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NEOLITHIC/AENEOLITHIC BLUESCHIST AXES: NORTHERN SLOVAKIA

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Abstract: In a set of stone artefacts from sites located in the Popradská kotlina Basin and in the County of Spiš (northern Slovakia) we, among others, also identified axes made from blueschist. We consequently studied four of them using electron microprobe. Blueschists, raw material of mentioned axes, are composed of glaucophane, omphacite, garnet, albite, zoisite and other minerals in a subordinate amount. The composition of genetically significant blueschist phases is used to discuss the provenance of this raw material type. Comparing the presented composition of the blueschist minerals with those of the blueschist bodies known in surrounding geological units we incline to derive the raw material of the blueschist implements found in northern Slovakia from the blueschist occurrences in the Mesozoic Meliata Unit (southeastern Slovakia).

Key words: Northern Slovakia, Neolithic/Aeneolithic, Meliata Unit, implements, raw material, blueschists.

Introduction

In the Popradská kotlina Basin as well as in the County of Spiš archaeological excavations were realized on several sites in the past. Some of the documented Neolithic/Aeneolithic and Early Bronze Age implements are deposited in the Podtatranské múzeum in Poprad. From the set of artefacts we studied about 60 thin sections. Among them 6 thin sections is represented by rock-types containing also blue amphibole (Fig. l). Typological ranking and description of the raw material types used for implements construction are presented in details in paper by Hovorka & Soják (1997).

Glaucophane schists (blueschists) are a rarely occurring rock-type in central Europe. Their occurrences are described from several geological units. In spite of the fact that the majority of blueschist bodies have been known since the beginning of the 20th century, it is only in the very last years that their geodynamic setting has served as the main subject of intensive studies. Petrological studies become more effective by the use of electron microprobe in determination of the composition of the blueschist rock-forming minerals of individual occurrences. Systematic petrographic studies of the raw materials used by the Neolithic/Aeneolithic populations living in the territory of the modern Slovak Republic resulted in acceptance of the idea of long-distance transport of at least some stone artefacts (tools, weapons) from their source areas (Illášová & Hovorka 1995; Hovorka & Illášová 1996; Hovorka et al. 1997, 1998). On the other hand, in some places raw material of very local provenance was used (Banská et al. 1998).

Central European blueschist occurrences

At present the following occurrences of the blueschist are known in central Europe (Fig. 1):

1) Bodies of deca- to hectometre dimensions were already known by the end of the l9th century (references in Kamenický 1957) from the Meliata Unit cropping out within the belt on the southern rim of the Slovak Karst (Fig. l, area l). On the basis of the results of pioneering works by Kamenický (1957) and Reichwalder (1973), petrological studies in detail (Faryad 1995; Faryad & Henjes-Kunst 1997) were carried out in the last years. Some aspects of the problem were also studied by Ivan & Kronome (1996). Up to now information has been presented in a paper by Faryad (1997a).

2) In recent years, in eastern Slovakia, two pebbles (6×3×4 and 3×2×2 cm) of glaucophane schists from a small outcrop of Lower Cretaceous polymict conglomerates assigned to the Krížna Nappe (unit) were described in detail (Ivan & Sýkora 1993).

3) Other blueschist pebbles in conglomerates have been described from the following occurrences:

a) One pebble of blueschist was reported by Zoubek (1931) from the Paleogene conglomerates located close to the Pieniny Klippen Belt in the valley of the river Orava.

b) Detritus of blue amphiboles described by Mišík (1976) from the Pieniny Klippen Belt in the Váh river valley. Blueschist pebble problems was later studied by several authors (Martin 1991; Dal Piaz et al. 1995). A summary, and new results based on 24 pebble studies from the above mentioned geological unit is presented in paper by Faryad (1997b).

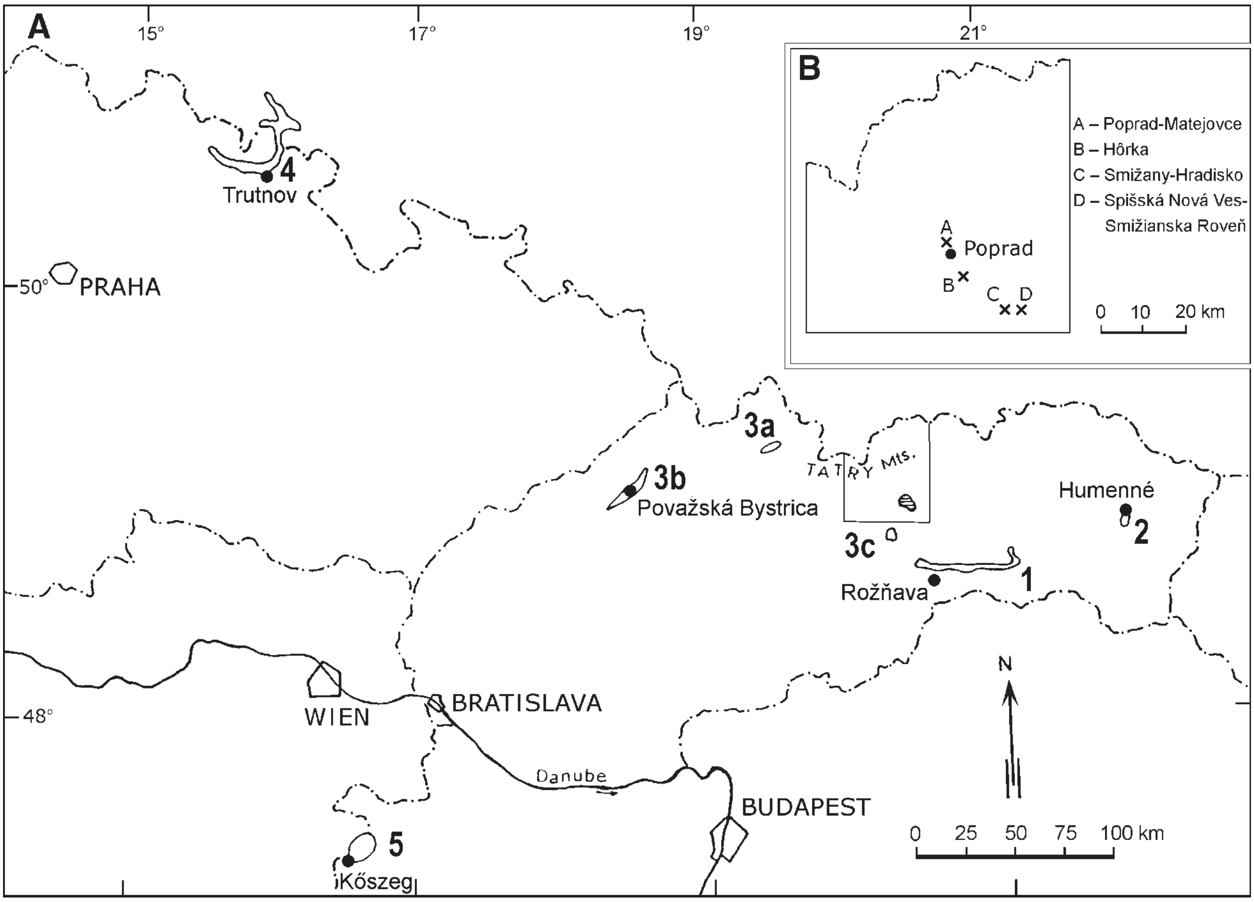


Fig. 1. A — Blueschist occurrences in central Europe: l. the Meliata Unit, 2. blueschist pebbles in the Lower Cretaceous conglomerates, 3: a. blueschist pebble in the Paleogene conglomerate in the Orava river valley, b. blueschist pebbles in the Cretaceous conglomerates of the Pieniny Klippen belt, c. blueschist pebbles in the Upper Cretaceous conglomerates by the Dobšiná Ice Cave, 4. geological units of Western Sudetes with blueschists occurrences, 5. the Rechnitz Unit of the Eastern Alps with blueschist occurrences. Shaded area to the SE of the Tatry Mts. — area is presented in Fig. B. **B —** Location of artefacts studied (x).

c) Blueschist pebbles were reported among pebbles of the Upper Cretaceous polymict conglomerates of the small (Gosau type) basin near the Dobšiná Ice Cave (Hovorka et al. 1990).

4) Glaucophane schists are known to occur in several geological units of the Western Sudetes (NE part of the Bohemian Massif) from the territory of the Czech Republic as well as from Poland. They are known from:

a) the Železný Brod crystalline complex, where Fediuk (1962) and later Cháb & Vrána (1979) and Quiraud & Burg (1984) described metatuffs of basic volcanics with blue amphibole,

b) another occurrence is located in the eastern rim of the Krkonoše Mts. (Smulikowski 1995). The Radčice Group crystalline complex (the Rýchory Mts.) bears typical mafic blueschists, which have been described in detail by Patočka et al. (1996).

c) Blueschists are also known to occur in the metamorphic complexes of the Kaczawa Mts. (Kryza et al. 1990).

5) In the Rechnitz Unit of the Eastern Alps on the Austrian-Hungarian frontier small bodies of glaucophane schist are known. They were described in the very last years by Kubovics (1983) and Lelkes-Felvári (1982).

Mineralogy and petrology

Gluacophane schists are the raw material of the artefacts from the following sites (in the text we use the original numbering):

— Spišská Nová Ves-Smižianska Roveň (2/95, 28/95),
— Smižany-Hradisko (385/85)
— Poprad-Matejovce (pit III, M-20-40)
— Hôrka
— fragment with denomination "Spiš x 2708"

Artefacts made from the gluacophane schists are dark-grey with a bluish tint, and very fine-grained. On the basis of their thin section appearence they do not belong to one rock type: four glaucophane schist axes are comparable to each other. They are represented by very fine-grained massive or slightly schistose rock without relics of primary (pre-blueschist development) mineral association or primary fabric. The leading rock-forming mineral is dark blue amphibol of long-columnar habit, with a felty character at terminations. In this rock type small crystals of clinopyroxene are also present as well as those of garnet, phengite, albite, titanite, quartz, biotite, zoisite and other minerals. A summary of the composition of the stable mineral phases present is expressed in Fig. 2.

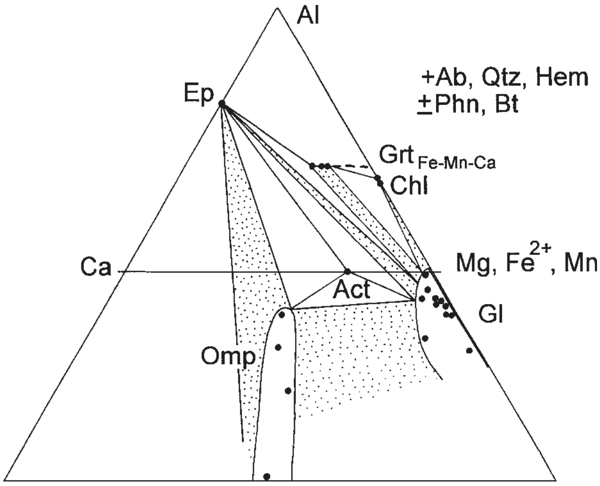


Fig. 2. Phase relations of the blueschist-made implements on the Al : Ca : Mg, Fe^{2+}, Mn plot. Ep — epidote-group minerals, Grt — garnet, Chl — chlorite, Act — actinolite, Gln — glaucophane, Omp — omphacite, Ab — albite, Qtz — quartz, Hem — hematite, Phn — phengite, Bt — biotite.

The complicated metamorphic history of this type of raw material is also documented by hair-like veinlets filled up by 2nd generation albite, zoisite and chlorite. Glaucophane schist artefacts containig garnet were found on the sites of Spišská Nová Ves-Smižianska Roveň (2/95) and Smižany-Hradisko (385/85). From the above mentioned types of raw material of the Neolithic/Aeneolithic implements (Plate I) we have carried out studies in detail.

In contrast to the rock-type characterized, above another fragment of axe from the site of Smižianska Roveň (28/95) is made from a different type of blueschist, represented by partly glaucophanized basalt with preserved ophitic fabric and primary (magmatic) clinopyroxene and ilmenite. The category of glaucophanized rocks also includes an artefact from the Hôrka site. In this case, the implement represents glaucophanized basalt/gabbro, in which blue amphibol overgrows actinolitic amphibole. For the time being we have concentrated on problems of the first type of blueschists (= 4 axes).

Blue amphibole

Deep blue pleochroic (following the gama direction) long columnar amphibole forms the dominant phase of the blueschists. The morphology of the amphibole crystals represents the favourable physical aspect of the given rock-type to be used as a raw material.

The results of microprobe studies on the blue amphiboles (Table 1) are summarized as follows: i) In various thin sections, the analysed amphiboles have a generally uniform composition, i) in the amphiboles classification (Leake 1978) they correspond to glaucophane and ferroglaucophane, while 2 analyses are projected into the field of crossite (Fig. 3). Their position near the boundary to the glaucophane and ferroglaucophane fields does not disturb the generally uniform and compact projection field in the above mentioned plot, i) CaO content is low, in one case it is over 1 weight per cent, i) the Al_2O_3 contents are similar in all analysed crystals: they vary in the range between 8.19 and 11.81 weight per cent (Table l). The majority of analyses fall into the range 9–10 weight per cent. i) Permanently high Na_2O content (over 7 per cent) indicates formation of the given rock-type under high pressure conditions.

Table 1: Microprobe analyses of Na-amphiboles and actinolite from blueschists (archaeological artefacts).

Mineral	Na-Amph (Gln)											Act
Sample	2/95		385/85	M-20-40		Hôrka			2708			385/85
SiO_2	54.27	53.26	56.70	54.84	54.24	55.65	55.93	56.90	56.48	57.32	56.83	54.99
TiO_2	-	0.03	0.05	0.22	-	0.10	-	-	0.07	0.01	0.05	-
Al_2O_3	9.07	9.59	8.19	9.64	9.99	10.93	9.56	10.07	11.81	10.80	9.97	0.77
FeO	21.53	20.83	13.74	21.41	21.25	12.00	13.04	12.34	12.47	12.42	13.37	14.57
MnO	0.13	0.15	0.04	0.12	0.24	0.15	0.23	0.05	0.03	-	0.07	0.28
MgO	4.64	4.88	10.17	3.63	3.61	9.78	10.14	10.00	8.71	9.35	9.37	15.22
CaO	0.89	1.95	0.44	0.41	0.22	1.02	0.52	0.81	0.71	0.44	0.69	11.63
Na_2O	6.99	7.04	7.67	7.17	7.55	7.36	7.43	7.19	7.33	7.67	7.17	0.63
K_2O	0.04	0.08	-	0.01	-	-	-	0.02	-	0.01	0.01	0.13
Total	97.56	97.81	97.00	97.45	97.10	96.99	96.85	97.38	97.61	98.02	97.53	98.22
Si	7.84	7.75	7.92	7.94	9.89	7.75	7.79	7.87	7.82	7.90	7.88	7.86
Al_{IV}	0.16	0.25	0.08	0.06	0.11	0.25	0.21	0.13	0.18	0.10	0.18	0.14
Al_{VI}	1.38	1.39	1.27	1.59	1.60	1.54	1.36	1.51	1.75	1.65	1.45	-
Ti	-	-	0.01	0.02	-	0.01	-	-	0.01	-	0.01	-
Fe^{3+}	0.53	0.25	0.59	0.28	0.30	0.39	0.70	0.45	0.23	0.27	0.48	0.40
Fe^{2+}	2.07	2.28	1.01	2.31	2.28	1.01	0.82	0.97	1.21	1.16	1.07	1.34
Mn	0.02	0.02	-	0.01	0.03	0.02	0.03	0.01	-	-	0.01	0.03
Mg	1.00	1.06	2.12	0.78	0.78	2.03	2.10	2.06	1.80	1.92	1.93	3.24
Ca	0.14	0.30	0.07	0.06	0.03	0.15	0.08	0.12	0.11	0.06	0.10	1.78
Na	1.96	1.98	2.08	2.01	2.13	1.99	2.00	1.93	1.97	2.05	1.93	0.17
K	0.01	0.01	-	-	-	-	-	-	-	-	-	0.02
X_{Fetot}	0.72	0.71	0.43	0.77	0.77	0.41	0.42	0.41	0.45	0.43	0.45	0.35

Formula based on 23 O and 13 cations

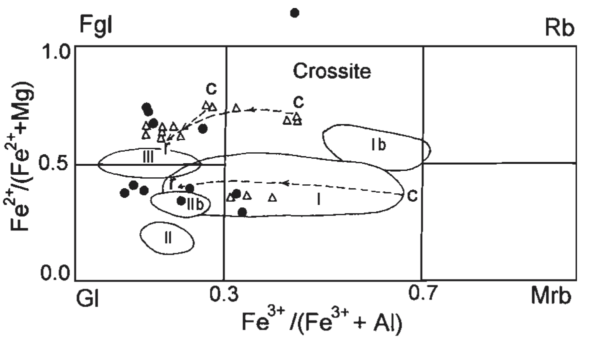


Fig. 3. Classification plot of amphiboles (Leake 1978). Fields I and II — composition of amphiboles from blueschist types I and II from the Meliata Unit described by Faryad (1995). Arrows indicate amphiboles composition zoning in direction core (c)–rim (r). Full dots — plot of analysed amphiboles (Table 1).

Pyroxene

Small (up to 0.3 mm) pyroxene xenoblasts are characterized by a very slight green tint of their pleochroic colour. In comparison to amphiboles, pyroxene is not a frequent phase (up to 10, mostly around 5 volume per cent). The pyroxene analyses presented in Table 2 correspond to omphacite (Morimoto et al. 1988), meanwhile one analysis is projected in the field of aegirine-augite (Fig. 4). Elevated aegirine molecules are characteristic of the analysed clinopyroxenes. The omphacite composition of the analysed clinopyroxenes are close to those of the Meliata Unit blueschists clinopyroxenes (see Faryad & Hoinkes 1999). The content of jadeite molecule in the clinopyroxenes studied varies in the range 25.6–37.1 mol. Jd. The lowermost value corresponds to the aegirine-augite (Fig. 4). The comparison to the clinopyroxenes of the blueschists from the Pieniny Klippen Belt (Faryad 1997b) projected onto Fig. 4 (field I) shows their differences.

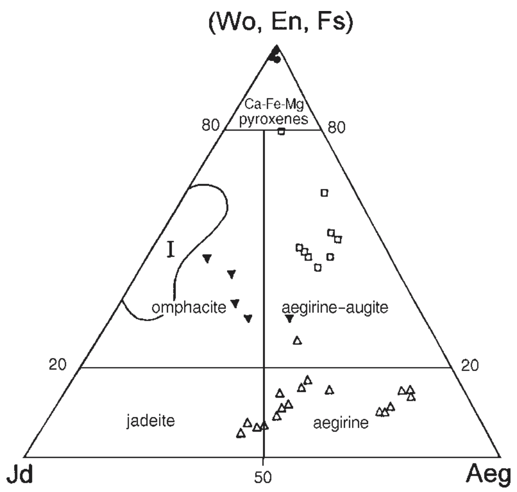


Fig. 4. Classification plot of pyroxenes (Morimoto et al. 1988). Empty triangles and squares — blueschist clinopyroxenes of the Meliata Unit (Faryad 1997a). Field I — projection plot of the clinopyroxenes; the Pieniny Klippen Belt blueschists (Faryad 1997b). Full triangles — plot of analysed clinopyroxenes (Table 2).

Table 2: Microprobe analyses of omphacite from blueschists (archaeological artefacts).

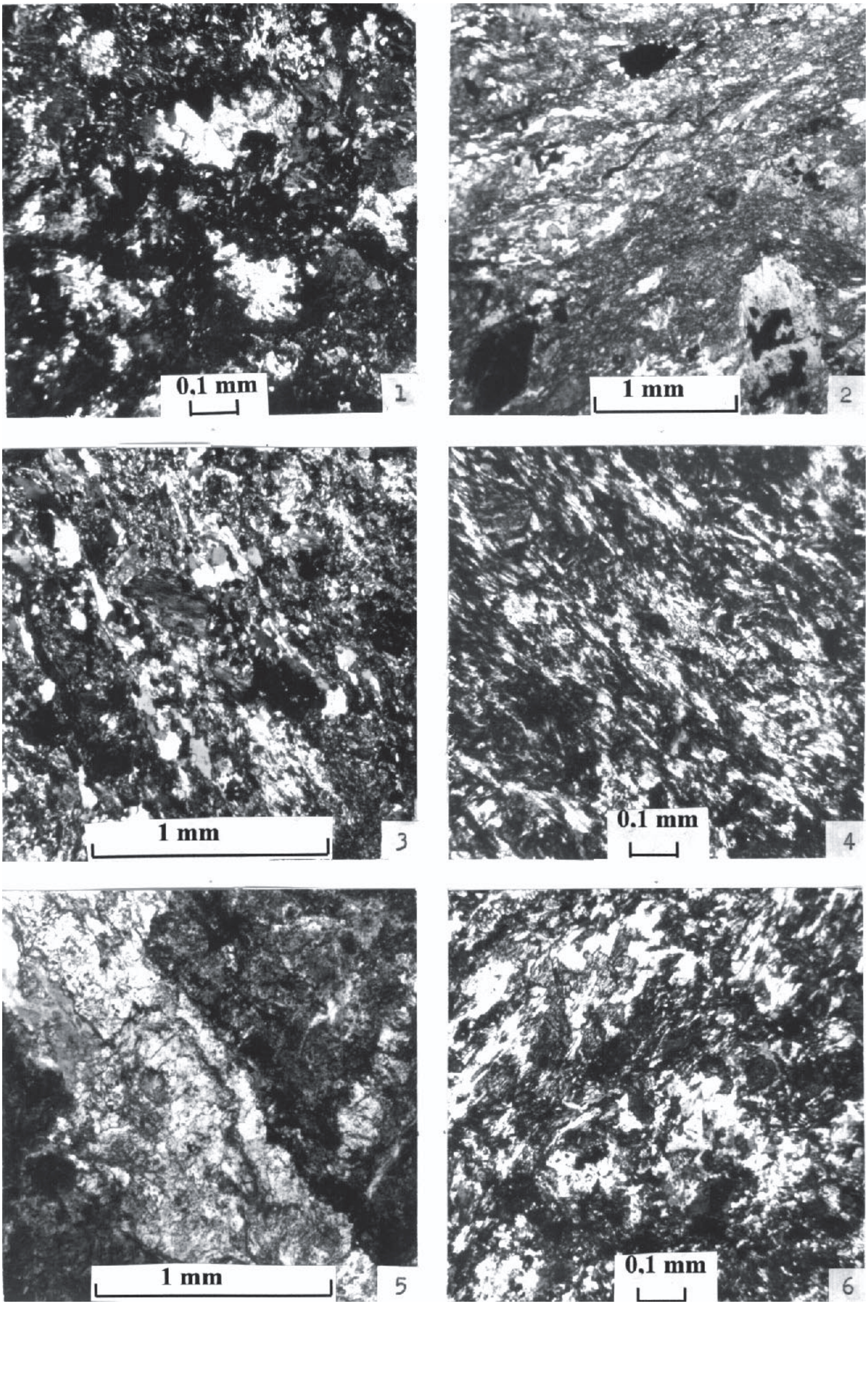
Mineral	Omp				
Sample	Hôrka			2708	
SiO_2	54.43	54.86	54.87	54.67	55.08
TiO_2	0.17	0.01	0.23	0.4	0.38
Al_2O_3	6.09	7.71	8.94	8.58	8.90
FeO	14.36	9.25	6.85	11.24	10.67
MnO	0.35	0.23	0.09	0.18	0.10
MgO	5.64	7.63	8.36	5.67	6.18
CaO	9.54	12.45	13.18	9.54	9.77
Na_2O	9.37	7.78	7.38	9.63	8.89
K_2O	-	0.04	0.07	0.02	-
Total	99.85	99.96	99.95	99.93	99.97
Si	2.04	2.01	1.99	2.02	2.02
Al_{IV}	-	-	0.01	-	-
Al_{VI}	0.27	0.33	0.37	0.37	0.38
Ti	0.01	-	0.01	0.01	0.01
Fe^{3+}	0.41	0.22	0.14	0.32	0.25
Fe^{2+}	0.04	0.06	0.07	0.03	0.03
Mn	0.01	0.01	-	0.01	-
Mg	0.31	0.42	0.45	0.31	0.34
Ca	0.38	0.49	0.51	0.38	0.38
Na	0.68	0.55	0.52	0.69	0.63
K	-	-	-	-	-
X_{Fetot}	0.59	0.40	0.31	0.53	0.49
Jd	25.6	32.1	36.8	35.5	37.1
Ac	39.2	21.3	13.3	30.1	23.9
Aug	35.2	46.6	49.9	34.4	39.0

The content of the jadeite molecule in the presented analyses is outside the content (38–60 mol. Jd.) reported by Faryad (l. c.) and in the presented analyses it varies in the range 32–37 mol. per cent Jd. The analysed clinopyroxenes are comparable to the clinopyroxenes from the Meliata Unit blueschist reported by Faryad & Hoinkes (1999) and are different from those of the blueschists from the Pieniny Klippen Belt (l.c.).

Garnet

In the studied glaucophane schist, garnet represents a characteristic (in spite of accessory amount only) silicate phase of the given rock. They are fine-grained (up to 0.2 mm), mostly idioblastic. Garnet crystals bear features of compositional zonality expressed by the change of their composition in the direction core–rim of crystals. This trend is evident on

Plate I. Fig. 1. Cumuloblasts of carbonates (light) in massive matrix of the glaucophane schist composed of fine-grained glaucophane, zoisite, albite, titanite and ore minerals. Poprad-Matejovce, X polars. **Fig. 2.** Parallel fabric of the glaucophane schist with perpendicular-oriented glaucophane (Gl) blasts with titanite enclosures. Smižianska Roveň, ||polars. **Fig. 3.** Parallel fabric of the glaucophane schist. Light spots: Gl + Ab, grey: Gl, dark: Ti, ore minerals. Smižianska Roveň, X polars. **Fig. 4.** Homogeneous, fine-grained glaucophane schists with well pronounced foliation. Poprad-Matejovce, X polars. **Fig. 5.** 1.5 mm veinlets filled up by epidote + glaucophane II in massive glaucophane schist. Poprad-Matejovce, ||polars. **Fig. 6.** Glaucophane schist — lighter irregular spots: Gl + Ab aggregates in fine-grained matrix of the rock composed of Gl + Zo + Ab + Ti + ore minerals. Hôrka, X polars.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the Alm : Spes : Gros plot (Fig. 5). By comparing the trends of composition change of individual garnet crystals, we conclude that by their composition and especially by the trend of changes, the analysed garnets are comparable to garnets of the lst group glaucophane schist reported by Faryad (1997a) from the Meliata Unit.

Table 3: Microprobe analyses of garnets from blueschists (archaeological artefacts).

Mineral	**Grt**				
Sample	**2/95**		**M-20-40**		
	core	rim	core	middle	rim
SiO_2	36.68	36.80	36.62	36.52	36.64
TiO_2	0.13	0.11	0.18	0.07	0.09
Al_2O_3	20.40	20.74	20.61	20.80	20.91
FeO	19.15	25.61	25.78	25.47	27.26
MnO	14.19	4.96	8.24	8.56	6.64
MgO	0.12	0.42	0.24	0.16	0.10
CaO	9.30	11.03	8.29	8.17	8.32
Total	99.97	99.67	99.96	99.75	99.96
Alm	41.9	56.2	57.0	56.7	60.8
Sps	31.5	11.0	18.5	19.3	15.0
Prp	0.5	1.7	1.0	0.7	0.4
Grs	26.1	31.1	23.5	23.3	23.8
X_{Fe}	0.99	0.97	0.98	0.99	0.99

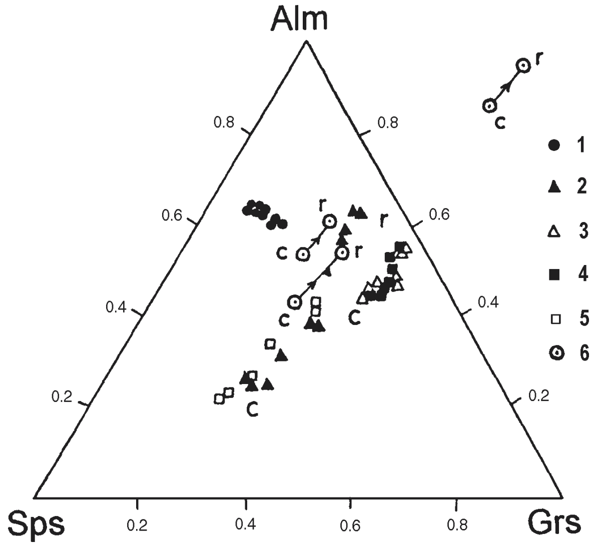

Fig. 5. Projections of analysed garnets in Pyr : Alm : Spes plot. Full dots — analysed garnets (Table 3 + additional analyses not presented in Table 3). Other symbols — projection plots of garnets; the Meliata Unit blueschist (Faryad 1975), c — core, r — rim of garnet crystals.

Table 4: Microprobe analyses of micas, chlorites, albite and titanites from blueschists (archaeological artefacts).

Mineral	**Bt**	**Phn**			**Chl**		**Ab**	**Ttn**	
Sample	**2/95**	**2/95**		**M-20-40**	**2/95**	**M-20-40**	**M-20-40**	**2/95**	**385/85**
SiO_2	36.35	51.63	51.29	50.30	24.40	24.24	68.62	30.81	30.89
TiO_2	0.51	0.19	0.14	0.30	-	-	-	37.40	37.48
Al_2O_3	13.52	23.20	25.44	27.14	18.83	19.06	18.98	1.72	1.85
FeO	30.11	6.38	5.20	5.60	35.68	37.50	-	1.16	0.91
MnO	0.22	0.07	0.02	0.12	0.42	0.35	-	0.02	-
MgO	6.86	2.64	2.77	1.68	9.13	7.53	-	0.20	0.01
CaO	0.16	-	-	0.04	0.12	-	0.15	28.37	38.72
Na_2O	0.14	0.23	0.13	0.27	0.12	0.04	11.67	-	-
K_2O	8.57	10.29	10.72	10.18	-	-	0.05	-	-
Total	96.46	94.63	95.71	95.63	88.70	99.72	99.47	99.58	99.86
Si	2.88	3.53	3.46	3.39	2.71	2.71			
Al_{IV}	1.12	0.47	0.54	0.61	1.29	1.29			
Al_{VI}	0.14	1.40	1.48	1.55	1.17	1.22			
Ti	0.03	0.01	0.01	0.01	-	-			
Fe	2.00	0.36	0.29	0.32	3.31	3.51			
Mn	0.01	-	-	0.01	0.04	0.03			
Mg	0.81	0.27	0.28	0.17	1.51	1.26			
Ca	0.01	-	-	-	0.01	-			
Na	0.02	0.23	0.02	0.04	0.03	0.01			
K	0.87	10.29	0.92	0.88	-	-			
X_{Fe}	0.71				0.69	0.74			
							An 0.7		

Garnets from the blueschists of the Pieniny Klippen Belt have not been reported yet, so comparison is impossible. The composition of the other minerals is presented in Table 4.

Discussion and conclusion

The Neolithic/Aeneolithic stone artefacts deposited in the Podtatranské múzeum in Poprad and studied by naked eyes as well as in thin sections allow us to make the following estimation: raw material of 6–8 per cent of all artefacts correspond to blueschists. From 6 pieces of which we have thin sections at our disposal, we studied four in detail using electron microprobe. These 4 samples correspond to fine-grained (0.2–0.4 mm) glaucophane schists s.s. (± garnet). The next two are constructed from partly glaucophanized: a) basalt, b) amphibolite.

The schistosity of blueschists probably reflects preferred orientation of pre-blueschist mineral association fabric of the original volcaniclastic rock. Beside leading blue amphibol (glaucophane) in the rock under consideration, omphacite, phengite, garnet, albite, quartz, titanite, zoisite, chlorite have also been identified. This suggests that the glaucophane schists of the Neolithic/Aeneolithic artefacts from the County of Spiš and the Popradská kotlina Basin have the composition of "standard" glaucophane schists. In the case of blue amphiboles they correspond to glaucophane and ferroglaucophane and are comparable to these minerals in the blueschists of the Meliata Unit. Similarly, the composition of the analysed garnets is also comparable to the composition of the garnets and trend of its changes in the blueschists of the above mentioned geological unit. The analysed clinopyroxenes plotted in the diagram (Fig. 4) are projected precisely in between the projection field of clinopyroxenes from the Meliata Unit blueschists and those of the Pieniny Klippen Belt.

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