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The Silistar Intrusive, Eastern Srednogorie Zone, Bulgaria: Structural Data and Potential for Porphyry Copper and Epithermal Systems

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Abstract: The Late Cretaceous Silistar intrusion comprises of gabbros, gabbro-diorites to quartz-diorites and aplites, that were emplaced into a volcano-sedimentary succession of similar age. Structural data suggest that this intrusion is part of a larger, partially exposed body. A dense network of primary and secondary joints, in many places filled with various ore and gangue minerals, is a conspicuous feature of the intrusion. Hydrothermal alteration affecting the intrusion and the wall rocks includes: uralitization (amphibole±epidote), secondary biotitization and propylitization. Propylitic alteration occurred in two stages: high temperature (epidote-actinolite-chlorite) and middle to low temperature (sericite-chlorite-carbonate-epidote and chlorite-sericite-carbonate). Products of later alteration events include quartz-adularia, quartz-carbonate, carbonate, quartz-zeolites and zeolites.

Apart from previously recognized contact-metasomatic mineralization, the presence of stockwork-type and disseminated pyrite and chalcopyrite mineralization, hosted by both the intrusion and the host rocks, is documented here. Two types of magnetite and pyrite (magmatic and metasomatic) are recognized.

Based upon the alteration products and ore minerals, the presence of two differing zones is suggested. The first zone, which closely coincides with the intrusion, is potassic and hosts py-ma-cpy-hm-(ilm). The second zone is propylitic with py-ma-cpy-hm-(ilm)+(sph+ga)+(bo+hz). Cu is the main ore element; Mo contents are very low or nil.

The types of ore mineralization and alteration products, along with structural data, show elements of both porphyry copper and epithermal systems and suggest their occurrence of such (and the first recognition of such) in the incipient rift zone of the Eastern Srednogorie Zone.

Key Words: Eastern Srednogorie, Bulgaria, Silistar intrusion, porphyry copper, epithermal

Silistar Sokulumu, Doğu Srednogorie Kuşağı, Bulgaristan: Yapısal Veri ve Porfiri Bakır ve Epitermal Sistem Potansiyeli

Özet: Gabro, gabro-diyorit, kuvars diyorit ve aplitlerden oluşan Geç Kratese yaşlı Silistar Sokulumu aynı yaşlı volkano-sedimanter bir istif içine yerleşmiştir. Yapısal veriler, Silistar sokulumunun geniş bir sokulumun kısmen yüzeylemiş bir parçası olduğuna işaret eder.

Çoğunlukla cevher ve gank mineralleri ile doldurulan ve yoğun bir ağ oluşturan birincil ve ikincil eklemler bu sokulumun önemli yapısal unsurlarıdır. Gerek sokulumu gerekse kenar kayaçları etkileyen hidrotermal alterasyonlar uralitleşme (amfibol±epidot), ikincil biyotitleşme ve profilitleşmedir. Profilitik alterasyon, yüksek sıcaklık (epidot-aktinolit-klorit) ve orta-düşük sıcaklık (serizit-klorit-karbonat-epidot ve klorit-serizit-karbonat) koşullarında olmak üzere iki aşamada gelişmiştir. Daha sonraki alterasyon olaylarının ürünleri arasında kuvars-adularya, kuvars-karbonat, karbonat, kuvars-zeolit ve zeolitler sayılabilir.

Daha önceleri tanımlanan kontak-metasomatik mineralleşmenin yanı sıra, sokulum ve yan kayaçda gelişen stokwork-tipli (ağsı) ve dissemine pirit ve kalkopirit mineralleşmesi bu çalışmada tanımlanmıştır. Magmatik ve metasomatik olmak üzere iki tip manyetit ve pirit belirlenmiştir.

Alterasyon ürünleri ve cevher minerallerine göre birbirinden farklı iki kuşağın varlığı ileri sürülmüştür. Sokulum içinde gelişen birinci kuşak daha çok potasik olup, py-ma-cpy-hm-(ilm) mineralleşmesi ile tanımlanırken; ikinci kuşak propilitik py-ma-cpy-km-(ilm)+(sph+ga)+(bo+hz) parajenezi ile karakterize olur. Cu ana cevher elementi iken, Mo içeriği ya çok azdır ya da hiç yoktur.

Cevherleşme ve alterasyon ürün tipleri ile yapısal veriler porfiri bakır ve epitermal sistem elamanlarını işaret eder ve oluşumlarının Doğu Srednogorie Kuşağı riftleşmesinin ilk aşamalarında gerçekleştiğini gösterir.

Anahtar Sözcükler: Doğu Srednogorie, Bulgaristan, Silistar sokulumu, porfiri bakır, epitermal

Introduction

The study area is located in the southernmost part of the Eastern Srednogorie Zone, on the Black Sea coast of Bulgaria near the border with Turkey (Figures 1 & 2).

The Srednogorie Zone of Bulgaria is accepted as the remains of a Late Cretaceous island-arc system, part of the active Alpine margin of Eurasia, the extension to the east of which are the Eastern Pontides of Turkey (e.g. Bergougnan & Fourquin 1980; Okay & Şahintürk 1997). The origin of this arc-system in Bulgaria is generally attributed to northward subduction (Boccaletti *et al.* 1974) related to the closing of the Vardar Ocean.

In the Srednogorie Zone, rocks of all magmatic groups are found, but basic and intermediate varieties (mainly of subalkaline trend) dominate (Dabovski *et al.* 1991). However, in the Eastern Srednogorie Zone, the rocks have a dissimilar petrochemical character. Basalts, (tholeiitic, calc-alkaline, subalkaline and alkaline) dominate. Ultrabasic rocks are typical, but acidic ones occur locally (Vassileff & Stanisheva-Vassileva 1981). The main features of the Eastern Srednogorie Zone, compared to the zone as whole, are higher magmatic activity and the presence of highly potassic alkaline magmatism. Based especially on the extremley high-K alkalinity of the rocks from the northern Eastern Srednogorie, an initial episode of back-arc rifting during the final stages of island-arc evolution is suggested (Boccaletti *et al.* 1978; Stanisheva-Vassileva 1980). This concept is further supported by the abundance of high-K pillow and massive lavas, the huge thickness of the volcano-sedimentary section (over 4 km), the occurrence of an over 1300-m-thick hyaloclastic palagonitic tuffs, a regional low- temperature and low-pressure metamorphism, rapid thinning of the crust in a narrow zone, interpreted sedimentary and magmatic evolution, and seismic data (Georgiev *et al.* 2001). Therefore, in the Eastern Srednogorie Zone, from south to north, an island arc, an initial back-arc rift and a back-arc flysch trough have been distinguished (Dabovski *et al.* 1989, 1991). Presently, they are tectonically superimposed along north-vergent thrust zones, and the back-arc flysch trough and the northern margin of the rift zone are now involved in the frontal thrust sheets of the Balkan Fold-Thrust Belt, and the southern margin of the rift is poorly exposed and not imaged by seismic profiles (Georgiev *et al.* 2001) (Figures 1& 2). Based on petrographic and chemical analyses, three main zones have been distinguished in the Eastern Srednogorie Zone (Dabovski *et al.* 1991) (Figures 1 & 3). These zones interpreted as the remnants of the axial (Strandja volcano-intrusive region), rear (Yambol-Bourgas volcano-intrusive region) and back-arc rift (North Bourgas volcanic region) parts of a Late Cretaceous island-arc system (Georgiev *et al.* 2001).

As a metallogenic unit, the Srednogorie has a dominantly Cu specialization, being part of the Tethyan Eurasian metallogenic belt (Jankovic 1977, 1997; Vassileff & Stanisheva-Vassileva 1981). Numerous deposits and prospects of porphyry and epithermal types, related to the Late Cretaceous magmatism, are present (Figure 1). The study area is within the proposed back-arc rift zone (Dabovski *et al.* 1989, 1991), from which no evidence for porphyry-type or epithermal mineralization have been presented to date (e.g., Bogdanov 1987). Presently, the rocks from the proposed rift zone have been thrust over from the south by the island-arc zone (Petrova *et al.* 1992). However, due to poor outcrop, this relation cannot be observed directly (Figure 2). The diversity and density of different magmatic products allows the area to be defined as the “Silistar volcano-intrusive area”. This area is dominated mainly by the Late Cretaceous Silistar intrusion (Figures 2 & 4a).

Geological Setting

Silistar Intrusion

This visibly small intrusive body was described first by Konstantinov (1947, unpublished data), and named for the neighbouring village as the “Rezovo Pluton". Later, the same body was named the "Silistar intrusion", after the neighbouring small river (Stoinov *et al.* unpublished data). The intrusion has become known by this name in the Bulgarian geological literature.

The present-day exposure of the Silistar intrusion occupies a narrow belt along the Black Sea coast with a N–S dimension of about 1 km (Figures 2 & 4a). This belt consists of gabbros, gabbrodiorites to quartzdiorites, porphyritic diorites and aplites (Belivanov *et al.* 1992). Recently granodiorites and low-alkalic granite have been recognized there (Malyakov & Belmustakova 1999). Petrochemically, the rocks of the intrusion have been described as intermediate, belonging to the gabbro-diorite-basic diorite field (Malyakov & Belmustakova

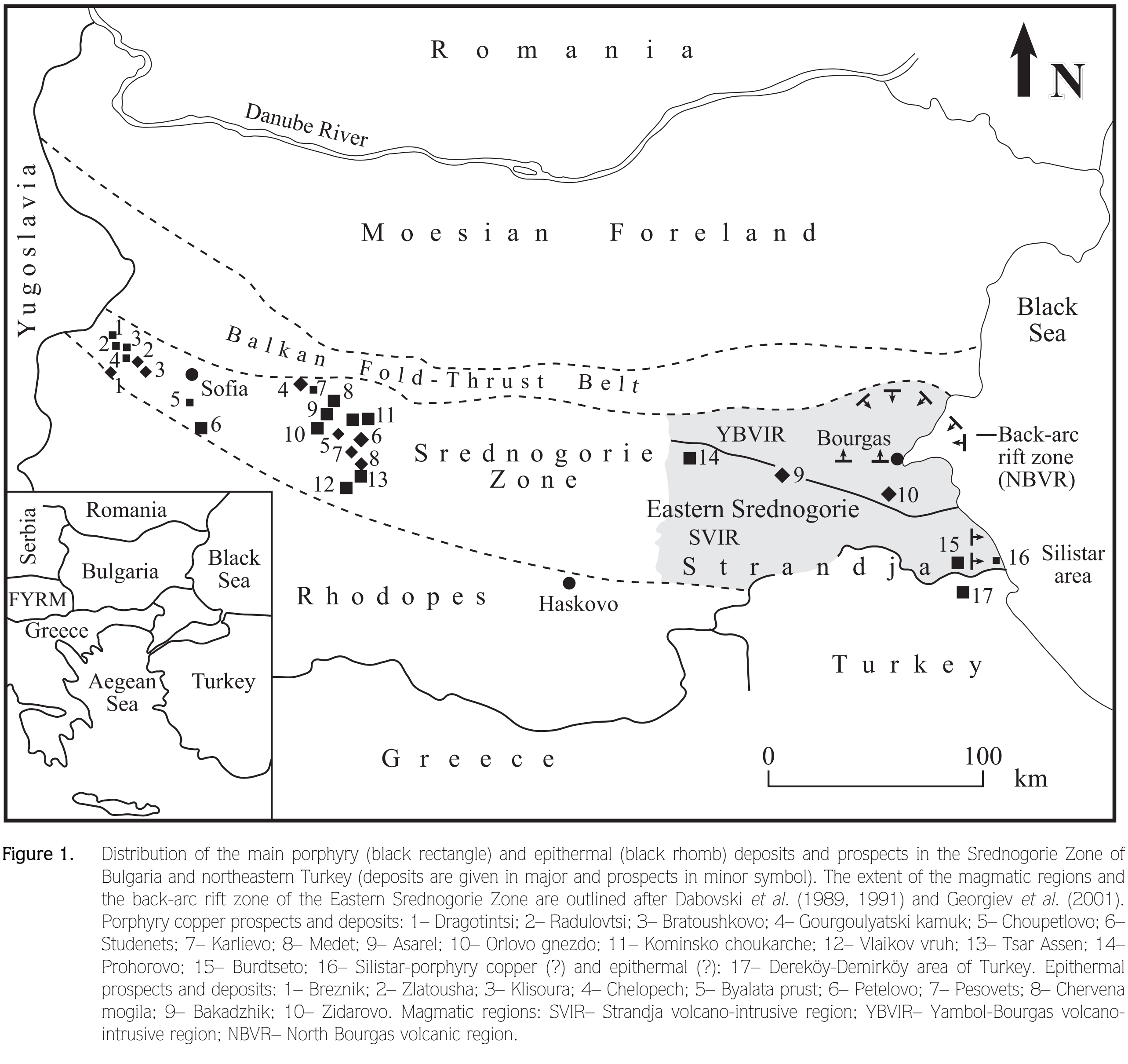

Figure 1. Distribution of the main porphyry (black rectangle) and epithermal (black rhomb) deposits and prospects in the Srednogorie Zone of Bulgaria and northeastern Turkey (deposits are given in major and prospects in minor symbol). The extent of the magmatic regions and the back-arc rift zone of the Eastern Srednogorie Zone are outlined after Dabovski *et al.* (1989, 1991) and Georgiev *et al.* (2001). Porphyry copper prospects and deposits: 1– Dragotintsi; 2– Radulovtsi; 3– Bratoushkovo; 4– Gourgoulyatski kamuk; 5– Choupetlovo; 6– Studenets; 7– Karlievo; 8– Medet; 9– Asarel; 10– Orlovo gnezdo; 11– Kominsko choukarche; 12– Vlaikov vruh; 13– Tsar Assen; 14– Prohorovo; 15– Burdtseto; 16– Silistar-porphyry copper (?) and epithermal (?); 17– Dereköy-Demirköy area of Turkey. Epithermal prospects and deposits: 1– Breznik; 2– Zlatousha; 3– Klisoura; 4– Chelopech; 5– Byalata prust; 6– Petelovo; 7– Pesovets; 8– Chervena mogila; 9– Bakadzhik; 10– Zidarovo. Magmatic regions: SVIR– Strandja volcano-intrusive region; YBVIR– Yambol-Bourgas volcano-intrusive region; NBVR– North Bourgas volcanic region.

1999; Belmoustakova & Malyakov 2001). Based on K_2O content, the rocks of the intrusion exhibit mainly a Ca-alkaline tendency, but tholeiitic varieties are also present, thus corresponding to the rocks of the axial part of the volcanic arc (Strandja Volcano Intrusive Region on Figure 1) (Figure 3). However, the host rocks tend to be enriched in potassium. Numerous porphyritic dikes of dioritic, quartz-dioritic, trachytic and andesitic composition cut the intrusion and its host rocks (Figures 2, 4a & 5 b). A single E–W-striking, dike-like body of dacite (rhyodacite) about 10 m thick cuts the southern part of the intrusion, as well as the aplites and probably the post-intrusive dikes. It is suggested that this body is the youngest magmatic product in the area.

Based upon microscopic studies of the rock-forming minerals, as well as on field observations, Belmustakova & Malyakov (2001) provided evidence for the genesis of this pluton through differentiation during crystallization and the mixing of two partially crystallized parent magmas.

Due to the lack of outcrop on shore and with the sea lying to the east, the structure of the intrusion is ascertain. Based on the thermal zone around the

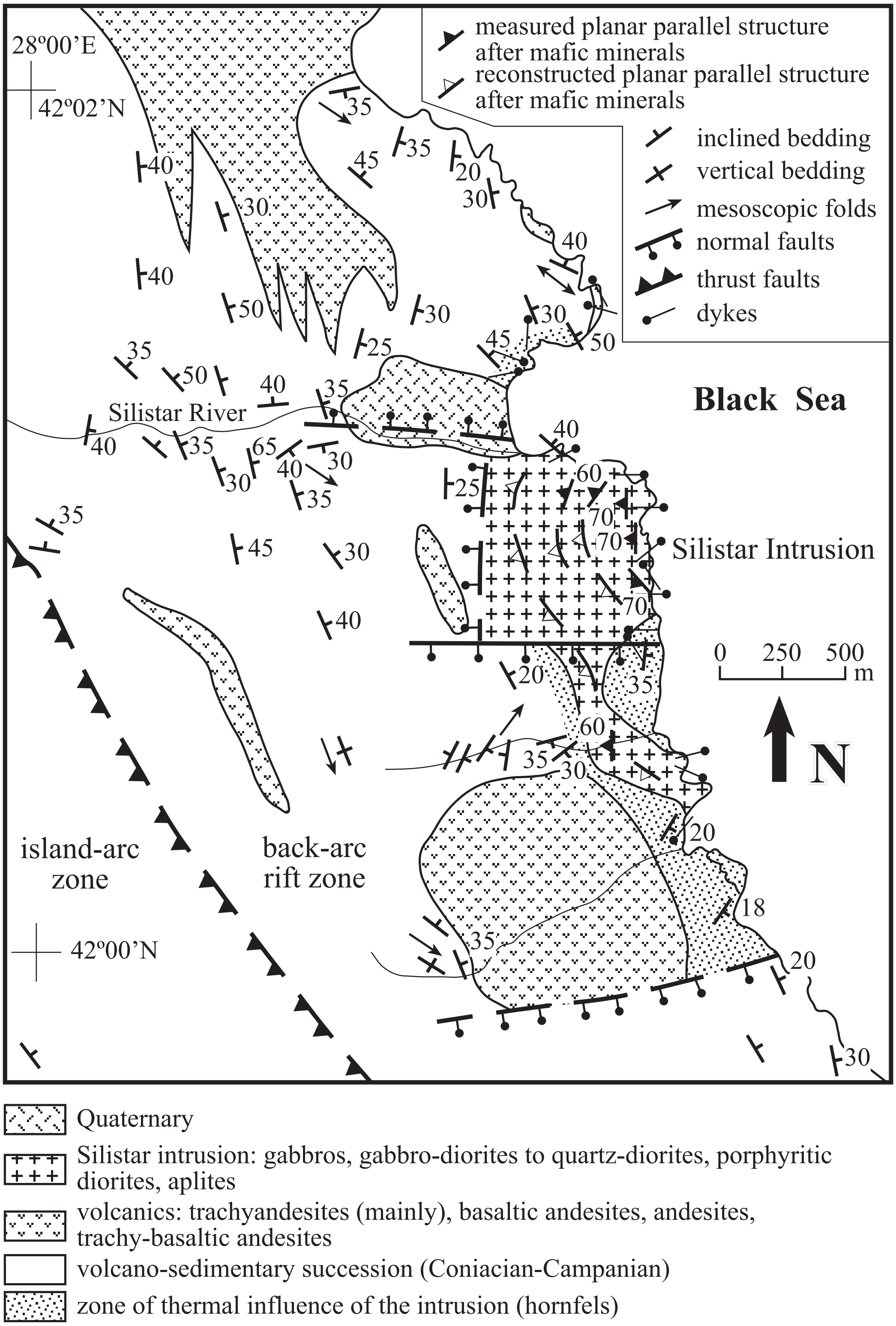

Figure 2. Geological map of the Silistar volcano-intrusive area (for location, see Figure 1).

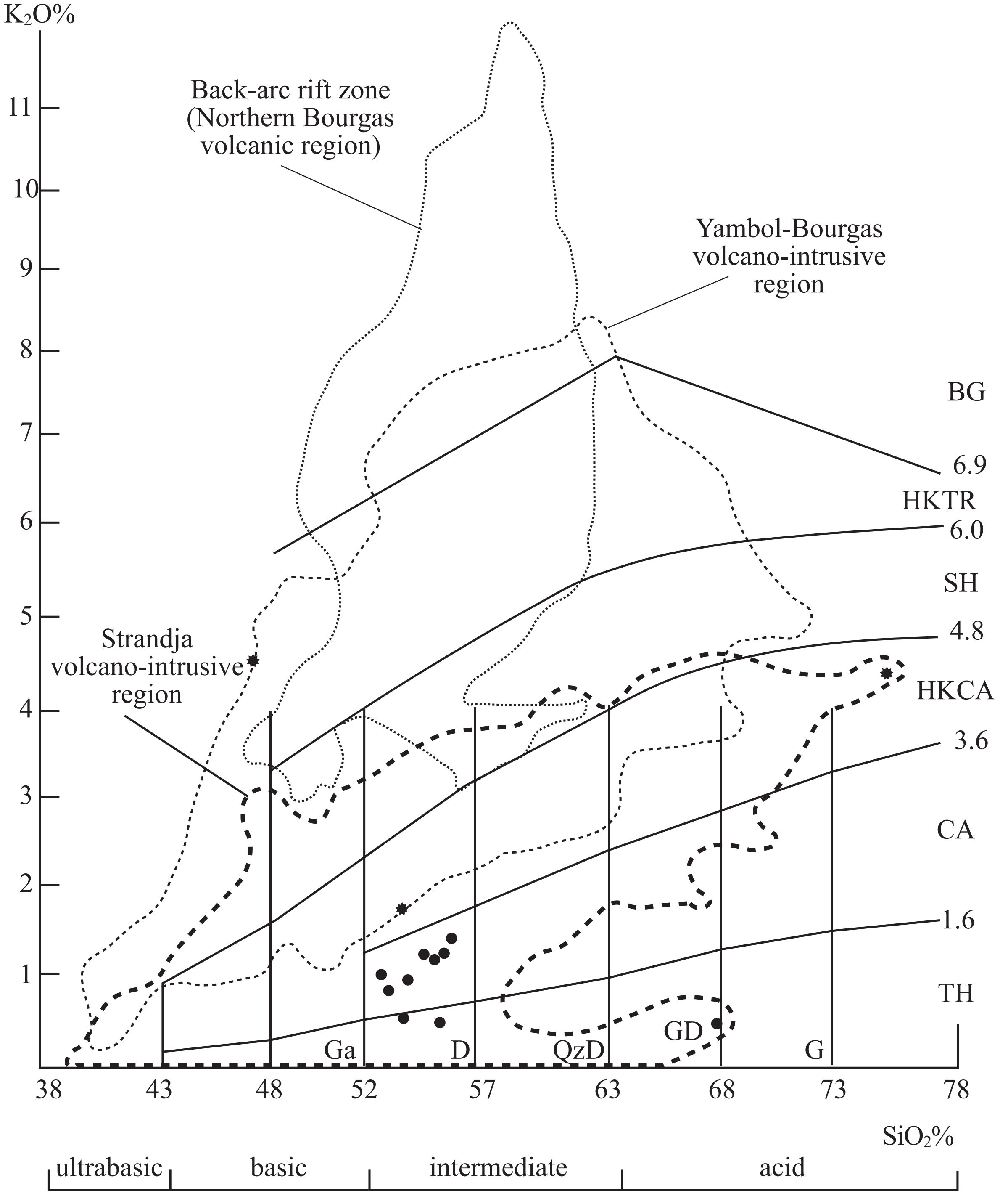

Figure 3. K_2O/SiO_2 diagram (wt %) of the rocks from the Eastern Srednogorie Zone (contours) on the diagram of Peccerilo & Taylor (1976) extended and modified by G. Stanisheva-Vassileva, Y. Yanev, A. Harkovska (modified from Dabovski *et al.* 1991) with addition of the rocks from the Silistar area (in symbols). The rocks from the intrusion are shown by heavy dots (data from Malyakov & Belmustakova 1999). The host rocks of the intrusion are volcanics, shown by asterisks (data from Coulacsasov *et al.* 1964; Stanisheva and Vassileff 1966). The location of the magmatic regions is shown on Figure 1. Magmatic series: TH– tholeiitic; CA– calc- alkaline; HKCA– high-K calc-alkaline; SH– Shoshonitic (K-transitional); HKTR– high-K transitional; BG– Bulgaritic (hyper-K transitional to alkaline). Ga– gabbro; D– diorite (andesite); QzD– quartz diorite; GD– granodiorite; G– granite (rhyolite).

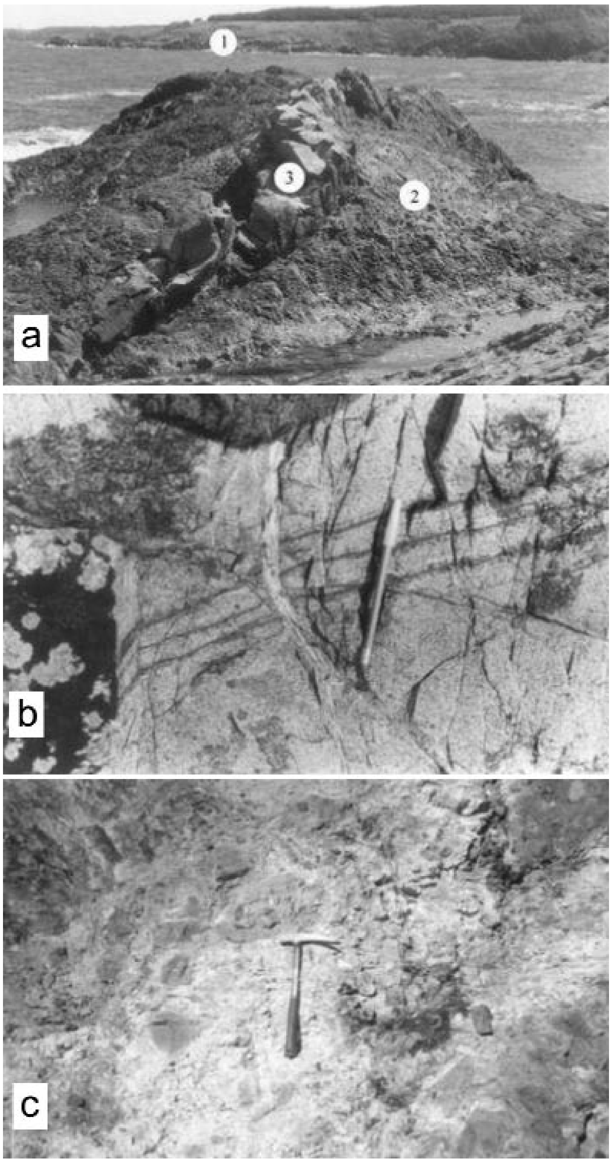

Figure 4. **(a)** Silistar intrusion (1) and wall rocks- trachyandesite flow (2) cut by porphyritic diorite dike (3). View from north to south; **(b)** stockwork-type mineralization into the Silistar intrusion (pyrite, chalcopyrite) cut by late carbonate-zeolite veinlets (light); **(c)** altered explosive breccia in the country rocks of the Silistar intrusion.

intrusion, as well as on planar parallel structures, it is suggested that the intrusion has a circular form, not less than 1.5 km in diameter, or possibly slightly elliptical, elongated generally in a N–S direction. In the exposed part of the intrusion, planar parallel structures (Figure 5b) defined by the accumulation of mafic material (mainly amphibole crystals) indicate a westward dip (250°–270°) for the intrusion at 70°-80° (Belivanov *et al.* 1992). The studies of Malyakov & Belmustakova (1999) corroborate this finding. Apparently, a significant part of the body is offshore.

The intrusion is most probably a stock- or dome-like body. Plotted data of planar structures (dikes and planar parallel structures and joints; Figures 5a, b) exhibit a linear parallelism and axial symmetry, which indicate the dip direction of the intrusion. Joints are well developed, but statistically only gently dominating joint groups are expressed, suggesting a stockwork-like fracturing. In many cases, the joints are filled with quartz-calcite and quartz-epidote along with ore minerals (Figure 4b). The joint filling is consistent and not dependent on the strike of the joints. Primary Q, S and L type joints are also recognized (Malyakov & Belmustakova 1999). The strike of the dikes coincides with statistically expressed joint groups (Figures 5b, c).

Host rocks

Rocks that host the Silistar intrusion belong to a Upper Cretaceous volcano-sedimentary succession of Coniacian–Campanian age for which several contradicting lithostratigraphic subdivisions exist (overview given in Nachev & Dimitrova 1995). In the area of interest, the succession is represented mainly by volcano-sedimentary rocks and tephroids of varying extent and composition, among which psammites tend to dominate. Clastic sedimentary rocks and carbonate rocks are scarce or lacking. The general trend of the rock succession is NNW–SSE, dipping to the east, with folds observed locally (Figures 2 & 5a). Volcanic rocks, mainly of trachyandesitic composition, (Stanisheva & Vassileff 1966) are particularly widespread and occur as lava flows, pillow-lava flows and possibly as cross-cutting bodies.

A diatreme has been recognized in the wall rocks of the intrusion (Figure 4c). Morphologically, the diatreme is a NE–SW-elongated body, about 10 m thick. Its explosive breccia consists of diverse rock fragments, with trachybasaltic andesites, basaltic andesites and andesites dominating. Fragments of tephroids are subordinate, and only one clast of intrusive rock (subvolcanic porphyritic diorite or fine-grained diorite) has been found. All rocks in the explosive breccia are hydrothermally altered, with groundmass virtually absent.

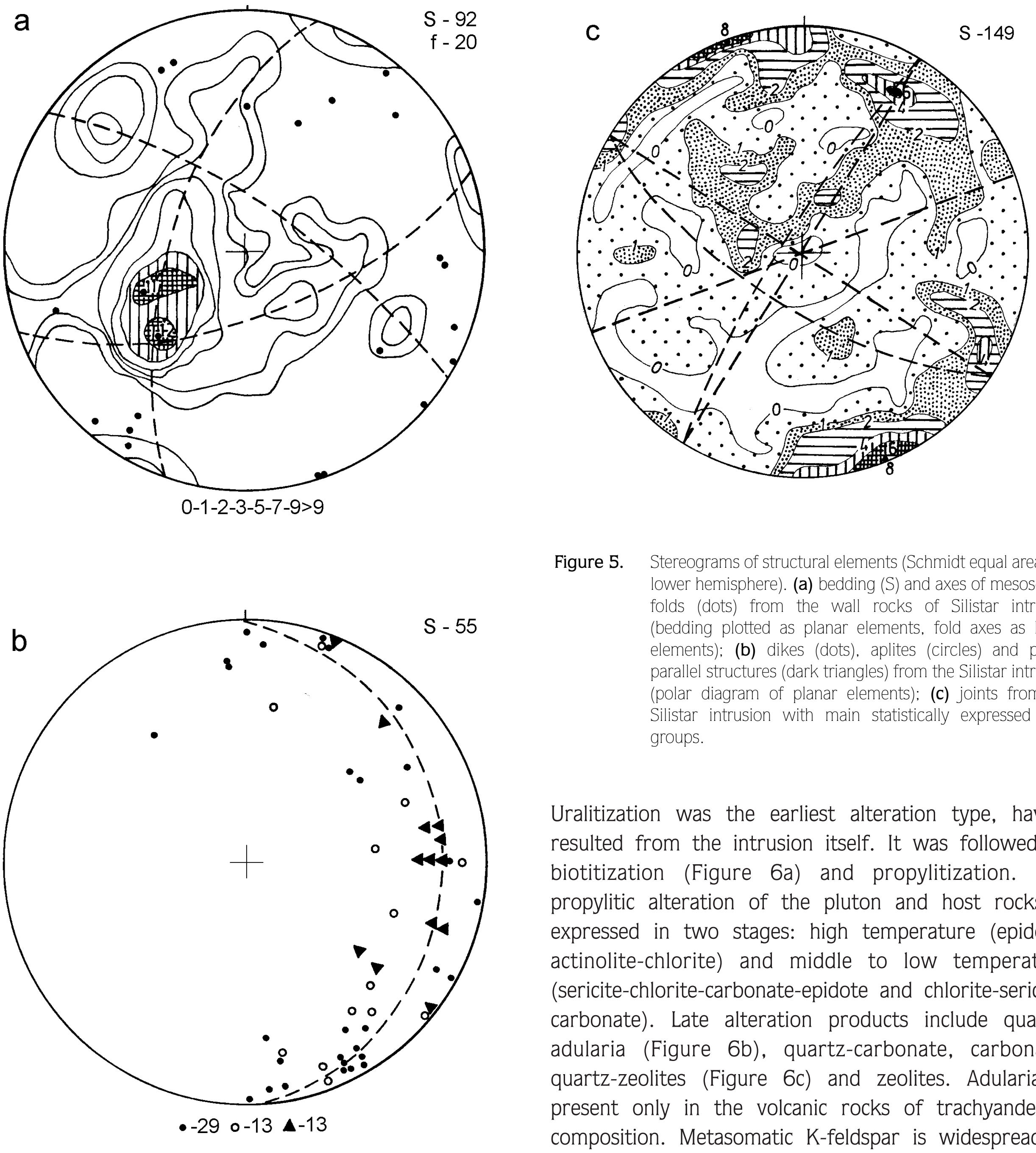

Figure 5. Stereograms of structural elements (Schmidt equal area net, lower hemisphere). **(a)** bedding (S) and axes of mesoscopic folds (dots) from the wall rocks of Silistar intrusion (bedding plotted as planar elements, fold axes as linear elements); **(b)** dikes (dots), aplites (circles) and planar parallel structures (dark triangles) from the Silistar intrusion (polar diagram of planar elements); **(c)** joints from the Silistar intrusion with main statistically expressed joint groups.

Metasomatic and Ore Products

Wall-rock Alteration– The intrusion has a well-developed alteration aureole (300–400 m wide) in its northern and southern parts, where hornfels formed and uralitization (amphibole±epidote) is notable. To the west of the intrusion, poor outcrops and lack of contact effect suggest a fault boundary with the host rocks (Figure 2).

Uralitization was the earliest alteration type, having resulted from the intrusion itself. It was followed by biotitization (Figure 6a) and propylitization. The propylitic alteration of the pluton and host rocks is expressed in two stages: high temperature (epidote-actinolite-chlorite) and middle to low temperature (sericite-chlorite-carbonate-epidote and chlorite-sericite-carbonate). Late alteration products include quartz-adularia (Figure 6b), quartz-carbonate, carbonate, quartz-zeolites (Figure 6c) and zeolites. Adularia is present only in the volcanic rocks of trachyandesitic composition. Metasomatic K-feldspar is widespread in these rocks, and has been suggested to be of autometasomatic origin (Stanisheva & Vassileff 1966), as result of a mineral-forming process of "… relatively high-temperature K-alkaline character". However, our discovery of adularia suggests the expression of a later lower temperature epithermal process probably not related to the process described by Stanisheva & Vassileff (1966).

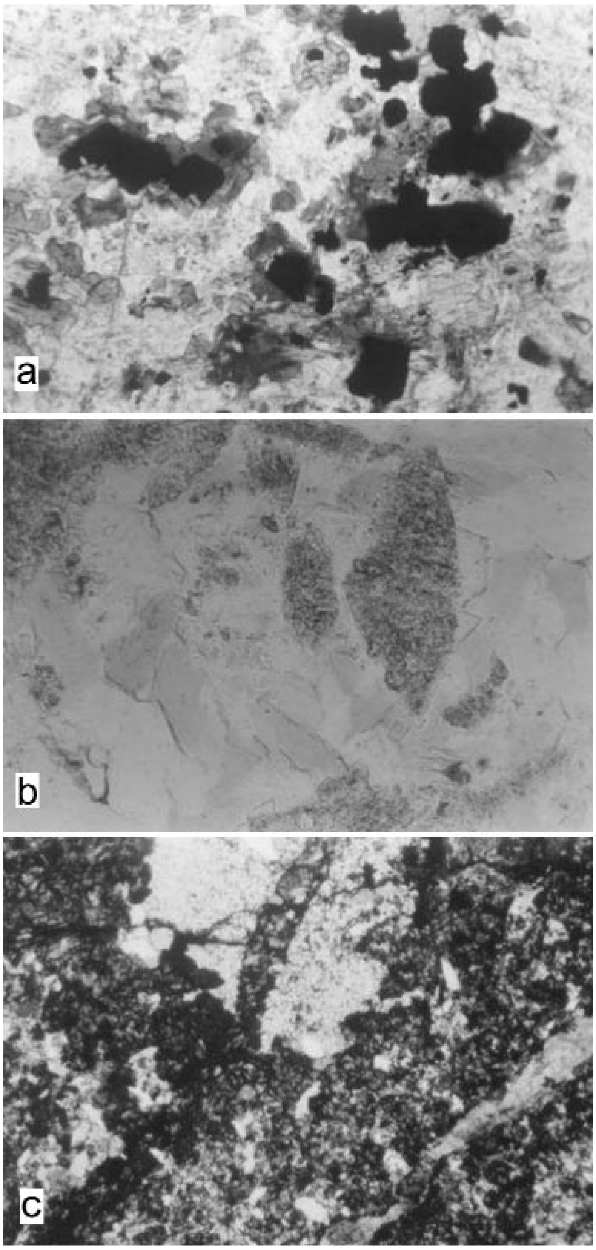

Figure 6. **(a)** Secondary biotite and ore mineralization in quartz-diorite; parallel polars, x 150; **(b)** quartz-adularia mineralization, superimposed on epidote-chlorite-sericite alteration; parallel polars, x 300; **(c)** quartz-sericite-carbonate metasomatic rock; crossed polars, x 75.

Based upon the mineral assemblages, it is possible to suggest two general zones of alteration (Figure 7). The first one (southern) is characterised by ep-chl-car-ser-bio-act±zeol, and the second one (northern) is characterised by chl-ep-Ser-car±zeol. The first zone (where bio and act occur) probably represents the potassic core of a porphyry system. It is possible that a late retrograde overprint (higher temperature propylitic) has affected the potassic zone. The second (northern) zone probably reflects a lower-temperature propylitic alteration event.

Ore mineralization– The currently known Cu-mineral occurrences of the Silistar area have been described as: (1) contact-metasomatic in origin and vein in morphology, with pyrite, magnetite, chalcopyrite and hematite (unpublished data, former Committee of Geology of Bulgaria), or (2) vein-like type representing “a rock block of 10x10 m” and ore mineralization “represented by veinlets of malachite, azurite, chalcopyrite and colusite (?)” (Kovachev 1994).

All cited descriptions refer to the immediate contact zone or narrow zones in the intrusion itself. Our data show a much larger mineralised area (Figure 7), at distances of up to 1.5 km (north and south) from the pluton. Farther to the south and north, mineralization has not been observed. This fact clearly suggests a causal relationship between the intrusion and the mineralization. The lack of outcrop to the west does not permit a tracing of the mineralised halo on land. In addition to the previously known contact-metasomatic mineralization, our data also show the presence of stockwork-type and disseminated pyrite and chalcopyrite mineralization, hosted by both the pluton and the host rocks (Figures 4b, 7 & 8).

The most abundant ore minerals in the intrusion and its host rocks are magnetite, pyrite and lesser ilmenite. These three minerals define a pervasive as well as fracture-controlled (Figures 7, 4b & 8a) N–S-oriented mineralized belt along four km of coast line. Ilmenite occurs as small idiomorphic to xenomorphic inclusions. Magnetite is locally strongly inhomogeneous, mainly due to ilmenite lamellae (titanomagnetite). However, not all of the inhomogeneities are from ilmenite. Elevated Mn contents (1–2 wt% MnO, by microprobe) in many cases suggests the presence of pyrophanite ($MnTiO_3$) or jacobsite ($MnFe_2O_4$). The small size of the inclusions, however, does not permit their precise determination.

A significant part of the magnetite, especially in the host rocks, is homogeneous. Ramdohr (1962) suggested that such magnetite is of metasomatic origin. This magnetite can be recognized by its Cr content (about 1 wt % Cr_2O_3). The development of metasomatic magnetite

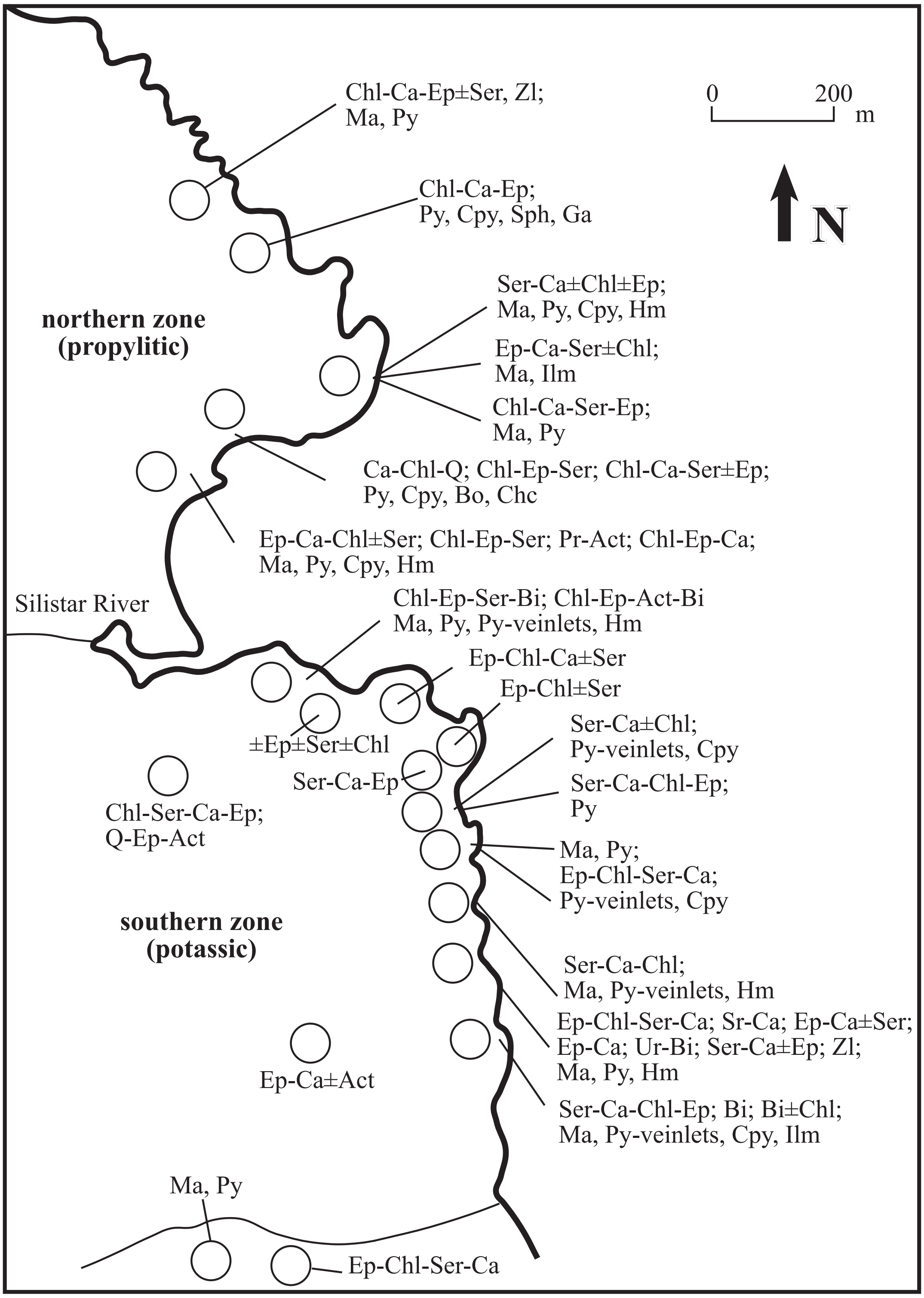

Figure 7. Types of ore mineralization and wallrock alteration in the Silistar area. (the figure covers the same area as Figure 2). Gangue minerals: Ser– sericite, Ca– carbonate, Chl– chlorite, Ep– epidote; Pr– prehnite, Ur– uralite, Act– actinolite, Bi– biotite, Zl– zeolite; Ore minerals: Ma– magnetite, Py– pyrite, Cpy– chalcopyrite, Hm– hematite, Ilm– ilmenite, Sph– sphalerite, Ga– galena, Bo– bornite, Chc– chalcocite.

is also obvious in the present case. Therefore, we distinguish two types of magnetite: magmatic and metasomatic types. The metasomatic origin of pyrite in the magmatic rocks is indicated by the large amount of silicate inclusions which are relicts of the replaced matrix (Figures 8b, c).

In many cases hematite and limonite developed at the expense of pyrite and magnetite crystals; they occur also as impregnations over strongly oxidized mineralization.

Paralleling the disseminated mineralization are numerous veinlets and mineralised zones along zones of fracturing up to 50 cm in width. These vein-like zones consist mainly of pyrite that occurs as small, idiomorphic cubic crystals, included in soft-filling oxidized material. Almost all of the mineralised fractures also contain chalcopyrite that occurs as small xenomorphic grains. Locally chalcopyrite occurs as idiomorphic crystals up to 8 mm in maximum dimension. In most cases, the ore minerals are sealed by quartz and carbonates. In isolated cases, bornite and chalcocite, as well as sphalerite, galena and tetradymite have also been identified. It is notable that pyrite from the intrusion everywhere contains rounded inclusions of chalcopyrite and pyrrhotite. Such inclusions have not been observed in pyrite of the host rocks. Secondary Cu minerals, mainly malachite and azurite, are abundant.

Based upon the types of ore mineralization, two zones with diffuse boundaries may be identified: southern and northern ones (Figure 7). The southern one is characterized by py-ma-cpy-hm-(ilm) and probably coincides to the potassic zone of alteration. Typical of the northern zone is py-pa-cpy-hm-(ilm)+(sph+ga)+(bo+hz).

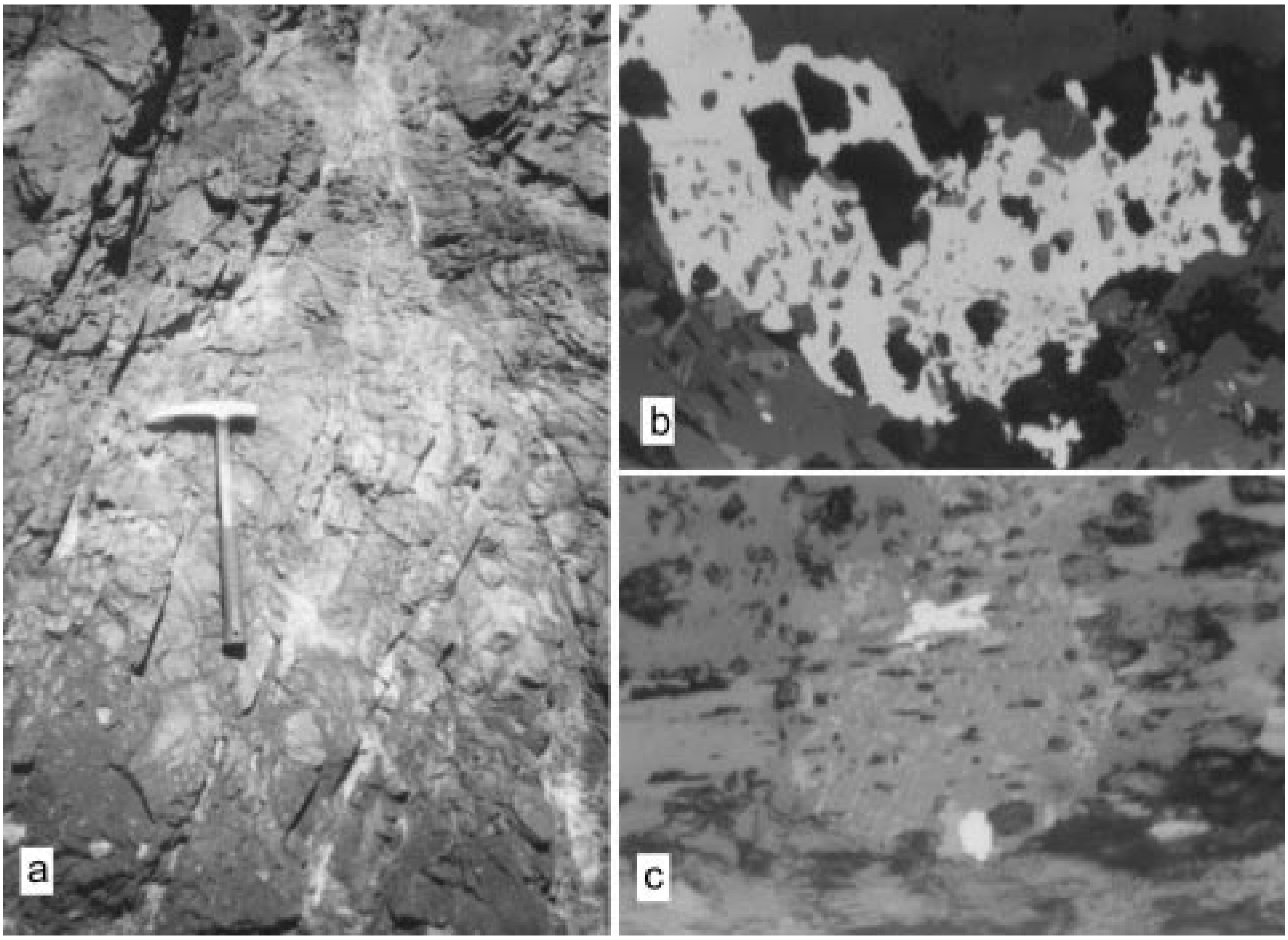

Figure 8. **(a)** Stockwork-type mineralization developed in the wall rocks of the Silistar intrusion (pyrite, chalcopyrite, magnetite, malachite); **(b and c)** metasomatic pyrite replacing silicate grains. Perthite-like texture of pyrite is inherited by the replaced silicates; reflected light, x 300.

As described above, pyrite has different features in each one of these zones.

The main ore minerals, as well as spectral analyses, define Cu as the main economic commodity (Table 1). Our semi-quantitative analyses show Cu contents in many cases exceeding 0.1% and reaching up to 1.1% (Kovachev 1994). Molybdenum is either very low or absent. Silver is present in abundances up to 1 ppm, gold has not been detected, and tungsten contents of up to 3 ppm have been determined in many places. Titanium is permanently presented (1500–3000 ppm) with contents quite oftenly exceeding 6000 ppm. Metasomatic processes seem to have played the dominant role in ore formation.

Discussion and Conclusions

Our data show a much larger mineralized area than previously known, and suggest the presence of both porphyry and epithermal systems. The process of biotitization, accompanied by actinolite only in the intrusion, suggests a core of potassic alteration, a typical element of porphyry systems. Propylitic alteration, and stockwork-type and disseminated pyrite-chalcopyrite mineralization, and widespread halos of pyrite and metasomatic magnetite are also characteristic elements of porphyry copper systems. Porphyry deposits with high magnetite contents are usually gold-rich (e.g., Sillitoe 1979, 1996); such a possibility remains to be tested in the Silistar area. Furthermore, such gold-rich systems tend to be impoverished in molybdenum (Sillitoe 1996), which is the case in the study area. The high magnetite content may also indicate the roots of a porphyry copper system (Sillitoe 1973; Sawkins 1990). The presence of late alteration products with minerals typomorphic for epithermal systems (quartz-adularia), as well as some low temperature Pb-Zn mineralization may indicate the development of a low-sulfidation system.

Our data show that Cu sharply dominates, especially relative to Mo base metals. This suggests pure porphyry copper mineralization.

Table 1. Contents (in ppm) of some ore elements in mineralized and altered rocks of the Silistar area.

	Cu	Mo	Pb	Zn	Ag
Contact-metasomatic zone of the Silistar intrusion					
hornfels with sulfides and malachite	>1000	0.1	5	60	0.3
hornfels with sulfides and malachite	>1000	-	0	250	1
hornfels	150	0.3	3	<30	<0.1
Zones with ore mineralization					
sulfide zone (Py, Cpy) from the Silistar intrusion with malachite	>1000	<0.1	5	100	0.3
stockwork mineralization (Ma, Py, Cpy, Ilm) in altered gabbrodiorite from the intrusion	>1000	-	1	60	0.3
oxidized sulfide zone in the host rocks, northern of the intrusion	1200	3	25	120	0.3
strongly fractured ore zone (Py, Cpy, Bo, Chc, Ma) in the host rocks, northern of the intrusion	>>1000	9	8	-	1
Rocks of the Silistar intrusion					
gabbrodiorite	6	<0.1	4	-	-
gabbrodiorite	<1	-	5	30	<0.1
altered gabbrodiorite	90	-	4	100	-
aplite	6	<0.1	2	-	-
host rocks of the Silistar intrusion					
altered volcanics	35	0.1	6	90	0.1
propylitic psammitic tephroid	35	-	6	-	-
trachyandesite	10	3	12	-	<0.1
trachyandesite dyke	15	-	3	-	<0.1
gabbrodiorite dyke	3	-	-	60	<0.1
trachyandesite lava flow	15	3	6	60	-
porphyritic diorite dyke	30	<0.1	3	150	0.2
porphyritic diorite dyke with pyrite	1	-	1	60	0.1
basaltic andesite	30	-	15	100	-

Detection limit in ppm: Cu and Pb - 1; Mo and Ag - 0.1; Zn - 30; The upper limit for Cu is 1000 ppm (semi-quantitative analyses)

Porphyry Cu deposits related to Late Cretaceous subduction-related magmatism are well known from the Bulgarian as well as the Turkish parts of the Srednogorie-Strandja intrusive chain (Figure 1). In Bulgarian territory, the closest deposit is the Burdzeto ore deposit of the Malko Turnovo ore district (Bogdanov 1987), and in Turkey the closest deposits are those of the Dereköy-Demirköy area (Ohta *et al.* 1988; Gültekin 1999). The Silistar ore occurrence has many similarities to those deposits but, in general, those deposits have high Mo and base metal contents; tungsten may be present or absent. In comparison, the Silistar area rocks have negligible Mo and W contents. The aforementioned deposits are located in the axial part of the Late Cretaceous volcanic arc. In contrast, the Silistar prospect is located in the suggested back-arc zone of initial rifting (Boccaleti *et al.* 1978; Dabovski *et al.* 1991; Georgiev *et al.* 2001). Our data suggest, for the first time, the presence of elements of porphyry and epithermal systems in the area, within the anticipant rift zone of the Late Cretaceous island-arc system.

It has been largely accepted that porphyry copper and molybdenum deposits are characteristic of the subduction zones, but porphyry molybdenum deposits are also known from rift areas (e. g. Sillitoe 1972; Westra & Keith 1981; Sawkins 1990). However, rift zones are not the typical geodynamic environment for the porphyry copper-type deposits. It should be mentioned that the chemistry of the Silistar intrusion corresponds to the axial part of the volcanic arc, and the intrusion cuts the rift filling. This contradiction requires further investigations if a correct explanation is to be set forth. One of them could be situated oblique to arc extension. The presence of such mineralization in our case could also be attributed to the initial stage of rifting, and the location of the area on the margin of the suggested rift zone. A pure extensional regime probably never developed in the Eastern Srednogorie Zone.

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