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Mapping the radiolarite outcrops as potential source of raw material in the Stone Age: Characterisation of Polish part of the Pieniny Klippen Belt

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Abstract

Radiolarite is a siliceous rock originated from the deep-sea sedimentation of radiolarian skeletons. It is a well-known raw material, commonly used during the Stone and Early Bronze Age in Europe. It is diversified in colour and other macroscopic features. The richest and most important deposits in Poland are located in the Pieniny Klippen Belt, itself a part of a geological unit which appears also in other countries in the Carpathian Mountains (Romania, Ukraine, Slovakia and Austria). Excavations conducted in this area since 1970s by P. Valde-Nowak and J. Rydlewski revealed abundant evidence of Palaeolithic processing workshops and camps. Exploitation of the radiolarite took place in the Pieniny Klippen Belt since the Middle Palaeolithic through the Upper Palaeolithic, which was confirmed by further studies by P. Valde-Nowak in Obłazowa Cave. The distribution of radiolarite materials is documented in Poland since the Middle Palaeolithic until the Early Bronze Age, but occurred mostly during the Late Palaeolithic.

Keywords: radiolarite, Stone Age, Pieniny Klippen Belt, raw material, Poland.

Résumé

La radiolarite est une roche siliceuse, composée essentiellement de squelettes de radiolaires, formée dans les sédiments marins profonds. C'est un matériau bien connu, communément utilisé en Europe durant la Préhistoire et l'Age du Bronze ancien. Sa couleur, ainsi que d'autres caractères macroscopiques, sont variables. Les gisements les plus riches et les plus importants, en Pologne, sont situés dans la zone du Pieniny Klippen. Ils font partie d'une formation géologique qui existe aussi dans d'autres régions des Carpathes (Roumanie, Ukraine, Slovaquie et Autriche). Des fouilles menées dans cette région depuis les années 1970 par P. Valde-Nowak et J. Rydlewski ont mis au jour de riches vestiges d'ateliers de taille et de campements paléolitiques. L'exploitation de la radiolarite a lieu dans la zone du Pieniny Klippen du Paléolithique moyen au Paléolithique supérieur, ce qui a été confirmé par les travaux de P. Valde-Nowak à la grotte d' Obłazowa. Bien que la distribution de mobilier en radiolarite est attestée en Pologne du Paléolithique moyen jusqu' au Bronze ancien, son utilisation principale a lieu au cours du Paléolithique supérieur.

***Mots-clés** : radiolarite, Préhistoire, zone du Pieniny Klippen, matière première, Pologne.*

1. INTRODUCTION

Radiolarite is a siliceous rock originated from the skeletons of radiolarians in a deep-sea context. Radiolarites are present in many geological units and were commonly used during the Stone and Early Bronze Age in Europe. In some regions it was the main raw material.

In Poland there are a lot of well-known siliceous rocks of a good quality that were used by prehistoric societies - especially flints, but also radiolarites. One of the most important sources of good quality radiolarites in Central Europe is the Pieniny Klippen Belt (PKB) in the Carpathians, also in Poland.

This paper presents the problematics of the use and significance of radiolarite in Poland. It focuses on the issue of the outcrops as potential sources that could be exploited by prehistoric societies, as well as on the scale of its use in the territory of Poland.

2. GENERAL DESCRIPTION OF RADIOLARITES AND THEIR OUTCROPS

Radiolarite originates from skeletons of radiolarians mainly below the Carbonate Compensation Depth level (CCD; KSIĄŻKIEWICZ, 1972; BOLEWSKI & PARACHONIAK, 1982; ELEKES *et al.,* 2000, p. 501). Radiolarites were formed in marine sediments starting at least from the Palaeozoic, and massively deposited in the Mesozoic (ELEKES *et al.,* 2000, p. 501). They also appear among the shallow rock deposits (BOLEWSKI & PARACHONIAK, 1982).

Radiolarite is characterised by its distinct, varied colour, gloss and degree of translucency that depends on genetic and post-diagenetic factors. Due to its properties comparable with flint and the richness of its sources, this rock was an excellent source of raw material for the Stone Age community. It is found in many parts of Europe, being in some places the basic raw material.

Deep-sea sediments occur in limited areas, including the Polish part of the PKB, where the manganese and steel-grey radiolarites are present (KOZŁOWSKI *et al.*, 1981; RYDLEWSKI, 1989b, 2009; PAWLIKOWSKI, 2009). Radiolarites of the transitional and shallow series are widespread in all areas (KOZŁOWSKI *et al.*, 1981; PŘICHYSTAL, 2013). These are red radiolarites, in various shades - liver-like, cherry red, or burgundy. They cover a range from waxy to dull, with a slight degree of transparency. This variety is most commonly found among Stone Age inventories and is the easiest to identify. There are also common green and yellow radiolarites of various shades (BIRKENMAJER, 1979; KOZŁOWSKI *et al.*, 1981; RYDLEWSKI, 1989b, 2009; PAWLIKOWSKI, 1992; CHEBEN & ILLÁŠOVÁ, 1997). Radiolarites are the subject of weathering processes, which affect their primary characteristics (RYDLEWSKI, 1989a-b; BRANDL *et al.*, 2013).

Primary radiolarite deposits occur in many of Europe's mountain ranges, e.g. the Carpathians, the Alps (KSIĄŻKIEWICZ, 1972; BIRKENMAJER, 1979; RYDLEWSKI, 1989b), as well as other geological units continuing on extensive areas. An important source of this raw material for Central Europe and for Poland is the already mentioned PKB, which is the geological unit that separates the Outer Carpathians from the Inner Carpathians. It occurs in the area between Romania in the south-east, eastern Slovakia, Poland (Podhale and Pieniny), Slovakia and Moravia (Vlarska Pass, White and Small Carpathians), Austria in the vicinity of Vienna, where alpine radiolarites are also recognised (BIRKENMAJER, 1979; RYDLEWSKI, 1989b; BRANDL *et al.*, 2013; PŘICHYSTAL, 2013). Layers of dark Ordovician-Carboniferous radiolarites occur in many mountainous areas of Europe, formed during the Palaeozoic mountain orogenic movements. These radiolarites are found e.g. in the Świętokrzyskie Mountains, the Sudetes, the Czech Massif, reaching the Pyrenees and Cornwall (PAWLIKOWSKI, 1992; MIGASZEWSKI *et al.*, 1999; PŘICHYSTAL, 2013, p. 68). Radiolarites are also found in the Outer Flish Carpathian, in the so-called Silesian and Sub-silesian series that continues along the Carpathian Arc in Poland and in neighbouring areas (KSIĄŻKIEWICZ, 1972; BOLEWSKI & PARACHONIAK, 1982). They were also used during the Stone Age (RYDLEWSKI, 1989a-b; VALDE-NOWAK, 2009). As for now, no archaeological researches have been conducted on the use of Tatra Mountains radiolarites (BOLEWSKI & PARACHONIAK, 1982; PAWLIKOWSKI, 1992, 2009) or these from the Świętokrzyskie Mountains (BOLEWSKI & PARACHONIAK, 1982; MIGASZEWSKI *et al.*, 1999).

In Hungary the richest outcrops of radiolarites are located in the Szentgal region (Szentgal type radiolarite), Bakonyscernye mountains, Gerecse (Lábatlan, Dunaszentmiklós, Tata) and in neighbouring areas (ELEKES *et al.,* 2000; PŘICHYSTAL, 2013, p. 129-131).

Radiolarites are also found within secondary deposits. They are readily available albeit in a limited size (RYDLEWSKI, 1989b; CHEBEN & ILLÁŠOVÁ, 1997). Examples of radiolarites that were acquired during the Stone Age from such sources are the Cretaceous 'Gliwice radiolarites' in Upper Silesia (FOLTYN *et al.*, 2009). They are also commonly found as boulders in the valleys of Slovakia, Moravia (Wag and Vlara rivers), Austria, Hungary (Danube Valley) and were used during the Stone Age (ELEKES *et al.*, 2000; PŘICHYSTAL, 2013; BRANDL *et al.*, 2015). In Poland, radiolarite from secondary deposits is

recorded as well in archaeological material (e.g. from the Dunajec Valley: RYDLEWSKI, 1989a-b; WILCZYŃSKI *et al.*, 2014).

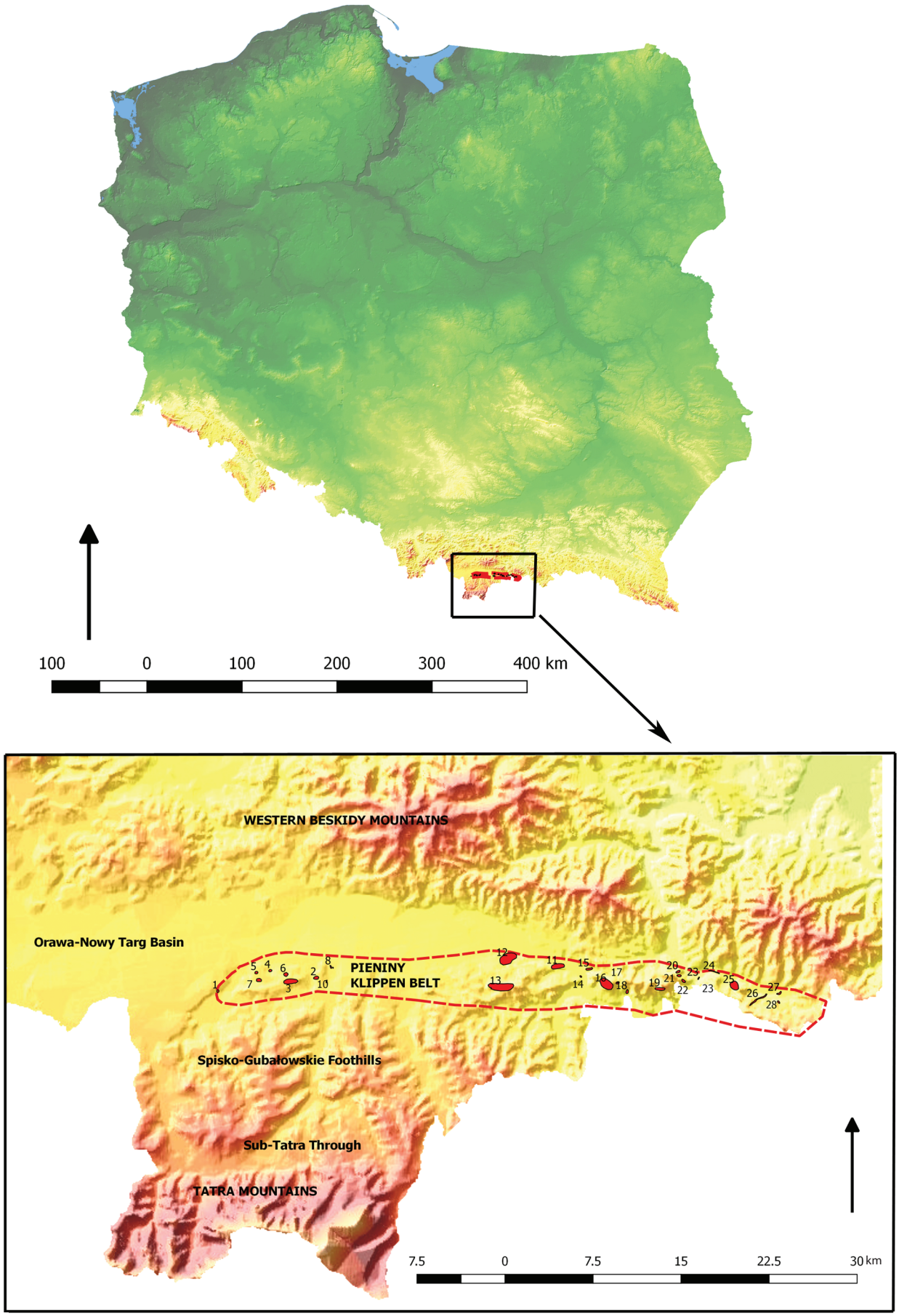
3. HISTORY OF RESEARCH ON THE POLISH RADIOLARITE INVENTORIES

Radiolarite is the subject of research since the first decades of the 20th century. Its outcrops have been identified in the Vlarska Pass in western Slovakia and the raw material was distinguished among the assemblages of sites located in Moravia and Slovakia (SKUTIL, 1947; KOZŁOWSKI *et al.*, 1981). At the same time discoveries of radiolarite mines were made in Austria and Hungary, showing its important role in the inventory of the Stone Age sites (TRNKA, 2011; BIRÓ & REGENYE, 2007). Also in Poland attention was paid to this raw material among Palaeolithic inventories (CZAPKIEWICZ, 1936; LINDNER, 1937). For a long time, the idea of long-distance, Slovak, Hungarian or Alpine origins of artefacts discovered at sites located in Poland was maintained (JURA, 1939; KOWALSKI & KOZŁOWSKI, 1959; GINTER, 1974; KOZŁOWSKI *et al.*, 1981; RYDLEWSKI, 1989a-b). It was even more emphasised, that the products of Polish flint varieties were commonly found among the inventory of sites in the neighbouring areas, including the territory nearby the radiolarite outcrops (KOZŁOWSKI, 1957; POŁTOWICZ, 2007; WIŚNIEWSKI *et al.*, 2012, p. 398). Information about the deposits of radiolarite located in the territory of Poland, especially in the Pieniny Klippen Belt was included. However, it was emphasised that their quality was not equal to that of neighbouring areas (KOWALSKI & KOZŁOWSKI, 1959; BIRKENMAJER, 1979). In the 1970s and 1980s field research in the area of radiolarite outcrops in Poland in PKB and comparative laboratory studies revealed that this material was exploited and processed during the Stone Age (RYDLEWSKI & VALDE-NOWAK, 1977, 1978a, 1978b; KOZŁOWSKI *et al.*, 1981; VALDE-NOWAK, 1977). Similarly, although on a smaller scale in other parts of Poland, radiolarites were relatively late to be classified as potential sources of raw materials obtained during the Stone Age. The research focused on the area of Upper Silesian 'Gliwice radiolarite' (GINTER, 1973, 1974; FOLTYN *et al.*, 2009) and in the Flish Carpathians in south-eastern Poland (so-called flysch radiolarite: RYDLEWSKI, 1989a-b; VALDE-NOWAK, 2009; VALDE-NOWAK *et al.*, 2014). Studies on the distribution of radiolarite for individual regions and periods of the Stone Age were made (e.g. SCHILD, 1975, p. 267-270; KOZŁOWSKI *et al.*, 1981; CYREK, 1983; RYDLEWSKI, 1989a-b; SULGOSTOWSKA, 2005). A detailed presentation of the sites located at and around radiolarite outcrops has already been proposed (KOZŁOWSKI *et al.*, 1981; RYDLEWSKI, 1989a-b, 2009; FOLTYN *et al.*, 2009), but their numbers are still increasing.

The exact division into varieties was made at the same time for samples from radiolarite outcrops in the Polish part of PKB, taking into account genetic and macroscopic features (groups I/1 - II/3, VALDE-NOWAK, 1979; KOZŁOWSKI *et al.*, 1981), red, green and manganese radiolarites, including division of PKB into lithostratigraphic units and formations (BIRKENMAJER, 1979; KOZŁOWSKI *et al.*, 1981; RYDLEWSKI, 1989b), as well as for Slovak radiolarites derived from abundant high-quality raw materials in the Vlara River Valley of the White Carpathians (groups 1-8, CHEBEN & ILLÁŠOVÁ, 1997) and Hungarian sources (ELEKES *et al.*, 2000; BIRÓ, 2002). Among these deposits are all colour variants. Attempts to isolate the characteristics of radiolarites indicating the origin of particular outcrops within the Carpathian Arc (CHEBEN & ILLÁŠOVÁ, 1997; KOZŁOWSKI *et al.*, 1981; CHEBEN & CHEBEN, 2009), as well as distinguishing Carpathian and Alpine resources (BRANDL *et al.*, 2013), whether from other regions (e.g. ELEKES *et al.*, 2000) have been made several times. Some of them have yielded positive results (e.g. BRANDL *et al.*, 2013).

4. LOCALISATION AND CHARACTERISATION OF THE PIENINY KLIPPEN BELT (PKB) IN POLAND

The Pieniny Klippen Belt is the Mesozoic and Palaeozoic rock formation that runs among the Tertiary domain (KOZŁOWSKI *et al.*, 1981). The Polish part of this formation is well recognised (BIRKENMAJER, 1979). The radiolarite deposits found therein are equally well documented


100 0 100 200 300 400 km
WESTERN BESKIDY MOUNTAINS
Orawa-Nowy Targ Basin
PIENINY
KLIPPEN BELT
Spisko-Gubałowskie Foothills
Sub-Tatra Through
TATRA MOUNTAINS
7.5 0 7.5 15 22.5 30 km

and described (KOZŁOWSKI *et al.*, 1981; RYDLEWSKI, 1989a-b). In Poland PKB is visible on the surface in the area between Stare Bystre and the Małe Pieniny Mountains (Fig. 1). In the west the belt is covered by younger sediments. It usually consists of units (succession, series) of rocks formed in the area of sedimentation. The shallowest is the Czorsztyńska unit. Czertezicka and Niedzica are the transitional series, and the Braniska and Pieniny units are the deepest ones. Other units are located in Slovakia and nearby regions (BIRKENMAJER, 1979).

Similarly made deposits compose so-called lithostratigraphic formations. Formations with radiolarite-bearing layers are the Sokolica, Czajakowa and Jarmuta formations. Some formations are divided into smaller units (BIRKENMAJER, 1979; KOZŁOWSKI *et al.*, 1981).

According to previous research (BIRKENMAJER, 1979; KOZŁOWSKI *et al.*, 1981; RYDLEWSKI, 1989a-b, 2009), the Polish section of the PKB was divided into three parts: west from Stare Bystre to Krempachy, central part of Pieniny Spiskie from Białka and Branisko to Niedzica and western part from Czorsztyn through Sromowce Średnie to the Flaki massif and Małe Pieniny Mountains (Fig. 1).

Radiolarites are also found in many parts of the PKB as secondary deposits, in valleys streams, rivers and showers. They also occur on Orava (western part of Podhale) in the form of erratic boulders, although the PKB is covered here by younger sediments.

The outcrops of the western groups are located between the Stare Bystre and Szaflary. Radiolarites occur in the slopes of easily accessible hills and well visible peaks, such as the Red Rock in Stare Bystre or Raniszberg in Maruszyna/Szaflary, as well as in the streams and other natural unveilings (Fig. 2). They are also present in secondary position in stream valleys, e.g. Wielki Rogoźnik or smaller streams, but in the form of rare and relatively small nodules. Another situation is the Biały Dunajec Valley, where radiolarites occur in its steep banks and in all parts of the river valley in Szaflary and Biały Dunajec villages. These are good quality and easily accessible materials. Most of the above-mentioned outcrops are rich in red and green variants, but the manganese-type is present too. A steel-grey variant is well represented in the western slope of Szaflary-Bór Hill (Fig. 2).

A very important zone in the central part of PKB is the Branisko-Hombark Massif and its neighbouring areas. This is an elongated hill with mild slopes, where the primary outcrops of good quality red variant radiolarite are probably located. The better source for selected good quality raw materials is the fluvioglacial fan of Branisko and the valley of the Branisko stream. These are rich and valuable resources that were certainly used during the Stone Age. Radiolarites of few variants occur also near the Obłazowa Cave and Kramnica Mount, near the Krempachy village. They occur mainly in streams and on the natural unveilings. Comparable to Branisko source are the Falsztyn radiolarites, that are also of very good quality and its primary and secondary outcrops are rich in raw materials (Fig. 3). Nearby are the radiolarites of Niedzica - Castle Hill and neighbouring outcrops that are recently covered by the waters of an artificial lake made in the small Dunajec river turn.

The eastern group is the richest in radiolarite outcrops but it is also the most mountainous region of all those mentioned above. There are outcrops in the rocky mountains, such as Flaki, Three Crowns (Fig. 3), Sokolica Jarmuta or the valleys and streams such as Harcygrund, Grajcarek (Fig. 1). This region is lesser accessible

Fig. 1 – (opposite page) Location of the Pieniny Klippen Belt and the main radiolarite outcrops (after BIRKENMAJER, 1979; KOZŁOWSKI *et al.*, 1981; RYDLEWSKI, 1989b, 2009, simplified).
1: Stare Bystre; 2-3: Maruszyna; 4-7: Szaflary; 8: Branisko; 9 and 11: Niedzica; 10: Falsztyn – Kosarzyska; 12: Harcygrund Valley; 13: Kapuśnica Mountain; 14: Flaki Massif; 15: Rabsztyn; 16: Żłobiny – Biała Skała; 17: Trzy Korony; 18: Kurnikowa Rock; 19: Czertezik; 20: Sokolica; 21-24: Szczawnica ; 25: Jarmuta; 26: Dolina potoku Krupianka; 27: Jaworki; 28: Homole.

than the above mentioned, but the richest in all radiolarite variants - red, green, steel-grey or manganese. In these regions the greatest Palaeolithic workshops processed radiolarites are known from all of the PKB sources (RYDLEWSKI & VALDE-NOWAK, 1977, 1978b-c, 1982c, 1982d).

Most of the above described outcrops could be possible sources for raw material for Stone Age communities. There are good quality and accessible radiolarites, certainly known by these societies.

5. THE POSSIBILITIES OF ACQUISITION OF RADIOLARITES IN PKB

In the Polish part of Pieniny Klippen Belt there is no direct evidence for mining methods of radiolarite exploitation, but examples are known from the neighbouring areas. In the PKB range numerous workshops processing local radiolarite were discovered. The oldest mining tools in Europe also originated from this region (see below). It is therefore very possible that radiolarite was also exploited in this area through

Fig. 2 – Examples of radiolarite outcrops and samples of raw material from western group of PKB; 1-3, 6, 9: Maruszyna; 4, 5, 7, 8: Szaflary.

mining, as suggested for comparable contexts e.g. in Italy (MAGGI *et al.,* 1995).

Primary radiolarite deposits were exploited by mining methods during the Neolithic and Aeneolithic, as indicated by the examples from Austria (Mauer-Antonshöhe, BRANDL *et al.*, 2013, 2015), Slovakia (Vrsatecke Podhradie, Bolesov-Tri Kopce and other, CHEBEN & CHEBEN, 2015), Hungary (Tata - Kálvariadomb, Bakonycsernye - Tűzkövesheghy and others, ELEKES *et al.*, 2000) or in Italy (MAGGI *et al.,* 1995).

An interesting example of the direct use of radiolarite from the rock wall is the Neolithic mine complex situated in the Lagorara Valley in the Apennines (Italy). They were extracted with hard tools directly from the high vertical rocky

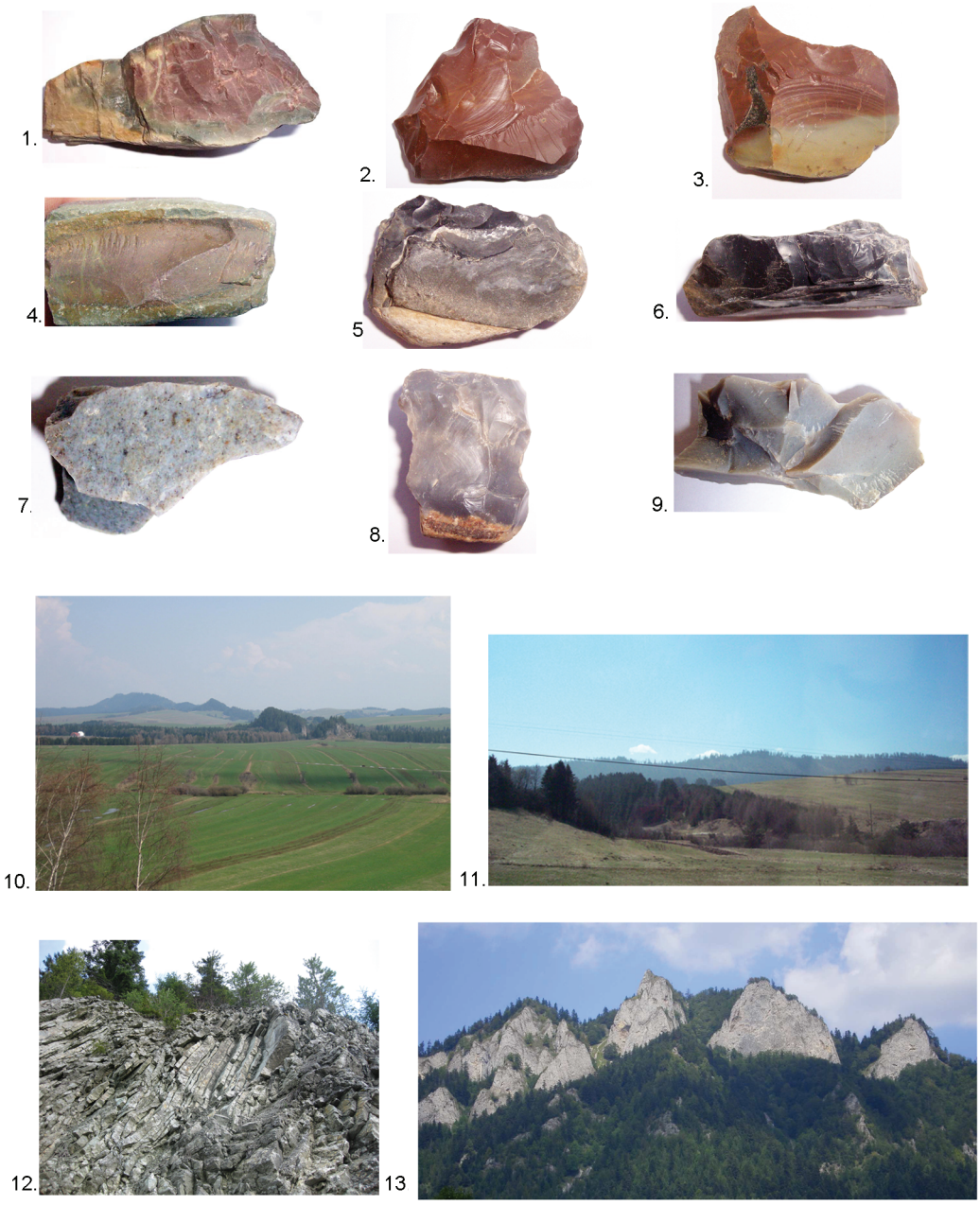


Fig. 3 – Examples of radiolarite outcrops and samples of raw material from central and eastern group of PKB. 1, 4: Falsztyn; 2-3, 5-6: Branisko; 7-9: Flaki Massif; 10: View on central part of PKB from Cisowa Rock. In the foreground – Obłazowa and Kramnica Rocks; 11: Branisko Hill; 12: Flaki Massif; 13: Trzy Korony Mount).

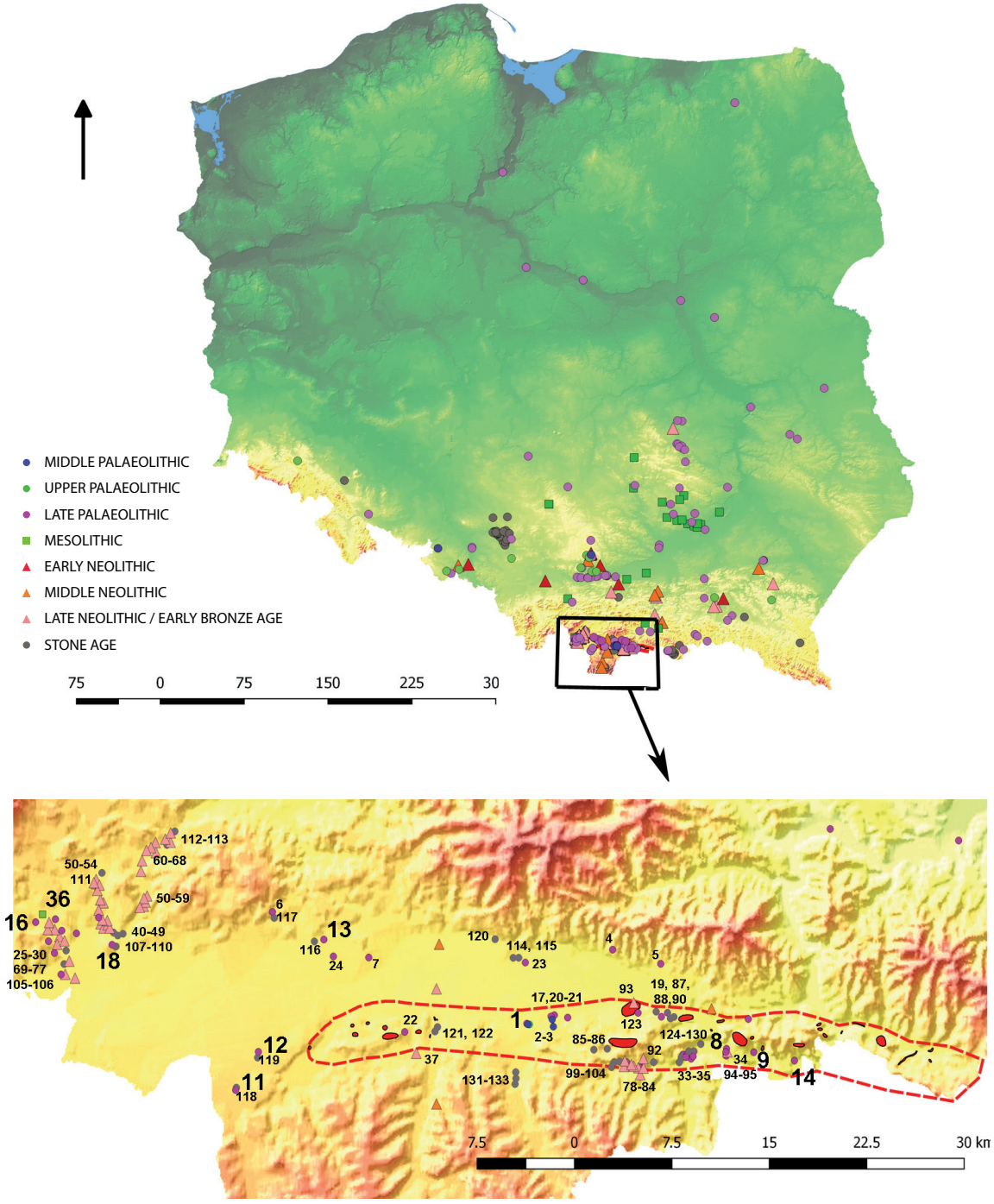


Fig. 4 – Upper part: Location of the Stone Age sites, where the presence of radiolarite artefacts has been confirmed in the territory of Poland; Lower part: Main sites located in the range of PKB or its vicinity. 1: Nowa Biała site 2, Obłazowa Cave; 2-3: Krempachy; 4: Szlembark; 5: Maniowy; 6, 117: Odrowąż; 7: Krauszów; 8: Sromowce Wyżne 'site 2'; 9: Sromowce Wyżne-Kąty; 10: (8 on the map): Sromowce Wyżne, 'site 8'; 11: Koniówka site 1; 12: Podczerwone site 1; 13: Dział, site 1; 14: Sromowce Niżne, site 1; 15 (1 on the map): Nowa Biała, 'site 1'; 16: Lipnica Wielka, 'site 2'; 17: Krempachy, 'site 1'; 18: Jabłonka, 'site 22'; 19, 87-88, 90: Falsztyn; 20-21: Krempachy; 22, 89, 91: Maruszyna; 23: Łopuszna; 24: Długopole; 25-30: Lipnica Wielka; 31, 107-110: Jabłonka; 33-35, 124-130: Niedzica; 36: Lipnica Wielka, 'site 8'; 37: Bańska; 38, 123: Frydman; 39, 94-95: Sromowce Wyżne; 40-49: Jabłonka; 50-54, 111: Zubrzyca; 55-59: Orawka; 60-68: Podwilk; 69-77, 105-106: Lipnica Wielka; 78-84, 99-104: Łapsze Niżne; 85-86: Dursztyn; 92: Niedzica; 93: Frydman; 96-97, 112-113: Podwilk; 114-115: Ostrowsko; 116: Dział; 118: Koniówka; 119: Podczerwone; 120: Waksmund; 121-122: Szaflary; 131-133: Białka Tatrzańska.

slope. Further processing was made at the foot of the wall. Traces of all stages of this activity have been preserved until recent times (MAGGI *et al.,* 1995).

In Western Slovakia, mining activity shows a different character. These were pits or deep shafts sunk in the surface, such as Vrsatecke Podhradie, Krivoklat, Bolesov - Tri Kopce. As in Valle Lagorara, initial processing was conducted in the mining area (CHEBEN & ILLÁŠOVÁ, 1997; CHEBEN & CHEBEN, 2009).

In the mine located in the Mauer - Antonshöhe hill in Vienna, Austria, deep shafts with small galleries were found (TRNKA, 2011). In Hungary, where radiolarite was one of the basic raw materials, numerous mines and processing workshops were discovered. One of the most important mines is Szentgál - Tüzköveshegy - 'flint hill' in the Bakony Mountains with mining pits and shafts (BIRÓ, 1995; ELEKES *et al.*, 2000). This raw material was probably already worked in the Middle and Late Palaeolithic, as evidenced by its presence in sites from this period. However, there are no indicators of its mining before the Neolithic (TAKÁS-BIRÓ, 1986, BIRÓ & REGENYE, 2007). In the Bakony Mountains, there are several other radiolarite outcrops that were exploited in the Stone Age. Bakonycsernye - Tüzkövesarow or Hárskut - Édesvismajor, Veszprém, but archaeological research was not carried out (BÁCSKAY, 1995; BIRÓ & REGENYE, 2007). In the Gereccse Mountains, the remains of numerous mines were also found. Both at the Dunaszentmiklós - Hosszuvontató and at Lábatlan - Margiltetö, or in Lábatlan - Piszniceteto (Komárom district), exploitation made directly from the rock was confirmed. Radiolarites were collected most likely from the exposed part of the deposit (as in the Apennines; BÁCSKAY, 1995).

Within the range of the radiolarite outcrops in PKB one Middle Palaeolithic site Nowa Biała 2 (Obłazowa Cave) has been recognised (Fig. 4). The composition of the inventory in the settlement levels of the Mousterian culture (XXb, XVII, XVI, XV, XIII) and the Micoquian level (XVIIIb), confirms the intensive use of local varieties of radiolarite, especially the red ones (MADEYSKA *et al.*, 2002; VALDE-NOWAK, 2010; VALDE-NOWAK & NADACHOWSKI, 2013; CIEŚLA & VALDE-NOWAK, 2014). Higher in the stratigraphy, mostly in the Upper Palaeolithic levels of the cave in Obłazowa, the raw material of individual inventories is more diversified, but the products made of local radiolarites are predominant. In Layer XI (Szeletian settlement level), the majority of the material was made of red radiolarite (VALDE-NOWAK *et al.*, 2003). In the Layer VIII of the cave in Obłazowa (Gravettian - Pavlovian), green radiolarite slightly overlaps with other variants. From this layer came two antler wedges, classified as mining girders, one of which ornamented (VALDE-NOWAK *et al.*, 2003, p. 56). They are believed to be the oldest mining tools from Poland. Another antler tool was also discovered as a stray find probably at the Kłodne site in the Pieniny area itself, but this hoe-shaped antler artefact is not available for analysis (a Neolithic age cannot be excluded; ŻAKI, 1958).

The largest number of PKB sites on which radiolarite artefacts are recorded is associated with Late Palaeolithic, starting with the Magdalenian culture, with which the largest processing workshops in this area are connected. In the eastern part of the PKB, the radiolarite that was processed was green, with a small share of the other varieties (Sromowce Wyżne - Kąty; RYDLEWSKI & VALDE-NOWAK, 1982c-d; RYDLEWSKI, 1989a-b, 2009; VALDE-NOWAK *et al.*, 2005; Sromowce Wyżne, st. 8; DROBNIEWICZ *et al.*, 1997). It is believed that radiolarites were sourced directly from its slopes, and supplemented by pieces of river nodules. There are also numerous Magdalenian sites where the local red variety dominates (Koniówka st. 1, Podczerwone st. 1; RYDLEWSKI & VALDE-NOWAK, 1981a, d, e; RYDLEWSKI, 1989a-b; VALDE-NOWAK, 1991).

The Arch Backed Piece technocomplex in the area of PKB covers two sites: Sromowce Niżne 1 (RYDLEWSKI & VALDE-NOWAK, 1977, 1978b; RYDLEWSKI, 1989b) and Nowa Biała 1 (VALDE-NOWAK, 1986, 1987; VALDE-NOWAK & KRASZEWSKA, 2014). In Sromowce Niżne, the green and grey radiolarites are the most common while on the site of Nowa Biała 1 the red variety dominates (VALDE-NOWAK, 1987; RYDLEWSKI, 1989b). This is similar to the Magdalenian sites situated within the PKB deposits, the situation

is consistent with the distance from individual sites to the large outcrops in which other variants predominate (Fig. 4).

There are several larger sites of Tanged Point Cultures in the vicinity of the PKB (like Lipnica Wielka 2, Dział I/85). These sites, however, are not located in the direct range of the primary sources of PKB radiolarites, which may explain the minor presence of this material in their inventories (RYDLEWSKI & VALDE-NOWAK, 1978a, 1978c, 1979a, 1982a-d; RYDLEWSKI, 1985). Other sites from this period are the remnants of short-term camps, especially in the eastern part of the PPS, where all varieties of radiolarites occurred (Krempachy, Fig. 4; RYDLEWSKI, 1989b, 1990).

The Mesolithic settlements within the Pieniny radiolarite is limited to several settlement points and a larger camp and workshop in Lipnica Wielka 8, located a dozen or so kilometres to the west of the outcrop. Except for the vast majority of Jurassic flints, the red and green radiolarite varieties were also processed there (RYDLEWSKI, 1989a-b, 2006; Fig. 4).

There are no sites dated to the Early Neolithic where local radiolarite was used, but there are numerous settlements from the Neolithic and Early Bronze Age located in the vicinity of the Pieniny deposits: the Biały Dunajec, Frydman as well as tributaries of the Czarna Orawa in the west (Fig. 4; VALDE-NOWAK, 1980; RYDLEWSKI & VALDE-NOWAK, 1981h; KOPACZ & VALDE-NOWAK, 1987; RYDLEWSKI, 1989a-b; KOPACZ, 2001).

6. DISTRIBUTION OF RADIOLARITES AND THE PROBLEM OF THE IDENTIFICATION OF THEIR PROVENANCE

Evaluating the distribution of radiolarite is a complex issue. Primary and secondary radiolarite outcrops are located in Slovakia, Austria, Hungary, Czech Republic and in many other regions. Most of the outcrops of good quality radiolarite in Poland are to be found in the Pieniny Klippen Belt. The problem of the identification of the local, specific source outcrop of the lithic material is still a work in progress and is not easy to solve.

Apart from the distribution of radiolarites originating from the southern and western parts of Europe, primarily PKB radiolarite (VALDE-NOWAK, 1979; KOZŁOWSKI *et al.*, 1981), 'Gliwice' (FOLTYN *et al.*, 2009) and Flysh radiolarite (VALDE-NOWAK, 2009) were the subject of distribution during the Stone Age. In Poland there are currently over 300 sites from all periods of the Stone Age, where radiolarite artefacts have been recorded (Fig. 4).

The oldest Middle Palaeolithic inventories with imported radiolarites come from the Ciemna Cave (Cracow-Czestochowa Upland). It is a hand axe connected with the Micoquian cultural level made of the steel-grey radiolarite and the Levallois point from the level containing the Mousterian components (SOBCZYK & VALDE-NOWAK, 2012, p. 49-50). Another specimen from this period also probably made of radiolarite is the tool from the site no 2 in Lisięcice in Głubczyce in Silesia (WIŚNIEWSKI, 2006, p. 218). So far these are the only known sites in Poland of such a distant chronology, where the presence of radiolarite can be confirmed.

Among younger inventories, radiolarites were relatively abundant among assemblages of the sites concentrated in and around Cracow and Silesia. They were present in the large Szeletian camps (Kraków Zwierzyniec, Lubotyn st. 11; SAWICKI, 1949; KOWALSKI & KOZŁOWSKI, 1959; KOZŁOWSKI *et al.*, 1981; KOZŁOWSKI, 2006; MAŃKA, 2006; BOBAK & POLTOWICZ-BOBAK, 2010) as well as Jerzmanowice culture sites (Nietoperzowa Cave in Jerzmanowice, Mamutowa Cave; CHMIELEWSKI, 1975).

At Gravettian sites occurring outside the outcrops, radiolarite was noted in the inventory of rich sites, such as Cracow Spadzista in Małopolska, Cyprzanów I or Marzankowice in Silesia (DROBIEWICZ *et al.*, 1976; KOWALSKI & KOZŁOWSKI, 1959; KOZŁOWSKI *et al.*, 1981). In the Upper Palaeolithic, Flysch radiolarite was used, as indicated by the inventory of the Epigravettian site of Ujazd in Podkarpacie, where the import of the red radiolarite from PKB was also confirmed (VALDE-NOWAK, 2006).

The most common variant among the imports of radiolarites during Magdalenian culture

is red, occurring in the Maszycka cave, Wilczyce and other great and important sites (KOZŁOWSKI *et al.*, 1981; SULGOSTOWSKA, 2005; GINTER *et al.*, 2007; WIŚNIEWSKI, 2008). As researches indicate, the red radiolarite from Dzierżyslaw comes from the Moravian and Slovak outcrops (GINTER *et al.*, 2002, p. 120, 2007). The yellowish variety radiolarite, previously unknown from older Palaeolithic sites, has appeared in several Magdalenian culture sites, including the Maszycka Caves (KOZŁOWSKI, 1963; KOZŁOWSKI *et al.*, 1981; WIŚNIEWSKI, 2008; SULGOSTOWSKA, 2005). It was originally suggested that it was connected with Alpine deposits. The hypothesis of an Upper Silesian Gliwice origin was recently proposed (FOLTYN *et al.*, 2009). Among the Magdalenian inventories located outside the radiolarite outcrops no production from the green variety of radiolarite has been recorded so far (SOBKOWIAK-TABAKA, 2011); some researchers are therefore inclining towards the non-Polish south-western origins hypothesis. It is worth mentioning, however, that the red variety of the radiolarite occurs in all known outcrops, and on the Polish territory its exploitation can be also confirmed.

Among imported artefacts of Arch Backed Piece sites, mainly red radiolarites, usually appear individually. The exception is the site of Nowy Młyn III/77 (Rydno) (SCHILD *et al.*, 2011; SULGOSTOWSKA, 2005). Single specimens of the yellow-red variety were recorded at Wola Boksicka/Bokszycka (KOZŁOWSKI *et al.*, 1981; SULGOSTOWSKA, 2005) and in Pawłów on the Sandomierz upland (LIBERA *et al.*, 2008).

Most of the sites where the imported radiolarite artefacts were recorded are associated with Tanged Point Cultures settlements, which also cover the widest geographical range. Individual specimens are found in the sites located far away from the outcrops, located in Mazovia (Gulin, Marki - Warszawa, Mińsk Mazowiecki, LIBERA, 1998; SULGOSTOWSKA, 2005, p. 194) and even in the northern part of Poland (JURZYSTA, 2010). The greatest concentrations, however, are located in the south of Poland, on the Cracow-Czestochowa Upland, where they have been recorded since the 1930s on sites in Borek Fałęcki, Cracow-Kobierzyn, Cracow-Tyniec (Bagno) or Zakrzów (KOWALSKI & KOZŁOWSKI, 1959), as well as many others, regularly increasing this inventory (e.g. STEFAŃSKI & WILCZYŃSKI, 2012). Radiolarite is also commonly found in the site inventories from that period on the Sandomierz and Lublin Uplands (south eastern part of Poland). The most numerous examples come from Chwalibogowice, Wilkowa or Opatowiec (SCHILD, 1975; KOZŁOWSKI *et al.*, 1981; LIBERA, 1998; SULGOSTOWSKA, 2005). Similarly, although on a smaller scale, this raw material was used in sites located in the western and south-western parts of Poland (Janów, Wąsosz Górny, Byczeń; GINTER, 1963; SCHILD, 1975; SOBKOWIAK-TABAKA, 2011; SULGOSTOWSKA, 2005). In the Tanged Point Culture assemblages the radiolarite was also obtained from other Polish outcrops. In Silesia (Gliwice) it can be identified in workshops and camp-sites in Zabrze - Mikulczyce or Gliwice - Sobiszowice (GINTER, 1974; FOLTYN *et al.*, 2009). The radiolarite was also used in the Flysh Carpathians, which is confirmed by the raw material inventory of several sites (Żegiestów, Czermna st. 6, Żeglce st. 10, Nienaszow st. 6, Trzebowisko st. 11; RYDLEWSKI, 1989a-b, 1990; SULGOSTOWSKA, 2005; WAWRZCZAK, 2010).

In the early phase of the Mesolithic, there were few sites with radiolarite imports, but in the later phase it was distributed on a larger scale (CYREK, 1983, p. 111-112; SULGOSTOWSKA, 2005). The Early Mesolithic can be combined with one of the sites located on the Sandomierz Gorge (Chwalibogowice, Dziesławice, Borzym, Żerniki; SULGOSTOWSKA, 2005). In the Late Mesolithic, in the Sandomierz Upland, in the Malopolska Upland and in the Carpathian Foothills, this material appears more frequently, albeit often individually (Dąbrówka, Borki Radkowice, Borzym, Grabowa, Jamno, Janina, Lubania, Połaniec, Ruszcza, Zrębin; VALDE-NOWAK, 1979; KOZŁOWSKI *et al.*, 1981, RYDLEWSKI, 1989b; SULGOSTOWSKA, 2005). Exceptional are the sites in Strzelce and Brzozówka, where they were more numerous (SULGOSTOWSKA, 2005), the Mesolithic sites in Mucharz in the Skawa River basin (RYDLEWSKI & VALDE-NOWAK, 1979a-c; VALDE-NOWAK & TARASIŃSKI, 2010) as well as Luta type trapezium made of red-green radiolarite found in Sułkowice (Gościbia) in Komornica cultural context (VALDE-NOWAK, 2012). In the area of the 'Gliwice' radiolarite deposits in the

Mesolithic inventory of the sites in Dzierżno (sites no 3, 5, 6), there are workshops of red local variety (GINTER, 1973; KOZŁOWSKI *et al.*, 1981; FOLTYN *et al.*, 2009).

In the Neolithic (Aeneolithic) the presence of artefacts made of red radiolarites was reported but they are relatively rare, in contrast with the nearby mining areas in Slovakia, Austria or Hungary. Imports focus on Podkarpackie (e.g. Rzeszów Piastów, KOZŁOWSKI & KOZŁOWSKI, 1977; KOZŁOWSKI *et al.*, 1981; BALCER, 1983), in Silesia (Pietrowice Wielkie, BUKOWSKA-GEDIGOWA, 1980) and in Małopolska (Bolechów, Złota and Czchów; MADEJ & VALDE-NOWAK, 2001; CZEKAJ-ZASTAWNY, 2008; Nowy Sącz - Biegonice, CABALSKA, 1967; KOZŁOWSKI *et al.*, 1981; Jawczyce - ZOLL-ADAMIKOWA & NIŻNIK, 1963), with subsequent Aeneolithic groups such as the Baden culture in the Cracow-Czestochowa caves (ROOK, 1980, p. 52) and Cracow-Witkowice II (Cracow, Poland; RYDLEWSKI & VALDE-NOWAK, 1981g), or the Funnel Beaker Culture – Racibórz-Studzienna (KOZŁOWSKI *et al.*, 1981), Sieklówka in Podkarpacie (GANCARSKI, 1989).

In the Late Neolithic and Bronze Age, radiolarites are present on sites in Małopolska and Podkarpacie (WŁODARCZAK, 2006; ZOLL-ADAMIKOWA & NIŻNIK, 1963). The most abundant collection comes from the Maszkowice, located on the Dunajec River, at a slight distance from the Pieniny and Flysch resources. The share of radiolarites accounted for over 60 % of the inventory. All radiolarite variants occurring in PKB (red, green, steel-grey) were used. A significant percentage of these are sites connected with the Epicorded Ware Culture of the Carpathian region, where among the inventories most often are locally produced artefacts (KOPACZ & VALDE-NOWAK, 1987; VALDE-NOWAK, 1989).

In the area of the Gliwice radiolarite, many of the sites from surface and excavation studies do not have precise dating either. They probably are the remnants of local radiolarite processing workshops (FOLTYN *et al.*, 2009). Large groups of individual artefacts were also found at sites located along the main Carpathian watercourses - the Dunajec and Poprad Valleys (TUNIA, 1977). A large number of these sites indicate a significant impact of radiolarite, especially in some regions, which are usually associated with local processing, but also show its significance in particular periods of the Stone Age.

7. DISCUSSION

Radiolarites, as an extremely colourful, varied resource, were certainly of interest to the Stone Age communities, both for their technological and aesthetic qualities. Its symbolic meaning, especially the red variety, was already emphasised in the literature (SULGOSTOWSKA, 2005; STEFAŃSKI & WILCZYŃSKI, 2012). Neighbouring areas are known for examples of the production of prestigious jewellery (from the Szentgal radiolarite, cf. TAKÁS-BIRÓ, 1986), or selected blades made of this raw material stored as treasures (Zabrze-Mikulczyce, FOLTYN *et al.*, 2009), as well as the production of distinctive 'special' tools - leaf points in transitional cultures of the Upper Palaeolithic or small leaf points in Tanged Point Cultures. Symbolic caches can also be seen in some mine shafts in Mauer-Antonshöhe (BRANDL & TRNKA, 2015). The technical characteristics of the raw material also had to be satisfactory. This is evidenced by the use of radiolarites by communities with different technological traditions.

The Pieniny Klippen Belt is a geological unit particularly rich in great quality radiolarites that were used during the Stone Age. Evidence of its distribution should be considered as a strong possibility, especially among Late Palaeolithic inventories on the territory of Poland.

As for now in Poland there are no direct traces of the exploitation of rock walls or underground mining. As observed in neighbouring areas, such complicated exploitation systems are characteristic of the Neolithic, but are not known for the Palaeolithic or Mesolithic. In PKB or any other outcrop in Poland, there are just a few traces of Neolithic or Aeneolithic activity. Similarly, radiolarite as an imported material did not acquire the same importance in the Polish Neolithic as to the neighbouring areas, or as to its success in the Polish earlier Stone Age. It is

notable that Polish raw materials, such as Jurassic flints or chocolate flints, had an important significance in Slovakia, and in areas located over a dozen kilometres from the PKB outcrops, e.g. in Velky Slavkov. A similar situation can be found in Moravia and in Hungary, which may suggest that the radiolarites from these outcrops could also have been imported to the Polish territory.

As already mentioned, the problem of identifying the primary sources of radiolarite artefacts has already been widely discussed. New methods of exploring these commodities are being introduced, yielding a number of positive results (see CHEBEN & ILLÁŠOVÁ, 1997, p. 61; BRANDL *et al*., 2013) which in the future will open the possibility of making even more precise studies on the radiolarite use from Polish outcrops.

8. CONCLUSION

In conclusion we may say that the above data indicates that the radiolarite played an important role in the Stone Age in the Polish territory that goes beyond the boundaries of its deposits, and even over a considerable distance. This raw material has been used extensively in the Palaeolithic, as evidenced by numerous processing workshops and settlement points related to the exploitation of deposits, as well as widely distributed. The oldest traces date back to the Middle Palaeolithic. The widest range of its propagation is towards the end of the period, and related to Tanged Point Cultures settlements, especially Mazovian. Radiolarite was also used in the Mesolithic, especially the later part of the period. In the Polish Early Neolithic and Aeneolithic, its lesser significance contrasts with neighbouring areas, where in Slovakia, Hungary or Austria, mining methods of exploitation played a key role (BIRÓ, 2002; BIRÓ *et al*., 2007). Concentrations of sites with radiolarite assemblages occur at several points. Their highest density is in the area of occurrence of radiolarite deposits and their vicinity. Most imported radiolarites are found in the Sandomierska Valley and in the vicinity of Cracow, and later in Podkarpacie, in the basin of Poprad and Dunajec, in Upper Silesia, but imports could extend to a few hundred kilometres further. They appear in the northern regions of Poland, such as Mazovia or Kujawy, according to the principle of the 'Fall-off effect' (e.g. SULGOSTOWSKA, 2005).

The problem of primary sources of radiolarite artefacts in Poland is still open and studies in this subject need to be continued.

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