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Petrographical investigations and provenance analyses of the raw materials of Neolithic stone tools from different localities southeast of Leipzig (Saxony, Germany)

Petrographische Untersuchungen und Herkunftsanalysen des Rohmaterials neolithischer Steingeräte von verschiedenen Fundstellen südöstlich von Leipzig (Sachsen, Deutschland)

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Abstract

The present study is based on a cooperation of the Sektion Petrographie at the Senckenberg Naturhistorische Sammlungen Dresden, Museum für Mineralogie und Geologie and the Landesamt für Archäologie Sachsen. Neolithic grinding and rubbing stones from three excavation localities (Rathendorf, Bruchheim near Geithain and Roda) in West Saxony (between Chemnitz and Leipzig) have been investigated regarding the provenance of their raw materials and identifying the rock material used for the production of the stone tools. The material of the 291 artefacts was macroscopically classified and compared with rock samples of the collection of the Sektion Petrographie. Thus, potential source areas of the raw materials of the artefacts could be determined. Similar rock samples have been taken from the surroundings of the Neolithic excavation localities. For compositional, textural and structural analyses, thin sections were made of all reference samples and selected artefact samples as well (polarisation microscopy). Additionally, scanning electron microscopy (SEM) and energy dispersive X-ray spectroscopy (EDX) investigations of respective thin sections revealed the mineralogical and chemical composition.

The major part of the analysed artefacts is represented by rhyolites, rhyolitic tuffs, sandstones and granites – with the rhyolites forming the most important raw material for the production of grinding and rubbing stones. Especially the mineralogical composition and the structure of rocks strongly influence their utilisation for grinding or rubbing stones.

The source areas of the raw materials of the artefacts are situated within a radius of ca. 100 km around the Neolithic excavation localities. In this context, the Saxonian Granulite Massif (Sächsisches Granulitgebirge) and the more northward located Northwest Saxonian Volcanic Complex (Nordwestsächsischer Vulkanitkomplex; mainly vulcanites of Rotliegend/Permian age) are placed a great importance. Occasionally, the raw materials of the artefacts come from the western Erzgebirge (Westerzgebirge), the sourroundig area of Leipzig or the Vogtland.

Kurzfassung

Die vorliegende Arbeit basiert auf einer Kooperation zwischen der Sektion Petrographie der Senckenberg Naturhistorischen Sammlungen Dresden, Museum für Mineralogie und Geologie und dem Landesamt für Archäologie Sachsen. Es wurden neolithische Mahl- und Reibsteine von drei Fundplätzen (Rathendorf, Bruchheim bei Geithain und Roda) in Westsachsen (zwischen Chemnitz und Leipzig) hinsichtlich der Herkunftsgebiete ihrer Rohstoffe untersucht bzw. galt es, das Spektrum der für die Anfertigung der Steinwerkzeuge genutzten Gesteine zu klären. Das Material der 291 Artefakte wurde makroskopisch klassifiziert und mit Gesteinsproben aus der Sammlung der Sektion Petrographie verglichen. Somit konnten potentielle Herkunftsgebiete der Artefaktrohstoffe identifiziert werden. Vergleichbare Gesteinsproben wurden in der Umgebung der neolithischen Fundstellen genommen. Von allen Referenz- sowie von ausgewähltenr Artefaktproben wurden Dünnschliffpräparate hergestellt, die mittels Polarisationsmikroskopie auf Mineralbestand, Struktur und Gefüge analysiert wurden. Weiterhin konnten durch die Untersuchungen einzelner Dünnschliffe am Rasterelektronenmikroskop (SEM) sowie mit energiedispersiver Röntgenspektroskopie (EDX) auch Fragen bezüglich der mineralogisch-chemischen Zusammensetzung geklärt werden.

Der Großteil der analysierten Artefakte besteht aus Rhyolithen, Rhyolithtuffen, Sandsteinen und Graniten – wobei Rhyolithe besonders häufig als Rohstoffmaterial für die Mahl- und Reibsteine genutzt wurden. Insbesondere die mineralogische Zusammensetzung und das Gefüge haben einen großen Einfluss auf die Verwertung der Gesteine als Mahl- oder Reibsteine.

Die Herkunftsgebiete der Artefaktrohstoffe befinden sich in einem Umkreis von bis zu ca. 100 km um die neolithischen Fundstellen. Von großer Bedeutung sind dabei das Sächsische Granulitgebirge sowie der weiter nördlich gelegene Nordwestsächsische Vulkanitkomplex (vor allem Vulkanite des Rotliegenden/Perms). Nur vereinzelt stammen die Rohmaterialien der Artefakte aus dem Westerzgebirge, dem Leipziger Umland oder dem Vogtland.

1. Introduction

During the last decade, a new motorway (BAB72) was built between Chemnitz and Leipzig in West Saxony. Due to the construction works, three localities with occurrences of Neolithic (5500–2000 cal BC) artefacts were detected. Subsequently, the Landesamt für Archäologie Sachsen documented and collected these archaeological sites of Rathendorf (RDF-04), Bruchheim near Geithain (KOQ-01) and Roda (POA-01) during a field season from May to November 2007. The digs were limited to the construction area, and for none of the three excavation localities the complete expansion has been recorded.

The settlement remains comprised post-holes of several Early Neolithic (5500–4000 cal BC) houses and different kind of pits. Many of them were filled with settlement waste such as ceramic shards and stone implements. Most of these prehistoric relics date into the Linear Pottery Culture (5500–5000 cal BC) or the Stroked Pottery Culture (5000–4500 cal BC).

The stone tools (mainly grinding and rubbing stones) from the archaeological localities of Rathendorf, Buchheim and Roda have been investigated for the provenance of their raw materials within the present study. Therefore, these artefacts were petrographically characterised by macroscopical classification as well as scanning electron microscopy (SEM) and energy dispersive X-ray spectroscopy (EDX) analyses. Furthermore, they were compared with reference samples of the collection of the Sektion Petrographie.

The provenance analysis of stone tools is an essential part of interdisciplinary archaeological investigation. Its aim is to clarify, whether the Neolithic population has searched itself for the raw materials used for the production of the stone tools in the closer area, or if the raw materials came from farther regions and reached the Neolithic settlements by trade or own expeditions. Another possibility is that the Neolithics used already finished stone tools, coming from other settlement areas and proving an active exchange.

1.1. Geographical and geological overview of the investigation area

The archaeological excavation localities of Rathendorf, Bruchheim near Geithain and Roda are situated in West Saxony, between Chemnitz and Leipzig, directly adjoining to Thuringia (Fig. 1). According to Mannsfeld & Richter (1995), the investigation area is located in the Mittelsächsisches Lösshügelland, partly forming the foreland of the Erzgebirge and extending between the Freiberg and Zwickau Mulde rivers. This region has a transitional character, connecting the Erzgebirge in the south, dominated by Palaeozoic and Tertiary units, with the completely different landscape in the north, showing glacial influence and Holocene deposits (Haubold 1996). The fertile soils on top of the plateaus in the Mulde-Lösshügelland developed from the several metre thick decalcified loess and were used for agriculture since earliest times (Mannsfeld & Richter 1995).

Geomorphologically, the area displays the regular repeat of two relief features, valleys and plateaus. The deeply incising valleys formed by the Zwickau and Freiberg Mulde, the Chemnitz, the Zschopau and the Striegis rivers cause a mountainous scenery, exposing the rock units of the Saxonian Granulite Massif (Sächsisches Granulitgebirge). Especially the Chemnitz and Zwickau Mulde rivers are characterised by V-shaped valleys. Partly, these valleys even are canyon-like, steep with forested and rough, rocky slopes. The alternation of narrow V-shaped (high resistance and hardness) and wide

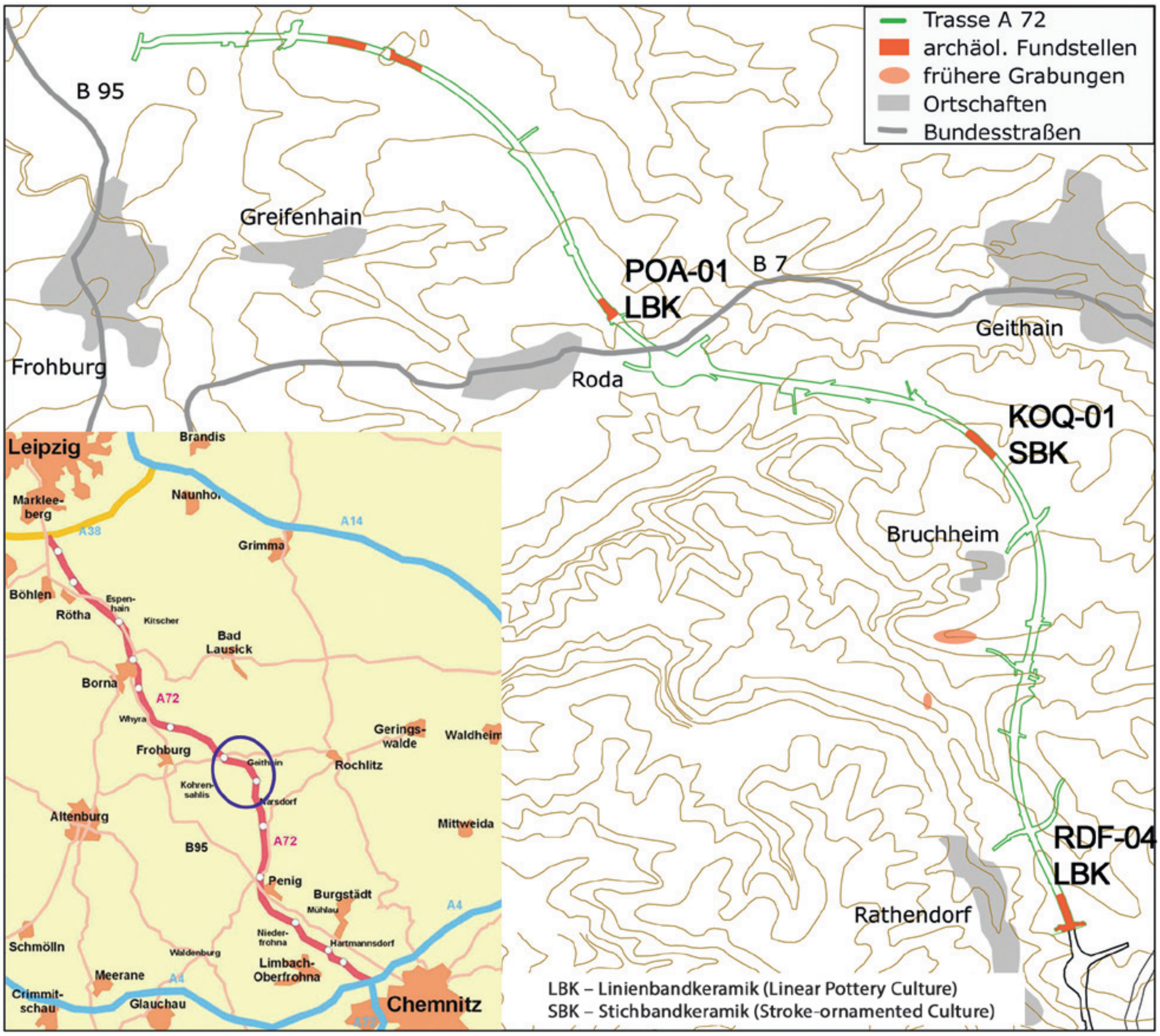

Fig. 1. The investigation area in West Saxony with the three archaeological excavation localities of Rathendorf, Bruchheim near Geithain and Roda (slightly modified, with kind permission of the Landesamt für Archäologie Sachsen).

Abb. 1. Das Untersuchungsgebiet in Westsachsen mit den drei Fundplätzen Rathendorf, Bruchheim bei Geithain und Roda (leicht verändert, mit freundlicher Genehmigung des Landesamtes für Archäologie Sachsen).

flood-plain valleys (low resistance and hardness) nicely illustrates how the shape of a valley strongly depends on the resistance and hardness of the basement units. The plateaus have plain and undulating forms. Furthermore, they are covered by loess or loessoid sediments (Oehmig 2006, Mannsfeld & Richter 1995).

The excavation localities are located adjacent to the the Northwest Saxonian Volcanic Complex (Nordwestsächsischer Vulkanitkomplex) and the Saxonian Granulite Massif. These two geological structures are supposed to represent the potential source areas for the majority of the raw materials of the artefacts.

The Saxonian Granulite Massif (Fig. 2) specifically influences the geological situation of the Sächsisches Mulde-Lösshügelland. Its granulitic core is covered by low-grade metamorphic schists and slates. The granulite is a leucocratic, fine- to medium-grained, high-grade metamorphic rock (high-pressure and high-temperature conditions of granulite facies), containing quartz, different types of feldspar (orthoclase, microcline, plagioclase) and garnet. The covering units can be subdivided into an inner and an outer zone. The former includes mica schists and gneissoid mica schists, whereas the latter is composed of phyllites and other low-grade metamorphic rocks. As these covering units are more resistant against weathering, they occur rampart-like around the granulite core.

The Northwest Saxonian Volcanic Complex (Fig. 2) is generally related to the structure of the Northwest Saxonian Basin (Nordwestsächsische Senke). It is defined by SW – NE and SE – NW-striking fault systems and composed of volcano-sedimentary deposits of mainly Rotliegend (Permian) age, partly overlain by Cenozoic sediments (Walter & Schneider 2011). Acidic vulcanites, ignimbrites and tuffs (e.g., Rochlitz Rhyolitic Tuff) are observed with intercalations of (pyroclastite-rich) fanglo-

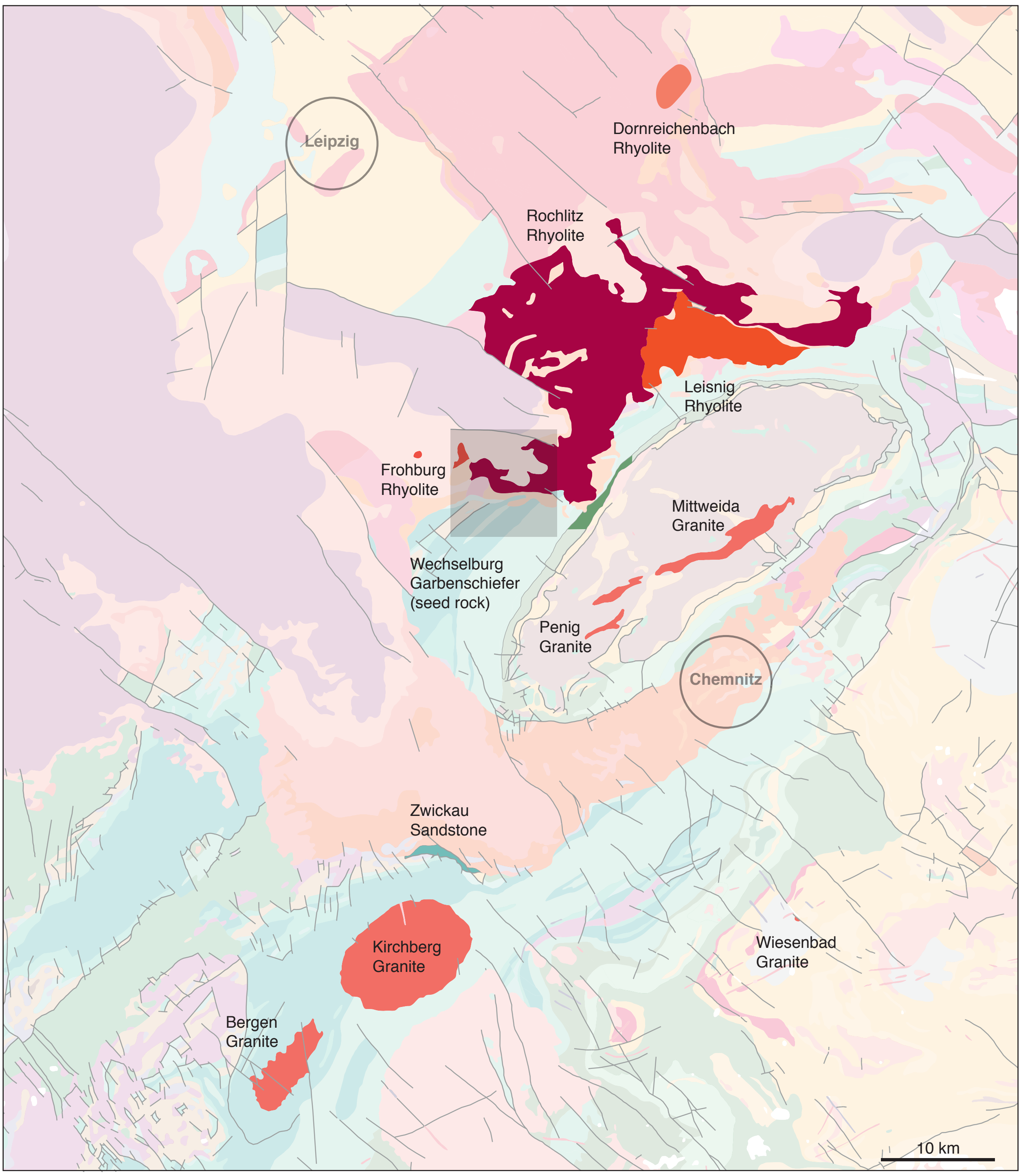

Fig. 2. Detail of the general geological map of Saxony, showing the potential source areas of the raw materials of the investigated artefacts. The quadrat marks the investigation area.

Abb. 2. Ausschnitt aus der geologischen Übersichtskarte von Sachsen, hervorgehoben sind die potentiellen Herkunftsgebiete der Rohmaterialien der untersuchten Artefakte. Das Quadrat markiert das Untersuchungsgebiet.

merates, conglomerates, (pyroclastite-rich) sand-, silt and claystones (Walter & Schneider 2011). The Rochlitzer Berg (Rochlitz Mount; 353 m above sea level) is located at the southern margin of the Northwest Saxonian Basin, at the border to the Saxonian Granulite Massif. It represents the remains of a former stratovolcano. Its prominent ignimbrite has been radiometrically dated at 294.4 ± 1.8 Ma (Walter 2012).

1.2. Archaeological basic information

The investigated artefacts (grinding and rubbing stones) mainly date into the Early Neolithic, the so-called Linear Pottery Culture, named after the typical linear decoration, ornamenting the pottery of this culture. The ornaments of the bowls and bulgy pots (piriform vessels) are

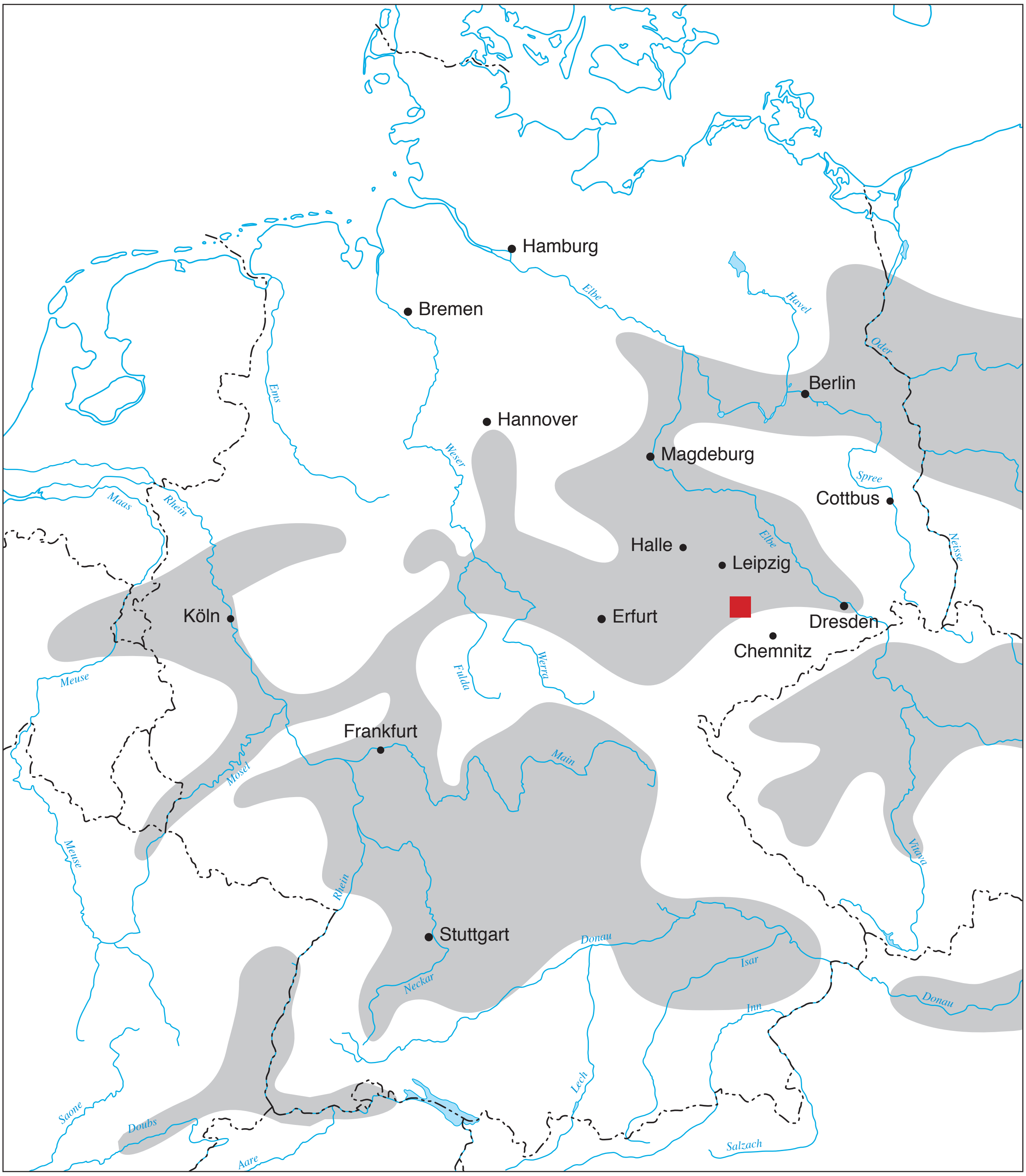

Fig. 3. Distribution of the Linear Pottery Culture in Germany (modified after Probst 1999). The investigation area is marked by a red quadrat.

Abb. 3. Die Verbreitung der Linienbandkeramik in Deutschland (verändert nach Probst 1999). Das Untersuchungsgebiet ist durch ein rotes Quadrat markiert.

carved as single lines or more complex linear patterns (Probst 1999).

The Linear Pottery Culture extended from Hungary over Bohemia along the Elbe River to Central Germany and ranged during the first two centuries (5500–5300 cal BC) onto the east bank of the Rhine River (Fig. 3). During this period, society and economy changed from hunter-gatherers to a sedentary living with a mixed farming economy. In contrast to the Mesolithic (Middle Stone Age), the Neolithic is thus characterised by domesticated animals and plants, large-scale settlements with robust built houses of wood, wattle and daub as well as ceramics and polished stone tools (Haßmann & Reuter 1996).

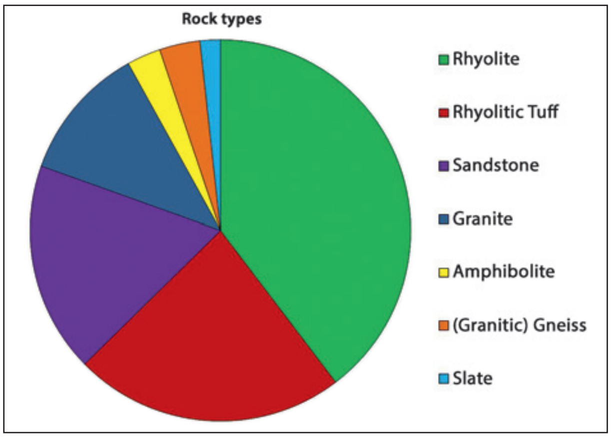

Fig. 4. Relative frequency of the rock types used as raw materials for the production of stone tools by macroscopical analysis.

Abb. 4. Relative Häufigkeiten der Gesteinsarten, die als Rohmaterialien für die Herstellung der Werkzeuge genutzt wurden nach makroskopischer Analyse.

2. Analytical methods

Primarily, the artefacts have been classified by macroscopical analysis. They have been subdivided into the established petrographical rock types – igneous, sedimentary and metamorphic. As most of them did not show any new failure surfaces, a reliable macroscopical determination was difficult to make. Considering the archaeological significance the artefacts, no new failure surfaces could be created. Additionally, the stone tools were investigated by incident light microscopy to complement their macroscopical classification.

Subsequently, they were compared with rock samples of the collection of the Sektion Petrographie. Reference samples from possible source areas for the raw materials of the artefacts were selected. Special attention was given to reference material from areas, directly adjoining to the Neolithic localities.

Fieldwork and sampling of rocks from petrographically corresponding units in the surroundings of the excavation localities followed.

For further and more detailed studies, the preparation of thin sections was necessary. In the laboratory of the Sektion Petrographie, thin sections of all rock samples, serving as reference material, and also of selected artefacts were made for the comparison by microscopical analyses (polarisation microscopy, SEM and EDX). The thin sections of the artefacts and reference samples were investigated, regarding their petrographical characteristics such as texture and structure as well as their mineralogical and chemical composition. For polarisation microscopy, a Leica DM4500P microscope was used. SEM and EDX analyses were done with a SEM ZEISS EVO 50 instrument. The SEM analysis was conducted in the backscattered electron (BSE) modus.

3. Results

The macroscopical investigation of all 291 artefacts helped to get a general overview of the raw materials and the relative frequency of the rock types used for the production of stone tools (Fig. 4). Diverse varieties of rhyolites, rhyolitic tuffs, granites and sandstones dominate as raw materials. Furthermore, the combination of different specific analytical methods such as polarisation microscopy, SEM and EDX provides the basis for the comparison of artefacts and reference samples and finally allows identifying the provenance of the raw materials of the Neolithic stone tools.

3.1. Analysis by polarisation microscopy

Essential and accessory minerals as well as texture and structure were determined for a number of 30 selected artefact and 18 reference samples by thin section analysis, using polarisation microscopy (MacKenzie et al. 1989). Based on the results of this investigation, the stone tools were assigned to the matching reference samples with an equating petrography (Tab. 1). Rhyolites represent the raw material of twelve of the stone tools. For this rock type, four important local varieties, differing in colouration and mineralogical composition, are known from the study area (Rochlitz, Frohburg, Leisnig and Dornreichenbach rhyolites). Generally, the acidic extrusive rhyolites are characterised by a porphyritic texture (coarse-grained phenocrysts in a fine-grained or compact matrix). Some rhyolites have a hyaline groundmass (sample KOQ-01, 784-2) or foreign inclusions (sample POA-01, 14-4). The quartzes often show recrystallization phenomena and the feldspars are typically twinned (e.g., plagioclase, sanidine). The biotite and feldspar components usually tend to form idiomorphic crystals. Sporadically, opaque ore minerals occur [see samples KOQ-01, 884-1 and RDF-04, 566-1(1)].

Eight artefact samples are classified as granites. Different varieties of them are named as Kirchberg, Wiesa, Mittweida and Bergen granites. Another small occurrence of granite is known from Penig. These leucocratic rocks predominantly consist of quartz, feldspar (plagioclase, alkali feldspar) and biotite. The quartzes are normally transparent and colourless. The plagioclases are usually white or grey, but effected by alteration their colour can change to bright greenish-grey or green. The orthoclases cover a wide colour spectrum, ranging from brick-red and brown to light grey. The feldspars cause the prevailing colouration of the granites. In addition to biotite, yielded in all of the granitic artefact samples, also muscovite may occur (sample RDF-04, 812-4). Further accessory minerals are augite, apatite and zircon.

Table 1. Petrographical classification of artefacts by use of polarisation microscopy.
Tabelle 1. Petrographische Bestimmung der Artefakte mittels Polarisationsmikroskopie.

Artefact	Petrography
Sample POA-01, 14-4: grinding stone fragment	Leisnig Rhyolite
Sample POA-01, 103-2: rubbing stone fragment	Frohburg Rhyolite
Sample POA-01, 103-9: grinding stone fragment	Rhyolite
Sample KOQ-01, 378-4: grinding stone	Leisnig Rhyolite
Sample KOQ-01, 784-2: grinding stone fragment	Rochlitz Rhyolite (Mutzscheroda) or Leisnig Rhyolite
Sample KOQ-01, 884-1: grinding stone fragment	Rochlitz Rhyolite (Mutzscheroda)
Sample KOQ-01, 890-1: grinding stone fragment	Granite from Penig
Sample RDF-04, 27-1(1): runner stone	Sandstone from Berthelsdorf near Hainichen
Sample RDF-04, 27-1(2): slate	Phyllitic slate from Methau
Sample RDF-04, 69-14: slate	Phyllitic slate
Sample RDF-04, 207-8: grinding stone	Dornreichenbach Rhyolite
Sample RDF-04, 566(1): grinding stone	Frohburg Rhyolite
Sample RDF-04, 566(2): grinding stone	Sandstone from Zwickau (Schloss Osterstein)
Sample RDF-04, 871-1: grinding stone fragment	Rhyolitic tuff from Wendishain (Nachtgrund)
Sample RDF-04, 654-1: solid rock	Wechselburg Garbenschiefer (seed rock)
Sample RDF-04, 677-9: grinding stone	Granite from Penig
Sample KOQ-01, 299-2: grinding stone fragment	Rhyolitic tuff from Rüdigsdorf (near Kohren-Salis)
Sample KOQ-01, 766-4: grinding stone	Sandstone from Zwickau (Schloss Osterstein)
Sample KOQ-01, 784-1(1): grinding stone	Rochlitz Rhyolite or rhyolite from Baderitz near Mügeln
Sample KOQ-01, 784-1(2): grinding stone	Rochlitz Rhyolite (Röhrgrund)
Sample KOQ-01, 847-1: grinding stone	Rochlitz Rhyolite (Röhrgrund)
Sample KOQ-01, 855-4: grinding stone fragment	Sandstone from Berthelsdorf near Hainichen
Sample RDF-04, 57-8: grinding stone	Mittweida Granite
Sample RDF-04, 575-7: grinding stone	Rhyolite
Sample RDF-04, 575-2: grinding stone fragment	Mittweida Granite/Kirchberg Granite
Sample RDF-04, 706-6: grinding stone fragment	Bergen Granite from Treuen (Kuxenberg)
Sample RDF-04, 812-4: hammerstone	Wiesa Granite
Sample RDF-04, 999-1: grinding stone	Wiesa Granite
Sample RDF-04, 654-3: solid rock	Sandstone
Sample RDF-04, 677-8: grinding stone	Mittweida Granite/Kirchberg Granite

As a mafic component hornblende is observed, too. The texture of the investigated granites is fine- to medium-grained (Mittweida and Wiesa granites). An exception forms the granite from Penig (samples KOQ-01, 890-1 and RDF-04, 677-9).

Sandstones are identified as the raw material of five artefacts. Apart from quartz, nearly all of them contain abundant mica – the only exception marks sample RDF-04, 654-3 (very low content of mica). The colouration of the sandstones varies between light grey [sample RDF-04, 27-1(1)], brown or red (sample RDF-04, 654-3). Red sediment colours can be indicators for haematite (Vinx 2008). Usually, the sandstones used for the production of artefacts show siliceous cementation (sample KOQ-01, 766-4) and are mainly fine-grained.

Three of the grinding stones were made from slate material. Two of them consist of phyllitic slate [samples RDF-04, 27-1(2) and RDF-04, 69-14] and another one of typical Wechselburg Garbenschiefer (seed rock; sample RDF-04, 654-1). The former contain chlorite, quartz and little white mica flakes (muscovite or sericite). According to Vinx (2008), the characteristical silky lustre of phyllite is caused by these fine-grained micas (especially the sericite), occurring on the cleavage planes. The samples RDF-04, 27-1(2) and RDF-04, 69-14 are clearly foliated, showing aligned clay minerals and mica components. The garbenschiefer or seed rock, representing the second type of slate used as raw material for the production of Neolithic artefacts is named after the grain sheaf-like small nodules it has. This rock type yields muscovite, biotite and fine-grained quartz. Partially, the micas are altered.

Finally, two types of rhyolitic tuff (from Wendishain and Rüdigsdorf) were determined, serving as raw material for the stone tools. The main components of these rhyolitic tuffs are feldspar (sanidine, orthoclase), quartz and mica (predominantly biotite). In addition, especially the rhyolitic tuff from Wendishain bears fragments of rocks (foreign inclusions), containing quartz and mica (e.g., slate/phyllite; sample RDF-04, 871-1). Both types of rhyolitic tuffs have a porphyritic texture with coarse-grained phenocrysts, occurring in a fine-grained matrix and a typically high porosity. Furthermore, the rhyolitic tuff from Rüdersdorf is characterised by its sandstone-like appearance.

Table 2. Descriptions of the reference and the artefact samples based on SEM and EDX analyses: **E**, essential minerals; **A**, accessory minerals; **S**, structure and texture.

Tabelle 2. Referenzgesteins- und Artefaktbeschreibungen basierend auf der SEM- und EDX-Analysen: **E**, Hauptmineralbestand; **A**, akzessorische Minerale; **S**, Gefüge, Textur und Struktur.

<table>
<tr><th>Reference sample</th><th colspan="2">Artefact sample</th></tr>
<tr><td colspan="3">Frohburg Rhyolite</td></tr>
<tr><td>E: quartz, feldspar (orthoclase, sanidine)
A: mica (biotite), montmorillonite, rutile/other varieties of titanium
S: porphyritic</td><td colspan="2">E: quartz, feldspar (orthoclase, sanidine)
A: mica (biotite), montmorillonite or kaolinite, rutile/other varieties of titanium, haematite, zircon
S: porphyritic</td></tr>
<tr><td colspan="3">Granite from Penig</td></tr>
<tr><td>E: quartz, feldspar (orthoclase, microcline, albite)
A: mica (biotite, muscovite), kaolinite/smectite, rutile/other varieties of titanium
S: holocrystalline, equigranular</td><td colspan="2">E: many quartz, feldspar (orthoclase, microcline, albite)
A: abundant mica (predominantly biotite), zircon
S: holocrystalline, equigranular</td></tr>
<tr><td colspan="3">Phyllitic slate from Methau</td></tr>
<tr><td>E: scattered grains of quartz and feldspar (orthoclase) in the matrix, clay minerals (smectite)
A: mica (sericite), garnet
S: foliated, fine-grained matrix</td><td><u>Artefact I</u>
E: clay minerals, feldspar (orthoclase), fine grained quartz
A: mica (biotite, muscovite, sericite), haematite
S: foliated</td><td><u>Artefact K</u>
E: matrix consisting of quartz and feldspar (orthoclase, albite)
A: mica (sericite), haematite, zircon
S: foliated</td></tr>
<tr><td colspan="3">Rochlitz Rhyolite (Mutzscheroda)</td></tr>
<tr><td>E: quartz, alkali feldspar, plagioclase
A: kaolinized feldspar
S: porphyritic</td><td colspan="2">E: quartz, feldspar (orthoclase, sanidine)
A: kaolinized feldspar, zircon, rutile
S: porphyritic</td></tr>
<tr><td colspan="3">Rhyolitic tuff from Wendishain</td></tr>
<tr><td>E: feldspar (orthoclase, nepheline?), quartz
A: mica (biotite, muscovite), augite
S: porphyritic, porous, foreign inclusions (phyllite/slate fragments)</td><td colspan="2">E: fine-grained quartz, feldspar (orthoclase, sanidine)
A: clay minerals (smectite, kaolinite), zircon, augite
S: porphyritic with a high porosity</td></tr>
<tr><td colspan="3">Leisnig Rhyolite</td></tr>
<tr><td>E: quartz, feldspar (orthoclase, sanidine)
A: mica (biotite), clay minerals (smectite), augite
S: porphyritic</td><td colspan="2">No sample available.</td></tr>
<tr><td colspan="3">Wechselburg Garbenschiefer (seed rock)</td></tr>
<tr><td>E: matrix consisting of quartz and feldspar
A: mica (biotite), garnet
S: foliated</td><td colspan="2">No sample available.</td></tr>
<tr><td colspan="3">Bergen Granite</td></tr>
<tr><td>E: quartz, feldspar (orthoclase, microcline)
A: mica (biotite), zircon, augite?
S: holocrystalline, directionless structure</td><td colspan="2">No sample available.</td></tr>
<tr><td colspan="3">Wiesa Granite (Wiesenbad)</td></tr>
<tr><td>E: quartz, feldspar (plagioclase, orthoclase)
A: mica, apatite, fluoride, rutile/cassiterite
S: holocrystalline, medium-grained</td><td colspan="2">No sample available.</td></tr>
<tr><td colspan="3">Leipzig Greywacke (Großzschocher)</td></tr>
<tr><td>E: feldspar (orthoclase, albite), quartz
A: clay minerals, zircon, rutile, apatite
S: fine-grained</td><td colspan="2">No sample available.</td></tr>
</table>

3.2. Analyses by scanning electron microscopy (SEM) and energy dispersive X-ray spectrometry (EDX)

16 thin sections of reference and artefact samples were investigated, regarding their texture and structure as well as their mineralogical and chemical composition by use of scanning electron microscopy (SEM). Moreover, also energy dispersive X-ray spectrometry (EDX) was used to determine the distribution and concentration of chemical elements. An overview of the results obtained by these SEM and EDX analyses is given in Tab. 2.

3.3. Comparison and potential source areas

In summary, a comparison of all investigated samples, considering the different analytical methods is provided, correlating the reference and respective artefact samples

Table 3. Comparison of the artefact and reference samples.
Tabelle 3. Vergleich der Artefakt- und Referenzproben.

Reference sample	**Comparable artefact** (macroscopical investigation)	**Comparable artefact** (microscopical investigation)	**Remarks**
Sample 1: **Frohburg Rhyolite**	POA-01, 103-2 RDF-04, 566-1(1)	POA-01, 103-2 RDF-04, 566-1(1)	Both artefacts correspond to the reference samples, regarding the mineralogical composition and fabric.
Sample 2: **granite from Penig**	KOQ-01, 890-1 RDF-04, 677-9	KOQ-01, 890-1 RDF-04, 677-9	Both artefacts correspond to the reference samples regarding the mineralogical composition and fabric. These three samples, show an identical grain size and a medium- to coarse-grained texture.
Sample 3: **Rochlitz Rhyolitic Tuff** (Rochlitzer Berg, Mount Rochlitz)	POA-01, 103-9 KOQ-01, 884-1	No comparable artefact.	Both artefact samples are identified as rhyolites by means of macroscopical analysis. Sample POA-01, 103-9 cannot be classified as Rochlitz Rhyolite Tuff. Sample KOQ-01, 884-1 is similar to the Rochlitz Rhyolite.
Sample 4: **phyllitic slate from Methau**	RDF-04, 27-1(2) RDF-04, 69-14	RDF-04, 27-1(2) (RDF-04, 69-14)	The reference sample and sample RDF-04, 27-1(2) are identical, regarding the grain size. Both are classified as phyllitic slates. Sample RDF-04, 69-14 is also a slate, but it does not correspond to the slate variety known from Methau.
Sample 5: “**Lagergranit**” **Auenbachtal**	No comparable artefact	No comparable artefact.	
Sample 6: **Rochlitz Rhyolite** (Mutzscheroda)	POA-01, 14-4 KOQ-01, 784-2	KOQ-01, 784-2 KOQ-01, 884-1 (KOQ-01, 784-1(1))	Sample POA-01, 14-4 is a rhyolite, but it does not correspond to the Rochlitz Rhyolite. It probably represents a Leisnig Rhyolite (sample 9). Samples KOQ-01, 784-2 and 6 are identical with respect to their mineralogical composition and distribution of minerals. The same applies to sample KOQ-01, 884-1. Sample KOQ-01, 784-1(1) firstly was classified as rhyolite from Baderitz, but according to the analysis by polarization microscopy, it can also represent a Rochlitz Rhyolite.
Sample 8: **rhyolitic tuff from Wendishain** (Nachtgrund)	RDF-04, 871-1	RDF-04, 871-1	Both samples are similar with regard to their mineralogical composition. An accordance with the rhyolitic tuff from Wendishain is not clearly evidenced.
Sample 9: **Leisnig Rhyolite** (Zöllnermühle)	KOQ-01, 378-4	KOQ-01, 378-4 POA-01, 14-4 (KOQ-01, 784-2)	Both artefact samples (samples KOQ-01, 378-4 and POA-01, 14-4) are classified as Leisnig Rhyolite, due to their mineralogical composition, textural and structural fabric.
Sample 11: **Dornreichenbach Rhyolite** (Wurzen**)**	RDF-04, 207-8	RDF-04, 207-8	The artefact is classified as Dornreichenbach Rhyolite (same mineralogical composition, textural and structural fabric).
Sample 12: **Wechselburg Garbenschiefer** (seed rock)	RDF-04, 654-1	RDF-04, 654-1	The artefact is classified as Wechselburg Garbenschiefer (seed rock; same mineralogical composition, textural and structural fabric).
Sample 13: **Mittweida Granite**	RDF-04, 57-8 RDF-04, 575-2	RDF-04, 57-8 RDF-04, 575-2 (RDF-04, 677-8)	The three artefact samples correspond very well to the reference sample, regarding the mineralogical composition, textural and structural fabric. Sample RDF-04, 677-8 possibly represents a Kirchberg Granite (sample 16).
Sample 14: **sandstone** (Rotliegend) **from Berthelsdorf** near Hainichen	KOQ-01, 855-4 RDF-04, 654-3	KOQ-01, 855-4 (RDF-04, 27-1(1))	Sample KOQ-01, 855-4 and sample 14 show an identical mineralogical composition. Sample RDF-04, 654-3 is also a sandstone, however, its mineralogical composition does not correspond to that of sample 14. Sample RDF-04, 27-1(1) is a sandstone, containing mica and thus, it is very similar to the reference sample.
Sample 15: **Bergen Granite from Treuen** (Kuxenberg)	RDF-04, 706-6	RDF-04, 706-6	Both samples have the same mineralogical composition (rich in mica, containing quartz and feldspar), textural and structural fabric.
Sample 16: **Kirchberg Granite** (Borberg)	RDF-04, 757-7 RDF-04, 677-8	(RDF-04, 677-8)	Microscopical analyses revealed that sample RDF-04, 757-7 is not a granite, but a rhyolite. Sample RDF-04, 677-8 probably corresponds to the Mittweida Granite (sample 13).
Sample 17: **Wiesa Granite** (Wiesenbad)	RDF-04, 812-4 RDF-04, 999-1	RDF-04, 812-4 RDF-04, 999-1	All three samples have an identical mineralogical composition and show a strong textural and structural similarity. Their main components are equal.
Sample 18: **Leipzig Greywacke** (Großzschocher)	RDF-04, 27-1(1)	No comparable artefact.	Both samples are similar in their mineralogical composition, but the texture of sample H is more granulitic than that one of sample 18. The artefact sample is a fine-grained sandstone, not a greywacke. It nicely corresponds to the sandstone from Berthelsdorf (sample 14).
Sample 19: **Rochlitz Rhyolite** (Röhrgrund)	KOQ-01, 784-1(2) KOQ-01, 847-1	KOQ-01, 784-1(2) KOQ-01, 847-1	Both artefact samples have the same mineralogical composition, textural and structural fabric as the reference sample (porphyritic structure).
Sample 20: **carboniferous sandstone from Zwickau** (Schloss Osterstein)	RDF-04, 566-1(2) KOQ-01, 766-4	RDF-04, 566-1(2) KOQ-01, 766-4	The samples are very similar, regarding their mineralogical composition (fine-grained quartz, mica and some feldspar).

Fig. 5. Comparison of two artefacts (samples B and E) and the corresponding reference samples (samples 1 and 6): **a**, Frohburg Rhyolite (left: artefact, right: reference sample); **b**, Rochlitz Rhyolite (Mutzscheroda; left: artefact, right: reference sample). Scale: 5 cm.

Abb. 5. Vergleich zweier Artefakte (Proben B und E) und der zugehörigen Referenzgesteinsproben (Proben 1 und 6): **a**, Frohburger Rhyolith (links: Artefakt, rechts: Referenzmaterial); **b**, Rochlitzer Rhyolith (Mutzscheroda; links: Artefakt, rechts: Referenzmaterial). Maßstab: 5 cm.

(Tab. 3). The first results obtained by the macroscopical classification of artefact samples had to be partly revised after the microscopical analyses by polarisation microscopy, SEM and EDX. Two examples are chosen, evidencing and illustrating the validity of the compiled correlation of artefact and reference samples (Fig. 5). It is superbly demonstrated that each sample pair consists of the same material.

4. Discussion and conclusions

The rocks used as raw materials for the production of Neolithic stone tools are identified to come from the adjacencies of the three excavation localities in West Saxony. Their classification based on macro- and microscopical analyses (polarisation microscopy, SEM and EDX) corresponds to that of the reference samples from the Saxonian Granulite Massif and the Northwest Saxonian Volcanic Complex, leading to the assumption that these two geological regions represent the main source areas. More precisely, typical lithological units the raw materials accord with regarding their mineralogical and chemical composition and fabric are the Mittweida Granite, the granite from Penig, the Wechselburg Garbenschiefer (seed rock) and the phyllitic slate from Methau from the Saxonian Granulite Massif as well as the Dornreichenbach, Leisnig, Frohburg and Rochlitz rhyolites and the rhyolitic tuff from Wendishain from the Northwest Saxonian Volcanic Complex (Northwest Saxonian Basin). Further regions raw materials occur from are the western Erzgebirge (Westerzgebirge; Wiesa and Kirchberg granites) and the Vogtland (Bergen Granite from Treuen). The sandstone used for the production of the investigated artefacts is suggested to come primarily from the Zwickau area. Only one specimen is supposed to represent a sandstone from Berthelsdorf. The provenance of two artefact samples made from slate material cannot be definitely determined, but their close similarity to the slate units from Methau has to be noted. Microscopical analyses helped to identify the putative Leipzig Greywacke (Großzschocher) raw material as sandstone, thus excluding the respective locality as potential source area. In conclusion, the raw materials for the production of the stone tools come from localities situated within a distance of 7 km (Rochlitz) to 100 km (Treuen) from the Neolithic excavation sites. From the archaeological point of view, this implicates a remarkable range of coverage.

The broad accordance of the chemical and mineralogical composition as well as of the textural and structural properties of the artefact and reference samples, tested and proved by different analytical methods, provides a reasonable correlation. The results presented herein allow to state that the source areas of the raw materials used for the production of Neolithic stone tools are situated especially in the regions of the Saxonian Granulite Massif and the Northwest Saxonian Volcanic Complex.

The frequency scale of rock types used for the production of artefacts reflects a broad knowledge about the properties of the raw materials. Rhyolites and rhyolitic tuffs dominate, implicating a long life expectancy, resulting from their high hardness (Mohs hardness: 6 – 7) and good resistance against weathering – this characteristics analogously apply for the granites. Additionally, the rhyolitic tuffs are well suited for processing, due to their compactness and equality in grain size. A noteworthy exception marks the use of sandstones and phyllites/slates as raw materials. Both rock types weather easily and their high content of mica causes low hardness (Mohs hardness: 2 – 3). Thus, they are very sensitive to mechanical stress. Another negative feature concerning the phyllites and slates is caused by their foliation. Probably, the Neolithics recognised the impracticalness of these raw materials very quickly and this may be the reason why only few artefacts of the respective rock types were found at the archaeological excavation sites of Neolithic settlements.

A further important task is to reason out how the different rocks, which were used in early Neolithic settlements, got to the localities. One possibility is that the raw materials were transported by glacial drift during the ice age, mainly the Elster glacial period. Another possibility is that the raw materials used for stone artefacts may have been transported by fluvial action of the Zwickau Mulde River and its tributaries from the south (Vogtland, Erzgebirge) to areas nearby the Neolithic settlements. The first option is the more likely one, as the examined raw materials of the stone artefacts mainly come from northeastern areas. Sporadically, even Scandinavian granites occur. A third possiblity would be an anthropogenic transport by trade relations between different Neolithic families or lineages. Most of the Neolithic settlements in West Saxony are concentrated west and northwest of the three archaeological excavation localities, which are dealt within this article. Probably, there was a lively trade of goods with farmers of these neighbouring areas in Thuringia and around Leipzig.

Future research projects on this topic should include detailed analyses of all artefacts to determine additional source areas. A precise differentiation, concerning the provenance of the used raw materials, can only be guaranteed by the combination of comprehensive macro- and microscopical analytical methods.

5. Summary

The present results make a significant contribution to geoarchaeological topics, relating to the Neolithic in Saxony. Grinding and rubbing stones were investigated, regarding the provenance of their raw materials. After macroscopical classification of the stone tools, thin sections of the artefact samples were analysed microscopically and compared with that of reference samples from characteristical lithological units of potential source areas. Hence, the source areas of the raw materials used for the production of stone tools in the Neolithic could be determined, situated within a radius of up to 100 km around the respective excavation localities. The provenance mainly focusses on the regions of the Saxonian Granulite Massif and the Northwest Saxonian Volcanic Complex. Different local varieties of according rock types were identified. They are dominated by rhyolites and rhyolitic tuffs as the Neolithics may have been recognised their excellent suitability for the use as stone tools. Their high hardness and resistance against weathering provides a long life expectancy for the grinding and rubbing stones.

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7. References

Haßmann, H.; Reuter, U. (1996): Die Jungsteinzeit. – In: Leipzig und sein Umland – Archäologie zwischen Elbe and Mulde. – Führer zu archäologischen Denkmälern in Deutschland, Band 32. – 39 – 42, Stuttgart (Theiss Verlag).

Haubold, F. (1996): Das Rochlitzer Land. – Mitteilungen des Landesvereins Sächsischer Heimatschutz e.V., **1/1996**: 14 – 20, Mügeln.

Henningsen, D.; Katzung, G. (2002): Einführung in die Geologie Deutschlands. – 1 – 214, Heidelberg, Berlin (Spektrum Akademischer Verlag).

MacKenzie, W.S.; Donaldson, C.H.; Guilford, C. (1989): Atlas der magmatischen Gesteine in Dünnschliffen. – 1 – 141, Stuttgart (Enke).

Mannsfeld, K.; Richter, H. (Eds., 1995): Naturräume in Sachsen. – Forschungen zur deutschen Landeskunde, Band 238. – 1–228, Trier (Selbstverlag).

Oehmig, K. (2006): Die Pflanzen von Penig und Umgebung – einschließlich der Gebiete des Messtischblattes Burgstädt. – 7– 11, Grimma (winterwork).

Probst, E. (1999): Deutschland in der Steinzeit. – Jäger, Fischer und Bauern zwischen Nordseeküste und Alpenraum. – 1–619, München (Orbis Verlag).

Vinx, R. (2008): Gesteinsbestimmung im Gelände. – 1–469, 2. Auflage, Berlin (Springer).

Walter, H. (2006): Das Rotliegend der Nordwestsächsischen Senke. – Veröffentlichungen des Museums für Naturkunde Chemnitz, **29**: 157–176, Chemnitz.

Walter, H. (2012): Rotliegend im Nordwestsächsischen Becken. – Schriftenreihe der Deutschen Gesellschaft für Geowissenschaften, **61**: 517–529, Hannover.

Walter, H.; Schneider, J.W. (2011): 3.3 Perm – Rotliegend. – In: Pälchen, W.; Walter, H. (Eds.): Geologie von Sachsen I – Geologischer Bau und Entwicklungsgeschichte. – 223–257, Stuttgart (Schweizerbart).

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