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Metabasite Artefacts from the Neolithic Settlement at Brno-Holásky/Tuřany Compared to the Potential Source Rocks within the Želešice Metabasite Body Based on Petrography and Mineralogy

Kristýna Trnová[1*], Petr Gadas[1], Jaroslav Bartík[2], David Buriánek[1,3], Antonín Přichystal[1], Karel Slavíček[1]

[1]*Department of Geological Sciences, Faculty of Science, Masaryk University, Kotlářská 267/2, 611 37 Brno, Czech Republic*
[2]*Institute of Archaeology of the Czech Academy of Sciences, Čechyňská 363/19, 602 00 Brno, Czech Republic*
[3]*Czech Geological Survey, Leitnerova 204/22, 602 00 Brno, Czech Republic*

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ABSTRACT

The Želešice metabasite body served as a significant area for the exploitation of raw material for the production of polished stone tools in the Neolithic. This study is based on petrographical and mineralogical comparisons of the artefacts from the Želešice-type metabasite collected in the Neolithic settlement (and workshop) at Brno-Holásky/Tuřany with the various rock types occurring around the Želešice metabasite body. The determination of the most probable locations of Neolithic exploitation within the Želešice metabasite body is given. The three main rock varieties of the artefacts from Želešice metabasite have been specified. They match well in their petrography and mineralogy with the rock types determined in the source region. The artefacts with pebble surfaces were most likely obtained from the nearby Bobrava riverbed.

1. Introduction

Neolithic cultures are characterised by the construction of permanent settlements, agriculture and stock raising. These changes were accompanied by the beginning of the exploitation of raw material for manufacturing polished stone industry. Some polished stone industries (*e.g.* axes, chisels and hatchets) were subject to extensive distribution and have been found in a number of settlements over central and western Europe (*e.g.* Přichystal, 2000, Přichystal and Trnka, 2001; Spišiak and Hovorka, 2005; D'Amico and Starnini, 2006; Pétrequin *et al.*, 2008). Especially low- to medium-metamorphosed basic rocks represent the most common raw material due to their optimal technological workability (easy production) and physical properties (*e.g.* toughness), suitable for a wide range of uses (Štelcl and Malina, 1975; Přichystal, 2013). Two main metabasic rock types were particularly utilised for production of stone axes in what is now the Czech Republic during the Neolithic period (5,500 to 4,300 BC): (a) metabasites from the Železný Brod Crystalline Unit in the Jizera Mountains (former term actinolite-hornblende hornfels) and (b) metabasites from the Brno Batholith from the Želešice metabasite body (amphibolite to greenschist).

Jizera Mountains-type metabasites were quarried and manufactured during the Early to Middle Neolithic periods (Šída *et al.*, 2014, p.91) in the northern Bohemia (south-east of Jablonec nad Nisou). These stone tools were traded over distances of several hundred kilometres and were found in many sites from Germany to southern Moravia and north-western Hungary (*e.g.* Bukovanská, 1992; Klomínský

*Corresponding author. E-mail: kristynatrna@gmail.com

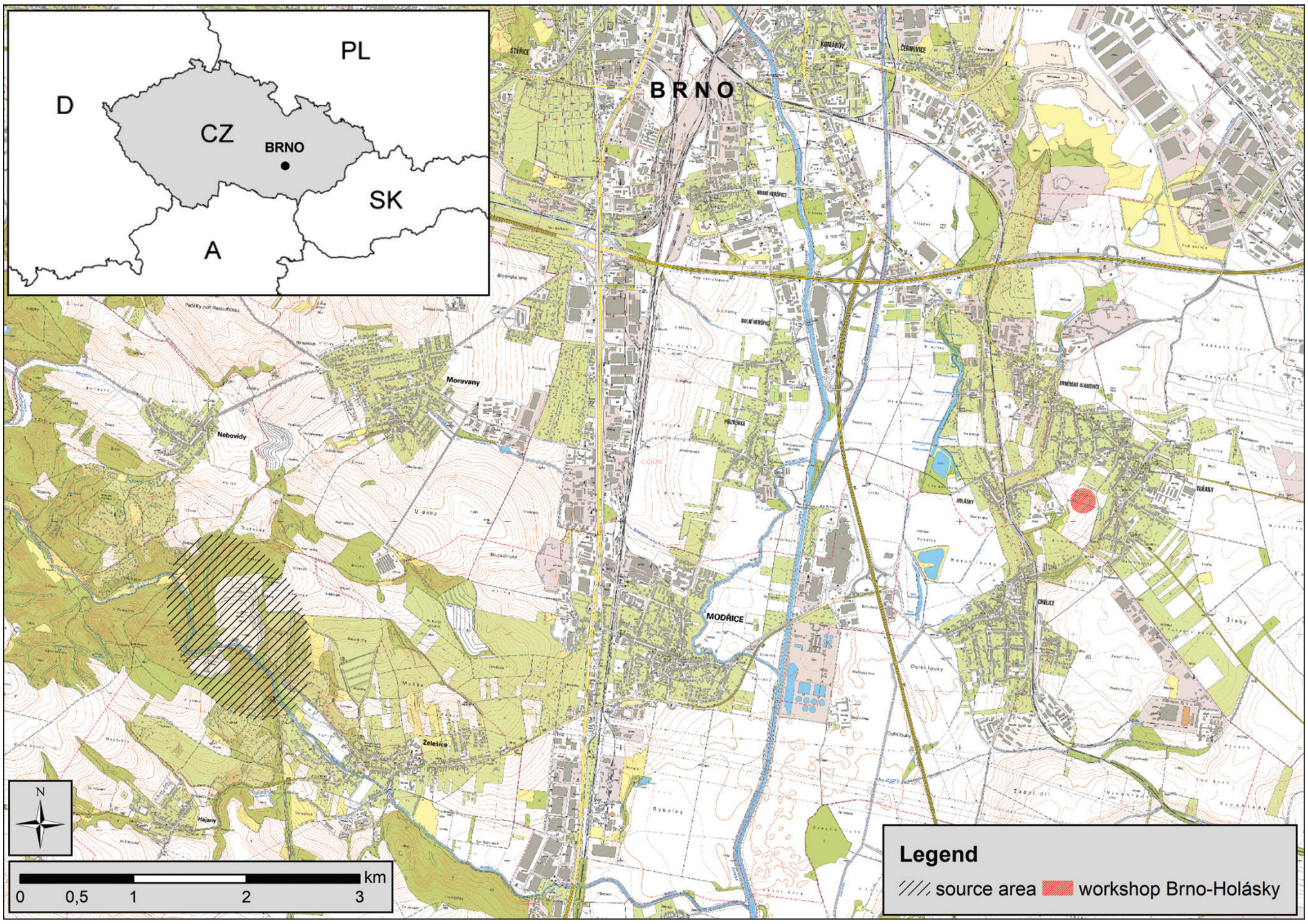


Figure 1. Situation of the Brno-Holásky/Tuřany settlement and the source area near Želešice on the background of the cadastral map. Source: State Administration of Land Surveying and Cadastre. Graphics by J. Bartík.

et al., 2002; Přichystal, 2002; Šrein *et al.*, 2003; Klomínský *et al.*, 2004; Šída, 2007; Šída *et al.*, 2014).

The second important type of metabasite (Želešice-type) was exploited and utilised mainly in the Lengyel culture (Late Neolithic period) in the southern Moravia in the close vicinity of Brno (Koštuřík *et al.*, 1984; Kuča and Vokáč, 2008; Přichystal, 2013). The beginnings of the exploitation of these metabasites are dated to the Ia phase of the Linear Pottery culture and it started to dominate in the earlier phases of the Lengyel culture (Lengyel I), when stone tools from the Jizera Mountains-type metabasite are already rare (Vokáč, 2008). The artefacts made of metabasic rocks from the Želešice-type metabasite very often occur around Neolithic settlements, and not only in the surroundings of Brno. They were also exported to all over Moravia and to a lesser extent beyond its borders. Outcrops of the chlorite-actinolite greenschist, amphibolite to epidote amphibolite are situated near Želešice, about 5 km south of Brno (Gregerová *et al.*, 1986; Buriánek, 2005; Veverka, 2016; Hanžl *et al.*, 2019). There is an extensive workshop area in the vicinity of the outcrop, while four large and several smaller primary workshops have so far been documented in more detail (Bartík *et al.*, 2015a; 2015b). The aforementioned workshops focused on the production of preforms, especially axes, but there is no evidence of final polishing.

Another type of Late Neolithic workshop with a complete operational chain of production (the obtained raw material, preforms and finished stone artefacts) is located in the wider surroundings of the city of Brno. They include the workshop at the Lengyel culture settlement in Brno-Holásky/Tuřany (Figure 1), which currently contains the largest analysed set of finished artefacts and in particular production waste (*e.g.* Bílá, 1974; Trnová, 2017).

This prehistoric settlement is located on the border of two cadastral territories (Brno-Holásky and Brno-Tuřany) about 7 km south-east of the Brno city centre (specifically the field of findings called "U Tuřan"). The location of the site is characterised by its elevation of about 225 m a.s.l. and a gentle, gradual slope dropping to the inundation of the stream Tuřanský potok, which flows about 150 m east of the settlement. The site is multicultural. The settlement began already in the Early Neolithic, but evidence of human activities (including a workshop) from the Late Neolithic prevailed. The settlement has been mentioned in earlier archaeological and petrographic studies (Červinka, 1948; Chleborád, 1950; Bílá, 1974; Trnová, 2017) and it is significant for abundant findings of polished stone industry from various raw materials. In this paper we concentrate on the material from the Želešice-type metabasite, being the most represented on this site. A further reason is that, up to now, only hypotheses have been expressed as to how the raw material could have been obtained (*cf.* Bartík *et al.*, 2015a), but the exact locations of the prehistoric exploitation within the Želešice metabasite body have not been determined. Our investigation is based on the combined interpretation of field-collected and published geological data (Buriánek, 2005; Veverka, 2016; Trnová *et al.*, 2018; Hanžl *et al.*, 2019), on macroscopic and microscopic observations, as well as a mineralogical and petrographic analysis conducted on representative samples of the polished stone industry from the Želešice-type metabasite and the potential raw materials collected through geological surveys in the presumed source area. The main purpose of the paper is to give an archaeological (basic technological and typological) evaluation of the polished stone industry from the Neolithic settlement at Brno-Holásky/Tuřany and to determine the most probable locations of prehistoric exploitation within the Želešice metabasite body and, furthermore, to specify the exploitation behaviour of the Neolithic people.

2. Geographical and geological context of the site and source area

Landforms on the southern edge of the current Brno agglomeration include the Bobrava Highlands to the west, the alluvial plain of the Svratka to the south and the slightly undulating terrain in the east. The area south and east of the Brno agglomeration is characterised by widely exposed Cenozoic sediments (Holocene to Miocene). The Neolithic settlement at Brno-Holásky/Tuřany is located in the lowlands on the Pleistocene Tuřany terrace of the Svratka River. Miocene sediments were deposited during the late stages of Alpine orogeny in a foreland geotectonic environment (clays and sands of the Carpathian Foredeep). Pleistocene loess and Pleistocene to Holocene alluvial deposits compose a considerable part of this area. In contrast, the hills of the Bobrava Highlands are dominantly composed of the Neoproterozoic metamorphic and plutonic rocks of the Brno Batholith (Zapletal, 1922; Hanžl *et al.*, 2019). The Brno Batholith (formerly Brno Massif) is composed of the Eastern and Western granodiorite complexes (consisting of granite and granodiorite), separated from each other by the Central Basic Belt, which is formed by two segments: a volcanic Metabasite Zone (low-grade metamorphic basalt and rhyolite) in the east and a plutonic Diorite Zone (mainly medium to low-grade metamorphic basic and ultrabasic plutonic rocks) in the west (Hanžl and Melichar, 1997; Leichmann and Höck, 2008).

The Želešice-type metabasite crops out in the larger and smaller gorges, rivers (*e.g.* Bobrava River) and streams developed in the eastern edge of the Bobrava Highlands. The Želešice metabasite body is exposed along the south-west margin of the Central Basic Belt (Diorite Zone). The dominant metamorphic foliation is north-south trending and westly dipping (Hanžl *et al.*, 2019). The Želešice metabasite body has sharp intrusive contact with westward Amp-Bt granodiorite of the Brno Batholith. The eastern contact with other rocks of the Central Basic Belt (metagabro, metadiorite and serpentinite) is tectonically reworked. The Želešice metabasite body consists of actinolite-chlorite-epidote schist to chlorite schist (greenschist), medium to fine-grained amphibolite and epidote amphibolite, medium-grained melanocratic amphibolite, biotite and cordierite-biotite hornfels to gneiss and ultramafic rocks (Gregerová *et al.*, 1986; Buriánek, 2005; Veverka, 2016).

3. Material and methods

During the petroarchaeological prospections, 903 artefacts of the polished stone industry and macrolithic tools were collected in the Neolithic settlement at Brno-Holásky/Tuřany over the course of a few years. Most of them (860 pieces; 95.2%) is represented by the artefacts from the Želešice-type metabasite. In this collection, there are 684 pieces of preforms including raw material and debitage, 176 finished artefacts (102 axes, 14 shoe-last celts (a tree-felling tool), 44 pebble hammers and 16 samples of other types of polished stone industry, *e.g.* fragments of hoes, hammer-axes, *etc.*) that have been gathered. All stone artefacts were obtained by surface survey. Systematic field excavation and geophysical prospecting is a planned goal of future research. In the group of the potential source rocks, the main rock types were sampled within the Želešice metabasite body and analysed using the same methods as the artefacts. Various rock types distinguished in the collection of the Želešice-type metabasite artefacts were classified according to the former research of Bartík *et al.* (2015a) into three main varieties and labelled using Arabic numerals (1, 2 and 3). There were evaluated different rock types within the Želešice metabasite body and the most similar rocks to the metabasites from the studied settlement were chosen for further investigation. These selected rock types of the source region were labelled using Roman numerals (I, IIa, IIb and III). We use the term "metabasite" as a superordinate word for the terms "greenschist" and "amphibolite".

Laboratory research was based on petrographical characteristic of thin sections using the polarising microscope and electron microprobe analyser Cameca SX100 at the Joint Laboratory of Electron Microscopy and Analysis of the Department of Geological Sciences at the Faculty of Science, Masaryk University, and the Czech Geological Survey. The conditions of the WDX measurements were: an accelerating voltage of 15 kV, a beam current of 10–20 nA and beam diameter 1–5 μm. Natural minerals and synthetic phases were used as standards. The raw data were reduced using PAP matrix corrections (Pouchou and Pichoir, 1985). The crystal-chemical formulae of feldspars were calculated on a basis of 8 oxygens, amphiboles on a basis of 23 anions and classified according to Leake *et al.* (1997). Stoichiometric calculations and charts were carried out using the FormCalc, Formula, and Triplot programs. Abbreviations of mineral names according to Whitney and Evans (2010) were used to label the minerals in the photographs: amphibole (Amp), plagioclase (Pl), magnetite (Mag), ilmenite (Ilm), chlorite (Chl), titanite (Ttn), pyrite (Py).

Petrophysical study of the material is based on the measurement of magnetic susceptibility using the KT-6 portable kappameter. Each sample was measured 5 times and the highest value of the MS was recorded. For MS evaluation, samples with a minimum single dimension of at least 35 mm were selected to cover the central part of the kappameter (Bartík *et al.*, 2015a; Bradák *et al.*, 2009).

The artefacts were classified from the standpoint of technology and typology based on Salaš (1984), Sklenář and Hartl (1989), and Zápotocký (2012). Axes, shoe-last celts and their fragments were categorised similarly according to their shape, state of preservation, presence of tectonic fissures or damage. Raw materials, preforms, and debitage were sorted into the technological categories according to Bartík *et al.* (2015a). The presence of polishing, pebble surface and tectonic fissures were marked. The shape of the preforms and state of preservation was determined. The artefacts were weighed (g) and measured – length, width, and height (mm). Each piece of debitage was sorted into categories by size. In this paper, we summarise only the results of the basic technological-typological analysis; further analysis, including metrics, is contained in the work by Trnová (2017).

4. Results

The results of the research are based on the macroscopic characteristic of the artefacts and the potential source rocks, the measurement of magnetic susceptibility, petrographic and mineralogical composition, and evaluation of the artefacts from an archaeological point of view.

4.1 Macroscopic characteristic of the artefact varieties and the rock types

Among the group of the artefacts, three main rock varieties from the Želešice-type metabasite were distinguished – as varieties according to Bartík *et al.* (2015a). The artefacts from the Želešice-type metabasite represent 95.2% of all the polished stone industry collected in the settlement at Brno-Holásky/Tuřany. Variety 1 is the most represented (98.3 %) and characterised by its grey-green colour, according to the Munsell color rock chart (Rock-color chart, 1995) 10GY 5/2 GREYISH GREEN, 5GY 6/1 GREENISH GREY and 5GY 4/1 DARK GREENISH GREY. There is often visible metamorphic foliation with lighter shades on the surfaces than the fresh fracture, and tectonic fissures are also common. The rock is often penetrated by lighter veins, sometimes it is possible to see grains of magnetite. Variety 2 is represented by 1.0% of the Želešice-type metabasite artefacts and is very similar to variety 1 but commonly contains porphyroblasts of feldspar easily visible with the naked eye. In some cases, these varieties change into each other. Variety 3 is represented by 0.7% of the artefacts from the Želešice-type metabasite and is characterised by a medium-grained texture and lacking, or has poorly developed, metamorphic foliation. Its colour is darker than is the case of varieties 1 and 2 and can be described as 5GY 2/1 GREENISH BLACK according to the Munsell color rock chart.

In the area of the Želešice metabasite body, the main types of metabasites which are similar to the rock varieties found in the collection of the Želešice-type metabasite artefacts were chosen. Rock type I is characterised by a greenish colour, sometimes with the presence of rusty shades caused by alterations of iron minerals. The rock is fine- to medium-grained and foliated. Rock type II is medium- to fine-grained with well-developed foliation and macroscopically can be divided into two subgroups – group IIa with light porphyroblasts of feldspar and group IIb sometimes with higher contents of epidote with a greenish shade. Rock type III is characterised as a medium-grained dark rock with poorly-developed or lacking metamorphic foliation.

4.2 Magnetic susceptibility (MS)

In the group of the raw material, preforms and debitage, the average value of MS of the predominant variety 1 is 11.19×10^{-3} SI units, for variety 2 it is 6.57×10^{-3} SI units and for variety 3 the average MS is 9.86×10^{-3} SI units. The axes represented by variety 1 shows an average value of 11.33×10^{-3} SI units and variety 2 represented by one sample has the MS of 22.2×10^{-3} SI units. The average value of shoe-last celts in variety 1 is 10.23×10^{-3} SI units, for pebble hammers in variety 1 it is 22.85×10^{-3} SI units and 0.35×10^{-3} SI units for variety 2, which was represented by only one sample. In the group of the rest of the artefacts (fragments of hoes, hammer-axes, drill core, *etc.*) the average MS is 14.00×10^{-3} SI units for variety 1 and 4.16×10^{-3} SI units for variety 2, which was also represented by only one sample.

According to the rock varieties in general, the average value of MS of variety 1 measured on 804 samples is 13.92×10^{-3} SI units, the average value of MS of variety 2 measured on nine samples is 8.32×10^{-3} SI units and the average value of MS of variety 3 measured on five samples is MS 9.86×10^{-3} SI units (Table 1, Figure 2).

Magnetic susceptibility of the source rocks was measured on the greenschist situated in the southern margin of the Želešice metabasite body (average MS 17.03×10^{-3} SI units), on the porphyroblastic amphibolite with porphyroblasts of feldspar from the western part of the Želešice metabasite body (average MS 7.14×10^{-3} SI units), on the fine-grained epidote amphibolite from the new Želešice quarry (average MS 92.43×10^{-3} SI units) and on the medium-grained melanocratic amphibolite from the old Želešice quarry (average MS 11.10×10^{-3} SI units). The values of magnetic susceptibility by rock type are summarised in Table 1 and Figure 2.

4.3 Petrography and mineral chemistry of the artefacts from the Želešice-type metabasite

Three main rock types have been collected in the Neolithic settlement at Brno-Holásky/Tuřany as polished stone

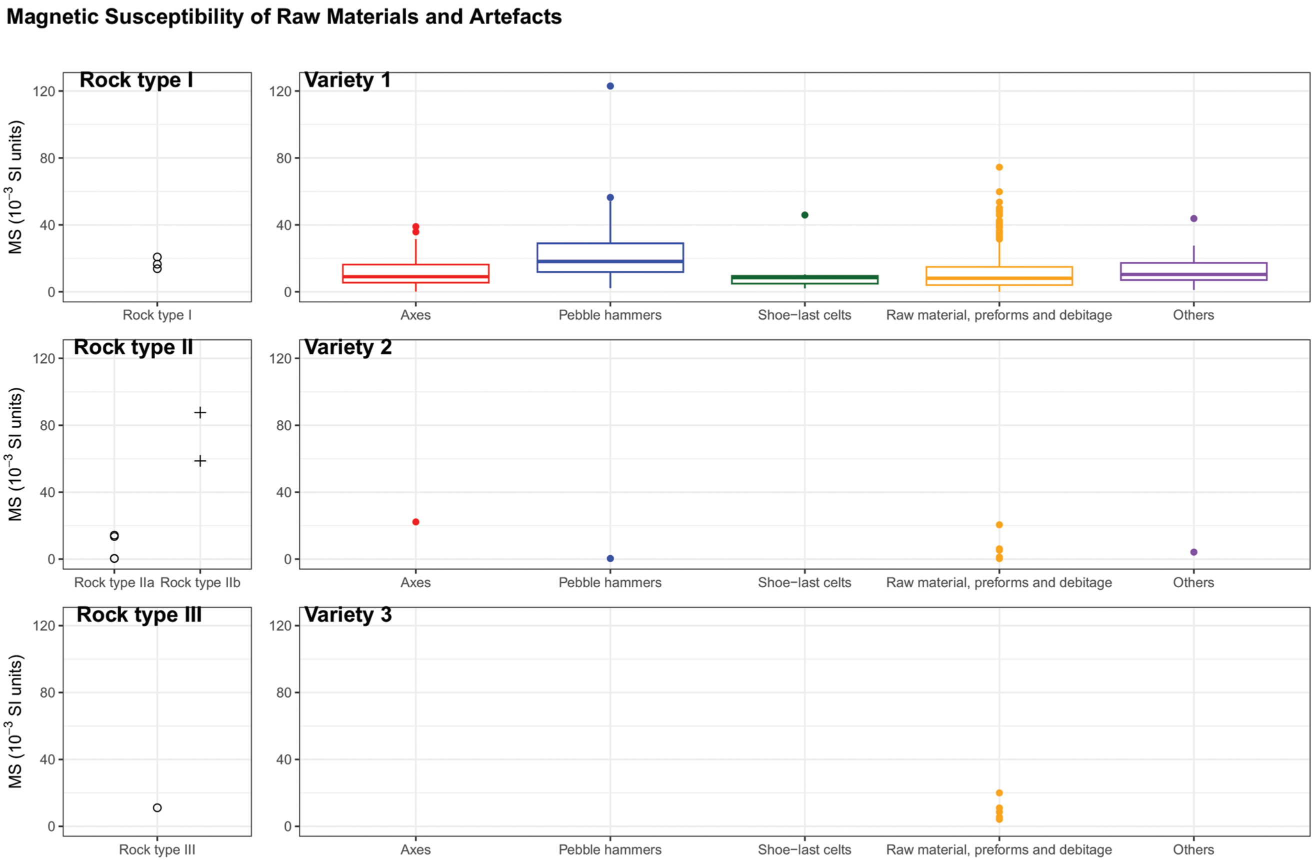


Figure 2. Graph of the values of magnetic susceptibility of various rock types from source region and groups of the artefacts.

Table 1. Values of magnetic susceptibility of various rock types from source region and types of the artefacts with respect to the three rock varieties.

Sample	Rock type/Variety	Artefact type	n	mean	sd	median	min	max	range
Raw material	Rock type I	–	3	17.0	3.5	16.5	13.8	20.8	7.0
Artefact	Variety 1	Axes	100	11.3	8.7	9.0	0.2	39.0	38.9
		Pebble hammers	43	22.8	19.9	18.1	2.2	123.0	120.8
		Shoe-last celts	12	10.2	11.5	8.4	2.1	45.9	43.9
		Raw material, preforms and debitage	635	11.2	10.3	8.1	0.0	74.5	74.5
		Others	14	14.0	11.6	10.4	1.1	43.8	42.7
Raw material	Rock type IIa	–	4	7.1	7.8	7.0	0.4	14.3	13.9
Raw material	Rock type IIb	–	3	92.4	36.4	87.6	58.7	131.0	72.3
Artefact	Variety 2	Axes	1	22.2	–	22.2	22.2	22.2	–
		Pebble hammers	1	0.4	–	0.4	0.4	0.4	–
		Shoe-last celts	0	–	–	–	–	–	–
		Raw material, preforms and debitage	6	6.6	7.3	5.7	0.3	20.5	20.2
		Others	1	4.2	–	4.2	4.2	4.2	–
Raw material	Rock type III	–	1	11.1	–	11.1	11.1	11.1	–
Artefact	Variety III	Axes	0	–	–	–	–	–	–
		Pebble hammers	0	–	–	–	–	–	–
		Shoe-last celts	0	–	–	–	–	–	–
		Raw material, preforms and debitage	5	9.9	6.3	8.6	4.2	20.0	15.8
		Others	0	–	–	–	–	–	–

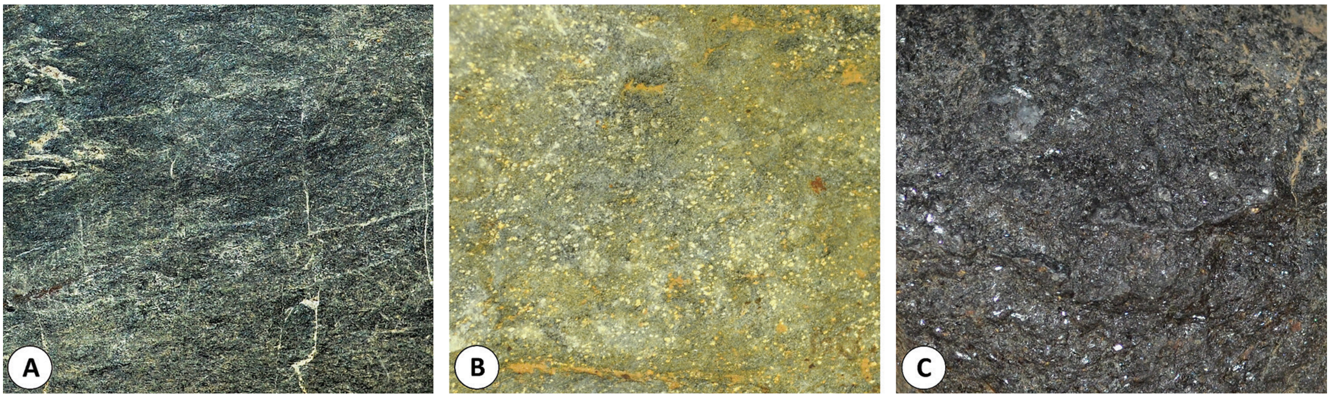


Figure 3. Varieties of the Želešice-type metabasite. A – Variety 1, B – Variety 2, C – Variety 3. Photo by J. Bartík.

artefacts. The Želešice-type metabasites from Želešice were stated as the dominating raw material (more than 95.2% of all studied artefacts), metabasites from the Jizera Mountains (2.9% of the artefacts) and microdiorites of the Brno Batholith (1.4%) follow. The rest of the collection (0.4%) is represented by other rocks (gneiss and sedimentary rocks).

Metabasic artefacts collected in the Brno-Holásky/Tuřany Neolithic settlement with Želešice source region consist of three rock varieties (metabasite of the Želešice-type, variety 1–3; Figure 3). The most common variety 1 is characteristic by grey-green colour, distinctive metamorphic foliation and the common presence of tiny veins which are mostly oriented at an oblique angle to the foliation. The rock was described as fine-grained and epigranular, but with frequent phenocrysts of opaque minerals. The second variety is very similar. The difference is in the higher contents of feldspar. These two varieties can shade into each other. The third group is the least represented variety and is distinctive for its dark greenish black colour, indistinctive metamorphic foliation, and medium-grained texture with phenocrysts of amphibole (Trnová, 2017).

Variety 1 of the Želešice-type metabasite artefacts was described as amphibole-rich greenschist to amphibolite (Figure 3: A). Metamorphic foliation is well developed in this variety, which represents 98.3% of the artefacts from the Želešice-type metabasite. In terms of composition, fine-grained amphibole predominates along with plagioclase. Intersections of these two minerals are very common. Amphiboles have a green, grey-green, or light beige colour and a composition of actinolite to magnesio-hornblende with some transitions to tschermakite, ferro-tschermakite, ferro-hornblende, ferro-pargasite, and edenite (Figures 4 and 5; classification according to Leake *et al.*, 1997). Relatively larger grains of amphibole show apparent cleavage. In some cases, amphibole is replaced by chlorite. Plagioclases (Figure 6) also show a wide range of basicity within one rock sample (An_{0-98}).

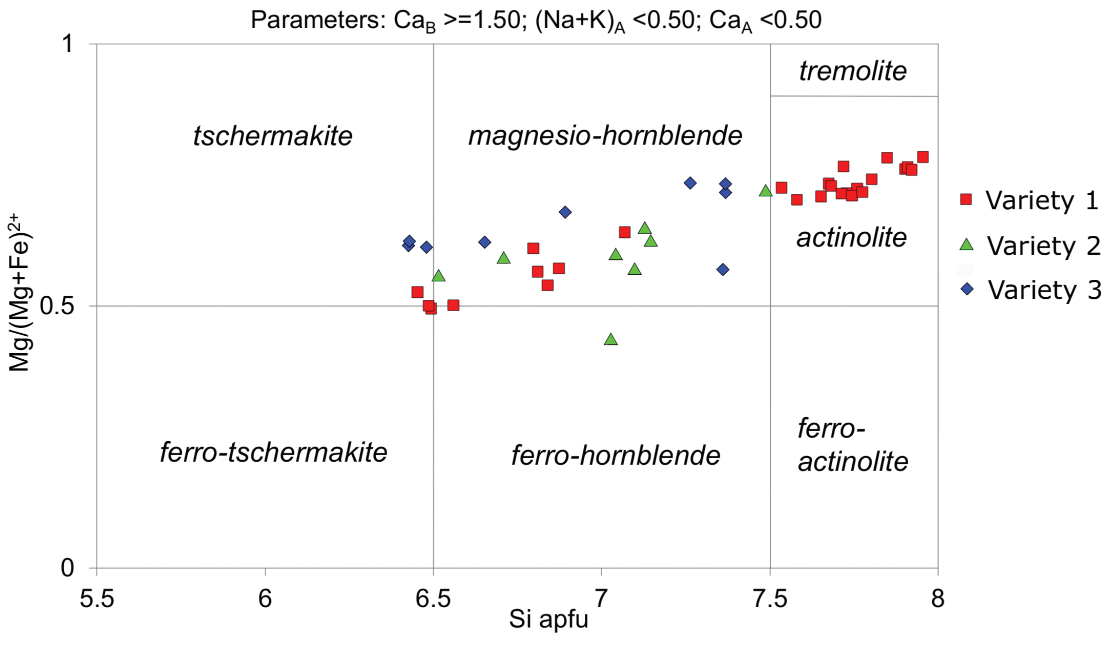


Figure 4. Composition of Ca-amphiboles from the artefacts in the classification diagram according to Leake *et al.* (1997).

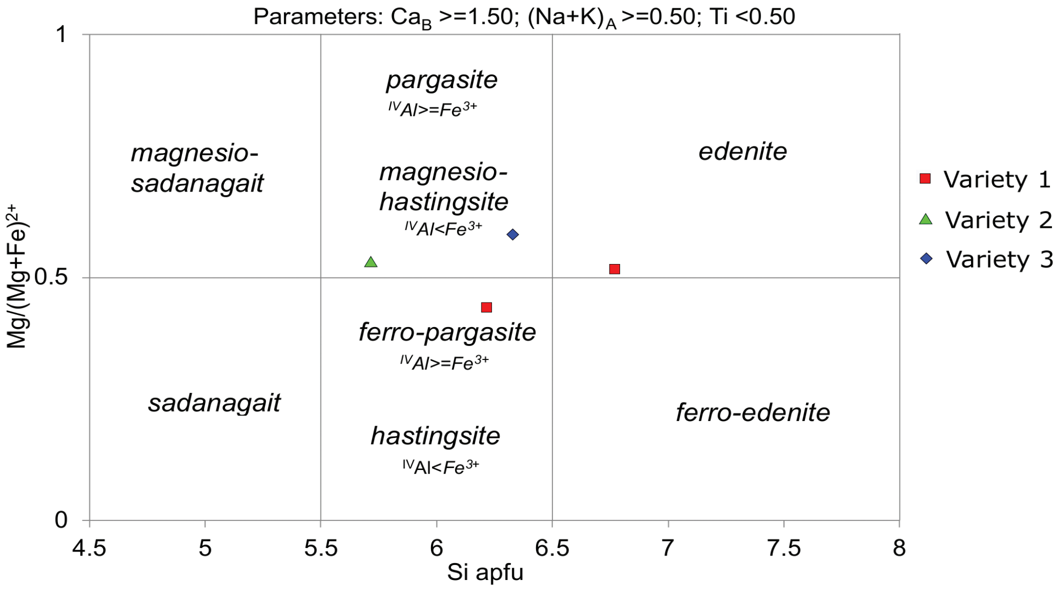


Figure 5. Composition of Ca-amphiboles from the artefacts in the classification diagram according to Leake *et al.* (1997).

Each plagioclase grain most often shows a core with higher anorthite component. Alterations of plagioclase into secondary minerals are very common. Opaque minerals (especially magnetite) are frequently represented in this metabasite type. In some samples, chalcopyrite, pyrite, and sphalerite were found as accessory minerals. Magnetite (Figure 7) is a common accessory mineral as compared to the somewhat rarer ilmenite. In addition, apatite, chlorite and epidote are present rarely. Secondary-formed grains of quartz occur in some samples. The veins are usually filled with amphibole, plagioclase, opaque minerals, or quartz (Trnová, 2017).

Variety 2 represents 1.0 % of the artefacts from the Želešice-type metabasite. The texture, structure, and composition are very similar to the first variety and the rocks can be described as amphibolite with porphyroblasts of feldspar (Figure 3: B). The second variety differs especially in higher contents of feldspar which creates lenses or areas of about a few mm. In terms of composition, fine-grained amphibole predominates along with plagioclase. Intersections of these two minerals are common. In some cases, amphibole is replaced by chlorite. Amphiboles are usually needle-columnar shaped with a composition of magnesio-hornblende, ferro-hornblende, and pargasite (Figures 4 and 5, classification according to Leake *et al.*, 1997). The grains of amphiboles as well as plagioclases are commonly zoned. The composition of the plagioclases ranges from oligoclase to anorthite ($An_{17–91}$;

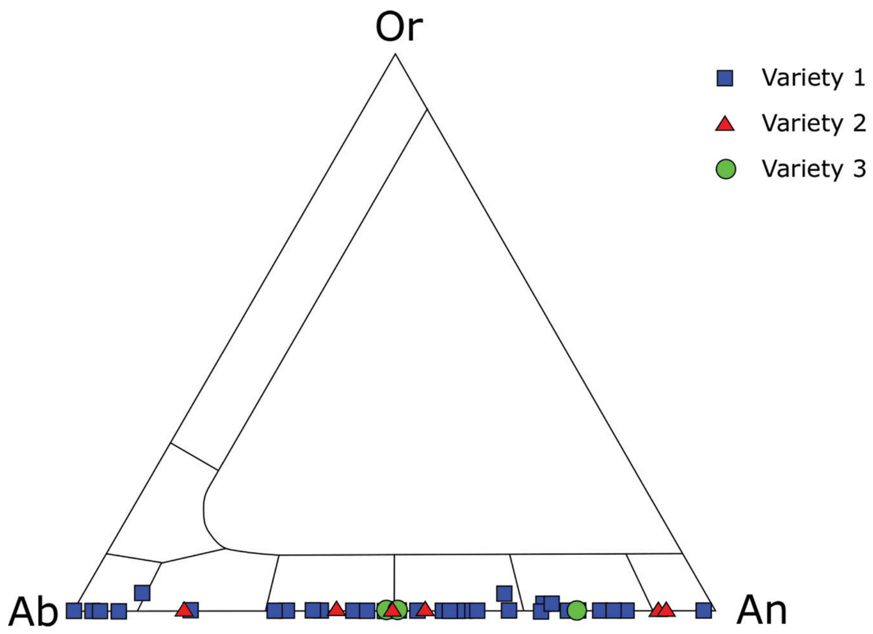


Figure 6. Composition of feldspars in the artefacts.

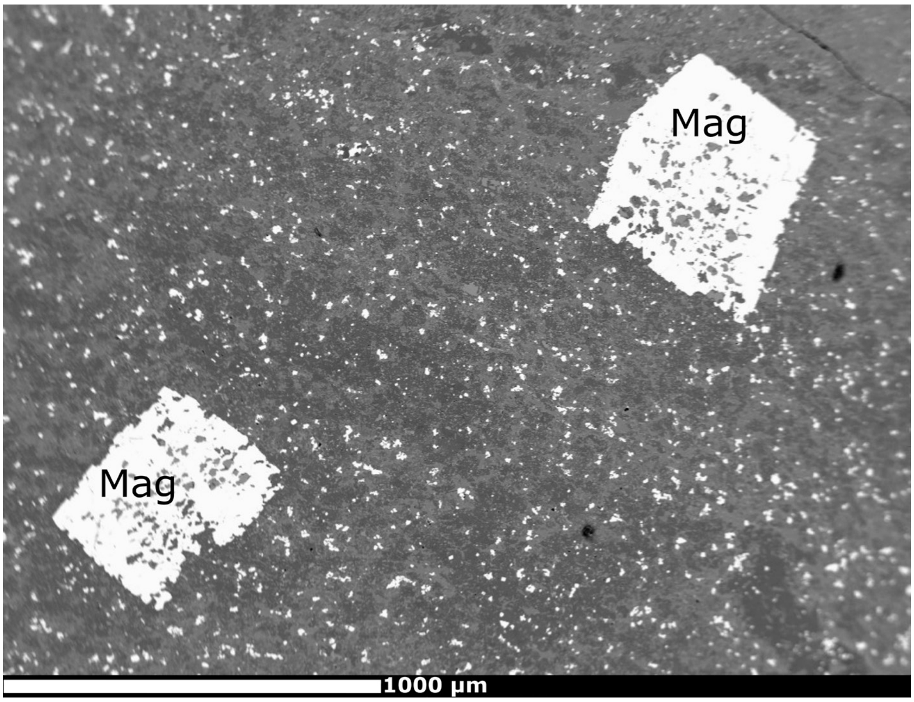


Figure 7. Porphyroblasts of magnetite with smaller magnetite grains in the groundmass – variety 1 of the artefacts.

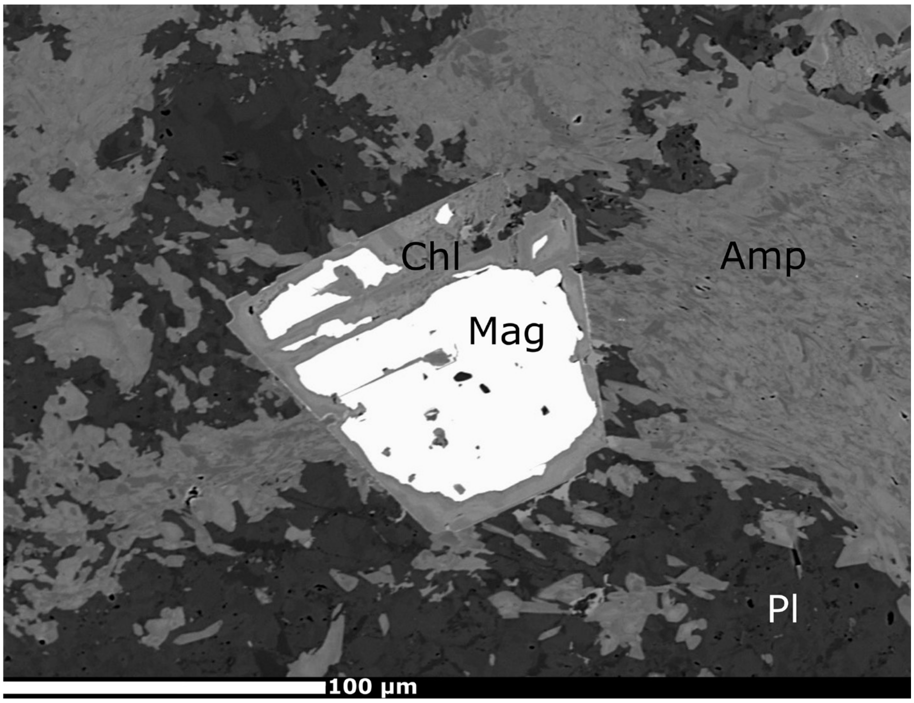


Figure 8. Chloritized magnetite in variety 2 of the artefacts.

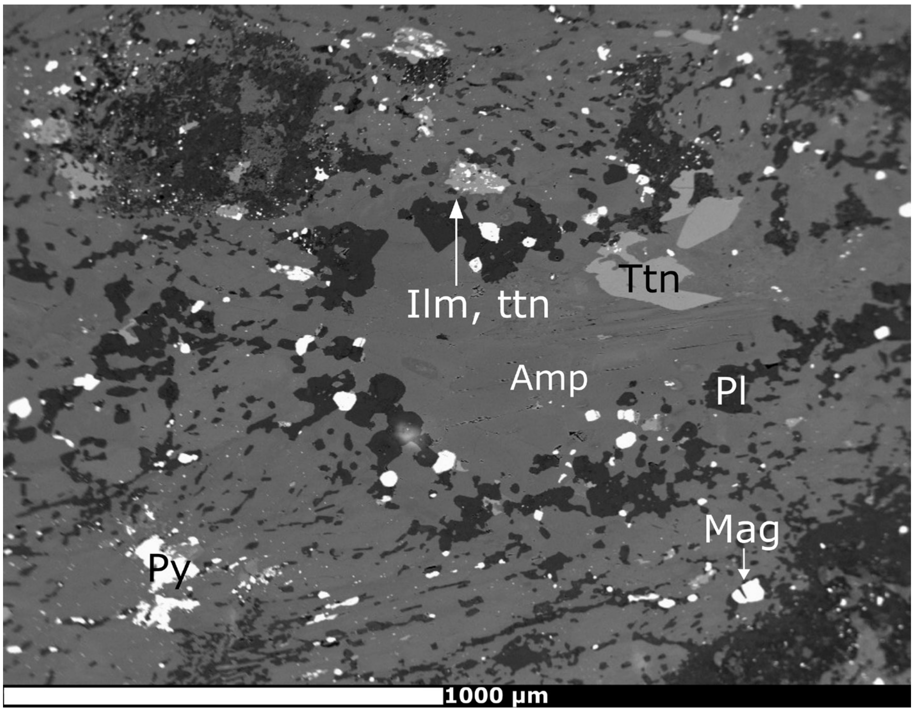
Figure 6). Accessory minerals are represented by magnetite (chloritized magnetite was found as a unique feature, Figure 8), ilmenite, albite, apatite, chalcopyrite, pyrite, sphalerite, and quartz.

Variety 3 represents 0.7 % of the artefacts from Želešice metabasite. This variety is medium grained and darker than the previous varieties (Figure 3: C). The structure is massive or with poorly developed metamorphic foliation. The rock can be determined as amphibolite. In terms of composition, medium to coarse grained amphibole predominates. Amphibole is composed of magnesio-hornblende, tschermakite, and pargasite (Figure 4 and 5, classification according to Leake *et al.*, 1997). Amphiboles and plagioclases are commonly zoned. The composition of the plagioclases ranges from andesine to bytownite (An_{48-78}; Figure 6). Accessory minerals (Figure 9) are represented by magnetite, ilmenite, apatite, epidote-clinozoisite, calcite, titanite, pyrite or pyrrhotite, chalcopyrite, and zircon.

4.4. Petrography and mineral chemistry of the metabasites in the Želešice metabasite body

Based on our previous study, we subdivided metabasites from the Želešice metabasite body into the three main types:

Figure 9. Accessory minerals detected in rock variety 3 – medium-grained amphibolite.



Rock type I Greenschist to chlorite schist dominates mainly in the north-eastern (less so the south-eastern) part of the body (Figure 10). However, they often form up to 1 m thick layers within amphibolite. In the thin section, the fine- to medium-grained, foliated greenschist consists predominately of chlorite, actinolite, epidote, albite, quartz, and magnetite. Amphiboles correspond mainly to actinolite, less so magnesio-hornblende (Figure 11; classification

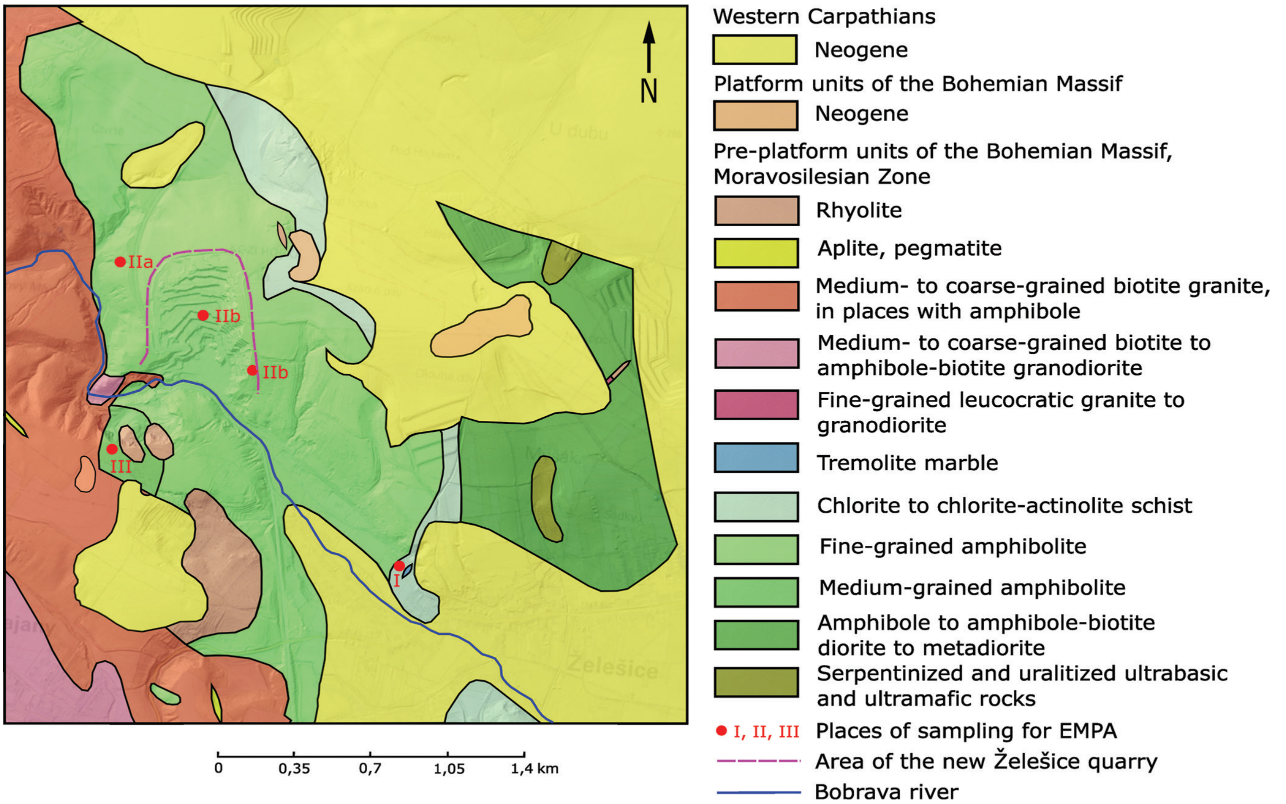


Figure 10. Uncovered geological map of the interested source area according to Buriánek *et al.* (2020) on the background of Altitude analysis with locations of sampling for the electron microprobe analyses of all three main rock types. Source: State Administration of Land Surveying and Cadastre. Graphics by K. Trnová.

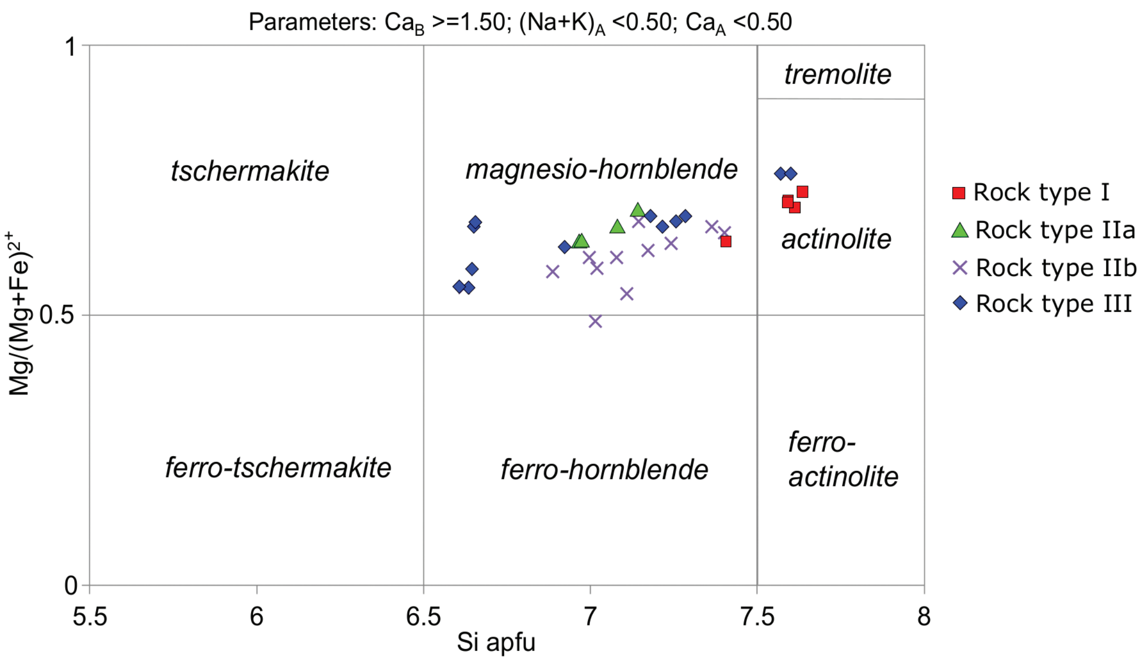


Figure 11. Composition of Ca-amphiboles from potential raw material in the classification diagram according to Leake *et al.* (1997). I – greenschist, IIa – fine-grained porphyroblastic (Pl) amphibolite, IIb – fine-grained epidote amphibolite, III – medium-grained melanocratic amphibolite.

according to Leake *et al.*, 1997). The content of actinolite is variable from 1 to 60 vol. %. Actinolite occurs as prismatic aggregates oriented parallel to the rock foliation. The composition of the feldspar grains corresponds to oligoclase-andesine ($An_{22-35;}$ Figure 12). Albite which occurs in the groundmass and epidote are subhedral to anhedral elongated grains. Quartz occurs as elongated lenticular grains and aggregates along foliation planes. Magnetite appears as small, randomly distributed grains and occurs as inclusions in other minerals.

Rock type II Medium- to fine-grained amphibolite and epidote amphibolite with well-developed foliation is the dominant rock type in the Želešice metabasite body. The most common mineral assemblage consists of amphibole, plagioclase ± epidote and/or magnetite. The nematoblastic texture is defined by columnar magnesio-hornblende, less

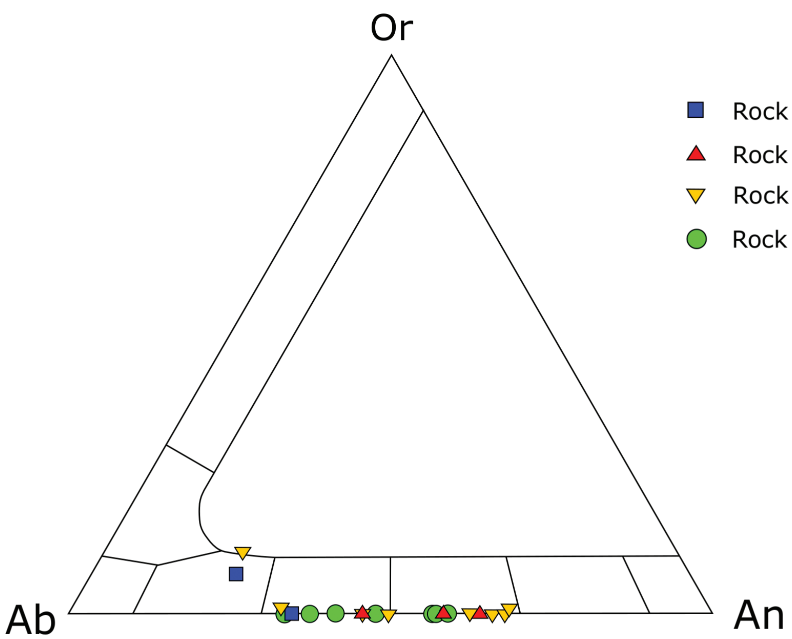


Figure 12. Composition of feldspars in potential source rocks, Želešice metabasite body.

so ferro-hornblende (Figure 11; classified according to Leake *et al.*, 1997) and interstitial plagioclase ($An_{21–68}$; Figure 12). A rim of later actinolite overgrows the magnesio-hornblende. Elongated epidote crystals are very common locally. Magnetite, ilmenite, and apatite are typical accessory minerals. The amphibolite contains several-millimetre-thick leucocratic stripes with a high content of sodic plagioclase (rarely also K-feldspar) and quartz, which resemble migmatisation close to the contact with granodiorite (Hanžl *et al.*, 2019). The rock type II has been divided into two subgroups – IIa with the presence of porphyroblasts of feldspar which was sampled in the area of the western part of the Želešice metabasite body and IIb which is characterised by higher contents of epidote also with secondary albite (Veverka, 2016) and is abundant in the area of the new Želešice quarry.

Rock type III Medium-grained melanocratic amphibolite with poorly developed foliation consists of prismatic crystals magnesio-hornblende, less so actinolite (Figure 11; classified according to Leake *et al.*, 1997) and equant to elongate xenoblastic grains of plagioclase ($An_{34–58}$; Figure 12). Relicts of enstatite grains (X_{Fe} = 0.39) are rarely present. Quartz, magnetite, ilmenite, and apatite are accessory minerals. Tables 2 and 3 include selected analyses of the amphibole

Table 2. Selected analyses of amphiboles according to the artefact raw material varieties and different rock types from the source region.

Artefact variety/rock type	var 2	var 2	var 3	var 3	I	I	IIa	IIa	IIb	IIb	III	III
SiO_2 *wt.%*	49.07	51.01	46.37	54.49	56.11	55.01	51.18	49.42	49.44	53.10	46.55	46.39
TiO_2	0.18	0.14	1.07	0.30	b.d.l.	b.d.l.	0.34	b.d.l.	b.d.l.	b.d.l.	0.37	0.33
Al_2O_3	5.32	4.94	9.66	2.57	0.37	0.48	5.45	6.26	5.57	2.41	9.01	9.27
Cr_2O_3	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.	0.04	0.04
CaO	12.26	12.97	12.16	12.23	12.80	12.84	12.22	11.98	12.62	12.53	11.66	11.84
FeO_{tot}	21.31	16.58	14.78	11.09	11.24	12.26	13.21	14.10	19.27	13.71	16.57	16.45
MnO	0.52	0.35	0.38	0.38	0.56	0.47	b.d.l.	b.d.l.	0.46	0.48	0.25	0.30
MgO	9.34	12.46	13.30	17.13	16.90	15.88	14.65	13.95	10.37	14.47	11.43	11.38
Na_2O	0.44	0.45	1.67	0.46	b.d.l.	b.d.l.	0.56	0.59	0.75	0.50	1.03	1.05
K_2O	0.06	0.09	0.27	0.05	b.d.l.	b.d.l.	b.d.l.	b.d.l.	0.18	b.d.l.	0.17	0.17
F	b.d.l.	0.07	0.12	0.09	b.d.l.	b.d.l.	0.02	0.03	0.04	0.03	0.04	0.04
Cl	0.17	0.04	0.03	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.	0.75	0.64	b.d.l.	b.d.l.
H_2O*	2.05	2.11	2.10	2.17	2.20	2.17	2.16	2.11	1.90	1.97	2.08	2.09
O=F	0.00	–0.03	–0.05	–0.04	0.00	0.00	–0.01	–0.01	–0.02	–0.01	–0.02	–0.02
O=Cl	–0.04	–0.01	–0.01	0.00	0.00	0.00	0.00	0.00	–0.17	–0.14	0.00	0.00
sum oxide	**100.68**	**101.17**	**101.85**	**100.93**	**100.18**	**99.11**	**99.78**	**98.43**	**101.17**	**99.69**	**99.19**	**99.33**
Si *apfu*	7.028	7.099	6.426	7.369	7.636	7.614	7.080	6.974	7.015	7.402	6.635	6.606
Ti	0.019	0.015	0.112	0.031	–	–	0.035	–	–	–	0.040	0.035
Al	0.898	0.810	1.578	0.410	0.059	0.078	0.889	1.041	0.931	0.396	1.514	1.556
Cr	–	–	–	–	–	–	–	–	–	–	0.005	0.005
Ca	1.881	1.934	1.805	1.772	1.866	1.904	1.811	1.811	1.918	1.871	1.781	1.806
Fe^{2+}_{tot}	2.553	1.930	1.713	1.254	1.279	1.419	1.528	1.664	2.287	1.598	1.975	1.959
Mn	0.063	0.041	0.045	0.044	0.065	0.055	–	–	0.055	0.057	0.030	0.036
Mg	1.994	2.585	2.748	3.453	3.429	3.277	3.021	2.935	2.193	3.007	2.429	2.416
Na	0.122	0.121	0.449	0.121	–	–	0.150	0.161	0.206	0.135	0.285	0.290
K	0.011	0.016	0.048	0.009	–	–	–	–	0.033	–	0.031	0.031
F	–	0.031	0.053	0.038	–	–	0.009	0.013	0.018	0.013	0.018	0.018
Cl	0.041	0.009	0.007	–	–	–	–	–	0.180	0.151	–	–
OH	1.959	1.960	1.940	1.962	2.000	2.000	1.991	1.987	1.802	1.836	1.982	1.982
O	22.959	22.960	22.940	22.962	23.000	23.000	22.991	22.987	22.802	22.836	22.982	22.982
sum cat.	**14.570**	**14.550**	**14.922**	**14.461**	**14.334**	**14.347**	**14.515**	**14.586**	**14.639**	**14.467**	**14.724**	**14.739**
XMg	0.439	0.573	0.616	0.734	0.728	0.698	0.664	0.638	0.490	0.653	0.552	0.552

Notes: *H_2O was calculated on basis of stoichiometry, b.d.l. = below detection limit.

Table 3. Selected analyses of feldspars according to the artefact raw material varieties and different rock types from the source region.

Artefact variety/rock type	var 1	var 1	var 2	var 2	var 3	var 3	I	I	IIa	IIa	IIb	IIb	III	III
P_2O_5 *wt.%*	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.	0,16	0,14	0,02	b.d.l.
SiO_2	53.92	66.26	59.13	57.18	49.23	57.02	60.20	58.17	51.99	55.83	50.82	50.22	53.74	56.23
Al_2O_3	29.28	20.23	26.08	23.39	32.19	27.64	26.89	28.10	30.17	26.85	29.95	30.14	29.20	27.53
Fe_2O_{3tot}	0.27	0.39	0.19	2.16	0.49	0.23	0.07	b.d.l.	0.04	0.03	0.16	0.08	0.21	0.46
CaO	11.77	1.43	8.67	9.78	16.46	10.32	4.22	6.70	13.17	9.12	14.43	13.78	11.69	9.93
K_2O	0.06	0.08	b.d.l.	b.d.l.	b.d.l.	0.06	1.11	b.d.l.	b.d.l.	b.d.l.	0.18	0.06	0.04	0.03
Na_2O	4.68	10.34	6.92	5.56	2.57	6.04	7.36	7.03	4.16	5.99	3.68	3.71	4.96	6.12
F	b.d.l.	b.d.l.	b.d.l.	0.09	0.09	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.
sum oxide	**99.97**	**98.72**	**100.96**	**97.95**	**100.99**	**101.28**	**99.84**	**100.00**	**99.53**	**97.82**	**99.36**	**98.11**	**99.85**	**100.26**
P *apfu*	–	–	–	–	–	–	–	–	–	–	0.006	0.005	0.001	–
Si	2.436	2.939	2.620	2.640	2.239	2.533	2.670	2.585	2.370	2.556	2.334	2.329	2.434	2.526
Al	1.559	1.058	1.361	1.273	1.725	1.447	1.406	1.472	1.621	1.449	1.621	1.648	1.558	1.458
Fe^{3+}_{tot}	0.009	0.013	0.006	0.075	0.017	0.008	0.002	–	0.002	0.001	0.005	0.003	0.007	0.015
Ca	0.570	0.068	0.411	0.484	0.802	0.491	0.201	0.319	0.643	0.448	0.710	0.685	0.567	0.478
K	0.003	0.004	–	–	–	0.003	0.063	–	–	–	0.011	0.003	0.002	0.002
Na	0.410	0.889	0.594	0.498	0.227	0.520	0.633	0.605	0.368	0.531	0.328	0.333	0.435	0.533
F	–	–	–	0.013	0.013	–	–	–	–	–	–	–	–	–
sum cat.	**4.987**	**4.971**	**4.994**	**4.972**	**5.010**	**5.003**	**4.975**	**4.981**	**5.003**	**4.985**	**5.009**	**5.001**	**5.004**	**5.011**
An *mol.%*	58.0	7.1	40.8	49.2	77.9	48.4	22.4	34.5	63.6	45.7	67.7	67.1	56.4	47.2
Ab	41.7	92.5	59.0	50.6	22.0	51.3	70.6	65.5	36.4	54.3	31.3	32.6	43.3	52.6
Or	0.3	0.4	0.2	0.2	0.1	0.3	7.0	0.0	0.0	0.0	1.0	0.3	0.2	0.2

Note: b.d.l. = below detection limit

and feldspar composition of artefacts and rock types from the source area.

4.5 Evaluation of the archaeological material

The collection of artefacts made of the Želešice-type metabasite contains almost all stages of the operational chain of production of the polished stone industry in this locality. The smallest fraction of the production waste is missing. However, it is caused by the method of the acquisition of the analysed collection. Proportional representation of the technology categories radically distinguishes them from the state we know from the area of the primary workshops in the surroundings of the source area near Želešice (*cf.* Bartík *et al.*, 2015a). The presence of finished and very often also used (according to macroscopically visible use-wear traces) polished artefacts (Figure 13) is the fundamental difference. From the typological point of view non-drilled tools such as axes (13.2%; 70% of finished artefacts) and shoe-last celts (2.8%; 15% of finished artefacts) are predominant in the settlement at Brno-Holásky/Tuřany. The ratio of the drilled tools (hammer-axes, hoes and drill cores) is low (together 2.4%). Among the predominating axes, there are mainly trapezoidal and slightly trapezoidal forms with a straight rear edge and then axes represented to a much lesser degree that have a triangular or rectangular shape when viewed from the front. From the perspective of the individual varieties of the Želešice-type metabasite utilised, variety 1 predominates (98.3%) at the analysed workshop. The proportion of varieties 2 (1%) and 3 is low (0.7%). In the case of variety 3, we have no evidence of finished polished artefacts.

For the classification of the workshop, the composition of the products from the processing of polished stone industry, which comprises 688 pieces (76% of the total amount of the studied artefacts, Table 4), is absolutely essential. The representation of individual technological categories is summarised in Table 5, from which it follows that the preforms (Figure 13) of the non-drilled artefacts (46.5 %) constitute the most significant part when compared to the primary workshops. In contrast, raw materials with use-wear traces, or without them (<1 %) just as in the production waste in its various forms of debitage (with predominantly technical flakes over fragments), were found here in noticeable lower amounts than around the primary workshops. Based on the high number of preforms of the polished stone tools and the relatively low amount of debitage and blocks of raw material, it is possible to state that the site represents a so-called "secondary workshop". For now, the most probable hypothesis appears to be that the metabasites from the Želešice area mostly reached the settlement at Brno-Holásky/Tuřany already in the form of preforms, which were then further individually 'finished' here before polishing. Only a minor part was brought here in the form of blocks

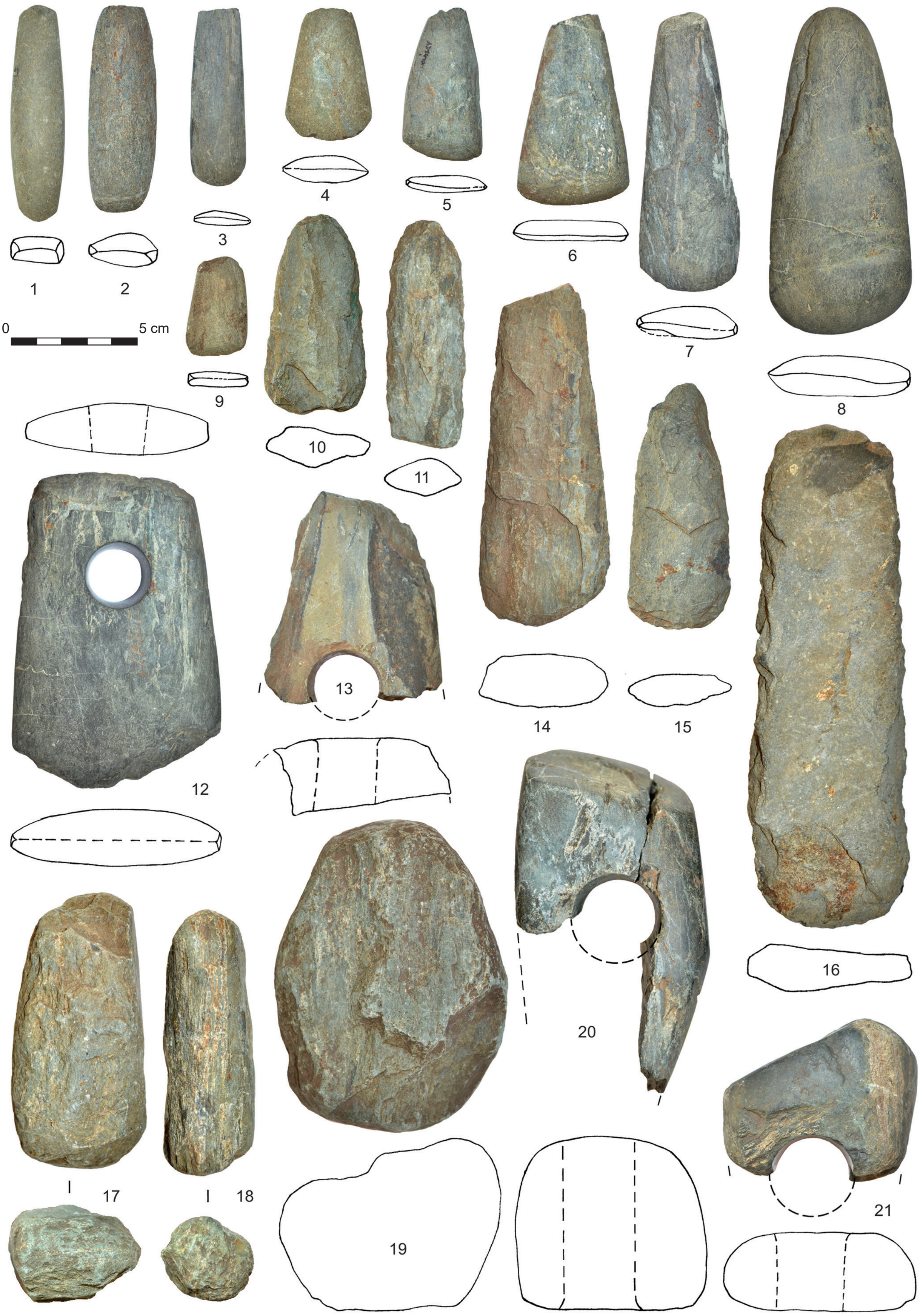


Figure 13. Artefacts from variety 1 of the Želešice-type metabasite (1–3: shoe-last celts, 4–9: axes, 10, 11, 14–16: preforms of axes, 12: hoe, 13, 20, 21: hammer-axes, 17–19: hammer-stones with pebble surface). Photo by J. Bartík.

Table 4. Collection of the polished stone industry from Brno-Holásky/Tuřany.

Finished artefacts and preforms	Želešice metabasite-type	Jizerské Mts. metabasite-type	Microdiorite (Brno Batholith)	Other	Total	
					pc	%
Preforms	684	0	4	0	688	76.2
Axes	102	13	3	1	119	13.2
Shoe-last celts	14	11	0	0	25	2.8
Hammer-stones	44	0	0	0	44	4.9
Other	16	2	6	3	27	3
pc	**860**	**26**	**13**	**4**	**903**	
%	**95.24**	**2.88**	**1.44**	**0.44**		**100**

Table 5. Representation of technological categories of the production chain of the polished stone industry from Brno-Holásky/Tuřany according to the varieties of Želešice-type metabasite.

Abb.	Technological categories	Rock variety			Amount	
		I	II	III	pc	%
1	Raw material	2	0	0	2	0.29
2	Raw material with testing scars	4	0	0	4	0.58
3	Core	1	0	0	1	0.15
4	Fragment	61	3	0	64	9.36
5	Fragment with technological retouch	46	0	2	48	7.02
6	Flake	61	0	2	63	9.21
7	Flake with technological retouch	156	1	0	157	22.95
8	Crested flake from core	0	0	0	0	0
9	Crested blade from core	0	0	0	0	0
10	Blade	10	0	0	10	1.46
11	Chips (<30 mm)	15	0	0	15	2.19
12	Splinters	0	0	0	0	0
13	Initial preform	28	0	0	28	4.09
14	Preform	288	2	2	292	42.69
∑	**pc**	**672**	**6**	**6**	**684**	
	%	**98.25**	**0.88**	**0.88**		**100.00**

of raw material or pebbles, as evidenced by the remnants of pebble surfaces found on 6.58% of the products. Although the locality is multicultural, the majority of the workshop activities connected to the processing of metabasites of interest could be dated to the Lengyel culture, based on the typology of the artefacts. The rest of the findings of material culture, such as ceramics, figural sculptures, and the raw material spectrum of the chipped industry, allow more precise dating to the first stage of the Moravian Painted Ware culture (Lengyel I). The present state of research precludes an exact description of the appearance or structure of the workshop. Up to now, it is uncertain if it was a surface workshop or if the production concentrated on specialised features. It will also be important to discover spatial relationships between the workshop and the settlement structures during future research. For the present, it appears that according to the distribution of other material culture the remains of the workshop activities overlap with the area of the settlement.

5. Discussion

From the standpoint of macroscopic and microscopic observation, the majority of the studied artefacts (variety 1, 98.3%) from Brno-Holásky/Tuřany workshop correspond to rock type I and partly to rock type IIb. The main macroscopic signatures of these types are their greenish colour, fine–medium-grained texture, and well-developed metamorphic foliation. These features resemble mainly greenschist mapped in the north-eastern and south-eastern part of the Želešice metabasite body with some transitions to amphibolite. Varieties 2 and 3 are minor constituents in the artefacts. Amphibolite labelled as rock type II forms the main part of the Želešice metabasite body. The subgroup IIa with porphyroblasts of feldspar was found in the western part of the Želešice metabasite body. The mineral composition mostly corresponds to variety 2 (1% of the artefacts) and also the composition of the amphiboles corresponds and is typical for amphibolite. The medium-grained melanocratic amphibolite was mapped around the old Želešice quarry. It was labelled as rock type III in this investigation and matches very well to variety 3 (0.7%) of the artefacts. The mineral composition is similar, and the amphiboles are represented in both cases mostly by magnesio-hornblende. In these cases, the basicity of plagioclases seems not to be the determinative feature for provenance studies.

The measurement of magnetic susceptibility which shows us the presence of magnetic minerals was applied to all metabasite varieties of the artefacts and all types of potential source rocks. Variety 1 which is the most abundant group of metabasite artefacts has an average MS of 13.92×10^{-3} SI units, and rock type I has an average MS of 17.03×10^{-3} SI units. The average value of magnetic susceptibility of variety 2 is 8.32×10^{-3} SI units and of the corresponding rock type IIa it is 7.14×10^{-3} SI units. Rock type IIb shows the highest values of MS, about 92.43×10^{-3} SI units. Finally, variety 3 has an average MS of 9.86×10^{-3} SI units and rock type III about 11.10×10^{-3} SI units. From these preliminary results we could say that the MS values of the varieties from the artefacts are like the values of MS of the various rock types from the provenance region. With respect to the artefact typology, pebble hammers show the highest average values of MS and shoe-last celts the lowest. Even though the smallest samples (<35 mm) were eliminated from our analysis, it is possible that the results are affected by the differences in size of the artefacts in each group.

The number of artefacts of varieties other than variety 1, and all the raw materials, were not sufficient to provide a thorough statistical analysis of the MS values. Therefore, the comparison between the means of each variety for raw material and artefacts provided here is only a preliminary data examination. It is obvious that rock types I, IIa and III yielded low values of MS ($<20\times10^{-3}$ SI units), rendering the method probably unsuitable for the classification of the named rock types. However, these rock types are well distinguishable to the naked eye lowering the need to use this method for such a purpose. On the other hand, a potential can be seen in identifying rock type IIb with high values of MS (mean $> 90\times10^{-3}$ SI units). This rock type is often difficult to distinguish from rock type I only by macroscopic observation. It can therefore be differentiated by means of magnetic susceptibility whether it is rock type I (greenschist) or rock type IIb (amphibolite) in the case artefacts of variety 1.

The differences between the artefacts' material and the rocks of the source region have also been discussed previously (Trnová *et al.*, 2018), when the main difference was found to be in the higher content of epidote in the source rocks, especially around the new Želešice quarry. The rocks in the new Želešice quarry show a wide range of contents of different minerals including quartz, feldspar, and biotite (Veverka, 2016) and the exact location of the Neolithic exploitation is hard to determine. The question is what the composition of the rocks was in the extracted part of the new and old Želešice quarries. Prehistoric exploitation in these areas is highly probable.

The presence of pebble surfaces on some of the artefacts (6.58%) indicates that a part of the raw material was acquired in the Bobrava riverbed, so the pebble surfaces facilitated subsequent processing of the raw material to produce polished stone tools.

6. Conclusions

Variety 1 described as greenschist with transitions to amphibolite, is the most abundant group (98.3%) of the artefacts from the Želešice-type metabasite, variety 2, described as amphibolite with porphyroblasts of feldspar, is 1% and variety 3 determined as melanocratic medium-grained amphibolite is 0.7% of the artefacts.

Certain rock types from the source region around the Želešice metabasite body are very close in their petrography and mineralogy to the artefacts found in the Neolithic settlement at Brno-Holásky/Tuřany. We can roughly match the varieties distinguished within the artefacts with the rock types occurring in the area of the Želešice metabasite body. Variety 1 of the artefacts is formed by greenschist with transitions to amphibolite and corresponds partially to rock type I classified as greenschist and partially to rock type II classified as amphibolite. The presence of greenschist was mapped mainly in the north-eastern and less so in the south-eastern part of the Želešice metabasite body. Amphibolite labelled as rock type II forms the main part of the Želešice metabasite body. Especially rock type IIa with porphyroblasts of feldspar is very similar to variety 2 of the artefacts which are also of amphibolite composition and contain porphyroblasts of feldspar. This rock type was found in the western part of the Želešice metabasite body. The last variety 3 of the artefacts described as melanocratic medium-grained amphibolite matches with rock type III. This type of amphibolite was mapped around the old Želešice quarry, in the south-western part of the Želešice metabasite body. The presence of pebble surfaces on some of the preforms of the polished stone tools indicates the collecting of this material from the local Bobrava riverbed. The measurement of the magnetic susceptibility of the rocks seems to be a complementary method for the provenance studies. In the future, it will be necessary to analyse other workshops petrographically in more detail, which could then even better specify the places of prehistoric exploitation.

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