Istituto di Geoscienze e Georisorse

Seminario On Line
giovedì 02 luglio 2020
Ore 11.00 GoToMeeting

Consiglio Nazionale delle Ricerche

Il magmatismo Cenozoico innescato dalla convergenza Africa-Arabia-Eurasia

Samuele Agostini
Istituto di Geoscienze e Georisorse, CNR, Pisa

PRIN 2017- Intraplate deformation, magmatism and topographic evolution of a diffuse collisional belt: Insights into the geodynamics of the Arabia-Eurasia collisional zones

PRIN 2017 *Intraplate deformation, magmatism and topographic evolution of a diffuse collisional belt: Insights into the geodynamics of the Arabia-Eurasia collisional zones*

- **PI – Unit 1 Claudio Faccenna (UNIROMA3)**
- **Unit 2 William Cavazza (UNIBO)**
- **Unit 3 Massimiliano Zattin (UNIPD)**
- **Unit 4 Carla Braitenberg (UNITS)**
- **Unit 5 Gianfranco Di Vincenzo (IGG-CNR Pisa)**

PRIN 2017 *Intraplate deformation, magmatism and topographic evolution of a diffuse collisional belt: Insights into the geodynamics of the Arabia-Eurasia collisional zones*

Unit 5 IGG-Pisa Gianfranco Di Vincenzo

Participants
Michele Lustrino (DST-UniRoma1)
Samuele Agostini
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Participant
Maria Laura Balestrieri (IGG-CNR Firenze)

PRIN 2017 *Intraplate deformation, magmatism and topographic evolution of a diffuse collisional belt: Insights into the geodynamics of the Arabia-Eurasia collisional zones*

WP1–Definition of spatio-temporal patterns of collisional deformation (UdR1-3)

Tasks:

Main exhumation events and their distribution at regional scale

Structural styles/patterns in the sequential evolution of intraplate deformation

Role of structural inheritance in controlling deformation

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WP2–Quantification of the magnitude of vertical movements (UdR1-3)

Tasks:

Rates and mechanisms of regional subsidence predating collisional deformation

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WP3–Definition of the major tectono-stratigraphic and environmental changes from sedimentary archives (UdR1-4)

Tasks:

Source-to-sink sediment transfer

Long-term paleoclimatic and paleoenvironmental record changes

Major deformation and erosional events

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WP4-Elaboration of a petrogenetic model for the generation of igneous activity in space and time (UdR1, UdR4-5).

Tasks:

<u>Relationships between arc-type and intraplate volcanism and their spatio-temporal association with different tectonic settings</u>

<u>Characterization of “intraplate-like" districts developed inside the collision zone</u>

<u>Role of deformation in controlling the space-time distribution of intraplate magmatism</u>

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WP5 - Modeling geodynamic processes responsible for topographic development (UdR1, UdR5)

Tasks:

Subduction vs. collision dynamics for regional topographic evolution

Large-scale mantle flow and crustal deformation in the formation of orogenic plateaus

Inherited regional structural boundaries and the time-space progression of deformation

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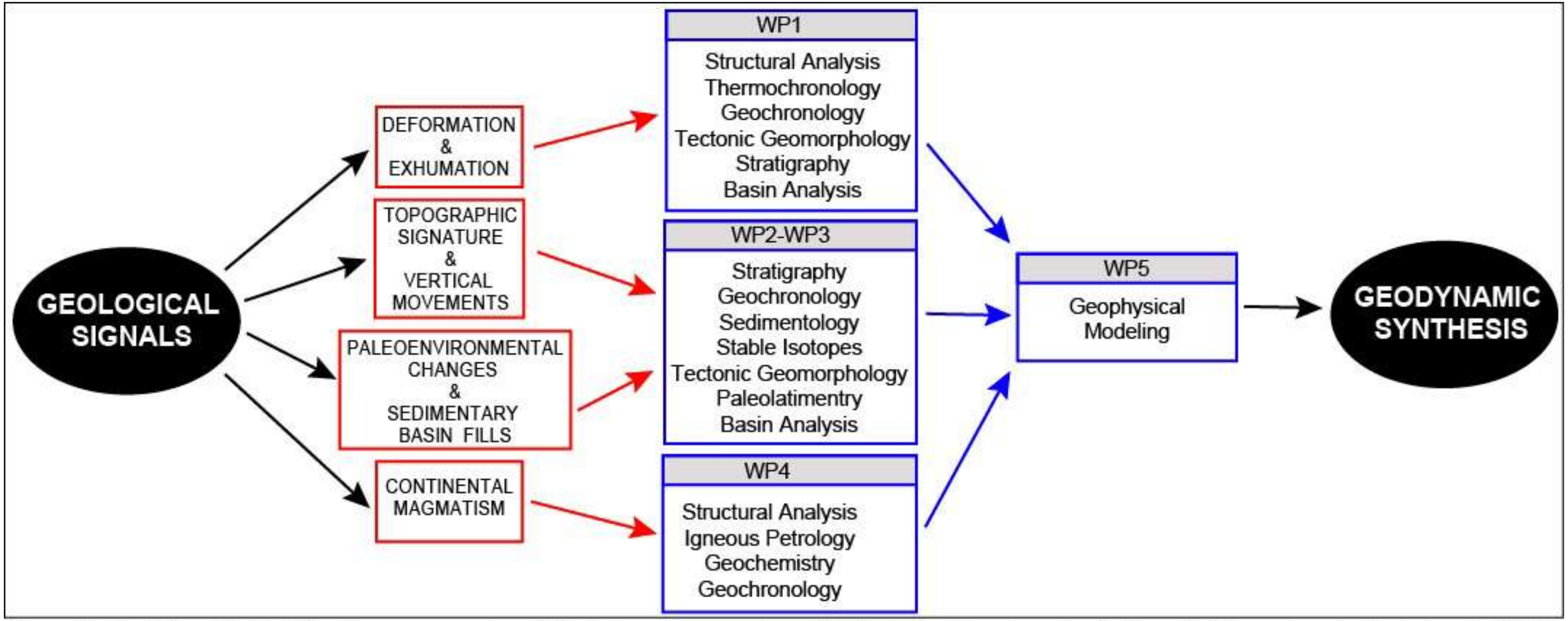
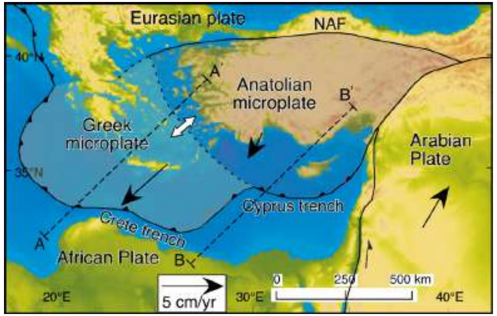


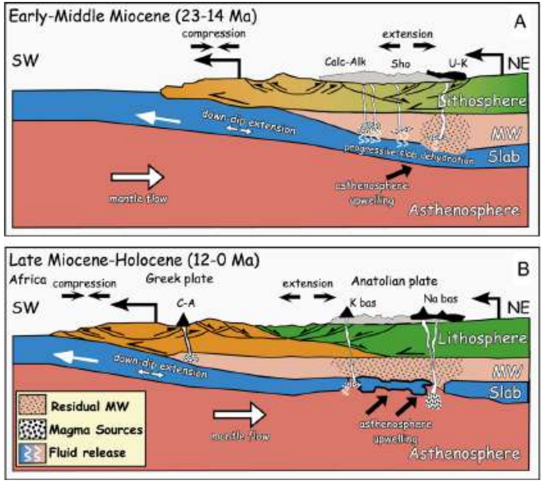
Figure 3. Workflow highlighting the proposed multidisciplinary approach, which includes the characterization of different geological signals (WP1 to WP4), the development of a geophysical model (WP5) based on available geophysical data and our new and published geological data, and finally the elaboration of a comprehensive geodynamic synthesis.

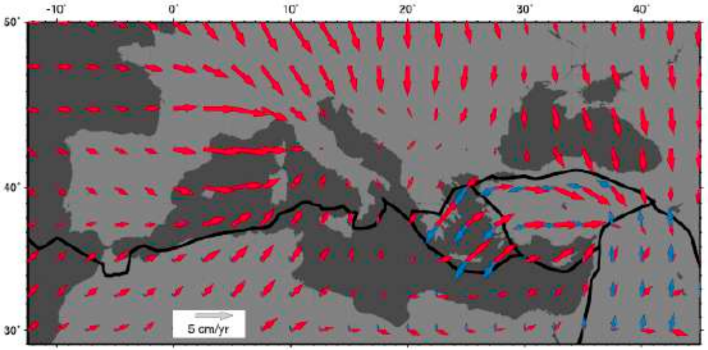
Pros and Cons

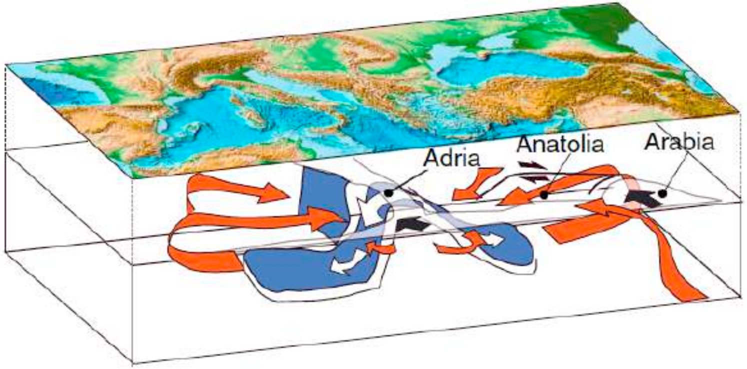
Pros	Cons
Big project, lot of units, lot of objectives, lot of methods…	Big project, lot of units, lot of objectives, lot of methods…
More extension	Less comprehension
Different point of views	~~Different point of views~~

Different point of views





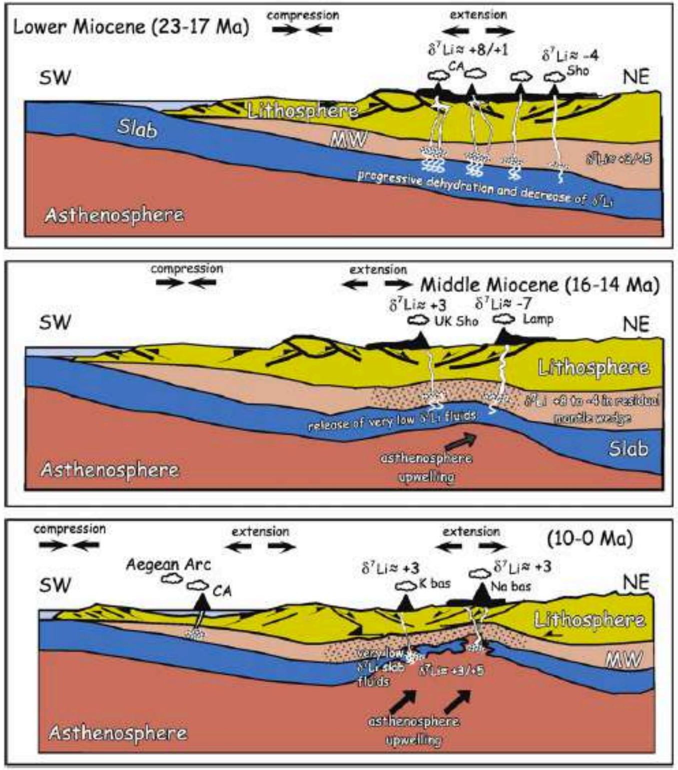




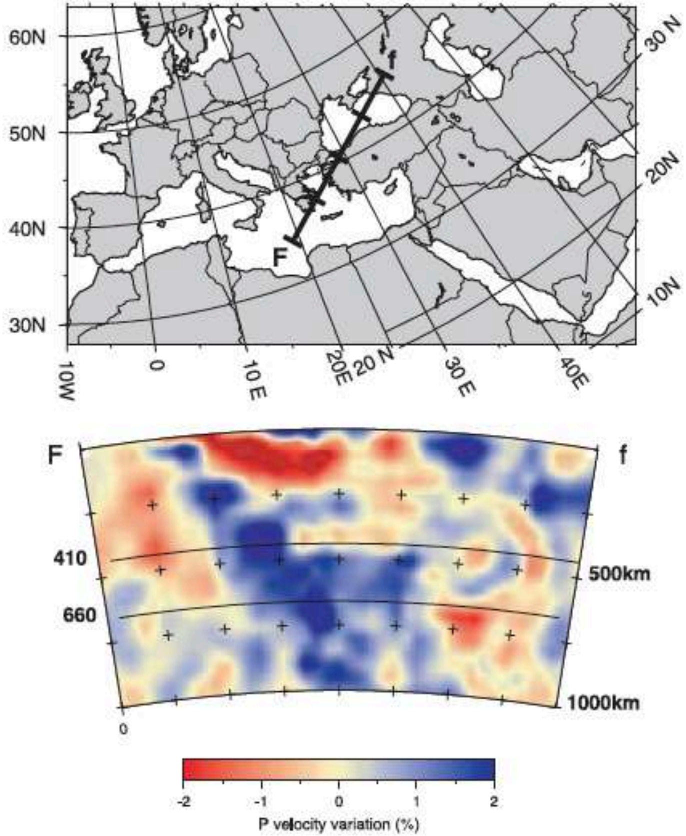
Agostini et al., 2010 (Tectonophysics)

Faccenna et al., 2014 (Review of Geophysics)

Different point of views
Geochemistry vs. Geophysics?

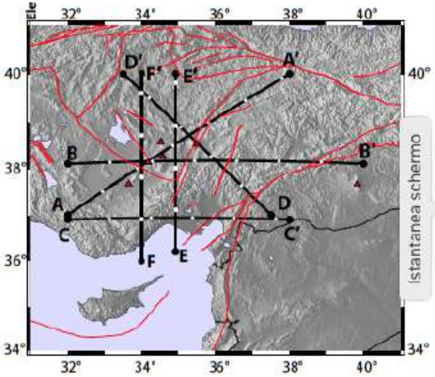


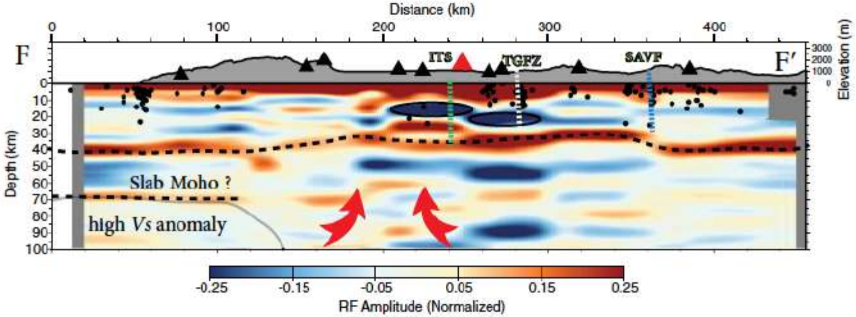
Agostini et al., 2008 (EPSL)

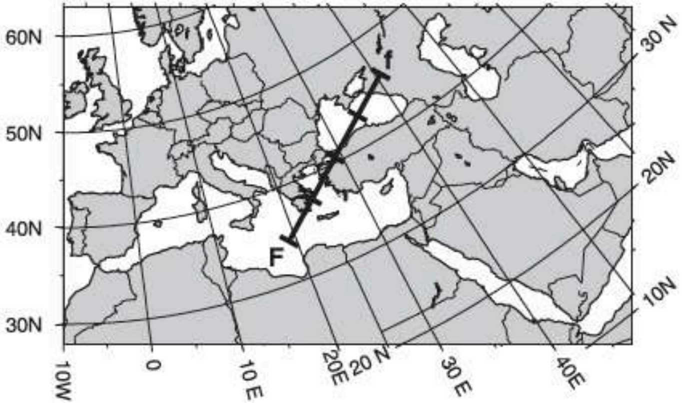


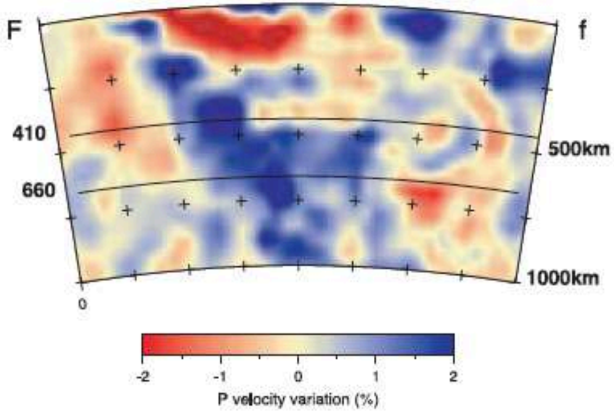
Piromallo and Morelli, 2003 (JGR)

Different point of views
Geophysics vs. Geophysics





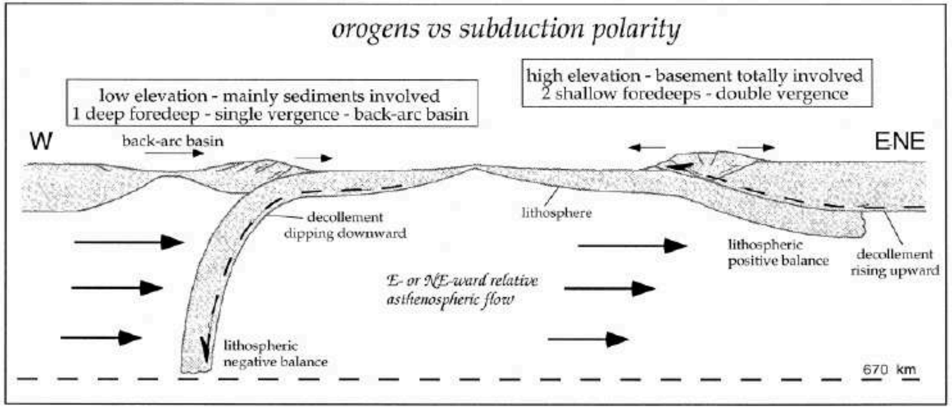


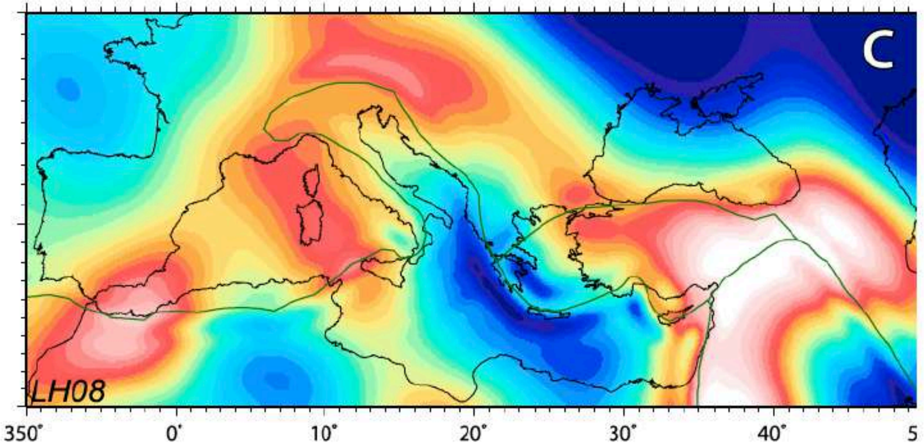


Abgarmi et al., 2017 (Geosphere)

Piromallo and Morelli, 2003 (JGR)

Westward drift of Lithosphere vs. Dynamic Topography

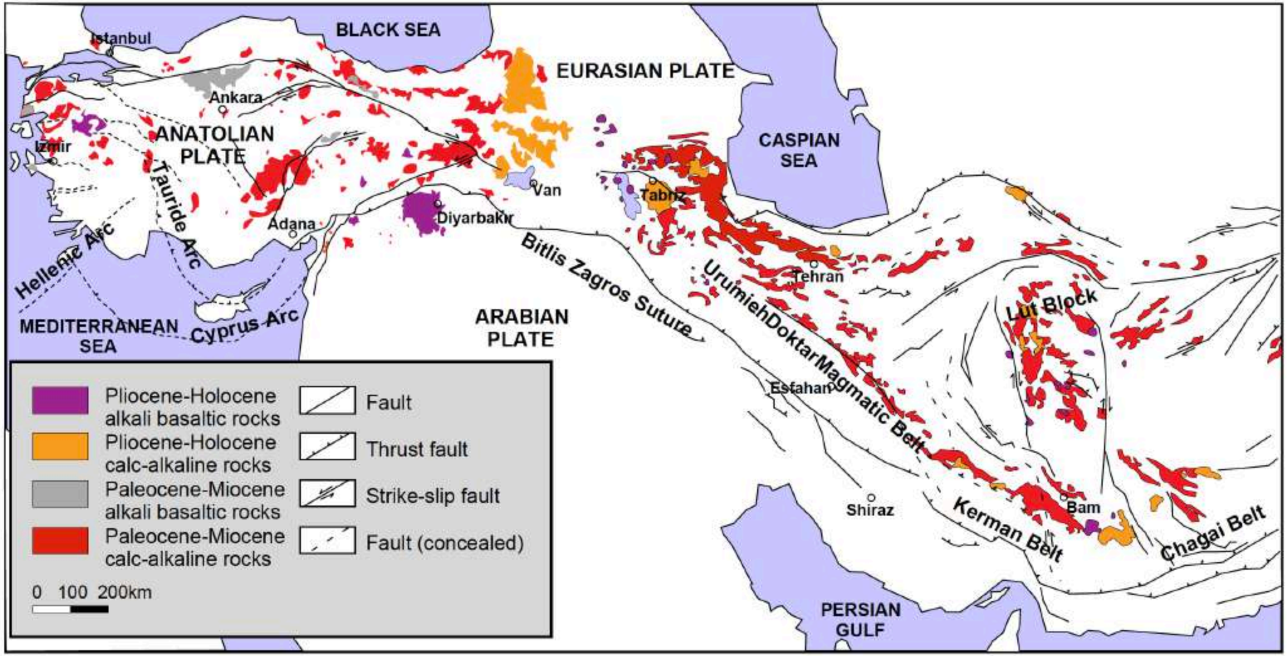




Doglioni et al., 1999 (ESR)

Boschi et al., 2010 (GRL)

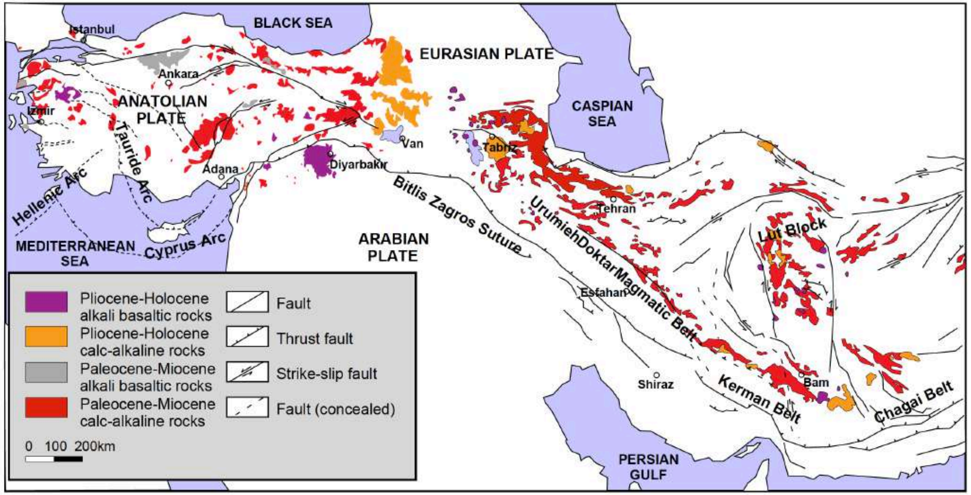
Magmatism and Geodynamic Evolution of Eurasia-Africa-Arabia converging systems

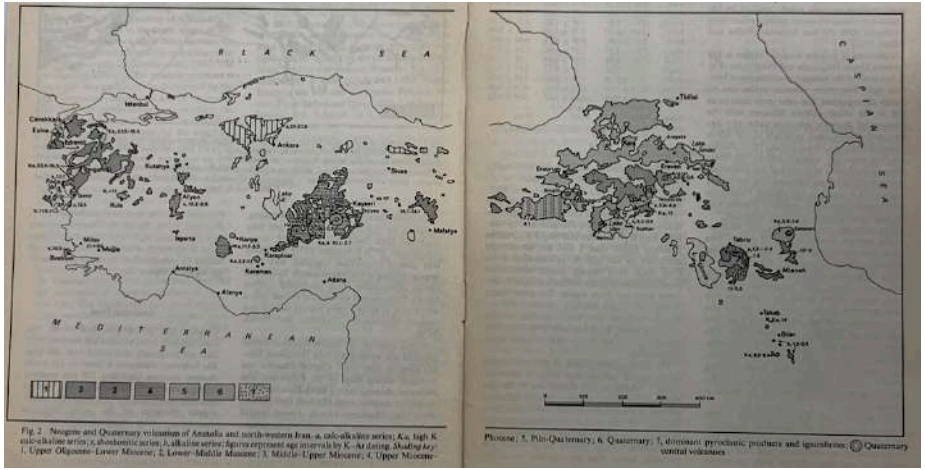


Main objectives:

- Identify the characters of magma mantle sources and describe the magma formation and evolution processes
- Interactions between sub-slab and slab-modified sources.
- Time evolution of erupted products (and of their mantle sources)
- Relationships between geodynamic framework, timing and geochemical characters of products

Magmatism and Geodynamic Evolution of Eurasia-Africa-Arabia converging systems





Innocenti et al., 1982 (Andesites)

Arabian plate: new and old topic

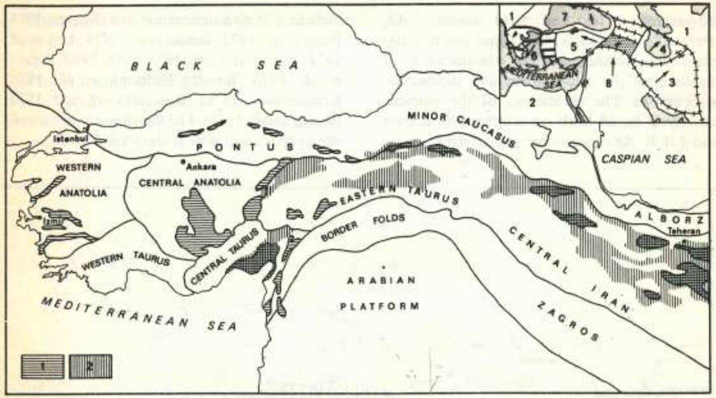


Fig. 1 Structural sketch map of Turkey and north-western Iran. Horizontally hatched areas (1) show Neogene to Quaternary subsiding depressions; vertically hatched areas (2) are Oligo-Miocene molassic basins. *Inset*: plate boundary and motions in Middle East after McKenzie (1977); the dotted area represents the zone of lithosphere deformation of Van (Innocenti *et al.*, 1976); the arrow length is approximately proportional to the velocity relative to Eurasia; plates are labelled as follows: 1, Eurasian; 2, African; 3, Iranian; 4, South Caspian; 5, Turkish; 6, Aegean; 7, Black Sea; 8, Arabian

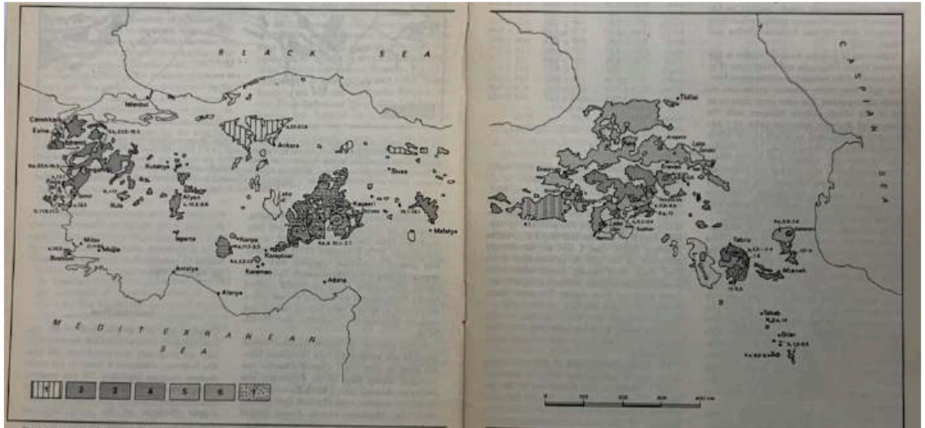
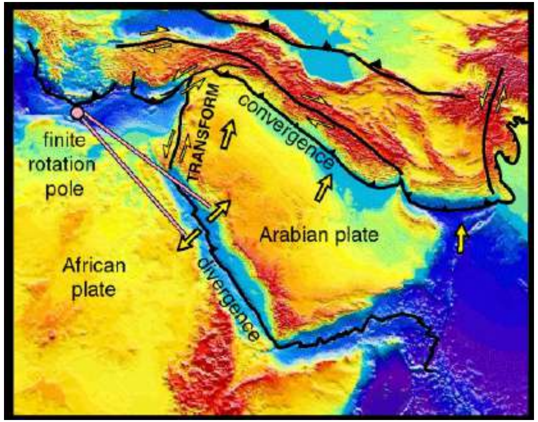


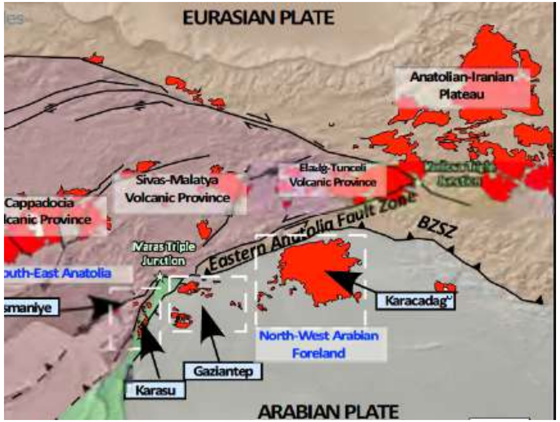
Fig. 2 Neogene and Quaternary volcanism of Anatolia and north-western Iran. a, calc-alkaline series; Ka, high K calc-alkaline series; s, shoshonitic series; h, alkaline series; figures represent age intervals by K–Ar dating. *Shading key*: 1, Upper Oligocene–Lower Miocene; 2, Lower–Middle Miocene; 3, Middle–Upper Miocene; 4, Upper Miocene–Pliocene; 5, Plio-Quaternary; 6, Quaternary; 7, dominant pyroclastic products and ignimbrites; Quaternary central volcanoes

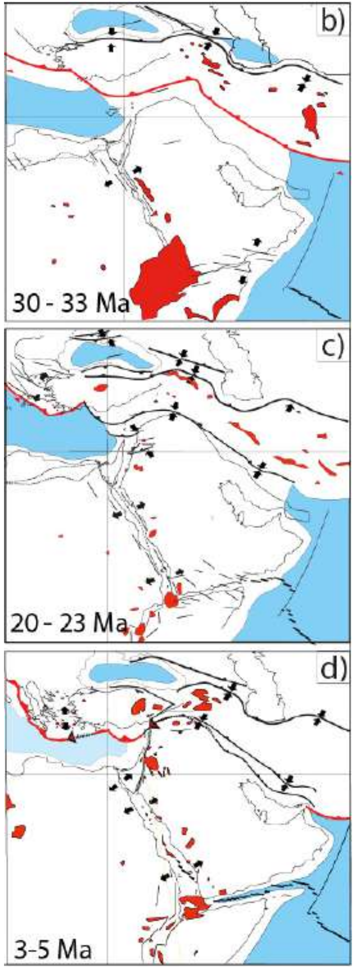
Innocenti et al., 1982 (Andesites)

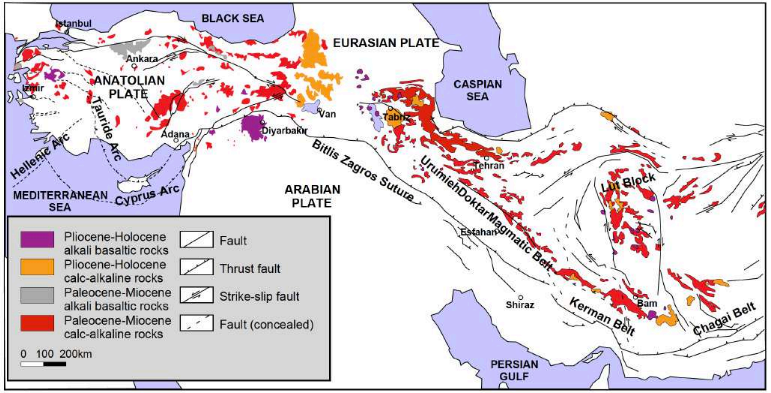
Arabian plate: perfect for Plate Tectonics



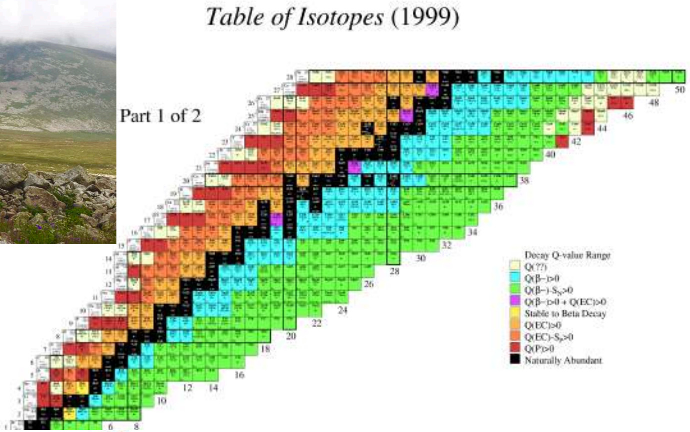
(https://www.see.leeds.ac.uk/structure/leb/tectonics/regional/regional.htm)

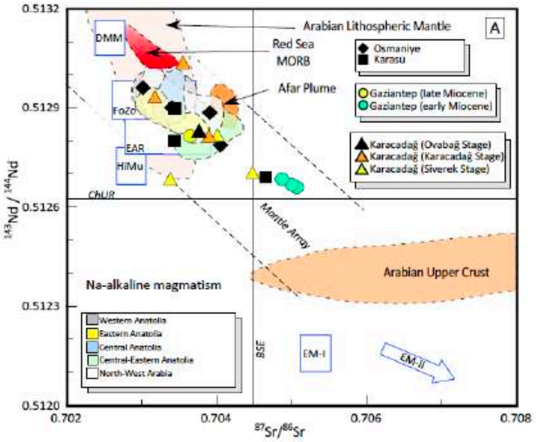


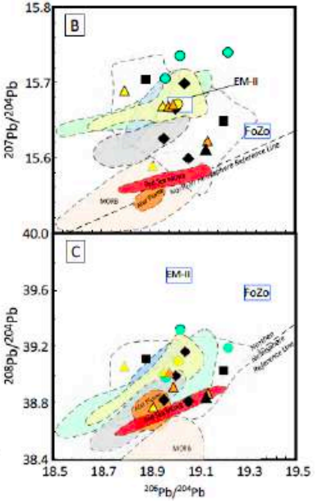


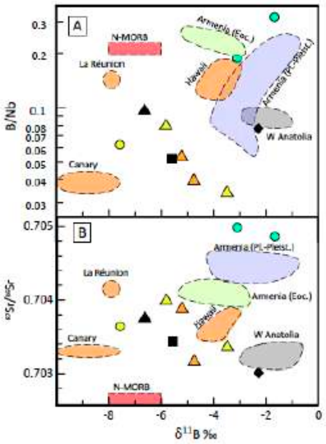


Arabian plate: perfect for isotope geochemistry



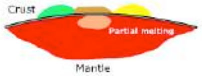


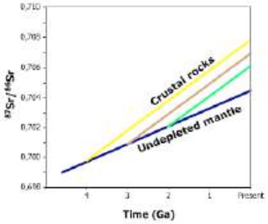


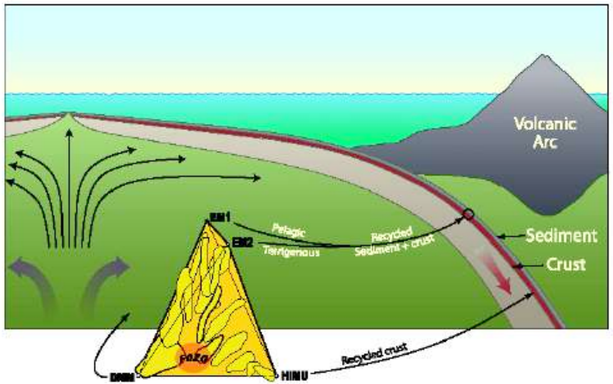


Arabian plate: perfect for radiogenic isotope studies

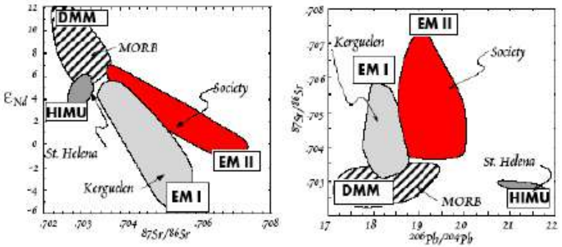
- Their ratio changes significantly in geological times
- Their ratio does not change significantly in human times
- Earth reservoirs have (or acquired) a different parent/daughter ratio
- Earth reservoirs have different radiogenic isotope ratio
- Radiogenic isotopes are natural watches for geological time
- Radiogenic isotopes can be used to trace Earth reservoirs





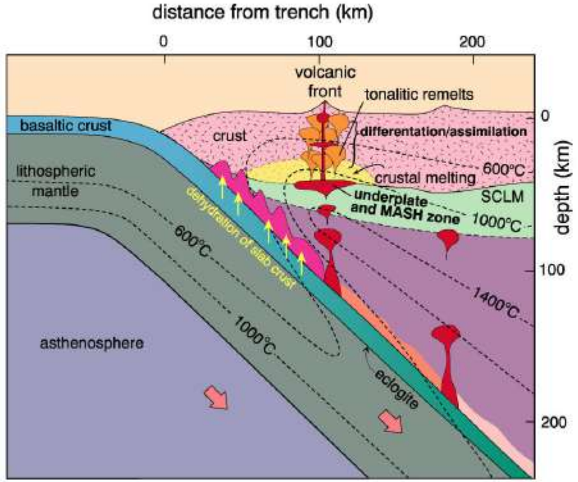


(from Workman et al., 2004, G^3)

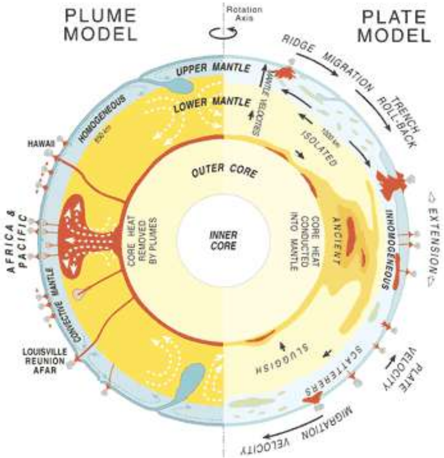


Arabian plate: perfect for radiogenic isotope studies?

- These isotope systematics provide partly equivocal informations, because they record a parent-daughter fractionation, whose age and location are not known.
- To what extent are mantle “enrichments” due to superficial processes?
- Where mantle re-fertilization takes place?



(From: http://geol.lsu.edu/henry/ Geology3041/3041syllabus.htm)



(From: http://www.mantleplumes.org/ images/PlumePlateEarth_350.gif)

Arabian plate: perfect for stable isotope studies

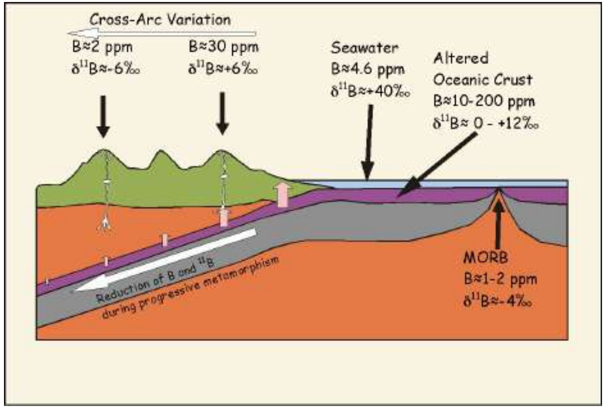
Unambiguous evidence of the occurrence of shallower processes can be provided by stable light isotopes (e.g. H, O, C, S, Li, B), whose variations reflect only low temperature episodes.

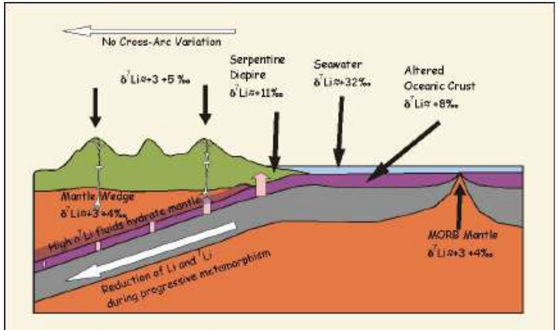
Why? Isotopic composition of stable light isotopes only change as a consequence of isotope fractionation, which is negligible at high T (T≥1000 °C).

Indeed H, O, C, S, Li and B isotope composition is the same in enriched and depleted mantle.

Therefore, light stable isotopes are able to trace the recycling of superficial material in the mantle and re-fertilization of mantle domains.

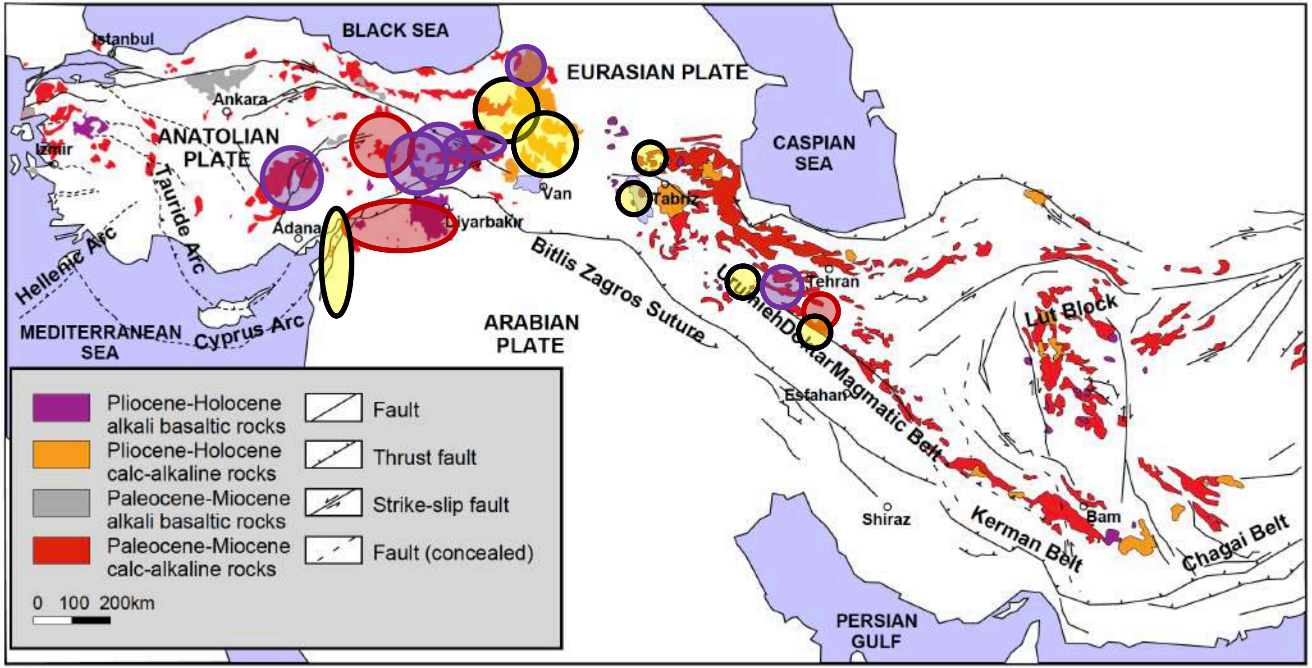
WARNING: negligible means less than 0.5‰

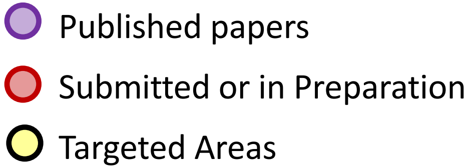




δ^7Li Data from Elliott et al., EPSL, 220 (2004) 231-245

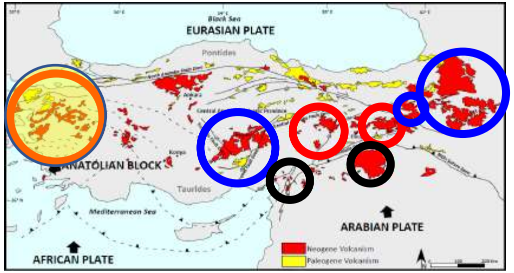
Magmatism and Geodynamic Evolution of Eurasia-Africa-Arabia converging systems



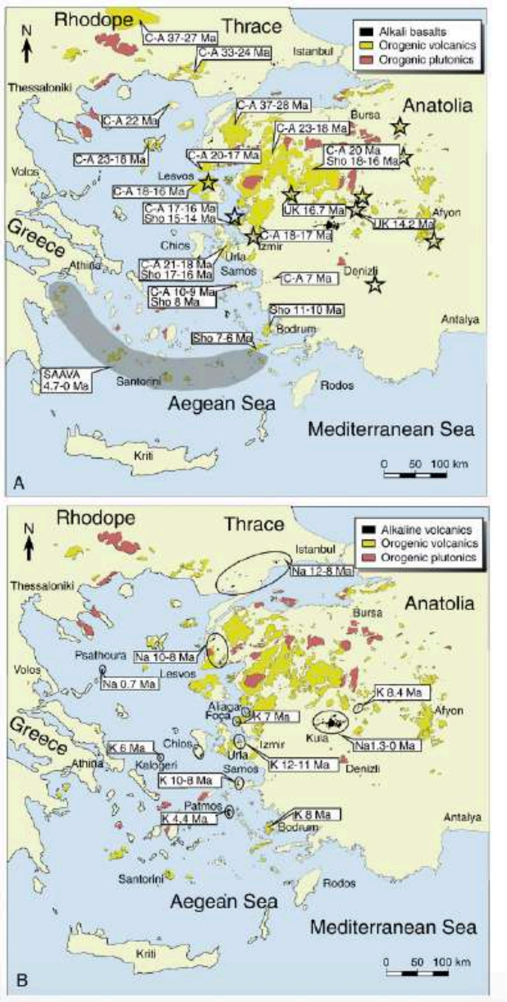


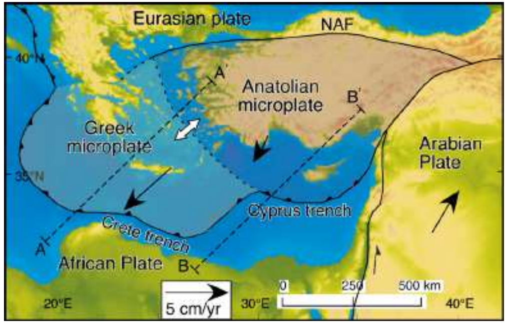
Collaborations with Univ Leeds and Armenian Academy of Sciences (for Armenia), Shahid Behesti & other Univ (for Iran), several universities in Turkey…

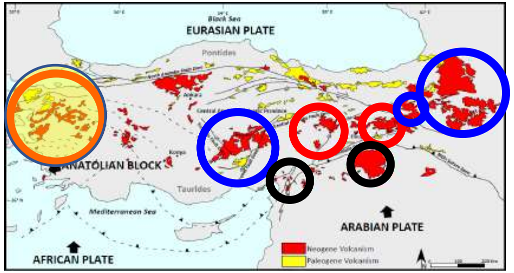
Western Anatolia (and Aegean)

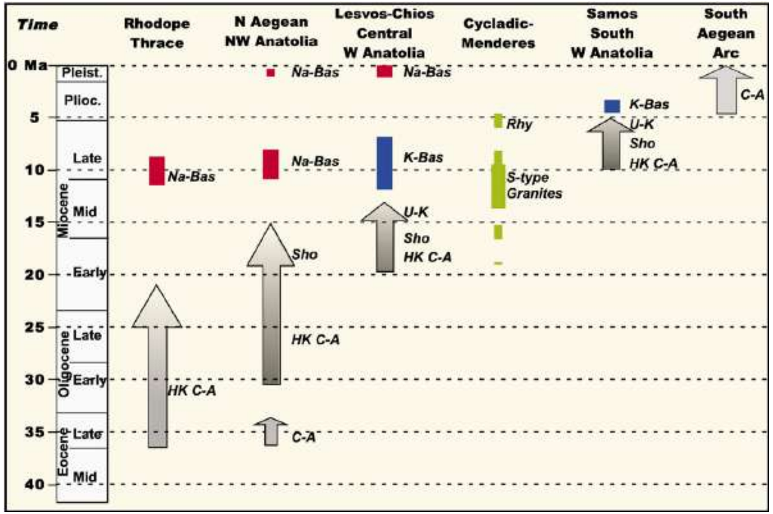


Western Anatolia (and Aegean)



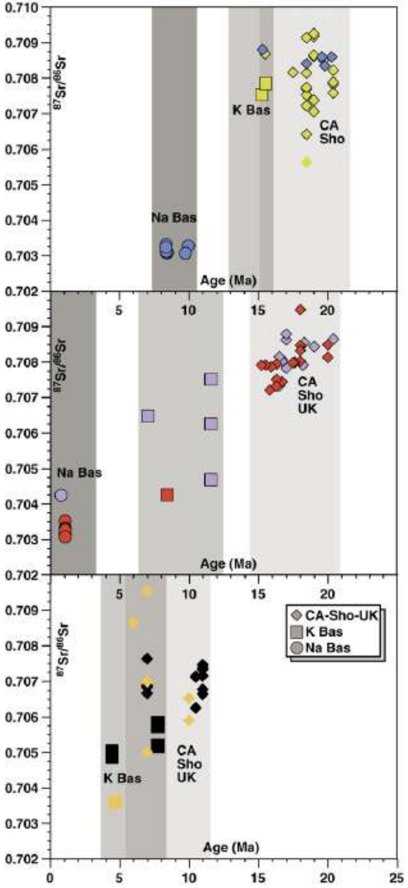


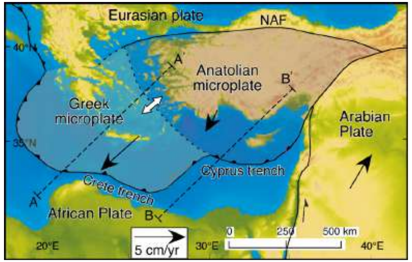


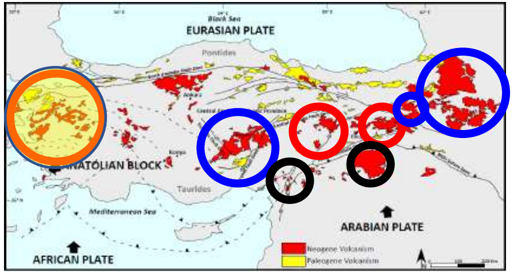


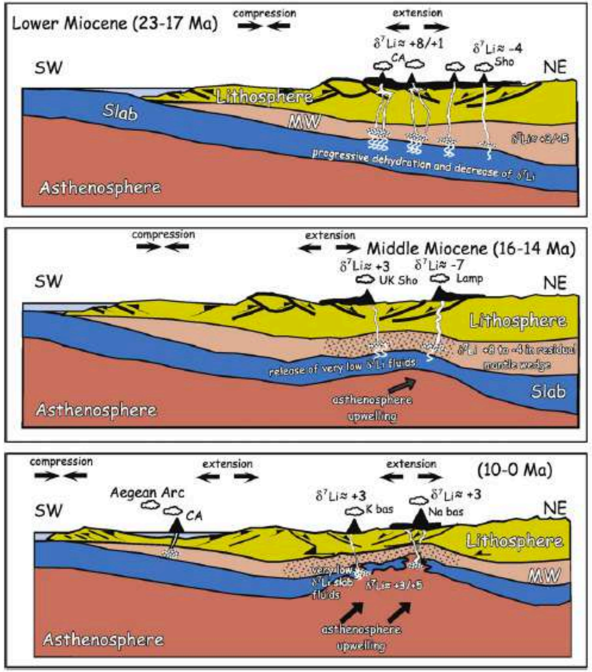
Agostini et al., 2010 (Tectonophysics)

Western Anatolia (and Aegean)



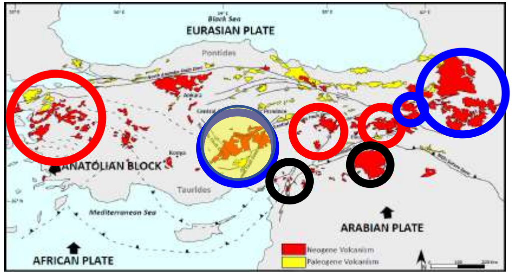




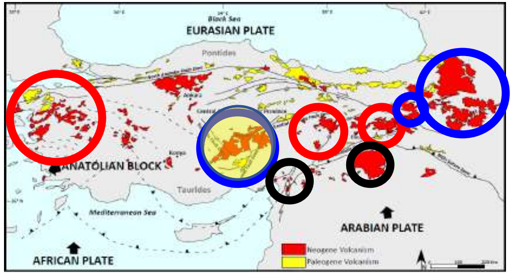


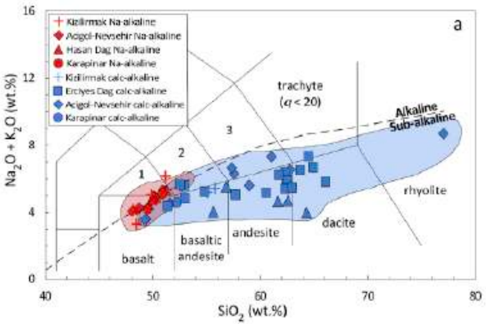
Agostini et al., 2008 (EPSL), Agostini et al., 2010 (Tectonophysics)

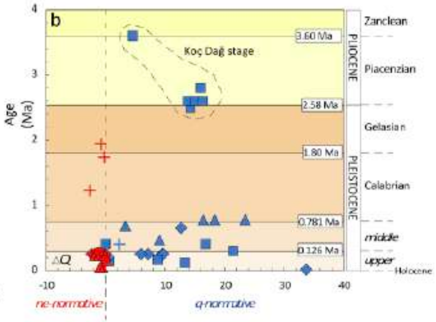
Central Anatolia (Cappadocia)

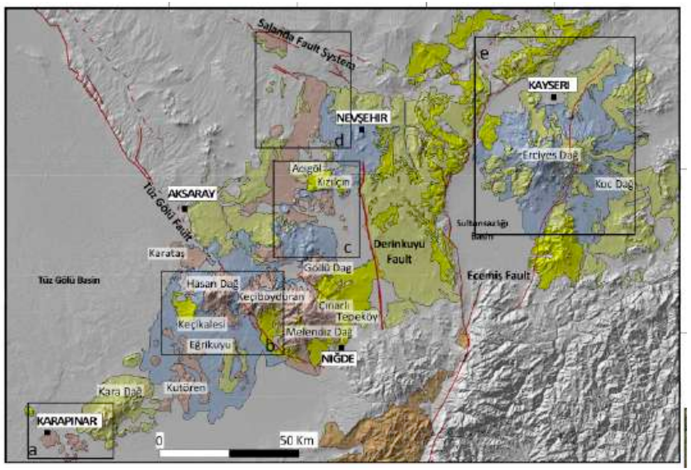


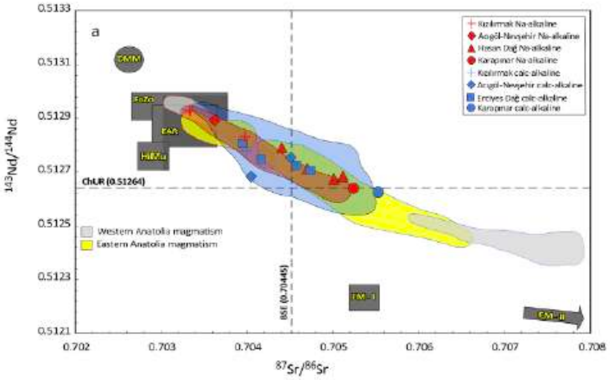
Central Anatolia (Cappadocia)





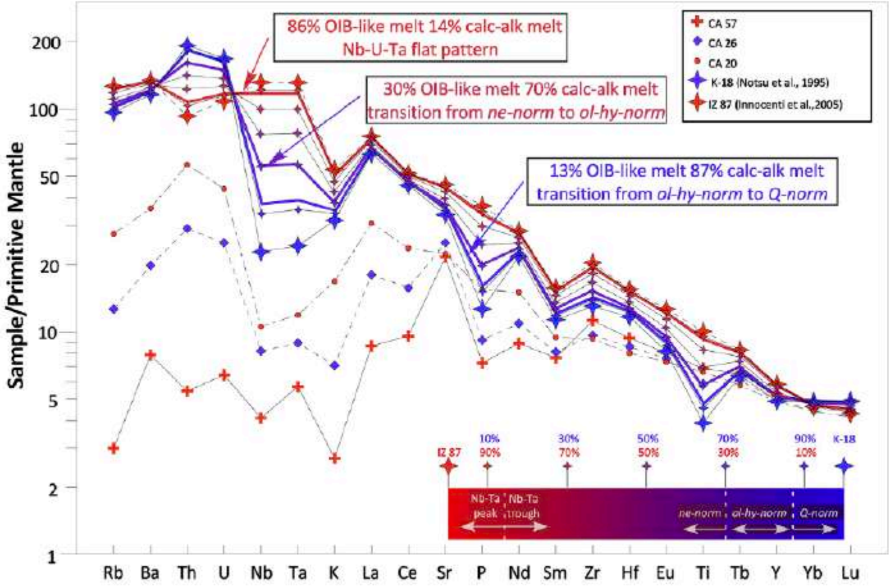


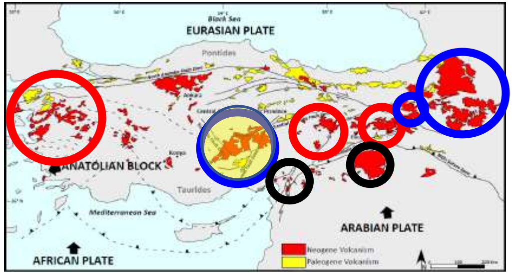


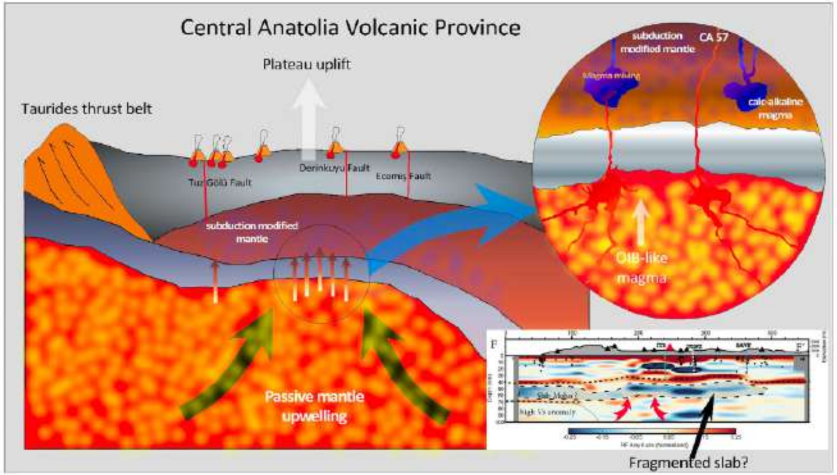


Di Giuseppe et al., 2018 (Lithos)

Central Anatolia (Cappadocia)

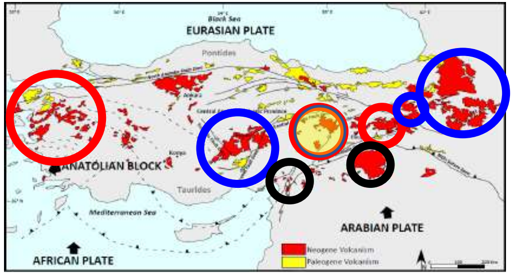


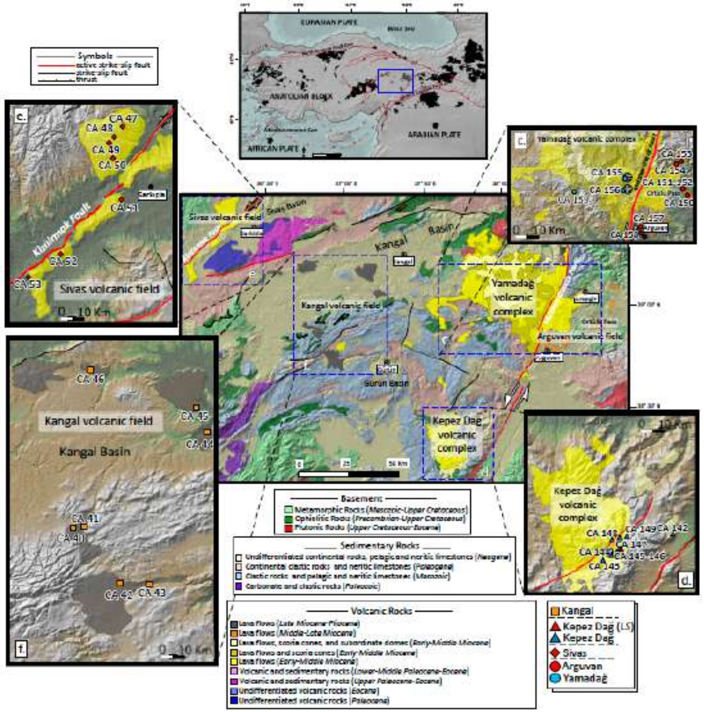


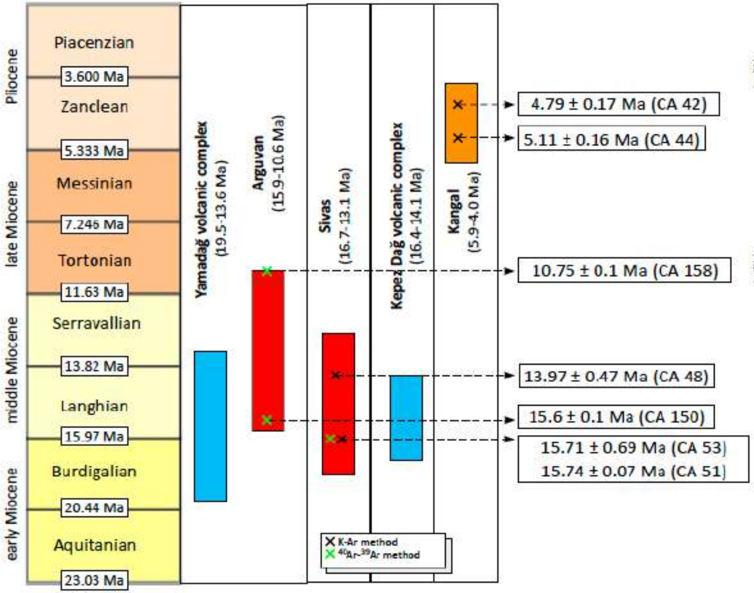


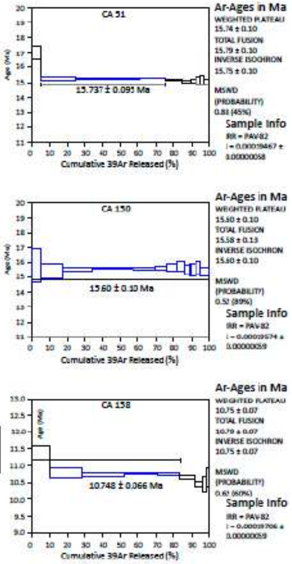
Di Giuseppe et al., 2018 (Lithos)

Central Eastern Anatolia



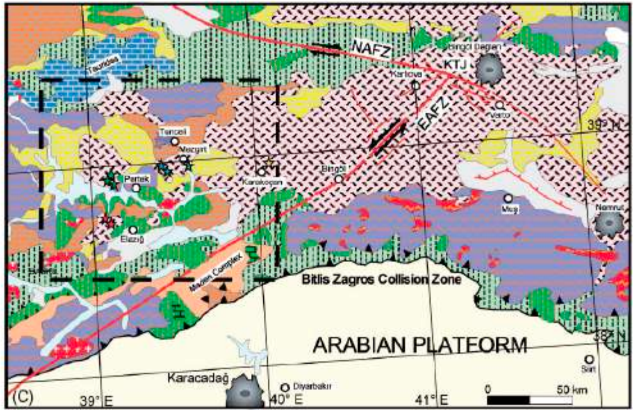


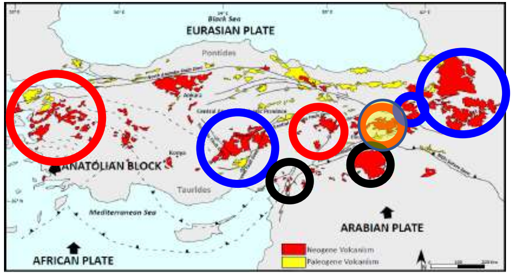


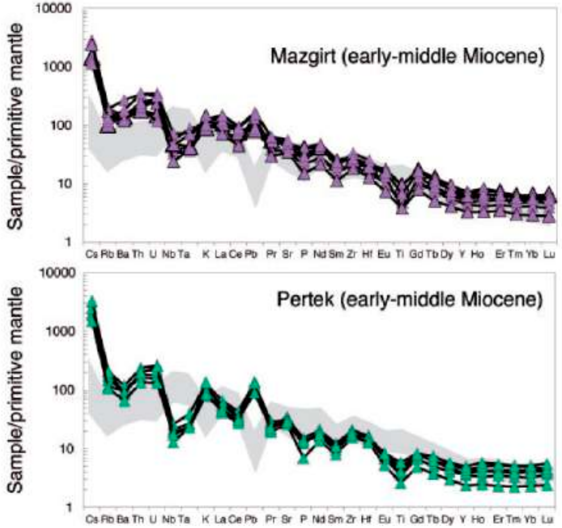


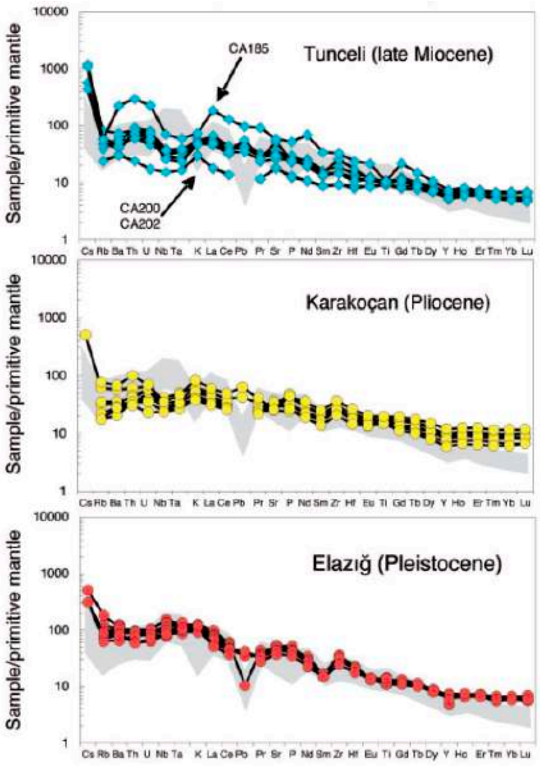
Di Giuseppe et al. (submitted)

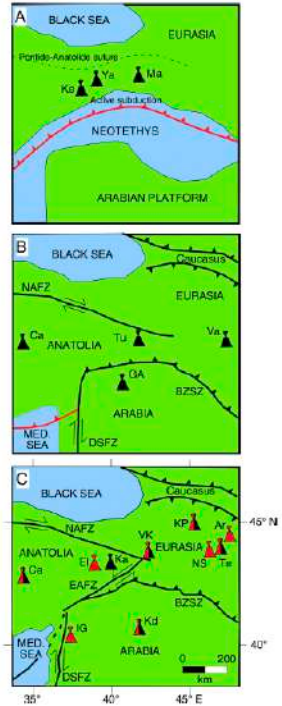
Eastern Anatolia





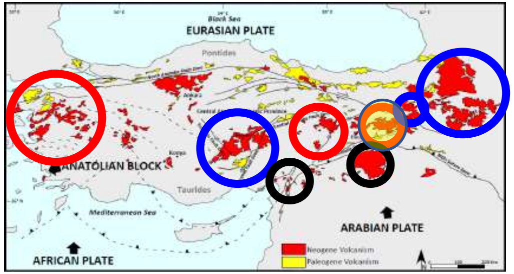




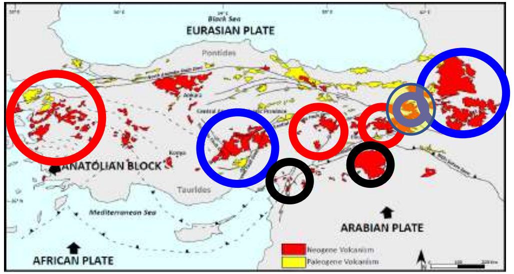


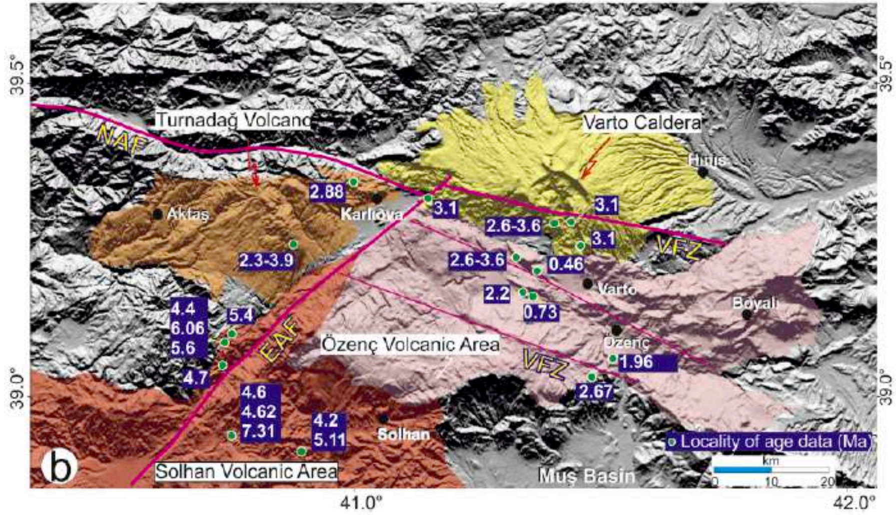
Di Giuseppe et al., 2017 (J Petrol); Agostini et al., 2019 (It J Geosci)

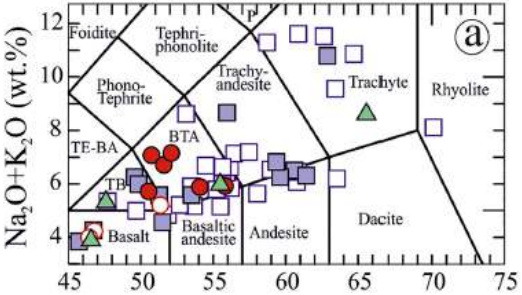
Eastern Anatolia

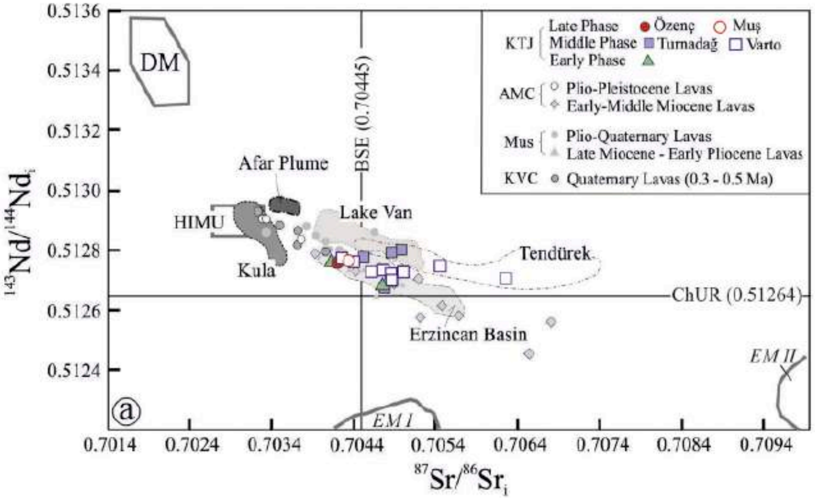


Karliova Triple Junction



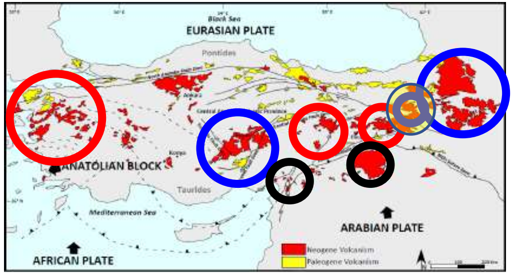




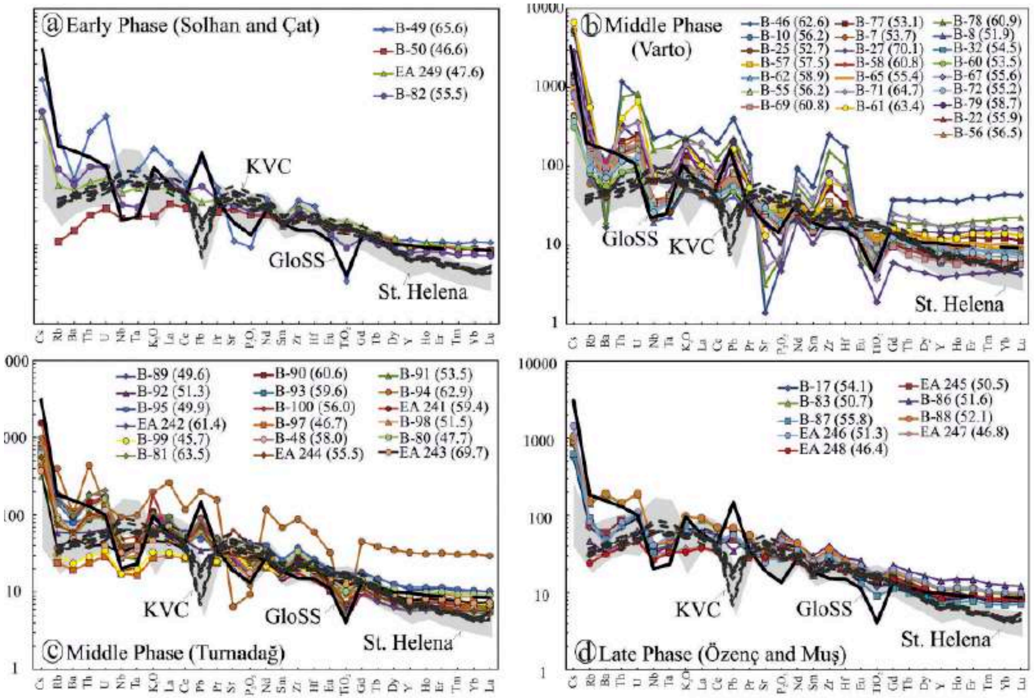


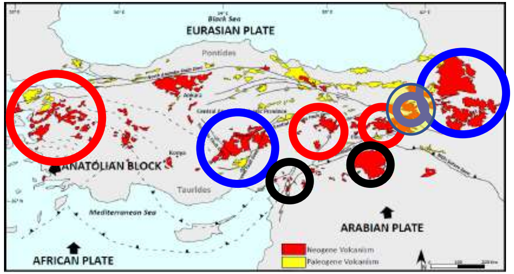
Karaoğlu et al., 2020 (Lithos)

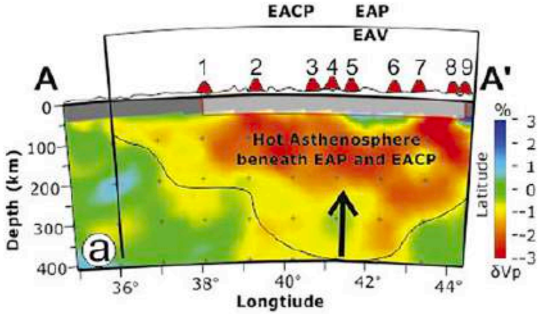
Karliova Triple Junction

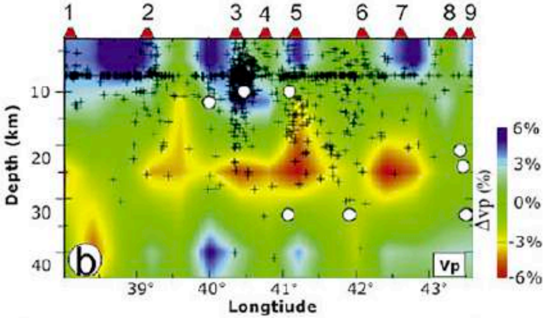


Karliova Triple Junction







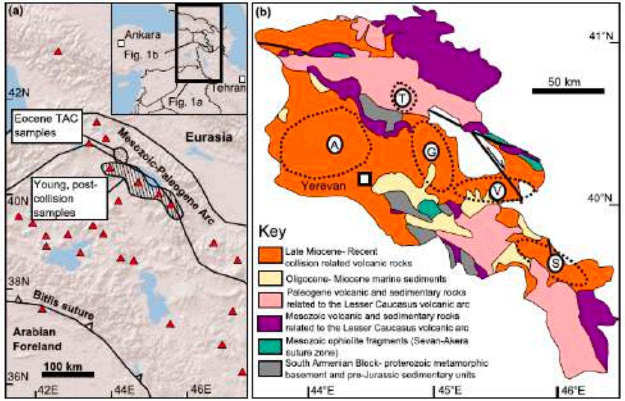


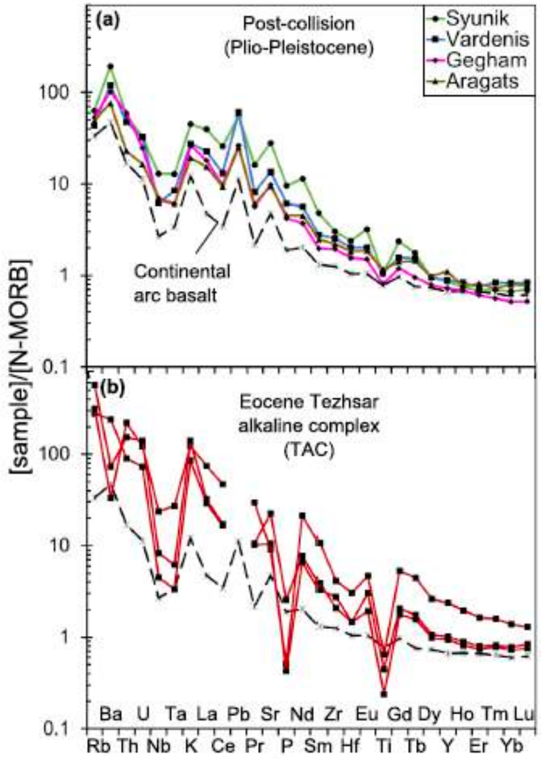
Volcanoes
1: Yamadağ 2: Tunceli 3: Turnadağ 4: Bingöl 5: Varto caldera
6: Nemrut caldera 7: Süphan 8: Etrüsk 9: Tendürek

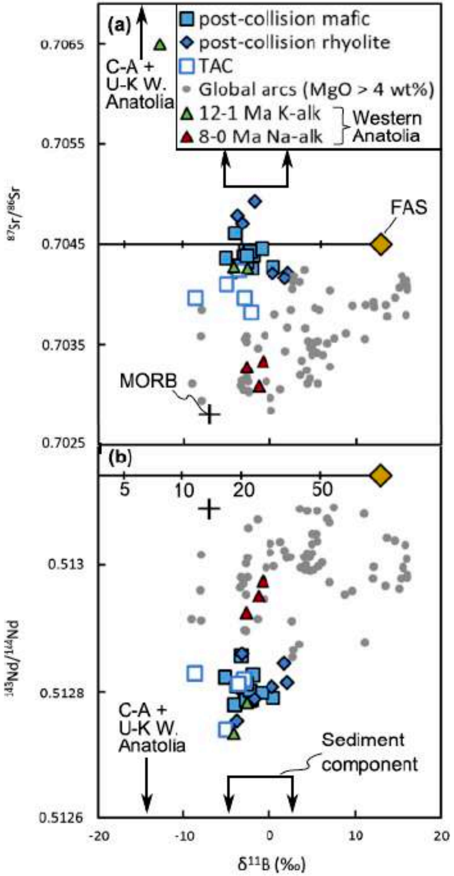
Karaoğlu et al., 2020 (Lithos)

Armenia

Armenia



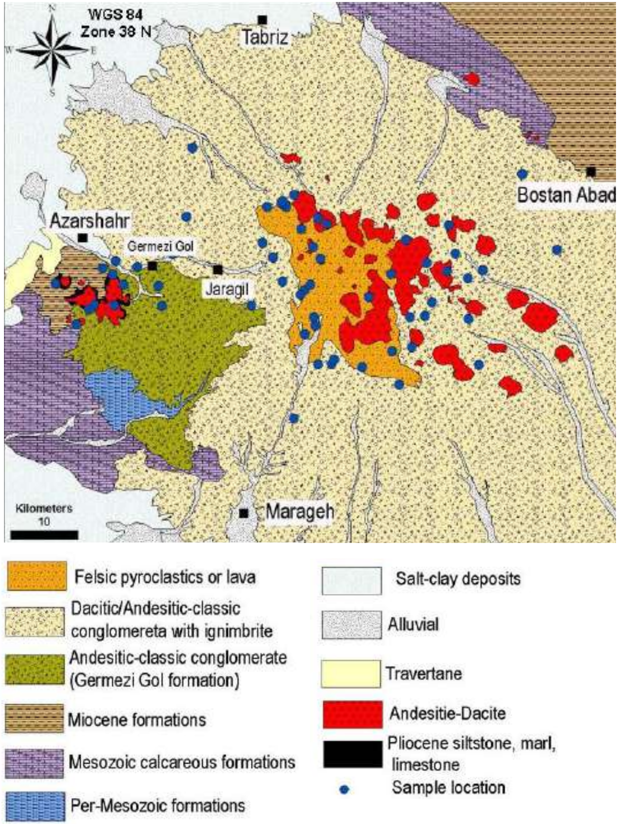


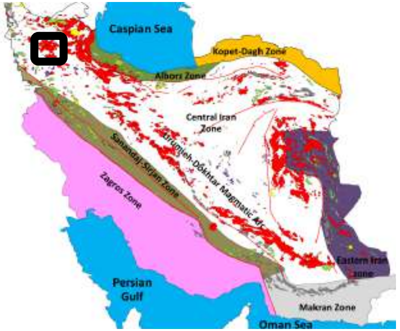


Sugden et al., 2020 (EPSL)

Iran

Iran (Sahand)

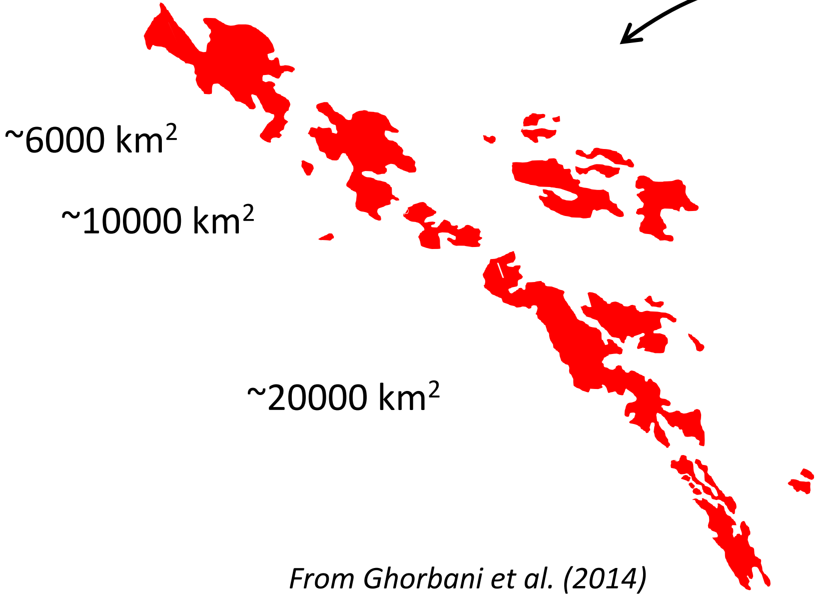




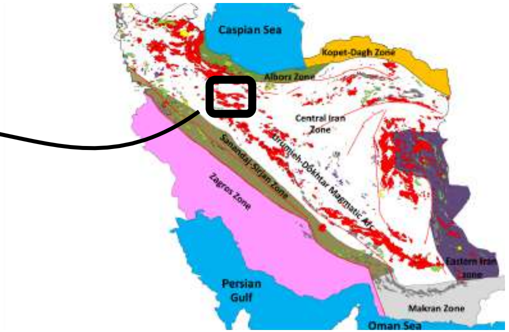
~7200 km^2
3600 m.a.s.l.

- <u>Quaternary age</u>: high-K andesitic and dacitic magma
- <u>10-5 Ma</u>: calcalkaline dacitic magma
- <u>12-9 Ma</u>: calcalkaline basaltic andesites/andesites

Iran (Tafresh)



From Ghorbani et al. (2014)



~ <u>15 Ma (Mid. Miocene)</u>: dacites

~ <u>19 Ma (Early Miocene)</u>: enriched Nb-Ta basalts

~ <u>26 Ma (Late Oligocene)</u>: calcalkaline andesites

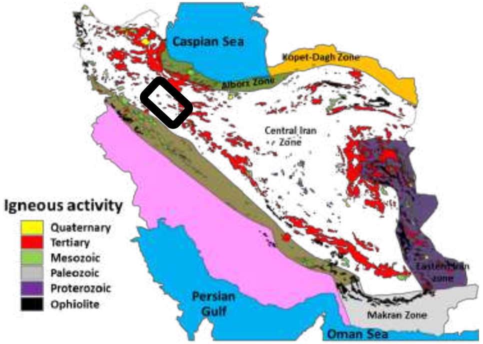
~ <u>35 Ma (Late Eocene)</u>: calcalkaline basalt

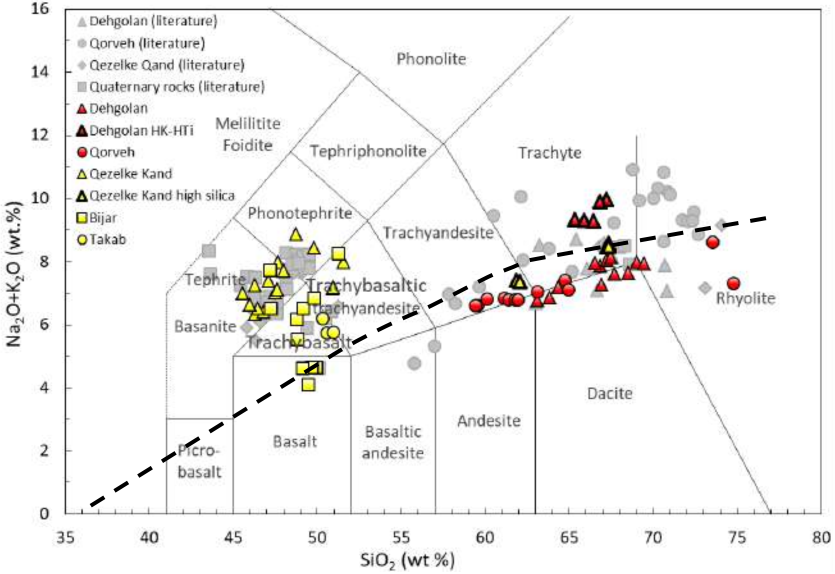
Coeval volcanism in CENTRAL UDMA (Tafresh-Kashan-Nain area)

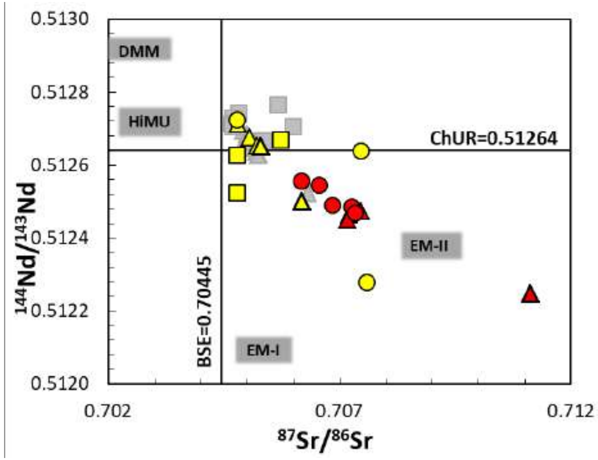
Iran (Bijar-Qorveh)

- Late Miocene (9-8 Ma): dacitic-rhyolitic domes and pyroclastic deposits

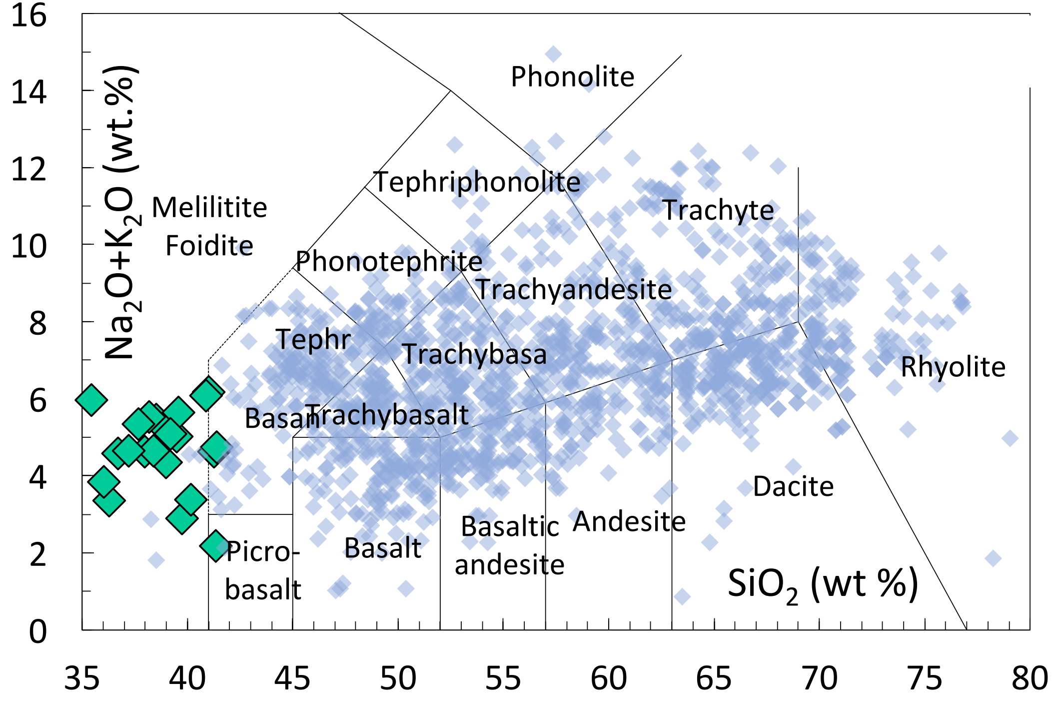
- Quaternary (1.3-0.5 Ma): strongly SiO_2 undersaturated alkaline spatter, cinder cones and lavas

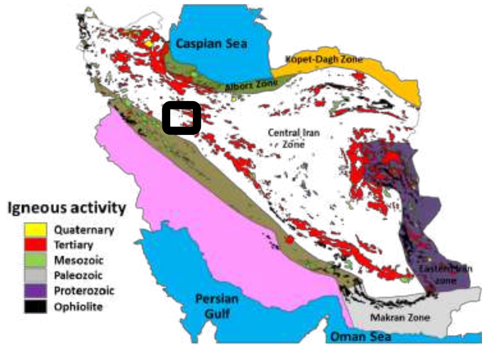


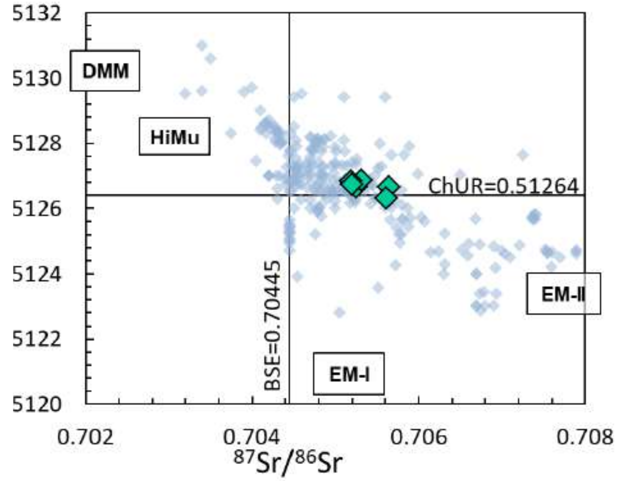




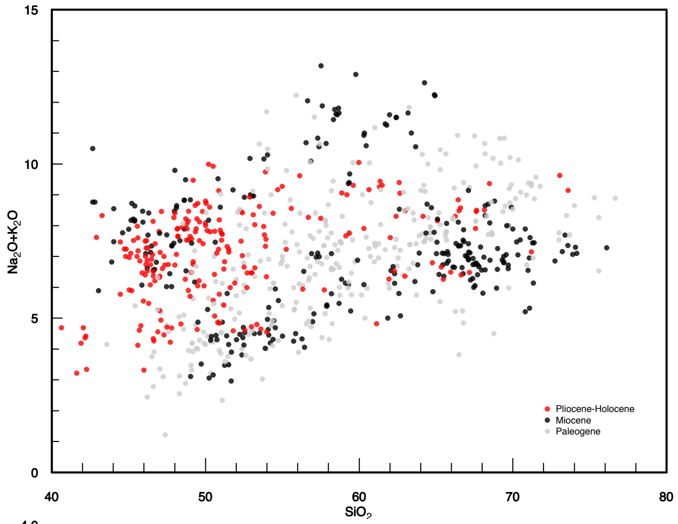
Iran (Nowbaran)

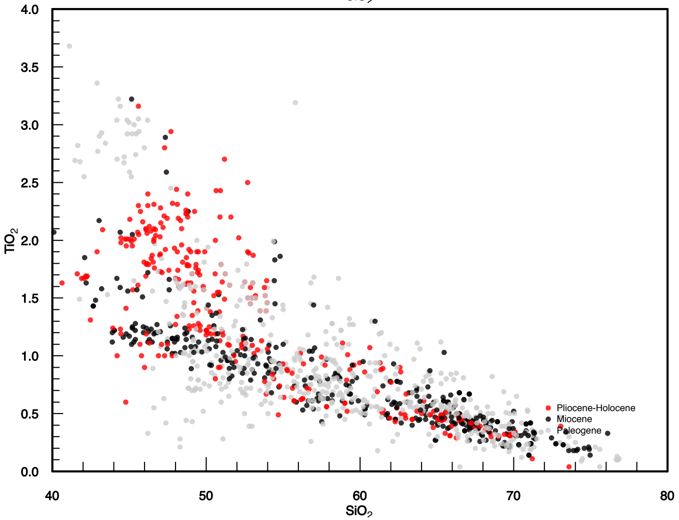


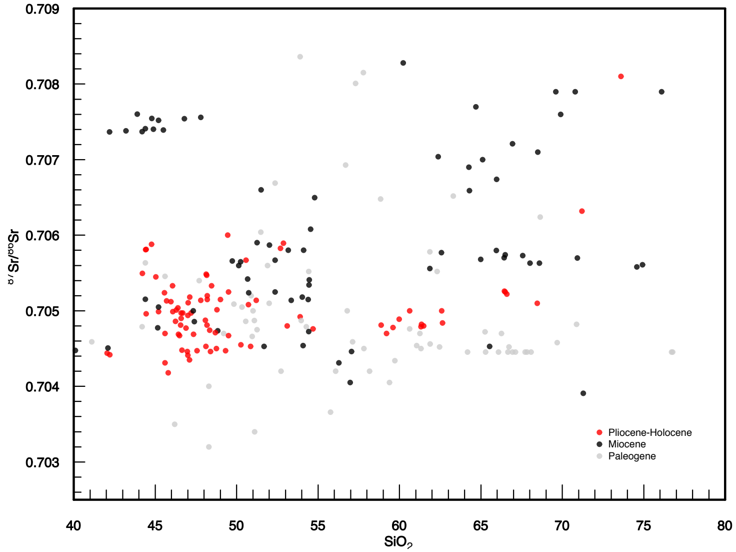




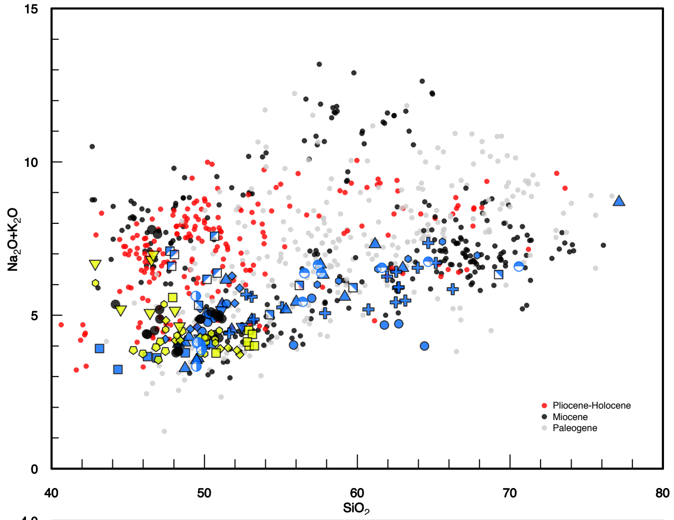
Iran vs. Anatolia

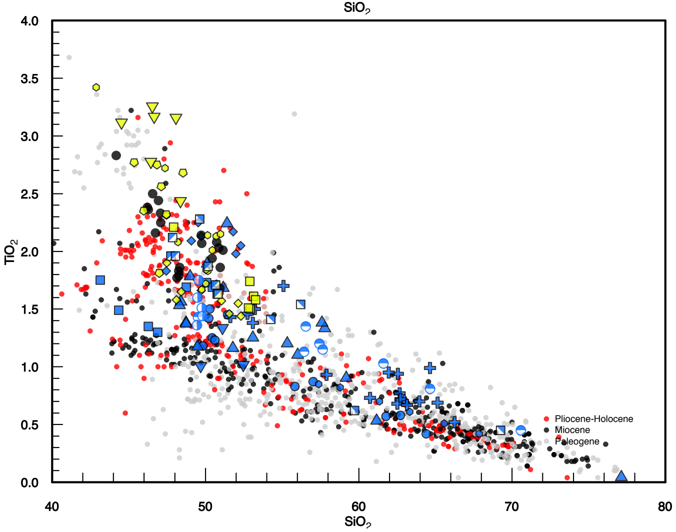


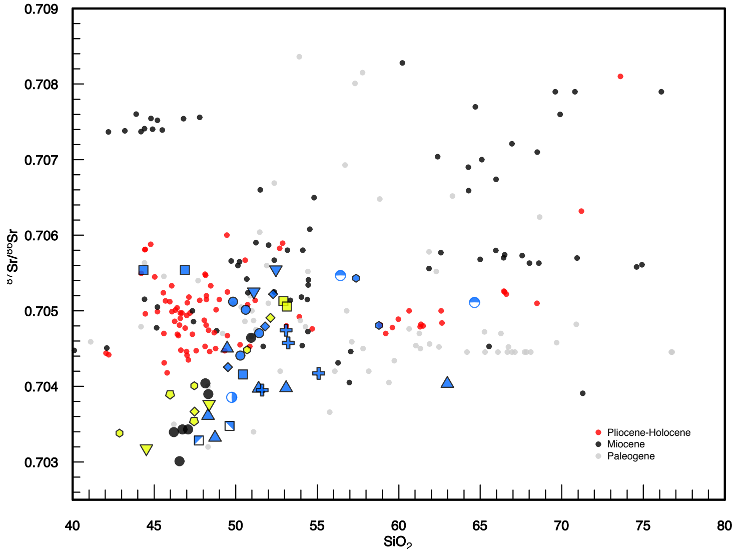




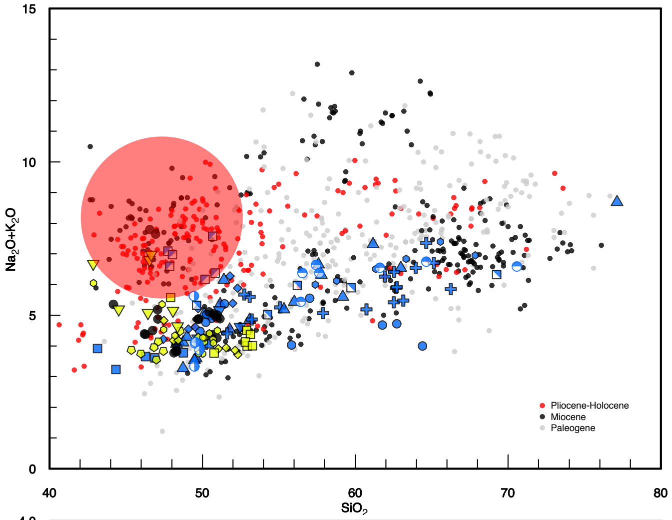
Iran vs. Anatolia

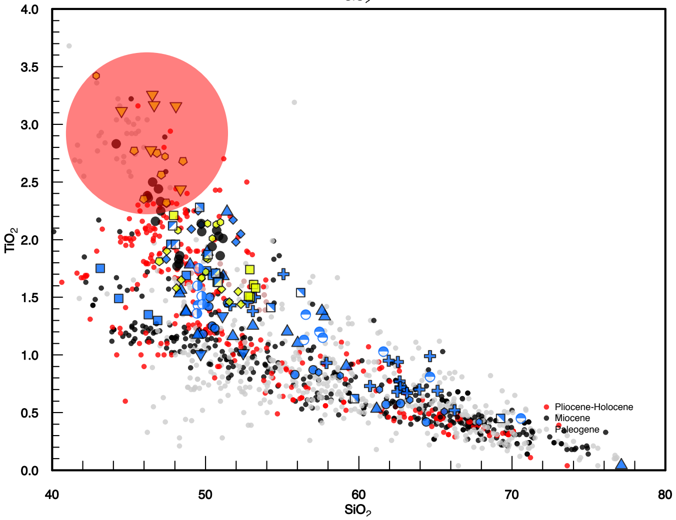


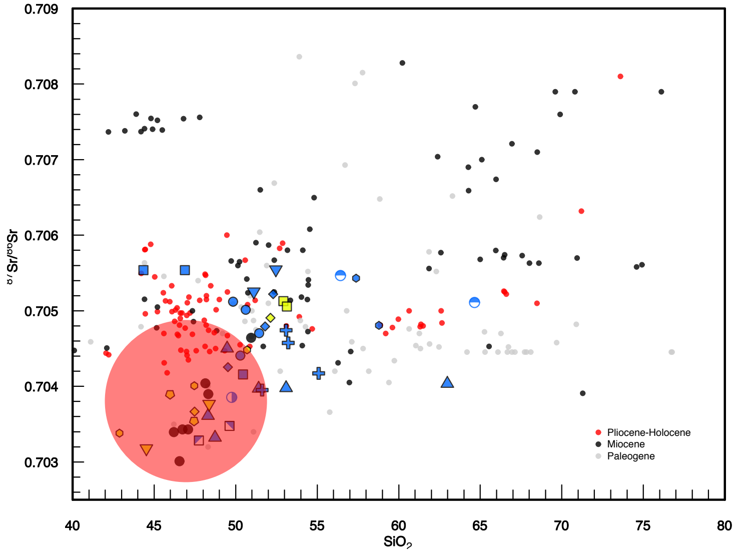




Iran vs. Anatolia



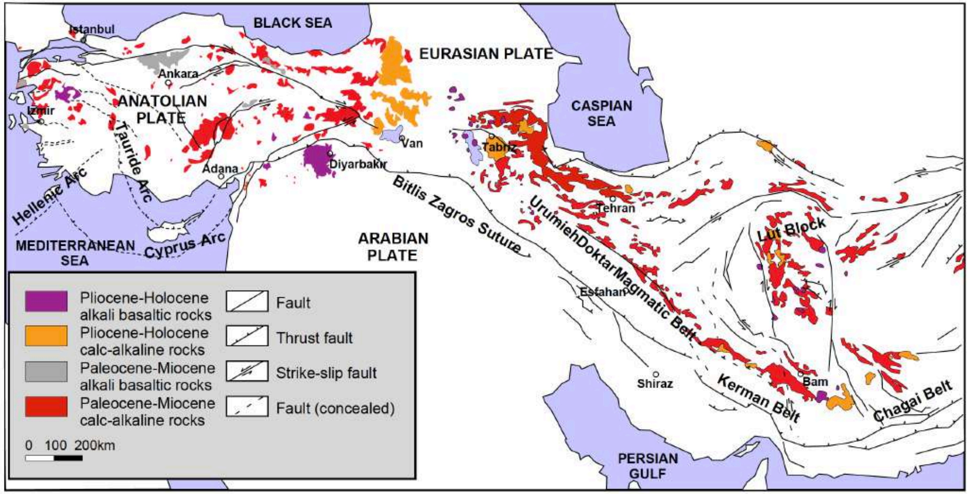


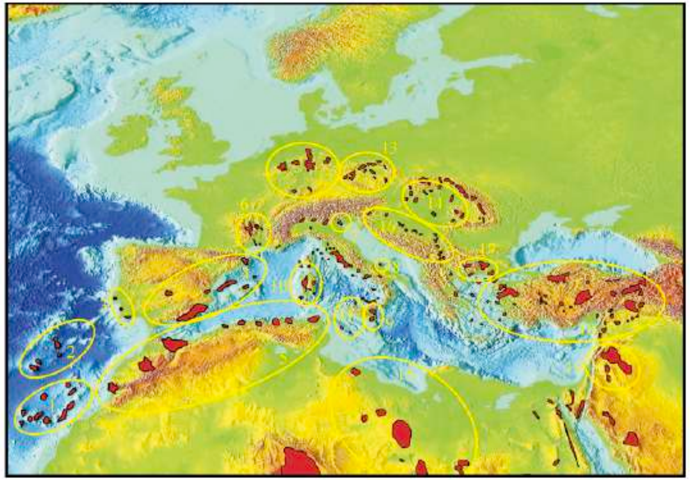


Sub-continental “OIB-type” basalts

- Common in Continental rift or extensional areas
- Common throughout Mediterranean (CiMACI, EAR…)
- Similar to Oceanic Island Basalts
- Plume Related?
- May carry mantle xenoliths

- Typical features: Ol-phyiric, Na-alkaline, $^{87}Sr/^{86}Sr$ = 0.7025-0.7040



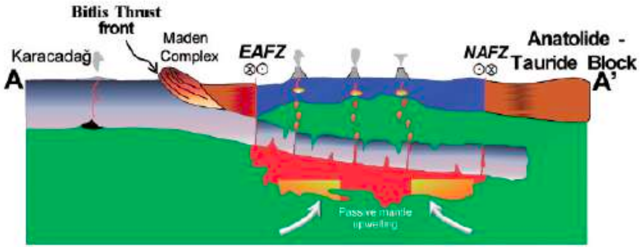


Lustrino and Wilson, 2007 (ESR)

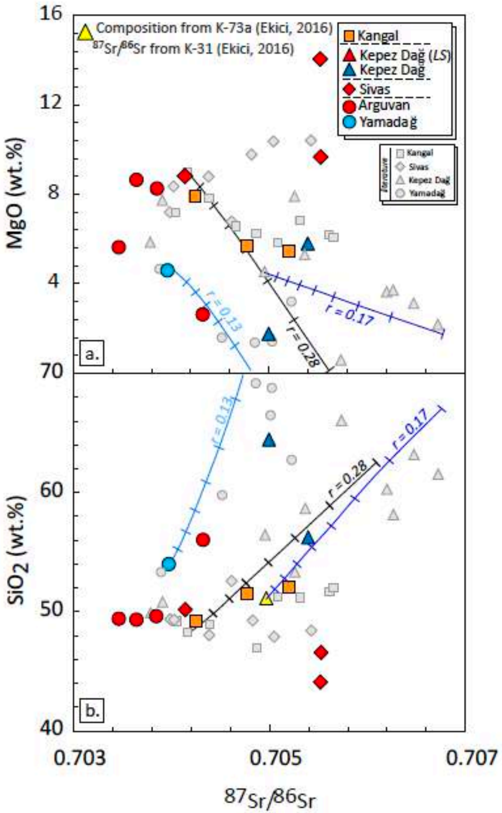
- Found in Western, (Central), Eastern, Southeastern Anatolia
- Not found in Iran

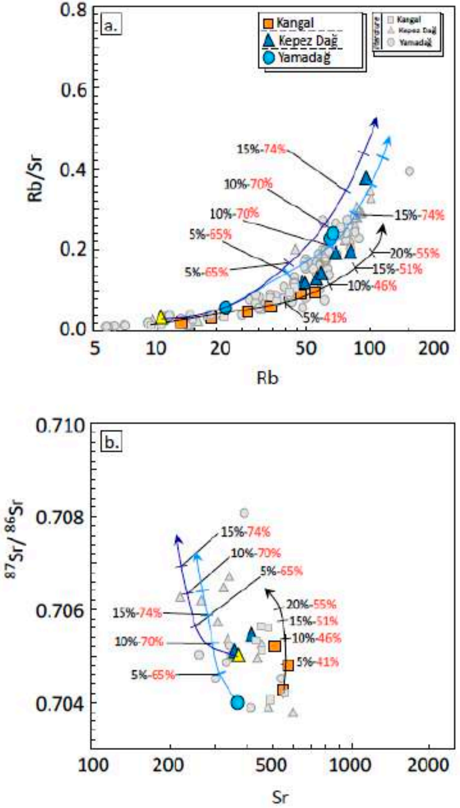
Sub-continental “OIB-type” basalts

- Found in Western, (Central), Eastern, Southeastern Anatolia
- Not found in Iran



- More widespread as we think
- Sourced in sub-slab mantle
- Primary characters may be obliterated during upraise
- Different kind of interactions lead to different final products
- Primary characters preserved in extensional zones or pull-apart basin linked to transcurrent/transform faults



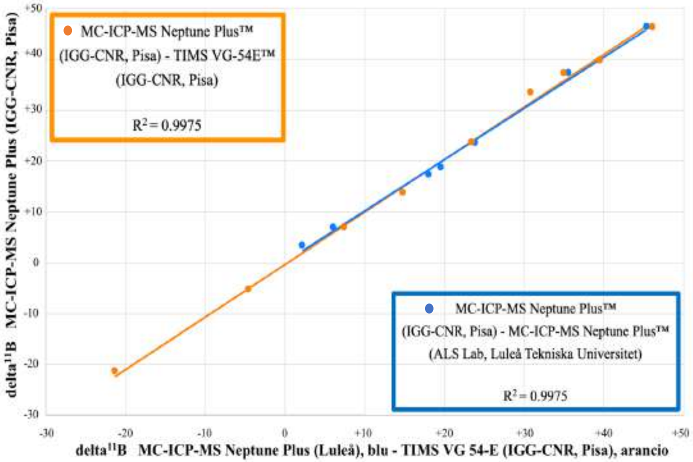


B isotopes with Neptune MC-ICP-MS

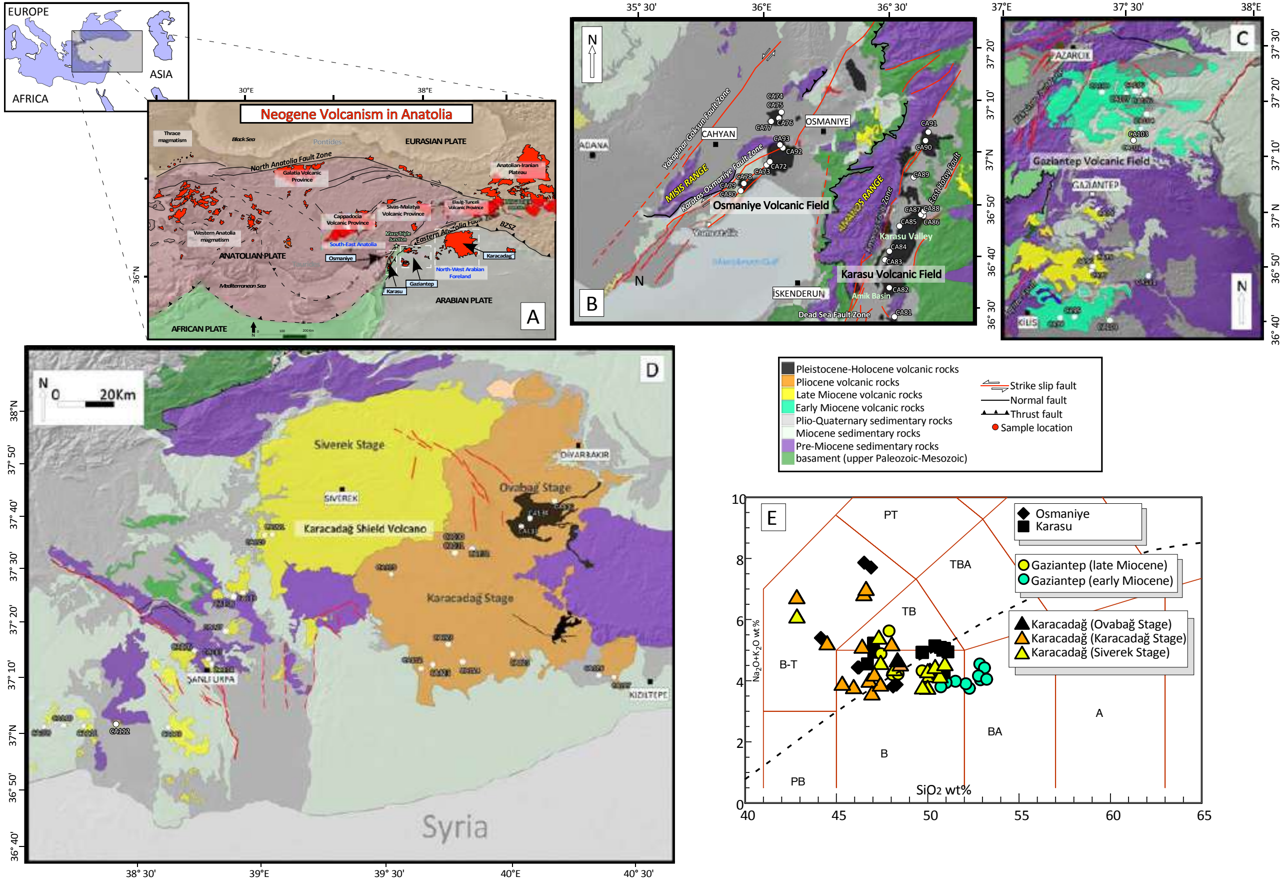
W Anatolia data: VG 54E TIMS (2005)
New data: Neptune Plus MC-ICP-MS (2019)

Very similar chemical procedure
Lots of advantages during analyses

- 100 ng of boron needed against 2000 ng
- Easy to measure sample with less than 1-2 ppm of B
- External reproducibility better than 0.5‰ for all of the samples
- Data Intercalibration performed

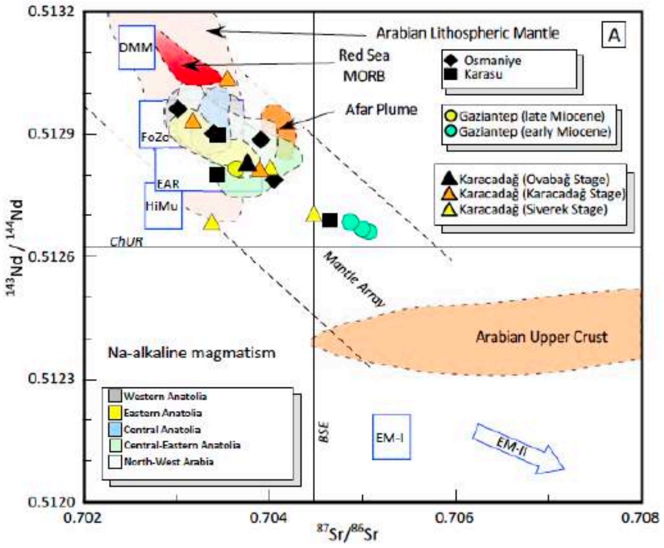


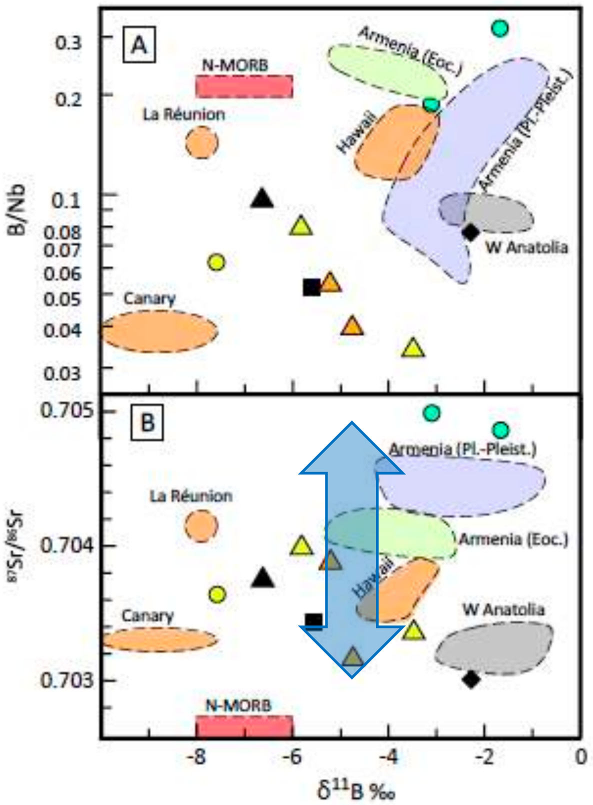
South East Anatolia



Agostini et al., in prep.

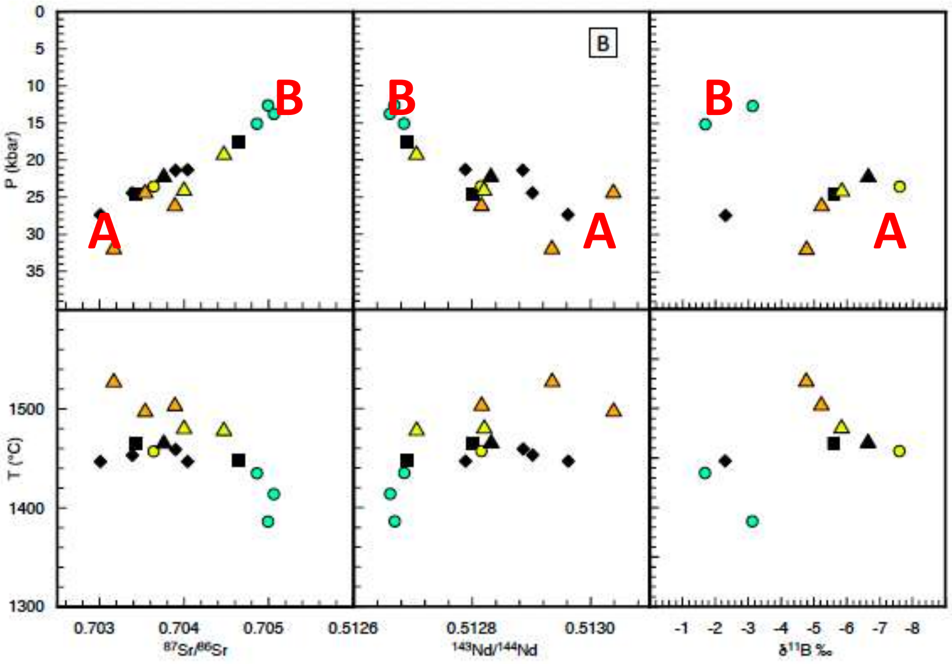
South East Anatolia





Agostini et al., in prep.

South East Anatolia

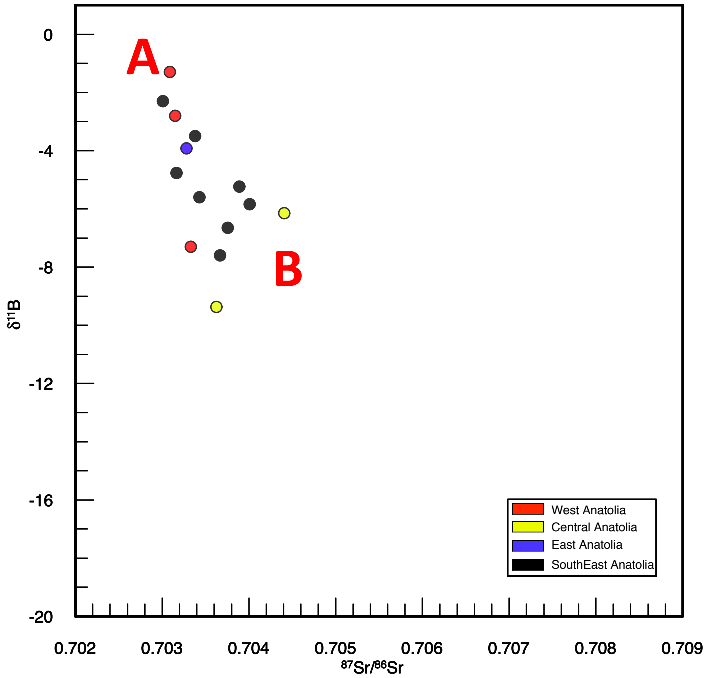


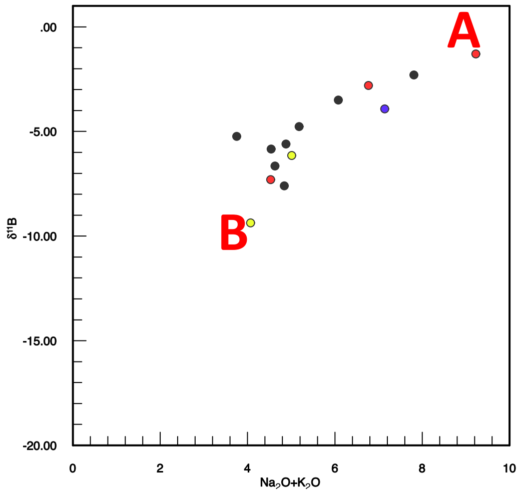
Sample sourced in sub-lithospheric mantle with **no** subduction imprint distribute in a trend along two end-members:

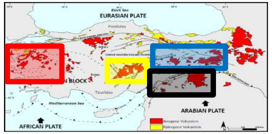
- A) deeper, more depleted (lower $^{87}Sr/^{86}Sr$), ^{11}B enriched domain, generating more alkaline magmas
- B) shallower, more enriched, ^{11}B-depleted (or normal?) domain, generating less alkaline magmas

Agostini et al., in prep.

Not only South East Anatolia







Same trend for rocks coming from distances of > 2000 km and belonging to different plates

Sample sourced in sub-lithospheric mantle with **no** subduction imprint distribute in a trend along two end-members:

- A) deeper, more depleted (lower $^{87}Sr/^{86}Sr$), ^{11}B enriched domain, generating more alkaline magmas
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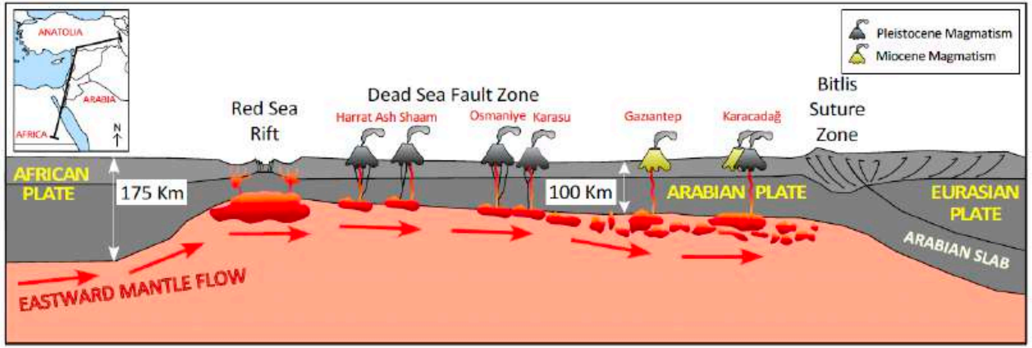
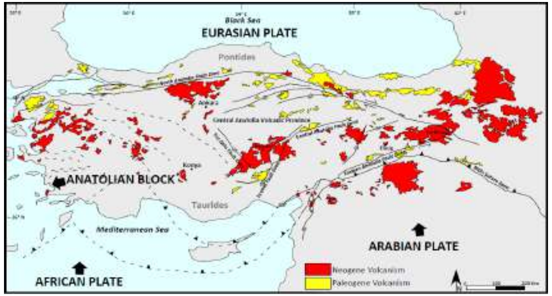
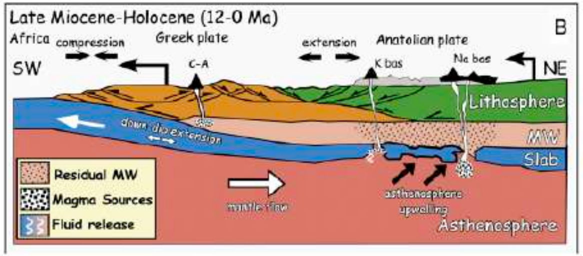
South East Anatolia

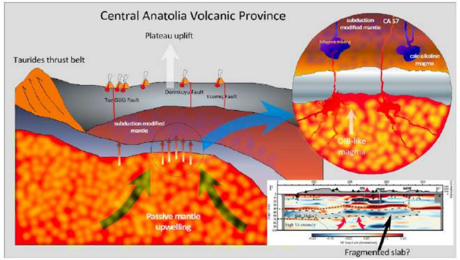




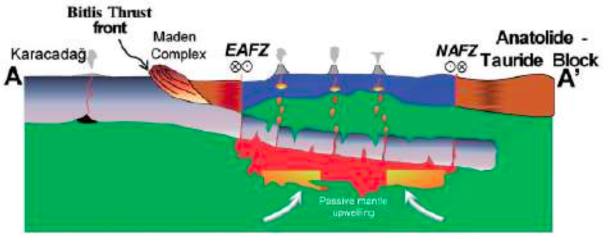
Western Anatolia



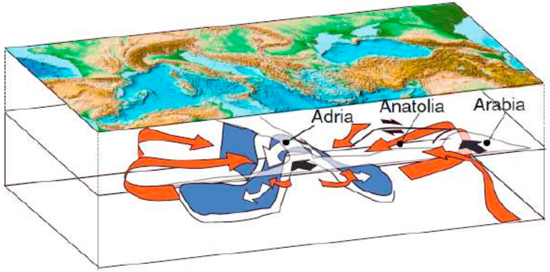
Central Anatolia



Eastern Anatolia



Alternative Model

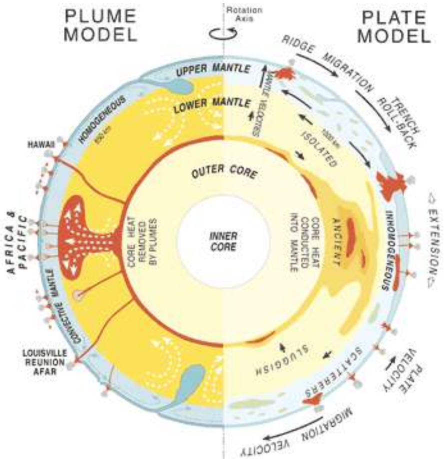


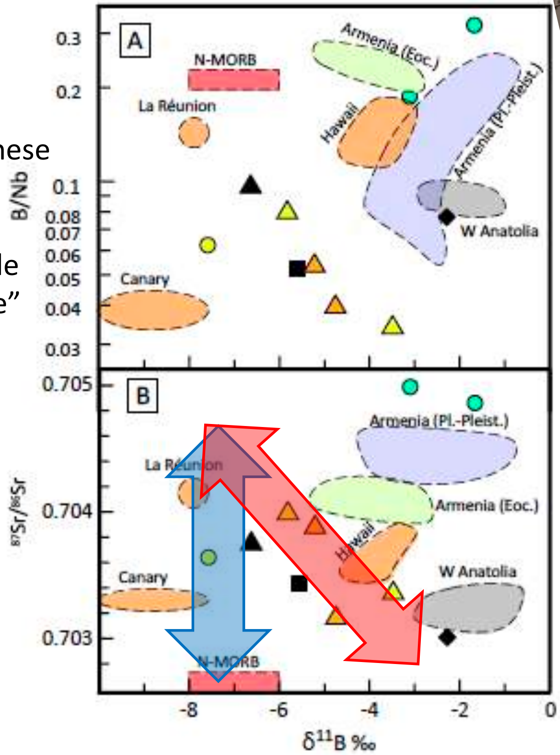
Take home message:

- Any sub-slab mantle underneath Anatolia and Arabia is African Subcontinental Mantle

Why Sub-continental “OIB-type” basalts?

- Oceanic basalts from MORBs to OIBs are perfect windows on the underlying mantle. They are often emplaced as primary or near-primary magmas
- What if sub-continental mantle is different from sub-oceanic mantle? We need more windows.
- Adding more isotope systematics is necessary to fully open these windows.
- After more than 3 Ga of subduction, more than 4 Ga of mantle recycling, is there any “primitive mantle” or “depleted mantle” left?





Sub-oceanic Mantle

Sub-continental Mantle?

Arabian plate: perfect for stable isotope studies

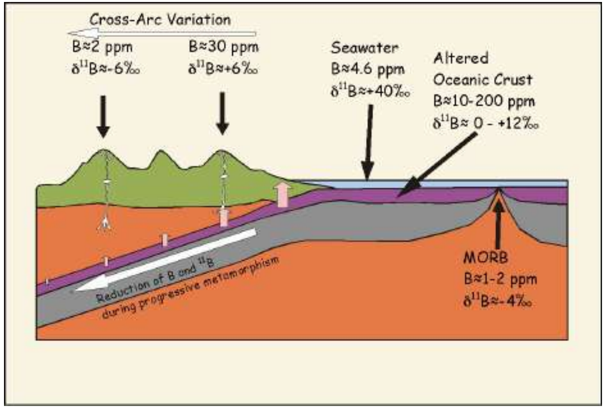
Unambiguous evidence of the occurrence of shallower processes can be provided by stable light isotopes (e.g. H, O, C, S, Li, B), whose variations reflect only low temperature episodes.

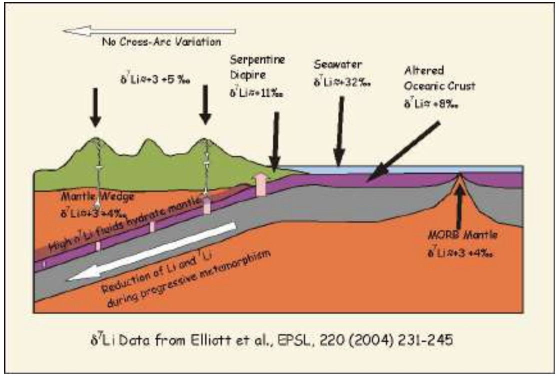
Why? Isotopic composition of stable light isotopes only change as a consequence of isotope fractionation, which is negligible at high T (T≥1000 °C).

Indeed H, O, C, S, Li and B isotope composition is the same in enriched and depleted mantle.

Therefore, light stable isotopes are able to trace the recycling of superficial material in the mantle and re-fertilization of mantle domains.

WARNING: negligible means less than 0.5‰





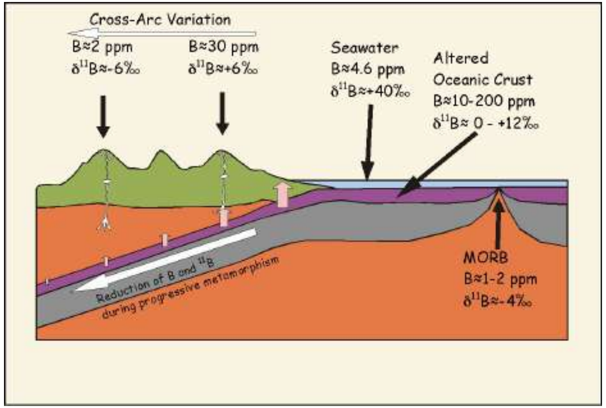
Arabian plate: perfect for ~~stable~~ isotope studies

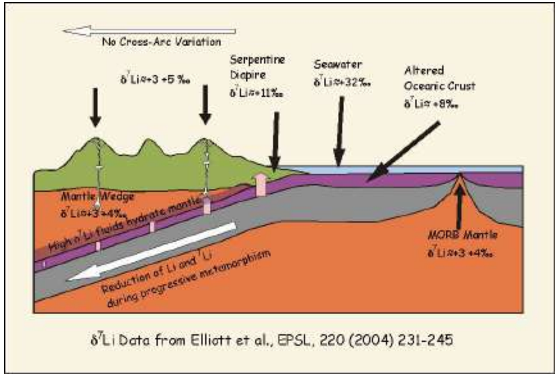
Unambiguous evidence of the occurrence of shallower processes can be provided by stable light isotopes (e.g. H, O, C, S, Li, B), whose variations reflect **mostly** low temperature episodes.

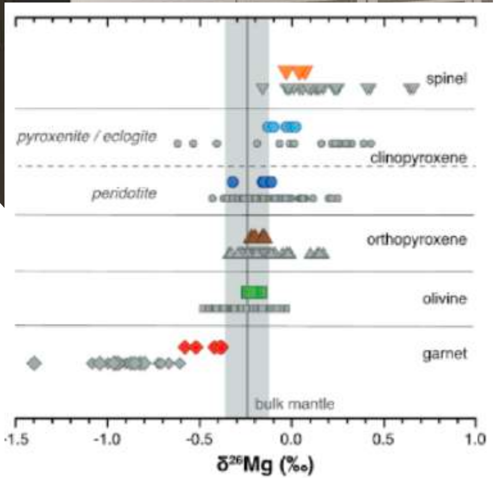
Why? Isotopic composition of stable light isotopes only change as a consequence of isotope fractionation, which is **less than 1‰** at high T (T≥1000 °C).

Indeed H, O, C, S, Li and B isotope composition **is the same (within 1‰) in pristine and depleted mantle after magma estraction.**

Therefore, ~~**light**~~ stable isotopes are able to trace the recycling of superficial material in the mantle and re-fertilization of mantle domains **and other magma depletions events.**







Stracke et al., 2018 (GCA)