Primitive high-K ankaramitic magmas in the Eastern Srednogorie continental arc: comparison between melt inclusion geochemistry and bulk-rock compositions

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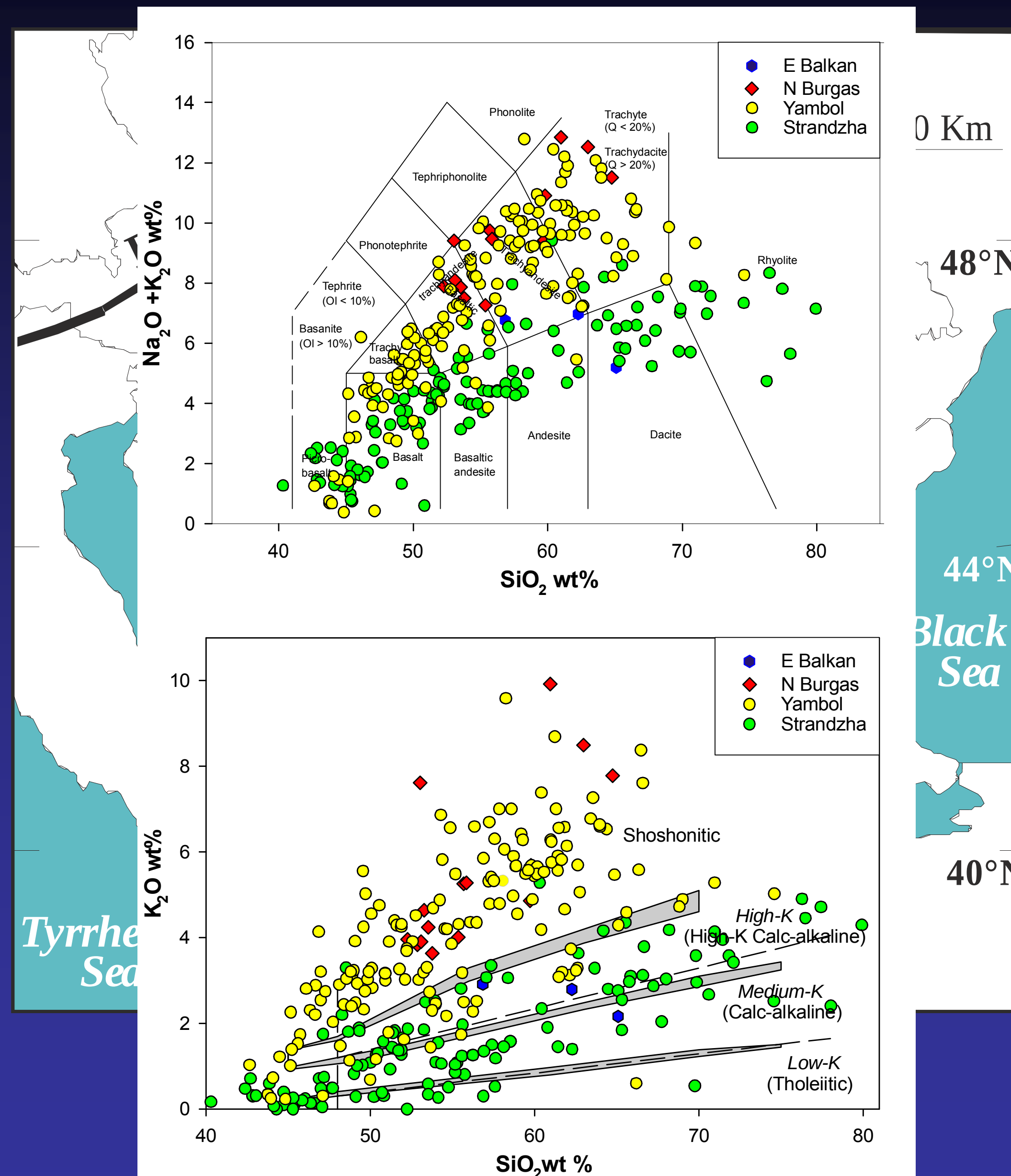
Eastern Srednogorie in ABTS belt

ESZ - the most interesting part of the entire ABTS belt from magmatic point of view

Large distribution of mafic to ultramafic rocks

- *Strong variation in K*
- *Mafic magmas - prime goal of any petrological study in the island arcs*



Task

- Focus - ankaramitic MI in a cumulitic rock and the ankaramitic lavas and dikes from the Central part of the ESZ

Aims :

– Through study of the composition of MI and lavas to prove the existence of the ankaramitic magma

– To put constrains on the origin of the Eastern Srednogorie ankaramites.

What is ankaramite?

- High MgO, CaO and CaO/Al_2O_3 >1
- Two groups: a silca-poor, hy –normative group and an alkali-rich, ne-normative group (Sciano et al., 2000; Kogiso and Hirschman, 2001)
  - 1-st group - mid-ocean ridges, back-arcs, and ocean islands
  - 2-nd group - arc environment

Analytical techniques

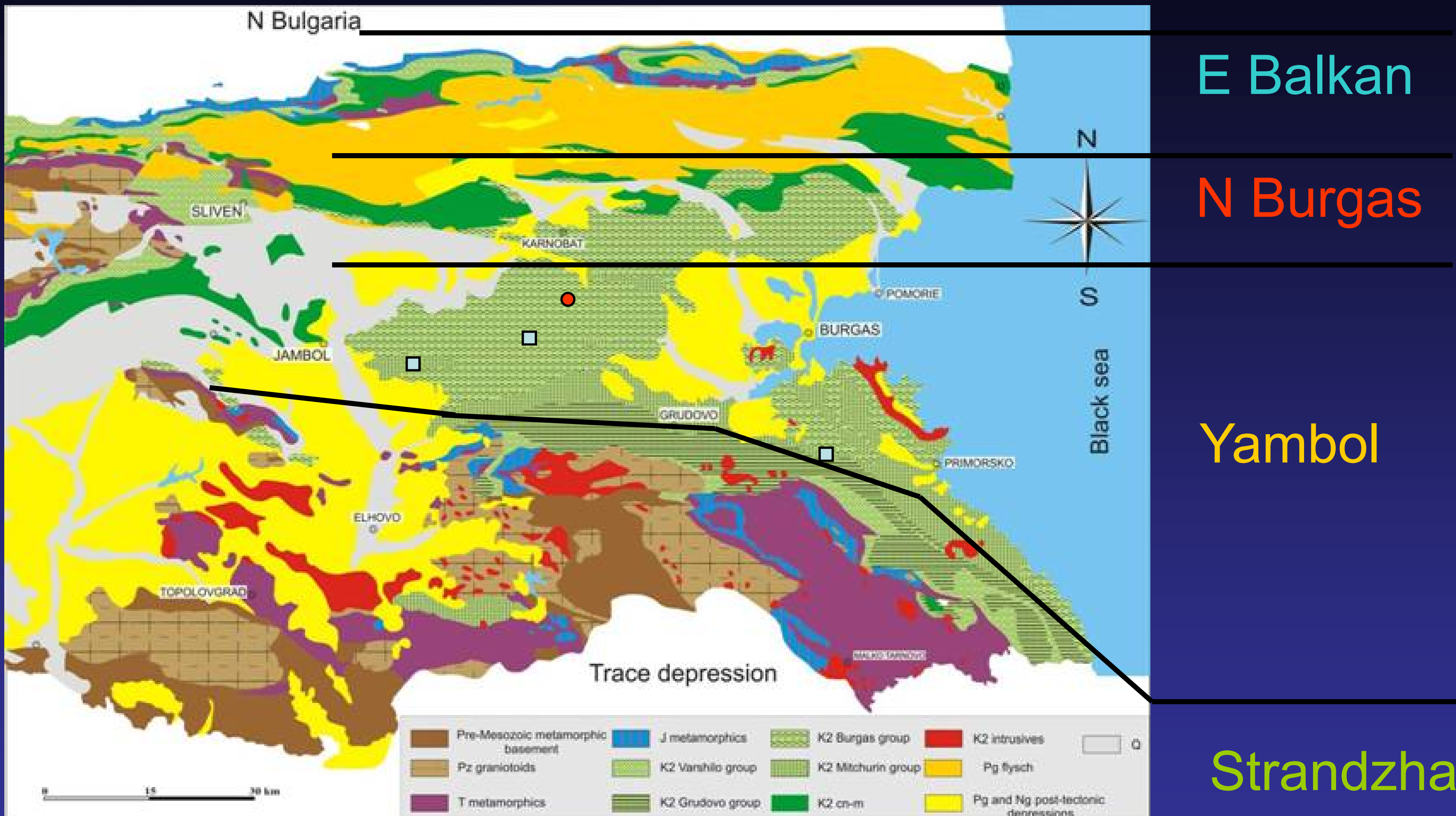
- Major and trace elements of bulc rocks – XRF University of Florence and Zurich and LA-ICP/MS in glass from XRF in Zurich

- Major elements of minerals and MIs - JEOL 870 Superprobe at the University of Florence and ….at the University of Zurich

- Trace elements of MIs - LA ICP/MS in the laboratories at the University of ETH, Zurich and University of Perugia

- Sr and Pb Isotopic data - at the University of Zurich

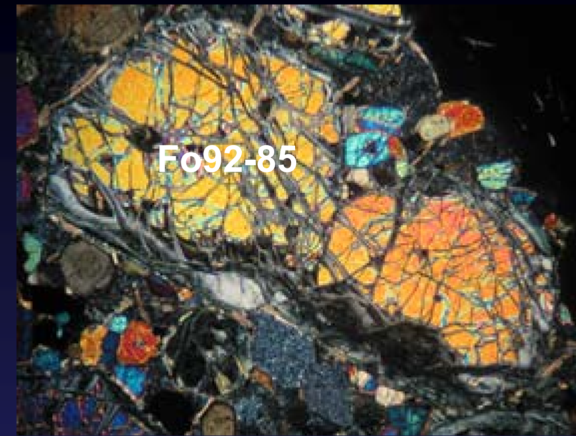
Sample location

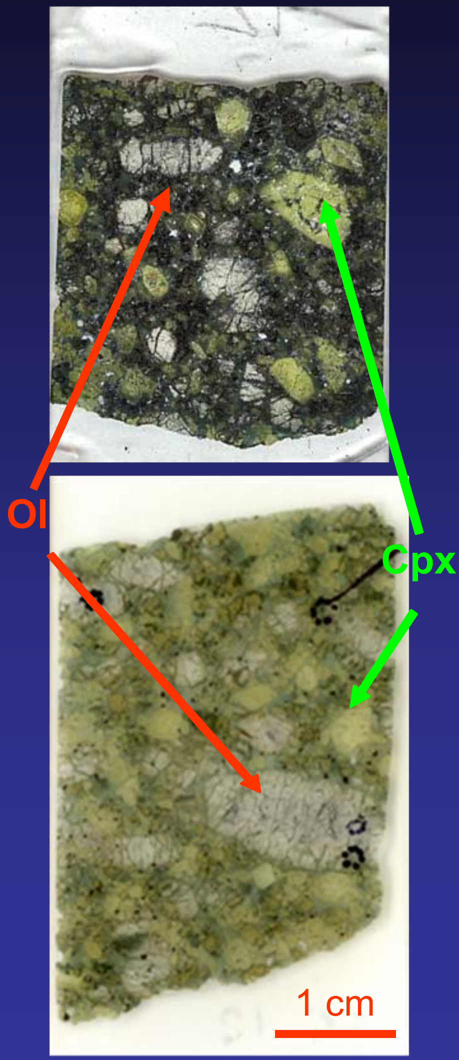


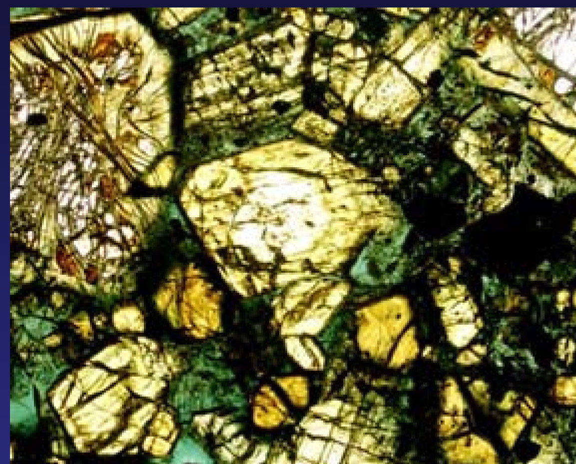
- "Picrite" - Dragantsi
- Ankaramites

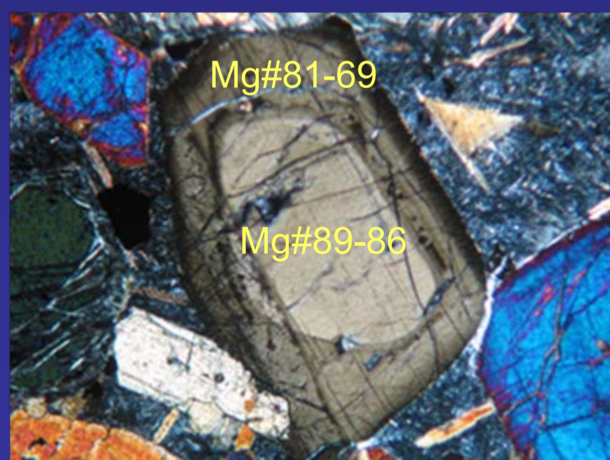
Cumulitic lava "picrite" & MI

Petrography and mineral chemistry









"Picrite"-strongly porphyritic- 60-70% phenocrysts- Ol, Cpx, Sp

Gm – chloritised glass, Bio, KFs, Pl, Ap

Phenocrysts

Ol=Fo_{92-85} ; CaO - 0.53-0.40 wt. %; NiO - 0.1-0.12 wt.%

Cpx- unzoned core (Mg#-89-86, oscilatory outer zone – Mg #81-69

Sp - Cr# 74-80; micropheno Cr# 65-67

T, fO_2 & H_2O content

Spinel-olivine geothermometer of Ballhaus et al. (1991), temperatures scatted between 900 and 1205 ^{o}C. The highest temperatures are likely to be close to the liquidus temperature of the magma, whereas remainder reflect post-enrapment re-equilibration

Oxygen fugacity using the oxygen barometer of the same authors is between +1 and +2 log units above FMQ buffer

H_2O content calculated by difference to 100 from the EPMA ~3 wt. %, supported by the elevated SiO_2/MgO+FeO>2.3

T-1205-900

fO_2 =+1 to +2log units above QFM

H_2O~3wt.%

Cumulitic rock

Major and trace element composition

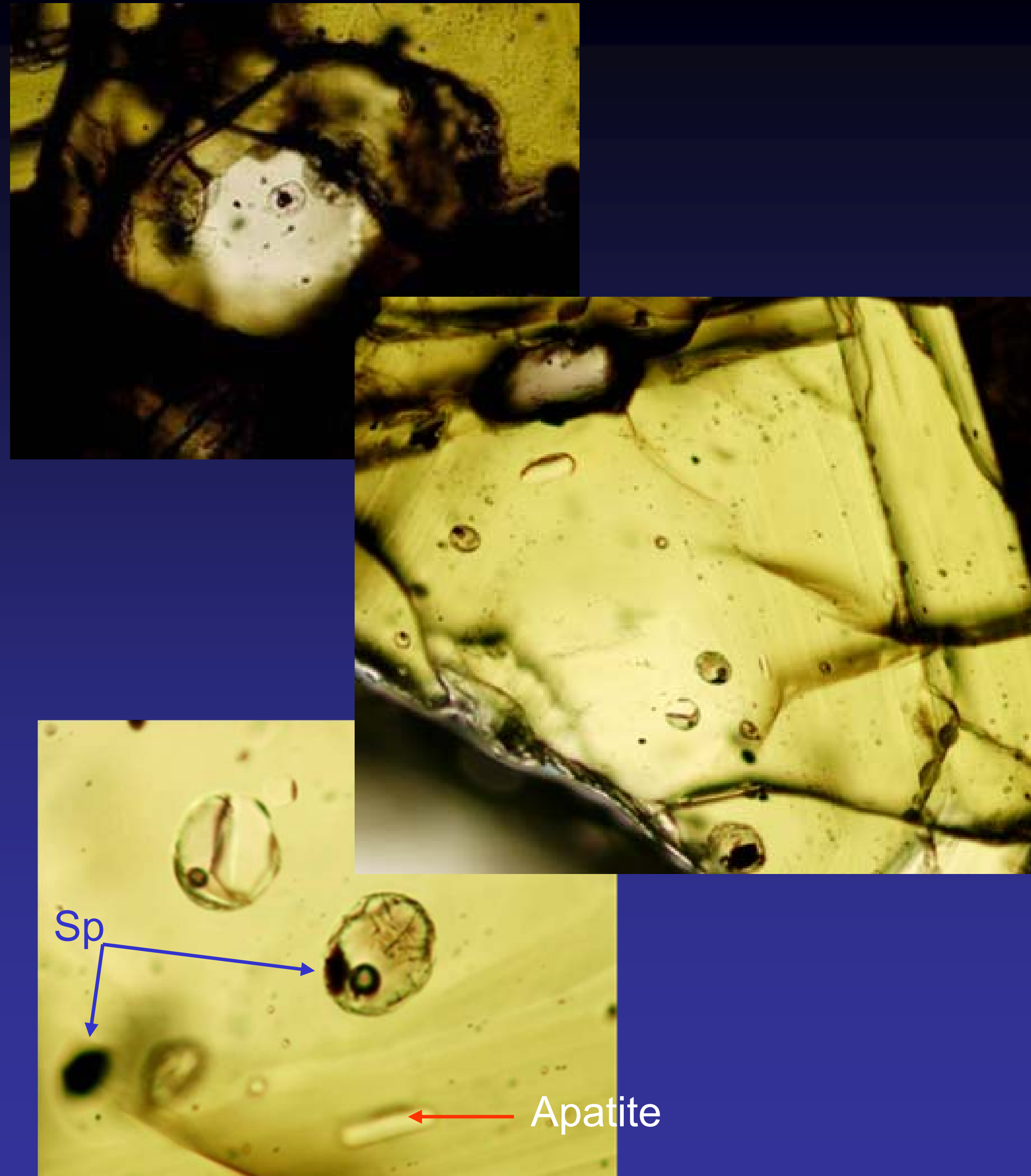
- "picrite" – in accord with their cumulitic nature: low silica (SiO_2~44 wt%), high MgO (24.4 wt%) and FeO (11.2 wt.%); very low Na_2O (0.14 wt.%) and K_2O (0.29 wt. %). Mg# of this rock - 79.6, CaO/Al_2O_3 ratio is 1.78
- high Ni (531 ppm) and Cr (1900 ppm); low LILE
- more primitive than the composition of MIs

SiO_2	43.91
TiO_2	0.26
Al_2O_3	4.34
Fe_2O_3	6.69
FeO	5.12
MnO	0.22
MgO	24.39
CaO	7.72
Na_2O	0.14
K_2O	0.29
P_2O_5	0.13
LOI	6.79
CaO/Al_2O_3	1.78
Mg#	79.6

V	106
Cr	1900
Co	97
Ni	531
Rb	11
Sr	87
Y	7
Ba	69

Melt Inclusions

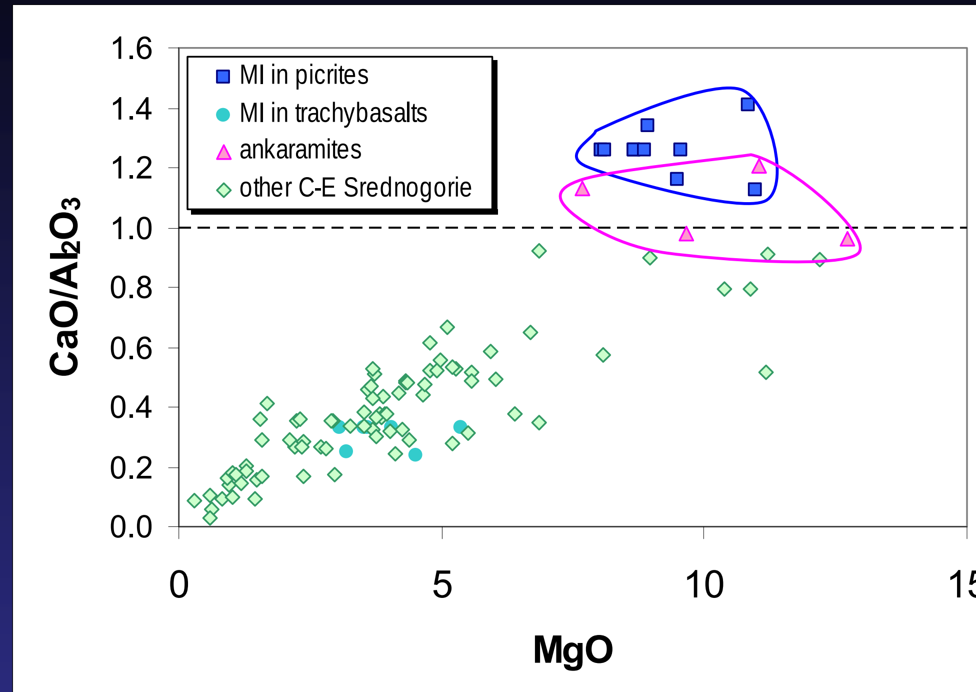
- both olivine and clinopyroxene
- rounded, ellipsoidal, negative crystal forms
- size - few microns to 40 µm
- two phase (glass and shrinkage bubles) ± spinel
- glass – colourless



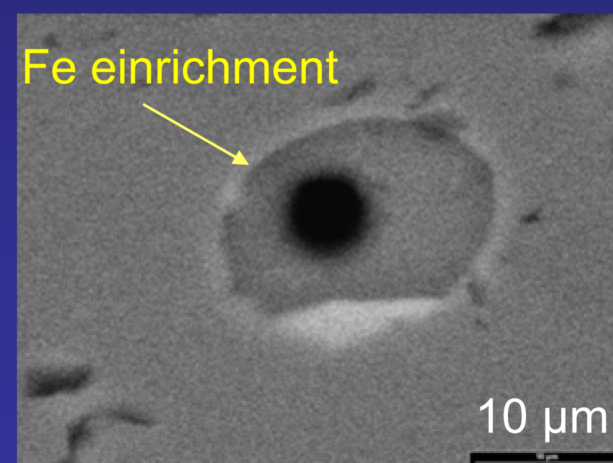
Melt inclusion composition

Major elements

	EPMA SG12	LA-ICP/MS SG12	XRF Bulc rock
SiO_2	51-52	47-51	43.91
TiO_2	~1	0.3-0.6	0.26
Al_2O_3	~16.0	9.4-11.6	4.34
FeO	~3.1	7.5-10.7	11.21
MnO	~0.1	0.1-0.2	0.22
MgO	~1.0	7.5-10.8	24.39
CaO	~17.2	13.5-15.0	7.72
Na_2O	~2.6	1.5-2.1	0.14
K_2O	~3.4	2.0-4.0	0.29
P_2O_5	~0.7		0.13



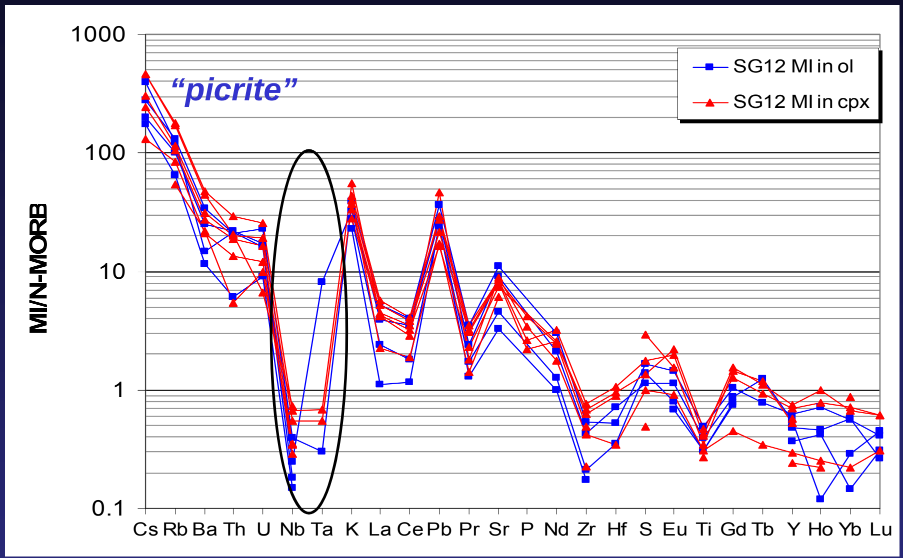
- LA analyses show lower SiO_2, : Al_2O_3, CaO and alkaline elements and higher MgO and FeO
- Lower FeO and MgO of the EPMA - caused by post-entrapment modification, due to crystallization of Fe-rich olivine onto the walls of MI and diffusion of Fe into host Ol.
- high CaO/Al_2O_3 > 1 –ankaramites; high K_2O/Na_2O>1; shoshonitic ankaramites

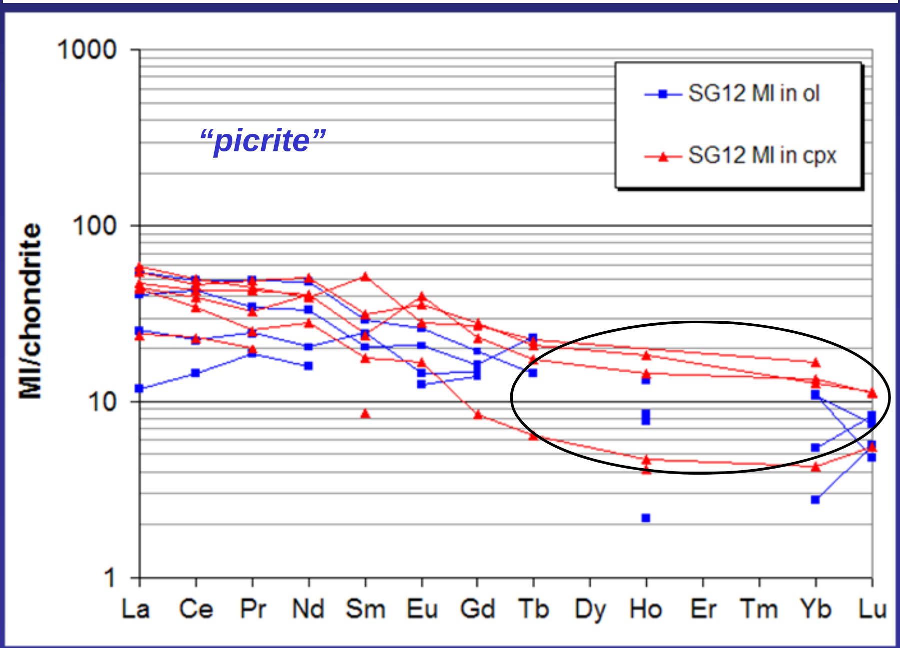


BS image

Melt inclusion composition

Trace elements





- Ol- and Cpx-hosted MIs show strong subduction-related signatures with pronounced Nb-Ta throg; Zr, Hf and Ti negative anomalies and K, Pb, Sr spikes

- Enrichment in LILE and LREE relative to HFSE and HREE

- Flat HREE

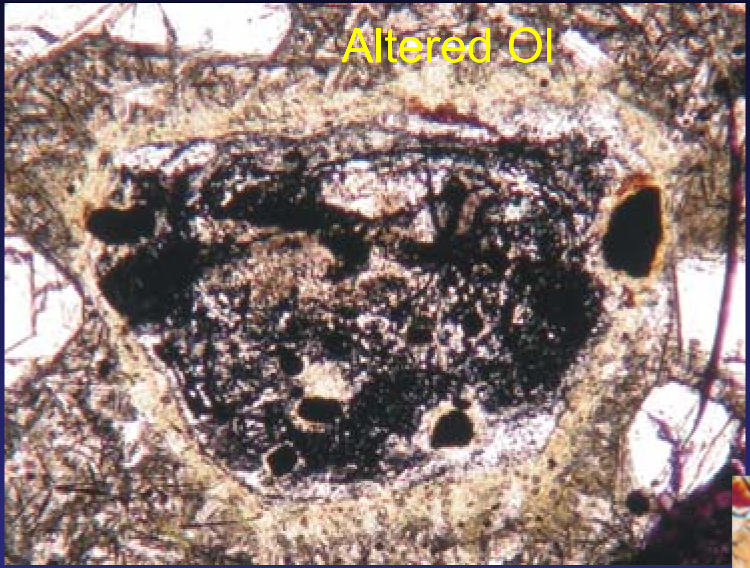
Ankaramitic lavas
Petrography

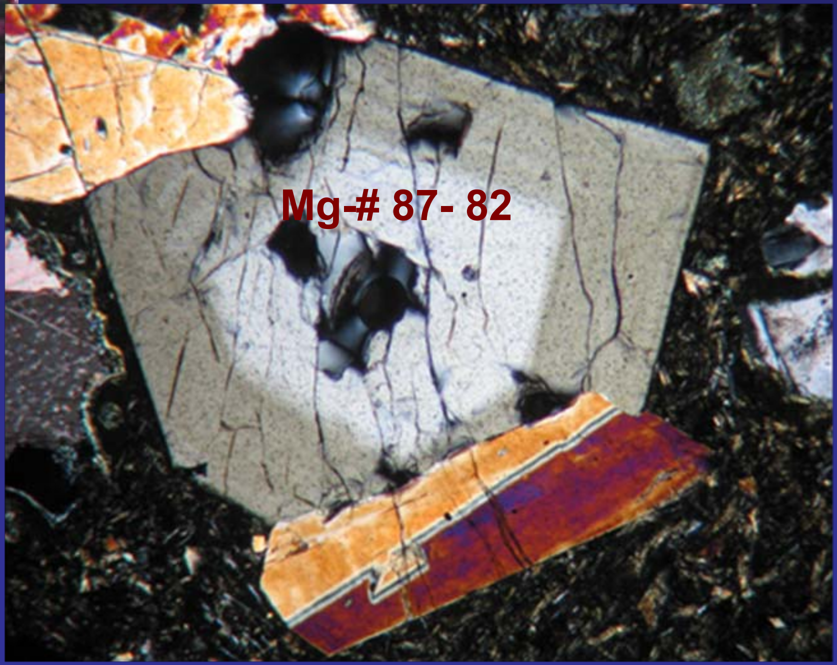
Strongly porphyritic: phenocrysts of Ol, Cpx, rare Sp

Gms- Cpx and analcite microlites in San mesostasis

Ol –always altered

Cpx – strongly zoned or sieved; core- diopside - Mg-# 87- 82 ; outer zone -Ti augite Mg # to 66



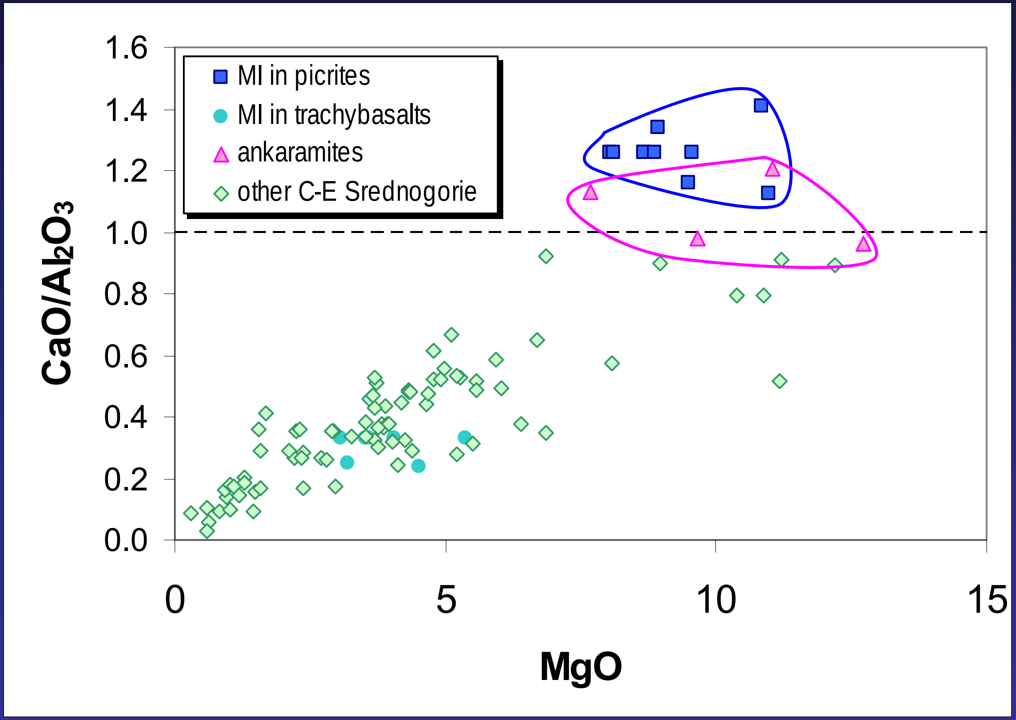


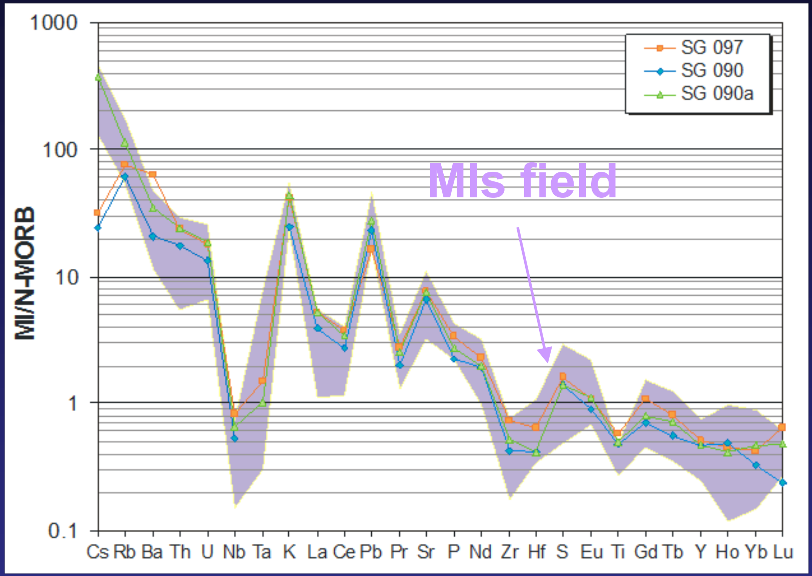
Ankaramitic lava flows and dykes

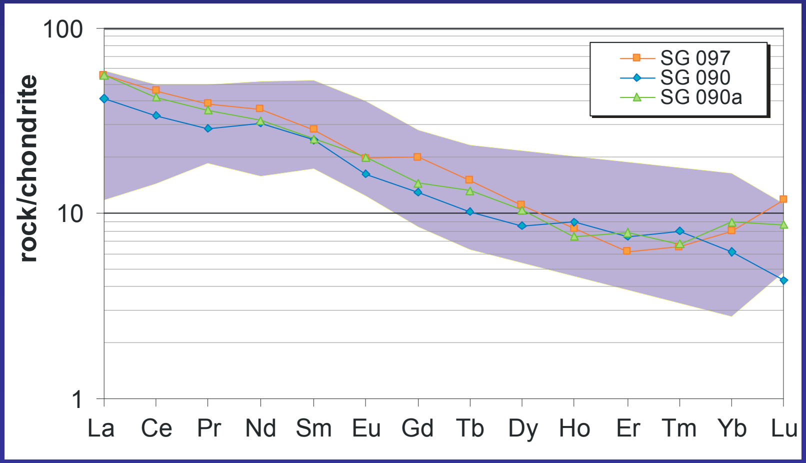
Major and trace elements

Ne-normative; Mg# 63.4-69.4

High-CaO -10.3 -13.4; Al_2O_3 11.0-12.2







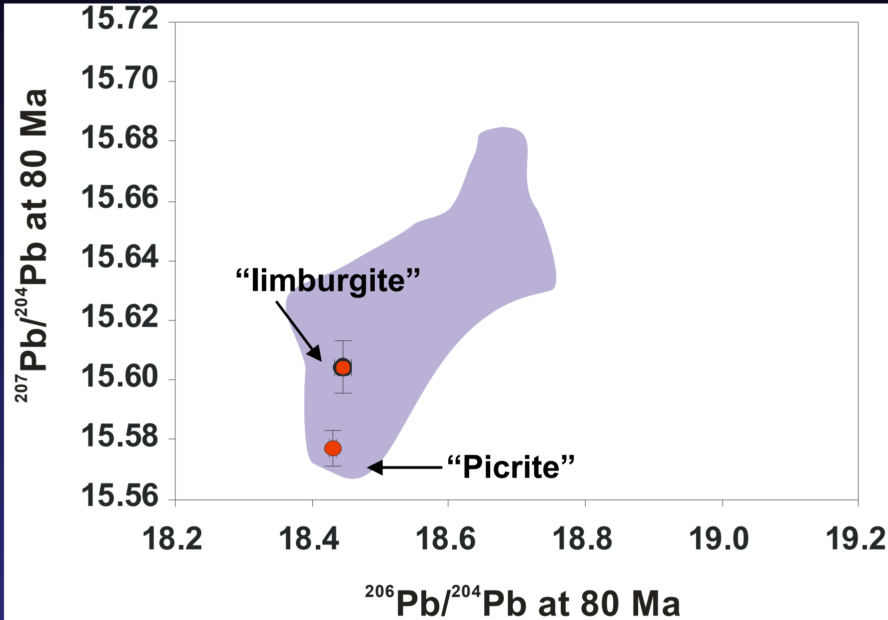
N-MORB normalized patterns and chondrite normalized patterns of lavas – display strong resemblance to MI but narrower variations

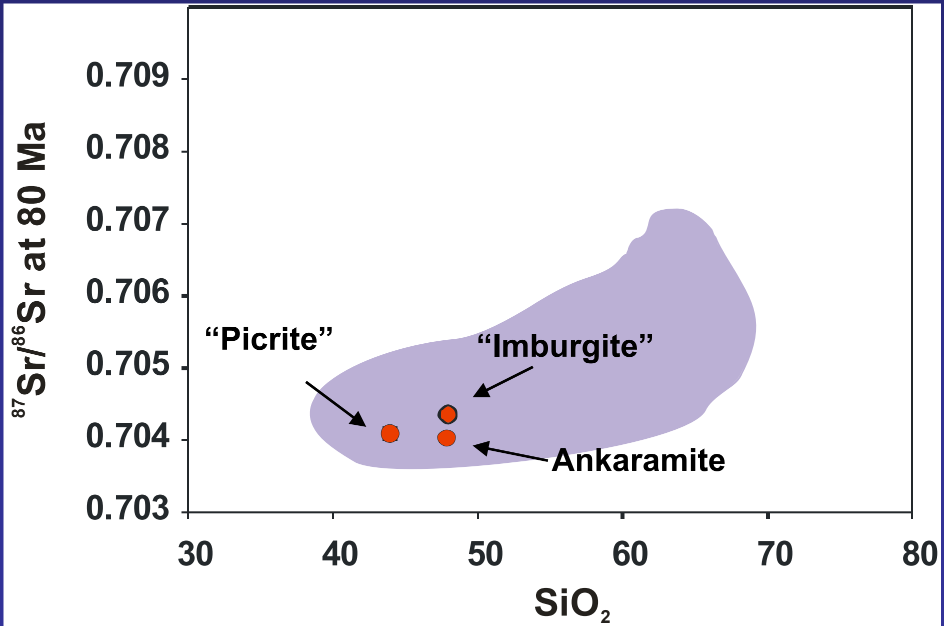
Ankaramitic lavas

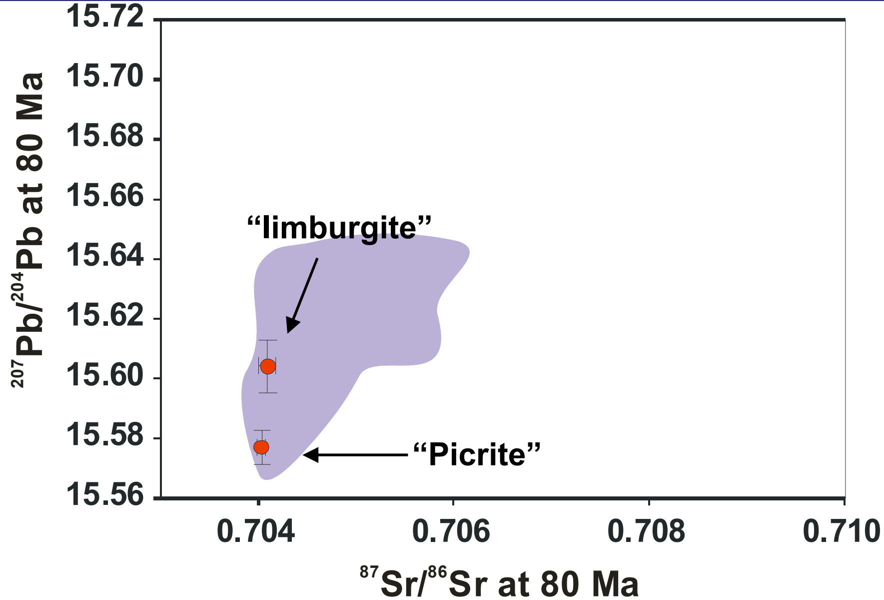
Sr and Pb Isotopic compositions

- The picrite hosting MIs and an ankaramite lava have indistinguishable Sr isotopic values and are **among the least radiogenic Eastern Srednogorie rocks**

- Pb isotopes of the picrite are among the least radiogenic compared to the other Eastern Srednogorie rocks







Discussion

In the following discussion we will address two issues :

- **Do the ankaramiric melts exist?**
- **Where they have been generated?**

Do the ankaramitic melts exist?

The existence of ankaramitic magma - debate.

– the ankaramites - a variety of picrite enriched in Ca by accumulation of clinopyroxene.

– findings of Ne-normative ankaramitic MI in island-arc rocks - designated as a distinctive magma type (Sciano et al., 2000).

– doubt on the ankaramitic characteristics of the MI melt inclusions:

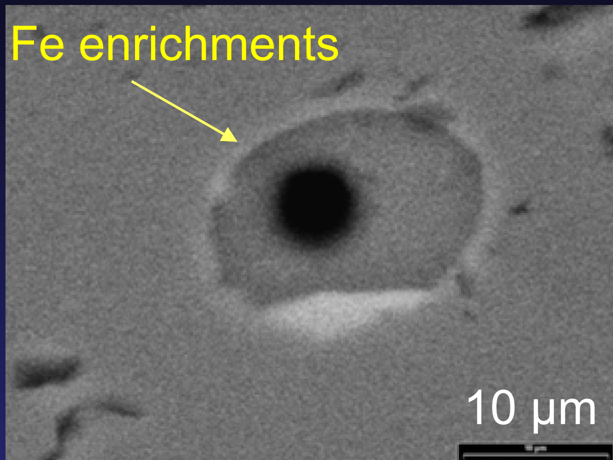
– high-Ca content and CaO/Al_2O_3 ratio in high-Mg olivines - the result of diffusion of Ca through the olivine lattice or as the result of local melting reactions.

Arguments in favor of the primary high-Ca melt in the ESZ

Two lines of evidence:

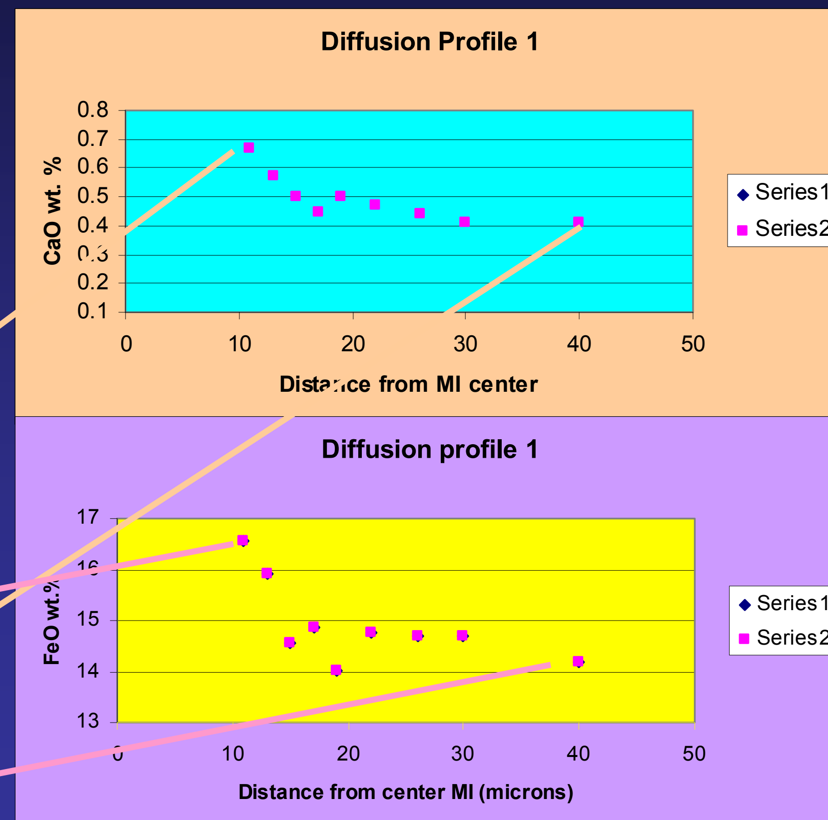
- **Generally high CaO contents of the Ol - (0.53-0.39 wt. %); much higher than those in typical subduction-related magmas - 0.25-0.15 wt. %**
- **Diffusion Fe and Ca from the MI into host Ol**

Diffusion phenomena

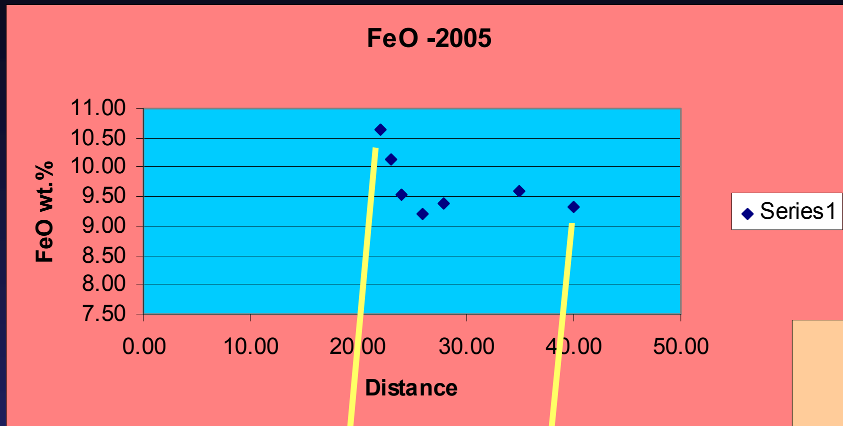


BSE image

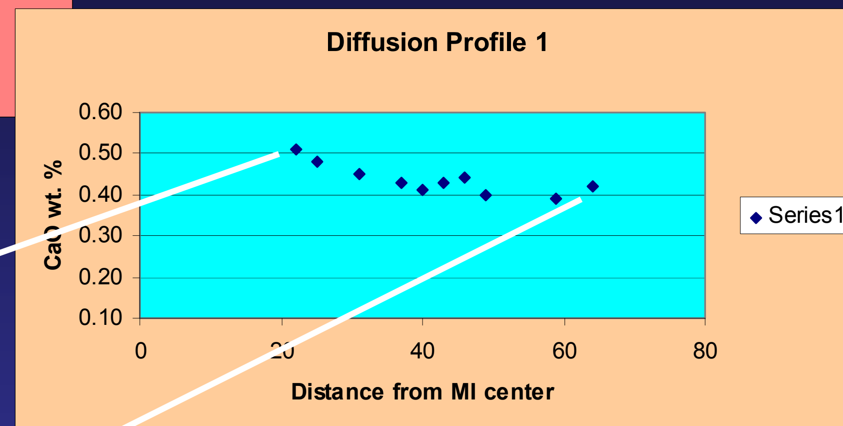
High-resolution profiles (2-3 µm steps) from MI located into the rim of an Ol crystal (Fo $_{85}$)

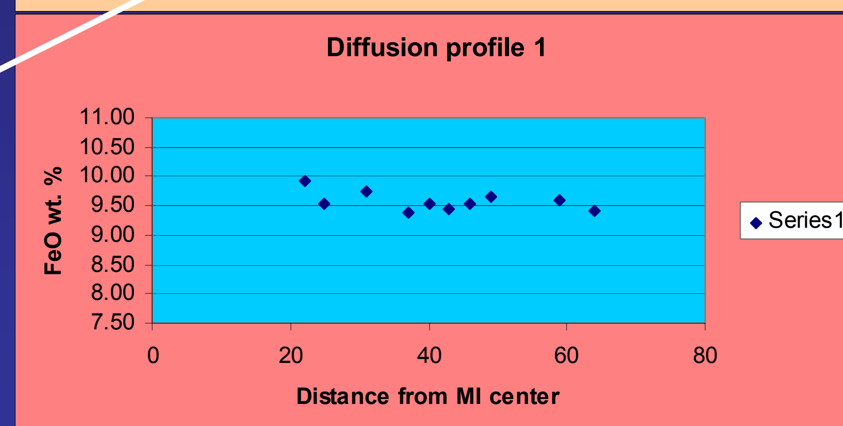


Diffusion phenomena



High-resolution profiles (2-3 μm steps) from MI located into Ol core (Fo_{90})

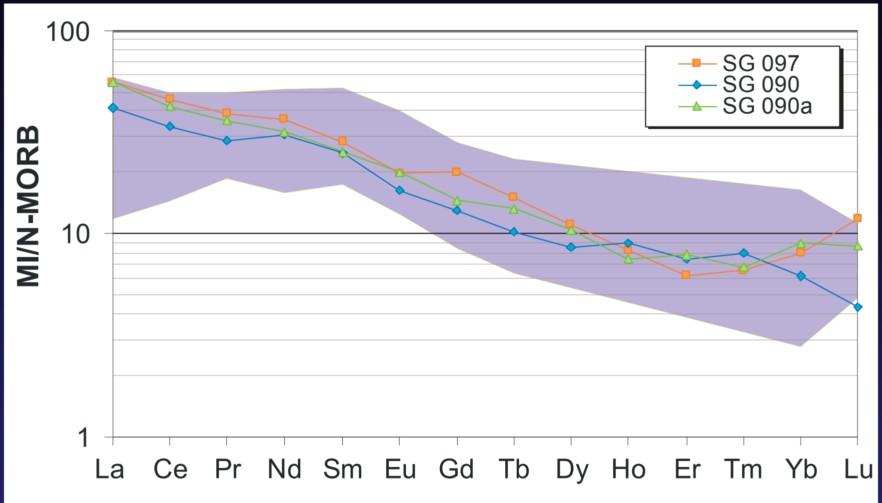


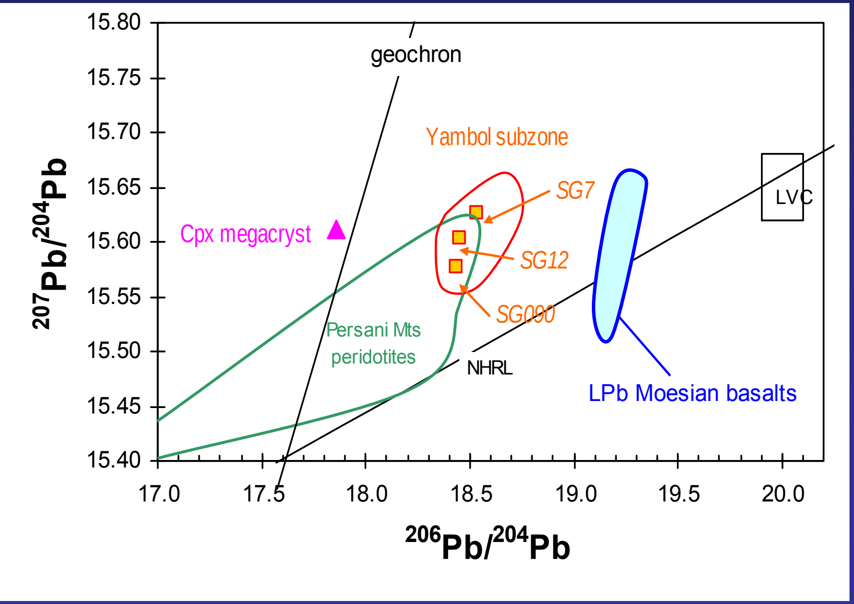


Conclusion: no diffusion of CaO from the hosting melt; there is a diffusion of Ca from the MI into the host Ol

Where the ankaramites have been generated?

- Flat HREE distribution - generation in a non-garnet lithospheric source
- This is confirmed by the isotopic difference with the asthenospheric-derived WP basalts and EAR
- Termodynamic calculations - Ne-normative Ca-rich melts melts can not be produced by partial melting of common lherzolite mantle compositions
- Lower crustal and upper mantle pyroxenites (Sciano et al., 2000)
- Melting experimental work with variable Ca-rich pyroxene + olivine + amphibole assemblages at 0.5-1 GPa and temperatures of 1175-1350 oC (Medard et al., 2 006)
- Problems – Low Mg/Fe ratio of the melts and low Fo content of Ol; high TiO_2





May be in metasomatised mantle source (Cpx, Ol +Amph & Phl !!!

Conclusions

- **Ne-normative ankaramites are the most primitive magmas in the Yambol subzone of the Eastern Srednogorie zone**
- **Diffusion profiles around the MIs suggest that the high-Ca content is a primary feature of the ankaramitic magma and not the result of accumulation of Cpx**
- **Flat HREE patterns of the ankaramites suggest a derivation in a non-garnet lithospheric source**
- **Pb isotope differences between the WP alkaline basalts and LVC and ankaramites exclude contribution from the asthenospheric reservoirs**
- **Remelting of Ca-rich pyroxene + olivine + amphibole cumulitic assemblages is slightly possible mechanism for the generation of the ankaramites**


Thank you !