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THE MIOCENE HUMBOLDT FORMATION IN NORTHEASTERN NEVADA

ROBERT P. SHARP
University of Illinois

ABSTRACT

The Humboldt formation of northeastern Nevada consists of 5,800 feet of continental deposits which range in grain size from coarse fanglomerate to fine shale and in composition from lake deposits of limestone and oil shale to stream-laid conglomerate, sandstone, and mudstone interbedded with fine pyroclastics of water-laid and air-borne types. These beds may be divided into three members: (1) a lower member, mostly lake beds; (2) a middle member characterized by ash and tuff beds; (3) an upper member, mostly stream-laid deposits. Vertebrate and plant remains indicate a late Miocene age and an environment more humid than the present.

The formation occupies basins separated by northward-trending fault-block mountains. It was originally deposited in a large irregular depression or a series of connected intermontane basins, which have become basins of sedimentation through warping or faulting. In the area considered, some of the basin and mountain blocks have been outlined by faulting during deposition of the Humboldt beds, and that fault pattern has been perpetuated by movements continuing to the present.

INTRODUCTION

This paper presents data on Miocene basin deposits in northeastern Nevada known as the "Humboldt formation." Since these deposits may have originally covered an area conservatively estimated at 40,000 square miles, it is obvious that the 2,000 square miles considered here are only a small part of the whole and that a number of years will be required to make a complete study. For that reason many problems associated with the broader physiographic relations of Humboldt time remain unsolved.

GEOGRAPHIC RELATIONS

The center of the area covered by these Miocene deposits lies in the vicinity of Elko and the Ruby–East Humboldt Range[1] in Elko County, northeastern Nevada. Elko is located at 115°47′ W. Long. and 40°50′ N. Lat., 200 miles west of Salt Lake City, Utah. Figure 1 shows in rough outline the areal extent of the Tertiary basin deposits in northeastern Nevada. All these deposits do not necessarily belong

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[1] Not to be confused with the Humboldt Range of west-central Nevada, 150 miles farther west, studied by G. D. Louderback, *Bull. Geol. Soc. Amer.*, Vol. XV (1904), pp. 298–364.

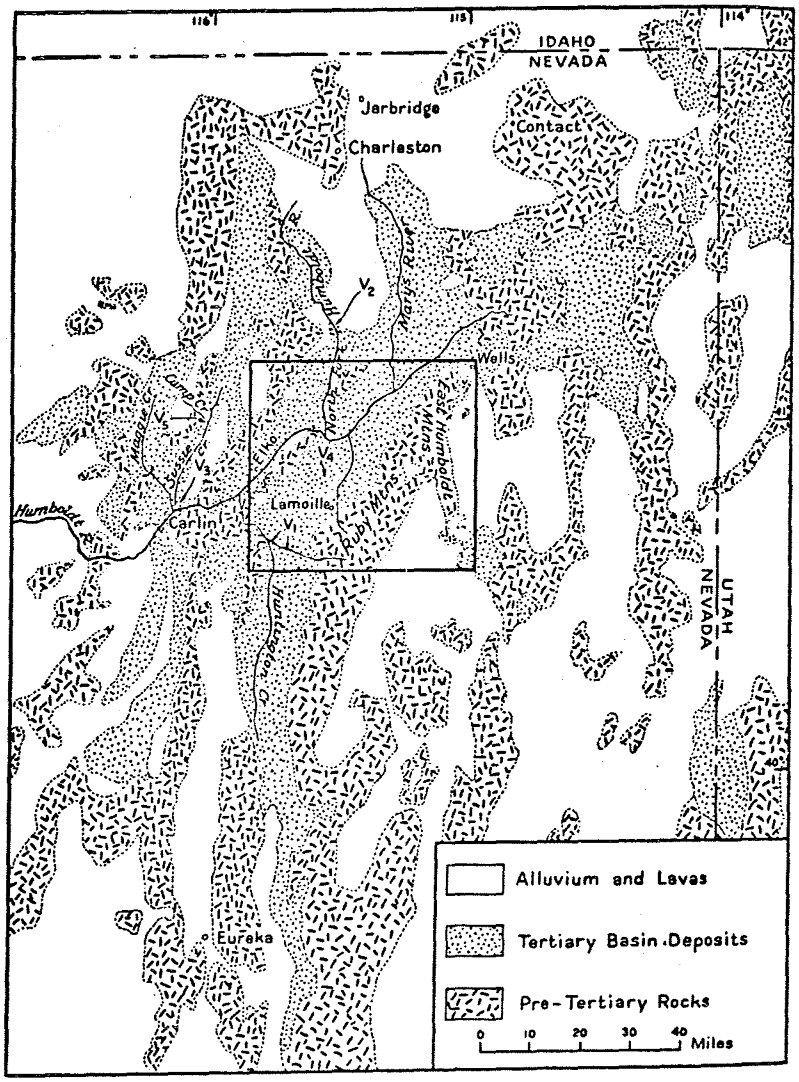

FIG. 1.—Map showing distribution of Tertiary basin deposits in northeastern Nevada, modified from the U.S. Geological Survey map of the United States (1933). The rectangle in the center represents the area here considered. (Figure 9 shows this area on a larger scale and in greater detail.) Vertebrate-fossil localities referred to in the text are shown by V_1–V_5.

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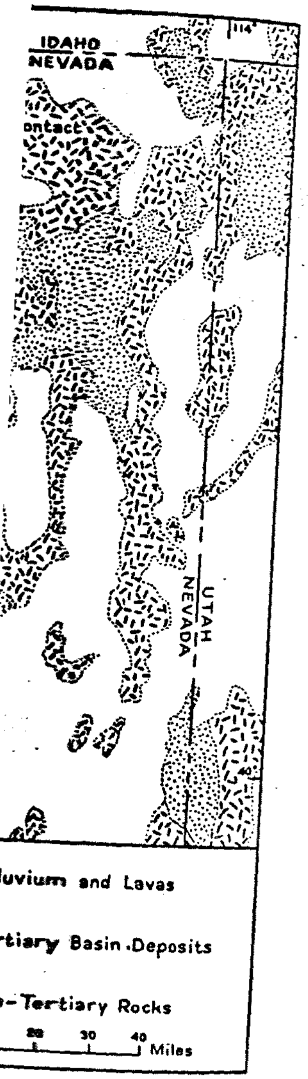
[5] *Ibid.*, p. 91.



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to the same formation, although it seems likely that they are closely related.

PREVIOUS WORK

King[2] and his associates first described these beds in 1877–78. King divided the basin deposits in the vicinity of Elko and the Ruby–East Humboldt Range into an Eocene and a Pliocene group. The Eocene group was correlated with the Green River formation of Utah and Colorado, and the Pliocene deposits were named the "Humboldt group." Fish and plant remains were reported from the Eocene beds; and a small vertebrate fauna, thought to be of Pliocene age, was collected from the Humboldt group at Bone Valley on the North Fork of the Humboldt River. Evidence will be presented which shows that both the Eocene and Pliocene beds described by King are parts of the same formation, which is of Miocene age.

In 1914 Merriam[3] described a small vertebrate fauna from the McKnight Ranch on the North Fork of the Humboldt River. He concluded that the fauna indicated a stage in the latter half of the Miocene. Merriam pointed out that the McKnight locality is the same stratigraphically, if not geographically, as King's "Bone Valley" site. This site furnished the fauna on the basis of which King assigned a Pliocene age to the Humboldt group.

Winchester[4] discussed the oil shale in the basin deposits near Elko, which he referred to the Green River formation. In a footnote,[5] however, Winchester reports that J. P. Buwalda has discovered a Middle or Upper Miocene vertebrate fauna in beds equivalent to the oil shale, showing that they are not to be correlated with the Eocene Green River formation.

FORMATION NAME

Various names have been applied to the Tertiary basin deposits of the Elko region. This confusion has been caused largely by the fact

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[2] Clarence King, "Geological Exploration of the Fortieth Parallel," *Prof. Paper 18, Engineer. Dept., U.S. Army*, Vol. I (1878), pp. 392–93, 438–39, and Vol. II (1877), p. 540.

[3] J. C. Merriam, "The Occurrence of Tertiary Mammalian Remains in Northeastern Nevada," *Univ. Calif. Pub. Dept. Geol.*, Vol. VIII (1914), pp. 275–81.

[4] Dean E. Winchester, "Oil Shale of the Rocky Mountain Region," *U.S. Geol. Surv. Bull. 729* (1923), pp. 91–102.

[5] *Ibid.*, p. 91.

that King described what he thought were both Pliocene and Eocene beds. Data will be presented in the following pages to show that only one formation is present. This will be called the "Humboldt formation." It includes the "Humboldt group," as originally defined by King, and the so-called "Eocene deposits," which had erroneously been correlated with the Green River formation of Utah and Colorado. The Humboldt formation, as here defined, consists of beds deposited chiefly in the late Miocene and possibly in the early Pliocene. It is suggested that the section of these beds exposed along Huntington Creek, a tributary of the South Fork of the Humboldt River, should be taken as the type section. The Lake Lahontan beds (Quaternary)[6] of western Nevada should not be included in this formation. Schmitt[7] has used the name "Humboldt formation" tentatively for some Pennsylvanian beds of New Mexico, but the usage advocated in the present article has priority.

LITHOLOGY OF DEPOSITS

The Humboldt formation consists of continental deposits of fluviatile and lacustrine origin, including fanglomerate, conglomerate, sandstone, mudstone, siltstone, shale, lignite, oil shale, diatomite, limy shale, limestone, and rhyolitic tuff and ash beds. A few thin rhyolite flows are interbedded in the formation on the flanks of the East Humboldt Mountains. Conglomerate, sandstone, mudstone, and shale make up the greater part of the formation.

BRECCIA

Basal breccia.—Breccia has been noted at the base of the Humboldt formation at a number of localities. These basal breccias are composed of angular fragments of the immediately underlying rock, which in many places is Carboniferous limestone. Some of the breccias have developed almost *in situ* by disintegration and spalling of exposed bedrock; others indicate considerable movement of material and resemble slope-wash breccia and fanglomerate.

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[6] G. D. Louderback, "Period of Scarp Production in the Great Basin," *Univ. Calif. Pub. Dept. Geol.*, Vol. XV (1924), p. 36.

[7] Harrison Schmitt, "The Central Mining District, New Mexico," *Amer. Inst. Min. Met. Eng., Contr. No. 39* (1933), pp. 2 and 13.

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Interbedded breccia.—At the north end of the East Humboldt Mountains on the east flank, N.E. $\frac{1}{4}$, Sec. 35, T. 37 N., R. 61 E., a limestone breccia is interbedded in the Humboldt formation. This breccia ranges from light to dark gray and is composed of extremely angular fragments of limestone, 1 inch to several feet in diameter, embedded in a well-cemented matrix of limestone chips. The matrix makes up only 10–15 per cent of the whole rock. The breccia has been formed at the base of a steep slope, presumably a fault scarp, largely under the influence of gravity. In a single outcrop, 50 × 75 feet, the breccia is composed entirely of a uniform type of limestone, which suggests derivation from a single exposure. The lithologic differences between limestone beds in the pre-Tertiary rocks, from which the breccia was derived, are of such magnitude that a breccia of this uniform composition could come only from a relatively small outcrop. Largely for this reason, the breccia is thought to represent a slide and not a talus deposit, since the latter would be derived from a number of outcrops and therefore would contain blocks of several types of limestone.

Two distinct beds of breccia, separated by several hundred feet of coarse fanglomerate, have been observed. The lower breccia bed is the more extensive and crops out more or less continuously for 2 miles along the strike, parallel to the front of the range. The maximum thickness observed is about 100 feet, though the upper boundary is difficult to determine, for the breccia grades upward into fanglomerate. The lower breccia is underlain by silt, sandstone, and pebble-conglomerate beds.

The limestone breccia dips 25° eastward and lies a mile east of the bold scarp of the East Humboldt Mountains. Derivation from a newborn fault scarp in Miocene time is postulated for the following reasons: (1) The base of the present scarp exposes limestone similar to that composing the breccia. (2) The breccia appears to have come from a source to the west. (3) The abrupt lithologic change from silt, sandstone, and pebble-conglomerate to coarse limestone breccia indicates a quick change in deposition, such as would be caused by sudden uplift of a block by faulting. (4) The extreme coarseness of the overlying fanglomerate also indicates that it has been derived from a steep scarp. Deposits accumulated largely under the influence of gravity at the foot of a scarp should be succeeded by slope wash and fan deposits. Two separate beds of breccia may indicate separate uplifts along the fault, but the upper breccia is of such limited extent that it may be a feature so local as to be due to some other and unknown cause.

Longwell[8] has recently described similar but more extensive breccias, which he regards as landslide breccias, on the flanks of the Virgin and Black mountains in the Boulder Reservoir region of Arizona and Nevada, and in another case from the Triassic beds of the Connecticut Valley. These breccias are also associated with fanglomerate (or fan breccia). Longwell has presented facts which strongly suggest that the breccias and associated fanglomerates were derived from an actively growing fault scarp.

Post-Humboldt movement along the fault at the east base of the East Humboldt Mountains indicates that the present scarp is younger than the Miocene scarp, from which the breccias were derived.

FANGLOMERATE

The thickest and most extensive fanglomerate is associated with the breccias just described. This fanglomerate is brown, gray, or nearly black, depending upon the type of rocks composing it. Angular fragments, a fraction of an inch up to 4 feet in length, of white, gray, buff, or black limestone, quartzite, and pebble conglomerate compose the fanglomerate (Fig. 2). These fragments are imbedded in a sparse, sandy to gravelly matrix. Some red, sandy lenses are interbedded in the mass. In places the fanglomerate is composed largely of quartzite fragments, in other places largely of limestone fragments; and all gradations between these two types of lithology seem to exist. It is well cemented and forms bluffs and prominent outcrops.

This fanglomerate immediately overlies the breccias described above and is transitional into them. It has been derived from the same fault scarp as the breccias, but at a later time, when the scarp was more eroded and dissected. The coarse detritus from the scarp

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[8] C. R. Longwell, "Geology of the Boulder Reservoir Floor, Arizona-Nevada," *Bull. Geol. Soc. Amer.*, Vol. XLVII (1936), pp. 1420–29; "Sedimentation in Relation to Faulting," *ibid.*, Vol. XLVIII (1937), pp. 434–38.

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was deposited in long, sloping fans, closely resembling those found at present along fault scarps.

On the west side of the Ruby Mountains, near the entrance to Secret Pass, a red fanglomerate, 200 feet thick, has been traced for a mile along the strike, subparallel to the mountain front. This fanglomerate may be related to the same uplift which produced the breccias and fanglomerate described above.

FIG. 2.—Fanglomerate interbedded in the Miocene Humboldt formation along the east flank of the East Humboldt Mountains. The fragments in the fanglomerate are limestone and quartzite. This fanglomerate has been derived from an actively growing fault scarp 2 miles to the west.

CONGLOMERATE

Basal conglomerate.—Basal conglomerate beds, 20–200 feet thick, have been mapped in several localities. At each locality these beds rest directly upon pre-Miocene rocks, chiefly Carboniferous limestone or quartzite. The conglomerate beds contain roundstones[9] up to $1\frac{1}{2}$ feet in diameter.

Interbedded conglomerate.—Conglomerate was deposited near elevated areas which were supplying detritus to the Humboldt formation. Along the flanks of the Ruby–East Humboldt Range, con-

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[9] Term suggested by F. A. Fernald (*Science*, Vol. LXX [new ser., 1924], p. 240) for pebbles, cobbles, and boulders, etc., in a conglomerate.

glomerate containing roundstones of the various rock types exposed in these mountains is abundant, indicating that an elevated mass occupied the present site of this range in Humboldt time.

Along Huntington Creek, south of Twin Bridges, conglomerate beds are abundant 1,400 feet above the base of the formation. The lowermost conglomerate in this locality is composed almost entirely of limestone with subordinate quantities of chert roundstones. Successive conglomerate beds higher in the section contain more roundstones of crystalline rocks, such as quartzite, gneiss, and granite. At 2,000 feet above the base a conglomerate bed contains roughly 50 per cent limestone and 50 per cent crystalline roundstones. At 2,300 feet above the base a conglomerate contains 75 per cent crystalline material; at 2,800 feet, 90 per cent crystalline material; and at 3,300 feet, approximately 100 per cent crystalline material. These relations indicate a gradual uncovering of the crystalline rocks which underlie the limestone within the mountain blocks.

FIG. 3.—Conglomerate in the middle member of the Humboldt formation along Huntington Creek 2 miles south of Twin Bridges. This conglomerate contains pebbles and cobbles of limestone, quartzite, and granitic rocks.

The conglomerate in the Humboldt formation is a stream-laid deposit. Some of the conglomerate on the South Fork of the Humboldt River and on Huntington Creek contains well-rounded cobbles

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[18] These terms are used in the
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up to 6 inches in diameter. These cobbles are at least 8–10 miles from a possible source, as far as known, and indicate transportation and deposition by a moderately powerful stream (Fig. 3).

SANDSTONE, MUDSTONE, SILTSTONE, AND SHALE[10]

Sandstone, mudstone, siltstone, and shale, with considerable intermixed fine pyroclastic material, grade one into the other and make up the larger part of the Humboldt formation. These beds are white, brown, tan, and light green. They are composed of mineral fragments of the same type and origin as the roundstones in the conglomerate. Large quantities of fine pyroclastic material are intermixed with the detrital mineral fragments in many localities.

FIG. 4.—Conglomerate, sandstone, mudstone, and ash beds of the Humboldt formation along the north side of the South Fork of the Humboldt River, 2 miles above Twin Bridges, looking north.

FIG. 5.—Gently dipping conglomerate, sandstone, mudstone, and shale beds of the Humboldt formation along Huntington Creek south of Twin Bridges, looking northeast.

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[10] These terms are used in the sense defined by the Committee on Sedimentation (*Rept. Comm. Sed., Nat. Res. Coun., 1936–37*, pp. 97–98).

The oil shale of the Humboldt formation is a thin-bedded, dark-colored, petroliferous shale exposed near the base of the formation in the Elko Range south of Elko. This shale contains considerable carbonaceous material and small fresh-water shells. Winchester[11] reports six separate groups of oil-shale beds in the vicinity of Elko; a single group of beds is seldom over a few feet or a few tens of feet thick. Dark-brown beds of lignite, a few inches thick, are interbedded with the oil shale.

FRESH-WATER LIMESTONE

Fresh-water limestone crops out near the base of the formation at a number of localities. The limestone is white to light brown, chalky to dense and finely crystalline, and ranges from thin beds a fraction of an inch thick to rather massive beds a few feet thick. Wherever observed, the limestone contains many shells of fresh-water gastropods and pelecypods. Along Huntington Creek near Twin Bridges the limestone contains a great number of irregular black, gray, and white nodules of chert, ranging from an inch to a foot in diameter.

Where exposures are good, the limestone is seen to rest directly on a basal conglomerate or breccia and to pass upward into limy shale, silt, sandstone, and ash. The oil-shale beds at Elko overlie the limestone. A thickness of 870 feet of limestone has been measured on Huntington Creek; this is the greatest thickness exposed.

DIATOMITE

Two groups of diatomite beds, each 7–10 feet thick, crop out near Carlin, 25 miles west of Elko. The diatomite is pure white, loose and friable, and moderately massive.

ASH AND TUFF

Ash and tuff beds are abundant about 1,000 feet above the base of the formation, and pyroclastic material is a common constituent of many beds higher in the formation. Many of the tuff beds are massive and give no evidence of being water-laid. They are composed of fragments and crystals of quartz, feldspar, biotite, glass, and angular fragments of rhyolite, and in places are lapilli tuff.[12] Most of the ash

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[11] *Op. cit.*, pp. 98–100.

[12] C. K. Wentworth and Howel Williams, "The Classification and Terminology of the Pyroclastic Rocks," *Nat. Res. Coun. Bull. 89* (1932), p. 47.

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beds are water laid and thin bedded. They are composed chiefly of fragments of volcanic glass and minor quantities of quartz and feldspar fragments.

RELATIVE PERCENTAGES OF LITHOLOGIC TYPES

An attempt has been made, in the accompanying table, to estimate the relative percentages, by volume, of the various types of sedimentary beds in the Humboldt formation. At best this is only a crude estimate, although for the localities studied it is based on detailed sections. As far as the whole formation is concerned, it may be considerably in error.

Type of Bed	Percentage of Formation by Volume
Limestone	5–10
Conglomerate	10–15
Sandstone, shale, mudstone, siltstone, etc.	60–75
Ash and tuff	5–10
Fanglomerate and breccia	2–3

STRATIGRAPHY AND THICKNESS

The Humboldt formation in the area studied possesses distinct lithologic characteristics which facilitate its division into three members as follows:

LOWER MEMBER

The lower member is composed of shale, oil shale, fresh-water limestone, sandstone, and conglomerate. Oil shale and limestone beds identify this member. In places the limestone and oil shale grade laterally into mudstone, sandstone, and conglomerate, and the member loses its distinctiveness. The lower member is 800–1,000 feet thick at places of maximum thicknesses but is missing or indeterminate at other places.

MIDDLE MEMBER

The middle member is characterized by rhyolitic tuff and ash. Tuff and ash beds are found throughout the formation, but they are particularly abundant in the middle member. A single outcrop of ash or tuff does not identify this member, but a thickness of a hundred feet or so of associated tuff and ash beds is distinctive within the writer's experience. Volcanic activity of an explosive nature seems to have been at a peak at this time. The middle member has a maximum measured thickness of 1,300 feet.

UPPER MEMBER

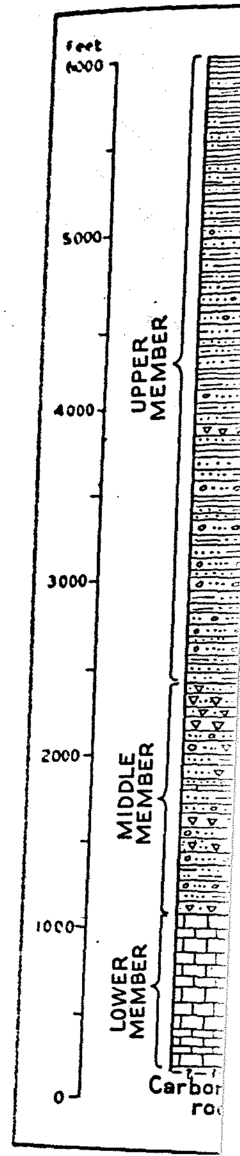
The upper member consists of fine conglomerate, sandstone, mudstone, siltstone, and shale beds. Mudstone and shale are abundant near the top. The conglomerate is distinguished by a large proportion of quartzite and granitic pebbles, compared to the number composed of limestone. This member is identified by its great thicknesses of mudstone and shale and the relative paucity of conglomerate beds. The maximum measured thickness of the upper member is 3,600 feet, although it may be much thicker, for the top of the formation is not known.

Figure 6 is a series of columnar sections from various places in the area considered. The three members of the formation are indicated in these sections.

THICKNESS OF THE HUMBOLDT FORMATION

Near the city of Elko a well drilled for oil reach a depth of 3,200 feet in the Humboldt formation without reaching the base. The average dip in the vicinity of the well is 10°, and, assuming a straight hole and no structural complications, the thickness of beds drilled through is about 3,100 feet. Since the collar of the well is located an unknown distance below the top of the formation, the conclusion seems justified that the formation is more than 3,100 feet thick in the vicinity of Elko. The possibility that some of these beds do not belong to the Humboldt formation is not very strong, for the base of the formation is exposed at several places in the Elko Range near by and no trace of an older Tertiary formation is found.

By far the best-exposed and most continuous section of the Humboldt formation is along Huntington Creek south of Twin Bridges, where a section has been measured in detail by a pace and compass traverse. The data of this traverse are presented in column *A* of Figure 6. The base of the formation is exposed near Twin Bridges, but structural complications made an exact measurement from the base impossible. The section has been measured from a bed approximately 100 feet above the base to the eroded top of mudstone beds an unknown distance below the true top of the formation. A



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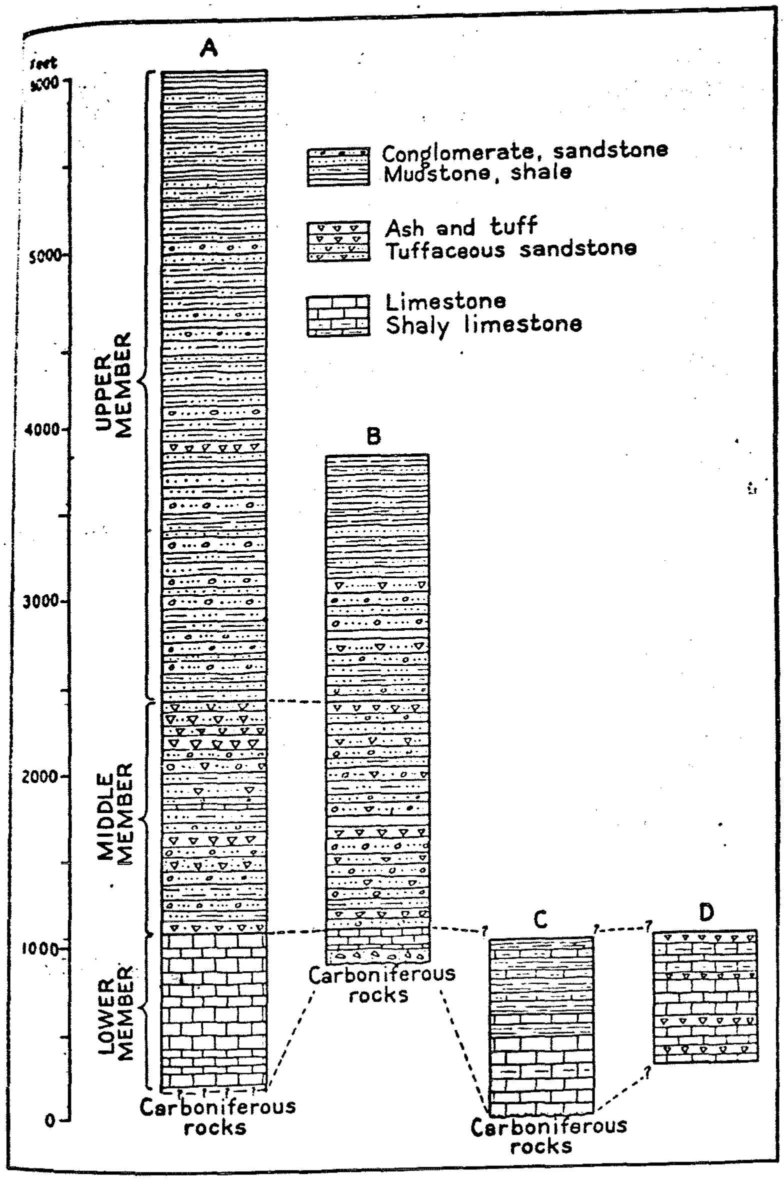

FIG. 6.—Columnar sections of the Miocene Humboldt formation. Section *A* measured along the east bank of Huntington Creek, starting immediately south of Twin Bridges and extending 4.6 miles to the south. Section *B* is a composite section measured on a series of cuesta faces in Lamoille Valley starting ¼ mile east of Twin Bridges and extending to Secret Pass, 25 miles to the northeast. Section *C* is from the Elko Range immediately south of Elko. Section *D* is from the east side of the Valley Mountains.

thickness of 5,800 feet has been measured in this way, and the formation is thicker by an unknown amount, although it is probably not everywhere so thick in the wide area of exposure in northeastern Nevada. This section along Huntington Creek should be considered the type section of the Humboldt formation, for it is the most completely exposed section of these beds known.

STRUCTURE

The Humboldt formation lies in a series of elongated basins separated by northward-trending, fault-block mountains. These basins have an average north-south length ranging from 25–100 miles and an east-west width in most places not over 25 miles.

UNCONFORMITY AT BASE

As far as known, the Miocene Humboldt formation rests upon a basement of pre-Tertiary rocks. No older Tertiary sedimentary rocks are known anywhere in the area studied. In several localities the Humboldt rests unconformably on Carboniferous rocks. This unconformity is particularly well exposed in the Elko Range near Elko, and it can be traced continuously 9 miles south to the gorge of the South Fork of the Humboldt River. Unconformable contacts between the Miocene and pre-Tertiary rocks have also been noted in the Burner Basin, 4 miles east of Elko; near Twin Bridges; near Thorpe Creek on the west flank of the Ruby Mountains; on Sheep Creek a bit farther south; and at the gorge of the Humboldt River west of Elko.

In several places beds of the middle member and even of the upper member overlap the lower beds and rest directly upon pre-Miocene rocks. A coarse conglomerate which rests directly on Carboniferous limestone at the mouth of Thorpe Creek may be taken as an example. This conglomerate contains a number of roundstones of gneiss, quartzite, and igneous rocks in addition to limestone. Along Huntington Creek roundstones of gneiss, quartzite, and igneous rocks do not appear lower than the middle member. Therefore, the base of the formation at the mouth of Thorpe Creek is within the middle member, at least, and considerable overlap of later over earlier beds is indicated.

FOLDS

Within the basins the Humboldt beds have gentle dips not over 15°, but near the foot of the mountains the structure is more complex with dips up to 50°. Near the mountains the basin deposits seem to be broken into separate blocks with diverse dips. The sections of Figure 7 show folds in the basin deposits; but these folds are largely diagrammatic and based upon reversals of dip, which may be related to either folding or faulting. In all probability the underlying basement has been fractured and faulted, and the overlying beds have yielded by faulting, folding, or warping. Near Twin Bridges on Huntington Creek a broad, open anticline has been mapped. This fold trends roughly northwest and the beds on the flanks dip from 20°–28°. Winchester[13] mentions warping and folding of the Humboldt formation in the Elko Range. However, it is clear that the Humboldt has not been folded by intense compressional forces; and it may well be that the folds, such as they are, represent normal faults in the underlying basement.

FAULTS

Many of the mountain ranges separating the areas of basin deposits are fault-block mountains, bounded on one or both sides by faults which separate the pre-Miocene rocks of the mountain blocks from the Miocene basin deposits. This relation is demonstrated along the west flank of the Ruby–East Humboldt Range, where streams have deeply dissected the mountain front and the forelying basin deposits. The Miocene beds dip toward the mountain block in many places; and ample evidence for faulting, such as truncation of structures and beds, triangular facets, actual exposures of the fault zone, and recent piedmont scarps, demonstrates that the basin deposits are separated from the rocks of the mountain block by a fault or faults. Where seen, the fault planes have basinward dips, and the faults are normal. Subsidiary normal faults of small displacements have also been observed in the basin deposits at several places.

RELATION TO YOUNGER ROCKS

In the Elko Range, pyroxene andesite and olivine-pyroxene basalt flows, breccia, and an associated tuff bed lie unconformably on the

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[13] *Op. cit.*, pp. 94 and 96.

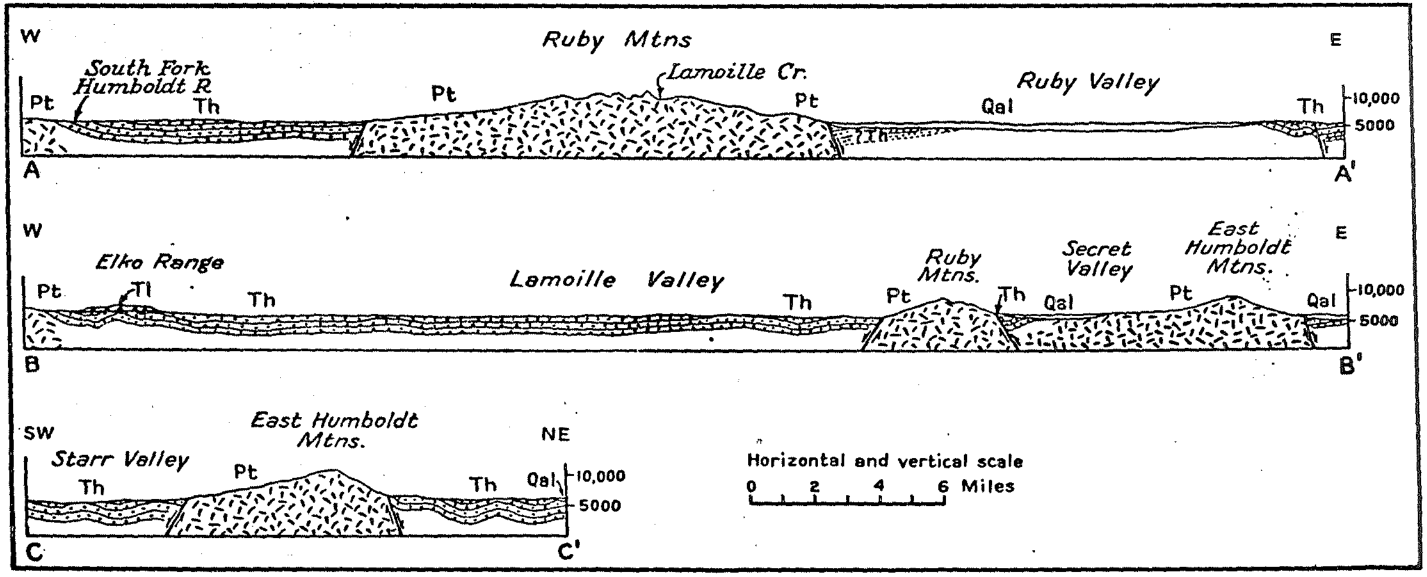

Fig. 7.—Structure sections illustrating the relations of the Miocene Humboldt formation (*Th*) to the older pre-Tertiary rocks (*Pt*) and to the younger Pliocene (?) lavas (*Tl*) and Quaternary alluvium (*Qal*). The locations of these sections are shown on the geological map, Fig. 9.

Miocene beds (Fig. 8). The suggestion is made that the rocks above the unconformity are of Pliocene age. As will be shown later, deposition of the Humboldt continued well into the late Miocene and possibly into the Pliocene. The time interval indicated by the post-Humboldt deformation and erosion prior to the extrusion of the lavas seems to be long enough to place them in the Pliocene. They appear too old to be Pleistocene. At the south tip of the East Humboldt Mountains, pyroxene andesite rests unconformably on Humboldt beds and overlaps Carboniferous limestone to the north and west. Basalt and andesite have also been noted lying unconformably on Humboldt beds north of the town of Deeth, on Maggie Creek north of Carlin, and in the low hills west of Huntington Creek.

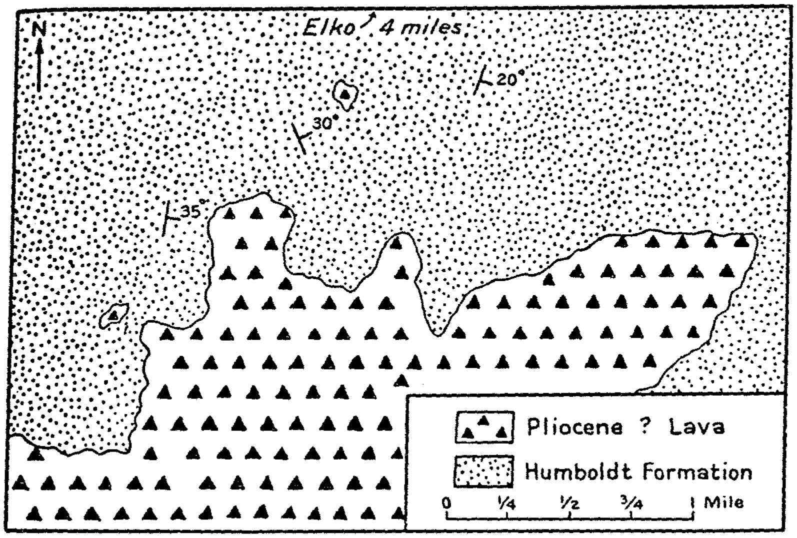

Fig. 8.—Pace and compass map made in the Elko Range 4 miles south of Elko; see Fig. 9 for exact location. This map shows the gently tilted Pliocene lavas overlying unconformably the deformed beds of the Miocene Humboldt formation.

Quaternary terrace and pediment gravels also rest unconformably on the eroded edges of the deformed Miocene beds.

RELATION OF THE HUMBOLDT FORMATION AND LAVAS

Rhyolite flows interbedded with the Humboldt beds have been mapped on the flanks of the East Humboldt Range. Petrographic study shows that these lavas are characterized by large (5 mm.)

Structure sections illustrating the relations of the Miocene Humboldt formation (*Th*) to the older pre-Tertiary rocks (*Pt*) and to the younger Pliocene (?) lavas (*Tl*) and Quaternary alluvium (*Qal*). The locations of these sections are shown on the geological map, Fig. 9.

resorbed phenocrysts of quartz and orthoclase set in a groundmass which has a latite-like texture. Seventy miles to the north of Elko, in the Jarbidge mining district near the Idaho-Nevada border, are at least 6,000 feet of rhyolite, thought by Schrader[14] to be Miocene (?) and Pliocene (?). Specimens of the Miocene (?) rhyolite collected at Jarbidge are so similar to the rhyolite interbedded in the Humboldt along the flanks of the East Humboldt Mountains as to suggest that they came from a common source. The similarity is even more striking in thin section. Schrader[15] reported lignitic shale and dark slaty sandstone seemingly interbedded with the Miocene (?) rhyolite near Jarbidge. It is highly probable that these sediments belong to the Humboldt formation. In addition, the large amount of rhyolitic ash and tuff in the middle member of the formation suggests contemporaneous volcanism somewhere in the vicinity. In short, the Miocene (?) rhyolite at Jarbidge appears to be contemporaneous with the Humboldt and, at least locally, is interbedded with it.

The relations of the Pliocene (?) lavas, rhyolite, andesite, and basalt, of northernmost Nevada and southern Idaho, to the Humboldt formation have not been determined. However, reconnaissance indicates that at Contact, 50 miles north of Wells, rhyolite lavas overlie unconformably basin deposits which are similar to, and probably belong to, the Humboldt. This rhyolite and other Pliocene (?) rhyolites of northernmost Nevada and southern Idaho are typically hypohyaline, tridymite rhyolites, strongly flow banded. They are much fresher than the Miocene rhyolites of Jarbidge and the Elko area and in no way resemble them.

Pyroxene andesite and olivine-pyroxene basalt flows and breccias overlie unconformably the Humboldt beds near Elko, as shown on the sketch map (Fig. 8). Similar relations between Humboldt beds and andesitic or basaltic lavas have been noted at the south tip of the East Humboldt Mountains (Fig. 9), at a point 5 miles north of Elko on the Mountain City road, on Maggie Creek north of Carlin,

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[14] F. C. Schrader, "The Jarbidge Mining District, Nevada, with a Note on the Charleston District," *U.S. Geol. Surv. Bull. 741* (1923), pp. 17–21.

[15] *Ibid.*, p. 14.

a few miles north of Deeth, and west of Huntington Creek near Twin Bridges.

In this study andesite and basalt have never been found interbedded in the Humboldt formation but, where observed, overlie it unconformably. Coarse-grained rhyolitic lava has been observed interbedded with the formation, and fine-grained rhyolite has been observed overlying unconformably beds which may belong to the Humboldt. Although none of this evidence is compelling, it seems probable that much of the great mass of rhyolite north of the region studied is of Miocene age. This region was probably the volcanic center which supplied much of the pyroclastic material interbedded in the Humboldt formation.

AGE OF THE HUMBOLDT FORMATION

Vertebrate fragments have been collected or reported from the Humboldt formation at five localities:[16] (1) on the South Fork of the Humboldt River in several places along the cuesta on the north side of the road to Lee;[17] (2) on the North Fork of the Humboldt River near the McKnight Ranch, Merriam's[18] McKnight locality and King's[19] "Bone Valley" site; (3) near the "Triolite" mine 3 miles northeast of the town of Carlin, which is 25 miles west of Elko on U.S. Highway 40 (the place where fragments are most abundant is the southeast corner of Section 7, T. 33 N., R. 53 E.); (4) in Lamoille Valley along Rabbit Creek about 3 miles northeast of the Rossi Ranch, in the northwest quarter of Section 11, T. 34 N., R. 57 E.; (5) on Camp Creek, $\frac{1}{4}$–$\frac{1}{2}$ mile above the junction with Sussie Creek (this junction is 21 miles by road up Sussie Creek from U.S. Highway 40 [the Sussie Creek road turns off 2 miles east of Carlin], and the locality is in the southwest quarter of Section 36, T. 36 N., R. 53 E.).

The vertebrate fragments collected on the South Fork of the Humboldt River come chiefly from sandy-mudstone beds near the base of the middle member. The exact stratigraphic relations of

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[16] Names of local residents who can be of assistance in finding fossil localities: Mr. R. A. Kinne, of the municipal water department, Elko, Nevada, and Mr. Gerald Trescarte, Lamoille, Nevada.

[17] These localities are all shown on Fig. 1 as V_1–V_5, respectively.

[18] *Op. cit.*, pp. 276–77.

[19] *Op. cit.*, Vol. I., p. 439.

King's "Bone Valley" site are unknown. The bones at the "Triolite" mine near Carlin are in sandy-mudstone beds 10 feet above the diatomite bed worked at the mine. The fossiliferous beds have been traced along the strike for about $\frac{3}{4}$ mile, and vertebrate fragments have been found throughout that distance. These beds are only a few hundred feet above the base of the formation, but there is good evidence of considerable overlap here, and they are probably in the middle member. The fossils on Rabbit Creek in Lamoille Valley are in sandstone and mudstone beds in the upper member. The Camp Creek locality is in sandy-mudstone beds interbedded with ash. The exact stratigraphic relations of these beds are not known, but their lithology suggests that they belong to the middle member of the Humboldt. By far the best locality seen, and the one most worthy of consideration as a possible collecting site, is the Camp Creek locality (V_5). Here whole bones are imbedded in the rock, and vertebrate remains have been found through a stratigraphic thickness of several hundred feet. All the material collected has been placed in the hands of Dr. Chester Stock, of the department of geology, California Institute of Technology, Pasadena, California.

The only vertebrate forms described from the Humboldt formation are those listed by Merriam[20] from the McKnight locality on the North Fork of the Humboldt River. These forms are:

Merychippus, sp., near *isonesus* (Cope)
Merycodus (?) sp.
Camelid, sp.
Carnivore fragments

According to Merriam, they indicate a stage in the latter half of the Miocene. Buwalda[21] has collected a vertebrate fauna from beds reported to be the same as King's Eocene. This fauna has been determined as Middle or Upper Miocene but has not been described, and the exact localities are not known to the writer.

Plant remains have been collected by various workers from the oil shale and associated beds in the vicinity of Elko near the base of the Humboldt, and the following species are listed by Knowlton.[22]

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[20] *Op. cit.*, p. 276.

[21] Winchester, *op. cit.*, p. 91.

[22] F. H. Knowlton, "A Catalogue of the Mesozoic and Cenozoic Plants of North America," *U.S. Geol. Surv. Bull. 696* (1919), p. 796.

Comptonia partita
Carpinus elkoana
Fagus feroniae Un
Fagopsis longifolia
Ficus jynx Unger
Lycopodium prom
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Planera ungeri Et
Populus richardso
Salix elongata O.
S. media Heer
Sapotacites coriace
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[23] H. L. Mason, "Fossil Records
Wash. Pub. 346 (1927), pp. 154–56.

[24] *Ibid.*, p. 140.

Comptonia partita (Lesquereux) Berry
Carpinus elkoana Lesquereux
Fagus feroniae Unger
Fagopsis longifolia (Lesquereux) Hollick
Ficus jynx Unger
Lycopodium prominens Lesquereux
Myrica brongniarti ? Ettingshausen
M. drymeja (Lesquereux) Knowlton
Planera ungeri Ettingshausen
Populus richardsoni ? Heer
Salix elongata O. Weber
S. media Heer
Sapotacites coriaceus (Lesquereux) Knowlton
Sequoia affinis Lesquereux
S. angustifolia Lesquereux
Thuja garmani Lesquereux
Myrica undulata (Heer) Schimper

Knowlton gives these forms as Miocene. The plants listed above have been collected from King's so-called "Eocene beds" near Elko. They definitely prove that the beds belong to the Miocene Humboldt formation and are not to be correlated with the Green River formation.

Mason[23] mentions two conifers from the Tertiary beds near Elko and gives the age of these deposits as Oligocene or Miocene.[24]

In this study some plant remains were collected from the oil-shale beds at the Catlin oil-shale plant near Elko, Sec. 22, T. 34 N., R. 55 E. Mr. William C. Darrah, of Harvard University, has studied these specimens and has kindly furnished the following note.

> The flora found in the oil shale at Elko, Nevada, is characterized by a small number of species which have very limited distributions. A half-dozen species are not known from any other locality. A few, such as *Sapotacites coriaceus* (Lesquereux) Knowlton and *Sequoia affinis* Lesquereux, which are of late Miocene age, are good "index species." A few poorly defined species, such as *Fagus feroniae* Unger, are useless for purposes of correlation. In view of the fact that the Lower and Middle Miocene floras of western North America are well known, the considerable number of endemic species in the Elko district further suggests a late Miocene age. The oil shale at Elko is most probably within the upper third of the Miocene.

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[23] H. L. Mason, "Fossil Records of Some West American Conifers," *Carnegie Inst. Wash. Pub. 346* (1927), pp. 154–56.

[24] *Ibid.*, p. 140.

As this flora comes from the lower member of the Humboldt formation, it indicates that even the lower part of the formation is probably not older than late Miocene. The upper part of the Humboldt may possibly extend into the Lower Pliocene, although there is no direct evidence to support this statement.

In summary, all the evidence indicates that the Humboldt formation was laid down in the latter part of the Miocene, with deposition possibly extending into the Pliocene.

CONDITIONS OF DEPOSITION

MODE OF DEPOSITION AND PHYSIOGRAPHIC RELATIONS

The relatively fine-grained deposits at the base of the Humboldt formation indicate either that the mountain masses supplying detritus were not very high or that they were far distant from the Elko region in the early part of Humboldt time. Moderately large, permanent rivers flowed into a lake in which the limestone, oil shale, and related beds were deposited. The lack of deposits of soluble salts indicates that this body of water was drained, but the direction and nature of this drainage cannot be determined from the data at hand. In the area considered, no evidence of a single large through-flowing river, such as the existing through-flowing rivers of the Basin and Range province, like the Rio Grande or Humboldt, has been found.

The coarser deposits in the middle member of the formation reflect greater relief, presumably related to faulting, and perhaps drier climatic conditions in middle Humboldt time. The somewhat finer deposits, mudstone and shale, near the top of the formation probably indicate reduced relief near the end of the Humboldt period. The lack of lake beds near the top of the formation shows that the lake was filled up or dried up by that time. The conglomerate of the Humboldt formation is clearly a river deposit; and many of the sandstone, mudstone, and silt beds are river flood-plain deposits. As at least 75 per cent of the deposits are fluviatile, the use of the term "lake beds" to describe the whole formation is incorrect.

In northernmost Nevada and southern Idaho large volumes of lava were extruded, presumably, in what had theretofore been a part of the area receiving Miocene deposits. These lavas accumulated to a thickness of at least 6,000 feet and formed a broad table-land, or

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[27] Elizabeth Oliver,
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[28] R. W. Chaney, "
Vol. IV (1922), p. 222;
Carnegie Inst. Wash. P
River Basin with Spec
Pub. 346 (1927), p. 79.

dome. Near the edges of this table-land, or dome, the lava was interbedded with sedimentary deposits belonging to the Humboldt formation. This volcanic center probably supplied much of the pyroclastic material in the Humboldt beds 70 miles to the south in the Elko region. Part of this pyroclastic material was re-worked by streams and intermixed with other material; however, much of it was incorporated in the formation with little or no re-working by water.

The similarity of the Humboldt formation to other mid-Tertiary deposits of southern Idaho and western Nevada suggests that they were deposited under somewhat similar conditions and that possibly certain basins had a common watershed and even some continuity of area. However, the broader questions of the physiographic conditions of the mid-Tertiary in the Great Basin await the study of many other small areas like that considered here.

ENVIRONMENT

The Elko region has an arid to semiarid climate. Average annual rainfall is 6–10 inches in the basins and 15–18 inches in the mountains. The conditions during the deposition of the Humboldt formation must have been considerably different. The vertebrate fauna collected from the Humboldt indicates a climate somewhat more humid than the present—a climate which could support vegetation suitable for grazing animals, such as horses and camels. The plant remains point to a humid climate, in some cases with rainfall of 24–40 inches, as suggested by La Motte,[25] Berry,[26] Oliver,[27] Chaney,[28]

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[25] R. S. La Motte, "The Upper Cedarville Flora of Northwestern Nevada and Adjacent California," *Carnegie Inst. Wash. Pub. 455* (1936), p. 89.

[26] E. W. Berry, "The Flora of the Esmeralda Formation in Western Nevada," *U.S. Nat. Mus. Proc.*, Vol. LXXII, Art. 23 (1927), p. 3; "A Revision of the Flora of the Latah Formation," *U.S. Geol. Surv. Prof. Paper 154H* (1929), p. 234; "Miocene Plants from Idaho," *U.S. Geol. Surv. Prof. Paper 185E* (1934), p. 101.

[27] Elizabeth Oliver, "A Miocene Flora from the Blue Mountains, Oregon," *Carnegie Inst. Wash. Pub. 455* (1936), p. 35.

[28] R. W. Chaney, "Flora of the Payette Formation," *Amer. Jour. Sci.*, 5th ser., Vol. IV (1922), p. 222; "The Mascall Flora, Its Distribution and Climatic Relations," *Carnegie Inst. Wash. Pub. 349* (1925), p. 43; "Geology and Paleontology of the Crooked River Basin with Special Reference to the Bridge Creek Flora," *Carnegie Inst. Wash. Pub. 346* (1927), p. 79.

and MacGinitie[29] for some of the mid-Tertiary western fossil floras, which contain forms similar to those in the Humboldt.

La Motte[30] has suggested that the Forty-nine Camp region of northwestern Nevada had both summer and winter rains. The Elko region 250 miles farther east probably also had summer and winter rains, as its geographical location is favorable to both.

As deposition of the Humboldt formation extended through a considerable part of the late Miocene and possibly into the early Pliocene, conditions probably changed during such a long time. The best evidence of humid climate is found near the base of the formation. Higher up, the vertebrate fauna seems to reflect less humid conditions, suggesting that the climate may have become progressively drier during the deposition of the formation. This seems to fit in well with the general picture obtained from other mid-Tertiary deposits of western United States as outlined by Clements and Chaney[31] and by Dorf.[32] A relatively humid climate in the Miocene and a drier climate in the Pliocene seems to be the general rule. The uplift of the fault-block mountains to the west, cutting off moisture from the Pacific Ocean, had not taken place to any great extent in early Humboldt time, though the less humid conditions of late Humboldt time may indicate that such uplifts were beginning to have effect.

ORIGIN OF THE MIOCENE BASINS OF DEPOSITION

The origin of the Tertiary basins of deposition in the Great Basin has long been a problem. The solution to this problem lies in the nature of the Tertiary deposits and in their relations to the pre-Tertiary rocks. The basins must have been either structural or erosional or, perhaps, in part both. If the basins were entirely erosional, some change in drainage must have occurred which caused them to become basins of sedimentation. The Miocene floras in the Great

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[29] Harry D. MacGinitie, "The Trout Creek Flora of Southeastern Oregon," *Carnegie Inst. Wash. Pub. 416* (1933), p. 39.

[30] *Op. cit.*, p. 89.

[31] F. E. Clements and R. W. Chaney, "Environment and Life in the Great Plains," *Carnegie Inst. Wash. Suppl. Pub. 24* (1936), pp. 1–54.

[32] Erling Dorf, "Pliocene Floras of California," *Carnegie Inst. Wash. Pub. 412* (1930), pp. 34–66.

Basin indicate annual-rainfalls from 24 to 40 inches,[33] which is certainly sufficient to maintain an integrated drainage unless some diastrophic change occurred, causing a disintegration of the drainage. The basins of deposition may have been developed in part by erosion, but diastrophism seems to have been the immediate factor causing them to become basins of sedimentation.

If the basins were of tectonic origin, they may have originated by warping or faulting. The lower member of the Humboldt formation is composed largely of fine-grained material. These fine-grained deposits indicate that the basins came into existence slowly and without sudden upheavals of any large magnitude. Small-scale faulting or gentle warping could account for the initiation of the basins. Spurr,[34] Louderback,[35] and Davis[36] have suggested that these basins originated through warping, but they have presented no evidence in support of this view. At a later date, at least in the Ruby–East Humboldt region, faulting has definitely played an important part in outlining the basins. Faulting during the deposition of the Humboldt formation is indicated by the interbedded breccia and fanglomerate at the north end of the East Humboldt Mountains near Wells. These coarse deposits have been described in the section of the paper treating lithology, and the reasons for considering that they were deposited at the foot of a fault scarp are given there.

The exact outline of the original area covered by the Humboldt formation in northeastern Nevada cannot be given as yet. It was a large area extending at least 150–200 miles from north to south and a corresponding distance east and west. The outcrops of the formation were once more continuous than at present, for late Cenozoic faulting has created basins separated by mountains. The area receiving deposits was not a single and simple basin. It may have been a series of connected intermontane basins or an irregular depression

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[33] La Motte, Berry, Oliver, Chaney, and MacGinitie, in the works previously cited.

[34] J. E. Spurr, "Origin and Structure of the Basin Ranges," *Bull. Geol. Soc. Amer.*, Vol. XII (1901), p. 266.

[35] G. D. Louderback, "Basin Range Structure of the Humboldt Region," *Bull. Geol. Soc. Amer.*, Vol. XV (1904), p. 337.

[36] W. M. Davis, "The Peacock Range, Arizona," *Bull. Geol. Soc. Amer.*, Vol. XLI (1930), p. 312.

with island-like highlands within its borders. One of these highlands occupied the present site of the Ruby–East Humboldt Range, and from it detritus was poured into the basins by local streams.

In the main, the Elko area was made favorable for deposition by an extensive and gradual differential warping or small-scale faulting, which, combined with erosion, produced a series of depressions separated or broken by low ridges. After deposition had continued for some time, the depressions were blocked out by faulting. The present pattern of mountain and basin blocks was outlined by faulting during Humboldt time and has been perpetuated by periods of recurrent faulting, continuing to the present.

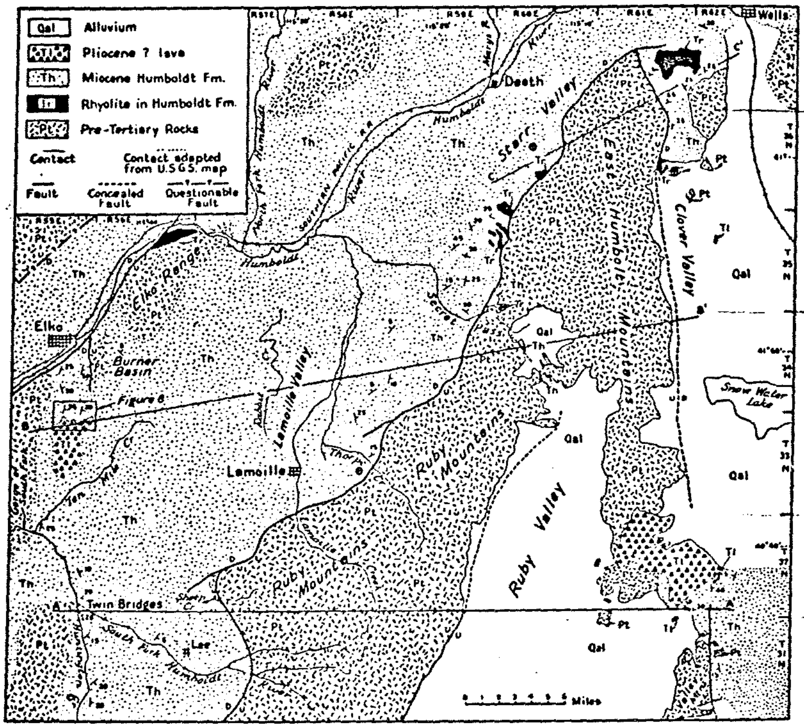

FIG. 9.—Geological map of the Humboldt formation in the vicinity of the Ruby–East Humboldt Range. The location of this map is shown in Fig. 1.

SUMMARY

The Humboldt formation is composed chiefly of conglomerate, sandstone, mudstone, and shale. Considerable rhyolitic ash and tuff,

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and smaller amounts of fresh-water limestone, oil shale, diatomite, breccia, fanglomerate, and thin interbedded rhyolite flows compose the remainder of the formation. The sedimentary deposits are of fluviatile and lacustrine origin.

Three members can be distinguished. A lower member, 800–1,000 feet thick, is identified by limestone and oil shale. A middle member, 1,300 feet thick, is identified by an abundance of rhyolitic ash and tuff beds. An upper member, 3,600 feet thick, is identified by thick sections of sandstone, mudstone, and shale with few conglomerate beds. The Humboldt formation has a measured thickness of 5,800 feet, and it may be thicker.

Vertebrate and plant remains indicate that the formation was deposited in the latter part of the Miocene, with deposition extending possibly into the Pliocene.

As far as known, the basin deposits rest on a basement of pre-Tertiary rocks. This contact, where exposed, is a distinct unconformity. At present, the Humboldt beds lie in a series of basins separated by fault-block mountain ranges of older rocks. At the edges of many of these basins the Miocene beds are separated from the older rocks of the mountains by normal faults. The structure of the Miocene beds is simple in the center of the basins and complex at the edges.

Data are presented which suggest that Miocene (?) lavas to the north of the general area of basin deposits are interbedded with the Humboldt beds near Jarbidge.

The beds of the Humboldt formation were deposited in a series of connected intermontane basins or an irregular depression, which, in early Humboldt time, was covered in part by a lake or lakes; later the lakes dried up or were filled up. The greater part of the formation was deposited along river courses and on flood plains by moderately large, permanent streams. The initially low relief was increased in middle Humboldt time, presumably by faulting, and somewhat reduced by erosion toward the end of the Humboldt period. Contemporaneous volcanism, 70 miles north of the Elko region, built a broad lava table-land, or dome, and supplied large quantities of fine pyroclastic material to the Humboldt formation.

The flora and vertebrate fauna from the Humboldt indicate conditions considerably more humid in the later Miocene than at present.

The nature of the Humboldt beds and their relations to the pre-Miocene rocks show that, although deposition of the formation may have started in consequence of widespread warping or small-scale faulting, some of the mountain and basin blocks were outlined by faulting at a later time during the deposition of the Humboldt formation. This fault pattern has been perpetuated by post-Humboldt movements extending to the present.

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[1] Published by permission of the

[2] A. C. Spencer, H. B. Kümmel, J
Surv. Folio 161 (1908).