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ARCHAEOMETRIC INVESTIGATION OF THE STONE TOOLS OF THE VATYA CULTURE (PEST COUNTY, HUNGARY)

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Abstract. With the analysis of the middle Bronze Age (2000–1350 BC) Vatya culture findings in Pest county (Central Hungary) comprising of more than 400 polished stone tools and instrument tools this is the first archaeometric study with such scale in Hungary. In order to characterize petrographically the raw-material of the stone tools macroscopic and microscopic stone analyses were made together with mineralogical and geochemical analyses. In the course of the work a new digital database the Archaeometric Stone Tool Database was established. Based on the results, the material of the instrument stones is mainly sandstone and quartzite that were easy to collect from their source areas. Local volcanics, mostly amphibole containing andesite variations dominated among the material of the polished stone tools. Ophiolites (metamorphic basic rocks, serpentinized basic and ultrabasic rocks) were the raw-material of stone axes that indicate either more distant travels for raw-material or exchange import.

Keywords. Archaeometrics, Carpathian Basin, Vatya culture, polished stone tools, instrument tools

1. INTRODUCTION

Petroarchaeology is a specific part of archaeometrics involving the mineralogical, petrological, geochemical and other geological, physical and chemical analysis of mineral or stone material tools for archaeological purposes (Herz & Garrison, 1998; Rapp & Hill, 1998).

In case the geological view is applied in studying archaeological tools, questions can be answered that could be researched less effectively by other methods. Results can contribute to the better understanding of the lifestyle, movements and technical development of stone cultures (Pető & Kelemen, 2000; Szakmány, 2009).

Based on this approach, we have been studying the stone tool findings of the middle Bronze Age Vatya culture since 1996 in the framework of an archaeologist – geologist co-operation. The results were of significant interest from both archaeological and geological points of view (Farkas–Pető, 2008; Horváth et al., 1999; 2000a; 2000b; 2001; Pető et al., 2002).

The middle Bronze Age (2000-1350 BC) Vatya culture occupying the central part of the Danube-Tisza Interfluve (Fig. 1) has special significance from several aspects as it controlled the most important routes in the Carpathian Basin: the Danube and the associated smaller river network in central Hungary. Natural conditions of this area determined fundamentally the lifestyle of the culture in which agriculture had a central role. This is one of the most completely explored Bronze Age tell culture in Hungary with variable settlement types, multi-layered society, marked and united findings (Bóna, 1992).

The analysis of more than 400 stone tools of the Vatya culture from Pest county presented here is the closing stage of our research. Analysing the known polished stone tools and instrument stones of the whole culture presents the opportunity for such overall statistical analyses that would not be possible on the basis of only a few localities, tools or instrument types.

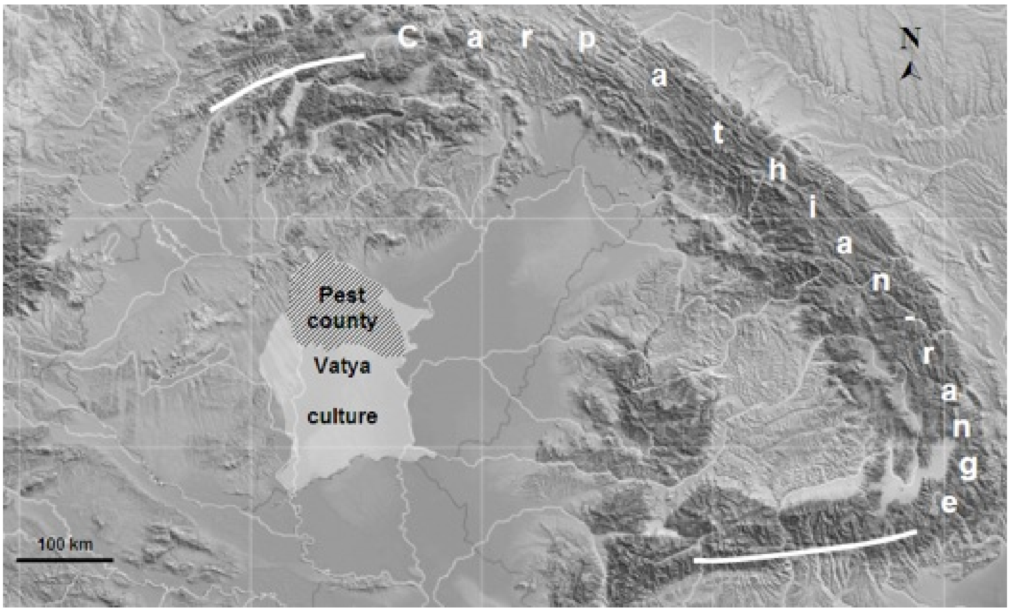

Figure 1. Area of the Vatya culture (middle Bronze Age) in the Carpathian Basin

2. MATERIAL AND METHODS

2.1. Archaeological findings

The stone tool findings presented in this paper are owned by several museums and local historical collections including: Kossuth Lajos Museum, Cegléd; Hungarian National Museum, Budapest, Prehistoric Collection; Blaskovich János Museum, Tápiószele (from the local historical collection at Gyömrő); Arany János Museum, Nagykőrös; Ferenczi Museum, Szentendre; Local Historical Collection, Solymár.

2.2. Literature analysis and field research

In order to identify potential raw-material source areas the literature was analysed then rock samples were taken for comparative analysis from the most probable source areas of the stone tools.

2.3. Macro- and microscopic rock analyses

Macroscopic and microscopic analyses for the comparative characterization of stone tools were performed in the Department of Mineralogy and Geology, University of Debrecen.

At the museums the stone tool types were classified into petrographic groups based on macroscopic characters. Destructive analyses were performed on mostly damaged samples the detailed analysis of which could represent their own group and in this way they became standards.

In order to keep to the least destruction principle cylindrical samples (10-30 mm; ∅=8 mm) were taken by a special (own) construction diamond micro-core-driller (Farkas-Pető, 2008, Pető & Farkas, 2002) or from cuts in the tools or from their chops parallel laminae were prepared in order to create thin-sections. Optic characterization and photo documentation were made using a Nikon Microphot-SA type research microscope.

Mineralogical composition of the samples was determined primarily by microscopic identification controlled by *XRD analyses* carried out in the XRD Laboratory of the Geological and Geophysical Institute of Hungary using a Philips PW 1710 diffractometer applying Cu anticathode and graphite monochromator at 2 ϴ°/minute paper velocity. Parameters of the pipe current were 30 mA and 40 kV. Interpretation was carried out using a multiple query software at +/- 10% error rate.

2.4. Geochemical analyses

Major element analysis of the rocks was carried out in the analytical laboratory of the Department of Mineralogy and Geology, University of Debrecen based on the following chemical procedures: Na_2O and MgO was determined by atomic absorption method with a Zeiss-Jena AAS-1 spectrometer. SiO_2, TiO_2, Al_2O_3, CaO, K_2O and total iron (as Fe_2O_3) were determined by WDXRF method with a Rigaku 3063P spectrometer. A tungsten anode X-ray tube was used at 30 kV and 15mA. For Al_2O_3 and SiO_2, an EDDT single crystal was used, other elements were determined by using a Ge(111) crystal. All measurements were made in vacuum. The international nomenclature (Le Bas et al, 1986, Rollinson, 1993) was used for naming the magmatites.

2.5. Archaeometric stone tool database

The first rock based stone register in Hungary, the Lithoteca was established in the Hungarian National Museum and it has become available electronically (T. Bíró & T. Dobosi, 1991; T. Bíró, 2005, T. Bíró et al., 2000). On the basis of this idea we created the Archaeometric Stone Tool Database during the years of studying the stone tools of the Vatya culture. The primary base of this new register is the detailed archaeological-petrographic-geochemical characterization of the stone tools with the identification of the probable source area.

3. RESULTS

3.1. Overall characteristics of the stone tools of the Vatya culture in Pest county

From the polished stone tools and instrument stones of the Vatya culture found in Pest county (Fig. 2) 410 were analysed archaeologically and petrographically, the data of which are summarized in Table 1.

3.2. Results of the petrographic-geochemical analysis of the findings

Classification of the raw-material of stone tools was made according to rock species. This system is followed in this chapter.

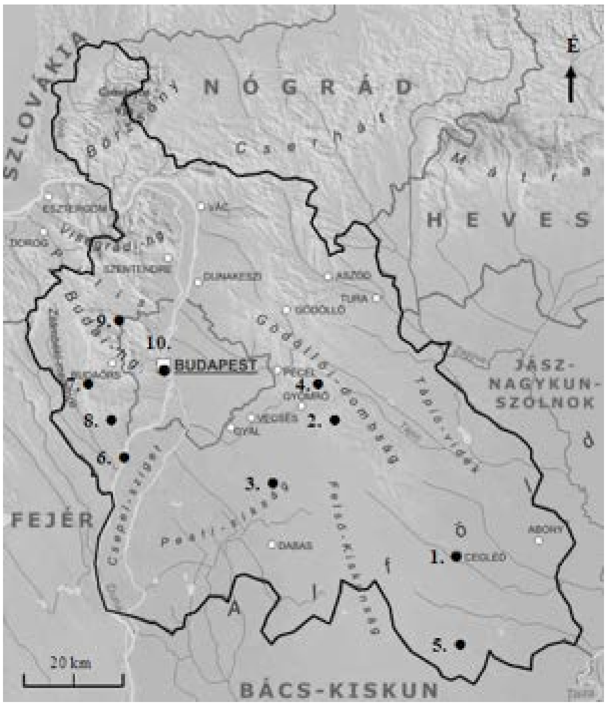

Figure 2. Location of the Vatya localities in Pest county (Hungary): 1. Cegléd-Öregszőlők; 2. Gomba-Várhegy; 3. Kakucs-Balladomb; 4. Mende-leányvár; 5. Nagykőrös-Földvár; 6. Százhalombatta-Földvár; 7. Biatorbágy (Bia); 8. Érd-Érdliget; 9. Solymár-Várhegy; 10. Budapest belterülete (Várhegy-Budavári palota, Kis-Velence, Lágymányos, Soroksár-Várhegy, Péteri-major).

3.2.1. Sandstones

Most frequent rock type of the raw-material of tools, primarily the instrument stones (grinding stones and sheets) is sandstone that forms a very heterogeneous group (Table 1).

Table 1: Raw-material of the Vatya instrument stones and polished stones in Pest county

Rock types	Tool types			∑
	Polished stone tools (stone axe, hatchet, chisel, hammer, mace, amulet)	Instrument stones (grinding stone, grinding sheet, grindstone, anvil, polishing-stone, mortar, pounder, whetstone)	Other (ballast, unprocessed pieces, etc.)	
Sandstone	11	157	10	178
Limestone	-	8	3	11
Volcanics (amphibole and pyroxene andesites, basaltic andesites and their tuffs)	26	29	7	62
Intrusive igneous rocks (diorite, granite)	1	2	3	3
Ophiolites (serpentinized ultrabasics; metamorphic volcanics)	29	-	-	29
Quartzite – metamorphic sandstone, pelagic siliceous sediments	12	68	27	107
Other metamorphic rocks	1 (amfibole schist)	1 (gneiss)	-	2
Other (unidentified)	6	8	4	18
∑	86	273	51	410

Further sub-classes can be identified within this group based on the macroscopic and microscopic analyses:

- *Permian red sandstone* (4 pieces)

This is a reddish brown coloured, strongly cemented sandstone. Certain samples show micro-stratification and slight, flat dipping cross-bedding. Textural orientation is the result of the oriented position of mica sheets (mainly biotite, weathered biotite and muscovite) along the beds. The size of the mica sheets is 0.1 mm generally, they are of mm size occasionally. Colour variation of the material can be the result of the pulsating load in-wash from the terrestrial background.

In thin-section the grains are of equal size suggesting good sorting, they are, however, slightly rounded indicating short transportation.

Quartz prevails in its composition together with biotite, weathered biotite, polysynthetic acid plagioclase with twinning laminae and at places sericitized potassium feldspar. High number of weatherable constituent suggest near terrestrial background (Fig. 3). This area was probably composed of granitoid rocks. Moderately weathered character indicates arid-semi-arid palaeoclimate. Deposition took place in nearshore, calm water of marine environments (e.g. on shelves).

In the spaces between grains re-crystallized silica gel films coloured by brown ironstone can be observed. Subordinately carbonate cementing can also be found. These can be syndiagenetic as well.

These sandstones presumable represent the Balaton Uplands variation (Fig. 16) of the Permian red sandstone formation (Gyalog, 1996; Császár, 1997).

- *Hárshegy type sandstone* (135 pieces)

The rock used mostly as raw-material for grinding stones is grey, compact, middle to coarse grained sandstone and fine grained conglomerate.

Its colour is determined by the frequency of coloured minerals and the amount of brown ironstone dissolved from them. The distribution and coating character of this colouring mineral also influence the colour of the rock. Slight bedding is general in the rocks, their grains are not oriented within the strata. Orientation is mainly caused by the distribution of the brown ironstone colouring material. The size of the greatest grains rarely exceeds 2-5 mm, the dominant grain-size is between 0.5 and 1.5 mm. Constituents are generally slightly or moderately rounded, well rounded grains are rare.

Constituents of this sandstone include particles from metamorphic quartzite, silicified metamorphic siltstone and metamorphic sandstone (Fig. 4), however, brown ironstone impregnated rock fragments and minerals are also visible from which brown ironstone dissolution is possible. The rock contains igneous minerals subordinately, however, most of these are altered, hardly identifiable. Some mica, mainly muscovite also appears. Pores are abundant in the rocks. This can be partly explained by the fall of loose grains but the texture was originally compact and porous in variable ratio. Siliceous dissolution appears along certain grain boundaries and this accounts for the high strength of the rocks.

Based on the above, a not too distant mostly metamorphic, subordinately igneous terrestrial background seems to be probable and the sandstone was reworked several times. Its deposition could have taken place in marine conditions with a slight sorting according to grain-size. This rock type can be identified with the rocks of the Hárshegy Sandstone Formation (Gyalog, 1996; Császár, 1997) exposed in several outcrops in the margin of the Buda Mountains (Fig. 16).

- *Neogene (Miocene-Pliocene) sandstones* (39 pieces)

Within the group of instrument stones mostly grindstones and moulds were prepared from this type of sandstone due to their relatively rough surface, moderate hardness and effective porosity enabling the degassing of castings.

This group involves brownish grey, slightly cemented (can be broken by hand), fine-middle grained, micaceous, volcanogenic sandstones rich in dark constituents.

Structural orientation and stratified, sedimentary character of the sandstone can be seen best at small magnification in thin-section (Fig. 5).

Their grains are slightly rounded, fractured and mainly hypidiomorphic. Altered biotite dominates the material with less amphibole appearing with orientation similar to the stratification. Certain pyroxenes, green and brown amphiboles, biotites, some pale ironless versions together with plagioclases with twin laminae and quartz can be identified among the grains. Variable amount of micropatitic carbonate matrix and brown ironstone covered silica glass (hyalite?) can be observed in the space among the grains.

The shallow marine – nearshore characteristics of the rock type, the mixed composition and age of its constituents, its moderately consolidated calcareous cementing suggest that it could have been a Miocene-Pliocene formation that are generally widespread in the western margin of the Buda Mts. and can be found elevated in the northern edge of the Tétény plateau (e.g. Érd, Diósd) (Hámor, 1998) (Fig. 16).

3.2.2. Limestones

Limestone as raw-material occurred subordinately among instrument stones (11 pieces): chopping tool, grinding stone, polishing stone and whetstone are made of limestone.

Several types are found that represent the material of various age and character of Mesozoic and Cenozoic carbonates. The analysis was made difficult by the low number of samples and the patina formed on the original tools.

Regarding the material of five tools they are presumably represent Triassic or Jurassic formations. These are brownish grey, compact, partly small crystalline partly saccharoidal textured rocks with generally splintery fractures and little amount of biogenic constituents and with calcite veins. Their grains are of micropatite-patite size.

The material of two tools is strongly consolidated, dark grey coloured with the signs of compression with some clay. The rock contains radiolarian remnants, foraminifers, shell fragments(?). Their probable age can be either upper Triassic or Jurassic.

In the case of three tools it is probable that their material belongs to the Miocene Rákos Limestone Formation (Gyalog, 1996; Császár, 1997). Their colour is pale yellow, their material is slightly micro-porous but hard with splintery and conchoidal fracture. In thin-section it is visible that the strongly biogenic rock is composed mainly of choral, algae and less micro-fossils (e.g. foraminifers) and some hardly identifiable shell fragments (Fig. 6). It is possible that its initial material was choral sand formed in the wave dominated zone of nearshore environments. Pores with the diameter of 10-100 microns can be seen in the rock with calcite coatings on their edges. Some pores are filled with calcite.

The material of one tool is strongly porous, immature, slightly diagenetized, light grey – brownish grey limestone. Similar rocks can be observed in certain Sarmatian formations (Gyalog, 1996).

3.2.3. Volcanics

Andesites were abundant (59 pieces) among both instrument stones and polished tools: biotite and hypersthene containing amphibole andesite, amphibole andesite, augite containing hypersthene andesite, hypersthene andesite, hypersthene containing augite andesite, amphibole containing hypersthene andesite and subordinately biotite containing andesitic dacite tuff and basic andesite tuff together with one basalt stone tool.

Volcanic stone tools are discussed from the more basic to the more acid rock types. One of the tools (Szhb-Fv-E-SAX-76.c) is made of basalt or basaltic andesite. Only one thin-section made of its splinter was available for analysis therefore it is not representative. On the surface of the dark grey – black, compact, very fine grained rock a faint orientation was visible, however, it was not possible to identify its fenocrystals macroscopically. In thin-section a perfectly oriented, fluvial texture was seen with tiny constituents of equal size and with trachytic character at places (Fig. 7). Its dominant constituents are feldspar laths smaller than 30 μm the almost straight extinction of which suggests sanidine supported also by the presence of a few Karlsbad twins. In the matrix, very tiny brownish black, altered coloured components and opaque grains can be seen enclosed and coloured by brown ironstone.

Pyroxene containing amphibole andesites (hypersthene and hypersthene-augite containing amphibole andesites) generally widespread effusive rocks composing the majority of the Börzsöny and Dunazug Mountains. These are similar versions regarding their origin. The differences are caused by the local enrichment of coloured components. These are mostly grey and compact rocks, however, depending on their volatile contamination they can be porous and oxihydrated, red as well. Their porphyric constituents are zonal plagioclases with twin laminae apart from amphibole and/or pyroxene and biotite occurs at places as well. Texture of the hypersthene containing amphibole andesites is porphyric, pilotaxitic-hyalopilitic while the hypersthene-augite containing versions' have micro-holocrystalline–porphyric, subvolcanic texture (Fig. 8).

Texture of the *amphibole containing pyroxene andesites* can be either pilotaxitic or micro-holocrystalline-porphyric as well indicating that both volcanic and subvolcanic levels are exposed near the location of origin. Regarding the coloured components augite, hypersthene and amphibole with resorbed margin are characteristic while discoloured components are represented by neutral plagioclases (Fig. 9).

The dark grey micro-holocrystalline amphibole andesite is of mixed characteristics the phenocrysts of which include neutral plagioclase, brown amphibole, few hypersthene and biotite, however, seldom some quartz also appear.

Based on the macro- and microscopic studies and the major element analyses (Tables 2 and Fig. 11) although the basaltic andesite rock versions show differences in their mineral composition they are genetically closely related formations representing subvolcanic and volcanic levels, different lava facies and different volcanic activity phases. Comparing the results of our analyses with the major element composition of the rocks of the region (Harangi et al, 2007; Karátson et al., 2000, 2007; Korpás, 1998, Póka et al., 2004) they show similarities to the Badenian neutral volcanics of the Visegrád and Börzsöny Mts. and some of the Cserhát as well. These rocks are classified as Mátra Andesite Formation (Gyalog, 1996; Császár, 1997) (Fig. 16).

In these areas three major activity stages are identified in the Badenian volcanism (Harangi, 1994). The primary stage of the volcanic activity yielding pyroxene containing amphibole andesites was in the lower and middle part of the Badenian. The second stage of fissure or vein volcanism producing smaller amount of thick laminar amphibole containing pyroxene andesites that form ground of higher elevation than the previous group. Apart from the fresh rocks – especially in the Visegrád Mts. – oxidized versions also appear. The third stage of the neutral Badenian volcanism was of subvolcanic and vein like character the late products of which represent a transition towards the more acidic (dacite) fourth stage.

Based on the material, macroscopic and microscopic conditions and geochemical analysis (Table 4, Fig. 11) of a stone axe (Péteri major-Kb-83.4.) it is a metamorphosed dolerite. Such Jurassic rocks can be found in smaller outcrops around Szarvaskő (Szakmány, 2009), Bükk Mts. (Fig. 16).

3.2.4. Intrusive magmatites

The material of a stone axe (Szhb-Fv-Kb-SAX-9.) is a dark grey rock with white patches and compact texture that can be polished easily. Based on the major element analysis (Table 2) this rock is *diorite*. Potential source areas can the localities along the Maros river (Zarand Mts.: Păuliș, Bârzava) (Ianovici et al., 1976) (Fig. 16).

Two grinding stones were made of *granite*. One of them (Szhb-Fv-Ö-2.) is a light greyish red, equigranular, small-intermediate grain-sized rock. Its characteristic constituents are variably altered, sericitized potassium feldspars that enclose other feldspars, some plagioclases and biotite in large amount as inclusions. Larger minerals show the signs of initial perthitic intergrowth. Their extinction shows a slight undulation. The older more acidic plagioclase generation shows myrmekitic intergrowth at places (Fig. 10). Variable altered biotite can be 5-7%. The rock was affected by hydrometasomatic processes. A tiny apatite needle can be observed in the sample as an inclusion.

The other sample (Kakucs-Bd-Ö-72.) is a light red, fine grained (max. 1-3 mm), altered two mica (micro)granite that is rich in biotite but contains muscovite and muscovitized biotite as well. Yellowish pink potassium feldspar and in less amount white plagioclase is also characteristic.

Samples can be related to the palingenetic granites in Transdanubia (Fülöp, 1994, Gyalog & Horváth, 2000) based on the microscopic analysis. The first sample could be originated from the Velence Mts. while the second rather resembles the granites at Mórágy, Mecsek Mts. (Fig. 16).

3.2.5. Ophiolites

Most of the ophiolite like stone tools (29 pieces) are of subvolcanic origin, compact, fine-grained, dark grey – black, micro-porphyric *metamorphic basic rocks* and *serpentinized basic – ultrabasic rocks* that suffered from greenschist or occasionally amphibolite metamorphism. Their material is hard but can be polished easily.

Their original texture is either slightly oriented or not oriented at all, however, the dynamometamorphic structure as a result of compression shows some kind of orientation. On certain samples a lizardite layer can be observed. The rocks are variably serpentinized therefore their texture is variable as well. Optically remnant textures and metamorphic modifications can also be observed. Reticular chrysotile has the most typical appearance (Fig. 12). Some of them have sub-ophitic texture, they are relatively fresh while others are strongly altered tectonite serpentinite that were steatitized at places.

Element composition is influenced by hydrothermal and epigene replacements, dissolution and enrichment as well. In certain cases the alteration is of such extent that the original constituents and textural characteristics cannot be recognised. Processes mobilizing elements may result in anomalies of concentration or dissolution. Results of the microscopic analyses (Figs 12, 13, 14) were supported by XRD analyses as well. Variable degree of serpentinisation, chloritic or carbonate metamorphic-metasomatic alterations are characteristic for the samples.

Outstanding magnesium content is found (Table 3) in one sample (Szhb-Fv-Kb-17.) that can be explained by the high baumite content. Cummingtonite and clinozoizite also appear in the mineral composition (Szb-Fv-Kb-130.) (Fig. 13). Table 3 summarizing the major element composition reveals that a significant standard deviation is characteristic for these rocks showing both alkaline and calc-alkaline characters.

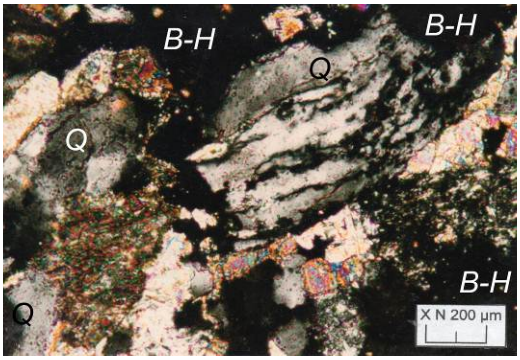

Figure 3. Microscopic image of a stone axe made of Permian red sandstone (Szhb-Fv-Kb-6.) (***Q***=quartz-quartzite, ***B-H***= brown ironstone)

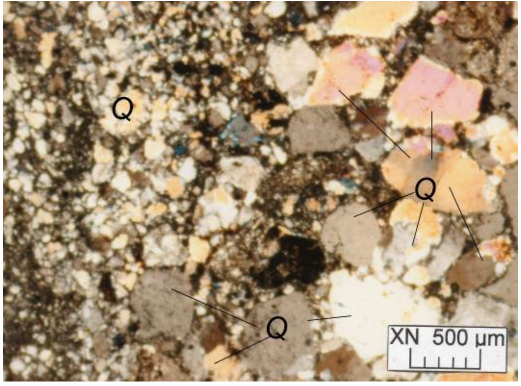

Figure 4. Microscopic image of a grinding sheet (Solymár-Vh-Öl-7.) composed of Hárshegy type sandstone (***Q***=quartz-quartzite)

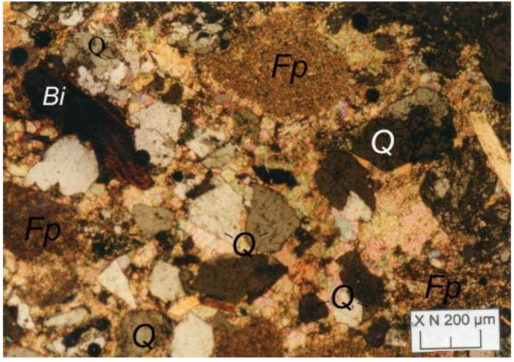

Figure 5. Microscopic image of a grinding stone (Szhb-Fv-Ö-4.) of Neogene sandstone (***Q***=quartz-quartzite; ***Bi***=biotite, ***Fp***=feldspar)

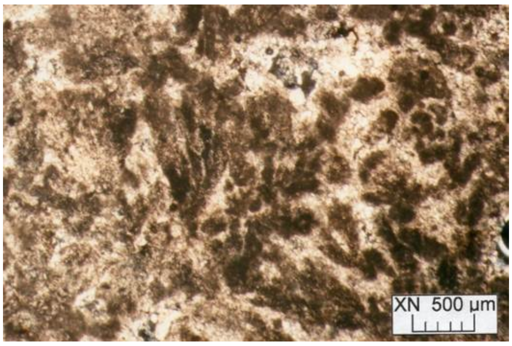

Figure 6. Microscopic image of a grinding stone (Szhb-Fv-Ö-SAX-81) composed of biogenic limestone

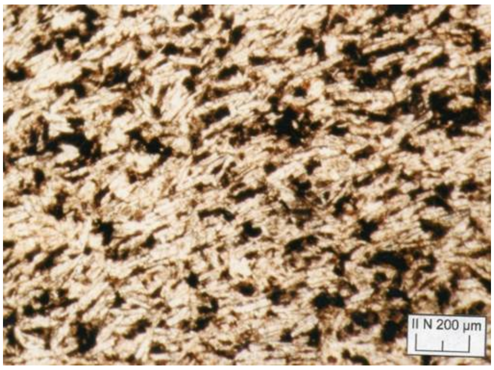

Figure 7. Microscopic image of a stone tool (Szhb-Fv-E-SAX-76.c.) composed of basalt showing the characteristically orientated plagioclase laths

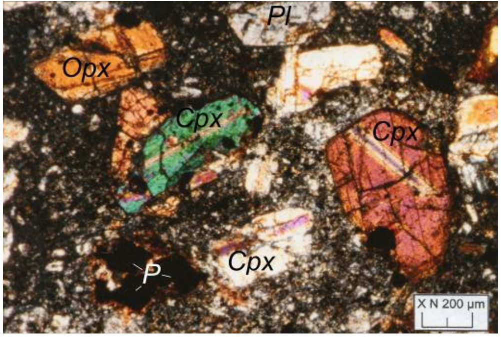

Figure 8. Microscopic image of a hammer (Szhb-Fv-K-5.) composed of amphibole containing hypersthene andesite (***Pl***=plagioclase ***Opx***=ortopyroxene;***Cpx***=clinopyroxene,***P***=pyrite)

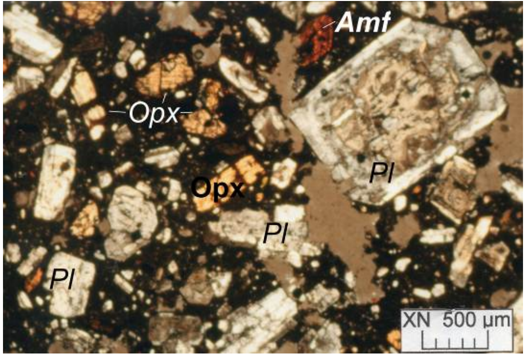

Figure 9. Microscopic image of a grinding stone (Kakucs-Bd-Ö-175) made of hypersthene containing amphibole andesite (***Pl***=plagioclase, ***Amf***=amfibole; ***Opx***=ortopyroxene)

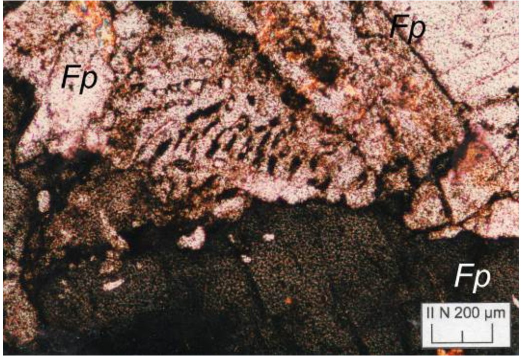

Figure 10. Microscopic image of a grinding stone (Szhb-Fv-Ö-2.) made of granite. The older more acidic plagioclase generation shows myrmekitic intergrowth (***Fp*** = feldspar)

Table 2. Major element composition of stone tools made of igneous rocks (weight%)

Sample	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	CaO	MgO	Na_2O	K_2O	P_2O_3	(+)H_2O	(-)H_2O	CO_2	total
Cegléd-Ösz-Kb-87.10.19 pyroxene andesite	56.39	0.61	19.46	3.25	282	0.21	7.10	4.77	2.78	1.96	-	0.86	0.45	0.14	100.79
Szhb-Fv-Kb-20. pyroxene andesite	58.56	0.86	17.55	4.55	3,01	0.15	8.13	4.17	2.23	2.44	0.29	1.38	-	-	100.06
Szhb-Fv-K-Kb-28. pyroxene andesite	56.26	0.71	17.29	0.60	6,29	0.11	7.51	3.06	1.94	3.45	0.17	2.30	-	-	99.69
Szhb-Fv-Kb-3. pyroxene andesite	55.72	0.85	17.50	4.49	2,97	0.15	8.00	4.11	2.20	2.41	0.20	1.71	-	-	100.31
Kakucs-Bd-Ük-106. amph. pyroxene andesite	57.20	0.68	16.97	3.74	3,59	0.31	6.56	1.94	2.88	2.14	-	0.83	0.40	0.10	97.35
Kakucs-Bd-Ö-175. amph. pyroxene andesite	60.41	0.47	18.31	3.78	1,81	0.20	7.01	2.47	2.67	2.20	-	0.21	0.18	0.32	100.03
Nagykőrös-Fv-Ö-64.893. amph. pyroxene andesite	53.72	0.77	20.17	3.05	2,72	0.20	10.33	2.11	2.91	1.29	-	0.58	0.51	1.66	100.01
Nagykőrös-Fv-Ö-90.21.3. pyrox. amphibole andesite	56.23	0.68	17.48	4.08	2,64	0.28	7.83	3.70	2.52	2.64	-	0.85	0.31	0.51	99.74
Kakucs-Bd-Ö-21. amphibole andesite	55.43	0.76	20.66	4.45	3,24	0.32	7.84	2.14	3.12	1.89	-	0.13	0.11	0.23	100.33
Solymár-Vh-Ö-6. amphibole andesite	59.71	0.51	18.62	3.96	1,64	0.36	6.06	2.73	2.65	1.67	-	0.80	0.13	0.25	99.08
Szhb-Fv-Csk-Ö-SAX-12.a. amphibole andesite	57.27	0.65	19.71	5.77	0,62	0.13	6.74	3.12	2.44	1.84	-	1.75	0.27	0.24	100.56
Szhb-Fv-Kb-SAX-32. amphibole andesite	55.55	0.86	19.36	3.65	2,97	0.21	7.95	4.29	2.20	2.02	-	0.92	0.28	0.47	100.73
Szhb-Fv-E-SAX-55. amphibole andesite	56.58	0.53	20.69	6.17	0,62	0.30	7.37	2.46	3.12	1.24	-	1.57	0.29	0.31	101.24
Péteri major-Kb-83.4.1. dolerite, metam. dolerite	48.72	1.26	19.59	4.71	5.13	0.45	9.44	7.26	3.73	0.43	-	2.97	0.14	0.47	104.30
Szhb-Fv-Kb-SAX-9. diorite	54.96	0.80	26.05	0.40	6.13	0.35	0.74	1.49	1.82	3.03	-	3.83	0.11	0.24	99.95

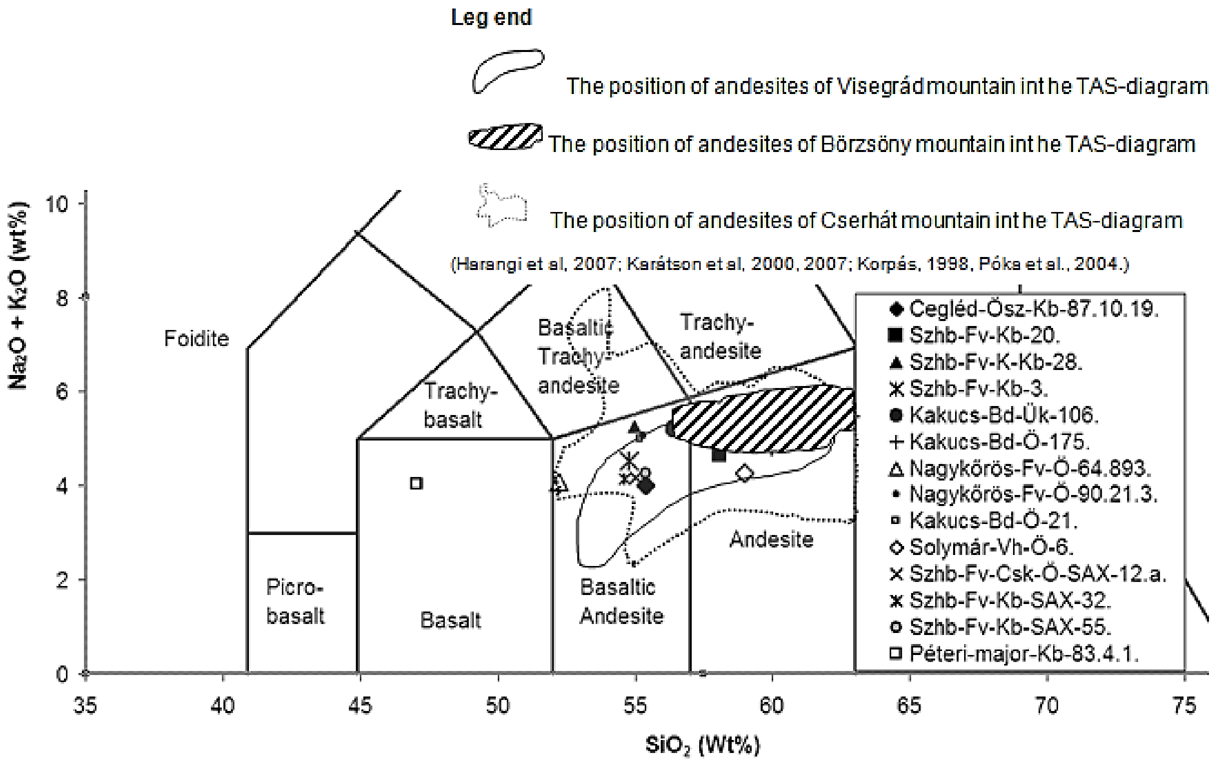

Figure 11. Material of stone tools made of volcanics and the volcanics of the potential source areas in the Total Alkali Silica (TAS) diagram.

Based on our analyses this rock series represents the mixed type of ophiolite series in which subvolcanic blocks could have been pressed into the plastic ultrabasic rocks in the course of obduction. Probably hydrothermal and epigene solution movements affected the heterogeneous formation already in an allochtonous position along the zones of foliation and brecciation.

The material of this group could be originated from the east Alpine region, the Dinaric Mountains, Slovakia, the Czech Massif or the ophiolites from the Maros valley. Based on our initial studies the samples can be related to certain parts of the greenschist formations (Koller, 1985; Höck & Koller, 1987, 1989) in the Mesozoic obducted ophiolite series in the Rohonc window in the eastern Alps (Fig. 16).

The east Alpine part of the mostly oceanic remnants of the Penninikum pinched into nappes is exposed at a few places in a form of erosion windows. In their material Mesozoic ophiolite remnants dominate but pelagic and platforms sediments together with crystalline basement remnants from the edge of the continental crust. This is a heterogeneous melange like formation associated with the tectonic events of the Cretaceous–Eocene. The Rohonc Mts. is part of the Rohonc structural window at the eastern end of the Alps the western, higher parts of which containing serpentinite and gabbro blocks belong to Austria. Its Hungarian part is represented by the Kőszeg Mts. the lower formations of which are composed of carbonaceous phillite, quartz phillite and quartzite.

The original ultrabasic-basic composition of the Rohonc formation is also suggested by a few liquid magmatic ore minerals (e.g. magnetite, chromite, chalcopyrite). Due to the variable metamorphic-metasomatic processes the altered rocks are rich in secondary mineral associations, dynamometamorphic and hydrometasomatic sections. Pale chlorite schists, amphibole schists, tourmaline and actinolite containing associations, bronzite rich versions, chrisotile veins, fibrous asbestos and talc also appears at places. Hydrothermal and oxidation-cementation processes are indicated by the occurrence of quartz, calcite, opal, pyrite, few sphalerite, stephanite, brown ironstone, iron ochre, malachite, manganite, etc.

Well known formation of the east Alpine formation is the serpentinized ophiolite complex that has been mined for several decades. The complex is divided into two larger and several smaller blocks in the course of the Alpine tetonic events. The material of this greenish black – blackish green serpentinite mass is suitable for carving and polishing ornaments from it near Bernstein (Amber Stone). The material was used for making stone axes during the Neolithic in Central Europe (Bernardini et al., 2012, Szakmány, 2009, Péterdi, 2011).

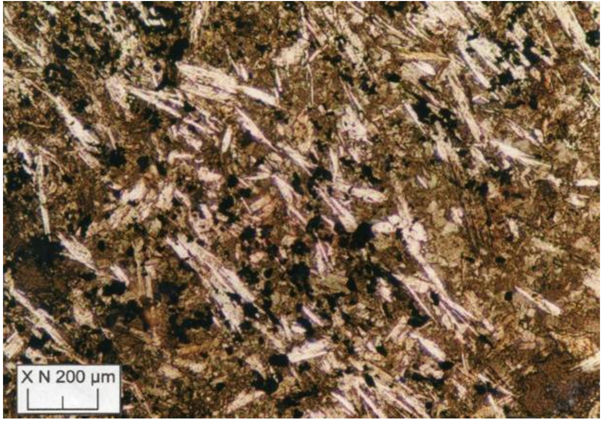

Figure 12. Microscopic image of a chisel hatchet (Szhb-Fv-Kb-17.) made of serpentinized ultrabasic rock with antigoritic texture

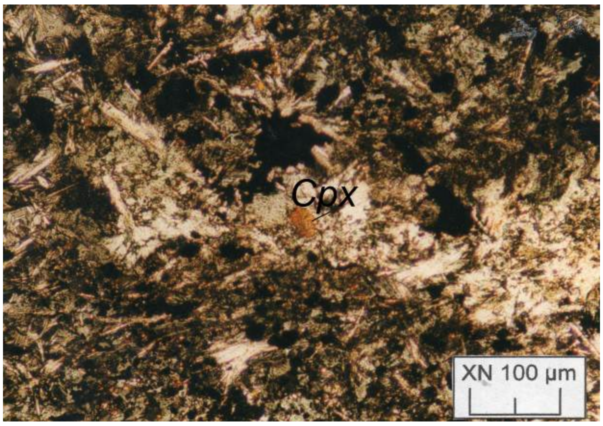

Figure 13. Microscopic image of a stone axe (Szhb-Fv-Kb-130.) made of serpentinized metamorphic basic rock with clinozoizite in bundles, chlorite and some mica (***Cpx*** = clinopiroxene)

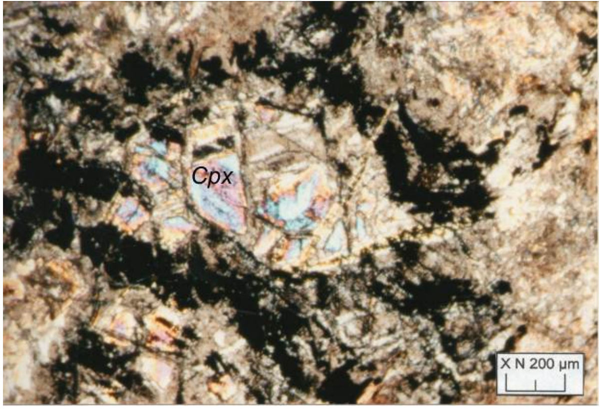

Figure 14. Microscopic image of a stone axe (Szhb-Fv-SAX-Kb-8.) made of serpentinized ultrabasic rock with altered pyroxene crystal that is enclosed by opaque weathering products (***Cpx*** = clinopiroxene)

3.2.6. Quartzites, pelagic silica sediments

The most frequent stone type among handstones, groundstones and smoothing stones is quartzite the initial material of which could be metamorphic sandstone, metamorphic siltstone or the segregational quartz lenses of a parametamorphic series (Fig. 15).

Such rocks appear at several places in the Palaeozoic-Mesozoic basement of the Carpathian Basin (Fülöp, 1990, 1994). As the most resistant rocks they accumulate in the river load partly in reef barriers and partly in alluvial fans also.

Considering the Vatya culture, closest source areas could be the Danube load of the Pest Plain (Fig. 16) where gravel pits are numerous even today. The studied tools are made of moderately rounded river gravel.

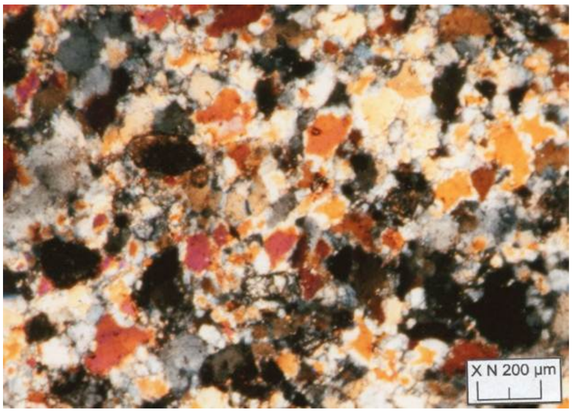

Figure 15. Microscopic image of a tool (Nagykőrös-Fv-E-90.19.24. 1.) showing quartzite grains in a metamorphic sandstone with a compact texture

4. CONCLUSIONS

The tool making man selected the most suitable stones from the available types for making tools according to their function. It is probable that he relied on the field and material experience and tool making skills of former cultures. Via the experience of several cultures and generations the most suitable raw-material types for certain tools were identified. While harder quartz containing stones (e.g. granite) and silica cemented conglomerates were used for making grinding stones, for axes making andesite was widely used.

Serpentinized ultrabasic and metamorphic basic rocks from the ophiolite series of the eastern Alps appear solely as raw-material for polished stone tools in the area of the Vatya culture mainly as material of tools for ornamental and religious purposes. This type was the raw-material for the stone axes of several cultures in Central Europe during the Neolithic (Bernardini et al., 2012) therefore it is presumable that the Vatya culture acquired the material via not a single collection in large amount but through long-term trade relationship.

Numerous conclusions can be drawn from the petrological and geoarchaeological-archaeometric analyses of the material of the stone tools of the Vatya culture found in Pest county.

Table 3. Major element composition of stone tools made of metamorphic basic and serpentinized ultrabasic rocks and of the samples taken from the possible source areas (weight%)

Sample	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	CaO	MgO	Na_2O	K_2O	P_2O_3	(+)H_2O	(-)H_2O	CO_2	sum
Szhb-Fv-Kb-SAX-71. metamorphic basic rock	49.74	2.80	19.48	0.86	9.62	0.47	9.54	5.95	1.48	0.48	-	0.23	0.04	0.47	101.15
Szhb-Fv-Kb-16. serpentinized basic rock	52.70	1.33	10.80	2.09	11.12	0.15	5.57	13.79	0.29	1.88	0.27	2.90 !	-	-	100.17
Szhb-Fv-Kb-SAX-8. serpentinized ultrabasic rock	39.77	0.06	5.44	3.47	2.65	0.41	3.23	32.31	0.05	1.44	-	9.99 !	0.13	0.83	99.77
Soroksár-Vh-Kb-14. serpentinized ultrabasic rock	43.26	0.06	18.03	1.28	2.18	0.30	12.18	18.60	1.09	0.98	-	0.06	0.09	0.29	98.42
Szhb-Fv-Kb-23. serpentinized ultrabasic rock	39.27	1.87	17.87	5.43	7.20	0.20	11.29	8.18	3.26	2.46	0.57	1.47	0.20	-	99.27
Szhb-Fv-Kb-17. serpentinized ultrabasic rock	41.22	0.03	1.43	4.31	2.12	0.07	0.29	37.25!	0.10	2.00	0.01	11.49 !	0.19	-	100.51
Rohonc-Bernstein ethalon sample	33.82	0.48	8.91	8.19		-	1.59	36.20	0.05	0.12	-	11.02 !	0.19	-	100.57

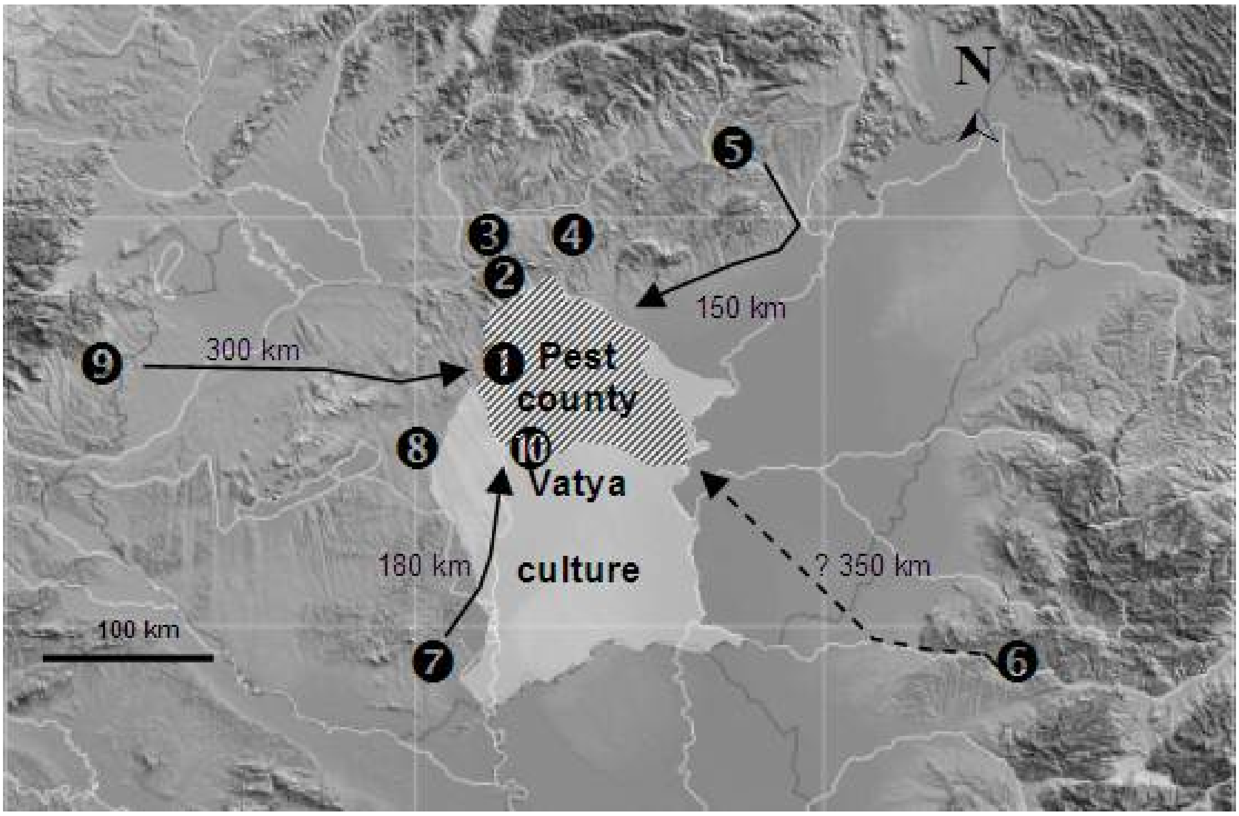

Figure 16. Presumable source areas of the raw-material of the stone tools of the Vatya culture in Pest county **Sandstones:** ❶ Buda Mts.; **Andesites:** ❷ Visegrád Mts., ❸ Börzsöny, ❹ Cserhát; **Dolerite:** ❺ Bükk Mts., Szarvaskő; **Diorite:** ❻ Maros valley (Zaránd Mts.); **Granite:** ❼ Velence Mts., ❽ Mecsek, Mórágy block; **Ophiolites** (metamorphic basic, serpentinized basic ultrabasic rocks): ❾ East Alpine ophiolites, Rohonc, Bernstein; **Quartzites, pelagic sediments, other metamorphic rocks:** ❿ Pleistocene gravel in the Pest Plain.

This group with developed stone industry was probably collecting raw-material from nearby sources, mainly in their own dwelling places, however, more distant routes of collection or exchange trade are also possible. Our analyses also support the idea of close raw-material source areas (Buda Mts., Visegrád Mts., Börzsöny, Cserhát, Velence Mts., Pest Plain) (Fig. 16).

In our opinion the distance from which raw-material arrived is around 2-50 km in the case of stones from around their own dwelling places while it would be around 100-400 km in the case of import stones. The latter one indicate mostly E-W movement and trade, however, N-S also seems probable but in more limited volume and extent (Fig. 16).

The most important result of the study of more than 1000 stone tools of the Vatya culture is the system (Archaeometric Stone Tool Database) in which the functional and petrographic characteristics of the tools are stored in a modern, internationally accessible form that can be extended and developed. The system is capable of containing a series of exact analyses results adding to the reliability and reproducibility of the investigations. A further advantage of its application is the reduction of the necessity of destructive analyses. In case practice justifies the effectiveness and usefulness of the system, it could be used for the establishment of other archaeometric databases.

The analyses were extended over the comparative study of the rock types in the most probable raw-material source areas. Based on these the origin of the stone material can be determined with great certainty. The origin of the different rock types can be determined with different probability, however, their later punctuation is made possible by the digital record.

If the demand, movements and technology are described based on all these their comparison to other research data (e.g. export-import, advancement of technologies) this can make the image of the given culture clearer.

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