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Radiolarite studies at Krems-Wachtberg (Lower Austria): Northern Alpine versus Carpathian lithic resources

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A R T I C L E I N F O

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A B S T R A C T

This paper is a contribution to research concerning the origin of high quality radiolarites in an archaeological context. The present case study is focussed on radiolarite finds from the Gravettian site at Krems-Wachtberg in Lower Austria. Radiolarite represents a major raw material group within the assemblage, consisting of over 10,000 lithic artifacts. Comparative samples from radiolarite sources from Austria, Slovakia and western Poland were investigated. Visual, microscopic, mineralogical and petrological/geochemical analysis using XRD and LA–ICP–MS was applied. The combination of these methods allowed differentiation between raw material sources from the Northern Calcareous Alps and the Carpathian Mountains. These results allowed determination of the provenance of 10 radiolarite artifacts from the Krems-Wachtberg site. Due to the importance of radiolarite in lithic assemblages throughout Central Europe and adjacent areas, various approaches concerning the provenance of such artifacts have been undertaken. Research goals mainly focussed on possibilities of a differentiation between source areas on a larger scale, and regionally on the differentiation between single outcrops known for prehistoric raw material procurement activities. Nevertheless, previous studies fell short of expectations, precluding a cogent system for raw material sourcing.

1. Introduction

Radiolarites with exceptional knapping properties occur regularly at Upper Palaeolithic sites in Lower Austria (e.g. Montet-White, 1991, p. 219; Einwögerer, 2003, p. 88; Binsteiner et al., 2008, pp. 185–190). Investigation concerning the provenance of radiolarites from Upper Palaeolithic sites has reignited an old problem, more specifically, questions regarding the use and distinction between Northern Alpine and Carpathian sources. Most researchers assert that high quality radiolarites were not available within the spectrum of river gravels from alpine catchment areas (e.g. from the Danube River) in Lower Austria during Palaeolithic times. Conversely, the Carpathian Mountains have excellent radiolarites, sparking a debate concerning the role this source region played in Palaeolithic raw material procurement in Northern Austria.

Since 2006, the raw materials of the lithic finds from the Gravettian site of Krems-Wachtberg were systematically analysed under the auspices of the Austrian Academy of Sciences. A sample collection was established, a raw material database was created, and every artifact was microscopically analysed (Brandl and Reiter, 2008). The investigations were primarily aimed at the separation of local and non-local raw materials.

Beyond chronological and spatial dynamics concerning the use of local and non-local resources ("exotic sources"), there are social–anthropological considerations that help understand meaningful differences in human action. The presence of mainly local material demonstrates two important considerations: it is evidence of both acceptable knapping properties of the available raw material, and a reflection of astute choices of prehistoric people. Recognising the presence or absence of raw material from nearby sources can establish conceivable boundaries and the demarcation of territory and influences from certain groups (social, political and ideological).

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Non-local raw material procurement allows reconstruction of probable mobility patterns, contact between groups and related exchange networks (e.g. Kaczanowska, 1986; Zimmermann, 1995; Kegler-Graiewski and Zimmermann, 2003; Zvelebil, 2006; Mateiciucová, 2010). Recently, the processes linking "settlement dynamics" to lithic resources in the Alpine regions were discussed by Della Casa (2005).

According to these investigations, the majority of the lithics from Krems-Wachtberg can be assigned to local sources. Minor parts of this assemblage represent regional, and only a few pieces can be considered long-distance imports. As such, it was evident that most raw material groups were local and only a small number of non-local origin. However, all high quality radiolarites in the assemblage remained indeterminable.

2. Radiolarite: petrography, palaeontology and genesis

2.1. Petrography

2.1.1. Terminology: definition of "radiolarite"

Radiolarite is a member of the chert group. Basically, every sedimentary SiO_2-rock (siliceous) formed by means of mainly biochemical processes can be referred to as "chert". Accordingly, the rock matrix is primarily built from fossilized microorganisms. Regarding the geological genesis, the chert group is subdivided into chert and flint. In Europe, chert formed during the Jurassic and flint during the Cretaceous. The predominating microfossil inclusions are used in order to define subvarieties of chert, such as radiolarite, spiculite, or spongiolite.

Unfortunately, there is no internationally standardized terminology of these subvarieties. Usually, they are defined depending on the percentage of microfossils included in the material, varying between 30% and 70% fossil content of one kind visible under the microscope. One solution for this problem was suggested by Brandl (2010), defining chert varieties according to the "index fossil". This is the microfossil obviously dominating the inclusion pattern, independent of the percentage of visible inclusions. According to that terminological system, a radiolarite is a chert of Jurassic age showing radiolarians as the main traits and structural element (Brandl, 2010, p. 185; Cheben and Cheben, 2010, pp. 24–26).

2.1.2. Petrographical description

Radiolarite can be defined as a siliceous rock with a micro- (<20 μm) to cryptocrystalline (<1 μm) structure. It appears in stratified beds or nodules in the shape of concretions. The rock matrix is composed of radiolarian and diatom tests, spicula of calcareous marine sponges, and regularly contains several silicon dioxide minerals and mineral varieties (quartz, moganite, opal, chalcedony). Admixtures of silty, clastic quartz, clay minerals, calcite, muscovite, biotite, rutile and tourmaline are also common in radiolarites (Mišík, 1969, pp. 15–126; Bechter et al., 2010, p. 24; Cheben and Cheben, 2010, p. 25). The SiO_2 content of radiolarite ranges between 80 and 90%, but depending on the genetic environment it can show lower values. Especially, calcite as secondary fill of fissures and cavities caused during rock forming processes, is an influencing factor (Cheben and Cheben, 2010, p. 25).

Radiolarian skeletal remains in radiolarites occur in various degrees of preservation. Depending on the recrystallisation processes of the rock material during diagenesis, the tests can be perfectly preserved or completely dissolved. In the latter case, these so-called "phantoms" are only detectable under the microscope due to their lack of pigment (Mateiciucová, 2008, p. 48). If preserved, the radiolarian tests are commonly composed of SiO_2 – minerals and mineral varieties, or, in the course of pseudomorphosis replacing the silica, of calcite or chlorite (Mateiciucová, 2008; Cheben and Cheben, 2010). Bechter et al. (2010) conducted Raman-mapping of radiolarians in Eastern Alpine radiolarite (Vienna Mauer site). They detected a higher amount of moganite in the radiolarian tests in comparison to the surrounding rock material and the fill of the fossil remains. They hypothesize a slower transformation of the radiolarian tests into α-quartz (which is the final diagenetic state of chert) than the surrounding rock matrix. Cheben and Cheben (2010) analysed the fill of radiolarian skeletons and found two generations of metacolloidal SiO_2, and in other cases two generations of chalcedony. Most frequently, the fill consisted of chalcedony and clay minerals, containing calcite. The latter can form the radiolarian test itself, occur as a monocrystal in the rock matrix or – in rarer cases – absorb the organism and crystallize around the test. The observation of calcite-rhomboedra filling in the hollow space of the radiolarian skeleton in an initial phase of diagenesis was also made by Pristacz (2008), who analysed samples from the Vienna Mauer radiolarite mining site. Subsequently, the calcified radiolarian tests were filled with calcite or SiO_2-spherolites [chalcedony?] were formed.

Radiolarites show a high variation in colour. They range from black to dark-brown, grey-tones, green, bluish, auburn, brick-red, orange, to yellow. The elements responsible for colouration are still subject to discussion. Red is commonly attributed to Fe-oxides and hydroxides as well as hematite. Darker colours can be caused by Mg-chlorites or the presence of Fe^{3+} clay minerals, carbonates, and pyrite. Fe-chlorites are supposed to be responsible for green radiolarite varieties (Cheben and Cheben, 2010, p. 25).

2.1.3. Palaeontology

Radiolarians are small microorganisms, typically in a range between 10 and 100 μm. They are planktonic protozoa, non-motile unicellular organisms with an amorphous silica skeleton exclusive to marine environments. The test is the most characteristic morphological feature of radiolarians. The shape of radiolarian tests can vary from spherical, concentric to conical and show a higher complexity with radiating spines. The largest diversity and number of species occurs in the Equatorial region (Ozsvárt, 2008). Radiolarians as a taxon show a long range, they occur in the Palaeozoic and last until recent times. In rock-forming quantities, however, they are typical for the Mesozoic (Elekes et al., 2000, pp. 501–502).

Previous studies have demonstrated that the ratio of radiolarians contained in limestones is unstable, varying between 30 and 90%. Almost 70% of the radiolarian remains detected in radiolarites are assigned to Spumellaria, and 30% to Nassellaria. In Jurassic radiolarites, 90% of the matrix is composed of radiolarian skeletons, prevailingly of the Spumellaria type (Polák and Ondrejícková, 1993, p. 410; Cheben and Cheben, 2010, p. 26).

2.1.4. Genesis of radiolarite

As the radiolarians lifecycle ends, their skeletal remains accumulate on the ocean floor. Approximately 1–10% of all marine siliceous debris is deposited. Only very specific environments allow for radiolarian accumulations in rock-forming quantities. Ideal conditions are found in deep-marine facies, where other marine fauna is generally scarce and low water temperature prevents substantial accumulation of carbonate rock material. Such environments exist below the "carbonate compensation depth" (CCD), along submarine volcanic arches in deep sea areas (Elekes et al., 2000, pp. 501–502). During the Jurassic, the CCD was at about 2000 m below sea level. In comparison, it is nowadays at around 4000–5000 m (Cheben and Cheben, 2010, p. 25). The accumulated radiolarian tests form a stratum of radiolarian silt. Radiolarite formation processes from radiolarian silt happen through diagenesis