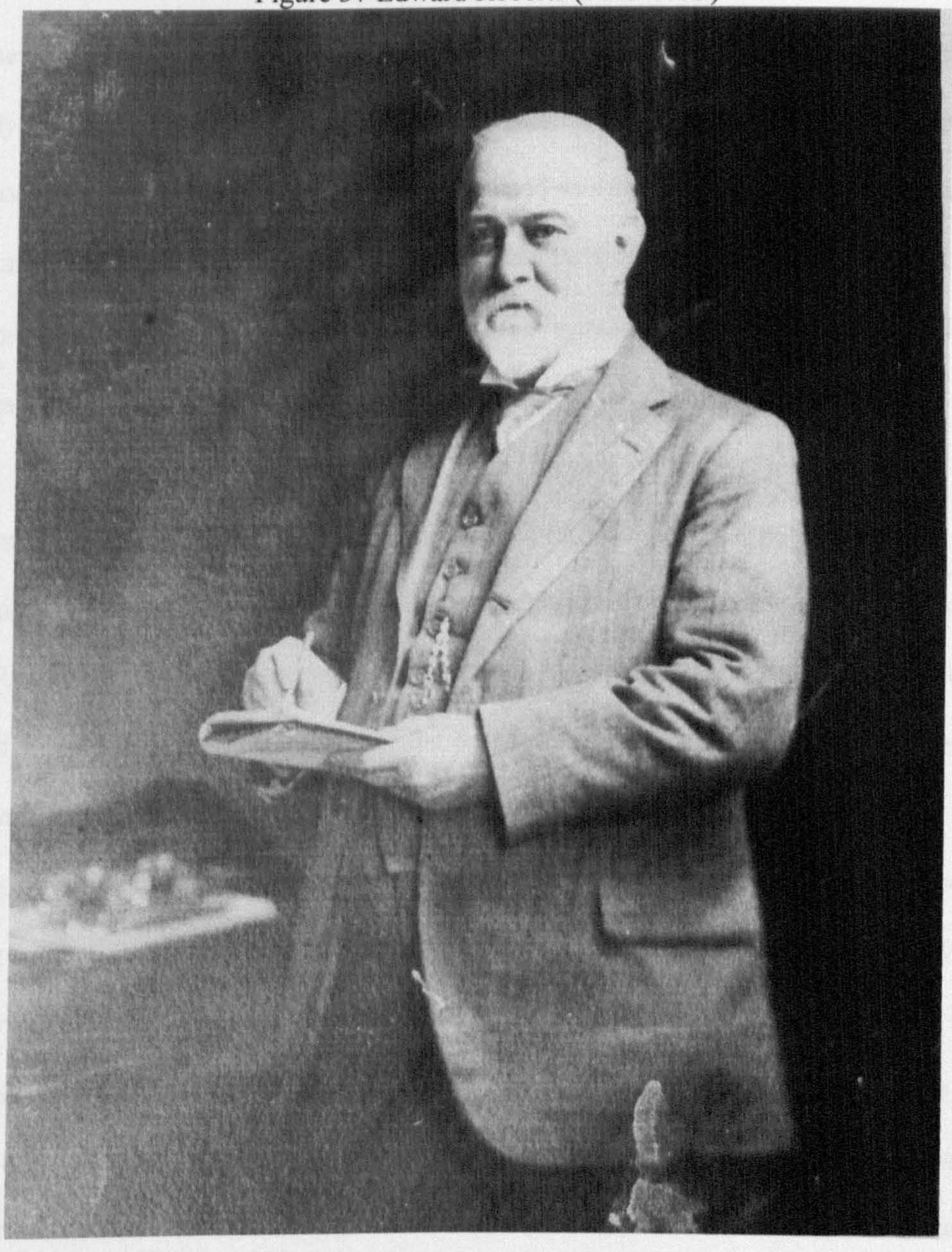
[366] CUL Additional 7656 K.130; Joe D. Burchfield, *Lord Kelvin and the age of the earth*, (London, 1990).
[367] Sylvanus P. Thompson, *The life of Lord Kelvin*, (New York, 1976).
[368] Cartwright, *Tides a scientific history*.
[369] Peter G. Tait and William Thomson, *Treatise on natural philosophy*, (Oxford, 1867).
[370] William Thomson, *British Association for the Advancement of Science Report*, (London, 1868), 489-505.
[371] Edward Roberts, *British Association for the Advancement of Science Report*, (London, 1868), 505-510.
[372] CUL RGO 6/207/125.
[373] CUL Additional 7656 K.169.

Figure 37 Edward Roberts (1845-1933)



Reproduced by courtesy of Liverpool Museum

Initially, the *Committee for the purpose of promoting the extension, improvement, and harmonic analysis of Tidal Observations* was large in number. It included Burdwood, who had succeeded Dessiou in directing the Admiralty's tables. So far, those tables, although a supplementary part of the almanac, had been compiled down at the Admiralty, on Whitehall. As the Hydrographer would not alter the construction of the tables, the accommodation address of its compilation remained the same; while Roberts directed the new tidal investigation from the Nautical Almanac Office, at 3 Verulam Buildings, in Gray's Inn. The result established a permanent diversity of tidal output in Britain.

The new investigation was more powerful than the old. Rather than a synthetic analysis of merely the extrema, the harmonic analysis, appreciating the whole tide, would serve a better purpose. The problem of a massive computing need was not at first realised. The committee did consider that direct observation would probably be more accurate, than the records of the then most perfect tide-gauge. One of the committee's undertakings was to devise a reliable tide-gauge, but its main interests were considerations of the physics of tides.

Thomson and some of his volunteers made an attempt on an analysis, but it required committed work. With a grant from the British Association to defray expenses, Thomson gave Roberts the job of completing it. The selected observations for analysis, were a full year of Ramsgate's, from 1864. Despite the stated misgiving about gauges, those Ramsgate observations were from such an automatic device, but it was one initially considered trustworthy. But unfortunately it was not -- as part of the instrument stuck on the sea-bed during springs. Roberts's occupation was that of an Almanac computer, consequently he could only work on tides during his free time. Therefore, it took Roberts until August 1868 to finish the analysis. However Thomson had found an ideal tidal computer in Roberts. Flushed with the success of the Atlantic cable, the newly knighted Thomson was distinctly in the ascendency. Not only did he persuade the Superintendent of the Almanac to allow Roberts to give his whole time to tides, but succeeded in getting Dessiou assistants also. With this handsome arrangement duly made, Roberts swept on with alacrity, discussing other British and several French ports.

The problem that now arose was that there did not appear to be a great many records of a sufficient quality or quantity available, for harmonic analysis. The excellent Liverpool record was of course readily available, as was the later series made by Parkes in Bombay. Data from the three ports of Ramsgate, Liverpool and Bombay, made up the first harmonic investigation of tides. However, in total for Ramsgate and partially for Liverpool, the new investigation was without a purpose. For the home ports, with its semi-diurnal tide, the Admiralty already had a method which worked well. Their Lordships had no need to finance a new investigation around the British Isles.

One of the first beneficiaries of the new method was the privately produced tide-tables for Liverpool. Holden's annual tables, beginning in 1770 and running onwards for 205 annual editions, although no longer made, remain the world's longest running tidal serial.[374] They were famous; and the data from which they derive had formed a very important part of Lubbock's investigation. The quality of the Holden predictions improved from shortly after Thomson announced his new approach. Roberts said that he had calculated them since about 1870.[375] As they were superior to the Admiralty table for Liverpool until 1915, clearly Roberts employed the new method there. Ramsgate was a Royal Harbour and did not enjoy a similar set of privately made tables. Therefore it would have seemed that the greater potential lay in India – but that was not to be.

Roberts concluded his report with the reason why he did not particularly use London observations. This was because of a substantial change having taken place in the Thames tide over the previous twenty-five years. The changes he attributed to recent events included: removal of obstructions, extensive dredging and construction of the embankment.

Roberts was highly optimistic of the benefits they hoped to derive from the investigation. In addition to what Thomson had listed, Roberts anticipated learning of both an approximation to the depth of the sea, and the retardation of the earth's rotation. It was almost an aside when he said that, the benefit to come from knowledge of tidal height – at any time – is very great. Apart from increased accuracy, this was the fundamental advantage of the harmonic method, over the synthetic.

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[374] Philip L. Woodworth, *Three Georges and one Richard Holden: The Liverpool tide table makers*, Transactions of the Historic Society of Lancashire and Cheshire, CLI, (2002), 19-51.

With the harmonic method the germ of a second element toward the Indian tables came into being. The method however required testing.

## 9.6 HARMONIC PREDICTIONS

Co-operation across the Channel might not have been of the first order; for a Frenchman had pioneered a form of harmonic analysis as early as 1842.[376] It was a perhaps primitive form and did not have the influence of the later, more rigorous method.

The United States Coast Survey had given their utmost co-operation to pleas for help from the early tidal investigators.[377] A reciprocal request came in 1846 from the Washington observatory.[378] What they wanted was for Airy to supply formulas, with which they could reconstruct the deficient American Almanac. Co-operation existed across the Atlantic if not the Channel.

Typical, was the chance offer of a new tidal theory, sent to Britain from the American interior, Cincinnati in Ohio.[379] The offer came in early 1870, before the Association published the tidal committee reports of the preceding year.[380] Thomson's delayed report shows that, he then added Fort Point, near San Francisco, to the previous three places of observation.

For the Pacific, there had been some Fijian observations available to Thomson at the start; they, however, were too short a series. Trying to select a Pacific port, he had learnt from

375 CUL DAR 251/5208.
376 David E. Cartwright, *Rémi Chazallon – a forgotten "ingénieur hydrographe"*, History of Oceanography, XV, (2003), 2-3.
377 Whewell R.6.20[50].
378 CUL RGO 6/203/31.
379 Adams 15.1.1.
380 William Thomson, *British Association for the Advancement of Science Report*, (London, 1870), 120-5.

their publications that the Coast Survey had installed automatic gauges on their west coast. In November 1868 he asked the Superintendent of the Survey for a trustworthy series. By April 1869, Roberts was in receipt of the Fort Point data, the place which the Superintendent had selected. There were then four observation stations: Liverpool, Ramsgate, Bombay and Fort Point. The latter prove to be particularly special because it had the largest diurnal tidal component. This was the element which had been troublesome to Parkes with Bombay.

By September 1870, Roberts had gone on to compare his consequent predictions for Fort Point with the next series of observations. Julius E. Hilgard (1825-1891), of the Washington Observatory, sent these to him. When he sent the second set, Hilgard said that he would be, 'surprised if you can get reliable constants out of even two complete years'. Roberts obtained an important result. The comparison done by Roberts was with only one year but the agreement was remarkably good. The result from Fort Point had vindicated the harmonic analysis. Harmonic analysis could provide all of the sensible tidal components for prediction.

Thomson presented the bulk of the results to the British Association meeting, coincidentally held at Liverpool in 1870. Some of the available data was quite old. That of Liverpool and Fort Point was from the end of the 1850s. A further set came from Karachi, for the two years beginning 1 May 1868.[381] With the Karachi set, Roberts compared predictions from the harmonic analysis and Parkes' method, together with the actual recorded heights of November 1869. His published his comparison as a graph at the end of the 1870 report.

By that stage of the investigation, further work on Ramsgate was beginning to show that it had some similarity, in its characteristics, to Liverpool. Liverpool, an important station because of its long record, was without a large enough diurnal tide for further examination.

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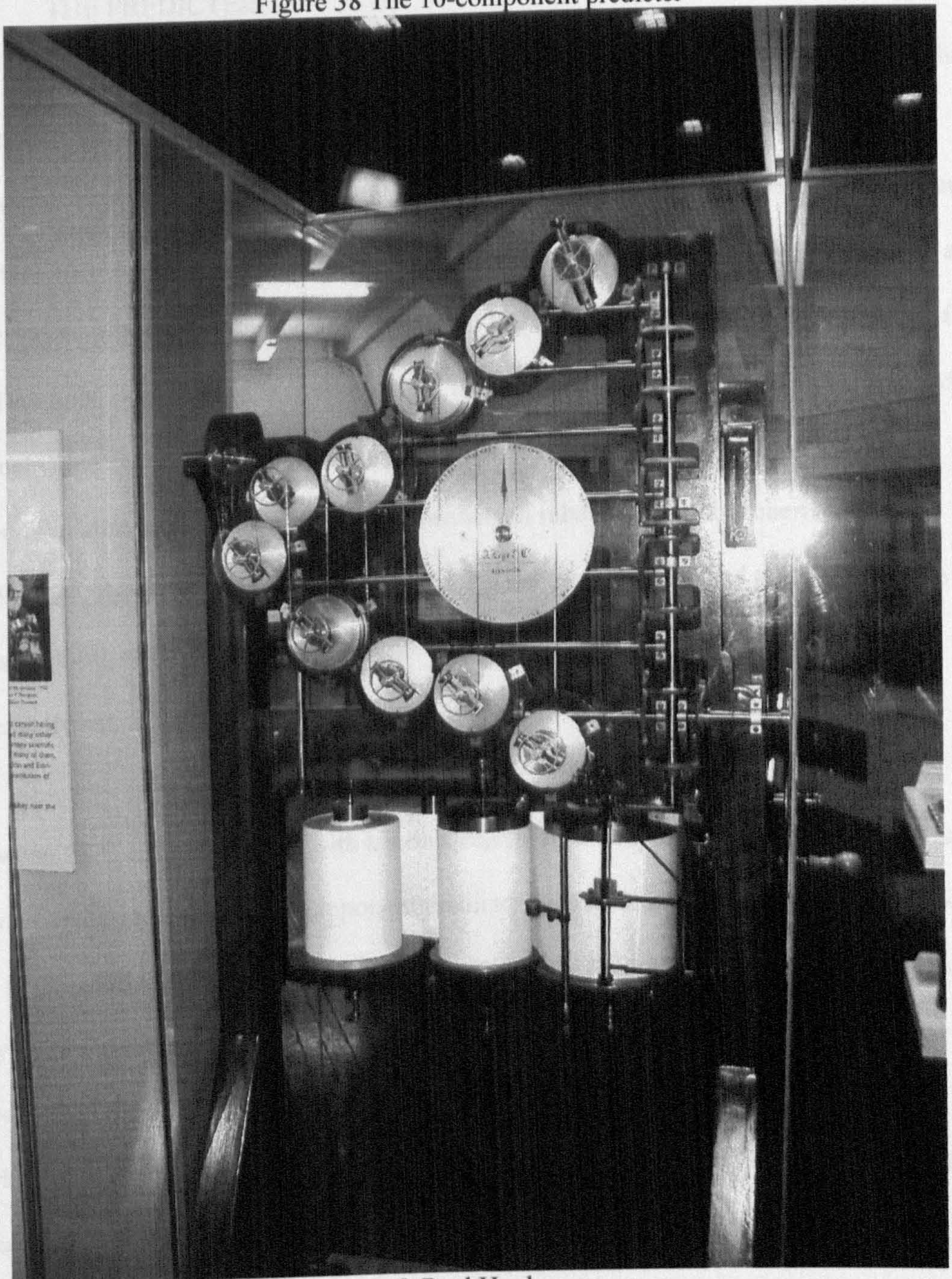
[381] Edward Roberts, *British Association for the Advancement of Science Report*, (London, 1870), 125-151.

However, despite Fort Point showing the worth of the harmonic method, some of the original optimism was beginning to wane. Thomson then saw that solving the necessary equations, by direct calculation, was a very labour-intensive process.

Thomson acknowledged, in the conclusion to the second report, that perhaps Airy had been the first to use harmonic analysis with one particular aspect of tides. Thomson then recognised that the plan for calculating predictions, for the strongly twice-a-day Atlantic tides, was quite sound. He saw that the synthetic method was acceptable for the British coast. But, he pointed out, for the rest of the oceans, where diurnal tides were strong; the computation needed was a higher level.

Parkes had successfully accomplished this for the first time at a location beyond the North Atlantic. While Parkes had modified the basic synthesis for Bombay and Karachi, his modification had been empirical. This was what Thomson meant by Parkes' method being only practically sufficient. Bolstered by the authority of the committee, Thomson believed that he should apply the harmonic system instead. He particularly asked for more observation stations in India; offering the allure that Indian predictions could then be as good and reliable as those in England. He referred to the harmonic system's searching character; that it had an exhibition facility, which was altogether independent of theory. However, he knew that the new system demanded more computing power.

Figure 38 The 10-component predicter



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The harmonic method had stood up well to the test. Yet, without some answer to the calculation burden, the harmonic method would not prevail – demand could not justify the cost of huge manual calculation as it stood.

## 9.7 THE PREDICTER

The tide predicter is an analogue calculating machine, an early form of computer.[382] During his career, Thomson took out patents for seventy devices, none of which were for tidal apparatus.[383] In the summer of 1873 the first working tide predicter was constructed under Roberts' direction, in London (Figure 38).[384] Consisting ten components, it has attracted a description of the British Association predicter. Roberts showed Thomson the predicter, for the first time, that October. At the showing, Thomson expressed surprise that Roberts had not named it 'the Sir William Thomson predicter'. Thomson, with his good regard for Roberts' mathematical skills, kept up a professional relationship with Roberts until June 1879. Then, that summer, Thomson shunned and deserted Roberts, and turned to Andrew Wilson Baird, of the Royal Engineers, for computation. He did so as a result of Roberts repeatedly naming a new machine as his own.[385]

Between 1873 and about 1881, with his own company in Scotland, Thomson produced an alternative design, in an eight component predicter (Figure 39).[386] Although never applied to any practical use by himself, he was able to sell it to the French in 1901.[387] Meanwhile, in May 1878 the Indian Government commissioned a larger tide predicter for themselves, directly from Roberts.[388] In the April following, the Indian predicter was brought to a workable condition.[389] That spring, Thomson invited Roberts to write a description of the Indian predicter, that Thomson would present to the Royal Society.[390] Thomson went so far

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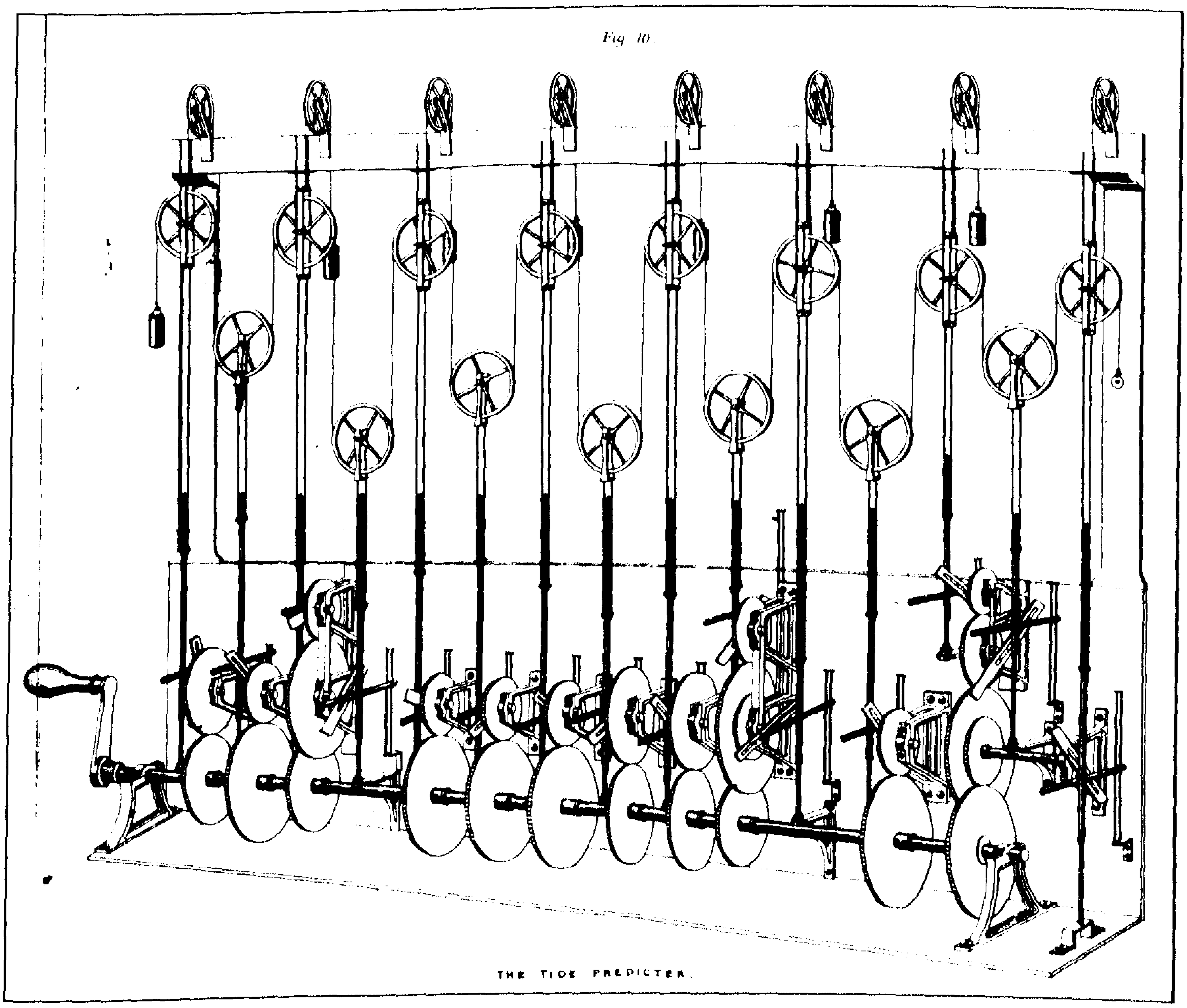
[382] Both *predicter* and *predictor* appear in The Concise Oxford Dictionary.
[383] Silvanus P. Thompson, *The life of Lord Kelvin,* (New York, 1976), 1275-7.
[384] London, Science Museum, Inv. no. 1876-1129.
[385] James Forrest, *Discussion on tidal instruments*, Minutes of Proceedings of the Institution of Civil Engineers, LXV, (1881), 26-64.
[386] William Thomson, *The tide gauge, tidal harmonic analyser, and tide predicter*, Minutes of Proceedings of the Institution of Civil Engineers, LXV, (1881), 2-25; The analyser is: London, Science Museum, Inv. no. 1896-60.
[387] Anonymous, *Tide Predicting Machines,* (International Hydrographic Bureau, special publication no 13), (Cannes, July 1926), 13.
[388] James Forrest, *Discussion on tidal instruments*, Minutes of Proceedings of the Institution of Civil Engineers, LXV, (1881), 26-64; CUL Additional 7342 R.87.
[389] Peter G. Tait and William Thomson, *Treatise on natural philosophy,* (Oxford, 1867); Additional MSS, 7342 R.94.
[390] Edward Roberts, *The tide predicter*, Nature, XXIII, (1881), 555.

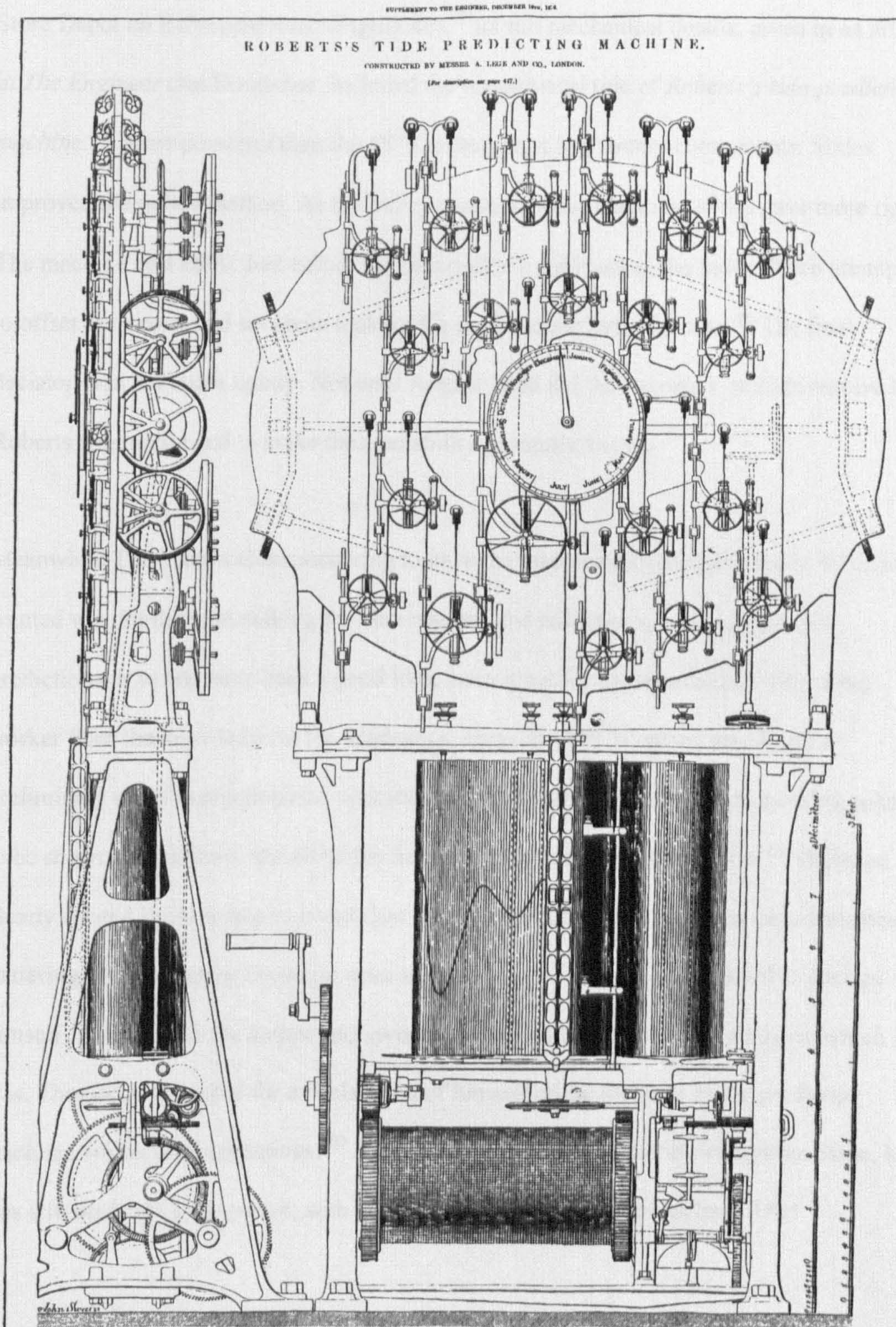
as to offer the paper's formal reading but required Roberts to change the title. The original title alluded to Roberts as the inventor rather than Thomson. Roberts stood his ground. Rebuffed, Thomson then arranged for the Society's secretary, rather than himself, to be the paper's official communicator.[391] Preferring not to enter the fracas, the secretary sought a neutral title for the paper from Roberts.[392]

Figure 39 Thomson's 8-component tide predicter[393]




[391] Edward Roberts, *Preliminary note on a new tide-predicter*, Proceedings of the Royal Society, XXIX, (1879) 198-201.
[392] CUL Additional 7656 RS.1425.
[393] *Tidal instruments*, Minutes of Proceedings of the Institute of Civil Engineers, LXV (1881) Plate I.

Figure 40 Roberts' 20-component predicter



As the India Office machine was rather large, they kept it down in Lambeth, at the Indian Store Depot on Belvedere Road (Figure 40).[394] Its full mechanical details, given in an article in *The Engineer* that December, included the unequivocal title of *Roberts's tide-predicting machine*.[395] More powerful than the 1873 prototype, it had twenty components. Slides improved the pulley method. As the pulleys were an approximation, slides gave more rigour. The machine cost £800. Just before the description's publication, the India Office attempted to offset their costs and set about making the machine available for hire.[396] The final decision was not taken lightly. Not until August 1880 did the Secretary of State resolve that Roberts was authorised to make the availability generally known.[397]

Meanwhile Thomson was manoeuvring to have the machine moved out to India. What he wanted was for the man making the observations and reductions, to also make the predictions. It would have been a good idea, were it not for the remoteness of the field worker from the knowledge of the academics. Early in 1880 Thomson sent Baird a preliminary set of instructions for operating the predicter.[398] When Baird responded, asking to be shown exactly how, the difficulty involved was immediately apparent.[399] Thomson clearly invited Baird to improve and then publish the instructions; the idea must have been flattering. Unfortunately Thomson went a little too far. Thomson asked Baird to declare himself, Thomson, as the author and inventor of the system of harmonic analysis, which he was. Thomson also asked for a declaration of himself as the designer of the predicting machine, which was contentious.[400] Although Baird side-stepped this contentious issue, he was still made the joint author, with Roberts, of the Indian tide tables from 1881.

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[394] Additional MSS, 7342 S.572; CUL Additional 7342 R.96.
[395] Edward Roberts, *Roberts's tide-predicting machine*, The Engineer, XXXXVIII, (Dec. 19, 1879), Plate facing page 447 + 447 – 450.
[396] CUL Additional 7342 S.572.
[397] Anonymous, *Nature*, XXIII, 1881, 467.
[398] CUL Additional 7342 B5; a later copy of instructions is preserved in CUL Additional 7342 PA.200.
[399] CUL Additional 7342 B.4.

While corresponding with Baird, keeping him fully up to date, Thomson was also planning a soirée on tidal machines, at the Institute of Civil Engineers. Thomson's purpose with the soirée was to try to impose his primacy of invention. The reading and discussions took place over three evenings of March 1881. As the record of the soirée is only minutes of the meeting, so it is without emotion. Unfortunately the garbled minutes are the only record to exist; and they mix up an account of a model donated to the Science Museum in 1881 with one donated in 1876.[401] A more natural and open correspondence ensued in the journal *Nature*, clearly showing that the tide predicter had a mixed parentage.

## 9.8 THE PREDICTER'S ORIGINS

'A description of a machine for finding the numerical roots of equations and tracing a variety of useful curves', which Francis Bashforth (1819-1912) described in 1845 may be called the model idea.[402] Seeing the need for a computing aid, Thomson sought to design such a harmonic machine. Then in August 1872, at Thomson's behest, Roberts met Beauchamp Towers, a young construction engineer. At the meeting, where they discussed making a mechanical tide predicter, Towers suggested adapting Wheatstone's chain and pulley. Thomson then put the whole idea to the British Association meeting in Brighton. With funding from the Association, Thomson then had a wooden model (Figure 41) made, by J. White (d.1884) of Glasgow. Thomson also proposed making a second model.

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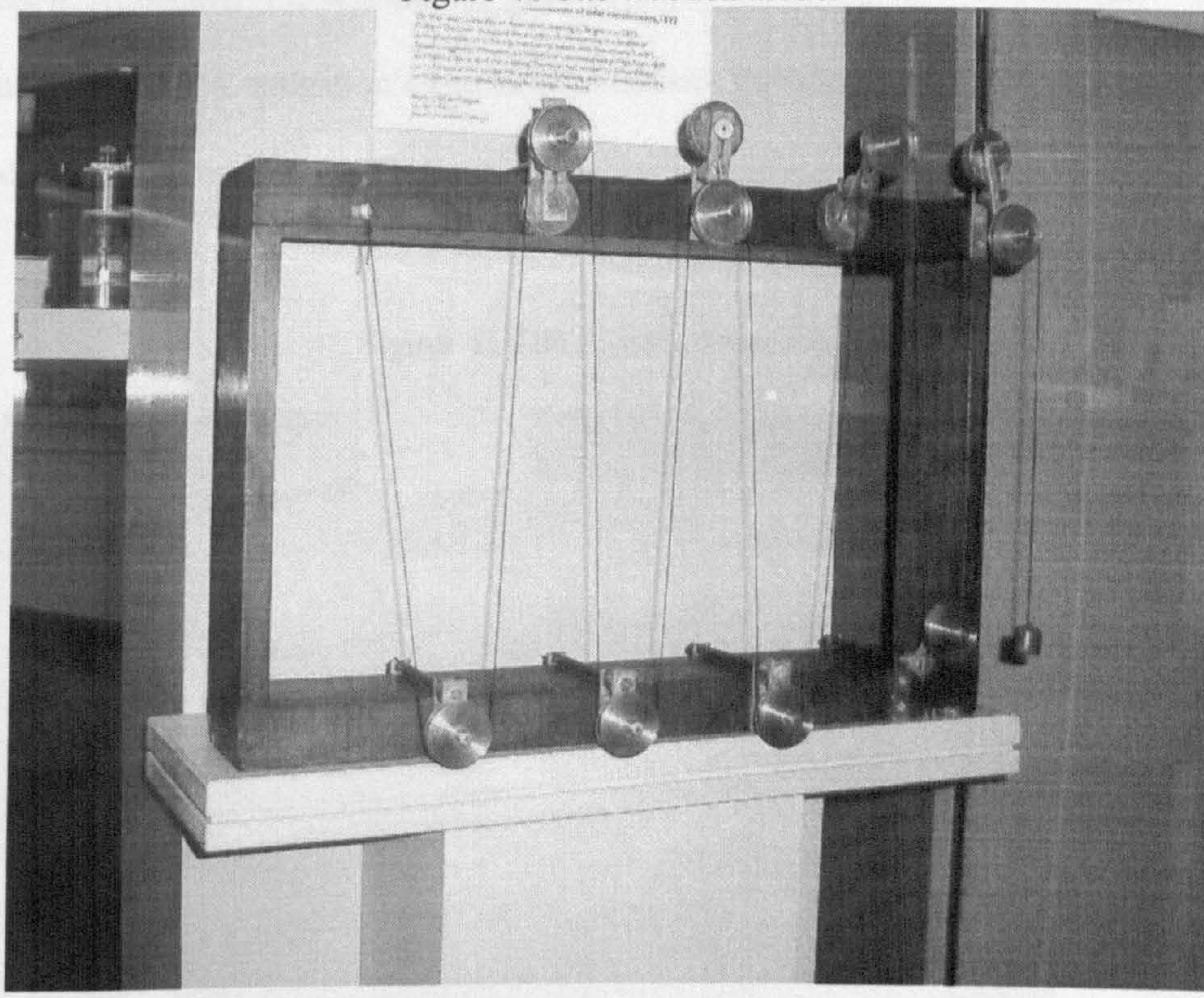
[400] CUL Additional 7342 B.59a.
[401] Compare: Anita McConnell, *Geophysics & Geomagnetism*, (London, 1986) 24-5; with: William Thomson, *The tide gauge, tidal harmonic analyser, and tide predicter*, Minutes of Proceedings of the Institution of Civil Engineers, LXV, (1881), 16-17.
[402] Francis Bashforth, *Tide-predicting machines*, Nature, XXIV, (1881), 53.

Figure 41 The wooden model



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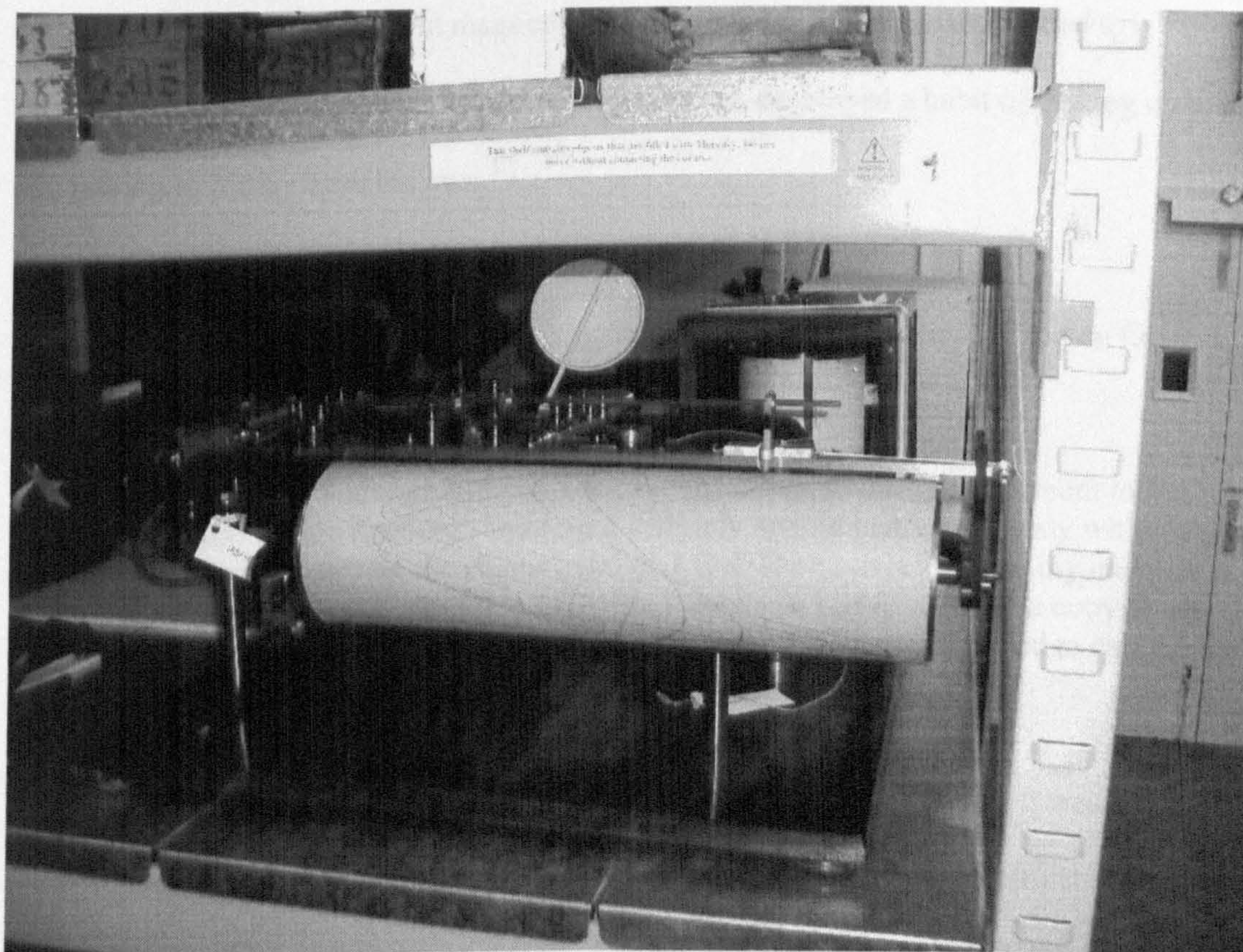
There were problems with Thomson's wooden model which Roberts assisted in solving. While Thomson was away, Roberts devised another model which worked. Made of metal, this model has two-components; and the parallel slides are in a horizontal plane Figure 42.[403] Begun in February, Roberts showed the new model to Thomson in May 1873. Roberts then made a second two-component model to incorporate Thomson's ideas. Thomson's suggestions, for it to be in a vertical plane and without slides, were not a success. From June, based upon the horizontal model, Roberts directed the manufacture of a ten-component fully working machine – the British Association machine.[404]

Alexander Légé, of London, constructed both the horizontal model and British Association machine. The machine cost £155.[405] All of the disbursements from the funds went through

[403] London, Science Museum, Inv. no. 1881-13.
[404] London, Science Museum, Inv. no. 1876-1129.
[405] Additional MSS, 7342 R.82.

Thomson. Altogether, the Association gave £1,380 to the harmonic investigation.[406] While Thomson was the investigation's part-time chairman, Roberts was a Nautical Almanac full-time organic computer.

Figure 42 The 2-component model



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Roberts exhibited the British Association machine in September1873, at their Bradford meeting. Then the Queen opened the exhibition at South Kensington, where they first gave it a public display, before sending it off to the 1878 Paris Exhibition.[407] While Thomson was planning his soirée, he donated the very first wooden model to the museum, and got the Association to donate the horizontal metal model. Thomson did not donate the unsuccessful

[406] O. J. R. Howarth, *The British Association for the advancement of science: a retrospect 1831-1931*, (London, 1931), 271.
[407] CUL Additional 7342 R.91; *Catalogue of the special loan collection of scientific instruments at the South Kensington Museum in 1876,* 3rd edition (London, 1877).

model, which now appears lost. The International Geographical Congress at Venice in 1881, attended by Baird rather than Roberts, again exhibited some apparatus.[408]

After the soirée, Thomson publicly mixed up both chronology and descriptive names. He described the late-made analyser as the first made predicter.[409] (Thomson produced similar confusion, patenting the ancient magnetic compass but with which he descended to litigation.[410]) Recent scholarship considers him to have developed a habit of picking up ideas and talking as if they were his own.[411]

Professor Bashforth concluded the public correspondence innocuously.[412] Then on October 25th of 1881, Bashforth wrote to John Couch Adams.

> 'When I passed through London I went to the South Kensington Museum to see Thomson's Tide Predicter, and found it simply my old instrument, only without the provision for keeping the chains parallel. I find Thomson referred to my machine in his paper before the Institution of C. Engineers – so I have sent him a copy of my lithograph. I do not know Mr. Roberts but I think he is hardly entitled to call the new machine his own.'[413]

It seems possible for Bashforth to have been referring to the concept as his. It was the same concept in all: of the wooden model, the two component metal model, the British Association machine and Thomson's predicter. The South Kensington Museum contemporaneously held all four pieces. A decade later Bashforth reprinted his original description, to which he added an appendix on the predicter. Annotated by him, one copy sets out his claim.[414] Bashforth's diagram (Figure 43) is of a four component machine.

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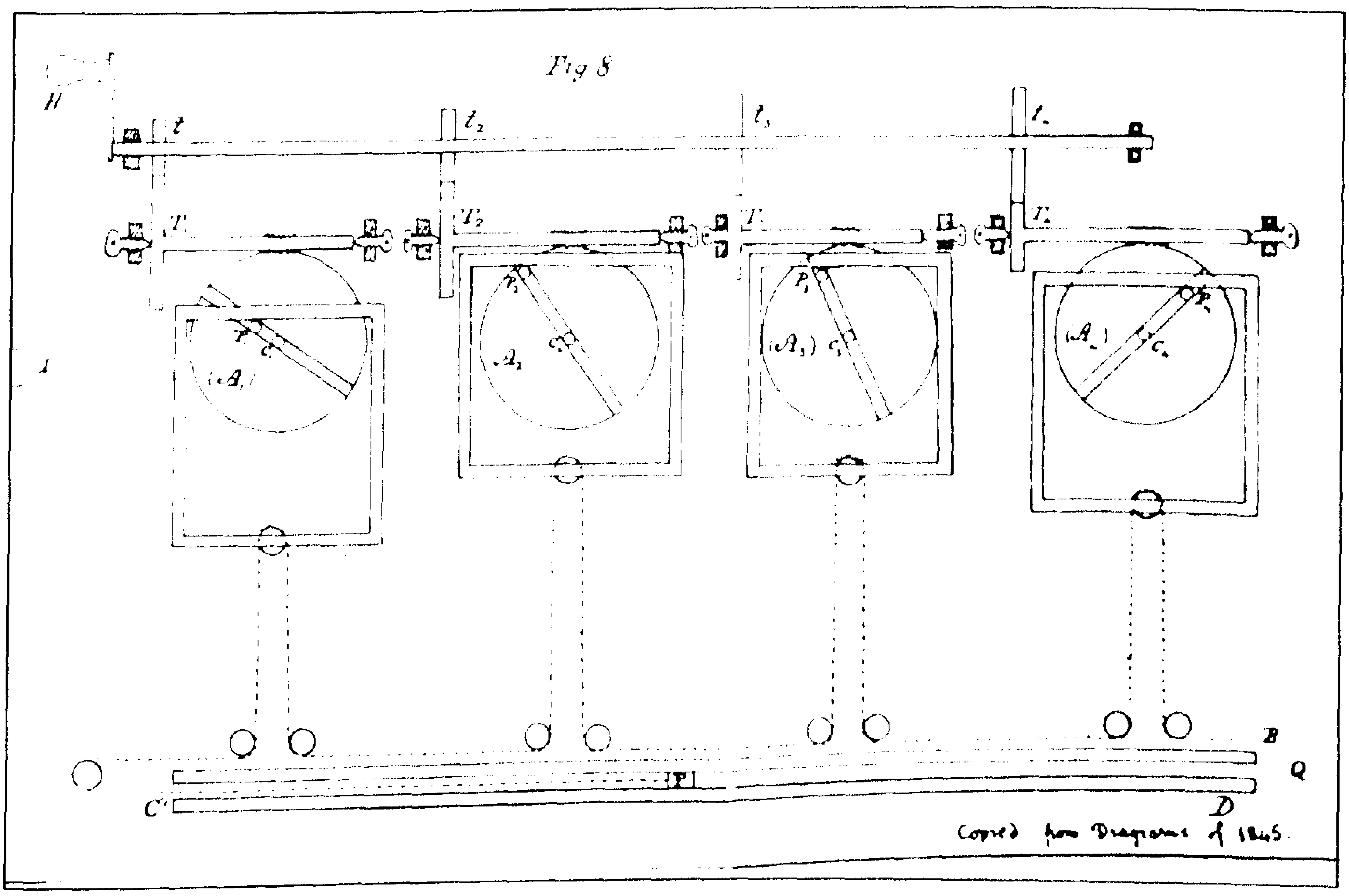
408 CUL DAR 251/3025.
409 William Thomson, *The tide predicter*, Nature, XXIII, (1881), 482; Edward Roberts, *The tide predicter*, Nature, XXIII, (1881), 555; William Thomson, *The tide predicter*, Nature, XXIII, (1881), 578.
410 W. E. May, *Lord Kelvin and his compass*, The Journal of Navigation, XXXII, (1 January 1979), 122-134.
411 David Linley, *Degrees Kelvin*, (London, 2004), p181.
412 Francis Bashforth, *Tide-predicting machines*, Nature, XXIV, (1881), 53.
413 Adams 3.14.2.
414 Francis Bashforth, *Reprint of a description of a machine for finding the numerical roots of equations and tracing a variety of useful curves ... communicated to the British Association 1845 with an appendix containing extracts from papers relating to the invention of the tide predicter*, (Cambridge, 1892). (The annotations are in the British Library copy.)

Figure 43 Bashforth's 1892 rendition of a 4-component diagram of 1845

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With the available evidence, rather than having just one inventor, it seems sensible to consider that the tide-predicter had several contributors. In 1882, at the Southampton meeting of the British Association, Thomson gave an *Evening Lecture*. In a later published text of the lecture, he properly acknowledged Bashforth – but not Roberts. There Thomson wrote:

> The first instrument which I designed and constructed for use as a Tide Predictor was described in the Catalogue of the Loan Collection of Scientific Apparatus at South Kensington in 1876.[415]

As the name of the actual constructor, Légé, is visible in the middle plate of that machine (Figure 38), it alone throws Thomson open to simple plagiarism. Is it not ironic, that the device discussed between Towers and Roberts resulted in an Indian predicter, as their discussion took place onboard the *Lalla Rookh* – Thomson's yacht – named after a princess of Indian tragedy?

[415] William Thomson, *Popular Lectures and Addresses in Three Volumes, Volume III Navigational Affairs*, (London, 1891), 184. NB The mixture of the suffixes, -er and -or, to predict, is Thomson's.

## 9.9 TABLES FOR THE INDIAN PORTS

Thomson had tried as early as 1876 to get the Admiralty Hydrographer, Sir Frederick John Owen Evans (1815-1885), to adopt the harmonic method for the British home ports.[416] That incumbent came to outrightly reject Thomson's invitation.[417] The office changed hands in 1884 and again in 1904. Early in 1903, when they knew that the then hydrographer was on his way out, they also hoped a change of policy would follow.[418] It did not; it was not until the second decade of the twentieth century before change came.

In addition to Holden's private initiative in Liverpool, there was one other attempt to produce tables by the new method for a British port. It was for a year following the successful introduction of the method at Liverpool. This other attempt was during the time of Roberts' conflict with Thomson. Roberts produced a tide table for London Bridge, for 1883.[419] As no more were issued, rather than conclude they were of poor quality or otherwise a commercial failure, one may suspect that he received official opposition; no doubt fuelled by Thomson's attitude.

Sometime in 1872, when General Walker decided to follow the British Association recommendations, Baird, a Captain in the Royal Engineers was on leave in Britain. The Survey deputed Baird to study the new tidal method and did so under Thomson.[420] He subsequently went out to India, first setting up meteorological observations in the Gulf of Kutch. It was not until 1877 that the Indian Government gave instructions to make tidal observations at all their principal ports. The purpose of the observations was for general

[416] CUL Additional E.89.
[417] CUL Additional E.92.
[418] CUL DAR 251/5208.
[419] Edward Roberts, *A tide-table for 1883*, (London, 1883). The only known copy of this is in the British Library.
[420] CUL DAR 251/3025.

scientific interest: their utility for making tidal predictions, for navigation, was a secondary consideration.[421]

In February 1872, the Association ordered Thomson to apply to the Indian Government, to get them to pay for observations. There was some delay before beginning observations, but when sufficient did become available they speedily gave them analysis and then put to prediction. By March 1878 the India Office, paying out £120, had predictions for Bombay and Karachi fully printed.[422] Roberts did all of the work for the tables; they were for the year of 1880.[423] Probably because of them being for somewhere remote from London, they also included the following year's January. Roberts initially printed the tables for the two ports separately; but he soon put them together, and with Baird added more ports until it became an oceanic set of tide tables.

Roberts made the preliminary Indian predictions with the British Association calculator, housed at South Kensington. Whilst he ran off predictions for Mauritius, Fremantle and other Indian Ocean ports in early 1878, plans for the new machine were already underway.[424] They added Aden that same year and resumed work on Fiji.[425]

The machine for the Indian Government was explicitly for the production of tides for twelve Indian ports as well as Aden. Aden was important to the government as a bunkering port.

Roberts and Baird quickly developed a necessary close co-operation. Baird issued a report, where he reduced observations for Bombay, Karachi and Okha. Local computers, in Pune,

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[421] Andrew Wilson Baird, *A Manual for Tidal Observations and their reduction by the method of Harmonic Analysis*, (London, 1886).
[422] CUL Additional 7342 R.86.
[423] Edward Roberts, *Tide-Tables for the Port of Bombay for the year 1880*, (London, 1879); Edward Roberts, *Tide-Tables for the Port of Kurrachee for the year 1880*, (London, 1879).
[424] CUL Additional 7342 R.87.
[425] CUL Additional 7342 R.89.

did the reduction. His report in November 1878 was on data gathered in prior to 1877. The report he made twelve months later: for Bombay, Karachi and Aden, was on 1878 data.[426]

By July 1880, Baird's investigation was expanding rapidly. Karwar, Baypore, Paunchbar (between India & Ceylon), Madras, Vizagapatam, Port Blair (in the Andamans), Rangoon, Elephant Point, Moulmein and Amherst he added first. He was also to shortly establish other stations at False Point, Sangor, Diamond Harbour (on the Hooghly), Calcutta, Bhanvagar (head of Gulf of Cambay) and probably Negapatan.[427]

Roberts computed data for the serial, with the Indian predicter located in London, for over four decades.[428]. Roberts manipulated the machine to compute the predictions. The predictions for 1880 were deduced by coefficients supplied by Baird, with Roberts cited as the sole author. This changed in 1881 to the long-held title of *Tide-Tables for the Indian Ports*. They were prepared in London to 1922, and subsequently by the Survey of India in Dehra Dunn. Published in two parts from 1889 to 1924, Part 1 contained the Western Ports, and Part 2 the Eastern and Burma Ports. It was not until 1931 that the title slightly altered to accommodate the whole Indian Ocean littoral.

Table 3 displays the swift expansion, port by port, of the Indian tide tables. Doodson & Légé brought a new predicting machine, into the tables' production for 1955. The ongoing serial remains as a table of Indian and only selected foreign ports. Inflation has lifted the price to 2,000 rupees.[429]

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[426] CUL Additional 7342 PA.196.
[427] CUL Additional 7342 B.4.
[428] Adams 12.14.3.
[429] Anonymous, *Indian tide tables 2003*, (Dehra Dun, 2002).

## 9.10 INTERNATIONAL DEVELOPMENT

The British Association reconstituted the committee in 1883: with Thomson gone, Adams alone survived from the old committee.[430] On the committee with Adams, there was just George Darwin sitting. They found that they were engaged in the supervision of the reduction of Indian tidal observations; it was an extensive observation series for a developing publication. In 1887, on the verge of reappointment elsewhere, then Baird also became a part of the tidal committee.[431]

Thomson of course did not drop out of tides; he went on to manufacture many tide gauges as well as other predicters. He also formed another small committee in 1885; this was in order to reduce Dover observations and connect them with observations made on the continental coast.[432] The experiment was an early use of co-ordinating Greenwich Time. Interestingly for the comparison, he used a common datum-plane of twenty feet below the Ordnance datum of Great Britain. Unfortunately, despite the obvious differences in measurement units, the data gathered in was bad.

The initial results were rather poor. The observations taken at Dover, Ostend and Boulogne, were in separate countries.[433] It had seemed to be a difficult task to get full co-operation across three political units. However, after Thomson's death, Roberts graciously revisited the data; he even published the results.[434]

When Darwin became chairman, the distribution of the investigative forms, in addition to Washington and some British ports, was also via Paris, Berlin and Vienna. Full International

430 George Howard Darwin, *British Association for the Advancement of Science Report*, (London, 1883), 49-117.
431 CUL DAR 251/3218.
432 James N. Shoolbred, *British Association for the Advancement of Science Report*, (London, 1885), 60.
433 CUL DAR 251/2852.
434 Edward Roberts, *Re-reduction of Dover tidal observations for 1883-4 etc*, Proceedings of the Royal Society, (A), LXXXVIII, (1913), 230-233.

exchange of information was not agreed until 1896.[435] Yet the early cross-channel difficulty contrasted with transatlantic co-operation.

The United States Coast Survey was quicker on the uptake. They had designed their own predicter by 1882. They used that particular machine, for predictions, from 1885 through to 1914. The American machine summed nineteen constituents. In Britain, there was a deliberate coordination of the American and Indian method of investigation. Darwin's wife being herself an American no doubt facilitated this.

The American activity directly inspired the Canadians to promote new tidal observations for the harmonic method.[436] The Canadians were explicitly interested in producing tide tables because of heavy shipping losses. Ready with a list of wrecks, their needs were most pressing in 1884, but it took another three years before obtaining funds for an effective harmonic investigation.[437] The Canadians did the converse to what happened in India; they sent their observations to England for reduction, because of the fully developed calculating system there.[438]

When the Geographical Society of Australasia wrote asking for advice, as they proposed to begin observations, Baird gave a wide view.[439] Observations were already coming in from South Africa; and both Hong Kong and Singapore were starting observations. Baird indicated how their apparatus in India was about to become spare; he considered it ought to be made available for colonial use.

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[435] Steacy D. Hicks, *The tide prediction centenary of the United States Coast and Geodetic Survey*, International Hydrographic Review, IVIV part 2, (1967), 121-131.
[436] Alexander Johnson, *British Association for the Advancement of Science Report*, (London, 1885) 33-34.
[437] Alexander Johnson, *Report of the committee ... appointed for the purpose of promoting tidal observations in Canada*, British Association for the Advancement of Science Report 1885, 33-34.
[438] CUL DAR 251/3037.
[439] CUL DAR 251/3025.

## 9.11 AFTER EFFECTS

In the end, Baird did not compile any instructions for the predicter. He did, however, write at least three scientific papers. His manual for making observations and reducing them by harmonic analysis became a standard.[440] As early as January 1883 Baird had set his sights on becoming a fellow of the Royal Society. The Indian tidal investigation had trained observers, and numerous automatic recording gauges, strategically placed around the entire coast. It was in a commanding position to make useful commentary on oceanic events. Krakatoa, a very large volcano on Java in the East Indies, blew up in a most spectacular fashion on 27 August 1883. The Indian tide gauges recorded the consequent tidal wave, particularly its time of passing. Conscious of his scientific goal, Baird immediately wrote a letter to *Nature* about the event. Then he contributed a paper on it to the Royal Society.[441] He got closer to his goal in a joint tidal paper with Darwin and Thomson.[442] Baird's election to the fellowship in 1885 was largely due to the strong sponsorship of interested parties: Darwin and Thomson.[443]

By 1883, after eleven years of work, the end of the large Indian investigation was coming into focus.[444] Baird continually fed Roberts with reductions, who, by then, was spending much time on the predicter. Trouble with Port officials re-emerged but Baird, the engineer, kept the ascendancy.[445]

When Baird transferred out of tidal duties in 1886, he had already begun to wind down the large investigation in India.[446] The Survey planned the wind down. However, with their able computers in Poona having spare capacity, they then transferred some reduction work from

[440] Andrew Wilson Baird, *A manual for tidal observations and their reduction by the method of harmonic analysis*, (London, 1886).
[441] Andrew Wilson Baird, *On the tidal disturbances caused by the volcanic eruptions at Java 27th and 28th August 1883*, (Calcutta, 1884).
[442] Andrew Wilson Baird, George Howard Darwin and William Thomson, *British Association for the Advancement of Science Report*, (London, 1886), 40-58.
[443] CUL DAR 251/2530.
[444] CUL Additional MSS, 5750 28.

England. They got the observations of the three ports of Thomson's latest investigation. Baird initially transferred temporarily to the Mint at Calcutta, and became Deputy Surveyor-General of the Survey of India. In that capacity he was still able to supervise, at a distance, the remaining tidal work. At the end of 1888 Baird became Master of the Mint, then the world's largest, and lost direct contact with the tidal branch.[447] He said its work was done.

During the wind down the Survey envisaged that they would continue to observe tides in India at about six places: four permanent stations at important places, and perhaps two places selected for scientific purposes.[448]

After Baird withdrew to those other duties, several Survey officers followed on as the first named author of the tide tables. Thomson, by then president of the Royal Society, heavily promoted the formation of a National Physical Laboratory. As it was not actually brought into existence until 1902, naming the Laboratory as the tables' second author in 1897, now appears curiously premature. By about 1903, with the Indian predicter relocated to Teddington, the new Laboratory took over its operation.[449] However, Roberts remained as a third author down to 1906. Having become purely a tidal computer at the expense of any Almanac duties, the Superintendent summarily dismissed Roberts.

Although Thomson then finally achieved his snub, Roberts remained active in tidal work for many more years. First, he set up a tide predicting company, with his son. With a new predicter, the company immediately won the *Grand Prix* at the Franco-British Exhibition held in London. The son's name, Herbert William Thomson Roberts (1874-1930), reflected a once mutual admiration. Then at the outbreak of the Great War, the vital need for predictions required bringing Roberts back into the Admiralty. In 1914, due to a

[445] CUL Additional MSS, 5750 45.
[446] CUL DAR 251/2858.
[447] CUL DAR 251/3262.
[448] CUL DAR 251/3025.

combination of his own hard work and various deaths, he had arrived in a position of being the country's only tidal expert at the outbreak of that war.[450] He had already gained the status of Independent Scientific Officer, and become a Fellow of the Royal Astronomical Society in 1872 and of the Statistical Society in 1882. During those early days, Roberts had been a member of a tidal committee, albeit one a little obscure.[451]

By 1912 the Admiralty transformed their set into a proto world tide table. Beyond Europe, that table then included twenty-two ports across the Empire; seven were Indian ports. Clearly the physical expansion of the Indian predicter in 1891 had extended the machine's worth.[452] At that time, he changed one of the original components and added four more. Despite later designs, it was the original plans of the successful Indian predicter which was the direct source for the machine built in Germany, between 1915 and 1916.[453]

After the 1914-18 conflict, with the Indian tables for 1922 already printed, the tide predicter was overhauled. Then the Government of India had it relocated a second time, and installed it at Dehra Dun – in India.[454] Immediately for the 1923 tables, the set was rationalised and Persian Gulf ports added. Priced in both rupees and sterling, unfortunately the cost of the newly patriated table quadrupled. At nearly eleven shillings, and still only for the northern shore of the Indian Ocean, it compared unfavourably with the world set of tables, for sale in London at three shillings.

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449 Edward Pyatt, *The National Physical Laboratory a history*, (Bristol, 1983).
450 Harold D. Warburg, *The Admiralty tide tables and North Sea tidal predictions*, The Geographical Journal, LIII Jan-Jun, (1919), 308-330.
451 William Thomson, *Committee appointed for the purpose of considering the Datum-level of the Ordnance Survey of Great Britain*, Report of the British Association for the Advancement of Science, (1878), 219.
452 CUL DAR 251/5207.
453 Anonymous, *Tide Predicting Machines*, (International Hydrographic Bureau, special publication no 13), (Cannes, July 1926), 59. The plans are those in *The Engineer* article by Roberts.
454 An image of the machine, exhibiting the added components, is in: Cartwright, *Tides a scientific history*, 107.

It was an even worse bargain in 1925, down to one volume and with fewer ports. However, that edition included its first mention of any Indian citizen. Computer M. Chatterji had taken responsibility for the riverain tides, and Rāi Sahib Hanuman Prasad for the printing.

The volume returned to a competitive price in 1931, but edition's name *Tide Tables for the Indian Ocean* was curious. While its enlargement included African ports, there were also many of the European Atlantic and the Asian Pacific. The current volume contains that Gulf of Tonkin port, Do Son (or Batsha), which had inspired Newton so many years ago.

## 9.12 CONCLUSION

It was not the introduction of tidal study to India which re-vitalised science there. That uplift was within the larger Survey of India. However, this chapter has demonstrated the important role played, by the creation of the Indian Tide Tables, in the development of world tidal studies. Creation of the Indian tables was the first practical output of the harmonic method. The tables were the vehicle of the tidal research programme.

The investigators of the harmonic method formed a network of correspondents. This chapter is largely the result of much transcription of their original correspondence. The network focussed principally on London, Cambridge, and Poona in India. It is those correspondents' manuscripts, rather than their published papers, which display the difficulty that they overcame. The investigators depended upon Indian work for the method's proving. In turn, the ascent of geodesy accomplished in India, was dependent upon a proper understanding of the sub-continent's tides. The abundance and quality of Indian computers – people – achieved the not inconsiderable reduction of masses of observation; this was the tidal analysis. In addition, the area which this aspect of the Survey covered was similarly massive; it stretched the full extent of the ocean's northern littoral, from Aden to Rangoon.

Darwin perfected the harmonic tidal method, devised by newly knighted Thomson. When Darwin chaired the British Association meeting in Capetown, he also received a knighthood – explicitly for his tidal work.

The massive amount of computing, demanded by the harmonic method, would have severely hampered them had a calculating aid not been found. Resulting from combined work, so successful was the mechanical computer, that it was not supplanted until the 1960s – with the development of electronic computers. The protracted Indian investigation resulted in a powerful prediction method; it was one available for the tides of the whole world. To this day, it is the harmonic method of predicting tides, which remains in predominant use across the globe.

The next two chapters deal with one notable mechanical failure – Thomson's tidal analyser, and also with other mechanical developments across the world.

# CHAPTER 10 MECHANICAL COMPUTING AIDS

## 10.1 INTRODUCTION

The synthetic method of tidal prediction, developed by 1830, needed lots of computing. With invention of the superior harmonic method forty years later, the computing demand then increased massively. Although adding machines were available, none were up to the task of the new harmonic work.

Harmonic analysis and prediction is the method used to this day. The method's work falls into two parts: first analysis of past observation and secondly tidal prediction. The consecutive stages are mirror images of each other. Intermediary to the two stages are a set of parameters, related to the tide of a particular port. In the terminology of the subject, the parameters of the place concerned are the *tidal constants*. Once drawn from analysis, and beyond revision, the constants hold good for all time. The constants then allow a port's tides to be predicted.

The harmonic method first attracted wide scientific interest in 1867, and took about three years to develop. Upon development, its massive computing need was immediately apparent. In addition to being a brilliant theoretician, William Thomson often facilitated practical solutions to various problems. Considering the tidal record as the sum of several constituent waves, he ventured two mechanical devices to the treatment of tides. As his mathematical method was descended from Fourier's theory, so similarly were his tidal machines developed from the practical ideas of others. One was for the records' analysis, another for the synthesis of future tides. From one idea that Thomson identified, the human computer, Edward Roberts, constructed a machine which dealt with prediction. Thomson's own attempt to mechanically find the constants failed.

There was a public row over the predicter's authorship. That argument has obscured the history of other tidal inventions. With the bickering waged at soirées of the Civil Engineers published in the pages of *Nature*, the successful machine has achieved written attention. This chapter brings attention to other explicitly tidal calculating machines: an abacus and other predicters, and to the analyser itself.

## 10.2 THE CONSTANTS OF A PORT

Tidal prediction uses an analysis of the past as its base, because of the stationarity of the tidal signal. Until the late twentieth century, ink traced out analogued past tides mechanically; since then the tidal record has become digitised. The mechanical record was continuous; the digital record, commonly made once every fifteen minutes, effects a continuous record. While the digital record is immediately available for analysis, the analogue trace requires reducing to a machine readable form, suitable for analysis in a process called digitisation; it is a not inconsiderable task.

Once available, the record is then analysed in order to extract the harmonic tidal constants. The late Victorians' optimum analysis took 365 sets of 24-hourly data points. An analysis was, and remains, needed for the extraction of each separate set of constants. Until the 1960s all this analysis was by hand.

The curve of the tidal record simulates the sum of several constituent waves. In the early investigation, Thomson and then Darwin viewed the constituent parts as resulting from partial phantom satellites within the moon or sun. The record actually forms a periodic oscillation, generated by and related to, the motions and attractive forces of the moon, sun and earth system. As the frequency of each influence is known, then harmonic analysis can determine the amplitude and phase of that constituent. A series of sinusoids represent each element. The parameters – the amplitude and phase – of each sinusoid are the harmonic tidal constants. This type of analysis works because, in the long run, the average value of each function is Mean Sea Level.

David Cartwright's recent history of tidal science gives the theoretical aspects of harmonic analysis. In addition, David Pugh's up to date handbook for engineers, and scientists, gives a practical explanation of the necessary filters for the various tidal time series.[455]

Modern computers facilitate analysis of very long records, such as over the cycle of 18.6 years. To the early investigators, an ideal analysis, with which to obtain the principal lunar constants, was to obtain the mean curve of at least 365 lunar days. Which ever mean curve is obtained, beyond meteorological influences, it then represents only the astronomical tide. The amplitude and phase of one part is taken for the lunar semidiurnal constants, $M_2$. A straight forward analysis, across the normal solar day, produces the solar constants, $S_2$. $S_2$ is analogous to $M_2$. The differences between the parts taken and those remaining give the constants of diurnal inequality – the inequalities from declination. $O_1$ is lunar, $P_1$ solar, and a third, the $K_1$ harmonic, is of both solar and lunar origin. Further analysis, across the anomalistic month, reveal constants for the lunar ellipticity, $N_2$.

For every influence wanting consideration, each set of constants needs an analysis. Generally, the more constants that are put into prediction, the better it will be. Experience, based upon local response characteristics, enables a decision upon that exact depth of investigation. However, helpful statistical techniques can slightly accelerate the task. Darwin's tidal abacus forms one of those techniques with which to combat differing lengths of period.

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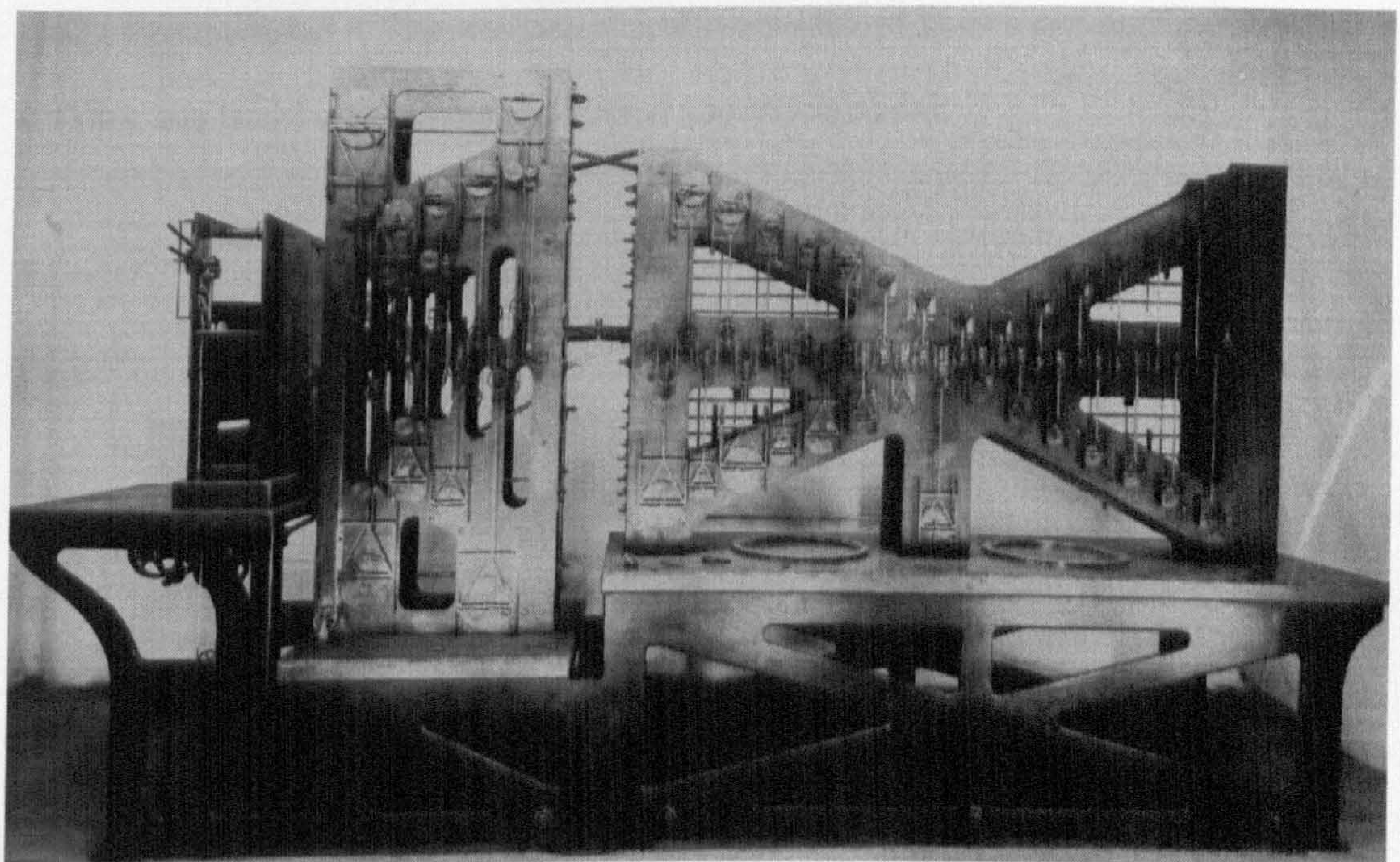
[455] Cartwright, *Tides a scientific history*; Pugh, *Tides, surges and mean sea-level*.

Figure 44 The U.S. tide-predicting machine No.2.



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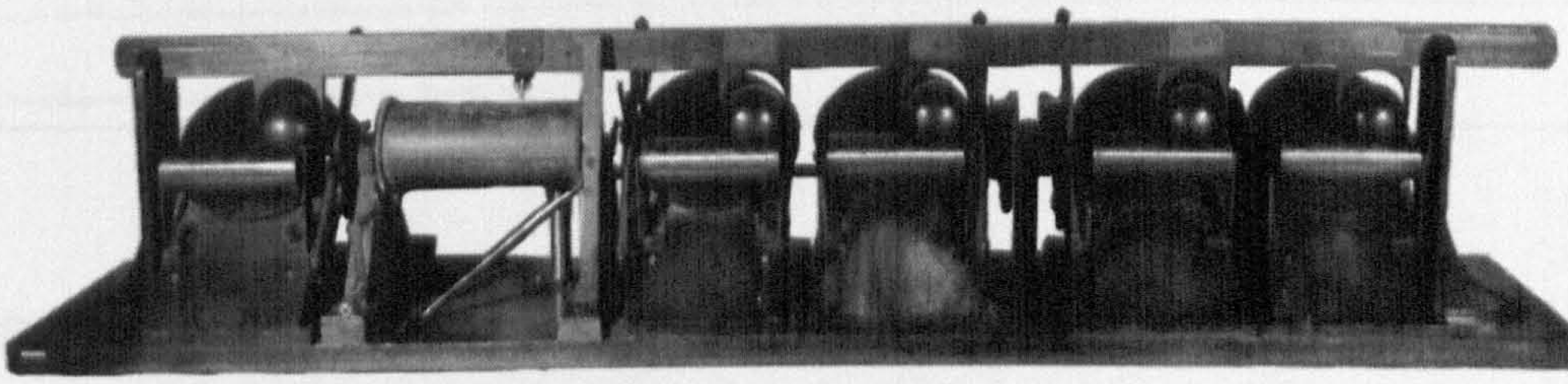
Within the century following the harmonic method's invention, the bulk of predictions were obtained with tide predicting machines. However, the very first predictions were calculated by hand, and the later ones by electronic computer. The earliest machinery limited what could be obtained. The first experimental predicter could only deal with ten sets of constants. The later operational predicter dealt with twenty amplitudes and phases. Then, the progress of the investigators introduced more components. Setting the constants in and then manipulating the machine brought forth predictions of the height and time, of the High and Low Waters of each day for the future. Even with the mechanical help, for every port it remained a big job. However, it was the physical capacity of the predicter which determined the amount of analysis to be undertaken. Second stage capacity, set the amount of first stage work required. That situation remained in place until digital computers opened up the practical possibility of considering all and any relevant tidal influences.

The tide predicter, an early analogue computer, was an explicit invention for this specialist purpose. Without its aid, tidal prediction in many parts of the world would never have come about, until the digital age. The analogue device was such a success that only the electronic computer superseded it. The mechanical predicter sustained its own success for over nine decades, and lasted until 1966 in the United States (Figure 44).

Figure 45 Thomson's 5-component model analyser.



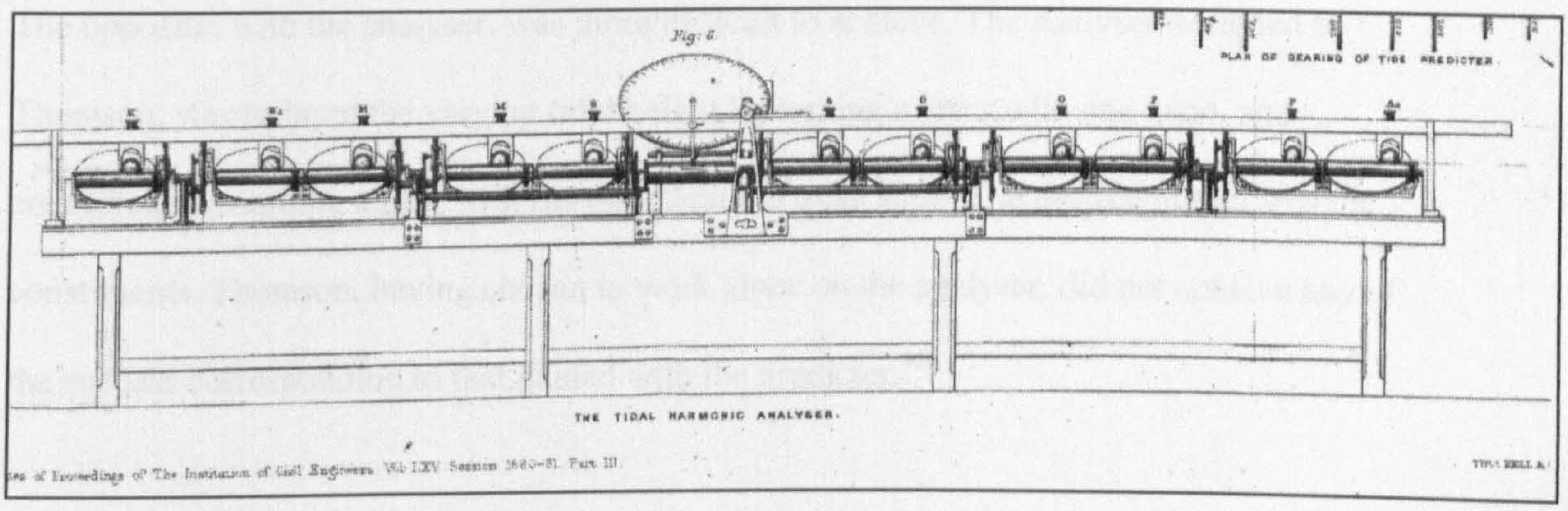
Hunterian Museum and Art Gallery, University of Glasgow

## 10.3 THE ANALYSER

However the mechanical computer was only for use with prediction; it was not for the analysis of observations. The analysis and prediction are reciprocal or complementary functions of one another. The constants are both the result of analysis and the starting point of prediction. Simply turning the output pointer of the early predicters, in relationship to a tidal record, could not put the process into reverse and produce constants. It was impossible for the gearing of those predicters to work backwards.

Thomson had been the catalyst for the predicter's successful construction; yet its original idea stemmed back to that of Francis Bashforth's design of 1845. Shortly after Thomson's practical conception of the predicter, he set to considering an analyser. The ball-disk-and-cylinder integrator, invented by his brother James, inspired Thomson. Thomson saw the possibility of it solving differential equations; that is, for it to extract harmonic coefficients from waveform data.

Figure 46 Thomson's 11-component analyser




Appearing in early 1876, Thomson gave his first paper on his potential analyser with two more, each elaborating on its theoretical use.[456] While appealing to the government grant committee of the Royal Society, that spring, he had not then fully realised the machine.[457] Edward Roberts calculated the analyser's gearing for him. However, in contrast to Roberts's successful operation of the predicter, Thomson intended another official to have the analyser work. As with the predicter, Thomson first made a model analyser. The model (Figure 45) had five components.[458] The transition to an eleven component functional analyser (Figure 46) by April 1879 appears not to have been at all successful. There were problems in overcoming torque loss between stages. The analyser now resides dismantled in the bowels of the Science Museum.[459] There is no record of Thomson's analyser ever having been used on tides.

The predicter, the result of work by a number of people, was a great success. It used a lot to produce a little. The number of constituent inputs was typically twenty to forty. This number was large when compared to a small moment of predicted height output. By winding the

[456] William Thomson, *On an instrument for calculating ($\int\varphi(x)\psi(x)dx$), the integral of the product of two given functions,* Proc. Roy. Soc., **24** (1876), 266-8; William Thomson, *Mechanical integration of the linear differential equations of the second order with variable coefficients,* Proc. Roy. Soc., **24** (1876), 269-271; William Thomson, *Mechanical integration of the linear differential equations of any order with variable coefficients,* Proc. Roy. Soc., **24** (1876), 271-5.

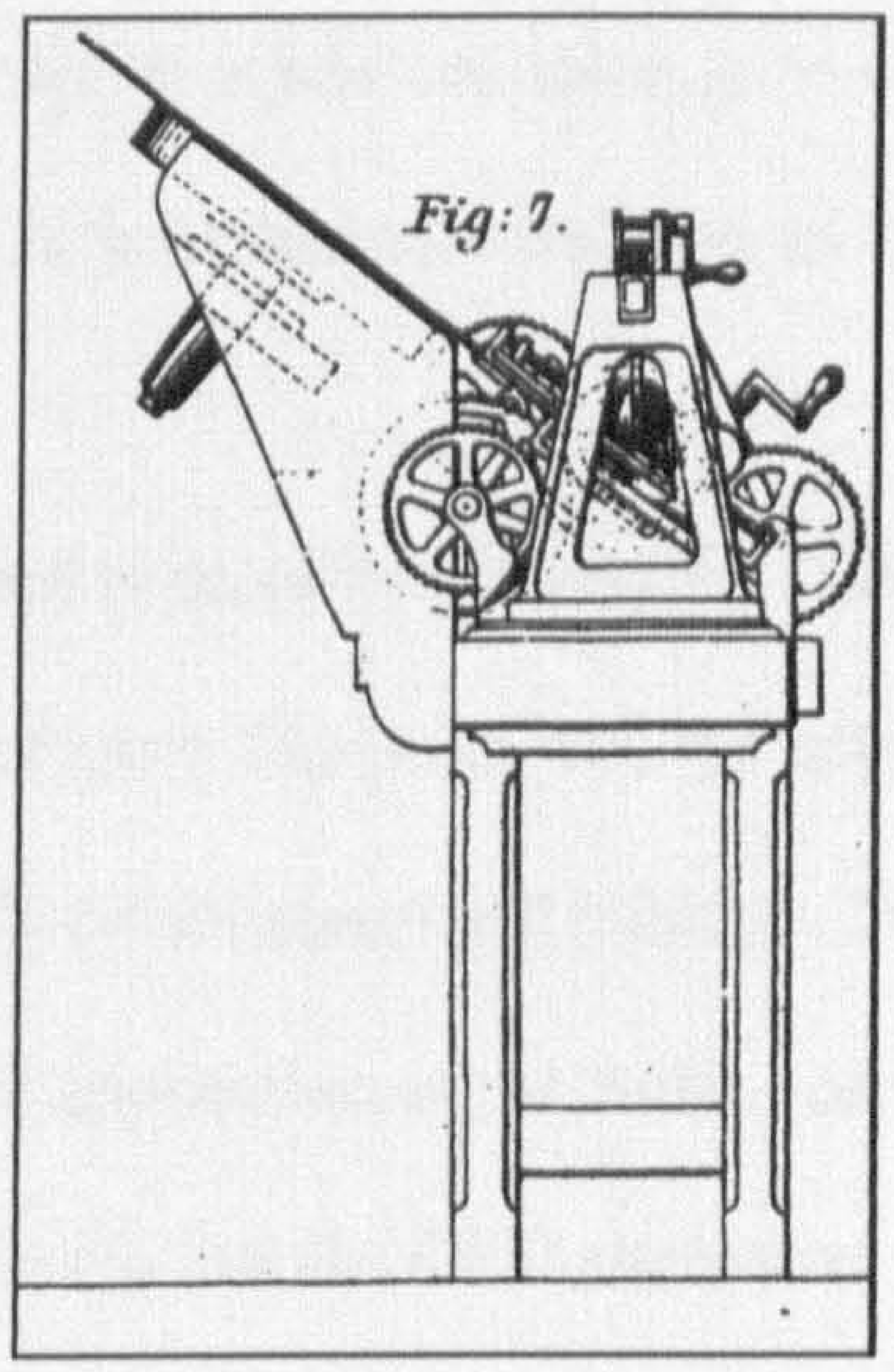
[457] William Thomson, *Harmonic Analyzer,* Proc. Roy. Soc., **27** (1878), 371-3.

[458] This is preserved in the Hunterian Museum, Glasgow. George Green and John T. Lloyd, *Kelvin's Instruments and the Kelvin Museum,* (Glasgow, 1970).

machine on with time, it could expeditiously affect a continuous output of varying heights. The opposite, with the analyser, was more difficult to achieve. The analyser designed by Thomson, was to input the varying tidal height by turning a lever with one hand, and concurrently cranking a gear with the other hand to input time. The desired output was the constituents. Thomson, having chosen to work alone on the analyser, did not achieve any of the success corresponding to that gained with the predicter.[460]

The two handles are plainly visible in the side view of Thomson's analyser.

Figure 47 Side view of Thomson's analyser




For other scientific purposes, an improved form of Thomson's analyser evolved in 1894.[461] Then in 1909 Mader's analyser was used on New Zealand tides, and others followed by 1930.[462] Some were speedy and accurate but their expense and delicacy limited their use to some extent. During the early days, an American, Michelson and Stratton machine of 1898

[459] William Thomson and P. G. Tait, *Treatise on natural philosophy,* (Cambridge, 1903).
[460] I am grateful to Steve Hutcheon of Brisbane, Australia, for the idea of this explanation.
[461] George Robert Stibitz, *Mathematical instruments,* Encyclopaedia Britannica, (London, 1959), volume 15, 69-73.
[462] Joseph Proudman, *Report on harmonic analysis of tidal observations in the British Empire,* British Association for the Advancement of Science Report of the Eighty-Eight Meeting, (London, 1920), 323-345.

handled eighty constants. This machine worked both ways equally well: as an analyser and as a predicter, and at one time applied to tidal work.[463]

## 10.4 AMERICAN, AUSTRALIAN AND GERMAN PREDICTERS

In its early life, the noun describing the predicting machine attracted two different suffixes. As that arcane difference continues to attract attention, it is then for the following reasons that the suffix -*er* is used in this paper.

In this case, both Webster's and the Oxford English dictionary have a similar orthography. Commonly, the suffix -*or* denotes an inanimate agent, as in conveyor, resistor and sensor; whereas the suffix -*er* denotes an instrument or machine, as in poker and computer.

The suffix -*er* was correctly used to describe the very first tide-predicting machinery of the 1870's, (a time before aircraft proper). The noun with the suffix -*or*, in referring to an aircraft tracking instrument is therefore somewhat dubious. The suffix -*er* is merely given as an alternative. Because the 1884 application of the suffix -*or* was American, to tide-predicting machinery, is it not ironic that the OED alternative citation of 1885 is also American? Thomson favoured -*er* in 1881, but within ten years changed to -*or*.[464] By 1898, Inglis in Australia deflected lexical argument with use of the phrase *tide-prediction*, the very phrase subsequently given in 1915 to the second United States machine (Figure 44). However, as all of those machines are now defunct, this orthographic exposition is academic.

The analysers and several predicters built in Victorian Britain were all big; but the prototype two component predicter, of 1873, had measured only 35 cm high. The involved gearing

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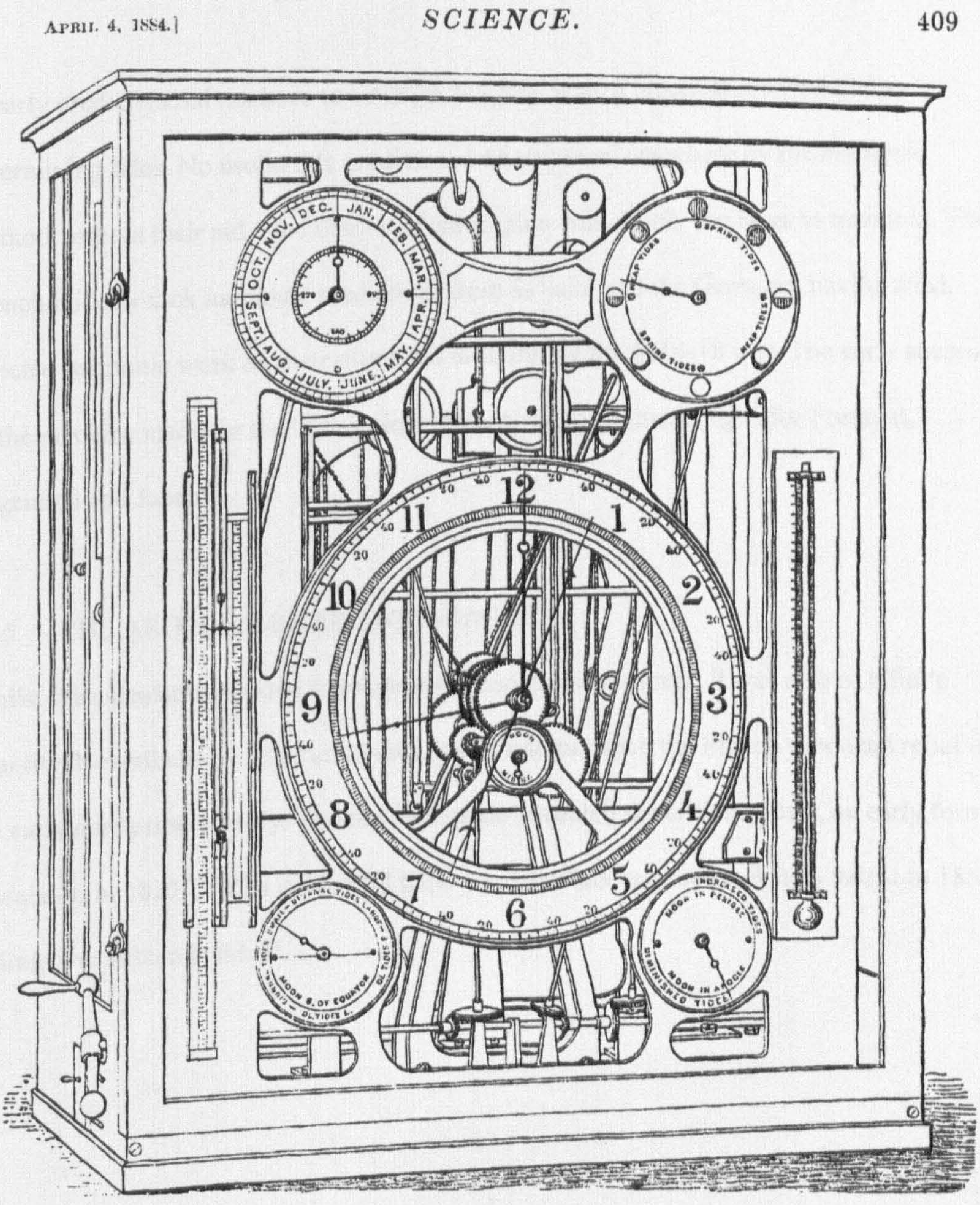
[463] Vannevar Bush, *Harmonic analysis*, Encyclopaedia Britannica, (London, 1959), volume 11, 199-202.

forces then increased with each component added and the framework made sturdier in response. Thus each generation became successively larger and heavier. Later, the development of extremely compact forms of these early designs took place, for other areas of analysis.

Alexander Inglis (1845-1921), the Adelaide harbour master, made two machines of an independent design.[465] Avoiding any gearing increase, he employed fixed curves rather than cammed pulleys. Using timber construction material, these machines also avoided massive weight. The first, with fourteen components, was in use for twenty years. The second, cannibalised from the first but with only eleven components, achieved continuous output with circular curves. These Adelaide machines of 1897 and 1918 were extraordinarily innovative, yet their workings were simple to perceive.[466] Like the first predicter, the Australian machine achieved an output across the whole tide but it was not conducive to continuous production. The tidal research programme conducted in Australia remained highly independent from that undertaken in Britain.

[464] William Thomson, *The tide gauge, tidal harmonic analyser, and tide predicter*, Minutes of Proceedings of the Institution of Civil Engineers, LXV, (1881), 16-17; William Thomson, *Popular Lectures and Addresses in Three Volumes, Volume III Navigational Affairs*, (London, 1891).
[465] Alexander Inglis, *Description of a tide-predicting machine*, Australasian Association for the Advancement of Science, Volume VII Sydney 1898, 239-241.
[466] *The Advertiser*, (Adelaide, 1897), Dec. 28 page 3 column c; Alexander Inglis, *A new tide predicter*, (Adelaide, 1918).

Figure 48 The Ferrel predicter




The ideas of Thomson triggered several tidal research programmes; the largest of which was that conducted in America. There, William Ferrel (1817-1891), the mathematician, produced another independently designed predicter in 1884 (Figure 48). Stemming from his harmonic research into high and low water data, the machine derived tidal maxima and minima. Whilst this machine could operate into infinity, it was limited to extrema alone. Employing nineteen constituents, it was the first to give the derivative of the predicted tide.[467] Conducive to this design's success, the machine was of a modest table-top size.[468]

Clearly predicters did not have to be large, but they were a practical prerequisite to determining tides. No useful tide prediction was sustained anywhere by the harmonic method without their aid - the burden of calculation was simply too large to maintain. The French initially took harmonic predictions from Britain; and the Germans, having tried, rejected harmonic work on their own tides until during the 1914-18 war. The early success, of the machine made for the Indian Government, led to further designs for Portugal, Argentina and Japan.

## 10.5 THE ARITHMOMETER AND ABACUS

Whilst the calculation needed to produce the constants was great, it was also of a finite quantity. Nevertheless a substantial task, it was one to which the French produced relief in the early nineteenth century. Thomas de Colmar invented the arithmometer, an early form of calculator, in 1820.[469] This successful table top calculator received a British patent in 1851, selling over fifteen hundred.

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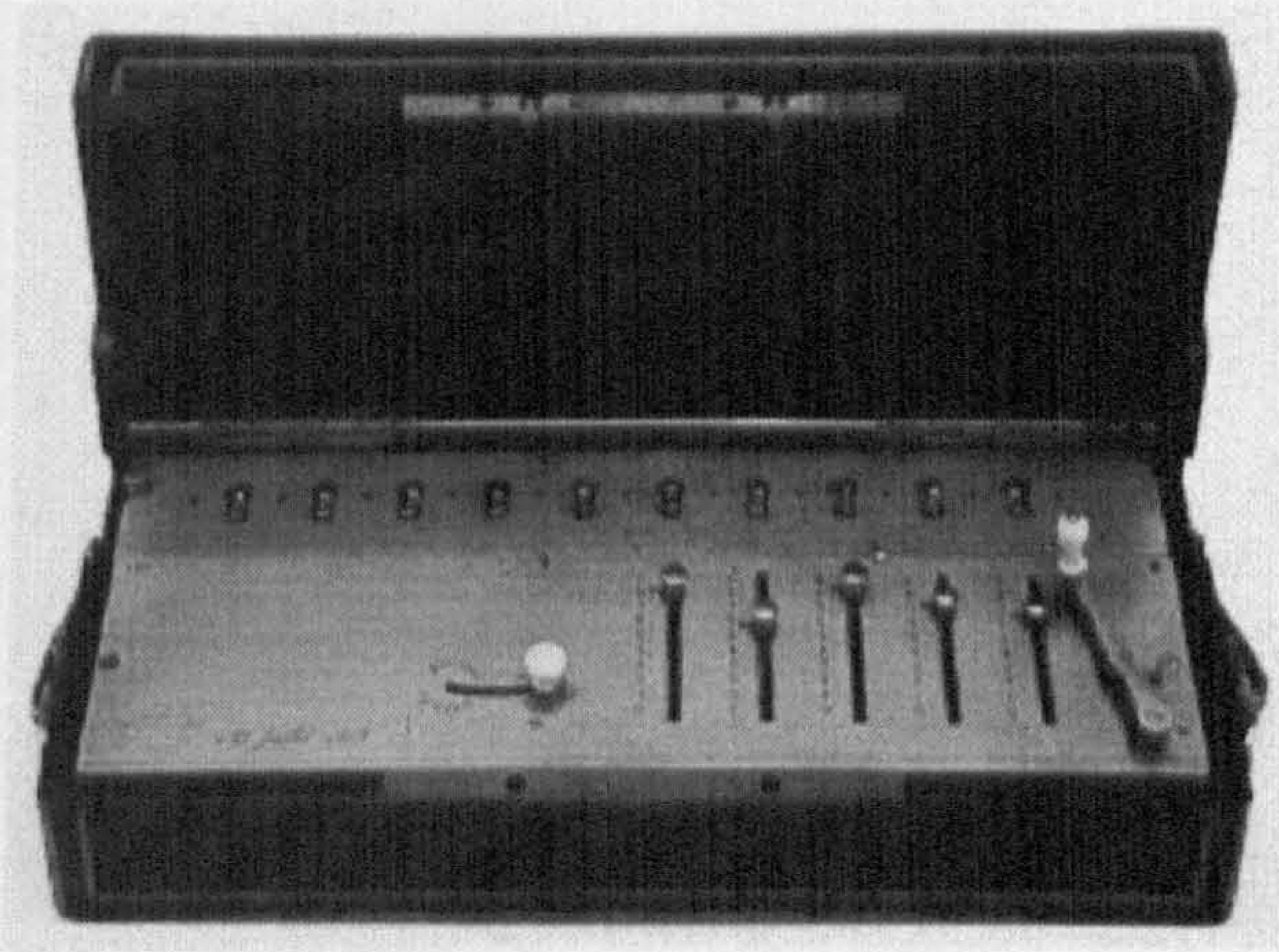
[467] Cartwright, *Tides a scientific history*.

[468] William Ferrel, *The maxima and minima tide predicting machine*, Science, 1884 volume 3, 408-410.

[469] George C. Chase, *History of Mechanical Computing Machinery*, Annals of the History of Computing, Volume 2, Number 3, July 1980.

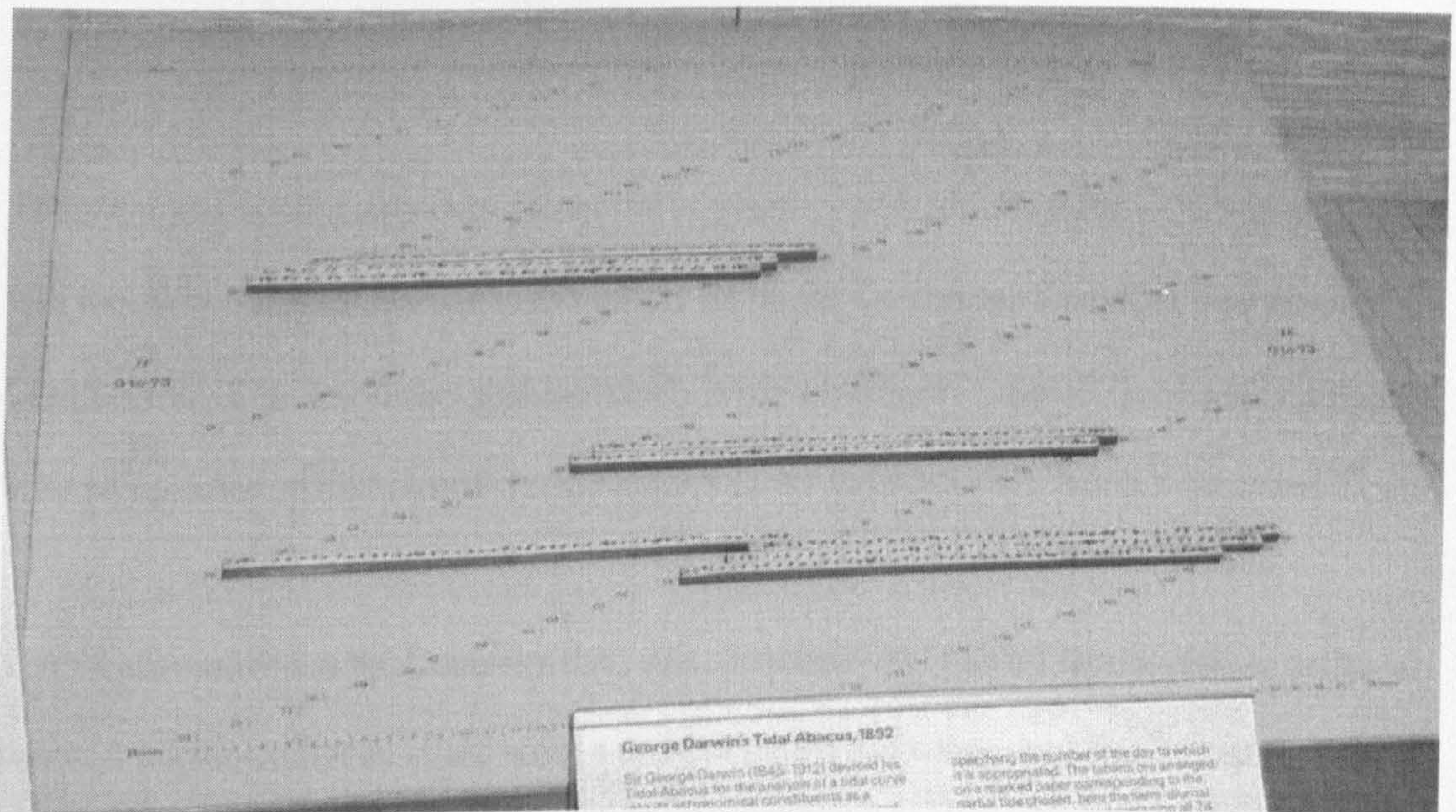
Figure 49 The arithmometer



Although arithmometers were a boon to the early, harmonic tidal analysts, that available at St. John's College in Cambridge, was a bit faulty.[470] John Couch Adams, who was the only academic investigator to see the Indian research programme through from start to finish, operated this arithmometer. His field worker, Andrew Wilson Baird, even had an arithmometer out in India. The calculator was a great aid, but that it still took Baird and a clerk two days to reduce the observations from only one station, displays the quantity of their labours.[471] Despite that, the arithmometer enabled them to increase the number of figures they dealt with by two, to six figures.[472] Clearly the arithmometer, a machine for general purposes, benefited the analysis of tidal constants.

[470] Adams 12.41.3.
[471] CUL Additional 5750 41.
[472] CUL Additional 5750 49.

Figure 50 The tidal abacus




© Paul Hughes

After Thomson, George Darwin then headed the harmonic investigation. It was upon him, in Cambridge, that the network of tidal correspondents focussed. Because of the Government of India promoting the research programme, the correspondence was inherently international. Altogether, forty-one people communicated with Darwin from beyond Britain; one of whom was Dr A. C. Börgen (1843-1909) of Whilelmshaven.

Darwin knew only too well how fearfully laborious the computing was, and was conscious of its cost to the Indian Survey.[473] One labour saving device, employed in the United States Coast Survey, was a card template pierced with holes. Then in August 1889, Börgen outlined his concern with methods of computing.[474] He considered it a 'tedious feature, to write out the same numbers so many times, in different ways'. Though Börgen found it disheartening he had two stratagems. One was to use different ink for sine and cosine; another was to use narrow strips of paper. This appears to be the germ of Darwin's idea of a special tidal abacus. Darwin thought the Indian procedure held unnecessary labour. He saw

[473] George Howard Darwin, *The tides and kindred phenomenon in the solar system,* (London, 1898).
[474] CUL DAR 251/3605

that both the American and German procedures attained the same end; yet he considered that their requiring diagonal addition disadvantaged them.

Thomson was not the only entrepreneurial academic involved with tides – Darwin's brother was too. When Horace Darwin (1851-1928) set up the Cambridge Scientific Instrument Company in 1878, it widened that university town's facilities.[475] By 1891, nineteen months after Börgen had written, a prototype abacus was out in Dehra Dun, being field tested.[476]

The £8 abacus, which the Company then sold, consisted of 74 strips of xylonite, or artificial ivory. A human computer could write a number on the strip once, and then adjust the strip as required. Darwin claimed his facility reduced the amount of calculation to less than a quarter of what it had been. As it cost more than £20 to reduce a year of observations, he considered that the permanent apparatus would pay for itself within one period.[477]

It was the end of 1892 before Darwin gave his results of using the abacus to the Royal Society. With the first devices only being available in February, production appears not to have gone ahead until he gave the paper. The Leiden observatory had one in use the month following and Börgen gained a complimentary one.[478] He offered another to Van der Stok in Batavia and Robert W. Chapman (1866-1942) received one in Adelaide.[479] In New Zealand, their usefulness continued into 1913.[480] By then, the one which Roberts had the advantage of, had passed into the hands of the National Physical Laboratory.[481]

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[475] M. J. Cattermole, *Horace Darwin's shop*, (Cambridge, 1987).
[476] CUL DAR 251/3767
[477] George H. Darwin, *On an apparatus for facilitating the reduction of tidal observations*, Proceedings of the Royal Society of London, 1892, Volume 52, 345-389.
[478] CUL DAR 251/4043 + 4044.
[479] CUL DAR 251/4019 + 4025.
[480] C. E. Adams, *Harmonic tidal constants of New Zealand ports (Wellington and Auckland)*, Australasian Association for the Advancement of Science, Volume 14 (Melbourne) 1913, 18-19.
[481] Anita McConnell, *Geophysics & Geomagnetism*, (London, 1986).

By the early twentieth century, there was a varied array of calculating aids used for tidal work. They included the Mercedes adding machine and the Millionaire calculating machine. In addition, the Brunsviga calculating machine possessed a printing attachment, and the Coradi co-ordinatograph enabled curve plotting.[482]

## 10.6 CONCLUSION

The replication of a full tidal analysis for each separate port is one of the elements that significantly distinguish the synthetic from the harmonic methods. Almost by definition it exemplifies the uplift in quality between methods. The other aspect is that the continuous predicters gave an output of the whole tidal profile – rather than just high water time and height.

Fortunately, the successful tidal construction initiated by Thomson, was for the incessant part of the calculating task. After Ferrel produced his machine, Thomson sometimes called predicters – continuous machines. Considered an early analogue computer, the predicter was an extraordinarily powerful tool. Darwin's tidal abacus was a further attempt to lighten the calculating load. Throughout the first half of the twentieth century, improved statistical routines were applied but the process still remained still highly laborious. Those were the main functional aids available to the scientists until the 1960s, when they began to deploy digital computers on tides.

The modern electronic computer appears to perform the harmonic analysis and prediction at the touch of a button. Whilst it is an almost instantaneous operation, the operation disguises the programme writing involved. By the time of writing the programmes, tidal analysis was well understood. That was not the case at the beginning of the harmonic investigation. Then, as now, the theoretical understanding of the tidal ocean remained incomplete. This short

[482] C. E. Adams, *Harmonic tidal constants of New Zealand ports (Wellington and Auckland)*, Australian Association for the Advancement of Science Report of the Meeting, 1913, volume 14, 18-

chapter sets out some of the difficulty involved in the empirical ascent of tidal science, and enumerates several of its early aids.

19.

# CHAPTER 11 WORLD WIDE PREDICTION 1896 – TODAY

## 11.1 INTRODUCTION

Successful tide tables first appeared in Liverpool in the late eighteenth century – though their derivation method remained a secret.[483] Then the successful prediction method which Lubbock published in 1828, he found adaptable for other ports.[484] That utility allowed the Admiralty to enter the field of tide prediction within five years. Through the following seventy years, the scope of that prediction volume grew to cover all of the British Isles. The French were the first to emulate its success. Later, when the Government of India financed research for a superior method, that newer method was in turn emulated in the United States. That American volume became the first tidal volume to represent each continent. Turning full circle, the Admiralty then followed the U.S. in producing its own world wide edition. For the first time, this chapter sets out that development of global tide tables.

The early prediction method, which has lately attracted the generic term of synthetic, is one of parameterisation. The main parameter relates high water to the moon's transit across the meridian. The addition of a number of variations allow for the effects of the body's angular distance form the equator, linear distance from earth, the time of year and the stage in the fortnightly tidal cycle. Whilst it is a method sufficiently robust to remain viable, it is only effective with strongly diurnal or semi-diurnal tides; it does not function as well with tides of a mixed nature. In addition the analysis and prediction is limited to the extreme turning points of sea level, to the time and elevation of high and low waters. This method needs at least a year of observations with which to predict times, and nineteen years for elevation.

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[483] Philip L. Woodworth, *Three Georges and one Richard Holden: The Liverpool tide table makers*, Transactions of the Historic Society of Lancashire and Cheshire, Volume 151 2002, 1-51.
[484] Michael S. Reidy, *The flux and reflux of science the study of the tides and the organization of early Victorian science*, (PhD thesis, University of Minnesota, 2000); Paul Hughes and Alan D. Wall, *The Admiralty Tidal Predictions of 1833: Their Comparison with Contemporary Observation and with a Modern Synthesis*, The Journal of Navigation, LVII, (2004), 1-12.

The later prediction method attracted the term harmonic from the start. The most significant difference, between the two methods, is that the harmonic deals with all of the tidal profile. It deals with the variation in elevation along a continuous time function. The harmonic method treats the whole daily modulation of sea level as the sum of several, separate harmonic tides. Each constituent tide has its own frequency, amplitude and phase. Only a month of observations enable useful predictions; and most constituents come from a year of observations. By the harmonic method, all of the tidal record is analysed. Harmonic prediction offers the elevation for any moment in the future, and also the time of any future elevation. However, in the interests of economy, tide tables derived from the harmonic method generally restrict themselves to giving high and low water time and elevation.

The harmonic method, developed during the 1870's, caught the British home table in a curious twist. The incumbent Hydrographer later came to describe the tides around the British Isles as 'the most simple that are anywhere found'.[485] He meant that as the suitability of British tides to treatment by the synthetic method yielded good predictions, one could not expect the Admiralty to fund any new tidal research programme. Fortunately, Indian geodetic demands did fund a research programme for the new method. While tide tables for occasional British ports, such as Liverpool, individually came to benefit from the harmonic research, it took the extreme event of warfare to induct this change into the Admiralty's, whose tables were for a substantially more significant area than one estuary.

Until 1833, prediction tables were only for individual ports or small areas. The Admiralty's was the first country-wide set of tide tables. However, the employment of its synthetic method, in parts beyond NW Europe, gave less than satisfactory results. From 1867 onwards tide tables were developed for both Bombay and Karachi – but for no further afield in the sub-continent. From about the same year, the United States independently extended coverage along its own vast coasts. Though in neither continent were the synthetically derived predictions reliable. But, with the subsequent application of the harmonic method to those Indian ports, their tidal predictions then became respectably reliable. Overnight, there was a method available for use anywhere in the world. However, for useful prediction tables to come about for any place, good observations and complex computation would need financing.

## 11.2 SYNTHETIC & HARMONIC COMPARISON

Naturally, there were problems in some places. The encroachment of the Thames Embankment out into the river is an example.[486] It was among a number of factors which had an influence upon the tidal regime prevailing there. Because of such considerable changes, the tidal heights had increased by over twenty inches in as many years. The change also gave a suitable opportunity to test the new harmonic method by comparing it against the older synthetic method. Though Roberts did not publish his contemporary test, I have recreated part of it. The result (Figure 51) has a differing base for each method. Unfortunately, contemporary observations are not available, so that part I can not effect. However, the curves do exhibit a clear conformity in their predictions.[487]

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[485] William J. L. Wharton, *Hydrographical Surveying*, second edition, (London, 1898), 174.

[486] Edward Roberts, *Thames Tides*, (London, 1882). A copy of this pamphlet is located in the Royal Geographical Society, MG706a. The pamphlet explains the special flood use of Roberts' 1883 tide table.

[487] The synthetic curve is derived from the Admiralty tide table, the harmonic curve is derived from: Edward Roberts, *A tide table for London Bridge for 1883*, (London, 1882).

Figure 51 HW predictions at London Bridge by two contemporary methods


The similar output in London, by the two predicting methods, meant that a research programme to develop the new method could not merit financing directly to the benefit of home waters.

## 11.3 FRENCH CONTRIBUTION

The second set of country-wide tables was those for France. Begun by Pierre-Simone Laplace (1749-1827), at Brest it enjoyed one of the earliest of all sea-level records. During the early nineteenth century, other French scientists built upon the knowledge fostered by him and the Academy of Science. The Brest record of data gave suitable material for subsequent investigators. The product of the French investigation, the *Annuaire des Marées des Côtes de France*, appeared for the first time in 1839. Though interrupted two years later, its publication from then on assumed a regular format.

Assiduous amateurs initially dominated the Admiralty table. Their scientific pursuit became the focus of a massive correspondence network. In contrast, the French investigators were paid professionals. The hydrographic engineers, Pierre Daussy and Rémi Marie Chazallon

(1802-1872), succeeded Charles Francois Beautemps-Beaupre (1766-1855), the contemporary French Hydrographer. These Frenchmen corresponded with the growing international network based in Britain. The Great Peace which descended on Franco-British relations after 1815 allowed much scientific co-operation. This enabled the French table to carry predictions for four of the British ports opposing their coast.

Chazallon edited the French table, from its inception up to 1861. He also succeeded in pioneering a primitive form of harmonic analysis for the table.[488] His success sits precisely within the context of contiguously developing theory. Chazallon's practical development was about three years after George Airy (1801-1892) had discussed similar theory with William Whewell (1794-1866).[489] However, Chazallon's foray was a full quarter century before William Thomson's (1824-1907) more rigorous harmonic treatment of tides. In turn, Thomson gained his insight from Fourier's *Théorie analytique de la chaleur* of 1822.

Chazallon did not give his full prediction treatment to all of the French ports, but several, including Brest, were. By 1874 the French volume for home waters grew to treat fifteen ports. The volume for that year acknowledged the early work of John Lubbock (1803-1865) and Whewell; and the quality of predictions increased.

For a number of years, the French considered the tide of the whole north and west coasts of France as if it was in a direct relationship to that at Brest. Brest sits right in the middle of the French tidal coast. South of Brest, tidal action is almost instantaneous; eastward, up the Channel, it acts progressively later. Brest got the full analytical treatment, with the remaining French ports then considered subordinate to Brest. It was an old idea, having circulated within the Royal Society two hundred years previously. Despite the attempt of subornment not persisting on the domestic coast, they made a further attempt to extend the

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[488] David E. Cartwright, *Rémi Chazallon a forgotten "Ingénieur Hydrographe"*, History of Oceanography, September 2003 No 15.

idea to the rest of the world. Inspired by the French, it was an idea also considered later in Canada in 1901.[490] As a principle – for small areas only – it still survives in the treatment of secondary ports.

However, Gabriel Héraud (1839-1914) eventually sustained a more successful investigation in Indo-China, leading to a set of tables for the French colonies. The French portfolio then widened, with a volume based upon Tonkin added in 1873.[491]

## 11.4 THE FIRST WORLD WIDE TIDE TABLE

At the time of American independence, the mapping of that continent's coasts largely lay in foreign hands. By 1807, the government of the subsequent United States created the Coast Survey – the continent's first major scientific institution. Achieving little output up to 1832, the Coast Survey needed a superintendent.[492] Still engaged at the Franklin Institute, Alexander Dallas Bache (1806-1867), had recently toured several European scientific institutions. His eventual appointment to the Survey, by the President in December 1843, became a productive choice.

Bache had been appointed professor of natural history at Philadelphia in 1828, then the scientific centre of the emergent country. There, Bache deliberately involved himself with the Coast Survey's work. Initially, their only tidal interest concerned making vulgar establishments of each port.[493] Impressed with the newly formed British Association for the Advancement of Science, he became another international correspondent of that scientific

[489] CUL RGO 6/499/208.
[490] CUL DAR 251/4927, 5221.
[491] G. Héraud, *Annuaire de Marées de la Cochinchine et du Tonkin*, (Paris, 1873).
[492] Hugh Richard Slotten, *Patronage, practice, and the culture of American science*, (Cambridge), 1994.
[493] Whewell, R.6.20[176a].

network from 1833.[494] To it, he reported the Coast Survey's progress on both their Atlantic and Pacific tidal investigations.

In all, Bache published sixty-two papers on tides.[495] His reports, ranging across the breadth of American culture, indicate his difficulty then. On the east coast the President took a direct interest; on the other hand, on the west coast, Red Indians were besetting the investigation.[496] Several months later Bache enthusiastically joined up with Whewell's ambition of a global view of tides; for him, Bache produced a co-tidal map of the Western Atlantic coast, including Nova Scotia.

Bache superintended the survey of the whole United States' coast. He knew what he wanted with tides, and within weeks appointed Charles H. Davis (1807-1877) in charge of hydrography.[497] Davis advanced the simple data to corrected establishments and established long term tidal observation, so necessary for prediction by the synthetic method.

In Britain, tide table production intertwined with that of the Nautical Almanac from inception, through to 1907. As privately produced American almanacs were fully integrated, the United States Government envisaged a similar arrangement for their almanac.[498] However an almanac counts out time, or longitude; and that graticule, as for all American cartography, remained dependent on European sources.

Under license from the British Admiralty, an American abridgement of the Nautical Almanac had existed since 1811. This New York publication was a pragmatic alliance

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494 Hugh Richard Slotten, *Patronage, practice, and the culture of American science*, (Cambridge), 1994, 32.
495 Slotten, *Patronage, practice, and the culture of American science*, 117.
496 Whewell, R.6.20[50].
497 Craig B. Waff, *Navigation vs. astronomy: defining a role for an American Nautical Almanac, 1844-1849*, Proceedings Nautical Almanac Office Sesquicentennial Symposium U.S. Naval Observatory March 3-4 1999, (Washington), 1999, 83-128.
498 National Archives, Washington DC, (hereafter Washington), RG 23 13.

against the vicissitudes of the dividing Atlantic. Consequently, American mariners, astronomers and geodesists were content using standard European almanacs during the first half of the nineteenth century.[499] They had made attempts to construct an American almanac from both French and German sources. Dissatisfied with those, in late 1846 Mathew Maury (1806-1873) then sought, from the Astonomer Royal, for a copy of the: "Formula, by which the calculations for the British Nautical Almanac", are made.[500] At the Federal capital in Washington, Davis then succeeded to the first appointment as Superintendent of the Nautical Almanac in 1849.

In Washington, they constructed the almanac and the requisite tidal tables at the same time, publishing each for the first time in 1852. With the American almanac published three years in advance, and the tidal data in the Coast Survey's annual report only one year in advance, it illustrates a variable degree of completeness.

The data was composed of requisite tables for a number of ports, and from these tables the mariner could then calculate tidal predictions. The listed values included the mean lunitidal interval of high water, the maximum variation from the mean, the range and duration. Further corrections were possible for the solar year.[501] They based the tidal tables of 1852 on data only gathered in since 1844. Bache was under political pressure to be productive, which was difficult, as he only had complete tidal records of a few years. Despite that, Bache took the decision to publish information early. As Bache said, "Our survey is not done but in progress."[502]

Not surprisingly they continued publishing annual auxiliary tables and curves after the outbreak of civil warfare in 1860. The last tables by the lunitidal interval method were for

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[499] Waff, *Navigation vs. astronomy: defining a role for an American Nautical Almanac.*
[500] CUL RGO 6/203/31.
[501] H. E. Finnegan, *Historical note on tide predictions,* Journal Coast Geodetic Survey, 1953, 100-2.
[502] Whewell, R.6.20[53]. The emphasis is that of Bache.

1864. When the Confederacy collapsed the following year, a full twenty year cycle of observations had accumulated in the interim. It was from those observations that daily predictions of HW for 1867 came from. Additions of LW were inserted the year after that. Those American predictions were from the synthetic method.[503] Having previously met him in Europe, Bache had modelled the survey itself upon lines advocated by Alexander Humboldt. With separate east and west coastal volumes, the tables contained predictions for four Pacific and fifteen Atlantic ports.

In America, synthetic predictions then exclusively came from this method for the seventeen years up to 1884.[504] However, the tides of America's coasts have a noticeable diurnal component, and really needed treating by a method which could deal with this element. The Coast Service's William Ferrel (1817-1891) was the first foreign scientist to be inspired by Thomson's work on Indian tides. Ferrel built his own tide-predicting machine. His machine, although with only nineteen constituents, was then able to supply superior American predictions from the harmonic method. From 1885 onwards, harmonic predictions rapidly took over from synthetic prediction in the United States tide table. A new thirty-seven constituent machine came into operation in 1910. Not supplanted by an electronic computer until 1966, the long usage of this second mechanical predicter illustrates its considered efficiency.

The idea of an explicitly universal tidal examination re-emerged with Crawford Pasco (1818-1898), a naval officer retired to Australia and chairman of the Antarctic Exploration Committee.[505] This came in 1887, when the Canadians were asking the British to conduct their analysis. Arising out of a desire to fully appreciate the monsoon, it was indeed a truly Humboldtian aspiration of research reaching across different subjects.

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[503] Washington, RG 23 72, 123; *Tide tables United States and foreign ports for the year 1896*, (Washington), p20.
[504] Stacey D. Hicks, *The tide prediction centenary of the United States Coast and Geodetic Survey*, The International Hydrographic Review, 1967 volume 44 part 2, 121-131.

> This has impressed me with the desirability of an organised system for tidal observations in all parts of the world on the coasts of Continent and on Islands where stations are established, observing not only the Rise and Fall and times of HW at full and change, but also, where practicable, the direction and strengths of current all of which I would suggest should be taken in conjunction with a Meteorological Register which would furnish data to determine the effect of the Monsoons and changes of season elsewhere on the tidal system and ocean current.

However, no further concerted action was taken at that time within the area of British Imperial interest.

First devised in 1830, all the early gauges for tidal observation were floatation apparatus. The technology, improved in the United States with a pneumatic gauge in 1892, succeeded with exports to Europe.[506] Three years after the free offer of Canadian predictions, the U.S. government actively sought international tidal co-operation. The U.S. addressed letters to their foreign consulates abroad, asking for predictions or tidal observations of their host's ports. The data which then came forth enabled the U.S. to produce a set of international tables for 1896; it included the daily tides of seventy world-wide ports. The bulk of predictions were from their own and the two British investigations, but others were included. The tabulations, of one German and four French predictions which it contained, were explicitly from Ferrel's machine.[507] This was in contrast to their being reproductions of predictions exchanged between the national hydrographers.

Significantly the U.S. tables included a set of predictions for at least one port on each continent. With that volume, the Coast Survey achieved the first world wide tide table. In the centenary year of its table the United States provided tide times and heights for 251 ports across the globe.

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[505] CUL DAR 251/3024.

[506] United Kingdom Hydrographic Office, SLB10 HH63 188-190, 10th February 1892.

[507] *Tide tables United States and foreign ports for the year 1896*, (Washington), p20.

## 11.5 TABLE PROLIFERATION

The synthetic method found prediction, of strongly semi-diurnal tides, to be highly suited to treatment by it. Where successful though, synthesised predictions generally gave only the time and height of HW. In addition it prove to be intactable to the solution of mixed tides. The more powerful harmonic method came more than forty years afterwards, during the 1870s. The harmonic method's ultimate potential, was not only the prospect of predicting the whole spectrum, but that it should deal with every tidal type. The harmonic method then came as a breakthrough for the tides of India, followed by the United States and then Australia. In contrast, this theoretically more rigorous method initially gave poor results in some European waters.

At the proving stage, Thomson tested his new harmonic method by treating the tides of San Francisco, Liverpool and Bombay. Satisfied, Thomson then approached the Hydrographer, with a mind for him to use the harmonic method in the Admiralty tide tables. Thomson made that approach in 1876; and at that time, the Hydrographer gave the proposal a proper consideration.[508] He even suggested which ports might be best to investigate for the diurnal tide; he added that the investigation ought really to dwell on equatorial or southern ocean ports.[509] However, beyond one or two British ports worthy of improvement, he concluded that they already held a good quantity of information about the home ports.

George Darwin then took over the ongoing Indian investigation; he raised the method to its first pitch of perfection. From his Cambridge base, Darwin directed the train of Baird's harmonic investigation on the whole Indian coast. Then Darwin approached that same Hydrographer for a second time. By then the Hydrographer had become resolute, and outrightly rejected any tinkering with the Admiralty tables.[510] His tide table, already

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[508] CUL Add 7342 E89.
[509] CUL Add 7342 E90.
[510] CUL Add 5750 101.

established for several decades, afforded sound practical predictions. Crucially, he stated that it was not the province of the Admiralty to provide tide tables for colonial ports.

With a workable edition in existence there was little hope of the Admiralty funding a new investigation for home ports. The Government of India then provided funds for a programme of harmonic analysis. Beyond British India, it was other countries which immediately took up the advantage of the new method for their domestic coasts.

During the second half of the nineteenth century shipping disasters in the Gulf of St Lawrence was a cause of growing concern. Then in the year of the Prime Meridian conference in Washington, the British Association for the Advancement of Science held its meeting for 1884 in Montreal. One result was the formation of a committee to produce Canadian tide tables.[511] Despite it being a time of insurrection, these various influences goaded the Canadian government into a limited funding of tidal investigation.[512] However, it took until 1887 before the funding became adequate. At that point they saw that the calculation facility, already paid for by the Government of India, could augment their effort.[513]

By that time serendipity came into play, when they lighted upon long series of observation records, hidden away in a government office. Some of the two Canadian port records dated back to 1851. Their harmonic analysis produced a set of predictions for 1891.[514] Immediately it was felt that the promulgation of the predictions was insufficiently wide enough. In response to this, the Canadian government freely distributed their predictions to each of the leading foreign tide table compilers. They even went so far as to give the data to newspapers; this distribution was an early example of its type.

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[511] Thomas E. Appleton, *Usque ad Mare*, (Ottawa, 1969).
[512] CUL DAR 251/2529, 2550.
[513] CUL DAR 251/2826, 3040.
[514] CUL DAR 251/3205.

By 1898 the Canadian tidal department were publishing predictions for three ports. Within a very short number of years this had grown to two volumes, as in the United States: one for the Atlantic coast and another for the Pacific coast.[515]

By the nineteenth century's end, there were predictions available for several isolated colonial ports: these included Singapore, Hong Kong and South Africa. In Australia observations were underway at Hobart, by 1822.[516] Hobart became the site of that continent's first self-registering tide gauge, and these investigations rose to be part of a comprehensive programme. The Australians took a contrasting view to the Canadians over calculations, and had built their own tide predicter by 1897.[517] Alexander Inglis (1845-1921),

[515] W. Bell Dawson, *Tide Tables for the Eastern Coasts of Canada for the year 1907*, (eleventh year of issue), (Ottawa, 1906); W. Bell Dawson, *Tide tables for the Pacific Coast of Canada for the year 1907*, (seventh year of issue), (Ottawa, 1906).
[516] Thomas Brisbane, *Table of the rise of the tide at Hobart Town, Van Diemen's Land, in April and May1822, and January 1823*, Edinburgh Journal of Science, volume 3, 1825 p100.
[517] *The Advertiser*, (Adelaide, 1897), Dec. 28 page 3 column c.

the harbour master at Adelaide, made this first Australian predicter. He used the recent four years of observations collected by the Geographical Society of Australasia with which to make predictions.[518] Brisbane tide tables had been available since 1882 but appeared not to have gained reliability, appreciable enough to shipping interests, until about nine years later.[519]

German trade expanded significantly in the second half of the nineteenth century. Then conclusion of the Franco-German war in 1871 was largely coincident with publication of the harmonic method. Although the *Gezeitentafeln* appeared only eight years later, it would seem that initially the Germans based their tables on the synthetic method.[520] Subsequently, A. C. Börgen activated a string of tidal correspondence with the networkers in Britain, from 1884 onwards.[521] He then undertook harmonic analysis of the Heligoland and Wilhelmshaven tides, and produced predictions by the new method.[522] Though all was not well with these, and Börgen returned to adoption of the synthetic method.[523] He appears to have led the German officials to also positively reject the harmonic method for their early tide tables.[524]

By then the British network had become highly international. Beyond the European or English speaking world, Japan was an active part of the increasingly international tidal effort. The Land Survey there undertook observations at fourteen ports from 1895.[525] The Japanese table dates from 1900. In 1914 they followed on from Brazil, in obtaining a predicter from Thomson. Within a decade they had a daily set of tables for 26 ports. While

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[518] CUL DAR 251/5188; Alexander Inglis & R. W. Chapman, *Description of a tide-predicting machine*, Australasian Association for the Advancement of Science Report of the Meeting, 7 (Sydney, 1898) 239-241; CUL DAR 251/3025.
[519] Anonymous, *Harbours and Marine Queensland 1824-1985, 124.*
[520] Hugo Lentz, *Von der Flut und ebbe des Meeres*, (Hamburg), 1873.
[521] CUL DAR 251/2524.
[522] CUL DAR 251/2524.
[523] C. Börgen, *Darlegung der Berechnungsweise fur die Angaben der Gezeitentafeln*, Annalen der Hydrographie, 1907.
[524] Warburg, *The Admiralty tide tables*, p309.

the first predicter succumbed to an earthquake, it was quickly replaced. Despite the success of the Japanese predicters, even by 1925 their volume was restricted to Far Eastern ports.

## 11.6 BATTLE OF HELIGOLAND BIGHT

Herbert Edward Purey-Cust (1857-1938) became the Admiralty Hydrographer in 1909. On the Admiralty tide tables' title page he named himself editor. Although the table had included the French port of Brest almost from the beginning, until Purey-Cust's time the annual was primarily for Great Britain. Then by inserting German ports, he plunged the tide table into international expansion. It came at a difficult time.

When Purey-Cust launched the expansion in 1910, the contemporary European political scene was becoming unstable. Britain and France had signed the *entente cordiale* only in 1904. Therefore, it is curious that it was the German coast that facilitated the British table's foreign expansion. Then with the Agadir crisis in 1911, gun-boat diplomacy took a new turn. Consequently, hydrographic intelligence assumed an increase in importance. This became particularly so, as the draught of capital ships, the *Dreadnought* class, significantly deepened.[526]

The demand for superior hydrography came at the end of more than a century of progressive chart improvement. This fresh demand was military, coming after improvement fuelled by trade. Tide prediction had also improved: but neither was the improvement universal nor was adequate data collected for analysis. The exchange of tide predictions between hydrographic offices, for the 1910 publication, was a significant practical counterbalance. The idea was for a mutual Anglo-German publication programme.

[525] George H. Darwin, *The tidal survey of Japan*, Nature, No 2201 Volume 88, January 4th 1912, 315-6.
[526] Arthur J. Marder, *From the Dreadnought to Scapa Flow*, (Oxford, 1961).

As the mutual programme developed, an imbalance quickly became apparent. In the summer of 1913, the British noted that the Germans had more up-to-date hydrography than the Admiralty.[527] When war broke out, naturally the Anglo-German exchange ceased. Yet, the continued availability in Britain, of predictions for German waters, was of almost vital importance.[528] Unfortunately, Britain's prediction capacity was, at that time, severely curtailed. In August 1914 Britain was bereft of a tidal authority.

At that time, the Hydrographer's naming as the editor of the tidal volume misconstrued his relationship to the branch. Tidal prediction was only part of his responsibilities. However, it had been the successive pecuniarily cautious hydrographers who had declared newer prediction methods wanting in European waters.

By the time war was declared, the reserve of tidal expertise in Britain had sunk to a diminished and dispersed state. Darwin, the man who had perfected the newer method died in 1912; then the computer employed for the older method, had also recently died. In addition, the Indian Government had removed their tide predicting machine from Admiralty premises. Edward Roberts (1845-1933), the machine's expert manipulator was therefore made redundant.

Comparison between the hydrographic capacities, of the vying nations, appears to be the catalyst that eventually introduced change at the Admiralty. There were problems finding success with the harmonic method in shallower eastern parts of the North Sea. Consequently the Admiralty initiated a new research programme, thereby creating the tidal branch. However, it was Harold D. Warburg in 1912, who began this re-enlivening of the

[527] Archibald Day, *The Admiralty hydrographic service 1785-1919*, (London, 1967), 255.
[528] Harold D. Warburg, *The Admiralty tide tables and North Sea tidal predictions*, The Geographical Journal, Vol LIII Jan-Jun 1919, 308-330.

Admiralty's tidal expertise.[529] Despite Roberts's sacking, the Admiralty re-instated him into the increasing tidal effort of 1914 without question. They brought the department into existence at the eleventh hour, in the very last weeks of peace.

There was some German material available for the department to work on. Some short records of German tidal observations were held in Britain. The shortness of quantity required their treatment to be by the harmonic method, rather than the synthetic. It was known since 1895, that differing predictions could come from two harmonic analyses of the same observations.[530] Warburg had learned that these differences were index errors, rather than methodical.[531] To be effective, the synthetic method required long series of observations for analysis. Before Warburg, it was also poor at solving diurnal tides. In his desperate need Warburg resorted to hybrid calculation; synthesised times and harmonic heights offered a part solution. The experience of Roberts, having worked continuously on tides since 1868, was an invaluable addition to the new harmonic work at the Admiralty. Concurrently, Warburg's department pursued what was to become his *equation* method.

Warburg became the head of the Tidal Branch. The equation method is probably the most elaborate adaptation of the synthetic method. Warburg claimed to have exhausted the possibilities of the synthetic approach. Warburg produced a yield from the equation method where either the semi-diurnal or diurnal tide is predominant. However the method has proven to be intractable to mixed tides.[532] It is probable that the equation method was an algebraic development of an earlier, graphical attempt.[533] William J. L. Wharton (1843-1905), a Hydrographer preceding Purey-Cust, had developed the graphical method.[534]

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[529] For this, see Day p257. It refers to the United Kingdom Hydrographic Office, H.D. 1015/1913 Appendix C,7.
[530] Cambridge University Library (hereafter CUL), DAR 251/4255.
[531] Warburg, *The Admiralty tide tables*, p310.
[532] Arthur T. Doodson & Harold D. Warburg, *Admiralty manual of tides*, (London, 1941), p117.
[533] William J. L. Wharton, *Hydrographical Surveying*, second edition, (London, 1898).

The equation method was of considerable value during the 1914-18 conflict. Heligoland, an island in what is now the German Bight had been in British hands up to 1890. Observational data was accreted with respect to Heligoland. Bizarrely, the new German government under direct British permission had collected an earlier set of data there, and a copy was available.[535] The United States supplied a later set. In addition, the capture of a copy of some predictions, for the use of the German fleet, provided a check. The British results for Heligoland, obtained from the equation method, agreed almost exactly with those calculated in Germany. Warburg also ran a back check, of the equation and harmonic method, and found a large percentage of improvement for Heligoland.

After the Great War broke out in the summer of 1914, the Admiralty tables continued to carry predictions for German ports. Ephemeredes in general are prepared several years in advance, as was the 1915 tidal edition; and it was fortuitously so with the following year. The Admiralty calculated predictions for German ports, in the two subsequent editions of 1917-8, by the harmonic method. As they knew that the predictions were of poor quality or erroneous – their public issue forms a type of dissimilation propaganda. Those promulgations resulted in a German *Notice to Mariners*. The notice gave a caution about the accuracy of British prediction for Wilhelmshaven. (Wilhelmshaven predictions were a derivative of Heligoland's.)

As part of military strategy, Warburg kept his equation method secret at the time; nor has it received any elaboration since.[536] The Admiralty issued special predictions, employing his better results, to the Royal Navy for the remaining years of conflict. Similarly, in the public domain at least, none of those predictions now exist.

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[534] CUL DAR 251/4866.
[535] United Kingdom Hydrographic Office, MB 21 HH51 53-54, 16th February 1877.
[536] Harold Dreyer Warburg, *Tides and tidal streams*, Cambridge 1922.

The Germans had a complementary problem; they needed predictions for British waters. Much of the data, with which to make predictions for British port, had been widely published in preceding years. Therefore the problem, for his counterpart hydrographer, should have been easier than it had been for Warburg. It was not. The magnitude of their problem lay in the size of the area, which the Germans needed to calculate tides for: the entire British Isles' coastline is tidal. Years before, A. C. Börgen (1843-1909) had been without a predicter, but Darwin had at that time loaned him a special tidal abacus.[537] Clearly, by 1914, the abacus was no longer sufficient for such an increased computing demand. However, by 1915 Heinrich Rauschelbach constructed a predicter at Potsdam, in Germany

[537] CUL DAR 251/4044.

(Figure 53).[538] The published plans of the Indian predicter were a help to him; the two machines – the German and Indian – are so distinctly alike.

The two sides fought the naval battle of Heligoland Bight in August 1914. The struggle for the bight's predictions, during the rest of the Great War, was to favour the creation of a second portfolio of world tidal predictions.

### 11.7 THE 1921 ADMIRALTY TABLE

When William Wharton became Hydrographer in 1884 he could not avoid taking an interest in the harmonic method, its developments were so active.[539] Under him, the Hydrographic Office became the conduit for harmonic investigations in the Far East and Australia. They were investigations whose finance did not come within the scope of the Indian Government; although *Tide tables for the Indian ports* had had an international scope since 1882. That nature of its composition was directly because of imperial extent. The volume had grown quickly to encompass the whole of the Indian Ocean's northern littoral – which was that tables' financial province.

The United States Coast Survey had taken up the harmonic method in 1882. The Survey first produced an international set of predictions for 1896, and it was at least a year in advance. When Wharton inspected a copy as early as January 1895, he compared both of the harmonic tables. Between the Indian and American tables he found some occasional differences. For Aden, for example, some times differed by fifty-eight minutes; while with Calcutta, heights differed by over two feet.[540] The Americans had derived their own constants, with which to make the predictions. Both the British and Americans had used the same set of observations with which to make different sets of constants. Wharton wondered

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[538] Anonymous, *Tide Predicting Machines*, (Cannes), (International Hydrographic Bureau, special publication no. 13) July 1926, 59.
[539] CUL DAR 251/2720, 3216, 3442, 3443.
[540] CUL DAR 251/4255.

which predicting machine had been the one to have diverged the most from reality. They had known for some time that manipulating the machines differently gained them variable results.[541] At that time, Wharton could clearly justify withholding the harmonic method from predicting home-port tides.

When, in 1912, the Admiralty eventually extended the reach of their tide tables beyond Europe, it instantly became a skeletal table of the whole ocean. The addition of those colonial ports was the first witting contribution to the tables from the harmonic method. This second proto-global set was then composed of both synthetically and harmonically derived predictions. In addition, the Admiralty made up their enlarged table from the product of several research programmes. Comprehensive programmes included the British, German, Indian and Canadian. Isolated research results came from Singapore, Hong Kong, Australia and New Zealand. The reach of the Admiralty volume was wide, but that of the American edition was wider. It also had a different composition. Naturally, any predictions came from on site, native observations. However, the predictions calculated in America were as a result of their own analysis. All of the American predictions were from their own, singular programme.

The Panama Canal opened in the same month of 1914 as did the Great War. The following year the Admiralty featured predictions for the Pacific end of the canal in their expanding volume. The work of Warburg implies that by about then, London predictions were compiled from the harmonic method. During the war he compared American and British predictions, for both London and Panama. They were each computed from the same set of constants, but their mode of computing produced different results. In some cases, the differences amounted to fifteen minutes of time.[542]

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[541] CUL DAR 251/3624.
[542] Warburg, *The Admiralty tide tables*.

After the armistice of 1918, the Admiralty accomplished ever more predictions by the newer methods. Within two years, the volume noted times by the 24 hour clock and in 1921 included United States ports. By then the Admiralty set were also tables of world wide tidal predictions.

## 11.8 CONCLUSION

The development of tidal prediction has been distinctly a science founded upon dedication and co-operation. That is not to say that warfare did not interfere; and the needs of warfare were as equally partial with American citizenry as anywhere. The requisite tables in the 1864 report were specially published for the naval forces of the Union rather than the Confederacy. Similarly, the Americans produced restricted predictions for the Pacific for the concluding months of their conflict there in 1945.

However, systematic open tidal investigation stemmed back to the late 1820s. In those early decades the investigators had succeeded in bringing several foreign governments into scientific co-operation. Co-operation was then later re-vitalised by the United States in 1894. Yet it would seem that the one-off supply of data, as opposed to the commitment to exchange, were of differing orders. In 1909, Purey-Cust's immediate predecessor had to undertake actual negotiations with colonial governments, to affect a hydrographic exchange. There was an obvious mutual advantage, were the central power to include several widespread colonial ports in the increasingly important set of tables.[543] However it had been with the German Hydrographer that the Admiralty succeeded in establishing an earlier exchange.

Raw from war experience, by 1919 it then became the explicit aim of the Admiralty tidal department to calculate their own predictions of alien foreign ports. In sharp contrast, the

[543] Day, *The Admiralty hydrographic service*, 218.

authorities of allied Dominion and colonial ports were trusted to be capable of supplying acceptable predictions.[544]

The time of the expansion of tidal prediction to the entire globe coincided with a state of transition among the world trade powers. With their defined territorial interests, the dominance of European powers was adjusting to the rapidly expanding American market; at that time enlargening globally, beyond any singular colonial mindset. A sign of this transition was that the United States, rather than Britain, realised the first global tide table.

The most significant twentieth-century development in tidal work was the replacement of human computers with electronic ones. The replacement was coincident with the invention of a newer method of tidal prediction.[545] This response method, while powerful, has not succeeded in supplanting the harmonic method. However, computing in general has affected both analysis and prediction; it has also eliminated a massive burden and reduced error.

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[544] Warburg, *The Admiralty tide tables*.
[545] W. H. Munk and David E. Cartwright, Tidal spectroscopy and prediction, Philosophical Transactions of the Royal Society of London, (1966), A259, 53-81.

Another development has been publication of predictions on the web. The Service Hydrographique et Océanographique de la Marine of France is excellent. The American, National Oceanographic and Atmospheric Administration, also publish on the web for the coasts of North America.

A hard-copy paper form of the American world wide tide tables also exists. Those tables are no longer under the aegis of the Federal Government, instead, although derived from the national agency they are now published commercially.

The Admiralty publish predictions on the web and also in book form. The reach of both forms is world wide. Observations in home waters are made for three years and the improved harmonic method is the dominant method in use. With predictions for standard ports abroad, the Admiralty have returned to receiving them from the appropriate authorities; even though there may be nothing known of the foreign method. This is not quite the backward step, to the state existing prior to 1828, which it might seem. The foreign predictions generally do to stand up to comparison with observation.

The mutual international exchange of prediction has prevailed. Several countries which once produced global tide tables, now no longer do so. This loss seems inexplicable, for the exchange ought to favour the country with the lowest publication and distribution costs. The cost of the four Admiralty volumes is £20 each; those produced in America are £14. The cheaper volumes are especially favoured, because they are compulsory equipment for ships entering American waters. However, notwithstanding two advantages, the American volumes are a distinct rarity on ships trading internationally.

# CHAPTER 12 SUMMARY

## 12.1 INTRODUCTION

This chapter draws together the main findings of chapters three to eleven. Listed in the bibliography, eight articles publish the separate findings of chapters four to eleven, in peer reviewed academic journals. In addition, other authors in the field have utilised this research.[546]

Although the basis of the research has been study of original documentary tidal sources, considerable experience, gained working among tides and with tide tables in a forty year career as a seaman, reinforces it.

## 12.2 STATISTICAL ANALYSIS

Throughout the whole nineteenth century, a healthy level of scepticism prevailed as to the accuracy of the different methods. The *Philosophical Transactions* exhibit several early comparisons. Those, and a modern comparison, are of London data. Although the investigators published the observational data, precipitating the comparisons in this thesis, they only ever referred to it obliquely. In the interim it appears to have been forgotten about. Previous to this thesis, no one had published an analysis of that data. As a result of this investigation, that data's analysis (part 8.6) extends comparison to a much wider geographic area. These comparisons have additional merit, in that it was also possible to produce modern calculations for the period under review.

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[546] Benjamin C. Sheesley, *A Humboldtian Science Framework for William Whewell's Tidal Maps*, University of Wisconsin MSc. thesis, 2002; Cartwright, *The Tonkin tides revisited;* Michael S. Reidy, *Masters of Tidology: The Cultivation of the physical sciences in early Victorian Liverpool*, The Historical Society of Lancashire and Cheshire, (2003), 51-77.

The first comparison is essentially one concerned with the *time* of high water. The Proudman Oceanographic Laboratory has preserved many years of the manuscript observations for Sheerness, one of the foundation ports. These observations were used to inspect 1836 (part 8.8), the year when *heights* were first introduced into the Admiralty tables.

By chance this study also lighted upon a year which had both synthetic and harmonic predictions for one British port. The statistical study of this1883 data (part 11.2), was only partly successful owing to lack of contemporary observational data. The duality continues to exist of British synthetic predictions and American harmonic predictions, for several other ports and for several years. For an investigation of this data to be worthwhile it needs co-incident observations, and none appear to be available.

## 12.3 A RETROSPECTIVE OF PREDICTION

The eight chapters of narrative (chapters 4 to 11) address a largely continuous gap in the knowledge rather than addressing discrete issues. The thesis presents new information in a continuous thread of knowledge. I have obtained this information by going directly to the sources. The sources include Carolingian and later medieval diagrams, East Indian Company records and over two thousand pieces of tidal correspondence.

I have achieved the specific aims, set out in chapters 1 and 2, in the following ways. *How* and *when* the primitive method was developed is set out with medieval diagrams (chapters 4 & 5); and its culmination of *when* is within the chapter on Dessiou (chapter 7). *Where* this method was written up was in monasteries across Europe; and advanced most of all in Britain. *Why* the method was initiated is as a result of religious interests in time. The transition to the modern methods partly developed from Tonkin (chapter 6) and with Dessiou (chapters 7 & 8).

*How* the modern tide tables were made I relate explicitly in chapter 10 on mechanical aids, and to a lesser extent in parts 9.7 & 9.8, referring to the predicter; *when* this was achieved I give thoroughly in the Admiralty, Indian and World chapters (8, 9 & 11). *Who* principally achieved this, I give for the first time in chapters 7 to 11 inclusively. *Why* this arose was because of banking interests and the demands of Indian geodesy. *Where* these advances were achieved was largely in Britain, but also in India and America.

I have critically studied ten tidal diagrams from the first millennium. The ascent of the primitive prediction method is set out. The explanation of a late medieval tidal diagram, with which other commentators had failed, is now complete, and its context identified. I have examined data, among a set of sailing directions referred to by Isaac Newton, in manuscript.

The former items extend the historical work of Cartwright and Deacon. The middle chapters trace some of the transfer from empirical primitive prediction to the synthesis of inductively produced prediction.

I based chapters 7, 8, 9, 10 and 11 upon transcripts of tidal manuscripts, explicitly sought as the backbone of this thesis. The transcripts exceed two thousand items, holding over half a million words. The transcript collection now lodges in the library of the Proudman Oceanographic Laboratory. This thesis has only drawn the most direct story from the texts. There is ample scope for further research.

Before taking up tides fulltime, Dessiou was a substantial cartographer, one of whom little was previously known. On Dessiou hydrography, chapter 7 underpins the first systematic tidal investigation. Its composition arose directly out of a request, to the study, to supply a biography of the man who compiled the first Admiralty tide table. This chapter breaks new ground, displaying the characteristics that went into the making of a complete hydrographer.

Building on the work of Reidy, chapter 8 elaborates some of the difficulty encountered while constructing the tide tables. A strength of Reidy's thesis was the espousal of how the first investigation was by means of a network of correspondents. I have corroborated this concept extensively; that is to say, I confirm the concept in this chapter on the synthetic investigation. I also show that a network, extending more pervasively across continents, was essential to the later harmonic investigation (chapter 9). In the early twentieth century, when the global tide tables were being established, it is indicated how the harmonic programme's network was fractured by growing nationalism. The nature, extent and composition of each network, including another little known network in America, I detail in chapter 3.

Further original contribution exists in chapter 9. Here, the formation of the harmonic investigation is set out for the first time. Much illustrative material has been unearthed, and here included into tidal history for the first time. Via this medium of imagery, I make clearer the previously confused primacy, of who invented the tide predicter. Chapter 9, the one preceding it together with the two following, combine to give greater emphasis to the associate workers, than has so far prevailed.

On computing aids, chapters 9 & 10 bring an account of all these devices together. I particularly set the machines into their explicit tidal context. It particularly attempts a plain explanation of the modern prediction method. Lighting upon a very simple, but previously much neglected Australian predicter, considerably helped.

The final contribution builds upon the seminal papers of Hicks and Warburg. Chapter 11 confirms that the Americans established the first set of tide tables for the complete globe. I also demonstrate how the 1914-18 war precipitated the second global set, the Admiralty's. This and two preceding chapters inadvertently give primary history of the Nautical Almanac Office; it includes something of the similar American office. Because of the paucity of archives from these offices, which are important to astronomers, further work can ascend from this basis.

## 12.4 DEFICIENCIES

The study has some known deficiencies. Because of practical constraints, only a little of the large amount of material located in Washington has been transcribed. The biographers of two early American hydrographers, particularly Williams and Slotten, appear to have either ignored or overlooked this resource. The National Archives of India catalogue other source material existing in Delhi. Paradoxically, the director of the institution both granted access to this material, while I corresponded from Britain, but then denied access when I visited the archive; so that I did not see any of the Survey's tidal material.

The story of how tide tables developed largely comes to a close in the mid twentieth century. Even with electronic computers, prediction today is still by the methods developed by that date. Developed in the 1960s, the response method has supplanted neither the residual synthetic usage nor the major harmonic method. Within the physical size constraint of a thesis, the *development* of tide tables has been fully set out.

This study leaves open one larger area of research. This is the break-up of present-day tidal research into increasingly smaller programmes. It has been shown how one tidal research department came about in Britain, in the Hydrographic Office. I then show how another, separate British tidal research department grew out of the Nautical Almanac Office. This duplication of programmes has continued in Britain. The Hydrographic Office has relocated from Whitehall to Taunton. The tidal work of the Almanac descended, first to the National Physical Laboratory, and then it passed to the Tidal Institute at Bidston Observatory.

The Proudman Oceanographic Laboratory in Liverpool has since replaced the Observatory. The tidal work which originally passed to the Institution was largely the Roberts predicting machine work. That area of tidal research extended through Joseph Proudman's theoretical work; more recently, tidal measurement and model developments have been undertaken.

It is likely that further material is locatable in France, to those with the facility of that language. Division also occurred in America, with tidal research programmes being presently undertaken at both the *National Oceanographic and Atmospheric Administration* and the *Scripps Institution of Oceanography*.

Publication of current papers has also dispersed, from being neatly within a small number of journals. Results now appear in a huge range of periodicals. A starting point to classifying twentieth century developments would be completion of the existing bibliography. There is there, of course, an added problem; the modern papers, as for the earlier papers, only relate success stories. The difficulties encountered, exist more in the manuscripts of the scientists who struggled with a problem; and it takes time for the release of personal papers to enter an accessible domain.

## 12.5 FUTURE RESEARCH

There is a profusion of research into tidal history still to be undertaken. It is likely that most of the tidal data up to the time of Newton is fully collated. Further factual data is known of among the records in the later, numerous medieval undertakings. These are located in places often unassociated with either science or tides. For one tide-skirt county alone – Yorkshire – there are abundant tidal, port records. They exist for Howden among the records of the Bishop of Durham,[547] for the rivers Ouse and Trent among the records of the Corporation of Hatfield Chace,[548] for the whole of maritime Yorkshire among the Admiralty Court records and those of the Merchant Venturers.[549]

[547] Durham University Library.
[548] Nottingham Universty Library.

From Newton's time onwards, the ignorance of what material exists increases in line with the profusion of published literature. Simple awareness, rather than systematic searching, has revealed examples of the presence of tidal literature at the Newcastle Literary Institute, in Edinburgh University Library and a tidal monument on the street of Scalloway, Shetland. The Trinity Houses of Hull, Newcastle and Belfast are obvious founts of knowledge, deserving of an assiduous search.

It would be sensible to proceed with a list of the papers and artefacts held in private institutions, in public and academic libraries, and in the county and city record offices. Consider extending the search beyond Britain and Ireland. I have shown an abundance of material to inspect in America; this material is ideal for telling how the synthetic method was inadequate. It is very clear that there is unrecorded material in the numerous other countries which were also British protectorates, colonies or dominions. This material exists among the proceedings of their colonial scientific institutions, largely founded along the lines of home societies. These resources have much valuable tidal material.

The search for historical tidal records has to cater to the past and be aware of the present. Until very recently, ocean going ships were as little as one hundred feet in length. Consequently, their ports were often very well inland, such as Gainsborough. The valuable records of King's Lynn, retained by the once important port, are now an inconsequential and vulnerable part of a global conglomerate. Because of their descent through ownership many navigation records have ended up associated with railways.[550] While it is relatively common to schedule trains according to the tides, it can not be unique for the Benbecula air service to be so set.

[549] Borthwick Institute, York University.
[550] TNA RAIL 800.

The transition from analogue to digital recording devices took place within only the past two decades. The old gauges and other artefacts are fast disappearing from crowded store rooms. Largely out of Kelvin's vanity, several prototype tidal analysers and predicters are properly preserved. That was fortuitous; a less happy state presently exists with the final stereotypes. It is pressingly urgent to conserve their manipulation instructions, from people who are still alive.

This study has given some consideration, to the prediction method in use before the understanding of the heliocentric solar system. As that understanding grew from the time of Copernicus, and was accelerated by Newton, so did the common method of prediction – that used by seamen – grow in sophistication. A useful study would be to investigate this common method further, particularly for the eighteenth century.

But finding records and further investigation is not enough. People made the records and artefacts, and they must have had a tangible purpose in mind. The nineteenth century Admiralty tide tables affected the production of the people who were predicting tides purely for one locality. Their stories must be one of a fascinating scientific study. Indeed, the works of the independent local producers live on in the computer age. There are a multitude of independent predicting programmes for sale, whose activity deserves a concerted recording. This could combine with a precise history of the institutions currently prescribing world-wide tidal prediction. Such a one is the Proudman Oceanographic Laboratory. If only to eliminate unnecessary duplication, a comprehensive survey of the modern prediction capacity would be highly appropriate.

## 12.6 CONCLUSIONS

The development of tide tables and tidal science has been highly dependent on five open networks of correspondents, ranging across the periods discussed. Albeit in an unwitting fashion, Bede was in advance of Marin Mersenne (1588-1648), the acknowledged early scientific networker. That contrasts sharply with the explicit intent of the commercial network under the East India Company. Only the three nineteenth-century networks were deliberately for tidal advancement. Then, during the war of 1914-8, networking expired as the research programmes entered an in-house phase of secretiveness; one from which, there has been only a recent emergence.

The prediction of tides achieved considerable success in the nineteenth century; the process was experimental science on a grand time scale. That century encompassed three levels of the science; and they led to a further revisionary improvement at the outbreak of the following century. Reidy and Sheesley are among the commentators who have described the investigation of tides, as the expression of the Humboldtian scheme. This study extends that thesis. The Humboldtian ambition was to understand the geographical distribution of interconnected physical and natural phenomenon over a large area. This study culminates at the establishment of two portfolios of tide tables; the tides derive from astronomy and the tables encompass Earth.

The first vision for a world wide tide table was also directly within the Humboldtian ideal, where understanding in one scientific sphere spring-boards to another. The vision held that completing tides and currents would lead to more knowledge about the monsoon.

Governments, including the British, French, Indian, United States and Canadian, funded several significant research programmes investigating tides. The programmes were a straight marriage of pure science and pragmatic need. Investigating tides was a main plank in the introduction of science, or of modern science, to several countries. This applied particularly to India, North America and Australasia. In the early Victorian period, tidal analysis gave a practical outlet to Fourier's then new mathematics. The higher investigation invented considerable mechanical calculating machines. The mechanical machines were such formidable tools that only electronic computers supplanted them in the late twentieth century.

Over time, there was an ascent in the science of tides. First came the creation of the body of port establishments; these were the lists begun in the medieval period. While the establishments achieved their peak in Dessiou's time, present-day Whittaker's Almanac still lists them. Establishments are very powerful; they remain current, because they constitute such simple information. In their crudest form, they give the time of a port's spring tide. But establishments, like the synthetic method which followed, are of best use where there is a clear tidal pattern. Unquestionably the list of establishments, particularly when arranged in a geographic order as affected in the *Flye*, is a Humboldtian exercise. Bede held unwitting pre-Humboldtian concepts and also Davenport to a lesser extent.

Secondly there was the daily synthesis of predictions. These came as a modestly superior mathematical approach to finding establishments and allocating parameters throughout the Saros cycle. This was on the face of it a reversal of the Humboldtian thrust, because in its utilitarian output it concentrated on one locality; conversely they were investigating on the concerted, grander area scale, which was Humboldtian. They said they were systematising and looking for laws but, once having established their process the loop closed, and the systematic investigation then became arrested by its success. In other locations, others vainly tried to copy them, but usually tidal characteristic denied them success, when checking past prediction against present observation.

A purely theoretical approach at last came in to play with the harmonic analysis. This approach was obviously Humboldtian, and extended the geographic area of success considerably but not completely. Tidal science remains partly empirical. Where theoretically derived predictions succeed they are used. Where non-harmonic predictions produce a better fit with the actuality then they fare better.

Tide tables have come about as much by intellectual curiosity, as by commercial need. They concentrate on height of water level, in time; primarily, they concentrate on the time and level of extreme height. They are not the primary resource of tidal flow, as was the case with the sixteenth-century Flye. Tidal theory itself shows that it is tractive flow, rather than any change in absolute oceanic level, that drive tides.

During much of the twentieth century, two separate groups of pilots operated on two separate parts of the Upper Humber. One group freely operated their ships within the rectilinear flow. The other group lay pinned down until the flood had significantly diminished, before they could turn their ships out of the tideway. By the time they left the river, the tide had fallen a crucial amount – perhaps as much as twelve inches. This part of the high tide, the fall before slack, was not so readily apparent to the former group because they were not similarly constrained. The tidal phenomenon imposed itself upon one group, with the other group oblivious to its stimulus. Perhaps future tidal investigations can concentrate on timing the moment of change in the normal rectilinear direction; and simultaneously move closer toward an absolute understanding of tidal theory. This change in direction is of as much commercial interest as it was centuries ago.

This research precipitated from a much smaller view than that of Humboldt's. The view is through juxtaposed dimensions. This aspect was born out of first-hand experience of tides on an ordinary European river. A website, entitled *daylight is worth a foot of water*, has held aloft the research. The real relationship expressed within the phrase, between the necessary daylight with which to locate oneself and an old flotation measure, comes from the piloting world. This is a world where ships, with desperately small under keel clearances, are conducted along narrow, unlit rivers. Those pilots practise their trade as an art, rather than as a science. Feeling their way in the dark; being pushed along by the roaring flood, or fearful that the ebb is dropping away; without a gauge of precise position and hence the amount of water available – to them: daylight is indeed worth a foot of water.

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**APPENDIX 1** CATALOGUE OF CORRESPONDENCE

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| 3 | 3 | | CUL Add 5749 3 | Godley JA | Darwin GH | 01/05/1884 |
| 4 | 4 | | CUL Add 5749 5 | Hoey JC | Darwin GH | 21/05/1884 |
| 5 | 5 | | CUL Add 5749 17 | Bonney TG | Darwin GH | 21/10/1884 |
| 6 | 6 | | CUL Add 5749 18 | Wharton WJ | Darwin GH | 07/10/1884 |
| 7 | 7 | | CUL Add 5749 24 | Roberts E | Darwin GH | 08/05/1883 |
| 8 | 8 | | CUL Add 5749 27 | Baird AW | Roberts E | 16/05/1883 |
| 9 | 9 | | CUL Add 5749 30 | Baird AW | Darwin GH | 28/12/1882 |
| 10 | 10 | | CUL Add 5749 33 | Baird AW | Darwin GH | 18/04/1883 |
| 11 | 11 | | CUL Add 5748 50 | Morice CCD | Darwin GH | 07/08/1895 |
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| 143 | 8 | | CUL RGO 6/499/22 | Airy GB | Beaufort F | 10/01/1842 |
| 144 | 9 | | CUL RGO 6/499/23 | Beaufort F | Airy GB | 11/01/1842 |
| 145 | 10 | | CUL RGO 6/499/24 | Beaufort F | Airy GB | 20/01/1842 |
| 146 | 11 | | CUL RGO 6/499/25 | Airy GB | Beaufort F | 01/03/1842 |
| 147 | 12 | | CUL RGO 6/499/27 | Beaufort F | Airy GB | 03/03/1842 |
| 148 | 13 | | CUL RGO 6/499/28 | Airy GB | Beaufort F | 07/03/1842 |
| 149 | 14 | | CUL RGO 6/499/29 | Beaufort F | Airy GB | 08/03/1842 |
| 150 | 15 | | CUL RGO 6/499/30 | Airy GB | Beaufort F | 09/11/1842 |
| 151 | 16 | | CUL RGO 6/499/31 | Airy GB | Beaufort F | 18/11/1842 |
| 152 | 17 | | CUL RGO 6/499/32 | Beaufort F | Airy GB | 10/11/1842 |
| 153 | 18 | | CUL RGO 6/499/33 | Airy GB | Beaufort F | 19/01/1843 |
| 154 | 19 | | CUL RGO 6/499/35 | Beaufort F | Airy GB | 21/02/1843 |
| 155 | 20 | | CUL RGO 6/499/36 | Airy GB | Beaufort F | 28/02/1843 |
| 156 | 21 | | CUL RGO 6/499/37 | Airy GB | Beaufort F | 13/05/1843 |
| 157 | 22 | | CUL RGO 6/499/38 | Beaufort F | Airy GB | 16/05/1843 |
| 158 | 23 | | CUL RGO 6/499/39 | Airy GB | Beaufort F | 19/05/1843 |
| 159 | 24 | | CUL RGO 6/499/42 | Airy GB | Bunt TG | 28/12/1840 |
| 160 | 25 | | CUL RGO 6/499/43 | Bunt TG | Airy GB | 29/12/1840 |
| 161 | 26 | | CUL RGO 6/499/44 | Bunt TG | Airy GB | 28/04/1841 |
| 162 | 27 | | CUL RGO 6/499/45 | Airy GB | Bunt TG | 24/04/1841 |
| 163 | 28 | | CUL RGO 6/499/46 | Bunt TG | Airy GB | 22/04/1841 |
| 164 | 29 | | CUL RGO 6/499/48 | Airy GB | Bunt TG | 01/03/1842 |
| 165 | 30 | | CUL RGO 6/499/49 | Bunt TG | Airy GB | 02/03/1842 |
| 166 | 31 | | CUL RGO 6/499/50 | Bunt TG | Airy GB | 01/03/1842 |
| 167 | 32 | | CUL RGO 6/499/51 | Airy GB | Bunt TG | 07/03/1842 |
| 168 | 33 | | CUL RGO 6/49952 | Bunt TG | Airy GB | 09/03/1842 |

| | | | Document | From | To | Date |
|---|---|---|---|---|---|---|
| 169 | 34 | | CUL RGO 6/499/53 | Airy GB | Bunt TG | 11/11/1842 |
| 170 | 35 | | CUL RGO 6/499/54 | Bunt TG | Airy GB | 14/11/1842 |
| 171 | 36 | | CUL RGO 6/499/57 | Corteen R | Airy GB | 12/08/1843 |
| 172 | 37 | | CUL RGO 6/499/58 | Airy GB | Corteen R | 14/08/1843 |
| 173 | 38 | | CUL RGO 6/499/59 | Airy GB | Corteen R | 21/08/1843 |
| 174 | 39 | | CUL RGO 6/499/60 | Corteen R | Airy GB | 24/08/1843 |
| 175 | 40 | | CUL RGO 6/499/64 | Airy GB | de Morgan A | 07/02/1838 |
| 176 | 41 | | CUL RGO 6/499/67 | Airy GB | de Morgan A | 05/01/1841 |
| 177 | 42 | | CUL RGO 6/499/70 | Airy GB | de Morgan A | 11/01/1841 |
| 178 | 43 | | CUL RGO 6/499/73 | Airy GB | de Morgan A | 20/04/1843 |
| 179 | 44 | | CUL RGO 6/499/74 | de Morgan A | Airy GB | |
| 180 | 45 | | CUL RGO 6/499/82 | Airy GB | Godfray H | 14/08/1843 |
| 181 | 46 | | CUL RGO 6/499/91 | Gutch JWG | Cambrian | 23/12/1837 |
| 182 | 47 | | CUL RGO 6/499/94 | Gutch JWG | Airy GB | 02/03/1838 |
| 183 | 48 | | CUL RGO 6/499/96 | Airy GB | Gutch JWG | 29/08/1838 |
| 184 | 49 | | CUL RGO 6/499/99 | Gutch JWG | Airy GB | 02/04/1839 |
| 185 | 50 | | CUL RGO 6/499/101 | Airy GB | Gutch JWG | 24/04/1839 |
| 186 | 51 | | CUL RGO 6/499/104 | Hewitt W | Beaufort F | 31/08/1840 |
| 187 | 52 | | CUL RGO 6/499/113 | Hopkins C | Airy GB | 28/09/1843 |
| 188 | 53 | | CUL RGO 6/499/130 | Hopkins C | Airy GB | 06/11/1843 |
| 189 | 54 | | CUL RGO 6/499/131 | Airy GB | Hopkins C | 07/11/1843 |
| 190 | 55 | | CUL RGO 6/499/134 | Kelland P | Airy GB | 15/08/1842 |
| 191 | 56 | | CUL RGO 6/499/135 | Airy GB | Kelland P | 17/08/1842 |
| 192 | 57 | | CUL RGO 6/499/136 | Kelland P | Airy GB | 20/08/1842 |
| 193 | 58 | | CUL RGO 6/499/137 | Airy GB | Kelland P | 23/08/1842 |
| 194 | 59 | | CUL RGO 6/499/138 | Kelland P | Airy GB | |
| 195 | 60 | | CUL RGO 6/499/142 | Lubbock JW | Airy GB | 07/03/1843 |
| 196 | 61 | | CUL RGO 6/499/143 | Airy GB | Lubbock JW | 08/03/1843 |
| 197 | 62 | | CUL RGO 6/499/144 | Airy GB | Lubbock JW | 26/05/1843 |
| 198 | 63 | | CUL RGO 6/499/147 | Airy GB | Main | 09/12/1840 |
| 199 | 64 | | CUL RGO 6/499/156 | Airy GB | Nelson | 02/05/1839 |
| 200 | 65 | | CUL RGO 6/499/159 | Airy GB | Phillips J | 25/09/1839 |
| 201 | 66 | | CUL RGO 6/499/163 | Airy GB | Plana M | 21/07/1842 |
| 202 | 67 | | CUL RGO 6/499/168 | Airy GB | Roberton E de | 09/12/1840 |
| 203 | 68 | | CUL RGO 6/499/169 | Airy GB | Roberton E de | 14/12/1840 |
| 204 | 69 | | CUL RGO 6/499/170 | Airy GB | Roberton E de | 28/12/1840 |
| 205 | 70 | | CUL RGO 6/499/171 | Roberton E de | Airy GB | 29/12/1840 |
| 206 | 71 | | CUL RGO 6/499/172 | Airy GB | Roberton E de | 21/01/1842 |
| 207 | 72 | | CUL RGO 6/499/173 | Airy GB | Roberton E de | 22/03/1842 |
| 208 | 73 | | CUL RGO 6/499/174 | Airy GB | Roberton E de | 11/11/1842 |
| 209 | 74 | | CUL RGO 6/499/177 | Ross JC | Airy GB | |
| 210 | 75 | | CUL RGO 6/499/181 | Airy GB | Sabine E | 11/10/1841 |
| 211 | 76 | | CUL RGO 6/499/182 | Sabine E | Airy GB | 13/10/1841 |

| | | | Document | From | To | Date |
|---|---|---|---|---|---|---|
| 212 | 77 | | CUL RGO 6/499/185 | Slee C | Whewell W | 30/01/1843 |
| 213 | 78 | | CUL RGO 6/499/187 | Airy GB | Slee C | 13/09/1843 |
| 214 | 79 | | CUL RGO 6/499/190 | | Airy GB | 30/04/1834 |
| 215 | 80 | | CUL RGO 6/499/192 | Airy GB | Stratford WS | 29/11/1842 |
| 216 | 81 | | CUL RGO 6/499/198 | Washington J | Airy GB | 18/07/1842 |
| 217 | 82 | | CUL RGO 6/499/204 | U.S.J. | | 01/01/1838 |
| 218 | 83 | | CUL RGO 6/499/208 | Whewell W | Airy GB | 18/11/1839 |
| 219 | 84 | | CUL RGO 6/499/209 | Whewell W | Airy GB | 06/02/1840 |
| 220 | 85 | | CUL RGO 6/499/261 | Airy GB | Whewell W | 09/03/1840 |
| 221 | 86 | | CUL RGO 6/499/263 | Airy GB | Whewell W | 31/10/1840 |
| 222 | 87 | | CUL RGO 6/499/264 | Whewell W | Airy GB | 04/11/1840 |
| 223 | 88 | | CUL RGO 6/499/267 | Whewell W | Airy GB | 04/12/1840 |
| 224 | 89 | | CUL RGO 6/499/271 | Whewell W | Airy GB | 08/12/1840 |
| 225 | 90 | | CUL RGO 6/499/272 | Airy GB | Whewell W | 12/12/1840 |
| 226 | 91 | | CUL RGO 6/499/274 | Whewell W | Airy GB | 28/12/1840 |
| 227 | 92 | | CUL RGO 6/499/277 | Whewell W | Airy GB | 27/01/1841 |
| 228 | 93 | | CUL RGO 6/499/278 | Whewell W | Airy GB | 23/01/1841 |
| 229 | 94 | | CUL RGO 6/499/280 | Airy GB | Whewell W | 03/02/1841 |
| 230 | 95 | | CUL RGO 6/499/281 | Airy GB | Whewell W | 10/04/1841 |
| 231 | 96 | | CUL RGO 6/499/284 | Whewell W | Airy GB | 24/01/1842 |
| 232 | 97 | | CUL RGO 6/499/286 | Airy GB | Whewell W | 22/01/1842 |
| 233 | 98 | | CUL RGO 6/499/288 | Airy GB | Whewell W | 11/11/1842 |
| 234 | 99 | | CUL RGO 6/499/290 | Airy GB | Whewell W | 03/01/1843 |
| 235 | 100 | | CUL RGO 6/499/291 | N.Y.D.M. | | |
| 236 | 101 | | CUL RGO 6/499/292 | Whewell W | Airy GB | 18/01/1843 |
| 237 | 102 | | CUL RGO 6/499/299 | Whewell W | Airy GB | 22/02/1843 |
| 238 | 103 | | CUL RGO 6/499/309 | Whewell W | Airy GB | 29/05/1843 |
| 239 | 104 | | CUL RGO 6/499/314 | Sherrif W | Airy GB | 03/09/1840 |
| 240 | 105 | | CUL RGO 6/499/315 | Sherrif W | Airy GB | 08/12/1840 |
| 241 | 106 | | CUL RGO 6/499/316 | Airy GB | Sherrif W | 02/12/1840 |
| 242 | 107 | | CUL RGO 6/499/318 | Airy GB | Sherrif W | 02/01/1840 |
| 243 | 108 | | CUL RGO 6/499/319 | Airy GB | Sherrif W | 04/01/1841 |
| 244 | 109 | | CUL RGO 6/499/320 | Sherrif W | Airy GB | 11/06/1840 |
| 245 | 110 | | CUL RGO 6/499/370 | Airy GB | Sherrif W | 10/05/1841 |
| 246 | 111 | | CUL RGO 6/499/373 | Airy GB | Colby T | 21/02/1842 |
| 247 | 112 | | CUL RGO 6/499/374 | Airy GB | Colby T | 10/01/1842 |
| 248 | 113 | | CUL RGO 6/499/375 | Yelland N | Airy GB | 22/02/1842 |
| 249 | 114 | | CUL RGO 6/499/376 | Yelland N | Airy GB | 23/02/1842 |
| 250 | 115 | | CUL RGO 6/499/377 | Yelland N | Airy GB | 01/03/1842 |
| 251 | 116 | | CUL RGO 6/499/378 | Airy GB | Yelland N | 03/03/1842 |
| 252 | 117 | | CUL RGO 6/499/402 | Airy GB | Yelland N | 12/03/1842 |
| 253 | 118 | | CUL RGO 6/499/403 | Yelland N | Airy GB | 17/03/1842 |
| 254 | 119 | | CUL RGO 6/499/404 | Airy GB | Yelland N | 18/03/1842 |

| | | | Document | From | To | Date |
|---|---|---|---|---|---|---|
| 255 | 120 | | CUL RGO 6/499/405 | Yelland N | Airy GB | 29/03/1842 |
| 256 | 121 | | CUL RGO 6/499/406 | Yelland N | Airy GB | 24/02/1843 |
| 257 | 122 | | CUL RGO 6/499/407 | Yelland N | Airy GB | 25/02/1843 |
| 258 | 123 | | CUL RGO 6/499/420 | Airy GB | May C | 10/03/1842 |
| 259 | 124 | | CUL RGO 6/499/421 | May C | Airy GB | 11/03/1842 |
| 260 | 125 | | CUL RGO 6/499/422 | Airy GB | May C | 12/03/1842 |
| 261 | 126 | | CUL RGO 6/499/423 | May C | Airy GB | 14/03/1842 |
| 262 | 127 | | CUL RGO 6/499/424 | Airy GB | May C | 15/03/1842 |
| 263 | 128 | | CUL RGO 6/499/425 | May C | Airy GB | 24/03/1842 |
| 264 | 129 | | CUL RGO 6/499/426 | Airy GB | May C | |
| 265 | 130 | | CUL RGO 6/499/427 | May C | Airy GB | 24/04/1842 |
| 266 | 131 | | CUL RGO 6/499/428 | Airy GB | May C | 19/04/1842 |
| 267 | 132 | | CUL RGO 6/499/429 | Airy GB | May C | 07/05/1842 |
| 268 | 133 | | CUL RGO 6/499/430 | May C | Airy GB | 10/05/1842 |
| 269 | 134 | | CUL RGO 6/499/431 | May C | Airy GB | 11/10/1842 |
| 270 | 135 | | CUL RGO 6/499/432 | Airy GB | May C | 13/10/1842 |
| 271 | 136 | | CUL RGO 6/499/433 | Jones J | Airy GB | 31/10/1842 |
| 272 | 137 | | CUL RGO 6/499/434 | Airy GB | May C | 01/11/1842 |
| 273 | 138 | | CUL RGO 6/499/453 | Airy GB | May C | 27/05/1843 |
| 274 | 139 | | CUL RGO 6/499/454 | May C | Airy GB | 03/05/1843 |
| 275 | 140 | | CUL RGO 6/499/458 | Colby T | Airy GB | 07/05/1840 |
| 276 | 141 | | CUL RGO 6/499/461 | Airy GB | Colby T | 16/05/1842 |
| 277 | 142 | | CUL RGO 6/499/463 | Yelland N | Airy GB | 28/12/1842 |
| 278 | 143 | | CUL RGO 6/499/464 | Airy GB | Yelland N | 11/05/1843 |
| 279 | 144 | | CUL RGO 6/499/465 | Yelland N | Airy GB | 08/05/1843 |
| 280 | 145 | | CUL RGO 6/499/468 | | Airy GB | 03/05/1843 |
| 281 | 146 | | CUL RGO 6/499/469 | Airy GB | Yelland N | 14/04/1843 |
| 282 | 147 | | CUL RGO 6/499/470 | Airy GB | Yelland N | 13/04/1843 |
| 283 | 148 | | CUL RGO 6/499/471 | Yelland N | Airy GB | 12/04/1843 |
| 284 | 149 | | CUL RGO 6/499/473 | Yelland N | Airy GB | 15/03/1843 |
| 285 | 150 | | CUL RGO 6/499/474 | Airy GB | Yelland N | 01/03/1843 |
| 286 | 151 | | CUL RGO 6/499/475 | Colby T | Airy GB | 28/02/1843 |
| 287 | 152 | | CUL RGO 6/499/476 | Airy GB | Colby T | 27/02/1843 |
| 288 | 153 | | CUL RGO 6/499/478 | Airy GB | Yelland N | 10/05/1843 |
| 289 | 154 | | CUL RGO 6/499/479 | Yelland N | Airy GB | 26/05/1843 |
| 290 | 155 | | CUL RGO 6/499/480 | Airy GB | Yelland N | 27/05/1843 |
| 291 | 156 | | CUL RGO 6/499/481 | Airy GB | Yelland N | 27/05/1843 |
| 292 | 157 | | CUL RGO 6/499/482 | Airy GB | Yelland N | 15/06/1843 |
| 293 | 158 | | CUL RGO 6/499/483 | Yelland N | Airy GB | 17/06/1843 |
| 294 | 159 | | CUL RGO 6/499/484 | Airy GB | Yelland N | 19/06/1843 |
| 295 | 160 | | CUL RGO 6/499/485 | Airy GB | Yelland N | 19/06/1843 |
| 296 | 161 | | CUL RGO 6/499/486 | Airy GB | Colby T | 21/06/1843 |
| 297 | 162 | | CUL RGO 6/499/487 | Campbell W | Airy GB | 28/08/1843 |

| | | | Document | From | To | Date |
|---|---|---|---|---|---|---|
| 298 | 163 | | CUL RGO 6/499/488 | Yelland N | Airy GB | |
| 299 | 164 | | CUL RGO 6/499/489 | Yelland N | Airy GB | 20/11/1843 |
| 300 | 165 | | CUL RGO 6/499/490 | Airy GB | Yelland N | 30/12/1843 |
| 301 | 166 | | CUL RGO 6/499/491 | Yelland N | Airy GB | 30/12/1843 |
| 302 | 167 | | CUL RGO 6/499/492 | Hornsby PI | Airy GB | 01/01/1844 |
| 303 | 168 | | CUL RGO 6/499/493 | Hornsby PI | Airy GB | 01/01/1844 |
| 304 | 169 | | CUL RGO 6/499/494 | Airy GB | Yelland N | 10/01/1844 |
| 305 | 170 | | CUL RGO 6/499/495 | Yelland N | Airy GB | 11/01/1844 |
| 306 | 171 | | CUL RGO 6/499/496 | Airy GB | Yelland N | 26/02/1844 |
| 307 | 172 | | CUL RGO 6/499/497 | Yelland N | Airy GB | 27/02/1844 |
| 308 | 173 | | CUL RGO 6/499/498 | Airy GB | Yelland N | 28/02/1844 |
| 309 | 174 | | CUL RGO 6/499/499 | Yelland N | Airy GB | 18/04/1844 |
| 310 | 175 | | CUL RGO 6/499/500 | Airy GB | Colby T | 15/05/1844 |
| 311 | 176 | | CUL RGO 6/499/501 | Airy GB | Colby T | 17/06/1844 |
| 312 | 177 | | CUL RGO 6/499/502 | Yelland N | Airy GB | 29/06/1844 |
| 313 | 178 | | CUL RGO 6/499/507 | Colby T | Airy GB | 09/09/1844 |
| 314 | 179 | | CUL RGO 6/499/508 | Airy GB | Miller Prof | 13/09/1844 |
| 315 | 180 | | CUL RGO 6/499/509 | Larcom H | Airy GB | 22/10/1844 |
| 316 | 181 | | CUL RGO 6/499/512 | Airy GB | Larcom H | 02/11/1844 |
| 317 | 182 | | CUL RGO 6/499/514 | Airy GB | Colby T | 02/11/1844 |
| 318 | 183 | | CUL RGO 6/499/515 | Larcom H | Airy GB | 12/11/1844 |
| 319 | 184 | | CUL RGO 6/499/518 | Airy GB | Larcom H | 16/11/1844 |
| 320 | 185 | | CUL RGO 6/499/521 | Airy GB | Hamilton WR | 18/09/1844 |
| 321 | 186 | | CUL RGO 6/499/522 | Hamilton WR | Airy GB | 14/10/1844 |
| 322 | 187 | | CUL RGO 6/499/526 | Bald W | Dunlop H | 08/02/1841 |
| 323 | 188 | | CUL RGO 6/499/529 | Airy GB | Beaufort F | 16/01/1841 |
| 324 | 189 | | CUL RGO 6/499/530 | Beaufort F | Airy GB | 20/01/1841 |
| 325 | 190 | | CUL RGO 6/499/532 | Beaufort F | Airy GB | 22/01/1841 |
| 326 | 191 | | CUL RGO 6/499/533 | Gage J | Dessiou JF | 19/01/1841 |
| 327 | 192 | | CUL RGO 6/499/539 | Airy GB | Beaufort F | 23/01/1841 |
| 328 | 193 | | CUL RGO 6/499/540 | Beaufort F | Airy GB | 25/01/1841 |
| 329 | 194 | | CUL RGO 6/499/541 | Smart JN | Dessiou JF | 21/01/1841 |
| 330 | 195 | | CUL RGO 6/499/542 | Beaufort F | Airy GB | 13/02/1841 |
| 331 | 196 | | CUL RGO 6/499/547 | Airy GB | Bunt TG | 16/02/1841 |
| 332 | 197 | | CUL RGO 6/499/548 | Bunt TG | Airy GB | 19/01/1841 |
| 333 | 198 | | CUL RGO 6/499/552 | Caley E | Airy GB | 28/01/1841 |
| 334 | 199 | | CUL RGO 6/499/554 | Clibborn E | Airy GB | 03/02/1841 |
| 335 | 200 | | CUL RGO 6/499/557 | Dall P | Airy GB | 09/02/1843 |
| 336 | 201 | | CUL RGO 6/499/559 | Airy GB | Dall P | 14/02/1843 |
| 337 | 202 | | CUL RGO 6/499/562 | Dix F | May C | 01/02/1841 |
| 338 | 203 | | CUL RGO 6/499/567 | Airy GB | Dunlop H | 21/01/1841 |
| 339 | 204 | | CUL RGO 6/499/569 | Dunlop H | Airy GB | 09/07/1841 |
| 340 | 205 | | CUL RGO 6/499/572 | Edwards G | Airy GB | 29/01/1841 |

| | | | Document | From | To | Date |
|---|---|---|---|---|---|---|
| 341 | 1 | | CUL Add 7342 A6 | Adams JC | Thomson W | 04/09/1876 |
| 342 | 2 | | CUL Add 7342 A23 | Airy GB | Thomson W | 04/02/1870 |
| 343 | 3 | | CUL Add 7342 B4 | Baird AW | Thomson W | 22/07/1880 |
| 344 | 4 | | CUL Add 7342 B5 | Thomson W | Baird AW | 24/03/1881 |
| 345 | 5 | | CUL Add 7342 B6 | Thomson W | Baird AW | 31/03/1881 |
| 346 | 6 | | CUL Add 7342 B7 | Thomson W | Baird AW | 14/04/1881 |
| 347 | 7 | | CUL Add 7342 D8 | Darwin GH | Thomson W | 02/11/1878 |
| 348 | 8 | | CUL Add 7342 D9 | Darwin GH | Thomson W | 08/11/1878 |
| 349 | 9 | | CUL Add 7342 D10a | Darwin GH | Thomson W | 06/01/1882 |
| 350 | 10 | | CUL Add 7342 D11 | Darwin GH | Thomson W | 28/01/1882 |
| 351 | 11 | | CUL Add 7342 D13 | Darwin GH | Thomson W | 12/04/1882 |
| 352 | 12 | | CUL Add 7342 D14 | Darwin GH | Thomson W | 08/05/1882 |
| 353 | 13 | | CUL Add 7342 D14a | Darwin GH | Thomson W | 24/05/1882 |
| 354 | 14 | | CUL Add 7342 D15 | Darwin GH | Thomson W | 11/06/1882 |
| 355 | 15 | | CUL Add 7342 D16 | Darwin GH | Thomson W | 16/06/1882 |
| 356 | 16 | | CUL Add 7342 D17 | Darwin GH | Thomson W | 19/06/1882 |
| 357 | 17 | | CUL Add 7342 D17a | Darwin GH | Thomson W | 29/06/1882 |
| 358 | 18 | | CUL Add 7342 D18 | Darwin GH | Thomson W | 01/07/1882 |
| 359 | 19 | | CUL Add 7342 D18a | Darwin GH | Thomson W | 12/07/1882 |
| 360 | 20 | | CUL Add 7342 D18b | Darwin GH | Thomson W | 15/07/1882 |
| 361 | 21 | | CUL Add 7342 D18c | Darwin GH | Thomson W | 18/07/1882 |
| 362 | 22 | | CUL Add 7342 D18d | Darwin GH | Thomson W | 25/07/1882 |
| 363 | 23 | | CUL Add 7342 D18e | Darwin GH | Thomson W | 30/07/1882 |
| 364 | 24 | | CUL Add 7342 D18f | Darwin GH | Thomson W | 03/08/1882 |
| 365 | 25 | | CUL Add 7342 D18g | Darwin GH | Thomson W | 04/08/1882 |
| 366 | 26 | | CUL Add 7342 D18h | Darwin GH | Thomson W | 07/08/1882 |
| 367 | 27 | | CUL Add 7342 D18i | Darwin GH | Thomson W | |
| 368 | 28 | | CUL Add 7342 D19 | Darwin GH | Thomson W | 06/01/1883 |
| 369 | 29 | | CUL Add 7342 D20 | Darwin GH | Thomson W | 29/01/1883 |
| 370 | 30 | | CUL Add 7342 D21 | Darwin GH | Thomson W | 22/02/1883 |
| 371 | 31 | | CUL Add 7342 D25 | Darwin GH | Thomson W | 11/04/1884 |
| 372 | 32 | | CUL Add 7342 D26 | Darwin GH | Thomson W | 10/11/1884 |
| 373 | 33 | | CUL Add 7342 D28 | Darwin GH | Thomson W | 08/09/1885 |
| 374 | 34 | | CUL Add 7342 D29 | Darwin GH | Thomson W | |
| 375 | 35 | | CUL Add 7342 D31 | Darwin GH | Thomson W | |
| 376 | 36 | | CUL Add 7342 D32 | Darwin GH | Thomson W | 12/02/1886 |
| 377 | 37 | | CUL Add 7342 D33 | Darwin GH | Thomson W | 13/04/1886 |
| 378 | 38 | | CUL Add 7342 D36 | Darwin GH | Thomson W | 24/02/1887 |
| 379 | 39 | | CUL Add 7342 D37 | Darwin GH | Thomson W | 26/02/1887 |
| 380 | 40 | | CUL Add 7342 D39 | Darwin GH | Thomson W | 10/10/1887 |
| 381 | 41 | | CUL Add 7342 D39a | Darwin GH | Thomson W | 07/04/1898 |
| 382 | 42 | | CUL Add 7342 D40 | Darwin GH | Thomson W | 10/02/1902 |
| 383 | 43 | | CUL Add 7342 D41 | Thomson W | Darwin GH | 10/02/1902 |

| | | | Document | From | To | Date |
|---|---|---|---|---|---|---|
| 384 | 44 | | CUL Add 7342 E89 | Evans FJ | Thomson W | 04/10/1876 |
| 385 | 45 | | CUL Add 7342 E90 | Evans FJ | Thomson W | 10/10/1876 |
| 386 | 46 | | CUL Add 7342 E91 | Evans FJ | Thomson W | 09/01/1877 |
| 387 | 47 | | CUL Add 7342 E92 | Evans FJ | Thomson W | 17/01/1877 |
| 388 | 48 | | CUL Add 7342 E92a | Thomson W | Evans FJ | 19/01/1877 |
| 389 | 49 | | CUL Add 7342 E93 | Evans FJ | Thomson W | 18/01/1877 |
| 390 | 50 | | CUL Add 7342 E94 | Evans FJ | Thomson W | 20/01/1877 |
| 391 | 51 | | CUL Add 7342 E95 | Evans FJ | Thomson W | 12/03/1878 |
| 392 | 52 | | CUL Add 7342 E96 | Evans FJ | Thomson W | 22/01/1884 |
| 393 | 53 | | CUL Add 7342 I18 | Govt of India | Thomson W | |
| 394 | 54 | | CUL Add 7342 P6 | Hope W | Thomson W | 19/05/1890 |
| 395 | 55 | | CUL Add 7342 P6a | Thomson W | Hope W | 22/05/1890 |
| 396 | 56 | | CUL Add 7342 P7 | Hope W | Thomson W | 27/05/1890 |
| 397 | 57 | | CUL Add 7342 P36 | Pearson J | Thomson W | 28/08/1879 |
| 398 | 58 | | CUL Add 7342 R59 | Thomson W | Darwin GH | 29/05/1882 |
| 399 | 59 | | CUL Add 7342 R59a | Baird AW | Thomson W | 24/02/1881 |
| 400 | 60 | | CUL Add 7342 R77 | Roberts E | Thomson W | 05/01/1872 |
| 401 | 61 | | CUL Add 7342 R78 | Roberts E | Thomson W | 20/05/1872 |
| 402 | 62 | | CUL Add 7342 R79 | Roberts E | Thomson W | |
| 403 | 63 | | CUL Add 7342 R80 | Roberts E | Thomson W | 07/01/1873 |
| 404 | 64 | | CUL Add 7342 R81 | Roberts E | Thomson W | 24/05/1873 |
| 405 | 65 | | CUL Add 7342 R82 | Roberts E | Thomson W | 11/10/1873 |
| 406 | 66 | | CUL Add 7342 R83 | Roberts E | Thomson W | 20/02/1875 |
| 407 | 67 | | CUL Add 7342 R84 | Thomson W | Roberts E | 03/09/1875 |
| 408 | 68 | | CUL Add 7342 R85 | Roberts E | Thomson W | |
| 409 | 69 | | CUL Add 7342 R86 | Roberts E | Thomson W | 09/03/1878 |
| 410 | 70 | | CUL Add 7342 R87 | Roberts E | Thomson W | 13/03/1878 |
| 411 | 71 | | CUL Add 7342 R87a | Roberts E | Thomson W | 09/09/1876 |
| 412 | 72 | | CUL Add 7342 R88 | Roberts E | Thomson W | 05/04/1878 |
| 413 | 73 | | CUL Add 7342 R89 | Chadwick O | Roberts E | 28/12/1878 |
| 414 | 74 | | CUL Add 7342 R90 | Roberts E | Thomson W | 09/01/1879 |
| 415 | 75 | | CUL Add 7342 R91 | Roberts E | Gray A | 09/01/1879 |
| 416 | 76 | | CUL Add 7342 R92 | Roberts E | Thomson W | 14/01/1879 |
| 417 | 77 | | CUL Add 7342 R93 | Roberts E | Thomson W | 19/03/1879 |
| 418 | 78 | | CUL Add 7342 R94 | Roberts E | Thomson W | 21/03/1879 |
| 419 | 79 | | CUL Add 7342 R95 | Roberts E | Thomson W | 14/04/1879 |
| 420 | 80 | | CUL Add 7342 R96 | Roberts E | Thomson W | 22/05/1879 |
| 421 | 81 | | CUL Add 7342 S397 | Stokes GG | Thomson W | 04/11/1861 |
| 422 | 82 | | CUL Add 7342 S571 | Strachey R | Thomson W | 15/01/1876 |
| 423 | 83 | | CUL Add 7342 S572 | Strachey R | Thomson W | 18/11/1879 |
| 424 | 84 | | CUL Add 7342 S573 | Strachey R | Thomson W | 20/01/1883 |
| 425 | 85 | | CUL Add 7342 S574 | Strachey R | Thomson W | |
| 426 | 86 | | CUL Add 7342 S575 | Strachey R | Thomson W | |

| | | | Document | From | To | Date |
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| 427 | 87 | | CUL Add 7342 W1 | Walker JT | Strachey R | 12/12/1882 |
| 428 | 88 | | CUL Add 7342 W87 | Wharton WJ | Thomson W | 14/06/1886 |
| 429 | 89 | | CUL Add 7342 LB455 | Thomson W | Baird AW | 15/06/1882 |
| 430 | 90 | | CUL Add 7342 LB458 | Thomson W | Baird AW | 30/06/1882 |
| 431 | 91 | | CUL Add 7342 LB459 | Thomson W | Baird AW | 07/07/1882 |
| 432 | 92 | | CUL Add 7342 LB445 | Thomson W | Darwin GH | 29/05/1882 |
| 433 | 93 | | CUL Add 7342 LB446 | Thomson W | Darwin GH | 30/05/1882 |
| 434 | 94 | | CUL Add 7342 LB447 | Thomson W | Darwin GH | 01/06/1882 |
| 435 | 95 | | CUL Add 7342 LB457 | Thomson W | Darwin GH | 30/06/1882 |
| 436 | 1 | | CUL Add 7656 C.475 | Christie WHM | Stokes GG | 20/06/1855 |
| 437 | 2 | | CUL Add 7656 C.476 | Christie WHM | Stokes GG | 07/10/1885 |
| 438 | 3 | | CUL Add 7656 C.754 | Awdry RD | Stokes GG | 18/08/1887 |
| 439 | 4 | | CUL Add 7656 H.398 | Haughton S | Stokes GG | 04/09/1862 |
| 440 | 5 | | CUL Add 7656 H.400 | Haughton S | Stokes GG | 21/02/1863 |
| 441 | 6 | | CUL Add 7656 H.401 | Haughton S | Stokes GG | 14/06/1868 |
| 442 | 7 | | CUL Add 7656 H.402 | Haughton S | Stokes GG | 13/03/1875 |
| 443 | 8 | | CUL Add 7656 H.403 | Haughton S | Stokes GG | 16/03/1875 |
| 444 | 9 | | CUL Add 7656 H.404 | Haughton S | Stokes GG | 20/03/1875 |
| 445 | 10 | | CUL Add 7656 H.405 | Haughton S | Stokes GG | 22/03/1875 |
| 446 | 11 | | CUL Add 7656 H.406 | Haughton S | Stokes GG | 17/07/1877 |
| 447 | 12 | | CUL Add 7656 K.130 | Thomson W | Stokes GG | 29/10/1861 |
| 448 | 13 | | CUL Add 7656 K.135 | Thomson W | Stokes GG | 14/04/1862 |
| 449 | 14 | | CUL Add 7656 K.138 | Thomson W | Stokes GG | 08/07/1862 |
| 450 | 15 | | CUL Add 7656 K.140 | Thomson W | Stokes GG | 16/07/1862 |
| 451 | 16 | | CUL Add 7656 K.159 | Thomson W | Stokes GG | 21/03/1867 |
| 452 | 17 | | CUL Add 7656 K.169 | Thomson W | Stokes GG | 17/08/1869 |
| 453 | 18 | | CUL Add 7656 K.170 | Thomson W | Stokes GG | 14/02/1870 |
| 454 | 19 | | CUL Add 7656 K.183 | Thomson W | Stokes GG | 08/02/1872 |
| 455 | 20 | | CUL Add 7656 K.185 | Thomson W | Stokes GG | 14/10/1872 |
| 456 | 21 | | CUL Add 7656 K.192 | Thomson W | Stokes GG | 17/11/1873 |
| 457 | 22 | | CUL Add 7656 K.205 | Thomson W | Stokes GG | 12/03/1876 |
| 458 | 23 | | CUL Add 7656 K.213 | Thomson W | Stokes GG | 20/12/1876 |
| 459 | 24 | | CUL Add 7656 K.214 | Thomson W | Stokes GG | 30/01/1877 |
| 460 | 25 | | CUL Add 7656 K.220 | Thomson W | Stokes GG | 20/12/1877 |
| 461 | 26 | | CUL Add 7656 K.232 | Thomson W | Stokes GG | 10/06/1879 |
| 462 | 27 | | CUL Add 7656 K.234 | Thomson W | Stokes GG | 11/07/1879 |
| 463 | 28 | | CUL Add 7656 K.260 | Thomson W | Stokes GG | 17/12/1882 |
| 464 | 29 | | CUL Add 7656 K.268 | Thomson W | Stokes GG | 05/02/1883 |
| 465 | 30 | | CUL Add 7656 K.372 | Thomson W | Stokes GG | |
| 466 | 31 | | CUL Add 7656 P.136 | Pearson J | Stokes GG | 07/07/1875 |
| 467 | 32 | | CUL Add 7656 P.137 | Pearson J | Stokes GG | 30/11/1876 |
| 468 | 33 | | CUL Add 7656 P.138 | Pearson J | Stokes GG | 15/04/1881 |
| 469 | 34 | | CUL Add 7656 P.139 | Pearson J | Stokes GG | 15/06/1875 |

| | | | Document | From | To | Date |
|---|---|---|---|---|---|---|
| 470 | 35 | | CUL Add 7656 P.140 | Pearson J | Stokes GG | 27/10/1881 |
| 471 | 36 | | CUL Add 7656 RS.549 | Bunt TG | Stokes GG | 26/11/1866 |
| 472 | 37 | | CUL Add 7656 RS.1417 | Roberts E | Thomson W | 07/06/1879 |
| 473 | 38 | | CUL Add 7656 RS.1417a | White W | Roberts E | 06/06/1879 |
| 474 | 39 | | CUL Add 7656 RS.1425 | Roberts E | Stokes GG | 05/07/1879 |
| 475 | 1 | | StJ AC 3.14.2 | Bashforth F | Adams JC | 25/10/1881 |
| 476 | 2 | | StJ AC 6.35.1 | Darwin GH | Adams JC | 31/05/1876 |
| 477 | 3 | | StJ AC 6.35.2 | Darwin GH | Adams JC | 23/09/1876 |
| 478 | 4 | | StJ AC 6.36.1 | Darwin GH | Adams JC | |
| 479 | 5 | | StJ AC 6.36.2 | Darwin GH | Adams JC | |
| 480 | 6 | | StJ AC 6.36.3 | Darwin GH | Adams JC | |
| 481 | 7 | | StJ AC 6.37.1 | Darwin GH | Adams JC | 19/05/1882 |
| 482 | 8 | | StJ AC 6.37.2 | Darwin GH | Adams JC | 14/06/1882 |
| 483 | 9 | | StJ AC 6.37.3 | Darwin GH | Adams JC | |
| 484 | 10 | | StJ AC 6.38.1 | Darwin GH | Adams JC | 22/12/1882 |
| 485 | 11 | | StJ AC 6.38.2 | Darwin GH | Adams JC | 26/12/1882 |
| 486 | 12 | | StJ AC 6.39.1 | Darwin GH | Adams JC | 29/12/1882 |
| 487 | 13 | | StJ AC 6.39.2 | Darwin GH | Adams JC | 29/12/1882 |
| 488 | 14 | | StJ AC 6.39.3 | Darwin GH | Adams JC | 29/12/1882 |
| 489 | 15 | | StJ AC 6.39.4 | Darwin GH | Adams JC | 31/12/1882 |
| 490 | 16 | | StJ AC 6.40.1 | Darwin GH | Adams JC | 19/01/1883 |
| 491 | 17 | | StJ AC 6.40.2 | Darwin GH | Adams JC | 23/01/1883 |
| 492 | 18 | | StJ AC 6.40.3 | Darwin GH | Adams JC | 29/01/1883 |
| 493 | 19 | | StJ AC 6.40.4 | Darwin GH | Adams JC | 13/02/1883 |
| 494 | 20 | | StJ AC 6.41.1 | Darwin GH | Adams JC | 28/03/1883 |
| 495 | 21 | | StJ AC 6.41.2 | Darwin GH | Adams JC | 16/04/1883 |
| 496 | 22 | | StJ AC 6.42.1 | Darwin GH | Adams JC | 23/04/1883 |
| 497 | 23 | | StJ AC 6.42.2 | Darwin GH | Adams JC | 29/04/1883 |
| 498 | 24 | | StJ AC 6.42.3 | Darwin GH | Adams JC | 11/05/1883 |
| 499 | 25 | | StJ AC 6.43.1 | Darwin GH | Adams JC | 23/06/1883 |
| 500 | 26 | | StJ AC 6.43.2 | Darwin GH | Adams JC | 10/07/1883 |
| 501 | 27 | | StJ AC 6.43.3 | Darwin GH | Adams JC | 27/07/1883 |
| 502 | 28 | | StJ AC 6.44.1 | Darwin GH | Adams JC | 02/08/1883 |
| 503 | 29 | | StJ AC 6.44.2 | Darwin GH | Adams JC | 04/08/1883 |
| 504 | 30 | | StJ AC 6.44.3 | Darwin GH | Adams JC | 13/09/1883 |
| 505 | 31 | | StJ AC 6.45.1 | Darwin GH | Adams JC | 06/05/1883 |
| 506 | 32 | | StJ AC 6.45.2 | Darwin GH | Adams JC | 17/07/1883 |
| 507 | 33 | | StJ AC 6.45.3 | Darwin GH | Adams JC | 04/12/1883 |
| 508 | 34 | | StJ AC 6.45.4 | Darwin GH | Adams JC | |
| 509 | 35 | | StJ AC 6.46.1 | Darwin GH | Adams JC | 16/08/1885 |
| 510 | 36 | | StJ AC 6.46.2 | Darwin GH | Adams JC | 02/03/1889 |
| 511 | 37 | | StJ AC 6.47.1 | Darwin GH | Adams JC | 01/01/1887 |
| 512 | 38 | | StJ AC 6.48.1 | Darwin GH | Adams JC | |

| | | | Document | From | To | Date |
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| 513 | 39 | | StJ AC 6.48.2 | Darwin GH | Adams JC | |
| 514 | 40 | | StJ AC 6.48.3 | Darwin GH | Adams JC | |
| 515 | 41 | | StJ AC 9.9.1 | Heath DD | Adams JC | |
| 516 | 42 | | StJ AC 9.20.1 | Hilgard JE | Adams JC | 18/03/1885 |
| 517 | 43 | | StJ AC 9.20.2 | Ferrel W | Hilgard JE | 10/03/1885 |
| 518 | 44 | | StJ AC 12.41.1 | Roberts E | Adams JC | 14/11/1887 |
| 519 | 45 | | StJ AC 12.41.2 | Roberts E | Adams JC | 27/01/1882 |
| 520 | 46 | | StJ AC 12.41.3 | Roberts E | Adams JC | 19/06/1882 |
| 521 | 47 | | StJ AC 12.42.1 | Roberts E | Adams JC | 17/07/1882 |
| 522 | 48 | | StJ AC 12.42.2 | Roberts E | Adams JC | 20/07/1882 |
| 523 | 49 | | StJ AC 12.42.3 | Roberts E | Adams JC | 03/08/1882 |
| 524 | 50 | | StJ AC 12.42.4 | Roberts E | Adams JC | 10/08/1882 |
| 525 | 51 | | StJ AC 12.43.1 | Roberts E | Adams JC | 18/08/1882 |
| 526 | 52 | | StJ AC 12.43.2 | Roberts E | Adams JC | 25/08/1882 |
| 527 | 53 | | StJ AC 12.44.1 | Roberts E | Adams JC | 11/11/1882 |
| 528 | 54 | | StJ AC 12.44.2 | Roberts E | Adams JC | 16/11/1882 |
| 529 | 55 | | StJ AC 12.44.3 | Roberts E | Adams JC | 22/11/1882 |
| 530 | 56 | | StJ AC 12.44.4 | Roberts E | Adams JC | 01/12/1882 |
| 531 | 57 | | StJ AC 12.45.1 | Roberts E | Adams JC | 03/02/1883 |
| 532 | 58 | | StJ AC 12.45.2 | Roberts E | Adams JC | 14/02/1883 |
| 533 | 59 | | StJ AC 12.45.3 | Roberts E | Adams JC | 27/02/1883 |
| 534 | 60 | | StJ AC 12.45.4 | Roberts E | Adams JC | 28/02/1883 |
| 535 | 61 | | StJ AC 12.46.1 | Roberts E | Adams JC | 08/03/1883 |
| 536 | 62 | | StJ AC 12.46.2 | Roberts E | Adams JC | 16/03/1883 |
| 537 | 63 | | StJ AC 12.46.3 | Roberts E | Adams JC | 10/02/1886 |
| 538 | 64 | | StJ AC 12.46.4 | Roberts E | Adams JC | 29/12/1886 |
| 539 | 65 | | StJ AC 12.47.1 | Roberts E | Adams JC | 03/01/1887 |
| 540 | 66 | | StJ AC 12.47.2 | Roberts E | Adams JC | 11/05/1887 |
| 541 | 67 | | StJ AC 12.47.3 | Roberts E | Adams JC | 28/05/1887 |
| 542 | 68 | | StJ AC 12.47.4 | Roberts E | Adams JC | 20/01/1890 |
| 543 | 69 | | StJ AC 13.2.3 | Rohrs JH | Adams JC | |
| 544 | 70 | | StJ AC 13.3.1 | Rohrs JH | Adams JC | |
| 545 | 71 | | StJ AC 13.5.3 | Rohrs JH | Adams JC | |
| 546 | 72 | | StJ AC 13.7.3 | Rohrs JH | Adams JC | |
| 547 | 73 | | StJ AC 13.8.3 | Rohrs JH | Adams JC | |
| 548 | 74 | | StJ AC 13.15.1 | Routh EJ | Adams JC | 24/03/1866 |
| 549 | 75 | | StJ AC 14.46.2 | Thomson W | Adams JC | 04/07/1867 |
| 550 | 76 | | StJ AC 14.46.3 | Thomson W | Adams JC | 05/07/1867 |
| 551 | 77 | | StJ AC 14.47.1 | Thomson W | Adams JC | 13/03/1875 |
| 552 | 78 | | StJ AC 14.47.3 | Thomson W | Adams JC | 17/07/1876 |
| 553 | 79 | | StJ AC 14.48.1 | Thomson W | Adams JC | 24/08/1876 |
| 554 | 80 | | StJ AC 14.55.1 | Taylor A | Adams JC | 28/11/1874 |
| 555 | 81 | | StJ AC 15.1.1 | Vaughen D | Adams JC | 03/01/1870 |

| | | | Document | From | To | Date |
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| 556 | 82 | | StJ AC 16.1.1 | Adams JC | Stokes GG | 13/05/1881 |
| 557 | 83 | | StJ AC 16.9.1 | Adams JC | Cayley A | 12/02/1879 |
| 558 | 84 | | StJ AC 16.53.1 | Adams JC | Roberts E | 07/08/1882 |
| 559 | 85 | | StJ AC 24.6.1 | Darwin GH | Adams JC | 24/12/1879 |
| 560 | 86 | | StJ AC 24.6.2 | Darwin GH | Adams JC | 16/08/1883 |
| 561 | 1 | | CUL DAR 251/1380 | Thomson W | Darwin GH | 30/08/1885 |
| 562 | 2 | | CUL DAR 251/1592 | Denison FN | Darwin GH | 21/08/1900 |
| 563 | 3 | | CUL DAR 251/1935 | Thomson W | Darwin GH | 13/03/1888 |
| 564 | 4 | | CUL DAR 251/2036 | Chisholm H | Darwin GH | 21/02/1905 |
| 565 | 5 | | CUL DAR 251/2037 | Chisholm H | Darwin GH | 27/02/1905 |
| 566 | 6 | | CUL DAR 251/2057 | Darwin GH | Larmor J | 15/01/1906 |
| 567 | 7 | | CUL DAR 251/2060 | Simpson M | Darwin GH | 24/01/1906 |
| 568 | 8 | | CUL DAR 251/2061 | | | |
| 569 | 9 | | CUL DAR 251/2412 | Holden ES | Darwin GH | 16/08/1884 |
| 570 | 10 | | CUL DAR 251/2413 | Chamberlin TC | Darwin GH | 25/08/1884 |
| 571 | 11 | | CUL DAR 251/2414 | Ball RS | Darwin GH | 22/06/1885 |
| 572 | 12 | | CUL DAR 251/2415 | Ball RS | Darwin GH | 25/06/1885 |
| 573 | 13 | | CUL DAR 251/2416 | Ball RS | Darwin GH | 27/06/1885 |
| 574 | 14 | | CUL DAR 251/2417 | Ball RS | Darwin GH | 03/10/1885 |
| 575 | 15 | | CUL DAR 251/2418 | Chamberlin TC | Darwin GH | 23/05/1884 |
| 576 | 16 | | CUL DAR 251/2487 | Strachey R | Darwin GH | 09/05/1885 |
| 577 | 17 | | CUL DAR 251/2488 | Strachey R | Darwin GH | |
| 578 | 18 | | CUL DAR 251/2497 | Wharton WJ | Darwin GH | 02/07/1885 |
| 579 | 19 | | CUL DAR 251/2515 | Roberts E | Darwin GH | 25/01/1886 |
| 580 | 20 | | CUL DAR 251/2516 | Baird AW | Darwin GH | 22/10/1885 |
| 581 | 21 | | CUL DAR 251/2517 | Atchison AT | Darwin GH | 08/10/1885 |
| 582 | 22 | | CUL DAR 251/2518 | Roberts E | Darwin GH | 21/09/1885 |
| 583 | 23 | | CUL DAR 251/2519 | Strachey R | Darwin GH | |
| 584 | 24 | | CUL DAR 251/2520 | Baird AW | Darwin GH | 28/09/1885 |
| 585 | 25 | | CUL DAR 251/2521 | Baird AW | Darwin GH | 10/08/1885 |
| 586 | 26 | | CUL DAR 251/2522 | Darwin H | Darwin GH | 22/05/1885 |
| 587 | 27 | | CUL DAR 251/2524 | Borgen AC | Darwin GH | 27/06/1884 |
| 588 | 28 | | CUL DAR 251/2526 | Borgen AC | Darwin GH | 30/06/1884 |
| 589 | 29 | | CUL DAR 251/2527 | Walker JT | Darwin GH | 01/04/1885 |
| 590 | 30 | | CUL DAR 251/2528 | Strachey R | Darwin GH | 09/05/1885 |
| 591 | 31 | | CUL DAR 251/2529 | Johnson A | Darwin GH | 07/05/1885 |
| 592 | 32 | | CUL DAR 251/2530 | Baird AW | Darwin GH | 01/06/1885 |
| 593 | 33 | | CUL DAR 251/2531 | Baird AW | Darwin GH | 29/01/1885 |
| 594 | 34 | | CUL DAR 251/2532 | Doberck W | Darwin GH | 08/03/1885 |
| 595 | 35 | | CUL DAR 251/2533 | Pearson J | Darwin GH | 09/06/1884 |
| 596 | 36 | | CUL DAR 251/2534 | Roberts E | Darwin GH | 16/04/1885 |
| 597 | 37 | | CUL DAR 251/2536 | Roberts E | Darwin GH | 11/01/1885 |
| 598 | 38 | | CUL DAR 251/2537 | Atchison AT | Darwin GH | 04/12/1885 |

| | | | Document | From | To | Date |
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| 599 | 39 | | CUL DAR 251/2538 | Roberts E | Darwin GH | 20/01/1886 |
| 600 | 40 | | CUL DAR 251/2540 | Roberts E | Darwin GH | 16/01/1886 |
| 601 | 41 | | CUL DAR 251/2541 | Cunningham D | Darwin GH | 21/12/1885 |
| 602 | 42 | | CUL DAR 251/2542 | Baird AW | Darwin GH | 22/10/1885 |
| 603 | 43 | | CUL DAR 251/2543 | Baird AW | Darwin GH | 21/12/1885 |
| 604 | 44 | | CUL DAR 251/2544 | Baird AW | B.A.A.S. | 22/10/1885 |
| 605 | 45 | | CUL DAR 251/2545 | Baird AW | Darwin GH | 12/11/1885 |
| 606 | 46 | | CUL DAR 251/2546 | Walker JT | Darwin GH | 02/12/1885 |
| 607 | 47 | | CUL DAR 251/2547 | Roberts E | Darwin GH | 06/04/1885 |
| 608 | 48 | | CUL DAR 251/2548 | Roberts E | Darwin GH | 05/09/1885 |
| 609 | 49 | | CUL DAR 251/2549 | Roberts E | Darwin GH | 05/09/1885 |
| 610 | 50 | | CUL DAR 251/2550 | Johnson A | Darwin GH | 13/08/1885 |
| 611 | 51 | | CUL DAR 251/2551 | Roberts E | Darwin GH | 19/08/1885 |
| 612 | 52 | | CUL DAR 251/2552 | Baird AW | B.A.A.S. | 27/07/1885 |
| 613 | 53 | | CUL DAR 251/2553 | Baird AW | Darwin GH | 27/07/1885 |
| 614 | 54 | | CUL DAR 251/2554 | Adams JC | Darwin GH | 31/12/1884 |
| 615 | 55 | | CUL DAR 251/2562 | Adams JC | Darwin GH | 31/08/1886 |
| 616 | 56 | | CUL DAR 251/2563 | Allnutt JFW | Darwin GH | 07/08/1886 |
| 617 | 57 | | CUL DAR 251/2648 | Stokes GG | Darwin GH | 07/08/1886 |
| 618 | 58 | | CUL DAR 251/2661 | Walker JT | Darwin GH | 13/02/1886 |
| 619 | 59 | | CUL DAR 251/2662 | Walker JT | Darwin GH | 08/02/1886 |
| 620 | 60 | | CUL DAR 251/2706 | Wharton WJH | Darwin GH | 07/10/1886 |
| 621 | 61 | | CUL DAR 251/2708 | Whitehouse A | Roberts E | 15/09/1886 |
| 622 | 62 | | CUL DAR 251/2709 | Roberts E | Darwin GH | 05/08/1886 |
| 623 | 63 | | CUL DAR 251/2710 | Baird AW | Darwin GH | 31/07/1886 |
| 624 | 64 | | CUL DAR 251/2711 | Roberts E | Darwin GH | 23/07/1886 |
| 625 | 65 | | CUL DAR 251/2712 | Allnutt JFW | Darwin GH | 29/07/1886 |
| 626 | 66 | | CUL DAR 251/2714 | Roberts E | Darwin GH | 15/07/1887 |
| 627 | 67 | | CUL DAR 251/2715 | Roberts E | Darwin GH | 13/04/1886 |
| 628 | 68 | | CUL DAR 251/2716 | Roberts E | Darwin GH | 19/04/1886 |
| 629 | 69 | | CUL DAR 251/2719 | Roberts E | Darwin GH | 07/04/1886 |
| 630 | 70 | | CUL DAR 251/2720 | Wharton WJ | Darwin GH | 22/03/1886 |
| 631 | 71 | | CUL DAR 251/2721 | Baird AW | Darwin GH | 21/02/1886 |
| 632 | 72 | | CUL DAR 251/2826 | Johnson A | Darwin GH | 14/06/1887 |
| 633 | 73 | | CUL DAR 251/2827 | Gordon AR | Darwin GH | 07/06/1887 |
| 634 | 74 | | CUL DAR 251/2831 | Crone C | Darwin GH | 02/06/1887 |
| 635 | 75 | | CUL DAR 251/2832 | Baird AW | Darwin GH | 25/04/1887 |
| 636 | 76 | | CUL DAR 251/2833 | Baird AW | Darwin GH | 30/04/1887 |
| 637 | 77 | | CUL DAR 251/2839 | Baird AW | Darwin GH | 11/04/1887 |
| 638 | 78 | | CUL DAR 251/2842 | Johnson A | Darwin GH | 12/03/1887 |
| 639 | 79 | | CUL DAR 251/2844 | Baird AW | Darwin GH | 11/03/1887 |
| 640 | 80 | | CUL DAR 251/2845 | Baird AW | Darwin GH | 26/02/1887 |
| 641 | 81 | | CUL DAR 251/2846 | Baird AW | Darwin GH | 18/01/1887 |

| | | | Document | From | To | Date |
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| 642 | 82 | | CUL DAR 251/2847 | Connor EJ | Darwin GH | 18/01/1887 |
| 643 | 83 | | CUL DAR 251/2848 | Roberts E | Darwin GH | 24/01/1887 |
| 644 | 84 | | CUL DAR 251/2852 | Baird AW | Darwin GH | 02/12/1886 |
| 645 | 85 | | CUL DAR 251/2853 | Connor EJ | Baird AW | |
| 646 | 86 | | CUL DAR 251/2855 | Stewardson HC | Darwin GH | 03/12/1886 |
| 647 | 87 | | CUL DAR 251/2856 | Roberts E | Darwin GH | 08/11/1886 |
| 648 | 88 | | CUL DAR 251/2858 | Baird AW | Darwin GH | 15/10/1886 |
| 649 | 89 | | CUL DAR 251/2896 | Crone C | Darwin GH | 28/07/1887 |
| 650 | 90 | | CUL DAR 251/3020 | Rennie J | Darwin GH | 09/12/1887 |
| 651 | 91 | | CUL DAR 251/3021 | Thomson W | Darwin GH | 09/12/1887 |
| 652 | 92 | | CUL DAR 251/3022 | Jarrad FW | Darwin GH | 15/11/1887 |
| 653 | 93 | | CUL DAR 251/3023 | Baird AW | Darwin GH | 31/10/1887 |
| 654 | 94 | | CUL DAR 251/3024 | Pasco C | Darwin GH | 13/09/1887 |
| 655 | 95 | | CUL DAR 251/3025 | Baird AW | Pasco C | 31/10/1887 |
| 656 | 96 | | CUL DAR 251/3026 | Rennie J | Darwin GH | 12/11/1887 |
| 657 | 97 | | CUL DAR 251/3028 | Roberts E | Darwin GH | 08/11/1887 |
| 658 | 98 | | CUL DAR 251/3029 | Roberts E | Darwin GH | 02/11/1887 |
| 659 | 99 | | CUL DAR 251/3031 | Johnson A | Darwin GH | 08/10/1887 |
| 660 | 100 | | CUL DAR 251/3032 | Johnson A | Darwin GH | 28/05/1887 |
| 661 | 101 | | CUL DAR 251/3033 | Macalister D | Darwin GH | 15/10/1887 |
| 662 | 102 | | CUL DAR 251/3034 | Connor EJ | Darwin GH | 12/10/1887 |
| 663 | 103 | | CUL DAR 251/3035 | Connor EJ | Darwin GH | 12/10/1887 |
| 664 | 104 | | CUL DAR 251/3036 | Connor EJ | Darwin GH | 15/08/1887 |
| 665 | 105 | | CUL DAR 251/3037 | Baird AW | Darwin GH | 06/08/1887 |
| 666 | 106 | | CUL DAR 251/3038 | Endor AR | Darwin GH | 05/08/1887 |
| 667 | 107 | | CUL DAR 251/3040 | Johnson A | Darwin GH | 20/07/1887 |
| 668 | 108 | | CUL DAR 251/3041 | Darwin GH | Gordon AR | |
| 669 | 109 | | CUL DAR 251/3042 | Wharton WJ | Darwin GH | 02/07/1887 |
| 670 | 110 | | CUL DAR 251/3058 | Baird AW | Darwin GH | 18/03/1888 |
| 671 | 111 | | CUL DAR 251/3061 | Baird AW | Darwin GH | 08/05/1888 |
| 672 | 112 | | CUL DAR 251/3180 | Roberts E | Darwin GH | 24/06/1888 |
| 673 | 113 | | CUL DAR 251/3204 | Crone C | Darwin GH | 06/03/1888 |
| 674 | 114 | | CUL DAR 251/3205 | Johnson A | Darwin GH | 20/01/1888 |
| 675 | 115 | | CUL DAR 251/3206 | Dew-Smith AG | Darwin GH | 27/02/1888 |
| 676 | 116 | | CUL DAR 251/3208 | Baird AW | Darwin GH | 24/01/1888 |
| 677 | 117 | | CUL DAR 251/3211 | Connor EJ | Baird AW | 05/01/1888 |
| 678 | 118 | | CUL DAR 251/3212 | Roberts E | Darwin GH | 27/12/1887 |
| 679 | 119 | | CUL DAR 251/3213 | Crone C | Darwin GH | 28/12/1887 |
| 680 | 120 | | CUL DAR 251/3214 | Johnson A | Darwin GH | 24/12/1887 |
| 681 | 121 | | CUL DAR 251/3215 | Mcarthy D | Darwin GH | 20/12/1887 |
| 682 | 122 | | CUL DAR 251/3216 | Wharton WJ | Darwin GH | 20/12/1887 |
| 683 | 123 | | CUL DAR 251/3217 | Connor EJ | Darwin GH | 10/10/1887 |
| 684 | 124 | | CUL DAR 251/3218 | Baird AW | Darwin GH | 28/12/1887 |

| | | | Document | From | To | Date |
|---|---|---|---|---|---|---|
| 685 | 125 | | CUL DAR 251/3219 | Baird AW | Darwin GH | 02/01/1888 |
| 686 | 126 | | CUL DAR 251/3220 | Baird AW | Darwin GH | 19/01/1888 |
| 687 | 127 | | CUL DAR 251/3221 | Connor EJ | Darwin GH | 29/12/1887 |
| 688 | 128 | | CUL DAR 251/3222 | Clarke JW | Darwin GH | 21/02/1888 |
| 689 | 129 | | CUL DAR 251/3223 | Roberts E | Darwin GH | 20/02/1888 |
| 690 | 130 | | CUL DAR 251/3224 | Gordon AR | Darwin GH | 02/02/1888 |
| 691 | 131 | | CUL DAR 251/3225 | Johnson A | Darwin GH | 02/06/1888 |
| 692 | 132 | | CUL DAR 251/3227 | Roberts E | Darwin GH | 09/03/1888 |
| 693 | 133 | | CUL DAR 251/3228 | Connor EJ | Baird AW | 21/02/1888 |
| 694 | 134 | | CUL DAR 251/3229 | Gordon AR | Darwin GH | 17/04/1888 |
| 695 | 135 | | CUL DAR 251/3230 | Johnson A | Darwin GH | 16/05/1888 |
| 696 | 136 | | CUL DAR 251/3262 | Baird AW | Darwin GH | 20/12/1888 |
| 697 | 137 | | CUL DAR 251/3272 | Crone C | Darwin GH | 09/03/1889 |
| 698 | 138 | | CUL DAR 251/3274 | Baird AW | Darwin GH | 27/09/1888 |
| 699 | 139 | | CUL DAR 251/3295 | Dew-Smith AG | Darwin GH | 14/01/1889 |
| 700 | 140 | | CUL DAR 251/3439 | Darwin GH | Walker JT | |
| 701 | 141 | | CUL DAR 251/3440 | Baird AW | Darwin GH | 24/01/1889 |
| 702 | 142 | | CUL DAR 251/3441 | Baird AW | Darwin GH | 24/07/1888 |
| 703 | 143 | | CUL DAR 251/3442 | Wharton WJ | Darwin GH | 21/12/1888 |
| 704 | 144 | | CUL DAR 251/3443 | Wharton WJ | Darwin GH | 29/12/1888 |
| 705 | 145 | | CUL DAR 251/3444 | Roberts E | Wharton WJH | 09/06/1889 |
| 706 | 146 | | CUL DAR 251/3445 | Roberts E | Wharton WJH | 14/06/1889 |
| 707 | 147 | | CUL DAR 251/3446 | C.S.I.C. | Darwin GH | 31/12/1888 |
| 708 | 148 | | CUL DAR 251/3448 | C.S.I.C. | Darwin GH | 31/12/1888 |
| 709 | 149 | | CUL DAR 251/3449 | Roberts E | Darwin GH | 16/01/1889 |
| 710 | 150 | | CUL DAR 251/3451 | Dew-Smith AG | Darwin GH | 29/01/1889 |
| 711 | 151 | | CUL DAR 251/3453 | Allnutt JFW | Darwin GH | 08/04/1889 |
| 712 | 152 | | CUL DAR 251/3454 | Royeal MW | Darwin GH | 25/04/1889 |
| 713 | 153 | | CUL DAR 251/3461 | Allnutt JFW | Darwin GH | 09/10/1889 |
| 714 | 154 | | CUL DAR 251/3558 | Roberts E | Darwin GH | 26/11/1889 |
| 715 | 155 | | CUL DAR 251/3592 | Walker JT | Darwin GH | 15/10/1889 |
| 716 | 156 | | CUL DAR 251/3593 | Walker JT | Darwin GH | 04/07/1889 |
| 717 | 157 | | CUL DAR 251/3600 | Thuillier HR | Govt of India | 09/09/1889 |
| 718 | 158 | | CUL DAR 251/3601 | Wright T | Darwin GH | 08/02/1890 |
| 719 | 159 | | CUL DAR 251/3602 | Wright T | Darwin GH | 07/02/1890 |
| 720 | 160 | | CUL DAR 251/3605 | Borgen AC | Darwin GH | 21/08/1889 |
| 721 | 161 | | CUL DAR 251/3607 | Allnutt JFW | Darwin GH | 18/11/1889 |
| 722 | 162 | | CUL DAR 251/3608 | Allnutt JFW | Darwin GH | 28/11/1889 |
| 723 | 163 | | CUL DAR 251/3609 | Roberts E | Darwin GH | 29/11/1889 |
| 724 | 164 | | CUL DAR 251/3611 | Godley JA | Darwin GH | 28/11/1889 |
| 725 | 165 | | CUL DAR 251/3615 | Cardew P | Darwin GH | 27/10/1889 |
| 726 | 166 | | CUL DAR 251/3617 | Cardew P | Darwin GH | 31/10/1889 |
| 727 | 167 | | CUL DAR 251/3624 | Darwin GH | Wharton WJH | 29/06/1889 |

| | | | Document | From | To | Date |
|---|---|---|---|---|---|---|
| 728 | 168 | | CUL DAR 251/3625 | Wharton WJ | Darwin GH | 02/07/1889 |
| 729 | 169 | | CUL DAR 251/3626 | Crone C | Darwin GH | 12/06/1889 |
| 730 | 170 | | CUL DAR 251/3627 | Wharton WJ | Darwin GH | 01/08/1889 |
| 731 | 171 | | CUL DAR 251/3628 | Wharton WJ | Darwin GH | 18/07/1889 |
| 732 | 172 | | CUL DAR 251/3629 | Baird AW | Darwin GH | 22/01/1890 |
| 733 | 173 | | CUL DAR 251/3746 | Darwin GH | | |
| 734 | 174 | | CUL DAR 251/3762 | Wharton WJ | Darwin GH | 21/08/1890 |
| 735 | 175 | | CUL DAR 251/3766 | Hill J | Darwin GH | 21/04/1891 |
| 736 | 176 | | CUL DAR 251/3767 | Strahan G | Darwin GH | 21/04/1891 |
| 737 | 177 | | CUL DAR 251/3771 | Darwin GH | | |
| 738 | 178 | | CUL DAR 251/3774 | Horoyama S | Darwin GH | 09/02/1891 |
| 739 | 179 | | CUL DAR 251/3780 | Chapman RW | Darwin GH | 21/04/1891 |
| 740 | 180 | | CUL DAR 251/3782 | Baird AW | Darwin GH | 23/02/1891 |
| 741 | 181 | | CUL DAR 251/3787 | Darwin GH | Strahan G | 09/11/1890 |
| 742 | 182 | | CUL DAR 251/3788 | Strahan G | Darwin GH | 19/05/1890 |
| 743 | 183 | | CUL DAR 251/3789 | Allnutt JFW | Darwin GH | 14/04/1890 |
| 744 | 184 | | CUL DAR 251/3930 | Allnutt JFW | Darwin GH | 15/11/1892 |
| 745 | 185 | | CUL DAR 251/3935 | Abbe C | Darwin GH | 16/05/1893 |
| 746 | 186 | | CUL DAR 251/4002 | Eccles J | Darwin GH | 31/07/1893 |
| 747 | 187 | | CUL DAR 251/4003 | Wharton WJ | Darwin GH | 01/08/1893 |
| 748 | 188 | | CUL DAR 251/4007 | Wright T | Darwin GH | 25/09/1893 |
| 749 | 189 | | CUL DAR 251/4008 | Roberts W | Darwin GH | 13/06/1893 |
| 750 | 190 | | CUL DAR 251/4009 | Hill J | Darwin GH | 15/06/1893 |
| 751 | 191 | | CUL DAR 251/4010 | Connor EJ | Darwin GH | 15/06/1893 |
| 752 | 192 | | CUL DAR 251/4011 | Godley JA | Darwin GH | 14/07/1893 |
| 753 | 193 | | CUL DAR 251/4012 | Godley JA | Parker J | 14/07/1893 |
| 754 | 194 | | CUL DAR 251/4013 | Wright T | Darwin GH | 07/06/1893 |
| 755 | 195 | | CUL DAR 251/4014 | Eccles J | Darwin GH | 30/05/1893 |
| 756 | 196 | | CUL DAR 251/4018 | Strahan G | Darwin GH | 04/04/1893 |
| 757 | 197 | | CUL DAR 251/4019 | Beyland C dew | Darwin GH | 26/05/1893 |
| 758 | 198 | | CUL DAR 251/4020 | Baird AW | Darwin GH | 15/04/1893 |
| 759 | 199 | | CUL DAR 251/4021 | Connor EJ | Darwin GH | 27/04/1893 |
| 760 | 200 | | CUL DAR 251/4022 | Wright T | Darwin GH | 17/05/1893 |
| 761 | 201 | | CUL DAR 251/4023 | Darwin GH | Hill J | 02/05/1893 |
| 762 | 202 | | CUL DAR 251/4024 | C.S.I.C. | Darwin GH | 03/07/1893 |
| 763 | 203 | | CUL DAR 251/4025 | Chapman RW | Darwin GH | 05/06/1893 |
| 764 | 204 | | CUL DAR 251/4026 | Hill J | Darwin GH | 14/04/1893 |
| 765 | 205 | | CUL DAR 251/4027 | Wharton WJ | Darwin GH | 19/07/1890 |
| 766 | 206 | | CUL DAR 251/4028 | Wright T | Darwin GH | 22/07/1893 |
| 767 | 207 | | CUL DAR 251/4029 | | Darwin GH | |
| 768 | 208 | | CUL DAR 251/4030 | Braby EE | Darwin GH | 04/05/1893 |
| 769 | 209 | | CUL DAR 251/4031 | Doberck W | Robinson W | 23/03/1893 |
| 770 | 210 | | CUL DAR 251/4032 | Beyland C dew | Darwin GH | 10/06/1893 |

| | | | Document | From | To | Date |
|---|---|---|---|---|---|---|
| 771 | 211 | | CUL DAR 251/4033 | Stok JP van der | Darwin GH | 16/04/1893 |
| 772 | 212 | | CUL DAR 251/4034 | Wharton WJ | Darwin GH | 21/04/1893 |
| 773 | 213 | | CUL DAR 251/4036 | Doberck W | Darwin GH | 16/03/1893 |
| 774 | 214 | | CUL DAR 251/4040 | Eccles J | Darwin GH | |
| 775 | 215 | | CUL DAR 251/4041 | Borgen AC | Darwin GH | 21/04/1893 |
| 776 | 216 | | CUL DAR 251/4043 | Bahhuge I | Darwin GH | 11/03/1893 |
| 777 | 217 | | CUL DAR 251/4044 | Borgen AC | Darwin GH | 08/03/1893 |
| 778 | 218 | | CUL DAR 251/4045 | Borgen AC | Darwin GH | 16/03/1893 |
| 779 | 219 | | CUL DAR 251/4046 | Chapman RW | Darwin GH | 15/02/1893 |
| 780 | 220 | | CUL DAR 251/4048 | Wright T | Darwin GH | 14/08/1893 |
| 781 | 221 | | CUL DAR 251/4049 | Wright T | Darwin GH | 25/04/1893 |
| 782 | 222 | | CUL DAR 251/4050 | Borgen AC | Guyon | 28/04/1893 |
| 783 | 223 | | CUL DAR 251/4100 | Doberck W | Darwin GH | 14/12/1893 |
| 784 | 224 | | CUL DAR 251/4107 | Wright T | Darwin GH | 03/11/1893 |
| 785 | 225 | | CUL DAR 251/4109 | Stok JP van der | Darwin GH | 27/10/1893 |
| 786 | 226 | | CUL DAR 251/4111 | Dawson WB | Darwin GH | 22/01/1894 |
| 787 | 227 | | CUL DAR 251/4112 | Dawson WB | Darwin GH | 07/12/1893 |
| 788 | 228 | | CUL DAR 251/4188 | C.S.I.C. | Darwin GH | 25/01/1896 |
| 789 | 229 | | CUL DAR 251/4249 | Wright T | Darwin GH | 23/01/1896 |
| 790 | 230 | | CUL DAR 251/4251 | Thomson W | Guyon | 27/12/1894 |
| 791 | 231 | | CUL DAR 251/4255 | Wharton WJH | Darwin GH | 02/01/1895 |
| 792 | 232 | | CUL DAR 251/4265 | Hill J | Darwin GH | 02/12/1895 |
| 793 | 233 | | CUL DAR 251/4333 | Cabert F | Darwin GH | 28/04/1896 |
| 794 | 234 | | CUL DAR 251/4334 | C.S.I.C. | Darwin GH | 30/04/1896 |
| 795 | 235 | | CUL DAR 251/4337 | Wright T | Darwin GH | 01/06/1896 |
| 796 | 236 | | CUL DAR 251/4338 | Wright T | Darwin GH | 03/06/1896 |
| 797 | 237 | | CUL DAR 251/4339 | Roberts E | Darwin GH | 24/08/1896 |
| 798 | 238 | | CUL DAR 251/4354 | Hillier HM | Darwin GH | 22/05/1896 |
| 799 | 239 | | CUL DAR 251/4355 | Campbell C | Darwin GH | 14/07/1896 |
| 800 | 240 | | CUL DAR 251/4393 | Roberts E | Darwin GH | 09/03/1897 |
| 801 | 241 | | CUL DAR 251/4394 | Roberts E | Darwin GH | 13/05/1897 |
| 802 | 242 | | CUL DAR 251/4395 | Roberts E | Darwin GH | 25/02/1897 |
| 803 | 243 | | CUL DAR 251/4398 | Campbell JD | Darwin GH | 30/12/1896 |
| 804 | 244 | | CUL DAR 251/4399 | Wright T | Darwin GH | 15/12/1896 |
| 805 | 245 | | CUL DAR 251/4403 | Wright T | Darwin GH | 23/12/1896 |
| 806 | 246 | | CUL DAR 251/4405 | Roberts W | Darwin GH | 20/09/1896 |
| 807 | 247 | | CUL DAR 251/4406 | Darwin GH | | 19/12/1896 |
| 808 | 248 | | CUL DAR 251/4409 | Tizard T | Darwin GH | 17/08/1896 |
| 809 | 249 | | CUL DAR 251/4410 | Wright T | Darwin GH | 10/10/1896 |
| 810 | 250 | | CUL DAR 251/4411 | Roberts E | Darwin GH | 27/02/1897 |
| 811 | 251 | | CUL DAR 251/4475 | Darwin GH | Wharton WJH | 09/06/1898 |
| 812 | 252 | | CUL DAR 251/4492 | Baird AW | Darwin GH | 20/02/1899 |
| 813 | 253 | | CUL DAR 251/4526 | Dawson WB | Darwin GH | |

| | | | Document | From | To | Date |
|---|---|---|---|---|---|---|
| 814 | 254 | | CUL DAR 251/4621 | Wharton WJ | Darwin GH | 28/09/1898 |
| 815 | 255 | | CUL DAR 251/4691 | Dawson WB | Darwin GH | 12/04/1899 |
| 816 | 256 | | CUL DAR 251/4698 | Sim J | Ball RS | 28/03/1899 |
| 817 | 257 | | CUL DAR 251/4712 | Denison FN | Darwin GH | 21/09/1899 |
| 818 | 258 | | CUL DAR 251/4759 | Wharton WJH | Darwin GH | 20/07/1899 |
| 819 | 259 | | CUL DAR 251/4772 | Wright T | Darwin GH | 11/01/1900 |
| 820 | 260 | | CUL DAR 251/4774 | Young AE | Darwin GH | 02/06/1899 |
| 821 | 261 | | CUL DAR 251/4811 | Roberts E | Darwin GH | 04/04/1900 |
| 822 | 262 | | CUL DAR 251/4866 | Wright T | Darwin GH | 26/11/1900 |
| 823 | 263 | | CUL DAR 251/4869 | Wright T | Darwin GH | 09/02/1901 |
| 824 | 264 | | CUL DAR 251/4927 | Dawson WB | Darwin GH | 18/02/1901 |
| 825 | 265 | | CUL DAR 251/4969 | Roberts E | Darwin GH | 05/02/1901 |
| 826 | 266 | | CUL DAR 251/4974 | Darwin GH | Darwin GH | 11/03/1902 |
| 827 | 267 | | CUL DAR 251/5185 | Borgen AC | Darwin GH | 16/07/1903 |
| 828 | 268 | | CUL DAR 251/5186 | Burrard S | Darwin GH | 18/07/1902 |
| 829 | 269 | | CUL DAR 251/5188 | Darby J | Darwin GH | 19/08/1903 |
| 830 | 270 | | CUL DAR 251/5190 | Sprigge JA | Darwin GH | 11/08/1903 |
| 831 | 271 | | CUL DAR 251/5193 | Godley JA | Darwin GH | 24/10/1902 |
| 832 | 272 | | CUL DAR 251/5194 | Godley JA | Darwin GH | 28/10/1902 |
| 833 | 273 | | CUL DAR 251/5201 | Plummer WE | Darwin GH | 15/03/1903 |
| 834 | 274 | | CUL DAR 251/5202 | Plummer WE | Darwin GH | 04/03/1903 |
| 835 | 275 | | CUL DAR 251/5203 | Plummer WE | Darwin GH | 18/03/1903 |
| 836 | 276 | | CUL DAR 251/5204 | Roberts E | | 01/03/1903 |
| 837 | 277 | | CUL DAR 251/5207 | Roberts E | Darwin GH | 11/04/1891 |
| 838 | 278 | | CUL DAR 251/5208 | Roberts E | Darwin GH | 17/03/1903 |
| 839 | 279 | | CUL DAR 251/5209 | Satterly J | Darwin GH | 03/11/1902 |
| 840 | 280 | | CUL DAR 251/5210 | Shoolbred JN | Darwin GH | 22/05/1903 |
| 841 | 281 | | CUL DAR 251/5211 | Shoolbred JN | Darwin GH | 28/05/1903 |
| 842 | 282 | | CUL DAR 251/5212 | Shoolbred JN | Darwin GH | 10/09/1903 |
| 843 | 283 | | CUL DAR 251/5217 | Eccles J | Darwin GH | 29/04/1903 |
| 844 | 284 | | CUL DAR 251/5218 | Darwin GH | | 25/05/1903 |
| 845 | 285 | | CUL DAR 251/5220 | Dawson WB | Darwin GH | 23/03/1900 |
| 846 | 286 | | CUL DAR 251/5221 | Dawson WB | Darwin GH | 29/04/1902 |
| 847 | 287 | | CUL DAR 251/5223 | Wright T | Darwin GH | 24/06/1902 |
| 848 | 288 | | CUL DAR 251/5224 | Wright T | Darwin GH | 30/07/1902 |
| 849 | 289 | | CUL DAR 251/5225 | Wright T | Darwin GH | 15/11/1902 |
| 850 | 290 | | CUL DAR 251/5226 | Wright T | Darwin GH | 17/11/1902 |
| 851 | 291 | | CUL DAR 251/5227 | Wright T | Darwin GH | 03/12/1902 |
| 852 | 292 | | CUL DAR 251/5228 | Wright T | Darwin GH | 17/07/1903 |
| 853 | 293 | | CUL DAR 251/5229 | Wright T | Darwin GH | 14/09/1903 |
| 854 | 1 | | RSL HS.4.24 | Beechey FW | Herschel JFW | 06/03/1851 |
| 855 | 2 | | RSL HS.7.359 | Franklin J | Herschel JFW | 02/11/1838 |
| 856 | 3 | | RSL HS.8.3 | Galbraith W | Herschel JFW | 24/11/1849 |

| | | | Document | From | To | Date |
|---|---|---|---|---|---|---|
| 857 | 4 | | RSL HS.10.35 | Jevons WS | Herschel JFW | 23/06/1866 |
| 858 | 5 | | RSL HS.10.326 | Herschel JFW | Jevons WS | 30/06/1866 |
| 859 | 6 | | RSL HS.11.326 | Lubbock JW | Herschel JFW | 27/01/1840 |
| 860 | 7 | | RSL HS.12.144 | Maclear T | Herschel JFW | 22/07/1849 |
| 861 | 8 | | RSL HS.13.8 | Herschel JFW | | 02/10/1866 |
| 862 | 9 | | RSL HS.17.203 | Sharp W | Herschel JFW | 11/10/1849 |
| 863 | 10 | | RSL HS.17.351 | Herschel JFW | Thomson W | 11/08/1868 |
| 864 | 11 | | RSL HS.17.351b | Thomson W | Herschel JFW | 24/09/1868 |
| 865 | 12 | | RSL HS.17.460 | Vaughen D | Herschel JFW | 09/01/1871 |
| 866 | 13 | | RSL HS.18.184 | Whewell W | Herschel JFW | 14/01/1833 |
| 867 | 14 | | RSL HS.18.188 | Whewell W | Herschel JFW | 04/12/1836 |
| 868 | 15 | | RSL HS.18.191 | Whewell W | Herschel JFW | 22/02/1840 |
| 869 | 16 | | RSL HS.21.94 | Herschel JFW | Beaufort F | |
| 870 | 17 | | RSL HS.21.223 | Herschel JFW | Maclear T | 06/07/1837 |
| 871 | 18 | | RSL HS.21.224 | Herschel JFW | Whewell W | 22/07/1837 |
| 872 | 19 | | RSL HS.21.228 | Herschel JFW | Whewell W | 20/08/1837 |
| 873 | 20 | | RSL HS.24.59 | Herschel JFW | Thomson W | 25/08/1864 |
| 874 | 1 | | HOT LB1 123 | Hurd T | Hose | 17/03/1817 |
| 875 | 2 | | HOT LB1 124 | Hurd T | Martin KB | 28/02/1817 |
| 876 | 3 | | HOT LB2 111 | Parry WE | Dessiou JF | 27/02/1828 |
| 877 | 4 | | HOT LB2 173 | Parry WE | Cunningham D | 08/08/1828 |
| 878 | 5 | | HOT LB2 228 | Parry WE | Herbert J | 16/12/1828 |
| 879 | 6 | | HOT LB2 387 | Beaufort F | Barnett E | 19/10/1829 |
| 880 | 7 | | HOT LB2 392 | Beaufort F | Church | 29/10/1829 |
| 881 | 8 | | HOT LB2 397 | Beaufort F | Heron W | 31/10/1829 |
| 882 | 9 | | HOT LB2 409 | Beaufort F | Lubbock JW | 14/11/1829 |
| 883 | 10 | | HOT LB3 51 | Becher AB | Lloyd JA | 30/10/1830 |
| 884 | 11 | | HOT LB3 74 | Beaufort F | Pond J | 22/12/1830 |
| 885 | 12 | | HOT LB3 104a | Beaufort F | Lubbock JW | 20/01/1831 |
| 886 | 13 | | HOT LB3 233 | Beaufort F | Fitzroy R | 01/09/1831 |
| 887 | 14 | | HOT LB4 38c | Beaufort F | Mudge | 16/04/1832 |
| 888 | 15 | | HOT LB4 41 | Beaufort F | Stratford WS | 21/04/1832 |
| 889 | 16 | | HOT LB4 69 | Beaufort F | Washington J | 18/06/1832 |
| 890 | 17 | | HOT LB4 79 | Beaufort F | Washington J | 06/07/1832 |
| 891 | 18 | | HOT LB4 148 | Becher AB | Malcolm P | 10/10/1832 |
| 892 | 19 | | HOT LB4 160 | Beaufort F | Brown T | 31/10/1832 |
| 893 | 20 | | HOT LB4 160a | Beaufort F | Horsburgh J | 01/11/1832 |
| 894 | 21 | | HOT LB4 166 | Beaufort F | Children JG | 09/03/1832 |
| 895 | 22 | | HOT LB4 213 | Beaufort F | Parry WE | 15/01/1833 |
| 896 | 23 | | HOT LB4 215 | Beaufort F | Mudge | 17/06/1833 |
| 897 | 24 | | HOT LB4 216 | Beaufort F | Bullock | 18/06/1833 |
| 898 | 25 | | HOT LB4 217 | Beaufort F | Turner W | 18/01/1833 |
| 899 | 26 | | HOT LB4 217a | Beaufort F | Washington J | 18/01/1833 |

| | | | Document | From | To | Date |
|---|---|---|---|---|---|---|
| 900 | 27 | | HOT LB4 230 | Beaufort F | White M | 02/02/1833 |
| 901 | 28 | | HOT LB4 230a | Beaufort F | Aird | 04/02/1833 |
| 902 | 29 | | HOT LB4 235 | Beaufort F | Church | 07/02/1833 |
| 903 | 30 | | HOT LB4 236 | Beaufort F | Williams T | 08/02/1833 |
| 904 | 31 | | HOT LB4 236a | Beaufort F | Ross JC | |
| 905 | 32 | | HOT LB4 250 | Beaufort F | Mudge | 08/03/1833 |
| 906 | 33 | | HOT LB4 260 | Beaufort F | Whewell W | 23/03/1833 |
| 907 | 34 | | HOT LB4 273 | Beaufort F | Mudge | 15/04/1833 |
| 908 | 35 | | HOT LB4 275 | Beaufort F | Parry WE | 15/04/1833 |
| 909 | 36 | | HOT LB4 292 | Beaufort F | Mudge | 14/05/1833 |
| 910 | 37 | | HOT LB4 326 | Beaufort F | Cerquero J | 01/07/1833 |
| 911 | 38 | | HOT LB5 48 | Beaufort F | Lubbock JW | 27/09/1833 |
| 912 | 39 | | HOT LB5 48a | Beaufort F | Taylor PG | 27/09/1833 |
| 913 | 40 | | HOT LB5 55 | Beaufort F | Lubbock JW | 01/10/1833 |
| 914 | 41 | | HOT LB5 88 | Beaufort F | Herbert J | 15/11/1833 |
| 915 | 42 | | HOT LB5 102 | Beaufort F | Church J | 06/12/1833 |
| 916 | 43 | | HOT LB5 113 | Beaufort F | Williams J | 01/01/1834 |
| 917 | 44 | | HOT LB5 201 | Beaufort F | | 26/05/1824 |
| 918 | 45 | | HOT LB5 259 | Beaufort F | Hutchinson W | 01/08/1834 |
| 919 | 46 | | HOT MB3 305 | Beaufort F | Ross D | 27/07/1841 |
| 920 | 47 | | HOT MB3 360 | Beaufort F | Ross D | 11/01/1842 |
| 921 | 48 | | HOT LetsIn A.636 | Airy GB | Beaufort F | 28/02/1848 |
| 922 | 49 | | HOT LetsIn A.758 | Airy GB | Beaufort F | 10/09/1853 |
| 923 | 50 | | HOT LetsIn A.791 | Airy GB | Beaufort F | 02/04/1852 |
| 924 | 51 | | HOT LetsIn A.791c | Beechey FW | Beaufort F | 05/04/1852 |
| 925 | 52 | | HOT LetsIn A.791b | Airy GB | Beaufort F | 06/04/1852 |
| 926 | 53 | | HOT LetsIn B.627 | Bunt TG | Beaufort F | 28/10/1836 |
| 927 | 54 | | HOT LetsIn B.628 | Bunt TG | Beaufort F | 10/12/1847 |
| 928 | 55 | | HOT LetsIn B.629 | Bunt TG | Beaufort F | 09/11/1836 |
| 929 | 56 | | HOT LetsIn B.630 | Bunt TG | Beaufort F | 01/02/1843 |
| 930 | 57 | | HOT LetsIn B.631 | Bunt TG | Beaufort F | 30/04/1844 |
| 931 | 58 | | HOT LetsIn B.633 | Bunt TG | Beaufort F | 03/02/1838 |
| 932 | 59 | | HOT LetsIn B.635a | Bunt TG | Beaufort F | 20/02/1838 |
| 933 | 60 | | HOT LetsIn B.637 | Bunt TG | Beaufort F | 29/03/1839 |
| 934 | 61 | | HOT LetsIn B.639 | Bunt TG | Beaufort F | 14/08/1839 |
| 935 | 62 | | HOT LetsIn B.640 | Bunt TG | Beaufort F | 19/09/1839 |
| 936 | 63 | | HOT LetsIn B.643 | Bunt TG | Bristol Standard | 06/10/1840 |
| 937 | 64 | | HOT LetsIn B.647 | Bunt TG | Beaufort F | 07/10/1838 |
| 938 | 65 | | HOT LetsIn B.648 | Bunt TG | Beaufort F | 06/11/1837 |
| 939 | 66 | | HOT LetsIn B.649 | Bunt TG | Beaufort F | 14/10/1837 |
| 940 | 67 | | HOT LetsIn B.650 | Bunt TG | Beaufort F | 02/10/1837 |
| 941 | 68 | | HOT LetsIn B.651 | Bunt TG | Beaufort F | 31/08/1837 |
| 942 | 69 | | HOT LetsIn B.652 | Bunt TG | Beaufort F | 10/02/1838 |

| | | | Document | From | To | Date |
|---|---|---|---|---|---|---|
| 943 | 70 | | HOT LetsIn B.653 | Bunt TG | Beaufort F | 24/02/1838 |
| 944 | 71 | | HOT LetsIn B.654 | Bunt TG | Beaufort F | 05/11/1838 |
| 945 | 72 | | HOT LetsIn B.655 | Bunt TG | Beaufort F | 01/08/1838 |
| 946 | 73 | | HOT LetsIn B.656 | Bunt TG | Beaufort F | 10/12/1836 |
| 947 | 74 | | HOT LetsIn B.657 | Bunt TG | Beaufort F | 18/04/1837 |
| 948 | 75 | | HOT LetsIn B.661 | Burdwood J | Beaufort F | 19/12/1846 |
| 949 | 76 | | HOT LetsIn B.662 | Burdwood J | Beaufort F | 19/01/1847 |
| 950 | 77 | | HOT LetsIn B.663 | Burdwood J | Becher AB | 08/02/1847 |
| 951 | 78 | | HOT LetsIn B.990 | Barnett E | Beaufort F | 22/10/1829 |
| 952 | 79 | | HOT LetsIn B.1038 | Barnden | Beaufort F | 17/12/1837 |
| 953 | 80 | | HOT LetsIn B.1233 | Barnett E | Beaufort F | 14/08/1850 |
| 954 | 81 | | HOT LetsIn B.1239 | Bax HB | Beaufort F | 24/07/1850 |
| 955 | 82 | | HOT LetsIn B.1319 | Bunt TG | Beaufort F | 17/08/1850 |
| 956 | 83 | | HOT LetsIn B.1320 | Bunt TG | Beaufort F | 15/12/1848 |
| 957 | 84 | | HOT LetsIn B.1321 | Bunt TG | Beaufort F | 15/12/1847 |
| 958 | 85 | | HOT LetsIn B.1353 | Ballingell | Beaufort F | 07/01/1852 |
| 959 | 86 | | HOT LetsIn B.1441 | Bunt TG | Beaufort F | 16/12/1851 |
| 960 | 87 | | HOT LetsIn C.775 | Coode J | Beaufort F | 23/09/1851 |
| 961 | 88 | | HOT LetsIn C.923 | Chevallier E | Beaufort F | 12/03/1856 |
| 962 | 89 | | HOT LetsIn D.70 | Dessiou JF | Beaufort F | 11/06/1849 |
| 963 | 90 | | HOT LetsIn D.147 | Dessiou JF | Beaufort F | 15/10/1845 |
| 964 | 91 | | HOT LetsIn D.181 | Dayman J | Beaufort F | 07/04/1852 |
| 965 | 92 | | HOT LetsIn E.397 | Earl GW | Beaufort F | 01/07/1843 |
| 966 | 93 | | HOT LetsIn F.177 | Fitzroy R | Beaufort F | 30/06/1848 |
| 967 | 94 | | HOT LetsIn F.178 | Fitzroy R | Beaufort F | 07/12/1837 |
| 968 | 95 | | HOT LetsIn F.313 | Fitzroy R | Beaufort F | 03/06/1848 |
| 969 | 96 | | HOT LetsIn F.367 | Farghar R | Beaufort F | 22/09/1851 |
| 970 | 97 | | HOT LetsIn F.383 | Fitzroy R | Beaufort F | 01/11/1852 |
| 971 | 98 | | HOT LetsIn F.384 | Fitzroy R | Beaufort F | 01/11/1852 |
| 972 | 99 | | HOT LetsIn H.517 | Herbert J | Parry WE | 09/01/1829 |
| 973 | 100 | | HOT LetsIn H.566 | Herschel JFW | Beaufort F | 20/12/1835 |
| 974 | 101 | | HOT LetsIn H.677 | Hamilton J | Beaufort F | 18/11/1854 |
| 975 | 102 | | HOT LetsIn H.689 | Hartley WB | Washington J | 26/12/1835 |
| 976 | 103 | | HOT LetsIn I.52 | Innes G | Beaufort F | 19/11/1836 |
| 977 | 104 | | HOT LetsIn L.278 | Lubbock JW | Beaufort F | 16/02/1835 |
| 978 | 105 | | HOT LetsIn L.279 | Lubbock JW | Beaufort F | 19/02/1835 |
| 979 | 106 | | HOT LetsIn L.281 | Lubbock JW | Beaufort F | |
| 980 | 107 | | HOT LetsIn L.361 | Lord W | Beaufort F | 19/06/1841 |
| 981 | 108 | | HOT LetsIn L.363 | Lord W | Beaufort F | 28/02/1842 |
| 982 | 109 | | HOT LetsIn L.377 | Lord W | Beaufort F | 23/06/1843 |
| 983 | 110 | | HOT LetsIn M.746 | Hinarey W | Beaufort F | 19/09/1854 |
| 984 | 111 | | HOT LetsIn N.214 | Newman J | Beaufort F | 10/08/1847 |
| 985 | 112 | | HOT LetsIn R.82 | Rennie G | Beaufort F | 04/04/1844 |

APPENDIX 1

| | | | Document | From | To | Date |
|---|---|---|---|---|---|---|
| 986 | 113 | | HOT LetsIn R.340 | Ross D | Beaufort F | 20/10/1846 |
| 987 | 114 | | HOT LetsIn R.386 | Ross D | Beaufort F | 18/10/1841 |
| 988 | 115 | | HOT LetsIn R.443 | Ross D | Beaufort F | 04/11/1852 |
| 989 | 116 | | HOT LetsIn R.457 | Ross D | Beaufort F | 28/05/1852 |
| 990 | 117 | | HOT LetsIn R.458 | Ross D | Beaufort F | |
| 991 | 118 | | HOT LetsIn R.484 | Ross D | Beaufort F | 30/06/1851 |
| 992 | 119 | | HOT LetsIn R.491 | Ross D | Beaufort F | 17/10/1849 |
| 993 | 120 | | HOT LetsIn R.503 | Ross D | Beaufort F | 04/08/1854 |
| 994 | 121 | | HOT LetsIn R.536 | Ross D | Beaufort F | 12/12/1853 |
| 995 | 122 | | HOT LetsIn R.561 | Ross D | Beaufort F | 16/04/1853 |
| 996 | 123 | | HOT LetsIn R.578 | Raper H | Beaufort F | 11/08/1853 |
| 997 | 124 | | HOT LetsIn R.708 | Ross D | Burdwood J | 08/10/1850 |
| 998 | 125 | | HOT LetsIn R.708a | Beaufort F | Ross D | 09/10/1850 |
| 999 | 126 | | HOT LetsIn R.709 | Ross D | Beaufort F | 30/07/1850 |
| 1000 | 127 | | HOT LetsIn R.710 | Ross D | Beaufort F | 15/06/1850 |
| 1001 | 128 | | HOT LetsIn R.711 | Ross D | Beaufort F | 25/05/1850 |
| 1002 | 129 | | HOT LetsIn R.712 | Ross D | Beaufort F | 01/04/1850 |
| 1003 | 130 | | HOT LetsIn R.713 | Ross D | Beaufort F | 01/01/1850 |
| 1004 | 131 | | HOT LetsIn R.714 | Ross D | Beaufort F | 04/12/1849 |
| 1005 | 132 | | HOT LetsIn R.729 | Ross D | Beaufort F | 23/12/1848 |
| 1006 | 133 | | HOT LetsIn W.251 | Whewell W | Beaufort F | 26/08/1847 |
| 1007 | 134 | | HOT LetsIn W.252 | Whewell W | Beaufort F | 07/09/1847 |
| 1008 | 135 | | HOT LetsIn W.393 | Whewell W | Beaufort F | 14/05/1853 |
| 1009 | 136 | | HOT LetsIn W.412 | Whewell W | Beaufort F | 02/01/1854 |
| 1010 | 137 | | HOT LetsIn W.526 | Whewell W | Beaufort F | 10/03/1835 |
| 1011 | 138 | | HOT LetsIn W.527 | Whewell W | Beaufort F | 15/05/1835 |
| 1012 | 139 | | HOT LetsIn W.528 | Whewell W | Beaufort F | 15/07/1835 |
| 1013 | 140 | | HOT LetsIn W.529 | Whewell W | Dessiou JF | 21/11/1835 |
| 1014 | 141 | | HOT LetsIn W.530 | Whewell W | Beaufort F | 27/06/1835 |
| 1015 | 142 | | HOT LetsIn W.534 | Whewell W | Beaufort F | 26/07/1843 |
| 1016 | 143 | | HOT LetsIn W.535 | Whewell W | Beaufort F | 06/03/1844 |
| 1017 | 144 | | HOT LetsIn W.537 | Whewell W | Beaufort F | 16/11/1839 |
| 1018 | 145 | | HOT LetsIn W.540 | Whewell W | Beaufort F | 09/11/1835 |
| 1019 | 146 | | HOT LetsIn W.541 | Whewell W | Beaufort F | |
| 1020 | 147 | | HOT LetsIn W.542 | Whewell W | Beaufort F | |
| 1021 | 148 | | HOT LetsIn W.543 | Whewell W | Beaufort F | 19/03/1835 |
| 1022 | 149 | | HOT LetsIn W.544 | Whewell W | Beaufort F | 25/02/1837 |
| 1023 | 150 | | HOT LetsIn W.545 | Whewell W | Beaufort F | 10/01/1837 |
| 1024 | 151 | | HOT LetsIn W.546 | Whewell W | Beaufort F | 21/11/1834 |
| 1025 | 152 | | HOT LetsIn W.547 | Whewell W | Beaufort F | 19/11/1836 |
| 1026 | 153 | | HOT LetsIn W.548 | Whewell W | Beaufort F | |
| 1027 | 154 | | HOT LetsIn W.549 | Whewell W | Beaufort F | 07/04/1836 |
| 1028 | 155 | | HOT LetsIn W.550 | Whewell W | Beaufort F | 01/03/1833 |

| | | | Document | From | To | Date |
|---|---|---|---|---|---|---|
| 1029 | 156 | | HOT LetsIn W.551 | Whewell W | Becher AB | |
| 1030 | 157 | | HOT LetsIn W.552 | Whewell W | Beaufort F | 02/11/1835 |
| 1031 | 158 | | HOT LetsIn W.553 | Whewell W | Beaufort F | 26/11/1834 |
| 1032 | 159 | | HOT LetsIn W.554 | Whewell W | Beaufort F | 08/02/1835 |
| 1033 | 160 | | HOT LetsIn W.629 | Whewell W | Beaufort F | 17/12/1845 |
| 1034 | 161 | | HOT OrigMS 8.3.10 | Loney R | Beaufort F | 05/11/1846 |
| 1035 | 162 | | HOT OrigMS 12.1.2 | Lubbock JW | Beaufort F | 17/11/1830 |
| 1036 | 163 | | HOT OrigMS 12.1.3 | Lubbock JW | Beaufort F | 17/06/1831 |
| 1037 | 164 | | HOT OrigMS 23.6.1 | Whewell W | Beaufort F | 15/11/1833 |
| 1038 | 165 | | HOT OrigMS 26.6.12 | Huffman NH | Parker J | 02/08/1851 |
| 1039 | 1 | | GUL Kelvin A3 | Airy GB | Thomson W | 23/09/1867 |
| 1040 | 2 | | GUL Kelvin D1 | Thomson W | DaCunha | 17/01/1881 |
| 1041 | 3 | | GUL Kelvin D3 | Thomson W | Darwin GH | 11/09/1877 |
| 1042 | 4 | | GUL Kelvin D4 | Thomson W | Darwin GH | 28/10/1878 |
| 1043 | 5 | | GUL Kelvin D5 | Thomson W | Darwin GH | 30/10/1878 |
| 1044 | 6 | | GUL Kelvin D6 | Thomson W | Darwin GH | 04/11/1878 |
| 1045 | 7 | | GUL Kelvin D7 | Thomson W | Darwin GH | 07/11/1878 |
| 1046 | 8 | | GUL Kelvin D8 | Thomson W | Darwin GH | 08/01/1879 |
| 1047 | 9 | | GUL Kelvin D9 | Thomson W | Darwin GH | 11/05/1879 |
| 1048 | 10 | | GUL Kelvin D10 | Thomson W | Darwin GH | 15/06/1879 |
| 1049 | 11 | | GUL Kelvin D13 | Thomson W | Darwin GH | 17/08/1879 |
| 1050 | 12 | | GUL Kelvin D18 | Thomson W | Darwin GH | 22/08/1880 |
| 1051 | 13 | | GUL Kelvin D21 | Thomson W | Darwin GH | 11/01/1881 |
| 1052 | 14 | | GUL Kelvin D22 | Thomson FA | Darwin GH | 17/01/1881 |
| 1053 | 15 | | GUL Kelvin D23 | Thomson W | Darwin GH | 09/02/1881 |
| 1054 | 16 | | GUL Kelvin D34 | Thomson W | Darwin GH | 26/12/1881 |
| 1055 | 17 | | GUL Kelvin D43 | Thomson W | Darwin GH | 20/05/1882 |
| 1056 | 18 | | GUL Kelvin D44 | Thomson W | Darwin GH | 22/05/1882 |
| 1057 | 19 | | GUL Kelvin D45 | Thomson W | Darwin GH | 23/05/1882 |
| 1058 | 20 | | GUL Kelvin D46 | Thomson W | Darwin GH | 25/05/1882 |
| 1059 | 21 | | GUL Kelvin D47 | Darwin GH | Thomson W | 28/05/1882 |
| 1060 | 22 | | GUL Kelvin D48 | Thomson W | Darwin GH | 30/05/1882 |
| 1061 | 23 | | GUL Kelvin D49 | Thomson W | Darwin GH | 04/06/1882 |
| 1062 | 24 | | GUL Kelvin D51 | Thomson W | Darwin GH | 15/06/1882 |
| 1063 | 25 | | GUL Kelvin D52 | Thomson W | Darwin GH | 21/06/1882 |
| 1064 | 26 | | GUL Kelvin D53 | Thomson W | Darwin GH | 22/06/1882 |
| 1065 | 27 | | GUL Kelvin D54 | Thomson W | Darwin GH | 24/06/1882 |
| 1066 | 28 | | GUL Kelvin D56 | Thomson W | Darwin GH | 30/06/1882 |
| 1067 | 29 | | GUL Kelvin D58 | Thomson W | Darwin GH | 09/07/1882 |
| 1068 | 30 | | GUL Kelvin D59 | Thomson W | Darwin GH | 19/07/1882 |
| 1069 | 31 | | GUL Kelvin D60 | Thomson W | Darwin GH | 20/07/1882 |
| 1070 | 32 | | GUL Kelvin D63 | Thomson W | Darwin GH | 25/07/1882 |
| 1071 | 33 | | GUL Kelvin D64 | Thomson W | Darwin GH | 30/07/1882 |

| | | | Document | From | To | Date |
|---|---|---|---|---|---|---|
| 1072 | 34 | | GUL Kelvin D68 | Thomson W | Darwin GH | 30/09/1882 |
| 1073 | 35 | | GUL Kelvin D69 | Darwin GH | Thomson W | 12/10/1882 |
| 1074 | 36 | | GUL Kelvin D73 | Thomson W | Darwin GH | 04/12/1882 |
| 1075 | 37 | | GUL Kelvin D81 | Thomson W | Darwin GH | |
| 1076 | 38 | | GUL Kelvin D86 | Thomson W | Darwin GH | 24/11/1884 |
| 1077 | 39 | | GUL Kelvin D93 | Thomson W | Darwin GH | 16/07/1885 |
| 1078 | 40 | | GUL Kelvin D94 | Thomson FA | Darwin GH | 13/09/1885 |
| 1079 | 41 | | GUL Kelvin D95 | Thomson W | Darwin GH | 21/02/1886 |
| 1080 | 42 | | GUL Kelvin D99 | Thomson W | Darwin GH | 09/09/1887 |
| 1081 | 43 | | GUL Kelvin D100 | Thomson W | Darwin GH | 14/01/1888 |
| 1082 | 44 | | GUL Kelvin D104 | Thomson W | Darwin GH | 23/12/1888 |
| 1083 | 45 | | GUL Kelvin D107 | Thomson W | Darwin GH | 24/02/1890 |
| 1084 | 46 | | GUL Kelvin D109 | Thomson FA | Darwin GH | 08/09/1883 |
| 1085 | 47 | | GUL Kelvin D121 | Thomson W | Darwin GH | 23/03/1898 |
| 1086 | 48 | | GUL Kelvin D125 | Thomson W | Darwin GH | 09/11/1898 |
| 1087 | 49 | | GUL Kelvin M54 | Moriarty HA | Thomson W | 05/01/1867 |
| 1088 | 50 | | GUL Kelvin R30 | Roberts E | Thomson W | 15/06/1872 |
| 1089 | 51 | | GUL Kelvin T117 | Thomson J | Thomson W | 09/07/1862 |
| 1090 | 52 | | GUL Kelvin T192 | Thomson W | Thomson W | |
| 1091 | 53 | | GUL Kelvin T203 | Roberts E | Thomson W | 11/06/1868 |
| 1092 | 54 | | GUL Kelvin W1 | Walton W | Thomson W | 25/11/1866 |
| 1093 | 1 | | RSL LUB.A.96 | Airy GB | Sedgwick A | 28/11/1840 |
| 1094 | 2 | | RSL LUB.A.148 | Airy GB | Lubbock JW | 15/01/1840 |
| 1095 | 3 | | RSL LUB.A.164 | Airy GB | Lubbock JW | 25/01/1841 |
| 1096 | 4 | | RSL LUB.A.184 | Airy GB | Lubbock JW | 14/01/1852 |
| 1097 | 5 | | RSL LUB.B.37 | Baily F | Lubbock JW | 14/01/1840 |
| 1098 | 6 | | RSL LUB.B.54 | Baily F | Lubbock JW | 01/11/1832 |
| 1099 | 7 | | RSL LUB.B.71 | Baily F | Lubbock JW | 19/07/1835 |
| 1100 | 8 | | RSL LUB.B.128 | Barrow J | Lubbock JW | 09/03/1832 |
| 1101 | 9 | | RSL LUB.B.162 | Beaufort F | Lubbock JW | 22/02/1832 |
| 1102 | 10 | | RSL LUB.B.164 | Beaufort F | Lubbock JW | 12/04/1832 |
| 1103 | 11 | | RSL LUB.B.166 | Beaufort F | Lubbock JW | 15/05/1832 |
| 1104 | 12 | | RSL LUB.B.167 | Beaufort F | Lubbock JW | 27/09/1833 |
| 1105 | 13 | | RSL LUB.B.171 | Beaufort F | Lubbock JW | 23/12/1833 |
| 1106 | 14 | | RSL LUB.B.172 | Beaufort F | Lubbock JW | 20/02/1834 |
| 1107 | 15 | | RSL LUB.B.173 | Beaufort F | Lubbock JW | 14/03/1834 |
| 1108 | 16 | | RSL LUB.B.174 | Beaufort F | Lubbock JW | 05/06/1834 |
| 1109 | 17 | | RSL LUB.B.175 | Beaufort F | Lubbock JW | 30/07/1834 |
| 1110 | 18 | | RSL LUB.B.177 | Beaufort F | Lubbock JW | 17/02/1835 |
| 1111 | 19 | | RSL LUB.B.179 | Beaufort F | Lubbock JW | |
| 1112 | 20 | | RSL LUB.B.183 | Beaufort F | Lubbock JW | 20/10/1838 |
| 1113 | 21 | | RSL LUB.B.193 | Beaufort F | Lubbock JW | 26/02/1840 |
| 1114 | 22 | | RSL LUB.B.197 | Beaufort F | Lubbock JW | 04/11/1845 |

| | | | Document | From | To | Date |
|---|---|---|---|---|---|---|
| 1115 | 23 | | RSL LUB.B.440 | Yates J | Lubbock JW | 17/08/1833 |
| 1116 | 24 | | RSL LUB.B.444 | Phillips J | Lubbock JW | 28/10/1834 |
| 1117 | 25 | | RSL LUB.B.446 | B.A.A.S. | Lubbock JW | 20/11/1834 |
| 1118 | 26 | | RSL LUB.B.493 | Brown A | Lubbock JW | 12/03/1840 |
| 1119 | 27 | | RSL LUB.B.494 | Brown A | Lubbock JW | 21/03/1840 |
| 1120 | 28 | | RSL LUB.B.590 | Bunt TG | Lubbock JW | 22/02/1839 |
| 1121 | 29 | | RSL LUB.B.595 | Burdwood J | Lubbock JW | 15/11/1856 |
| 1122 | 30 | | RSL LUB.B.596 | Burdwood J | Lubbock JW | 20/11/1856 |
| 1123 | 31 | | RSL LUB.B.597 | Burdwood J | Lubbock JW | 02/10/1857 |
| 1124 | 32 | | RSL LUB.B.627 | Bywater T | Larcom H | 14/11/1835 |
| 1125 | 33 | | RSL LUB.B.628 | Bywater T | Lubbock JW | 05/12/1835 |
| 1126 | 34 | | RSL LUB.B.629 | Bywater T | Lubbock JW | 21/12/1835 |
| 1127 | 35 | | RSL LUB.C.293 | Coates T | Lubbock JW | 09/12/1828 |
| 1128 | 36 | | RSL LUB.C.296 | Coates T | Lubbock JW | 02/11/1830 |
| 1129 | 37 | | RSL LUB.D.110 | Denham HM | Lubbock JW | 24/04/1841 |
| 1130 | 38 | | RSL LUB.D.111 | Denham HM | Lubbock JW | 07/05/1841 |
| 1131 | 39 | | RSL LUB.D.124 | Dessiou JF | Lubbock JW | 15/03/1831 |
| 1132 | 40 | | RSL LUB.D.125 | Dessiou JF | Lubbock JW | 24/11/1831 |
| 1133 | 41 | | RSL LUB.D.126 | Dessiou JF | Lubbock JW | 24/02/1832 |
| 1134 | 42 | | RSL LUB.D.127 | Dessiou JF | Lubbock JW | 07/03/1832 |
| 1135 | 43 | | RSL LUB.D.128 | Dessiou JF | Lubbock JW | 14/04/1832 |
| 1136 | 44 | | RSL LUB.D.129 | Dessiou JF | Lubbock JW | 20/04/1832 |
| 1137 | 45 | | RSL LUB.D.130 | Dessiou JF | Lubbock JW | 26/04/1832 |
| 1138 | 46 | | RSL LUB.D.131 | Dessiou JF | Lubbock JW | 27/04/1832 |
| 1139 | 47 | | RSL LUB.D.132 | Dessiou JF | Lubbock JW | 17/05/1832 |
| 1140 | 48 | | RSL LUB.D.133 | Dessiou JF | Lubbock JW | 23/05/1832 |
| 1141 | 49 | | RSL LUB.D.134 | Dessiou JF | Lubbock JW | 20/12/1832 |
| 1142 | 50 | | RSL LUB.D.135 | Dessiou JF | Lubbock JW | 29/03/1833 |
| 1143 | 51 | | RSL LUB.D.136 | Dessiou JF | Lubbock JW | 06/05/1833 |
| 1144 | 52 | | RSL LUB.D.137 | Dessiou JF | Lubbock JW | 13/05/1833 |
| 1145 | 53 | | RSL LUB.D.138 | Dessiou JF | Lubbock JW | 07/08/1833 |
| 1146 | 54 | | RSL LUB.D.139 | Dessiou JF | Lubbock JW | 25/11/1833 |
| 1147 | 55 | | RSL LUB.D.140 | Dessiou JF | Lubbock JW | |
| 1148 | 56 | | RSL LUB.D.141 | Dessiou JF | Lubbock JW | 01/01/1834 |
| 1149 | 57 | | RSL LUB.D.142 | Dessiou JF | Lubbock JW | 31/07/1834 |
| 1150 | 58 | | RSL LUB.D.143 | Dessiou JF | Lubbock JW | 03/04/1835 |
| 1151 | 59 | | RSL LUB.D.144 | Dessiou JF | Lubbock JW | 13/06/1835 |
| 1152 | 60 | | RSL LUB.D.145 | Dessiou JF | Lubbock JW | 29/06/1835 |
| 1153 | 61 | | RSL LUB.D.146 | Dessiou JF | Lubbock JW | 27/08/1835 |
| 1154 | 62 | | RSL LUB.D.147 | Dessiou JF | Lubbock JW | 09/09/1835 |
| 1155 | 63 | | RSL LUB.D.148 | Dessiou JF | Lubbock JW | 10/09/1835 |
| 1156 | 64 | | RSL LUB.D.149 | Dessiou JF | Lubbock JW | 24/10/1835 |
| 1157 | 65 | | RSL LUB.D.150 | Dessiou JF | Lubbock JW | 09/11/1835 |

| | | | Document | From | To | Date |
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| 1158 | 66 | | RSL LUB.D.151 | Dessiou JF | Lubbock JW | 12/04/1836 |
| 1159 | 67 | | RSL LUB.D.152 | Dessiou JF | Lubbock JW | 03/06/1836 |
| 1160 | 68 | | RSL LUB.D.153 | Dessiou JF | Lubbock JW | |
| 1161 | 69 | | RSL LUB.D.154 | Dessiou JF | Lubbock JW | 05/01/1837 |
| 1162 | 70 | | RSL LUB.D.155 | Dessiou JF | Lubbock JW | 20/02/1837 |
| 1163 | 71 | | RSL LUB.D.156 | Dessiou JF | Lubbock JW | 24/02/1837 |
| 1164 | 72 | | RSL LUB.D.157 | Dessiou JF | Lubbock JW | 15/07/1837 |
| 1165 | 73 | | RSL LUB.D.158 | Dessiou JF | Lubbock JW | 26/07/1837 |
| 1166 | 74 | | RSL LUB.D.159 | Dessiou JF | Lubbock JW | 29/07/1837 |
| 1167 | 75 | | RSL LUB.D.160 | Dessiou JF | Lubbock JW | 10/08/1837 |
| 1168 | 76 | | RSL LUB.D.161 | Dessiou JF | Lubbock JW | 03/08/1837 |
| 1169 | 77 | | RSL LUB.D.162 | Dessiou JF | Lubbock JW | 23/09/1837 |
| 1170 | 78 | | RSL LUB.D.163 | Dessiou JF | Lubbock JW | 05/10/1837 |
| 1171 | 79 | | RSL LUB.D.164 | Dessiou JF | Lubbock JW | 18/04/1838 |
| 1172 | 80 | | RSL LUB.D.165 | Dessiou JF | Lubbock JW | 07/05/1838 |
| 1173 | 81 | | RSL LUB.D.166 | Dessiou JF | Lubbock JW | 20/07/1838 |
| 1174 | 82 | | RSL LUB.D.167 | Dessiou JF | Lubbock JW | 11/01/1839 |
| 1175 | 83 | | RSL LUB.D.168 | Dessiou JF | Lubbock JW | 23/01/1839 |
| 1176 | 84 | | RSL LUB.D.169 | Dessiou JF | | 29/12/1839 |
| 1177 | 85 | | RSL LUB.D.170 | Dessiou JF | Lubbock JW | 27/11/1851 |
| 1178 | 86 | | RSL LUB.G.36 | Gilbert D | Lubbock JW | 23/01/1830 |
| 1179 | 87 | | RSL LUB.H.8 | Hall J | Lubbock JW | 21/02/1830 |
| 1180 | 88 | | RSL LUB.H.9 | Hall J | Lubbock JW | 13/12/1833 |
| 1181 | 89 | | RSL LUB.H.11 | Hall J | Lubbock JW | 06/04/1835 |
| 1182 | 90 | | RSL LUB.H.55 | Harcourt WVV | Lubbock JW | 09/11/1831 |
| 1183 | 91 | | RSL LUB.H.56 | Harcourt WVV | Lubbock JW | 20/09/1833 |
| 1184 | 92 | | RSL LUB.J.154 | Jones J | Lubbock JW | 20/07/1835 |
| 1185 | 93 | | RSL LUB.J.155 | Jones J | Lubbock JW | 03/08/1835 |
| 1186 | 94 | | RSL LUB.J.156 | Jones J | Lubbock JW | 02/04/1836 |
| 1187 | 95 | | RSL LUB.J.157 | Jones J | Lubbock JW | 25/05/1836 |
| 1188 | 96 | | RSL LUB.J.158 | Jones J | Lubbock JW | 25/05/1836 |
| 1189 | 97 | | RSL LUB.J.159 | Jones J | Lubbock JW | 04/06/1836 |
| 1190 | 98 | | RSL LUB.J.160 | Jones J | Lubbock JW | 02/07/1836 |
| 1191 | 99 | | RSL LUB.J.161 | Jones J | Lubbock JW | 06/07/1836 |
| 1192 | 100 | | RSL LUB.J.162 | Jones J | Lubbock JW | 22/07/1836 |
| 1193 | 101 | | RSL LUB.J.163 | Jones J | Lubbock JW | 25/07/1836 |
| 1194 | 102 | | RSL LUB.J.164 | Jones J | Lubbock JW | 26/07/1836 |
| 1195 | 103 | | RSL LUB.J.165 | Jones J | Lubbock JW | 02/08/1836 |
| 1196 | 104 | | RSL LUB.J.166 | Jones J | Lubbock JW | 05/08/1836 |
| 1197 | 105 | | RSL LUB.J.167 | Jones J | Lubbock JW | 12/08/1836 |
| 1198 | 106 | | RSL LUB.J.168 | Jones J | Lubbock JW | 13/08/1836 |
| 1199 | 107 | | RSL LUB.J.169 | Jones J | Lubbock JW | 21/11/1836 |
| 1200 | 108 | | RSL LUB.J.170 | Jones J | Lubbock JW | 03/01/1837 |

| | | | Document | From | To | Date |
|---|---|---|---|---|---|---|
| 1201 | 109 | | RSL LUB.J.171 | Jones J | Lubbock JW | 01/04/1837 |
| 1202 | 110 | | RSL LUB.J.172 | Jones J | Lubbock JW | 04/04/1837 |
| 1203 | 111 | | RSL LUB.J.173 | Jones J | Lubbock JW | 05/04/1837 |
| 1204 | 112 | | RSL LUB.J.174 | Jones J | Lubbock JW | 18/08/1837 |
| 1205 | 113 | | RSL LUB.J.175 | Jones J | Lubbock JW | 22/08/1837 |
| 1206 | 114 | | RSL LUB.J.176 | Jones J | Lubbock JW | 16/10/1837 |
| 1207 | 115 | | RSL LUB.J.177 | Jones J | Lubbock JW | 12/03/1838 |
| 1208 | 116 | | RSL LUB.J.178 | Jones J | Lubbock JW | 15/03/1838 |
| 1209 | 117 | | RSL LUB.J.179 | Jones J | Lubbock JW | 30/10/1838 |
| 1210 | 118 | | RSL LUB.J.181 | Jones Jo | Lubbock JW | 06/09/1839 |
| 1211 | 119 | | RSL LUB.K.2 | Kater H | Lubbock JW | 30/10/1828 |
| 1212 | 120 | | RSL LUB.I.8 | Innes G | Lubbock JW | 17/04/1830 |
| 1213 | 121 | | RSL LUB.I.9 | Innes G | Lubbock JW | 15/02/1832 |
| 1214 | 122 | | RSL LUB.I.10 | Innes G | Lubbock JW | 03/03/1832 |
| 1215 | 123 | | RSL LUB.I.11 | Innes G | Lubbock JW | 22/12/1832 |
| 1216 | 124 | | RSL LUB.I.13 | Innes G | Lubbock JW | 21/05/1833 |
| 1217 | 125 | | RSL LUB.I.15 | Innes G | Lubbock JW | 10/07/1835 |
| 1218 | 126 | | RSL LUB.I.16 | Innes G | Lubbock JW | 22/02/1836 |
| 1219 | 127 | | RSL LUB.I.18 | Innes G | Lubbock JW | 08/04/1837 |
| 1220 | 128 | | RSL LUB.L.272 | Lloyd JA | Lubbock JW | 22/01/1830 |
| 1221 | 129 | | RSL LUB.L.273 | Lloyd JA | Lubbock JW | |
| 1222 | 130 | | RSL LUB.P.30 | Palmer HR | Lubbock JW | 10/02/1831 |
| 1223 | 131 | | RSL LUB.P.32 | Palmer HR | Lubbock JW | 07/11/1831 |
| 1224 | 132 | | RSL LUB.P.32 | Palmer HR | Lubbock JW | 10/11/1831 |
| 1225 | 133 | | RSL LUB.P.117 | Peirce W | Lubbock JW | 24/02/1831 |
| 1226 | 134 | | RSL LUB.P.118 | Peirce W | Lubbock JW | 07/03/1831 |
| 1227 | 135 | | RSL LUB.P.119 | Peirce W | Lubbock JW | 13/03/1831 |
| 1228 | 136 | | RSL LUB.P.120 | Peirce W | Lubbock JW | 30/10/1833 |
| 1229 | 137 | | RSL LUB.P.121 | Peirce W | Lubbock JW | 06/11/1833 |
| 1230 | 138 | | RSL LUB.P.122 | Peirce W | Lubbock JW | 23/12/1833 |
| 1231 | 139 | | RSL LUB.P.123 | Peirce W | Lubbock JW | 28/12/1835 |
| 1232 | 140 | | RSL LUB.P.124 | Peirce W | Lubbock JW | |
| 1233 | 141 | | RSL LUB.R.15 | Rennie G | Lubbock JW | 09/04/1835 |
| 1234 | 142 | | RSL LUB.R.114 | Roget PM | Lubbock JW | 31/08/1831 |
| 1235 | 143 | | RSL LUB.P.114a | Elliot GE | Barrow J | 29/08/1831 |
| 1236 | 144 | | RSL LUB.R.173 | Ross D | Lubbock JW | |
| 1237 | 145 | | RSL LUB.R.329 | Russell E | Lubbock JW | 18/11/1835 |
| 1238 | 146 | | RSL LUB.R.331 | Russell E | Lubbock JW | 30/07/1836 |
| 1239 | 147 | | RSL LUB.R.332 | Russell E | Lubbock JW | 08/08/1836 |
| 1240 | 148 | | RSL LUB.R.333 | Russell E | Jones J | |
| 1241 | 149 | | RSL LUB.R.334 | Russell E | Jones J | |
| 1242 | 150 | | RSL LUB.R.335 | Russell E | Lubbock JW | |
| 1243 | 151 | | RSL LUB.R.336 | Russell E | Lubbock JW | |

| | | | Document | From | To | Date |
|---|---|---|---|---|---|---|
| 1244 | 152 | | RSL LUB.R.337 | Russell E | Lubbock JW | 08/03/1837 |
| 1245 | 153 | | RSL LUB.R.338 | Russell E | Lubbock JW | 28/07/1837 |
| 1246 | 154 | | RSL LUB.R.339 | Russell E | Lubbock JW | |
| 1247 | 155 | | RSL LUB.R.340 | Russell E | Lubbock JW | |
| 1248 | 156 | | RSL LUB.R.381 | Russell JS | Lubbock JW | 24/08/1836 |
| 1249 | 157 | | RSL LUB.R.382 | Russell JS | Lubbock JW | 01/06/1837 |
| 1250 | 158 | | RSL LUB.R.383 | Russell JS | Lubbock JW | 24/06/1837 |
| 1251 | 159 | | RSL LUB.R.384 | Russell E | Lubbock JW | 20/03/1839 |
| 1252 | 160 | | RSL LUB.S.107 | Sheepshanks R | Lubbock JW | |
| 1253 | 161 | | RSL LUB.S.273 | Solly I | Lubbock JW | 07/05/1829 |
| 1254 | 162 | | RSL LUB.S.274 | Solly I | Lubbock JW | 06/11/1829 |
| 1255 | 163 | | RSL LUB.S.275 | Solly I | Lubbock JW | 14/06/1831 |
| 1256 | 164 | | RSL LUB.S.276 | Solly I | Lubbock JW | 16/12/1831 |
| 1257 | 165 | | RSL LUB.S.475 | Stratford WS | Lubbock JW | 08/06/1831 |
| 1258 | 166 | | RSL LUB.S.480 | Stratford WS | Lubbock JW | 10/03/1832 |
| 1259 | 167 | | RSL LUB.S.483 | Stratford WS | Lubbock JW | 04/04/1832 |
| 1260 | 168 | | RSL LUB.S.484 | Stratford WS | Lubbock JW | 06/04/1832 |
| 1261 | 169 | | RSL LUB.S.486 | Stratford WS | Lubbock JW | 04/05/1832 |
| 1262 | 170 | | RSL LUB.S.487 | Stratford WS | Lubbock JW | 15/05/1832 |
| 1263 | 171 | | RSL LUB.S.488 | Stratford WS | Lubbock JW | 31/05/1832 |
| 1264 | 172 | | RSL LUB.S.490 | Stratford WS | Lubbock JW | 09/06/1832 |
| 1265 | 173 | | RSL LUB.S.494 | Stratford WS | Lubbock JW | 28/05/1832 |
| 1266 | 174 | | RSL LUB.S.495 | Stratford WS | Lubbock JW | 20/06/1833 |
| 1267 | 175 | | RSL LUB.S.497 | Stratford WS | Lubbock JW | 24/10/1833 |
| 1268 | 176 | | RSL LUB.S.498 | Stratford WS | Lubbock JW | 02/12/1833 |
| 1269 | 177 | | RSL LUB.S.501 | Stratford WS | Lubbock JW | 20/12/1833 |
| 1270 | 178 | | RSL LUB.S.502 | Stratford WS | Lubbock JW | 23/12/1833 |
| 1271 | 179 | | RSL LUB.S.503 | Stratford WS | Lubbock JW | 24/12/1833 |
| 1272 | 180 | | RSL LUB.S.507 | Stratford WS | Lubbock JW | 22/04/1834 |
| 1273 | 181 | | RSL LUB.S.508 | Stratford WS | Lubbock JW | 14/05/1834 |
| 1274 | 182 | | RSL LUB.S.509 | Stratford WS | Lubbock JW | 23/06/1834 |
| 1275 | 183 | | RSL LUB.S.510 | Stratford WS | Lubbock JW | 21/08/1834 |
| 1276 | 184 | | RSL LUB.S.511 | Stratford WS | Lubbock JW | 04/11/1834 |
| 1277 | 185 | | RSL LUB.S.512 | Stratford WS | Lubbock JW | 10/03/1835 |
| 1278 | 186 | | RSL LUB.S.516 | Stratford WS | Lubbock JW | 01/06/1835 |
| 1279 | 187 | | RSL LUB.S.518 | Stratford WS | Lubbock JW | 09/07/1835 |
| 1280 | 188 | | RSL LUB.S.519 | Stratford WS | Lubbock JW | 24/08/1835 |
| 1281 | 189 | | RSL LUB.S.520 | Stratford WS | Lubbock JW | 24/09/1835 |
| 1282 | 190 | | RSL LUB.S.521 | Stratford WS | Lubbock JW | 16/10/1835 |
| 1283 | 191 | | RSL LUB.S.522 | Stratford WS | Lubbock JW | 23/10/1835 |
| 1284 | 192 | | RSL LUB.S.526 | Stratford WS | Lubbock JW | 09/05/1836 |
| 1285 | 193 | | RSL LUB.S.527 | Stratford WS | Lubbock JW | 27/03/1837 |
| 1286 | 194 | | RSL LUB.S.530 | Stratford WS | Lubbock JW | 14/10/1840 |

| | | | Document | From | To | Date |
|---|---|---|---|---|---|---|
| 1287 | 195 | | RSL LUB.S.531 | Stratford WS | Lubbock JW | 16/01/1841 |
| 1288 | 196 | | RSL LUB.S.532 | Stratford WS | Lubbock JW | 20/01/1841 |
| 1289 | 197 | | RSL LUB.S.533 | Stratford WS | Lubbock JW | 24/01/1841 |
| 1290 | 198 | | RSL LUB.S.534 | Stratford WS | Lubbock JW | 15/04/1841 |
| 1291 | 199 | | RSL LUB.W.163 | Washington J | Lubbock JW | 08/11/1831 |
| 1292 | 200 | | RSL LUB.W.250 | Whewell W | Lubbock JW | 17/11/1829 |
| 1293 | 201 | | RSL LUB.W.253 | Whewell W | Lubbock JW | 24/05/1830 |
| 1294 | 202 | | RSL LUB.W.254 | Whewell W | Lubbock JW | 23/01/1830 |
| 1295 | 203 | | RSL LUB.W.255 | Whewell W | Lubbock JW | 30/01/1831 |
| 1296 | 204 | | RSL LUB.W.264 | Whewell W | Lubbock JW | 06/07/1832 |
| 1297 | 205 | | RSL LUB.W.267 | Whewell W | Lubbock JW | 03/02/1832 |
| 1298 | 206 | | RSL LUB.W.269 | Whewell W | Lubbock JW | 06/06/1832 |
| 1299 | 207 | | RSL LUB.W.271 | Whewell W | Lubbock JW | 07/07/1833 |
| 1300 | 208 | | RSL LUB.W.272 | Whewell W | Lubbock JW | 27/07/1833 |
| 1301 | 209 | | RSL LUB.W.273 | Whewell W | Lubbock JW | 02/08/1833 |
| 1302 | 210 | | RSL LUB.W.274 | Whewell W | Lubbock JW | 22/09/1833 |
| 1303 | 211 | | RSL LUB.W.275 | Whewell W | Lubbock JW | 13/10/1833 |
| 1304 | 212 | | RSL LUB.W.276 | Whewell W | Lubbock JW | 18/10/1833 |
| 1305 | 213 | | RSL LUB.W.277 | Whewell W | Lubbock JW | 31/10/1833 |
| 1306 | 214 | | RSL LUB.W.278 | Whewell W | Lubbock JW | 07/11/1833 |
| 1307 | 215 | | RSL LUB.W.279 | Whewell W | Lubbock JW | 11/11/1833 |
| 1308 | 216 | | RSL LUB.W.281 | Whewell W | Lubbock JW | 15/11/1833 |
| 1309 | 217 | | RSL LUB.W.282 | Whewell W | Lubbock JW | 19/11/1833 |
| 1310 | 218 | | RSL LUB.W.283a | Whewell W | Stratford WS | 22/11/1833 |
| 1311 | 219 | | RSL LUB W.283b | Whewell W | Lubbock JW | 10/12/1833 |
| 1312 | 220 | | RSL LUB.W.284 | Whewell W | Lubbock JW | 10/12/1833 |
| 1313 | 221 | | RSL LUB.W.286 | Whewell W | Lubbock JW | 04/08/1834 |
| 1314 | 222 | | RSL LUB.W.287 | Whewell W | Lubbock JW | 07/09/1834 |
| 1315 | 223 | | RSL LUB.W.288 | Whewell W | Lubbock JW | 24/09/1834 |
| 1316 | 224 | | RSL LUB.W.289 | Whewell W | Lubbock JW | 11/11/1834 |
| 1317 | 225 | | RSL LUB.W.290 | Whewell W | Lubbock JW | 13/04/1835 |
| 1318 | 226 | | RSL LUB.W.291 | Whewell W | Lubbock JW | 22/04/1835 |
| 1319 | 227 | | RSL LUB.W.292 | Whewell W | Lubbock JW | 01/05/1835 |
| 1320 | 228 | | RSL LUB.W.293 | Whewell W | Lubbock JW | 26/09/1835 |
| 1321 | 229 | | RSL LUB.W.294 | Whewell W | Lubbock JW | 10/10/1835 |
| 1322 | 230 | | RSL LUB.W.295 | Whewell W | Lubbock JW | 20/10/1835 |
| 1323 | 231 | | RSL LUB.W.296 | Whewell W | Lubbock JW | 10/11/1835 |
| 1324 | 232 | | RSL LUB.W.297 | Whewell W | Lubbock JW | 13/11/1835 |
| 1325 | 233 | | RSL LUB.W.298 | Whewell W | Lubbock JW | 01/04/1837 |
| 1326 | 234 | | RSL LUB.W.299 | Whewell W | Lubbock JW | 25/06/1837 |
| 1327 | 235 | | RSL LUB.W.300 | Whewell W | Lubbock JW | 27/05/1838 |
| 1328 | 236 | | RSL LUB.W.301 | Whewell W | Lubbock JW | 02/02/1839 |
| 1329 | 237 | | RSL LUB.W.302 | Whewell W | Lubbock JW | 19/02/1839 |

| | | | Document | From | To | Date |
|---|---|---|---|---|---|---|
| 1330 | 238 | | RSL LUB.W.303 | Whewell W | Lubbock JW | 08/05/1839 |
| 1331 | 239 | | RSL LUB.W.309 | Whewell W | Lubbock JW | 07/07/1840 |
| 1332 | 240 | | RSL LUB.W.319 | Whewell W | Lubbock JW | |
| 1333 | 241 | | RSL LUB.Y.2 | Yates J | Lubbock JW | 21/01/1837 |
| 1334 | 242 | | RSL LUB.Y.4 | Yates JB | Dessiou JF | 19/08/1833 |
| 1335 | 243 | | RSL LUB.Y.5 | Yates JB | Dessiou JF | 11/11/1833 |
| 1336 | 244 | | RSL LUB.Y.6 | Yates JB | Dessiou JF | 24/09/1835 |
| 1337 | 1 | | Durban | Darwin GH | Neison E | 28/10/1884 |
| 1338 | 2 | | StA Forbes 1832 | Scoresby W | Forbes JD | 27/02/1832 |
| 1339 | 3 | | StA Forbes 1835 | Whewell W | Forbes JD | 08/12/1835 |
| 1340 | 4 | | StA Forbes LBII | Forbes JD | Whewell W | 07/01/1836 |
| 1341 | 5 | | Roorkee | Baird AW | Hennessey JBN | 04/12/1883 |
| 1342 | 6 | | NaMag | Beaufort F | | 20/03/1832 |
| 1343 | 7 | | Exeter | Thomson W | Lockyer JN | 10/01/1877 |
| 1344 | 8 | | BOD Dep BAAS 1/62 | Beaufort F | B.A.A.S. | 17/08/1831 |
| 1345 | 9 | | BOD Dep BAAS 60/38 | Page F | Giles F | 28/11/1833 |
| 1346 | 10 | | BOD Dep BAAS 60/41 | Giles G | Greenhough GB | 16/12/1833 |
| 1347 | 11 | | BOD Dep BAAS 60/50 | Evans FJ | B.A.A.S. | 28/04/1834 |
| 1348 | 12 | | HHL AAH 67m67 95 | Martin KB | Herschel JFW | 25/06/1857 |
| 1349 | 13 | | CUL CSI LB 1899.772 | Whipple RS | Darwin GH | 27/06/1899 |
| 1350 | 14 | | BMV HB 17.387 | Hendersdon VF | B.M.V. | 20/04/1836 |
| 1351 | 15 | | BMV HB 17.403 | Bunt TG | B.M.V. | 24/06/1836 |
| 1352 | 16 | | BMV HB 18.243 | Carpenter L | B.M.V. | 12/10/1838 |
| 1353 | 17 | | BMV HB 18.346 | Bunt TG | B.M.V. | 12/07/1839 |
| 1354 | 18 | | NMM MS.75.085 | Bunt TG | Bennett JJ | 03/02/1838 |
| 1355 | 19 | | Whitby | Holden M | Scoresby W | 06/11/1832 |
| 1356 | 20 | | BAO BIA 32079/1 | Bright S | Stutchbury S | 26/06/1837 |
| 1357 | 21 | | BAO BIA 32079/2 | Bright S | Stutchbury S | |
| 1358 | 22 | | BAO BIA 32079/3 | Bright R | Stutchbury S | 04/07/1836 |
| 1359 | 23 | | BAO BIA 32079/4 | Bright R | Stutchbury S | |
| 1360 | 24 | | BAO BIA 32079/5 | Bright R | Stutchbury S | 15/08/1837 |
| 1361 | 25 | | BAO BIA 32079/6 | Bright R | Stutchbury S | 16/12/1836 |
| 1362 | 26 | | BAO BIA 32079/7 | Bright R | Stutchbury S | 29/09/1835 |
| 1363 | 27 | | LRO 027 LYC 1/1/5 | Whewell W | Bennett TF | 31/10/1833 |
| 1364 | 28 | | BAAS 1840 | Bunt TG | Whewell W | 27/01/1840 |
| 1365 | 29 | | BAAS 1870 1 | Hilgard JE | Roberts E | 12/08/1870 |
| 1366 | 30 | | BAAS 1870 2 | Roberts E | Thomson W | 09/09/1870 |
| 1367 | 31 | | Thompson 619 | Thomson W | Gladstone | 04/11/1871 |
| 1368 | 32 | | The Times | Airy GB | The Times | 21/09/1869 |
| 1369 | 33 | | PRO ADM 106 3523 1 | Slade T | | 13/04/1761 |
| 1370 | 34 | | PRO ADM 106 3523 2 | Turner J | | 11/01/1759 |
| 1371 | 35 | | Wilson 1 | Thomson W | Stokes GG | 04/07/1879 |
| 1372 | 36 | | Wilson 2 | Thomson W | Stokes GG | 09/07/1879 |

| | | | Document | From | To | Date |
|---|---|---|---|---|---|---|
| 1373 | 37 | | Wilson 3 | Thomson W | Stokes GG | 09/07/1879 |
| 1374 | 1 | | Tri Add a.63.18 | Phillips J | Whewell W | 17/11/1834 |
| 1375 | 2 | | Tri Add a.63.19a | Weld CR | Whewell W | 17/11/1832 |
| 1376 | 3 | | Tri Add a.67.24 | Darwin GH | | 17/05/1896 |
| 1377 | 4 | | Tri Add a.80.71 | Beechey FW | Lubbock JW | |
| 1378 | 5 | | Tri Add a.200.26 | Airy GB | Whewell W | 24/11/1839 |
| 1379 | 6 | | Tri Add a.200.31 | Airy GB | Whewell W | 03/12/1840 |
| 1380 | 7 | | Tri Add a.200.33 | Airy GB | Whewell W | 05/12/1840 |
| 1381 | 8 | | Tri Add a.200.35 | Airy GB | Whewell W | 21/01/1840 |
| 1382 | 9 | | Tri Add a.200.36 | Airy GB | Whewell W | 27/01/1841 |
| 1383 | 10 | | Tri Add a.200.40 | Airy GB | Whewell W | 12/01/1842 |
| 1384 | 11 | | Tri Add a.200.42 | Airy GB | Whewell W | 27/02/1842 |
| 1385 | 12 | | Tri Add a.200.47 | Airy GB | Whewell W | 03/01/1843 |
| 1386 | 13 | | Tri Add a.200.48 | Airy GB | Whewell W | 14/02/1843 |
| 1387 | 14 | | Tri Add a.200.49 | Airy GB | Whewell W | 24/02/1843 |
| 1388 | 15 | | Tri Add a.200.50 | Airy GB | Whewell W | 06/03/1843 |
| 1389 | 16 | | Tri Add a.200.51 | Airy GB | Whewell W | 07/03/1843 |
| 1390 | 17 | | Tri Add a.200.52 | Airy GB | Whewell W | 27/05/1843 |
| 1391 | 18 | | Tri Add a.200.55 | Airy GB | Whewell W | 02/11/1844 |
| 1392 | 19 | | Tri Add a.200.58 | Airy GB | Whewell W | 01/03/1845 |
| 1393 | 20 | | Tri Add a.200.65 | Conybeare WD | Whewell W | 18/04/1835 |
| 1394 | 21 | | Tri Add a.200.69 | Airy GB | Whewell W | 24/10/1847 |
| 1395 | 22 | | Tri Add a.200.70 | Airy GB | Whewell W | 04/11/1847 |
| 1396 | 23 | | Tri Add a.200.77 | Airy GB | Whewell W | 31/12/1849 |
| 1397 | 24 | | Tri Add a.200.78 | Airy GB | Whewell W | 04/01/1850 |
| 1398 | 25 | | Tri Add a.200.89 | Airy GB | Whewell W | 03/02/1851 |
| 1399 | 26 | | Tri Add a.200.94 | Airy GB | Whewell W | 31/12/1851 |
| 1400 | 27 | | Tri Add a.200.96 | Airy GB | Whewell W | 17/07/1852 |
| 1401 | 28 | | Tri Add a.200.97 | Airy GB | Whewell W | 15/03/1852 |
| 1402 | 29 | | Tri Add a.200.98 | Airy GB | Whewell W | 18/03/1852 |
| 1403 | 30 | | Tri Add a.200.99 | Airy GB | Whewell W | 26/03/1852 |
| 1404 | 31 | | Tri Add a.200.100 | Airy GB | Whewell W | 07/04/1852 |
| 1405 | 32 | | Tri Add a.200.102 | Airy GB | Whewell W | 28/09/1852 |
| 1406 | 33 | | Tri Add a.200.103 | Airy GB | Whewell W | 10/11/1852 |
| 1407 | 34 | | Tri Add a.200.195 | Bache AD | Whewell W | 29/10/1834 |
| 1408 | 35 | | Tri Add a.200.197 | Bache AD | Whewell W | 04/06/1852 |
| 1409 | 36 | | Tri Add a.200.219 | Barlow P | Whewell W | 19/02/1833 |
| 1410 | 37 | | Tri Add a.201.4 | Bayley J | Rowdley J | 17/11/1834 |
| 1411 | 38 | | Tri Add a.201.7 | Beaufort F | Whewell W | 17/11/1832 |
| 1412 | 39 | | Tri Add a.201.8 | Beaufort F | Whewell W | 02/01/1836 |
| 1413 | 40 | | Tri Add a.201.9 | Beaufort F | Whewell W | 13/02/1843 |
| 1414 | 41 | | Tri Add a.201.10 | Beaufort F | Whewell W | 22/11/1844 |
| 1415 | 42 | | Tri Add a.201.11 | Beaufort F | Whewell W | 26/02/1846 |

| | | | Document | From | To | Date |
|---|---|---|---|---|---|---|
| 1416 | 43 | | Tri Add a.201.12 | Beaufort F | Whewell W | 26/01/1850 |
| 1417 | 44 | | Tri Add a.201.13 | Beaufort F | | 09/11/1852 |
| 1418 | 45 | | Tri Add a.201.59 | Bowditch NL | Whewell W | 27/09/1838 |
| 1419 | 46 | | Tri Add a.201.106 | Bronwin B | Whewell W | 13/11/1852 |
| 1420 | 47 | | Tri Add a.201.123 | Bunt TG | Whewell W | 26/07/1847 |
| 1421 | 48 | | Tri Add a.201.127 | Barrow J | Lubbock JW | |
| 1422 | 49 | | Tri Add a.201.130 | Bushey M | Whewell W | 05/05/1845 |
| 1423 | 50 | | Tri Add a.202.20 | Challis J | Whewell W | 05/12/1839 |
| 1424 | 51 | | Tri Add a.203.164 | Fitzroy R | Whewell W | 31/12/1837 |
| 1425 | 52 | | Tri Add a.203.165 | Fitzroy R | Whewell W | 06/09/1837 |
| 1426 | 53 | | Tri Add a.204.4 | Forbes JD | Whewell W | 04/10/1831 |
| 1427 | 54 | | Tri Add a.204.21 | Forbes JD | Whewell W | 26/06/1835 |
| 1428 | 55 | | Tri Add a.204.24b | Forbes JD | Whewell W | 12/11/1835 |
| 1429 | 56 | | Tri Add a.204.25 | Forbes JD | Whewell W | 07/01/1836 |
| 1430 | 57 | | Tri Add a.204.27 | Forbes JD | Whewell W | 10/03/1836 |
| 1431 | 58 | | Tri Add a.205.40 | Greenough GB | Whewell W | 23/02/1834 |
| 1432 | 59 | | Tri Add a.205.81 | Hall B | Whewell W | 07/12/1839 |
| 1433 | 60 | | Tri Add a.205.82 | Hall B | Whewell W | 29/01/1842 |
| 1434 | 61 | | Tri Add a.205.158 | Harris WS | Whewell W | 03/01/1849 |
| 1435 | 62 | | Tri Add a.206.60 | Hendersdon VF | Whewell W | 20/01/1832 |
| 1436 | 63 | | Tri Add a.207.23 | Herschel JFW | Whewell W | 25/01/1834 |
| 1437 | 64 | | Tri Add a.207.24 | Herschel JFW | Whewell W | 21/09/1834 |
| 1438 | 65 | | Tri Add a.207.25 | Herschel JFW | Whewell W | 07/02/1835 |
| 1439 | 66 | | Tri Add a.207.27 | Herschel JFW | Whewell W | 04/07/1835 |
| 1440 | 67 | | Tri Add a.207.28 | Herschel JFW | Whewell W | 25/07/1835 |
| 1441 | 68 | | Tri Add a.207.29 | Herschel JFW | Whewell W | 23/07/1837 |
| 1442 | 69 | | Tri Add a.207.71 | Herschel JFW | Whewell W | 23/12/1847 |
| 1443 | 70 | | Tri Add a.208.18 | Le Bas CW | Whewell W | 26/03/1840 |
| 1444 | 71 | | Tri Add a.208.27 | Lendbetter J | Whewell W | 28/01/1834 |
| 1445 | 71 | | Tri Add a.208.59 | Lloyd H | Whewell W | 05/04/1852 |
| 1446 | 73 | | Tri Add a.208.61 | Lloyd JA | Whewell W | |
| 1447 | 74 | | Tri Add a.208.68 | Lomart MF | Whewell W | 10/05/1847 |
| 1448 | 75 | | Tri Add a.208.70 | Lowrie WH | Whewell W | 25/06/1859 |
| 1449 | 76 | | Tri Add a.208.75 | Lubbock JW | Whewell W | |
| 1450 | 77 | | Tri Add a.208.77 | Lubbock JW | Whewell W | 28/10/1829 |
| 1451 | 78 | | Tri Add a.208.78 | Lubbock JW | Whewell W | 13/03/1831 |
| 1452 | 79 | | Tri Add a.208.79 | Lubbock JW | Whewell W | 17/03/1831 |
| 1453 | 80 | | Tri Add a.208.80 | Lubbock JW | Whewell W | |
| 1454 | 81 | | Tri Add a.208.82 | Lubbock JW | Whewell W | 15/10/1831 |
| 1455 | 82 | | Tri Add a.208.86 | Lubbock JW | Whewell W | 02/04/1832 |
| 1456 | 83 | | Tri Add a.208.87 | Lubbock JW | Whewell W | 03/04/1832 |
| 1457 | 84 | | Tri Add a.208.88 | Lubbock JW | Whewell W | 07/05/1832 |
| 1458 | 85 | | Tri Add a.208.90 | Lubbock JW | Whewell W | 29/06/1832 |

| | | | Document | From | To | Date |
|---|---|---|---|---|---|---|
| 1459 | 86 | | Tri Add a.208.91 | Lubbock JW | Whewell W | |
| 1460 | 87 | | Tri Add a.208.92 | Lubbock JW | Whewell W | 09/09/1832 |
| 1461 | 88 | | Tri Add a.208.93 | Lubbock JW | Whewell W | 23/04/1835 |
| 1462 | 89 | | Tri Add a.208.95 | Lubbock JW | Whewell W | 18/02/1839 |
| 1463 | 90 | | Tri Add a.208.96 | Lubbock JW | Whewell W | 17/06/1840 |
| 1464 | 91 | | Tri Add a.208.128 | Lyell C | Whewell W | 07/03/1837 |
| 1465 | 92 | | Tri Add a.209.66 | Moll G | Whewell W | 14/04/1835 |
| 1466 | 93 | | Tri Add a.209.67 | Moll G | Whewell W | 04/06/1835 |
| 1467 | 94 | | Tri Add a.209.68 | Moll G | Whewell W | 25/03/1837 |
| 1468 | 95 | | Tri Add a.209.69 | Moll G | Whewell W | 26/09/1837 |
| 1469 | 96 | | Tri Add a.211.148 | Ross D | Whewell W | 22/10/1847 |
| 1470 | 97 | | Tri Add a.211.149 | Ross D | Whewell W | 01/01/1850 |
| 1471 | 98 | | Tri Add a.211.150 | Ross JC | Whewell W | 17/06/1847 |
| 1472 | 99 | | Tri Add a.211.150a | Ross JC | Whewell W | 21/04/1852 |
| 1473 | 100 | | Tri Add a.212.118 | Smyth WH | Whewell W | 27/10/1835 |
| 1474 | 101 | | Tri Add a.212.119 | Smyth WH | Whewell W | 07/04/1837 |
| 1475 | 102 | | Tri Add a.212 148a | Pearson J | Whewell W | 07/10/1820 |
| 1476 | 103 | | Tri Add a.212.148 | Stanley O | Whewell W | 20/02/1848 |
| 1477 | 104 | | Tri Add a.212.149 | Stanley O | Whewell W | 24/05/1849 |
| 1478 | 105 | | Tri Add a.212.167 | Stutchbury S | Whewell W | 20/08/1834 |
| 1479 | 106 | | Tri Add a.214.36 | Washington J | Whewell W | 20/07/1847 |
| 1480 | 107 | | Tri Add a.214.52 | Whewell W | Lubbock JW | 05/06/1832 |
| 1481 | 108 | | Tri Add a.214.53 | Whewell W | Lubbock JW | 09/01/1833 |
| 1482 | 109 | | Tri Add c.51.159 | Whewell W | Jones J | 13/11/1833 |
| 1483 | 110 | | Tri Add c.51.167 | Whewell W | Jones J | 03/06/1834 |
| 1484 | 111 | | Tri Add c.66.32 | Ross JC | Washington J | 29/03/1837 |
| 1485 | 112 | | Tri Add c.90.81 | Ross JC | Whewell W | 12/06/1852 |
| 1486 | 113 | | Tri Add c.90.101 | Scoresby W | Whewell W | |
| 1487 | 114 | | Tri Add O.15.47.183 | Whewell W | Lubbock JW | 07/12/1829 |
| 1488 | 115 | | Tri Add O.15.47.184 | Whewell W | Lubbock JW | 04/05/1830 |
| 1489 | 116 | | Tri Add O.15.47.185.2 | Whewell W | Lubbock JW | 12/11/1831 |
| 1490 | 117 | | Tri Add O.15.47.204b | Whewell W | Lubbock JW | 20/10/1833 |
| 1491 | 1 | | UCL SDUK BUN.1 | Bunt TG | Coates T | 24/06/1842 |
| 1492 | 2 | | UCL SDUK DES.1 | Dessiou JF | Knight C | 29/11/1832 |
| 1493 | 3 | | UCL SDUK DES.2 | Dessiou JF | Coates T | 16/04/1833 |
| 1494 | 4 | | UCL SDUK DES.3 | Dessiou JF | Lubbock JW | 25/04/1833 |
| 1495 | 5 | | UCL SDUK LUB.1 | Lubbock JW | Coates T | |
| 1496 | 6 | | UCL SDUK LUB.2 | Lubbock JW | Coates T | 04/11/1829 |
| 1497 | 7 | | UCL SDUK LUB.3 | Lubbock JW | Coates T | 03/12/1829 |
| 1498 | 8 | | UCL SDUK LUB.4 | Lubbock JW | Coates T | |
| 1499 | 9 | | UCL SDUK LUB.5 | Lubbock JW | Wrottesley J | |
| 1500 | 10 | | UCL SDUK LUB.6 | Lubbock JW | Coates T | |
| 1501 | 11 | | UCL SDUK LUB.7 | Lubbock JW | Coates T | |

| | | | Document | From | To | Date |
|---|---|---|---|---|---|---|
| 1502 | 12 | | UCL SDUK LUB.8 | Lubbock JW | Coates T | |
| 1503 | 13 | | UCL SDUK LUB.9 | Lubbock JW | Coates T | 22/02/1832 |
| 1504 | 14 | | UCL SDUK LUB.10 | Lubbock JW | Coates T | 18/05/1833 |
| 1505 | 15 | | UCL SDUK LUB.11 | Coates T | Lubbock JW | 23/04/1833 |
| 1506 | 16 | | UCL SDUK LUB.12 | Beaufort F | Lubbock JW | 12/11/1833 |
| 1507 | 17 | | UCL SDUK LUB.13 | Lubbock JW | Coates T | 13/11/1833 |
| 1508 | 18 | | UCL SDUK LUB.14 | Lubbock JW | Coates T | 01/11/1833 |
| 1509 | 19 | | UCL SDUK LUB.15 | Pond J | Lubbock JW | 07/02/1831 |
| 1510 | 20 | | UCL SDUK LUB.16 | Lubbock JW | | |
| 1511 | 21 | | UCL SDUK LUB.17 | Lubbock JW | Coates T | 15/04/1833 |
| 1512 | 22 | | UCL SDUK LUB.18 | Lubbock JW | Coates T | 19/04/1833 |
| 1513 | 23 | | UCL SDUK LUB.19 | Lubbock JW | Coates T | |
| 1514 | 24 | | UCL SDUK LUB.20 | Lubbock JW | Coates T | |
| 1515 | 25 | | UCL SDUK LUB.21 | Lubbock JW | Coates T | 05/11/1833 |
| 1516 | 26 | | UCL SDUK LUB.22 | Beaufort F | Lubbock JW | 05/11/1833 |
| 1517 | 27 | | UCL SDUK LUB.23 | Stratford WS | Beaufort F | 04/11/1833 |
| 1518 | 28 | | UCL SDUK LUB.24 | Dessiou JF | Coates T | |
| 1519 | 29 | | UCL SDUK LUB.25 | Lubbock JW | Coates T | 14/12/1838 |
| 1520 | 1 | | Tri Whe R.6.20.43 | Acland AH | Whewell W | 06/11/1839 |
| 1521 | 2 | | Tri Whe R.6.20.44 | Acland AH | Whewell W | 17/01/1841 |
| 1522 | 3 | | Tri Whe R.6.20.45 | Airy GB | Whewell W | 23/01/1833 |
| 1523 | 4 | | Tri Whe R.6.20.46 | Airy GB | Whewell W | 09/03/1840 |
| 1524 | 5 | | Tri Whe R.6.20.47 | Airy GB | Whewell W | 09/02/1847 |
| 1525 | 6 | | Tri Whe R.6.20.48 | Alderson J | Whewell W | |
| 1526 | 7 | | Tri Whe R.6.20.49 | Andrews T | Whewell W | 02/01/1850 |
| 1527 | 8 | | Tri Whe R.6.20.50 | Bache AD | Whewell W | 08/12/1833 |
| 1528 | 9 | | Tri Whe R.6.20.51 | Bache AD | Whewell W | 01/05/1834 |
| 1529 | 10 | | Tri Whe R.6.20.52 | Bache AD | Whewell W | 17/07/1834 |
| 1530 | 11 | | Tri Whe R.6.20.53 | Bache AD | Herschel JFW | 13/08/1852 |
| 1531 | 12 | | Tri Whe R.6.20.54 | Bache AD | Whewell W | |
| 1532 | 13 | | Tri Whe R.6.20.55 | Bache AD | AAAS | |
| 1533 | 14 | | Tri Whe R.6.20.56 | Baily F | Whewell W | 14/09/1836 |
| 1534 | 15 | | Tri Whe R.6.20.57 | Barrow J | Whewell W | 18/09/1839 |
| 1535 | 16 | | Tri Whe R.6.20.58 | Barrow J | Whewell W | |
| 1536 | 17 | | Tri Whe R.6.20.59 | Basset J | Whewell W | 29/06/1836 |
| 1537 | 18 | | Tri Whe R.6.20.60 | Bayfield HW | Whewell W | 09/01/1843 |
| 1538 | 19 | | Tri Whe R.6.20.61 | Becher AB | Whewell W | 22/10/1832 |
| 1539 | 20 | | Tri Whe R.6.20.62 | Becher AB | Whewell W | 24/09/1833 |
| 1540 | 21 | | Tri Whe R.6.20.63 | Becher AB | Whewell W | 14/11/1836 |
| 1541 | 22 | | Tri Whe R.6.20.64 | Becher AB | Whewell W | 23/03/1833 |
| 1542 | 23 | | Tri Whe R.6.20.65 | Beaufort F | Whewell W | 25/03/1833 |
| 1543 | 24 | | Tri Whe R.6.20.66 | Beaufort F | Whewell W | 13/04/1833 |
| 1544 | 25 | | Tri Whe R.6.20.67 | Beaufort F | Whewell W | 11/06/1833 |

| | | | Document | From | To | Date |
|---|---|---|---|---|---|---|
| 1545 | 26 | | Tri Whe R.6.20.68 | Beaufort F | Whewell W | 05/04/1836 |
| 1546 | 27 | | Tri Whe R.6.20.69 | Beaufort F | Whewell W | 19/08/1847 |
| 1547 | 28 | | Tri Whe R.6.20.70 | Beaufort F | Whewell W | 27/07/1847 |
| 1548 | 29 | | Tri Whe R.6.20.71 | Beaufort F | Whewell W | 31/08/1847 |
| 1549 | 30 | | Tri Whe R.6.20.72 | Beaufort F | Whewell W | 08/09/1847 |
| 1550 | 31 | | Tri Whe R.6.20.73 | Beaufort F | Thomson W | 11/02/1848 |
| 1551 | 32 | | Tri Whe R.6.20.74 | Beaufort F | Whewell W | 31/12/1849 |
| 1552 | 33 | | Tri Whe R.6.20.75 | Beaufort F | Whewell W | |
| 1553 | 34 | | Tri Whe R.6.20.76 | Beaufort F | Whewell W | |
| 1554 | 35 | | Tri Whe R.6.20.77 | Beautemps-Beupre | Whewell W | 27/09/1847 |
| 1555 | 36 | | Tri Whe R.6.20.78 | Belcher E | Whewell W | 26/08/1847 |
| 1556 | 37 | | Tri Whe R.6.20.79 | Belcher E | Whewell W | 15/10/1847 |
| 1557 | 38 | | Tri Whe R.6.20.80 | Bennett TF | Whewell W | 12/11/1833 |
| 1558 | 39 | | Tri Whe R.6.20.81 | Blackwood J | Whewell W | 19/08/1847 |
| 1559 | 40 | | Tri Whe R.6.20.82 | Blackwood J | Beaufort F | 20/04/1843 |
| 1560 | 41 | | Tri Whe R.6.20.83 | Braaksma H | Whewell W | 24/01/1838 |
| 1561 | 42 | | Tri Whe R.6.20.84 | Brown J | Whewell W | 04/09/1837 |
| 1562 | 43 | | Tri Whe R.6.20.85 | Bunt TG | Whewell W | 13/02/1836 |
| 1563 | 44 | | Tri Whe R.6.20.86 | Bunt TG | Whewell W | 12/10/1835 |
| 1564 | 45 | | Tri Whe R.6.20.87 | Bunt TG | Whewell W | 29/10/1835 |
| 1565 | 46 | | Tri Whe R.6.20.88 | Bunt TG | Whewell W | 30/10/1835 |
| 1566 | 47 | | Tri Whe R.6.20.89 | Bunt TG | Whewell W | 31/12/1835 |
| 1567 | 48 | | Tri Whe R.6.20.90 | Bunt TG | Whewell W | 12/01/1836 |
| 1568 | 49 | | Tri Whe R.6.20.91 | Bunt TG | Whewell W | 17/02/1836 |
| 1569 | 50 | | Tri Whe R.6.20.92 | Bunt TG | Whewell W | 30/03/1836 |
| 1570 | 51 | | Tri Whe R.6.20.93 | Bunt TG | Whewell W | 09/04/1836 |
| 1571 | 52 | | Tri Whe R.6.20.94 | Bunt TG | Whewell W | 29/04/1836 |
| 1572 | 53 | | Tri Whe R.6.20.95 | Bunt TG | Whewell W | 21/05/1836 |
| 1573 | 54 | | Tri Whe R.6.20.96 | Bunt TG | Whewell W | 06/06/1836 |
| 1574 | 55 | | Tri Whe R.6.20.97 | Bunt TG | Whewell W | 06/01/1837 |
| 1575 | 56 | | Tri Whe R.6.20.98 | Bunt TG | Whewell W | |
| 1576 | 57 | | Tri Whe R.6.20.99 | Bunt TG | Whewell W | 09/02/1837 |
| 1577 | 58 | | Tri Whe R.6.20.100 | Bunt TG | Whewell W | 18/03/1837 |
| 1578 | 59 | | Tri Whe R.6.20.101 | Bunt TG | Whewell W | 29/03/1837 |
| 1579 | 60 | | Tri Whe R.6.20.102 | Bunt TG | Whewell W | 20/04/1837 |
| 1580 | 61 | | Tri Whe R.6.20.103 | Bunt TG | Whewell W | 27/05/1837 |
| 1581 | 62 | | Tri Whe R.6.20.104 | Bunt TG | Whewell W | 11/07/1837 |
| 1582 | 63 | | Tri Whe R.6.20.105 | Bunt TG | Whewell W | 10/09/1837 |
| 1583 | 64 | | Tri Whe R.6.20.106 | Bunt TG | Whewell W | 06/10/1837 |
| 1584 | 65 | | Tri Whe R.6.20.107 | Bunt TG | Whewell W | 30/09/1837 |
| 1585 | 66 | | Tri Whe R.6.20.108 | Bunt TG | Whewell W | 15/11/1837 |
| 1586 | 67 | | Tri Whe R.6.20.109 | Bunt TG | Whewell W | 22/11/1837 |
| 1587 | 68 | | Tri Whe R.6.20.109a | Green J | Bunt TG | 14/11/1837 |

| | | | Document | From | To | Date |
|---|---|---|---|---|---|---|
| 1588 | 69 | | Tri Whe R.6.20.110 | Bunt TG | Whewell W | 10/01/1838 |
| 1589 | 70 | | Tri Whe R.6.20.111 | Bunt TG | Whewell W | 22/01/1838 |
| 1590 | 71 | | Tri Whe R.6.20.112 | Bunt TG | Whewell W | 07/02/1838 |
| 1591 | 72 | | Tri Whe R.6.20.113 | Bunt TG | Whewell W | |
| 1592 | 73 | | Tri Whe R.6.20.114 | Bunt TG | Whewell W | 10/02/1838 |
| 1593 | 74 | | Tri Whe R.6.20.115 | Bunt TG | Whewell W | 20/02/1838 |
| 1594 | 75 | | Tri Whe R.6.20.116 | Bunt TG | Whewell W | 24/02/1838 |
| 1595 | 76 | | Tri Whe R.6.20.117 | Bunt TG | Whewell W | 24/02/1838 |
| 1596 | 77 | | Tri Whe R.6.20.118 | Bunt TG | Whewell W | 08/03/1838 |
| 1597 | 78 | | Tri Whe R.6.20.119 | Bunt TG | Whewell W | 12/03/1838 |
| 1598 | 79 | | Tri Whe R.6.20.120 | Bunt TG | Whewell W | 02/04/1838 |
| 1599 | 80 | | Tri Whe R.6.20.121 | Bunt TG | Whewell W | 26/05/1838 |
| 1600 | 81 | | Tri Whe R.6.20.122 | Bunt TG | Whewell W | 25/06/1838 |
| 1601 | 82 | | Tri Whe R.6.20.123 | Bunt TG | Whewell W | 28/06/1838 |
| 1602 | 83 | | Tri Whe R.6.20.124 | Bunt TG | Whewell W | 05/10/1838 |
| 1603 | 84 | | Tri Whe R.6.20.125 | Bunt TG | Whewell W | 26/12/1838 |
| 1604 | 85 | | Tri Whe R.6.20.126 | Bunt TG | Whewell W | 03/01/1839 |
| 1605 | 86 | | Tri Whe R.6.20.127 | Bunt TG | Whewell W | |
| 1606 | 87 | | Tri Whe R.6.20.128 | Bunt TG | Whewell W | 22/02/1839 |
| 1607 | 88 | | Tri Whe R.6.20.129 | Bunt TG | Whewell W | 27/02/1839 |
| 1608 | 89 | | Tri Whe R.6.20.130 | Bunt TG | Whewell W | 27/02/1839 |
| 1609 | 90 | | Tri Whe R.6.20.131 | Bunt TG | Whewell W | |
| 1610 | 91 | | Tri Whe R.6.20.132 | Bunt TG | Whewell W | 06/05/1839 |
| 1611 | 92 | | Tri Whe R.6.20.133 | Bunt TG | Whewell W | 10/02/1840 |
| 1612 | 93 | | Tri Whe R.6.20.134 | Bunt TG | Whewell W | 09/04/1840 |
| 1613 | 94 | | Tri Whe R.6.20.135 | Bunt TG | Whewell W | 17/04/1840 |
| 1614 | 95 | | Tri Whe R.6.20.136 | Bunt TG | Whewell W | 21/07/1840 |
| 1615 | 96 | | Tri Whe R.6.20.137 | Bunt TG | Whewell W | 31/07/1840 |
| 1616 | 97 | | Tri Whe R.6.20.138 | Bunt TG | Whewell W | 02/11/1840 |
| 1617 | 98 | | Tri Whe R.6.20.139 | Bunt TG | Whewell W | 04/11/1840 |
| 1618 | 99 | | Tri Whe R.6.20.140 | Bunt TG | Whewell W | 27/11/1840 |
| 1619 | 100 | | Tri Whe R.6.20.141 | Bunt TG | Whewell W | 14/01/1841 |
| 1620 | 101 | | Tri Whe R.6.20.142 | Bunt TG | Whewell W | 09/02/1841 |
| 1621 | 102 | | Tri Whe R.6.20.143 | Bunt TG | Whewell W | 28/07/1841 |
| 1622 | 103 | | Tri Whe R.6.20.144 | Bunt TG | Whewell W | 17/09/1841 |
| 1623 | 104 | | Tri Whe R.6.20.145 | Bunt TG | Whewell W | |
| 1624 | 105 | | Tri Whe R.6.20.146 | Bywater T | Whewell W | 14/11/1835 |
| 1625 | 106 | | Tri Whe R.6.20.147 | Bywater T | Whewell W | 21/11/1835 |
| 1626 | 107 | | Tri Whe R.6.20.148 | Bywater T | Whewell W | 16/12/1835 |
| 1627 | 108 | | Tri Whe R.6.20.149 | Bywater T | Whewell W | 30/04/1836 |
| 1628 | 109 | | Tri Whe R.6.20.150 | Campbell C | Whewell W | 04/02/1833 |
| 1629 | 110 | | Tri Whe R.6.20.151 | Carne J | Whewell W | 16/01/1833 |
| 1630 | 111 | | Tri Whe R.6.20.152 | Carpenter L | Whewell W | 06/02/1839 |

| | | | Document | From | To | Date |
|---|---|---|---|---|---|---|
| 1631 | 112 | | Tri Whe R.6.20.153 | Chazallount | Whewell W | 11/01/1848 |
| 1632 | 113 | | Tri Whe R.6.20.154 | Christie SH | Whewell W | 27/01/1838 |
| 1633 | 114 | | Tri Whe R.6.20.155 | Clarke JT | Whewell W | 27/09/1836 |
| 1634 | 115 | | Tri Whe R.6.20.156 | Clarke JT | Whewell W | 29/09/1836 |
| 1635 | 116 | | Tri Whe R.6.20.157 | Colby T | Whewell W | 25/07/1838 |
| 1636 | 117 | | Tri Whe R.6.20.158 | Collinson R | Whewell W | 19/08/1847 |
| 1637 | 118 | | Tri Whe R.6.20.159 | Colby T | Whewell W | 01/12/1837 |
| 1638 | 119 | | Tri Whe R.6.20.159a | Bunt TG | | |
| 1639 | 120 | | Tri Whe R.6.20.159b | Griffith R | Whewell W | 30/11/1837 |
| 1640 | 121 | | Tri Whe R.6.20.159c | Thomas R | Falmouth Packet | 25/11/1837 |
| 1641 | 122 | | Tri Whe R.6.20.160 | Conybeare WD | Whewell W | |
| 1642 | 123 | | Tri Whe R.6.20.161 | Coode J | Beaufort F | 22/07/1850 |
| 1643 | 124 | | Tri Whe R.6.20.162 | Daussy P | Whewell W | 08/08/1833 |
| 1644 | 125 | | Tri Whe R.6.20.163 | Daussy P | Whewell W | 10/04/1835 |
| 1645 | 126 | | Tri Whe R.6.20.164 | Denham HM | Whewell W | 24/09/1835 |
| 1646 | 127 | | Tri Whe R.6.20.165 | Dessiou JF | Whewell W | 10/01/1833 |
| 1647 | 128 | | Tri Whe R.6.20.165a | Dessiou JF | Atkinson T | 10/01/1833 |
| 1648 | 129 | | Tri Whe R.6.20.166 | Dessiou JF | Whewell W | 07/04/1833 |
| 1649 | 130 | | Tri Whe R.6.20.167 | Dessiou JF | Whewell W | |
| 1650 | 131 | | Tri Whe R.6.20.168 | Dessiou JF | Whewell W | 23/09/1833 |
| 1651 | 132 | | Tri Whe R.6.20.169 | Dessiou JF | Whewell W | 14/10/1834 |
| 1652 | 133 | | Tri Whe R.6.20.170 | Dessiou JF | Whewell W | 28/11/1836 |
| 1653 | 134 | | Tri Whe R.6.20.171 | Dessiou JF | Whewell W | 16/02/1837 |
| 1654 | 135 | | Tri Whe R.6.20.172 | Dessiou JF | Whewell W | 09/06/1838 |
| 1655 | 136 | | Tri Whe R.6.29.173 | Dessiou JF | Whewell W | 06/08/1838 |
| 1656 | 137 | | Tri Whe R.6.20.174 | Dessiou JF | Whewell W | 15/10/1838 |
| 1657 | 138 | | Tri Whe R.6.20.175 | Evans H | Greenhough GB | 28/06/1834 |
| 1658 | 139 | | Tri Whe R.6.20.176 | Everett E | Whewell W | 10/03/1848 |
| 1659 | 140 | | Tri Whe R.6.20.176a | Davis C | Everett E | 07/03/1848 |
| 1660 | 141 | | Tri Whe R.6.20.177 | Fitzroy R | Whewell W | 05/06/1848 |
| 1661 | 142 | | Tri Whe R.6.20.179 | Friend MC | Whewell W | |
| 1662 | 143 | | Tri Whe R.6.20.180 | Gairdner M | Whewell W | 15/09/1835 |
| 1663 | 144 | | Tri Whe R.6.20.181 | Garrett N | Long W | 22/09/1847 |
| 1664 | 145 | | Tri Whe R.6.20.182 | Goulburn H | Whewell W | 23/08/1835 |
| 1665 | 146 | | Tri Whe R.6.20.183 | Gower RH | Whewell W | 06/09/1833 |
| 1666 | 147 | | Tri Whe R.6.20.184 | Gower RH | Whewell W | 20/11/1832 |
| 1667 | 148 | | Tri Whe R.6.20.185 | Gower RH | Whewell W | 04/01/1833 |
| 1668 | 149 | | Tri Whe R.6.20.186 | Graham JD | Whewell W | 04/06/1839 |
| 1669 | 150 | | Tri Whe R.6.20.187 | Greaves C | Whewell W | |
| 1670 | 151 | | Tri Whe R.6.20.188 | Greaves C | Whewell W | 11/01/1837 |
| 1671 | 152 | | Tri Whe R.6.20.189 | Greaves C | Whewell W | 16/06/1838 |
| 1672 | 153 | | Tri Whe R.6.20.190 | Greaves C | Whewell W | 24/11/1838 |
| 1673 | 154 | | Tri Whe R.6.20.191 | Greenough GB | Whewell W | 31/03/1837 |

| | | | Document | From | To | Date |
|---|---|---|---|---|---|---|
| 1674 | 155 | | Tri Whe R.6.20.192 | Griffith R | Whewell W | 10/04/1837 |
| 1675 | 156 | | Tri Whe R.6.20.193 | Griffith R | Whewell W | 23/07/1838 |
| 1676 | 157 | | Tri Whe R.6.20.194 | Hall B | Whewell W | 25/03/1833 |
| 1677 | 158 | | Tri Whe R.6.20.195 | Hall B | Whewell W | 28/02/1833 |
| 1678 | 159 | | Tri Whe R.6.20.196 | Hall B | Whewell W | 16/03/1833 |
| 1679 | 160 | | Tri Whe R.6.20.197 | Robertson N | Hall B | |
| 1680 | 161 | | Tri Whe R.6.20.198 | Hall B | Whewell W | |
| 1681 | 162 | | Tri Whe R.6.20.199 | Hallett JH | Whewell W | 01/02/1838 |
| 1682 | 163 | | Tri Whe R.6.20.200 | Harford JS | Whewell W | |
| 1683 | 164 | | Tri Whe R.6.20.201 | Harris WS | Macauley JH | 07/01/1832 |
| 1684 | 165 | | Tri Whe R.6.20.202 | Harris WS | Whewell W | |
| 1685 | 166 | | Tri Whe R.6.20.203 | Henry W | Whewell W | 09/12/1833 |
| 1686 | 167 | | Tri Whe R.6.20.204 | Holden G | Whewell W | 27/09/1833 |
| 1687 | 168 | | Tri Whe R.6.20.205 | Holden G | Whewell W | 19/04/1834 |
| 1688 | 169 | | Tri Whe R.6.20.206 | Hussey JC | Whewell W | 10/09/1833 |
| 1689 | 170 | | Tri Whe R.6.20.207 | Innes G | Whewell W | 14/01/1835 |
| 1690 | 171 | | Tri Whe R.6.20.208 | Konig C | Greenough GB | 20/08/1834 |
| 1691 | 172 | | Tri Whe R.6.20.209 | Lloyd H | Whewell W | 19/05/1835 |
| 1692 | 173 | | Tri Whe R.6.20.210 | Lloyd JA | Whewell W | 18/07/1840 |
| 1693 | 174 | | Tri Whe R.6.20.211 | Long W | Whewell W | |
| 1694 | 175 | | Tri Whe R.6.20.212 | Lubbock JW | Whewell W | |
| 1695 | 176 | | Tri Whe R.6.20.213 | Lubbock JW | Whewell W | |
| 1696 | 177 | | Tri Whe R.6.20.214 | Lubbock JW | Whewell W | 07/07/1833 |
| 1697 | 178 | | Tri Whe R.6.20.215 | Lubbock JW | Whewell W | 06/08/1833 |
| 1698 | 179 | | Tri Whe R.6.20.216 | Lubbock JW | Whewell W | 22/08/1833 |
| 1699 | 180 | | Tri Whe R.6.20.217 | Lubbock JW | Whewell W | 23/08/1833 |
| 1700 | 181 | | Tri Whe R.6.20.218 | Lubbock JW | Whewell W | 13/10/1833 |
| 1701 | 182 | | Tri Whe R.6.20.219 | Lubbock JW | Whewell W | 18/10/1833 |
| 1702 | 183 | | Tri Whe R.6.20.220 | Lubbock JW | Whewell W | 15/10/1833 |
| 1703 | 184 | | Tri Whe R.6.20.221 | Lubbock JW | Whewell W | 17/10/1833 |
| 1704 | 185 | | Tri Whe R.6.20.222 | Lubbock JW | Whewell W | 25/10/1833 |
| 1705 | 186 | | Tri Whe R.6.20.223 | Lubbock JW | Whewell W | 02/11/1833 |
| 1706 | 187 | | Tri Whe R.6.20.224 | Lubbock JW | Whewell W | 08/11/1833 |
| 1707 | 188 | | Tri Whe R.6.20.225 | Lubbock JW | Whewell W | 12/11/1833 |
| 1708 | 189 | | Tri Whe R.6.20.226 | Lubbock JW | Whewell W | 16/11/1833 |
| 1709 | 190 | | Tri Whe R.6.20.227 | Lubbock JW | Whewell W | 23/11/1833 |
| 1710 | 191 | | Tri Whe R.6.20.228 | Lubbock JW | Whewell W | 09/12/1833 |
| 1711 | 192 | | Tri Whe R.6.20.229 | Lubbock JW | Whewell W | |
| 1712 | 193 | | Tri Whe R.6.20.230 | Lubbock JW | Whewell W | 05/08/1835 |
| 1713 | 194 | | Tri Whe R.6.20.231 | Lubbock JW | Whewell W | |
| 1714 | 195 | | Tri Whe R.6.20.232 | Lubbock JW | Whewell W | |
| 1715 | 196 | | Tri Whe R.6.20.233 | Lubbock JW | Whewell W | 29/09/1835 |
| 1716 | 197 | | Tri Whe R.6.20.234 | Lubbock JW | Whewell W | 27/10/1835 |

| | | | Document | From | To | Date |
|---|---|---|---|---|---|---|
| 1717 | 198 | | Tri Whe R.6.20.235 | Lubbock JW | Whewell W | |
| 1718 | 199 | | Tri Whe R.6.20.236 | Lubbock JW | Whewell W | 09/11/1835 |
| 1719 | 200 | | Tri Whe R.6.20.237 | Lubbock JW | Whewell W | 12/11/1835 |
| 1720 | 201 | | Tri Whe R.6.20.238 | Lubbock JW | Whewell W | 14/11/1835 |
| 1721 | 202 | | Tri Whe R.6.20.239 | Lubbock JW | Whewell W | 09/04/1836 |
| 1722 | 203 | | Tri Whe R.6.20.240 | Lubbock JW | Whewell W | 07/08/1836 |
| 1723 | 204 | | Tri Whe R.6.20.241 | Lubbock JW | Whewell W | 24/03/1837 |
| 1724 | 205 | | Tri Whe R.6.20.242 | Lubbock JW | Whewell W | 30/06/1839 |
| 1725 | 206 | | Tri Whe R.6.20.243 | Macrae J | Whewell W | |
| 1726 | 207 | | Tri Whe R.6.20.244 | Mackie D | Whewell W | 16/09/1836 |
| 1727 | 208 | | Tri Whe R.6.20.245 | Malcolm C | Whewell W | 26/06/1847 |
| 1728 | 209 | | Tri Whe R.6.20.246 | May C | Whewell W | 21/08/1835 |
| 1729 | 210 | | Tri Whe R.6.20.247 | Melvill E | Whewell W | 11/03/1837 |
| 1730 | 211 | | Tri Whe R.6.20.248 | Melvill E | Whewell W | 24/10/1839 |
| 1731 | 212 | | Tri Whe R.6.20.249 | | Whewell W | 09/04/1833 |
| 1732 | 213 | | Tri Whe R.6.20.250 | Newman J | Whewell W | 04/10/1847 |
| 1733 | 214 | | Tri Whe R.6.20.251 | Orlebar AB | Whewell W | 17/09/1847 |
| 1734 | 215 | | Tri Whe R.6.20.252 | Reid W | Whewell W | 09/03/1844 |
| 1735 | 216 | | Tri Whe R.6.20.253 | Rennie G | Whewell W | 16/02/1833 |
| 1736 | 217 | | Tri Whe R.6.20.254 | Rennie G | Whewell W | 02/03/1833 |
| 1737 | 218 | | Tri Whe R.6.20.255 | Rennie G | Whewell W | 06/03/1833 |
| 1738 | 219 | | Tri Whe R.6.20.256 | Rennie G | Whewell W | 30/03/1833 |
| 1739 | 220 | | Tri Whe R.6.20.257 | Rennie John | Whewell W | 27/05/1834 |
| 1740 | 221 | | Tri Whe R.6.20.258 | Rennie John | Whewell W | 20/03/1835 |
| 1741 | 222 | | Tri Whe R.6.20.259 | Richardson J | Whewell W | |
| 1742 | 223 | | Tri Whe R.6.20.260 | Ross D | Whewell W | 11/02/1837 |
| 1743 | 224 | | Tri Whe R.6.20.261 | Ross D | Whewell W | 06/05/1837 |
| 1744 | 225 | | Tri Whe R.6.20.262 | Ross D | Whewell W | 08/05/1837 |
| 1745 | 226 | | Tri Whe R.6.20.263 | Ross D | Whewell W | 12/05/1837 |
| 1746 | 227 | | Tri Whe R.6.20.264 | Ross D | Whewell W | 23/10/1838 |
| 1747 | 228 | | Tri Whe R.6.20.265 | Ross D | Whewell W | 03/10/1839 |
| 1748 | 229 | | Tri Whe R.6.20.266 | Ross D | Whewell W | 05/10/1839 |
| 1749 | 230 | | Tri Whe R.6.20.267 | Ross D | Whewell W | 05/10/1839 |
| 1750 | 231 | | Tri Whe R.6.20.268 | Ross D | Whewell W | 10/10/1839 |
| 1751 | 232 | | Tri Whe R.6.20.269 | Ross D | Whewell W | 20/07/1847 |
| 1752 | 233 | | Tri Whe R.6.20.270 | Ross D | Whewell W | 27/07/1847 |
| 1753 | 234 | | Tri Whe R.6.20.271 | Ross D | Whewell W | 31/07/1847 |
| 1754 | 235 | | Tri Whe R.6.20.272 | Ross D | Whewell W | 03/08/1847 |
| 1755 | 236 | | Tri Whe R.6.20.273 | Ross D | Whewell W | 04/08/1847 |
| 1756 | 237 | | Tri Whe R.6.20.274 | Ross D | Whewell W | 05/08/1847 |
| 1757 | 238 | | Tri Whe R.6.20.275 | Ross D | Whewell W | 07/08/1847 |
| 1758 | 239 | | Tri Whe R.6.20.276 | Ross D | Whewell W | 10/08/1847 |
| 1759 | 240 | | Tri Whe R.6.20.277 | Ross D | Whewell W | 14/08/1847 |

| | | | Document | From | To | Date |
|---|---|---|---|---|---|---|
| 1760 | 241 | | Tri Whe R.6.20.278 | Ross D | Whewell W | 21/08/1847 |
| 1761 | 242 | | Tri Whe R.6.20.279 | Ross D | Whewell W | 25/08/1847 |
| 1762 | 243 | | Tri Whe R.6.20.280 | Ross D | Whewell W | 27/08/1847 |
| 1763 | 244 | | Tri Whe R.6.20.281 | Ross D | Whewell W | 01/09/1847 |
| 1764 | 245 | | Tri Whe R.6.20.282 | Ross D | Whewell W | 10/09/1847 |
| 1765 | 246 | | Tri Whe R.6.20.283 | Ross D | Whewell W | 15/09/1847 |
| 1766 | 247 | | Tri Whe R.6.20.284 | Ross D | Whewell W | 17/09/1847 |
| 1767 | 248 | | Tri Whe R.6.20.285 | Ross D | Whewell W | 20/09/1847 |
| 1768 | 249 | | Tri Whe R.6.20.286 | Ross D | Whewell W | 22/09/1847 |
| 1769 | 250 | | Tri Whe R.6.20.287 | Ross D | Whewell W | 23/09/1847 |
| 1770 | 251 | | Tri Whe R.6.20.288 | Ross D | Whewell W | 24/09/1847 |
| 1771 | 252 | | Tri Whe R.6.20.289 | Ross D | Whewell W | 27/09/1847 |
| 1772 | 253 | | Tri Whe R.6.20.290 | Ross D | Whewell W | 11/10/1847 |
| 1773 | 254 | | Tri Whe R.6.20.291 | Ross D | Whewell W | 23/10/1847 |
| 1774 | 255 | | Tri Whe R.6.20.292 | Ross D | Whewell W | 26/10/1847 |
| 1775 | 256 | | Tri Whe R.6.20.293 | Ross D | Whewell W | 05/11/1847 |
| 1776 | 257 | | Tri Whe R.6.20.294 | Ross JC | Whewell W | 12/08/1847 |
| 1777 | 258 | | Tri Whe R.6.20.295 | Scoresby W | Whewell W | |
| 1778 | 259 | | Tri Whe R.6.20.296 | Simpson M | Whewell W | 27/03/1854 |
| 1779 | 260 | | Tri Whe R.6.20.297 | Smyth WH | Whewell W | 07/05/1832 |
| 1780 | 261 | | Tri Whe R.6.20.298 | Smyth WH | Hewitt W | 04/06/1832 |
| 1781 | 262 | | Tri Whe R.6.20.299 | Smyth WH | Thomas G | 04/06/1832 |
| 1782 | 263 | | Tri Whe R.6.20.300 | Smyth WH | Whewell W | 20/04/1861 |
| 1783 | 264 | | Tri Whe R.6.20.301 | Spenser R | Whewell W | 26/09/1832 |
| 1784 | 265 | | Tri Whe R.6.20.302 | Spenser R | Whewell W | 28/12/1832 |
| 1785 | 266 | | Tri Whe R.6.20.303 | Spenser R | Whewell W | 18/07/1834 |
| 1786 | 267 | | Tri Whe R.6.20.304 | Stanley O | Whewell W | |
| 1787 | 268 | | Tri Whe R.6.20.305 | Stevenson R | Whewell W | 14/06/1833 |
| 1788 | 269 | | Tri Whe R.6.20.306 | Stevenson R | Whewell W | 06/02/1834 |
| 1789 | 270 | | Tri Whe R.6.20.307 | Stratford WS | Whewell W | 18/11/1833 |
| 1790 | 271 | | Tri Whe R.6.20.308 | Stratford WS | Whewell W | 21/11/1833 |
| 1791 | 272 | | Tri Whe R.6.20.309 | Stratford WS | Whewell W | 05/12/1833 |
| 1792 | 273 | | Tri Whe R.6.20.310 | Sutchbury S | Whewell W | 05/10/1833 |
| 1793 | 274 | | Tri Whe R.6.20.311 | Sutchbury S | Whewell W | 12/10/1835 |
| 1794 | 275 | | Tri Whe R.6.20.312 | Dedel ? | Whewell W | 05/04/1838 |
| 1795 | 276 | | Tri Whe R.6.20.313 | Templer J | Whewell W | 31/01/1840 |
| 1796 | 277 | | Tri Whe R.6.20.314 | Waldegrave W | Whewell W | 08/12/1835 |
| 1797 | 278 | | Tri Whe R.6.20.315 | Waldegrave W | Whewell W | 27/10/1835 |
| 1798 | 279 | | Tri Whe R.6.20.316 | Waldegrave W | Whewell W | |
| 1799 | 280 | | Tri Whe R.6.20.317 | Walker W | Whewell W | 26/12/1836 |
| 1800 | 281 | | Tri Whe R.6.20.318 | Walker W | Whewell W | 10/12/1837 |
| 1801 | 282 | | Tri Whe R.6.20.319 | Walker W | Whewell W | 12/02/1839 |
| 1802 | 283 | | Tri Whe R.6.20.320 | Walker W | Whewell W | 22/09/1839 |

| | | | Document | From | To | Date |
|---|---|---|---|---|---|---|
| 1803 | 284 | | Tri Whe R.6.20.321 | Washington J | Whewell W | 18/07/1842 |
| 1804 | 285 | | Tri Whe R.6.20.322 | Van de Wayer S | Whewell W | |
| 1805 | 286 | | Tri Whe R.6.20.323 | Whewell W | Wood C | 05/12/1837 |
| 1806 | 287 | | Tri Whe R.6.20.324 | Whewell W | Moll G | 15/01/1838 |
| 1807 | 288 | | Tri Whe R.6.20.325 | Wilkes C | Whewell W | 06/05/1838 |
| 1808 | 289 | | Tri Whe R.6.20.326 | Wood C | Whewell W | 25/05/1837 |
| 1809 | 290 | | Tri Whe R.6.20.327 | Yates JB | Whewell W | 15/07/1833 |
| 1810 | 291 | | Tri Whe R.6.20.328 | Yates JB | Whewell W | 20/07/1833 |
| 1811 | 292 | | Tri Whe R.6.20.329 | Beacham JW | Whewell W | 08/11/1833 |
| 1812 | 293 | | Tri Whe R.6.20.332 | White GR | Argent J | 03/09/1833 |
| 1813 | 1 | | WSH RG 23 1 | Walker SC | Pourtales LF | 24/08/1849 |
| 1814 | 2 | | WSH RG 23 2 | Walker SC | Pourtales LF | 11/08/1849 |
| 1815 | 3 | | WSH RG 23 3 | Schutt CA | Rumpl | 01/08/1851 |
| 1816 | 4 | | WSH RG 23 4 | Schutt CA | Stevens JJ | 12/08/1851 |
| 1817 | 5 | | WSH RG 23 5 | Schutt CA | Stevens JJ | 12/08/1851 |
| 1818 | 6 | | WSH RG 23 6 | Schutt CA | Stevens JJ | 09/08/1851 |
| 1819 | 7 | | WSH RG 23 7 | Bache AD | Gordon WW | 03/12/1851 |
| 1820 | 8 | | WSH RG 23 8 | Gordon WW | Bache AD | 05/12/1851 |
| 1821 | 9 | | WSH RG 23 9 | Gordon WW | Bache AD | 01/11/1851 |
| 1822 | 10 | | WSH RG 23 10 | Gordon WW | Bache AD | 28/10/1851 |
| 1823 | 11 | | WSH RG 23 11 | Gordon WW | Bache AD | 20/10/1851 |
| 1824 | 12 | | WSH RG 23 12 | Gordon WW | | 17/10/1851 |
| 1825 | 13 | | WSH RG 23 13 | Bache AD | Gordon WW | 16/12/1852 |
| 1826 | 14 | | WSH RG 23 14 | Bache AD | Gordon WW | 25/11/1852 |
| 1827 | 15 | | WSH RG 23 15 | Ober MH | Bache AD | 19/11/1852 |
| 1828 | 16 | | WSH RG 23 16 | Bache AD | Gordon WW | 13/07/1852 |
| 1829 | 17 | | WSH RG 23 17 | Bache AD | Gordon WW | 12/07/1852 |
| 1830 | 18 | | WSH RG 23 18 | Bache AD | Pourtales LF | 03/07/1852 |
| 1831 | 19 | | WSH RG 23 19 | Bache AD | Gordon WW | 26/06/1852 |
| 1832 | 20 | | WSH RG 23 20 | Cordel E | Pourtales LF | 19/12/1852 |
| 1833 | 21 | | WSH RG 23 21 | Foster JG | Gordon WW | 25/10/1852 |
| 1834 | 22 | | WSH RG 23 22 | Foster JG | Gordon WW | 23/10/1852 |
| 1835 | 23 | | WSH RG 23 23 | Foster JG | Gordon WW | 09/07/1852 |
| 1836 | 24 | | WSH RG 23 24 | Edison AD | Pourtales LF | 28/09/1852 |
| 1837 | 25 | | WSH RG 23 25 | Gordon WW | | 07/07/1852 |
| 1838 | 26 | | WSH RG 23 26 | Gordon WW | Cox | 28/11/1852 |
| 1839 | 27 | | WSH RG 23 27 | Gordon WW | Bache AD | 23/10/1852 |
| 1840 | 28 | | WSH RG 23 28 | Gordon WW | Stevens JJ | 23/10/1852 |
| 1841 | 29 | | WSH RG 23 29 | Gordon WW | Bache AD | 22/10/1852 |
| 1842 | 30 | | WSH RG 23 30 | Gordon WW | Hunt EG | 09/10/1852 |
| 1843 | 31 | | WSH RG 23 31 | Offler JR | Gordon WW | 11/08/1852 |
| 1844 | 32 | | WSH RG 23 32 | Gordon WW | Bache AD | 21/07/1852 |
| 1845 | 33 | | WSH RG 23 33 | Gordon WW | Bache AD | 06/07/1852 |

| | | | Document | From | To | Date |
|---|---|---|---|---|---|---|
| 1846 | 34 | | WSH RG 23 34 | Bache AD | Stevens JJ | 29/06/1852 |
| 1847 | 35 | | WSH RG 23 35 | Gordon WW | Bache AD | 07/07/1852 |
| 1848 | 36 | | WSH RG 23 36 | Hein J | Bache AD | 08/07/1852 |
| 1849 | 37 | | WSH RG 23 37 | Gordon WW | Whiting EB | 10/05/1852 |
| 1850 | 38 | | WSH RG 23 38 | Gordon WW | Ober MH | 01/05/1852 |
| 1851 | 39 | | WSH RG 23 39 | Gordon WW | Bache AD | 06/03/1852 |
| 1852 | 40 | | WSH RG 23 40 | Gordon WW | Hugar | 03/03/1852 |
| 1853 | 41 | | WSH RG 23 41 | Gordon WW | Bache AD | 27/02/1852 |
| 1854 | 42 | | WSH RG 23 42 | Gordon WW | | 31/01/1852 |
| 1855 | 43 | | WSH RG 23 43 | Homand TS | Gordon WW | 03/11/1852 |
| 1856 | 44 | | WSH RG 23 44 | Homand TS | Stevens JJ | 06/08/1852 |
| 1857 | 45 | | WSH RG 23 45 | Huret EB | Gordon WW | 06/10/1852 |
| 1858 | 46 | | WSH RG 23 46 | Mitchell H | Gordon WW | 09/08/1852 |
| 1859 | 47 | | WSH RG 23 47 | Mitchell H | Gordon WW | 09/08/1852 |
| 1860 | 48 | | WSH RG 23 48 | Mitchell H | Gordon WW | 07/08/1852 |
| 1861 | 49 | | WSH RG 23 49 | Mitchell H | Gordon WW | 05/08/1852 |
| 1862 | 50 | | WSH RG 23 50 | Mitchell H | Gordon WW | 04/08/1852 |
| 1863 | 51 | | WSH RG 23 51 | Mitchell H | Gordon WW | 03/08/1852 |
| 1864 | 52 | | WSH RG 23 52 | Mitchell H | Gordon WW | 30/07/1852 |
| 1865 | 53 | | WSH RG 23 53 | Mitchell H | Gordon WW | 31/07/1852 |
| 1866 | 54 | | WSH RG 23 54 | Mitchell H | Gordon WW | 29/07/1852 |
| 1867 | 55 | | WSH RG 23 55 | Ober MH | Gordon WW | |
| 1868 | 56 | | WSH RG 23 56 | Ober MH | Gordon WW | 16/06/1852 |
| 1869 | 57 | | WSH RG 23 57 | Ober MH | Gordon WW | |
| 1870 | 58 | | WSH RG 23 58 | Ober MH | Bache AD | 10/05/1852 |
| 1871 | 59 | | WSH RG 23 59 | | | |
| 1872 | 60 | | WSH RG 23 60 | Stevens JJ | Gordon WW | 13/03/1852 |
| 1873 | 61 | | WSH RG 23 61 | Trausten JG | Williams J | 16/05/1852 |
| 1874 | 62 | | WSH RG 23 62 | Trowbridge WP | Gordon WW | 30/10/1852 |
| 1875 | 63 | | WSH RG 23 63 | Wurdermann G | Bache AD | 07/10/1852 |
| 1876 | 64 | | WSH RG 23 64 | Bache AD | Pourtales LF | 23/03/1855 |
| 1877 | 65 | | WSH RG 23 65 | Bache AD | Pourtales LF | 03/11/1855 |
| 1878 | 66 | | WSH RG 23 66 | Bache AD | Pourtales LF | 22/10/1855 |
| 1879 | 67 | | WSH RG 23 67 | Bache AD | Pourtales LF | 13/10/1855 |
| 1880 | 68 | | WSH RG 23 68 | Bache AD | Pourtales LF | 10/10/1855 |
| 1881 | 69 | | WSH RG 23 69 | Bache AD | Pourtales LF | 08/10/1855 |
| 1882 | 70 | | WSH RG 23 70 | Bache AD | Heaton H | 28/09/1855 |
| 1883 | 71 | | WSH RG 23 71 | Bache AD | Pourtales LF | 21/09/1855 |
| 1884 | 72 | | WSH RG 23 72 | Bache AD | Pourtales LF | 19/09/1855 |
| 1885 | 73 | | WSH RG 23 73 | Bache AD | Pourtales LF | 18/09/1855 |
| 1886 | 74 | | WSH RG 23 74 | Bache AD | Pourtales LF | 08/09/1855 |
| 1887 | 75 | | WSH RG 23 75 | Bache AD | Pourtales LF | 08/08/1855 |
| 1888 | 76 | | WSH RG 23 76 | Bache AD | Pourtales LF | 02/08/1855 |

| | | | Document | From | To | Date |
|---|---|---|---|---|---|---|
| 1889 | 77 | | WSH RG 23 77 | Bache AD | Benham HW | 18/02/1855 |
| 1890 | 78 | | WSH RG 23 78 | Bache AD | Pourtales LF | 30/07/1855 |
| 1891 | 79 | | WSH RG 23 79 | Bache AD | Pourtales LF | 05/04/1855 |
| 1892 | 80 | | WSH RG 23 80 | Cooper WW | Heaton H | 16/08/1855 |
| 1893 | 81 | | WSH RG 23 81 | Gibbs LR | Palmer WR | 08/11/1855 |
| 1894 | 82 | | WSH RG 23 82 | Heath DD | Bache AD | 25/07/1855 |
| 1895 | 83 | | WSH RG 23 83 | Bache AD | Heaton H | 19/07/1855 |
| 1896 | 84 | | WSH RG 23 84 | Meech LW | Bache AD | 10/09/1855 |
| 1897 | 85 | | WSH RG 23 85 | Meech LW | Bache AD | 31/05/1855 |
| 1898 | 86 | | WSH RG 23 86 | Meech LW | Bache AD | 03/02/1855 |
| 1899 | 87 | | WSH RG 23 87 | Meech LW | Bache AD | 03/01/1855 |
| 1900 | 88 | | WSH RG 23 88 | Mitchell H | Heaton H | 11/11/1855 |
| 1901 | 89 | | WSH RG 23 89 | Montomery DE | Pourtales LF | 06/03/1855 |
| 1902 | 90 | | WSH RG 23 90 | Pourtales LF | Bache AD | 20/12/1855 |
| 1903 | 91 | | WSH RG 23 91 | Pourtales LF | Bache AD | 11/12/1855 |
| 1904 | 92 | | WSH RG 23 92 | Pourtales LF | Bache AD | 01/10/1855 |
| 1905 | 93 | | WSH RG 23 93 | Pourtales LF | Benham HW | 25/10/1855 |
| 1906 | 94 | | WSH RG 23 94 | Pourtales LF | Benham HW | 01/10/1855 |
| 1907 | 95 | | WSH RG 23 95 | | | 12/06/1855 |
| 1908 | 96 | | WSH RG 23 96 | | Bache AD | 08/06/1855 |
| 1909 | 97 | | WSH RG 23 97 | Pourtales LF | Bache AD | 15/06/1855 |
| 1910 | 98 | | WSH RG 23 98 | Pourtales LF | Heaton H | 29/06/1855 |
| 1911 | 99 | | WSH RG 23 99 | Pourtales LF | Benham HW | 02/06/1855 |
| 1912 | 100 | | WSH RG 23 100 | Pourtales LF | Benham HW | 31/05/1855 |
| 1913 | 101 | | WSH RG 23 101 | Cassidy A | Trowbridge WP | 01/01/1854 |
| 1914 | 102 | | WSH RG 23 102 | Cassidy A | Trowbridge WP | 01/02/1854 |
| 1915 | 103 | | WSH RG 23 103 | Clark JC | Pourtales LF | 17/04/1854 |
| 1916 | 104 | | WSH RG 23 104 | Collins J | Benham HW | 01/09/1854 |
| 1917 | 105 | | WSH RG 23 105 | Cooper WW | Pourtales LF | 01/11/1854 |
| 1918 | 106 | | WSH RG 23 106 | Cooper WW | Pourtales LF | 13/10/1854 |
| 1919 | 107 | | WSH RG 23 107 | Cooper WW | Pourtales LF | 17/10/1854 |
| 1920 | 108 | | WSH RG 23 108 | Dean GW | Pourtales LF | 28/11/1854 |
| 1921 | 109 | | WSH RG 23 109 | Fairfield GA | Bache AD | 20/07/1854 |
| 1922 | 110 | | WSH RG 23 110 | Fairfield GA | Pourtales LF | 01/01/1854 |
| 1923 | 111 | | WSH RG 23 111 | Gibble JE | Benham HW | 23/05/1854 |
| 1924 | 112 | | WSH RG 23 112 | Pourtales LF | Gordon WW | 07/02/1853 |
| 1925 | 113 | | WSH RG 23 113 | Pourtales LF | Gordon WW | 14/02/1853 |
| 1926 | 114 | | WSH RG 23 114 | Pourtales LF | Stevens JJ | 28/02/1853 |
| 1927 | 115 | | WSH RG 23 115 | Pourtales LF | Stevens JJ | 08/03/1853 |
| 1928 | 116 | | WSH RG 23 116 | Pourtales LF | Stevens JJ | 08/03/1853 |
| 1929 | 117 | | WSH RG 23 117 | Pourtales LF | King MC | 10/03/1853 |
| 1930 | 118 | | WSH RG 23 118 | Pourtales LF | Bolles CP | 21/03/1853 |
| 1931 | 119 | | WSH RG 23 119 | Pourtales LF | Davis CH | 21/03/1853 |

| | | | Document | From | To | Date |
|---|---|---|---|---|---|---|
| 1932 | 120 | | WSH RG 23 120 | Pourtales LF | Bache AD | 01/04/1853 |
| 1933 | 121 | | WSH RG 23 121 | Pourtales LF | Bache AD | 02/04/1853 |
| 1934 | 122 | | WSH RG 23 122 | Pourtales LF | Bache AD | 04/04/1853 |
| 1935 | 123 | | WSH RG 23 123 | Pourtales LF | Bache AD | 04/04/1853 |
| 1936 | 124 | | WSH RG 23 124 | Pourtales LF | Benham HW | 07/04/1853 |
| 1937 | 125 | | WSH RG 23 125 | Pourtales LF | Benham HW | 09/04/1853 |
| 1938 | 126 | | WSH RG 23 126 | Pourtales LF | Benham HW | |
| 1939 | 127 | | WSH RG 23 127 | Pourtales LF | Benham HW | 01/05/1853 |
| 1940 | 128 | | WSH RG 23 128 | Pourtales LF | Bache AD | 13/05/1853 |
| 1941 | 129 | | WSH RG 23 129 | Pourtales LF | Bache AD | 18/05/1853 |
| 1942 | 130 | | WSH RG 23 130 | Pourtales LF | Mitchell H | 21/05/1853 |
| 1943 | 131 | | WSH RG 23 131 | Pourtales LF | Gordon WW | 23/05/1853 |
| 1944 | 132 | | WSH RG 23 132 | Pourtales LF | Benham HW | 01/06/1853 |
| 1945 | 133 | | WSH RG 23 133 | Pourtales LF | Bache AD | 01/06/1853 |
| 1946 | 134 | | WSH RG 23 134 | Pourtales LF | Bache AD | |
| 1947 | 135 | | WSH RG 23 135 | Pourtales LF | Bache AD | 14/06/1853 |
| 1948 | 136 | | WSH RG 23 136 | Pourtales LF | Bache AD | 14/06/1853 |
| 1949 | 137 | | WSH RG 23 137 | Pourtales LF | Bache AD | 12/06/1853 |
| 1950 | 138 | | WSH RG 23 138 | Pourtales LF | Bache AD | 18/06/1853 |
| 1951 | 139 | | WSH RG 23 139 | Pourtales LF | Foreman | 20/06/1853 |
| 1952 | 140 | | WSH RG 23 140 | Pourtales LF | Hove PB | 21/06/1853 |
| 1953 | 141 | | WSH RG 23 141 | Pourtales LF | Bache AD | 22/06/1853 |
| 1954 | 142 | | WSH RG 23 142 | Pourtales LF | Bache AD | 23/06/1853 |
| 1955 | 143 | | WSH RG 23 143 | Pourtales LF | Bache AD | 25/06/1853 |
| 1956 | 144 | | WSH RG 23 144 | Pourtales LF | Bache AD | 01/07/1853 |
| 1957 | 145 | | WSH RG 23 145 | Williams J | Bache AD | 18/06/1853 |
| 1958 | 146 | | WSH RG 23 146 | Pourtales LF | Hove PB | 29/06/1853 |
| 1959 | 147 | | WSH RG 23 147 | Pourtales LF | Reynolds | 01/07/1853 |
| 1960 | 148 | | WSH RG 23 148 | Pourtales LF | Bache AD | 01/07/1853 |
| 1961 | 1 | | CUL RGO 14.51.4 | May N | BOL | 01/12/1782 |
| 1962 | 2 | | CUL RGO 14.51.5 | May N | BOL | |
| 1963 | 3 | | CUL RGO 14.51.11 | Buckingham M | Chatham E | 06/01/1789 |
| 1964 | 4 | | CUL RGO 14.51.13 | Vallancey C | Parker H | 25/10/1789 |
| 1965 | 5 | | CUL RGO 14.51.17 | Dean E | BOL | 03/12/1804 |
| 1966 | 6 | | CUL RGO 14.51.21 | Oshea EM | Hind T | 07/01/1817 |
| 1967 | 7 | | CUL RGO 14.51.23 | Oshea EM | Hind T | 01/03/1817 |
| 1968 | 8 | | CUL RGO 14.51.25 | Oshea EM | Hind T | 05/03/1817 |
| 1969 | 9 | | CUL RGO 14.51.26 | Oshea EM | Hind T | 05/03/1817 |
| 1970 | 10 | | CUL RGO 14.51.27 | Oshea EM | Hind T | 06/03/1817 |
| 1971 | 11 | | CUL RGO 14.51.30 | Cohen L | Hind T | 12/05/1822 |
| 1972 | 12 | | CUL RGO 14.51.31 | Cohen L | Hind T | 16/05/1822 |
| 1973 | 13 | | CUL RGO 14.51.36 | Forman W | Young T | 06/05/1822 |
| 1974 | 14 | | CUL RGO 14.51.89 | Bevan B | Wollaston WH | 11/07/1822 |

| | | | Document | From | To | Date |
|---|---|---|---|---|---|---|
| 1975 | 15 | | CUL RGO 14.51.92 | Bevan B | Wollaston WH | 21/02/1823 |
| 1976 | 16 | | CUL RGO 14.51.93 | Bevan B | Wollaston WH | 19/03/1823 |
| 1977 | 17 | | CUL RGO 14.51.95 | Bevan B | Wollaston WH | 07/04/1823 |
| 1978 | 18 | | CUL RGO 14.51.96 | Bevan B | Young T | 16/04/1823 |
| 1979 | 19 | | CUL RGO 14.51.97 | Bevan B | Young T | 29/07/1823 |
| 1980 | 20 | | CUL RGO 14.51.99 | Bevan B | Young T | 13/11/1823 |
| 1981 | 21 | | CUL RGO 14.51.101 | Bevan B | Young T | 18/11/1823 |
| 1982 | 22 | | CUL RGO 14.51.102 | Bevan B | Young T | 15/01/1824 |
| 1983 | 23 | | CUL RGO 14.51.103 | Bevan B | Young T | 07/06/1824 |
| 1984 | 24 | | CUL RGO 14.51.104 | Bevan B | Young T | 19/09/1824 |
| 1985 | 25 | | CUL RGO 14.51.105 | Bevan B | Young T | 14/11/1824 |
| 1986 | 26 | | CUL RGO 14.51.106 | Bevan B | Young T | 04/12/1824 |
| 1987 | 27 | | CUL RGO 14.51.108 | Bevan B | Young T | 14/02/1825 |
| 1988 | 28 | | CUL RGO 14.51.109 | Bevan B | Young T | 11/07/1825 |
| 1989 | 29 | | CUL RGO 14.51.113 | Barrow J | Young T | 21/06/1823 |
| 1990 | 30 | | CUL RGO 14.51.116 | Coke H | Young T | 28/07/1824 |
| 1991 | 31 | | CUL RGO 14.51.117 | Abram J | Young T | 09/07/1824 |
| 1992 | 32 | | CUL RGO 14.51.131 | Rorie JJ | Young T | 20/03/1828 |
| 1993 | 33 | | CUL RGO 14.51.131a | Barrow J | Young T | 25/03/1828 |
| 1994 | 1 | | CUL RGO 5/223/1 | Innes G | Pond J | 22/01/1825 |
| 1995 | 2 | | CUL RGO 5/223/2 | Stratford WS | Pond J | 20/06/1831 |
| 1996 | 3 | | CUL RGO 5/223/3 | Curwin C | Pond J | 18/06/1824 |
| 1997 | 4 | | CUL RGO 6/203/31 | Thompson P | Airy GB | 16/12/1846 |
| 1998 | 5 | | CUL RGO 6/203/33 | Airy GB | Stratford WS | 17/12/1846 |
| 1999 | 6 | | CUL RGO 6/203/34 | Airy GB | Thompson P | 17/12/1846 |
| 2000 | 7 | | CUL RGO 6/203/35 | Stratford WS | Airy GB | 17/12/1846 |
| 2001 | 8 | | CUL RGO 6/203/36 | Airy GB | Stratford WS | 21/12/1846 |
| 2002 | 9 | | CUL RGO 6/203/37 | Airy GB | Stratford WS | 13/01/1847 |
| 2003 | 10 | | CUL RGO 6/203/38 | Airy GB | Stratford WS | 29/01/1847 |
| 2004 | 11 | | CUL RGO 6/203/39 | Stratford WS | Airy GB | 01/02/1847 |
| 2005 | 12 | | CUL RGO 6/203/84 | | | |
| 2006 | 13 | | CUL RGO 6/203/88 | Barrow J | Pond J | 24/11/1830 |
| 2007 | 14 | | CUL RGO 6/203/89 | South J | Barrow J | 23/11/1830 |
| 2008 | 15 | | CUL RGO 6/203/222 | Stratford WS | Airy GB | 05/10/1845 |
| 2009 | 16 | | CUL RGO 6/205/4 | Beaufort F | Airy GB | 30/03/1853 |
| 2010 | 17 | | CUL RGO 6/205/5 | Airy GB | Beaufort F | 31/03/1853 |
| 2011 | 18 | | CUL RGO 6/205/6 | Airy GB | Graham J | 05/04/1853 |
| 2012 | 19 | | CUL RGO 6/205/8 | Main R | Airy GB | 05/04/1853 |
| 2013 | 20 | | CUL RGO 6/205/10 | Glaisher J | Airy GB | 05/04/1853 |
| 2014 | 21 | | CUL RGO 6/205/11 | Airy GB | Main R | 06/04/1853 |
| 2015 | 22 | | CUL RGO 6/205/13 | Airy GB | Beaufort F | 06/04/1853 |
| 2016 | 23 | | CUL RGO 6/205/15 | Airy GB | Beaufort F | 07/04/1853 |
| 2017 | 24 | | CUL RGO 6/205/16 | Main R | Airy GB | 07/04/1853 |

| | | | Document | From | To | Date |
|---|---|---|---|---|---|---|
| 2018 | 25 | | CUL RGO 6/205/18 | Hind JR | Airy GB | 07/04/1853 |
| 2019 | 26 | | CUL RGO 6/205/19 | Airy GB | Glaisher J | 09/04/1853 |
| 2020 | 27 | | CUL RGO 6/205/20 | Airy GB | Hind JR | 09/04/1853 |
| 2021 | 28 | | CUL RGO 6/205/21 | Airy GB | Hind JR | 23/04/1853 |
| 2022 | 29 | | CUL RGO 6/205/22 | Airy GB | | 28/05/1853 |
| 2023 | 30 | | CUL RGO 6/205/23 | Airy GB | Beaufort F | 07/06/1853 |
| 2024 | 31 | | CUL RGO 6/207/123 | Hind JR | Airy GB | 18/08/1864 |
| 2025 | 32 | | CUL RGO 6/207/125 | Airy GB | Hind JR | 05/09/1864 |
| 2026 | 33 | | CUL RGO 6/207/126 | Stone EJ | Airy GB | |
| 2027 | 34 | | CUL RGO 6/207/127 | Hind JR | Airy GB | 08/09/1864 |
| 2028 | 35 | | CUL RGO 6/207/130 | Airy GB | Hind JR | 17/09/1866 |
| 2029 | 36 | | CUL RGO 6/207/131 | Hind JR | Airy GB | 11/10/1866 |
| 2030 | 37 | | CUL RGO 6/207/133 | Hind JR | Airy GB | 23/10/1866 |
| 2031 | 38 | | CUL RGO 6/207/135 | Airy GB | Hind JR | 24/10/1866 |
| 2032 | 39 | | CUL RGO 6/207/136 | Airy GB | Hind JR | 24/10/1866 |
| 2033 | 40 | | CUL RGO 6/208/3 | Airy GB | Hind JR | 01/04/1868 |
| 2034 | 41 | | CUL RGO 6/257/118 | Molison AR | Airy GB | 09/04/1868 |
| 2035 | 42 | | CUL RGO 6/257/129 | Airy GB | Molison AR | 11/04/1868 |
| 2036 | 43 | | CUL RGO 6/257/130 | Molison AR | Airy GB | 13/04/1868 |
| 2037 | 44 | | CUL RGO 6/257/132 | Airy GB | Molison AR | 16/04/1868 |
| 2038 | 45 | | CUL RGO 6/385/429 | Airy GB | Christie SH | 10/01/1842 |
| 2039 | 1 | | IOR F.4.1474 1 | Blunt W | E.I.C. | 14/02/1834 |
| 2040 | 2 | | IOR F.4.1474 5 | Barrow J | Auber P | 10/11/1832 |
| 2041 | 3 | | IOR F.4.1474 7 | Horsburgh J | Barrow J | 01/09/1834 |
| 2042 | 4 | | IOR F.4.1474 13 | | E.I.C. | 20/02/1833 |
| 2043 | 5 | | IOR F.4.1474 15 | Bushby GA | E.I.C. | 25/06/1833 |
| 2044 | 6 | | IOR F.4.1474 17 | Bushby GA | Ibbetson R | 25/06/1833 |
| 2045 | 7 | | IOR F.4.1474 19 | E.I.C. | Bentinck C | 17/01/1834 |
| 2046 | 8 | | IOR F.4.1474 25 | Bushby GA | E.I.C. | 28/01/1834 |
| 2047 | 9 | | IOR F.4.1474 27 | Parker H | Metcalfe CT | 13/02/1834 |
| 2048 | 10 | | IOR F.4.1474 29 | Kyd J | Greenlaw CB | 11/02/1834 |
| 2049 | 11 | | IOR F.4.1474 31 | Ibbetson R | Bushby GA | 30/10/1833 |
| 2050 | 12 | | IOR F.4.1474 32 | Murchison R | Ibbetson R | 23/10/1833 |
| 2051 | 13 | | IOR F.4.1474 33 | Wright CWH | Murchison R | 18/10/1833 |
| 2052 | 1 | | RSL LB 425.122 | Hudson J | Stratford WS | 02/06/1832 |
| 2053 | 2 | | RSL LB.425.123 | Hudson J | Dessiou JF | 02/06/1832 |
| 2054 | 3 | | RSL LB.425.231 | Lubbock JW | Beaufort F | 29/09/1832 |
| 2055 | 4 | | RSL LB.425.273 | Lubbock JW | Beaufort F | 16/11/1832 |
| 2056 | 5 | | RSL MA.193 | Lubbock JW | R.S. | 26/02/1837 |
| 2057 | 6 | | RSL MA.195 | Dessiou JF | R.S. | 31/08/1836 |
| 2058 | 7 | | RSL MC.1.179 | Lubbock JW | Gilbert D | 30/11/1829 |
| 2059 | 8 | | RSL MC.1.327 | Lubbock JW | R.S. | 30/08/1831 |
| 2060 | 9 | | RSL MC.2.32 | Vaughen W | Roget PM | 06/04/1832 |

| | | | Document | From | To | Date |
|---|---|---|---|---|---|---|
| 2061 | 10 | | RSL MC.2.108 | Elliot GE | Roget PM | 14/01/1834 |
| 2062 | 11 | | RSL MC.2.148 | Whewell W | R.S. | 26/01/1834 |
| 2063 | 12 | | RSL MC.2.178 | Dessiou JF | Lubbock JW | 27/06/1835 |
| 2064 | 13 | | RSL MC.15.116 | Godley JA | R.S. | 16/12/1890 |
| 2065 | 14 | | RSL MC.15.120 | Dawer RE | R.S. | 24/12/1890 |
| 2066 | 15 | | RSL MM.17.11 | Lubbock JW | Sharpey W | 06/02/1855 |
| 2067 | 16 | | RSL PT.19.11 | Lubbock JW | Lloyd JA | 06/06/1830 |
| 2068 | 17 | | RSL PT.19.12 | Hansfield J | Lloyd JA | 17/12/1830 |
| 2069 | 18 | | RSL RR.1.36 | Whewell W | R.S. | 04/04/1838 |
| 2070 | 19 | | RSL RR.2.164 | Whewell W | R.S. | 29/03/1852 |
| 2071 | 20 | | RSL RR.2.165 | Lubbock JW | R.S. | 01/06/1852 |
| 2072 | 21 | | RSL RR.2.262 | Airy GB | R.S. | 11/02/1850 |
| 2073 | 22 | | RSL RR.6.34 | Airy GB | Stokes GG | 23/11/1866 |
| 2074 | 23 | | RSL RR.6.36 | Haughton S | Stokes GG | 07/01/1867 |

## The document legend

| | |
|---|---|
| AC | Adams collection |
| Add | Additional manuscripts |
| BMV BIA | Bristol Merchant Venturers, Bristol Institute |
| BOD | Bodleian Library, Oxford |
| BRO | Bristol Record Office |
| CUL | Cambridge University Library |
| DAR | Darwin |
| Dep BAAS | Deposit of the BAAS |
| GUL | Glasgow University Library |
| HOT | United Kingdom Hydrographic Office, Taunton |
| HS | Herschel Papers |
| IOR | India Office records |
| Kelvin | Kelvin Papers |
| LB | Letter book |
| LRO | Liverpool Record Office |
| LUB | Lubbock papers |
| MA | Meteorological archives |
| MC | Miscellaneous correspondence |
| PT | Philosophical Transactions |
| RG 23 | Records of the Coast and Geodetic Survey |
| RGO | Royal Greenwich Observatory |
| RSL | Royal Society of London |
| RR | Referees Reports |
| SDUK | Society for the Diffusion of Useful Knowledge |
| StA | St. Andrews |
| StJ | St. John's College, Cambridge |
| Tri | Trinity College, Cambridge |
| UCL | University College, London |
| WSH | National Archives and Records, Washington |

**APPENDIX 2** LIST OF CORRESPONDENTS

| Correspondent | From | To | Total | Correspondent | From | To | Total |
|---|---|---|---|---|---|---|---|
| AAAS | 0 | 1 | 1 | Bennett TF | 1 | 1 | 2 |
| Abbe C | 1 | 0 | 1 | Bentinck C | 0 | 1 | 1 |
| Abram J | 1 | 0 | 1 | Bevan B | 15 | 0 | 15 |
| Acland AH | 2 | 0 | 2 | Beyland C dew | 2 | 0 | 2 |
| Adams JC | 25 | 82 | 107 | Blackwood J | 2 | 0 | 2 |
| Aird | 0 | 1 | 1 | Blunt W | 1 | 0 | 1 |
| Airy GB | 164 | 112 | 276 | BOL | 0 | 3 | 3 |
| Alderson J | 1 | 0 | 1 | Bolland GH | 6 | 1 | 7 |
| Allnutt JFW | 8 | 0 | 8 | Bolles CP | 0 | 1 | 1 |
| Andrews T | 1 | 0 | 1 | Bonney TG | 1 | 0 | 1 |
| Argent J | 0 | 1 | 1 | Borgen AC | 8 | 0 | 8 |
| Atchison AT | 2 | 0 | 2 | Bowditch NL | 1 | 0 | 1 |
| Atkinson T | 0 | 1 | 1 | Braaksma H | 1 | 0 | 1 |
| Auber P | 0 | 1 | 1 | Braby EE | 1 | 0 | 1 |
| Awdry RD | 1 | 0 | 1 | Bright R | 5 | 0 | 5 |
| B.A.A.S. | 1 | 4 | 5 | Bright S | 2 | 0 | 2 |
| B.M.V. | 0 | 4 | 4 | Bristol Standard | 0 | 1 | 1 |
| Bache AD | 33 | 44 | 77 | Bronwin B | 1 | 0 | 1 |
| Bahhuge I | 1 | 0 | 1 | Brown A | 2 | 0 | 2 |
| Baily F | 4 | 0 | 4 | Brown J | 1 | 0 | 1 |
| Baird AW | 71 | 9 | 80 | Brown T | 0 | 1 | 1 |
| Bald W | 1 | 0 | 1 | Buckingham M | 1 | 0 | 1 |
| Ball RS | 4 | 1 | 5 | Bullock | 0 | 1 | 1 |
| Ballingell | 1 | 0 | 1 | Bunt TG | 104 | 7 | 111 |
| Barlow P | 1 | 0 | 1 | Burdwood J | 6 | 1 | 7 |
| Barnden | 1 | 0 | 1 | Burrard S | 1 | 0 | 1 |
| Barnett E | 2 | 1 | 3 | Bushby GA | 3 | 1 | 4 |
| Barrow J | 8 | 3 | 11 | Bushey M | 1 | 0 | 1 |
| Bashforth F | 1 | 0 | 1 | Bywater T | 7 | 0 | 7 |
| Basset J | 1 | 0 | 1 | C.S.I.C. | 5 | 0 | 5 |
| Bax HB | 1 | 0 | 1 | Cabert F | 1 | 0 | 1 |
| Bayfield HW | 2 | 0 | 2 | Cam. UP | 1 | 0 | 1 |
| Bayley J | 1 | 0 | 1 | Cambrian | 0 | 1 | 1 |
| Beacham JW | 1 | 0 | 1 | Campbell C | 2 | 0 | 2 |
| Beaufort F | 94 | 133 | 227 | Campbell JD | 1 | 0 | 1 |
| Beautemps-Beupre | 1 | 0 | 1 | Campbell W | 1 | 0 | 1 |
| Becher AB | 6 | 2 | 8 | Cardew P | 2 | 0 | 2 |
| Beechey FW | 3 | 0 | 3 | Carne J | 1 | 0 | 1 |
| Belcher E | 2 | 0 | 2 | Carpenter L | 2 | 0 | 2 |
| Benham HW | 0 | 12 | 12 | Cassidy A | 2 | 0 | 2 |
| Bennett JJ | 0 | 1 | 1 | Cayley A | 1 | 1 | 2 |

| Correspondent | From | To | Total | | Correspondent | From | To | Total |
|---|---|---|---|---|---|---|---|---|
| Challis J | 1 | 0 | 1 | | Dayman J | 1 | 0 | 1 |
| Chamberlin TC | 2 | 0 | 2 | | de Morgan A | 1 | 4 | 5 |
| Chapman RW | 3 | 0 | 3 | | Dean E | 1 | 0 | 1 |
| Chatham E | 0 | 1 | 1 | | Dean GW | 1 | 0 | 1 |
| Chazallon AR | 1 | 0 | 1 | | Dedel ? | 1 | 0 | 1 |
| Chevallier E | 1 | 0 | 1 | | Denham HM | 3 | 0 | 3 |
| Children JG | 0 | 1 | 1 | | Denison FN | 2 | 0 | 2 |
| Chisholm H | 2 | 0 | 2 | | Dessiou JF | 66 | 8 | 74 |
| Christie SH | 1 | 1 | 2 | | Dew-Smith AG | 3 | 0 | 3 |
| Christie WHM | 2 | 0 | 2 | | Dix F | 1 | 0 | 1 |
| Church J | 0 | 3 | 3 | | Doberck W | 4 | 0 | 4 |
| Clark JC | 1 | 0 | 1 | | Dscoll R | 1 | 0 | 1 |
| Clarke JT | 2 | 0 | 2 | | Dubois E | 1 | 0 | 1 |
| Clarke JW | 1 | 0 | 1 | | Dunlop H | 1 | 2 | 3 |
| Clibborn E | 1 | 0 | 1 | | E.I.C. | 1 | 4 | 5 |
| Coates T | 3 | 19 | 22 | | Earl GW | 1 | 0 | 1 |
| Cohen L | 2 | 0 | 2 | | Eccles J | 4 | 0 | 4 |
| Coke H | 1 | 0 | 1 | | Edison AD | 1 | 0 | 1 |
| Colby T | 5 | 8 | 13 | | Edwards G | 1 | 0 | 1 |
| Collins J | 1 | 0 | 1 | | Elliot GE | 2 | 0 | 2 |
| Collinson R | 1 | 0 | 1 | | Endor AR | 1 | 0 | 1 |
| Connor EJ | 11 | 0 | 11 | | Evans FJ | 10 | 1 | 11 |
| Conybeare WD | 2 | 0 | 2 | | Evans H | 1 | 0 | 1 |
| Coode J | 2 | 0 | 2 | | Everett E | 1 | 1 | 2 |
| Coombs MA | 3 | 0 | 3 | | Fairfield GA | 2 | 0 | 2 |
| Cooper WW | 4 | 0 | 4 | | Falmouth Packet | 0 | 1 | 1 |
| Cordel E | 1 | 0 | 1 | | Farghar R | 1 | 0 | 1 |
| Corteen R | 2 | 2 | 4 | | Ferrel W | 1 | 0 | 1 |
| Cox | 0 | 1 | 1 | | Fitzroy R | 8 | 1 | 9 |
| Croll J | 1 | 0 | 1 | | Forbes JD | 6 | 2 | 8 |
| Crone C | 7 | 0 | 7 | | Foreman | 0 | 1 | 1 |
| Cunningham D | 1 | 1 | 2 | | Forman W | 1 | 0 | 1 |
| Curwin C | 1 | 0 | 1 | | Foster JG | 3 | 0 | 3 |
| DaCunha | 0 | 1 | 1 | | Franklin J | 1 | 0 | 1 |
| Dall P | 1 | 1 | 2 | | Friend MC | 1 | 0 | 1 |
| Darby J | 1 | 0 | 1 | | Gage J | 1 | 0 | 1 |
| Darwin GH | 97 | 442 | 539 | | Gairdner M | 1 | 0 | 1 |
| Darwin H | 2 | 0 | 2 | | Galbraith W | 1 | 0 | 1 |
| Darwin W | 0 | 2 | 2 | | Garrett N | 1 | 0 | 1 |
| Daussy P | 2 | 0 | 2 | | Gibble JE | 1 | 0 | 1 |
| Davis CH | 1 | 1 | 2 | | Gibbs LR | 1 | 0 | 1 |
| Dawer RE | 1 | 0 | 1 | | Gilbert D | 0 | 1 | 1 |
| Dawson WB | 7 | 0 | 7 | | Giles F | 0 | 1 | 1 |

| Correspondent | From | To | Total | | Correspondent | From | To | Total |
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| Giles G | 1 | 0 | 1 | | Hill J | 4 | 1 | 5 |
| Gladstone | 0 | 1 | 1 | | Hillier HM | 1 | 0 | 1 |
| Glaisher J | 1 | 1 | 2 | | Hinarey W | 1 | 0 | 1 |
| Godfray H | 0 | 1 | 1 | | Hind JR | 5 | 7 | 12 |
| Godley JA | 7 | 0 | 7 | | Hind T | 0 | 7 | 7 |
| Gordon AR | 3 | 1 | 4 | | Hoey JC | 1 | 0 | 1 |
| Gordon WW | 20 | 29 | 49 | | Holden ES | 1 | 0 | 1 |
| Goulburn H | 1 | 0 | 1 | | Holden G | 2 | 0 | 2 |
| Govt of India | 1 | 3 | 4 | | Holden M | 1 | 0 | 1 |
| Gower RH | 3 | 0 | 3 | | Homand TS | 2 | 0 | 2 |
| Graham J | 0 | 1 | 1 | | Hope W | 2 | 1 | 3 |
| Graham JD | 1 | 0 | 1 | | Hopkins C | 2 | 1 | 3 |
| Gray A | 0 | 1 | 1 | | Hornsby PI | 2 | 0 | 2 |
| Greaves C | 4 | 0 | 4 | | Horoyama S | 1 | 0 | 1 |
| Green J | 1 | 0 | 1 | | Horsburgh J | 1 | 1 | 2 |
| Greenlaw CB | 0 | 1 | 1 | | Hose | 0 | 1 | 1 |
| Greenough GB | 2 | 3 | 5 | | Hove PB | 0 | 2 | 2 |
| Griffith R | 3 | 0 | 3 | | Hudson J | 2 | 0 | 2 |
| Gutch JWG | 3 | 2 | 5 | | Huffman NH | 1 | 0 | 1 |
| Guyon | 0 | 2 | 2 | | Hugar | 0 | 1 | 1 |
| Hall B | 6 | 1 | 7 | | Hunt EG | 0 | 1 | 1 |
| Hall J | 3 | 0 | 3 | | Hurd T | 2 | 0 | 2 |
| Hallett JH | 1 | 0 | 1 | | Huret EB | 1 | 0 | 1 |
| Hamilton J | 1 | 0 | 1 | | Hussey JC | 1 | 0 | 1 |
| Hamilton WR | 0 | 1 | 1 | | Hutchinson W | 1 | 1 | 2 |
| Hansfield J | 1 | 0 | 1 | | Ibbetson R | 1 | 2 | 3 |
| Harcourt WVV | 2 | 0 | 2 | | Innes G | 11 | 0 | 11 |
| Harford JS | 1 | 0 | 1 | | Jarrad FW | 1 | 0 | 1 |
| Harris WS | 3 | 0 | 3 | | Jevons WS | 1 | 1 | 2 |
| Hartley WB | 1 | 0 | 1 | | Johnson A | 11 | 0 | 11 |
| Haughton S | 9 | 0 | 9 | | Jones J | 26 | 2 | 28 |
| Heath DD | 2 | 0 | 2 | | Jones Ja | 1 | 0 | 1 |
| Heaton H | 0 | 5 | 5 | | Jones Jo | 1 | 0 | 1 |
| Hein J | 1 | 0 | 1 | | Jones R | 0 | 2 | 2 |
| Hendersdon VF | 1 | 0 | 1 | | Kater H | 1 | 0 | 1 |
| Henderson T | 1 | 0 | 1 | | Kelland P | 3 | 2 | 5 |
| Hennessey JBN | 0 | 1 | 1 | | King MC | 0 | 1 | 1 |
| Henry W | 1 | 0 | 1 | | Knight C | 0 | 0 | 0 |
| Herbert J | 1 | 2 | 3 | | Konig C | 1 | 0 | 1 |
| Heron W | 0 | 1 | 1 | | Kyd J | 1 | 0 | 1 |
| Herschel JFW | 16 | 14 | 30 | | Larcom H | 2 | 3 | 5 |
| Hewitt W | 1 | 1 | 2 | | Larmor J | 0 | 1 | 1 |
| Hilgard JE | 2 | 1 | 3 | | Le Bas CW | 1 | 0 | 1 |

| Correspondent | From | To | Total | | Correspondent | From | To | Total |
|---|---|---|---|---|---|---|---|---|
| Lendbetter J | 1 | 0 | 1 | | Orlebar AB | 1 | 0 | 1 |
| Lloyd H | 2 | 0 | 2 | | Oshea EM | 5 | 0 | 5 |
| Lloyd JA | 4 | 3 | 7 | | Page F | 1 | 0 | 1 |
| Lockyer JN | 0 | 1 | 1 | | Palmer HR | 3 | 0 | 3 |
| Lomart MF | 1 | 0 | 1 | | Palmer WR | 0 | 1 | 1 |
| Loney R | 1 | 0 | 1 | | Parker H | 1 | 1 | 2 |
| Long W | 1 | 1 | 2 | | Parker J | 0 | 2 | 2 |
| Lord W | 3 | 0 | 3 | | Parry WE | 3 | 3 | 6 |
| Lowrie WH | 1 | 0 | 1 | | Pasco xC | 1 | 1 | 2 |
| Lubbock JW | 80 | 254 | 334 | | Pearson J | 8 | 0 | 8 |
| Lyell C | 1 | 0 | 1 | | Peddu WS | 1 | 0 | 1 |
| Macalister D | 1 | 0 | 1 | | Peirce W | 8 | 0 | 8 |
| Macauley JH | 0 | 1 | 1 | | Phillips J | 2 | 1 | 3 |
| Macdonald J | 1 | 0 | 1 | | Plana M | 0 | 1 | 1 |
| Mackie D | 1 | 0 | 1 | | Plummer WE | 3 | 0 | 3 |
| Maclear T | 1 | 1 | 2 | | Pond J | 1 | 5 | 6 |
| Macrae J | 1 | 0 | 1 | | Pourtales LF | 45 | 26 | 71 |
| Main R | 3 | 3 | 6 | | R.S. | 0 | 10 | 10 |
| Malcolm C | 1 | 1 | 2 | | Raper H | 1 | 0 | 1 |
| Malcolm P | 0 | 1 | 1 | | Reid W | 1 | 0 | 1 |
| Martin KB | 1 | 1 | 2 | | Rennie G | 6 | 0 | 6 |
| Martin TB | 0 | 0 | 0 | | Rennie J | 2 | 0 | 2 |
| May C | 8 | 10 | 18 | | Rennie John | 2 | 0 | 2 |
| May N | 2 | 0 | 2 | | Reynolds | 0 | 1 | 1 |
| Mcarthy D | 1 | 0 | 1 | | Richardson J | 1 | 0 | 1 |
| Meech LW | 4 | 0 | 4 | | Ritchie R | 1 | 0 | 1 |
| Melvill E | 2 | 0 | 2 | | Roberton E de | 1 | 6 | 7 |
| Metcalfe CT | 0 | 1 | 1 | | Roberts E | 117 | 8 | 125 |
| Miller Prof | 0 | 1 | 1 | | Roberts W | 2 | 0 | 2 |
| Mitchell H | 10 | 1 | 11 | | Robertson N | 1 | 0 | 1 |
| Molison AR | 2 | 2 | 4 | | Robinson W | 0 | 1 | 1 |
| Moll G | 4 | 1 | 5 | | Roget PM | 1 | 2 | 3 |
| Montomery DE | 1 | 0 | 1 | | Rohrs JH | 5 | 0 | 5 |
| Moriarty HA | 1 | 0 | 1 | | Romilly J | 0 | 2 | 2 |
| Morice CCD | 1 | 0 | 1 | | Rorie JJ | 1 | 0 | 1 |
| Mudge | 0 | 5 | 5 | | Ross D | 55 | 3 | 58 |
| Murchison R | 1 | 1 | 2 | | Ross JC | 6 | 1 | 7 |
| N.Y.D.M. | 1 | 0 | 1 | | Routh EJ | 1 | 0 | 1 |
| Neison E | 3 | 1 | 4 | | Royeal MW | 1 | 0 | 1 |
| Nelson | 0 | 1 | 1 | | Rumpl | 0 | 1 | 1 |
| Newman J | 2 | 0 | 2 | | Russell E | 11 | 0 | 11 |
| Ober MH | 5 | 1 | 6 | | Russell JS | 4 | 0 | 4 |
| Offler JR | 1 | 0 | 1 | | Ryder CH | 1 | 0 | 1 |

| Correspondent | From | To | Total | | Correspondent | From | To | Total |
|---|---|---|---|---|---|---|---|---|
| Sabine E | 1 | 1 | 2 | | Thuillier HR | 1 | 0 | 1 |
| Satterly J | 1 | 0 | 1 | | Tizard T | 1 | 0 | 1 |
| Schutt CA | 4 | 0 | 4 | | Trausten JG | 1 | 0 | 1 |
| Scoresby W | 3 | 1 | 4 | | Trowbridge WP | 1 | 2 | 3 |
| Secretary RS | 0 | 0 | 0 | | Turner J | 1 | 0 | 1 |
| Sedgwick A | 0 | 1 | 1 | | Turner W | 0 | 1 | 1 |
| Sharp W | 1 | 0 | 1 | | U.S.J. | 1 | 0 | 1 |
| Sharpey W | 0 | 1 | 1 | | Vallancey C | 1 | 0 | 1 |
| Sheepshanks R | 1 | 0 | 1 | | Van de Wayer S | 1 | 0 | 1 |
| Sherrif W | 3 | 4 | 7 | | Vaughen D | 2 | 0 | 2 |
| Shoolbred JN | 3 | 0 | 3 | | Vaughen W | 1 | 0 | 1 |
| Sim J | 1 | 0 | 1 | | Waldegrave W | 3 | 0 | 3 |
| Simpson M | 2 | 0 | 2 | | Walker JT | 8 | 1 | 9 |
| Slade T | 1 | 0 | 1 | | Walker SC | 2 | 0 | 2 |
| Slee C | 1 | 1 | 2 | | Walker W | 4 | 0 | 4 |
| Smart JN | 1 | 0 | 1 | | Walton W | 1 | 0 | 1 |
| Smyth WH | 6 | 0 | 6 | | Washington J | 4 | 6 | 10 |
| Solly I | 4 | 0 | 4 | | Wedgwood GN | 2 | 0 | 2 |
| South J | 1 | 0 | 1 | | Weld CR | 1 | 0 | 1 |
| Spenser R | 3 | 0 | 3 | | Wharton WJH | 19 | 4 | 23 |
| Sprigge JA | 1 | 0 | 1 | | Whewell W | 100 | 391 | 491 |
| Stanley O | 3 | 0 | 3 | | Whipple RS | 1 | 0 | 1 |
| Stevens JJ | 1 | 9 | 10 | | White GR | 1 | 0 | 1 |
| Stevenson R | 2 | 0 | 2 | | White M | 0 | 1 | 1 |
| Stewardson HC | 1 | 0 | 1 | | White TO | 4 | 1 | 5 |
| Stok JP van der | 2 | 0 | 2 | | White W | 1 | 0 | 1 |
| Stokes GG | 4 | 42 | 46 | | Whitehouse A | 2 | 0 | 2 |
| Stone EJ | 1 | 0 | 1 | | Whiting EB | 0 | 1 | 1 |
| Stotherd RH | 2 | 0 | 2 | | Wilkes C | 1 | 0 | 1 |
| Strachey R | 19 | 2 | 21 | | Williams J | 1 | 2 | 3 |
| Strahan G | 3 | 1 | 4 | | Williams T | 0 | 1 | 1 |
| Stratford WS | 42 | 8 | 50 | | Wollaston WH | 0 | 4 | 4 |
| Stutchbury S | 3 | 7 | 10 | | Wood C | 1 | 1 | 2 |
| Taylor A | 1 | 0 | 1 | | Wright CWH | 1 | 0 | 1 |
| Taylor PG | 0 | 1 | 1 | | Wright T | 25 | 0 | 25 |
| Templer J | 1 | 0 | 1 | | Wrottesley J | 0 | 1 | 1 |
| The Times | 0 | 1 | 1 | | Wurdermann G | 1 | 0 | 1 |
| Thomas G | 0 | 1 | 1 | | Yates J | 2 | 0 | 2 |
| Thomas R | 1 | 0 | 1 | | Yates JB | 5 | 0 | 5 |
| Thompson P | 1 | 1 | 2 | | Yelland N | 20 | 17 | 37 |
| Thomson FA | 3 | 0 | 3 | | Young AE | 1 | 0 | 1 |
| Thomson J | 1 | 0 | 1 | | Young T | 0 | 17 | 17 |
| Thomson W | 91 | 92 | 183 | | | | | |

# APPENDIX 2

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Anno 1678 in Tonqueen Fol 24
I have here according to your Order subjoined
some other noates very necessary to be known
by those who use this port vizt

1 Concerning the choice of time in respect
of the tides, for comeing over the Barr

My advise is that upon those severall following dayes
of the moons age in every perticular month of the yeare
no English Commander should upon any occasion
what so ever adventure over this Barr, unless he
have a pilott from the shoare who undertakes to bring
him in or that he hath only charge of some small Barks
or Junck that dreawes no more than 8 or 9 foot water

In the $\frac{1}{7}$ } Moons from the { $\frac{3}{17}$ to the $\frac{7}{21}$ } dayes of the moons age Exclusive

In the $\frac{2}{8}$ } Moons from the { $\frac{5}{14}$ to the $\frac{5}{18}$ } days of the moons age Exclu

& from the 27 of the $\frac{2}{8}$ } Moons to the 1st of the $\frac{3}{9}$ } Moons Ex

In the $\frac{3}{9}$ } Moons from the { $\frac{11}{25}$ to the $\frac{15}{29}$ } dayes of the moons age Exc

In the $\frac{4}{10}$ } Moons from the 3 to the $\frac{13}{27}$ } dayes of the moons age Exclusive

In the $\frac{5}{11}$ } Moons from the { $\frac{7}{21}$ to the $\frac{11}{15}$ } dayes of the moons age Exclu

In the $\frac{6}{12}$ } Moons from the { $\frac{15}{19}$ to the $\frac{9}{23}$ } dayes of the moons age Exclu

And excepting on those six dayes above mentioned
in every respective moon he may safely adventure
over the Barr any day provided always, that he
mistae not the time of tide but come over at halfe
flood or better & observe the Directions before given
though he may take notice that the highest tides will
be about 6 or 7 dayes after the waters first begining
to Encrease and the first days of the waters encrease
are

In the $\frac{1}{7}$ } Moons on the $\frac{5}{19}$ } dayes }

In the $\frac{2}{8}$ } Moons on the 3/16/29} dayes }

In the $\frac{3}{9}$ } Moons on the $\frac{13}{27}$ } dayes } of the Moons age

In the $\frac{4}{10}$ } Moons on the $\frac{11}{25}$ } dayes }

In the $\frac{5}{11}$ } Moons on the $\frac{9}{13}$ x } dayes }

In the $\frac{6}{x}$ } Moons on the $\frac{7}{x}$ } dayes }

Anno 1678 in Tonqueen Folio 25

It is needless to take notice in what hour the wat 473
Increase begins because the regular course of the tides is not from thence commenced in respect of the time of flowing & Ebbing

2 Concerning the different soundings on the Barr in certaine months

The Barr itself being about 1 mile ½ in length & no where Accepting its first Entrance exceeding halfe a Mile in breadth is very even; but yet affor. considerably different soundings in the same age & time of the tides according to the season of the yeare & wch seems to be somewt strange hath the highest tides in the northern . Monzoons as I have been Informed by those who are seemingly best able to give an Acc' thereof & I must needs say that the triall I now mad. on the Barr accorded with wt I understood from severall of ye Fishermen & others as to this month wch Induced me to enter. .eir Information as to the rest vizt that comeing over at halfe Flood (except on the dayes before mentioned as dangerous to come over) ther will be found according to the age of the tide

In the 3/4/5} Moons from 16 to 21 feet } Always the higher
In the 6/7/8} Moons from 19 to 24 feet } the flood is the lower
In the 9/10/11} Moons from 21 to 27 feet} will be the Ebb so that
In the 12/1/2} Moons from17 to 22 feet } according to the strength
of the tides at low water the Soundings are from 6 to 13 foot

3 Concerning the course of the tides

When the Reported Irregularity of the Ebbing & fflowing of the sea here came first under my consideration at a distance I was content to ffancy that I had guessed

Anno 1678 in Tonqueen Fol 26

Aright in ascribing ye occasion of it principally to the Indraughts & outlets of this Bay wch as I Imagined might give ye diferent times of the yeare in respect of the Monzoons & the currents accordingly shifting with severall other conceitedly coadjutant circumstances, the most considerable share in the unusual course of the tides & that consequently it would scarce be possible to discover any circumstances in them if their regiment depended so much upon accident & uncertainety

But dureing my continuance at Batsha I have observed such an order & constancy in the course of the tides that notwithstanding I must needs confess it diferrent from all that ever I observed in any other port yet not only from the coincidence similar alteration o. peculiar dayes of some perticular

moons in diferent Monzoons in respect of the
Increase & decrease as well as from their keeping
equall pace with moons riseing & setting in this
Horison in respect of the duration of their Influx
& reflux out also from that wch seems to render them
most of all iregular vizt the constant falling
back of fflood nearest 13 hours on every second
day of the waters age or Increase so that at the end of
15 dayes their is an Inversion of their motion
in respect of their begining to flow & Ebb, It is
evident that they are regularly Influenced, thought
not reconcileable with a dependance on the
Lunar Motion so far as wholly to free their naturall
course from the Interuption of some forreigne
intervening controulment nor for as much as it
will be satisfactory enough for any mans benefitt
of the tides to know when the flood & Ebb begins & when
there is the greatest & smallest Influxes without any new

Anno 1678 in Tonqueen — Fol 27 475

discourse of the causes of their defferances here from
those in other parts of the world a subject fitter
for pholosophers then seamen, I have here to avoid
over much tediousness, entred only the result of my
unintermitted observations of the tides daily course
dureing my stay at Batshe by wch those Commanders
who at this time of year come before this barr
may not only know when it will be most convenient
to come over supposeing no pilott goes off to bring
them in, but also perceive the reason why I gave caution
to forbear adventureing on such certaine days of the
moons age before mentioned vizt

On the first & second days of the waters Increase the
Influences are very small & uncertaine but afterwareds
the tides for 13 dayes are constant in their
course one fflood & ebb being compleated in 24 hour.
time equally shareing the space of a Lunar circuition
of the earth between them & every fflood begining
nearest ¾ of an hour later than the procedent fflood
& also considerably increasing in the highest of the tide
every day from the 3[d] unto the 6 & 7 dayes of the waers
age on wch two dayes the floodruns very high but on
he 8[th] day (wch may be accounted the lastf the spring
tide) the water begining gradually to decrease againe
retaining the same orderly differance of time in
each tide untill the next following first day of the
waters increase, when dureing a two dayes unsetledness,
there is a shifting of thetides in respet of the
begining of the fflood & ebb after wch said shifting
a constancy in their Inverted course is againe
retained in ye above mentionedorder for 13 dayes
followingas

For Example

On the 25 & 26 days of the 4 Moon, being the 2 first days
of the waters Increase the Influxes were very small
there (happening on the 26 day a falling back of the tides
about 13 hours)

Anno 1678 in Tonqueen Fol 28
But from the 27 day (wch was the 3rd day of the water Increase
after the last quarter) unto the 9th day of the 5th moons age
I noted a very constant course in the tides every flood
begining with the riseing of the moone & ending at its
setting, the following ebb in like manner continue
dureing the time of the moons absence from this
Hemisphere but on the said 9th day of the 5 moons age
being the first day of the wars Increase there the motion
was scearly perceiveable, on the 10 day there was another
falling back of the tides nearest 13 hours & on the 11 day
(wch was ye 3rd day of the waters Increase after the first
quarter of the moons ages the fflood haveing as I said
shifted the preceeding day, took its turne to begin
at the moons setting & end at its reseing & accordingly
the tides sucessively following assumed & kept a
constant regularity (the tides being at highest on the
16 of the moon wch was the 7 day of the waters age) untill
the 23 day of the said moons age on wch (being the first
day of the waters encrease) the Influx was again &
scarse discernible for its smallness on the 24 day the
tides fall back as I had found twice before to have
done on the same dayes of the waters age) nearest 13 hours
by wch meanes the fflood on the 25 day wch was the 3rd day of the
waters encrease after the last quarter of the moons)
now againe commenceed wth the riseing Moon whereby it
hath falne out alwayes to be high water between
noon & the following midnight every day dureing
my stay here

Soe that it may passe into a Corallary vizt
In the 4:5.& 6: changes of the moon from the 3rd day of the } ☾ Last quarter 22 days
the waters age after the last quarter to the 3rd day of the } ☾ 1st quarter 8 days
waters age after the first quarter of the following
moon the water begins to flow when the moon a
riseth & to Ebb againe when it setteth in this Horison

Anno 1678 in Tonqueen Fol 29
And the contrary from the 3rd day of the waters age 477
after the first quarter to the 3rd day of their age after
the last quarter excludeing always their motion
on the two first dayes of the waters increase because
of its smallness & uncertainety

I am informed by the inhbitants hereabouts th
this may hold for a rule from the 2nd to the end of the 7th
moon & that the converse therof holds true in the
other six months of the year vizt from the 8th to end
of the first moon according to wxh the tides fall out
to be at the highest in the Evening for 6 moneths successively
and the other halfe year in the morning that is
to say between midnight & the following noon
And though I cannot averr per truth of it yet I find
that the tide last year in the 11 moon wch occasionally
upon the ship Eagles departure hence I took some
notice of & entred in the close of my sea Journall
did fall out not disagreeing with what they affirme
& I am yet the rather induced to beleive that in every
annuall revolution there may be such a constancy

in this different motion of the tide appropriated
to each moiety of the year because that dureing my
days stay at Batsha I have found the predictions
of the natives confirmed by my own observation
of the tides falling out to be at highes alwayes
between noon & the succeeding midnight occasioned
by the above daid falling back at the end of 15 dayes
so that on every 3rd day of the waters encrease the Flood
begins at the hour wherein the day before it ended

To prevent mistakes in the Accompt of the
Moones

Though the difference of meridians between
this place & London together with the different
begining of their naturall day in their Accompts
here from that of ours & some Imperfections from wch
their astronomicall calulations are not free

Anno 1678 in Tonqueen Fol 30
May occasion a disagreement between our Accompt &
Theirs of the moons age yet it will never be so considerable
as to occasion any sensible or dangerous error
in the above mentioned reconking of the tides first
dayes of meress provided the numver of the Moneth be
not mistaken wherfore it may be sufficient to
Informe those who use this port that the first change
of the moon after the 15 day of January old stile is
reckoned for the begining of the year, & that moon
being accounted the first, the rest follow in order
untill the expiration of 12th wch compleats their
year alway except only in their Leap year & then
they have 13 moons takeing in one exterordinary
to make up the defficiente of the moons epact in
their Accompt, in wch year the first day of their new
years moon fallsout before the said 15 of January (as it
did this year upon the 12 being a leap year with them
so that they reckoned 2 moneths for one this year (that is
to say the 2nd & 3rd moon after their new years day they
called both 2nd moons) for otherwise the present moon
wch changed in July would have been the 7th whereas
how they account but the 6 moone & accordingly
doe the tides fall out But this Leap yeare being past
the first moon in the year must be reckoned to begin
on the change next following the 15 of January &
all other change accounted successively as above
said untill the Intervention of another Leap year

Thus haveing to the best of my power endeavoured
to comply wth your orders in every particular, I hope
my tediousness will need no apology to your selves & if
any other persons for whose benefitt you designed it be
angry at my prolicity they may soon please them
selfes by throwing by the paper with out any affront
to me for I will not think any man obliged take
the pains to read; what notwithstanding your Commands
made my duty to take pains to write & shall yet a great deal
the less be concerned at their censures in as much as the consciousness
of my faith fullness in this Essay, doth considerably recompense
my endeavours therein wth a self satisfaction I am Sir yours F.D.

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## APPENDIX 4 THE DESSIOU BIBLIOGRAPHY

Charts, Sailing Directions, Tide-tables and Tract
with a note of where one copy may be located and number of holdings per institution

| | | |
|---|---|---|
| AHWR | A. H. W. Robinson, *Marine Cartography in Britain*, 1962 p212. | 1 |
| ALP | Admiralty Library, Portsmouth | 5 |
| BL | British Library, London | 46 |
| Bodl | Bodleian Library, Oxford | 1 |
| CUL | Cambridge University Library, Cambridge | 7 |
| HOT | Hydrographic Office, Taunton | 35 |
| NMM | National Maritime Museum, London | 18 |
| Nott | Nottingham University, Nottingham | 1 |
| PRO | Public Record Office, London | 4 |
| RGS | Royal Geographical Society, London | 20 |
| Examples held at the following have not been sighted | | |
| ALL | Admiralty Library, London | 4 |
| BNE | Biblioteca National, Spain | 1 |
| Harv | Harvard University, USA | 1 |
| LoC | Library of Congress, USA | 3 |
| NLS | National Library of Scotland, Edinburgh | 1 |
| McM | MacMasters University, Canada | 1 |
| Mich | University of Michigan, USA | 2 |
| Minn | University of Minnesota, USA | 1 |
| MUN | Memorial University of Newfoundland, Canada | 1 |
| NYPL | New York Public Library, USA | 3 |
| PMG | Priaulx Museum, Guernsey | 1 |
| Rmsy | David Rumsey, USA | 1 |
| Ve | Polar Organisation, Venezuela | 1 |

The works of **JFD**, Joseph Foss Dessiou (1769-1853)

JFD1. HOT Chart of the Coast of Spain, from Cabrita to Frayles Point. By I. F. Dessiou, Master of HMS Dreadnought 1802.

JFD2. NLS The New Mediterranean Pilot. Joseph Foss Dessiou. Heather. 1802.

JFD3. BL A Chart of the English Channel extending from Dover to the Isles of Scilly and from Calais to the Bay of Brest, to which are added the South Part of the North Sea with the Entrance of the Thames. By J.F. Dessiou. Faden. 1804.

JFD4. BL A chart of the coast of Kent from Dover to Margate describing The Downs, Margate Road etc by I. F. Dessiou. Master of the Royal Navy. Faden. 1805.

JFD5. BL General Chart of the Mediterranean Sea, including the Gulf of Venice, Archipelago, and part of the Black Sea. by J.F. Dessiou Master of the Royal Navy. Faden. 1805.

JFD6. HOT A Chart of the Coast of Kent from Dover to Margate describing The Downs, Margate Road etc by I. F. Dessiou. Master of the Royal Navy. Faden. 1805.

JFD7. CUL Le Petit Neptune Français; or French Coasting Pilot, 3rd edition J. F. Dessiou, Master of the Royal Navy. Faden. 1805.

JFD8. CUL  Chart of the Strait of Gibraltar constructed in 1786 by Brigadier Don Vincent Tofino de San Miguel. To which have been added Ceuta and Tetuan Bays by J. F. Dessiou. Master of the Royal Navy. Faden. 1806.

JFD9. BL  Chart of the Adriatic Sea or Gulf of Venice Constructed from the Venetian, Neapolitan and French Observations by J. F. Dession. Master of the Royal Navy. Faden. 1806.

JFD10. BL  A new general Chart of the Mediterranean Sea, including the Adriatic or Gulf of Venice, the Archipelago of Greek Isles and Part of the Black Sea: by Joseph Foss Dessiou, Master of the Royal Navy. Faden. 1806.

JFD11. BL  Chart of the East Coast of England from Orfordness to the South Foreland, with the River Thames by J. F. Dessiou, Master of the Royal Navy. Faden. 1807.

JFD12. BL  A Chart of the Ethiopic or Southern Ocean, and part of the Pacific Ocean from the parallel of 3 degrees N to 56° 20' South by J. Foss Dessiou Master of the Royal Navy. Faden. 1808.

JFD13. HOT  Chart of the Strait of Dover comprehending the Coast of England from the North Foreland to Rye Harbour like-wise the Coast of France from Nieuport to the River Canche. I. Foss Dessiou, Master of the Royal Navy. Faden. 1808.

JFD14. HOT  A General Chart of the West Indies and Gulf of Mexico, by J. Foss Dessiou, Master, of the Royal Navy. Faden. 1808.

JFD15. BL  Chart of the Old Bahama Channel comprising the Coast of the Isle of Cuba from Icacos Point to Point Guarico by I. Foss Dessiou Master of the Royal Navy. Faden. 1808.

JFD16. BL  Chart of part of the Coast of Newfoundland, from Point Lance to Cape Spear. Second Edition Revised by J. Foss Dessiou. Faden. 1809.

JFD17. HOT  A Chart of Part of the Coast of Newfoundland, from Cape Spear to Cape Bonavista. 2nd Edition. Revised by J. Foss Dessiou. Faden. 1809.

JFD18. BL  The New Mediterranean Pilot, containing two hundred and twenty-four accurate plans ... and Joseph Foss Dessiou, Masters in the Royal Navy. Heather. 1810.

JFD19. BL  Directions for Navigating Part of the Coast of Labrador from Cape Charles to Sandwich Bay. 2nd Edition Revised by J. F. Dessiou. Faden. 1810.

JFD20. BL  Directions for Navigating the Bay of Placentia from Cape Chapeau Rouge to Cape St. Mary. 2nd Ed. Revised by J. F. Dessiou. Faden. 1810.

JFD21. BL  Directions for Navigating Part of the Coast of Newfoundland from Point Lance to Cape Spear. by J. F. Dessiou. Faden. 1810.

JFD22. BL  Directions for Navigating Part of the Coast of Newfoundland, from Cape Spear to Cape Bonavista. 2nd Edition. by J. F. Dessiou. Faden. 1810.

JFD23. BL  A Chart of Part of the East Coast of the North Sea from NIEUPORT to VLIELAND. by J. F. Dessiou. Master R.N. Faden. 1811.

JFD24. BL Chart of the coasts of Spain, France & Italy with the opposite Coast of Barbary. by I. F. Dessiou. Master R.N. Faden. 1811.

JFD25. BL Chart of part of the Coast of Devonshire from Rame Head to Exmouth by Joseph Foss Dessiou Master of the Royal Navy. Faden. 1811.

JFD26. HOT Chart of the Strait of Dover, Comprehending The Coast of England from the North Foreland to Rye Harbour Likewise the Coast of France From Nieuport to the River Canche. by I Foss Dessiou, Master of the Royal Navy. Second Edition.Faden. 1812.

JFD27. BL A Chart of the Coast of Kent from Dover to Margate. by I. F. Dessiou. Master of the Royal Navy. Second Edition. Faden. 1812.

JFD28. HOT A new General Chart of the North Sea or German Ocean, from the parallel of 50°25' to 64°12' North. By Joseph Foss Dessiou Master of the Royal Navy. Faden. 1812.

JFD29. ALP This Chart of the North Sea. Joseph Foss Dessiou Master of the Royal Navy. Faden. 1812.

JFD30. BL The Coast of Dorset, Hampshire and Sussex, from St Alban's Head to Selsea Bill. by Joseph Foss Dessiou Master of the RN. Faden. 1813.

JFD31. HOT Chart of Part of the Coast of Devonshire, from Rame Head to Exmouth. by Joseph Foss Dessiou Master of the Royal Navy. Second Edition. Faden. 1816.

JFD32. CUL Chart of the East Coast of England, from Orfordness to the South Foreland. by J. F. Dessiou, Master of the Royal Navy. Faden. 1816.

JFD33. HOT The Coast of Cornwall from Rame Head to Tintagel Head including the Scilly Islands. By Joseph Foss Dessiou, Master of the Royal Navy. Faden. 1816.

JFD34. HOT The Coast of Sussex and Kent from Selsey Bill To Dungeness. by Joseph Foss Dessiou; Master of the Royal Navy. Faden. 1816.

JFD35. HOT The Coast of Dorsetshire from Exmouth to St. Alban's Head. by Joseph Foss Dessiou, Master, of the Royal Navy. Faden. 1816.

JFD36. HOT Directions for Navigating Throughout the English Channel: the Southern Part of the North Sea fromYarmouth to the Downs, and from the River Maes to Cape Grisnez, comprehending also the Southern Coast of Ireland. Joseph Foss Dessiou Master of the Royal Navy, 3rd Edition. Faden. 1816.

JFD37. NMM Directions for navigating in and throughout the North sea from the Nore to the south Foreland of the Shetland Isles; and from Cape Grisnez to the Skaw, by the author, Joseph Foss Dessiou. Faden. 1816.

JFD38. CUL A new general chart of the coast of Brazil, from the River Amazon to the River Plate. by Joseph Foss Dessiou, Master, of the Royal Navy. Faden. 1818.

JFD39. HOT The Environs of Torquay, Reduced from the original Survey made by J. F. Dessiou, 1819.

JFD40. NMM Steel's East coast of England and Scotland Pilot, containing the following charts by Joseph Foss Dessiou. Master of the Royal Navy. 1819.

1. 1820 East coast of England from Folkestone to the Naze.
2. 1819 East coast of England from the Naze to the Spurn Point.
3. 1819 East coast of England and Scotland from the River Humber to Aberdeen.
4. 1819 North Sea.

JFD41. AHWR Chart of Burry River & Rossily Bay, byJoseph Foss Dessiou, Hydrographer. Norrie. 1824.

JFD42. Mich The practical navigator; being a complete epitome of navigation: Moore. 20th ed. by Joseph F. Dessiou. 1828.

JFD43. HOT Cayou Bajo de Cadiz From Mr Dessiou 26 Feb [18]30.

JFD44. CUL Divine and spiritual communications through Thomas Dowland to Elias Carpenter. J. F. Dessiou, of Lambeth. 1848.

JFD45. Nott A Chart of the English Channel, Extending from Dover to the Isles of Scilly and from Calais to the Bay of Brest. by Joseph Foss Dessiou, Master of the Royal Navy. 2nd Edition Wyld. 1848.

JFD46. PRO A Chart of the English Channel Extending from Dover to the Isles of Scilly and from Calais to the Bay of Brest. by Joseph Foss Dessiou, Master of the Royal Navy. 2nd Edition Wyld. 1851.

The twenty items with short signature, now attributed to Joseph Foss Dessiou:

Dessiou1. BL Sailing directions to be used with John Hamilton Moore's Chart of the British Channel, and the South-West Coast of Ireland. 6th Ed. by Joseph Dessiou. 1802.

Dessiou2. BL [The Coaster's Companion Containing Sailing Directions for the East Coast of England from London to the Shetland Isles, by John Hamilton Moore. 7th Edition. 1803.] A Table, Shewing the Tides on each side of the British Channel by J. Dessiou.

Dessiou3. BL A survey of Tor Bay. Mr. Jos. Dessiou. Steel. 1804.

Dessiou4. BL This survey of the Harbour of Dartmouth, by Joseph Dessiou. Second Edition. Faden. 1804.

Dessiou5. PMG Chart of the Coast of France, from Cherbourg to Brehout Is. By Joseph Dessiou. Laurie and Whittle. 1805.

Dessiou6. LoC This chart of the United States of America: including Halifax, Havannah, New Providence, and all the northern parts of the West Indies, by Captain J. Dessiou. Moore. 1805.

Dessiou7. NMM Harbours and islands in the English Channel ... Torbay From a Survey by Mr. Dessiou. 1806.

Dessiou8. HOT New General Chart of the Island of Newfoundland with all its Banks; the Gulph and River of St. Lawrence & the Bay of Fundy. by Joseph Dessiou. Laurie & Whittle. 1808.

Dessiou9. BL New Chart of the West Indies, Gulf of Mexico and Northern Provinces of South America. by Joseph Dessiou. Laurie & Whittle. 1809.

Dessiou10. NMM The seaman's complete daily assistant, by John Hamilton Moore, the sixth edition by Joseph Dessiou. 1809.

Dessiou11. BL The new Practical navigator, by John Hamilton Moore, the eighteenth edition by Joseph Dessiou. 1810.

Dessiou12. (private) New General Chart of the Island of Newfoundland, with all its Banks; the Gulph and River of St. Lawrence & the Bay of Fundy. by Joseph Dessiou. Laurie & Whittle. 1810.

Dessiou13. BL New Sailing Directions for the Mediterranean Sea. Joseph Dessiou. The Second Edition. Laurie & Whittle. 1811.

Dessiou14. McM New Chart of the Mediterranean Sea comprehending the coast from Cape St. Mary, (in Portugal) to Constantinople, and from Rabat, in Africa, to Alexandretto, or Scanderoon in Asia. By Joseph Dessiou Master Mariner. Laurie & Whittle. 1811.

Dessiou15. RGS Chart of the Coast of France, from Cherbourg to Brehout Is. By Joseph Dessiou. Laurie & Whittle 1812.

Dessiou16. Ve A New Chart of the West Indies, Gulf of Mexico, and Northern Provinces of South America, by Joseph Dessiou. Laurie & Whittle. 1813.

Dessiou17. HOT Plan of the proposed Portland Harbour. Surveyed & Sounded By Joseph Dessiou. 1813.

Dessiou18. Bodl The new Practical navigator, by John Hamilton Moore, the nineteenth edition, by Joseph Dessiou. 1810.

Dessiou19. PRO The new general chart of the West Indies. by Joseph Dessiou. Laurie & Whittle. 1818.

Dessiou20. NYPL The seaman's complete daily assistant, By John Hamilton Moore. 6th edition by Joseph Dessiou. 1819.

The works of **JD**, Joseph Dessiou (1743-1822)

JD1. BL This new and correct survey of Dartmouth Harbour. Joseph Dessiou 1770.

JD2. HOT Dartmouth this Plan of the Harbour, and River, with the Rocks. Joseph Dessiou 1782.

JD3. HOT This Survey of the Harbour of Dartmouth. Joseph Dessiou. 1790.

JD4. CUL The new Graving-Dock, with the Wharfs & Keys belonging [Dartmouth] J. Dessiou. Moore. 1793.