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CONTRIBUTION TO THE DISTRIBUTION OF JIZERSKÉ HORY METABASITES IN THE PERIOD OF LINEAR POTTERY CULTURE

ABSTRACT: Metabasites were absolutely prevalent raw materials for polished stone tools connected with the Linear Pottery culture (Linearbandkeramik, LBK) in Central Europe. Besides the key source of amphibole-rich metabasites in the Jizerské hory Mts. we already know a few other natural outcrops with their prehistoric using in the Bohemian Massif and some other can be supposed. In the article we have compared LBK polished tools from two different areas in the Czech Republic: the Bohemian-Moravian borderlands and Upper Odra river basin. In spite of natural occurrences of metabasites near the both areas, all studied polished tools have been made of the amphibole-rich metabasites from Jizerské hory Mts. It accentuates importance of the unique Neolithic mining field in the Jizerské hory Mts.

KEY WORDS: Linear Pottery culture – Polished tools – Metabasites – Bohemian-Moravian Borderlands – Upper Odra river basin – Prehistoric quarries – Jizerské hory Mts.

INTRODUCTION

In 2018, the Institute of Archaeology of the Silesian University in Opava, in cooperation with the Regional Museum in Litomyšl, conducted a survey of metabasite sources on the south-western edge of the Zábřeh Crystalline Unit (Mísař *et al.* 1983) in the vicinity of Moravská Třebová. The survey aimed at identifying a possible relationship between a settlement of the Linear Pottery Culture (Linearbandkeramik, LBK) in Staré Město 1 near Moravská Třebová with the outcrops of the surrounding metabasites. However, a field survey led by A. Přichystal showed that metabasites from the vicinity of Staré Město and Moravská Třebová (sampled from the hills Dubina, Třebovské hradisko, Strážný and Křížový vrch) show strong metamorphic foliation, along which they disintegrate plate-like during preparation of semi-finished products. Such flat pieces of what are probably the Dubina metabasites were found during the

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excavations at the archaeological site of Staré Město 1 where it served the laying out of the bottom of a furnace; they were also found in the settlement, both inside and outside of features (Janák *et al.* 2019). However, this material is not suitable for the production of polished industry because it easily disintegrates. The survey in 2018 thus showed that the sources of metabasites in the vicinity of the settlement were not usable; however, more distant outcrops of this material in the Zábřeh Crystalline Unit were not observed.

TWO STUDIED AREAS WITH THE LBK SETTLEMENTS

The core of the LBK settlement in the north of the Bohemian-Moravian borderlands (cf. Janák *et al.* 2020, obr. 1) comprises of two larger enclaves: in the east, it is the settlement around the course of the Jevíčka river (a right-hand tributary of the Třebůvka river that follows the north-south course of the Boskovice Furrow), hydrologically falling under the Morava river basin. Another similar enclave of settlements at a linear distance of 30–40 km to the northwest is in the Loučná river basin (a left tributary of the Elbe, which flows mostly in the east-west direction from Vysoké Mýto and Sezemice) and belongs to the Elbe river basin. About halfway between these settlements lie two isolated LBK settlements: in Hradec nad Svitavou (on the west bank of the Svitava river), excavated in 2014, during a small rescue research conducted by the Regional Museum in Litomyšl (Němcová, Kejval 2015), and the already mentioned settlement in Staré Město 1 (lying somewhat eccentrically to the

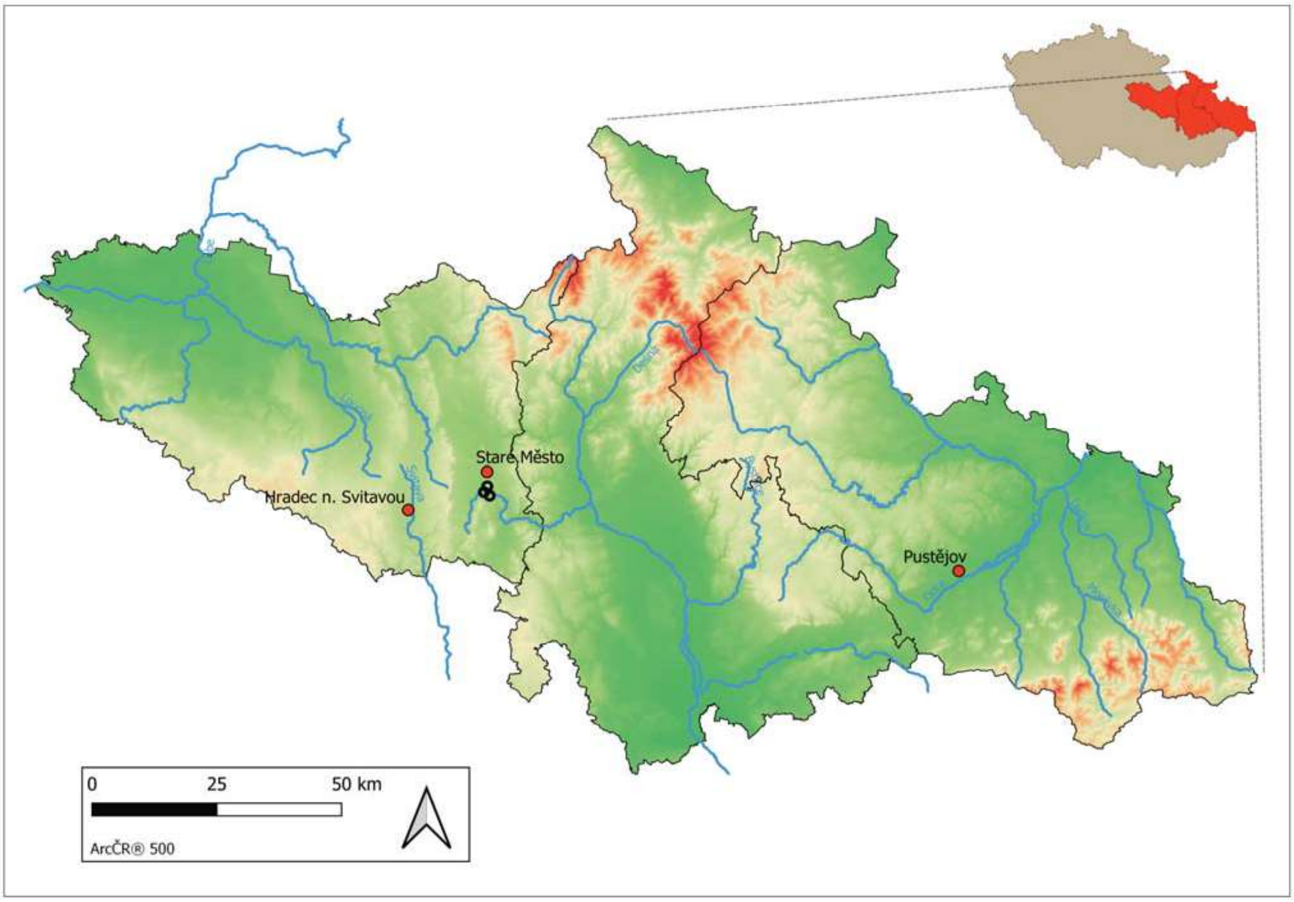


FIGURE 1: Map of archaeological localities with petrographically studied samples of polished tools. Hradec nad Svitavou; Staré Město near Moravská Třebová; Pustějov. Small empty circles – natural sources of metabasite near Moravská Třebová. Basic map from GeodatabázeArcČR®, free accessible at https://www. arcdata.cz/produkty/geograficka-data/arccr-4-0. Arranged by T. Petr using data of the authors.

northeast) on the upper Třebůvka river, which was excavated in 2018.

Raw material of 46 shoe-last celts and axe fragments from this site, which belonged (or might have belonged) to LBK and are deposited in the museums in Litomyšl or Pardubice, has been determined. The classification was performed without the use of thin sections, using stereomicroscopy and the measurement of magnetic susceptibility. According to this preliminary assessment, the material of almost half of the cases is metabasite of the Jizerské hory Mts. type, marginally supplemented by metabasite of the Želešice type or amphibolites. However, the second half of the determined finds could only be preliminarily identified as metabasite, and their local origin was not ruled out (Janák *et al.* 2018).

In this article, we want to extend the existing knowledge by analysing two fragments of polished tools obtained in new research of monocultural LBK site from documented settlements – in Hradec nad Svitavou (feature No. 574) and in Staré Město near Moravská Třebová (feature No. 500/18 in probe S1). However, it is far from just a question of whether and to what extent imported or local metabasites were used in the polished industry material base in the LBK settlement in the northern part of the Bohemian-Moravian borderlands. It is only one part of the broader issue of supplying LBK settlements with raw materials for polished tools. Therefore, for comparison, we also subjected two samples from the LBK settlement in Pustějov (the Upper Odra basin), so far the best examined site of the LBK distribution centre in the vicinity of Studénka on the silicites of the Cracow-Częstochowa Jurassic (SKCJ) transport route in a western direction (Janák *et al.* 2016a; *Figure 1*).

RAW MATERIAL BASIS OF LBK POLISHED TOOLS IN EAST CENTRAL EUROPE

In the past fifty years, it has been proven that in the East Central European LBK, metabasites were key raw materials for making polished industry – and essentially the only raw material for making working tools (Přichystal 2015). After the discovery and publication of the main source – large exploitation fields linked with workshops that used Paleozoic metabasites of the Železný Brod Crystalline Unit and were situated on the southern slopes of the Jizerské hory Mts. (Velké Hamry, Jistebsko), extensive efforts were made to identify the raw materials used, often on a mass scale, from this exploitation-production district, on archaeological localities that lie hundreds of kilometres away from the raw material source. Apart from these, other mining districts of more limited, usually local or regional reach, have been documented, although in individual cases the raw material may appear quite far from there. In the Brno region, such a source of the Proterozoic metabasite lies near Želešice (Přichystal 1984). Geologically, it is part of the central zone of the Brno batholith, and further east, in Slovakia, the Paleozoic metabasites of the Little Carpathians type occur between Pezinok and Pernek (Hovorka, Cheben 1997, Méres *et al.* 2004) and at the border of Hungary with the Austrian Burgenland, metabasite of the Felsöcsatár type (Szakmány 1996) is found. Despite different age, the genesis of the first three types of metabasites was similar – at the end of their development, they were subjected to thermal metamorphosis due to a contact with large granite bodies, and this transformation significantly improved their properties. The Felsöcsatár metabasite did not undergo such a process; it is a typical greenschist with more or less local significance. It should be mentioned that there is the possibility that other metabasite sources in the Bohemian Massif were exploited, such as those in the Eastern Sudetenland in the Hrubý Jeseník Mts. (namely the Sobotín amphibolite massif), the amphibolites from the Sázava river basin in Central Bohemia, which K. Žebera (1955) considered the dominant raw material in the whole of Bohemia in the Neolithic. However, research in the last years showed only local significance of amphibolites from the Sázava river basin (Přichystal 2015, 2018).

Although the raw material dominance of metabasites in the LBK population east of the Rhine is undoubted and the leading role of metabasites of the Jizerské hory Mts. type is clear, data for individual regions are still needed to expand the knowledge of 1) the proportion of individual metabasite types, the possibilities of their identifiability, the difference in the use of imported and local materials, the additional use of raw materials other than metabasites and 2) the ways and routes used for the import of metabasites (or other raw materials for polished industry).

The occurrence of metabasites from the Jizerské hory Mts. found in some settlements, burial sites and entire LBK areas that are relatively close to the source is dominant – Bohemia (Bylany, settlement – 98 %, Velímský 1969), South and Central Moravia (Velatice, settlement – 92 %, Rebrošová *et al.* 2012; burial site in Vedrovice – 85 %, Přichystal 2002; Kralice na Hané –

100 %, Přichystal, Šmíd 2011). Perhaps the same is true of Eastern and Central Germany; however, only summarising or very general data on the raw material of the LBK polished tools have been published there. According to a brief mention (Kaufmann 2012), out of 791 axes, 301 undrilled shoe-last celts and 72 drilled ones, which belonged to LBK and the Stroke Pottery culture and was deposited in the museum in Halle a.d. Saale, 89.7 % was made from this material ("nordböhmische amphibolite") according to P. Šída's determination – however, other details, such as the proportion of the LBK and post-LBK components, were not published. According to an assessments carried out in the early 1980s, metabasites ("Aktinolith-Hornblendeschiefer") represented 90 % of 775 examined pieces dated to the the linear and postlinear Neolithic ("Frühneolithic") in the West Brunshwick part of the northern foothills of the Harz. German authors assumed their origin in an unspecified area to the southeast – first in the Bohemian Massif and later either on the western edge of the Carpathians or as far as in the High Balkans (Schwarz-Mackensen, Schneider 1986: Fig. 2, Tab. 2 *et passim*); today we know that these are the metabasites of Jizerské hory Mts. type (Přichystal 2015, 2018). In any case, according to the publication, it is not possible to determine the proportion of the linear and postlinear Neolithic component in the mentioned 90 %, that is in about 700 pieces of polished tools, not even approximately.

Further away from their sources, the dominance of the North Bohemian metabasites is not so pronounced. Neolithic metabasite polished industry from central Hesse was examined in detail. It was probably made from the metabasite of the Jizerské hory Mts. type, although Smrčiny (Fichtelberge) has not been completely excluded as a source (Ramminger 2007). However, there is an observable regional development. The proportion of imported (possibly North Bohemian) metabasites, which was supposed to be clearly dominant in the early period of the LBK, began to decline in the Flomborn horizon in favour of basalts or what were possibly local metabasites of unspecified provenance (Ramminger 2007). Imported metabasites, such as the Jizerské hory Mts. type, likely played a key role in the Neolithic of northern Hesse; however, they had always been accompanied by a significant component (20–30 %) of local Cenozoic basalts (Kegler-Graiewski 2007: Fig. 81a, b), of which there are plenty in the area; the role of other rocks, including local metabasites, was probably only marginal. Currently, no such difference has been identified between linear and postlinear sites (Kegler-Graiewski 2007: Fig. 76a, b). The presence of metabasites, such as the Jizera Mountains type, is also documented further south in Germany – in Thuringia and northern Bavaria (Christensen *et al.* 2006). Without doubt, the Jizerské hory Mts. type metabasites have been found in Lesser Poland and further north (Greater Poland, Kujawy, Pomerania), but only relatively few of the pieces from the great mass of metabasite tool finds, which were analysed in detail, can be reliably categorised as such, although metabasites are the dominant raw material for the production of shoe-last celts and axes of the LBK in this area as well (cf. Krystek *et al.* 2011, Szydłowski 2017, with literature).

Somewhat better explored is Upper Silesia. Recently, we have studied the raw material base of the polished stone industry of the LBK from the Czech and Polish part of this region to obtain a general overview (Janák, Přichystal 2019). The research focused on 109 pieces from 25 sites, mostly individual tools or, more often, fragments found during older surveys, now deposited in museums. This usually consisted of surface stereomicroscopy accompanied by measurement of magnetic susceptibility. Only 6 thin sections were available, 3 of which were subjected to microprobe analysis. According to this assessment, 106 pieces of the total 109 were metabasites (101 fine-grained ones and 5 amphibolites), one was made of serpentinite (the half of a disc-shaped mace-head from Kotouč hill near Štramberk) and the raw material of two pieces was indeterminate due to burning. A total of 54 pieces were merely classified as "metabasite without further determination". In 33 samples the raw material was determined – to a different degree of probability – as metabasite of the Jizera Mountains type. Of the rest of identifiable pieces – apart from amphibolites – six pieces was made of the Želešice metabasite, seven pieces probably came from the Eastern Sudetenland, and one sample from the border of the two groups (Janák, Přichystal 2019). Metabasites of the Jizerské hory Mts. predominate among the finds that can be identified with a high probability (63.5 % of 52 pieces over metabasites of another type). The question is how dominant it was overall. It must be taken into account that the determination of LBK raw materials has been going on for many years (practically from the beginning of the new millennium) as part of the general determination of raw material base of the Neolithic and Eneolithic in Upper Silesia. During that time, knowledge kept developing, and it is probable that some pieces in which provenance could not be reliably determined 10 or 15 years ago might be determined today. The proportion of material from the Jizerské hory Mts. could therefore rise significantly. Nevertheless, it was hardly the only type of metabasites used as raw material for the production of LBK work tools in the upper Odra river basin, and they might have been less represented in areas closer to the North Bohemian sources.

This assumption is even more clearly supported by a preliminary analysis of the raw material of published polished tools from three excavated LBK settlements in Lower Silesia (Central Odra river basin): Niemcza (Lodowski 1973, Kulczycka, Leciejewiczowa 1981), Strzelin 16 (Wojciechowski, Cholewa 1995) and Strachów (Kulczycka, Leciejewiczowa 1997). We published the results of the 2010 revision determination of material from Niemcza and Strachów together with the Upper Silesian PI (Janák, Přichystal 2019). However, at that time they were examined from a different perspective than now, when it is mainly about understanding the role of the Jizera Mountains metabasites in the Lower Silesian LBK. Unfortunately, in none of these three cases are there all the relevant finds. The aim of the published comparison of the original classification with the revision one was mainly to point out the big differences between the generally used Czech and Polish raw material terminology and to try to remedy the situation. In this article, however, we discuss the raw material composition in terms of the polished tools origin in the three sites, with special emphasis on understanding the role of metabasites, such as the Jizerské hory Mts. in the Lower Silesian LBK. However, the proportion of PI pieces, whose determination was revised in 2010, in the total number of PI finds from these sites can only be very roughly estimated because Polish archaeological publications, following an established practice, do not distinguish between PI in our sense and the so-called macrolithic ("rough-shaped" and "other") lithic industry, which is why detailed data are usually missing. Apart from that, the data in publications often differ from the data accompanying the finds (especially as regards feature numbers), which further complicates the situation. If the finds from Strachów, re-determined in 2010, represented as many as 60 % (but more probably less than half) and the determination from Niemcza a little over a half of the total number of PI finds (Janák, Přichystal 2019), then in Strzelin they could certainly make up at least two-thirds, perhaps even more, although we must bear in mind that even in this case the exact number cannot be ascertained from the publication. In Strzelin 16, it was possible to identify three settlement horizons – the oldest belonged to the Gniechowice stage (LBK Ia), the middle to the music-note stage (LBK II), and the youngest to the final "Šárka" stage (LBK III) – which differed to a large extent (not exclusively) by a dislocation of features within the settlement. The only determined find, a fragment from metabasite of unspecified origin (Wojciechowski, Cholewa 1995), is connected with the oldest horizon. In 2010, the following artefacts found in features dated by pottery were assigned to the middle stage of the LBK: two large fragments (axes from pit No. 22 and a celt from pit No. 52) and eight small amorphous fragments, probably from a single tool, also from pit No. 22. Finally, a fragment of a shoe-last celt was found in topsoil (but in the context of the part of the settlement dated to this period) (Wojciechowski, Cholewa 1995: 98–100, Fig. 21: a, c). Shoe-last axe from clay pit No. 22 was made from metabasite of unspecified origin and the raw material in the remaining samples is metabasite from the Jizerské hory Mts. A total of four fragments were dated to the final "Šárka" horizon (Wojciechowski, Cholewa 1995). In pit No. 86, a fragment of shoe-last axe was found (Wojciechowski, Cholewa 1995: Fig. 34: a). In pit No. 95, the cutting edge half of a shoe-last celt was discovered (Wojciechowski, Cholewa 1995: Fig. 34: b) and two semi-finished shoe-last celts with the lengths of 19.2 cm and 17.2 cm, respectively (Wojciechowski, Cholewa 1995: Fig. 33a, b).

The fragment of the axe from pit No. 86 was made from metabasite changing into fine amphibolite, and its origin in the Hrubý Jeseník Mts. cannot be ruled out. The celt fragment from pit No. 95 is also from metabasite of unspecified origin, but both the semi-finished products are claimed have been made from the Jizerské hory Mts. metabasite.

As for the settlement at Niemcza, which is hard to date and usually dated to the final (Šárka) stage – despite the fact that fragments of Šárka pottery were only found in four of the 19 excavated pits (a total of five pieces, which amount to about 1 % of decorated LBK pottery) (Kulczycka, Leciejewiczowa 1981, Tab. 1). Of the 11 determined finds from LBK features, four are from the Jizerské hory Mts. metabasite, the remaining seven are from metabasites of unspecified origin.

As for Strachów, in 2010 we were able to study fragments of working tools using stereomicroscopy and measuring magnetic susceptibility. Twenty of these fragments undoubtedly came from a LBK environment, 18 of them reliably came from features, and two from a surface, but all of them were fragments of typical linear celts. So far, the occurrence of the metabasite from the Jizerské hory Mts. seems to be rather unique (only one sample), and a metabasite of the Želešice type or a metabasite potentially from the Eastern Sudetenland have not been confirmed at all, as in Niemcza. Otherwise, amphibole-rich metabasites surely dominated in Strachów, as 15 artefacts were made from it, that is 75 % of the studied samples. Of the remaining five artefacts, three were from igneous rocks, one was possibly from tremolititite, and one could not be determined.

This overview proves the dominance of metabasites in the LBK and the decisive role of metabasites of the Jizerské hory Mts. type. At the same time, however, we warn against assuming the predominance of this raw material was general, especially in areas farther away or more difficult to access from the range of intensively utilised North Bohemian sources (e.g., the Odra and Vistula river basins, Hesse). In them, perhaps, the leading role of a Jizerské hory Mts. type material among metabasites is not as clear as in Bohemia and Central Germany in the broadest sense (including Thuringia and Brunswick), although only collection from graves in Kralice is 100% confirmed from the Jizerské hory Mts. metabasites, especially if local sources of metabasites were available in these "more distant" areas. However, the intensive use of other (local) metabasites has so far been undoubtedly proven only for metabasites of the Želešice type and prevalently for south-western Moravia with the overlap to the south and south-east (Lower Austria, NW Hungary). At the same time, in the "more distant" areas, there seems to be a tendency for the gradual decline of metabasites in the postlinear period in general and for their replacement by local or closely located materials. There, perhaps much faster than in Bohemia, the western part of Moravia, or central Germany, the use of the Jizerské hory Mts. type material is ceasing (cf. Janák, Přichystal 2019). This process may begin even during the period of the LBK (Central Hesse, Lower Silesia), which could perhaps be explained at least in part by the decline of long-distance communication in the final period (stage III) of the LBK, which is indicative of an abrupt (?) end to the system of long-distance distribution of silicites from the Cracow – Częstochowa Jurassic (Janák *et al.* 2016a; for a remarkable hypothesis about the crisis character of this period of the LBK cf. Farrugia 2002). However, it is not clear to what extent such an explanation can be applied to Hesse, where the beginnings of the process should go much deeper, even to the Flomborn horizon.

DETERMINATION OF RAW MATERIAL FROM STARÉ MĚSTO, HRADEC NAD SVITAVOU, AND PUSTĚJOV

Four polished stone tools from two distant areas of the Czech Republic about 120 km apart as the crow flies, all made of various types of metabasites according to macroscopic determination, were examined in terms of the raw material used. We proceeded in three stages with increasing equipment complexity. The first stage was the basic non-destructive determination of the rock under a stereomicroscope and measurement of magnetic susceptibility with a hand-held kappameter. In this way, we have previously evaluated hundreds of pieces of polished industry from several museums in Polish and Czech Silesia. With experience with the appearance of rocks under a stereomicroscope, it is possible, in most cases, to perform a basic classification of stone raw material (metabasite, serpentinite, jadeite, eclogite, diorite, porphyric microdiorite, siltstone, sandstone). As metabasites clearly dominated during the period of the LBK, another question arose whether their individual sources can be distinguished or how significantly other metabasites contributed to the raw material base of the LBK people in addition to already known sources in the Jizerské hory Mts. and Želešice near Brno.

The second stage was the study of petrographic thin sections from the same samples under a polarising microscope and finally the highest level of examination was achieved by determination of the chemistry of individual minerals in polished thin sections using an electron microprobe. Unfortunately, these two higher stages of examination represent a destructive intervention in the artefact – cutting off a piece of it to make a thin section.

As is the electron microprobe concerned, the chemistry of all main components was determined using the wave dispersive analysis, i.e., amphiboles, plagioclases, chlorites and opaque minerals (ilmenite, magnetite) while energy dispersive analysis was applied for determination of major, minor and accesory minerals.

1. Pustějov – Dolní role, collection in the settlement 2016. Shoe-last celt (*Figure 2*)

Stereomicroscope: The artefact is characterised by a distinctive band-like structure in which dark green bands 1–2 mm thick alternate with light green-grey bands. The magnetic susceptibility of the rock reaches 0.56×10^{-3} SI, however, since the celt does not cover the whole head and its thickness is less than 5 cm, it will actually be slightly higher. Abundant parallel traces of polishing are visible under the stereomicroscope on the lower non-bulging surface. Furthermore, it is clear that the green bands are formed predominantly by fibrous amphibole, while the grey bands are dominated by feldspar occasionally with acicular amphibole. Accumulations of radially arranged acicular amphiboles have been observed, which we believe are typical of metabasites from the Jizerské hory Mts.

Polarising microscope: In the thin section, the rock has a characteristic nematoblastic texture with predominant fibrous or acicular amphiboles, which often form radially arranged ("sun-like") aggregates with striking interference colours. In some places, relics of older larger amphibole crystals can be seen. Allotriomorphic feldspar grains are relatively under-represented, which is related to the fact that the thin section captured a part with a predominance of green bands. Occurrences of ore (opaque) minerals are also noticeable, larger ones have hypidiomorphic limitations, smaller ones form irregular clusters. It is evident that it accumulates in bands rich in fibrous amphiboles and in parallel bands with metamorphic foliation. Their larger elongated shapes reach a length of up to 0.2–0.3 mm. Given their shapes and the measurement of magnetic susceptibility, it is evident that these are ilmenites. The presence of quartz was registered rarely. Small apatites were found from accessory minerals. The rock thus resembles a nephritoid and shows characteristics of high-quality metabasites mined in prehistory on the southern slopes of the Jizerské hory Mts. The occurrence of such nephritoid types in the Jizerské hory Mts. has already been mentioned by German authors in the period after the First World War.

Electron microprobe: The chemistry of all main components was determined, i.e., amphiboles, feldspars, and opaque minerals. Amphiboles are formed by two types of amphiboles – it is mainly a relatively homogeneous magnesium-hornblend from the group of Ca-amphiboles. In the classification diagram according to Leake *et al.* (1997), its position in most analyses lies near the border with actinolite. At the same time, it is clear that together with the amphiboles from the sample

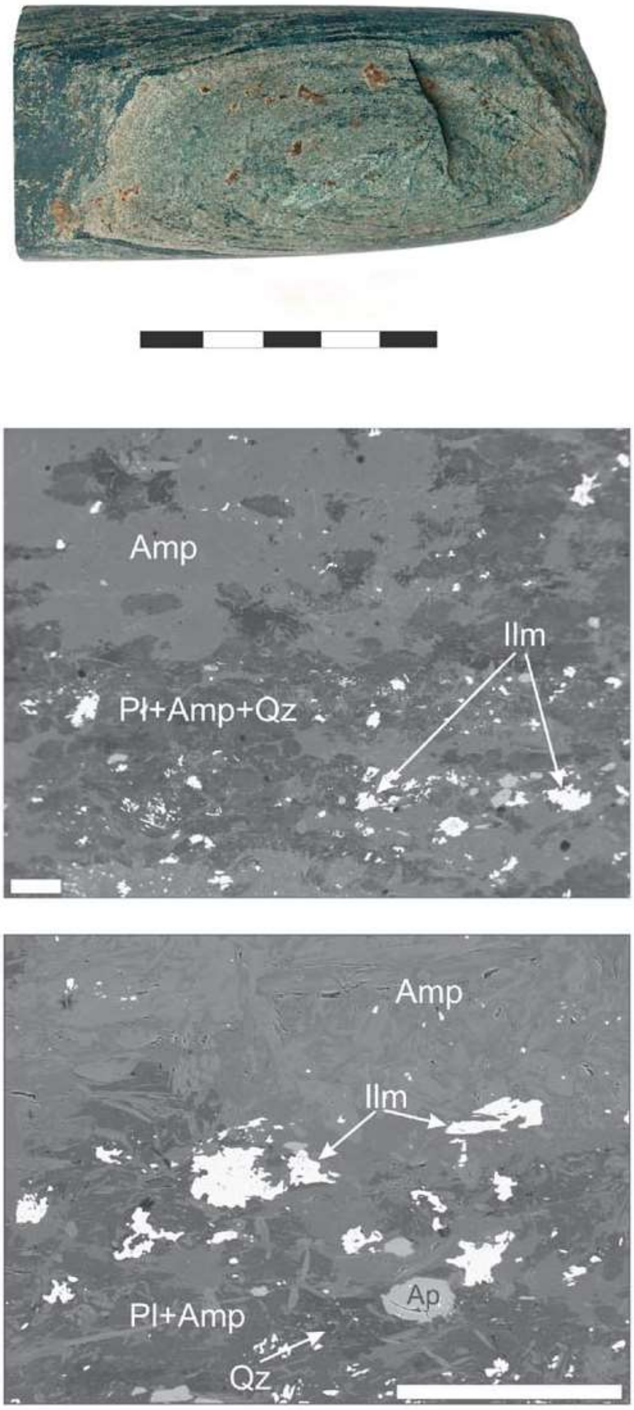


FIGURE 2: Pustějov 1 - Dolní role, surface survey in 2016. Shoe-last celt. 1 – Appearance of the tool, scale bar 5 cm (photo by V. Dudková); 2 and 3 – BSE images (scale bar 0.2 mm) of thin section, photo by P. Gadas. Mineral abbreviations according to Whitney and Evans (2010). Arranged by T. Petr.

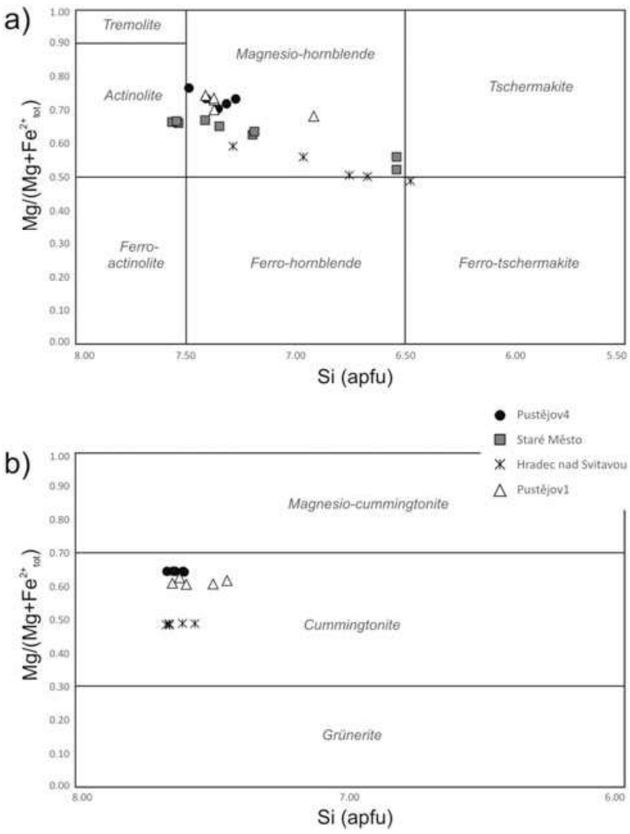


FIGURE 3: a) Classification diagram of Ca-amphiboles according to Leake *et al.* (1997) showing the composition of amphiboles from individual samples. All Fe assuming as Fe^{2+}. "apfu" = atom per formula unit. b) Cut of classification diagram of Mg-Fe-Mn amphiboles according to Leake *et al.* (1997) showing the composition of amphiboles from individual samples. All Fe assuming as Fe^{2+}. "apfu" = atom per formula unit.

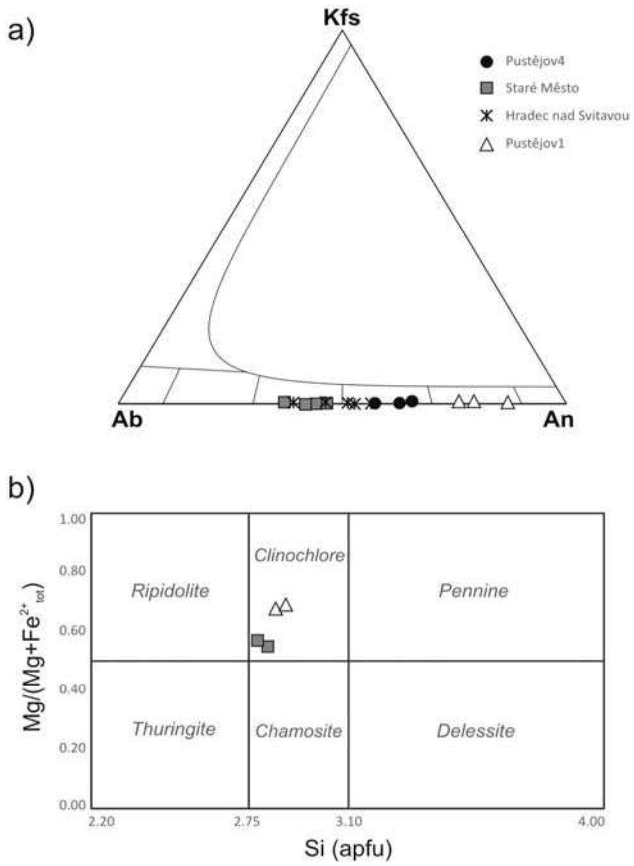


FIGURE 4: a) Triangular classification diagram of feldspars showing the composition of feldspars from individual samples. Mineral abbreviations according the Whitney and Evans (2010). b) Classification diagram of chlorites according to Melka (1965) showing the composition of chlorites from individual samples. All Fe assuming as Fe^{2+}. "apfu" = atom per formula unit.

Pustějov 4, these amphiboles are the most enriched in magnesium from the entire group of four artifacts (*Figure 3a*). The Na a K content is relatively low, possibly below the detection limit, as well as the content of other measured trace elements (Cr, Ni Ti. V, and Mn).

The second type of amphibole is slightly Ca-enriched, again relatively homogeneous cummingtonite from the group of Mg-Fe amphiboles and its chemistry overlaps with cummingtonite from the sample Pustějov 4 (*Figure 3b*). Similarly to the magnesium-hornblend, the content of trace elements is low or below the detection limit.

The feldspars from the sample Pustějov 1 are the most basic of the whole analyzed group and correspond to bytownit (*Figure 4a*). Like feldspars from other artefacts, they show a consistently increased Fe content^{3+}. They are partially converted to sericit. Quartz was found only sporadically. The opaque mineral is represented by ilmenite, sometimes leukoxenised with a content of pyrophanite or geikielite component up to 2.5 mol. %. Furthermore, the presence of Fe-sulfide, probably pyrite, was recorded. Fluorapatite forms small columns. Barite grains up to the size of 100 μm were rarely found in the cavities. Non-abundant chlorite corresponds to clinochlor by composition (*Figure 4b*).

2. Hradec nad Svitavou, research 2014, feature 574. Part of a shoe-last celt with the rest of an asymmetrically placed bore (*Figure 5*)

Stereomicroscope: The rock has a distinct planar parallel structure (but not banded), highlighted by the arrangement of larger whitish elongated feldspar grains. These form an indication of the microporphyric texture. The rock is intensely patinated; there is a greenish light grey patina of the thickness of up to 1 mm on the cutting for the thin section, inside the fresh rock is dark green. Magnetic susceptibility was measured to be 0.47 $\times 10^{-3}$ SI; again, it will be slightly higher due to smaller dimensions of the artefact. Unweathered pyrite crystals of tenths of a mm in size, sometimes arranged in beads up to 1 mm in length, are common.

Polarising microscope: The texture of the rock is slightly different from the previous artefact – granonematoblastic due to the greater proportion of allotriomorphic feldspar grains. Amphibole is present again in acicular to fibrous development, radially arranged aggregates are common, which grow across the metamorphic foliation of the rock and thus significantly improve its properties. Apparent are 2–5 mm long lenticular formations formed by several large grains of feldspar. The ore minerals of the ilmenite character are again arranged in parallel with the foliation and appear in parts rich in elongated amphiboles. The rock's properties are comparable to metabasite such as the Jizerské hory Mts. type.

Electron microprobe: Research has shown that the Ca-amphiboles of this artefact have the lowest magnesium content and, conversely, the highest iron content. The composition corresponds to the magnesium-hornblend with the transition from ferro-hornblend to ferro-tschermakite (*Figure 3a*). This metabasite also contained amphibole from the group of Mg-Fe amphiboles, it was already Fe-enriched cummingtonite (*Figure 3b*). The chemical composition of feldspar is in the range of andesine–acid labradorite (*Figure 4a*). Apatite forms grains and columns up to 50 μm in size. Quartz is represented relatively more than in the previous artefact. Of the ore minerals, in addition to ilmenite, there is relatively abundant pyrite, sometimes fused with chalcopyrite.

3. Staré Město near Moravská Třebová, research 2018, feature 500. Fragment of the cutting edge of a shoe-last axe (*Figure 6*)

Stereomicroscope: The raw material is slightly mottled, the mottles accumulate into non-continuous bands, which again makes the metamorphic foliation clear. Magnetic susceptibility is very low – 0.17 $\times 10^{-3}$ SI, but it is probably related to the fact that it is a small fraction weighing only 16.8 g.

Polarising microscope: Although the granonematoblastic texture is clearly visible in the thin section, the

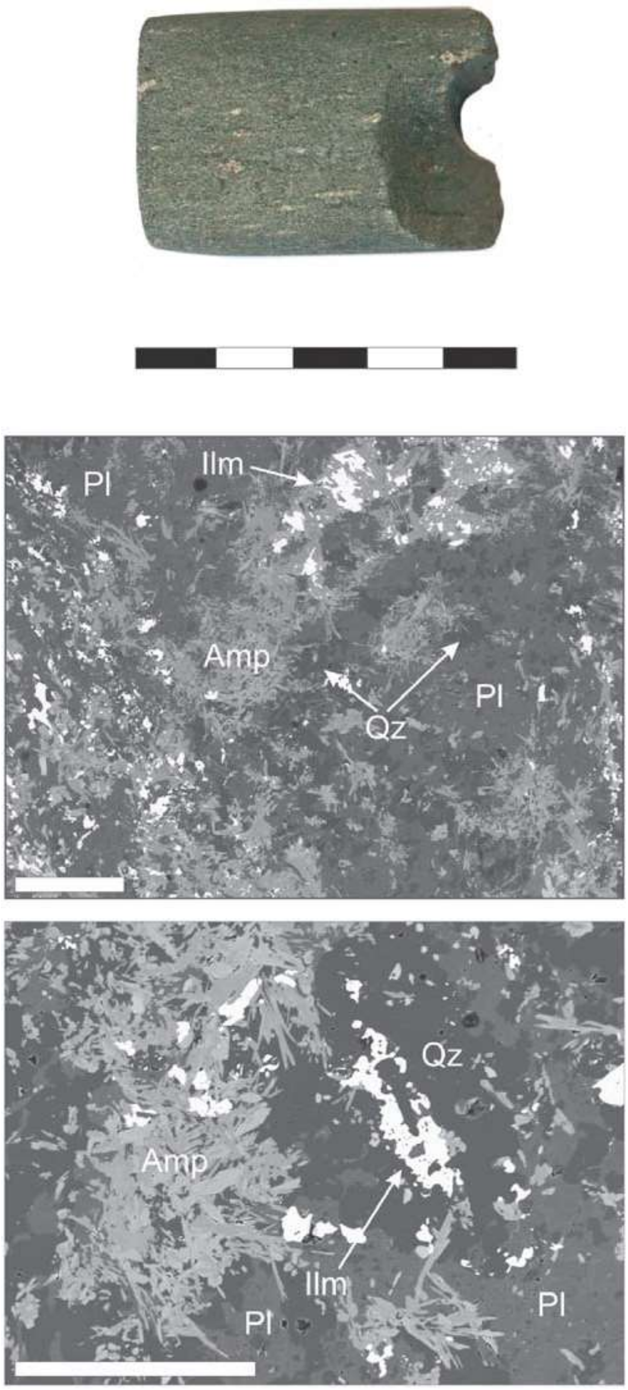


FIGURE 5: Hradec nad Svitavou, excavation in 2014, feature no. 574. Part of a shoe-last celt with the rest of an asymmetrically placed bore, scale bar 5 cm. 1 – Appearance of the tool (photo by V. Dudková); 2 and 3 – BSE images (scale bar 0.2 mm) of thin section, photo by P. Gadas. Mineral abbreviations according to Whitney and Evans (2010). Arranged by T. Petr.

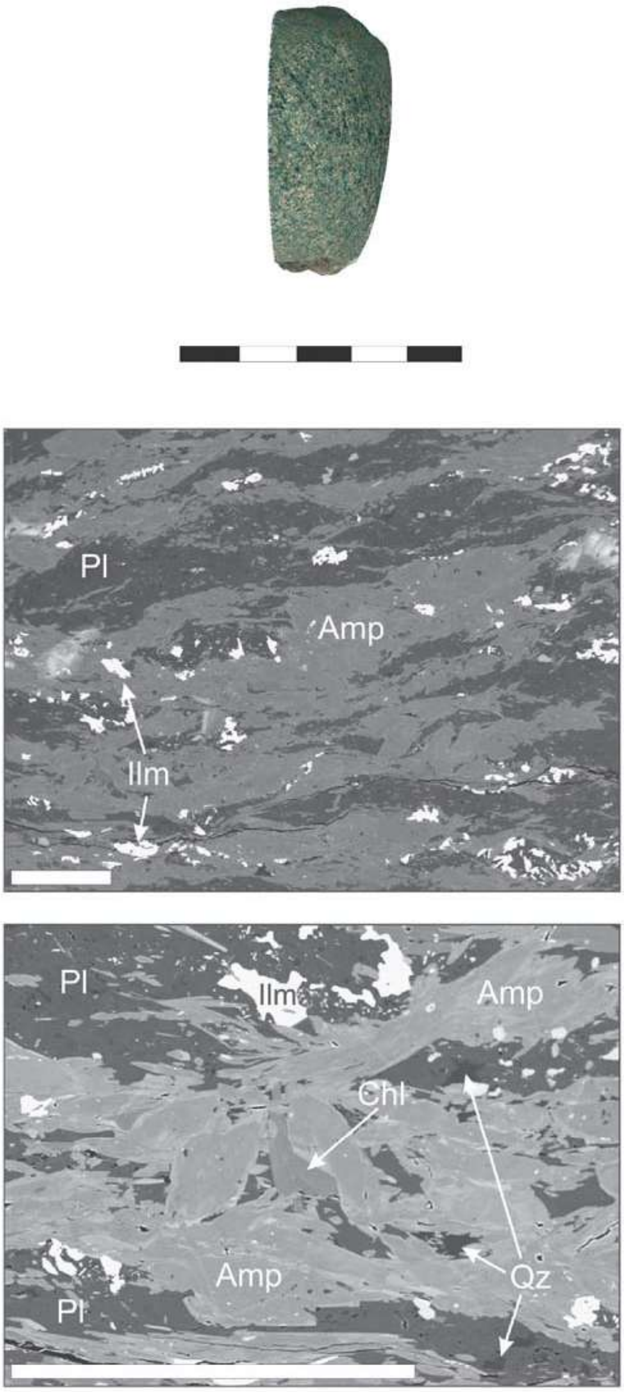


FIGURE 6: Staré Město near Moravská Třebová, excavation in 2018, feature no. 500. Fragment of the cutting edge of shoe-last axe, scale bar 5 cm. 1 – Appearance of the tool (photo by V. Dudková); 2 and 3 – BSE images (scale bar 0.2 mm) of thin section, photo by P. Gadas. Mineral abbreviations according to Whitney and Evans (2010). Arranged by T. Petr.

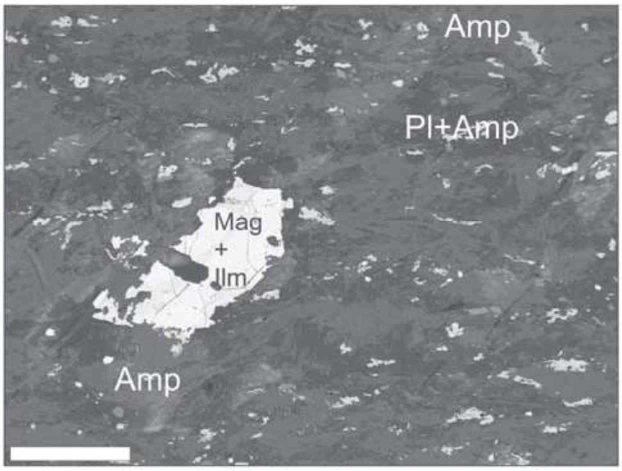
appearance is still different from the previous two artefacts. Metamorphic foliation is significantly bent, and there is a large number of small lenses formed by allotriomorphic feldspars. Elongated amphiboles are also present in the thin section, but are stretched predominantly with foliation and do not form conspicuous radially arranged aggregates, as seen in the previous two thin sections. Ore minerals are small – their accumulations are also bent and parallel to foliation, there are no shapes partially limited by crystal surfaces. The origin of this rock cannot be unambiguously determined even on the basis of a study under a polarising microscope.

Electron microprobe: Analyses showed the presence of only Ca-amphiboles, but in a wide range from actinolite through the full field of magnesium-hornblend to the border with tschermakite (*Figure 3a*). Some of the analyses also showed a slightly increased sodium content as well as a systematically increased fluorine content compared to the other artefacts. Amphiboles from the cummingtonite-grünerite group were not detected in the only metabasite analysed. As regards feldspar, this artefact contained the most acidic feldspars from the entire series analysed – the composition was only in the range of andesine (*Figure 4a*). Chlorite with the composition of Fe-enriched clinochlor (*Figure 4b*), a very small apatite with a size in µm units, occasionally small quartz grains up to 10 µm enclosed in plagioclase or amphiboles were also identified in the metabasite. Of the ore minerals dominated by ilmenite, it can rarely contain inclusions of sphalerite of a size of units of µm; again partially limonitized pyrite, sometimes even pyrrhotine, occur.

4. Pustějov – Dolní role, collection in the settlement 2013, smaller flat axe (*Figure 7*)

Stereomicroscope: It is a strongly patinated metabasite with a light greenish grey surface, with fine green mottles, in some places with a hint of bands. Although the height of the axe is only up to 8 mm, it is characterized by a high magnetic susceptibility of up to 11.7×10^{-3} SI. Inside, on a fresh cut, there is a dark green rock with no visible foliation. Large crystals of up to 0.5 mm of metallic shiny magnetite are noticeable, and amphiboles also achieve larger dimensions than in the common types of rocks from the Jizerské hory Mts.

Polarising microscope: There is a clear granonematoblastic to nematoblastic texture, and the rock is at first sight very close in thin section to metabasites from the Jizerské hory Mts. An amount of



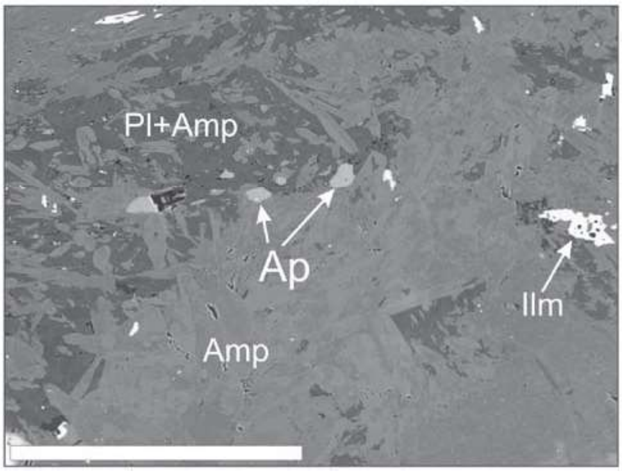


FIGURE 7: Pustějov 4 - Dolní role, surface survey in 2013. Small flat axe. 1 – Appearance of the tool, scale bar 5 cm (photo by V. Dudková); 2 and 3 – BSE images (scale bar 0.2 mm) of thin section, photo by P. Gadas. Mineral abbreviations according to Whitney and Evans (2010). Arranged by T. Petr.

acicular to fibrous amphiboles is arranged mainly in sheaves along the foliation; feldspars are relatively few. Apparent are ore minerals, some limited by crystal faces and reaching a size of several tenths of a millimetre. Despite the high magnetic susceptibility that would hint at the origin from Želešice near Brno, the microscopic appearance does not correspond to this source.

Electron microprobe: The research showed the presence of both types of amphiboles and, more importantly, their essentially identical composition with the sample Pustějov 1 (*Figure 3a, Figure 3b*). The chemistry of plagioclases fluctuates in the range of labradorite, i.e., again their composition most closely resembles the artefact Pustějov 1 (*Figure 4a*). Small xenomorphic fluorapatite is abundant.

The sample is exceptional in the presence of large grains of chemically relatively pure magnetite up to the size of the first tenths of a millimetre. It also merges with chemically very pure ilmenite, which, however, is converted into a mixture of rutile and titanite. Of ore minerals, chalcopyrite and pyrite in grains up to 10 μm are also rarely present.

DISCUSSION

Despite various minor deviations, it is clear that both artefacts from Pustějov can be reliably compared with amphibole-rich metabasites from the Jizerské hory Mts. It is necessary to emphasize the striking sameness in the composition of Ca-amphiboles and Mg-Fe amphiboles and, basically, feldspars. It was shown that the relatively high magnetic susceptibility of the artefact Pustějov 4 (11.7×10^{-3} SI) is not decisive for source localization in this case. It is true that magnetic susceptibility measured on many semi-finished products at mining sites in the Jizera Mountains was usually in significantly lower values, i.e., in the range of $0.6–1.3 \times 10^{-3}$ SI (Velké Hamry) or $0.65–0.85 \times 10^{-3}$ SI (Jistebsko), and samples with a high presence of fibrous amphiboles (nephritoids) achieved even lower magnetic susceptibility $0.25–0.5 \times 10^{-3}$ SI (Přichystal 2013). On the other hand, it is necessary to mention that semi-finished products with significantly higher magnetic susceptibility occasionally appeared in Velké Hamry: up to 8×10^{-3} SI. According to Klomínský *et al.* (2004), its values fluctuated in a large range of $0.4–54.5 \times 10^{-3}$ SI in the body of metabasite (in their publication hornblende-plagioclase hornfels) from artificial exposure during construction of building near village of Jeřmanice.

The metabasite from Hradec nad Svitavou also contains both Ca-amphiboles and Mg-Fe amphiboles, which is mentioned as a characteristic feature for metabasites of the Jizerské hory Mts. (Šída, Kachlík 2009, Přichystal 2013). The basicity of feldspars is a bit lower than in artefacts from Pustějov, but it still fits into the variance of metabasites from the Jizerské hory Mts. All its amphiboles have a relatively high Fe content, but even that does not exclude its provenance from the Jizerské hory Mts. (see the presence of ferro-hornblend in the paper of Šída *et al.* 2012). The presence of opaque minerals (ilmenite, pyrite, chalcopyrite) is also consistent.

The metabasite from Staré Město near Moravská Třebová is slightly different. It was the only one containing only Ca-amphiboles, however, in a wide range from actinolite through magnesium-hornblend to the border with tschermakite. However, the artificially exposed metabasite at Jeřmanice also contained only Ca-amphiboles (Klomínský *et al.* 2012). It also contained chlorite, which is, however, present in some bodies of metabasites of the contact halos of Tanvald granite, especially if they are further from contact (Šída *et al.* 2012).

Our research therefore shows that even on the basis of detailed mineralogical research, it is possible to determine the provenance of all studied metabasite artefacts in Neolithic mining fields in the Jizerské hory Mts. This is related to the fact that the metabasites from the contact halo of Tanvald granite were originally formed by a number of smaller bodies of various character – it could be positions of tuffs or tuffites, in porphyric varieties also sills (Šída *et al.* 2012: 10). The resulting rock was also dependent on its distance from contact with Tanvald granite and thus the intensity of temperature impact. In addition, some of the bodies were affected by secondary magnetitization. All this has caused them to be quite diverse, although many of the characteristics remain common to all of them.

CONCLUSIONS

Despite the doubts aroused by the mineralogical composition of the cutting edge fragment of an axe from Staré Město (sample 3) and high magnetic susceptibility of the axe from Pustějov (sample 4) during the preliminary (microscopic) determination, the origin of all four studied pieces could be traced back to the Jizerské hory Mountains. Our analyses indicated that the diversity of the local metabasites was probably greater than previously thought. This reinforces the relevance of the thesis about the key importance of sources in the Jizerské hory Mts. for the raw material base of the production of polished tools of the LBK in Eastern Central Europe, and from a methodological point of view, this underlines the crucial importance of microprobe analyses to determine more approximate provenance of metabasites as a raw material in general.

As regards the situation on the Bohemian-Moravian borderlands, the findings bring it closer to the situation further west, and also challenge the notion of a possible wider use of local sources (the nearby Zábřeh Crystalline Unit or even the more distant Eastern Sudetenland). However, it is far from being excluded, and the survey of a larger number of relevant polished tools using a microprobe from both parts of the border region, both from localities in the Jevíčka and Třebůvka (Pomoraví) river basins and from localities in the Loučná (Polabí) river basin, is the subject of future research.

The analysis of the axe from Pustějov (originally included among pieces with uncertain provenance) further emphasized the recently confirmed importance of raw materials from the Jizerské hory Mts. for distribution settlements on the route of long-distance transport of silicites from Cracow – Częstochowa Jurassic in the western direction and, generally, indications of intensive interweaving of the high proportion of both raw materials in them and in other localities (after all, this is also suggested by our sites in Hradec nad Svitavou and Staré Město near Moravská Třebová; although the chipped industry bodies are very small, SKCJ is dominant), but probably not in all (Janák, Přichystal 2019). However, a more detailed investigation of this phenomenon would again require analyses using a microprobe from various sites and, especially, analyses of another polished tool from Pustějov (so far three analyses are available from 18 relevant samples – in addition to one older analyse, cf. Janák *et al.* 2016b, there are new two ones – all pointed to the Jizerské hory Mts.) and also from a similar distribution settlement Racibórz 425, from where there are no thin sections available yet, but where, so far only according to stereomicroscopy, this concerns three maybe up to five pieces out of a total of eight specimens (Janák, Přichystal 2019: Tab. 2). The indication of the increased proportion of metabasites from the Jizerské hory Mts. on the transportation route of the SKCJ distribution system may hint at the notion that both commodities may have travelled (in an organised manner?) in the same way in the opposite direction. However, considerations about direct exchange of polished tools made of the North Bohemian raw material and (tested concretions) of silicites from Cracow area as exchange equivalents, sufficient arguments are not yet available (cf. Janák *et al.* 2016a, Janák 2018).

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