Compositional evolution of the Oligocene Zvezdel volcano, Eastern Rhodopes, Bulgaria

Raya Raicheva[1], Peter Marchev[1], Robert Moritz[2], Denis Fontignie[2], Hilary Downes[3]

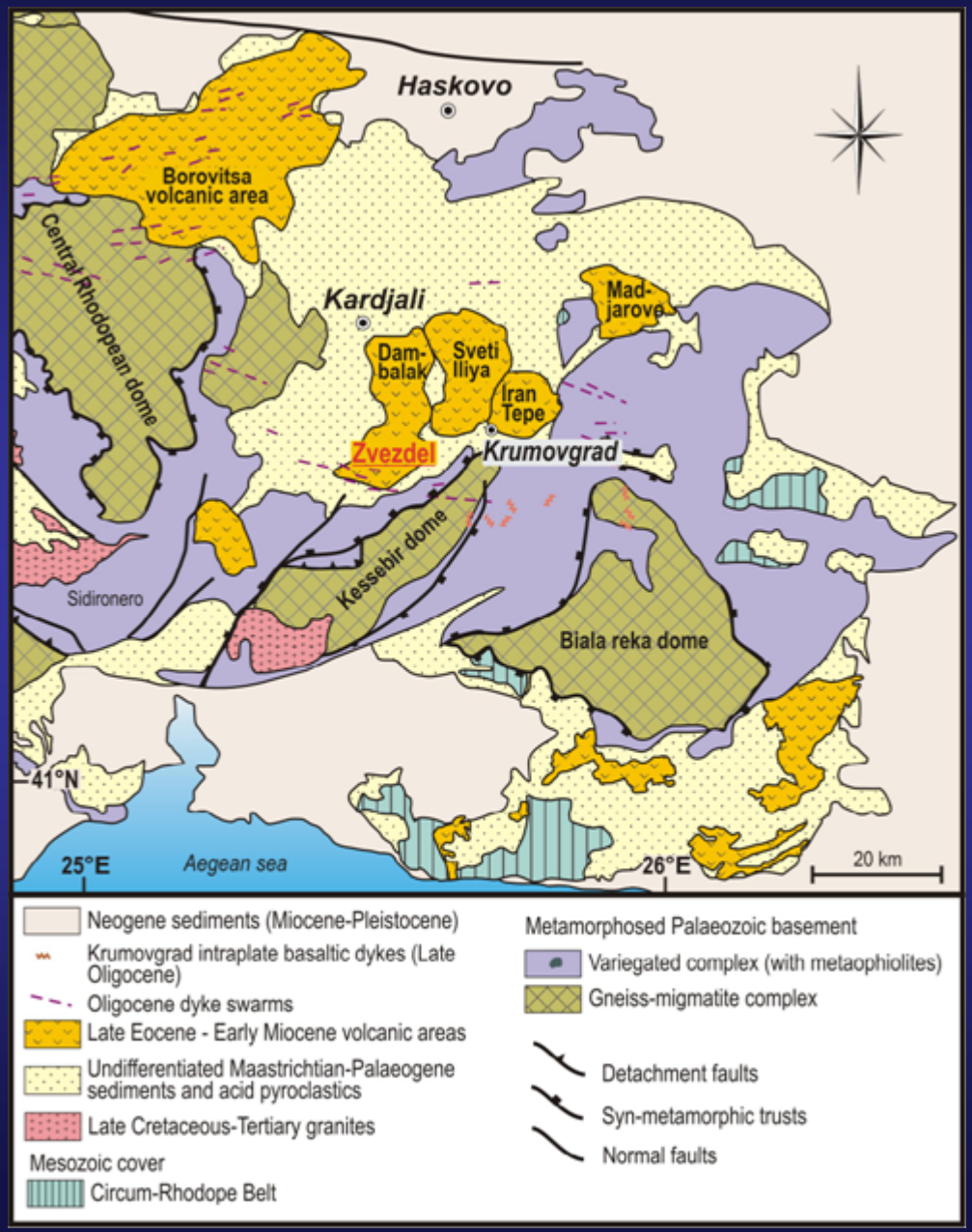
[1]Geological Institute, Bulgarian Academy of Sciences
[2]Institute of Earth Sciences, University of Geneva, Geneva, Switzerland
[3]School of Earth Sciences, Birkbeck College, London, UK

Paleogene volcanism in the Rhodope Massif

Eastern Rhodope Pg volcanism

✓ Highly variable chemical composition (basalts to rhyolites) - CA, HKCA, SHO and rare UHK, resulted from general increase of K from S to N

✓ Oligocene volcanic activity finished with intrusion of within-plate alkaline basalts

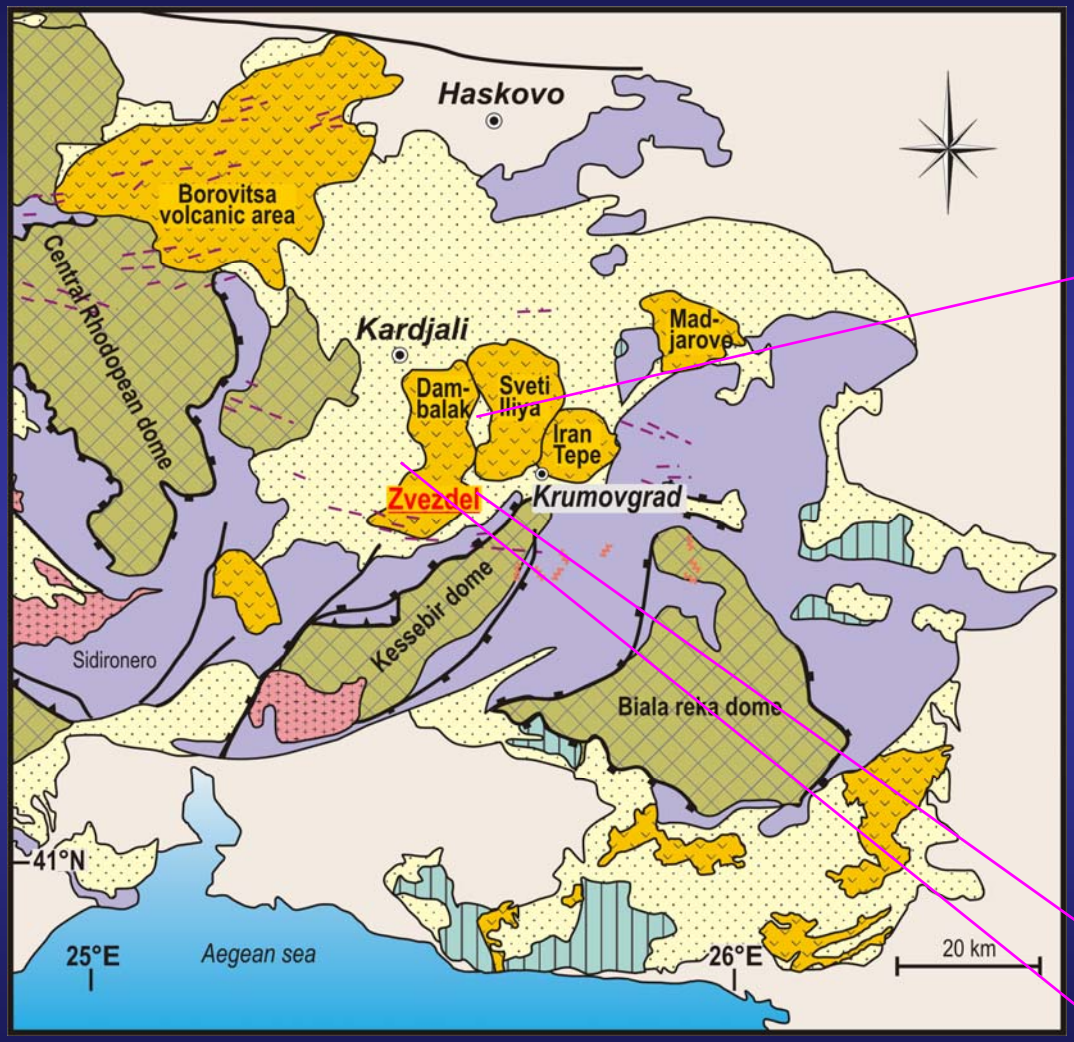


Goal:

Our major goal in this talk is to present the results of the our petrological study of Zvezdel volcano and to shed light on the processes which operated during the volcano evolution

We present the obtained data of chemical composition (major and trace elements and Sr and Nd isotopes) and brief petrography of the volcanic rocks

Stratigraphic position & age



Volcanic basement – Borovitsa pyroclastics - 32. 3 -31.8 Ma (Singer & Marchev, 2000; Moskovski et al., 2004)

Volcanic cover - Raven ignimbrites - 31.13 Ma Georgiev & Marchev, 2005)

Geology of the Zvezdel Volcano – Magmatic products

- lava flows, epiclastics, plugs, dykes, rare pyroclastics.
- comagmatic differentiated intrusive body of gabbroic to granosyenitic composition (Nedialkov & Pe-Piper, 1998; Yanev & Bardintzeff, 1997)

Volcano stratigraphy

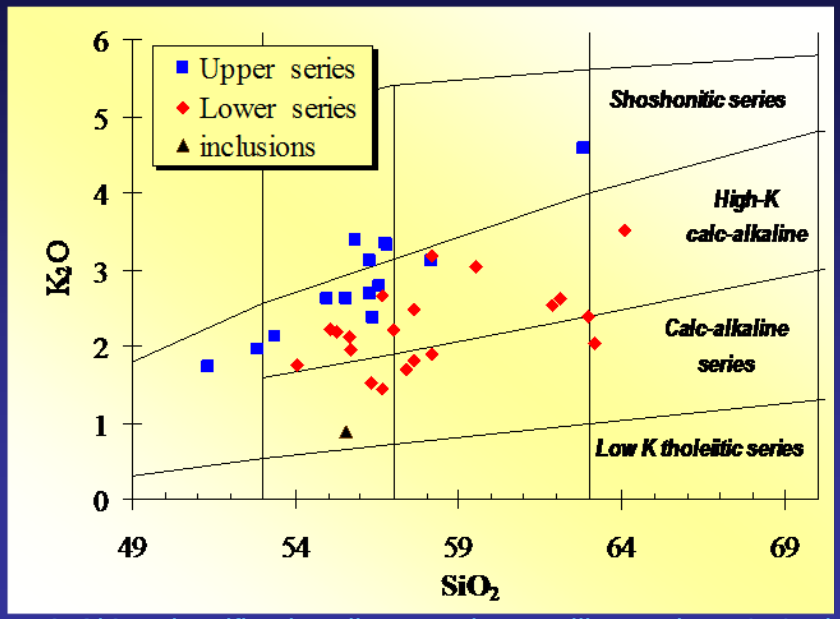
- Typical stratovolcano with parasitic cones (Nedialkov, Pe-Piper, 1998; Yanev et al., 1998)
- Dyke swarms

On the basis of stratigraphic position, as well as some petrographic and geochemical differences the rock were divided on two units - Lower and Upper series

Geological map 1:25000

Authors: Raicheva, Marchev

Classification and petrography of the volcanic rocks



K_2O-SiO_2 classification diagram (Peccerillo&Taylor, 1976 with modifications Marchev (1986)

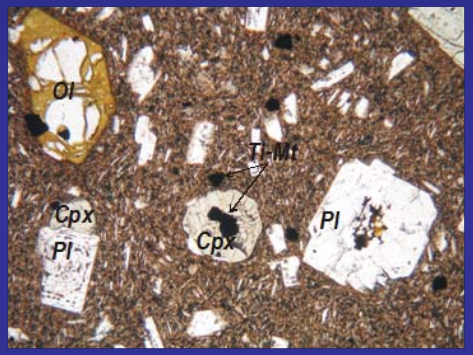
- Basalts to andesites – SiO_2 between 51.3 and 63.8
- Predominant lava type – basaltic andesites
- HKCA and subordinate CA and SHO varieties; Upper series with relatively higher K_2O

Phenocrysts:

All rock types

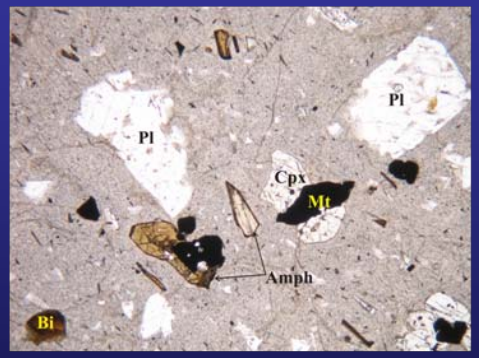
Pl, Cpx, Opx, Mt

Basalts + Ol



Basaltic andesites and shoshinites

± Ol.



Andesites and latites

± Ol

± Bi ± Amph

Accessories

Ap ± sulphides ± Zir

Typical petrographic features

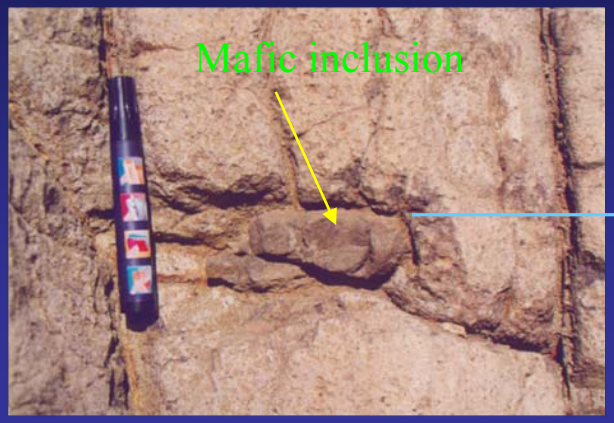
✓Wide range of pl, cpx and opx compositions and textutes in same sample.

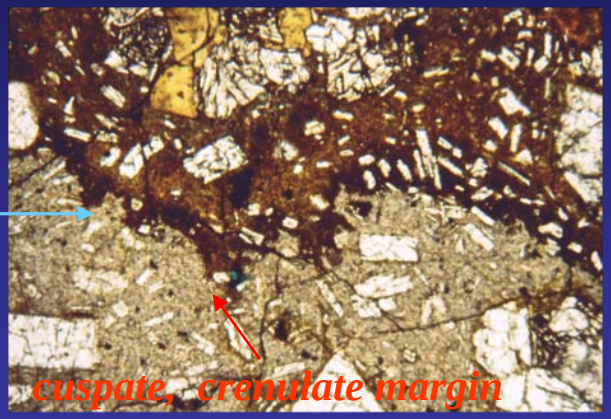
✓Upper series - appearance of high-Fe px (cpx Mg#<66, opx Mg#<64) which are not in equilibrium with any erupted magma

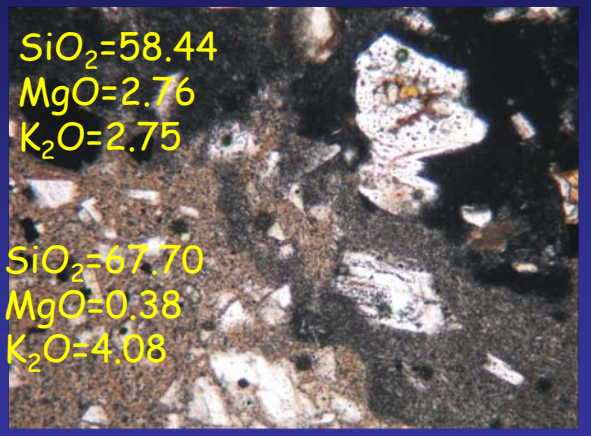
✓Lower series - high-Na Cpx - xenocrysts from layered mafic intrusions from lower crust - upper mantle boundary

Petrographical and mineralogical evidence for magma mixing

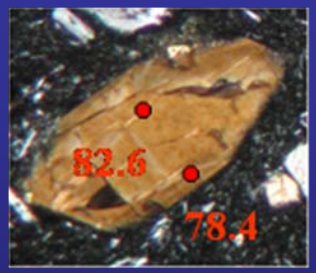
Mingling (Lower series) -magmatic enclaves and banded lavas

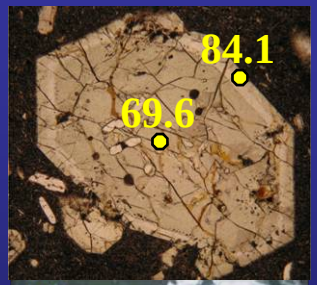


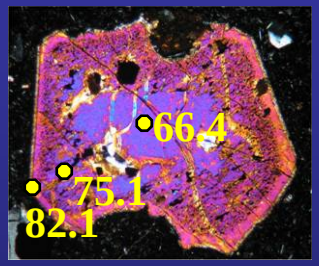


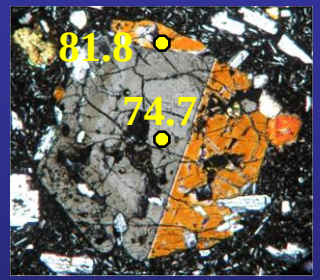


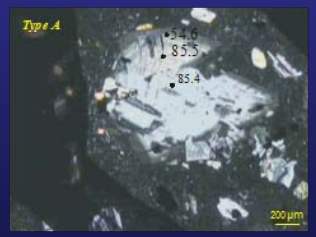
Mixing (Lower and Upper series)

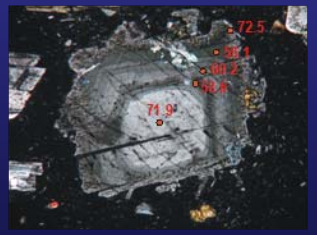


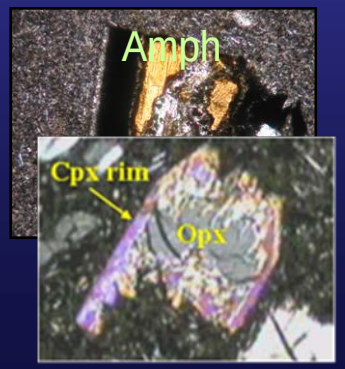






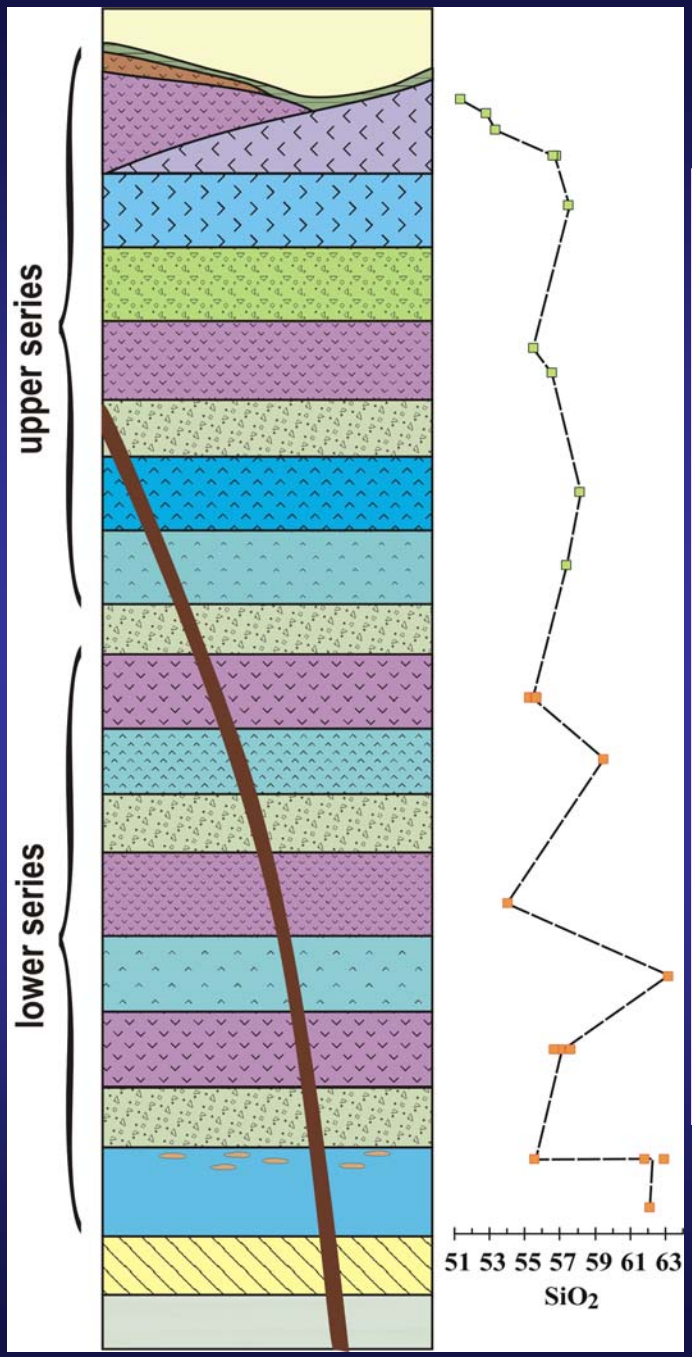


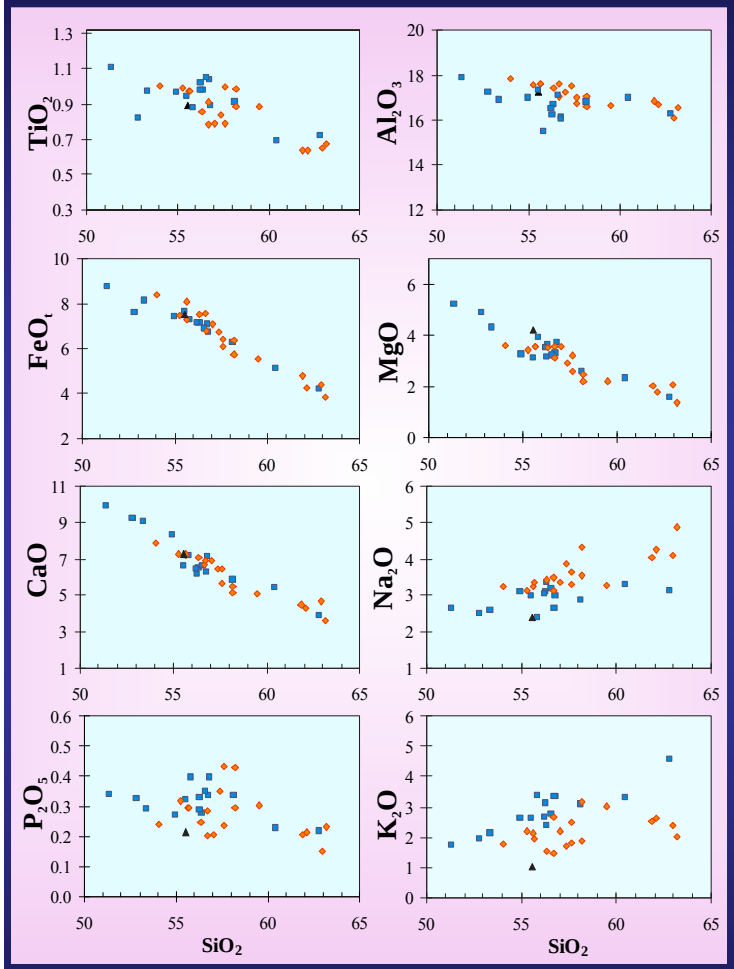




- Coexistence of distinct types of phenocrysts with different core composition, zonation and textures
- Reaction corona on water bearing minerals
- Coroded opx with mantle of cpx with significantly higher Mg#.

Chemical composition
- major elements





Linear negative trend for FeO, CaO, MgO - fractionation/mixing

Al_2O slightly decrease - Plag fractionation

P_2O_5 slightly decrease, scattering - apatite in at about 55-56 wt.% SiO_2

K_2O and Na_2O increase

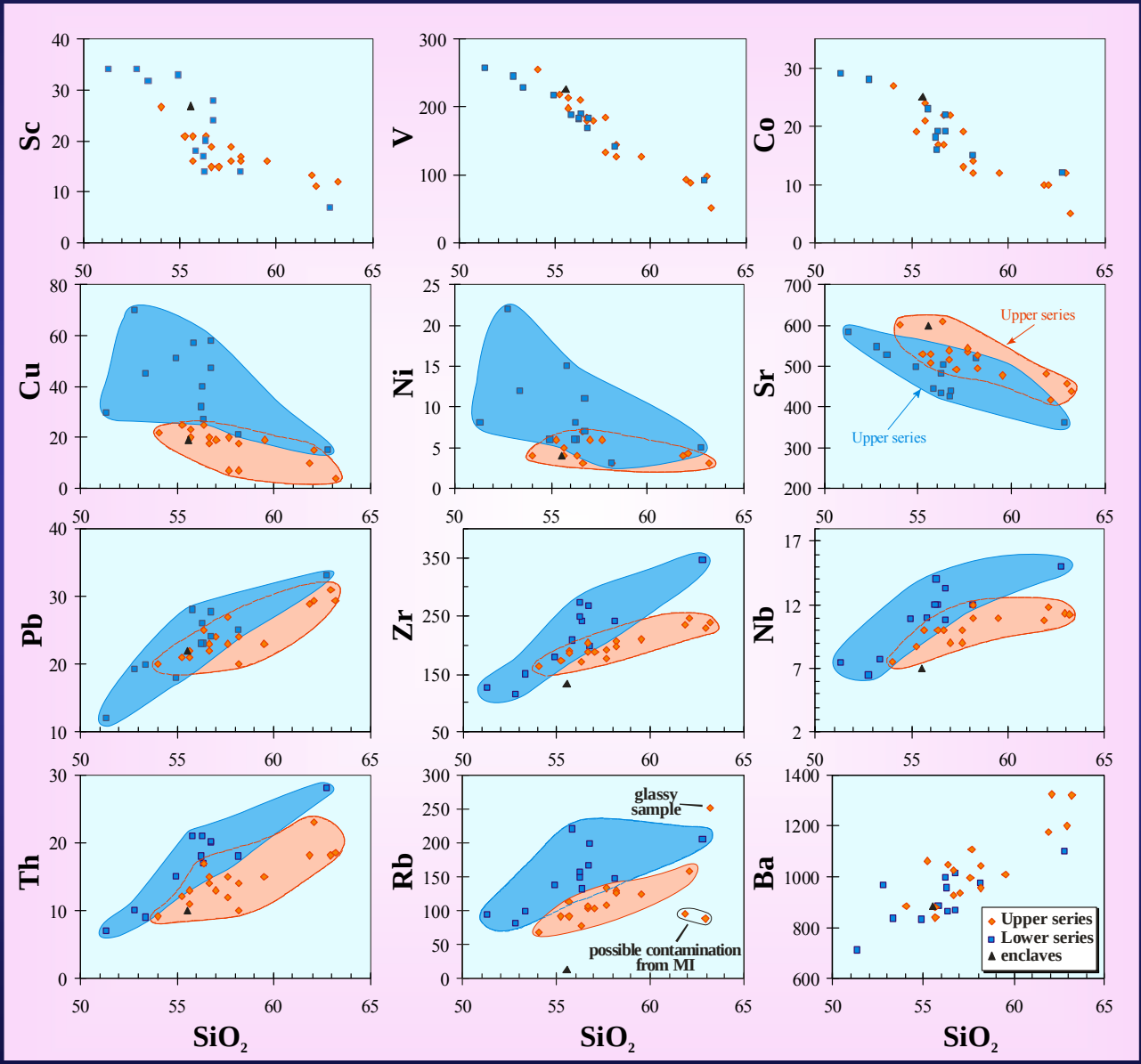
If we relate this to the stratigraphic position of the volcanic rocks, the most obvious difference between two series is higher concentration of K_2O and lower of Na_2O in the Upper series

Chemical composition - trace elements

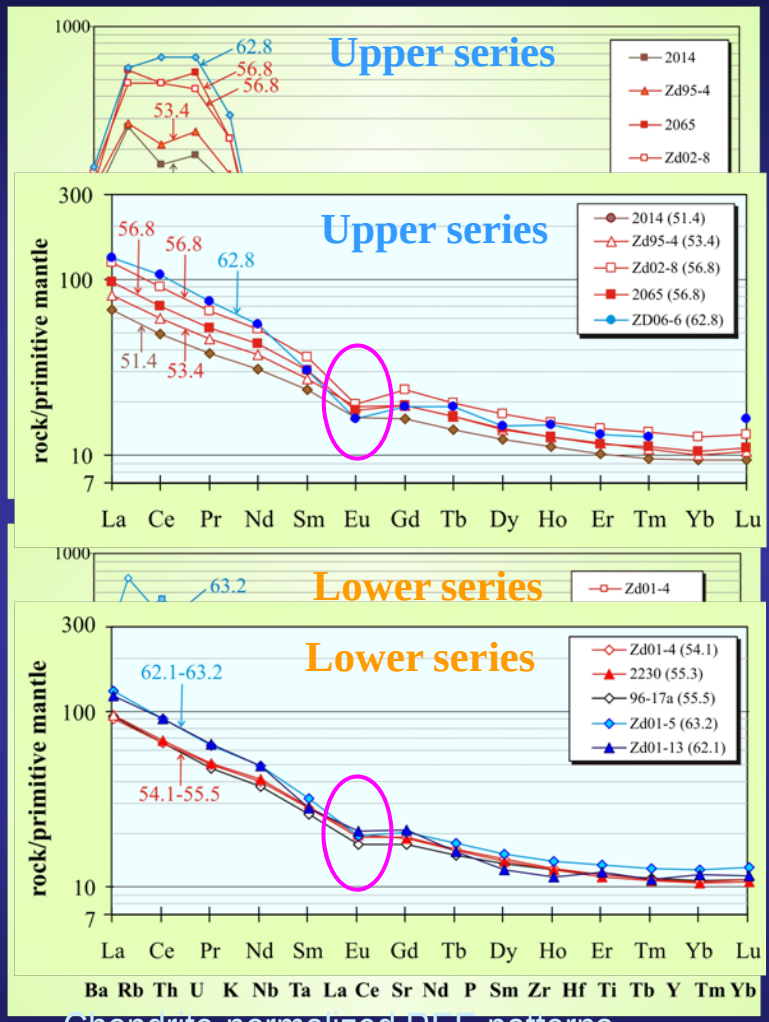
Decreasing of compatible elements (Sc, V, Co, Cu, Ni, Cr) and Sr - fractionation of ol, cpx, Ti-mt and Pl

Increasing of incompatible elements

Relatively higher Cu, Pb, Zr, Nb, Th, U and Rb and lower Sr in the Upper series.



Chemical composition



Chondrite-normalized REE patterns, normalizing values after Boynton (1984)

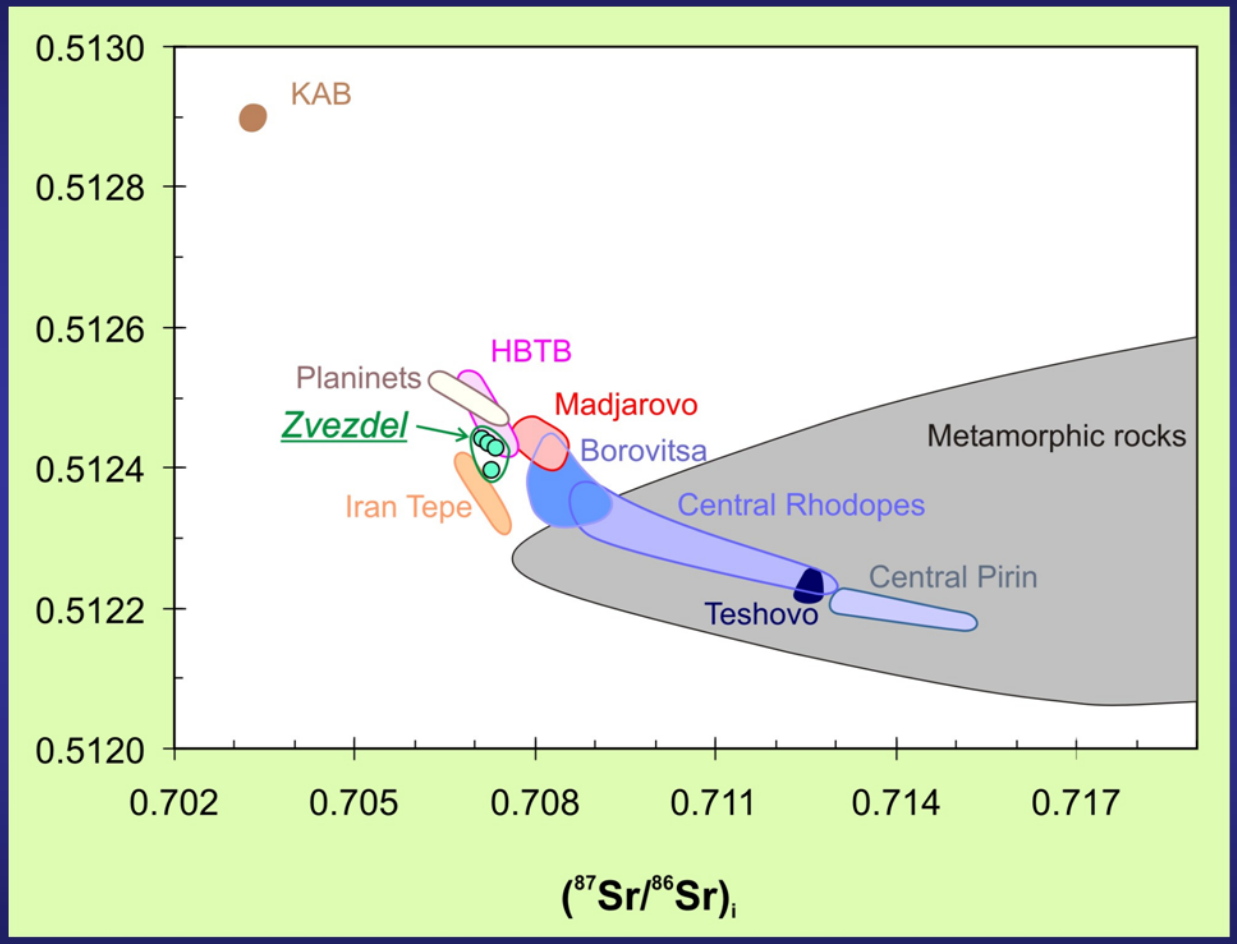
Chondrite-normalized multi-element patterns, normalizing values after Thompson et al. (1984)

- Typical pattern for lavas in convergent margins
- Enrichment of highly incompatible trace elements - Ba, Rb, Th, U, K
- Nb-Ta and Ti minimum
- Similar patterns of Lower and Upper series

- LREE enriched towards HREE, $(La/Yb)_N$ between 7.1 in basalts to 10.7 in the more evolved varieties

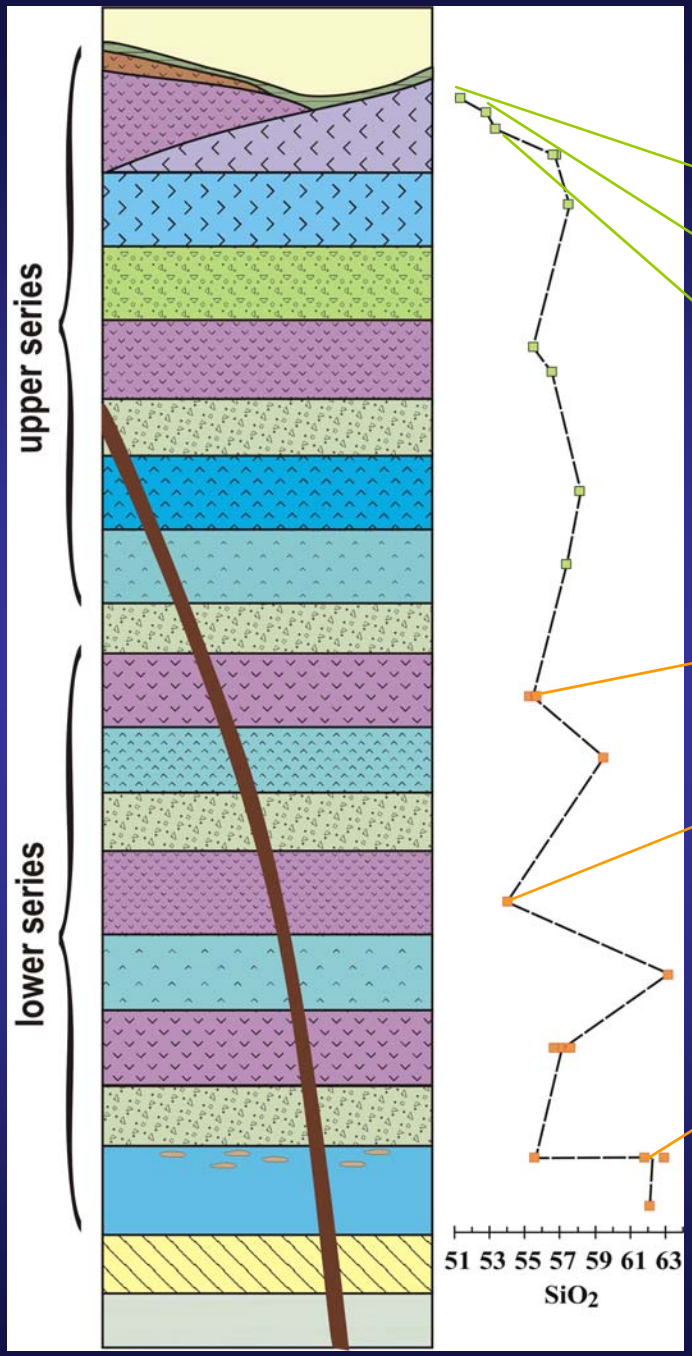
- negative Eu/Eu* from 0.86 in basalts to 0.66 in shoshonites and latites -fractionatin of pl

Chemical composition - Sr and Nd isotopes

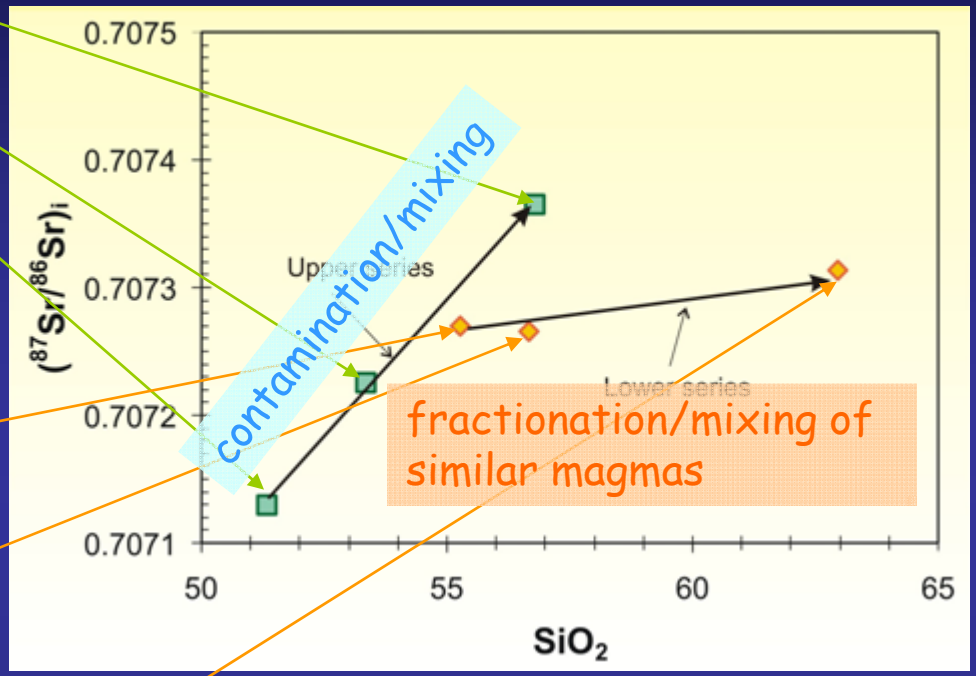


- ✓$(^{87}Sr/^{86}Sr)_i$ - 0.70713 to 0.70736
- ✓$(^{143}Nd/^{144}Nd)_i$ - 0.51240 to 0.51244
- ✓Isotopic composition of Zvezdel volcanics - in the range of East Rhodopean volcanic rocks, between Krumovgrad alkaline basalts and metamorphic basement.
- ✓From Ca-alkaline to Shoshonitic volcanoes Sr isotopes increase, at similar Nd isotope values

Chemical stratigraphy & Sr isotopic composition



Chemical stratigraphy



Sr isotopies - two distinct trends – sub parallel for the Lower series and steeper for Upper series

Evolutionary processes in Zvezdel volcano - inferences from chemical composition

Fractional crystallization

✓Ni and Cr decrease rapidly with increasing SiO_2 - fractionation of mafic phases

✓The shape of spidergrams and REE patterns change progressively - derivation by simple crystal fractionation from same parental magma

✓LREE/HREE increase with evolution - fractionation of Cpx and Opx

✓Increasing negative Eu/Eu* from 0.86 in basalts to 0.66 in evolved rocks - continuous fractionatin of pl

✓Sub parallel trend of Sr isotopes vs SiO_2 of the Lower series - fractionation – and/or mixing of magmas with similar isotopes

Magma mixing

✓Linear trend of MgO, CaO, FeO.

✓Petrographic evidence

Crustal contamination

✓No petrographic evidence, except rare lower crustal or upper mantle xenocrysts of cumulitic rocks,

✓The range of Sr isotopes in the Upper series indicates addition of a crustal component during evolution from basalts to shoshonites.

Conclusions

- Zvezdel volcano is a large strato- or shield volcano, comprised of CA to HKCA and rare Sho rocks
- Lavas show compositional range from basalts to acid andesites
- Volcanic activity span ~1 Ma. It occurs in two major episodes.
- Magma mixing, crustal contamination and fractional crystallization have been the major magma modifying processes, but each of them had different impact on the magma composition in the two episodes.
- The major, trace element and isotopic data of the Lower series can be explained by fractional crystallization; however, mineral composition requires mixing (mingling) of differently evolved single type parental magma.
- The geochemical, isotopic and petrographic features of the Upper series point to a mixing of a more contaminated and fractionated magma with a more primitive basaltic magma.


Thank you for the attention