Mineralia Slovaca, 42 (2010), 15 – 32
ISSN 0369-2086

Exploration results of Au porphyry mineralization in the Javorie stratovolcano

ROMAN HANES[1], FRANTIŠEK BAKOS[1], PETER FUCHS[1], PETER ŽITŇAN[1]
and VLASTIMIL KONEČNÝ[2]

[1]Eastern Mediterranean Resources – Slovakia, s. r. o. (EMED), Železničiarska 12,
969 01 Banská Štiavnica
[2]State Geological Institute of Dionýz Štúr, Mlynská dolina 1, 817 04 Bratislava

Abstract

Au-porphyry mineralization occurrences in the Javorie stratovolcano are related to intrusions of andesite to diorite porphyry. Overall potential of low grade (0.5 ppm Au) geological resources are estimated to 100 tons of Au. The most important mineralized orebody was verified in the northeastern part of the stratovolcano at Detva-Biely vrch locality. The other localities represent only mineralogical occurrences of Au porphyry mineralization. Quartz stockwork is the typical indicator of Au-porphyry mineralization. Mineralization is associated with Na- and K-silicate alteration, commonly overprinted by intermediate and advanced argillic assemblages. Multistage brecciation is a characteristic feature of the orebodies. The porphyry system at Kráľová is characteristic by the presence of Na- and K-silicate alteration overprinted by intermediate argillic alteration and Fe-oxide assemblage with minor content of Fe, Cu, Zn and Pb sulphides. Advanced argillic alteration has remobilization character. Pervasive pyrite–pyrrhotite rich phyllic alteration rimming the ore bodies and causing the geophysical IP anomalies is barren. Mineralized zones with increased Au grade over 0.1 ppm are accompanied by the increased Cu and Zn grades. The Au : Cu ratio is very low 1 : 0.02 to 0.09. Au porphyry mineralization is accompanied by economically insignificant occurrences of disseminated Mo mineralization, stockwork-disseminated Pb-Zn mineralization, Bi-Te mineralization and fracture-related zeolite mineralization.

Key words: Au porphyries, porphyry style alterations, porphyry intrusions, geochemistry, metallogeny, Detva-Biely vrch deposit, Central Slovakian Neogene Volcanic Field, Western Carpathians

Introduction

In the beginning of the 1990s the Javorie stratovolcano (Fig. 1) was considered to be insignificant metallogenetic province in terms of ore deposits. The discovery of epithermal high sulphidation Au mineralization in Podpolom quarry started a new exploration period which continues until today with a short break after gold price has plunged. This paper represents a summary of exploration results of EMED Mining Ltd. carried out in 2006 – 2009. The central zone of Javorie was covered by the stream and soil geochemical sampling (Fig. 2) using 200 by 200 m grid, hydrothermal-intrusive centres in 100 by 100 m grid. A new map with alteration and mineralization occurrences was compiled in 1 : 5 000 scale. Detailed petrology of rocks, mineralogical studies of alterations and genetical aspects of different breccia types were not subject of the study because the exploration nature of the works. Therefore we cannot make reasonable conclusions regarding the character of intrusions. References to the various types of alterations are only informative and all types of breccias are hereafter referred only as "breccias". Advanced exploration and drilling were realized at Detva-Biely vrch (total 44 drillholes), Zvolen-Kráľová (total 6 drillholes), Slatinské Lazy-Výboškovo (total 8 drillholes) and Pstruša-Garáty (total 3 drillholes). Only one hydrothermal-intrusive centre at the Biely vrch locality represents an economic accumulation of gold. The resource estimation made in 2009 stands at 140.2 Mt geological resources (JORC inferred category) of porphyry ore with the average grade 0.57 ppm Au using 0.3 ppm cut off. That represents 80 tons of gold (Chapman, 2009). Petrology, style of alterations and metallogeny of the mineralization at Biely vrch were studied in detail by Lexa et al. (2007).

Geological setting

The Javorie stratovolcano, situated in the eastern part of the Central Slovakian Volcanic Field is a relatively large compound volcano involving a volcano-tectonic graben and subvolcanic intrusive complex, formed by several stages of volcanic activity during Badenian to Sarmatian (Fig. 1).

The lower structural level (Stará Huta Complex) represents remnants of a large andesite stratovolcano of assumed Early to Middle Badenian age. The central zone contains a stratovolcanic complex of alternating lava flows

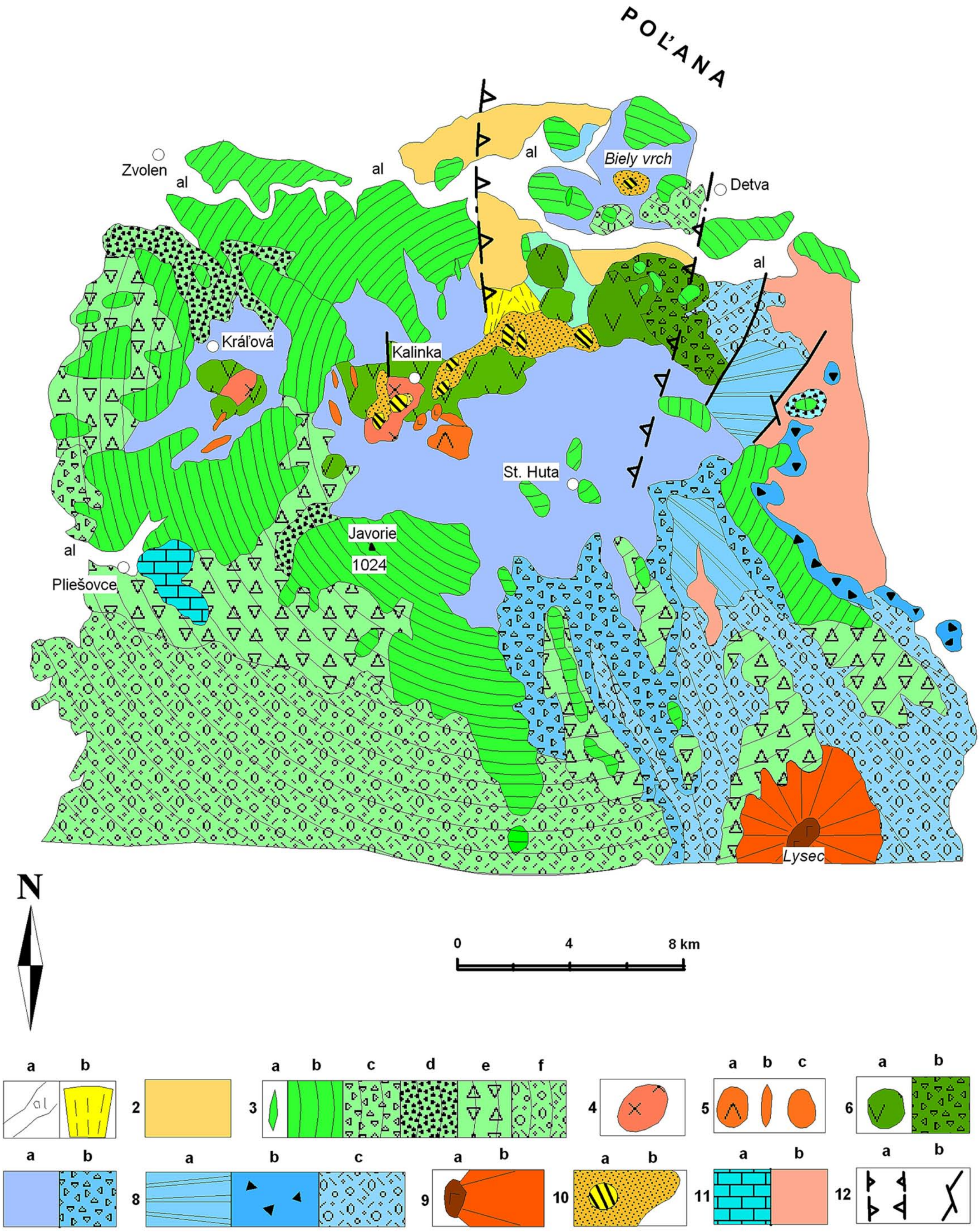


Fig. 1. Structural scheme of the Javorie stratovolcano (modified after Konečný et al., 1998). 1 – Quaternary: a – alluvial, b – proluvial deposits; 2 – Pliocene sediments (gravels, sands and silts); 3 – Upper structural level – Javorie Formation (Sarmatian): a – andesite dykes, b – effusive complex of proximal zone lava flows of pyroxene and amphibole-pyroxene andesites, c – hyaloclastite breccias, d – stratovolcanic complex of proximal zone (lava flows, block and pyroclastic flows), e – coarse to blocky epiclastic volcanic breccias, f – epiclastic volcanic breccias, conglomerates and sandstones of distal volcanic zone. Middle structural level (Upper Badenian): 4 – Kalinka and Králová intrusive complexes (diorite, quartz diorite and andesite porphyry stocks); 5 – Lohyňa intrusive-extrusive complex: a – amphibole-biotite-hypersthene dacite extrusion, b – hypersthene-amphibole andesite dyke, c – rhyodacite extrusion; 6 – Siroň Formation: a – extrusive domes (pyroxene-amphibole and amphibole pyroxene andesites), b – coarse epiclastic volcanic breccias; 7 – Blýskavica Formation: a – pyroxene andesite and basaltic andesite lava flows and hyaloclastite breccias, b – reworked hyaloclastites. Lower structural level (Middle Badenian): 8 – Stará Huta Formation: a – stratovolcanic complex (lava flows, pyroclastic and epiclastic volcanic breccias), b – block and ash pyroclastic flows, c – epiclastic volcanic breccias, conglomerates and sandstones of distal volcanic zone; 9 – Lysec volcano: a – pyroxene-amphibole andesite tholoids, b – pyroclastic and epiclastic cone complex of proximal zone; 10 – a – advanced argillic alteration, b – intermediate argillic alteration; 11 – Pre-Tertiary basement: a – Mesozoic rocks, b – crystalline rocks; 12 – Faults: a – faults limiting volcanotectonic depression, b – faults.

and subordinate pyroclastic rocks subsided downward at the base of the graben. It is exposed along the eastern margin of the volcano, where it is formed by pyroxene and hornblende-pyroxene andesite lava flows alternating with epiclastic breccias. The middle structural level represents filling of the volcanotectonic graben in the central and northern sectors of the volcano. Early stage of the graben subsidence was accompanied by activity of differentiated pyroxene-hornblende andesites to dacites, forming extrusive domes with related coarse breccias and epiclastic volcanic breccias/conglomerates in the distal zone (Siroň Formation). The late stage of the graben subsidence during the Upper Badenian was accompanied by effusive activity of olivine-bearing basalts, basaltic andesites and pyroxene andesites that due to a limnic environment formed a complex of lava flows and hyaloclastite breccias (Blýskavica Formation). The late stage of the graben subsidence during the Middle Badenian was accompanied by the activity of differentiated pyroxene-hornblende andesites to dacites, forming extrusive domes accompanied by proximal coarse reworked breccias and by distal epiclastic breccias and conglomerates (Rohy Formation). The subsided complexes of the graben filling were subsequently intruded by stocks of quartz-diorite porphyry that grade downward into diorites and monsodiorites. The emplacement of intrusions resulted in generation of hydrothermal systems and related alteration at Kráľová, Zaježová, Banisko, Skalka, Podpolom, Stožok and Biely vrch localities. Rare rhyodacite dykes postdate subvolcanic intrusions. The Sarmatian upper structural level is represented by a stratovolcanic complex of pyroxene to hornblende-pyroxene andesites (Javorie Formation), accumulated especially along former valleys on the volcanic slopes. In the proximal zone the lava flows alternate with pyroclastic flow deposits and coarse epiclastic volcanic breccias (Konečný et al., 1995).

Prevolcanic basement in north-eastern part of the Javorie stratovolcano is formed by crystalline rocks (granodiorites, tonalites, migmatites and gneisses) and southwestern part is formed also by the envelope Mesozoic sediments of the Veporic tectonic unit (Konečný et al., 1998).

Metallogeny and history of exploration

The Javorie region belongs among the most explored areas in Slovakia. The history of exploration activities can be split into several exploration periods. First exploration and research is connected with sulphur mines at Kalinka, exploited in the 18th century. The exploitation of native sulphur dates back to 1810. During the peak of sulphur mining in 1840 – 1860 about 300 tons of native sulphur was extracted. Data and information about mining works, location and structure of sulphur bodies and geological setting in close proximity can be found in works of Adler (1873), Zipser (1847) and Szontagh (1885).

After the second world war the exploration works were renewed on the locality Sírna baňa (Sulphur Mine) Kalinka by Geologický prieskum, n. p. during 1952 – 1954 (Klubert, 1955), but without positive results. Kuthan (1956) in his study of sulphur deposits in Kalinka assumed the origin of sulphur from solfatara, related to a one of the lateral craters of the Javorie volcano. During prospections for raw materials accompanied with mapping in 1 : 10 000 scale the small intrusions of variable petrographic composition were discovered in the vicinity of Vígľašská Huta-Kalinka village (Valach, 1966). Geochemical anomalies with increased content of Pb, Zn, Cu, Sn, Mo and Bi were detected and their relationship to the position of intrusive bodies was established too.

Structural drillhole KON-1 near Kalinka village in the whole profile down to 2 020 m confirmed a stock-like intrusive body of variable composition from diorite porphyry and quartz-diorite porphyry in the upper part and diorite to monzodiorite in the deeper part. The upper part of intrusion is strongly affected by advanced argillic alteration with abundant pyrite down to 370 m depth. The deeper part of the intrusion is characterized by prevailing actinolitization and biotitization. Zones of alterations show telescoping pattern. The weak porphyry type mineralization was confirmed in the form of veinlets and impregnations of galena, sphalerite, chalcopyrite, covellite and molybdenite (Konečný et al., 1977; Konečný and Mihaliková, 1981). The discovery of porphyry style mineralization initiated metallogenetic research project in the central volcanic zone of the Javorie stratovolcano (1977 – 1980). The project included geological mapping of the central volcanic zone in broader areas of Vígľašská Huta-Kalinka, Klokoč, Stožok localities at a scale 1 : 10 000, application of various geophysical methods, number of shallow drillholes to 30 – 50 m depth and some deep drillholes to 650 m depth. As a result 5 centres of hydrothermal activity have been discovered. These are related to the emplacement of the stock-like intrusive bodies of diorite to quartz-diorite porphyry as confirmed by drilling. Intrusive bodies are accompanied by the zones of advanced argillic alteration with scarce silica bodies (Štohl and Konečný, 1981). Two stages of mineralization were defined: first stage – high temperature porphyry type with Pb, Zn, Cu and Mo mineralization and the second stage – lower temperature mineralization with enargite, pyrite and sphalerite (Štohl et al., 1985).

The presence of several genetic types of magmatic-hydrothermal and hydrothermal-explosive breccias was discovered by drilling (Konečný and Štohl, 1991). The native sulphur deposit near Kalinka represents an accumulation within breccia fill in a hydrothermal-explosive breccia pipe. Breccias with limonite cement represent the youngest stage of hydrothermal-explosive activity. Material after explosive destruction of breccia pipe was after a short transport deposited in a local limnic basins around Stožok intrusive center (Konečný et al., 1998). The ferruginous breccias were subjected to local mining in the past.

New insight into metallogeny of the Javorie stratovolcano was brought by exploration of Rhodes Mining NL with gold discovery in Klokoč-Podpolom silica quarry (Štohl et al., 1999). Au mineralization was described from limonitized zones in advanced argillic altered rocks. The epithermal high sulphidation style of Au-mineralization is hosted by massive, locally friable sacharoidal silica and

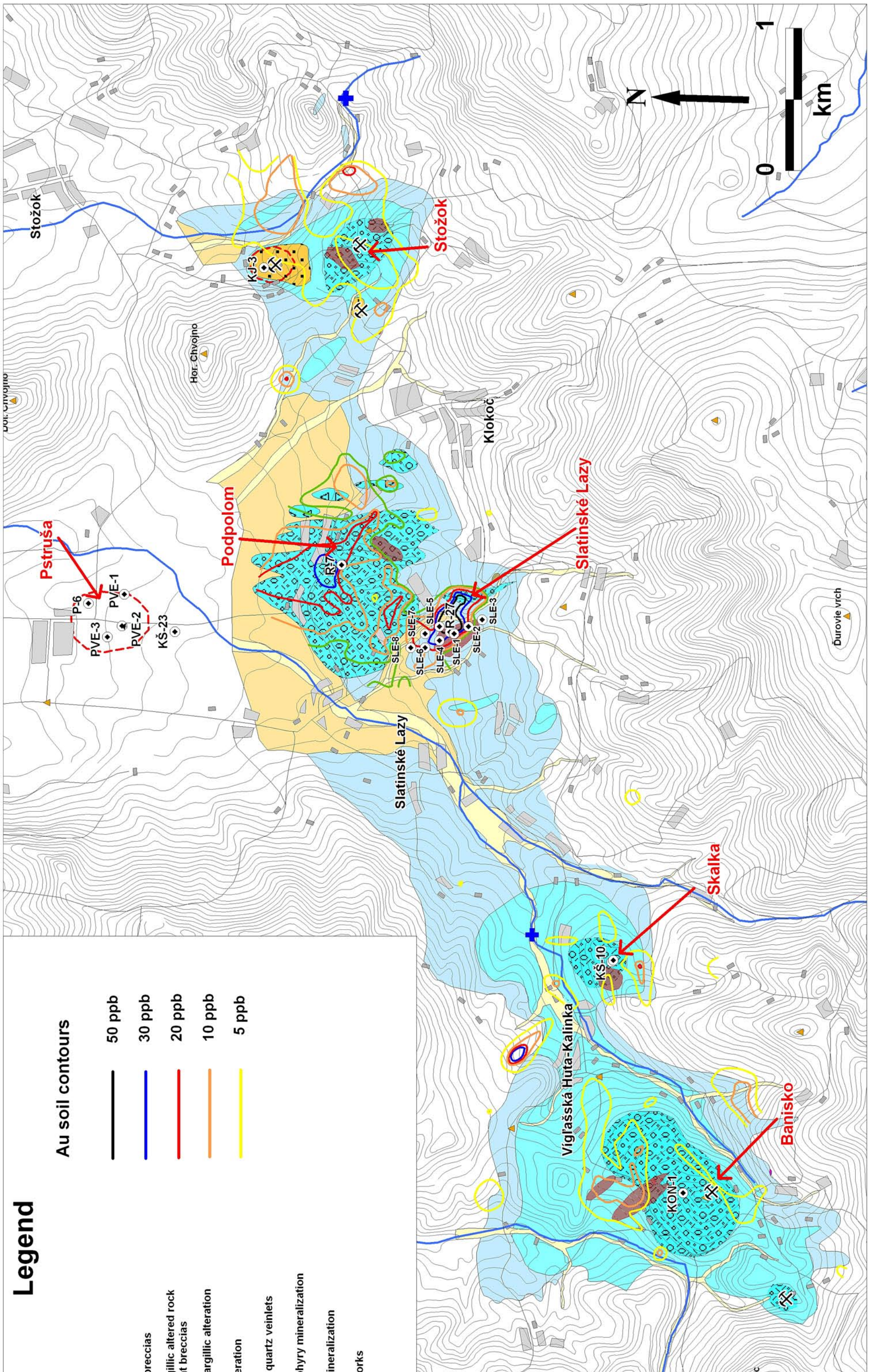


Fig. 2. Alteration and soil geochemistry map of the Javorie central zone.

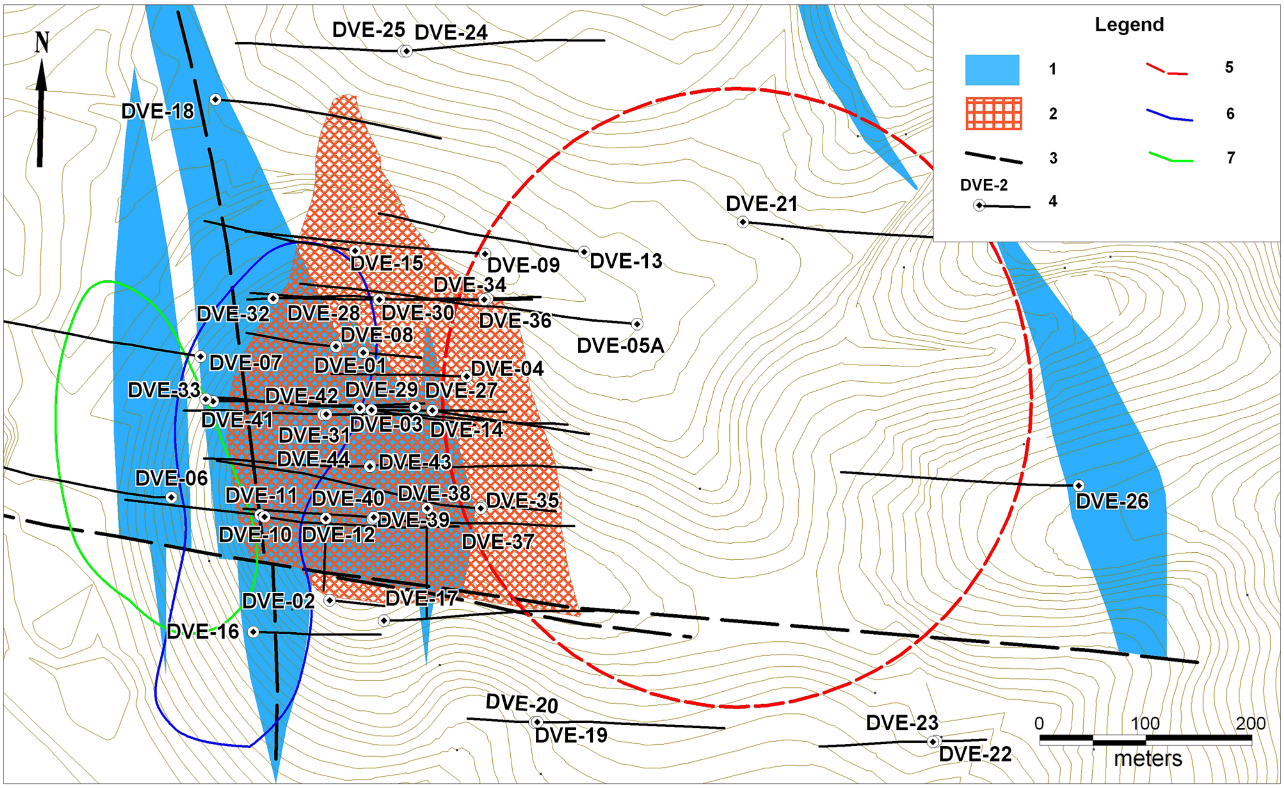


Fig. 3. 1 – Zones of the most intensive advanced argillic alteration, 2 – quartz stockwork, 3 – interpreted fault, 4 – drillhole, 5 – magnetic high anomaly, 6 – resistivity anomaly >300 Ωm at 350 m elevation (modified after Onescu et al., 2006), 7 – IP anomaly >40 mV/V at 350 m elevation (modified after Onescu et al., 2006).

hydrothermal-explosive breccias with impregnations of limonitized pyrite and pyrrhotite. Locally the zones with intensive advanced argillic alteration with kaolinite, illite, diaspore, alunite and pyrophyllite are present. Galena, sphalerite, enargite, luzonite, covellite, realgar, cinnabarite and stibnite occur rarely in association with pyrite and pyrrhotite. Au grades depend on the oxidation level. Maximum grades up to 22 ppm were identified in oxidized supergene enriched rocks; however, grades in non-oxidized parts of the deposit vary from 0.1 to 1 ppm. Preliminary resource estimates are around 1 – 1.5 Mt at 1.5 – 2 ppm Au. Au mineralization is related to stock-type diorite intrusion with features of Cu porphyry and related generation of large amount of hydrothermal-explosive breccias that allowed ascent of hydrothermal fluids (Štohl et al., 1999).

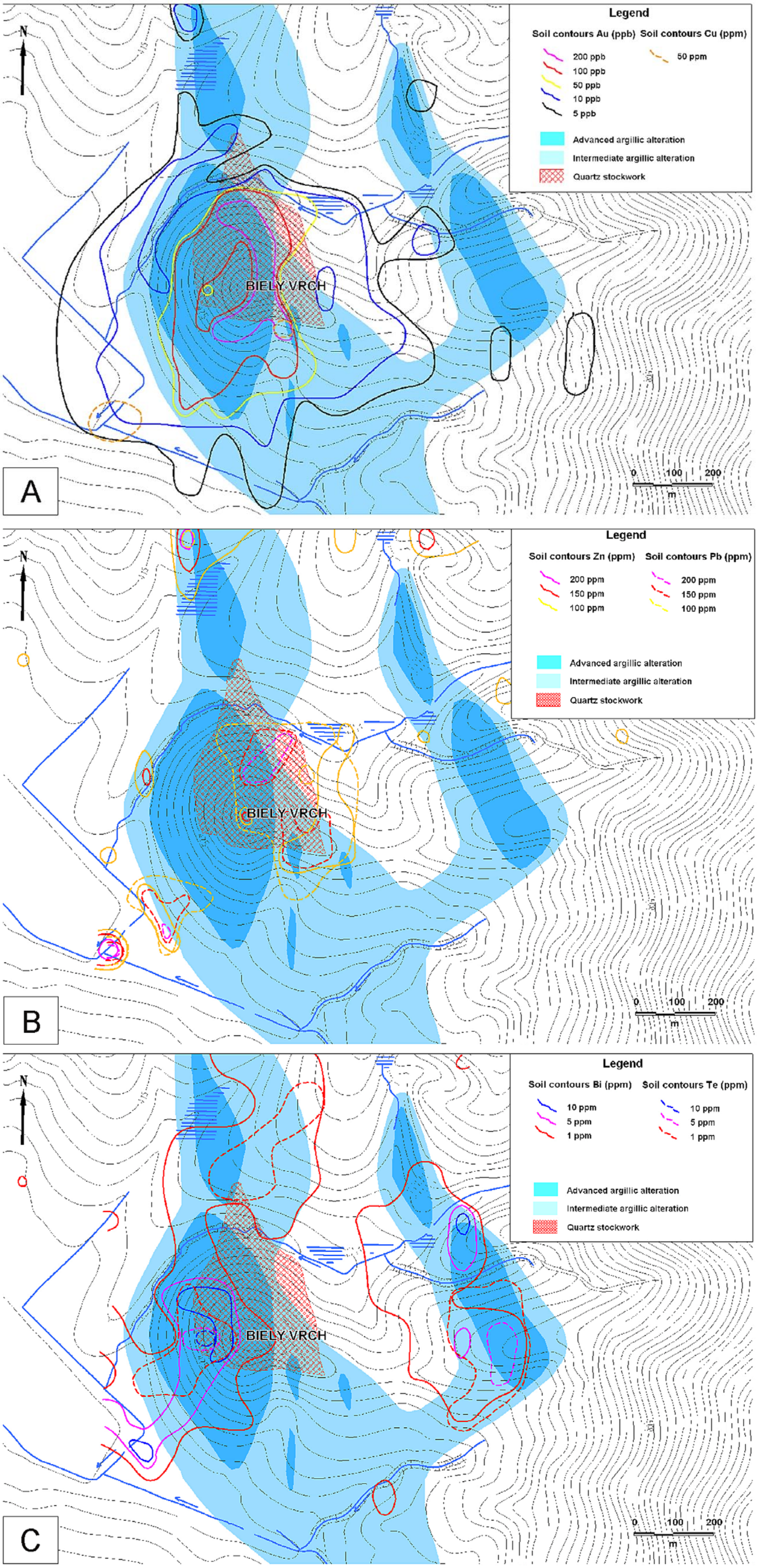
The local occurrence of Au mineralization with Au content up to 0.2 ppm was recorded in silicified, argillized and pyritized diorite porphyry north from Banisko intrusive--hydrothermal centre in road cut between Kalinka and Zaježová. The drillhole (R-25/46.3 m) drilled by Rhodes Mining intersected mineralization with average Au grade 0.09 ppm only (Štohl – verbal communication).

Another Au porphyry mineralization is located in Slatinské Lazy-Výboškovo south from Klokoč-Podpolom hydrothermal centre, discovered in drillhole R-27 with average grade in entire hole (50.3 m) 0.52 ppm Au (Rojkovič and Rojkovičová, 1999). Maximum Au grade 2.02 g/t Au was identified at 15.5 m depth. Cu and Zn concentrations reached anomalous values as well (up to 549 ppm Cu and Zn – 1 097 ppm).

Another independent centre of intrusive and hydrothermal activity – Kráľová was discovered by geological mapping on the western slopes of the Javorie stratovolcano (Konečný et al., 1985). The exploration focused on Cu--porphyry mineralization recognized the presence of tetradymite, gold and base metal mineralization. Canadian company Keylock Resources explored Kraľová in the period 1997 – 2000. Geochemical soil sampling revealed 300 by 600 m wide and 1 km long N-S trending altered zone with soil anomaly up to 440 ppb Au in the Požiar area (692 m). The tenement was abandoned due to unsatisfactory results (Pástor, 2000).

The data on geological structure of the Javorie stratovolcano and its evolution were summarized in the geological map of Javorie at scale 1 : 50 000 and in explanations to the map (Konečný et al., 1998).

Based on geological mapping by Dublan et al. (1997) the Biely vrch area was considered to be older stratovolcano in the basement of the Poľana stratovolcano. The presence of the Biely vrch intrusive-hydrothermal centre was not published yet. The first exploration results in the vicinity of Detva are mentioned by the Canadian company SloGold Resources Ltd. (Pomorský et al., 1999). The Au assays from stream sediment samples vary from 20 to 28 ppb and rock-chip samples contained up to 29 ppb of Au. The source of Au anomalies was considered to be



the propylitized and silicified andesite of the Rohy Formation. Potential of the Biely vrch prospect (as possible high sulphidation type epithermal gold occurrence similar to Klokoč-Podpolom) has been recognized by Konečný et al. (2002) and referred to by Lexa et al. (2002) in evaluation of the ore potential of Slovakia. The mapping of area north of Rohy (657 m) and west of Detva at a 1 : 10 000 scale during 2000 – 2001 confirmed the continuation of the Javorie volcanic structures to the north up to southern slopes of the Poľana stratovolcano. This mapping outlined at Biely vrch a centre of hydrothermal activity with zones of advanced argillic alteration. Detailed petrographic study and reinterpretation of DV-24 drillhole resulted in identification of apophysis of diorite porphyry intrusion. Rock chip assays from the Biely vrch area returned Au grades up to 1.11 ppm. Subsequently in the framework of consultations provided by the State Geological Institute of Dionýz Štúr to Mediterranean Minerals Ltd., Lexa (2005) has recommended the Biely vrch prospect as well as Au porphyry type mineralization for further exploration.

Since 1986 the hydrothermal-intrusive centres with advanced argillic alteration were explored for industrial minerals (pyrophyllite, alunite), however, their accumulations are minor and not of economic interest (Galko, 1998).

Methodology

Samples were collected from outcrops, floats and drillcores. Drill core (diameter HQ, NQ) was split to halves, diameter PQ to quarters using diamond saw. Samples were weighted, dried and milled with at least 70 % to pass 2 mm sieve. Later samples were split to 250 g and finally pulverized that >85 % of the sample was less than <0.075 mm. Samples of 30 g weight were used for assaying of Au using AAS (fire assay) in laboratory ALS CHEMEX Rosia Montana in Romania. Detection limit of this method is 0.01 ppm of Au. Splits of the remaining sample were assayed using ICP MS

Fig. 4. Alteration and soil geochemistry maps of the Biely vrch intrusive-hydrothermal centre: A – Au-Cu, B – Pb-Zn, C – Bi-Te.

(four acids digestion) at ALS CHEMEX Perth in Australia. Detection limits of this analytical method are: Ag – 0.5 ppm, Al – 0.01 %, As – 5 ppm, Ba – 10 ppm, Be – 0.5 ppm, Bi – Ca – 0.01 %, Cd – 0.5 ppm, Co – 1 ppm, Cr – 1 ppm, Cu – 1 ppm, Fe – 0.01 %, Ga – 10 ppm, K – 0.01 %, La – 10 ppm, Li – 10 ppm, Mg – 0.01 %, Mn – 5 ppm, Mo – 1 ppm, Na – 0.01 %, Ni – 1 ppm, P – 10 ppm, Pb – 2 ppm, Rb – 10 ppm, S – 0.01 %, Sb – 5 ppm, Sc – 1 ppm, Sr – 1 ppm, Th – 20 ppm, Ti – 0.01 %, Tl – 10 ppm, U – 10 ppm, V – 1 ppm, W – 10 ppm, Zn – 2 ppm, Zr – 5 ppm. Soil samples were collected from B horizon sieved to 2 mm fraction in the field later through a <0.18 mm screen in the lab. The fine fraction was retained for analysis using ICP MS (four acids digestion) method. The quality of assays was regularly checked by adding of certified reference materials from GEOSTATS PTY LTD to the set of samples. In addition to this about 5 % of the pulps have been sent to OMAC Laboratory in Ireland for assay. Third verification was repetition of assays of randomly selected samples. The standard deviation was 3.45 %.

Exploration results

Intrusive-hydrothermal centre Detva-Biely vrch

Detailed geochemical and technical works were realized by EMED Mining Ltd. in 2006 – 2008. Au soil anomaly >100 ppb extends on 350 x 300 m area. Exploration was followed by testing of the soil anomaly with 4 inclined drillholes to the depth 250 m in first stage (2006). The second stage of exploration in 2007 was focused on eastern boundary of the ore body and IP anomaly in the western part of the prospect. IP anomaly was caused by pervasive pyritization with no Au grade. Further exploration program continued with infill drilling. This stage was finished by testing of the southern boundary of the deposit. The first drillhole in 2008 confirmed northern boundary of the deposit. Drilling of aeromagnetic anomaly was negative. Only a small mineralized zone with Au content up to 0.5 ppm was identified 250 m E from the deposit in about 350 m depth. The last exploration stage comprised infill drilling in 100 by 100 m grid (Fig. 3).

The orebody at Biely vrch is located at western boundary of the intrusive centre with circular to slightly elliptic shape on the surface. The intrusion forms stock of andesite to diorite porphyry cca 300 m in diameter on the surface. Younger inter- to post-mineralization intrusion was detected in the drillhole DVE-41/453 – 456 m as a 3 – 4 m thick dyke (Fig. 6A). The younger porphyry is only slightly altered and contains weak barren quartz stockwork. Western boundary of the intrusion was intersected by drillhole DVE-6. Contact zone between the intrusion and andesite are superseded by breccias bodies. Andesite is locally cut by porphyry dykes, which are causing increased Au grade in the andesites up to lower 0.X ppm Au. The intrusion continues to north-west direction under the Zlatý vŕšok hill in the form of sill, where it was intersected by the drillhole DV-24 (Konečný et al., 2002). Au content in the sill reached maximum 0.2 ppm.

Soil geochemistry reveals anomalies over 400 ppb of Au associated with central parts of advanced argillic altered zones (Fig. 4A). Au anomaly correlates with Pb and Mo, however Zn creates patchy halos around the ore body (Fig. 4B). Cu anomalies reached only 50 ppm and create only small spots in the central part and in the area south of the orebody. Zones with advanced argillization, presence of magmatic-hydrothermal brecciation and pervasive pyritization are characterized with significant Bi and Te anomalies (Fig. 4C).

Occurrence of basement mega-xenoliths (granodiorite to tonalite) is a specific feature of the Biely vrch deposit (Figs. 5, 6B and C). Three such bodies were identified at the deposit. Xenoliths of small size (up to 0.5 m) are rare. The boundaries of mega-xenoliths are not apparent. The contact zone between basement xenoliths and porphyry intrusion is 2 to 10 m thick and generally strongly altered and enriched in gold. The presence of mega-xenoliths within the orebody probably served as a geochemical barrier. Several meters to several tens of meters of drillcore from the contact zone were assayed from 1 to 3 ppm Au, locally with even higher Au content. The central parts of bigger mega-xenoliths are generally depleted in Au; the grade reaches up to 0.5 ppm Au only.

Another typical feature of the deposit is the presence of breccias. At least 4 generations were identified. Breccias are mostly related to early stage of porphyry mineralization development. They represent at least 50 % of the overall ore body volume. Inter-mineralization breccias occur locally and in small scale. Post-mineralization breccias do not contain primary quartz stockwork, this can be observed only locally in clasts (Fig. 6d). They are developed mainly in W part of the locality out of the orebody, where they form 50 to 80 % of the total rock volume. The youngest generation of breccias (pebble dykes) occurs as fine grained rock flour filling some cracks, crosscutting even post-mineralization breccias. Greater thickness of the pebble dykes than 1 m has not been observed at Biely vrch.

The mineralization is accompanied by typical alterations. Their exact nature is described by Koděra et al. (2010). The primary K-silicate alteration occurs within E part of the deposit in subsurface zone. In the other parts this alteration is typical for deeper parts of the deposit (below 200 m depth). Zones with the high temperature alteration are generally retrogradely overprinted by the intense intermediate argillic alteration. Intermediate argillic alteration dominate in S and N parts of the deposit, preserved in the space between advanced argillic altered zones down to 200 – 300 m depth. Centers of advanced argillic altered zones are characteristic by the intense silicification and massive to vuggy silica bodies. Advanced argillic altered zones are associated with about N-S trending tectonic zones and disappear in a wedge-like form in the depth. In 300 – 400 m depth from the surface they appear only as 0.5 – 3 m thick ledges. The pervasive pyritization and pyrrhotitization are typical for the zone located W from the orebody. Broader area up to about 0.5 – 1 km from the Biely vrch intrusive center is affected by propylitization.

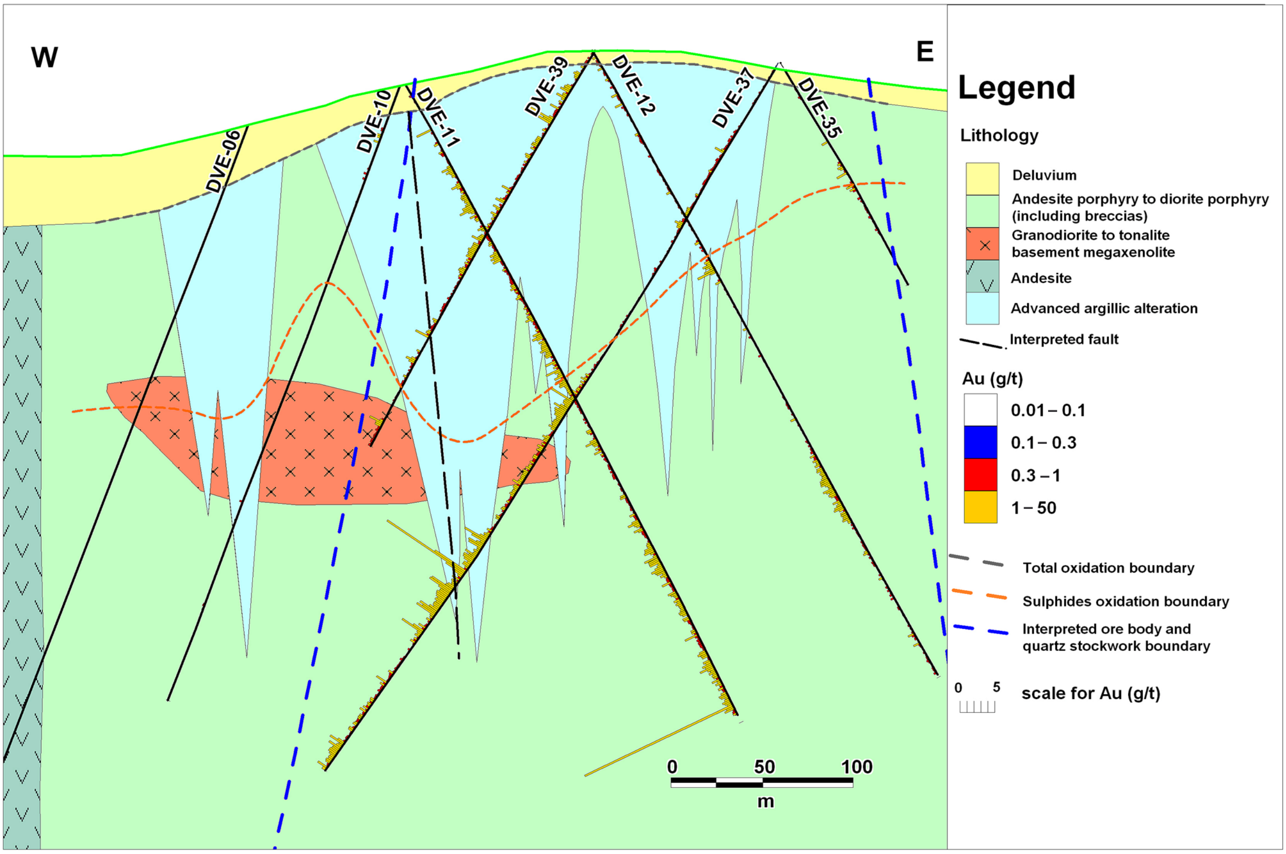


Fig. 5. Cross section through the Biely vrch deposit.

Au-porphyry mineralization at Biely vrch deposit is typical by the presence of quartz stockwork (Fig. 6E). It is the main macroscopic indicator of the mineralization and its presence outlines the orebody. The presence of the quartz stockwork is not the evidence of Au grade in the ore, but only the indicator of the mineralization. The quartz stockwork zone follows vertical to subvertical setting similar to the shape of the intrusion. Its vertical extent is unknown; exploration drilling confirmed its presence down still about 400 m below the surface. The orebody is delimited neither by lithology, nor by tectonics. The limits of the mineralization in all directions can be defined as gradual transition from the high through moderate to low Au grade ores. Geochemical boundaries correspond very well with geological indicators, such as decreasing density of quartz stockwork towards the outline of the deposit. The Au grade at the border of the deposit decreases from 0.3 to 0.05 ppm. Southern part of the deposit is delimited by a thick tectonic zone of E-W to ESE-WNW trend with probably subvertical dip.

Gold is the only economic mineral in the deposit. It was detected in macroscopic form in only one sample (Fig. 6F), where it fills out the crack of intermediate argillic altered rock (DVE-11/394.3 m). Maximum Au grade in one meter sample of the drillcore reached 45.2 ppm. The richest mineralized intercepts with the Au grade ranging 2 to 8 ppm were identified in the centre of advanced argillic altered zone. This zone is 5 to 30 m thick with max. length 100 m in the N-S direction. These high grade accumulations represent probably a product of remobilization of Au porphyry mineralization by the fluids responsible for advanced argillic alteration. Au grade in the other parts of the orebody varies between 0.3 to 2 ppm. Average Au grade within the superficial part of deposit is 0.79 ppm. The oxidation zone extends to the depth of 30 to 50 m, in the central zone to about 120 m depth. No relationships between Au grade and oxidation zone have been observed. Mineralized zones are typical by increased Cu and Zn grades, but correlations between Au and Cu (Fig. 10), or Au and Zn do not exist. Summary of other elements is shown in Tab. 1.

The pyrite content in the orebody is low and generally does not exceed 0.1 %. Locally, in S and N parts pyrite content reaches several %, up to 1 % in average in the intermediate argillic altered rocks. The western zone, typical with the presence of pervasive pyritization outside of the deposit, contains as much as 10 % of pyrite and pyrrhotite. Magnetite content in the orebody reaches in parts as much as 10 %. It is completely missing in the zones of advanced argillic alteration. It disappears on the margins of the orebody (except of E). From the other ore minerals chalcopyrite and molybdenite are relatively common. Macroscopic chalcopyrite is rare, maximum sizes of aggregates reach 1 mm. Molybdenite forms impregnations of up to 2 mm aggregates within the altered rock, or the filling of young, predominantly open cracks.

The Biely vrch intrusive center is also typical by the weak signs of younger mineralization. Thin carbonate veinlets with drusy galena and sphalerite were detected inside and outside of the deposit. Their presence is not systematic, rare and without economic importance. Eastern part of the deposit with absence of advanced argillic zones is characteristic by abundant zeolite stockwork. Zeolites (at least 3 species) occur in open cracks of tectonic zones from the surface down to the maximum depth verified by drilling (up to 400 m). The drillhole DVE-21 located in NE part of the intrusive centre intersected number of open cracks filled with drusy calcite. Geological mapping in this part of the intrusive centre defined zone of drusy quartz veinlets. The assays of these samples did not return any Au grades.

Intrusive-hydrothermal centre Stožok

Soil sampling revealed three main low grade anomalies (up to 19 Au ppb). Anomalies are located in the area south from Stožok-Šakovci on a small ridge between Stožok and Klokoč villages (Fig. 2). Their position reflects the presence of intermediate and advanced argillic altered zones (NW-SE trend), however, the central strongly silicified zone remains barren. In the last century the zones with sacharoidal silica were a subject of occasional exploitation (small quarries, adits, shafts) for construction purposes. Re-assayed advanced argillic to intermediate argillic rock with quartz veinlets from historical drillhole KJ-3 (80 to 110 m) returned Au grades in the range 0.1 – 0.27 ppm. The local dark-grey quartz veinlets found in the clasts of breccias in outcrops indicate the presence of porphyry style mineralization, however the rock samples had no Au grades. The epithermal mineralization has been found around Stožok-Pastorkovci area. Mineralization represents fragments and blocks of massive, cavernous to drusy white quartz without any metal content. The Stožok intrusive--hydrothermal centre is also typical by the presence of limonite breccias (epiclastic breccias with limonite cement), covering advanced argillic to intermediate argillic rocks, but with no Au content. Limonite breccias were in the past occasionally mined as a low quality Fe-ore.

Intrusive-hydrothermal centre Pstruša

According to suggestion of J. Štohl the locality Pstruša--Garáty was indicated as a highly prospective porphyry system. Higher contents of Cu and Zn (over 100 ppm) in historical assays from 160 – 360 m interval in the drillhole P-6 (Fig. 2) were considered to be the indicators of Au--porphyry mineralization. Relogging and reassaying of the historical core confirmed higher content of Au in the range from 0.02 to 1.22 ppm. The average Au grade in this section (29 samples in 5 – 10 metres interval) is 0.21 ppm. Mineralization in the drillhole P-6 is hosted by argillic altered andesites forming finger-like sections of the drillhole. Alteration varies from a weak propylitization, through phyllic alteration, intermediate argillic alteration up to strong advanced argillization. The mineralization is represented by the dark-grey quartz stockwork. Basement of sedimentary cover was intercepted in 90 m depth by the P-6 drillhole, where relatively fresh andesite in the hanging wall of the mineralization did not have any evidence of porphyry type alteration. Exploration philosophy was based on assumption that shallow ore body is developed on endocontact of diorite porphyry intrusion south from the drillhole P-6 towards drillhole KŠ-23. Three new drillholes were drilled at the locality. The drillhole PVE-1/101 m intersected the intrusion at depth 87 metres, drillhole PVE-2/112 m at depth 69 metres. The northeast drillhole PVE-3/99 m, situated closest to the drillhole P-6, has intersected andesite in the depth 78 m.

The exploration results indicate that thickness of sediments is decreasing gradually to south, but the basin boundaries are faulted. The northern part of the diorite porphyry intrusion is barren whereas very low grade mineralization is developed on exocontact. Phyllic to weak intermediate argillic alteration are present mostly. The average Au grade in drillholes PVE-1, 2, 3 reached 0.02 – 0.05 ppm. Maximum Au grade was 0.29 ppm in drillhole PVE-3 at depth 82 – 84 m. Porphyry type of quartz veinlets were identified only locally. Increased Au content in upper sediments is caused by clasts of altered rocks from mineralized systems in Javorie.

Intrusive-hydrothermal centre Klokoč-Podpolom

Soil sampling has confirmed several extensive Au anomalies starting from Slatinské Lazy intrusive centre, continuing to Klokoč-Podpolom finally disappearing towards north to Quaternary sedimentary basin (Fig. 2). The Podpolom anomaly (up to 52 ppb of Au) is 800 m wide and from the north to south it is 200 – 400 m long. Outline of the anomaly suggests probably structural control of Au mineralization. Significant Au anomaly was also recognized 800 m south from the Podpolom in the area around Sliačkovci. The rock chip sampling confirmed an anomaly with Au grade up to 0.18 ppm.

The channel samples collected from southern wall in Podpolom quarry have not confirmed high Au grades. The rock is strongly argillic altered with different degree of limonitization. The rock texture changes in profile from friable, sacharoidal or massive silica into the more clayous advanced argillic altered rock. Limonitization vary from slightly limonitized to pervasively strongly limonitized. Au grades on the southern wall vary from 0.1 to 1.12 ppm. Lack of the oxidized supergene enriched zones is possibly responsible for low grade values compared to the Rhodes data from the northern part of the quarry. Only five samples had grade higher than 0.6 ppm Au. Higher Au grades correspond roughly to more clayous samples whereas almost pure silica has lower Au grades. Relationship between intensity of limonitization and contents of Au has not been clearly confirmed. The highest value 1.12 ppm belongs to a sample of clayous silica within strongly limonitized zone of small thickness. The re-logging of drill cores from the Podpolom quarry (e.g. R-7/87 m) has identified porphyry style quartz stockwork in deeper levels of advanced argillic zones. The same type of stockwork is sporadically present in the wall of the Podpolom quarry.

Intrusive-hydrothermal centre Slatinské Lazy

Slatinské Lazy intrusive-hydrothermal centre neighbours closely with extensive Klokoč-Podpolom intrusive-hydrothermal centre in the north. Significant soil anomaly (59 ppb) extends on 200 m by 450 m area oriented in NW-SE direction (Fig. 2). Anomaly has sharp boundaries in comparison with other anomalies.

The intrusive centre is formed by andesite porphyry as well as by typical breccias. At the site at least 3 generations of breccias, similarly as in other localities in the Javorie stratovolcano can be identified. These can be distinguished primarily by their age relative to the mineralization and secondarily by their lithology. The first pre-mineralization breccias precede Au mineralization,

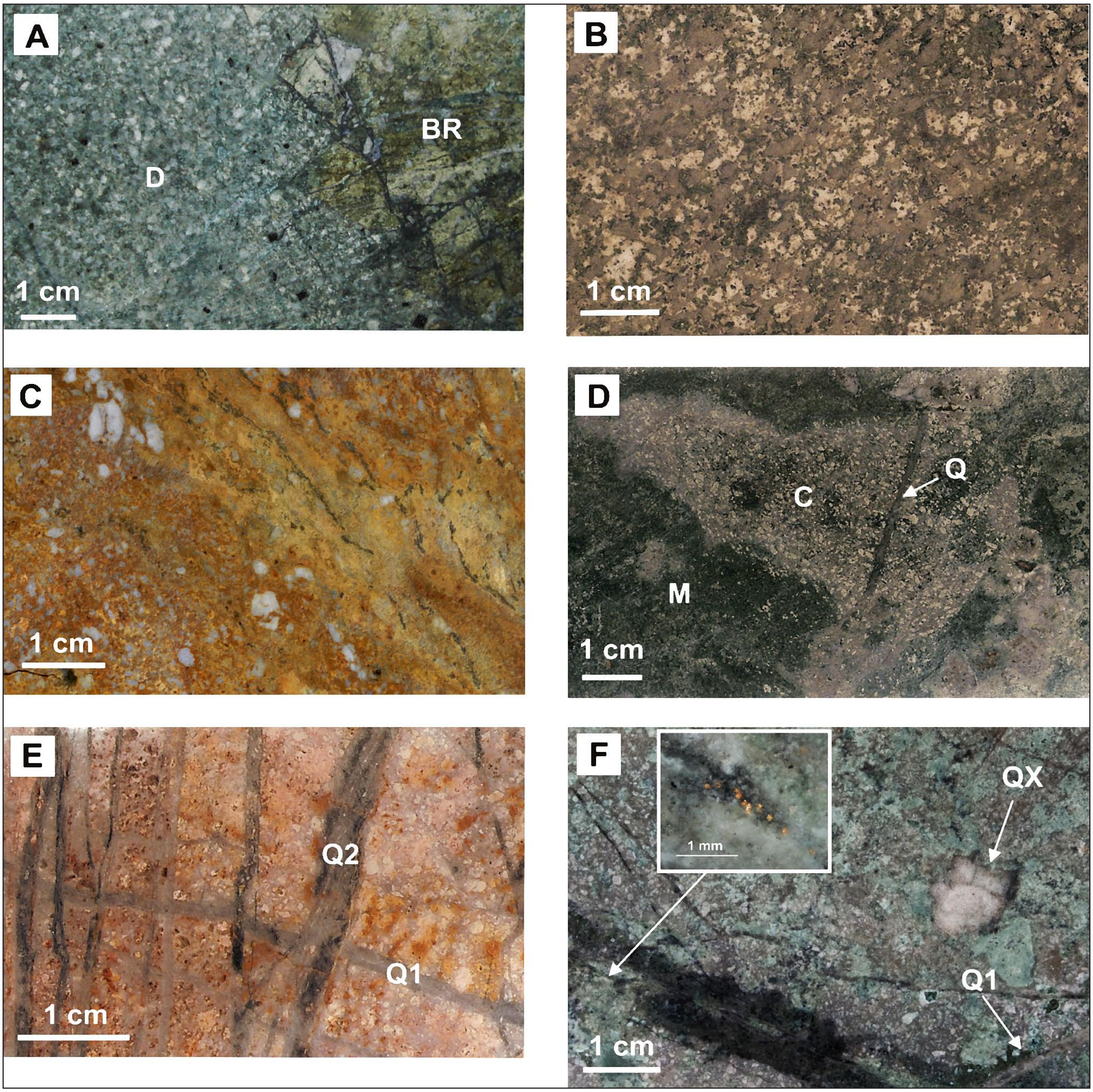


Fig. 6. Typical textures related to Au-porphyry mineralization in the Biely vrch intrusive-hydrothermal centre: A – contact of fresh younger porphyry dyke (D) and potassic altered breccia (BR) (DVE-41/451.8 m), B – intermediate argillic altered granodiorite to tonalite from the basement (DVE-31/437.3 m), C – brecciated oxidized intermediate argillic altered megaxenolith of the basement (DVE-6/160.2 m), D – post-mineralization breccia with the dark quartz vein (Q) in clast (C), (M) chloritized matrix (DVE-36/445.2 m), E – advanced argillic altered rock with two generation of Au-porphyry type of quartz veinlets (float), F – pre-mineralization breccia with quartz xenolith (QX), quartz veinlets (Q1) and visible gold related to young crack with intermediate argillic mineral assemblage.

but locally the brecciation can be observed even simultaneously with Au mineralization (inter-mineralization breccias). The thickness of the pre-mineralization breccias as well as inter-mineralization breccia zones reaches tens of meters. Later stage of intrusive activity is accompanied by the post-mineralization breccias. The process of post-mineralization brecciation was repeated during the evolution of intrusive-hydrothermal centre and resulted in at least two generations of post-mineralization breccias. The youngest generation has only local character and does not affect the Au mineralization. The thickness of these breccia dykes or pipes does not exceed 0.5 m. The older generation of post-mineralization breccias has strong destructive effect on Au mineralization. The thickness of this zones outreaches 50 m. Constructive effect of post-mineralization breccias has been observed in two sections of SLE-6 drillhole (108 – 110 m and 102 – 103 m). The post-mineralization brecciation introduced high grade fragments into the zone of relatively low grade ore (0.2 ppm Au) and Au content was increased to 2.5 – 4.2 ppm.

The intrusive-hydrothermal centre is characterized by massive alterations. A continuous zone with one type of alteration is not possible to determine. Older K-silicate altered zones accompanied by strong magnetitization are overprinted by later intermediate argillic alteration. Intensive sericitization, pyritization, chloritization and silicification are widespread in the surrounding area.

Mineralization at the Slatinské Lazy locality has been tested by 8 drillholes. The main orebody extents in 200 x 130 m area. Generally, it is formed by several mineralized zones elongated in NW-SE direction. Maximum thickness of mineralized zone with grade over 1 ppm Au is approximately 50 m, however, the other zones are only several metres thick. Quartz stockwork is a typical feature of the porphyry mineralization (Fig. 9A). At least four generations of quartz veinlets can be distinguished. Irregular impregnations of chalcopyrite, molybdenite, and base metal mineralization are present locally. The occurrence of zeolites at Slatinské Lazy prospect is very rare. Average Au grade within mineralized zones is estimated to be in the range 0.2 to 0.4 ppm, however, average grade of all drillholes is only 0.13 ppm. The higher content of Au is concentrated in few enriched mineralized zones (Tab. 2). The average chemical composition in selected mineralized drillholes is 0.27 ppm Au, Cu is 115 ppm, Zn 347 ppm, Mo 4.3 ppm. Maximum content of metals are 4.75 ppm Au, 0.32 % Cu, 0.70 % Zn and 0.06 % Mo. Analyses show no correlation between Au and Cu (Fig. 10), very weak correlation between Cu and Zn (0.64) and no correlation between Mo and Au, Cu or Zn.

According to the exploration results the resources of low grade porphyry ore down to 200 m depth could be estimated at 0.2 – 0.4 ppm average Au grade to 2.5 – 5 t Au.

Intrusive-hydrothermal centre Skalka

Intrusive rocks with the high sulphidation type of alterations at Skalka intrusive-hydrothermal centre extend over the area of approx. 800 x 1 200 m. The rock-

Tab. 1
Summary of the concentrations of selected elements in Detva-Biely vrch deposit

Element	Average content	Max. content
Ag	0.082 ppm	50.2 ppm
Cu	133 ppm	0.333 %
Zn	111 ppm	1 %
Pb	105 ppm	1 %
Mo	11 ppm	1 680 ppm
Fe	4.4 %	28 %
S	0.25 %	5.26 %
As	18 ppm	880 ppm
Bi	<2 ppm	136 ppm
Cd	1 ppm	387 ppm
Ni	2 ppm	380 ppm
Sb	<5 ppm	46 ppm

Tab. 2
Results of scout drilling in Slatinské Lazy-Výboškovo prospect

Drill hole	From (m)	To (m)	Length (m)	Au grade (ppm)
SLE-1	0	250	250	0.1
SLE-2	0	251	251	0.06
SLE-3	0	250.4	250.4	0.01
SLE-4	0	250	250	0.31
Including	99	150	51	1.21
SLE-5	0	250.5	250.5	0.27
Including	35	149	114	0.53
Including	81	98	17	0.93
Including	121	137	16	1.26
SLE-6	0	254.6	254.6	0.21
Including	103	139	37	0.80
SLE-7	0	250	250	0.03
SLE-8	0	250.2	250.2	0.07

Tab. 3
Results of scout drilling in Zvolen-Kráľová prospect

Drill hole	From (m)	To (m)	Length (m)	Au grade (ppm)
KVE-1	0	250.3	250.3	0.25
Including	0	65	65	0.55
Including	123	156	33	0.45
KVE-2	0	250.4	250.4	0.42
Including	95	133	38	1.03
KVE-3	0	247.4	247.4	0.33
Including	136	188	52	0.82
KVE-4	0	251	251	0.35
Including	60	85	25	0.83
KVE-5	0	250	250	0.23
KVE-6	0	250.1	250.1	0.16
Including	189	220	31	0.64

Tab. 4
Rough resource estimation of Au porphyry ore body according to drilling results in Zvolen-Kráľová prospect

Au grade (ppm)	Percentage of ore	Resources Mt	Total Au (t)
up to 0.1	–	over 100	up to 5
0.29	100	47.8	13.9
0.35	40	19.1	6.7
over 1	5	2.4	2.5

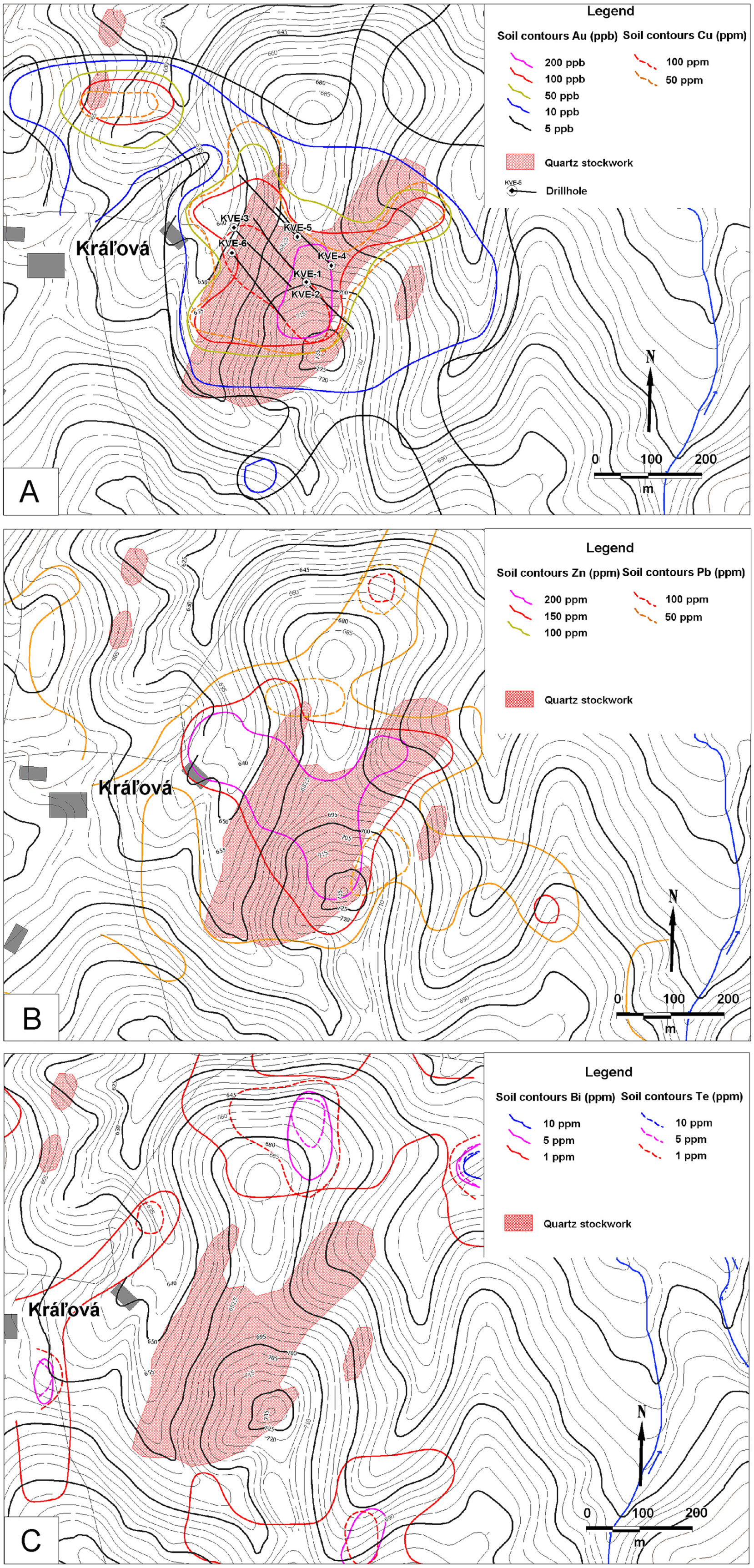


Fig. 7. Soil geochemistry maps of the Kráľová intrusive-hydrothermal centre: A – Au-Cu, B – Pb-Zn, C – Bi-Te.

-chip sampling from different types of rocks was carried out, but results were negative. Locally a stockwork or porphyry style veining was found, however, with no Au grade (Fig. 2). Re-logging and reanalysing of historical core from KŠ-10 and KŠ-10A drillholes show the presence of porphyry quartz stockwork but with no Au grade. Epithermal drusy quartz with pyrite is present in KJ-8 drillhole but with no Au grade as well. Soil sampling results from Skalka area show only a few very low grade anomalies (5 – 10 ppb Au). Anomalies are located concentrically in intermediate argillic rocks, whereas the central strongly silicified zone within advanced argillic lithocap is barren.

Intrusive-hydrothermal centre Banisko

Banisko intrusive-hydrothermal centre is approx. 2.5 km long and 1.5 km wide and is hosted by propylitic altered andesites and volcaniclastics. The central part is represented by extensive strongly silicified, locally limonitized breccias. All the porphyries are affected by propylitization, locally by intermediate argillic alteration. Advanced argillic and intermediate argillic rocks surround the centre concentrically with decreasing level of alteration towards the edges of the centre.

Soil sampling reveals similar trend as at other intrusive-hydrothermal centres where the central silicified zone is barren and surrounding intermediate argillic zone shows low grade anomalies (Fig. 2). Three low grade anomalies have been identified but only two exceed 10 ppb of Au. The largest anomaly is located north from Banisko hill and covers approx. 400 m by 600 m at the surface and reaches highest value of 17 ppb with approximate NW-SE trend. Another local low grade anomaly (up to 13 ppb) is located SE from Banisko, 400 m by 200 m in size, oriented to NE-SW.

Two mineralized zones with porphyry style quartz stockwork, oriented to NW-SE, have been identified in the central part of the intrusive-hydrothermal centre. Southern zone is approx. 450 m

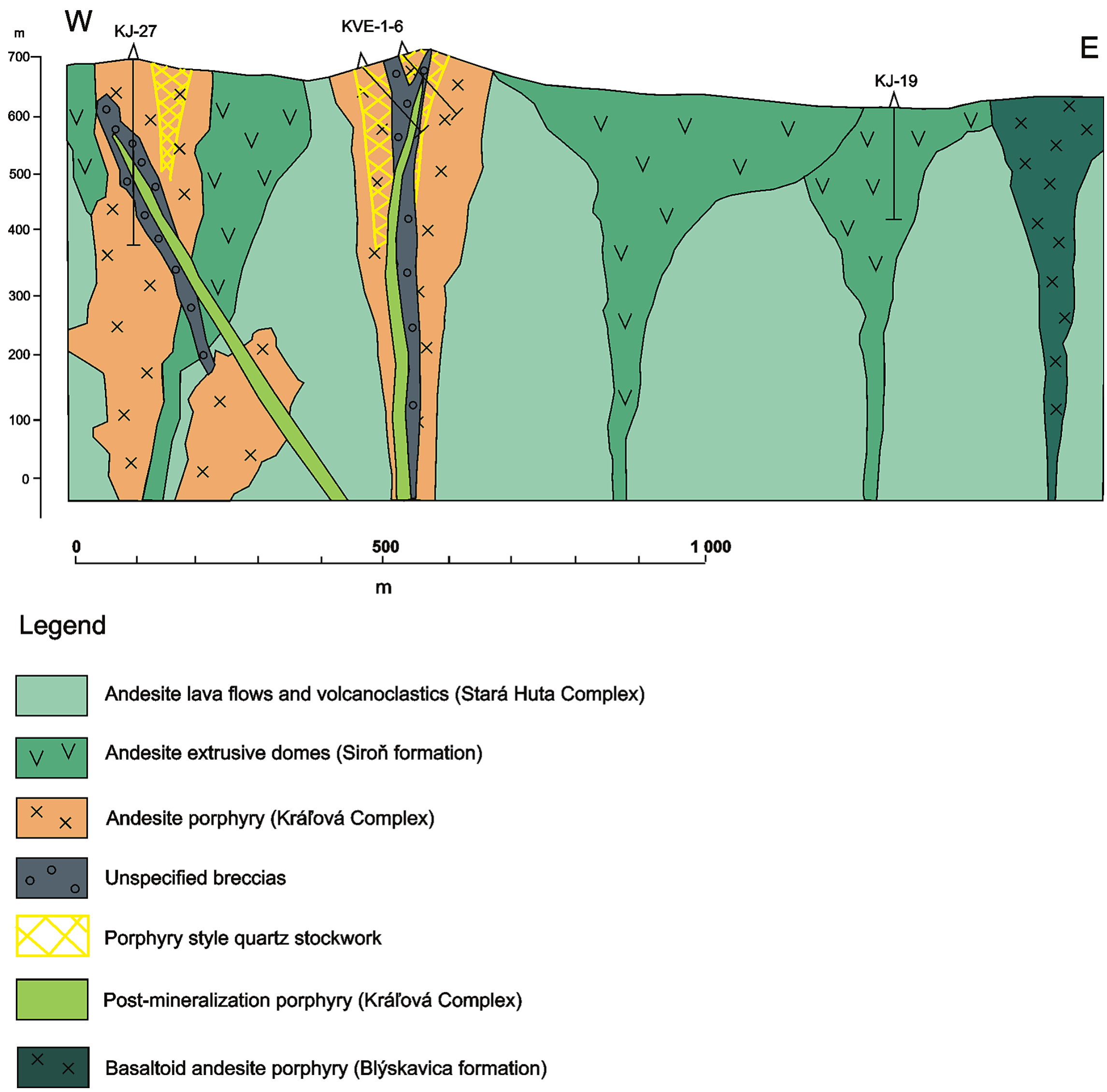
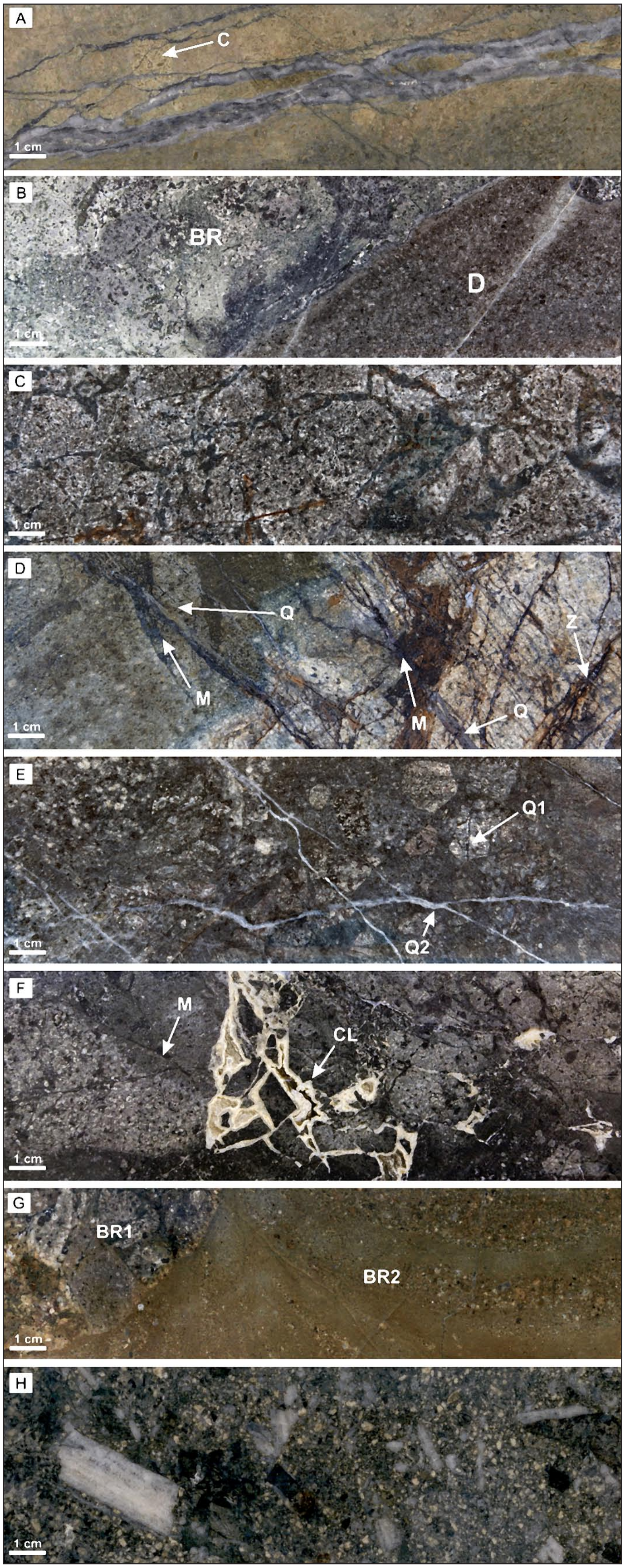


Fig. 8. Schematic section of Kráľová intrusive complex including the Au-porphyry deposit (modified after Konečný et al., 1998).

long and 150 m wide and it is well exposed in the small Banisko quarry beside the road from Kalinka to Zaježová. Dark quartz veinlets are hosted in advanced argillic altered diorite porphyry with small amount of breccias. The northern zone is 250 m long and 50 m wide and can represent continuation of the southern zone. Both zones represent low grade Au-porphyry mineralization. Rock chip samples collected in the quarry and in the surrounding area vary from 0.1 up to 1.95 ppm Au. Additional channel sampling of total 86 m (2 m assay interval) showed the average grade only 0.1 ppm Au, including 24 m interval with 0.19 ppm Au. The highest grade was 0.27 ppm Au. The data from channel sampling correspond quite well with the low grade soil anomaly. We assume that the high grade rock samples represent local enriched zones. Recent assays of Cu porphyry style mineralization from historical drillcore KON-1 (830 – 1 650 m) returned no Au and Cu grades.

Intrusive-hydrothermal centre Zaježová

The Zaježová intrusive-hydrothermal centre belongs to smallest intrusive-hydrothermal centres of the Javorie stratovolcano. It is approx. 1 km long and 100 to 400 m wide zone. It is formed mainly by propylitized to intermediate argillic altered rocks but mostly covered by andesite debris. A small intrusion of diorite porphyry outcrops in northern part of the area. The intrusion has no signs of mineralization and it is only slightly propylitized. Porphyry style mineralization was recognized in exocontact of the intrusion. Propylitized andesite with hairlike thin quartz--magnetite veinlets was found on the northern slope of Zaježová-Podlysec saddle close to the spring of Ľubica creek. Au grades from the collected rock samples were slightly increased varying from 0.01 to 0.08 ppm Au. This mineralization occurrence corresponds to the soil anomaly (up to 48 ppb Au), but the anomaly is only of a small extent.



Another weak anomaly (up to 16 ppb of Au) is located on north-western slopes of the Veľký Lysec hill (886 m). The recent re-assaying and re-logging of the drill core from KJ-20 shows increased content of Au (up to 0.1 ppm), Cu (up to 126 ppm) and Zn (up to 77 ppm). The sampled rock is strongly affected by intermediate argillic alteration, however, it is poor in porphyry style veinlets.

Intrusive-hydrothermal centre Kráľová

Detailed geochemical and technical works were carried out by EMED Mining Ltd. in 2006 – 2007. According to results of soil geochemistry Au anomaly extends over the area 350 by 300 m. Average content of Au in rock chip samples reached 0.9 ppm, maximum up to 5 ppm in outcrops. Exploration followed by 6 inclined drillholes to the depth of 250 m.

Soil geochemistry identified anomaly over 400 ppb of Au (Fig. 7A) which correlates approximately with Cu, Pb and Zn anomalies (Fig. 7B) whereas Bi and Te anomalies (Fig. 7C) create halos around the ore body.

Au-porphyry mineralization is hosted by stock-like intrusion of garnet-bearing andesite porphyry (Fig. 8). The ore body is locally cut by younger porphyry dykes (Fig. 9B). Thickness of dykes varies from few tens of cm up to several m. Intrusive breccias are present at boundaries of dykes. The presence of multistage breccias is typical for the porphyry mineralization. At least three generations of breccias have been recognized. Pre-mineralization and inter-mineralization breccias (Fig. 9E) of andesite porphyry are the most abundant rock types in the ore body (minimum 30 % of total volume). Initial breccias with no or very short distance transport of the material are also common (Fig. 9C). Considering their volume and size, breccia bodies are probably of the chimney shape. Older of the post-mineralization breccias are less developed in smaller volume with thickness from 0.1 m up to 35 m. Clasts are more rounded due to transport on longer distance, however angular fragments of quartz veins

Fig. 9. Slatinské Lazy-Výboškovo: A – porphyry style quartz veinlets in pre-mineralization breccia with rounded clasts (C) (SLE-1/110.3 m), Zvolen-Kráľová: B – contact of fresh younger porphyry dyke (D) with intermediate argillic altered pre-mineralization breccia (BR) (KVE-6/161.8 m), C – strongly intermediate argillic altered initial breccia with no transport of clasts (KVE-6/89.4 m), D – intensive quartz veinlets (Q) in pre-mineralization breccia cutting earlier magnetite veinlets and nests (M); the youngest are zeolite veinlets (Z) (KVE-4/105.5 m), E – inter-mineralization breccia with the first generation of quartz veinlets in clast (Q1) cut by younger generation of quartz veinlets (Q2) (KVE-6/126.3 m), F – angular clasts of hydrothermal breccia cemented with clay veinlets (CL) (KVE119.1 m), G – younger post--mineralization breccia (pebble dyke) with “gradational” layered psammitic to pelitic matrix (BR2) cutting older post-mineralization breccia (BR1) (KVE-1/183.2), H – post--mineralization breccia with fragments of porphyry style banded quartz veinlets (KVE-6/237.6 m).

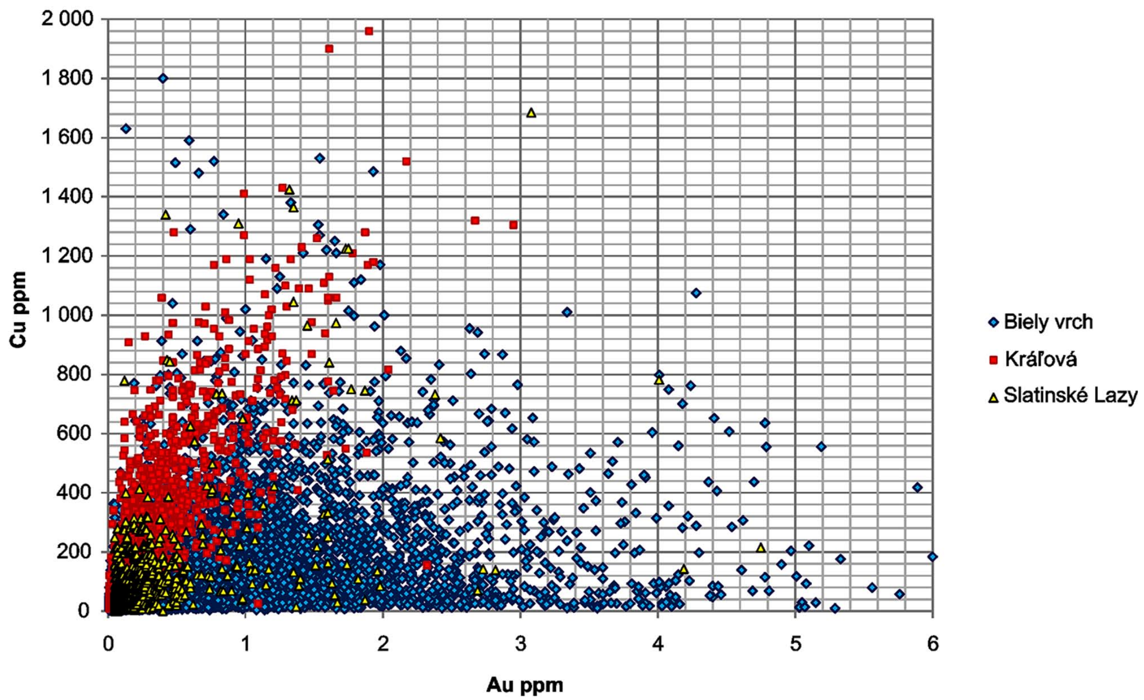


Fig. 10. Relationship between Au vs. Cu in the drill-core assays from Detva-Biely vrch (10 084 assays), Slatinské Lazy-Výboškovo (901 assays) and Zvolen-Kráľová (1 501 assays) intrusive-hydrothermal centres. Extreme values has been removed (Au >6 ppm, Cu >2 000 ppm).

can be also preserved (Fig. 9H). According to their size they probably form dykes. Younger generation of the post--mineralization breccias (pebble dykes) is characterized by fine-grained matrix with psammitic to pelitic fraction with signs of gradational layering (Fig. 9G). They represent filling of cracks with thickness from few cm up to several tens of cm.

Au porphyry mineralization is characterized by pervasive strong intermediate argillic alteration accompanied by Fe-oxide assemblage. Clay minerals and Fe-oxides form veinlets as well. The most abundant are magnetite veinlets (Fig. 9D, F), veinlets and hydrothermal breccias cemented by clay minerals are less common (Fig. 9F). The content of pyrite is very low (0.05 % in average). The advanced argillic alteration has not been recognized. Quartz stockwork shows at least four generations of quartz veinlets (Fig. 9D). Their succession has not been studied in detail however there is no correlation between density of veining and Au grade. For example, the continuous high grade ore with average grade 0.5 – 1 ppm Au (KVE-2/99 to 132 m) matches with low or very low density of quartz veining. The maximum thickness of the mineralized zone with average Au content approximately 1 ppm reached only 22 metres. Other mineralized zones with the same average content are only from 1 to 10 metres wide. Fragments and xenoliths of mineralized porphyry caused weak increase of Au content in brecciated boundaries of younger andesite porphyry dykes and post-mineralization breccias. The summary of Au grades in the drillholes is shown in Tab. 3.

Positive weak correlation between Au and Cu (0.74) (Fig. 10) and no correlation between Cu and Zn have been found at Kráľová Au porphyry system. The high grade ore with approximate content of Au around 0.8 – 1 ppm contains 0.05 – 0.1 % Cu. Zn varying from 0.08 % to 0.12 % is increased in the mineralized zone with high Au and Cu grades. Thickness of this zone reaches 20 – 30 m. Zn comes from fine-grained impregnation of yellow sphalerite. Content of Zn never drops below 100 ppm within the entire ore body. That indicates the general enrichment of Zn in Kráľová intrusive-hydrothermal centre while Au and Cu are increased only in local zones. The average content of metals in all drillholes are Au 0.29 ppm, Cu 0.026 %, Zn 0.053 % and Mo 0.001 %. Maximum contents of the metals are Au 2.95 ppm, Cu 0.41 %, Zn 0.96 % and Mo 0.04 %. No other metals present in remarkable concentrations have been found in the deposit. No correlation between Mo and Au, Cu or Zn has been found. Molybdenite is present in quartz veins, or forms impregnations in altered rock as well as in breccias.

Exploration drilling has been performed in the area 150 m x 300 m, covering approximately 60 % of prospective area with soil anomaly above 100 ppb. Drilling has determined that only 5 % of prospective area contains ore with average grade 1 ppm Au. If considering the average grade 0.29 g/t Au, density 2.55 t/m^3 and minimum vertical range 250 m, the ore body contains 47.8 Mt of the low grade porphyry ore with total content of Au 13.9 t. The rough resource estimation is shown in Tab. 4. Mineralized zones are subeconomic with increased contents of Cu and Zn.

Discussion

The discovery of Au porphyry style mineralization brought new ideas to metallogenesis of the Javorie stratovolcano. Types of alteration as well as the other features of mineralization are similar to other Au porphyries in the world (Sillitoe, 2000; Muntean and Einaudi, 2000; Seedorff et al., 2000). The presence of mineralization can be traced in stream sediments (up to 32 ppb Au), however, no longer transport of Au has been noticed. For instance, stream sediment anomaly at Zvolen-Kráľová disappears after few hundred meters of transport. Au mineralization can be also recorded in soils with ranges of up to 400 ppb Au. Except of Biely vrch, Klokoč-Podpolom, Slatinské Lazy and Kráľová intrusive-hydrothermal centres the other localities show only low grade soil anomalies (up to 50 ppb Au) associated with intermediate argillic alteration usually concentrically surrounding strongly silicified barren breccias. Generally, Cu, Pb, Zn soil anomalies overlap approximately with Au, whereas Bi and Te are usually associated with advanced argillic alteration zones. The most remarkable example of Bi-Te association with advanced argillic alteration assemblage shows the Biely vrch deposit and Beluj in Štiavnica stratovolcano (Bakos et al., 2010). However, Bi-Te anomaly rim around Au porphyry ore body was also found at Kráľová, where the advanced argillic lithocap is absent. According to Sillitoe (2000), Mo tends to define a partial geochemical halo, Pb and Zn form patchy outer halos. No outer halo of Mo was recognized in Javorie. Mo usually matches with Au anomalies, while Zn creates patchy halo anomaly at Biely vrch only.

The multistage development of mineralization with different types of intrusion is known from Au and Cu-Au porphyries worldwide (Sillitoe, 2000; Muntean and Einaudi, 2000). According to Sillitoe (2000) three stages of intrusive activity can be usually recognized on Au porphyry deposits in respect to mineralization; pre-mineralization, inter-mineralization and post-mineralization porphyry intrusions. The porphyry mineralization in Javorie is usually related to andesite or diorite porphyry. Identification of different types of intrusions within ore body is difficult due to strong alteration overprints. Small amount of younger porphyry dykes crosscutting older porphyry stock were recorded at Kráľová and Biely vrch. Second generation of porphyries (Biely vrch, Kráľová) contains the porphyry style quartz veinlets that indicate their inter-mineralization age. However content of Au in dykes reached only up to 0.05 ppm Au. Multistage intrusive centre has been possibly recognized especially also at Banisko system. Low mineralized diorite porphyry stock occurs on the surface (roadcut from Vígľašská Huta-Kalinka – Zaježová), while barren diorite to monzodiorite intrusion is located at depth >1 000 m (Konečný et al., 1977, 1998). However, due to lack of information it is not possible to distinguish whether the intrusion in depth represents the same body which is located on the surface or it represents a different post-mineralization event.

A unique phenomena represented by large megaxenoliths of the basement (tens of metres) were found at the Biely vrch system in depth from 140 to 220 m. Megaxenoliths represent a partial geochemical barrier for Au precipitation from fluids as Au grades are increased on boundaries xenoliths. Variscan basement was intersected by DV-24 borehole at depth 472 m about 500 m north from the Biely vrch locality (Mihaliková, 1985). It follows, that megaxenoliths were uplifted at least 200 m.

Typical alteration such as the primary potassic alteration overprinted by advanced argillization and retrograde intermediate argillic alteration were recognized in the intrusive-hydrothermal centres. However not every centre has all types of alteration preserved. The Biely vrch intrusive-hydrothermal centre shows medium erosion with only root zones of advanced argillic lithocap preserved as a N-S trending ledge zone. In the Kráľová intrusive-hydrothermal centre, located outside of the Javorie central zone no advanced argillic assemblage was developed. This fact can be interpreted as a deep erosion level or independent origin of intrusive centre without association to central zone of the Javorie stratovolcano. This intrusive-hydrothermal centre is developed in the deepest part of the volcanotectonic depression in Javorie. Sarmatian volcanic rocks are preserved in the surroundings of Kráľová, representing the youngest volcanic period of the stratovolcano (Konečný et al., 1998). It indicates that erosion level at Kráľová is very shallow. The possible local uplift of the central part of the intrusive centre could not exceed 100 – 200 m. Based on these interpretations we suggest that the intrusive-hydrothermal centre communicated with adjacent magmatic reservoir on the western edge of the Javorie stratovolcano. Compared to the central zone of Javorie there is no rhyodacite, dacite and only the andesite porphyry from Kráľová contains garnet.

Minimum three generations of porphyry type quartz veinlets have been recognized. Locally, there seems to exist a correlation with gold grades in the rock but generally, there is no consistent correlation between density of veinlets and gold grades. Even in some parts, there are no quartz veinlets and the rock still contains relatively high Au grade. World deposits have a good correlation between gold and banded quartz veinlets (Sillitoe, 2000; Muntean and Einaudi, 2000).

The intrusive-hydrothermal centres are also typical by a large amount of different types of breccias indicating multistage development. The origin of pre- and inter-mineralization breccias is related to porphyry mineralization development during emplacement of intrusions and release of fluids. The post-mineralization breccias had destructive character to Au grades. Locally, mineralized clasts are present in post-mineralization breccias therefore some Au grade can be preserved. The youngest stage of brecciation is represented by the narrow magmatic-hydrothermal breccias (pebble dykes).

Correlation of Au grades in soil anomalies with location of zones with advanced argillic alteration has been recognized at the Biely vrch and Klokoč-Podpolom systems only. Other localities show significant negative correlation. Strongly silicified central parts of intrusive-hydrothermal centres are characteristic by the strong leaching and removal of Au. At the locality Biely vrch, systematic high Au grades are associated with central N-S oriented strongly tectonized structure with intensive advanced argillic alteration. Nevertheless, the local narrow strongly silicified parts on Biely vrch are leached with rapid decrease of Au content. Advanced argillic alteration at Klokoč-Podpolom was considered to contain epithermal high-sulphidation Au mineralization (Štohl et al., 1999, 2000). However, Au mineralization could have been remobilized trough large pipes of breccias and fault zones from possible Au porphyry at depth.

According to classification of porphyry deposits based on Au/Cu ratios (Sillitoe, 2000), the Biely vrch system and other systems within the Javorie stratovolcano represent the Au porphyry mineralization. According to Seedorff et al. (2000) Au porphyry mineralization is associated with the diorite or syenite intrusions whereas Cu-Au and Cu deposits are likely associated with more acidic intrusions.

Within the Au porphyry ore bodies in Javorie neither native sulphur nor the anhydrite/gypsum were found with one exception. Native sulphur from the Vígľašská Huta-Kalinka locality is related to advanced argillic assemblage (Konečný and Štohl, 1991). The similar case is at Stožok and Skalka. The native sulphur at Pstruša is located in argillic rock at depth below 450 m (Pulec, 1965) in interpreted footwall of Au porphyry mineralization. However, according analogy from other localities in Javorie, advanced argillization is developed at maximum depth 300 to 370 metres. Due to significant depth of the native sulphur at Pstruša, we assume that this occurrence is related not only to the advanced argillic assemblage.

Conclusions

Results of systematic exploration of the Javorie stratovolcano can be summarized as follows:

• The central zone of the Javorie stratovolcano belongs to the most important gold provinces in the Western Carpathians. The total potential of geological resource exceeds over 100 tons of Au.

• Only Au porphyry mineralization has economic significance. Economic mineable deposit is present at Detva-Biely vrch only. Discoveries at Zvolen-Kráľová and Slatinské Lazy represent only subeconomic occurrences of low grade Au porphyries. Other localities such as Stožok – south from Šakovci, Pstruša-Garáty, Vígľašská Huta--Kalinka – Banisko, Zaježová-Podlysec belong to mineral occurrences of Au porphyry mineralization only.

• Important localities are associated with internal parts of intrusions, the exocontacts host only mineralogical occurrences of Au porphyry mineralization.

• Spatially the mineralization is associated with K-silicate alteration, magnetitization and intermediate argillic alteration.

• Quartz stockwork is a characteristic indicator of the Au-porphyry mineralization. There is no correlation between the intensity of quartz veinlets and Au grade.

• Direct impact of brecciation on the origin of Au porphyry mineralization is not clear. However minimum 50 % of the volume of high grade ore with the Au content over 1 ppm is hosted by the initial pre- to inter-mineralization breccias. Late stage of breccias, related probably to advanced argillic alteration, has moderate destruction effect on Au mineralization.

• The presence of megaxenoliths of basement has been recognized at Detva-Biely vrch deposit. Megaxenoliths represented partial geochemical barrier for Au precipitation from fluids.

• Advanced argillic alteration has remobilization character. However, massive, vuggy or sacharoidal silica shows significant decrease in Au content.

• Mineralized zones with Au content above 0.1 ppm are always accompanied by elevated contents of Cu, Zn, Pb, Mo and Cd. However, there is no correlation between Au and these elements except of Au porphyry system at Kráľová. Average Cu and Zn contents in the most Au porphyry systems in the Western Carpathians exceed 100 ppm; the average content of Pb varies in the range 10 to 100 ppm, Mo 1 – 10 ppm and Cd 0.1 – 2 ppm.

• Au porphyry mineralization is accompanied by economically unimportant presence of stockwork--disseminated Mo mineralization, stockwork Pb-Zn mineralization, Bi-Te mineralization and fracture-related zeolite mineralization.

• Fracture related zeolite mineralization is developed entirely outside of zones of advanced argillic alteration.

Acknowledgement. We gratefully acknowledge R. Sillitoe, J. Lexa, P. Koděra and J. Štohl for consultation on metallogenesis of porphyry mineralization in Javorie. Thanks to EMED Slovakia company for providing of the samples material and for the financial support of this work.

References

Adler, K., 1873: Suggestions about sulphur mines in Kalinka. *In: Földt. Közl. (Budapest) (In Hungarian).*

Bakos, F., Fuchs, P., Hanes, R., Žitňan, P. & Konečný, V., 2010: Au-porphyry mineralization in the mantle of the Štiavnica stratovolcano. *In: Miner. Slov. (Bratislava), 42, 1 – 14.*

Dublan, L., Bezák, V., Biely, A., Bujnovský, A., Halouzka, R., Hraško, Ľ., Köhlerová, M., Marcin, D., Onačila, D., Scherer, S., Vozárová, A., Vozár, J. & Žáková, E., 1997: Explanations to the geological map Poľana 1 : 50 000. *Bratislava, GS SR, Vyd. D. Štúra, 238 p. (In Slovak).*

Chapman, E., 2009: EMED: Biely vrch porphyry gold resource estimation, Slovakia, Resource Estimate. *Internal report EMED Slovakia, Snowden, Vancouver, 69 p.*

Galko, I., 1998: Vígľašská Huta-Kalinka – Stožok, ceramic raw materials. *Bratislava, ŠGÚDŠ (In Slovak).*

Klubert, J., 1955: The final report on research Kalinka – native sulphur. Turčianske Teplice. *Manuscript. Bratislava, archive ŠGÚDŠ (In Slovak).*

Koděra, P., Lexa, J., Biroň, A. & Žitňan, J., 2010: Gold mineralization and associated alteration zones of the Biely vrch Au-porphyry deposit, Slovakia. *In: Miner. Slov. (Bratislava), 42, 33 – 56.*

Konečný, V., Mihaliková, A. & Rojkovičová, Ľ., 1977: Structural borehole KON-1. *Manuscript. Bratislava, archive ŠGÚDŠ (In Slovak).*

Konečný, V. & Mihaliková, 1981: Intrusive complex of the Javorie Mts. *In: Geol. Zbor. Geol. Carpath. (Bratislava), 32, 247 – 268.*

Konečný, V., Mihaliková, A., Halouzka, R., Pulec, M., Miko, O., Dovina, V. & Planderová, E., 1985: Explanation to the geological map 1 : 25 000 (36-341) Krupina-1. *Manuscript. Bratislava, archive ŠGÚDŠ (In Slovak).*

Konečný, V. & Štohl, J., 1991: Magmato-hydrothermal and hydrothermal-explosive breccias in the central zone of the Javorie stratovolcano. *In: Zapad. Karpaty, Sér. Mineral. Petrogr. Geochém. Metalogen. (Bratislava), 14, 61 – 94 (In Slovak).*

Konečný, V., Lexa, J. & Hojstričová, V., 1995: The Central Slovakia Neogene Volcanic Field: A review. *In: Acta Volcanol., 7/2, 63 – 78.*

Konečný, V., Bezák, V., Halouzka, R., Konečný, P., Mihaliková, A., Marcin, D., Iglárová, Ľ., Panáček, A., Štohl, J., Žáková, E., Galko, I., Rojkovičová, Ľ. & Onačila, D., 1998: Explanation to the geological map of Javorie 1 : 50 000. *Bratislava, GS SR, Vyd. D. Štúra, 304 p. (In Slovak).*

Konečný, V., Lexa, J. & Žáková, E., 2002: Hydrothermal center Biely Vrch-Detva. Partial Report. *In: Lexa, J. et al., 2002: Metallogenetic assesment of the Slovak Republic. Final report. Manuscript. Bratislava, archive ŠGÚDŠ (In Slovak).*

Kuthan, M., 1956: Postvolcanic activity in Vígľašská Huta (before Kalinka). *In: Geol. Práce, Spr. (Bratislava), 3 (In Slovak).*

Lexa, J., Koděra, P., Biroň, A. & Bakos, F., 2007: Metallogenetic model of the Biely vrch Au porphyry deposit, Slovakia. *Internal report of EMED, Banská Štiavnica, 87 p.*

Marsina, K., Hojstričová, V., Konečný, V., Konečný, P., Lexa, J., Rojkovičová, Ľ. & Žáková, E., 1995: Comparison of skarn--Cu-porphyry objects in the central zone of the Štiavnica stratovolcano and their evaluation. *Manuscript. Bratislava, archive ŠGÚDŠ, 124 p. (In Slovak).*

Muntean, J. L. & Einaudi, M. T., 2000: Porphyry gold deposits of the Refugio District, Maricunga Belt, Northern Chile. *In: Econ. Geol. (New Haven), 95, 1 445 – 1 472.*

Mihaliková, K., 1985: Structural borehole DV-24, Zlatý Vŕšok – Poľana. Diploma thesis. *Manuscript. Bratislava, archive PriF UK (In Slovak).*

Pastor, J., 2000: Tenement Pliešovce Au, Ag. Final report on exploration carried out in 1997 – 1998. *Manuscript. Bratislava, archive ŠGÚDŠ, 5 p. (In Slovak).*

Pomorský, F., Antonická, B. & Piovarcsy, K., 1999: Golden program of Canadian company SloGold Resources Ltd. in Slovakia. *In: Miner. Slov. (Bratislava), 31, 199 – 202 (In Slovak).*

Pulec, M., 1965: Report on discovery of native sulphur deposit south of Pstruša village. *Manuscript. Bratislava, archive ŠGÚDŠ.*

Rojkovič, I. & Rojkovičová, Ľ., 1999: Porphyry copper mineralization with gold near Slatinské Lazy. *In: Miner. Slov. (Bratislava), 31, 263 – 268.*

Sillitoe, R. H., 2000: Gold-rich porphyry deposits: Descriptive and genetic models and their role in exploration and discovery. *In: SEG Rev., 13, 315 – 345.*

Seedorff, E., Dilles, J. H., Proffett, J. M. Jr., Einaudi, M. T., Zurcher, L., Stavast, W. J. A., Johnson, D. A. & Barton, M. D., 2005: Porphyry deposits: Characteristics and origin of hypogene features. *In: Econ. Geol., 100th Anniver. Vol. (New Haven), 251 – 298.*

Szontagh, T., 1885: Petrography of rocks in Zvolen district. *In: Földt. Közl. (Budapest), (In Hungarian)*.

Štohl, J., Konečný, V., Mihaliková, A., Žáková, E., Marková, M. & Rojkovičová, Ľ., 1981: Metallogenetic investigation in Javorie. *Manuscript. Bratislava, archive ŠGÚDŠ (In Slovak).*

Štohl, J., Határ, J., Mihaliková, A. & Žáková, E., 1985: Final report on the structural borehole KŠ-33 in Javorie. *Manuscript. Bratislava, archive ŠGÚDŠ (In Slovak).*

Štohl, J., Žáková, E. & Lexa, J., 1999: High-sulphidation epithermal gold deposit at Klokoč – Podpolom. *In: Molnár, F., Lexa, J. & Hedenquist, J. W. (eds.): Epithermal mineralization of the Western Carpathians. In: SEG, Guidebook Ser., 31, 197 – 202.*

Štohl, J., Lexa, J., Földessy, J., Konečný, P., Konečný, V., Kollárová, V., Onačila, D., Rojkovičová, Ľ. & Žáková, E., 2000: High-sulphidation epithermal gold mineralization at Podpolom, Javorie Mts., Slovakia. *In: Jacko, S., Janočko, J., Lexa, J. (eds.): Geology and prospecting in the Carpathians. In: Miner. Slov. (Bratislava), 32, 3, 257 – 262.*

Valach, J., 1966: A new results of geological-petrographic relations in the area of Vígľašská Huta-Kalinka. *In: Geol. Práce, Spr. (Bratislava), 38 (In Slovak).*

Vila, T. & Sillitoe, R. H., 1991a: Gold-rich porphyry systems in the Maricunga belt, Northern Chile. *In: Econ. Geol. (New Haven), 86, 1 238 – 1 260.*

Vila, T., Sillitoe, R. H., Betzhold, J. & Viteri, E., 1991b: The porphyry gold deposit at Marte, Northern Chile. *In: Econ. Geol. (New Haven), 86, 1 271 – 1 286.*

Zipser, F., 1847: Few notes on sulphur mines in Kalinka. *In: Hungarian doctors and naturalists, Sopron (In Hungarian).*

Onescu, F., Negrea, S. & Catrina, F., 2006: Electric survey, IP sources delineation, Biely vrch exploration project – Slovakia. *Internal report of EMED, Banská Štiavnica, 4 p.*

Rukopis doručený 1. 2. 2010
Revidovaná verzia doručená 15. 2. 2010
Rukopis akceptovaný red. radou 17. 2. 2010