Evolution of the Malko Tarnovo plutonism and its significance for the formation of the ore deposits in the region.

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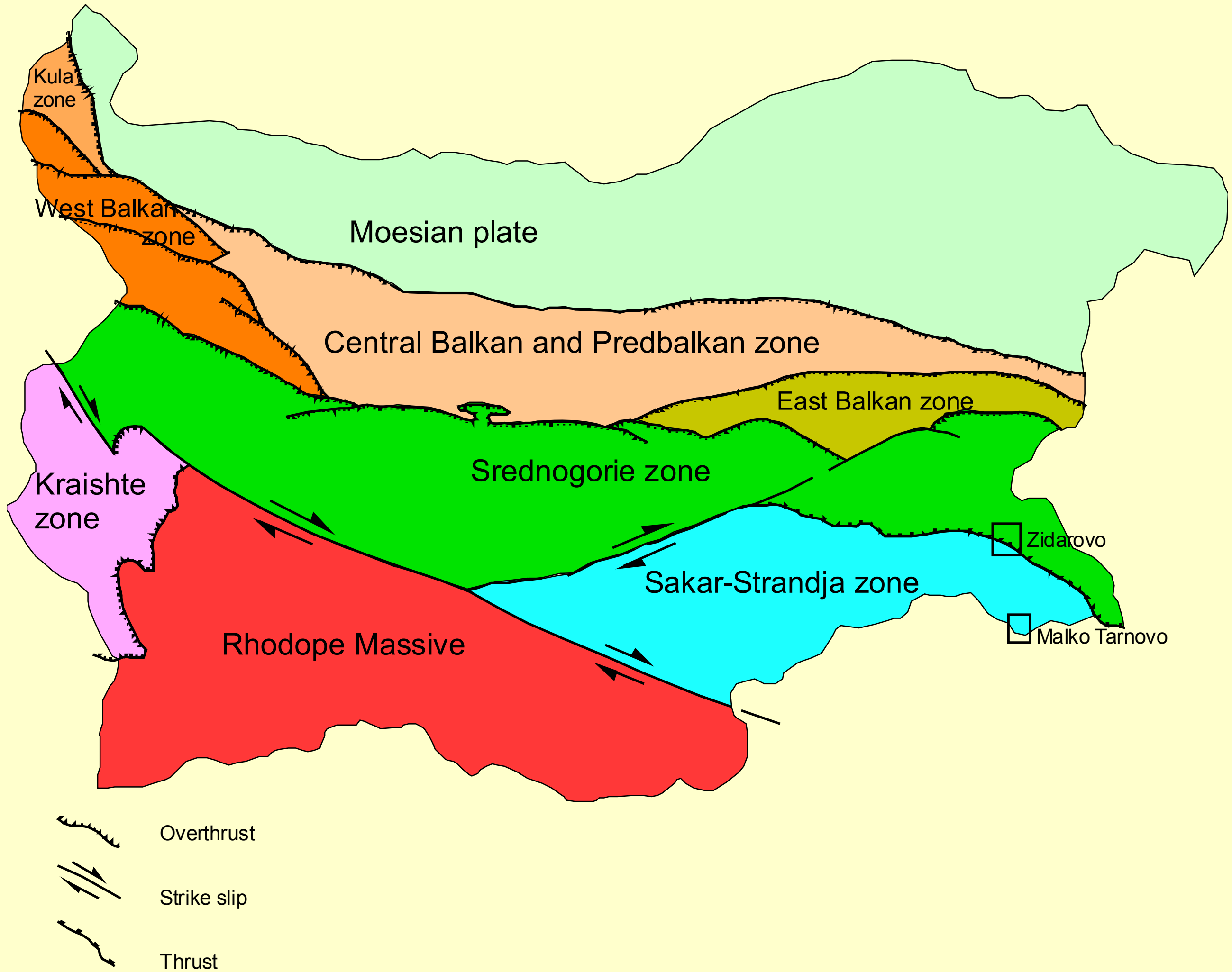
Introduction

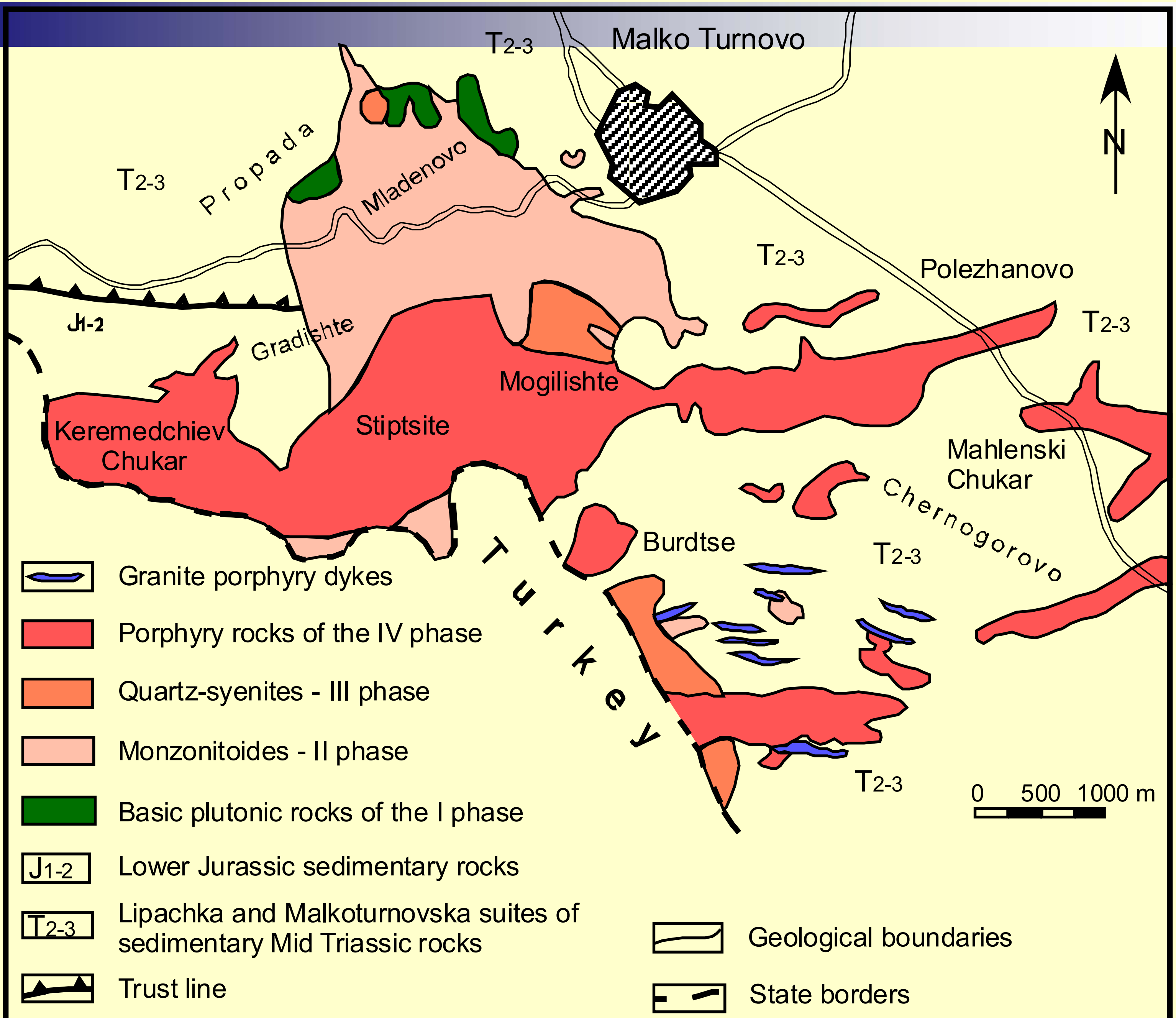
- The Malko Tarnovo pluton is situated at the border between Bulgaria and Turkey.
- In Bulgarian territory it covers 12 km^2 intruded in into the low grade metamorphosed terrigeneous and carbonate rocks of Upper Triassic and Lower Jurassic age.
- Until now the pluton was thought to be formed with 6 phases (Vassilev et al., 1964) or 3 phases (Popov & Chanev, 1980). Vassileff & Stanischeva-Vassileva (1981; 1986) mention the connection of the Cu-Au-base metal mineralization with monzonitoide magmatism and the Cu-Mo mineralization with the Ca-alkaline magmatism.
- The aim of the study is to give new data and new explanations of the magmatic petrology and it importance for the ore generation.



Kula zone
West Balkan zone
Moesian plate
Central Balkan and Predbalkan zone
East Balkan zone
Srednogorie zone
Kraishte zone
Rhodope Massive
Sakar-Strandja zone
Zidarovo
Malko Tarnovo
Overthrust
Strike slip
Thrust

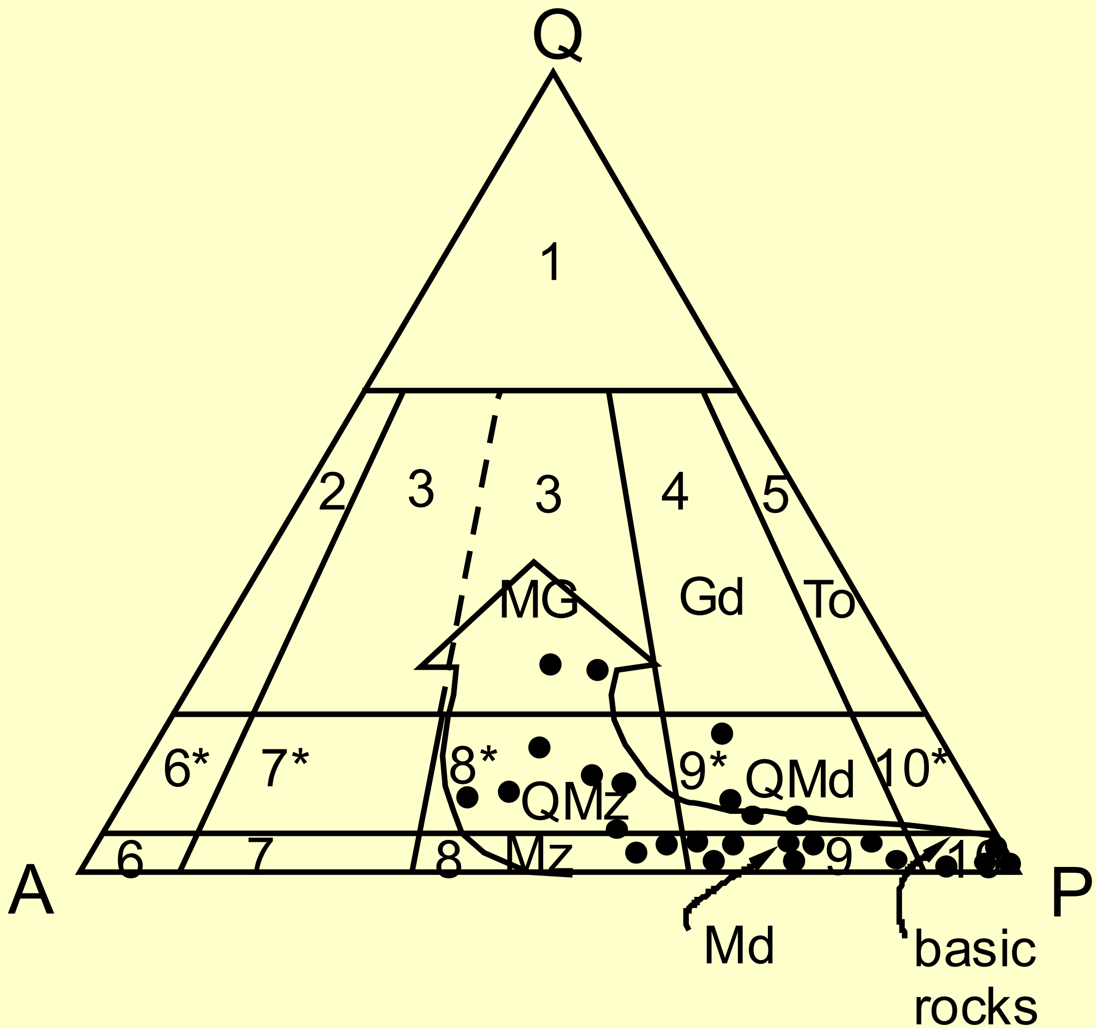
Geology

- Our investigation distinguish 4 intrusive phases based on the crosscutting borders between them: I) Basic rocks; II) Monzonitoids; III) Quartz-syenites; IV) Porphyry rocks.
- Two different type of ore deposits are related with the Malko Tarnovo pluton: 1/ Cu-Au-base metal vein- and skarn-hosted deposits (Gradishte, Propada and Mladenovo - Bogdanov, 1987); 2/ porphyry type Cu-Mo deposit (Bardtze - Bonev & Yordanov, 1983). Molibdenite-sheelitic to chalcopyrite-molibdenite-sheelitic ore mineralizations are established also.
- Rock metasomatic alteration is presented by magnesial and calcic skarns with thickness up to several hundreds of meters, high temperature K-alteration and Q-Ser alteration to greisen like alteration.
- In the formation of the pluton we distinguish two stages: 1/ the formation of the monzonitoide intrusion (I to III phases) with K-Ar age 77-74 Ma; 2/ the formation of the porphyritic IV phase with K-Ar age 66 Ma in a different than the first stage strain field and at lower depth.

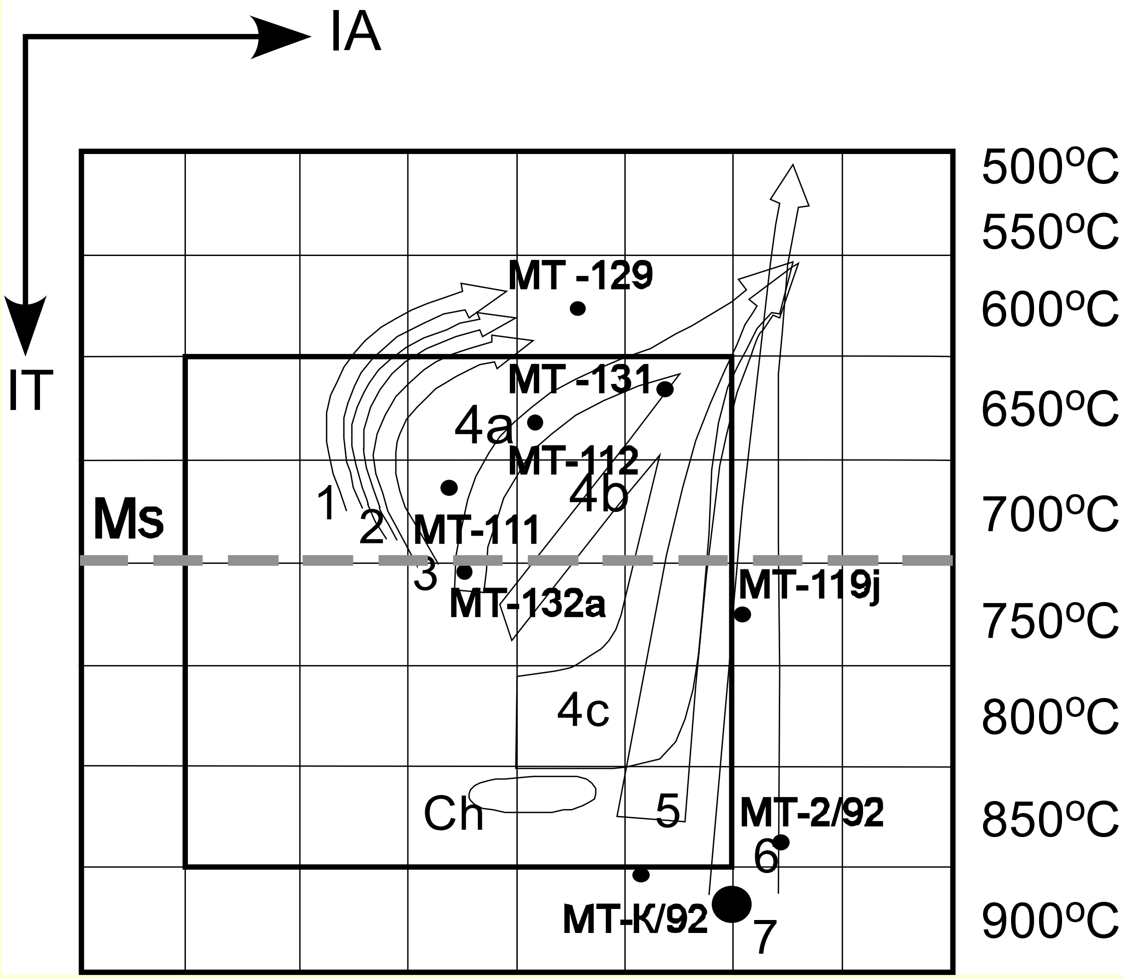


Malko Turnovo
T2-3
Propada
Mladenovo
N
T2-3
Polezhanovo
J1-2
Gradishte
Mogilishte
Stiptsite
Keremedchiev
Chukar
Mahlenski
Chukar
Chernogorovo
Burdtse
Turkey
T2-3
0 500 1000 m
Granite porphyry dykes
Porphyry rocks of the IV phase
Quartz-syenites - III phase
Monzonitoides - II phase
Basic plutonic rocks of the I phase
J1-2 Lower Jurassic sedimentary rocks
T2-3 Lipachka and Malkoturnovska suites of sedimentary Mid Triassic rocks
Trust line
Geological boundaries
State borders

Modal composition of the monzonitoides from Malko Tarnovo pluton



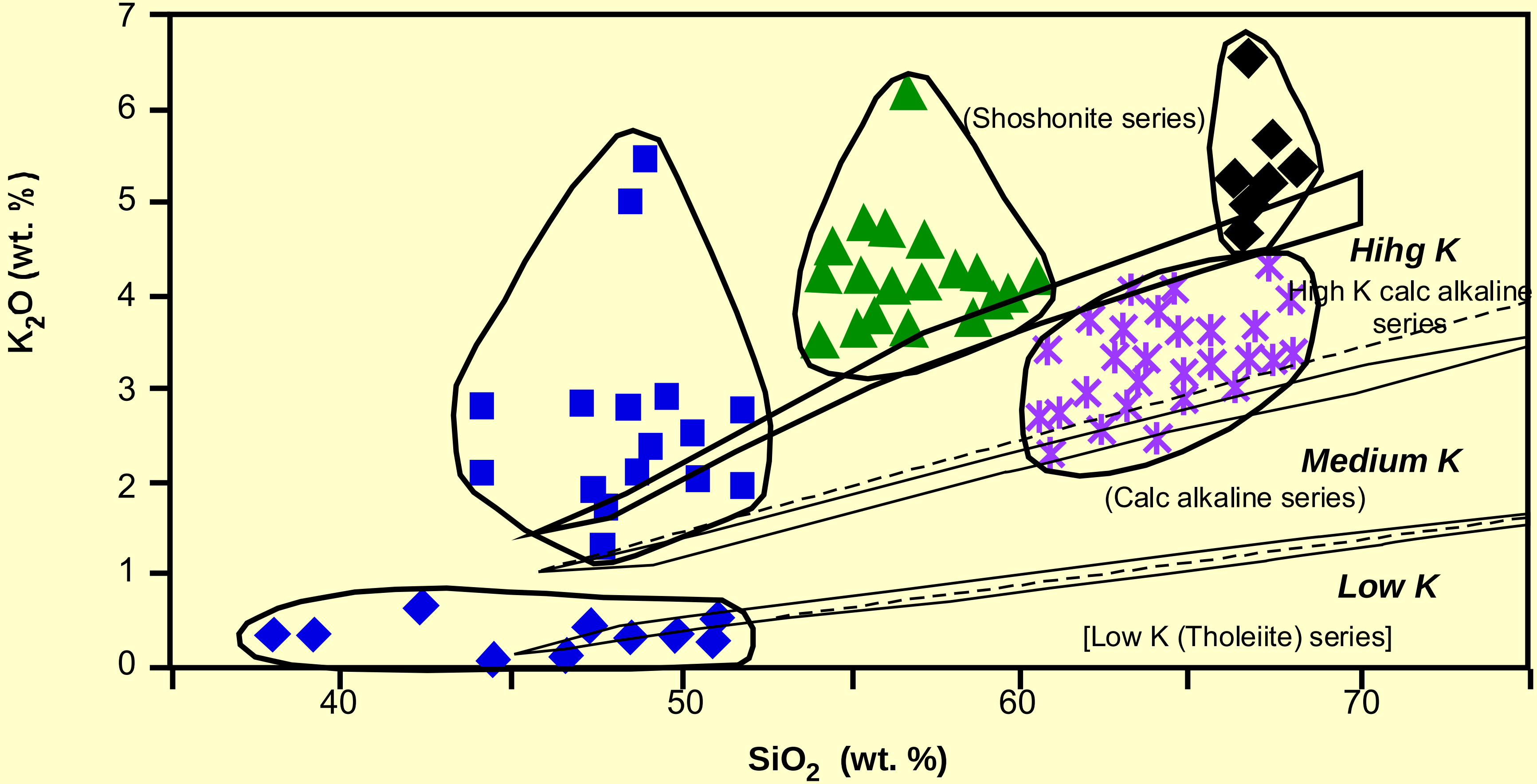
Zircon morphology after Pupin (1980)



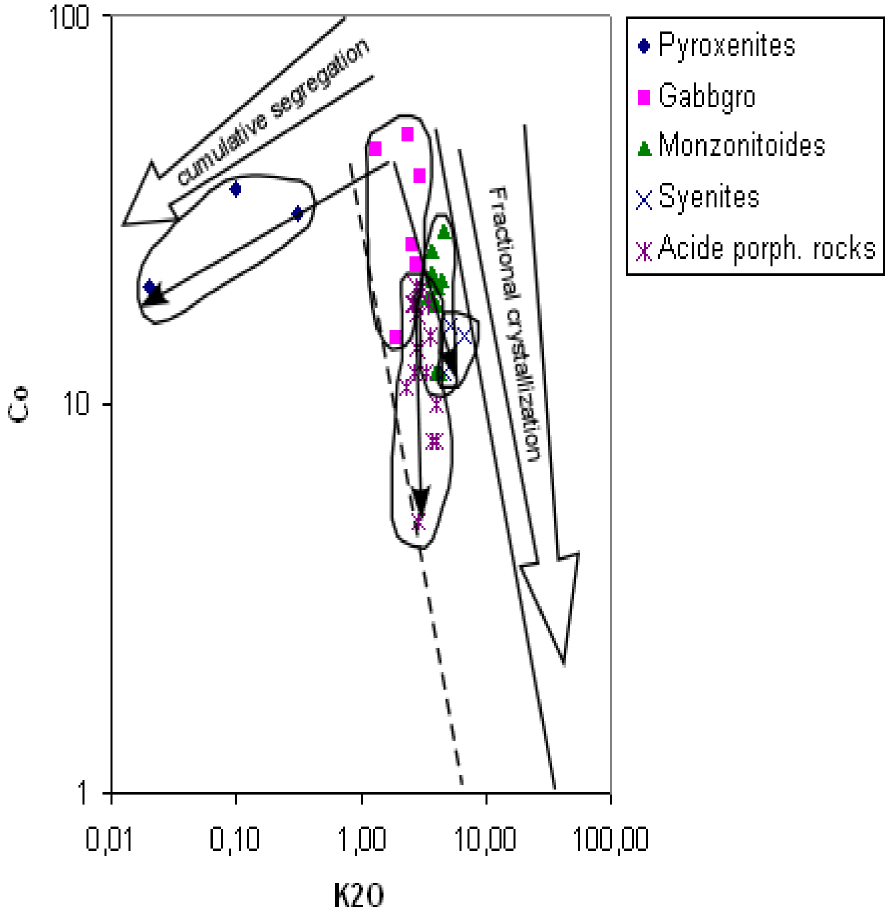
Chemical characteristics of the magmatic rocks

- Based on its chemical and textural characteristics the first basic phase is divided in two rock groups: a/gabbro to monzogabbro; b/ pyroxenite to gabbro-pyroxenite ortho- to mesocumulates.
- Monzonitoides build up an evolutionary trend in the high-K series
- Porphyritic rocks are medium-K to mainly high-K with K-alkalinity clearly lower than monzonitoides.
- Magmatic evolution of monzonitoides and porphyritic rocks is characterized by increasing of K_2O and Na_2O, Rb, Y, Zr, Ba, Nb and decreasing of all the others major oxides and V, Cr, Ni, Co, Sc.

K-alkalinity of the plutonic rocks from the Malko Tarnovo pluton



log Co – log K_2O diagram for the plutonic rocks of the MalkoTarnovo intrusion

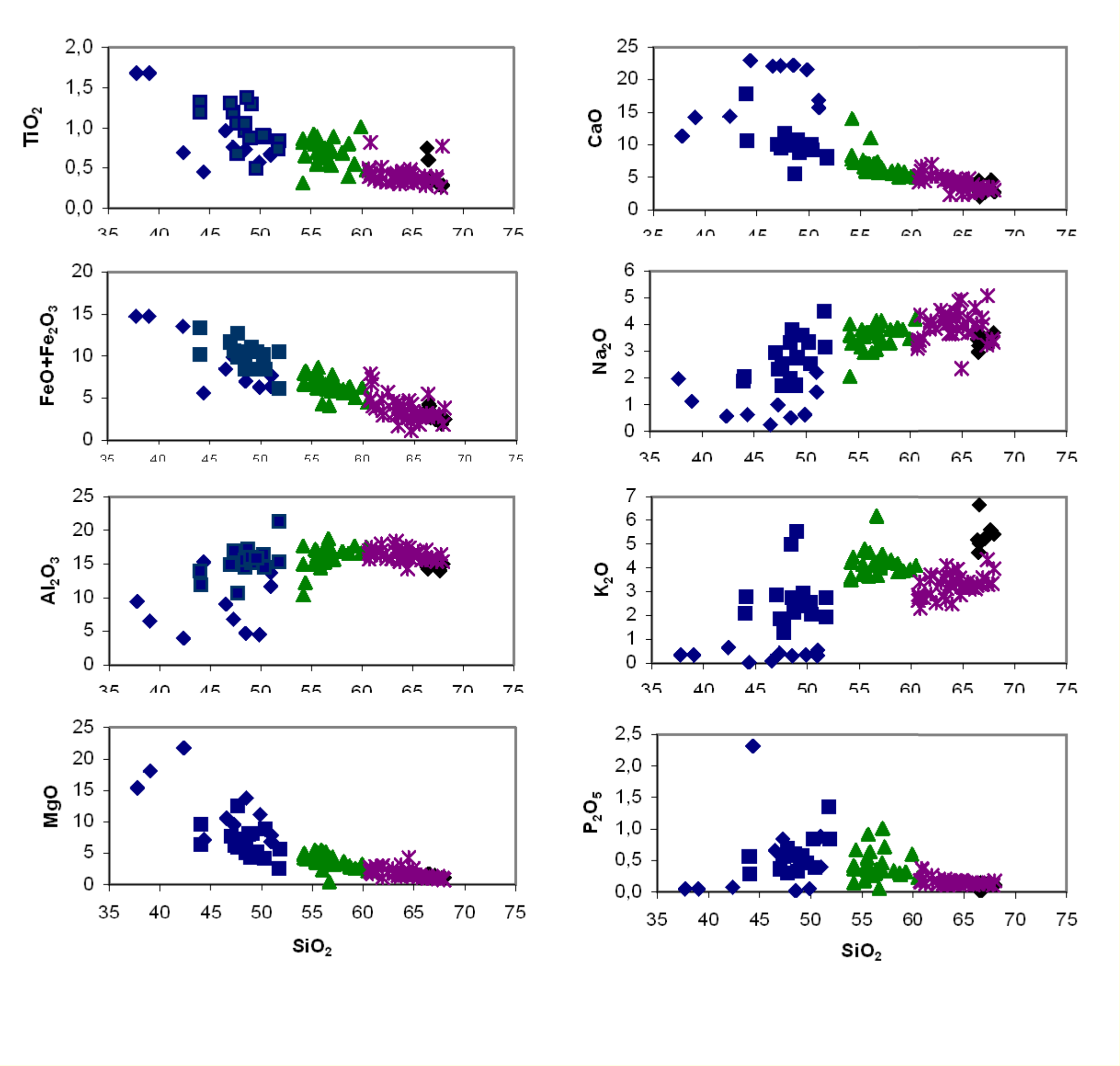


- Pyroxenites are cumulative facies segregated during the crystallization of the gabbro- to monzogabbro parental magma.
- The main mechanism of the magmatic differentiation is the fractional crystallization

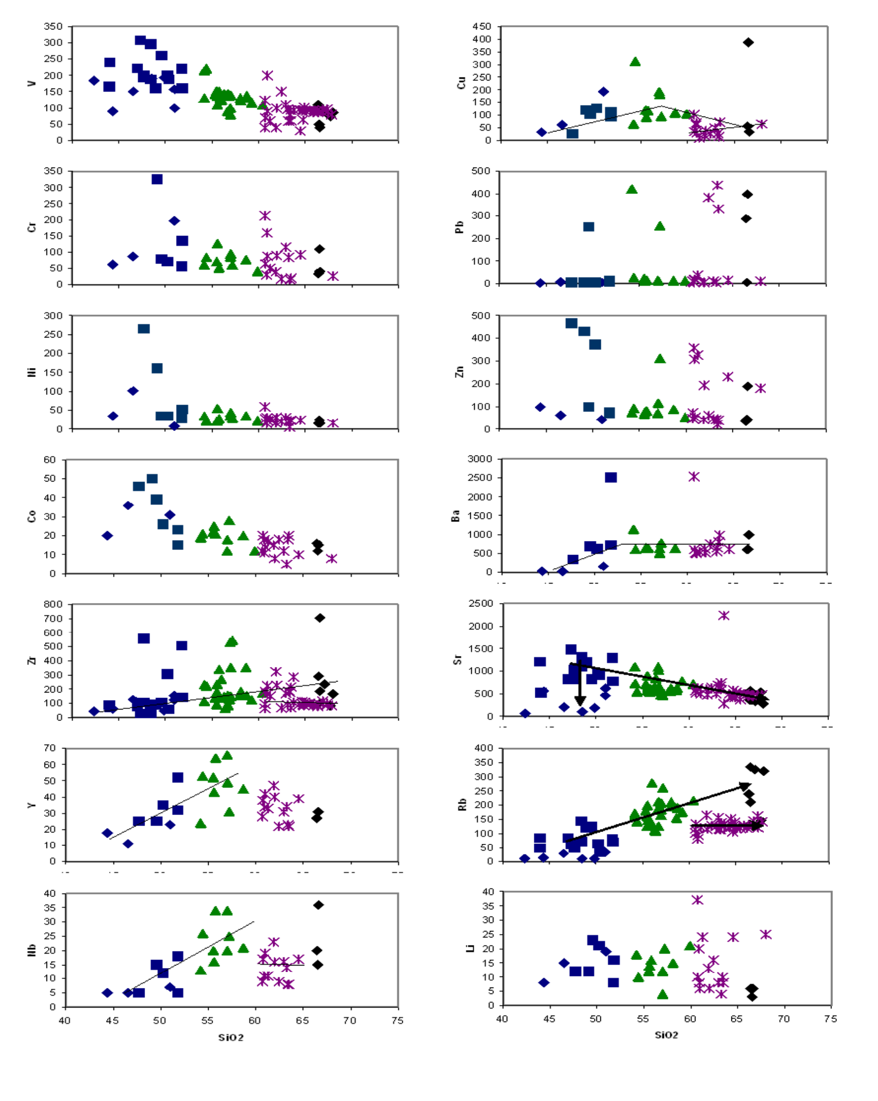
Chemical characteristics of the magmatic rocks

- Monzonitoides and porphyritic rocks show clearly different evolution trends for K_2O, Rb, Zr, Cu, Y and Nb.
- For about the same SiO_2, cumulates show higher values for CaO and MgO and lower contents for Al_2O_3, K_2O, Na_2O, TiO_2, Zn, Ba, Sr, Rb, Nb, V, Y compared to gabbros and monzogabbros.
- Cumulative rocks are formed mainly by the segregation and accumulation of CPx.
- The evolution of the monzonitoide magmatism is due mainly to the fractionation of CPx, Mt and in minor degree to Pl, Ol and Hb.
- The evolution of porphyritic intrusive rocks I due to the fractionation of Cpx, Mt, Hb and less Pl.

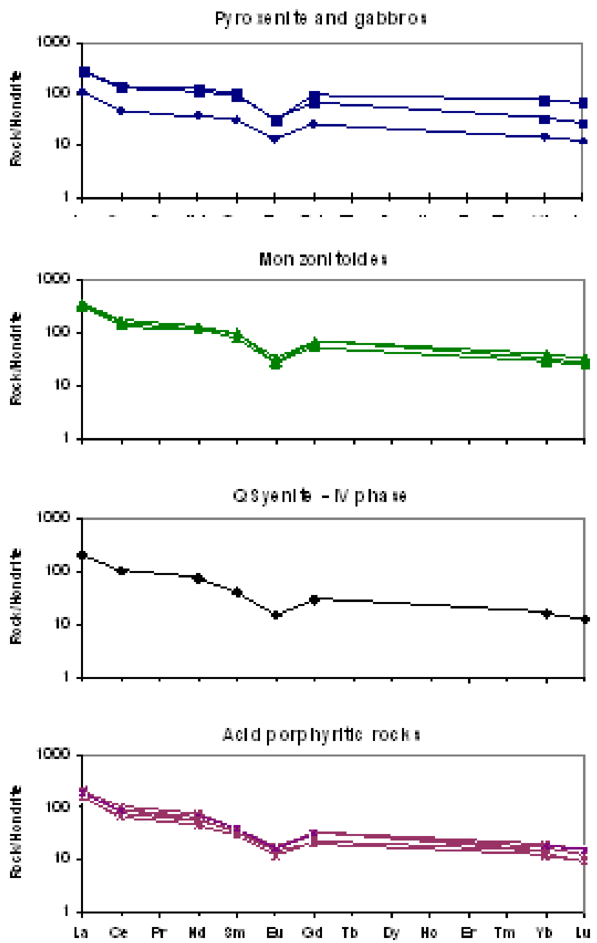
Harker diagrams for major oxides



Harker diagrams for trace elements

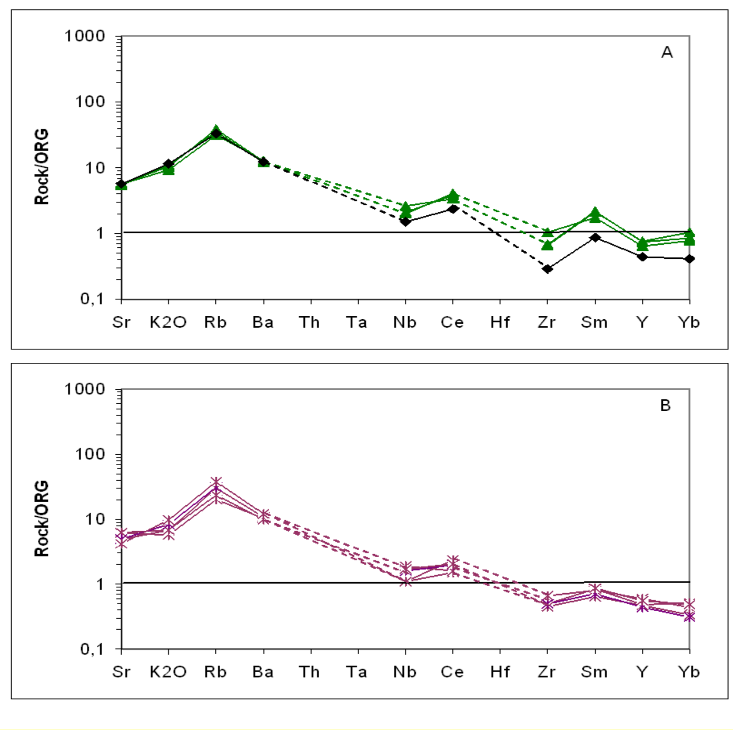


REE in plutonic rocks from the Malko Tarnovo intrusion



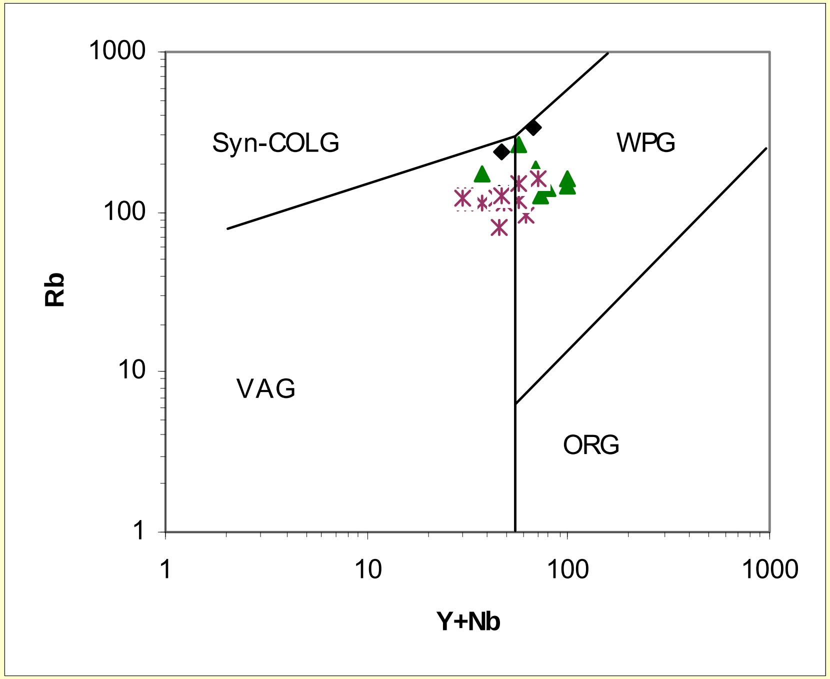
- The hondrite normalized patterns of all the plutonic rocks are with a slop from LREE to HREE and negative Eu anomaly.
- La/Yb ratio increases with magmatic evolution: basic rocks – 3.8-8; monzonitoides – 8-11,7; Q-syenites – 12.9; Porphyritic rocks – 9,5-15.3.
- The Eu anomaly shows small intra phase variations and for monzonitiodes is rather constant (0.31-0.44). For porphyritic rocks the Eu anomaly is smaller (0.47-0.6)
- The ΣREE increases from pyroxenites (114) to gabbros (304-344) to monzonites (340-382), but is smaller in Q-syenites (209). ΣREE for porphyritic rocks is 143-214.

ORG-normalized spidergrams for monzonites and porphyrites from Malko Tarnovo pluton



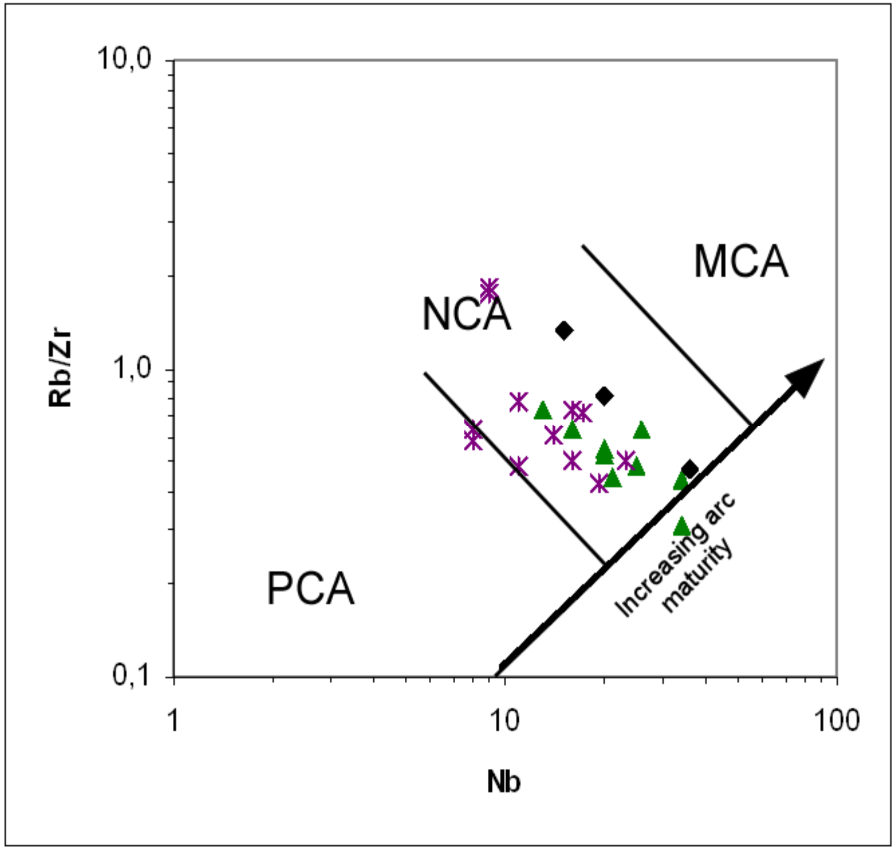
- ORG-normalized patterns for Monzonitoides and porphyritic rocks have the shape characteristic for volcanic arc granitoides with enrichment in LILE and negative anomalies for Nb and Zr.
- Porphyritic rocks differ from monzonitoides by their lower contents in HFSE and less pronounced negative anomalies.

Tectonic setting of the Malko Tarnovo magmatism



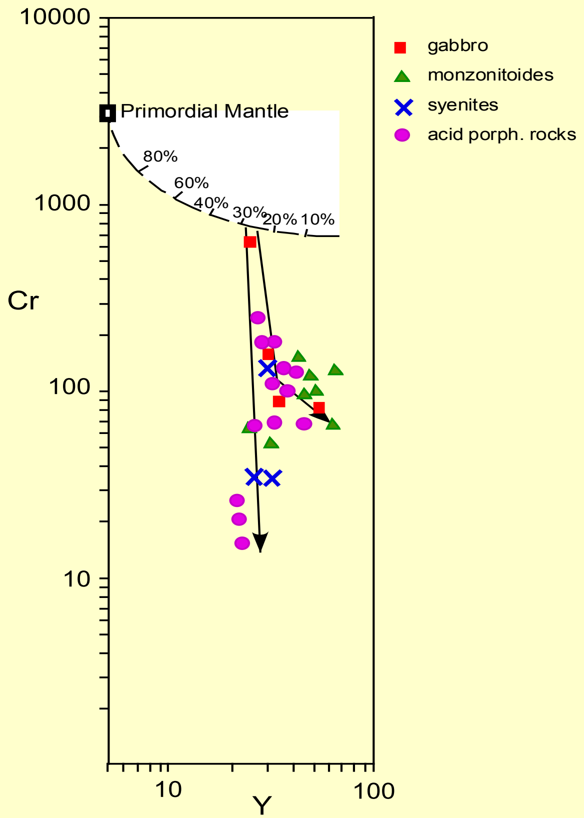
- The plots of the monzonitoides and the porphyritic rocks are at the border between the volcanic arc and within plate granitoides
- This peculiarity is probably due to the raised Na and K alkalinity
- According to the ORG normalized spidergram magmatism is synsubductional related to an active continental margin with relatively thick continental crust

Tectonic Tectonic setting of the Malko Tarnovo magmatism setting



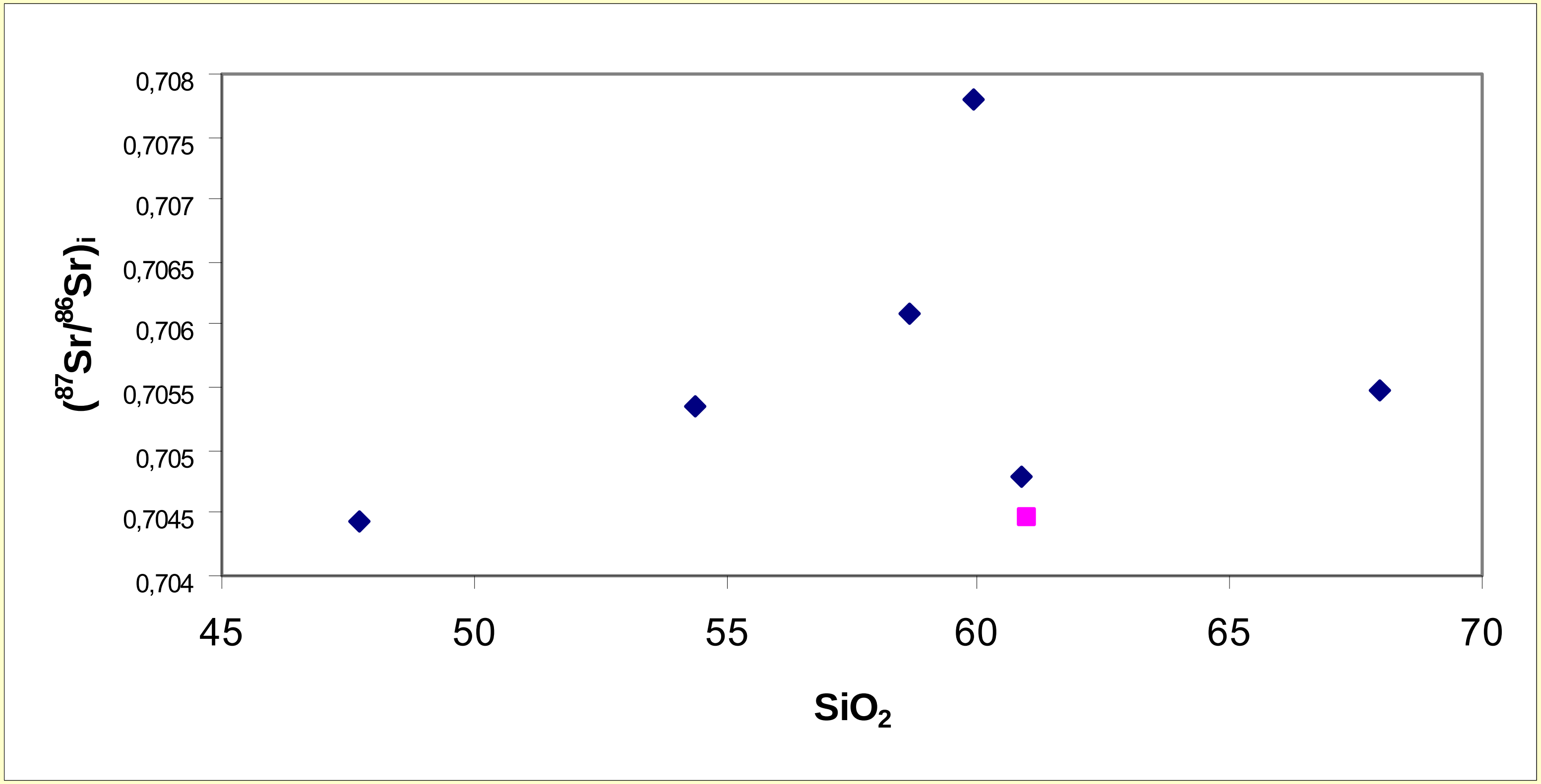
- According to the Rb/Zr – Nb diagram (Brown et al., 1984) the magmatism evolves in conditions of Normal continental arc.

Melting degree of the source



- According to the Cr-Y diagram the melting degree of the source is about 24-27%, characteristic for subductional setting.

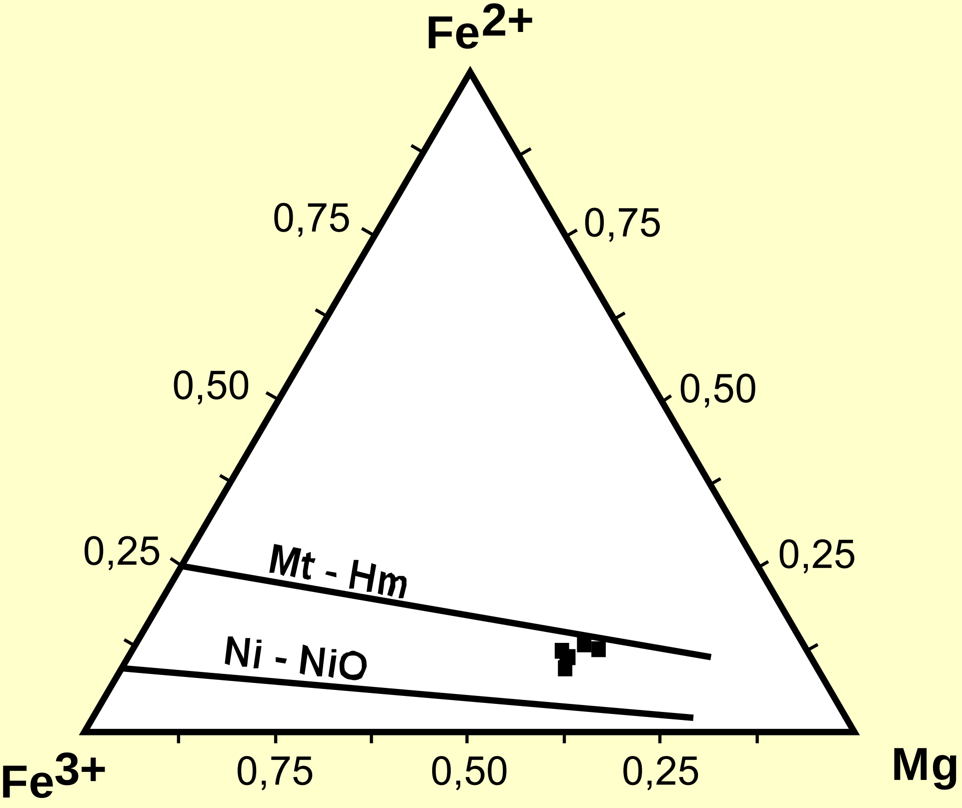
$^{87}Sr/^{86}Sr$ isotopic data



Thermo-barometric estimations

	T (^oC) - zircon morphology, Pupin (1980)	**T** (^oC) Hb-Pl geotherm. Blundy & Holland (1990)	**P** (kbars) Schmidt (1992)
Gabbroides		830 - 950	7.1
Monzonitoides	750 - 900	910 - 730	8.8 – 5.4
Porphyritic rocks	620 - 730	700 - 730	3.7 – 5.6

Oxygen fugacity



- The estimation of the fO_2 is based on the composition of Bi (monomineral fraction analyzed with classical chemical analysis)
- fO_2 for gabbro and syenites is about 0.5 to 1 unit below the Mt-Hm buffer; for porphyritic rocks – 1-2 units below the Mt-Hm buffer.
- Those are oxidized conditions of the melts favorable for the S and ore elements exsolution from the melt

Conclusions

- The Malko Tarnovo pluton is formed in two stages: 1/ from a monzonitoide and; 2/ a calc alkaline magma.
- The K-Ar age of the monzonitoide magmatic phases is 77-74 Ma and for the porphyritic rocks – 66 Ma.
- The main process of the magmatic evolution is the mineral fractionation (CPx, Mt, and less Ol, Hb, Pl.
- The parental magma of the monzonitoide phases is gabbroic formed during a 24-27 % melting of a mantle source. The magmatism is syn subdutional, most probably in an active continental margin.
- The magma is crust contamined during its evolution.
- The monzonitoide rocks are formed in a deeper level at 5.4 to 8.8 kb and higher temperature 750-900^{o}C. The porphyritic Ca-alk rocks had crystallised at shallower conditions 3.7-5.6 kb in a different strain field and lower temperatures – 600-700^{o}C.

Conclusions

- The monzonitoide and Ca-alk magmas are oxidized that is favorable for the exsolution of S and ore elements from the magma and the formation of the orthomagmatic ore-bearing hydrothermal fluid.
- The shallower depth of the porphyry rocks crystallization is more favorable for the earlier fluid saturation and earlier water exsolution from magma (formation of porphyry type deposit).