

Interplay between tectonics and magmatism during the last stages of continental breakup

The Manda Hararo rift segment, Afar, Ethiopia

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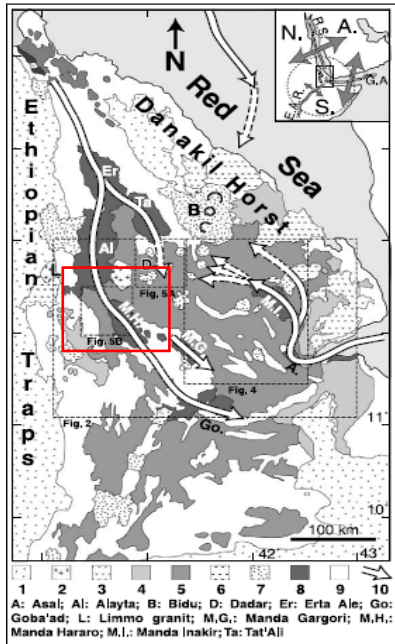
CRPG



Magmatic rifting and active volcanism conference
Addis Ababa, 11th January 2012



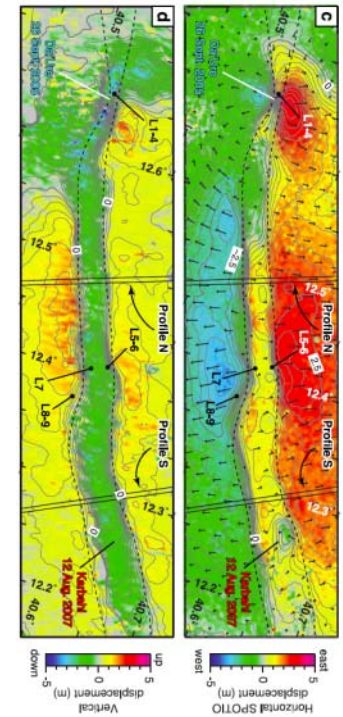
Topographic response to 2005 dike intrusion registered by INSAR



The Afar triple junction:

- Deformation already focused along rift segments
- Emplacement of new crust driven by dike injection

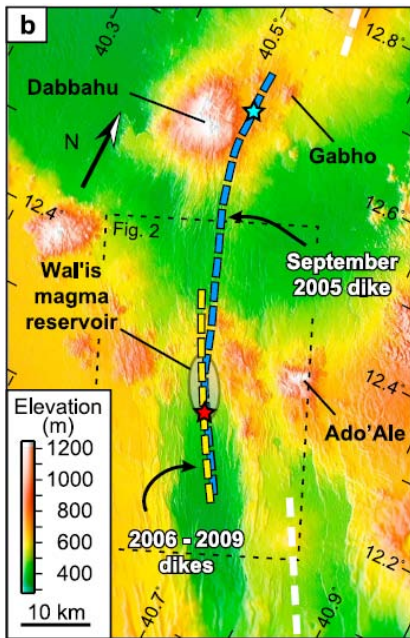
→ *the best location to observe the Continental-Oceanic Transition*



Grandin et al. 2009

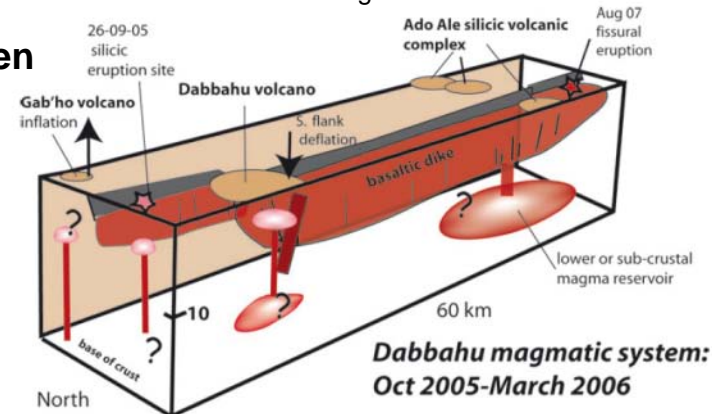
The 2005 event: provided information at the scale of a *single rifting event*.

- Dike injections induce a **topographic response** by fault reactivation
- Involve complex **interactions between magma bodies** along the rift axis



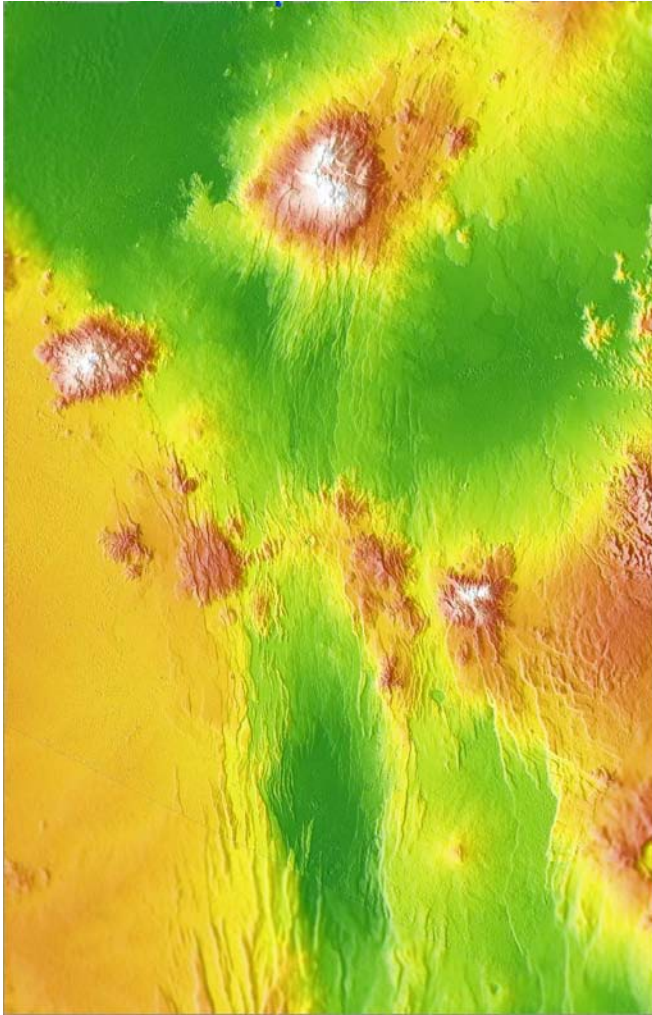
Grandin et al. 2010

Ebinger et al. 2008



Dabbahu magmatic system: Oct 2005-March 2006

Aim of the work



Are the current observations representative of the entire rift segment history?

How to create and maintain a rift segment at the ***magmatic cycle scale***? (10 to 100 ka)

Magma supply

- At least 2 magma chambers
- Stability through time?
- Replenishment recurrence?
- ...

Relationship
tectonics / topography

→ ***Require an accurate chronology of volcanic and tectonic events***

How to date magmatic and tectonic events?

Good arguments to use the cosmonuclides method for dating

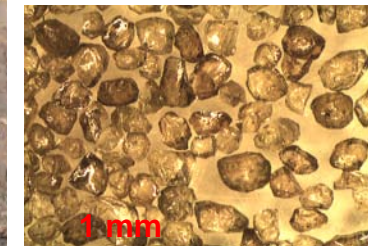
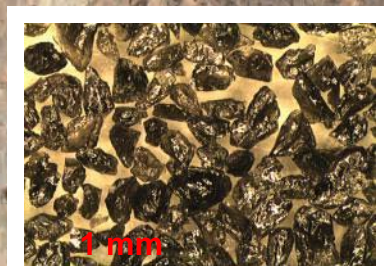
- Minimal erosion
- Surface exposure age dating
- **Applicable on flow surfaces and fault scarps**

In volcanic environment: ${}^3\text{He}$, ${}^{36}\text{Cl}$

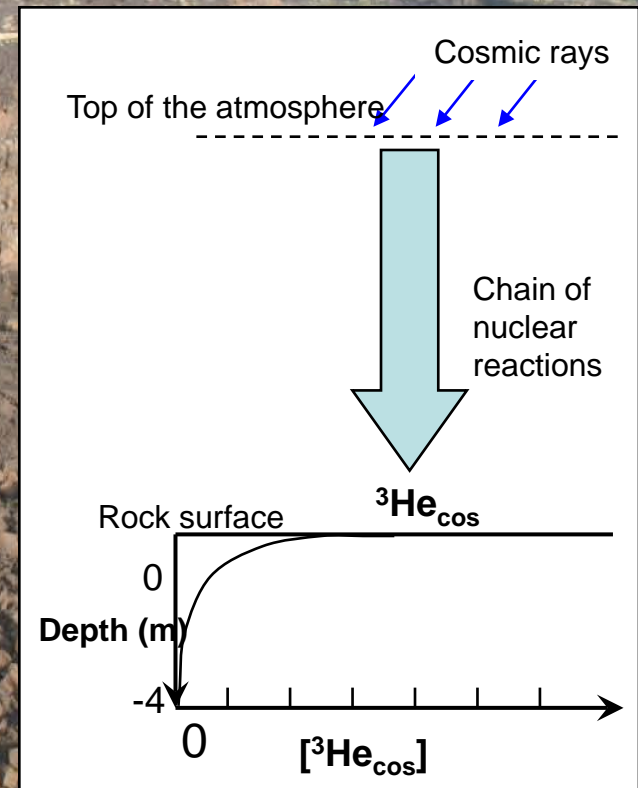
Sampling implications:



Preserved surfaces

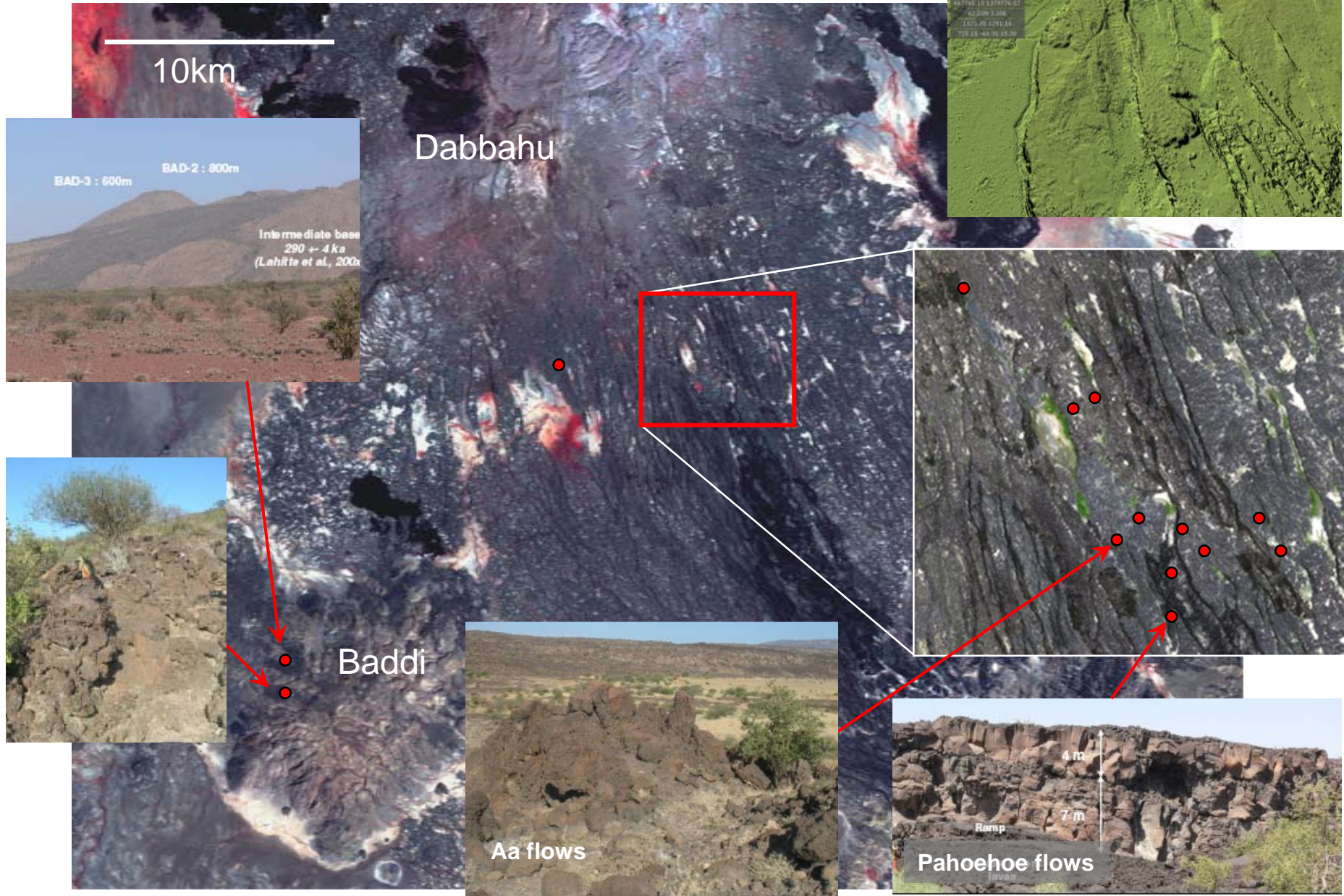


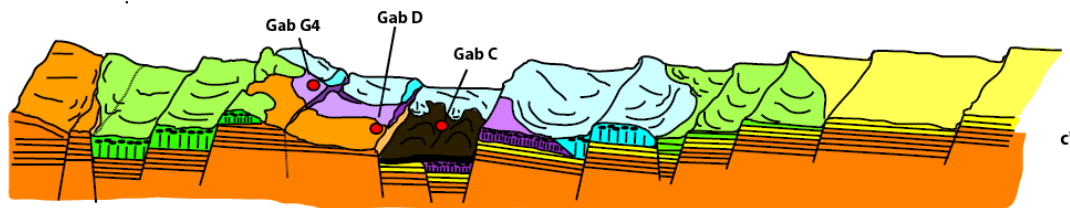
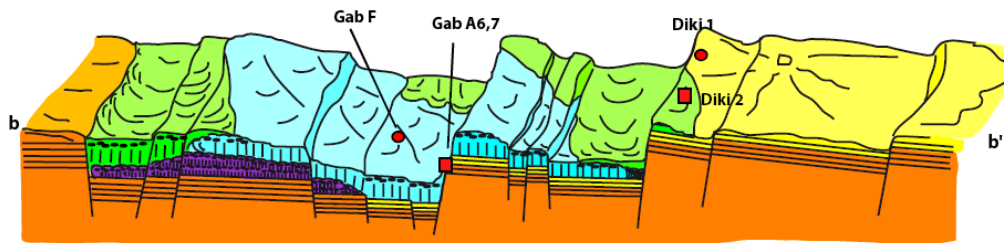
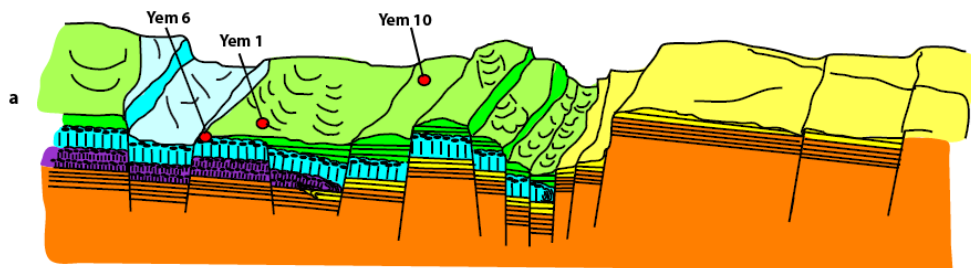
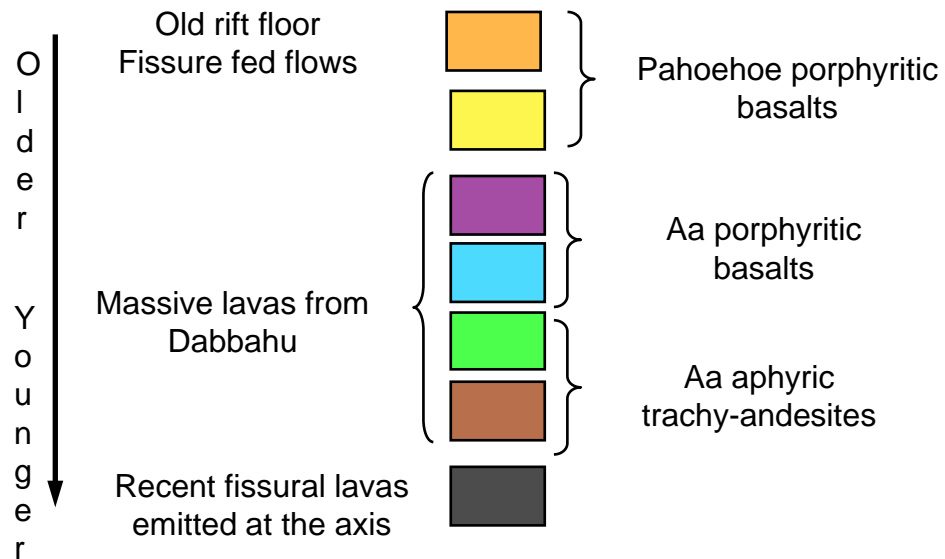
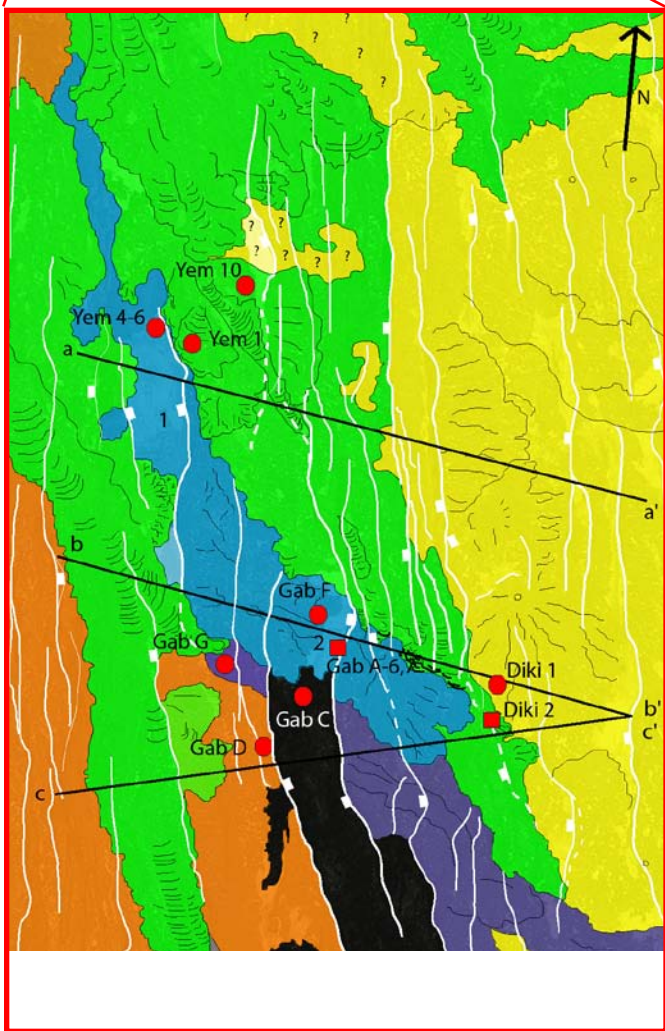
Mineral phases which retain ${}^3\text{He}_{\text{cos}}$ (olivines & pyroxenes)



$$t = {}^3\text{He}_{\text{cos}} / P$$

Sample sites

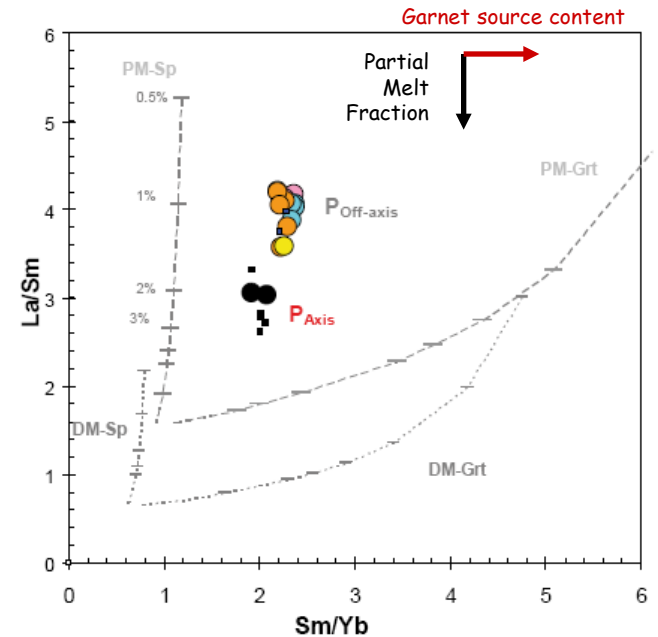




Geochemistry

Different partial melt fraction from a common source?

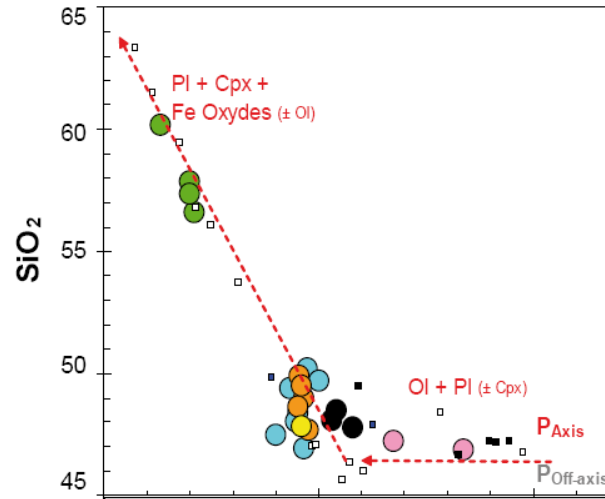
Trace elements ratio



Ferguson Thesis, 2011
More details see D. Pyle

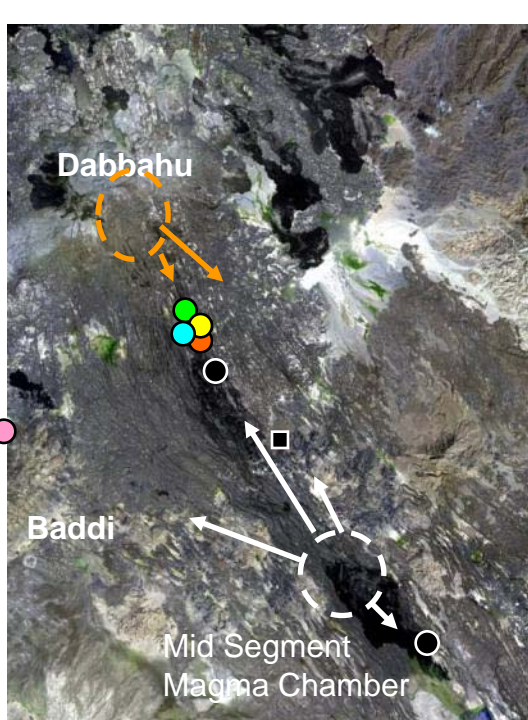
PM: Sun & McDonough 1989
DM: Workman 2004
Mantle mineralogy: Winter 2010
Partition coefficient: McDade et al. 2002

Major elements



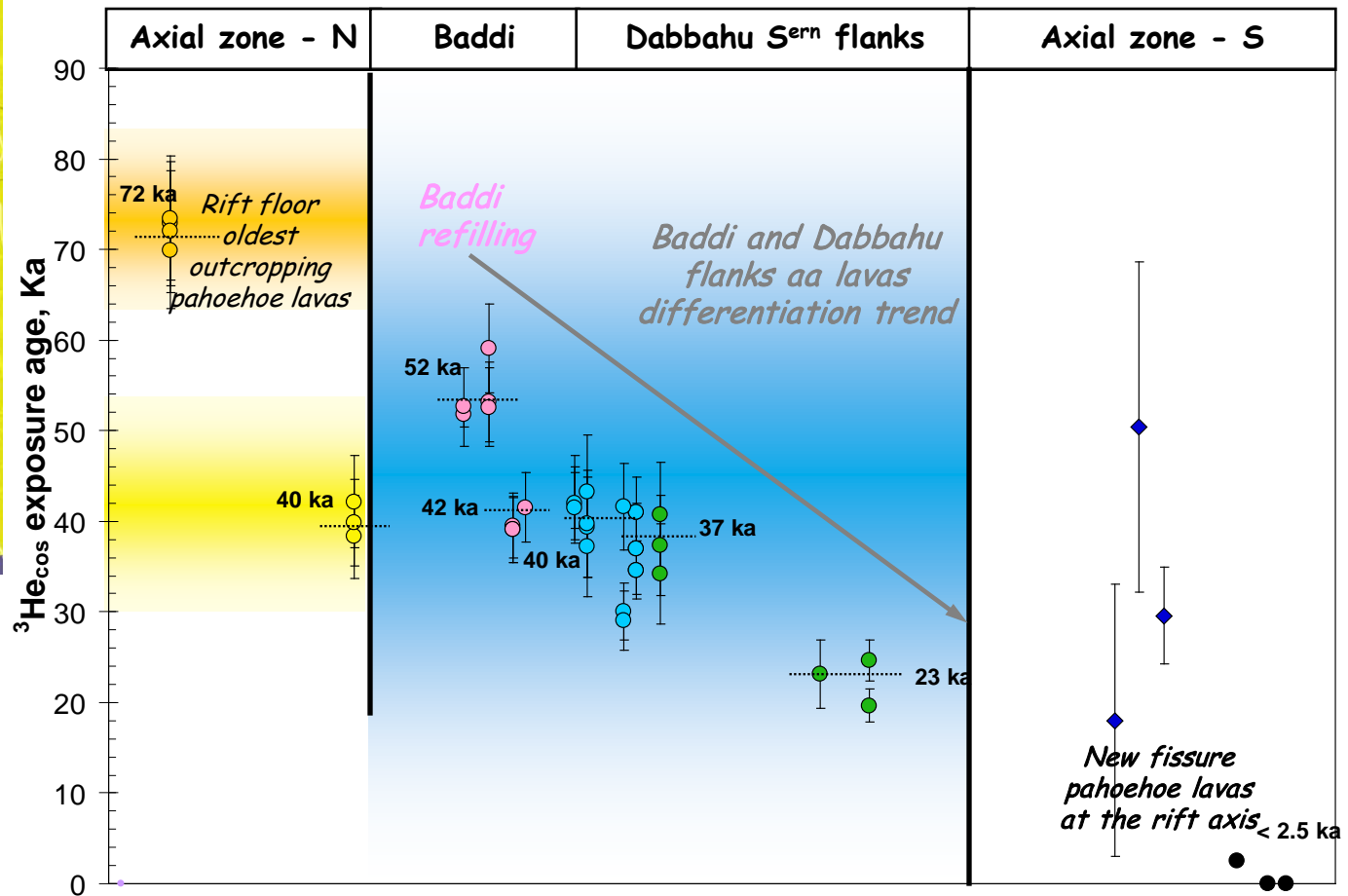
2 distinct trace elements signatures

→ Allows low partial melt fraction, off-axis products to be distinguished from those issued from the **Mid Segment Magma Chamber area.**



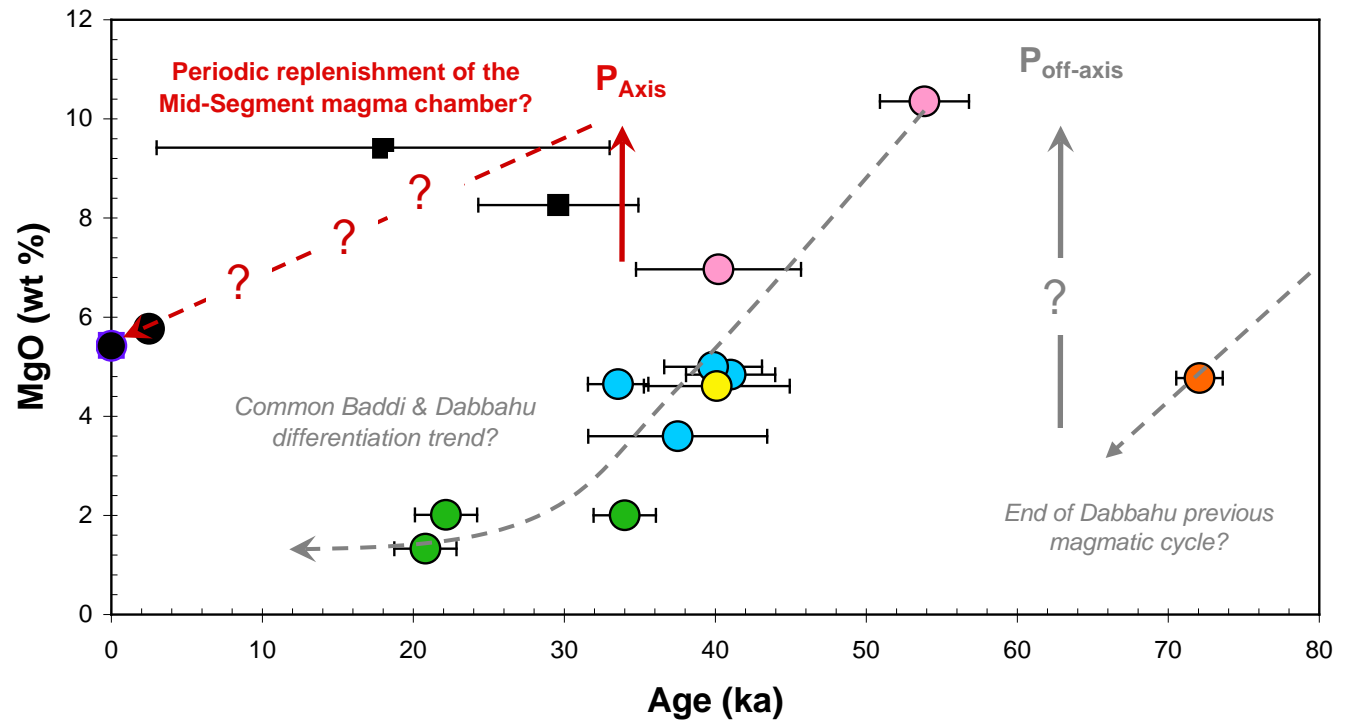
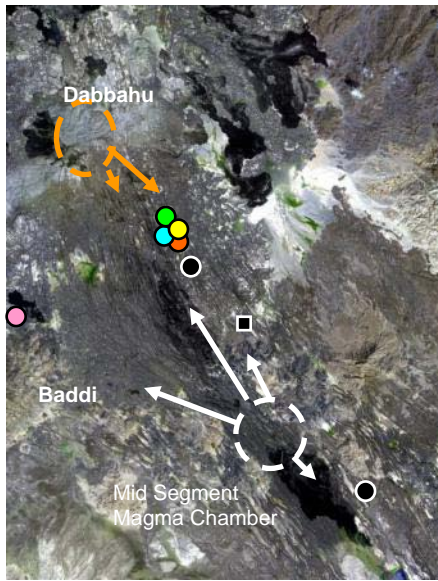
- Baddi
- Dabbahu a'a porphyric lavas
- Dabbahu differentiated lavas
- Dabbahu summit lavas - Field unpublished data
- Axial old pahoehoe lavas
- Axial younger pahoehoe lavas
- Historical eruptions
- Axial old fissure flows - Ferguson unpublished data
- Barberi et al. 1974

Chronology



- Oldest outcropping rift floor emplacement around 72ka
- Recovering starts ~ 40ka
- Intense Dabbahu activity at 40ka → "central" and fissure volcanism
→ **Dabbahu contributed to the building of rift topography**

Chronology



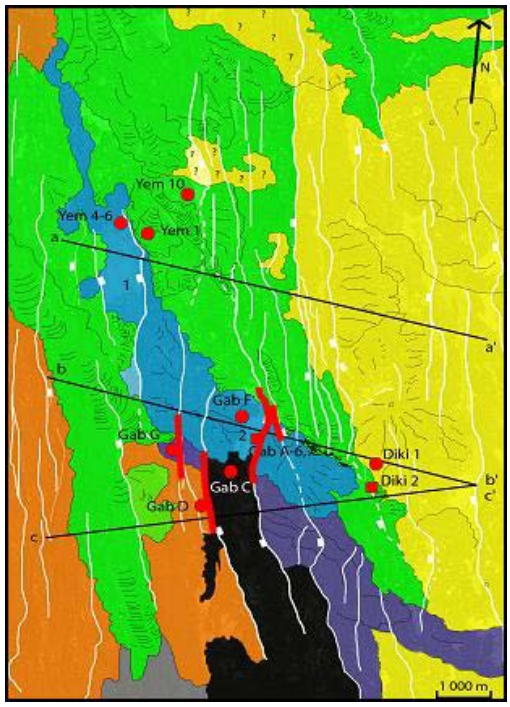
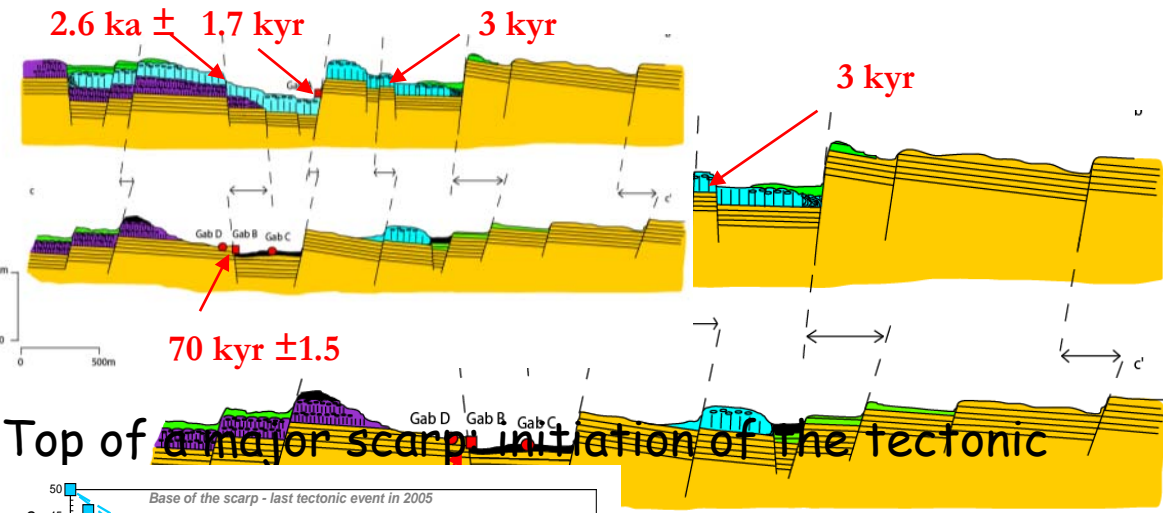
- Off-axis replenishment beneath Baddi around 50 ka
- Possible connexion at depth between Baddi & Dabbahu

→ 40ka-long magmatic cycle beneath Dabbahu?

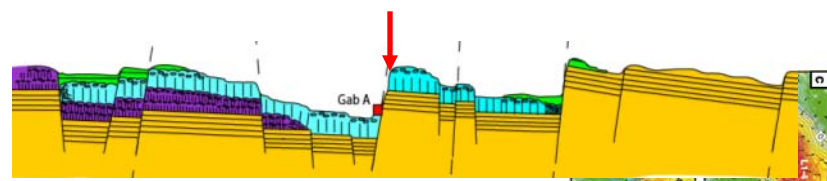
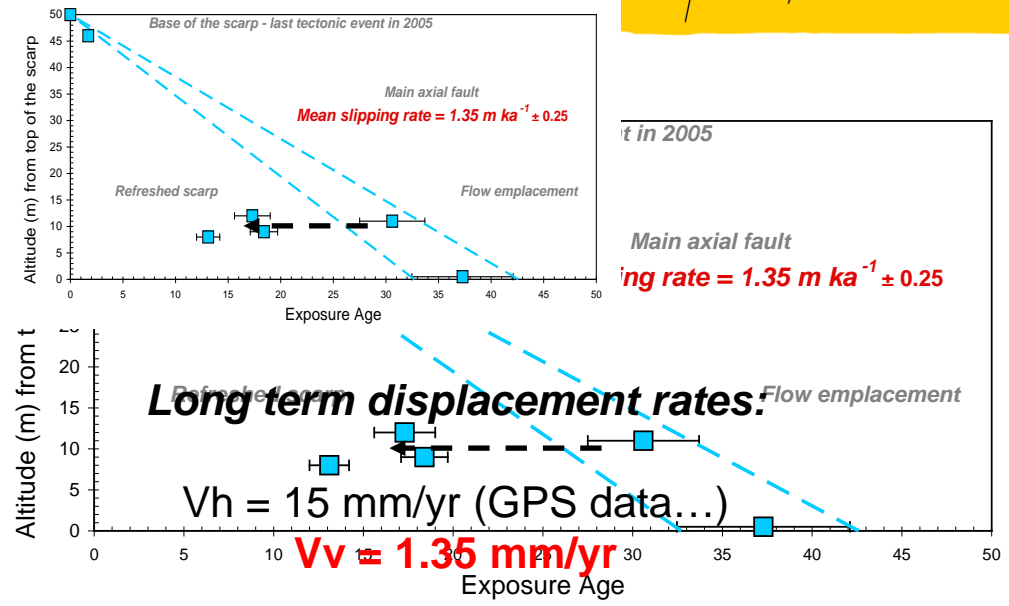
→ Not many data in the Southern part: replenishment around 30ka?

Dating fault activity

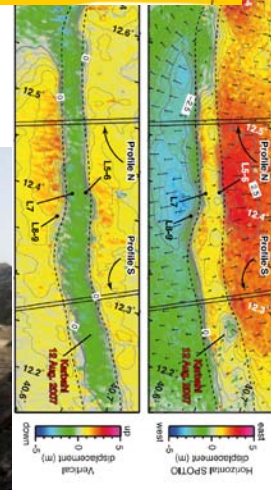
Bottom of the scarps: last tectonic event



Top of major scarp initiation of the tectonic



Short term displacement:

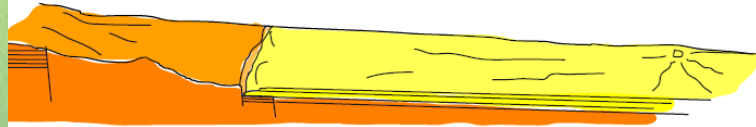
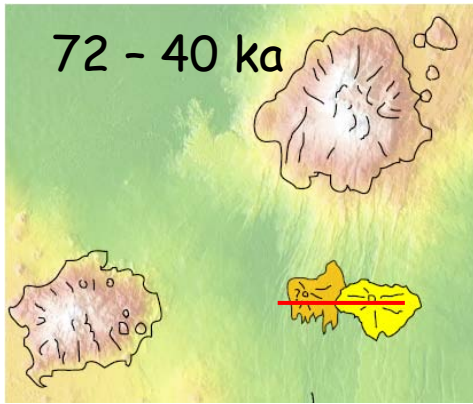


Discrepancy between [red box] and single rif [red box]

Conclusions

72 - 40 ka

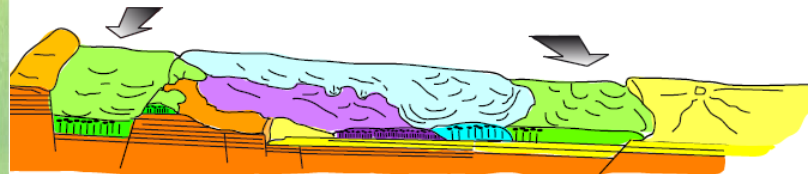
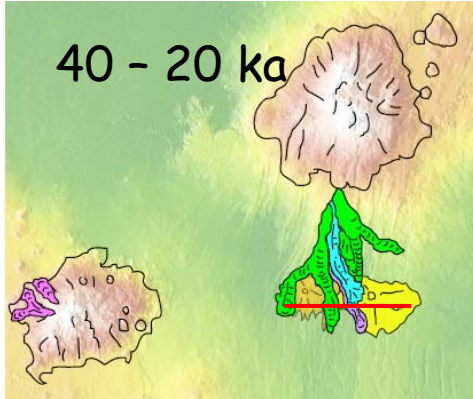
Old rift floor at 72 ka associated with minor scarps



- Baddi & Dabbahu: off-axis partial melting fraction
- Higher partial melting fraction at the axis, consistent with axial melt zone

40 - 20 ka

Major magmatic episode around 40ka at Dabbahu

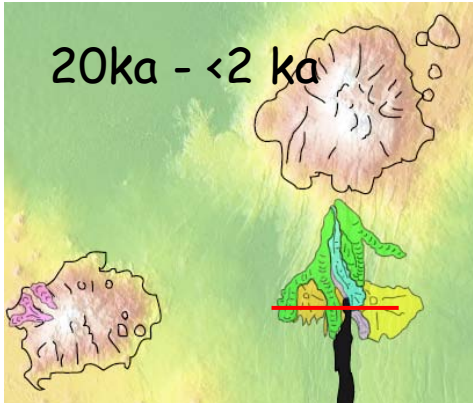


- Dabbahu: strongly implied in the acquisition of rift topography

Major topographic construction phase started around 30ka

- Recent axis flows:
 - from the Mid-Segment Magma Chamber

20ka - <2 ka



Thank you for your attention...

