Slovak Geol. Mag., 15, 2 (2015), 39 – 86

4. Reinterpretation of Panned Concentrates Exploration at the Territory of Slovakia

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Abstract. About 70% of the Slovak Republic territory is explored by panned concentrate survey. Implementation of regional projects of panned concentrate prospection covered almost the 35 year period (years 1962-1992) divided into four separate stages. Only lowlands and the areas with intense and widespread regulation of water flows have remained untouched by sampling. From about 65 thousand samples originally collected a database has been created keeping information on about 51,000 panned concentrates samples. The samples were located in JTSK coordinate system and displayed in the topographic groundwork at scale 1 : 50,000. Part of the panned concentrate samples was mineralogically re-evaluated using newer methods of identification, for example luminescence, dye tracing tests which has resulted in the most uniform processing and assessment of the sample material. The database has allowed to prepare distribution maps of selected types of minerals for the whole territory of Slovakia covered by the sampling. This relates to especially important mineral prospecting species or groups thereof, e.g.: cinnabar, scheelite, gold, barite, cassiterite, tungsten and others. There were also compiled distribution maps of potentially prospecting important accessory minerals such as monazite, xenotime, zircon, ilmenite, rutile, corundum, garnet and others. This way a digital database of panned concentrate samples was created, ideally with more than 60 variables for the sample. This database enables to produce different distribution and interpretive maps according to defined objectives. There is also stored panned concentrate material documentation, which ideally consists of oversize, magnetic, diamagnetic and paramagnetic fractions. An Atlas of Selected Heavy Minerals is published on the website of the State Geological Institute of Dionýz Štúr - Map Portal, Section Atlases.

Key words: heavy minerals, panned concentrate prospecting, localization maps, distribution maps

4.1 Introduction

The modern application of the old prospecting method of panning started in our conditions in the early 60s of the last century. From then until 2000 there were carried out in four stages 12 separate regional projects of the panned concentrate prospecting. All previously realized work covered about 70% of the territory of Slovakia, and there were taken around 65,000 samples. Their evaluation was focused mainly on prospecting minerals and contributed significantly to the knowledge of metallogeny in each regional geological unit. The panned concentrate prospection enabled to discover certain occurrences, or deposits (Ladomírov, Dubník, Jasenie, Sn mineralisation in Gemericum, W and Au mineralisation in Veporicum, etc). During nearly 40 years of the panned concentrate survey some methodologies were changing in assessing the panned concentrate samples and the number of monitored and assessed of minerals rose. Those archived samples which met the localization parameters were included together with passportisation sheets in the database for comprehensive processing and interpretation of mineralogical analyses of the panned concentrate samples. The database contains approximately 51,000 samples with more than 60 variables. On this basis, there were compiled Distribution (1:50,000) and Interpretation (1:800,000) maps for the territory of Slovakia covered by sampling (Bačo et al., 2004b).

4.2 Sampling and processing methodology

The goal of the re-interpretation of the panned concentrate survey in Slovakia was to collect and evaluate the available sample material of individual regional projects (Fig. 4.2) in a comparable manner. The first stage of the regional projects devoted to the panned concentrates survey began with prospecting work in the area of East-Slovakia Neovolcanites (Tab. 4.1, Fig. 4.1). The stage was aimed at a targeted search for prospecting significant minerals or group of such minerals. The initial stage brought a number of new knowledge, which resulted in the subsequent geological prospecting works.

The samples were taken at 250-500 m spacing intervals from recent sediment hydrological pattern. The volume of the sediment to be determined by panning was approximately 10 l after sieving through a sieve of 3 mm mesh. As a rule, the volume corresponded to that of a prospector's pan. This procedure and the volume were kept almost unchanged during solution of all projects within each stage. The evaluation methods in the individual projects were different, according to the objective pursued. From the first stage there has been preserved physically smallest number of samples (about 10,000). The passportisation sheets of individual samples refer to the location data, physical parameters of the sample, the results of mineralogical anal-

Tab. 4.1 Projects of regional panned concentrate prospecting – I[st] stage.

No	Project designation	Year of Completion	Coordinator	Number of Samples
	I[st] stage			27,339
1.	Vihorlat – Popričný, Prospection	1969	J. Slávik	2,780
2.	East Slovakia – Au	1971	I. Križáni	3,516
3.	Prešov-Tokaj Mts.	1972	J. Tözsér	3,032
4.	Kremnické vrchy Mts.	1972	J. Knésl	4,420
5.	Spiš-Gemer Mts. – South I. II.Prospection – Hg, Cu and other base metals	1973	I. Varga	873
6.	Vranov – Kelča – Hg Ores, Prospection	1977	I. Križáni	2,025
7.	Vysoké Tatry – Prešov, complex mineralogical-geochemical prospection	1979	I. Križáni	8,484
8.	Spiš-Gemer Mts. – High-Thermal Mineralisation, Prospection	1983	P. Malachovský	2,209

ysis and eventual chemical analyses allowed to process and finally include into the database about 27,339 of the samples (Fig. 4.2).

The second stage of the regional panning works (Tab. 4.2) adopted a uniform methodology for panned concentrate sampling, but still different ways of semi-quantitative evaluation of heavy minerals. In parallel with panning works the project 9j (Tab. 4.2) collected also the samples of stream sediments. This project covered a territory of the Tatricum and Veporicum Crystalline (Core Mountains) and partly their Mesozoic unit cover.

Tab. 4.2 Projects of regional panned concentrate prospecting – II[nd] stage.

No	Project designation	Year of Completion	Coordinator	Number of Samples
	II[nd] stage			
9.	Regional geochemistry of the W. Carpathians – Ores Prospection	1985	J. Knésl, V. Maťová	22,831
9a.	Malé Karpaty Mts.	1985	S. Polák, P. Hanas	1,413
9b.	Považský Inovec Mts.		S. Polák, P. Hanas	1,273
9c.	Tribeč Mts.		S. Polák, P. Hanas	668
9d.	Suchý – M. Magura Mts.		S. Mikoláš	1,217
9e.	Malá Fatra Mts.		S. Mikoláš	763
9f.	Veľká Fatra Mts.		G. Kravjanský, Z. Hroncová	600
9g.	Nízke Tatry Mts. – West		J. Knésl, V. Maťová	2,554
9h.	Nízke Tatry Mts. – East		J. Knésl, V. Maťová	2,450
9i.	Západné Tatry Mts.		G. Kravjanský, Z. Hroncová	393
9j.	Slovenské rudohorie Mts. – W part		P. Hvožďara, M. Linkešová	11,500

Based on the results of this stage there were implemented several prospecting projects, mainly in the Nízke Tatry Mts. and Veporicum. The sample material has been preserved to about 70%, but quite variably in the different regions. The preserved and well-localised panned concentrate samples and their passportisation sheets allow to process and include into the database about 18,500 of the samples (Fig. 4.2).

The third stage of the regional panning works (Tab. 4.3) was concentrated in the remaining parts of the territory of Slovakia, with the exception of the Danube and the East-Slovakian lowlands (Fig. 4.1). This stage of work is characterized by a uniform method of collection, mineralogical analysis and unified methodology of evaluation and interpretation. In this stage, the undersize fraction (< 0.16 mm) was for the first time chemically analysed and evaluated in the SQFD range (Semi-Quantitative Flame Diffraction). Although most of the work was done outside the potential appearance of ore resources, this stage did find a range of the anomalous regions of the secondary dispersion of significant prospecting minerals and elements. From this stage there has been preserved about 90% of the sample material.

The fourth stage (tab. 4.4) of the panned concentrate survey comprised the projects that were specifically targeted and covered the areas with poorly preserved sample material from the first or second stages of exploration. This was particularly the part of the territory of Gemericum and the Levočské vrchy Mts. area that was previously an area of special protection without the possibility of the panned concentrate sampling. These projects contributed the results of mineralogical analyses of 1,530 samples.

After the archival processing and revision of the panned concentrate samples and passportisation sheets the samples were marked in individual maps at 1:50,000 scale based on the sampling location maps of the respective projects and there were assigned to them topographic coordinates. In new maps there were plotted only unequivocally localised samples with preserved documentation material. Only in exceptional cases the samples were accepted whose location and contents were retrieved from the relevant distribution maps of individual minerals in their original projects. This way into the database there were transferred only localisation and content of those minerals (minerals of groups) that have been the subject of the distribution maps of respective projects, for example, in the case of the Crystalline of Suchý, Malá Magura, Žiar and Veľká Fatra Mts.

The obtained sample material is the primary database that includes original recordings with all the original data. It is archived and accessible, allowing the study of the original records. It has become also an underlying database for about 51,000 samples with more than 60

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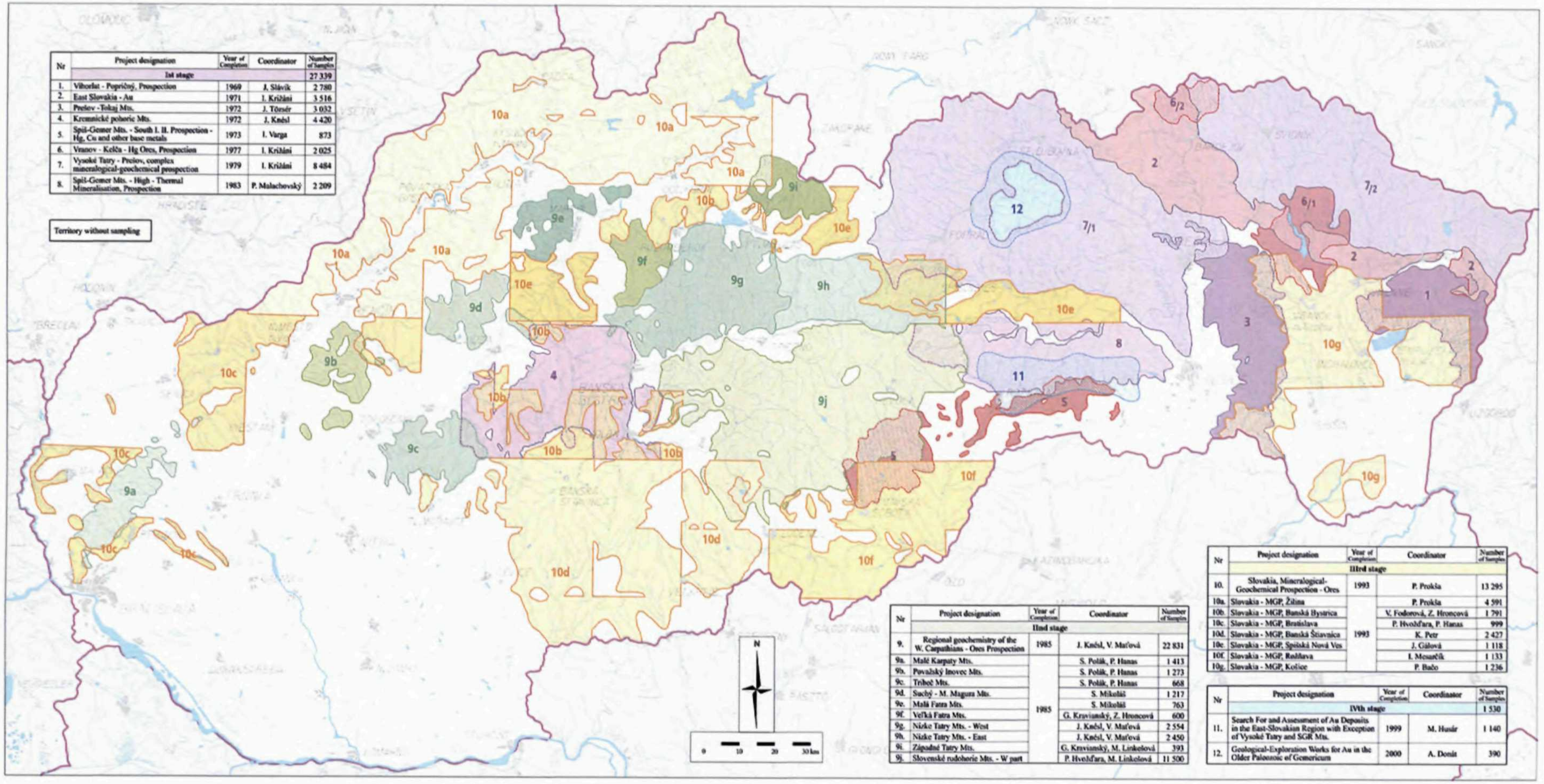
GENERAL MAP OF THE TASKS OF REGIONAL PANNING PROSPECTION

Fig. 4.1

REINTERPRETATION OF THE PANNED CONCENTRATES SURVEY IN THE TERRITORY OF SLOVAKIA



Nr	Project designation	Year of Completion	Coordinator	Number of Samples
	Ist stage			27 339
1.	Vihorlat - Popričný, Prospection	1969	J. Slávik	2 780
2.	East Slovakia - Au	1971	I. Križáni	3 516
3.	Prešov - Tokaj Mts.	1972	J. Töršér	3 032
4.	Kremnické pohorie Mts.	1972	J. Knésl	4 420
5.	Spiš-Gemer Mts. - South I. II. Prospection - Hg, Cu and other base metals	1973	I. Varga	873
6.	Vranov - Kelča - Hg Ores, Prospection	1977	I. Križáni	2 025
7.	Vysoké Tatry - Prešov, complex mineralogical-geochemical prospection	1979	I. Križáni	8 484
8.	Spiš-Gemer Mts. - High - Thermal Mineralisation, Prospection	1983	P. Malachovský	2 209

Nr	Project designation	Year of Completion	Coordinator	Number of Samples
	IInd stage			
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9b.	Považský Inovec Mts.		S. Polák, P. Hanas	1 273
9c.	Tribeč Mts.		S. Polák, P. Hanas	668
9d.	Suchý - M. Magura Mts.		S. Mikoláš	1 217
9e.	Malá Fatra Mts.		S. Mikoláš	763
9f.	Veľká Fatra Mts.		G. Kraviansky, Z. Hroncová	600
9g.	Nízke Tatry Mts. - West		J. Knésl, V. Maťová	2 554
9h.	Nízke Tatry Mts. - East		J. Knésl, V. Maťová	2 450
9i.	Západné Tatry Mts.		G. Kraviansky, M. Linkešová	393
9j.	Slovenské rudohorie Mts. - W part		P. Hvožďara, M. Linkešová	11 500

Nr	Project designation	Year of Completion	Coordinator	Number of Samples
	IIIrd stage			
10.	Slovakia, Mineralogical-Geochemical Prospection - Ores	1993	P. Prokla	13 295
10a.	Slovakia - MGP, Žilina	1993	P. Prokla	4 591
10b.	Slovakia - MGP, Banská Bystrica		V. Fodorová, Z. Hronçová	1 791
10c.	Slovakia - MGP, Bratislava		P. Hvožďara, P. Hanas	999
10d.	Slovakia - MGP, Banská Štiavnica		K. Petr	2 427
10e.	Slovakia - MGP, Spišská Nová Ves		J. Gálová	1 118
10f.	Slovakia - MGP, Rožňava		I. Mesarčík	1 133
10g.	Slovakia - MGP, Košice		P. Bačo	1 236

Nr	Project designation	Year of Completion	Coordinator	Number of Samples
	IVth stage			1 530
11.	Search For and Assessment of Au Deposits in the East-Slovakian Region with Exception of Vysoké Tatry and SGR Mts.	1999	M. Husár	1 140
12.	Geological-Exploration Works for Au in the Older Paleozoic of Gemericum	2000	A. Donát	390

Tab. 4.3 Projects of regional panned concentrate prospecting – III[rd] stage.

No	Project designation	Year of Completion	Coordinator	Number of Samples
	III[rd] stage			
10.	Slovakia, Mineralogical-Geochemical Prospection – Ores	1993	P. Prokša	13,295
10a.	Slovakia – MGP, Žilina	1993	P. Prokša	4,591
10b.	Slovakia – MGP, B. Bystrica		V. Fodorová, Z. Hroncová	1,791
10c.	Slovakia – MGP, Bratislava		P. Hvožďara, P. Hanas	999
10d.	Slovakia – MGP, B. Štiavnica		K. Petr	2,427
10e.	Slovakia – MGP, Sp. Nová Ves		J. Gálová	1,118
10f.	Slovakia – MGP, Rožňava		I. Mesarčík	1,133
10g.	Slovakia – MGP, Košice		P. Bačo	1,236

The distribution maps for each of the selected minerals and group of minerals at scale 1:750,000 were drawn up based on statistical processing of their contents. In order to show the distribution of the majority of minerals, they were displayed as isoplanes. While creating a set of grid points, kriging method was used with increments of 1 km

Tab. 4.4 Projects of regional panned concentrate prospecting – IV[th] stage.

No	Project designation	Year of Completion	Coordinator	Number of Samples
	IV[th] stage			1,530
11.	Search For and Assessment of Au Deposits in the East-Slovakian Region with Exception of Vysoké Tatry and SGR Mts.	1999	M. Husár	1,140
12.	Geological-Exploration Works for Au in the Older Paleozoic of Gemericum	2000	A. Donát	390

variables for each sample. The mineralogical analysis of the samples was consolidated into semi-quantitative classes: **a** (up to 10 grains of the panned concentrate or up to 1%), **b** (11 - 100, or up to 5%), **c** (101 – 500, or up to 10%), **I** (up to 25% of the panned concentrate sample), **II** (up to 50%) and **III** (above 50%).

From the database distribution maps were compiled for 37 kinds of minerals on 100 map sheets 1:50,000 covering all the sampled territory of Slovakia. At a scale of 1:750,000 distribution maps were compiled in the form of isoplanes for 37 kinds of minerals presented in 28 pieces of maps.

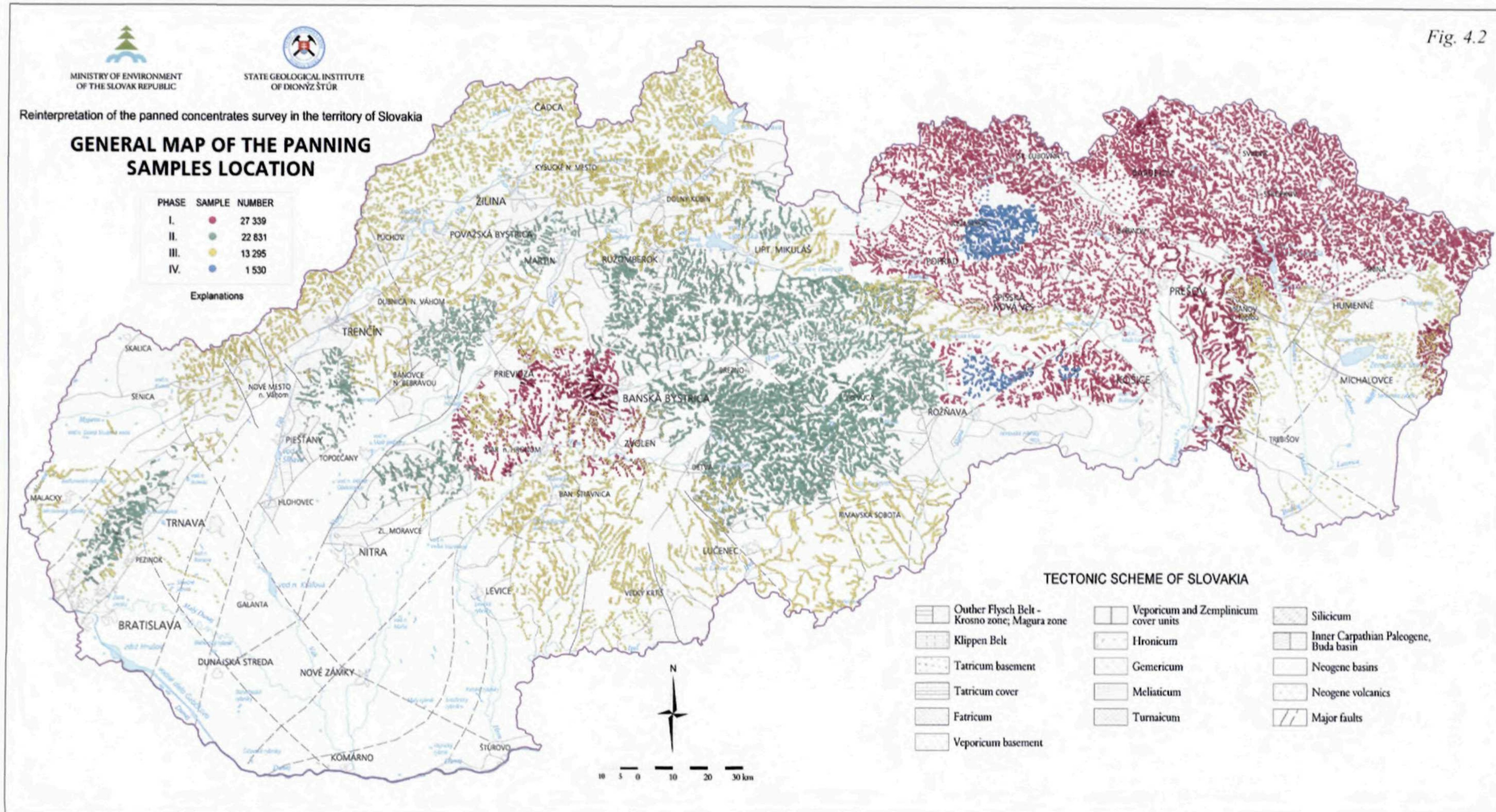
The database, representing an overview of more than 60 variables (physical quantities – particle size, weight, etc., mineralogical characteristics – types of minerals, and other heavy components), all the samples are presented as a public database (Annex of the final report Bačo et al., 2004b, and at the website www.geology.sk – Map Portal, Section Atlases). On its basis it is also possible to prepare purpose-made distribution maps depending on pursued aspect – geological, metallogenic, environmental and so on.

In the period of 1960-1993 there were carried out further local projects aimed at specific prospection or the overall characteristics of area under study. The amount of samples taken ranged from several dozen to several hundred. Among the projects which have a greater range, we can include those whose aim was sampling and evaluation of the eastern part of the Malá Magura Mts. (Böhmer & Hvožďara, 1969), a wider area of the Kremnické vrchy Mts. (Böhmer & Mecháček, 1978), the southern slopes of the central part of the Nízke Tatry Mts. – prospection for scheelite mineralisation (Pulec, 1976, 1977a, b), Javorie and Poľana Mts. (Böhmer & Antal, 1981), Branisko and Čierna Hora Mts. (Fulín, 1987) and the area of the contact zone of Veporicum and Gemericum (Határ et al., 1994). In the aggregate reinterpretation these projects have not been included because of the complete absence of documentation material – panned concentrate samples and very different methodology in their mineralogical evaluation.

and 3 km radius of selection, with a lower frequency of positive mineral occurrence there was used point display. A component of the map is the frequency distribution histogram according to the nature of the mineral displayed, either the number of grains or the relative size of semi-quantitative class. The ground layer of the Slovak territory display is the tectonic map (Biely et al., 1996) in the form of hatch patterns. The creation of isoplanes of mineral distribution was carried out in a graphical environment of the product Surfer, Golden Software and the actual map outputs were finalised in the environment MicroStation V7, Bentley Corp.

4.3 Results of the panned concentrates prospecting re-interpretation

The main result is the creation of the database and the distribution maps for selected minerals and mineral groups. Part of the map documents is an essential characteristic of evaluated mineral in panned concentrate specimens and general characteristics of the distribution documented statistically by selected parameters. The mineralogical analyses of samples in the scope of panned concentrate prospecting didn't quantified individual mineral species of certain groups of minerals, for example, group of garnet minerals, apatite, monazite, and tourmaline. Therefore their distribution maps show the potential of any specific mineral species present in certain group. While characterising individual minerals those properties are given that are identified in panned concentrate samples. Their magnetic characterisation applies to separation by isodynamic electromagnet at the following conditions: 1.2 Amp, side slope 15° and tilt of 20°, luminescence properties observed in the short-wave UV spectrum (monochrome, $\lambda = 254$ nm).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Reinterpretation of the panned concentrates survey in the territory of Slovakia
GENERAL MAP OF THE PANNING SAMPLES LOCATION
PHASE SAMPLE NUMBER
I. 27 339
II. 22 831
III. 13 295
IV. 1 530
Explanations
TECTONIC SCHEME OF SLOVAKIA
Outher Flysch Belt - Krosno zone; Magura zone
Klippen Belt
Tatricum basement
Tatricum cover
Fatricum
Veporicum basement
Veporicum and Zemplinicum cover units
Hronicum
Gemericum
Meliaticum
Turnaicum
Silicicum
Inner Carpathian Paleogene, Buda basin
Neogene basins
Neogene volcanics
Major faults
N
10 5 0 10 20 30 km
ČADCA
ŽILINA
POVAŽSKÁ BYSTRICA
MARTIN
RUŽOMBEROK
LIPT. MIKULÁŠ
TRENČÍN
PRIEVIDZA
BANSKÁ BYSTRICA
ZVOLEN
BAN. ŠTIAVNICA
LUČENEC
RIMAVSKÁ SOBOTA
ROŽŇAVA
KOŠICE
PREŠOV
HUMENNÉ
MICHALOVCE
TREBIŠOV
SPIŠSKÁ NOVÁ VES
POPRAD
SKALICA
SENICA
MALACKY
TRNAVA
PIEŠŤANY
TOPOĽČANY
HLOHOVEC
NITRA
ZL. MORAVCE
LEVICE
GALANTA
BRATISLAVA
DUNAJSKÁ STREDA
NOVÉ ZÁMKY
KOMÁRNO
ŠTÚROVO
PEZINOK
NOVÉ MESTO n. Váhom
BÁNOVCE n. BEBRAVOU
DUBNICA n. VÁHOM
PÚCHOV
KYSUCKÉ N. MESTO
DOLNÝ KUBÍN
VEĽKÝ KRTÍŠ
Fig. 4.2

4.3.1 Anatase TiO_2

H (hardness) = 5.5 – 6.0; **System:** Tetragonal

SG (specific gravity) = 3.8 – 4.0 $g.cm^{-3}$;

Magnetic properties: non-magnetic, and is concentrated in diamagnetic fraction.

Colour in the panned concentrate samples

Colour of anatase in the panned concentrate samples is mostly brown, cinnamon brown to reddish, in different grades and shades (Fig. 4.3a). This type of anatase is typical for the panned concentrates from the Tribeč Mts. Metallic-blue to black colour (Fig. 4.3b) dominates in the panned concentrates of the source areas in Veporicum consisting mainly of granitic rocks. Occasionally, in the panned concentrate samples also small colourless crystals occurred.

Lustre on smooth surfaces of translucent small crystals and small debris is distinct, diamond-like. On the darker coloured crystals of anatase the lustre is metallic. Roughened surfaces have a dull lustre.

Morphology in the panned concentrate samples

In the panned concentrate samples anatase is present mostly in the form of tetragonal dipyramids (Fig. 4.3b, 4.4a); the most common are base {111} and steeper {112} dipyramids and combination of them. The steeper one gradually passes into the prism plane (110). Part of small crystals of anatase may evolved secondary pyramid with reduced plane and the resulting shape is ditetragonal dipyramid (Fig. 4.4a). On the anatase of some sites there are developed pinacoidal planes {001} that can turn from the dipyramid shape

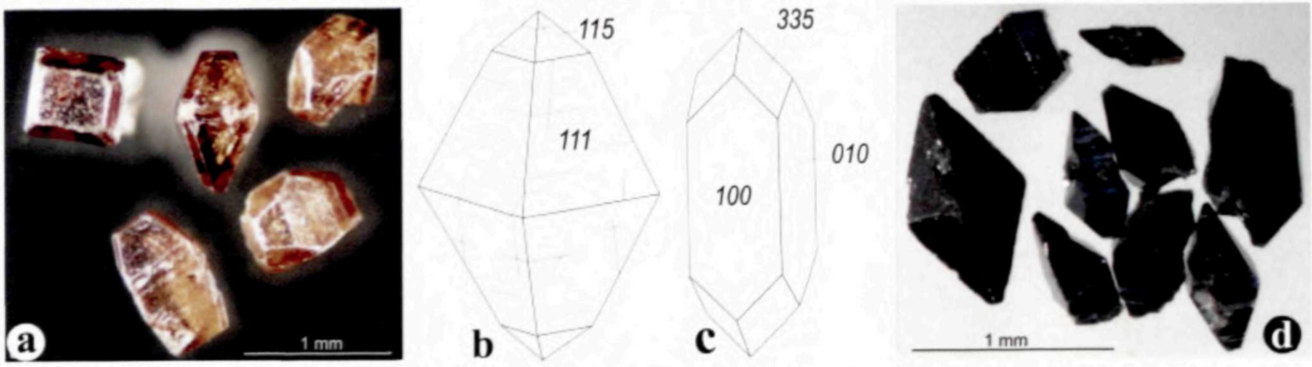


Fig. 4.3a, b, c, d Typical shapes and colour of anatase in the panned concentrate samples. For individual source areas these two features are often characteristic. Site: a – Tribeč, site Zlatno; d – Veporicum – Kocižský potok Brook. Drawings: Rösler, J. H., 1983. Photo: Z. Bačová.

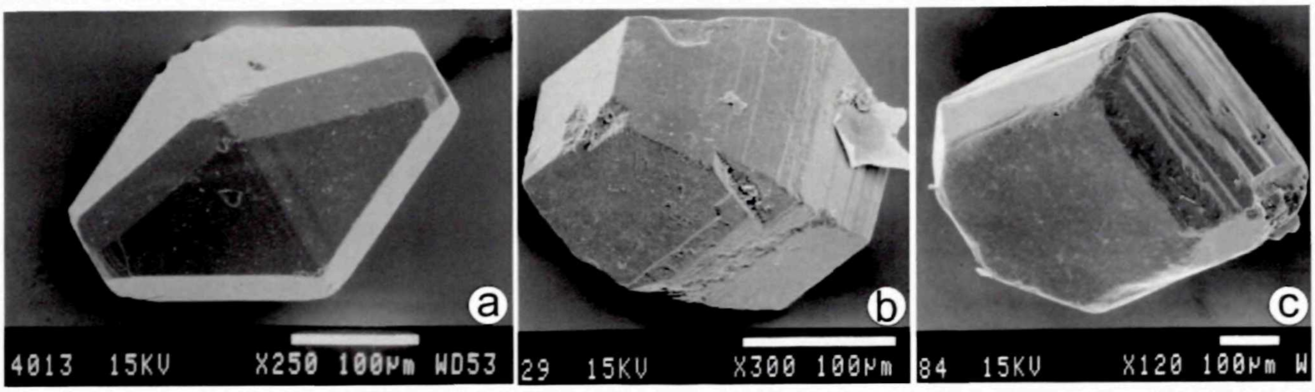


Fig. 4.4a, b, c Typical shapes of accessory anatase from source areas made of prevailingly granitoid rocks. a, c – Tribeč, site Zlatno; b – Tatricum – site Kráľova Lehota. Photo: SEM I. Holický.

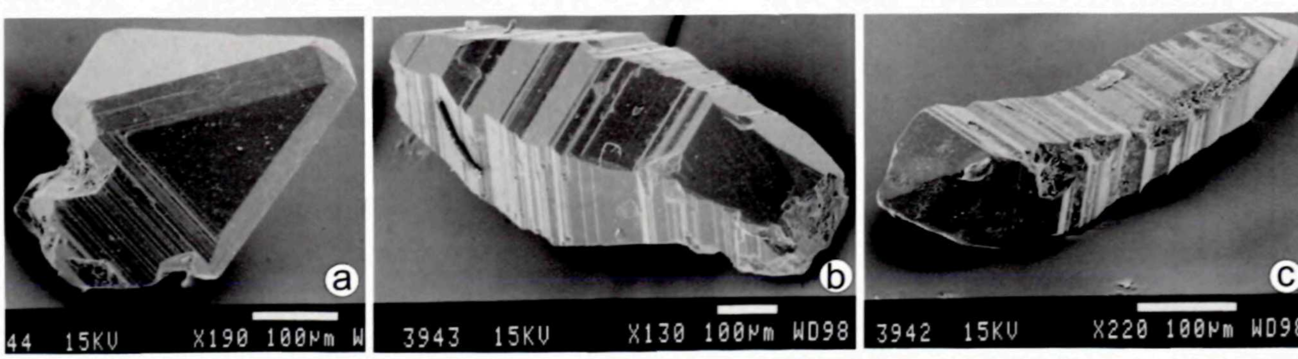


Fig. 4.5a, b, c Typical shapes of accessory anatase from the source areas made of metamorphic rocks of Veporicum, prevailingly. a, c – Veporicum, site Hnúšťa; b – site Pohronská Polhora. Photo: SEM I. Holický.

even into the tabular one (Fig. 4.3a and 4.4c).

Probably of typological importance are the anatases with irregular, hypidiomorphic development (various types of intergrowths even with cyclical pattern (Fig. 4.5a, b, c). Their occurrences are characteristic for the source areas made of metamorphic rocks, often with the presence of Alpine veins paragenesis. Epitaxial coalescence of anatase with other minerals has not been observed in the panned concentrate samples.

During transport due to their hardness and poor cleavability the anatases are very persistent and they become clastogenic component of sediments. Small crystals in the panned concentrate samples have typical dimensions of 0.5 to 1.0 mm, occasionally up to 2 mm.

Tab. 4.5 Presence of anatase in the panned concentrate samples according to content classes.

Database of samples	Negative	Content (semi-quantitative classes)					
	Positive	**a**	**b**	**c**	**I**	**II**	**III**
50,939	30,294	11,057	6,377	2,948	259	3	1
	58	22	13	5.79	0.51	0.006	0.002
	20,645	11,057	6,377	2,948	259	3	1
	41	53.56	30.89	14.28	1.25	0.01	0.00

General distribution characteristics

Anatase was observed in almost half of all evaluated panned concentrate samples (Tab. 4.5; Fig. 4.6a). The concentration of anatase in the panned concentrate samples ranges in the first content classes: a; b; c (Tab. 4.5; Fig. 4.6b, c).

Anatase is a typical accessory mineral and is present in the panned concentrate samples from source areas of almost all regional geological formations (Fig. 4.7). However, it is a typical accessory mineral of some Tatricum and Veporicum granitoids and metamorphic rocks of Veporicum, mainly. It is a component of the paragenesis of the mineralisation type of the Alpine veins.

The anatase has entered the Flysch units environment as clastogenic mineral. It is markedly absent in the Neogene volcanic rocks and Mesozoic carbonate environment (Fig. 4.7).

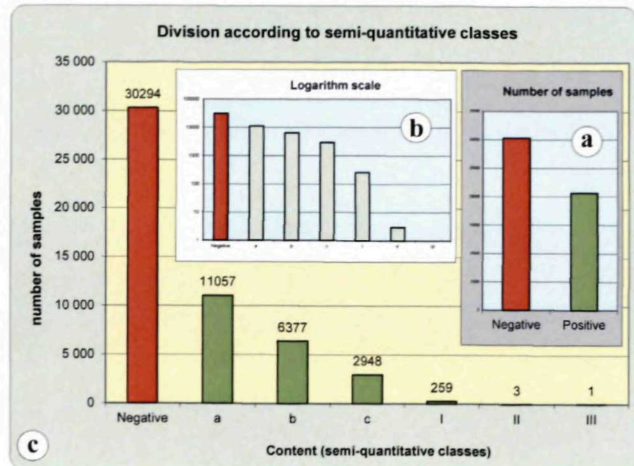


Fig. 4.6a, b, c Distribution of panned concentrate samples according to anatase presence – a. Concentration of anatase is mainly in the first and the second quantitative classes – b, c.

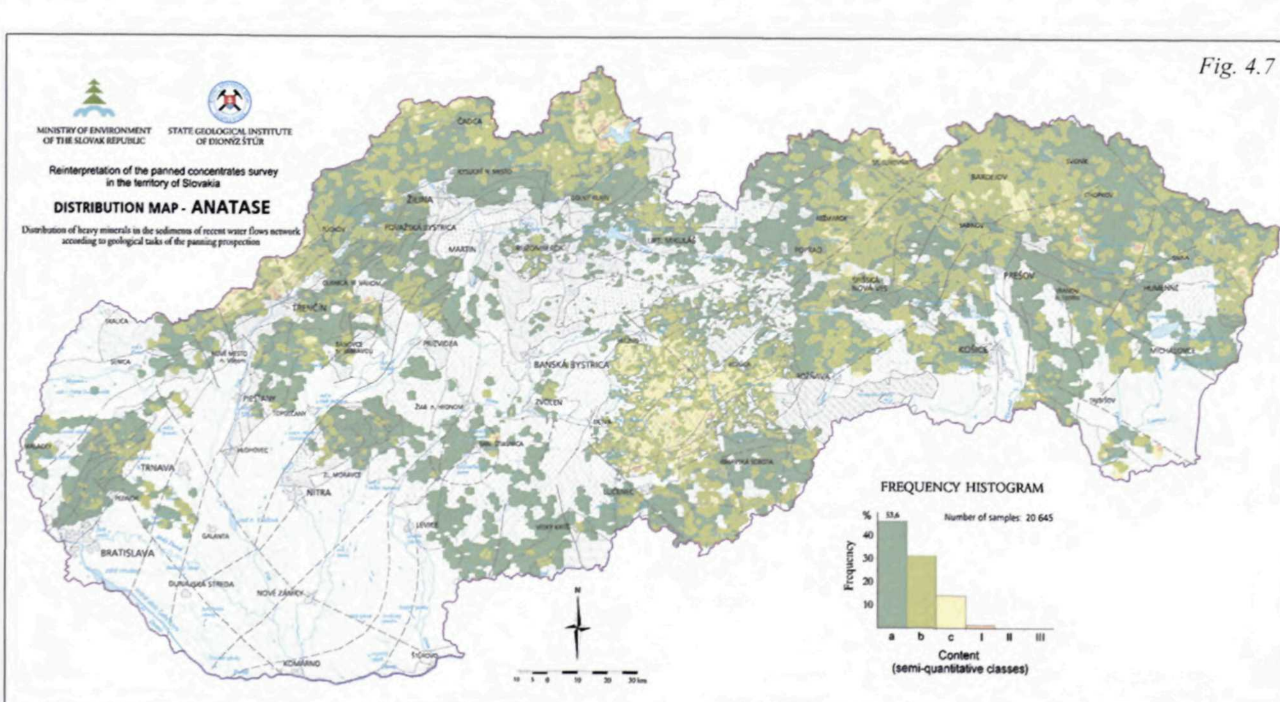


Fig. 4.7

4.3.2 Apatites

Chlorapatite $Ca_5(PO4)_3Cl$; Fluorapatite $Ca_5(PO_4)_3F$; Hydroxylapatite $Ca_5(PO_4)_3(OH)$

H = 4.5 (Cl) – 5.0 (F, Cl); **SG** = 3.16 – 3.22 g.cm^{-3}; **System:** Hexagonal

For the purposes of panned concentrate prospecting for minerals of apatite group (fluorapatite, chlorapatite, hydroxyapatite and other varieties) it was used customary common name apatite.

Magnetic properties: non-magnetic, and is concentrated in diamagnetic fraction.

Luminescence: greenish and orange, in some grains luminescence is indistinguishable.

Colour in the panned concentrate samples

Colour of apatite in the panned concentrate samples is most often white, grey-white, less often orange or brownish in different grades and shades (Fig. 4.8b). Smoke-coloured apatites originate from the environment of Neogene volcanic rocks. In some types of granitic rocks the apatites are translucent. Lustre on flat surfaces is glassy, on fracture planes or on corroded small crystals and grains it is dull.

Fig. 4.8a, b, c Typical shapes and colour of apatite in the panned concentrate samples. On small crystals of apatite prismatic planes dominate with regular and identical habit (a) or irregular (c) one. The crystal termination can be characterised by dominant pinacoid shape (a) or the pyramid (c). Drawings: Rösler, J. H., 1983. Photo (b): P. Bačo.

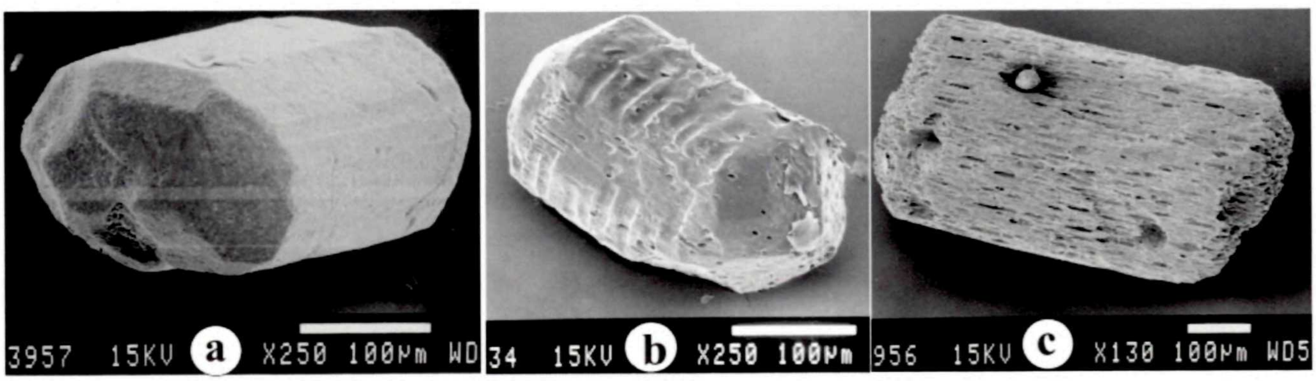


Fig. 4.9a, b, c The most frequent and typical shapes of small crystals of apatite from panned concentrate samples of individual geological environs. Typical and perfect shapes – combination of planes of prisms, pyramid and pinacoid (a). Characteristic are planes' surfaces with different manifestations of disintegration (b, c). Sites: Pukanec (a); Zamutov (b); Hodruša (c). Photo: SEM I. Holický.

Morphology in the panned concentrate samples

In the panned concentrate samples the apatites are present mostly in the form of hexagonal columnar, coarse-prismatic to small isometric crystals, on which dominating are prismatic planes (Fig. 4.9). During transport they are trimmed, rounded up and in the environment of sedimentary rocks (Flysch Zone) the apatites consist of fully rounded grains.

Epitaxial coalescence with other minerals of apatite in the panned concentrate samples doesn't occur, in general (e.g. with monazite). More often, in clear crystals dark cores can be observed. Size of small crystals, their fragments or grains in the panned concentrate samples is up to 0.5 mm, rarely up to 1.0 mm.

General distribution characteristics:

As accessory mineral, the apatite is present mainly in magmatic (Broska et al., 2012) and metamorphic rocks. Quite often it is also associated with various types of hydrothermal mineralisation. Its presence was recorded in

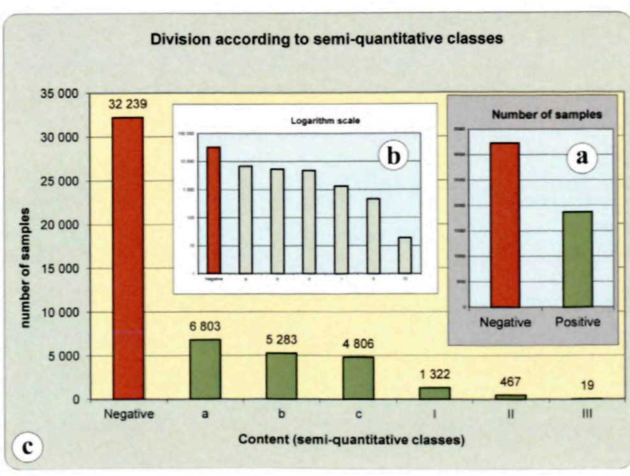


Fig. 4.10a, b, c Distribution of panned concentrate samples according to apatite presence – a. Concentration of apatite is mainly in the first and the second quantitative classes – b, c.

more than one third of the all evaluated panned concentrate samples (Tab. 4.6; Fig. 4.10a). The concentrations of apatite in the panned concentrate samples were observed almost evenly in the first content classes: a; b; c (Tab. 4.6; Fig. 4.10b, c).

Tab. 4.6 Presence of apatite in the panned concentrate samples according to content classes.

Database of samples	Negative / Positive	Content (semi-quantitative classes)					
		a	**b**	**c**	**I**	**II**	**III**
50,939	32,239	6,803	5,283	4,806	1,322	467	19
	63	14	10	9.43	2.60	0.92	0.04
	18,700	6,803	5 283	4 806	1 322	467	19
	37	36.38	28.25	25.70	7.07	2.50	0.10

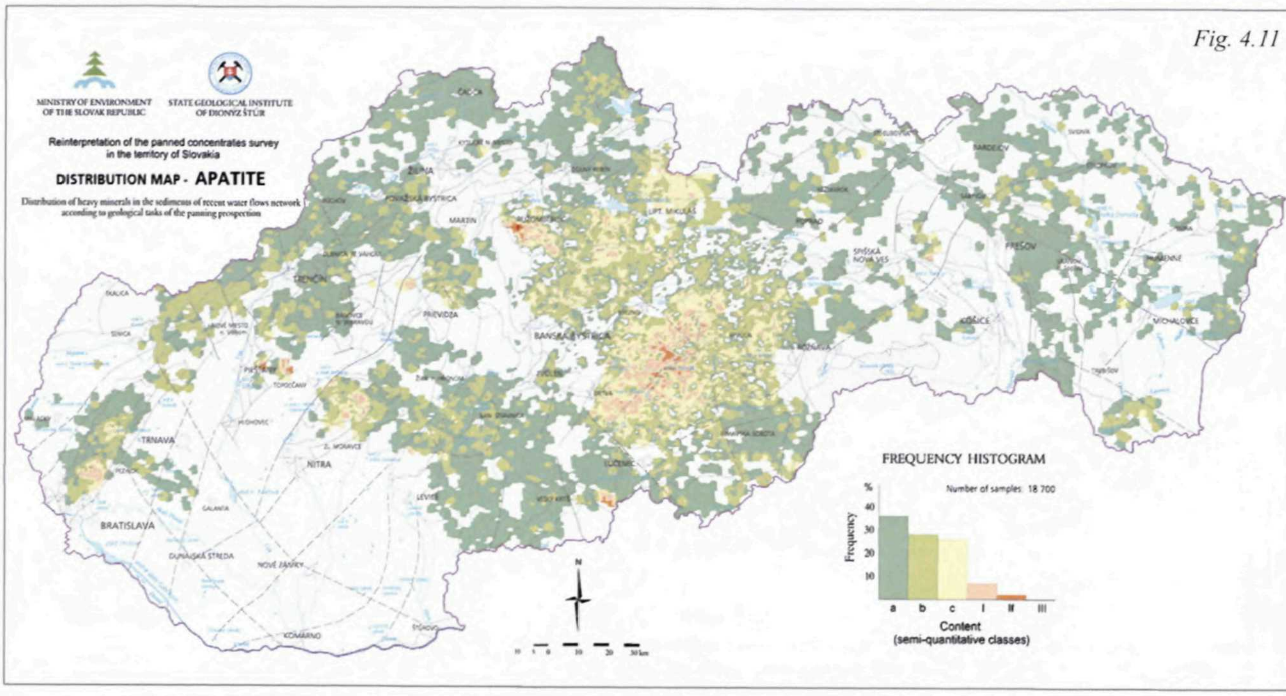


Fig. 4.11

In rare cases, within source area made of granites of the type I, for example, granitoids of the Sihla type (Fig. 4.11) the concentration of apatite in the panned concentrate samples is high and reaches higher content classes (I, II, and exceptionally up to III), i.e., they can create a significant portion of diamagnetic fraction, prevailing in the heavy fraction of panned concentrate samples. Similar concentrations were observed in the case of the source areas made of tonalites of Tribeč and Malé Karpaty Mts. (Fig. 4.11).

Increased incidence is also confirmed in territories made of the neovolcanic rocks. Significantly deficient are the areas made up of Mesozoic complexes and some parts of the Outer Flysch Zone.

4.3.3 Arsenopyrite FeAsS

H = 5.5 – 6.0; **SG** = 5.9 – 6.29 g.cm^{-3}; **System:** Monoclinic

Magnetic properties: concentrated in diamagnetic fraction

Colour in the panned concentrate samples

Colour of arsenopyrite in the panned concentrate samples is the most frequently grey-metallic, often with brown spots, as a manifestation of limonitisation (Fig. 4.12a, e). Near autochthonous occurrences or anthropogenic sources (dumps) small crystals have tin-white colour. Lustre on flat planes is metal, heavily corroded grains are dull.

Morphology in the panned concentrate samples

In the panned concentrate samples the arsenopyrite is often present in the form of pseudobipyramid - planes (101), and thereof fragments, rod-shaped and columnar {230}, and the small crystals and their fragments (Fig. 4.12b, c; Fig. 4.13a) and trimmed isometric grains originating from varied shapes (Fig. 4.12a). Besides the most common grains or grain aggregates the most common are the columnar fragments (Fig. 4.14a, b), in cross-section with strongly flattened rhombs (4.13a) and not uncommon in the tetragonal form and strongly flattened dipyramid (4.13b). On the columnar small crystals it can be observed grooving in the direction of extension (Figs. 4.12e and 4.13). Typical are also star-like intergrowths (Fig. 4.13c; Fig. 4.14c). Epitaxial overgrowth in the panned concentrate samples has not been observed.

Size of small crystals, their fragments or grains in the panned concentrate samples is normally within 0.5 to 1.0 mm. Grainy aggregates occur close to anthropogenic sources, and mainly in the dumps after mining activities, they can reach several mm.

Identification attributes: steel-grey colour, sometimes with brown spots (limonitisation), longitudinal grooving, rhombic cross-section, star-like intergrowths.

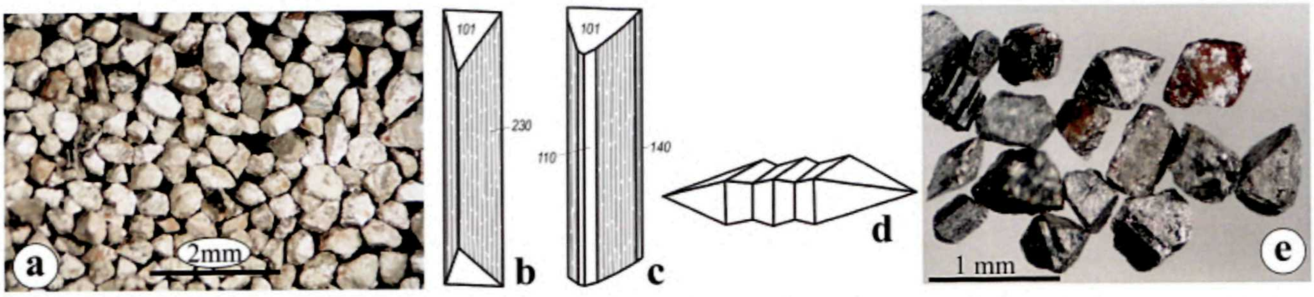


Fig. 4.12a, b, c, d, e Typical shapes and colour of arsenopyrite in the panned concentrate samples. Mostly it is present in the form of irregular sharply-edged fragments (a). Close to the source the crystal shapes are better preserved (b). Site: Nízke Tatry – Jasenie. Drawings: Rösler, J. H., 1983, Photo: P. Bačo.

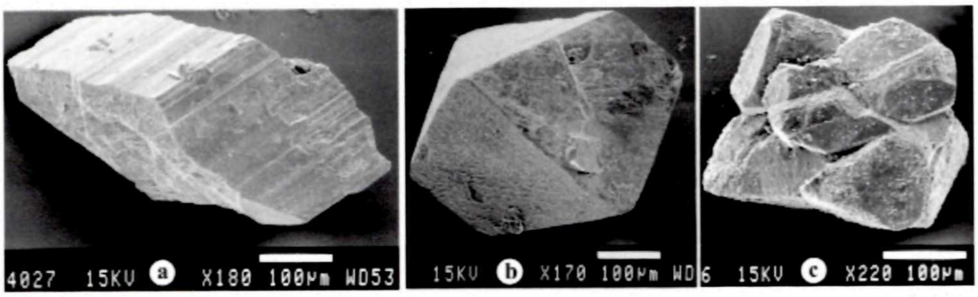


Fig. 4.13a, b, c Small crystals have columnar habit with longitudinal grooving. Characteristic is a rhombic cross-section. Sites: Jasenie-Kyslá (a); Hnúšťa (b); Horné Srnie, (c). Photo: SEM I. Holický.

General distribution characteristics:

Arsenopyrite is relatively common mineral in sulphide deposit occurrences. In the supergene environment arsenopyrite is not stable, and therefore its presence in the panned

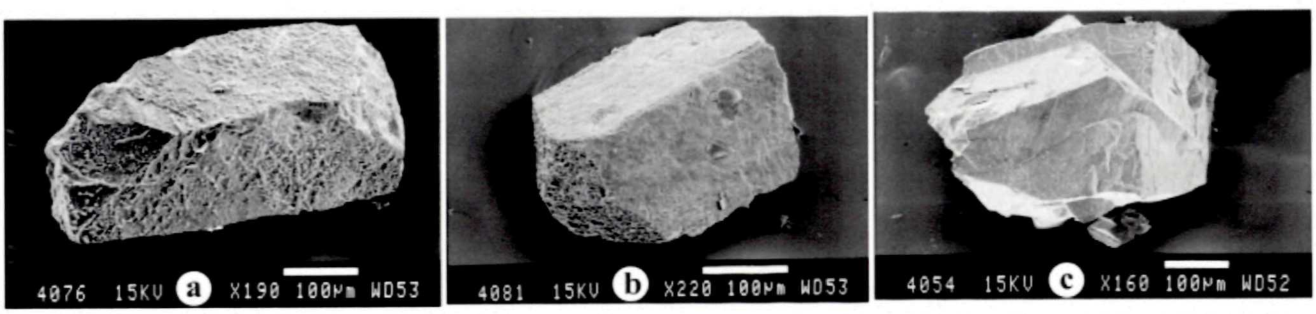


Fig. 4.14a, b, c In the panned concentrate samples besides of most common grains and granular aggregates of arsenopyrite, the fragments of columnar shape are present (a, b). Typical are also star-like intergrowths (c). Sites: Jasenie-Kyslá (a); Pezinok (b); Zlatá Idka (c). Photo: SEM I. Holický.

concentrate samples is often limited. Like the other sulphide minerals the arsenopyrite occurs mainly in the vicinity of anthropogenic sources – heaps and dumps near old workings.

Arsenopyrite was observed in a relatively small number of the assessed panned concentrate samples (Tab. 4.7; Fig. 4.15a). Its content is within the first concentration class: a; b, higher concentrations are very rare (Tab. 4.7; Fig. 4.15b).

Arsenopyrite is characterized by uneven distribution within geological formations, since it clearly reflects the presence of sulphide mineralisation (concentration in classes b and c) and not the rock – the lithological environment within the source areas. Regional extension is recorded in Veporicum, Gemericum and crystalline of the Malé Karpaty Mts., the Ďumbier part of the Nízke Tatry Mts. and the Žiar Mts. (Fig. 4.18).

In the other geological formations its presence is reported sporadically and its concentrations in the positive panned concentrate samples are within first quantitative classes (a, less b). Noteworthy is its distribution in the western parts of the Inner-Carpathian Paleogene and the Orava section of the Klippen Belt (Fig. 4.18).

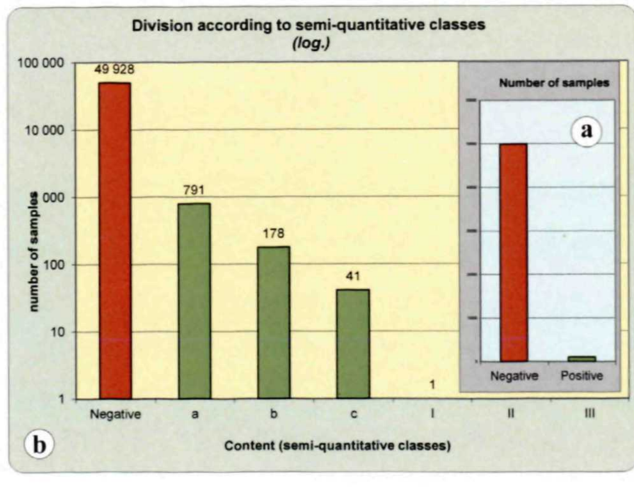


Fig. 4.15a, b Distribution of panned concentrate samples according to arsenopyrite presence – (a). Concentration of arsenopyrite is mainly in the first and the second quantitative classes – a, b (b).

Tab. 4.7 Presence of arsenopyrite in the panned concentrate samples according to content classes.

Database of samples	Negative	Content (semi-quantitative classes)					
	Positive	**a**	**b**	**c**	**I**	**II**	**III**
50,939	49,928	791	178	41	1	0	0
	98	1.553	0.349	0.080	0.002	0	0
	1,011	791	178	41	1	0	0
	2	78.24	17.61	4.06	0.10	0.00	0.00

4.3.4 Stibnite Sb_2S_3

H = 2.0 – 2.50; **SG** = 4.51 – 4.66 g.cm^{-3}; **System:** Rhombic
Magnetic properties: non-magnetic, and is concentrated in diamagnetic fraction

Colour in the panned concentrate samples

Colour of stibnite in panned concentrate samples is metallic grey, often with dark blue colour. Lustre on flat planes is metallic.

Morphology in the panned concentrate samples

In the panned concentrate samples stibnite is present only in the closest vicinity of the primary, but more often in the vicinity of anthropogenic sources. Small crystals are the most often thin-columnar and needle-like and the small crystals are "grooved" in the longitudinal direction (C-axis) (Fig. 4.16a, b, c.).

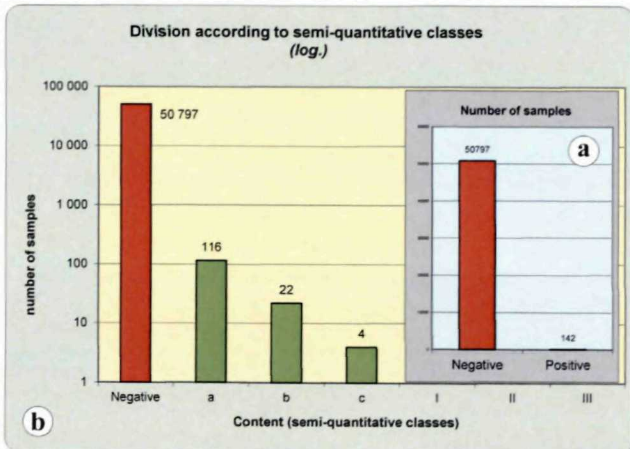


Fig. 4.17a, b Distribution of panned concentrate samples according to stibnite presence (a). Concentration of stibnite is mainly in the first and the second quantitative classes – a, b, (b).

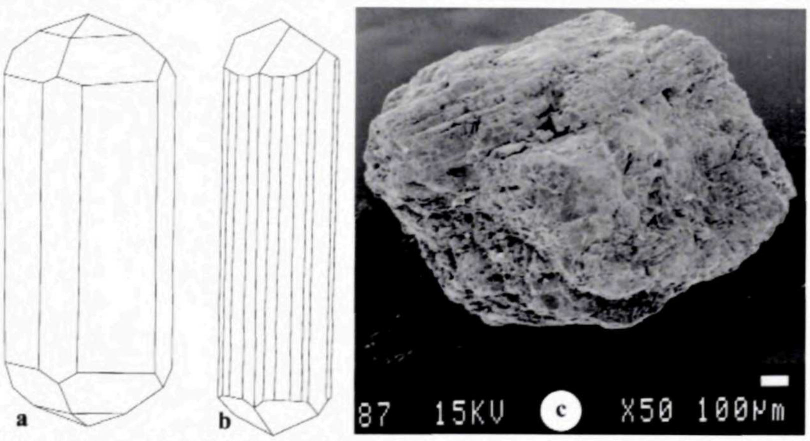


Fig. 4.16a, b, c Typical shapes of stibnite crystals from primary occurrences – a, b. In the panned concentrate samples it is often present in the form of grooved grains – c. Site: Nízke Tatry – below the heaps of the deposit Dúbrava. Drawings: Rösler, J. H., 1983. Photo: SEM I. Holický.

In the sediments fragments of stibnite are mostly present, with dominating cleavability planes (010). Occasionally there occur also fine-grained debris, especially near primary sources, which are mainly dumps of mining work in the area of primary deposits.

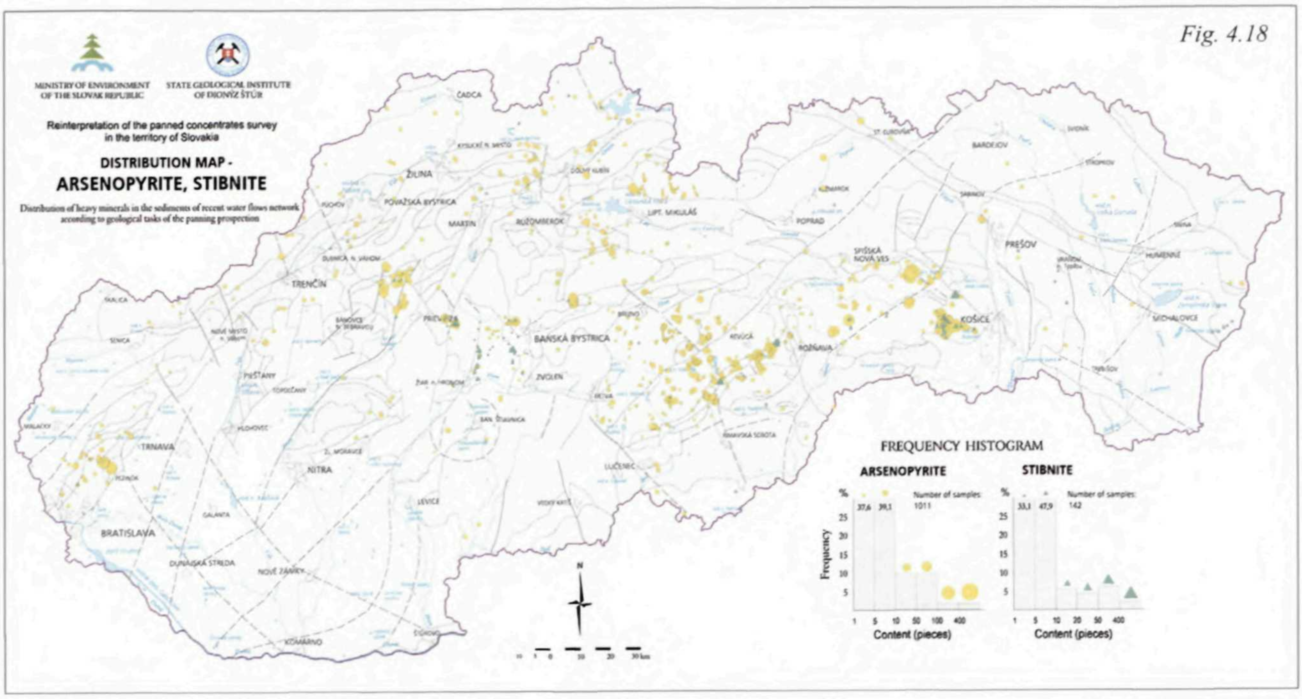
General distribution characteristics:

During transport the stibnite is due to very good cleavability an unstable mineral and very rapidly disappears from the proportion of heavy fraction sediments. Its presence always indicates the proximity of the primary source. In our conditions it is usually the presence of the anthropogenic generated resources - heaps and dumps after mining works.

Only a slight amount of stibnite was observed in the panned concentrate samples (Tab. 4.8). The concentration ranged mainly in the lowest semi-quantitative content class (a) and only rarely is in a greater amount (Fig. 4.17a, b). It was found in the area of Sb deposits in the Nízke Tatry Mts. (Dúbrava, Vyšná Boca), but mainly in the area of the Sb deposits in the Spiš-Gemer rudohorie Mts. (Poproč, Zlatá Idka, wider area of Čučma). It was also identified in the area of the Sb deposits in the Malé Karpaty Mts. (Fig. 4.18).

Tab. 4.8 Presence of stibnite in the panned concentrate samples according to content classes.

Database of samples	Negative	Content (semi-quantitative classes)					
	Positive	**a**	**b**	**c**	**I**	**II**	**III**
50,939	50,797	116	22	4	0	0	0
	100	0.23	0.04	0.01	0	0	0
	142	116	22	4	0	0	0
	0	81.69	15.49	2.82	0.00	0.00	0.00



4.3.5 Barite $BaSO_4$

H = 3.5; **SG** = 4.3 – 4.7 g.cm^{-3}; **System:** Rhombic

Magnetic properties: non-magnetic, and is concentrated in diamagnetic fraction

Luminescence: may be bluish and yellowish, but commonly indistinguishable

Colour in the panned concentrate samples

Colour of barite in the panned concentrate samples is usually white, sometimes the fragments are colourless to transparent and clear, or yellowish (due to the presence of Fe oxides). After using dye test the fragments and grains are covered with bright yellow barium chromate coating (Fig. 4.19c). Shine of barite on crystal planes is glassy to pearled, on irregular corroded grains dull.

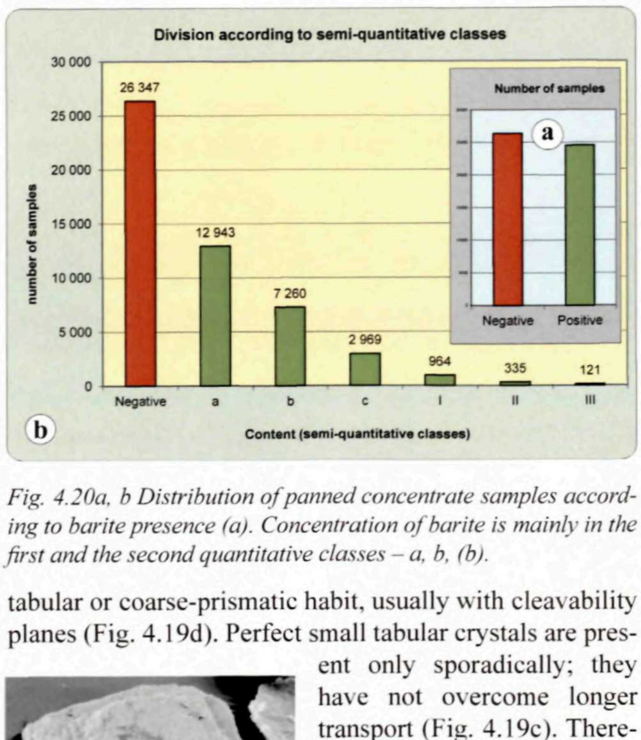


Fig. 4.20a, b Distribution of panned concentrate samples according to barite presence (a). Concentration of barite is mainly in the first and the second quantitative classes – a, b, (b).

Morphology in the panned concentrate samples

In the panned concentrate samples barite is present mostly in the form of irregular fragments, but always with tabular or coarse-prismatic habit, usually with cleavability planes (Fig. 4.19d). Perfect small tabular crystals are present only sporadically; they have not overcome longer transport (Fig. 4.19c). Therefore, they indicate the proximity of primary resources. After longer transport barite gets partly rounded, however, cleavability is well seen in stepwise morphology even on the finest grains (Fig. 4.19d). During transport, due to the hardness of barite and very good cleavability its grain share is significantly increasing without adequate volume changes.

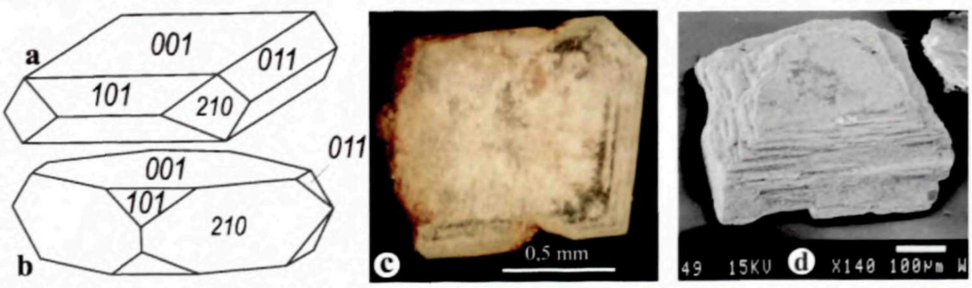


Fig. 4.19a, b, c, d Shapes of crystals, colour and cleavability of barite in the panned concentrate samples. Tabular habit of small crystals (a, b) with dominant shape of basal pinacoid on (001) plane. Very good cleavability predestines the most common morphological modification of barite in the panned concentrate samples. Colour of barite in the panned concentrate samples is white (depicted fragment of crystal with coating of barium chromate, which developed after dye test – c). Split-off fragment of barite with distinct planes of cleavability on (001) plane – d. Sites: Kremnica (c); Malužiná (d). Drawings: Rösler, J. H., 1983, Photo: P. Bačo, SEM I. Holický.

Tab. 4.9 Presence of barite in the panned concentrate samples according to content classes.

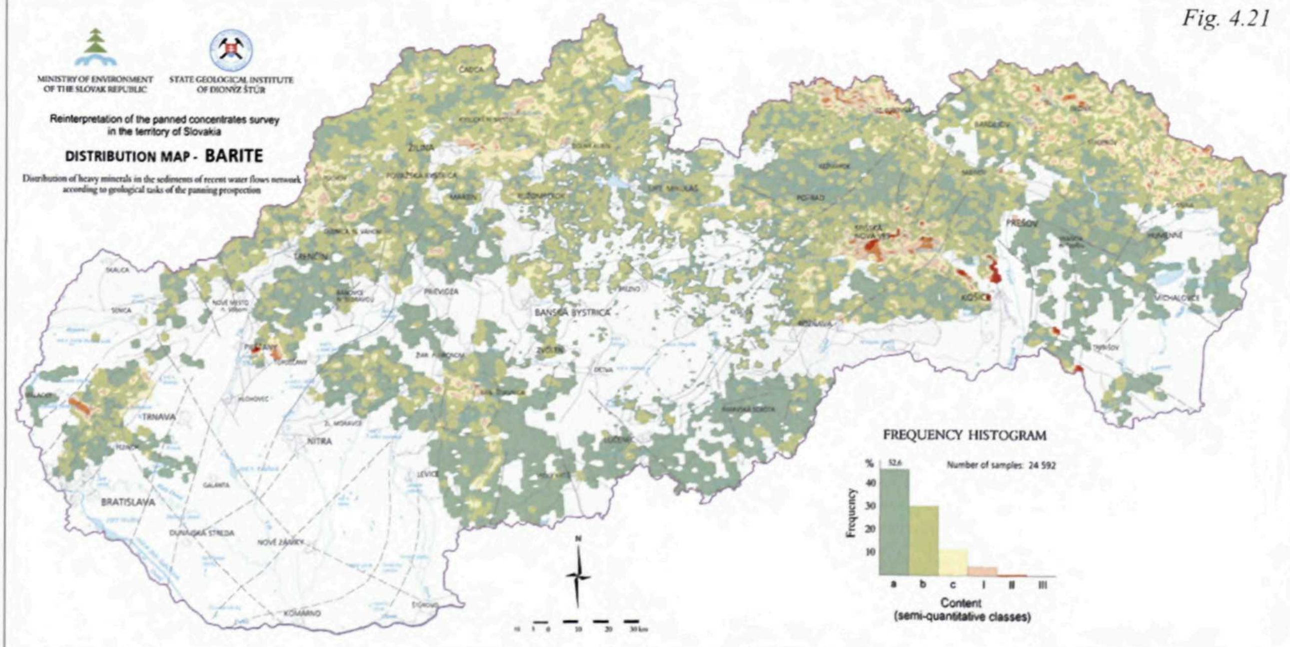
Database of samples	Negative / Positive	Content (semi-quantitative classes)					
		a	**b**	**c**	**I**	**II**	**III**
50,939	26,347	12,943	7,260	2,969	964	335	121
	52	25	14	5.83	1.89	0.66	0.24
	24,592	12,943	7,260	2,969	964	335	121
	48	52.63	29.52	12.07	3.92	1.36	0.49

Tab. 4.10 Presence of barite in the panned concentrate samples according to content classes. Selected map sheets at scale 1 : 50,000 illustrate areas with deposits and significant occurrences of barite, which is present in all content classes in the panned concentrate samples.

Map	**Database**	**Samples without mineral presence**		**Content (semi-quantitative classes)**											
	Number			a		b		c		I		II		III	
1:50 000	of samples	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%
Outer Flysch Zone – Magura and Dukla units															
27-14	283	2	1	32	11	78	28	76	27	48	17	37	13	10	4
27-32	828	65	8	323	39	222	27	108	13	71	9	33	4	6	1
28-31	690	172	25	159	23	152	22	97	14	64	9	31	4	15	2
28-32	768	39	5	217	28	246	32	164	21	81	11	17	2	4	1
28-43	819	31	4	219	27	257	31	161	20	110	13	31	4	10	1
Tatricum – Považský Inovec															
35-32	37	3	8	9	24	6	16	8	22	6	16	3	8	2	5
Gemericum – Poráč -Rudňany															
37-11	1529	631	41	476	31	285	19	107	7	23	2	5	0	2	0
37-12	452	55	12	145	32	148	33	63	14	23	5	15	3	3	1
37-21	487	34	7	120	25	113	23	88	18	50	10	52	11	30	6

Epitaxial intergrowths of barite with other minerals were not observed in the panned concentrate samples. Size of small crystals, their fragments or grains in the panned concentrate samples is up to 1.0 mm. In the area of historic barite mining (Rudňany) or mineralisation with barite (a large proportion of deposits in the Spiš-Gemer rudohorie Mts.) there are present in the panned concentrate samples from the close vicinity of such resources (dumps) usually fissile grains and fragments (up to 1 cm, occasionally even more). On the other hand, the size of the fragments from natural sources is very quickly fining up and size of grains is significantly <0.5 mm.

Fig. 4.21



Application of specific methods of identification: dye test, in which barite grains are covered with yellow coating of barium chromate.

General distribution characteristics:

Barite was identified in almost 50% of the collected panned concentrate samples (Tab. 4.9). Its concentration is confirmed in all semi-quantitative classes (Fig. 4.20) with the predominance of classes a – c, which greatly reflects its cleavability. Presence of such samples is even more pronounced outside of primary accumulation. Concentrations I-III are characteristic for barite deposits areas and occurrences, and such samples constitute about 3% of the total panned concentrate samples (Tabs. 4.9, 4.10).

Barite is typical epigenetic mineral associated with metallogenic processes of various types of deposits (barite, but also siderite), especially in Gemericum. Coincidence of maximum levels in samples with deposit areas is evident (Fig. 4.21). The higher content classes are also confirmed in areas of Central and Eastern Slovakia Neovolcanites with deposits of polymetallic and precious-metal low-sulphidation types.

Distribution of barite also points out to another fundamental genetic type of barite – sedimentary origin (Fig. 4.21). This is manifested in higher content classes for certain sedimentary rocks (some sections of Klippen Belt, Rača lithofacies unit of Magura Flysch). Part of these zones also coincides with sedimentary Mn mineralisation.

4.3.6 Cinnabarite HgS

H = 2.0 – 2.5; **SG** = 8.09 g.cm^{-3}; **System:** Trigonal

Magnetic properties: non-magnetic, and is concentrated in diamagnetic fraction

Colour in the panned concentrate samples

Colour of cinnabarite grains is rich-red, in earthy varieties brown-red (Fig. 4.22b, c; 4.23a, b).

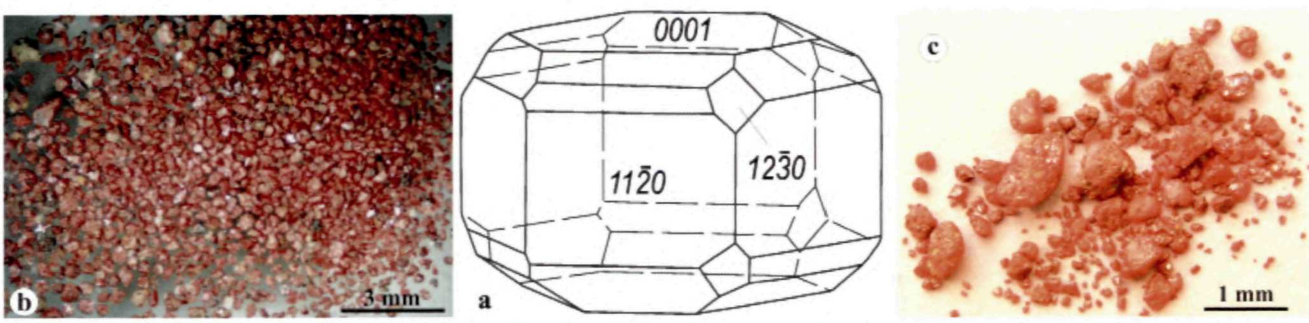


Fig. 4.22a, b, c Crystal shapes and colour of cinnabarite in the panned concentrate samples. Due to its cleavability in the panned concentrate samples it occurs almost exclusively in fissile fragments and well-rounded grains. Sites: Malachov (b); Tribeč – Zlatno (c). Drawing: Rösler, J. H., 1983. Photo: P. Bačo.

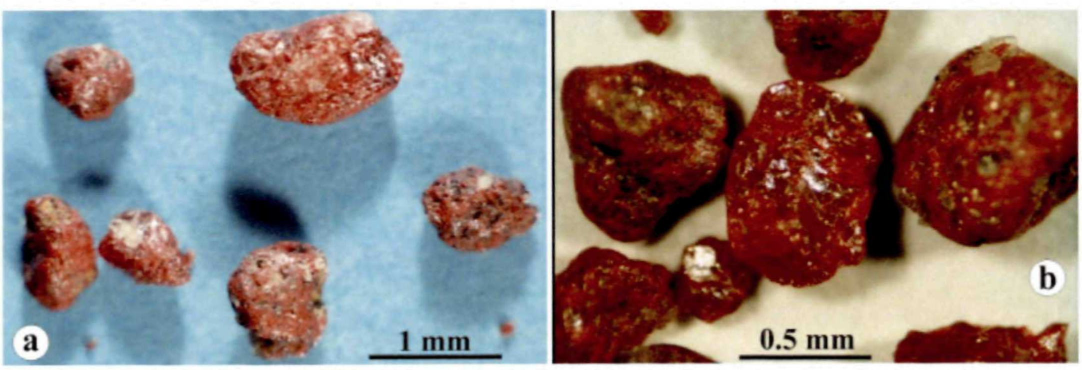


Fig. 4.23a, b Shapes of grains, colour and cleavability of cinnabarite in the panned concentrate samples. Site: Tribeč – Zlatno (a, b). Photo: P. Bačo.

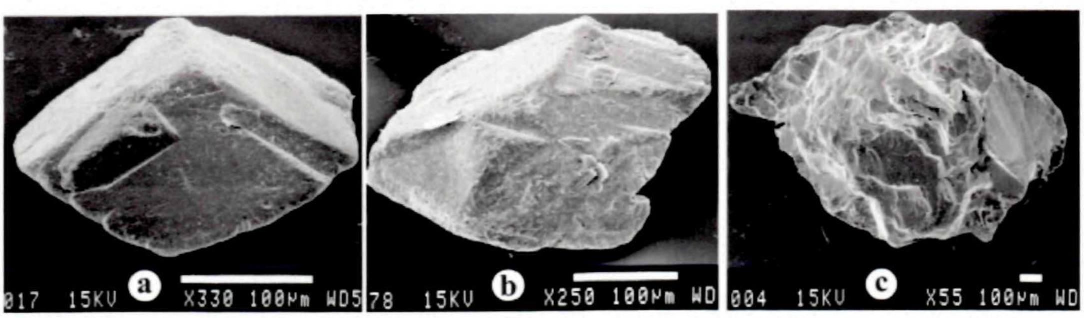


Fig. 4.24a, b, c Typical shapes of cinnabarite – morphology of rhombohedral small crystals and intergrowths. These forms are known mainly from Flysch Zone — its East-Slovakia section. Surface of these small crystals is smooth. Site: Nová Kelča (a, b) Malachov (c). Photo: SEM I. Holický.

Lustre is dull, but on the diamond-like fresh fracture surfaces. Thin leaf-like and flaky forms are translucent.

Morphology in the panned concentrate samples

In the panned concentrate samples the most common are irregular rounded grains with rough, but more often with a smooth surface. On the larger grains good cleavability is sometimes distinct along the (10$\bar{1}$0) plane or irregular fracturing. Near the primary sources there are observed rhombohedral or tabular crystal forms (Fig. 4.24a, b, c). During transport due to the brittleness and good cleavability it disintegrates into very fine particles, and it often concentrates in the lowest granularity classes. It is often gritty and crumbly, easily sliceable (Fig. 4.25a, b, c). Size of small crystals or grains of cinnabarite in the panned concentrate samples is typically up to 0.5 mm. Close to some autochthonous occurrences (e.g. Zlatno in the Tribeč Mts.), the size of grains achieves centimetre magnitude. In source areas of Flysch the size of grains is only 0.X mm.

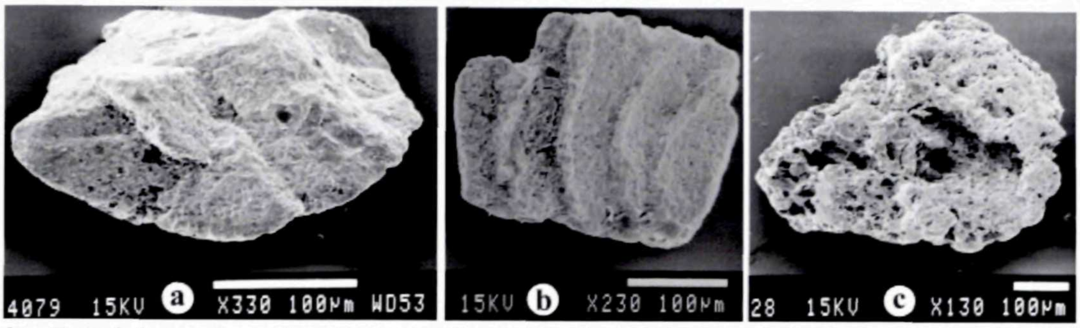


Fig. 4.25a, b, c Typical shapes of granular cinnabarite. Porous, "mushroom-like" form is known from the locality Malachov (b, c). From the locality Zlatno – Tríbeč Mts. (a) transitional type of cinnabarite is known. Photo: SEM I. Holický.

Identification attributes in the panned concentrate samples: intense red colour, very good cleavability.

General distribution characteristics

Cinnabarite is a typical epigenetic mineral and occurs mainly in the panned concentrate samples in source areas with cinnabarite mineralisation presence. Its content in positive panned concentrate samples is dominantly within the first quantitative class (Tab. 4.11, Fig. 4.26a).

Near the cinnabarite primary sources there are present panned concentrate samples having higher degree of concentration (Fig. 4.26 b, c), and the content can amount to several thousands grains – e.g. Malachov, Dubník (Červenica), Ladomírov. Cinnabarite was the first mineral, whose distribution in selected areas in Slovakia was identified by panned concentrate prospecting (Slávik, 1969; Knésl et al., 1972; Tözsér, 1972). The results that were achieved by this method have shown the appropriateness of its use both in the metallogenetically unpromising areas (Vihorlatské vrchy Mts.) or in the areas of historic mining (Malachov area). Cinnabar concentrations are common in the lower content classes.

In particular, cinnabarite exploitation itself and the creation of deposits and anthropogenic sources – heaps, conditioned the presence of content in II and III concentration classes (Tab. 4.12). This is particularly valid in the historically mined deposits such as Červenica – Dubník, or in the recent past, for example, Malachov, Rudňany, but also in primary occurrences without deposit accumulations, for example, Uderiná (Fig. 4.27).

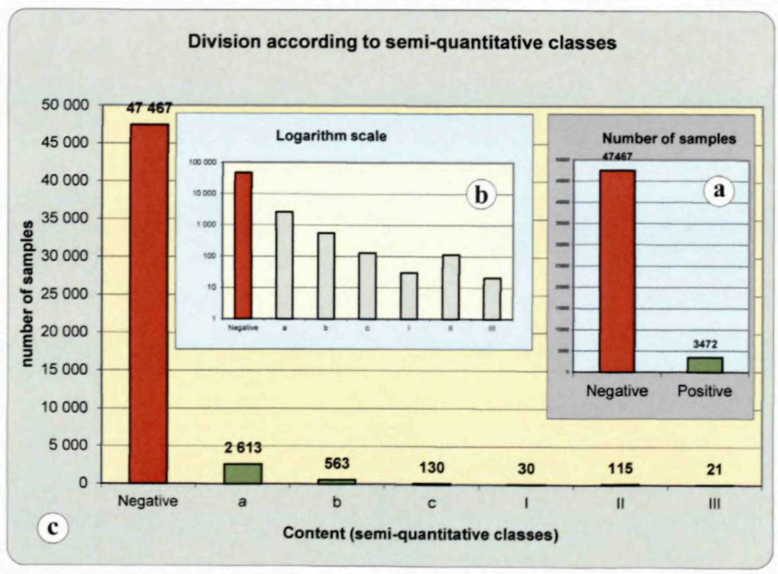


Fig. 4.26a, b, c Distribution of panned concentrate samples according to cinnabarite presence (a). Presence of cinnabarite is dominantly in the first semi-quantitative content class (b, c).

Tab. 4.11 Presence of cinnabarite in the panned concentrate samples according to content classes.

Database of samples	Negative	Content (semi-quantitative classes)					
	Positive	a	b	c	I	II	III
50,939	47,467	2,613	563	130	30	115	21
	94	5.13	1.11	0.26	0.06	0.23	0.04
	3,472	2,613	563	130	30	115	21
	7	75.26	16.22	3.74	0.86	3.31	0.60

Tab. 4.12 Presence of cinnabarite in the panned concentrate samples according to content classes. Selected map sheets at scale 1 : 50,000 illustrate the areas with deposits and significant occurrences of cinnabarite, which is present in the panned concentrate samples in higher content classes.

Map	Database	Samples without mineral presence		Content (semi-quantitative classes)											
	Number			a		b		c		I		II		III	
1:50 000	of samples	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%
Flysch Zone – Stebnícka Huta, Nová Kelča, Ladomírov															
27-24	506	443	88	30	6	22	4	10	2	1	0	0	0	0	0
28-31	690	669	97	18	3	2	0	1	0	0	0	0	0	0	0
28-34	934	830	89	74	8	18	2	7	1	3	0	2	0	0	0
38-22	231	210	91	11	5	6	3	4	2	0	0	0	0	0	0
Central Slovakia Neovolcanic Field, Kremnické vrchy Mts. – Malachov															
36-13	755	581	77	155	21	18	2	1	0	0	0	0	0	0	0
36-14	1,182	706	60	191	16	109	9	33	3	16	1	107	9	20	2
Southern Veporicum – Uderiná, Lovinobaňa, Cinobaňa															
36-43	858	758	88	62	7	27	3	5	1	2	0	4	0	0	0
36-44	797	714	90	62	8	20	3	1	0	0	0	0	0	0	0
Gemericum – Rákoš, Rudňany															
37-14	647	404	62	145	22	76	12	21	3	1	0	0	0	0	0
37-21	487	335	69	106	22	41	8	5	1	0	0	0	0	0	0
East-Slovakia Neovolcanites, Slanské vrchy Mts. – Zlatá Baňa, Dubník-Červenica															
38-11	1,370	1,106	81	186	14	56	4	20	1	2	0	0	0	0	0
38-12	487	410	84	66	14	8	2	3	1	0	0	0	0	0	0

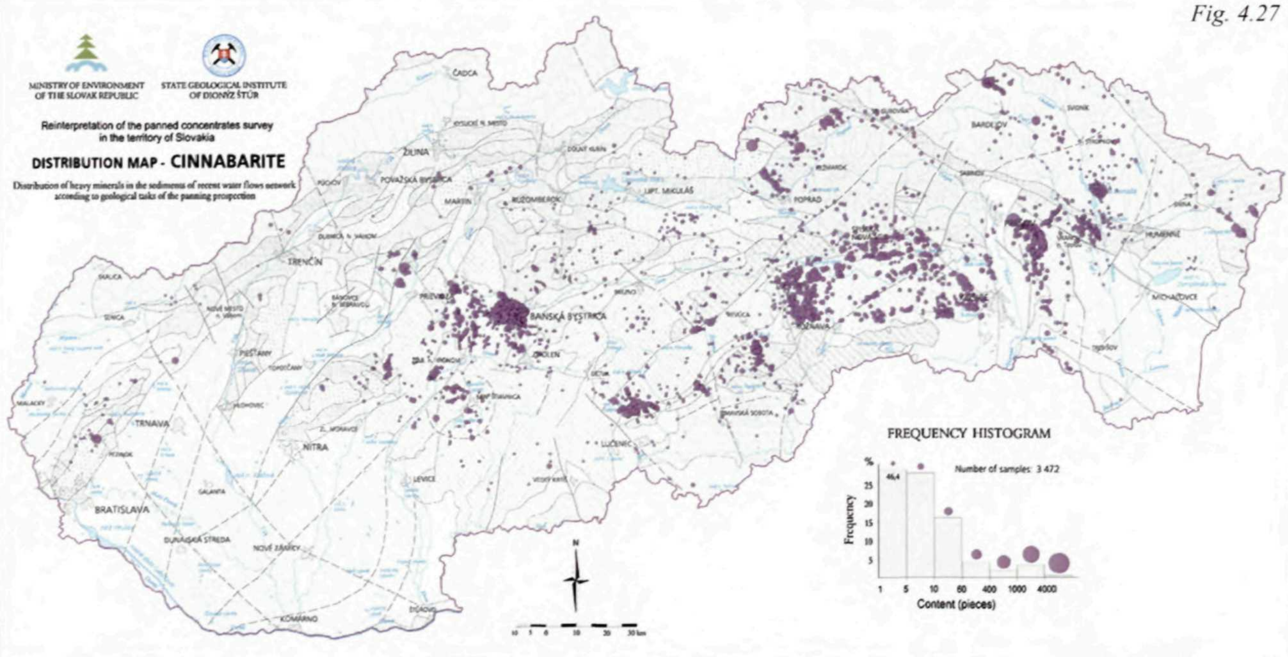


Fig. 4.27

The implemented projects of regional panned concentrate prospecting have found a number of indicia and deposit manifestations. Presence of cinnabarite and its regional distribution has allowed also important tectonic interpretations particularly in the Flysch Zone – the Outer and Inner ones (Križáni 1971; Križáni et al., 1979).

4.3.7 Galena PbS

H = 2.0 – 3.0; **SG** = 7.4 – 7.6 g.cm^{-3}; **System:** Cubic
Magnetic properties: non-magnetic, and is concentrated in diamagnetic fraction

Colour in the panned concentrate samples

Colour of galena in the panned concentrate samples is a lead-grey colour with setting-up hues. Lustre on flat surfaces (nearly always the fission planes) is metallic. It is usually covered with a thin layer of secondary minerals of white, yellowish, grey (anglesite, cerrusite) or to red (cerrusite) colour. Planes on small crystals can have up to metallic lustre.

Morphology in the panned concentrate samples

In the panned concentrate samples galena is very rarely present. On grain surfaces there are developed mainly hexahedron {100}, {111} less octahedron planes (Fig. 4.28a, c). They are mostly fragments; their shape is the result of perfect cleavability along (100) plane and they are therefore the fission fragments of the original crystals (Fig. 4.28b) or fine to coarse aggregates.

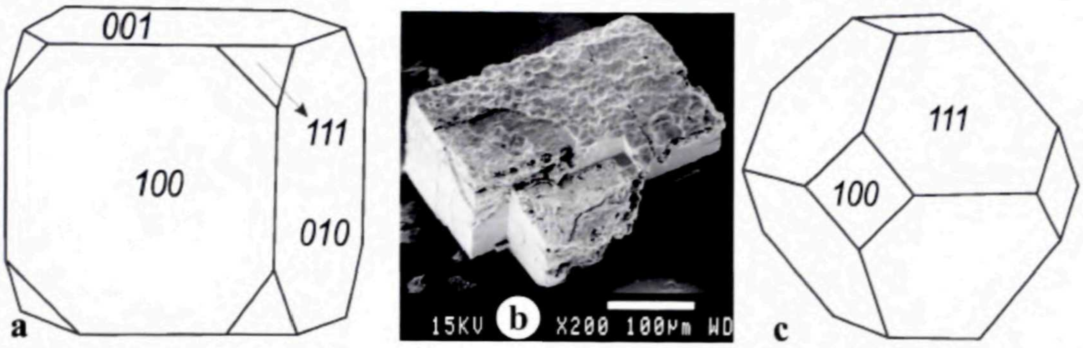


Fig. 4.28a, b, c Basic crystal shapes of galenite (a, c) and their fission fragments (b) in the panned concentrate samples. Thanks to good cleavability galena and sphalerite in the panned concentrate samples occur almost exclusively in fission fragments and well-rounded grains. Site: Slanské vrchy Mts. – Zlatá Baňa (b) – below the heap originating from mining activity. Drawings: Rösler, J. H., 1983, Photo: SEM I. Holický.

During transport and thanks to its excellent cleavability it quickly crumbles and this process facilitates its rapid oxidation and thus the disappearance in the heavy fraction. Size of fission fragments of small crystals in the panned concentrate samples reaches up to 0.5 mm.

General distribution characteristics:

The concentration of galena in positive panned concentrate samples is significantly conditioned by its properties in the supergene environment and it is present only in the first (a) semi-quantitative classes (Tab. 4.13; Fig. 4.29a, b). Its occurrence in all content classes almost always means immediate proximity of the primary source. It is almost always dump (heap) of mining works, and in some exceptional circumstances its content may be in the class c (Fig. 4.29b).

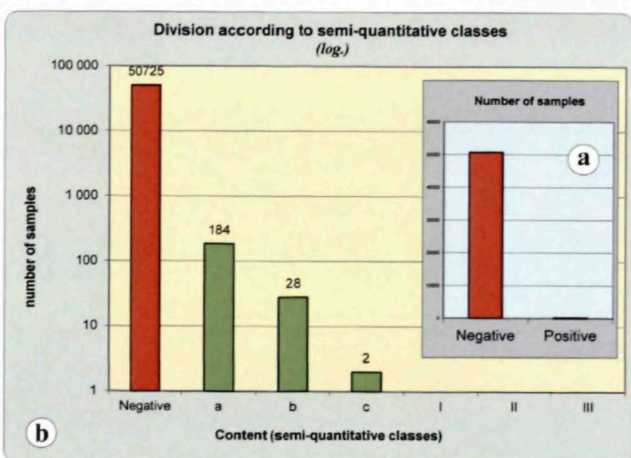


Fig. 4.29a, b Distribution of panned concentrate samples according to galena presence (a). Presence of galenite is dominantly in the first semi-quantitative content class (b).

Galena is a typical epigenetic mineral and in natural conditions it occurs along with sphalerite. It appears in polymetallic epithermal hydrothermal mineralisation types, forming important deposits (Fig. 4.33). This is only possible rock environ, from which it gets into the fluvial network and its transport is possible to a very short distance.

4.3.8 Sphalerite ZnS

H = 3.5 – 4.0; **SG** = 3.9 – 4.1 g.cm^{-3}; **System:** Cubic

Magnetic properties: non-magnetic, and is concentrated in diamagnetic fraction, Fe-varieties (marmatite) transit into paramagnetic fraction

Colour in the panned concentrate samples

Colour of sphalerite in the panned concentrate samples is mostly tan, sometimes with very light shades (variety cleiophane) occurring in the panned concentrate samples from Banská Štiavnica region. It is also often brown to brownish-black. Lustre on flat crystal planes or cleavage surfaces is diamond-like, the corroded grains are dull.

Morphology in the panned concentrate samples

In the panned concentrate samples sphalerite is seldom present in the form of small crystals. Most often it is present in the form of irregular angular fragments (Fig. 4.30) and near the primary occurrences they often contain characteristic grooving. On cleavage planes there can be seen grooving that developed due to primary contact among lamellar and penetrating intergrowths. During transport

Tab. 4.13 Presence of galena in the panned concentrate samples according to content classes.

Database of samples	Negative	Content (semi-quantitative classes)					
	Positive	a	b	c	I	II	III
50,939	50,725	184	28	2	0	0	0
	100	0.36	0.05	0.004	0	0	0
	214	184	28	2	0	0	0
	0	85.98	13.08	0.93	0	0	0

sphalerite is quickly (but more slowly than galena) disintegrating due to the good cleavability of the (110) plane and it becomes subject to the oxidation and turns to smithsonite. Size of fragments of small crystals or crystal clusters in the panned concentrate samples is up to 0.5 mm. Only in cases of immediate vicinity of polymetallic mineralisation with heaps the size of grains can be larger.

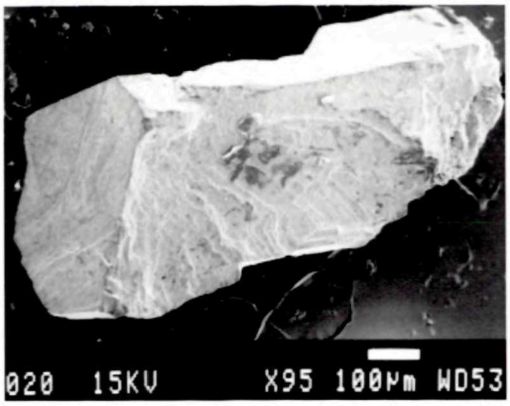


Fig. 4.30 Sphalerite is rare in the panned concentrate samples. Similarly to galena, it occurs in the panned concentrate almost exclusively in the form of fissile fragments and well-rounded grains. It is present close to primary sources, mostly of anthropogenic origin. Site: Pukanec. Photo: SEM I. Holický.

General distribution characteristics:

Sphalerite was observed only in very few samples. Like galena also sphalerite has been found in the panned concentrate samples only in the first semi-quantitative concentration class – a (Tab. 4.14; Fig. 4.31a).

Class b means the immediate proximity of the primary source, which is almost always dump (heap) originating from mining works from which they got to alluvial sediments; however its transport is possible only to a short distance, similarly as galena.

Sphalerite has a wider genetic range compared to galena and therefore its proportion and the presence in the panned concentrate samples is more frequent. More significant deposits with epithermal hydrothermal mineralisation with sphalerite are mainly in Neovolcanites, and to lesser extent the occurrences are known in Tatricum, Veporicum and Gemericum. Thanks to the mining of these deposits is has got to the surface and concentrations of sphalerite reach upper classes (b, c).

Presence of sphalerite in the environment of Outer Flysch Zone (Fig. 4.33) may be associated with cinnabarite mineralisation.

4.3.9 Chalcopyrite $CuFeS_2$

H = 3.5 – 4.0; **SG** = 4.1 – 4.3 g.cm^{-3}; **System:** Tetragonal

Magnetic properties: non-magnetic, and is concentrated in diamagnetic fraction

Colour in the panned concentrate samples

Colour of chalcopyrite in the panned concentrate samples is brass yellow to golden yellow, often impinged with bright colours - blue and purple, of different grades and shades. Lustre is metallic and opaque.

Morphology in the panned concentrate samples

In the panned concentrate samples chalcopyrite is present in the form of regular and sharp-edged grains and only sporadically the original pseudooctahedral or small tetrahedral crystals can be observed, or crystal planes in irregular fragments.

During transport occurs slow diminution as in the case of galena and sphalerite, it is quickly covered with a thin coating of Cu oxides. Size of small crystals, their fragments or grains in the panned concentrate samples is normally within range of 1.0 mm, and in the case of a source proximity there may occur even larger grains.

Tab. 4.14 Presence of sphalerite in the panned concentrate samples according to content classes.

Database of samples	Negative	Content (semi-quantitative classes)					
	Positive	**a**	**b**	**c**	**I**	**II**	**III**
50,939	48,814	1,780	286	58	1	0	0
	96	3.49	0.56	0.11	0.002	0	0
	2,125	1,780	286	58	1	0	0
	4	83.76	13.46	2.73	0.05	0.00	0.00

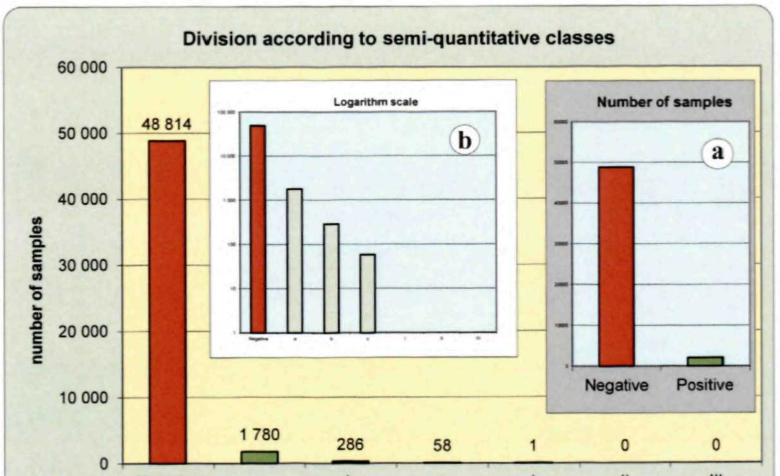


Fig. 4.31a, b Distribution of panned concentrate samples according to sphalerite presence (a). Presence of sphalerite is dominantly in the first semi-quantitative content class (c).

General distribution characteristics:

The occurrence of chalcopyrite, like most of sulphide minerals in the panned concentrate samples indicates the presence of a close primary source. In the case of chalcopyrite it is often an anthropogenic source – heap after mining operations. Its content in positive panned concentrate samples (Tab. 4.15) is strongly conditioned by its properties in the supergene environment and it is only in the first – **a** (less **b**, and rarely **c**) content classes.

Class c always means the immediate proximity of the primary source. Higher concentrations classes (I – III) are very rare, all-in-all 12 samples from the NW margin of the Suchý Massif, W of Valaská Belá. It is an area without any detailed interpretation.

Chalcopyrite, like other sulphide mineral, is a typical epigenetic minerals, and in natural conditions it occurs along with them. It occurs in base metal epithermal hydrothermal types of mineralisation forming important deposits (Fig. 4.33) as well in individual deposits, often along with siderite mineralisation, especially in Gemericum.

Sporadic occurrences of chalcopyrite were also recorded in the Outer Flysch Zone and Inner-Carpathian Paleogene. They are spatially separated from sphalerite (Fig. 4.33) as well as cinnabarite (Fig. 4.27) and therefore they represent independent type of mineralisation.

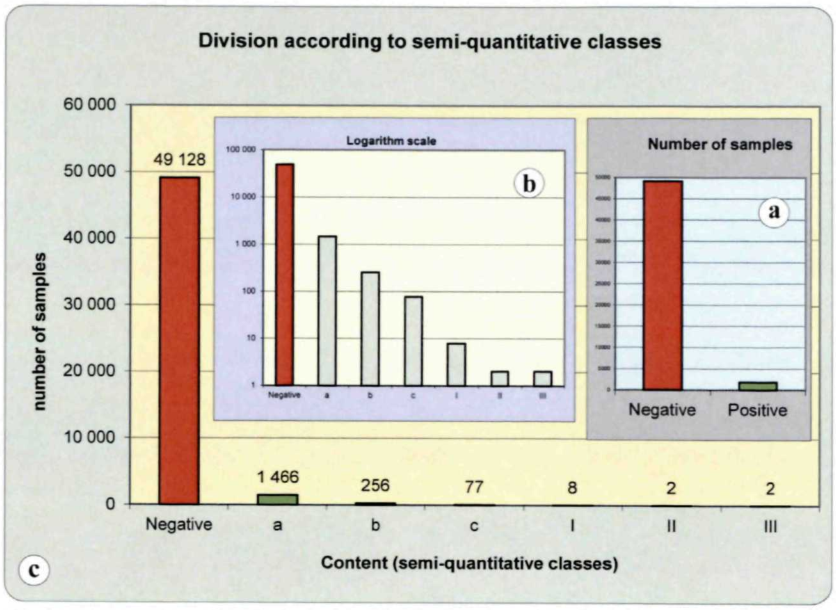


Fig. 4.32a, b, c Distribution of panned concentrate samples according to chalcopyrite presence (a). Presence of chalcopyrite is dominantly in the first semi-quantitative content classes (b, c).

Tab. 4.15 Presence of chalcopyrite in the panned concentrate samples according to content classes.

Database of samples	Negative / Positive	Content (semi-quantitative classes)					
		a	b	c	I	II	III
50,939	49,128	1,466	256	77	8	2	2
	96	2.88	0.50	0.15	0.02	0.004	0.004
	1,811	1,466	256	77	8	2	2
	4	80.95	14.14	4.25	0.44	0.11	0.11

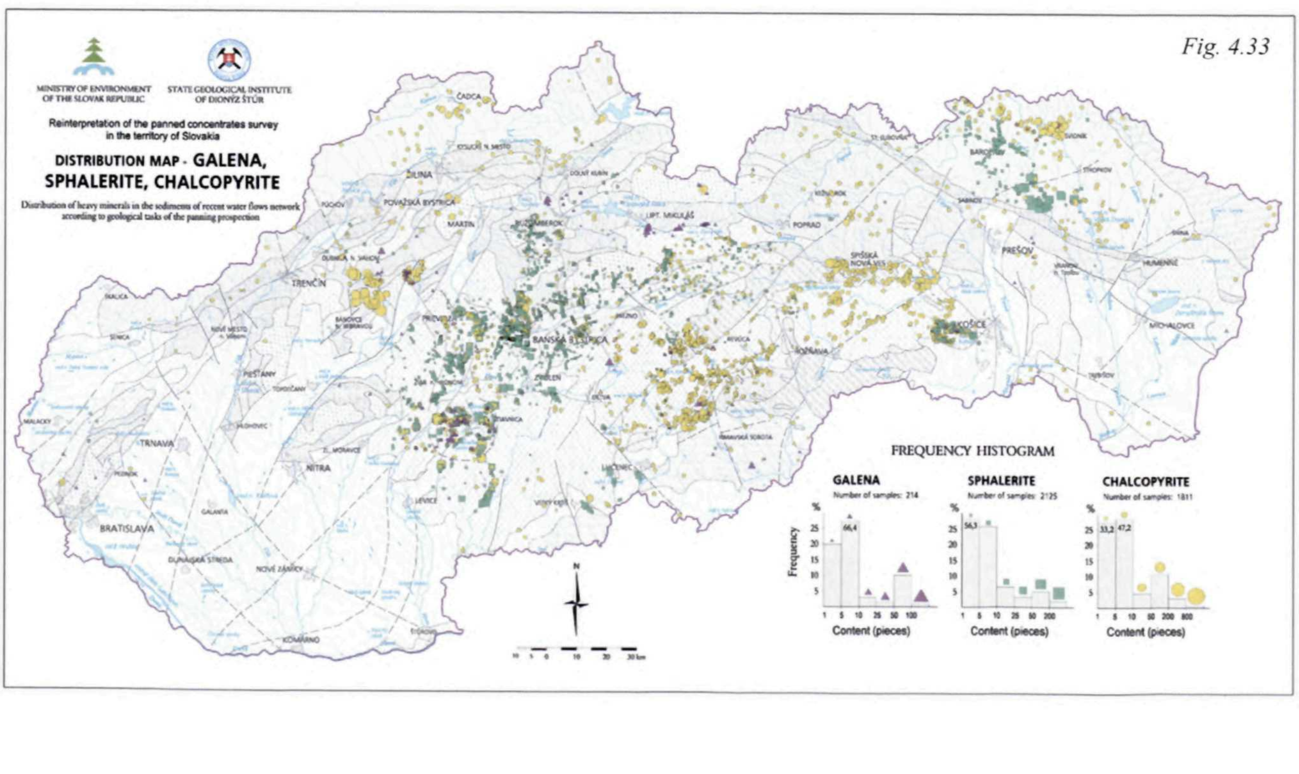


Fig. 4.33

Slovak Geol. Mag., 15, 2 (2015), 39 – 86

4.3.10 Garnets $(A^{2+}_3)(B^{3+}_2)(C_3)O_{12}$

A = Ca, Mg, Fe^{2+}, Mn^{2+}, Na, Y;
B = Mg, Al, Si, Sc, Ti, V, Cr, Fe^{3+}, Fe^{2+}, Mn^{3+} Cr, Zr, Sn
C = Al, Si, Fe^{3+}

Garnet crystal lattice is capable to take quite a lot of different cations and there are recorded around 20 varieties of silicate garnets (Broska et al., 2012). In practice of panned concentrate prospecting, the maps show the distribution of these minerals as a whole. In the scope of individual projects there were identified the most common varieties of garnets.

"Al garnets"

Pyrope $Mg_3Al_2(SiO_4)_3$ **Almandine $Fe^{2+}_3Al_2(SiO_4)_3$** **Spessartine $Mn^{2+}_3Al_2(SiO_4)_3$**

"Ca garnets"

Andradite $Ca_3Fe^{3+}_2(SiO_4)_3$ **Grossular $Ca_3Al_2(SiO_4)_3$** **Uvarovite $Ca_3Cr^{3+}_2(SiO_4)_3$**

H = 7.0 – 7.5; **SG** = 3.58 (pyrope) – 4.25 (almandine) g.cm^{-3}; **System:** Cubic

Magnetic properties: most commonly concentrated in paramagnetic (pure non-ferric varieties in diamagnetic) fraction

Colour in the panned concentrate samples

Colour of garnets in the panned concentrate samples is very diverse and depends on the predominant species (the proportion of its components) and clarity. The most commonly present almandine garnets are predominant species (Figs. 4.34a, b, c) and in this case the colour is light pink-red in various hues and shades, or brownish. With the growing pyrope species proportion the colour is bright red.

Grossular dominates in greenish garnets. In rare cases there have been also reported colourless and yellow, very small, but perfect rhombic dodecahedron garnets. Lustre on flat surfaces of the crystals is glassy, heavily corroded grains and granular masses are dull.

Morphology in the panned concentrate samples

In the panned concentrate samples the garnets are present mostly in the form of various preserved typical

Fig. 4.34a, b, c, d Colour varieties of the most common types of garnets, which are present in the panned concentrate samples. The most frequent are red and pink colours with various hues and shades. Sites: a – Jasenie; b – Ľubietová; c – Juskova Voľa; d – Ruská Bystrá. Photo: P Bačo

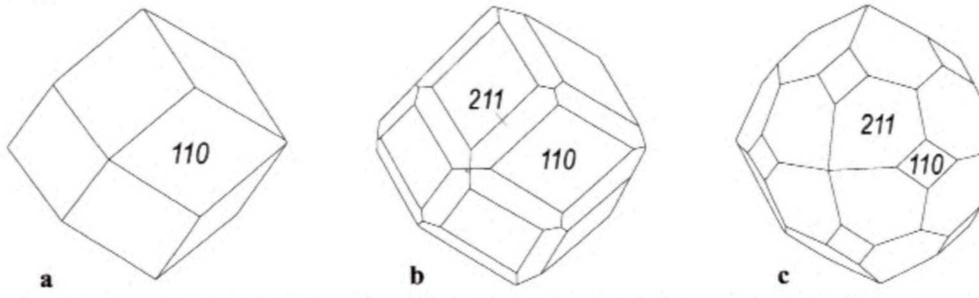


Fig. 4.35a, b, c Crystal shapes of garnets. Basic shape of garnets is rhombic dodecahedron {110}. Other crystal shapes are combinations of further basic habits – hexaoctahedrons of the cubic system. These shapes are typical and commonly present in the panned concentrate samples. Planes are often preserved even on fragments. Drawings: Rösler, J. H., 1983.

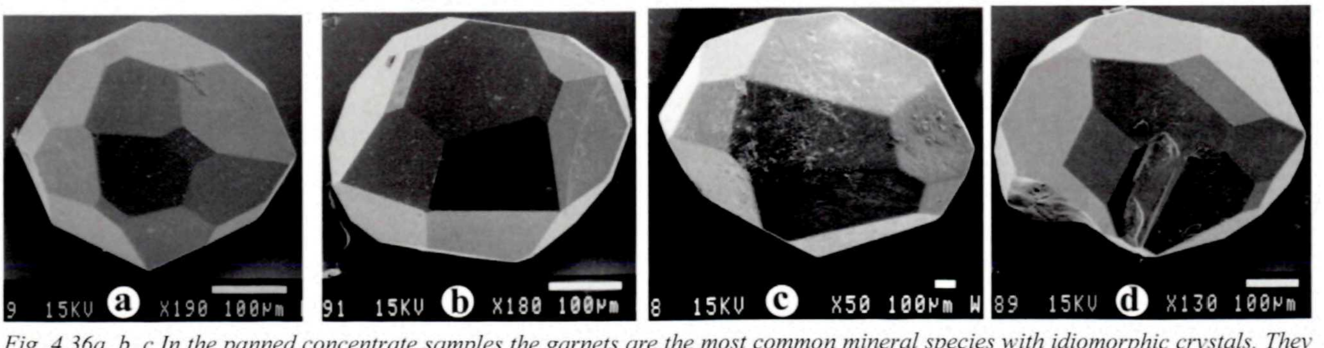


Fig. 4.36a, b, c In the panned concentrate samples the garnets are the most common mineral species with idiomorphic crystals. They are often present in perfect crystals representing basic shapes of hexaoctahedron and their combinations with variously developed planes. Sites: a – Malé Ozorovce, b – Zamutov, c – Juskova Voľa, d – Slanská Huta. Photo: SEM I. Holický.

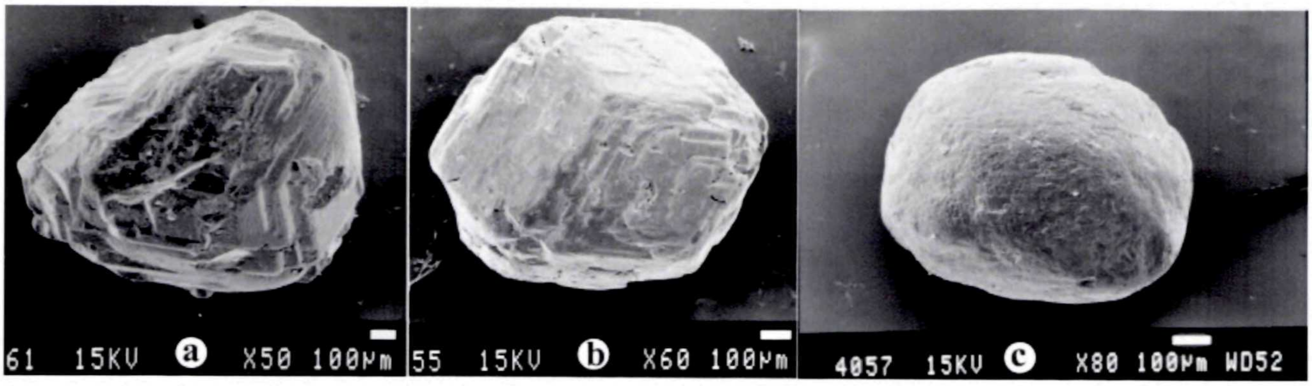


Fig. 4.37a, b, c Thanks to strong resistance in the course of transport the garnets preserve their original crystal shape. During longer transport they become more rounded (b, c) and inherited chemical and physical inhomogeneity is more pronounced (Fig. a, b). Sites: a – Ľubietová, b – Pezinok, c – Kolonica. Photo: SEM I. Holický.

rhombic dodecahedrons {110} with diverse size of individual planes.

The planes of the crystals are very often "grooved" with the skeletal development. Large proportion, particularly large fragments, has character of granular mass with signs of crystal planes. Irregular, often angular fragments of garnets originate from the source areas formed by metamorphic rocks, especially the Crystalline complexes of Tatricum and Veporicum.

During transport they are very stable due to their hardness and poor cleavability and the garnets' habit is retained in small crystals. However, quite common fragments of garnets are present in the vicinity of primary occurrences.

Size of small crystals, their fragments or grains in the panned concentrate samples is very variable and depends on the type of source rocks. Generally, in the Crystalline complexes of Tatricum and Veporicum garnets are present in all grain-size classes and often even reach the size of 1 cm.

In the source areas made of mostly intermediary and above all acidic volcanic rocks, the size of garnets attains typically 0.5 to 1.0 mm, less often up to 5 mm. In the environment of sedimentary rocks their size reaches up to 2 mm, greater grains are rather rare. In the vicinity of the Ruská Bystrá the source rock is Strihovce Member of the Krynica unit and garnets in the panned concentrate samples can reach over 5 mm (Fig. 4.34d).

General distribution characteristics:

Garnets are the most common minerals of heavy fraction of panned concentrate samples. Their concentration in the panned concentrate samples are in all semi-quantitative classes, a – III (Tab. 4.16). The well-preserved original small crystals originate from the neovolcanic areas. Garnets are mainly associated with acidic volcanism and their presence in the panned concentrate samples often points out hidden resources. In the sedimentary environs garnets are also good indicators of the initial presence of volcanic, volcaniclastic rocks.

Garnets are typical accessory minerals and in some cases the rock-forming minerals. For these reasons, they are among the most widespread mineral species in the heavy fraction from almost all regional geological formations (Fig. 4.39).

In the clastogenic sedimentary areas (Flysch Zone, Neogene sedimentary basins) they are the main, dominating minerals of panned concentrate samples (Fig. 4.39). Their predominance is due to their resistance in the supergene environment and ability to round-up during transport.

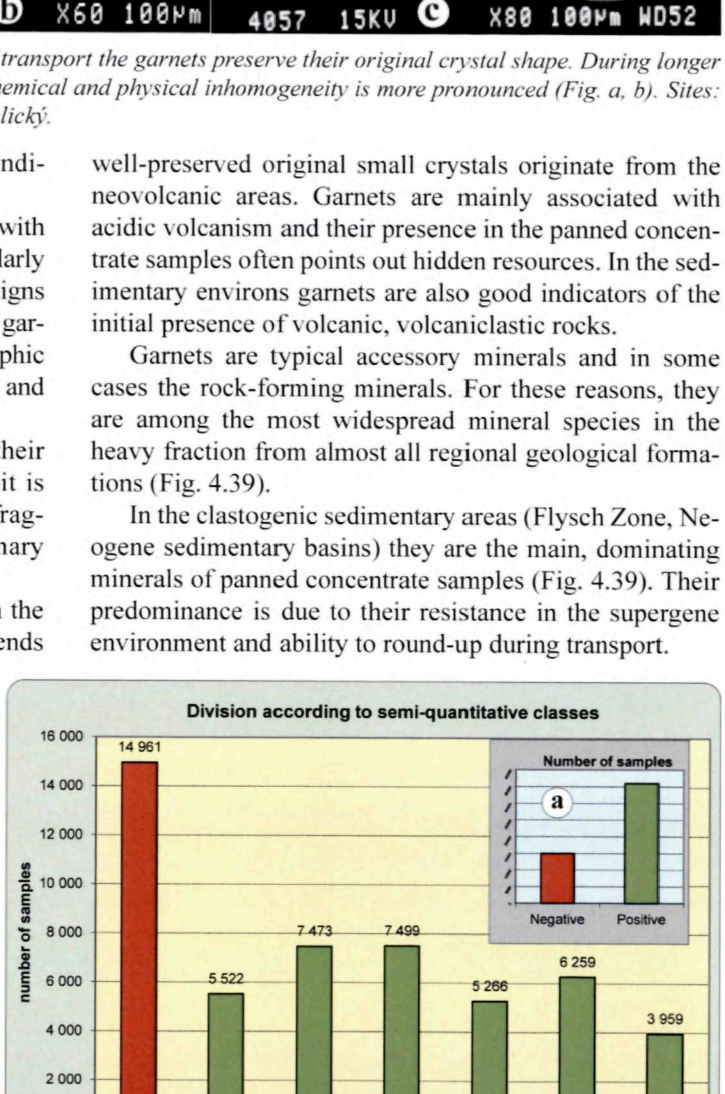
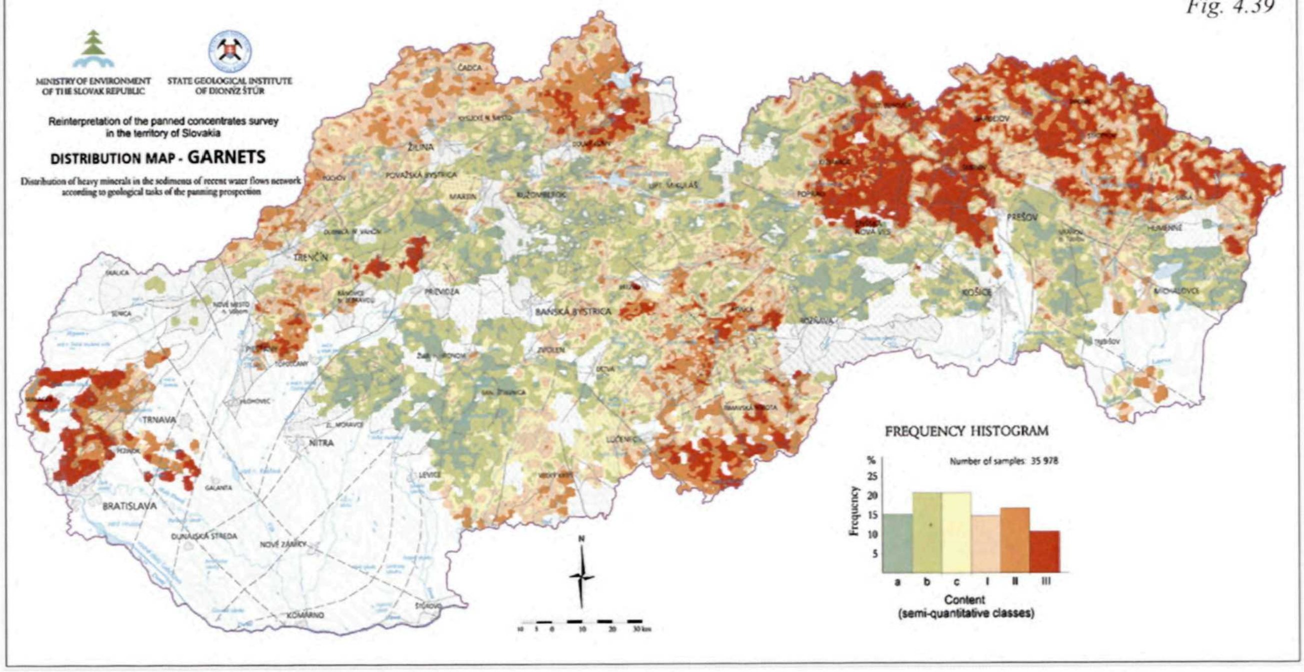


Fig. 4.38a, b Distribution of panned concentrate samples according to garnets presence (a). Garnet is almost proportionally present in all individual semi-quantitative content classes (b).

Tab. 4.16 Presence of garnets in the panned concentrate samples according to content classes.

Database of samples	Negative	Content (semi-quantitative classes)					
	Positive	**a**	**b**	**c**	**I**	**II**	**III**
50,939	14,961	5,522	7,473	7,499	5,266	6,259	3,959
	29	11	15	15	10	12	8
	35,978	5,522	7,473	7,499	5,266	6,259	3,959
	71	15	21	21	15	17	11

Fig. 4.39



4.3.11 Ilmenite $Fe^{2+}TiO_3$

H = 5.0 – 6.0; **SG** = 4.5 – 5.0 g.cm^{-3}; **System:** Trigonal

Magnetic properties: weakly magnetic, and is concentrated in paramagnetic fraction

Colour in the panned concentrate samples

Colour of ilmenite in the panned concentrate samples is mostly black. Lustre on flat planes is semi-metallic and metallic, sometimes dull. On the surface of small crystals and fragments leucoxenisation can be often seen – a greyish white to light-grey fine-grained material (a mixture of rutile, anatase and brookite).

Morphology in the panned concentrate samples

In the panned concentrate samples ilmenite is present in the form of small tabular crystals (Figs. 4.40a, 4.41a, b, d) as a combination of dominant planes {0001} of pinacoid and rhombohedrons {10$\bar{1}$1}, {10$\bar{1}$2} and other surfaces (Fig. 4.40b), but mainly thin plates with prevailing flat pinacoid (0001). In most cases, however, it creates to varying degrees rounded almost isometric grains with tabular habit.

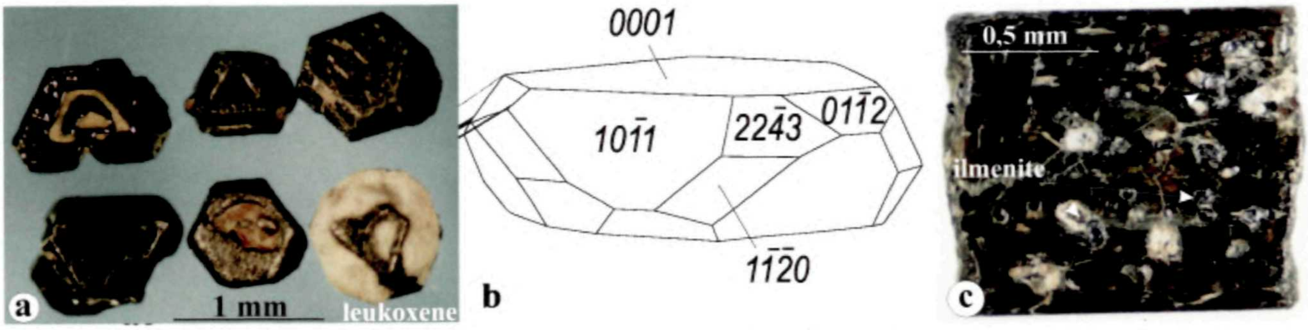


Fig. 4.40a, b, c Colour and lustre of ilmenite from panned concentrate samples. White coatings are made of leucoxene (a). Small crystals of ilmenite in tabular pyroxene (b). Sites: Poruba pod Vihorlatom – a; Ľubietová – c. Drawing: Rösler, J. H., 1983. Photo: P. Bačo.

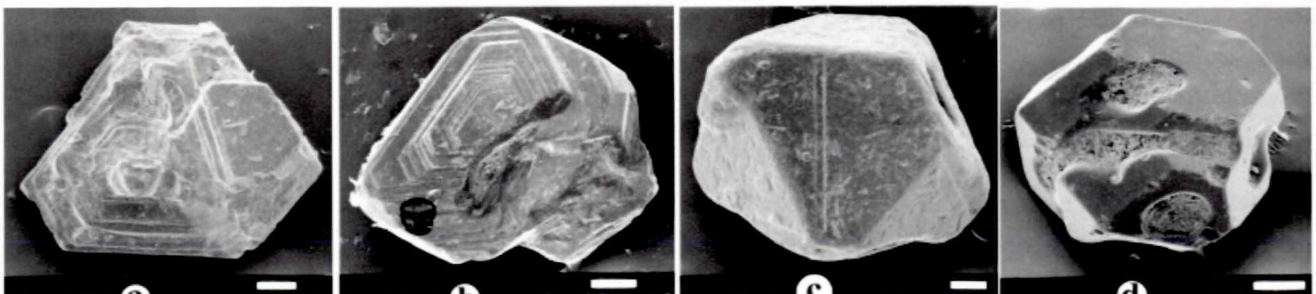


Fig. 4.41a, b, c, d In the panned concentrate samples ilmenite forms small crystals with tabular habit with very extensive range of combinations of individual crystal planes. Sites: a – Skároš, b – Nová Baňa, c – Slanská Huta, d – Banské. Photo: SEM I. Holický.

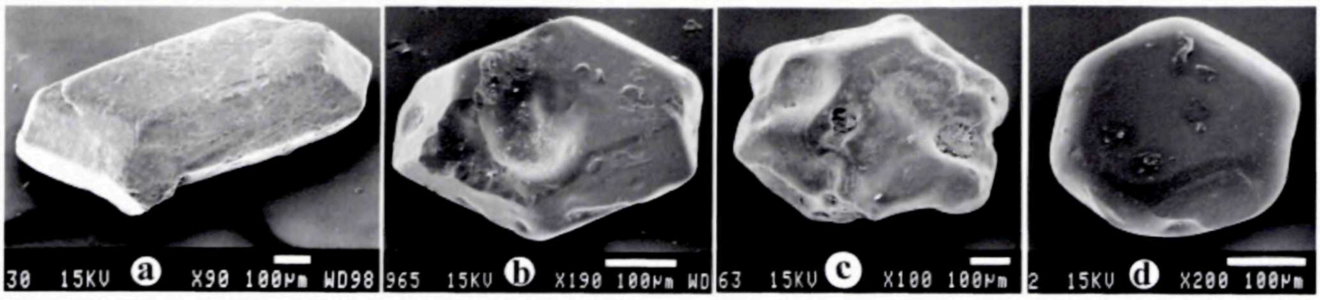


Fig. 4.42a, b, c, d During transport the ilmenite, like other resistant minerals, preserves its original crystal shape. During longer transport it becomes gradually more rounded Cavernous surface evolved due to selective leucoxenisation, whose products were subsequently decomposed within hypergenic environ. Sites: a – Slanská Huta, b – Nový Salaš, c, d – Bacúch. Photo: SEM I. Holický.

On crystals of ilmenite there are often seen a number of planes, and, often stepwise or skeletal habit and generally the dominating, increasingly diminishing pinacoid (0001) plane – Fig. 4.41a, b. Small crystals rich in variegated forms are mainly from the source areas of Neogene volcanic rocks of andesite composition. In other geological environments dominate isometric and small tabular crystals. Locally, in the panned concentrate samples ilmenite can be seen closed in younger minerals. Typical examples are the inclusions in pyroxenes of the Neogene volcanic rocks (Fig. 4.40c).

Very often in the panned concentrate samples the decomposition of ilmenite crystals – leucoxenisation – can be seen, manifested by fine-grained, usually white, sometimes yellowish, earthy mass (mainly composed of anatase, rutile and brookite). This fine-grain material substitutes small crystals of ilmenite up to the stage of full pseudomorphs (Fig. 4.40a). During transport the small crystals of ilmenite and mainly their edges are strongly rounding up (Fig. 4.42).

Size of small crystals or fragments of ilmenite in the panned concentrate samples is 0.5 to 2 mm, in some locations in Central and Eastern Neovolcanites (Poruba pod Vihorlatom) its size reaches up to 0.5 cm. In Flysch source areas the size of small crystals and their fragments attains 1 mm, typically up to 0.5 mm.

General distribution characteristics

Ilmenite is among the most abundant minerals of heavy fraction. It was recorded in almost 60% of evaluated panned concentrate samples (Tab. 4.17, Fig. 4.43a.). It is present from the lowest (a) up to the highest concentration classes (III). Character of distribution of individual concentration levels (Fig. 4.43b) points out that ilmenite is the most common part of almost every rock environment in the panned concentrate samples. It is a typical accessory mineral of the Neogene volcanic rocks of andesite composition and dominates in the panned concentrate samples (content classes I – III) of this environment (Fig. 4.44).

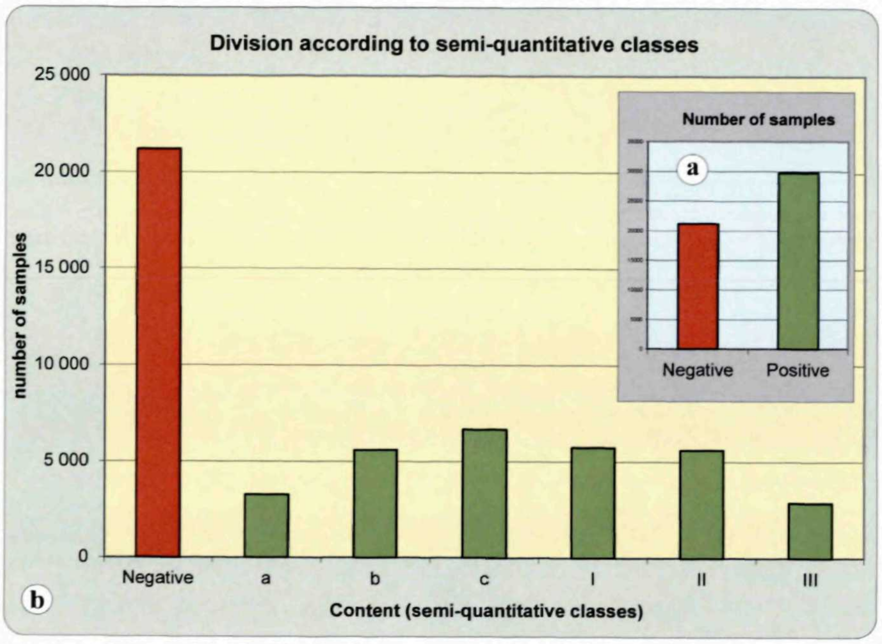


Fig. 4.43a, b Distribution of panned concentrate samples according to ilmenite presence (a) and according to its proportion in individual semi-quantitative content classes (b).

Distribution of ilmenite in the area east of the Vysoké Tatry Mts. may indicate the original extent of fluvioglacial sediments of the Vysoké Tatry Mts. and their redeposition by river network up to Klippen Belt.

Tab. 4.17 Presence of ilmenite in the panned concentrate samples according to content classes.

Database of samples	Negative	Content (semi-quantitative classes)					
	Positive	a	b	c	I	II	III
50,939	21,188	3,256	5,598	6,669	5,738	5,612	2,878
	41.6	6.39	11.0	13.1	11.3	11.0	5.65
	29,751	3,256	5,598	6,669	5,738	5,612	2,878
	58.4	10.9	18.8	22.4	19.3	18.9	9.67

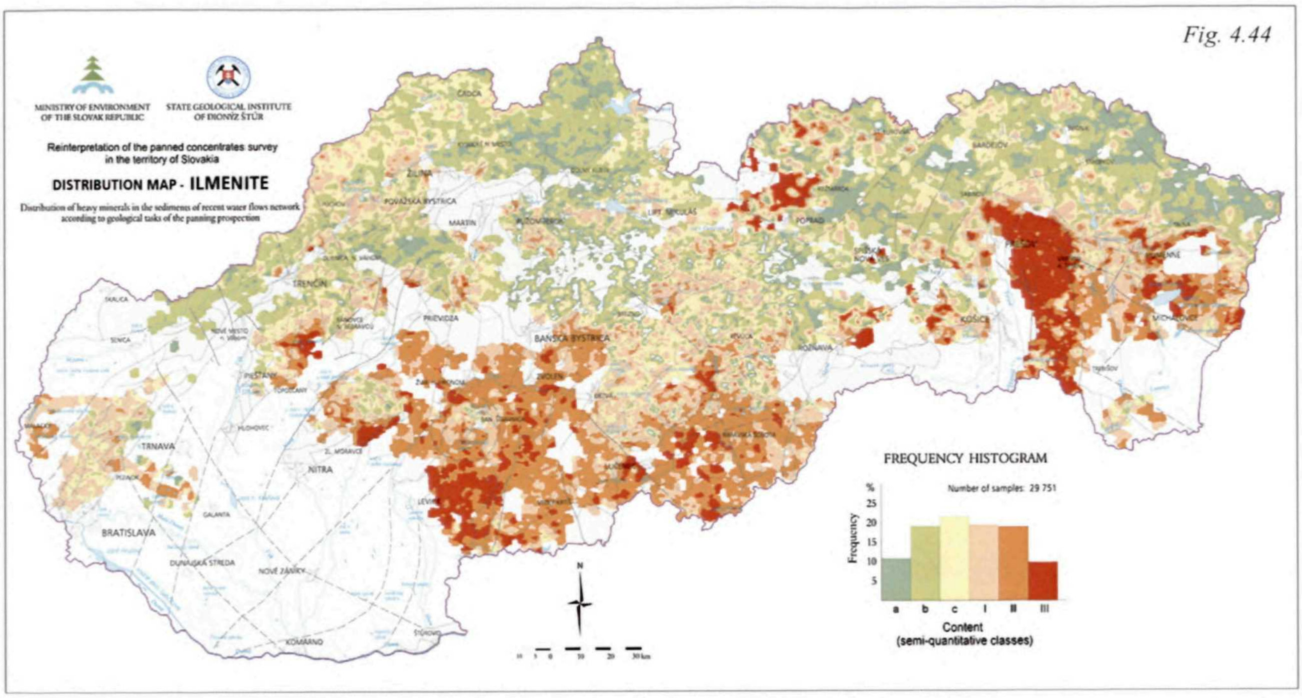


Fig. 4.44

4.3.12 Corundum Al_2O_3

H = 9.0; **SG** = 4.0 – 4.1 g.cm^{-3}; **System:** Trigonal

Magnetic properties: non-magnetic, and is concentrated in diamagnetic fraction

Colour in the panned concentrate samples

Colour of corundum in the panned concentrate samples is mostly blue, of different grades and shades. It can be also blue-grey, dark grey to black, as well as white and in thin tabular forms corundum is colourless and clear (Fig. 4.45a, b, c). Lustre on flat planes is glassy to diamond-like, the heavily corroded grains are dull. Corundum with intense blue colour is assessed as a sapphire (Fig. 4.45b, c).

Morphology in the panned concentrate samples

In the panned concentrate samples corundum is most often present in the form of coarse, but especially thin plates with prevailing (0001) planes highlighted by trigonal prism (Fig. 4.46a). It‘s a characteristic, unmistakable shape of small crystals of accessory corundum in different types of rock environment, but mainly in volcanic rocks. Common are also columnar and spherical shapes (Fig. 4.47b, c) which are couplers of prisms and steep pyramids. These shapes

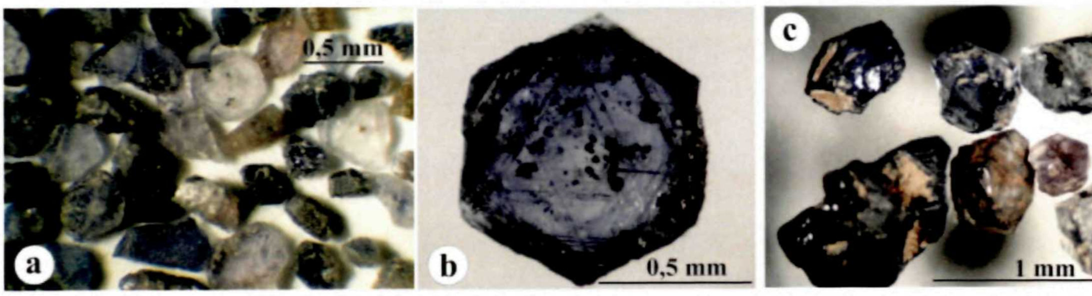


Fig. 4.45a, b, c Coloured varieties and lustre of corundum from panned concentrate samples from various types of source rocks. Sites: a – Remetské Hámre-Kapka, b – Juskova Voľa, c – Hajnáčka. Photo: P. Bačo.

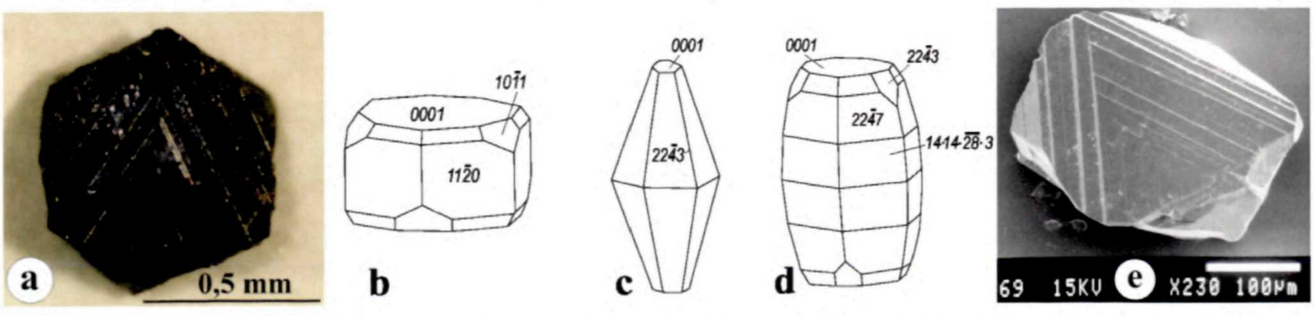


Fig. 4.46a, b, c In the panned concentrate samples corundum is mostly present in the form of a couple of very short trigonal prisms and basal pinacoids (a,b,e). Less frequent are shapes with preferred habit of ditrigonal prism and basal pinacoid – barrel-shaped (c,d). Sites: a – Juskova Voľa, e – Nová Baňa. Drawings: Rösler, J. H., 1983, Photo: P. Bačo, SEM I. Holický.

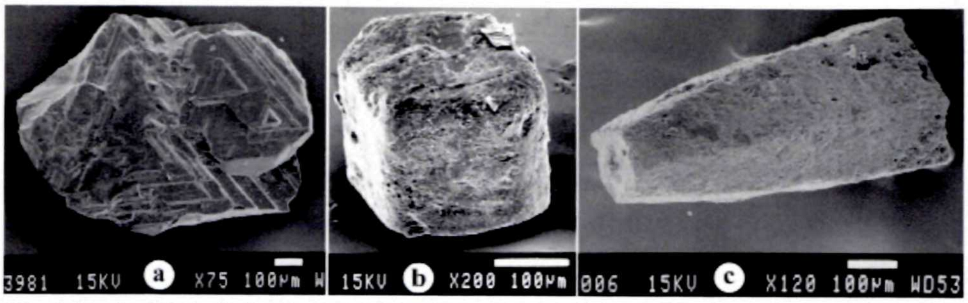


Fig. 4.47a, b, c Typical shapes of accessory corundum (a) and corundum from the environ of hydrothermal alterations. The minerals have preferred habit of ditrigonal prism and basal pinacoid – barrel-shaped habit (b,c). Sites: a – Hrabičov, b, c – Remetské Hámre-Kapka. Photo: SEM I. Holický.

are characteristic of corundum, which originated from high-sulphidation types of alterations in the environment of volcanic rocks (Remetské Hámre-Kapka). Planes of such small crystals are strongly resorbed – roughened.

Irregular, often angular fragments of corundum originate from source areas formed by metamorphic rocks and also basaltic rocks – Hajnáčka (Fig. 4.45c). During transport due to their hardness and very weak to absent cleavability they are very stable and rarely their morphologic change occurs.

Epitaxial intergrowths of corundum were not observed in the panned concentrate samples. In the translucent crystals it is possible to observe the inclusions of opaque minerals (Fig. 4.45b). In the corundum from Remetské Hámre-Kapka area there are often present inclusions of rutile. Size of small crystals, their fragments or grains in the panned concentrate samples is

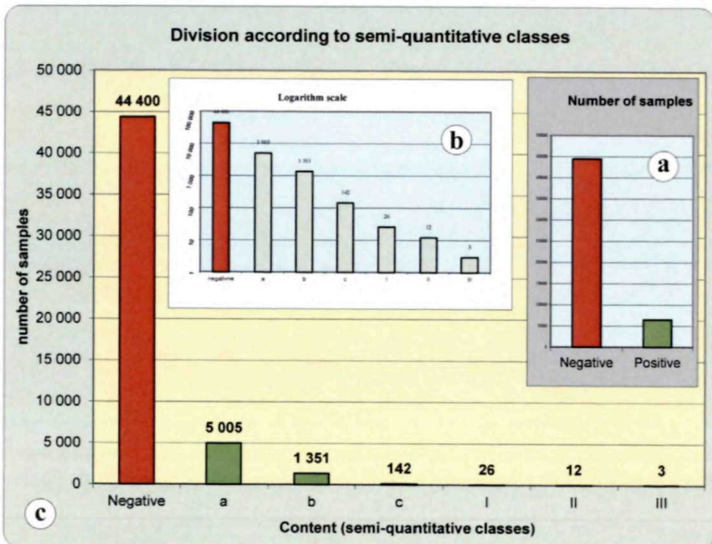


Fig. 4.48a, b, c Distribution of panned concentrate samples according to corundum presence (a) and according to proportion of individual semi-quantitative content classes (b, c).

Tab. 4.18 Presence of corundum in the panned concentrate samples according to content classes.

Database of samples	Negative	Content (semi-quantitative classes)					
	Positive	**a**	**b**	**c**	**I**	**II**	**III**
50,939	44,400	5,005	1,351	142	26	12	3
	87.2	9.8	2.65	0.28	0.05	0.02	0.01
	6,539	5,005	1,351	142	26	12	3
	12.8	76.5	20.7	2.17	0.40	0.18	0.06

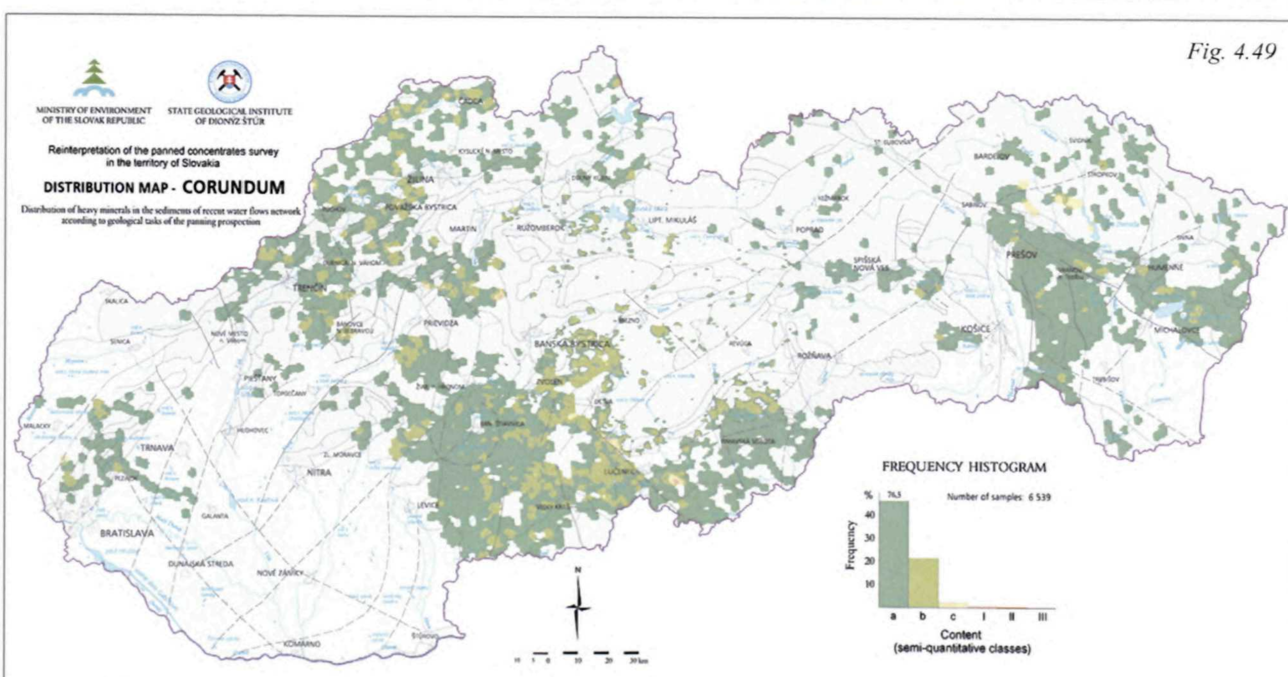


Fig. 4.49

normally within 0.5 to 1.0 mm. In the Hajnáčka area reach corundum of sapphire type several mm.

Identification attributes: Morphology, hardness, in some cases (especially gem varieties), luminescence – reddish colour.

General distribution characteristics

Panned concentrate samples containing corundum, represent a relatively small percentage of evaluated samples (Tab. 4.18). It is mainly present in the lowest concentration classes (a) – Fig. 4.48a.

Near the primary sources of hydrothermal alterations (Remetské Hámre-Kapka) its content may be characteristic in heavy mineral concentrates and it can achieve even semi-quantitative classes I and II.

Corundum is a relatively rare accessory mineral. However, it is characteristic for source areas dominated by Neogene volcanic rocks of andesite composition, less basalts (Fig. 4.49). Corundum, as the residual resistant mineral, can be an indicator of the presence of the original volcanic rocks, which due to denudation processes have been removed. As an example of such an area is the area of the Outer Flysch Zone near the Vihorlat Mts., and wider area of Tisovec and Klenovský Vepor.

4.3.13 Monazite Ce, La, $ThPO_4$

Varieties of monazites: Monazite-Ce $(Ce,La,Nd,Th)PO_4$; Monazite-La $(La,Ce,Nd)PO_4$; Monazite-Nd $(Nd,Ce,La)PO_4$

End members of monazites are as follows (Broska et al., 2012): Monazite $(Ce,La,Th)PO_4$; cheralite $Ca_{0,5}Th_{0,5}PO_4$; huttonite $(Th,U,Pb)SiO_4$.

H = 5.0 – 5.5; **SG** = 4.6 – 5.4 g.cm^{-3}; **System:** Monoclinic

Magnetic properties: concentrated in paramagnetic fraction

Luminescence: in general it is indistinguishable, occasionally orange colour

Colour in the panned concentrate samples

Monazites in the panned concentrate samples are highly variable in colour, but the most common are various shades of tan, and orange honey-yellow colours (Fig. 4.50a, b, c). Rarer colours are emerald green, greenish, reddish, brownish red and grey. Lustre on rarely preserved crystal surfaces is glassy, but on the present roughened surface of grains it is dull, mostly. Sometimes the surface of monazite grains from panned concentrate samples is coated with a layer of white granular masses of rabdofanite(?).

Morphology in the panned concentrate samples

In the panned concentrate samples monazites are present in the form of tabular isometric (Tab. 4.51b), less prismatic shapes which are rounded-up to different levels (Figs. 4.50a, b, c, 4.51a, c; 4.52a, b, c). The tabular shape is characterized by the development of pinacoidal and prismatic planes. On the isometrically developed grains the shapes are determined by almost the same development of pinacoids and prisms.

Elongated, prismatic small crystals are rare, outside the dominant pinacoidal planes there are more strongly represented prismatic planes. Size of the planes ultimately determines the appearance of small crystals (Fig. 4.52b).

In general, in the panned concentrate samples monazite is dominated by small crystals and their fragments, which are rounded-up to varying degrees. In the clastogenic sediments the fragments and small crystals have significantly rounded edges. The surface of small crystals

Fig. 4.50a, b, c Coloured varieties and lustre of monazite in the panned concentrate samples; source areas are made of granitic rocks, prevailingly. Sites: a – Kociha, b – Ipeľský Potok, c – Krná. Photo: P. Bačo.

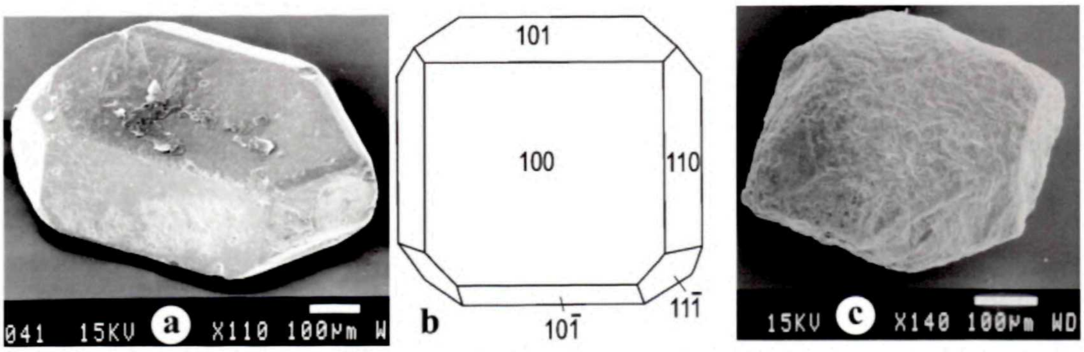


Fig. 4.51a, b, c In the panned concentrate samples monazite is present in the form of tabular (a) and isometric small crystals (b). Frequently, the smooth surface of planes (a) has not been preserved. Sites: a – Pohronská Polhora, c – Krná. Drawing: J. H. Rösler, 1983, SEM I. Holický.

Fig. 4.52a, b, c Monazite in the panned concentrate samples mostly creates small crystals with tabular habit with very wide scale of couples of individual crystal planes, which ultimately determine resulting habit. Sites: a, c – Krná, b – Kociha – Kocižský potok Brook. Photo: P. Bačo (b), SEM I. Holický.

and fragments is often rough and dull. Perfectly limited morphological shapes in the panned concentrate samples are curiosities – for example, Fig. 4.51a and Fig. 4.52b.

In the panned concentrate samples from different geological environments there can be observed intergrowths of two, as well as several single crystals of monazite. Random intergrowths with other types of minerals have been reported mainly from the South Veporicum – wider area of Krná, Kociha and Podrečany. The most common are intergrowths with zircon – with prismatic habit with different coefficient of elongation. Most of them are variously oriented intergrowths, on which the preferential orientation was not observed, or any coupling parallel to the plane – which could mean epitaxy (Fig. 4.53c, d).

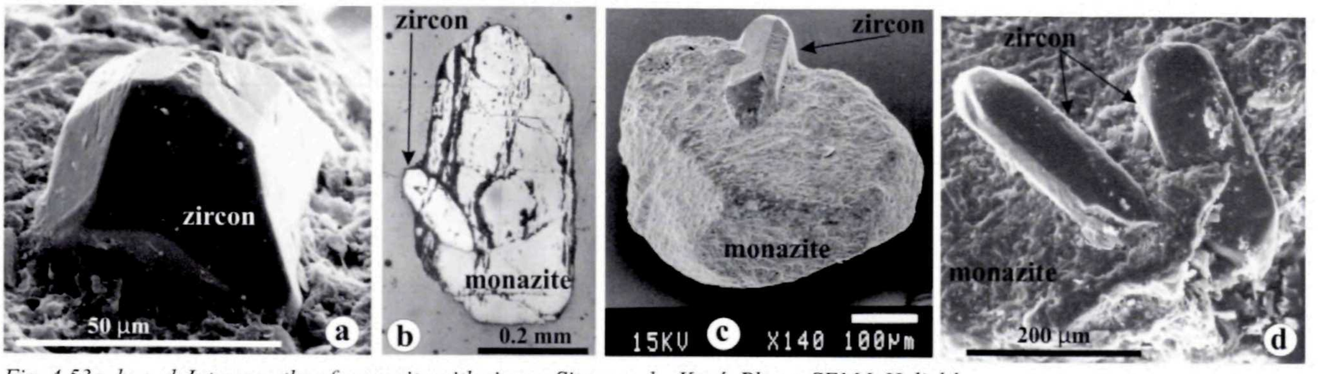


Fig. 4.53a, b, c, d Intergrowths of monazite with zircon. Site: a – d – Krná. Photo: SEM I. Holický.

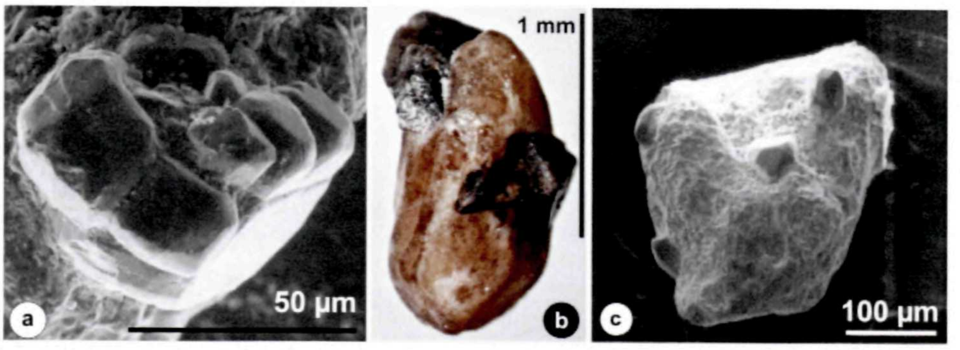


Fig. 4.54a, b, c Integrowths of monazite with zircon (a, c) and xenotime (b). Site: a, c – Krná, b – Kociha. Photo: P. Bačo, SEM I. Holický

The amount of individuals zircon overgrown with monazite is variable. They occur either alone (Fig. 4.54c) or in large clusters (Fig. 4.54a). Rarely there were also recorded separate intergrowths of zircons (Fig. 4.54b).

Size of small crystals or fragments, and to varying degrees rounded grains is 0.5 to 1 mm. Near-occurrence of some autochthonous source rocks (e.g. localities Krná, Podrečany, Pezinok) size of different crystals or their mutual intergrowths may achieve up to several mm. In source areas of the Flysch Zone the size of grains reaches only 0.X mm.

General distribution characteristics:

Monazite was observed in approximately one third of the panned concentrate samples (Tab. 4.19, Fig. 4.55a). It is present in the lowest (a) up to the highest concentration classes (III). Its content in the panned concentrate samples is quite variable and is strongly conditioned by the type of source rocks in source areas (Fig. 4.56). In positive samples it is typically present in the first quantitative classes (Fig. 4.55b, c).

Monazite is a typical accessory mineral and is present in the panned concentrate samples from source areas of almost all regional geological units. Exceptions are areas made of Neogene volcanism products, and some Tertiary sedimentary areas.

Tab. 4.19 Presence of monazite in the panned concentrate samples according to content classes.

Database of samples	Negative	Content (semi-quantitative classes)					
	Positive	**a**	**b**	**c**	**I**	**II**	**III**
50,939	34,107	11,355	4,220	726	411	108	12
	68	22	8.28	1.43	0.81	0.21	0.02
	16,832	11,355	4,220	726	411	108	12
	33	67.46	25.07	4.31	2.44	0.64	0.11

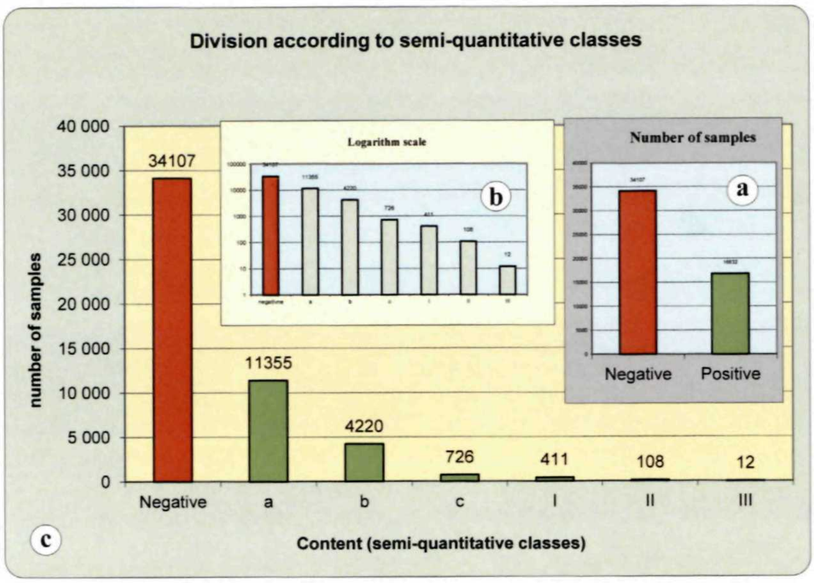


Fig. 4.55a, b, c Distribution of panned concentrate samples according to monazite presence (a) and according to proportion of individual semi-quantitative content classes (b, c).

Because of its relatively good resistant properties it enters sedimentary basins as part of clastogenic sediments. In such an environment it can often create more significant accumulations (Bačo et al., 2004a). In recent aluvial sediments of the river network, however, it is the most widely present in the source areas, which are formed by granitic rocks of type S (Broska, et al., 2012) – e.g. Bratislava Massif, SW part of the Tribeč Mts., etc.). From the source areas made of some types of granitic rocks there are known contents of the class II – Ipeľský Potok, Kociha, Pezinok. Elevated concentrations are also from the areas with the occurrence of paleoplacers – e.g. Poltár Formation in the Southern Slovakia Basin – Podrečany (Zuberec et al., 2004). It is fairly widely represented in source areas formed of metamorphic rock types such as Krná area.

4.3.14 Pyrite FeS_2

H = 6.0 – 6.5; **SG** = 4.9 – 5.2 g.cm^{-3}; **System:** Cubic

Magnetic properties: non-magnetic, and is concentrated in diamagnetic fraction, the intense limonitised one transits into paramagnetic fraction

Colour in the panned concentrate samples

Colour of pyrite in the panned concentrate samples depends on the genetic type and the way it has entered into the supergene environment. The original brass-yellow colour is kept close to the autochthonous occurrence - natural

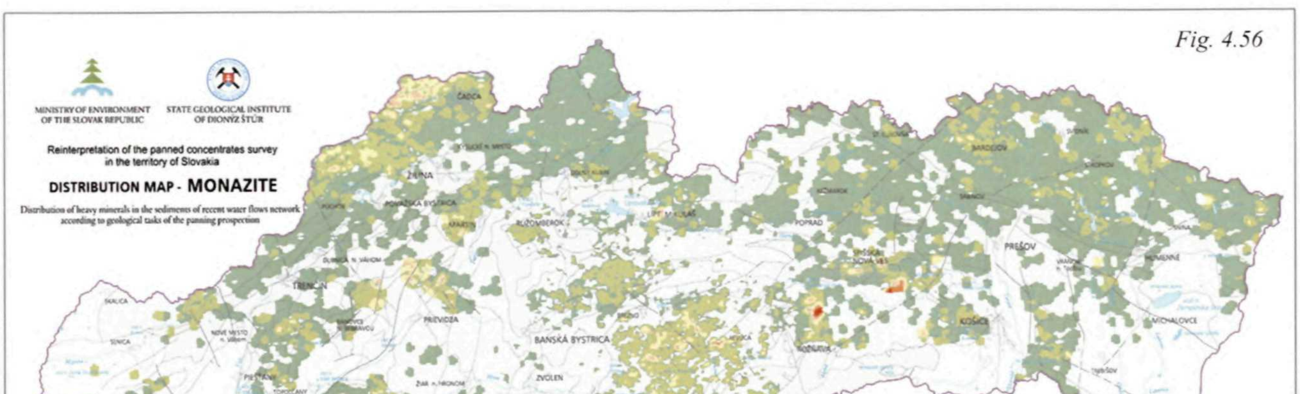


Fig. 4.56

or anthropogenic. Common are yellow-brown or so-called brownish coating colours. Lustre on the planes of fresh crystals is metal, or dull on limonitised parts and limonite pseudomorphs after pyrite.

Morphology in the panned concentrate samples

In the panned concentrate samples pyrite is present in the most diverse forms (Fig. 4.57a, b, c, d). Morphology of these shapes is characteristic and unique to the pyrite. There are often present perfect hexahedron {100} small crystals characteristic for accessory type, but also for epithermal mineralisation. Octahedron {111} small crystals (Fig. 4.58a, b, c, d) are present in the samples from the Flysch areas, mainly. Pentagonal dodecahedron {210} crystal shapes are mainly from the areas of epigenetic sulphide mineralisation. More common in the panned concentrate samples are different couplings and mutual intergrowths of basic shapes (Fig. 4.59a, b, c, d).

Besides cyclic and different contact intergrowths and aggregates there are present completely restricted intergrowths of pentagonal dodecahedrons (Fig. 4.60a, b, c), or shapes according to the Spinel Law (Fig. 4.59c). Characteristic is also grooving of hexahedron planes of small crystals, which is not generally applicable to the spatial distribution of this mineral. Quite common is its presence in the form of irregular fragments and grains, or isometric grains.

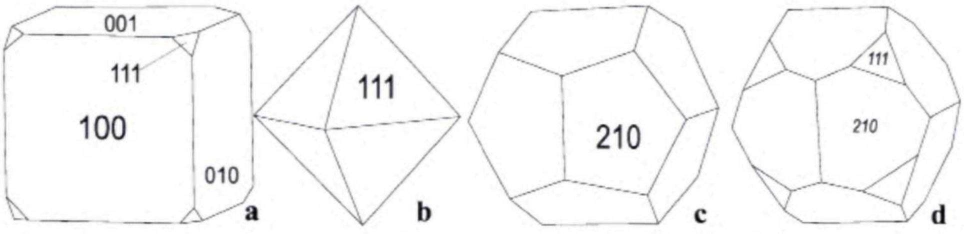


Fig. 4.57a, b, c, d Basic crystal shapes and couples of pyrite, which are mostly present in the panned concentrate samples. Drawings: J. H. Rösler, 1983.

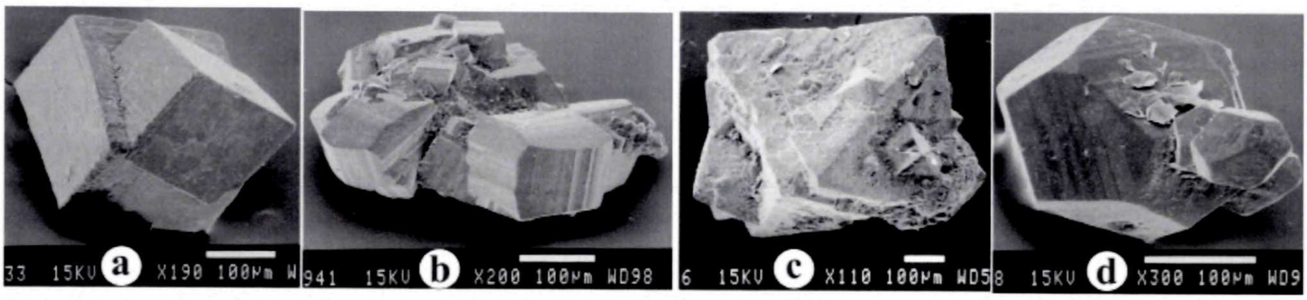


Fig. 4.58a, b, c, d In the panned concentrate samples pyrite is present in all basic shapes. Some shapes are characteristic for certain rock – source environ. Sites: a – Vernár, b – Livov, c – Hodruša Hámre, d – Kremnica. Photo: SEM I. Holický.

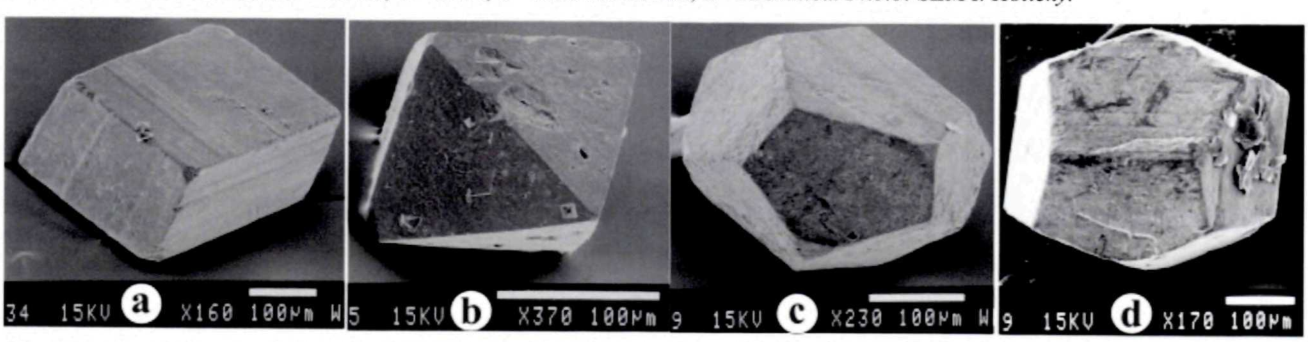


Fig. 4.59a, b, c, d Sites: a – Vernár, b – Kremnica, c – Kysucká vrchovina – Ráztoky, d – Vyšná Boca. Photo: SEM I. Holický.

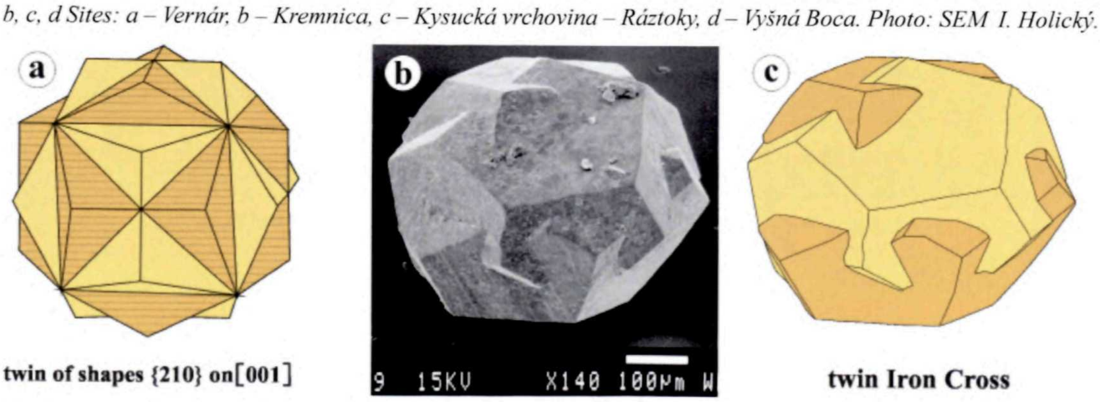


Fig. 4.60a, b, c Intergrowth of two crystals – twin of pentagonal dodecahedron {210}, twinning axis is [001]. Site: a – Nízke Tatry – Dúbrava. Drawings: a – Klein, 2006, c – Repčiak in Bačo et al., 2004. Photo SEM I. Holický.

Types of pyrites may also have some local typological relevance to the specific geological environment. Size of small crystals, their fragments, grains or aggregates in the panned concentrate samples is typically up to 2.0 mm. However, in the Flysch Zone their size rarely exceeds 2 mm.

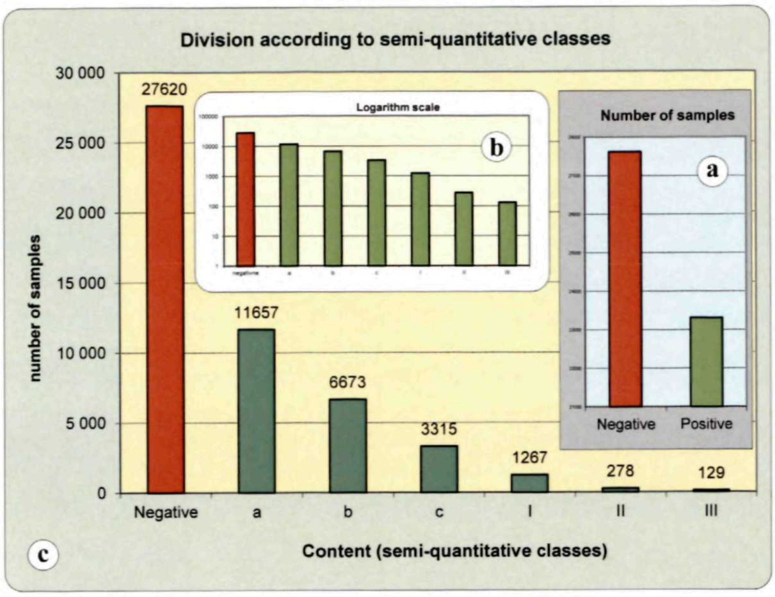


Fig. 4.61a, b, c Distribution of panned concentrate samples according to pyrite presence (a) and according to proportion of individual semi-quantitative content classes (b, c).

General distribution characteristics:

Pyrite is the fixed component of the heavy fraction (Tab. 4.20) and is one of the most stable sulphides in the panned concentrate samples. A significant proportion is observed primarily in the areas of epigenetic sulphide mineralisation, in which it is a stable accompanying mineral of almost all genetic types of ore mineralisations of deposit significance or their manifestations. In such areas the concentrations are within the highest classes.

Pyrite is present in almost all types of rocks and it is accompanying mineral of all the epigenetic and syngenetic ore mineralisations. Its occurrence in the panned concentrate samples, particularly those in the highest content classes (Fig. 4.61c) is partially limited by relatively weak resistance in supergene conditions. It is characteristic for all regional geological units (Fig. 4.62). Preferential binding at higher content classes is to the areas with the occurrence of ore mineralisation in the Central Slovakia Neovolcanic Field or Gemericum.

In the panned concentrate samples from sedimentary environment there are present pyritised tests of primarily foraminifera, molluscs and shellfish, various concretions and aggregates. In these types of source areas this form of pyrite appearance is often the dominant one.

Tab. 4.20 Presence of pyrite in the panned concentrate samples according to content classes.

Database of samples	Negative	Content (semi-quantitative classes)					
	Positive	**a**	**b**	**c**	**I**	**II**	**III**
50,939	27,620	11,657	6673	3315	1267	278	129
	54	23	13	6.51	2.49	0.55	0.25
	23,319	11,657	6673	3315	1267	278	129
	46	49.99	28.62	14.22	5.43	1,19	1.11

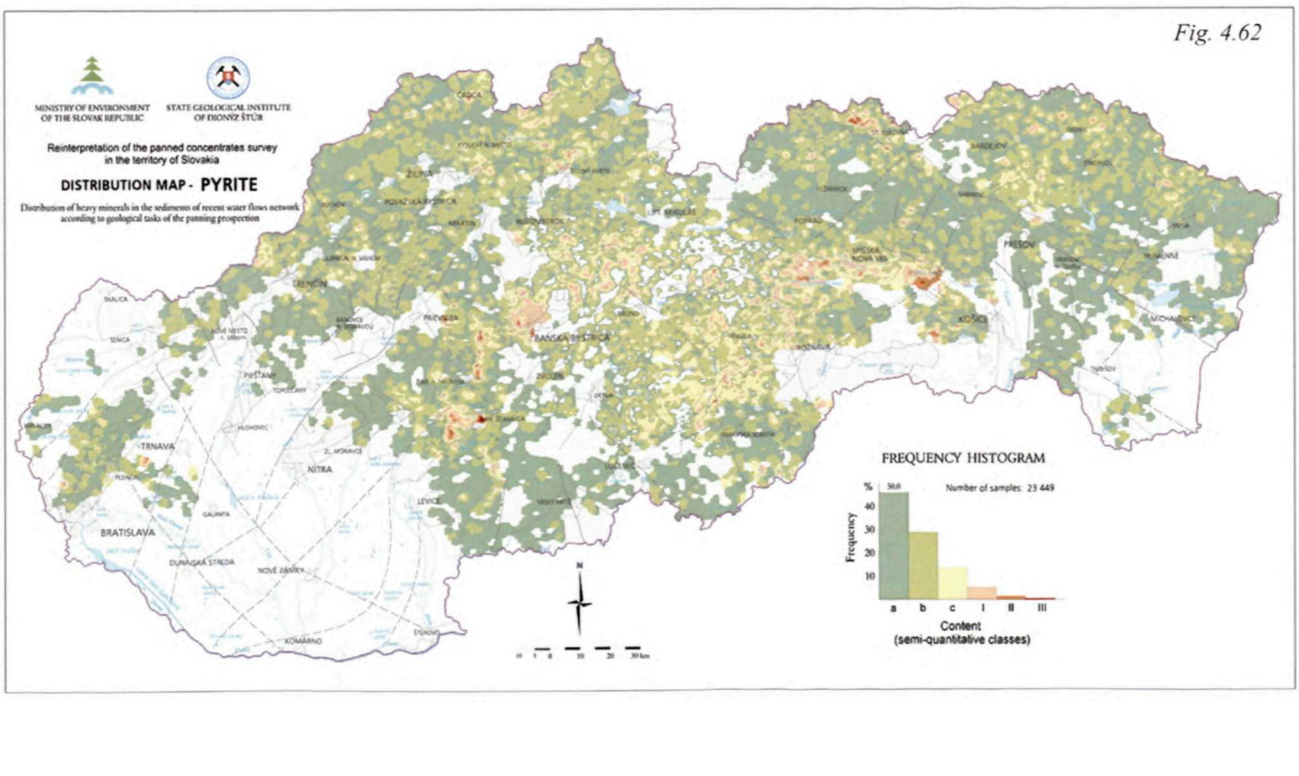


Fig. 4.62

4.3.15 Pyroxenes

In evaluating the panned concentrate samples there were determined individual mineral species, for example, Mg-Fe (e.g. enstatite), Ca-Na-Mg (e.g. augite), Ca-Mg (e.g. diopside) as subgroups of pyroxene uniformly - without distinction of mineral species. The reason, among others, is the possibility of macroscopic identifying and view of the distribution as well as effectiveness of panned concentrate prospecting.

H = from 5.5 to 6.0 (according to the type); **SG** = from 3.18 to 3.33 g.cm^{-3} (according to the type)

System: Monoclinic (augite, diopside); Rhombic (enstatite, Fe-enstatite – "hypersthene")

Magnetic properties: they are concentrated in paramagnetic fraction, rare non-ferric varieties can pass into the diamagnetic fraction.

Colour in the panned concentrate samples

Diopside in the panned concentrate samples is mostly green in different grades and shades. Colour of augite is mostly black, brownish black; Fe-enstatite (hypersthene) in various shades of green (Fig. 4.63a, d). Lustre of smooth planes is glassy or dull on the corroded grains.

Identification attributes: coarse-prismatic, prismatic, but also tabular shape of small crystals, greenish colour.

Application of specific methods of identification: To determine the species it is necessary the optical study, X-ray or electron microanalysis.

Morphology in the panned concentrate samples

Pyroxenes in the panned concentrate samples often retain the characteristic small crystals of tabular and columnar habit (Fig. 4.64a, b, c).

Diopside in the panned concentrate samples is present most often in the form of small short-columnar crystals and debris. Typical is its square cross-section (Fig. 4.63b). Augite in the panned concentrate samples is present mostly in the form of short columnar to small isometric crystals and their fragments. Typical for them are square and octagonal cross-sections. Fe-enstatite – "hypersthene" in the panned concentrate samples is present mostly in the form of short-columnar and tabular small crystals and their fragments. Typical are the rectangular and square cross-sections.

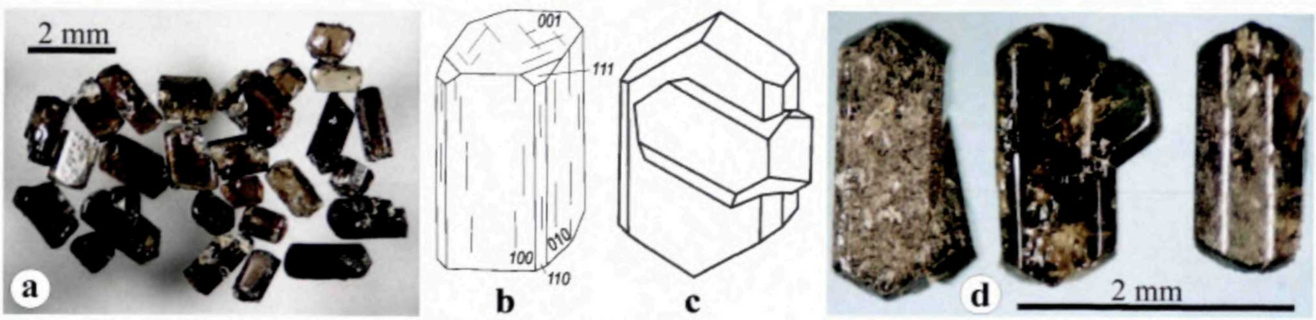


Fig. 4.63a, b, c, d Crystal shapes of the group of monoclinic and rhombic pyroxenes (b, c). Characteristic colour of small crystals and fragments is green in various shades and saturation. Dark colouration occurs often due to numerous inclusions of opaque minerals (Fig. 4.40c). Site: a, c – Ľubietová. Drawings: b, c – Rösler, J. H., 1983. Photo: P. Bačo.

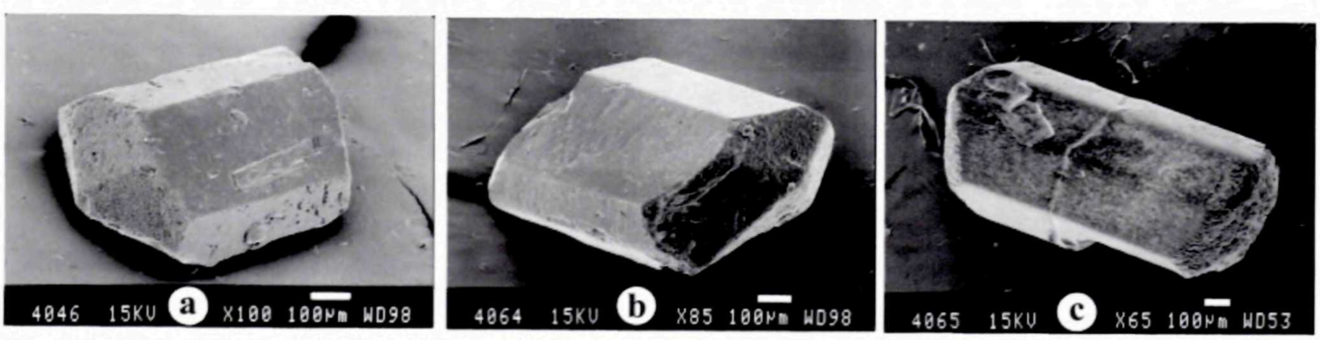


Fig. 4.64a, b, c Typical columnar habit of pyroxenes in the panned concentrate samples. Small crystals often terminate with dipyramid planes (a, b) or with magmatic-corroded planes of these pyramids (c). They are idiomorphic and typical in volcanic source areas. During transport the edges are quickly reworked, but their habit remains unchanged. Sites: a – Slanské vrchy Mts. – Slanská Huta, b, c – Slanské vrchy Mts. – Banské. Photo: SEM I. Holický.

Tab. 4.21 Presence of pyroxene in the panned concentrate samples according to content classes.

Database of samples	Negative	Content (semi-quantitative classes)					
	Positive	a	b	c	I	II	III
50,939	30,099	5,425	5,209	2,572	2,074	3,263	2,297
	59	11	10	5.0	4.1	6.4	4.5
	20,840	5,425	5,209	2,572	2,074	3,263	2,297
	41	26.03	25.00	12.34	9.95	15.66	42.34

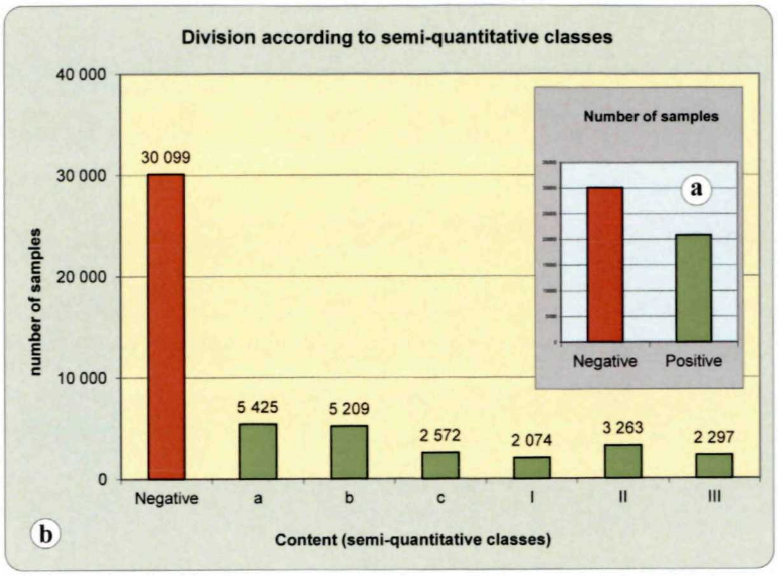


Fig. 4.65a, b Distribution of panned concentrate samples according to pyroxenes presence (a) and according to proportion of individual semi-quantitative content classes (b).

During transport pyroxenes are quite intensively processed and disintegrated due to good cleavability. Irregular grains, however, maintain the original habit, or the habit along the cleavability planes. Quite common are intergrowths of two or several small crystals often with a distinct crystal shape typical for pyroxenes (Fig. 4.63d). Epitaxial intergrowths of ilmenite (differently oriented, often magmatic-corroded) are quite commonly observed mainly from volcanic regions. The occurrence of the inclusions of ilmenite in the plane of the dominant prism is typical (Fig. 4.40c).

Size of small crystals in the panned concentrate samples from the environment of Neovolcanic rocks of andesite composition is typically up to 2.0 mm, or even above this size. Their average size from the other source areas is smaller.

General distribution characteristics:

Pyroxenes were recorded in more than one third of all evaluated panned concentrate samples (Tab. 4.21; Fig. 4.65a). Their concentration in positive panned concentrate samples is from the lowest (a) to the highest content classes (III) with a slight predominance of the first ones (a – c) – Fig. 4.65b. The concentration of pyroxenes is strongly dependent on the prevailing rock environment source areas. They are mostly the intermediary volcanic rocks and their contents are stable above 50% of heavy minerals (Fig. 4.66). In other areas the contents are in the first concentration classes (a – c).

Pyroxenes can be included to the discriminatory minerals that uniquely identify the type of geological environment in source areas. These are Neogene volcanic rocks of andesite composition. They are deposited by hydrological network present in the environment. The deficient source areas are those made of mostly carbonatic rocks and older clastogenic sedimentary rocks.

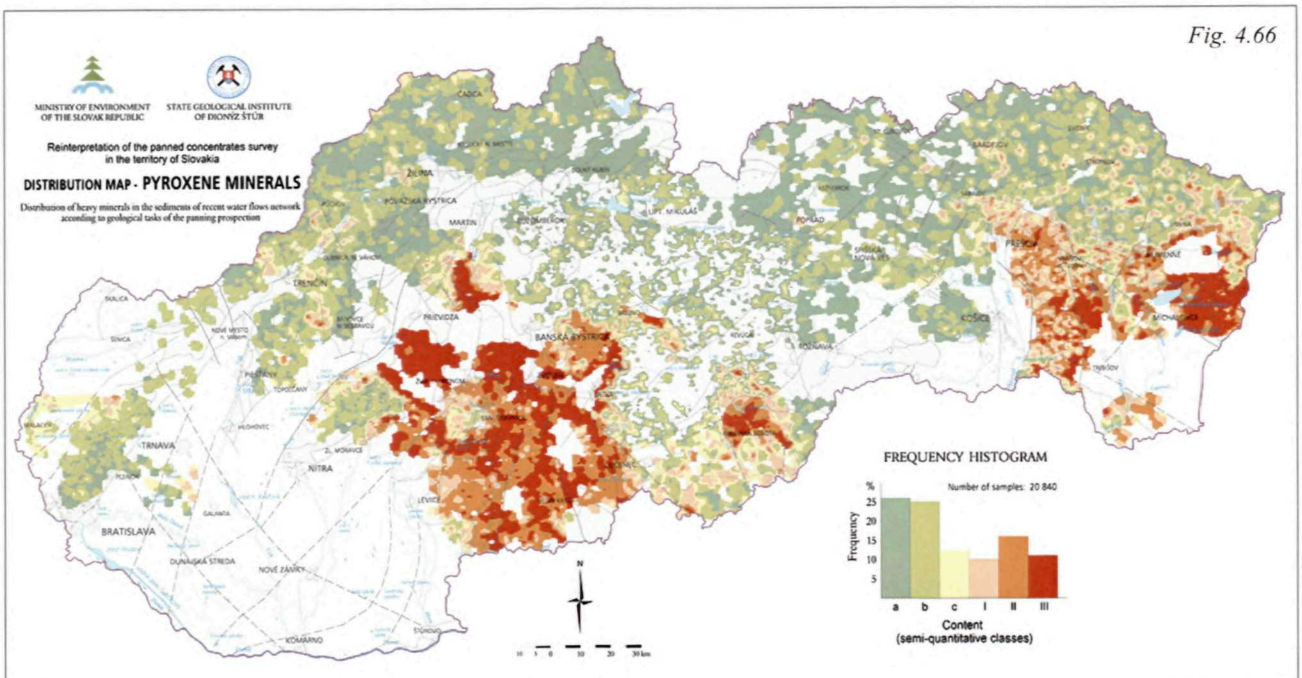


Fig. 4.66

4.3.16 Rutile TiO_2

H = 6.0 – 6.5; **SG** = 4.18 – 4.25 g.cm^{-3}; **System:** Tetragonal

Magnetic properties: concentrated in diamagnetic and partially in paramagnetic (variety nigrine) fraction

Colour in the panned concentrate samples

Colour of small crystals is deep reddish brown and brown (Fig. 4.67b) with a metallic to diamond-like lustre. It is also often dark brown to black in colour – nigrine

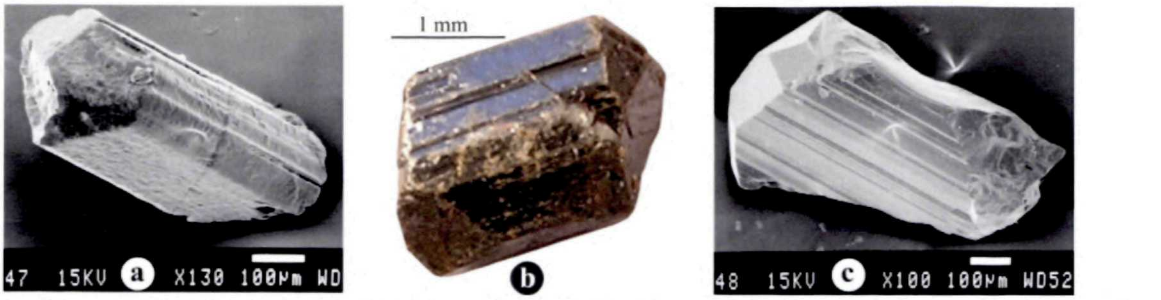


Fig. 4.67a, b, c Characteristic colour and shine of small crystals of rutile (b) with preserved columnar habit. On crystal planes of tetragonal prisms characteristic "grooving" is visible. Site: Sinec Massif – Kokava nad Rimavicou, Photo: P. Bačo. Photo: SEM I. Holický.

(variety containing Fe^{3+}, Fe^{2+}) and rare yellow to tan (sagenite). On the fresh and fracture or cleavage surfaces it has the metal to diamond-like shine.

Morphology in the panned concentrate samples

In the panned concentrate samples from areas of granitic and metamorphic rocks rutile is present in the form of small crystals of columnar habit with strong longitudinal "grooving".

In most cases, fragments of small crystals are present, rarely terminated with the pyramid planes. Characteristic are twin intergrowths on (101) plane in which the c-axis angle is 114° – "knee-shaped" intergrowth or on (301) – c-axis angle of 54° – "heart-shaped" intergrowth (Fig. 4.68a, b, c, d). Due to destruction during transport the small crystals are reshaped in varying degrees (Fig. 4.69a, c), preferably along cleavability (110) planes. In the source areas formed by sediments the fragments are reworked and well-rounded (Fig. 4.69b), but the original habit is often maintained as a result of high mechanical and chemical resistance.

Size of small crystals or fragments of rutile in the panned concentrate samples is from 0.5 to 2 mm, in some sites of the western part of the Slovenské rudohorie Mts. (mainly in the wider area of the Sinec Massif) the size can reach over 1 cm. In the Flysch source areas the fragments reach the size of 1 mm, exceptionally 5 mm.

Rutile is present in the form of inclusions in corundum and topaz. Fragments of quartz with rutile (sagenite) have not been recorded in the panned concentrate samples. Submicroscopic rutile is also a component of "leucoxene" – breakdown product of ilmenite.

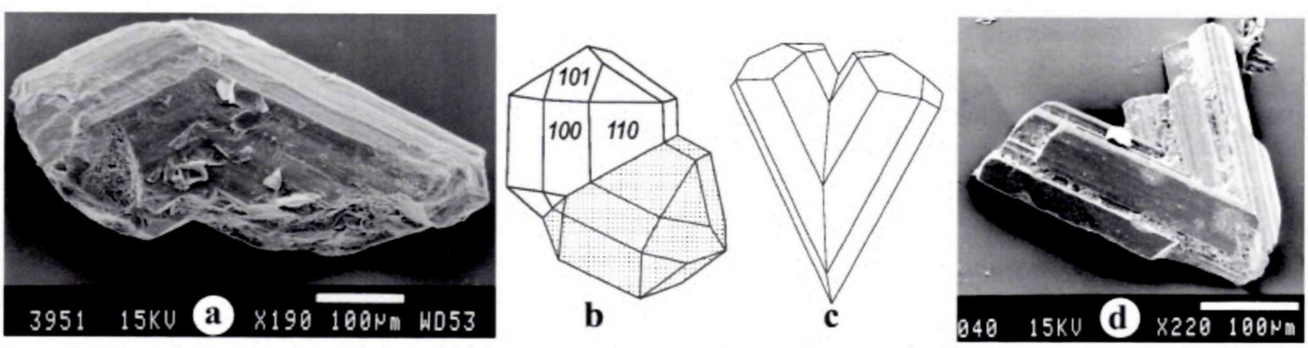


Fig. 4.68a, b, c, d Crystal of rutile with basal crystal planes, ditetragonal prism and ditetragonal dipyramid (b). These planes and shapes are present on very frequent, typical and characteristic intergrowths of rutile. Characteristic morphological sign of rutile in the panned concentrate samples are intergrowths on (101) plane, "knee-shaped" intergrowth (a, b) and on (301) plane, "heart-like" intergrowth (c, d). Sites: a – Sinec Massif – Kokava nad Rimavicou, d – Pohronská Polhora. Drawings: b, c – Rösler, J. H., 1983. Photo: SEM I. Holický.

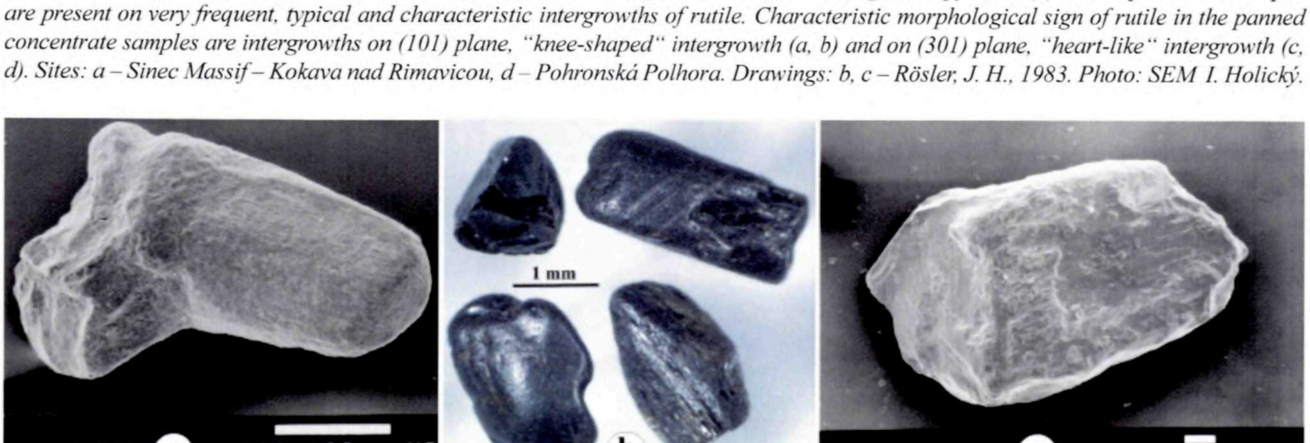


Fig. 4.69a, b, c Morphology of fragments and small crystals of rutile from various types of source areas. Fragments of rutile crystals preserve columnar habit. It is a frequent and typical shape of clastogenic type. Sites: a – Inner-Carpathian Paleogene – Nižné Repaše; Outer Flysch Zone: b — Ruská Bystrá, c – Kolonica. Photo: P. Bačo – b. SEM I. Holický – a, b.

Slovak Geol. Mag., 15, 2 (2015), 39 – 86

General distribution characteristics:

Rutile was detected in more than half of assessed panned concentrate samples (Tab. 4.22). Its content is common within the first quantitative classes (a – c) (Fig. 4.70b). In these classes it is present in almost all regional geological formations (Fig. 4.71). In the Crystalline areas its contents can locally reach the highest class, for example, wider area of the Sinec Massif.

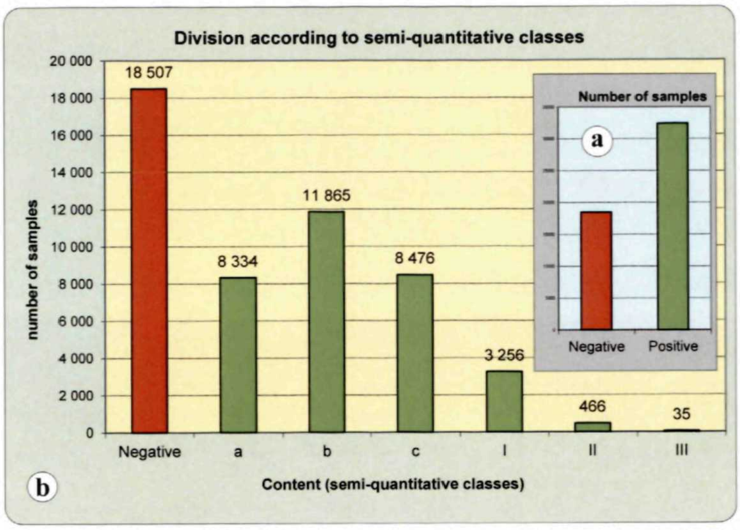


Fig. 4.70a, b Distribution of panned concentrate samples according to rutile presence (a) and according to proportion of individual semi-quantitative content classes (b).

Rutile is significantly present in the heavy fraction of sedimentary complexes of the Outer Flysch Zone, its eastern and western parts, and Inner-Carpathian Paleogene. Together with garnet they form the bulk of heavy fraction. Compared to the original association in other geological conditions a selective enrichment is typical (Fig. 4.71). From this point of view interesting significant enrichment is known from the source area formed by the Dukla unit in the vicinity of Smilno.

4.3.17 Scheelite $CaWO_4$

H = 4.5 – 5.0; **SG** = 6.10 – 5.5 g.cm^{-3}; **System:** Tetragonal

Magnetic properties: concentrated in diamagnetic fraction, the intergrowths with wolframite (ferberite) can pass into paramagnetic fraction

Luminescence (shortwave spectrum of ultraviolet radiation, monochromatic, λ = 254 nm): pure blue-white colour (Fig. 4.72b, c), white – at the content 0.5 % Mo, yellow – at > 0.5 % Mo

Colour in the panned concentrate samples

The most common colours are various shades of white – grey white, yellowish or colourless (Fig. 4.73a, b). In the panned concentrate samples there were rarely identified other colours of scheelite. It has a greasy to glassy lustre, small grains are translucent.

Tab. 4.22 Presence of rutile in the panned concentrate samples according to content classes.

Database of samples	Negative	Content (semi-quantitative classes)					
	Positive	a	b	c	I	II	III
50,939	18,507	8,334	11,865	8,476	3,256	466	35
	36.3	16.4	23.3	16.6	6.4	0.91	0.07
	32,432	8,334	11,865	8,476	3,256	466	35
	63.7	25.7	36.6	26.1	10.0	1.4	0.11

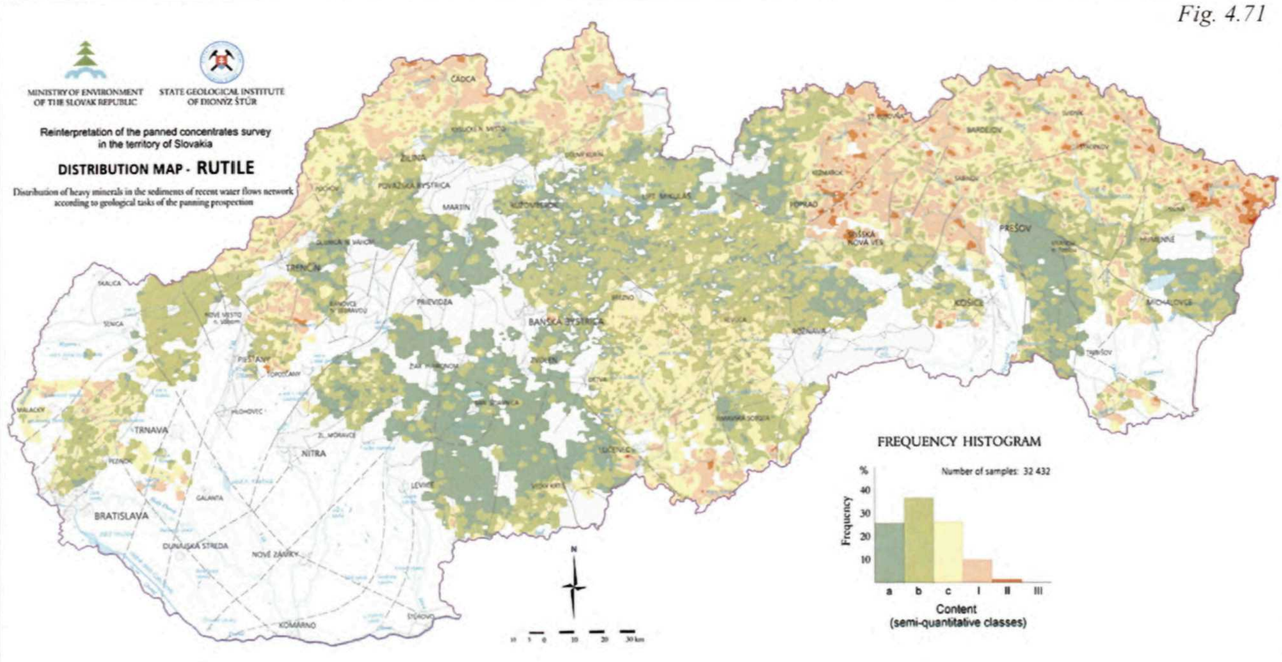


Fig. 4.71

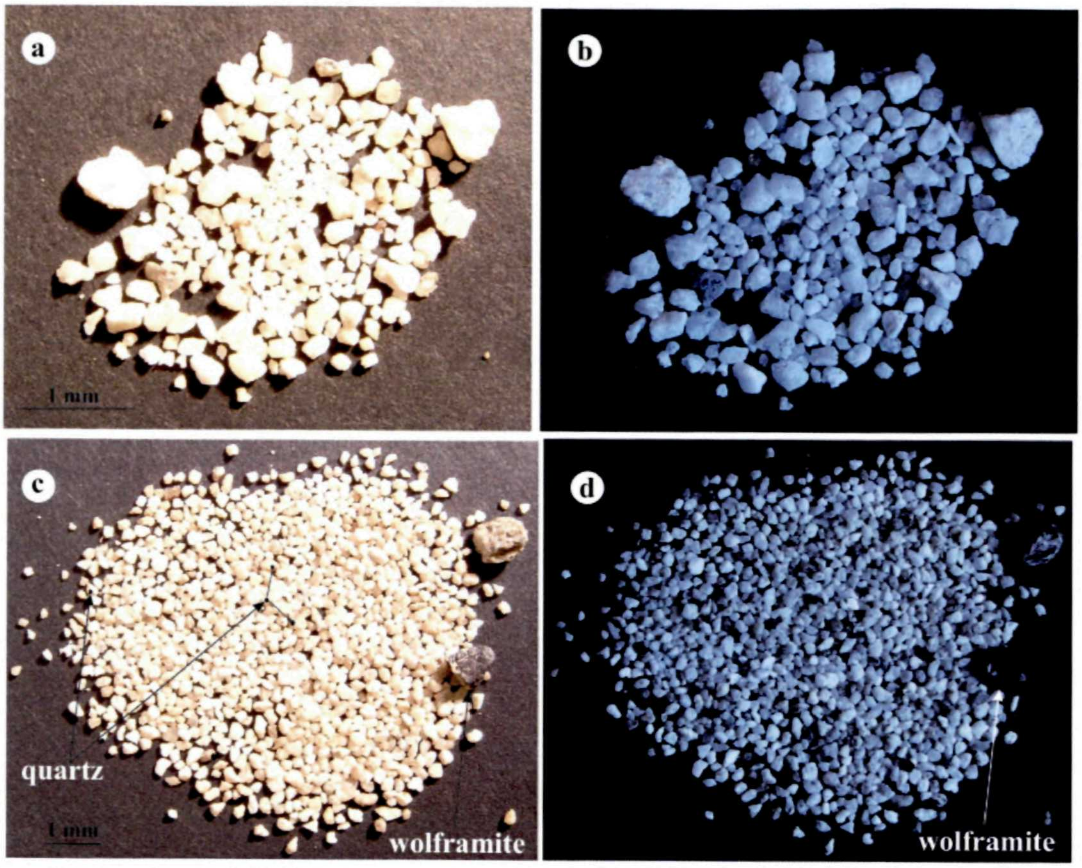


Fig. 4.72a, b, c, d For its colour and visual similarity to quartz in the panned concentrate samples it was disregarded in the first stages of regional prospecting. In Figs. a-b and c-d are examples of scheelite colours under daylight (a and c) and under ultraviolet light (b and d). In the sample (c) a larger wolframite grain is present intergrown with scheelite with very distinct luminescence effect. Under UV light quite distinguishable are tiny grains of quartz. Sites: a – Sopotnická dolina, c – Kokava nad Rimavicou – Bohaté. Photo: P. Bačo.

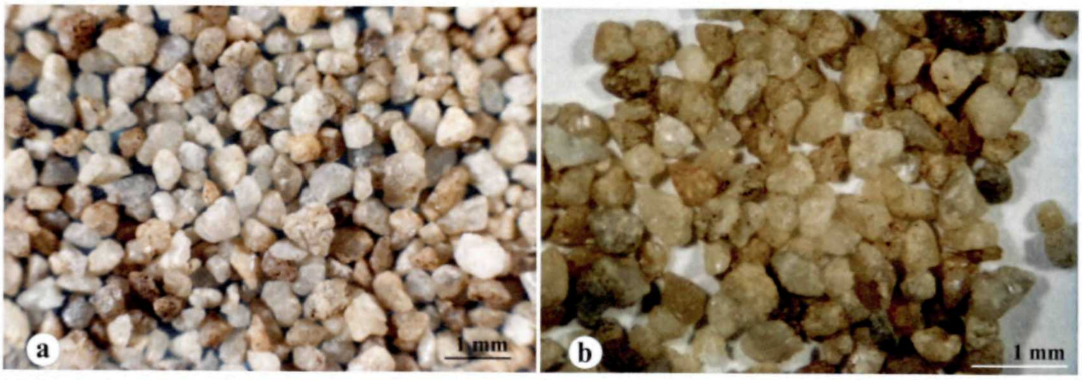


Fig. 4.73a, b Scheelite from panned concentrate samples intergrown with quartz. The grains are irregular with sharp edges. Characteristic colour is white with brownish parts. Sites: a – Jasenie – Kyslá, b – Kokava nad Rimavicou – Bohaté. Photo: P. Bačo.

Morphology in the panned concentrate samples.

In the panned concentrate samples scheelite is only rarely present in the form of crystals or their fragments. Mostly they consist of irregular grains with an uneven rough surface (Fig. 4.74a, d). Under destruction and during transport the fragments of small crystals are reworked to varying degree and they create isomorphic grains without any dominant shape. Surface of fragments of irregularly sharp-edged small crystals and isometric grains is glossy, but often rough and dull.

Epitaxial coalescence is rare, with the exception of mutual intergrowth with wolframite (Fig. 4.72c). Size of fragments of small crystals, but mostly of well-rounded grains, is up to 0.5 mm. In the areas with greater epigenetic accumulation (Core mountains - Tatricum with a variety of occurrences mainly in the Nízke Tatry Mts. and the Malé Karpaty Mts., further in Veporicum and Gemericum) or deposit occurrences (locality of the Nízke Tatry Mts. – Jasenie, Sopotnica Valley, Gemericum – Rochovce, Gemerská Poloma) the size of grains reaches several mm in mutual intergrowths with quartz.

General distribution characteristics

Scheelite has been identified in approximately 20% of the panned concentrate samples collected from all over Slovakia (Tab. 4.23, Fig. 4.75a). Scheelite content is mainly in the first semi-quantitative classes (a – c), this is valid

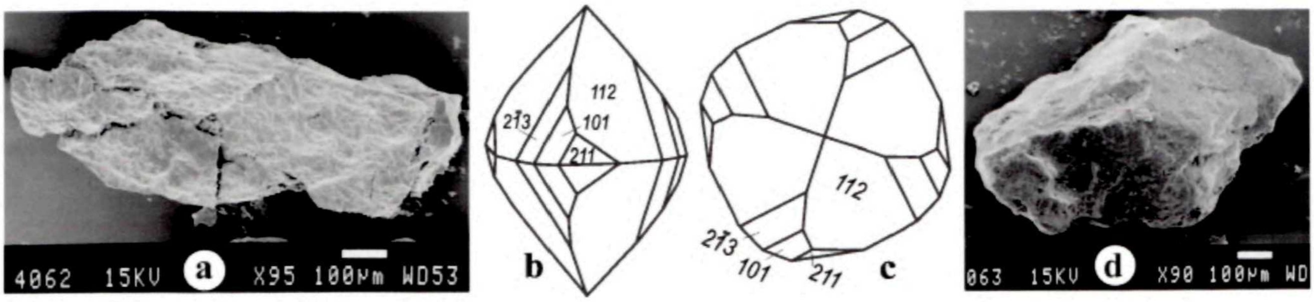


Fig. 4.74a, b, c, d Characteristic shape of scheelite crystals is a combination of tetragonal (proto)dipyramid and rudimentary planes of other pyramids (b, c). In the panned concentrate samples scheelite small crystals are rare and almost exclusively irregular fragments are present (a, d). Sites: a, d – Nízke Tatry – Jasenie – Kyslá. Drawings: b, c – J. H. Rösler, 1983. Photo: SEM I. Holický.

for up to 90% of positive samples (Fig. 4.75b, c). These concentrations characterise the geological environment of Tatricum and Veporicum Crystalline complexes. The stable presence is also in Gemericum. In other areas there have been recorded only sporadic occurrences (Fig. 4.76).

Presence of scheelite in the higher content classes (I and II) points to epigenetic mineralisation (Tab. 4.24). In the panned concentrate prospecting very significant presence of a large number of occurrences has been confirmed in Ďumbier part of the Nízke Tatry Mts. (from Vajsková Valley to the east to the conclusion of Sopotnica Valley to the west – Pulec, 1977a, b). These occurrences or deposit accumulations were indicated by the panned concentrate prospecting.

Concentrations of similar but smaller scale anomalies in the Veporicum, are bound mainly to the metamorphic complexes with a number of occurrences (wider area of Čierny Balog, Kokava nad Rimavicou, Hnúšťa, Muráň in the SE of Veporids – Hvožďara et al., 1985). In other Core mountains (Tatricum) there were reported similar occurrences especially in the Suchý, Malá Magura and Žiar Mts. (Mikoláš, 1985). Quite extensive is anomaly in the Západné Tatry Mts., which secondarily enriched the environment of the Inner-Carpathian Paleogene of the Liptov Basin (Linkešová, 1985). A similar effect of scattered accumulation is seen in Branisko and Čierna hora Mts. (Fulín, 1987).

In terms of the overall distribution it is in many places a clear coincidence with the main tectonic lines (Fig. 4.76). Significantly coincide anomalies in the Spiš-Gemer rudohorie Mts. with the Margecany-Lubeník failure. The deposit of the W-Mo ores near Rochovce shows significant scheelite anomaly.

Areas with absenting scheelite are Mesozoic carbonate complexes source areas and neo-volcanic rocks.

Tab. 4.23 Presence of scheelite in the panned concentrate samples according to content classes.

Database of samples	Negative	Content (semi-quantitative classes)					
	Positive	a	b	c	I	II	III
50,939	42,328	6,064	2,112	389	28	17	1
	83	12	4.15	0.76	0.05	0.033	0.002
	8,611	6,064	2,112	389	28	17	1
	17	25.70	37	26	10	1.44	0.11

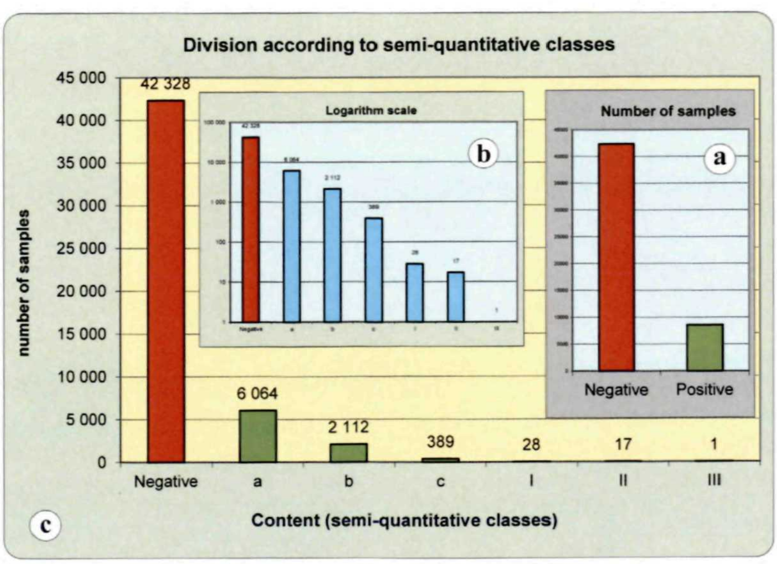


Fig. 4.75a, b, c Distribution of panned concentrate samples according to scheelite presence (a) and according to proportion of individual semi-quantitative content classes (b, c).

Deficient areas or only sporadical occurrences with very low levels are also the territories of the Inner-Carpathian Paleogene and Outer Flysch Zone

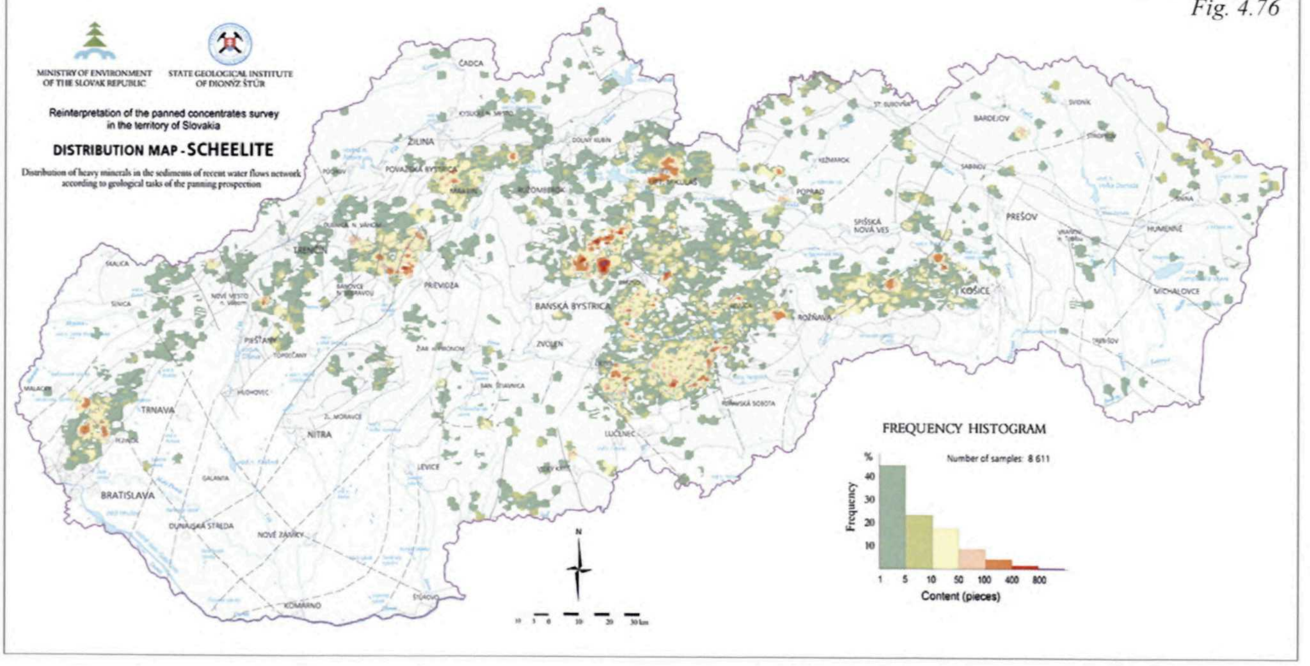
Slightly higher amounts (up to class b are recorded in NE part of the Dukla unit and in Spišská Magura (Klippen Belt on the border with Poland). In general we can say that scheelite is stably present in Tatricum and Veporicum complexes and is deficient in other regional geological units.

Part of the found anomalies of the secondary scattering of scheelite was subject to the later stages of deposit exploration. Currently wider area of Ochtiná and Rochovce is being verified. Prospective are some areas in Gemericum (e.g. Gemerská Poloma), in Veporicum and Malá Magura Mts. Tungsten was ranked among the critical metals for the countries of the European Union.

Tab. 4.24 Presence of scheelite in the panned concentrate samples according to content classes. Selected map sheets at scale 1 : 50,000 illustrate areas with deposit accumulations and significant occurrences of scheelite, which is present in the panned concentrate samples in higher content classes.

Map	Database	Samples without mineral presence		Content (semi-quantitative classes)											
	Number			a		b		c		I		II		III	
1:50 000	of samples	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%
Malá Fatra Mts.															
26-33	282	138	49	103	37	38	13	3	1	0	0	0	0	0	0
Západné Tatry Mts.															
26-44	496	310	63	123	25	31	6	31	6	1	0	0	0	0	0
Malé Karpaty Mts. – Pezinok area															
34-44	591	340	58	180	30	67	11	4	1	0	0	0	0	0	0
44-22	447	177	40	170	38	79	18	21	5	0	0	0	0	0	0
Suchý, Malá Magura Mts.															
35-22	530	277	52	156	29	89	17	8	2	0	0	0	0	0	0
35-24	286	155	54	66	23	52	18	12	4	0	0	0	0	1	0
Nízke Tatry Mts. – Jasenie, Sopotnica Valley															
36-21	1113	679	61	274	25	102	9	37	3	14	1	7	1	0	0
Veporicum – Čierny Balog, Pohronská Polhora, Kokava nad Rimavicou															
36-23	1155	615	53	293	25	198	17	42	4	3	0	4	0	0	0
36-24	1438	877	61	428	30	113	8	16	1	3	0	1	0	0	0
36-42	2143	902	42	780	36	394	18	63	3	3	0	1	0	0	0
36-43	858	384	45	260	30	175	20	36	4	1	0	2	0	0	0
36-44	797	277	35	244	31	222	28	50	6	2	0	2	0	0	0
Contact zone of Veporicum and Gemericum															
37-13	1394	887	64	375	27	110	8	21	2	1	0	0	0	0	0
37-31	999	566	57	330	33	95	10	8	1	0	0	0	0	0	0

Fig. 4.76



4.3.18 Spinel $MgAl_2O_4$

Variety Cr spinel with content of Cr_2O_3 35% – 58%
H = 7.5 – 8.0; **SG** = 3.58 g.cm^{-3}; **System:** Cubic

Magnetic properties: non-magnetic, and is concentrated in diamagnetic fraction, Fe^{2+} variety – picotite passes into paramagnetic fraction

Colour in the panned concentrate samples

Colour of spinel in the panned concentrate samples is usually black (Fig. 4.77a, c). Spinels of another colour in the panned concentrate prospecting were not disclosed. Lustre on flat surfaces is glassy, sometimes dull.

Morphology in the panned concentrate samples

In the panned concentrate samples spinel is present most frequently and almost exclusively in the form of octahedrons {111}. Frequent are intergrowths along the (111) planes, or cyclic intergrowths according to the Spinel Law

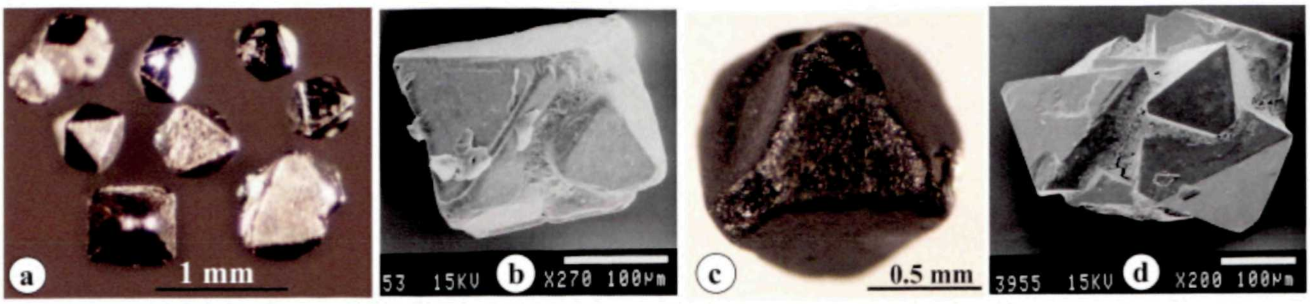


Fig. 4.77a, b, c, d Colour, lustre and crystal shapes of spinel in the panned concentrate samples. Characteristic colour of spinels is black-brown to black. Sites: a – Haligovce, b – Dubovica, c – Ruská Bystrá, d – Vyhne. Drawings: b, c – Rösler, J. H., 1983. Photo: P. Bačo, SEM I. Holický.

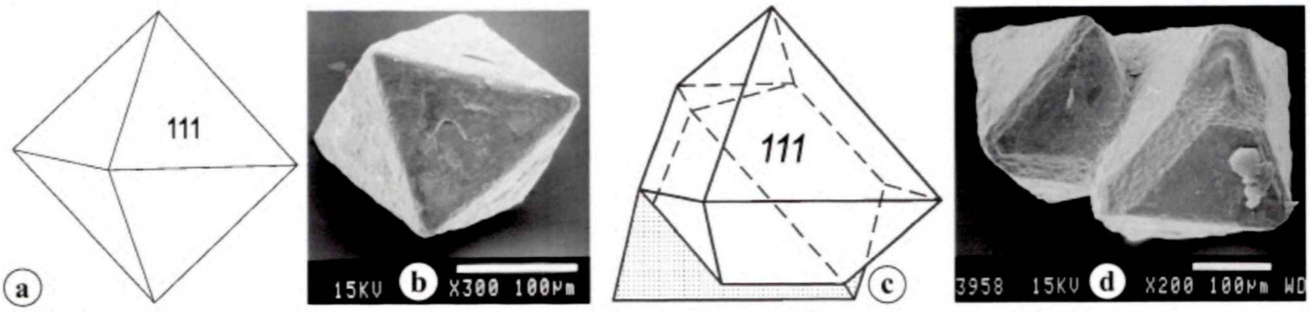


Fig. 4.78a, b, c, d Basic crystal shapes and couples of spinel, which are mostly present in the panned concentrate samples. The base shape of spinel crystals is octahedron {111} (a,). These shapes are typical for Cr-spinels in the panned concentrate samples and other crystal shapes have not been recorded. Frequent are intergrowths on (111) plane – Spinel Law (c, d and also Fig. 4.77a, b, d). Sites: b – Tvarožná, d – Fiľakovo. Drawings: J. H. Rösler, 1983. Photo: SEM I. Holický.

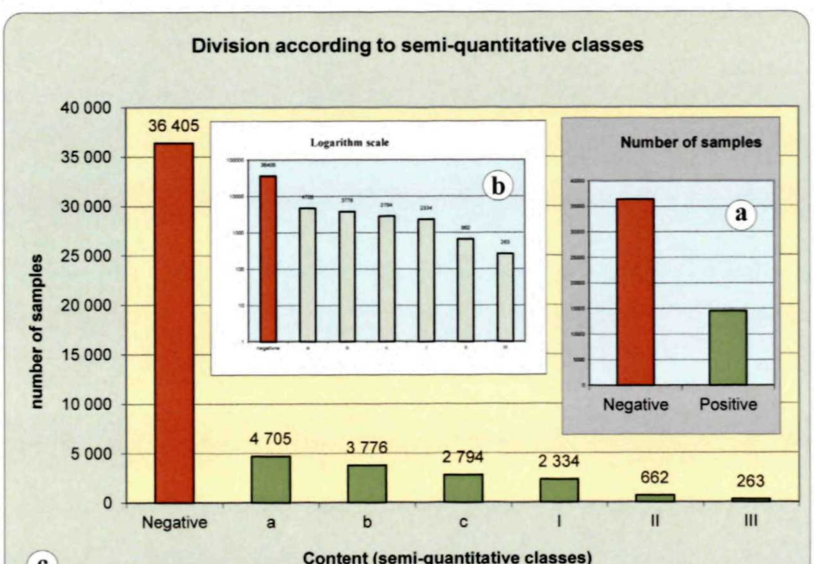


Fig. 4.79a, b Distribution of panned concentrate samples according to spinel presence (a) and according to proportion of individual semi-quantitative content classes (b, c).

(Fig. 4.77b; Fig. 4.78c, d). Although spinels are known primarily from flysch strata of clastogenic origin, they retain distinct octahedron habit. Only occasionally fragments of small crystals are found.

During transport due to their hardness and lack of cleavability they are very stable and only rarely morphologically changed.

Epitaxial intergrowths in the panned concentrate samples have not been observed. Microscopically, however, inclusions were found (pyrite) and non-uniformity (chrommagnetite rim) of Cr spinel (Spišiak et al., 2001). Size of small crystals of Cr-spinels, their fragments or grains in the panned concentrate samples is up to 0.5 and only occasionally up to 1.0 mm – usually of the cyclic intergrowths.

Identification attributes: octahedron habit and intergrowths according to the Spinel Law, black colour and glassy lustre, high hardness, non-magnetic behaviour.

General distribution characteristics

Panned concentrate samples containing spinel (Cr spinel) make up only about 30%

Tab. 4.25 Presence of spinel in the panned concentrate samples according to content classes.

Database of samples	Negative	Content (semi-quantitative classes)					
	Positive	a	b	c	I	II	III
50,939	36,405	4,705	3,776	2,794	2,334	662	263
	72	9	7	5	5.00	1.00	1.00
	14,534	4,705	3,776	2,794	2,334	662	263
	29	32.37	25.98	19.22	16.06	4.55	1.81

Tab. 4.26 Presence of spinel (chromspinel) in the panned concentrate samples according to content classes. Selected map sheets at scale 1 : 50,000 illustrate areas of the Eastern sector of the Outer Flysch Zone with spinel present in the panned concentrate samples in higher content classes.

Map	Database	Samples without mineral presence		Content (semi-quantitative classes)											
	Number			a		b		c		I		II		III	
1:50 000	of samples	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%
Eastern Sector of the Outer Flysch Zone															
27-24	506	400	79	7	1	16	3	16	3	35	7	28	6	4	1
27-32	828	56	7	121	15	166	20	141	17	143	17	94	11	107	13
27-41	667	165	25	31	5	103	15	129	19	96	14	68	10	75	11
27-43	906	13	1	30	3	168	19	305	34	342	38	34	4	14	2
28-31	690	135	20	55	8	93	13	95	14	123	18	163	24	26	4
Inner Carpathian Paleogene															
37-21	487	178	37	67	14	70	14	70	14	57	12	32	7	13	3
37-22	373	50	13	67	18	85	23	103	28	63	17	3	1	2	1

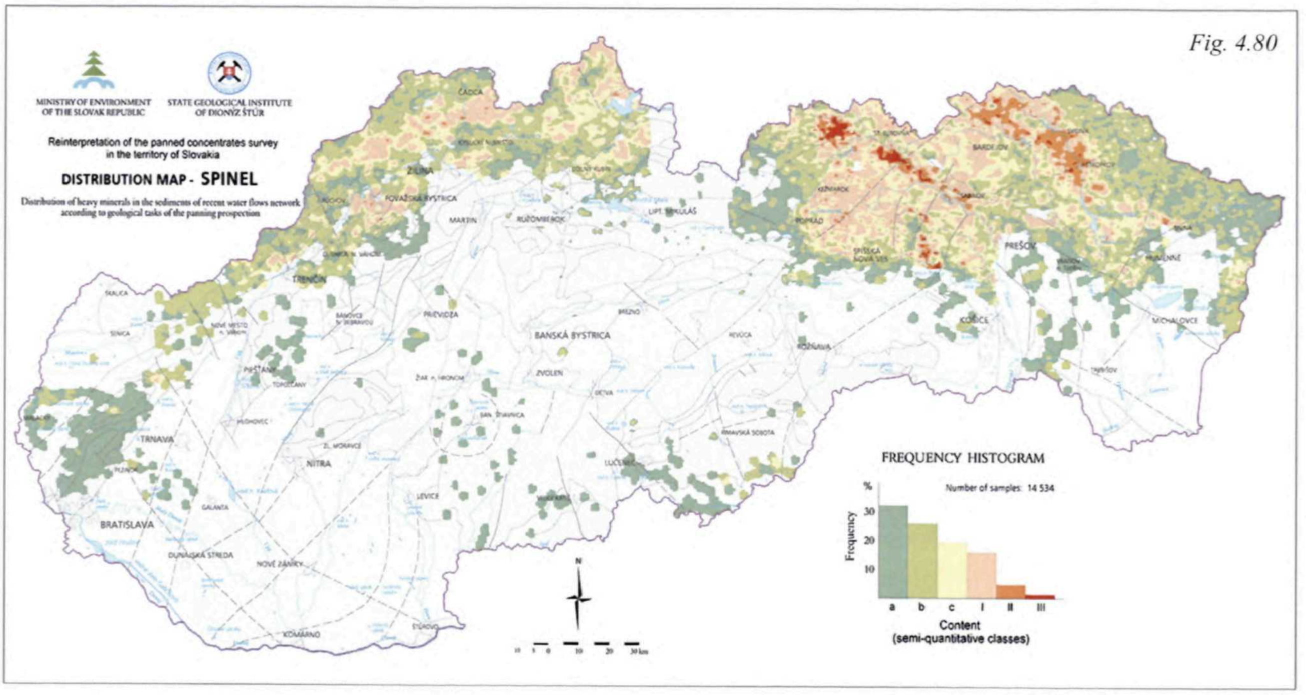


Fig. 4.80

of the total number of samples collected (Tab. 4.25). Its concentration in positive panned concentrate samples, however, is within all semi-quantitative classes (Tab. 4.25, Fig. 4.79b, c). It suggests a typology bound to the extend of the original source rocks.

Spatial distribution of positive panned concentrate samples is concentrated to the eastern part of the Outer Flysch Zone and Inner-Carpathian Paleogene (Fig. 4.80) with a hint of continuing in the Kysuce sector of the Flysch Zone (Bačo et al., 2004a). With a relatively small number of panned concentrate samples high frequency content of the highest grade – III is remarkable. Almost one third of the panned concentrate samples from a wider area of Cígeľka – Stropkov and Šambron to Sabinov has the dominant mineral spinel (Tab. 4.26 – map sheets 27-32, 27-41, 28-31).

The distribution and concentration of spinels is one of the most contrasting ones in the Slovak part of the Western Carpathians (Fig. 4.80). Cr spinels are present in the Inner-Carpathian Paleogene and Outer Flysch Zone. In other regional geological units the Cr spinels frequency in the panned concentrate samples is minimal.

High contrast in the distribution of Cr spinels is visible within the units of the Outer Flysch Zone and Inner-Carpathian Paleogene, where it is possible to identify several distinct zones and areas. Within the Inner-Carpathian Paleogene particularly evident is a significant connection to Šambron Zone (the interface between Inner-Carpathian Paleogene and Klippen Belt – Huty Formation). Presence of this formation around Branisko clearly shows the distribution of spinels (Fig. 4.80). A series of small local anomalies along the Klippen Belt and further to the SE in the Outer Flysch Zone is a significant anomaly in space of greywacke and arkosic sandstones. Sensitivity of the methodology is clearly reflected in the area of Smilno tectonic outlier. This confirms the high discriminatory level of this mineral. It can be used for very detailed interpretive procedures (Jablonský et al., 2001, Spišiak et al., 2001).

4.3.19 Titanite $CaTiSiO_5$

H = 5.0 – 5.5; **SG** = 3.45 – 3.55 g.cm^{-3}; **System:** Monoclinic

Magnetic properties: concentrated in paramagnetic and partially also in diamagnetic fraction

Colour in the panned concentrate samples

Colour of titanite is variable, most often are various shades of yellow, light brown to brown (Fig. 4.81b, 4.82c), it occur also green, grey and in exceptionally clear varieties. In the panned concentrate samples mainly from resedimented environment – Outer Flysch Zone – titanite hass dull surface, its colour and lustre losing saturation and intensity.

Fig. 4.81a, b, c Colour and lustre of small crystals of titanite (b) with preserved tabular habit. Sites: a, b – Veporicum – Sihla, c – Tribeč – Topoľčianky. Photo: P. Bačo. Photo: SEM I. Holický.

Morphology in the panned concentrate samples

In the panned concentrate samples titanite is present in the typical form of small crystals in the form of a highly flattened envelope with the wedge-like termination (Fig. 4.82a, b, c) and the dominant (111), (100) and (001) planes. More often, however, it is present in the form of fragments of small crystals with a characteristic strongly flattened rhombic cross-section and fragments on which it is dominating cleat plane (Fig. 4.81a, c) mainly according to twin lamellae (221). Only very rarely it has different crystal shape and this is decisive and unmistakable titanite form in the panned concentrate samples. In the course of destruction during transport small crystals are reworked to varying degree, with the original shapes and shape with a flat cleat (110) being preserved.

In source areas made of sediments the fragments are heavily reworked and rounded, oval with losing the original habit. The surface of small crystals and fragments is shiny, but often rough and dull.

General distribution characteristics:

Titanite was identified in approximately 1/5 of the assessed panned concentrate samples (Tab. 4.27). Titanite has content in the classes a – c (Fig. 4.83b, c) and normal distribution, indicating a relatively equitable distribution of the occurrence region. Samples containing titanite within higher concentration classes already define its own resources within the source area.

At the regional scale panned concentrate prospection has very clearly defined (Fig. 4.84) position of the granitic rocks of the I type that are most important concentrators of titanite within the Slovak part of the Western Carpathians (Broska et al., 2004). These titanite source rocks are present mainly in the Veporicum, Malá Magura and Malé Karpaty Mts. The highest concentration levels are known from the Tribeč Mts.,

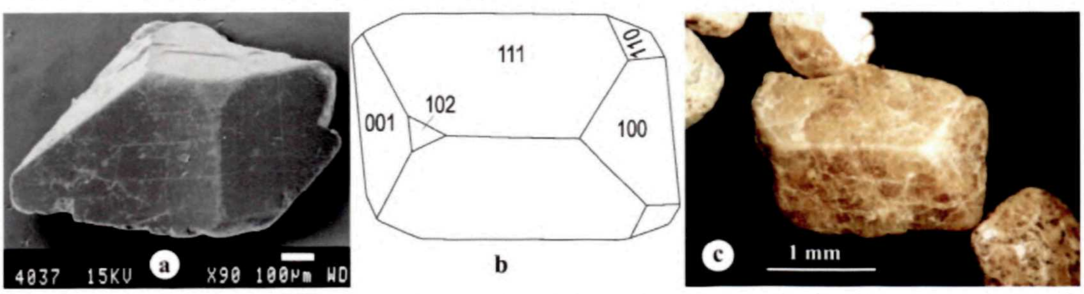


Fig. 4.82a, b, c "Envelope-shaped" small crystals with characteristic planes (111), (100) and wedge-shaped termination. Original shape is preserved on fissile fragments. Site: a – Veporicum – Sihla. Drawing: (b) J. H. Rösler, 1983, Photo: (c) P. Bačo, SEM I. Holický (a).

Tab. 4.27 Presence of titanite in the panned concentrate samples according to content classes.

Database of samples	Negative	Content (semi-quantitative classes)					
	Positive	a	b	c	I	II	III
50,939	41,735	2,157	3,088	2,600	762	497	100
	83	4	6	5	1.00	1.00	0.00
	9,204	2,157	3,088	2,600	762	497	100
	18	23.44	33.55	28.25	8.28	5.40	1.09

where it occurs in the highest concentration class (Fig. 4.83b, c) in the panned concentrate samples and creates the most intense anomalies within the territory of Slovakia (Fig. 4.84).

Distribution of titanite in other regional units of the Slovak part of the Western Carpathians is linked to specific local source environments. In general, these are mostly granitoid rocks of individual Core Mountains and Gemericum. Appearance in other areas is conditional on the deposition from the above areas.

In general, titanite poor areas are those of Neogene volcanism (in which significant Ti-bearer is ilmenite) and regional units made of Mesozoic carbonate rocks. Flysch Zone is characterized by deficiency of titanite in the concentrates, or its low contents. Only in the area of the Vysoké Tatry Mts. it is present in the source area of glacial-fluvial sediments or in the residues after these sediments. Slightly elevated concentrations are in the SE part of the Dukla unit, but without specific knowledge of the origin of titanite.

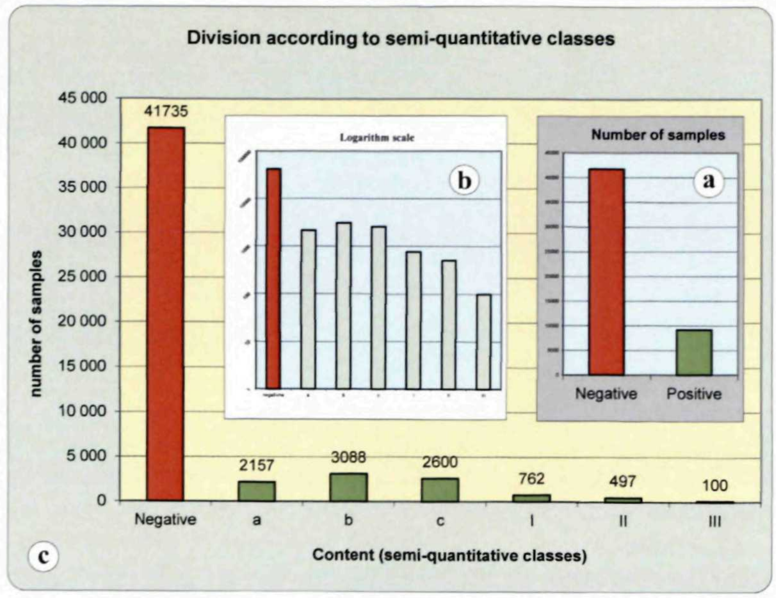
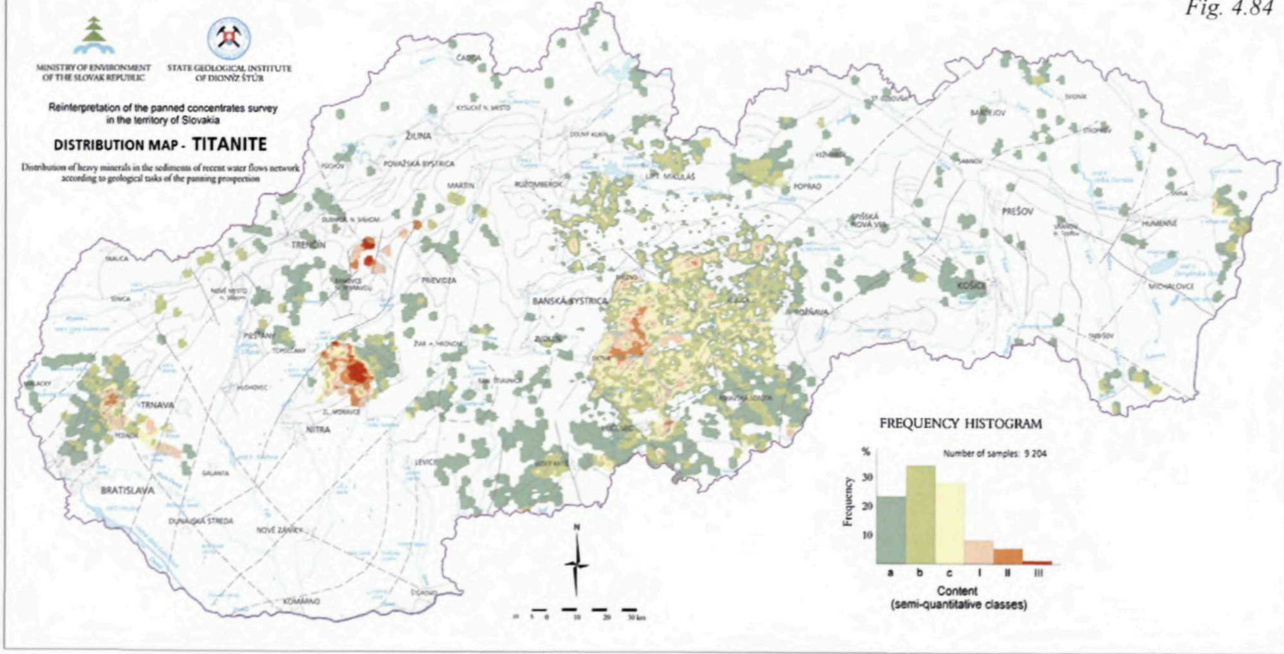


Fig. 4.83a, b, c Distribution of panned concentrate samples according to titanite presence (a) and according proportion of individual semi-quantitative content classes (b, c).

Fig. 4.84



4.3.20 Zircon $ZrSiO_4$

H = 7.5; **SG** = 4.6 – 4.7 (metamict varieties 3.6 – 4.0) g.cm^{-3}; **System:** Tetragonal

Magnetic properties: non-magnetic, and is concentrated in diamagnetic fraction

Luminescence: majority of zircons have orange and yellowish luminescence colour

Colour in the panned concentrate samples

Zircon in the panned concentrate samples is most often colourless, clear, with a gentle hue of yellowish or pink in colour (Fig. 4.85a, c). However, it has often variegated coloures in association (secondary) with colourless and clear crystals. Other most common colour is orange reddish (hyacinth) in different grades and shades. Less frequently it is present a dark brown to black zircon (cyrtolite).

Morphology in the panned concentrate samples

In the panned concentrate samples zircon is present in the form of crystals of columnar habit (Fig. 4.86a, b, c, d) with dominating prisms and dipyramid termination.

Typology of zircon (mainly autochthonous occurrence) is used for the genetic classification of granitic rocks as well as for temperature indices of host rocks (Western Carpathian granitoid rocks, Broska & Uher, 1991; Broska et al., 2012).

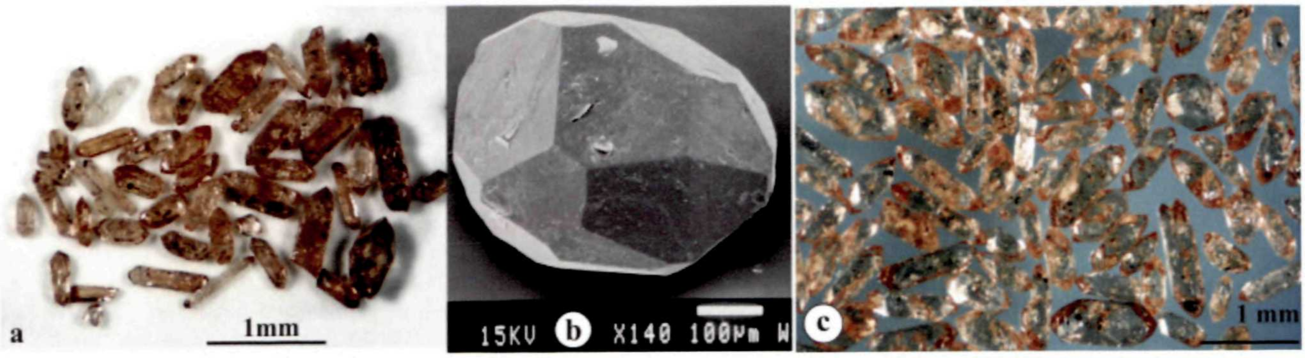


Fig. 4.85a, b, c Colour, lustre and crystal shapes of zircon in the panned concentrate samples. Zircons with colour and shapes typical for neovolcanic areas. Sites: a – Pukanec, b – Horné Plachtince, c – Juskova Voľa. Photo: a, c – P. Bačo, SEM b – I. Holický.

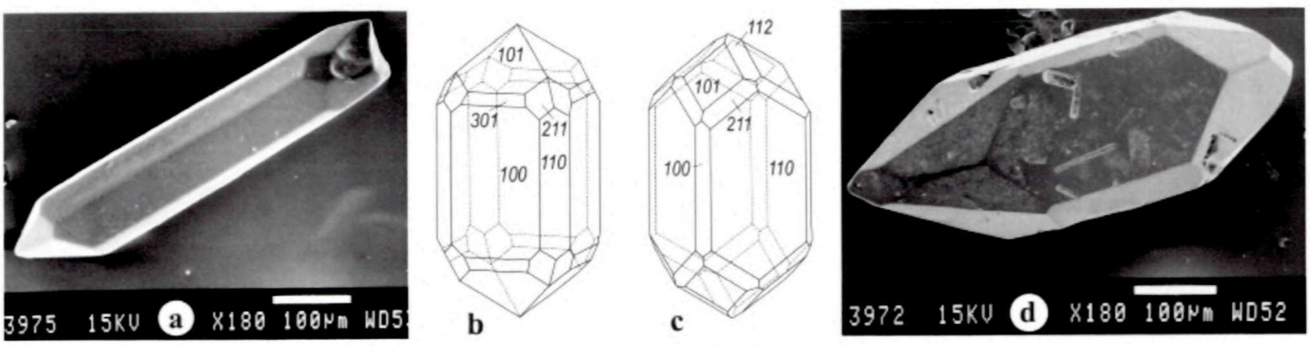


Fig. 4.86a, b, c, d Crystal shapes of zircon in the panned concentrate samples. Sites: a – Žemberovce, d – Výhne. Drawings: b, c – Rösler, J. H., 1983, Photo: SEM I. Holický.

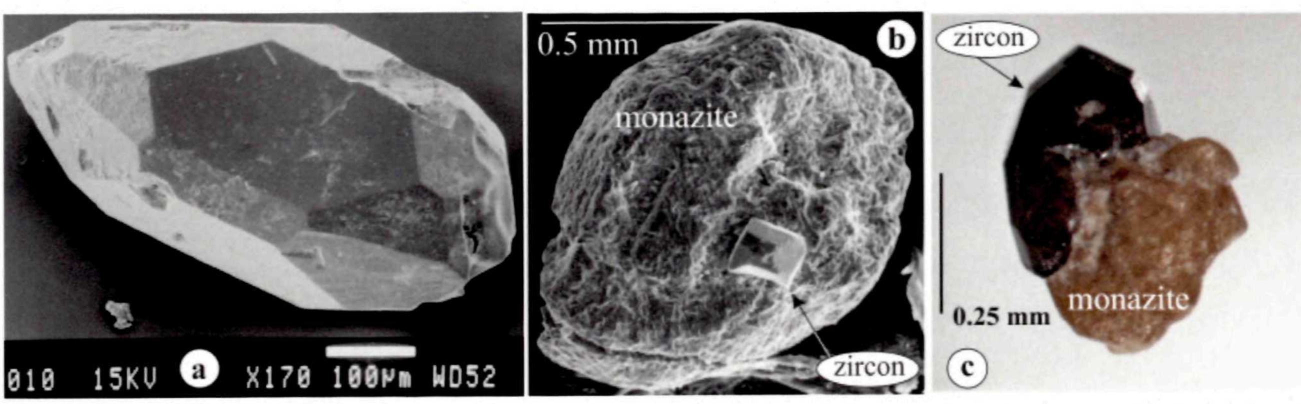


Fig. 4.87a, b, c Crystal shapes of zircon and intergrowths with monazite in the panned concentrate samples. Sites: a – Haligovce, Veporicum: b – Krná, c – Kociha, Photo: c – P. Bačo, SEM a, b – I. Holický.

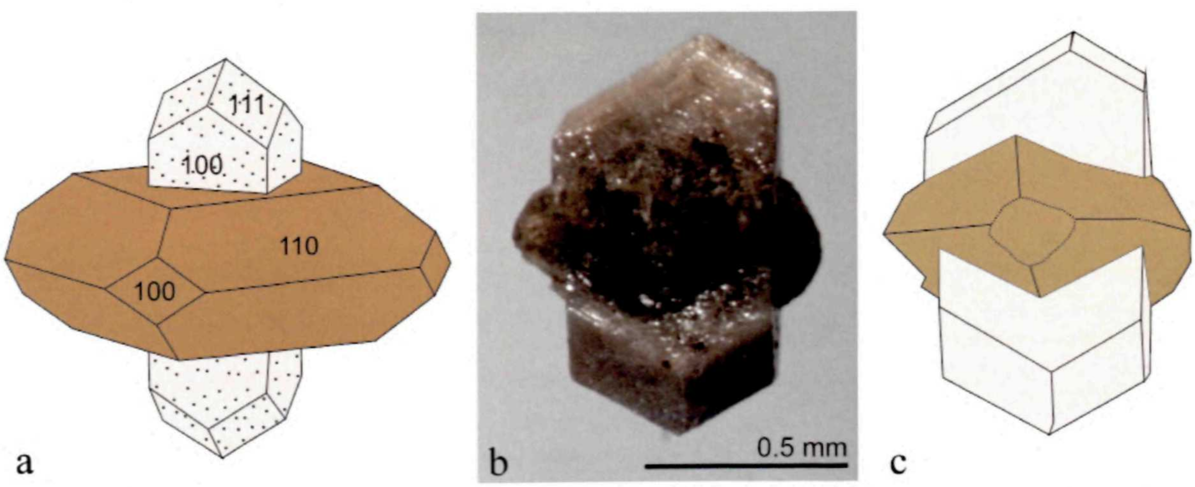


Fig. 4.88a, b, c Oriented interpenetration of xenotime with zircon. Site: b – Veporicum – Kociha. Drawings: a – Lukáč, 1968, c – Z. Bačová, Photo: b – Z. Bačová,

During the transport zircons remained stable due to their physical and chemical resistance. In the sedimentary areas in which zircon is clastogenic component, we can observe rounding of edges, the original habit, however, maintains. Size of small crystals in pannings is normally within 0.5 and 1.0 mm, larger grains are rare.

Intergrowths of zircons are very rare and were observed only on zircon coupled with monazite (Fig. 4.53 – 4; 4.87b, c).

Interesting is epitaxial intergrowth with the isostructure xenotime (4.88a, b, c). It is interpenetration twin in the direction of plane [001] (Lukáč, 1968).

General distribution characteristics

Zircon is among the most common minerals in the panned concentrate samples (Tab. 4.28; 4.89a). Its concentration is in all semi-quantitative classes with the most substantial share of the classes b and c (Fig. 4.89b).

Zircon is a typical accessory mineral and occurs in the panned concentrate samples from source areas of all regional geological units. To-date, more significant deposit accumulations of zircon are not known. However, it is present in the Danube garnet sands, where its presence may be of some prognostic significance.

Its physical and chemical stability makes it suitable as a dominant mineral in the heavy fraction for all types of sedimentary rocks (Fig. 4.89a, b). Peak concentrations are in the areas of primary occurrences, i.e. where source areas are formed by granitoid rocks. Elevated contents are known from samples of the sedimentary source areas.

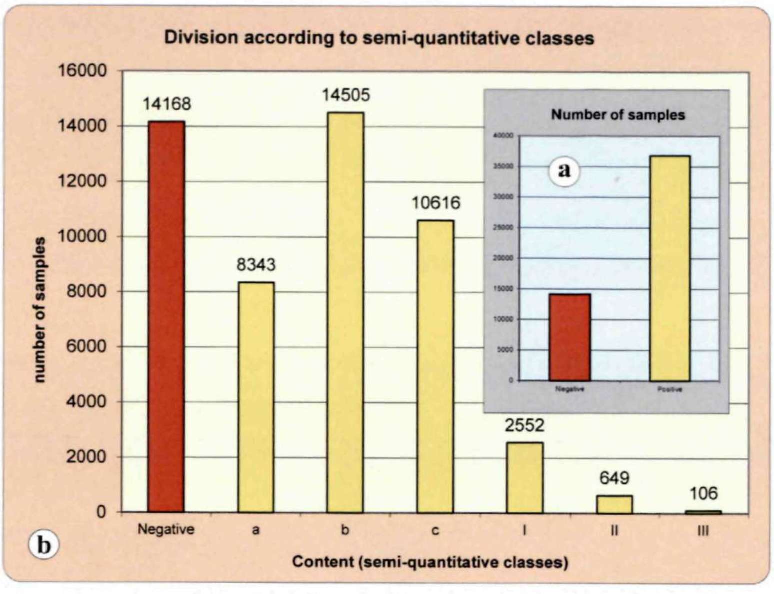


Fig. 4.89a, b Distribution of panned concentrate samples according to presence of zircon (a) and according to proportion of individual semi-quantitative content classes (b).

Tab. 4.28 Presence of zircon in the panned concentrate samples according to content classes.

Database of samples	Negative / Positive	Content (semi-quantitative classes)					
		a	b	c	I	II	III
50,939	14,168	8,343	14,505	10,616	2,552	649	106
	29	16	28	21	5.00	1.00	0.00
	36,771	8,343	14,505	10,616	2,552	649	106
	72	22.7	39.4	28.9	6.94	1.76	0.29

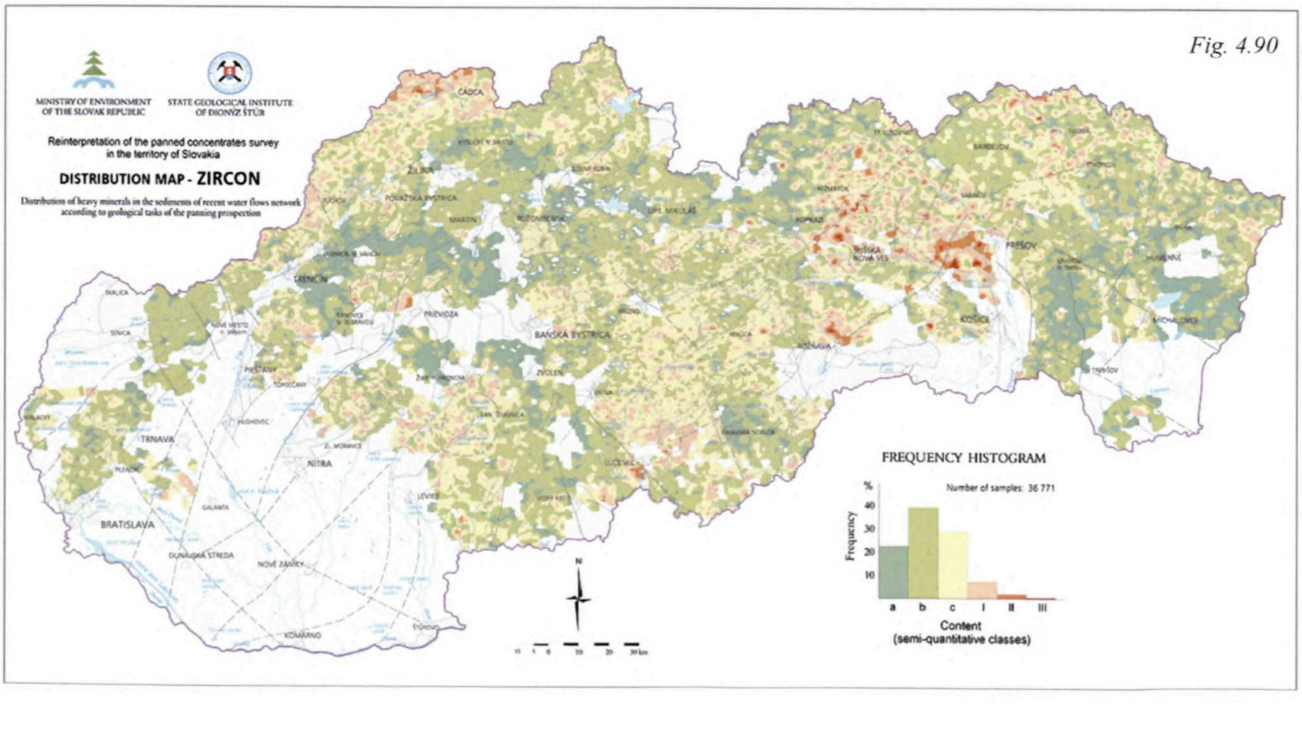


Fig. 4.90

4.3.21 Gold Au

H = 2.5 – 3.0; **SG** = 15.5 – 19.3 g.cm^{-3} (depending on impurities, mainly Ag); **System:** Cubic

Magnetic properties: gold is non-magnetic, and is concentrated in diamagnetic fraction

Colour in the panned concentrate samples

Colour of gold in the panned concentrate samples is clear golden yellow (Fig. 4.91a, b, c). It depends upon the genetic type of primary source according to which it can contain impurities of other metals (mainly Ag). These original colours preserves gold only in closest proximity of a primary occurrence.

Transport of gold flakes causes in hypergenic conditions a genuine rim, which has a bright yellow colour. Lustre of gold flakes is metallic.

Morphology in the panned concentrate samples

In the panned concentrate samples the gold flakes are present in the most diverse forms. Near the source original crystals (Fig. 4.92a, b, c, d) are preserved in dendritic forms (Fig. 4.93b) with partial rounding and softening of the edges. Gradually the original habit is diminishing, only locally the initial wire-like, or tinfoil habit is preserved (Fig. 4.93a, c; 4.94a, b, c; 4.95a, c).

In the panned concentrate samples from old mining areas there are present gold flakes, which have the features of mechanical working in ore crushers (Fig. 4.95c).

Thanks to transport, the gold flakes attain typical alluvial trimmed and flaky nature. Sometimes the gold flakes contain tiny penetrated grains of other minerals, usually quartz (Fig. 4.91c).

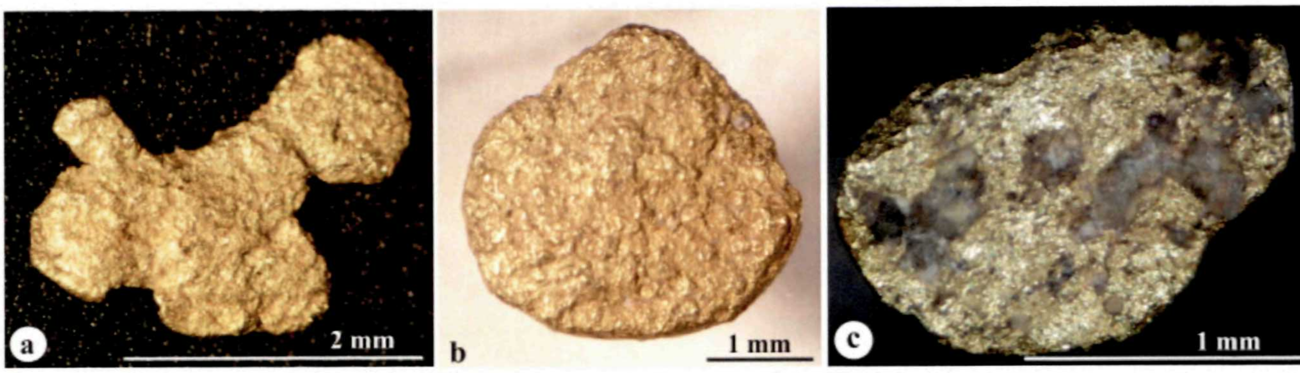


Fig. 4.91a, b, c Colour and lustre of gold in the panned concentrate samples. Colour and shades are dependent on impurities, mainly Ag. At its high content it has dark-yellow colour, at Cu-content it turns to reddish-yellow hue. Part of gold flakes can be coated by Mn- and Fe- oxides. Site: a – c Ruská Bystrá. Photo: P. Bačo.

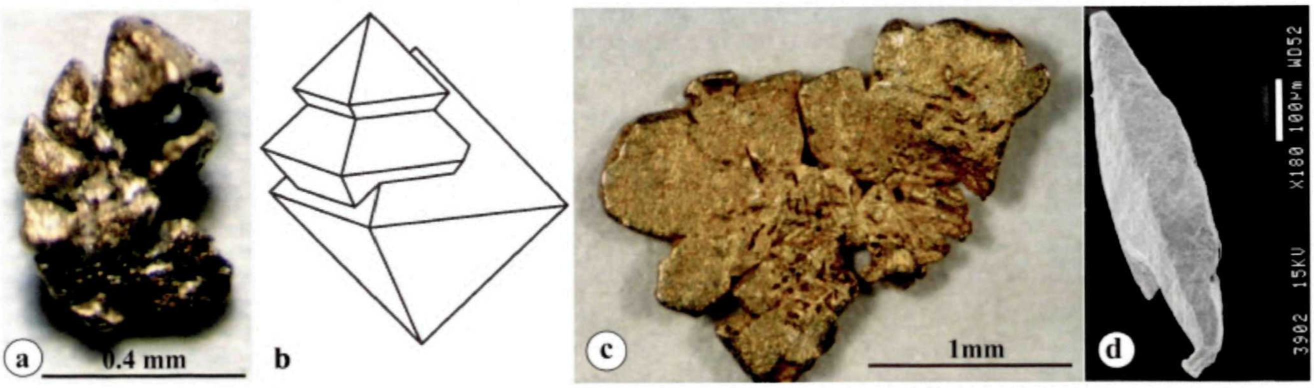


Fig. 4.92a, b, c, d Crystal shapes of gold in the panned concentrate samples. Rare octahedron and hexahedron shapes create by mutual combinations simple and complex couples. The gold in the panned concentrate samples occurs typically in the form of gold flakes, without preserved crystal planes. Site: a, c, d – Pukanec. Drawing: b – J. H. Rösler, 1983, Photo: a, c – P. Bačo: SEM d – I. Holický.

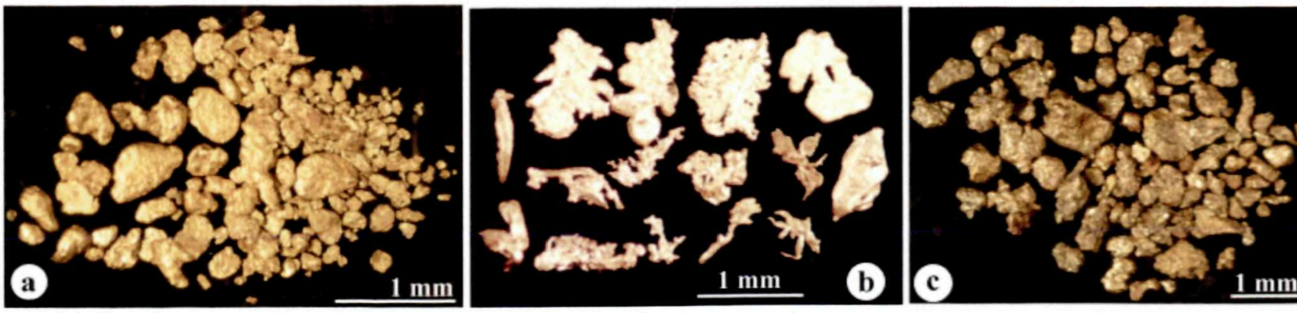


Fig. 4.93a, b, c Crystal shapes of gold close to the source (b); after short transport (a, c) in the panned concentrate samples. Alluvial gold flakes, examples of morphology from various geological environs. Sites: a – Ruská Bystrá, b – Pukanec, c – Selce. Photo: P. Bačo.

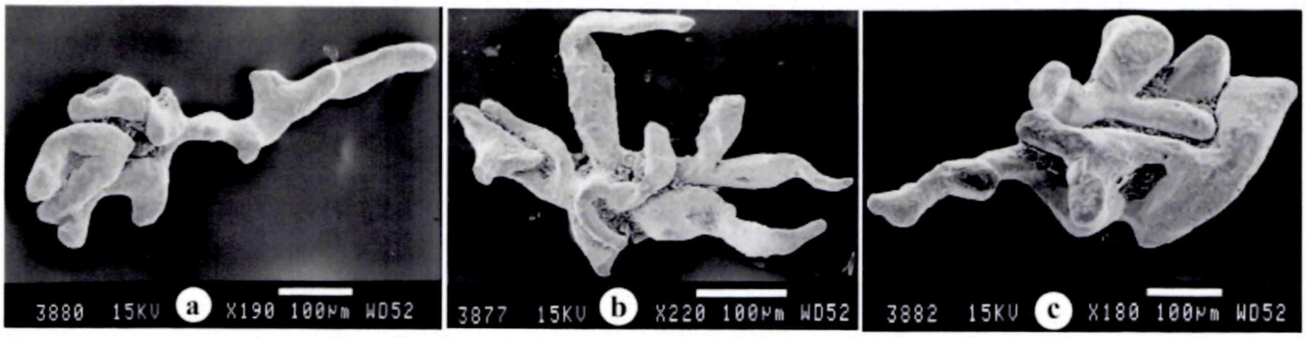


Fig. 4.94a, b, c Crystal shapes of alluvial gold which underwent short transport. Site: a-c Pukanec. Photo: SEM I. Holický.

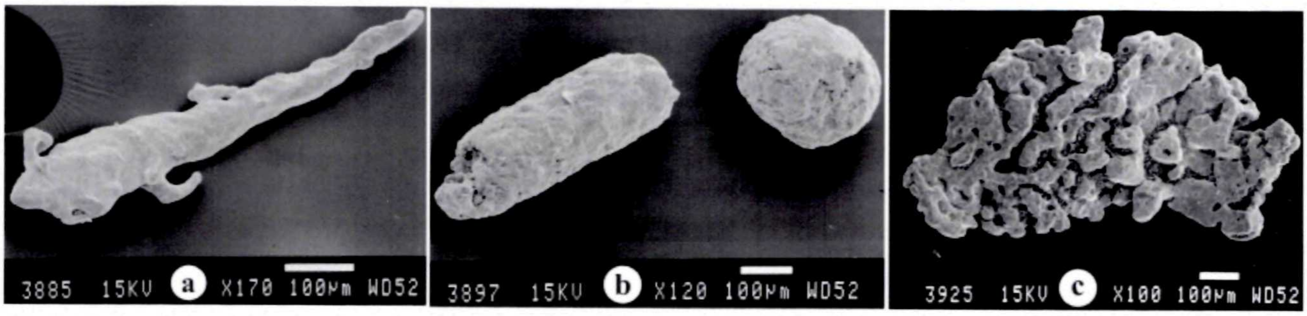


Fig. 4.95a, b, c Shapes of gold in the panned concentrate samples. Site: a-c Pukanec. Photo: SEM I. Holický.

Tab. 4.29 Presence of gold in the panned concentrate samples according to content classes.

Database of samples	Negative	Content (semi-quantitative classes)					
	Positive	**a**	**b**	**c**	**I**	**II**	**III**
50,939	47,590	3,271	75	3	0	0	0
	93.4	6	0	0	0.00	0.00	0.00
	3,349	3.71	75	3	0	0	0
	6.6	97.7	2.24	0.09	0.00	0.00	0.00

General distribution characteristics:

Gold (in the form of gold flakes) is quite rare mineral within the whole sampled territory (Tab. 4.29). Its presence was noted within the relatively small number of the panned concentrate samples. By contrast, they were captured virtually all of the primary gold mineralisations, which may pass into the alluvial deposits – placers (Tab. 4.30). Exceptions are impregnation types (Carlin), high-sulphidation and porphyry type of Au-mineralisations, which for obvious reasons (the form of gold in the ore – usually µm-grains of Au in quartz) didn't create secondary aureoles of gold in the form of gold flakes.

Gold was recorded mainly in the first and only exceptionally in the higher content classes (Fig. 4.95b, c). Due to the characteristics of gold, each occurrence creates a secondary aureoles, which have been recognized in the Slovak part of the Western Carpathians (Fig. 4.97, Tab. 4.30) – Bakos, Chovan et al., 2004.

In addition to well-known occurrences (with gold mining in the past) the panned concentrate prospecting detected gold appearance mainly in the Outer Flysch Zone, its Eastern section. There is a clear spatial coincidence with coarse-detrital facies of the Strihovce Member of the Krynica unit of the Magura Nappe.

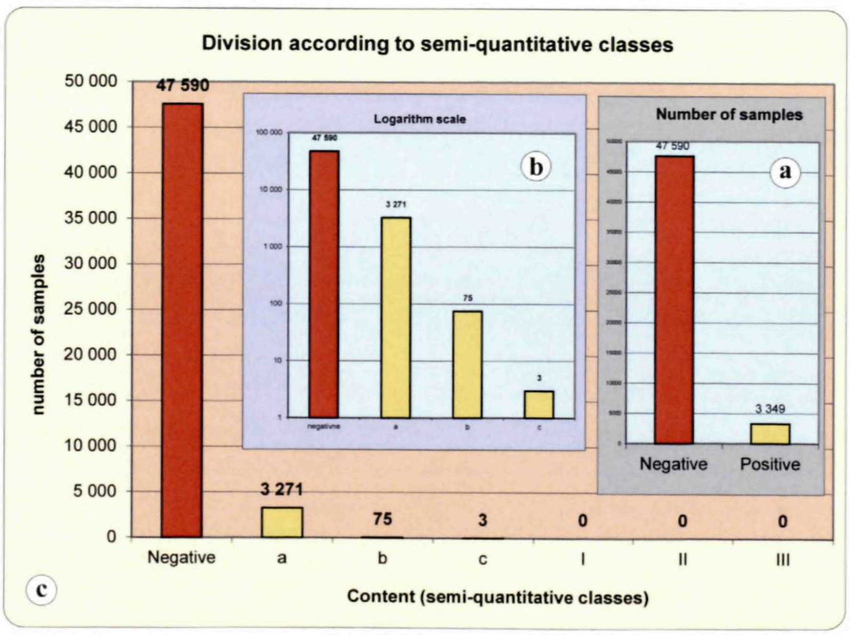
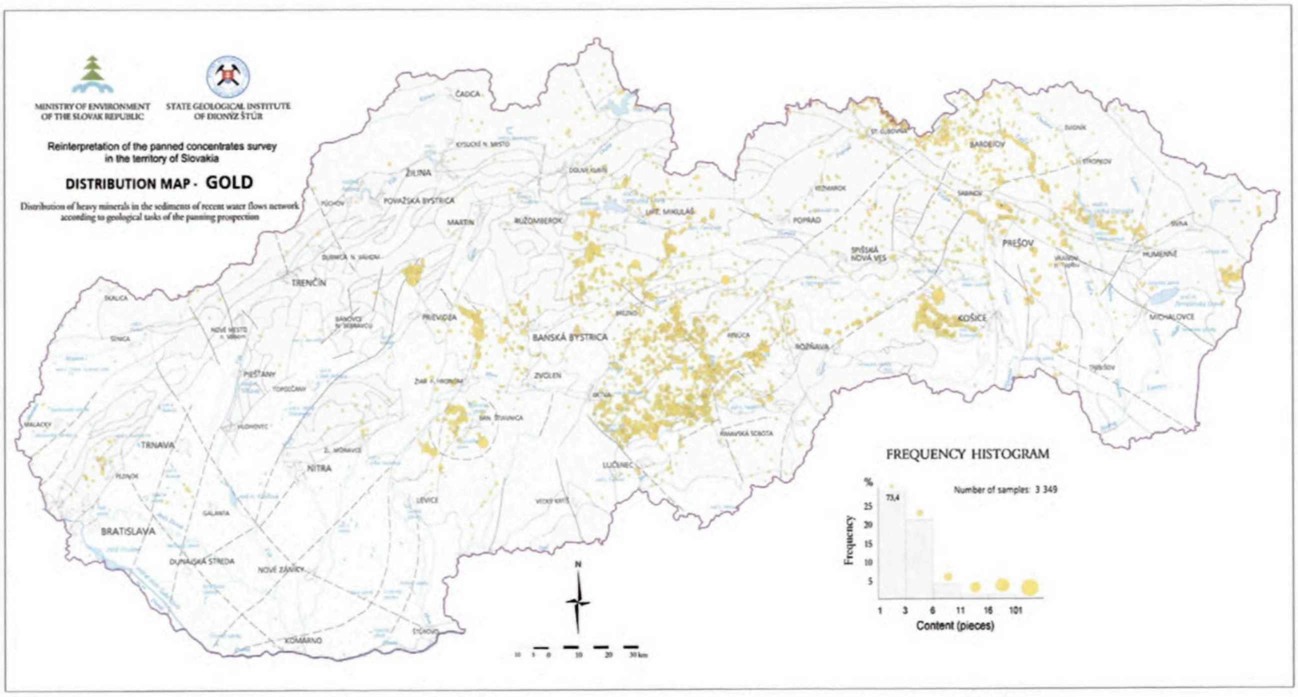


Fig. 4.96a, b, c Distribution of panned concentrate samples according to gold presence (a) and according to proportion of individual semi-quantitative content classes (b, c).



Tab. 4.30 Presence of gold (flakes) in the panned concentrate samples according to content classes. Selected map sheets at scale 1:50,000 illustrate areas with deposits and significant occurrences of gold, which is present in higher content classes in the panned concentrate samples.

Map	Database	Samples without mineral presence		Content (semi-quantitative classes)					
	Number of samples			a		b		c	
1:50 000		Number	%	Number	%	Number	%	Number	%
Area of Vysoké Tatry Mts. – Kriváň									
26-43	523	472	90	49	9	2	0	0	0
Suchý – Malá Magura									
35-22	530	472	89	53	10	5	1	0	0
Nízke Tatry Mts. – Magurka, Dúbrava, Nižná and Vyšná Boca									
36-21	1113	981	88	120	11	12	1	0	0
36-22	1050	981	93	67	6	2	0	0	0
Malé Karpaty Mts. – Pezinok, Limbach									
44-22	447	424	95	23	5	0	0	0	0
Veporicum – Kokava nad Rimavicou, Kociha, Hnúšta, Divín, České Brezovo									
36-42	2143	1829	85	310	14	4	0	0	0
36-43	858	714	83	139	16	5	1	0	0
36-44	797	588	74	199	25	10	1	0	0
Gemericum – Čučma, Poproč, Zlatá Idka, Henclová, Stará Voda									
37-23	811	704	87	99	12	6	1	2	0
37-24	380	289	76	90	24	1	0	0	0
Kremnické vrchy Mts.									
36-13	755	690	91	57	8	8	1	0	0
Štiavnické vrchy Mts. – Pukanec, Brehy, Banská Štiavnica, Hodruša									
36-33	530	444	84	80	15	5	1	1	0
Slanské vrchy Mts. S part – Byšta, Banské									
38-31	537	524	98	13	2	0	0	0	0
Outer Flysch Zone									
27-23	95	72	76	23	24	0	0	0	0
38-23	564	551	98	12	2	1	0	0	0

4.4 Conclusion

Panned concentrate prospection is a wide-spread search method of ore mineralisation types, dominantly. This highly effective method is used mainly in poorly-explored areas. However, its use has been justified even in regions with rich mining activities, which experienced some parts of the territory of Slovakia.

Within the "Re-interpretation Project" a large part of the panned concentrate samples were again mineralogically assessed using current methods (identification under UV light, dye tracing tests), and approximately 70% of the sample material uniformly processed and evaluated. The major part of the more than 50,000 records database has over 60 variables. The database has been created with sample documentation localised in the coordinate system and displayed in the topographic documents at scale 1:50,000. This has enabled to compile the distribution maps of selected types of minerals for the whole sampled territory of Slovakia. The database allows to construct similar maps from mineral species which have not been depicted in the last map works. The map outputs can be compiled not only for the whole territory of Slovakia, but also for the arbitrarily selected area. The database is publicly available.

The assembled distribution and interpretive maps of various types of minerals characterise various regional geological units throughout the Slovak part of the Western Carpathians. These minerals are Cr-spinel, corundum, pyroxenes, garnets and many other minerals. Some mineral types have a discriminatory character up to lithological level (monazites) and across regional geological units. Their applicability in the context of cross-correlation of the lithological types is a value added.

The results are crucial for raw materials appreciation of Slovakia. Secondary dispersion aureoles have contributed to characterisation of almost all deposits of ore resources. Based on their characteristics the regional units as well as local areas can be evaluated from their potential point of view. The database allows very detailed view into the arbitrarily selected area within the sampled territory. This is obvious in the scales 1:50,000 and possibly the greater scales for those types of materials, which are represented by e.g. cinnabarite, cassiterite, gold, scheelite or accompanying base metal deposits, for example, barite, cerrusite and wulfenite. Even a singular registered presence of certain rare minerals, for example, topaz, corundum, andalusite points to the presence of specific alteration processes associated with specific types of mineralisation. The presence of sulphide minerals, e.g. galena, sphalerite, stibnite almost always refers to the closeness of anthropogenic sources – heaps, which ultimately are also indication of mineralisation.

The panned concentrate prospection in the Slovak part of the Western Carpathians has become the basis for prognostic evaluation of gold. A large number of anomalies in various regional geological units has previously been subjected to a higher stage of geological research and exploration, but some of the secondary anomalies were still unverified and their sources have not been identified. The distribution map, prepared in the framework of the "Re-interpretation Project" provided also the basis for map supplement of the representative publication Gold in Slovakia (Bakos and Chovan et al., 2004).

To date, the panned concentrate prospecting shall find its particular importance in the environmental field. In fact, a panned concentrate sample contains a large portion of various anthropogenic substances, often with polluting action. Its distribution is recorded and studies of possible impacts on biotic aquatic environment may follow up.

Acknowledgements:

This work was supported by the Ministry of Environment, Division of Geology and Natural Resources through the project no. 20 98: Reinterpretation of Panned Concentrates Exploration at the Territory of Slovakia. The authors express their gratitude to peer reviewer for his constructive criticism and suggestions which have contributed to the improvement of the content of the work.

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