LATE CRETACEOUS MAGMATISM OF THE CHELOPECH REGION, CENTRAL SREDNOGORIE MAGMATIC ZONE, BULGARIA.

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Abstract:: The Late Cretaceous magmatism in Chelopech region is characterised by andesitic, latitic to trachydacitic lava flows (probably products of a chemically zoned magmatic chamber), subvolcanic bodies and altered dykes with latite chemistry. The Sr isotope (0.7049 to 0.7054) signature suggests derivation from melts generated in a mantle source modified by the addition of crustal material from the subducted slab.

Key words: Late Cretaceous volcanic arc andesites, Chelopech volcano, Sr isotopes, trace elements.

The Chelopech region is the host of Europe's largest gold deposit Chelopech, and is situated about 65 km east of Sofia at the foot of Stara Planina Mountain. It is within the northernmost part of the Panagyurishte ore district which includes many large porphyry-Cu and epithermal deposits. The Panagyurishte ore district belongs to the Central Srednogorie volcano-intrusive area, and is part of the Srednogorie Late Cretaceous island arc (Dabovski et al., 1991). The area is characterized by the development of Late Cretaceous volcano-plutonic complexes consisting mainly of andesites, dacites, granodiorites and quartz monzodiorites grouped in 4 temporal stages according to Lilov & Chipchakova (1999): Ist, >91; IInd, 91÷88; III^{d}, 88÷86; IVth, 67÷65 Ma.

The Chelopech deposit is located in the Chelopech Upper Cretaceous volcano (Popov et al., 2000). The basement below the Cretaceous rocks in the region is composed of metamorphic rocks of the Pirdop (Arda) and Bercovitca Groups with tectonic contacts between them. The Pirdop Group consists of two-mica migmatites with thin intercalations of amphibolites, hornblende-biotite and biotite gneisses (Dabovski, 1988). The Bercovica Group is a sedimentary - volcanic complex of island-arc association (Haydoutov, 2001). It consists of equal parts of sedimentary and volcanic rocks (spilites, keratophyres and their pyroclastics) metamorphosed under greenschist facies

conditions. Based on both radiometric and biostratigraphic constraints, the age of this association straddles the Precambrian-Cambrian boundary (540 Ma - Bowring & Erwin, 1998). This basement is transgressively overlain by Late Cretaceous (Turonian - Maastrichtian) sedimentary and volcanic rocks, about 2000 m in thickness.

The Upper Cretaceous volcanic and sedimentary succession. Late Cretaceous sedimentation starts with polymictic sandstones and conglomerates with coal-bearing interbeds probably of Turonian age up to 500 m thick (Moev & Antonov, 1980). These sedimentary rocks are cut by subvolcanic bodies (including dykes) and overlain by the products of the Chelopech volcano. Popov et al. (2000) also distinguished the presence of late subvolcanic bodies, but they are not proven by any dating.

Subvolcanic bodies and dykes. They are intruded in the Turonian sedimentary rocks and the basement rocks (Popov & Mutafchiev, 1980) and are exposed in the northern part of the region without any relationship with other volcanic rocks. The largest subvolcanic body is about 2 x 1km in size. The primary bedding of the sedimentary host rocks immediately close to the contact is nearly vertical. The subvolcanic body has a dome-like morphology. The dykes have an E-W orientation; one of them is about 6 km long.

The Chelopech volcano consists of andesitic to latitic lava flows grading into agglomerate flows in the upper levels, tuffs and epiclastic rocks. Subvertical columnar jointing is observed in the lava flows in some places. The preserved volcanic rocks form the limbs of an E-W synform (10 x 2 km) cut in the eastern part by a Neogene-Quaternary graben. The total thickness of the volcanic products is up to 1200 m according to drillings. In the western part, the agglomerate flows pass to psephitic and psamitic epiclastic rocks. Strongly hydrothermaly altered breccia and fine-grained rocks in the ore deposit are interpreted as volcanic breccia and tuffs (some are probably epiclastics). Data about the location of the volcanic center are not evident. It is probably covered by Neogene-Quaternary sediments. No evidences about a caldera subcidence.

These volcanic rocks in proximity of the ore deposit are cut by the Vozdol volcanic breccia, probably representing a younger neck (Vozdol volcano after Popov et al., 2000). They are highly porphyritic latites to andesites. The matrix of this volcanic breccia is lavic, and in the upper part consists of sedimentary material that shows destruction of the breccia and beginning of its redeposition in the Vozdol sandstones.

After the end of its activity, the Chelopech volcano has been partly eroded and covered by the Vozdol sandstones, limestones, and flysch sediments. The Vozdol sandstones (thickness up to 250 m) are probably freshwater (fluvial?) or coastal. They show cross-bedding. Two layers represen

conglomerates with fragments (up to 20 cm in size) of the Vozdol neck, and they could be interpreted as products of mud flows. These sandstones are only locally developed, and they are covered by red argillaceous limestones. These limestones (thickness up to 30-40 m) consist of fragments of different volcanic rocks and Vozdol sandstones. Calcareous nannofossils from these limestones indicate a Late Santonian to Campanian age (unpublished data of K. Stoykova, Geol. Inst. Bulg. Acad. Sci.). They are covered by flysch (Late Campanian - Early Maastrichtian according to K. Stoykova) composed of interbedding of calcareous sandstone, siltstone and argillite with a thickness up to 500 m.

The age of the Chelopech magmatic rocks is still poorly known. Only a few K-Ar age determinations are available (Lilov & Chipchakova, 1999). Andesite lavas (91 Ma) and altered rocks (argillic type from a borehole at 84 Ma and K-silicate-sericitic type from Chelopech deposit at 76 Ma) suggest a Turonian - Campanian age. The K-Ar age of the Vozdol volcanic rocks at 65 Ma is in contradiction with the geological relationships, since they are eroded and covered by Santonian to Campanian sediments.

Petrography. The Chelopech volcanic rocks are andesites, latites to trachydacites (Fig. 1 ***A, B***). The altered dykes are probably of latite chemistry.

The andesites are highly porphyritic. The phenocrysts (> 40%) consist of plagioclase, amphibole, minor biotite, and titanite. The accessories are apatite, zircon, and Ti-magnetite. The groundmass is composed of the same minerals, sometimes as microlites. The subvolcanic andesites contain rare corroded quartz crystals. The latites display similar petrographic characteristics, but zoned amphibole phenocrysts are also presented. They contain fine-grained, fully crystallized ellipsoidal shaped inclusions consisting of the same minerals (plagioclase, amphibole and biotite). This could be considered as evidences of magma mingling. The phenocryst mineralogy of the altered latite dykes is dominated by plagioclase and biotite and minor amounts of amphibole.

Mineral chemistry. The cores of plagioclase phenocrysts range between An_{38} and An_{51}. The rims are variable in composition and substantially overlap the field of the phenocryst cores (Fig. 1. ***C***). The composition of plagioclase microlites vary from An_{31} to An_{48}. The alkali feldspar ($Or_{86\div93}$) occurs as minor microlites in andesitic rocks. The amphiboles (Fig. 1. ***D***) with $Mg^{\#}$ between 0.48 and 0.67 plot on the limit of the magnesiohastingsite, pargasite, ferropargasite, hastingsite and Fe-edenite fields of Leake et al. (1997).

Trace elements. The MORB normalized patterns for the Chelopech volcanic and subvolcanic rocks (Fig. 1. ***F***) reveal an enrichment of LILE and in a lesser degree of some HFSE (Ce, Zr, P, Hf) with a strong negative Nb anomaly and depletion of the Fe-Mg elements. All these

features are typical for Island arc magmatic sequences with the magmatic assimilation of sedimentary material from the subducted slab. In comparison to island arcs from the SW Pacific (Papua New Guinea, Solomon Islands, New Hebrides, Fuji, Tonga-Kermadec Islands, New Zeland), NW Pacific (Kuriles, Kamchatka, Japan, Izu-Bonnin, Marians, Taiwan, the Philippines), and the Mediterranean (Aeolian and Aegean arcs) (data from Erwart 1982), the Chelopech volcanic rocks show small Sr, K_2O, Rb, Ba and Hf enrichments and depletions of TiO_2, Yb and Cr.

All rocks have fractionated LREE and relatively flat HREE patterns (Fig. 1. ***E***), as typically found in subduction related volcanic rocks. LREE enrichment ranges from 33 to 105 times chondritic, whereas chondrite normalized La/Yb ration vary from 10 to 13. Middle and heavy REE show relatively flat patterns, generally within 5 to 30 times that of chondritic ones. No Eu anomaly is observed, which suggests no plagioclase fractionation during the genesis of studied andesitic rocks.

Sr isotopes. The Sr isotopic composition of Late Cretaceous magmatic rocks from the Chelopech region display a small range between 0.7049 and 0.7054 (after 90 Ma correction). Generally the $^{87}Sr/^{86}Sr$ ratios fall within the field previously defined by Kouzmanov et al. (2001) with values from 0.7046 to 0.7061 (after 80 Ma correction) for the volcanic (andesite and dacite) and plutonic (granodiorite and granite) rocks from the southern part of the Panagyurishte ore district.

Conclusions.

The Chelopech Au-Cu deposit is located in Upper Cretaceous volcano without data for caldera subsidence. The volcanic rocks have a Ca-alkaline to shoshonitic affinity. The magma evolved from more acid andesites, latites and trachydacites (61÷63% SiO_2) to more basic ones (57÷58% SiO_2). This chemical evolution and the absence of a Eu anomaly suggests the presence of a chemically zoned magmatic chamber at depth (Hildreth, 1981). The Sr isotopic composition suggests derivation of the volcanic rocks from melts generated in a mantle source modified by the addition of crustal material from the subducted slab.

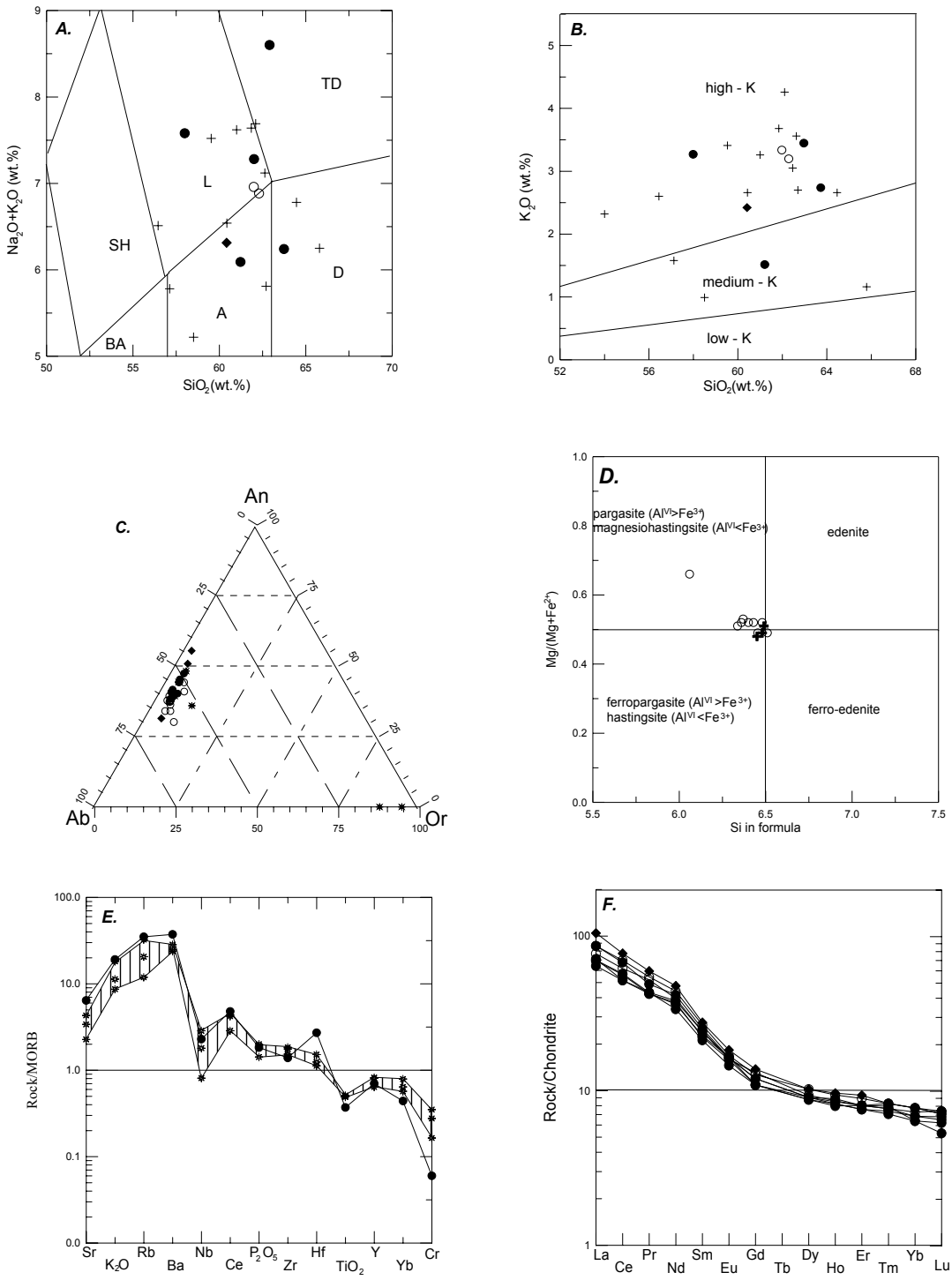

Fig. 1, *A*, TAS and ***B*,** SiO_2 vs. K_2O diagram after Le Maitre et al. (1989) for the Chelopech volcanic rocks (B, basalt; BA, basaltic andesite; A, andesite; D, dacite; SH, shoshonote, L, latite; TD, trachidacyte). Open circles, dykes; filed circles, lava flows; filed diamonds, subvolcanic rocks; crosses, published data. ***C*,** Ab-An-Or ternary diagram: filed circles, phenocrysts core; open circles, phenocrysts rim; filed diamonds, first generation phenocrysts; stars, groundmass microlites. ***D*,** classification of the analyzed amphiboles (after Leake et al.,1997). Circles, $Al^{VI}>Fe^{3+}$; crosses, $Al^{VI}<Fe^{3+}$. ***E*,** Chondrite-normalized REE patterns for Chelopech volcanic rocks (normalization after Nakamura values from Potts et al., 1981). ***F*,** MORB (Mid-ocean ridge basalt)-normalized trace element patterns for average composition of Chelopech volcanics (filed circles) and some typical island arc andesites mentioned in the text (data from Erwart, 1982). Normalization values after Pearce (1982).

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