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Eastern Anatolia: A hot spot in a collision zone without a mantle plume

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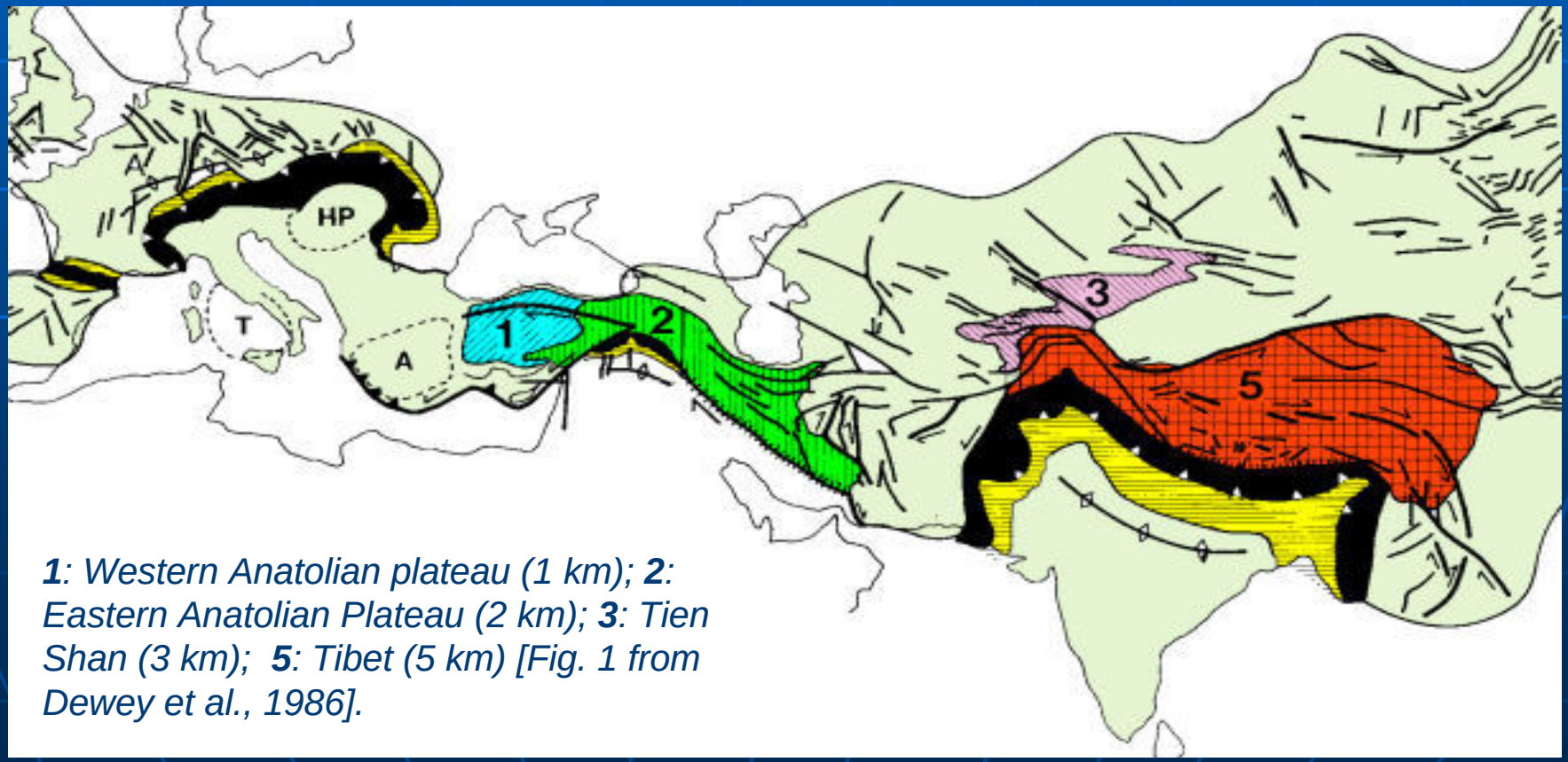
For detailed information, please visit:
http://www.mantleplumes.org/Anatolia.html

Objective

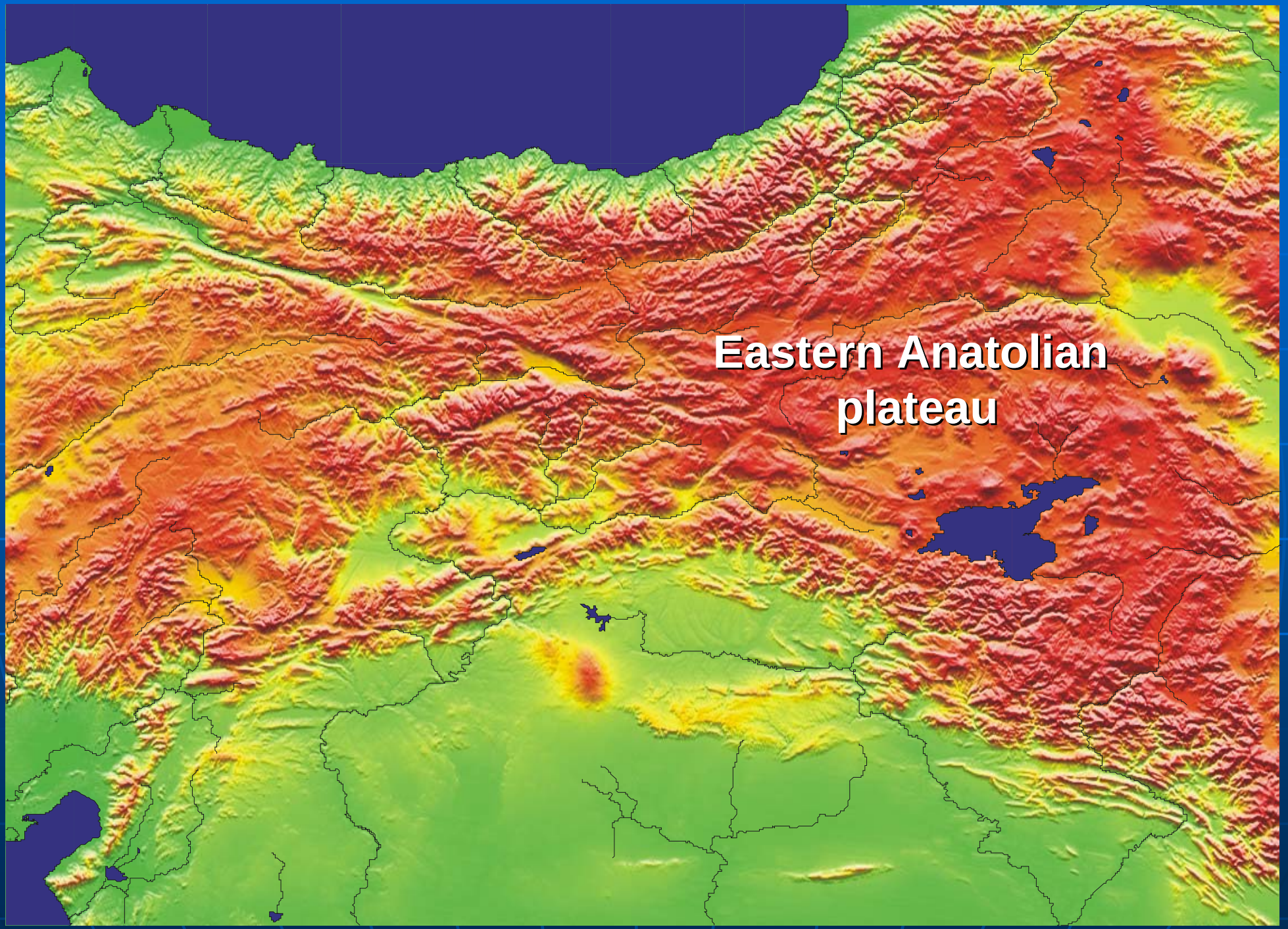
- To present an example from a collision zone where a shallow plate tectonic process has generated both regional lithospheric domal uplift and great volumes of magmatism in the absence of a mantle plume.

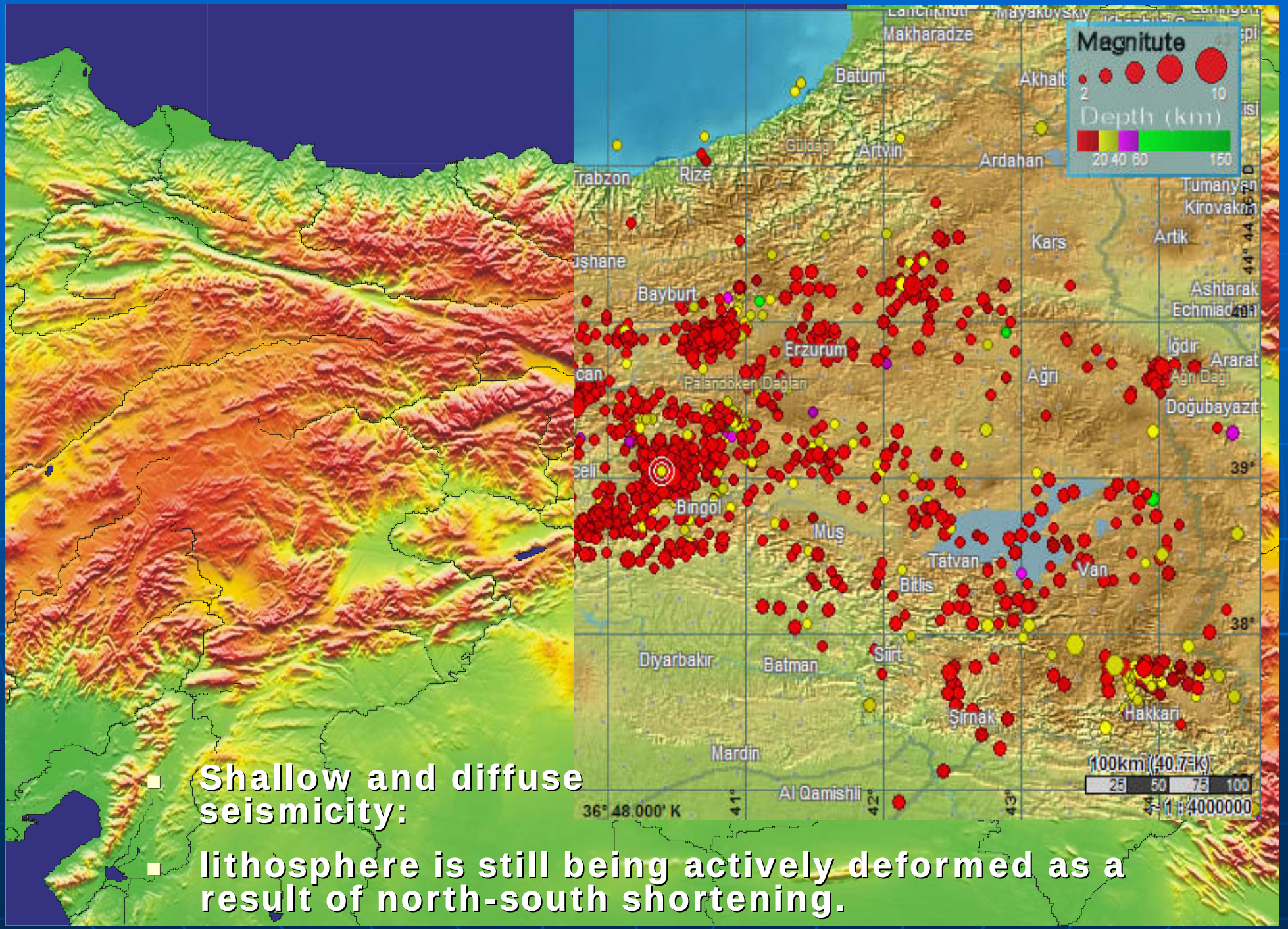
Eastern Anatolian plateau

- One of the best examples of a continental collision zone in the world.
- One of the high plateaus of the Alpine-Himalaya mountain belt (average elevation is ~1.5 - 2 km).
- one of the few regions where active continent-continent collision is currently taking place.

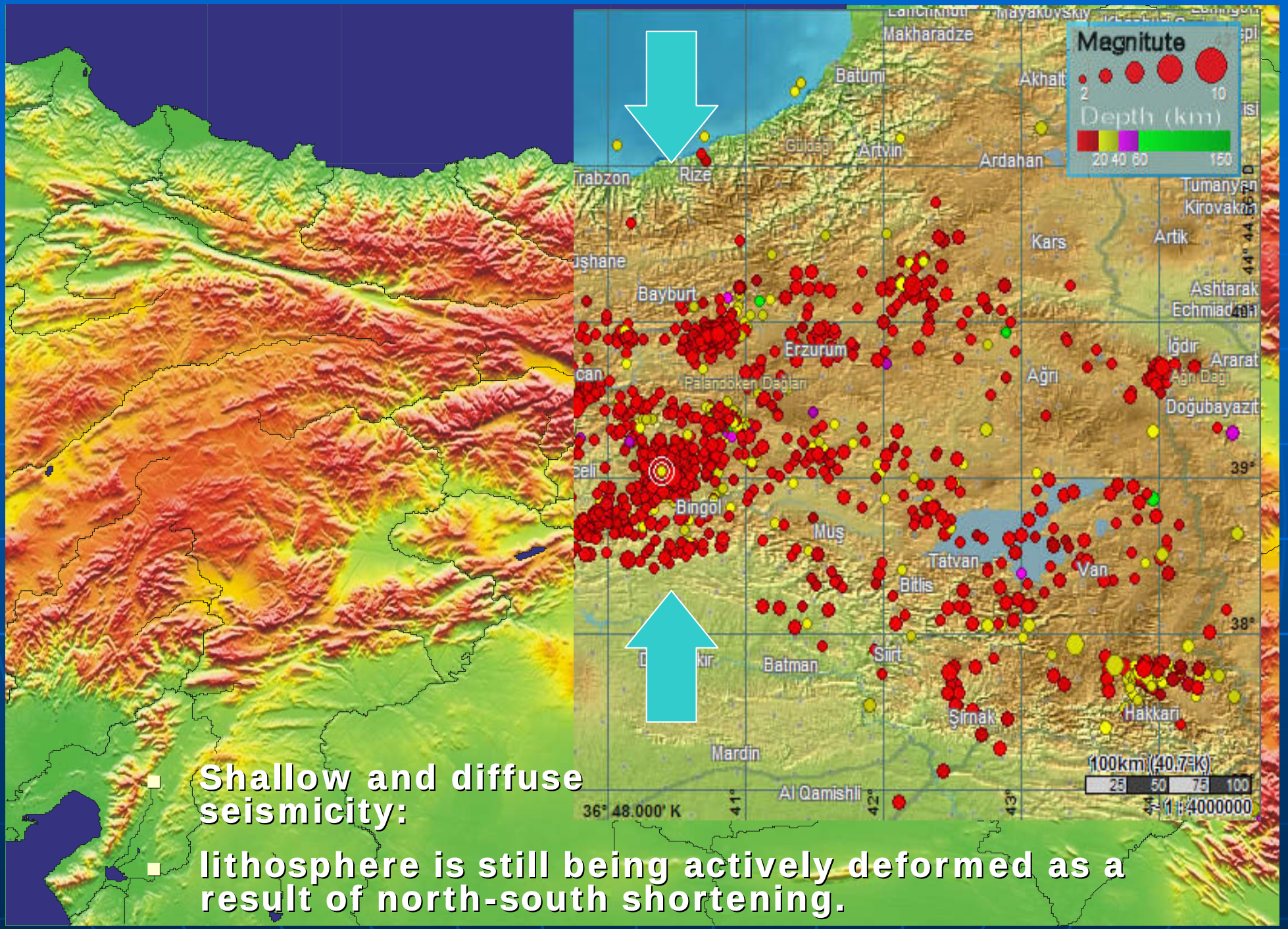


__1__: Western Anatolian plateau (1 km); __2__: Eastern Anatolian Plateau (2 km); __3__: Tien Shan (3 km); __5__: Tibet (5 km) [Fig. 1 from Dewey et al., 1986].


Eastern Anatolian
plateau



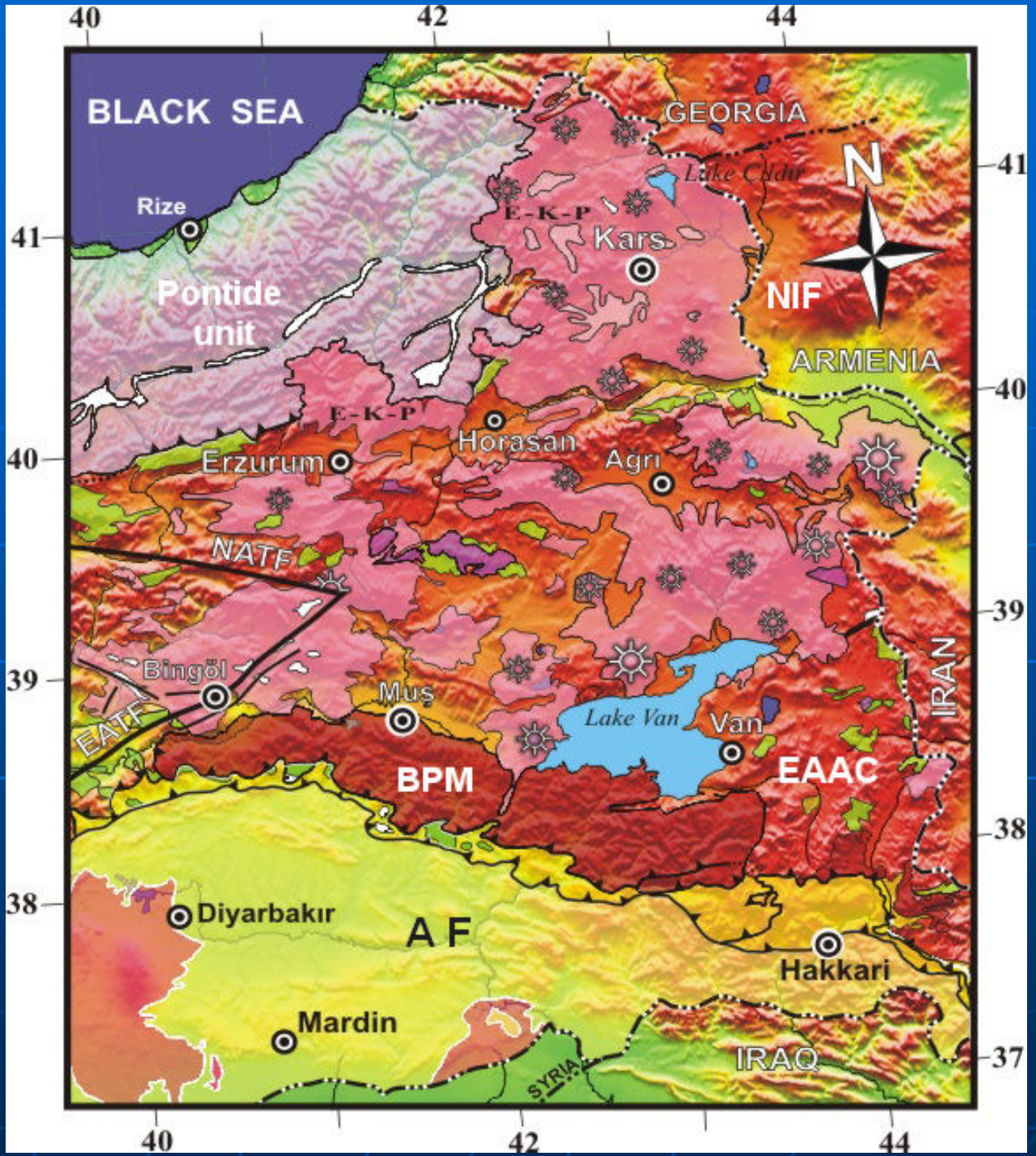
- **Shallow and diffuse seismicity:**
- **lithosphere is still being actively deformed as a result of north-south shortening.**

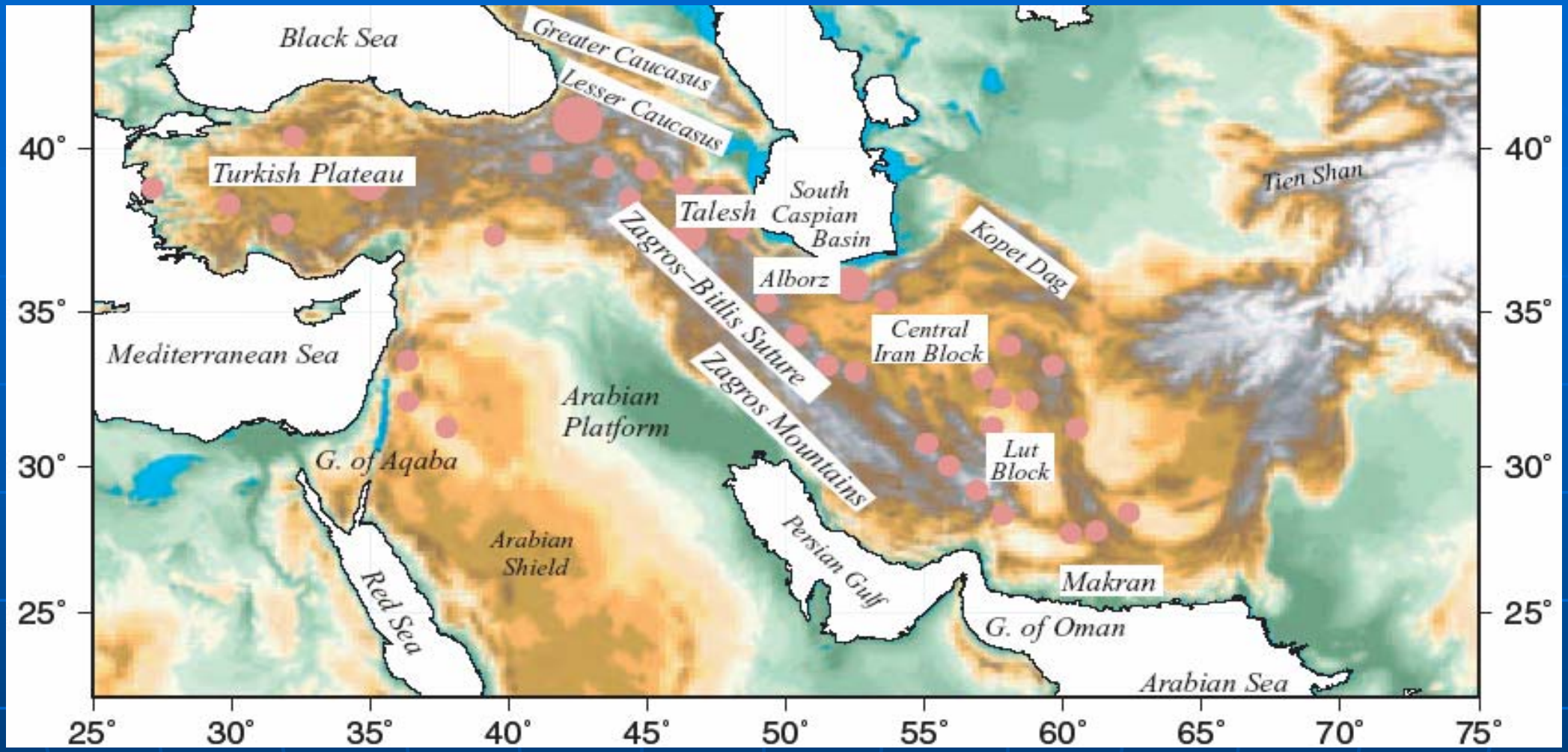


- **Shallow and diffuse seismicity:**
- **lithosphere is still being actively deformed as a result of north-south shortening.**
- **the collision is still in progress.**

- The region is covered with a widespread and thick collision-related volcanic sequence. (>1 km in thickness in places)

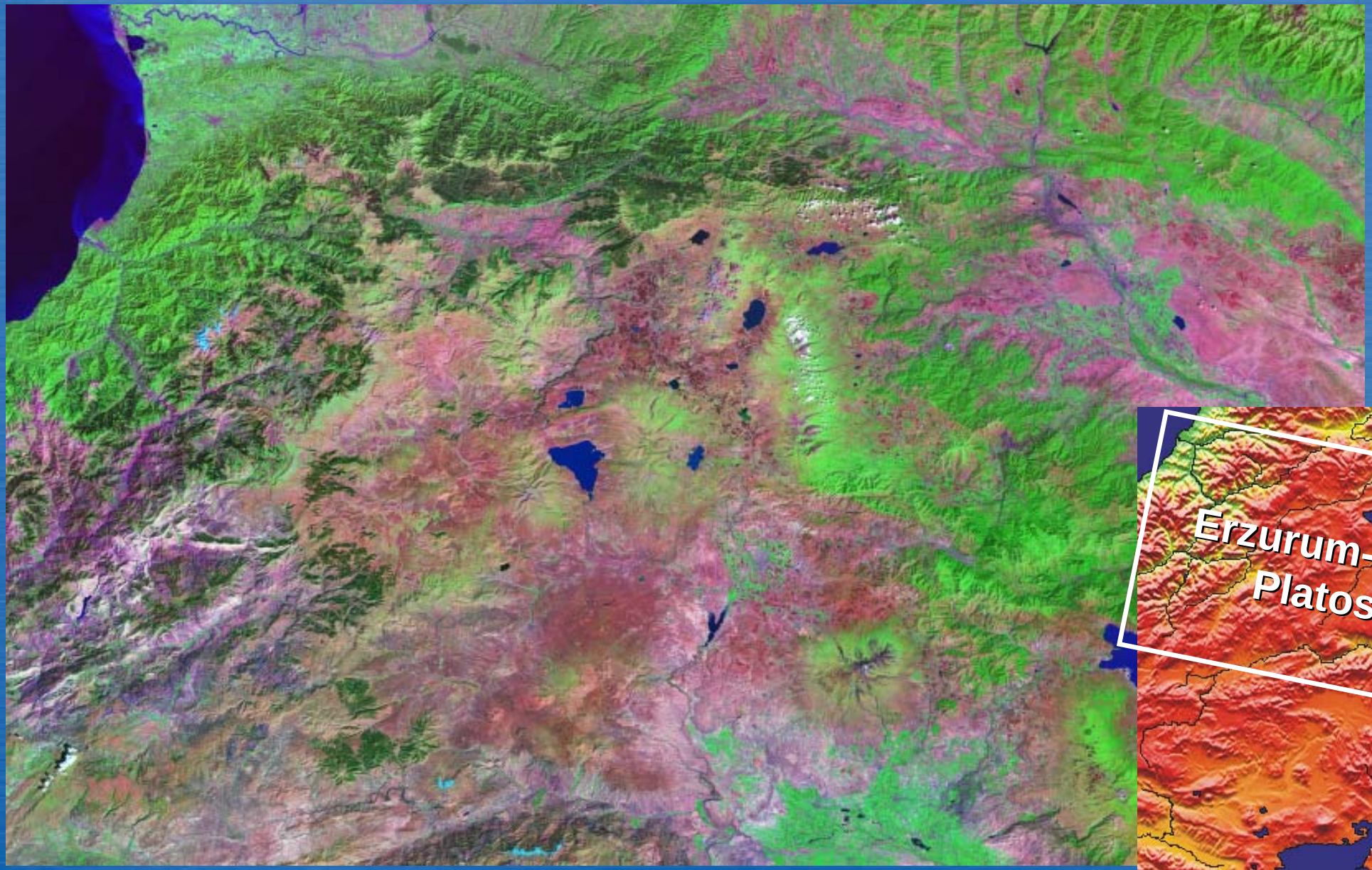
- Almost 2/3 of the region is covered by these volcanic units. (around 43000 km² in E Anatolia).



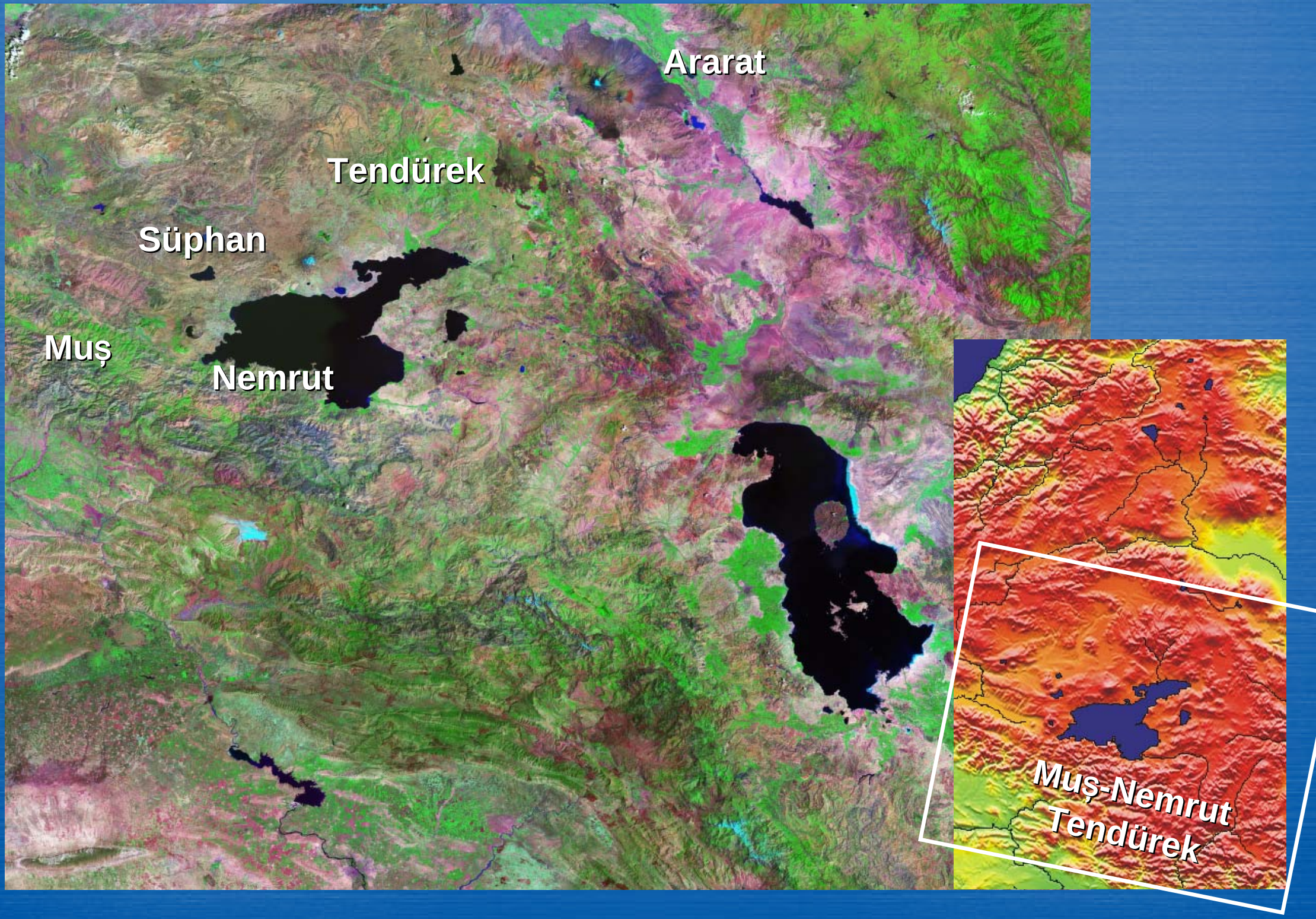


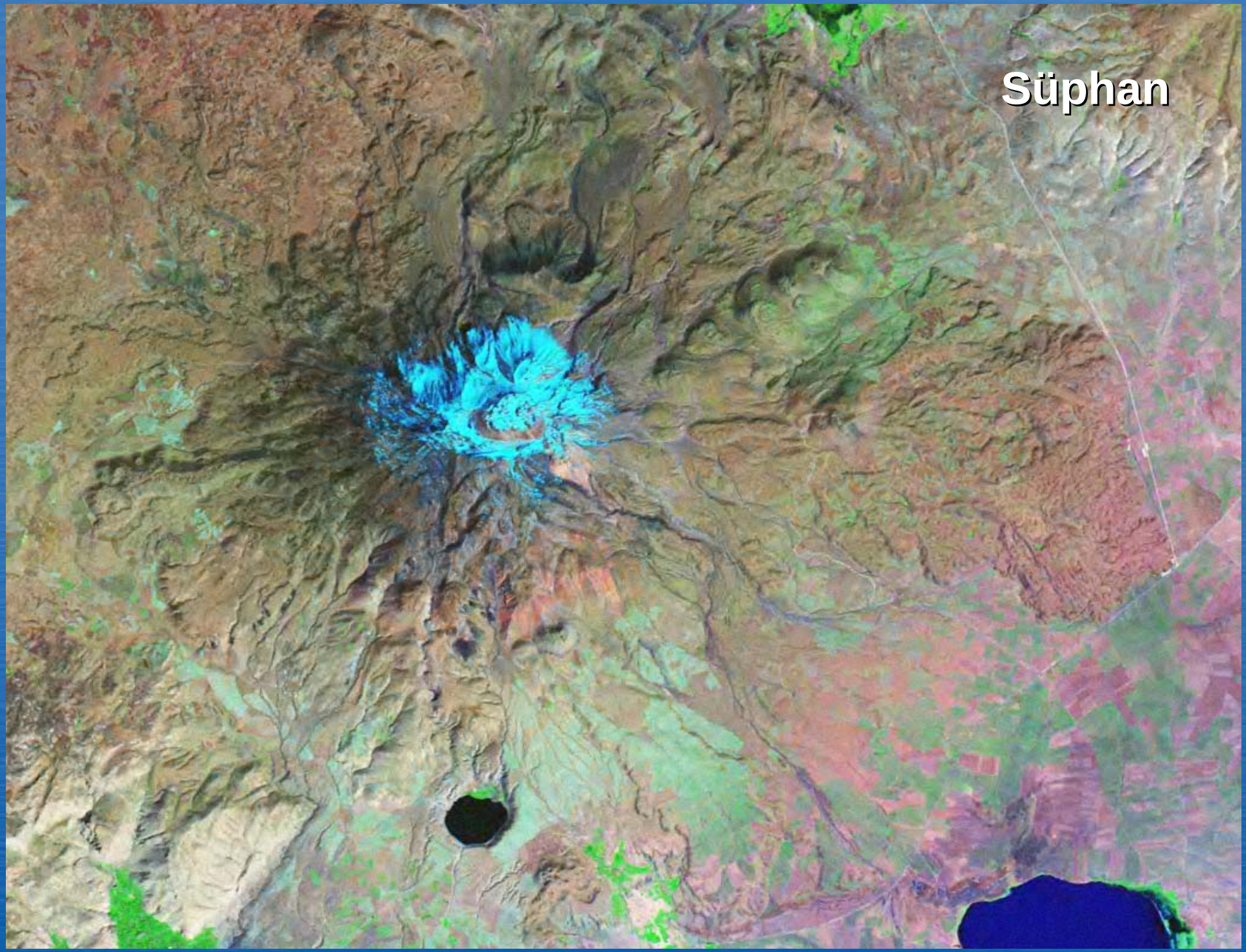
Distribution of Tertiary and Quaternary volcanoes in Turkey and neighboring countries **(Maggi & Priestly, 2005)**.

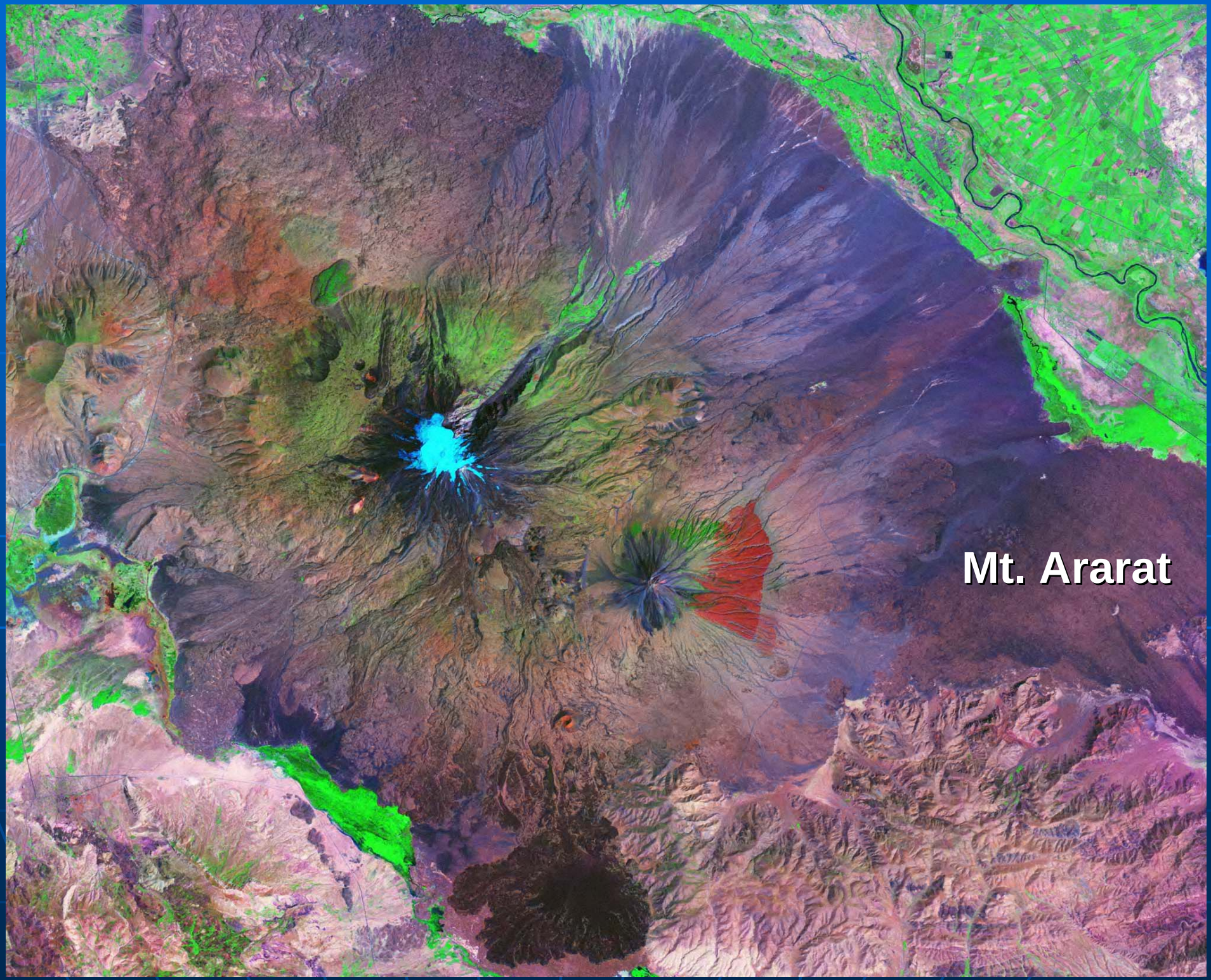
Turkey, Russia, Georgia, Armenia, Azerbaijan, Iran



MrSid view


Ararat
Tendürek
Süphan
Muş
Nemrut
Muş-Nemrut
Tendürek


Süphan

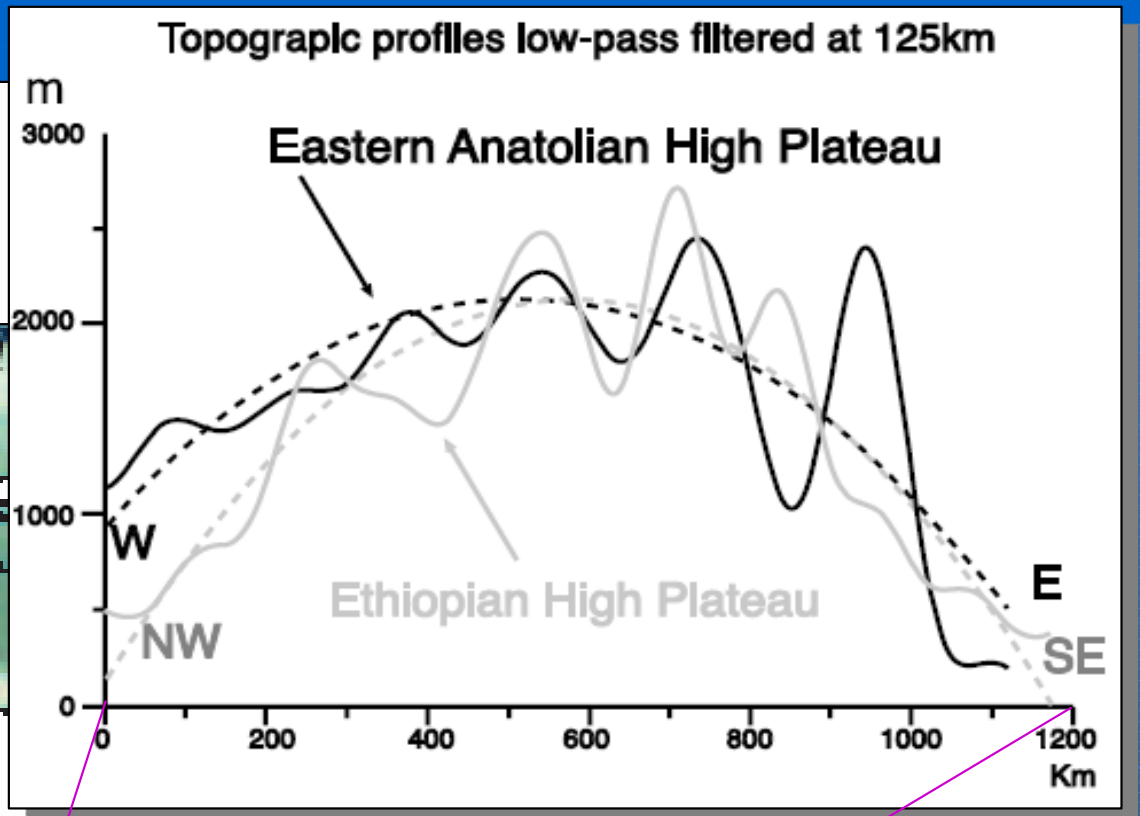

Mt. Ararat

Ignimbrite sheets on the EKP

Plateau basalts

Topographic profile

Comparison of the topography of Ethiopia with an E-W profile along the 40° parallel in Eastern Anatolia (Sengor et al., 2003).



25°
50°
45°
40°
Black Sea
Turkish Plateau
Lesser Caucasus
Alborz

North-south shortened asymmetrical dome

The map is from Maggi & Priestly (2005).

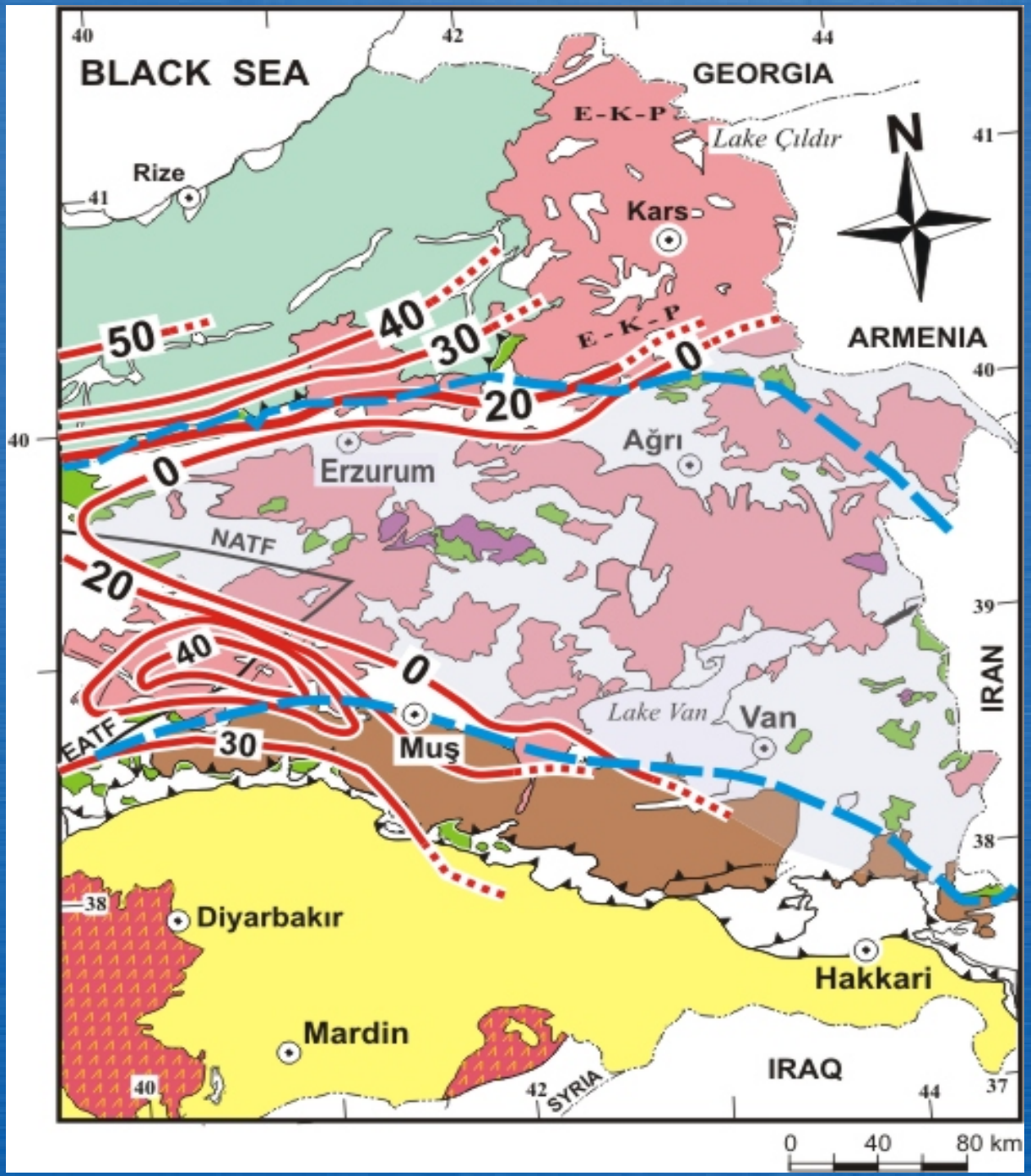
What has been going on beneath Eastern Anatolia?

Geophysical studies

ETSE Project

(Univ. of Cornell & Bogazici Univ.)

- **The mantle lithosphere is *either very thin or absent* beneath a considerable portion of the region.**
  - *[Regional wave propogation of Gok et al., 2000, 2003]*
  - *[Pn tomographic imaging of mantle lid volacity of Al-Lazki et al., 2003;*
  - *[Sandvol et al., 2003: GRL, V.30, 2003]*
- **This area coincides with the the extent of the Eastern Anatolian Accretionary Complex (Sengor et al., 2003).**



Contours (red) display the mantle lid (i.e. lithospheric mantle) thicknesses in km (Sengor et al., 2003).

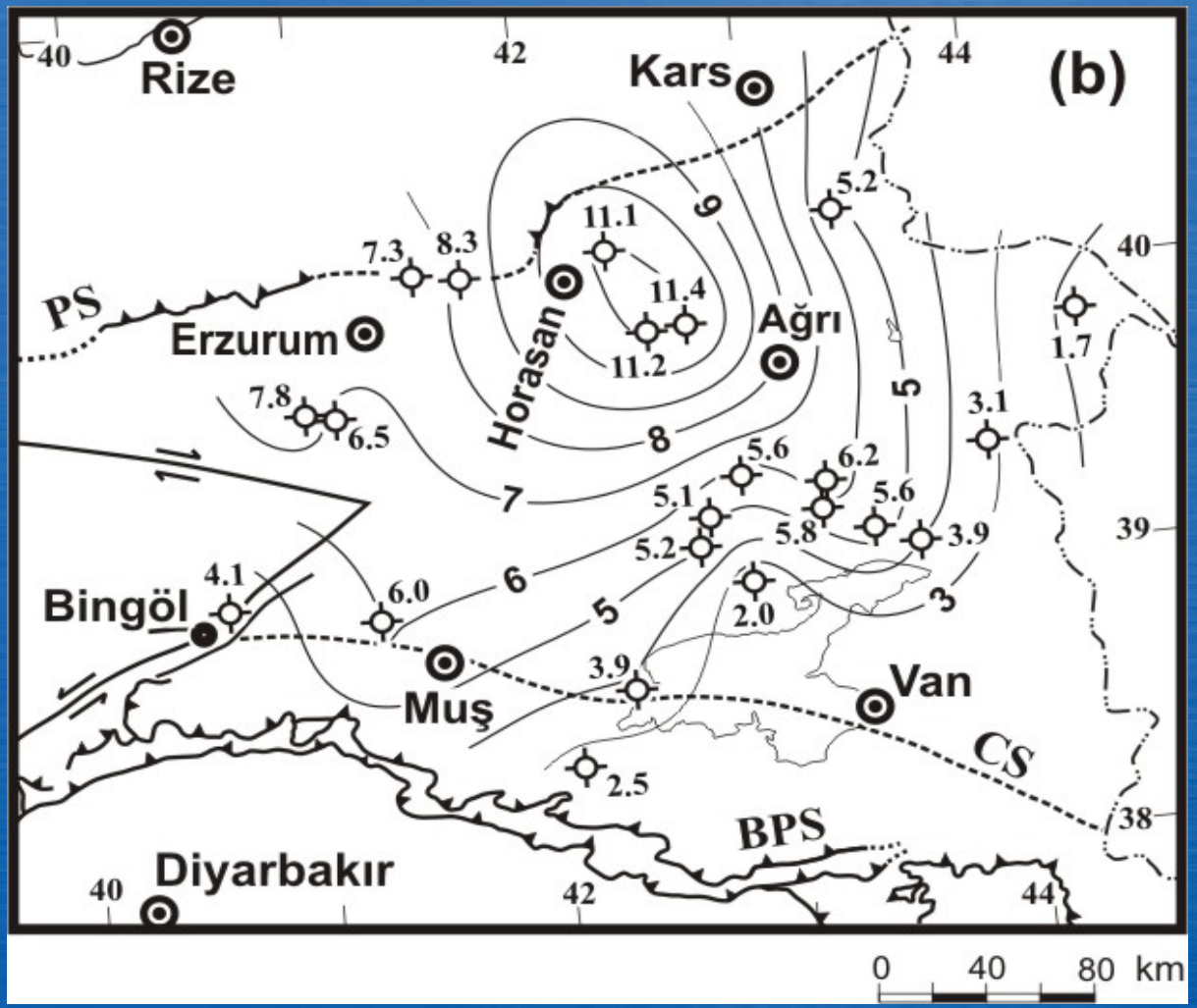
Volcanism

Migration of volcanism to the south over time

Distribution of the oldest radiometric (K/Ar) ages.

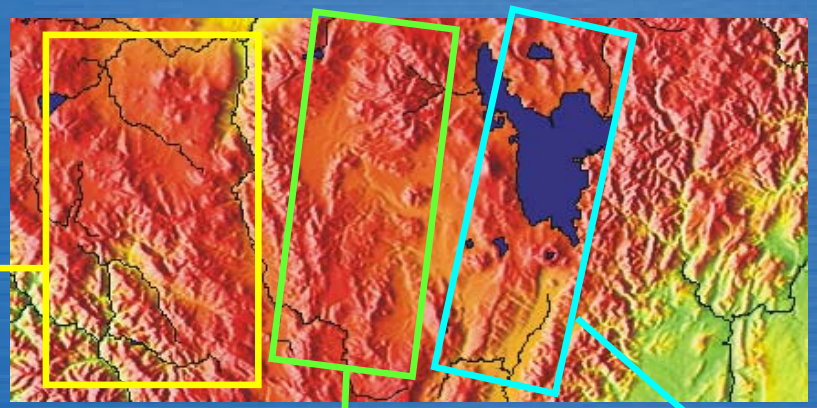
(Pearce et al., 1990; Ercan et al.,1990 and Keskin et al.,1998).

Initiation ages of the volcanism are contoured in 1-Myr intervals.

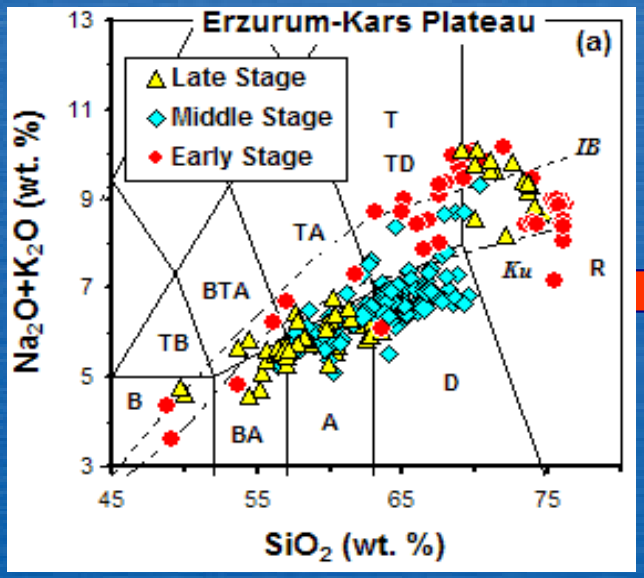


Spatial change in geochemical character

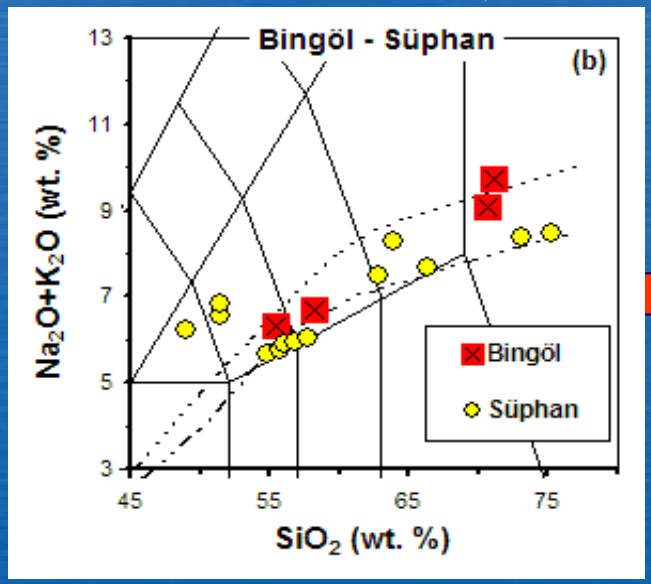
N



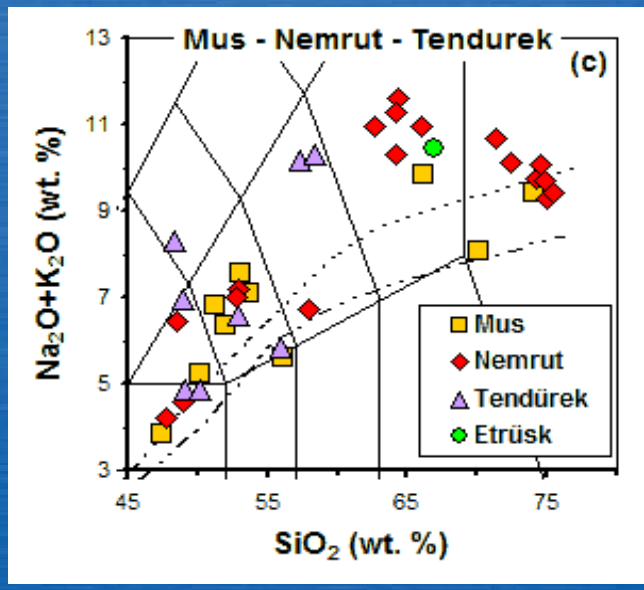
11 Ma to 1.5 Ma



~3.5 Ma to recent

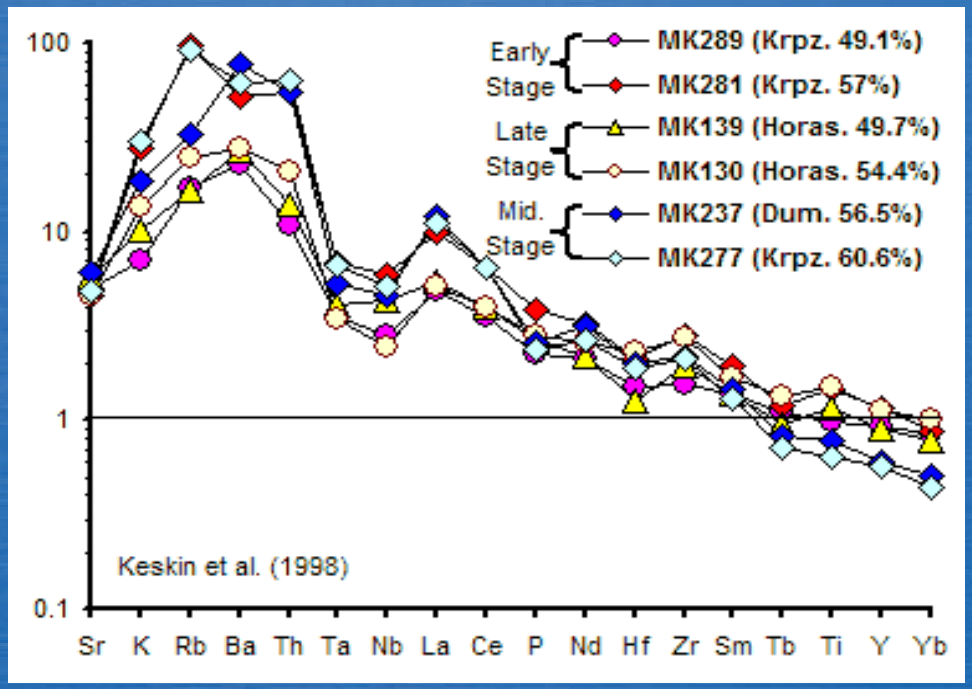


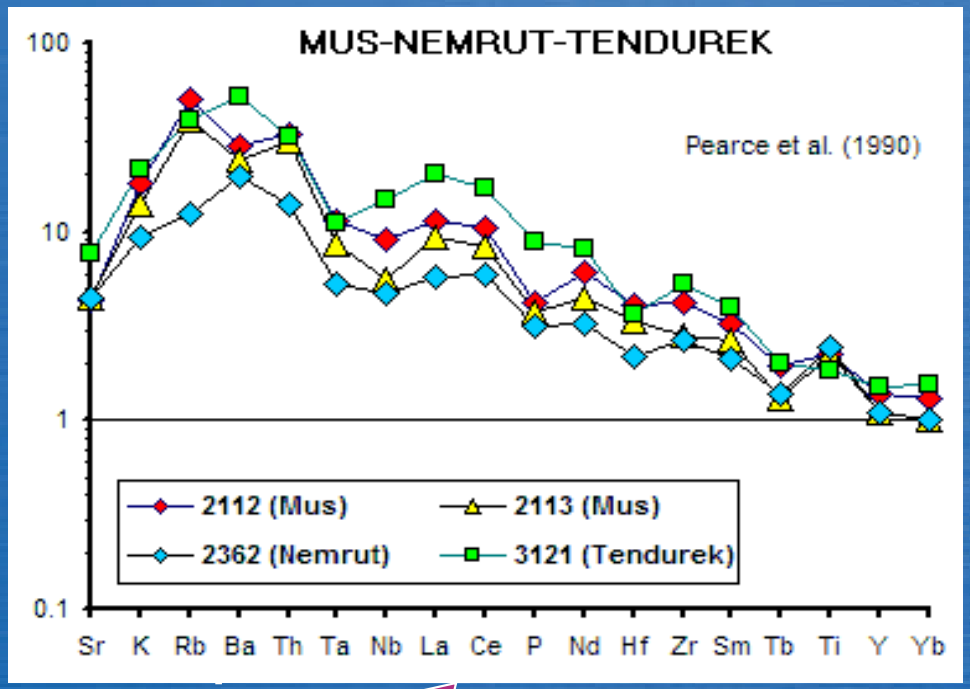
~1.2 Ma to recent



(Pearce et al., 1990; Keskin et al., 1998).

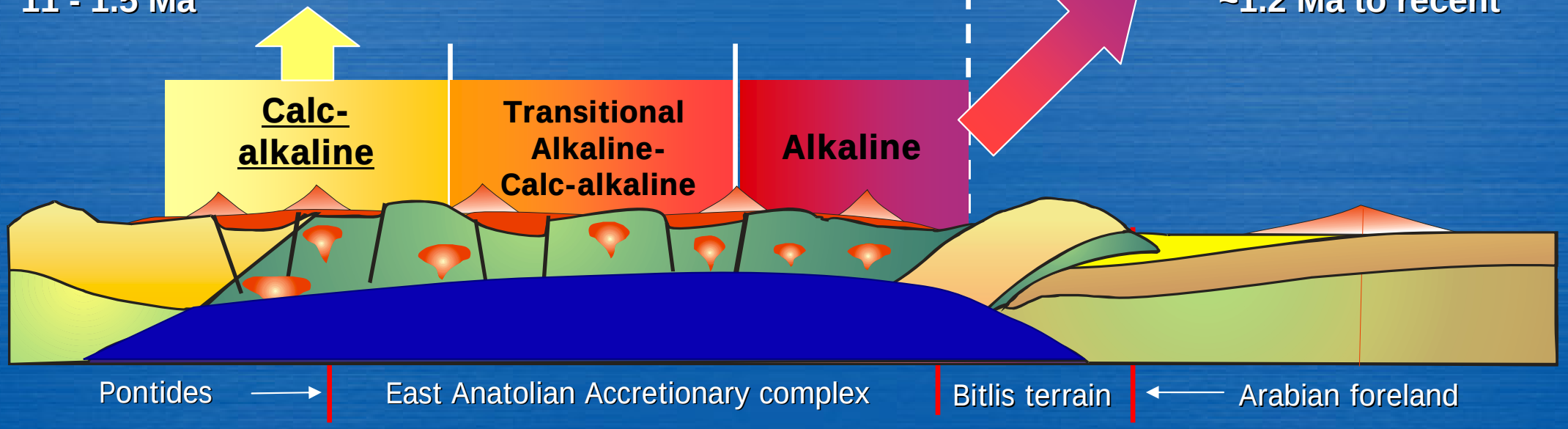
Nature of the source





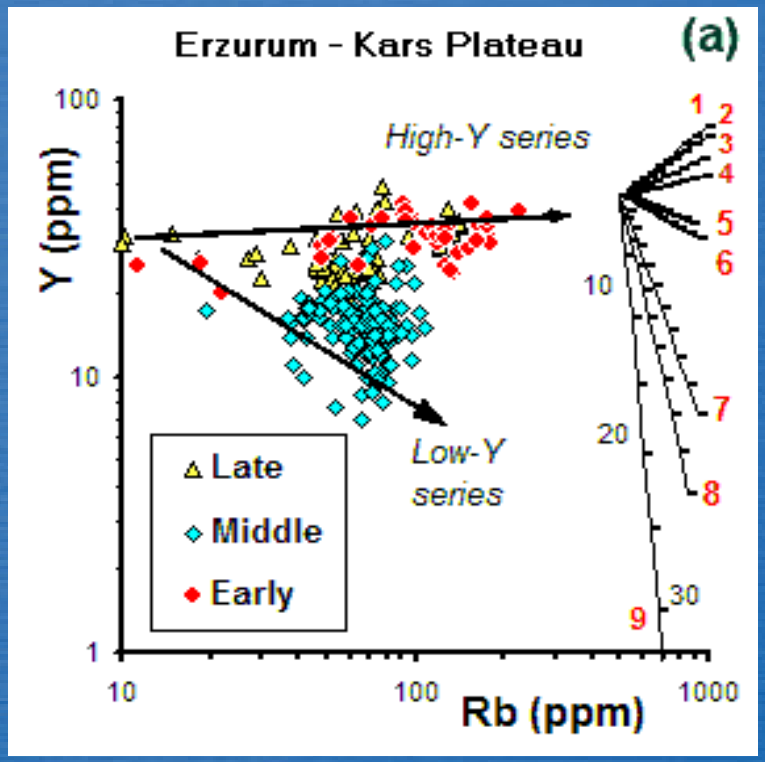
11 - 1.5 Ma

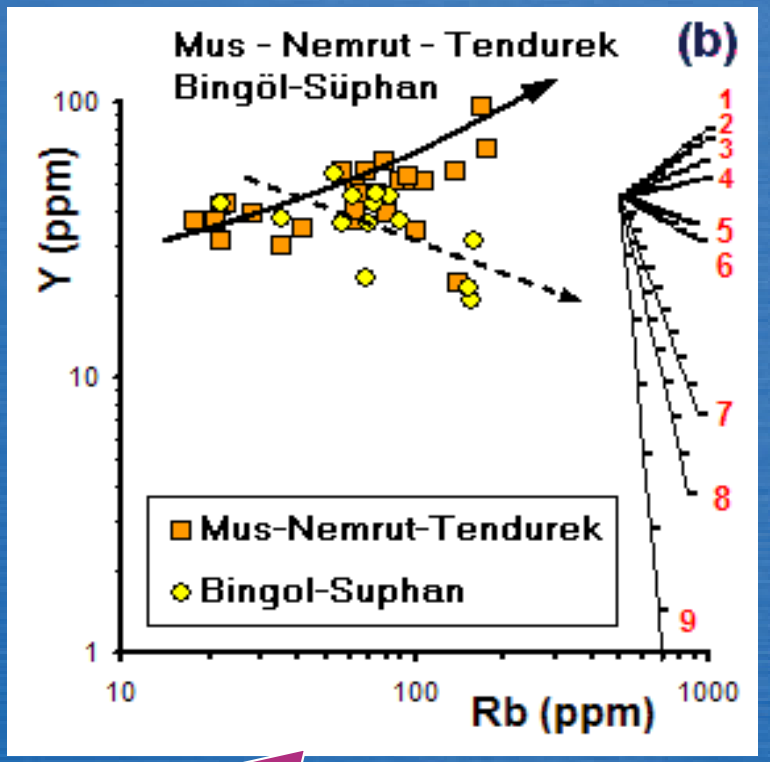
~1.2 Ma to recent



Hydrous vs. anhydrous FC

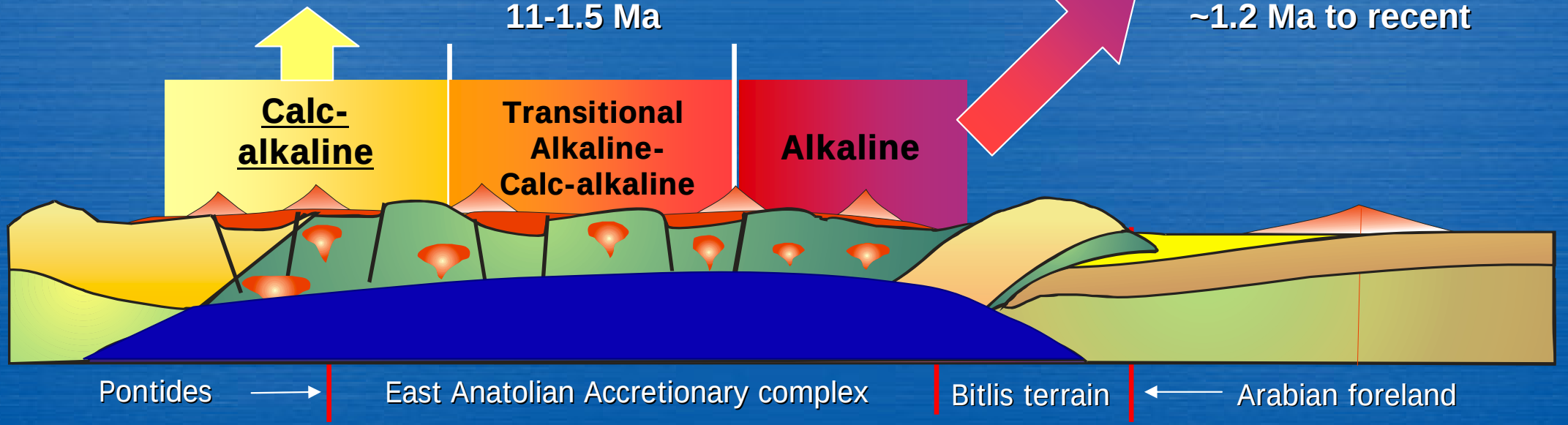
Modelling FC





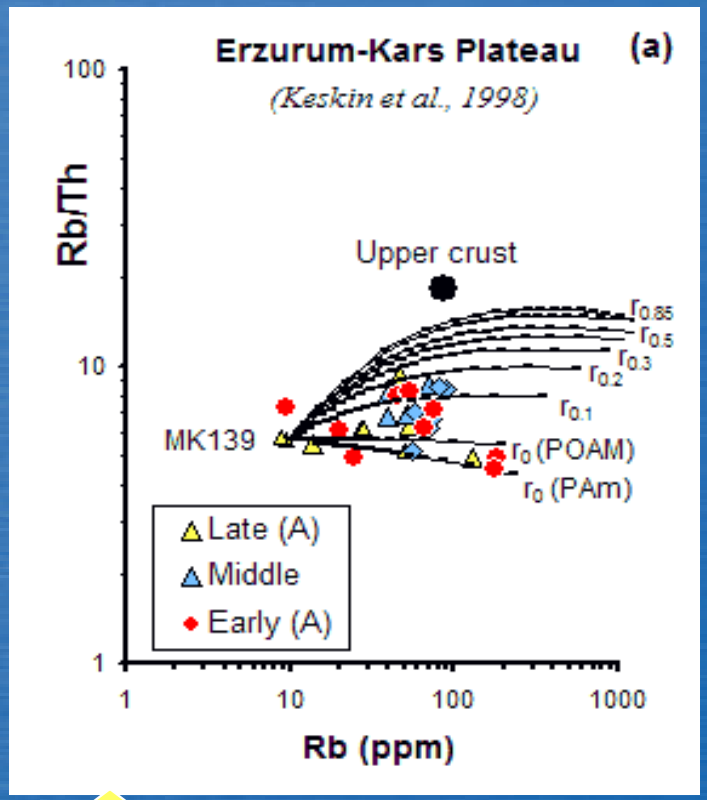
11-1.5 Ma

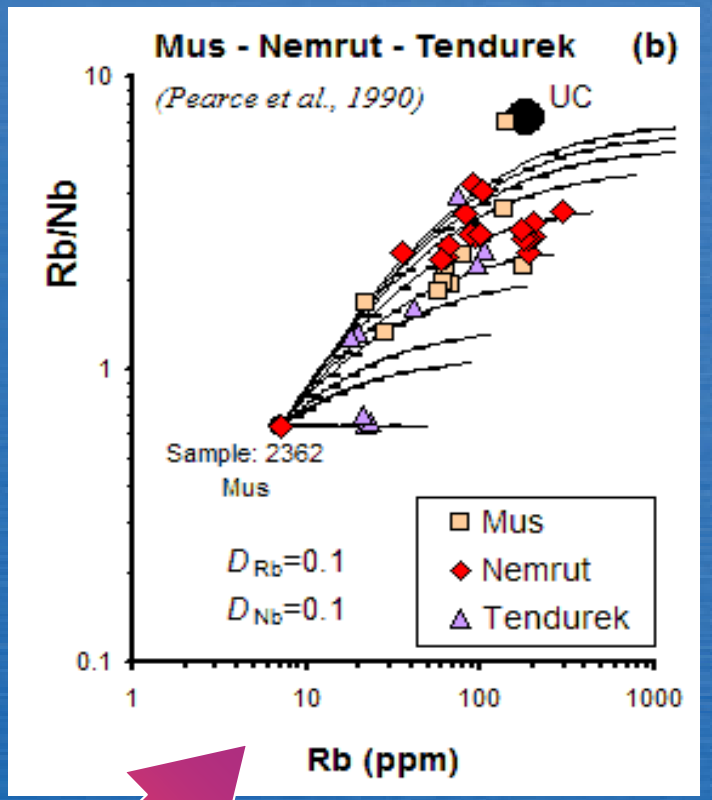
~1.2 Ma to recent



Crustal assimilation

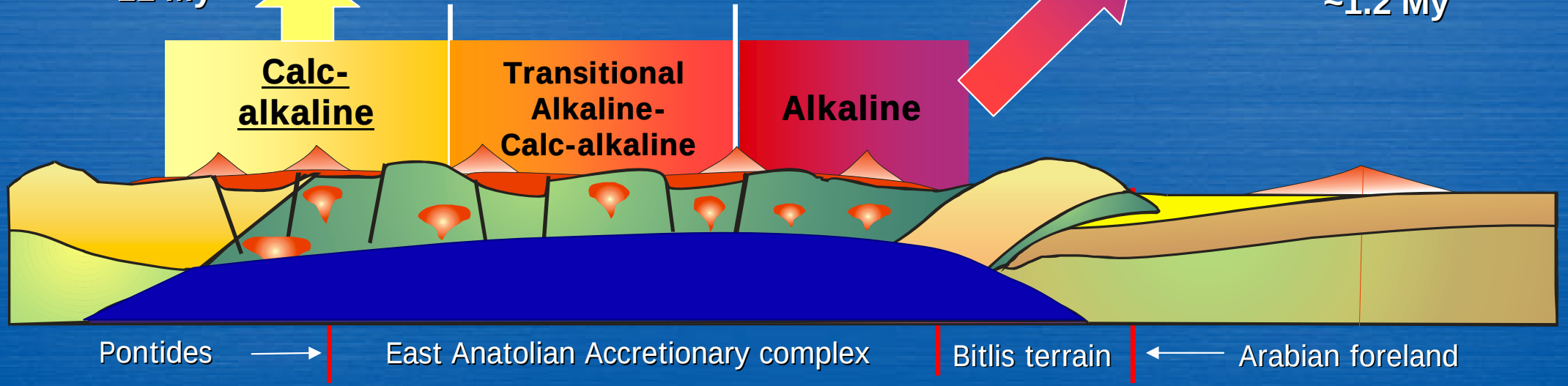
Modelling AFC





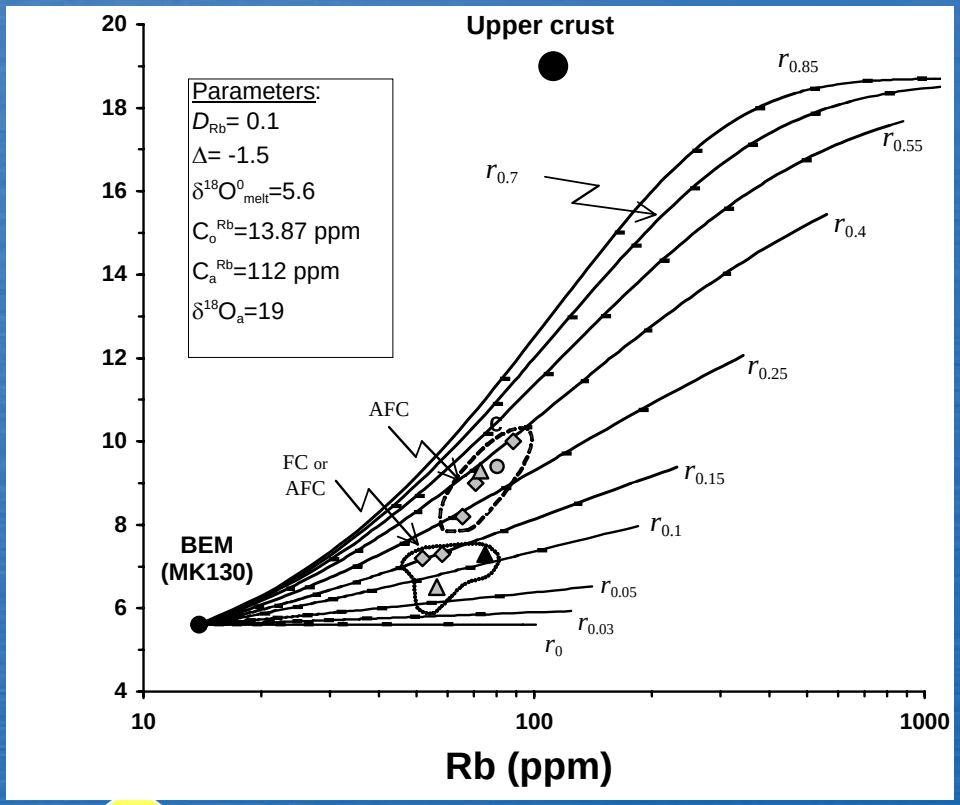
11 My

~1.2 My

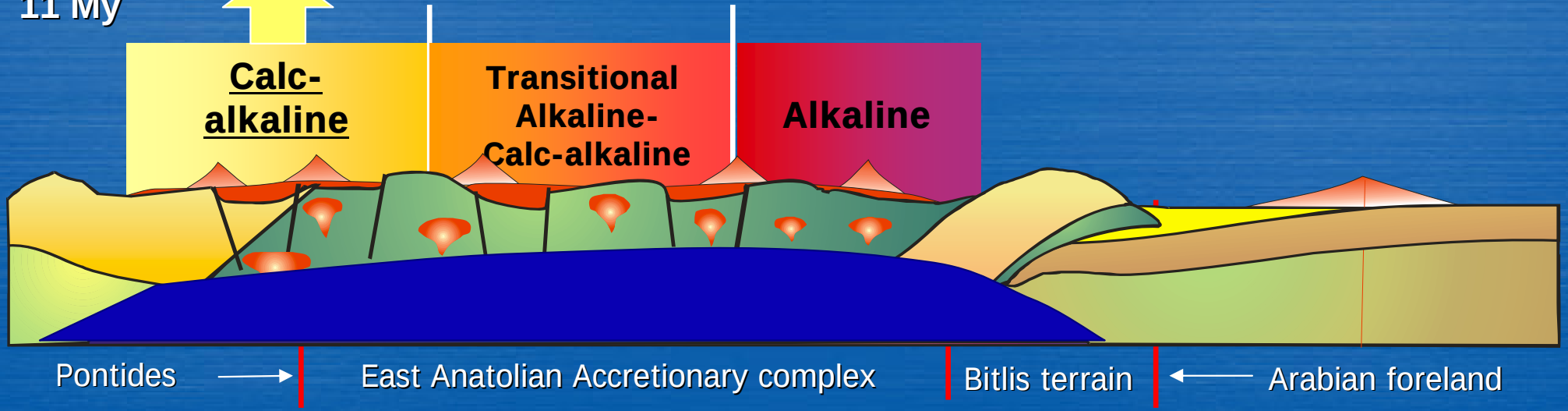


Crustal assimilation

Modelling AFC



11 My



The Eastern Anatolia plateau

- **Elevated and hence high**

  Elevation: ~1.5 - 2 km plateau.

- **Tectonically active**

  Mostly strike slip and reverse faults

- **Covered by a widespread and thick volcanic sequence**

  sometimes >1 km in thickness in places

- **Has an asymetrical domal shape**

- **A great proportion of it is devoid of a lithospheric mantle root**

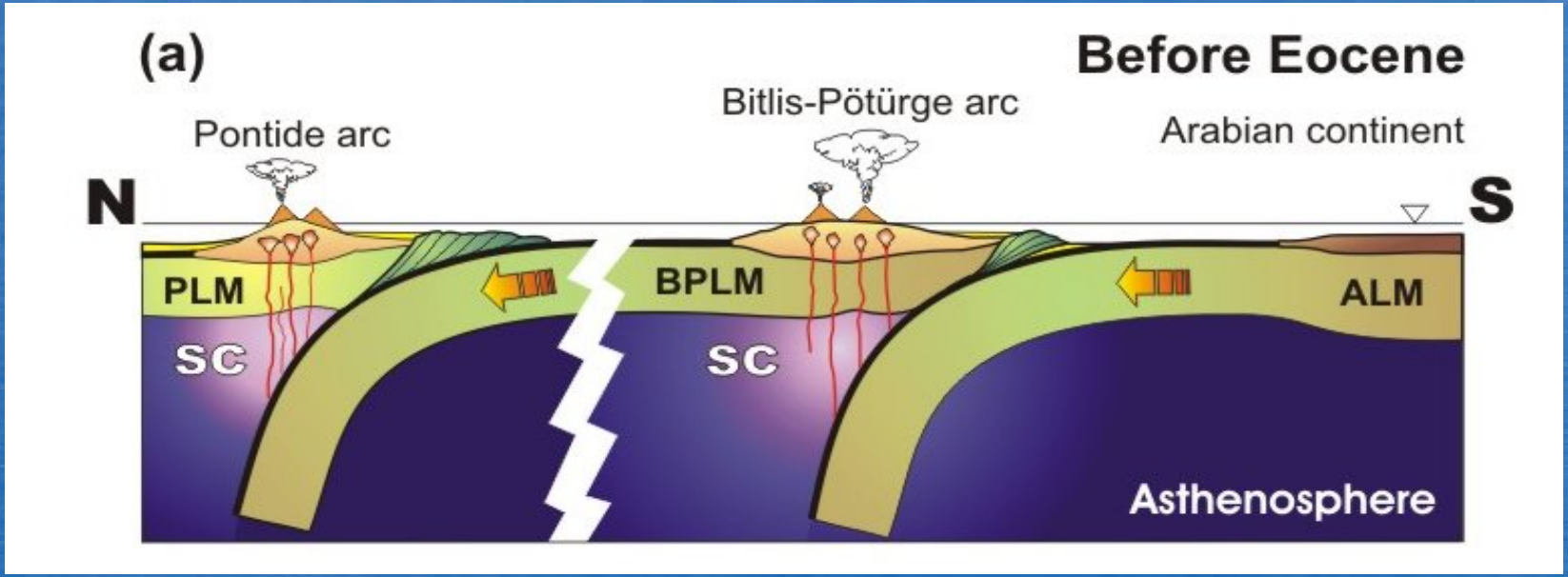
- **This coincides with the the extent of the Eastern Anatolian Accretionary Complex**

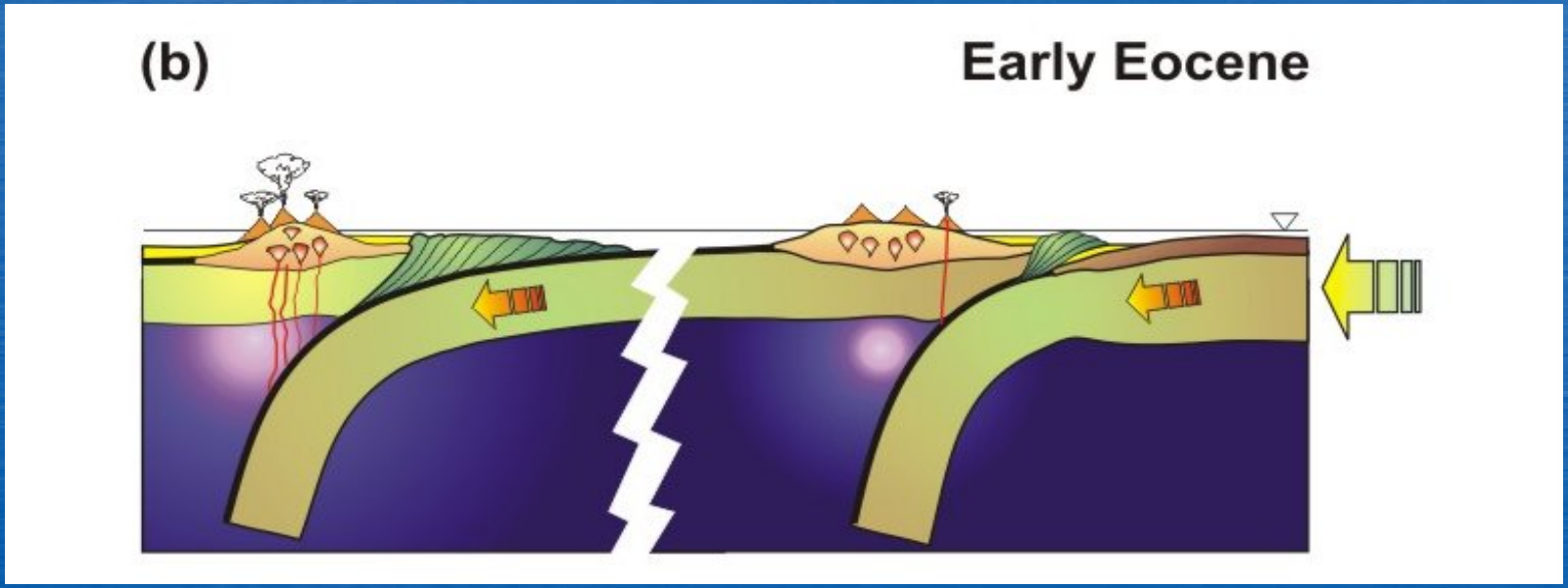
The collision-related volcanism

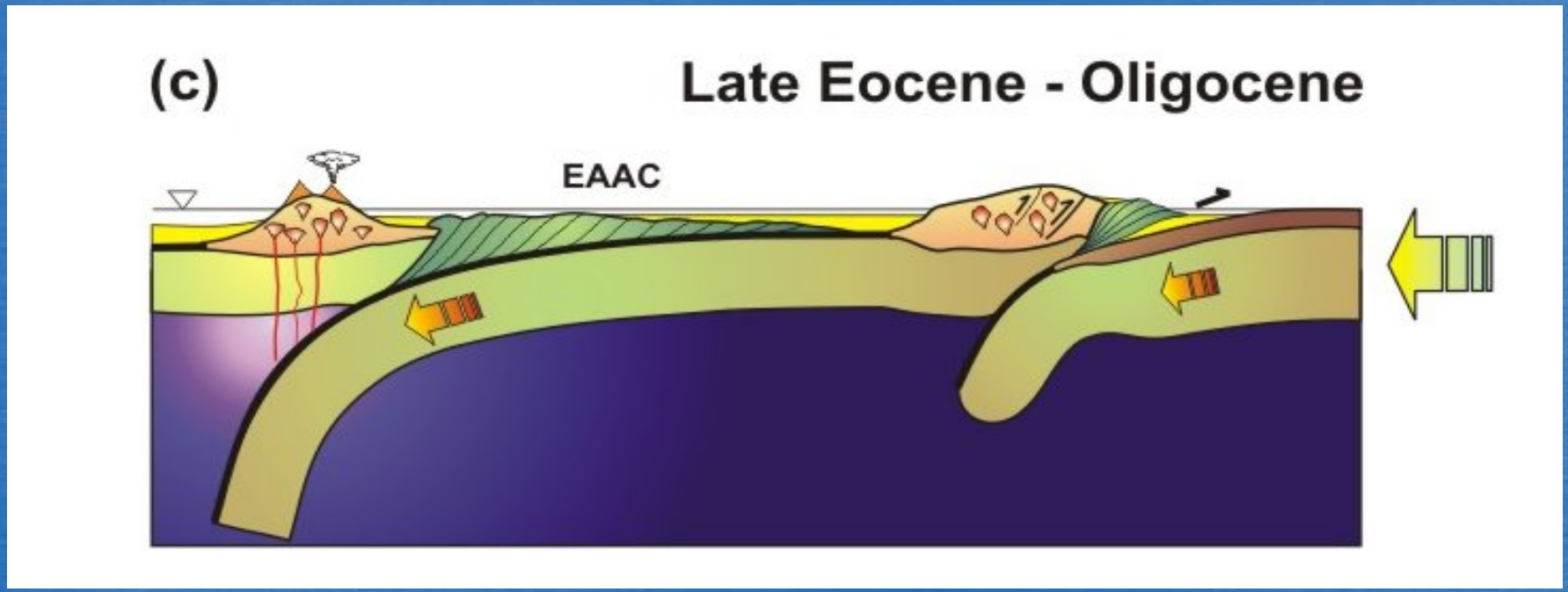
- Generated from a slightly-enriched mantle source
- Migrated to the south between 11 Ma and recent
- Display a gradual change in lava chemisry
- Asimilated more crustal material in the south than in the north

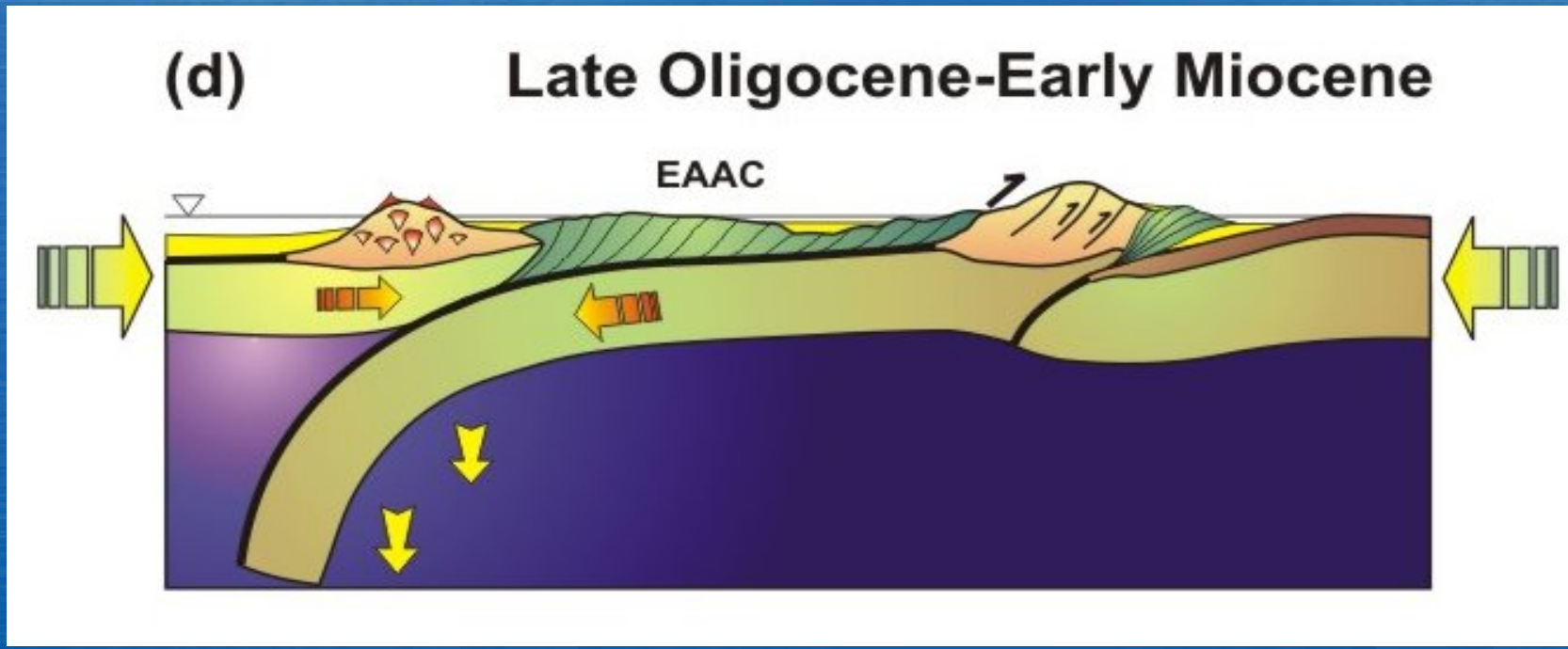
Evolution of the region

If we combine new geological, geophysical and geochemical data with the geological evolution of the region:

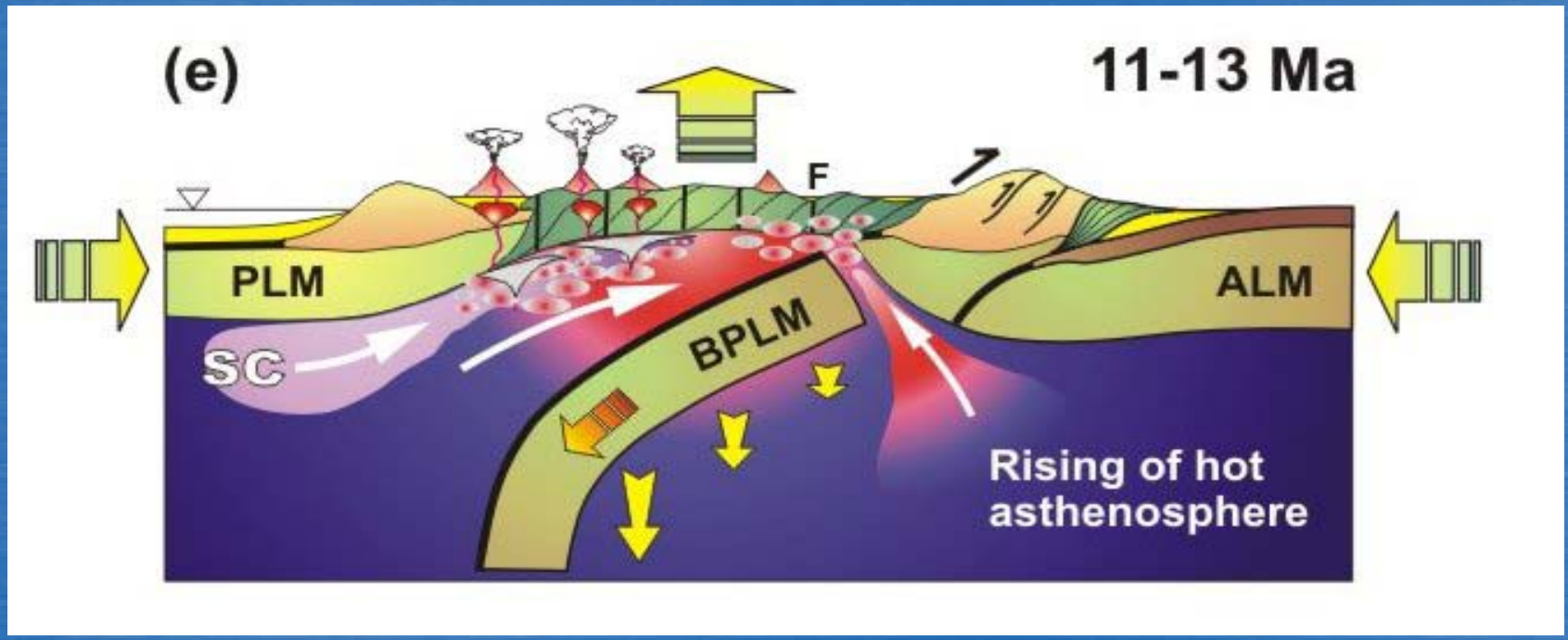


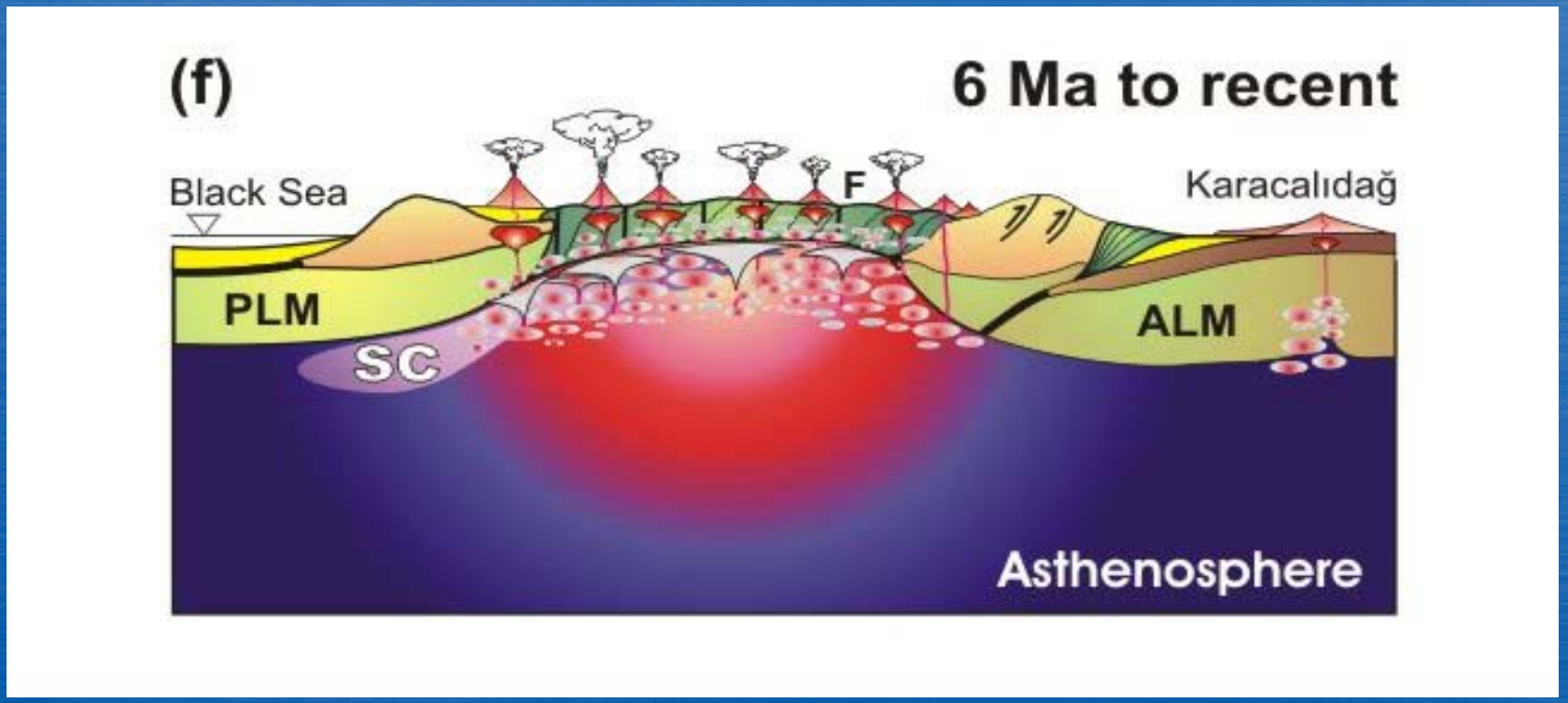






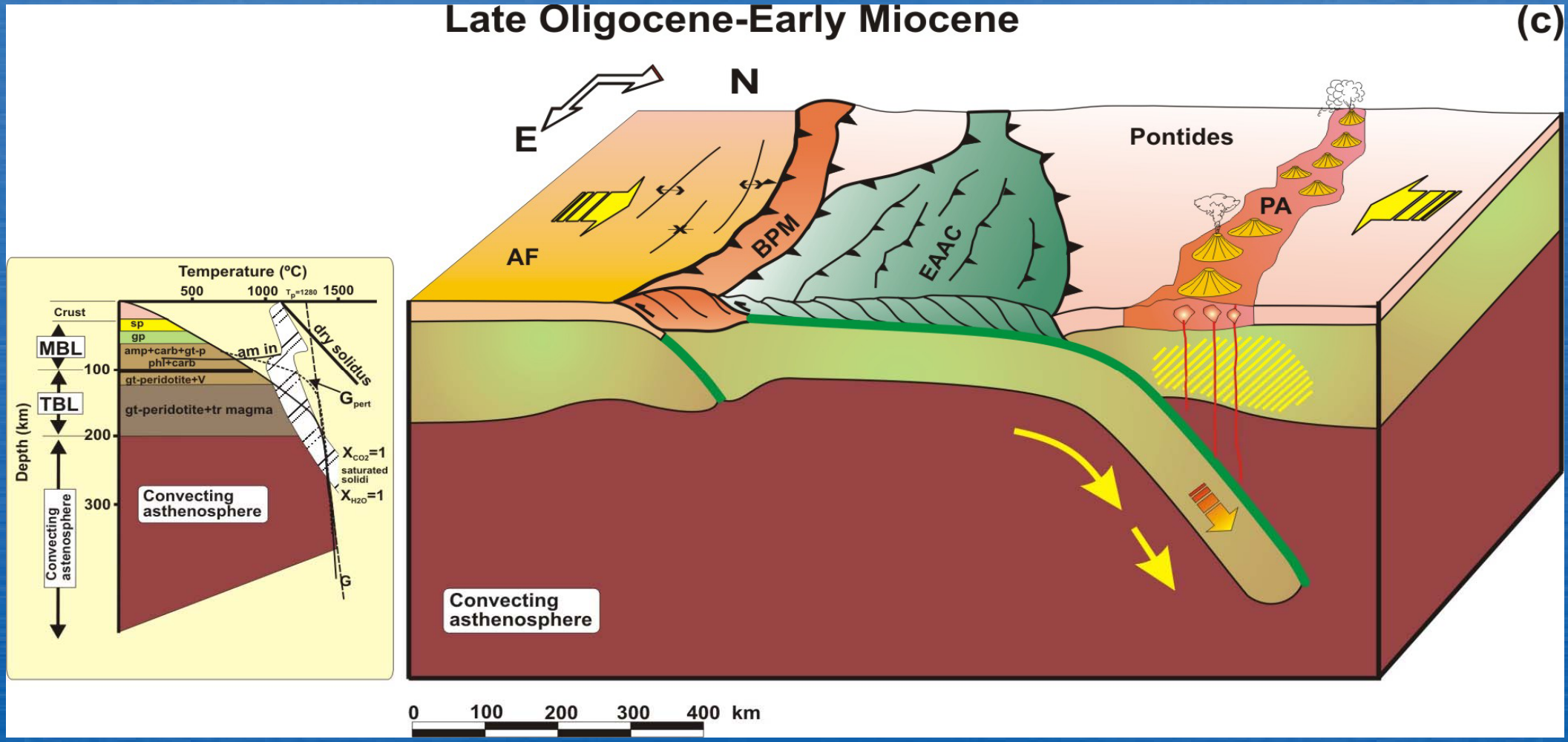
Shortening of EAAC followed by thickening over the slab. The hidden subduction possibly stopped



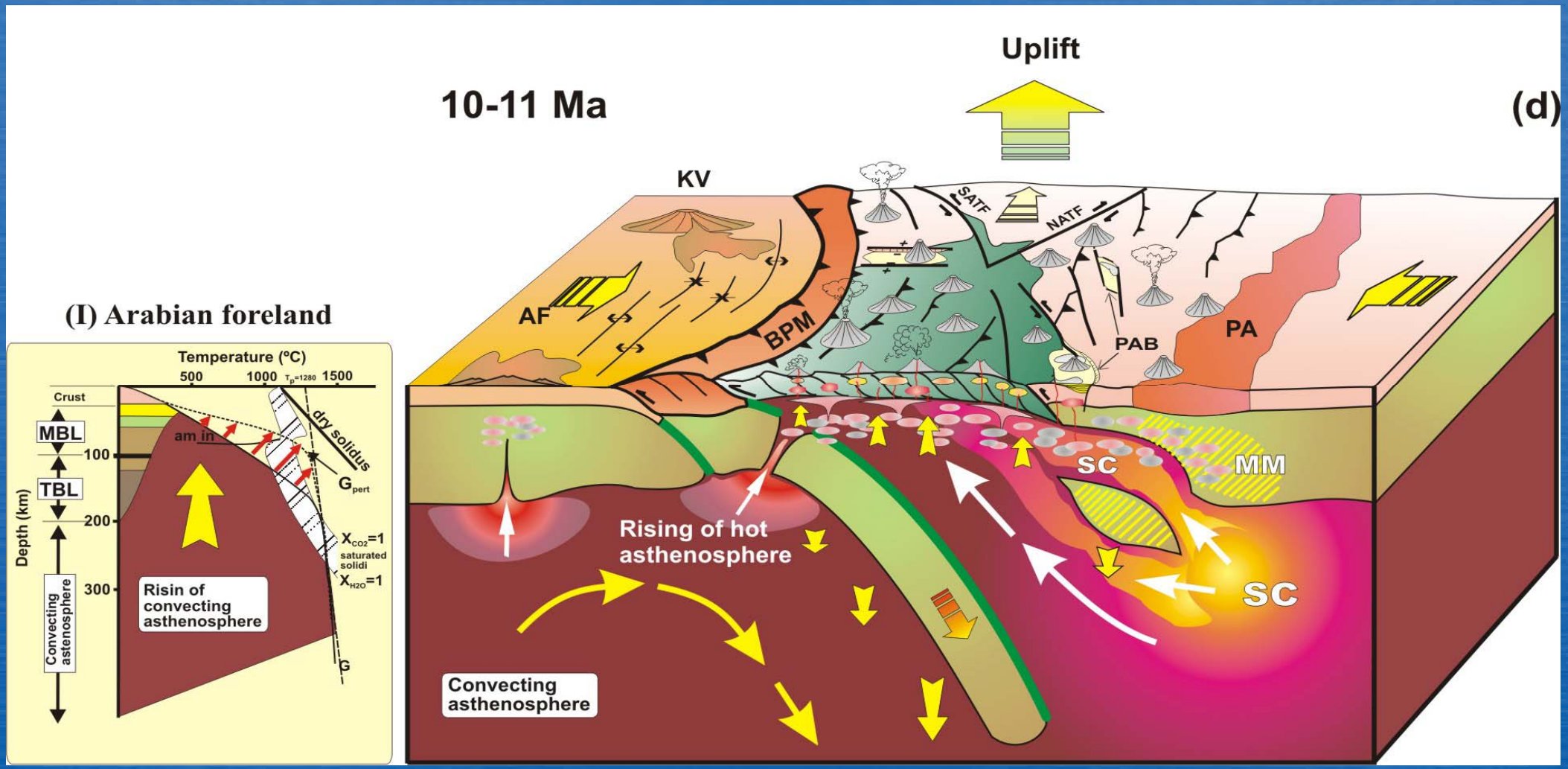


Being left unsupported by subduction, the oceanic lithospheric slab may have steepened and finally detached from the EAAC, opening out an asthenospheric mantle wedge, gradually widening to the south.

This possibly created suction on the asthenosphere, generating mantle flow to the south

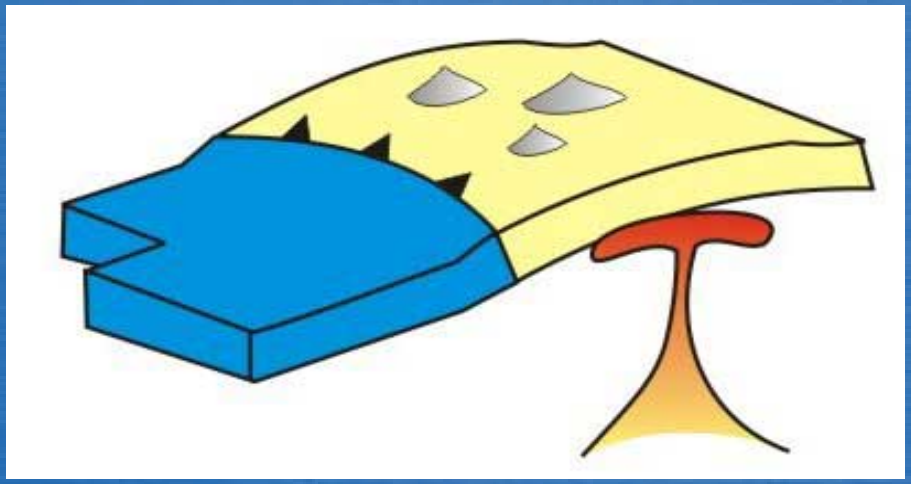


Slab steepening and breakoff beneath a subduction-accretion complex [Keskin, 2003].



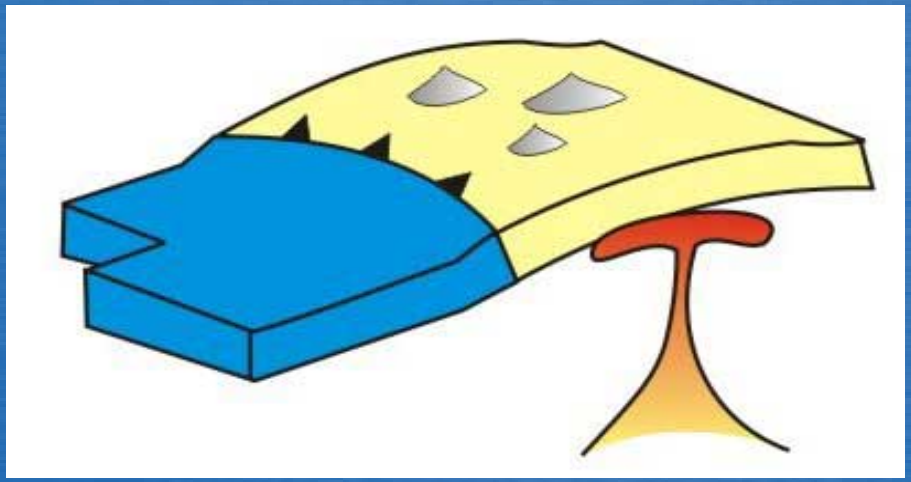
Slab steepening and breakoff beneath a subduction-accretion complex [Keskin, 2003].

Why plume model cannot be a viable model for the region?



- None of the fault systems and dyke swarms distributed ***radially***.
- Fault plane solutions of earthquakes indicate that the faults are either transform or reverse; ***not normal***.
- A plume model cannot explain why volcanic units contain a distinct subduction component in the north of Eastern Anatolia, and why this component gradually diminishes to the south.
- It is also difficult to explain by a plume model why volcanism migrated south with time, and why there is a gradual change in magma chemistry from calc-alkaline in the north to alkaline in the south.

Why plume model cannot be a viable model for the region?



- Volcanic activity over the last 6 Myr displays a temporal change from more regional-scale activity to localised activity on a set of aligned central volcanoes [P*earce et al.,* 1990].
- Such an evolutionary sequence is the reverse of what is expected in plume-related volcanic activity.

Conclusions

- The Eastern Anatolian high plateau can be regarded as a **"melting anomaly"** coinciding with a regional domal structure which is squeezed in a collision zone in the N-S direction.
- The mantle source region owed its exceptional fertility either to a subduction component inherited from a previous subduction event, to the oceanic crustal material previously subducted beneath the region, or to a combination of both.
- The Eastern Anatolian domal uplift is not related to a mantle plume.
- Slab-steepening and breakoff process can explain the voluminous magma generation and domal uplift in the region better than other competing geodynamic model.

Conclusions

- The Eastern Anatolian example is particularly important as it shows that shallow plate tectonic processes can generate both regional lithospheric domal structures and great volumes of magma in the absence of a mantle plume.
- The slab-steepening and breakoff process may be a very important process for Asian continent where subduction accretion complexes cover very large areas.

For detailed information, please visit:

http://www.mantleplumes.org/Anatolia.html