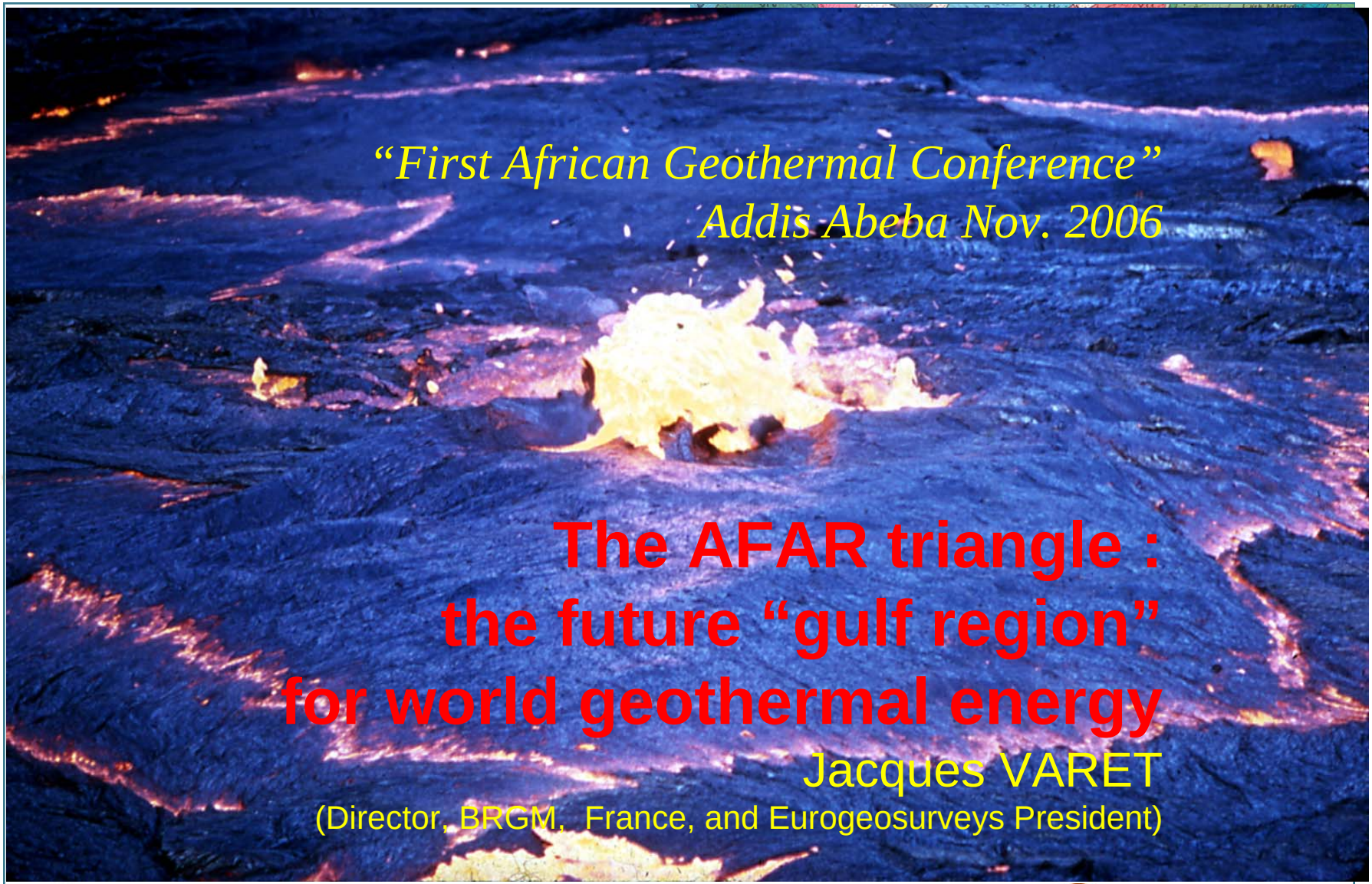

"First African Geothermal Conference"
Addis Abeba Nov. 2006

The AFAR triangle : the future "gulf region" for world geothermal energy

Jacques VARET
(Director, BRGM, France, and Eurogeosurveys President)

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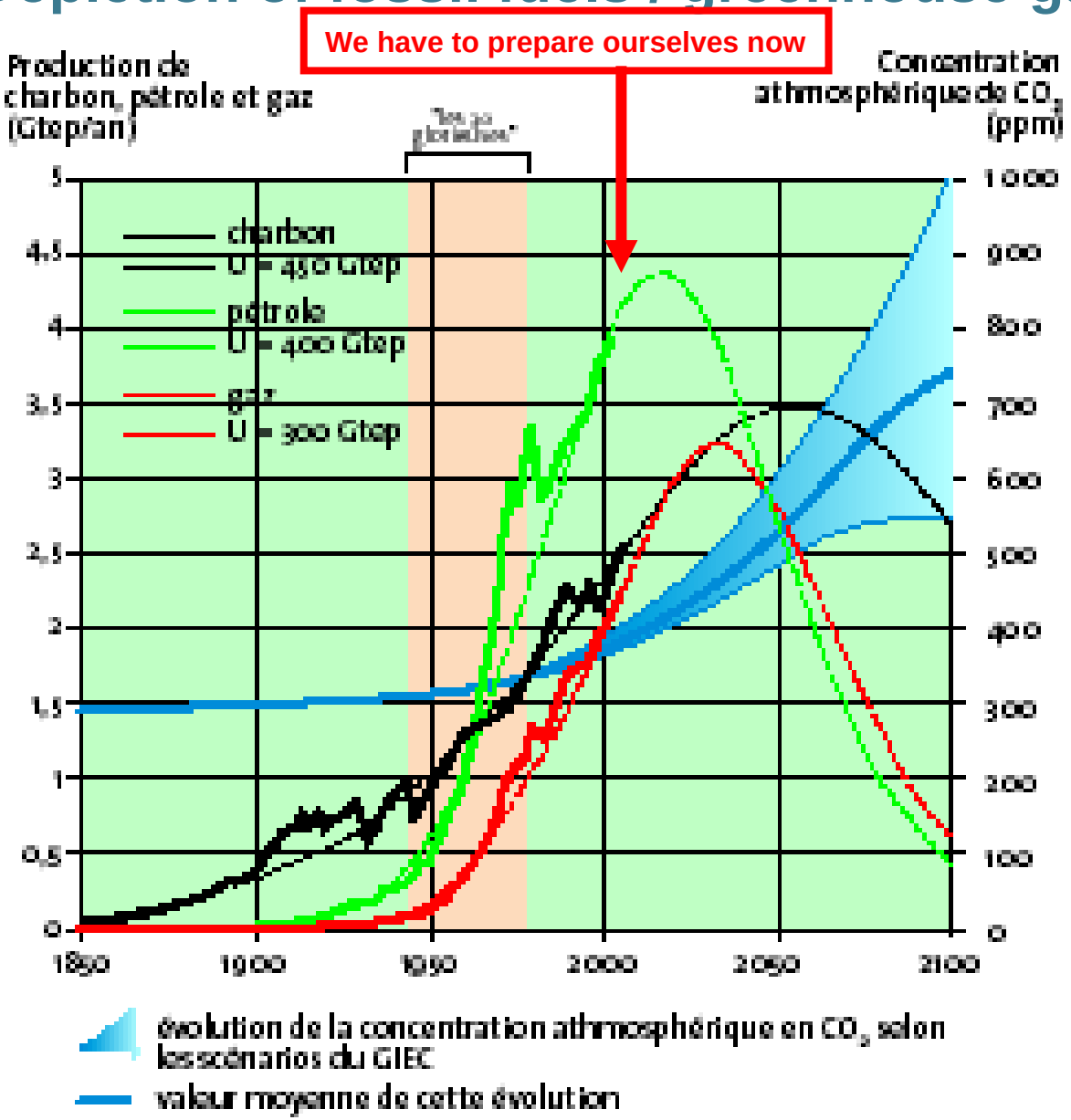
Depletion of fossil fuels / greenhouse gas emissions



The world economy relied mainly on oil & gaz

Two reasons for this to end soon (10-30 y):
-Resources
-Climate

Change: Better do it now !

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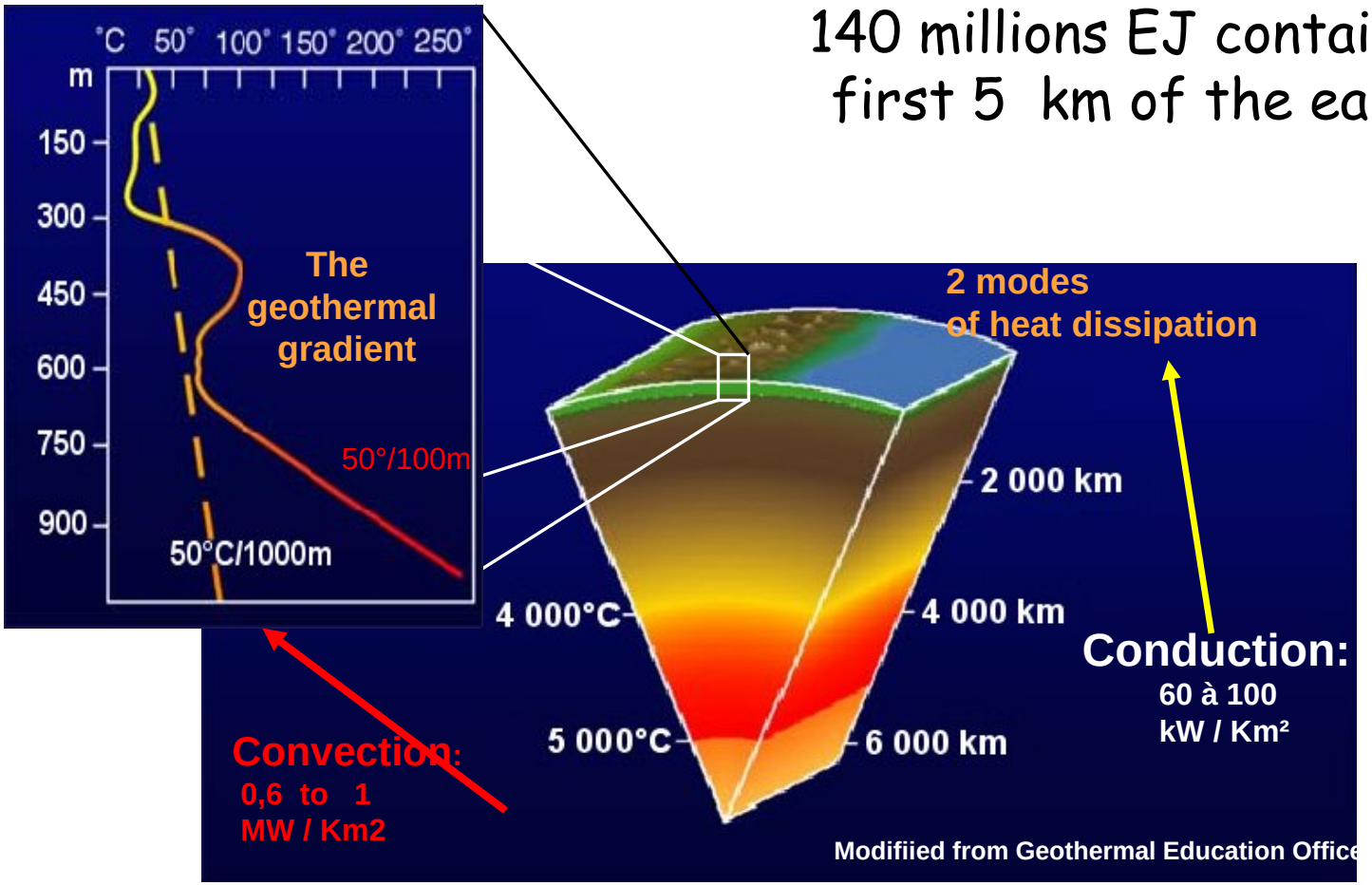
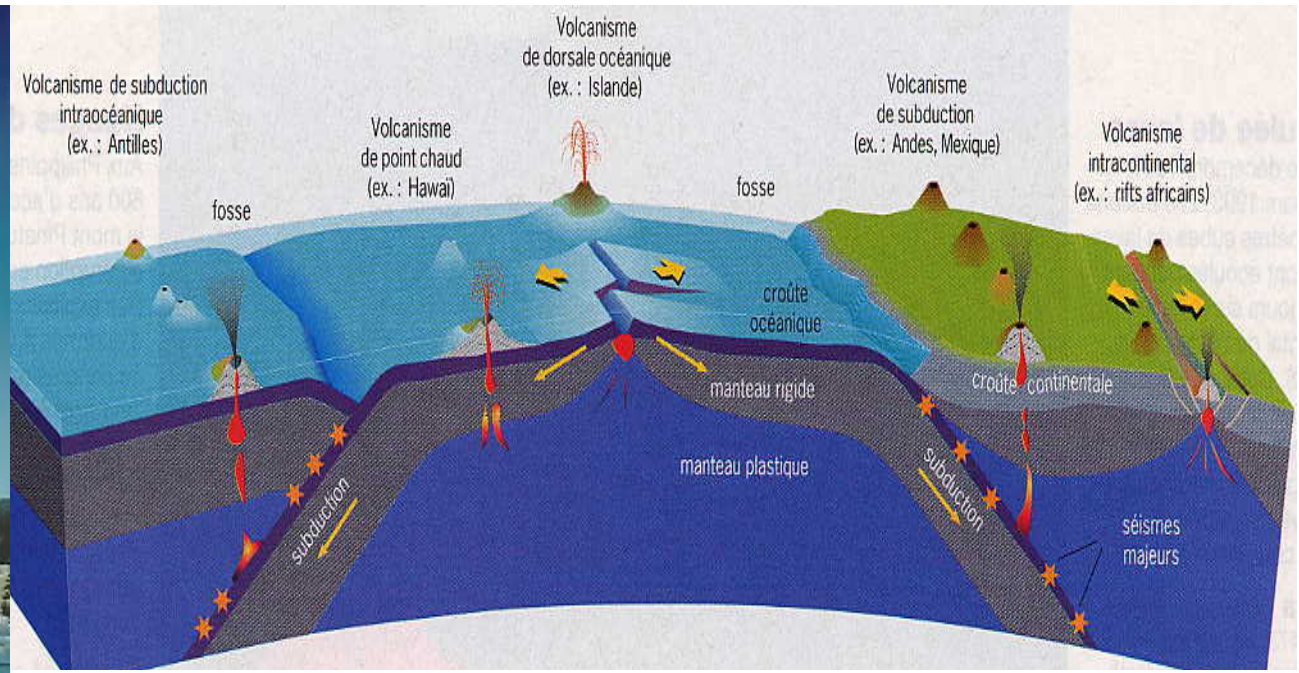
Geothermal energy : two modes of heat dissipation

140 millions EJ contained in the first 5 km of the earth crust

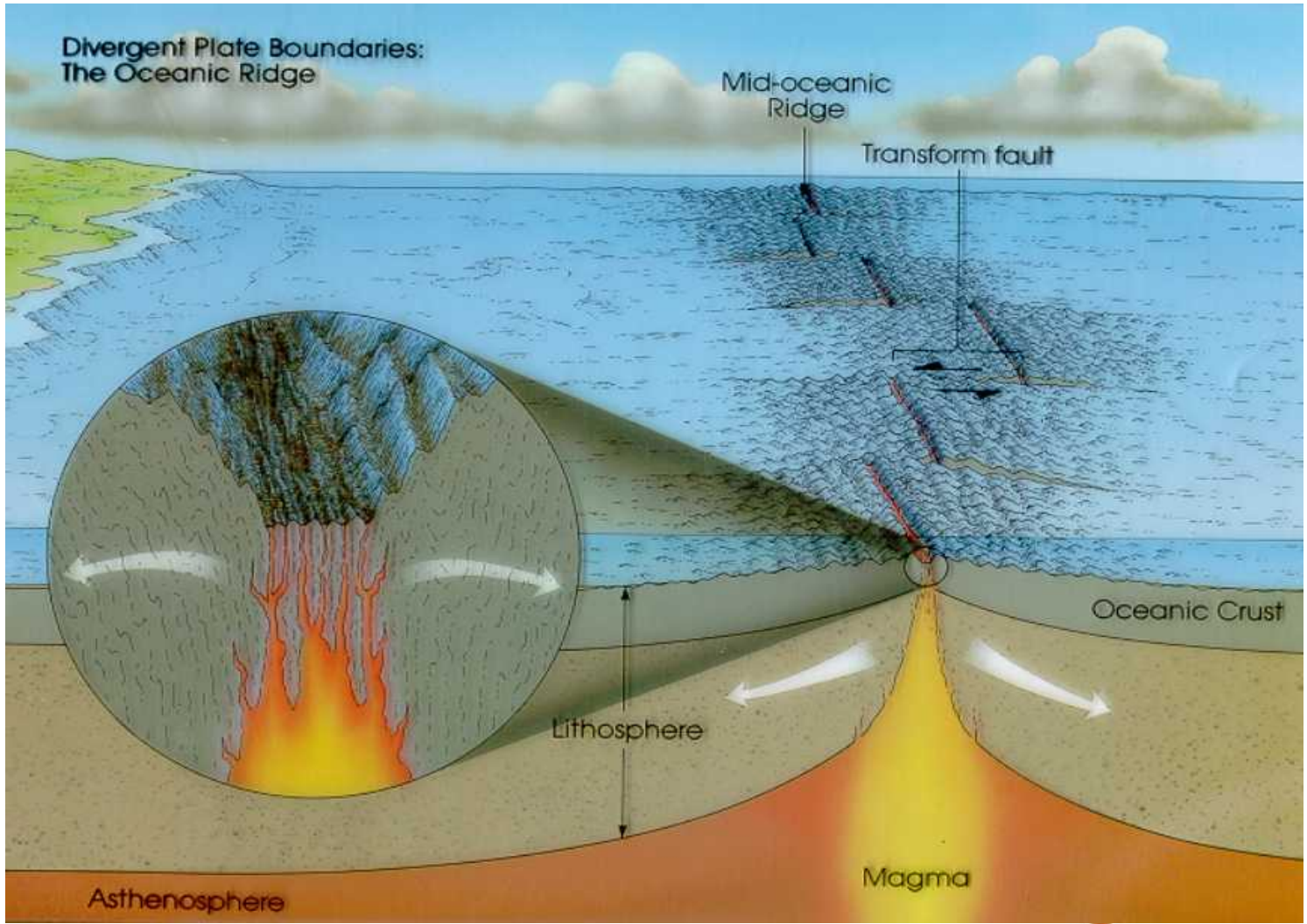


Geodynamic environment determine the type of geothermal resource



* **60 à 100 mW/m2 in stables zones**
  (i.e. 60-100 kW/Km2)
* **at leat ten times more in active zones**
  (i.e. of the order of the MW/Km2)

Oceanic ridges (MOR) : the best renewable energy suppliers on earth



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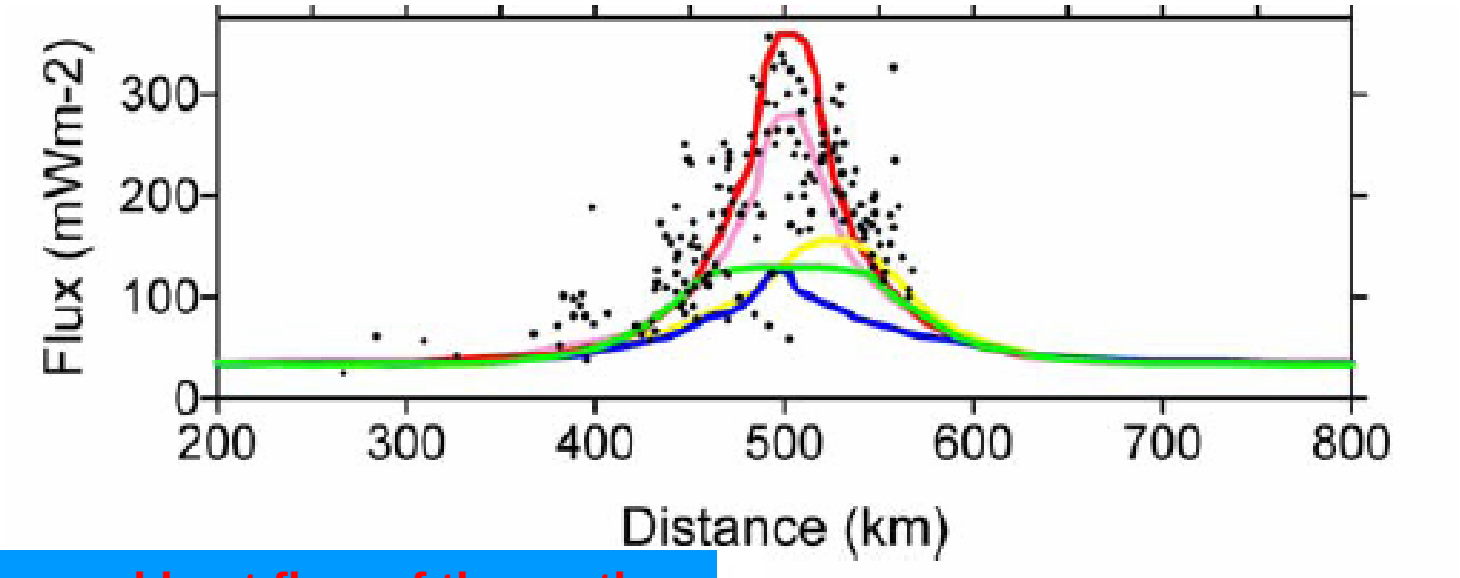
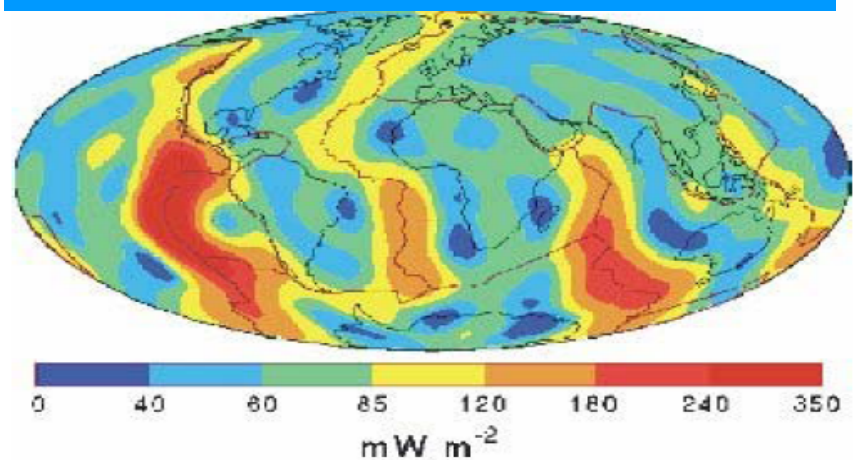
Oceanic ridges are the major earth heat flow dissipaters : 10 times higher

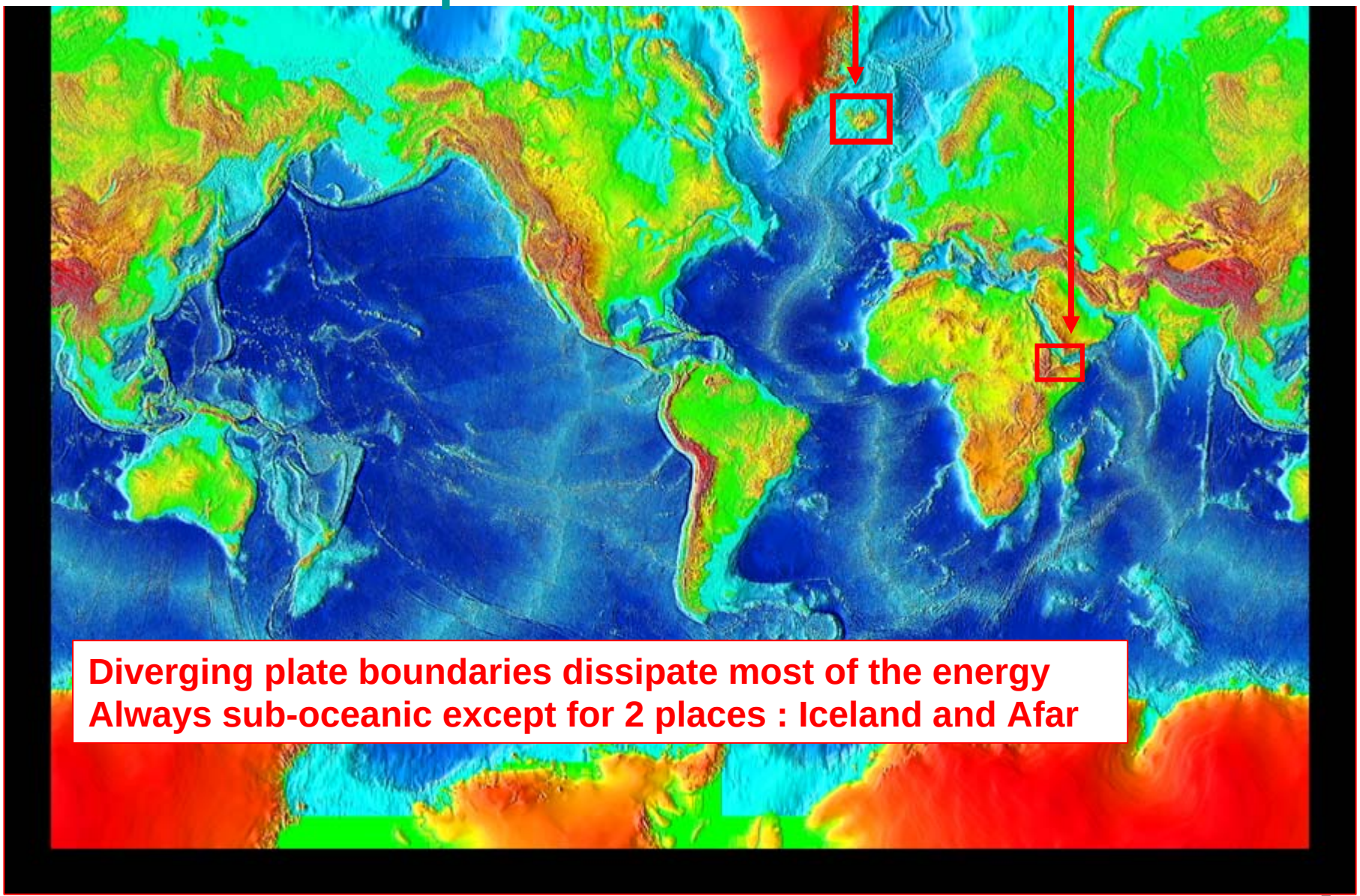


Thermal heat flow of the earth

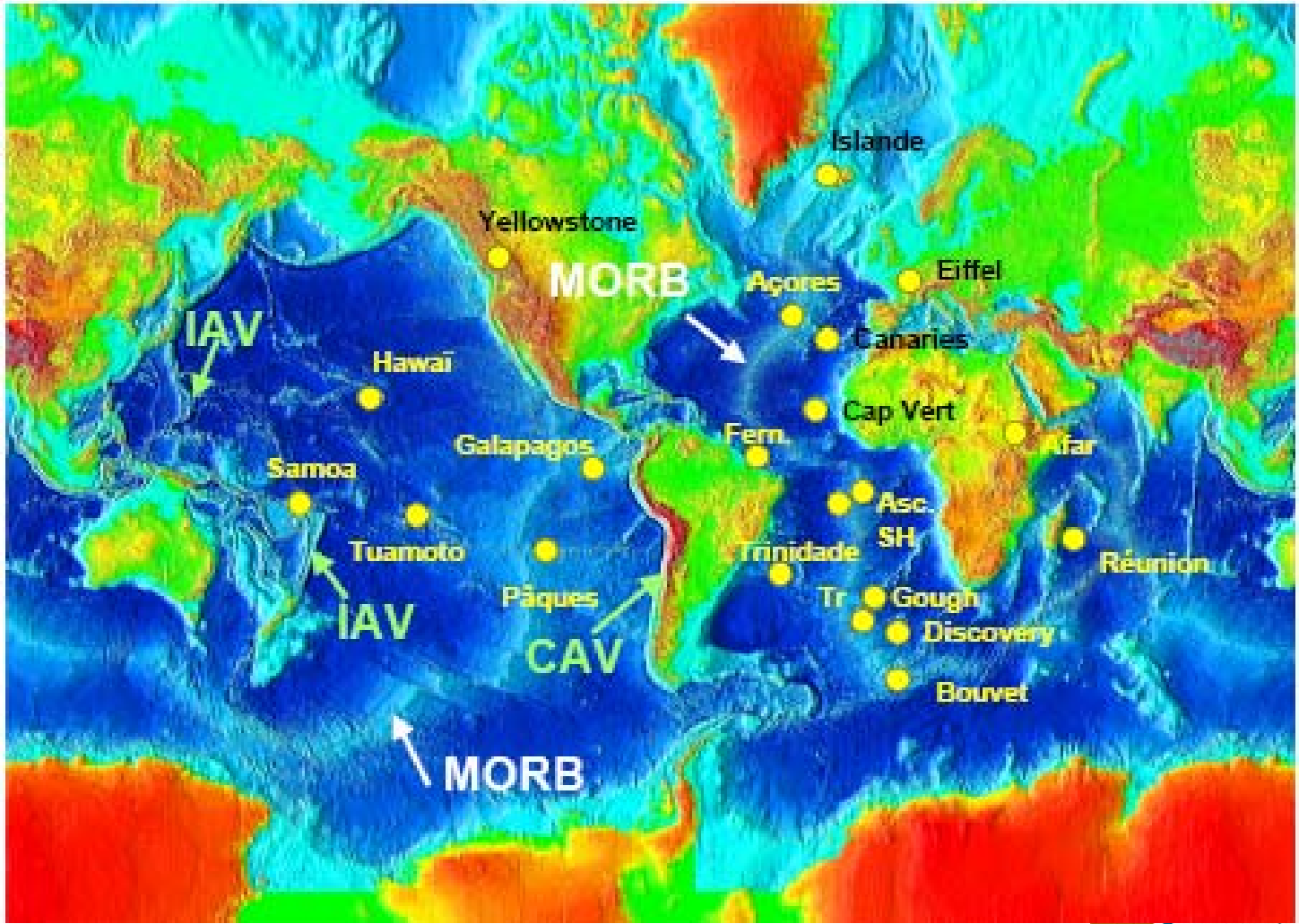


explained by partial melting of very shallow upper mantle along ridges axis

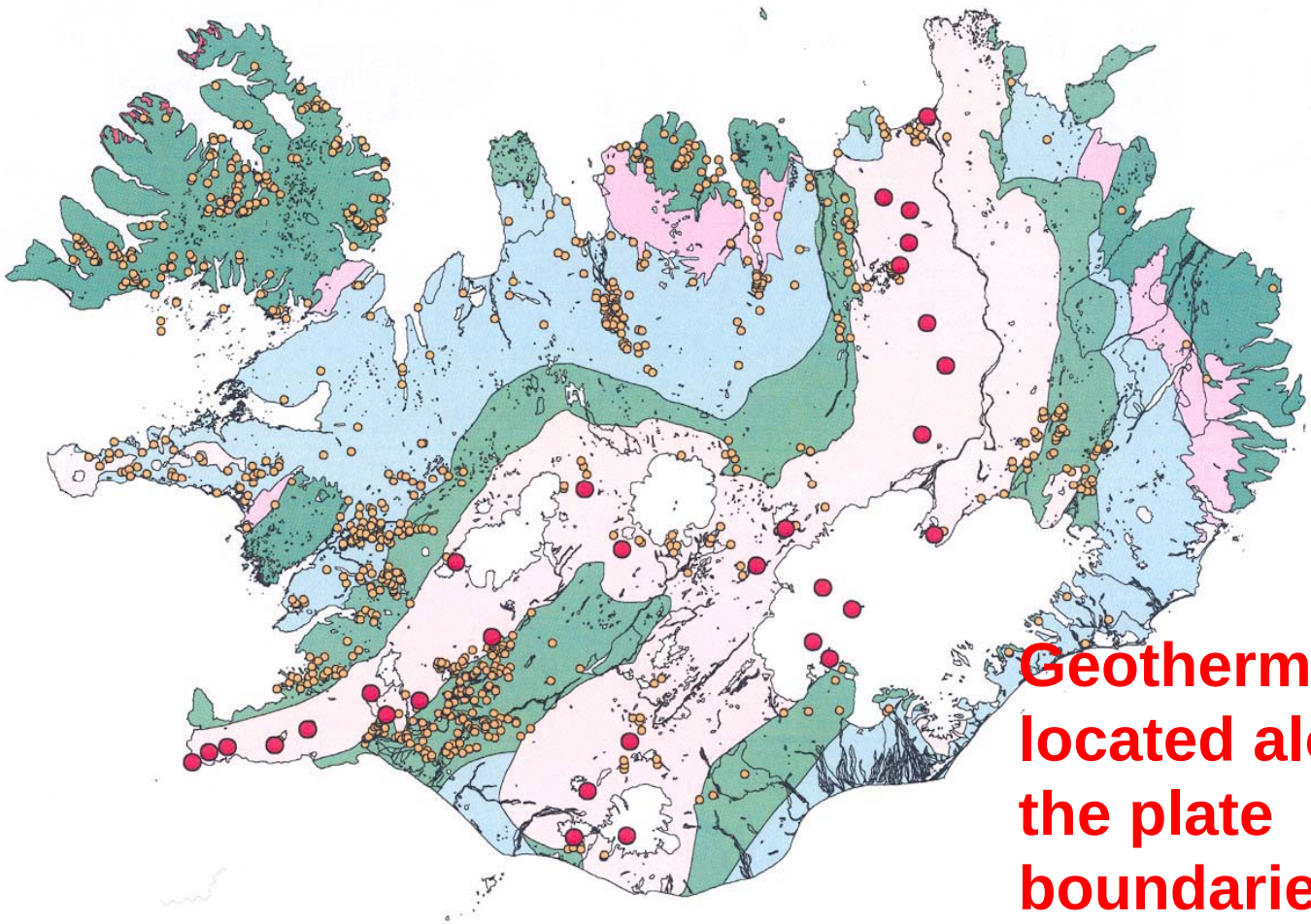
Mid-oceanic ridges : two places of exception on the planet : Iceland and Afar



And even more ! : Iceland and Afar aren't also hot spots ? (mantle plumes)



ZOOM at ICELAND : MAP of GEOTHERMAL SITES



Geothermal sites located along the plate boundaries

First A

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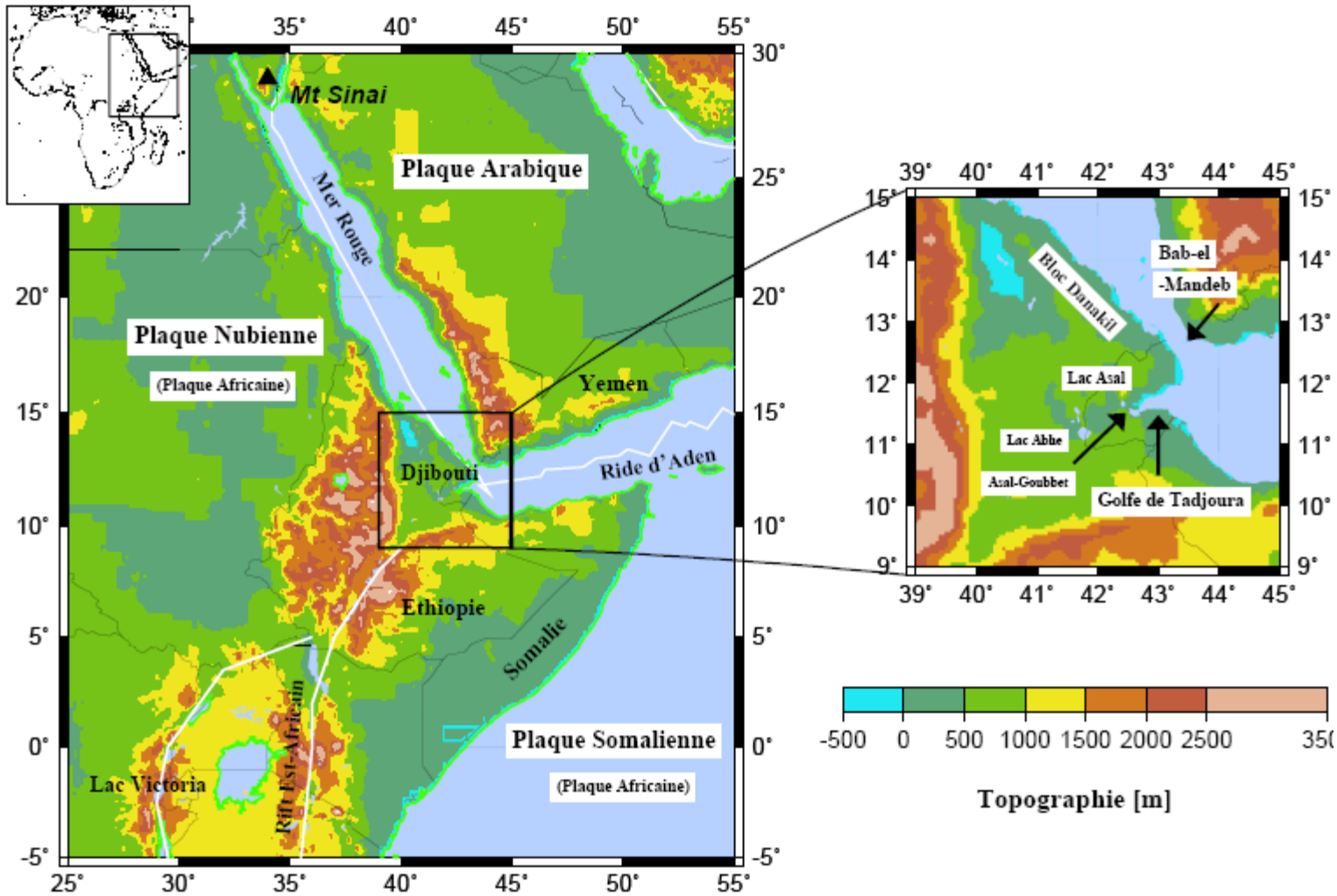
Zoom at Afar : where Red Sea and Aden ridge are found emerged



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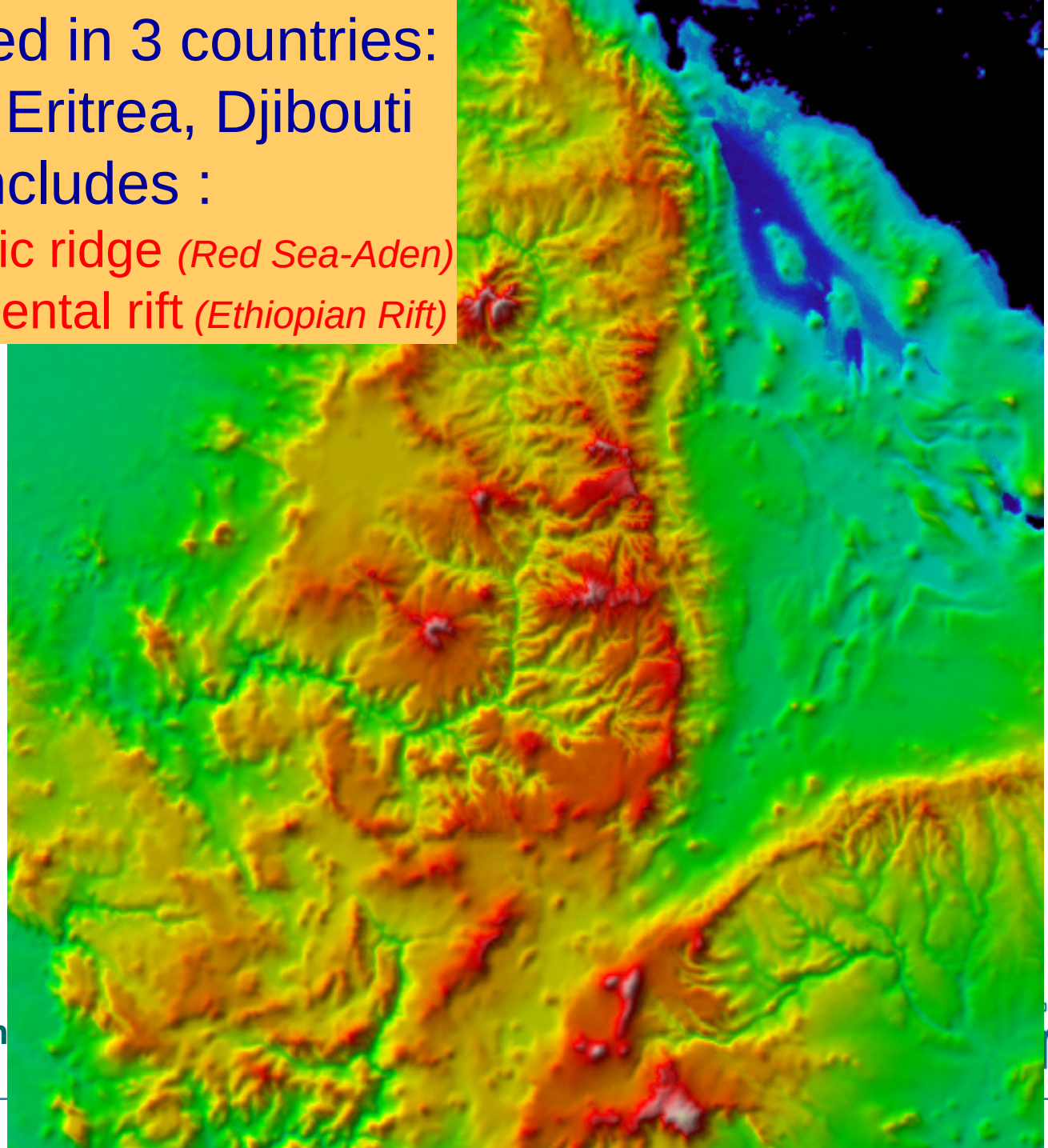
Afar located in 3 countries:
Ethiopia, Eritrea, Djibouti
Includes :

- One oceanic ridge *(Red Sea-Aden)*
- One continental rift *(Ethiopian Rift)*



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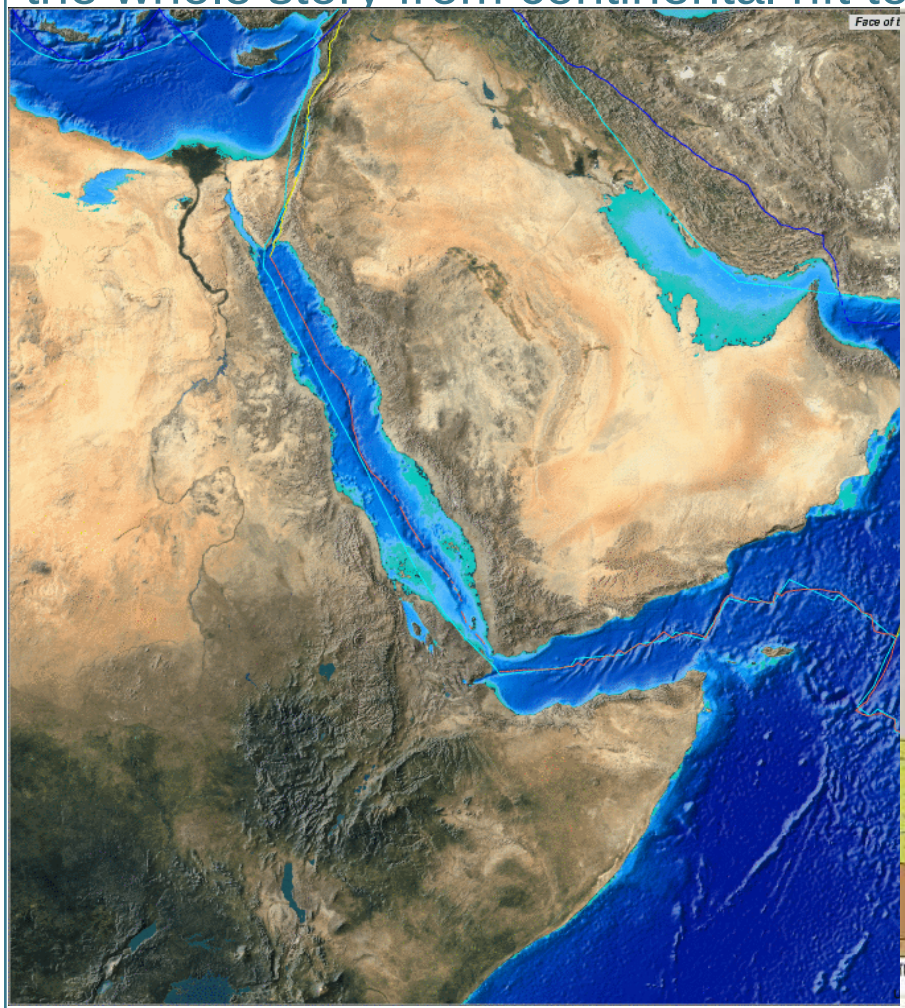
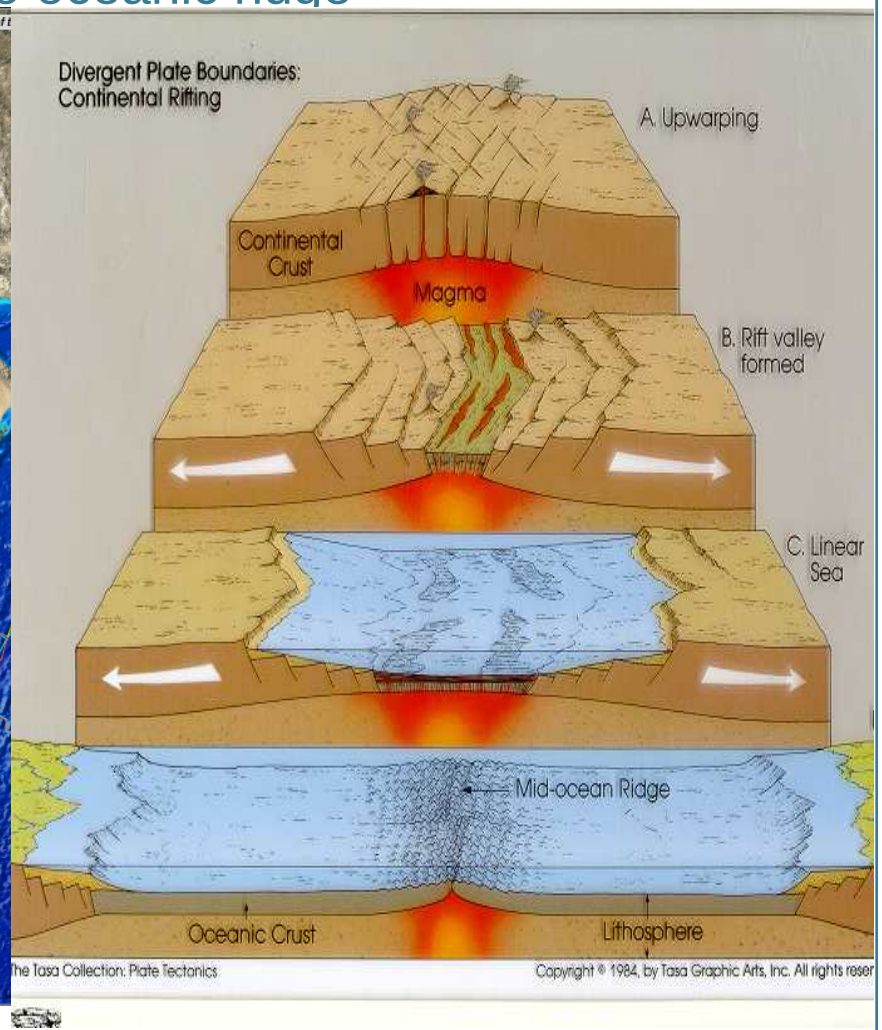
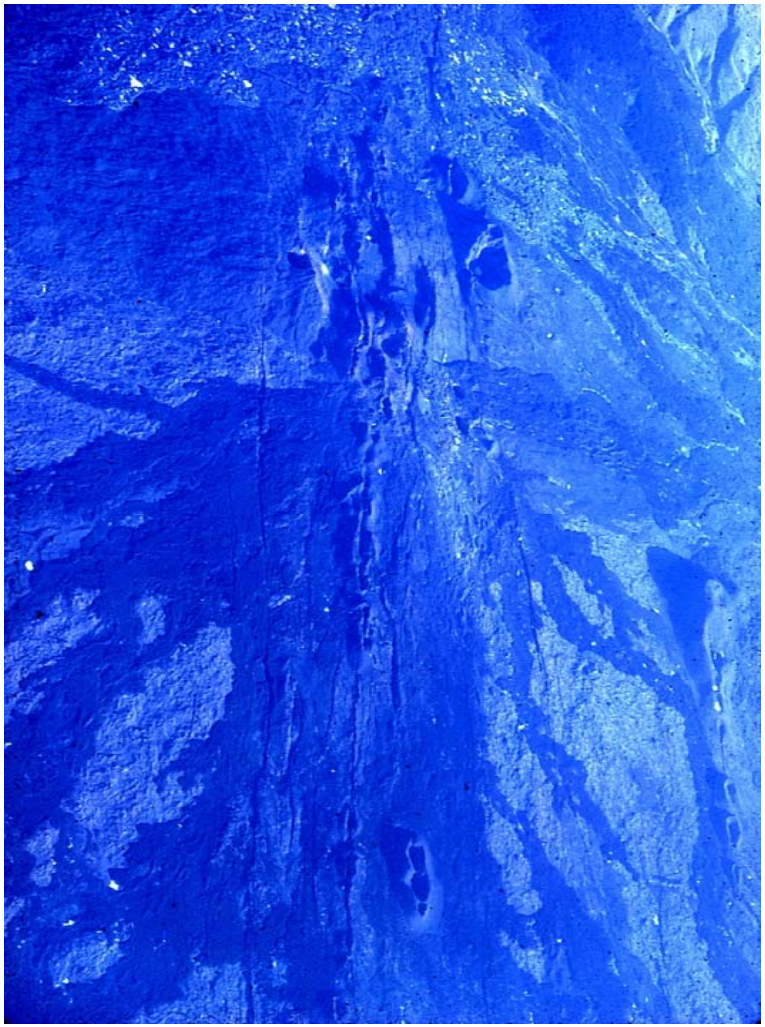
Afar oceanic ridge + continental rift = triple junction and hot spot

the whole story from continental rift to oceanic ridge





Along the rift axis (south Erta Ale range)

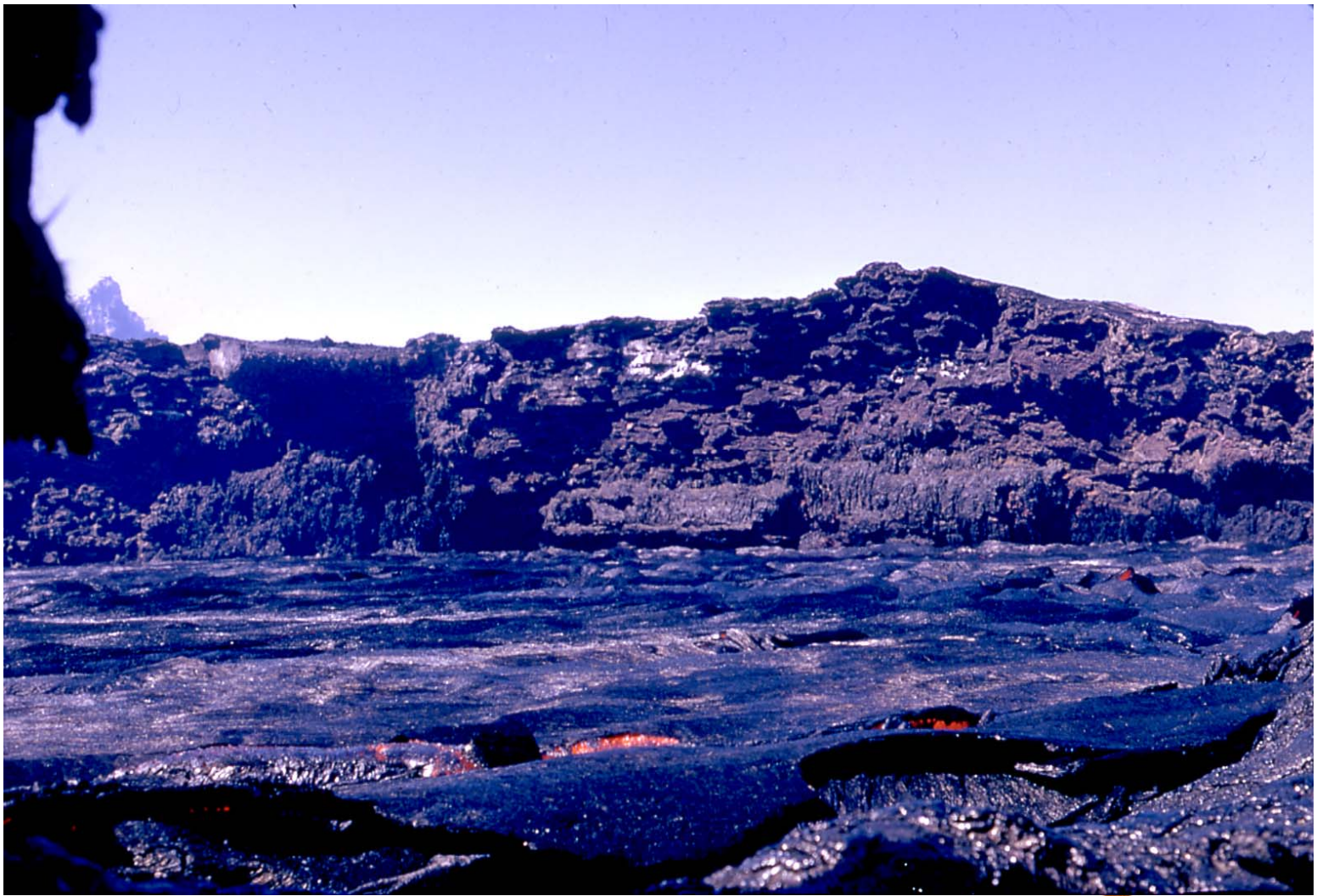


Elliptic calderas along rift axis : Erta Ale vocano

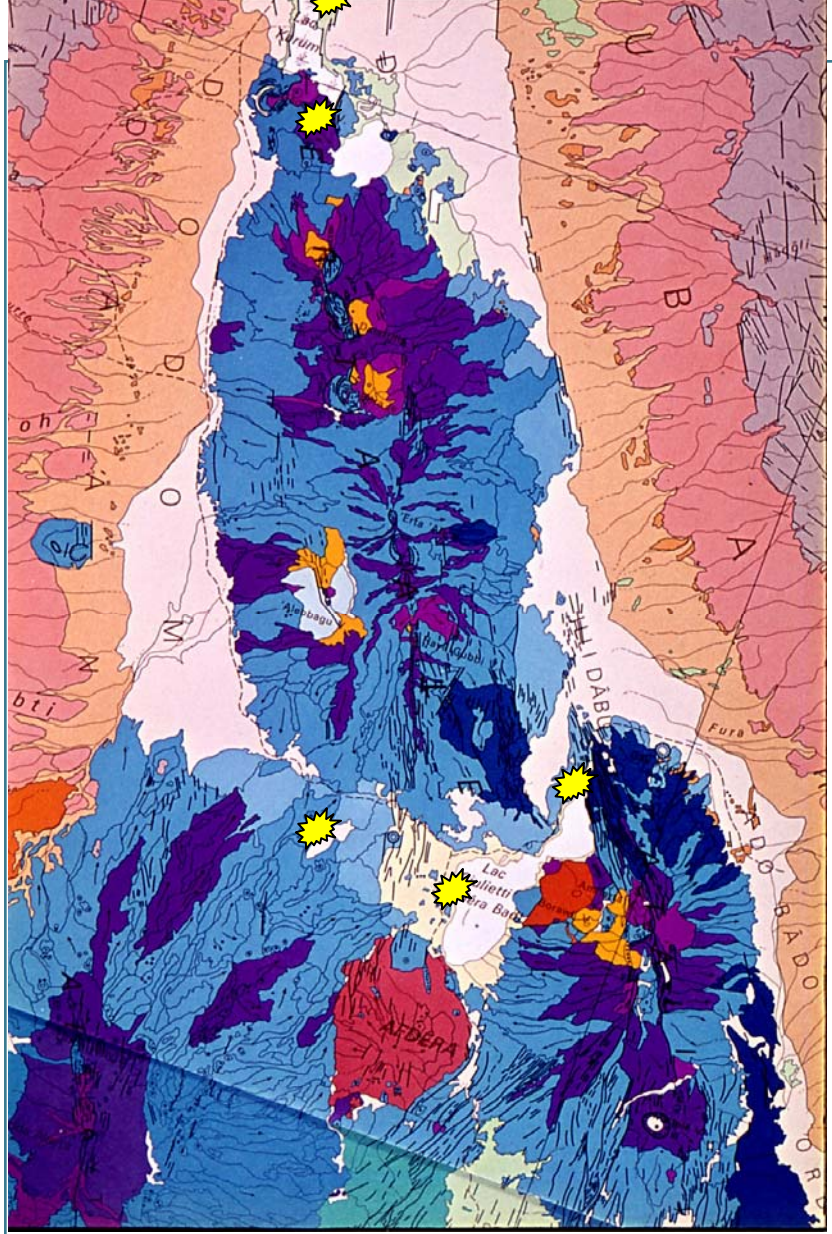
Erta Ale Lava lakes

Erta Ale northern lava lake

Erta Ale lava lake : micro plate tectonics



Erta Ale : be there at night !



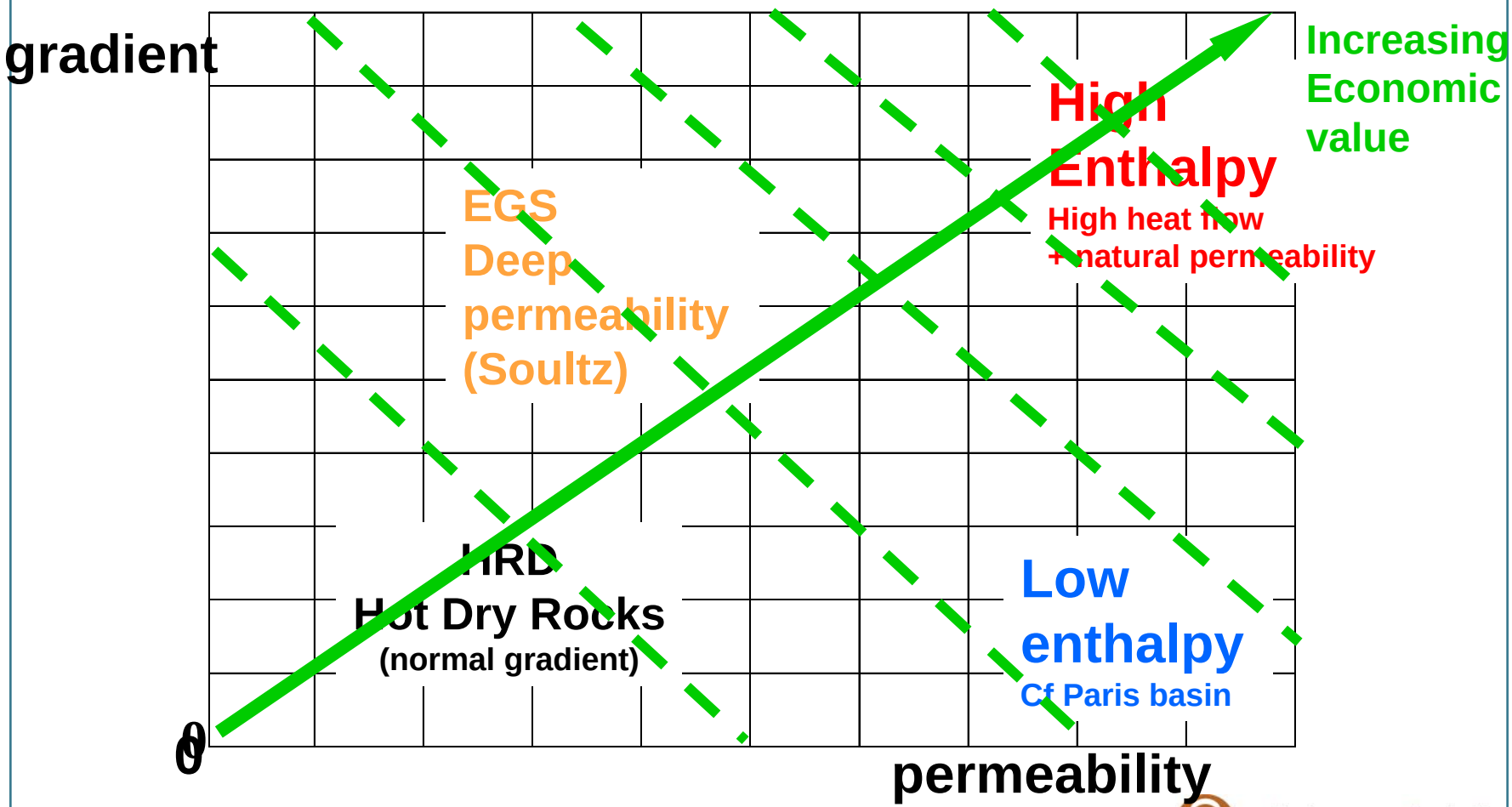
Right in the middle, along N Afar rift axis : the Erta Ale, Alayta and Tat Ali – Mat'ala axial volcanic ranges

Varet et al. CNR-CNRS, 1973

geothermal sites

Two key parametres for geothermal fields :

1: geothermal gradient (f. heat flow) 2: permeability (fractures)



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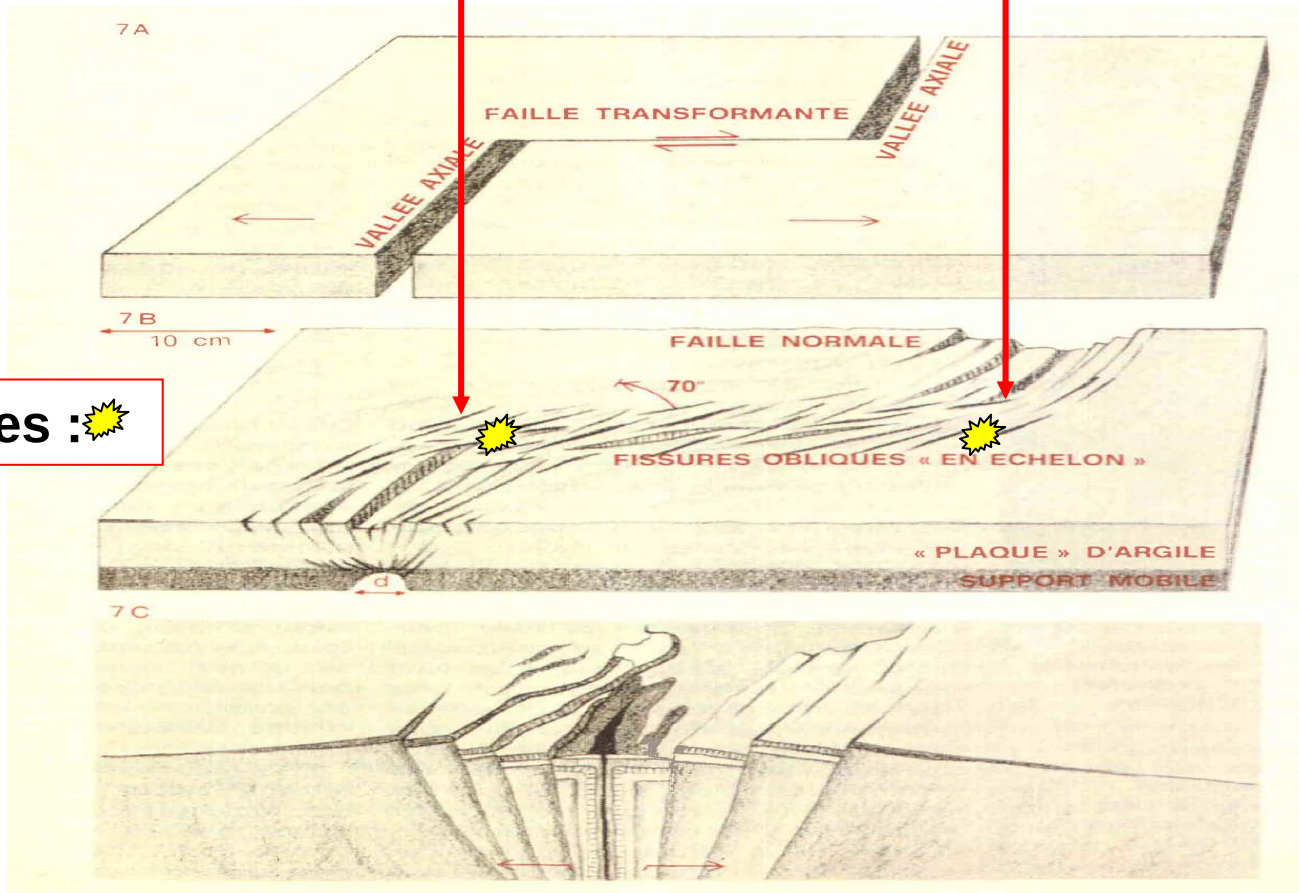
Axial volcanic rift zone and transform zones : a tool for geothermal exploration

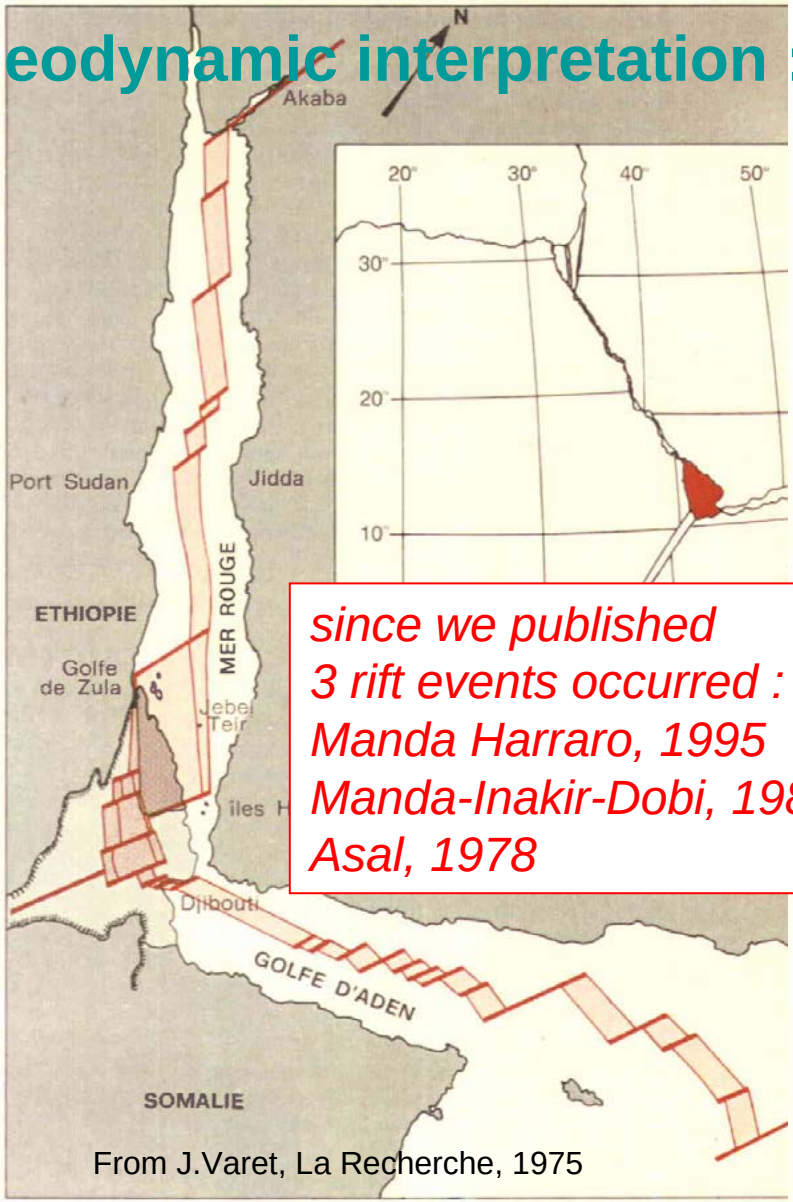
Crossing faults = frequent differentiated central volcano and/or hydrothermal zone



Geothermal sites :

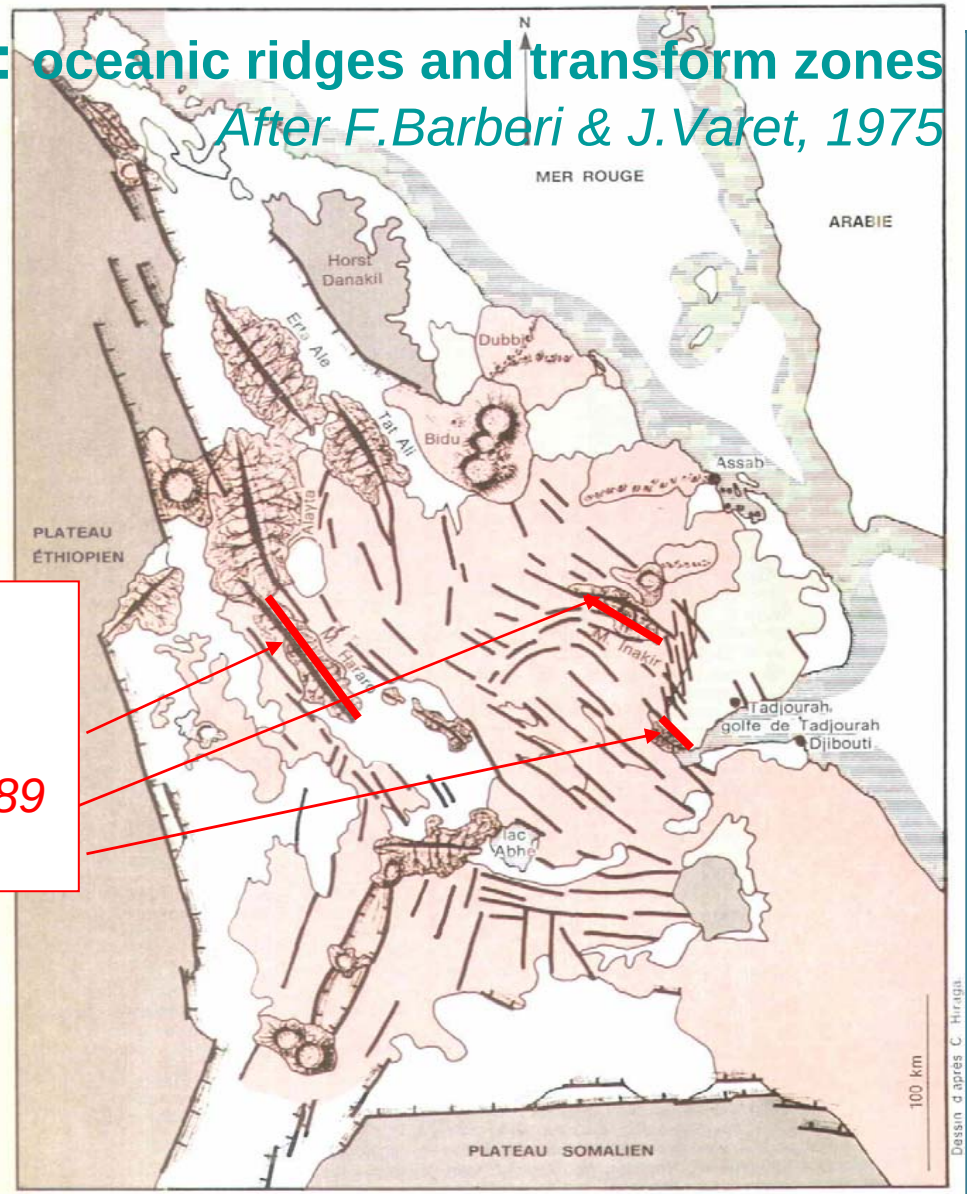
Geodynamic interpretation : oceanic ridges and transform zones

After F.Barberi & J.Varet, 1975



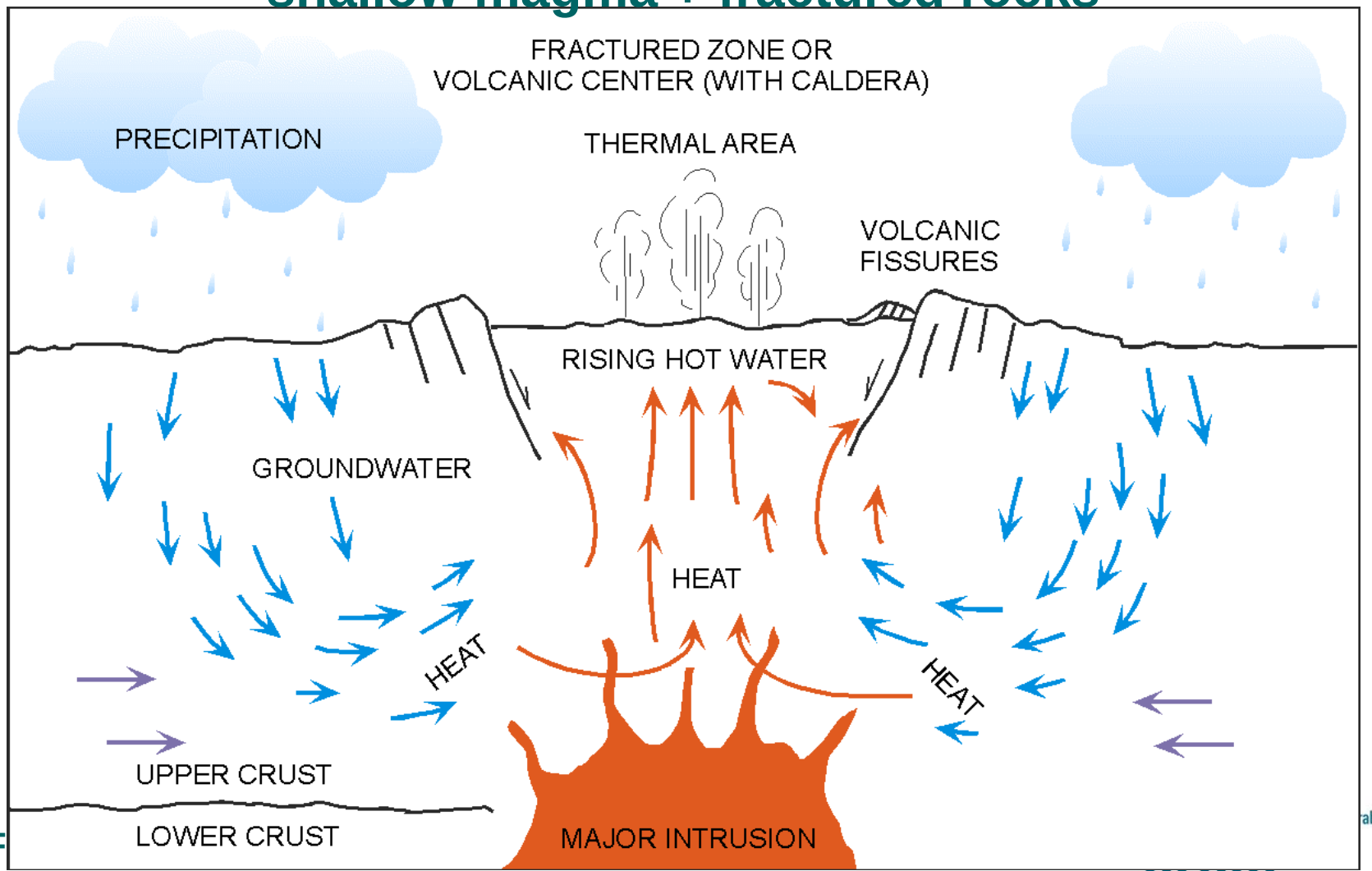
From J.Varet, La Recherche, 1975

since we published
3 rift events occurred :
Manda Harraro, 1995
Manda-Inakir-Dobi, 1989
Asal, 1978



All necessary ingredients for high temperature fields :

shallow magma + fractured rocks



Dallol geothermal zone

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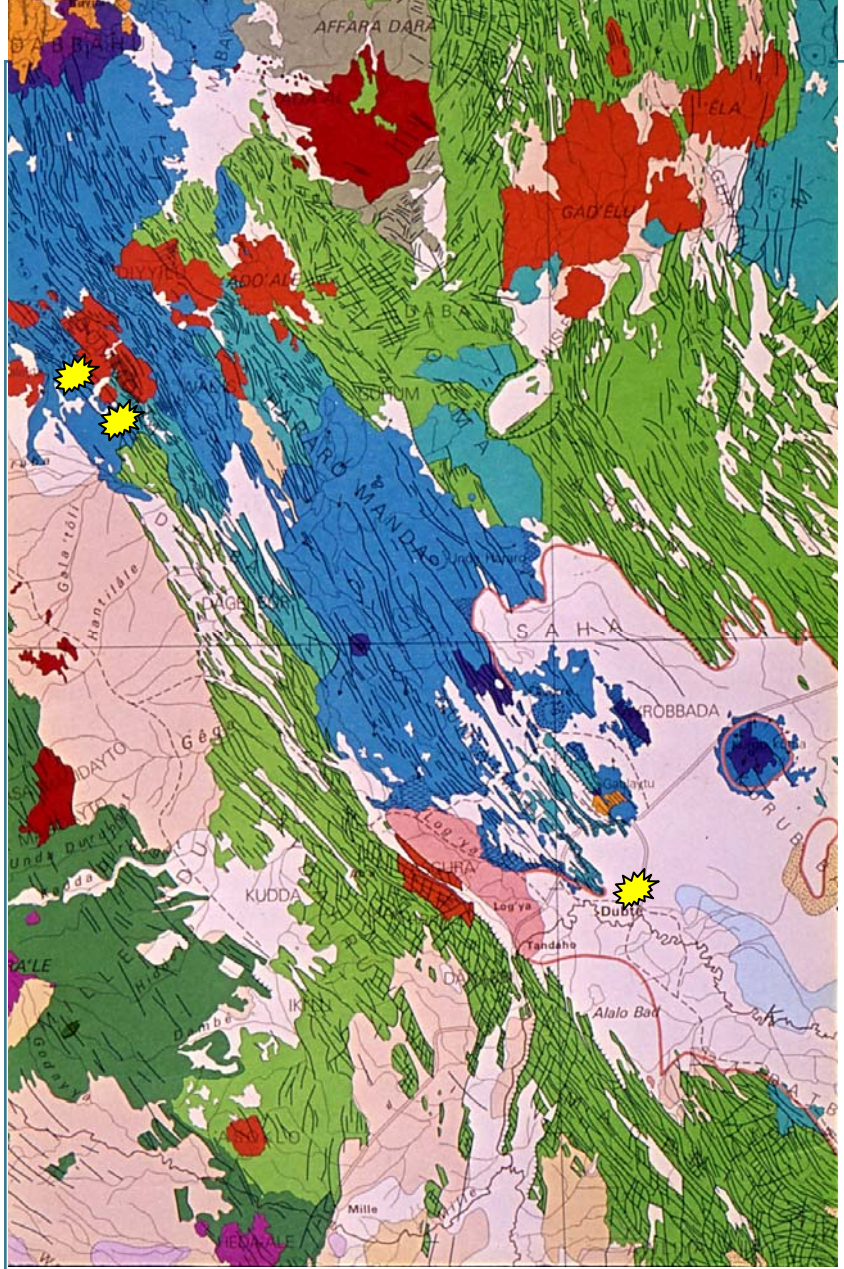
Dallol geothermal zone

Dallol boiling hotsprings



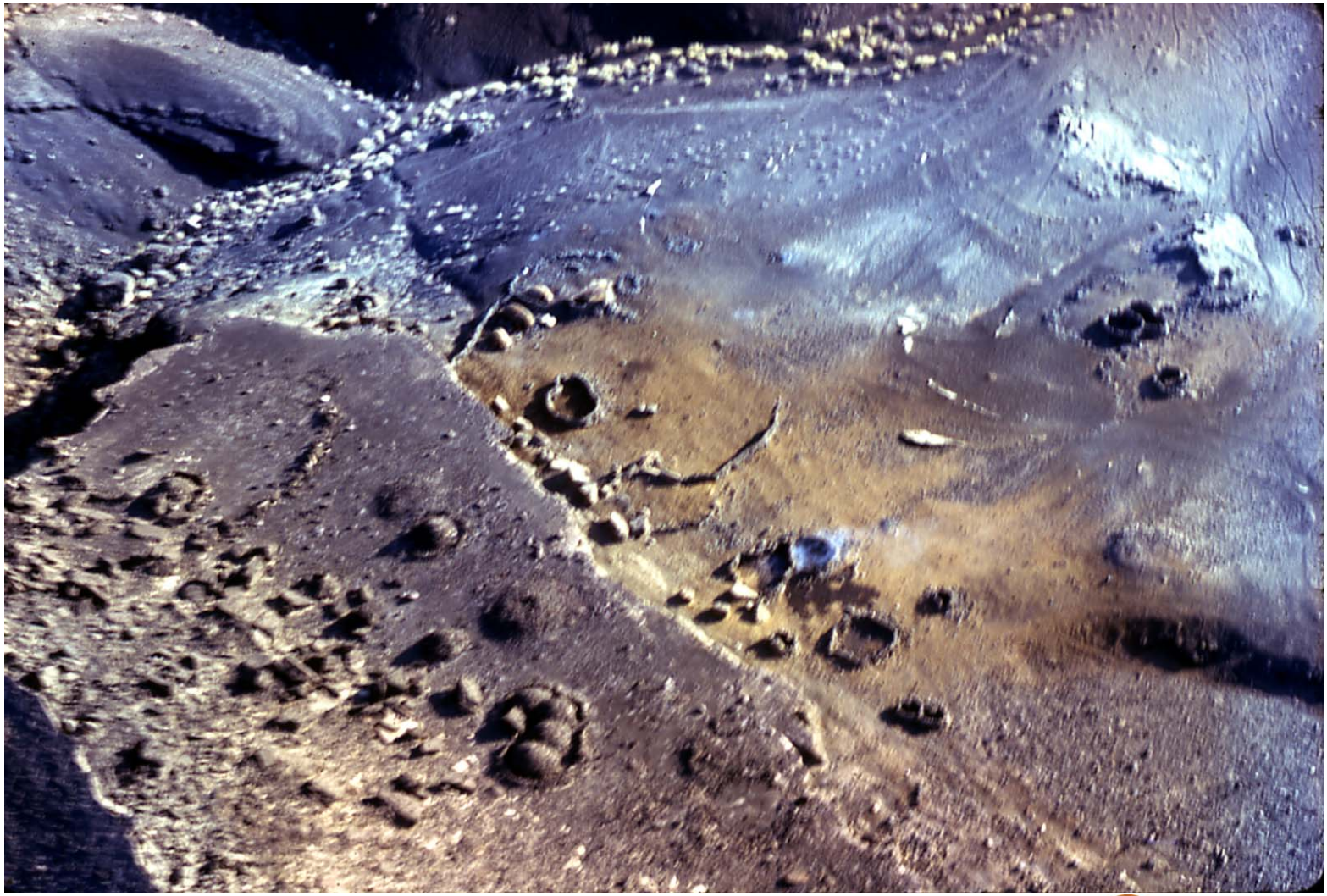
Alayta ridge,
Boina centre,
Manda Harraro ridge
(the fastest in Afar according to Treuil & Varet, 1973 as confirmed by 2005 volcano-tectonic event, cf. Gezahegn Yrgu this meeting)

Boina
and
Tendaho
geothermal sites

Boina steam vents along fault

Boina steam vents along fault; silica deposits

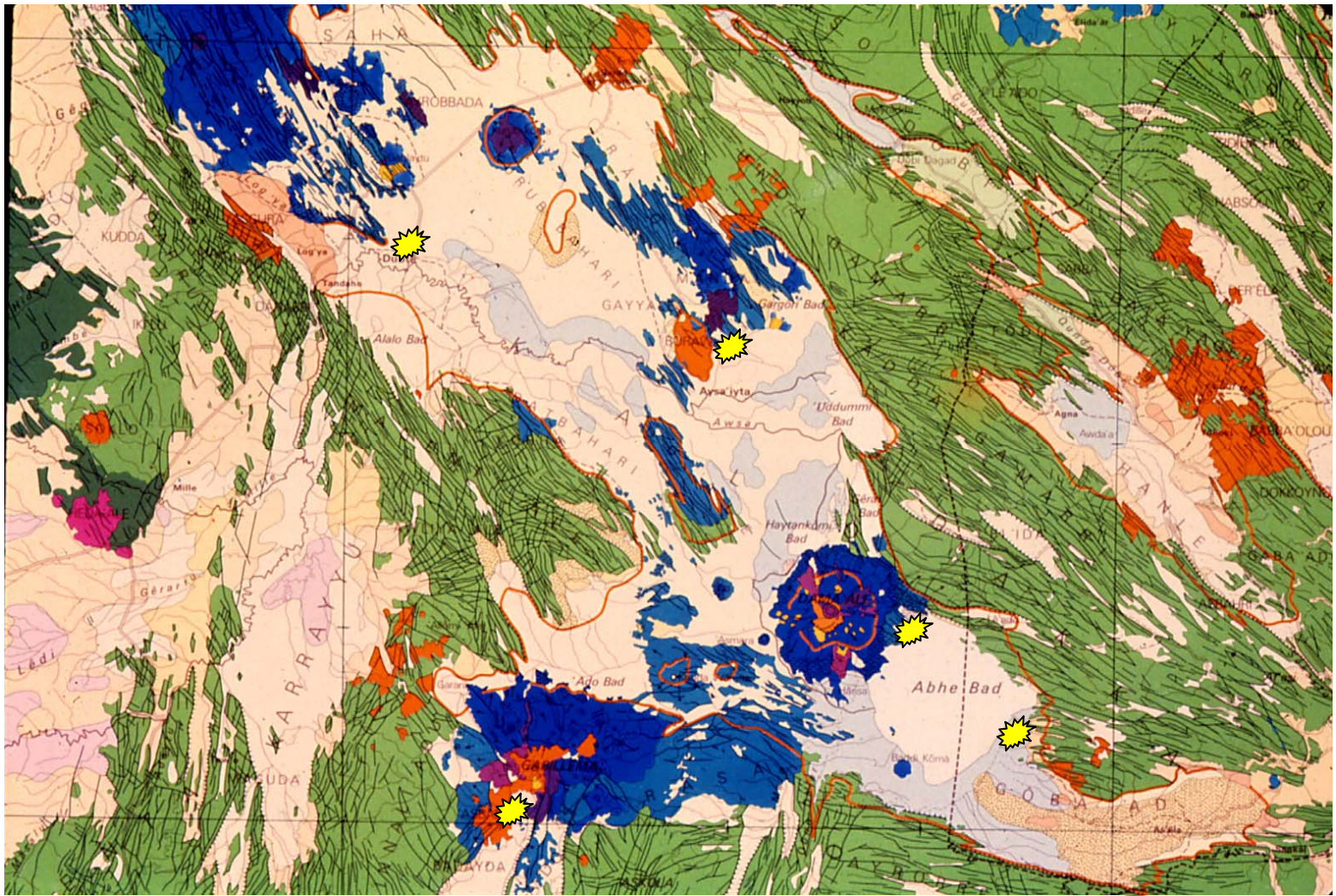
Boina : village capturing steam along fault, silica deposits



Captured steam : condensation of water, silica deposits

Central Afar

Varet et al. CNR-CNRS, 1979



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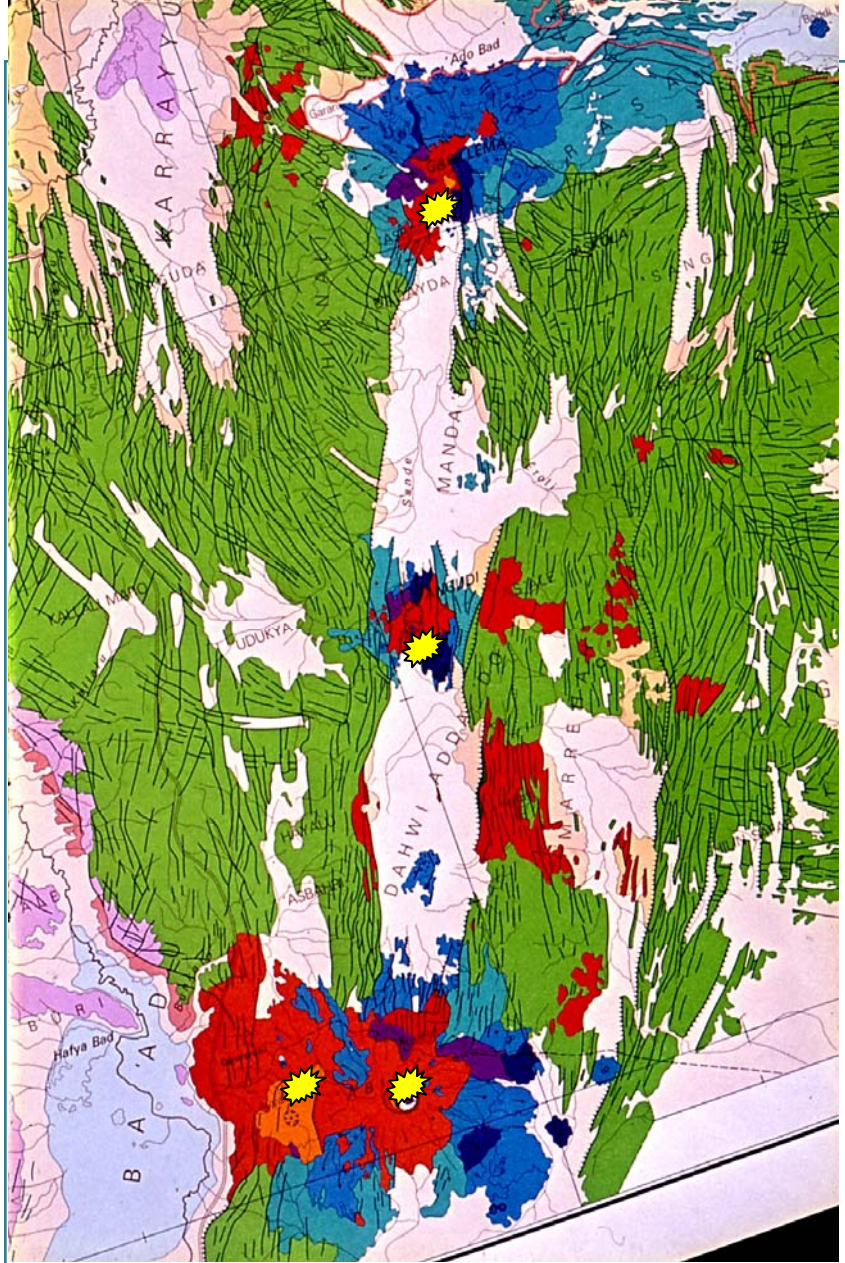
Tendaho alalo bad

Abhe bad



Differing from North and East oceanic Afar ridges,

the south Afar rift :
- *no axial range*
- *continental type*

geothermal sites linked with :
- *central volcanoes*
- *located along rift axis*

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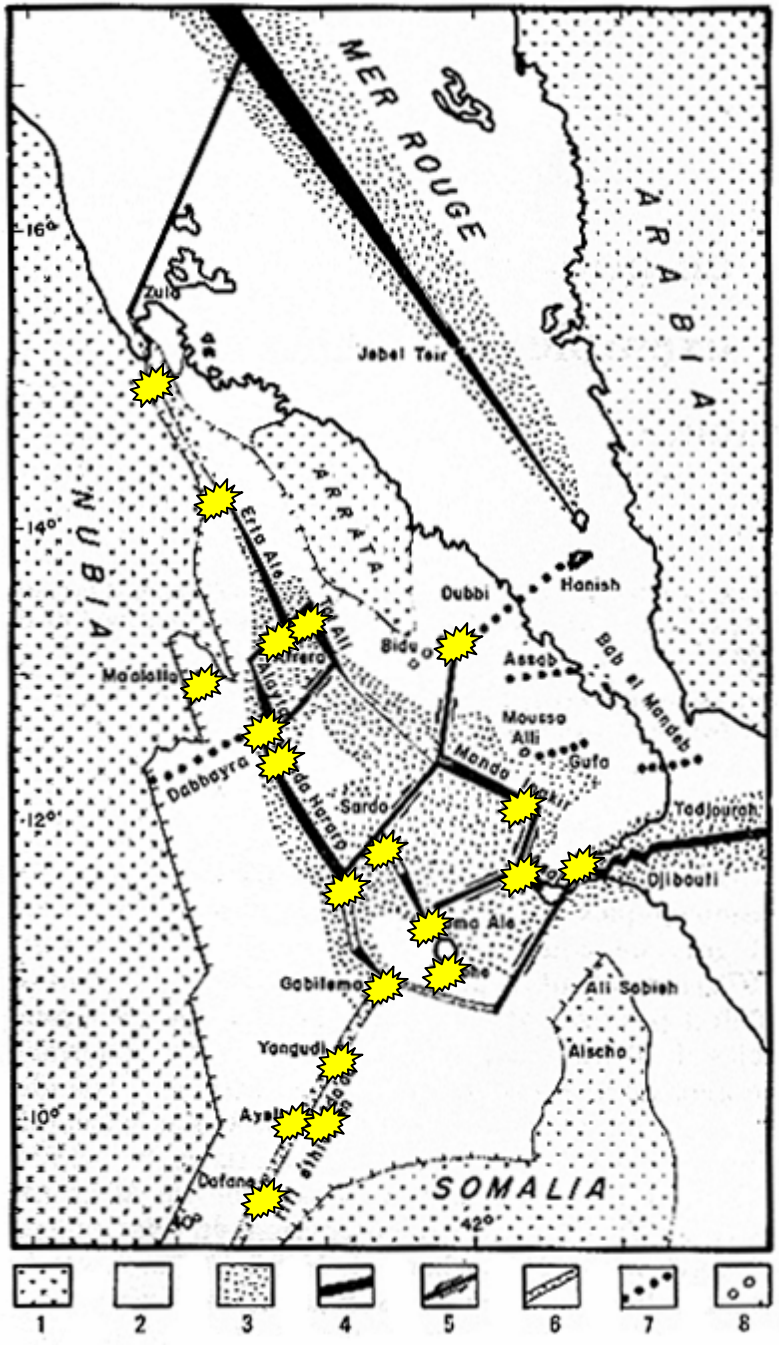
Afar Geodynamic Context (micro-plates Boundaries)

(F.Barberi et J.Varet)



Revisiting potential geothermal sites

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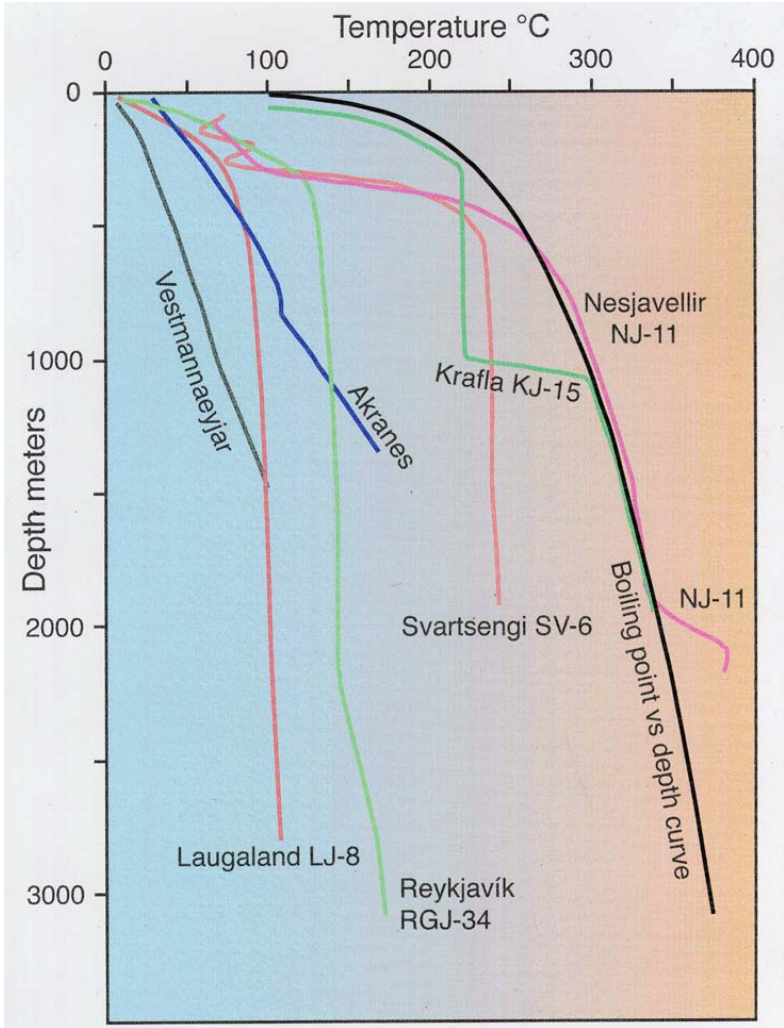
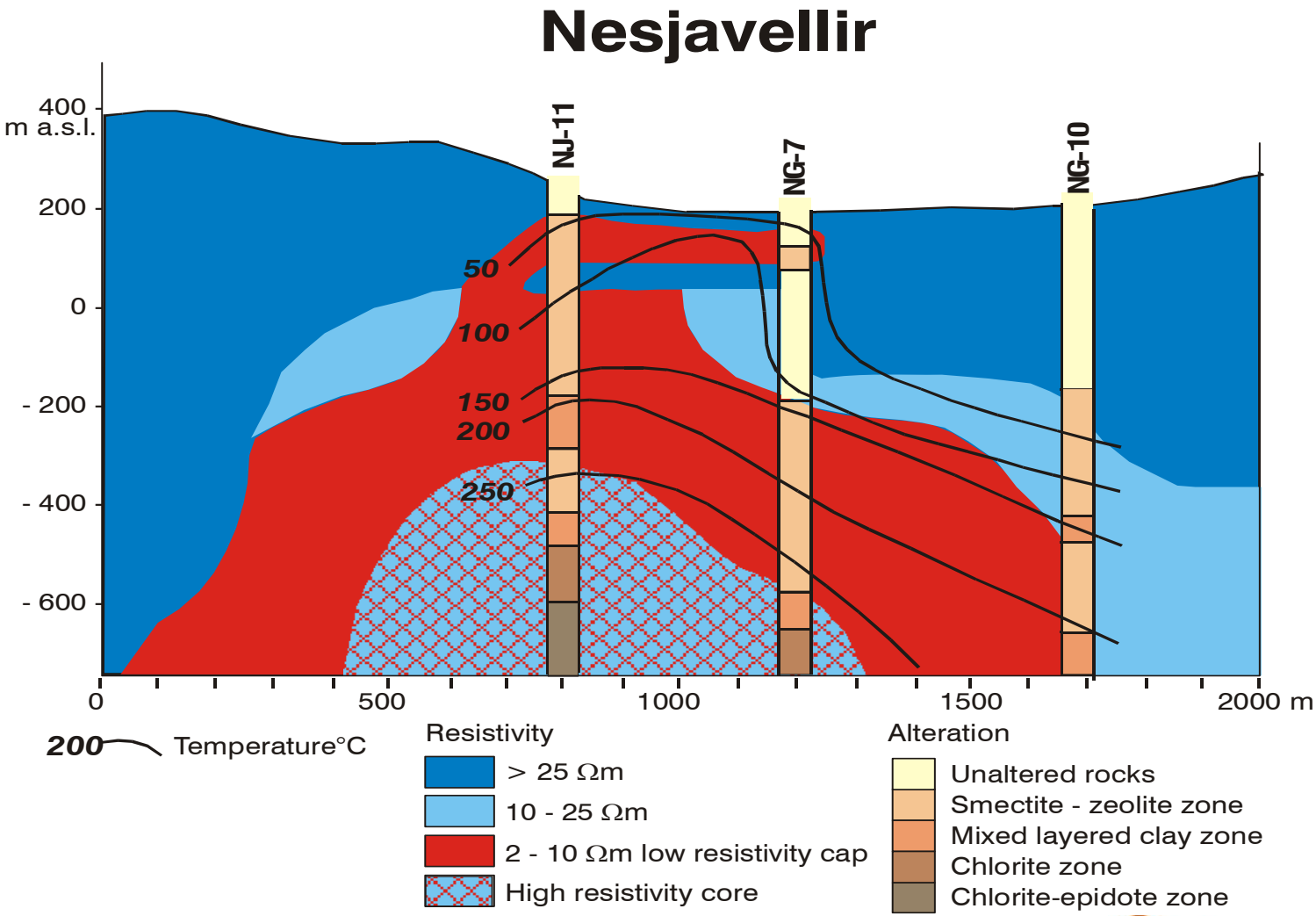
Main properties of rift geothermal systems *(source : ISOR, Iceland)*

- Fracture systems in low permeability volcanic rock
- Boreholes must cut through fractures
- Meteoric water, lowering salinity
- Convective systems

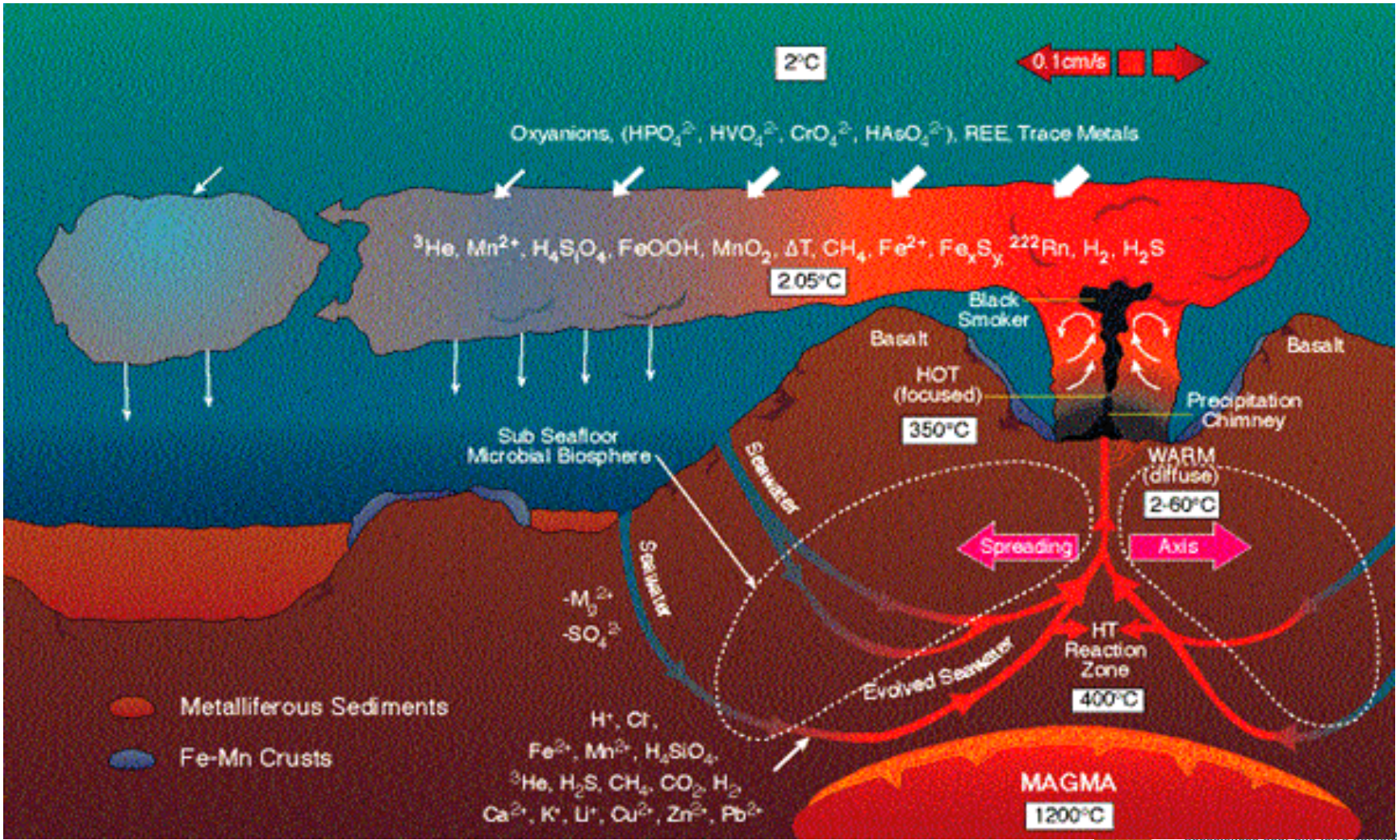


Hydrothermal mineralization controls permeability

source ISOR, Iceland



Geothermal sites on oceanic ridges also produce metals



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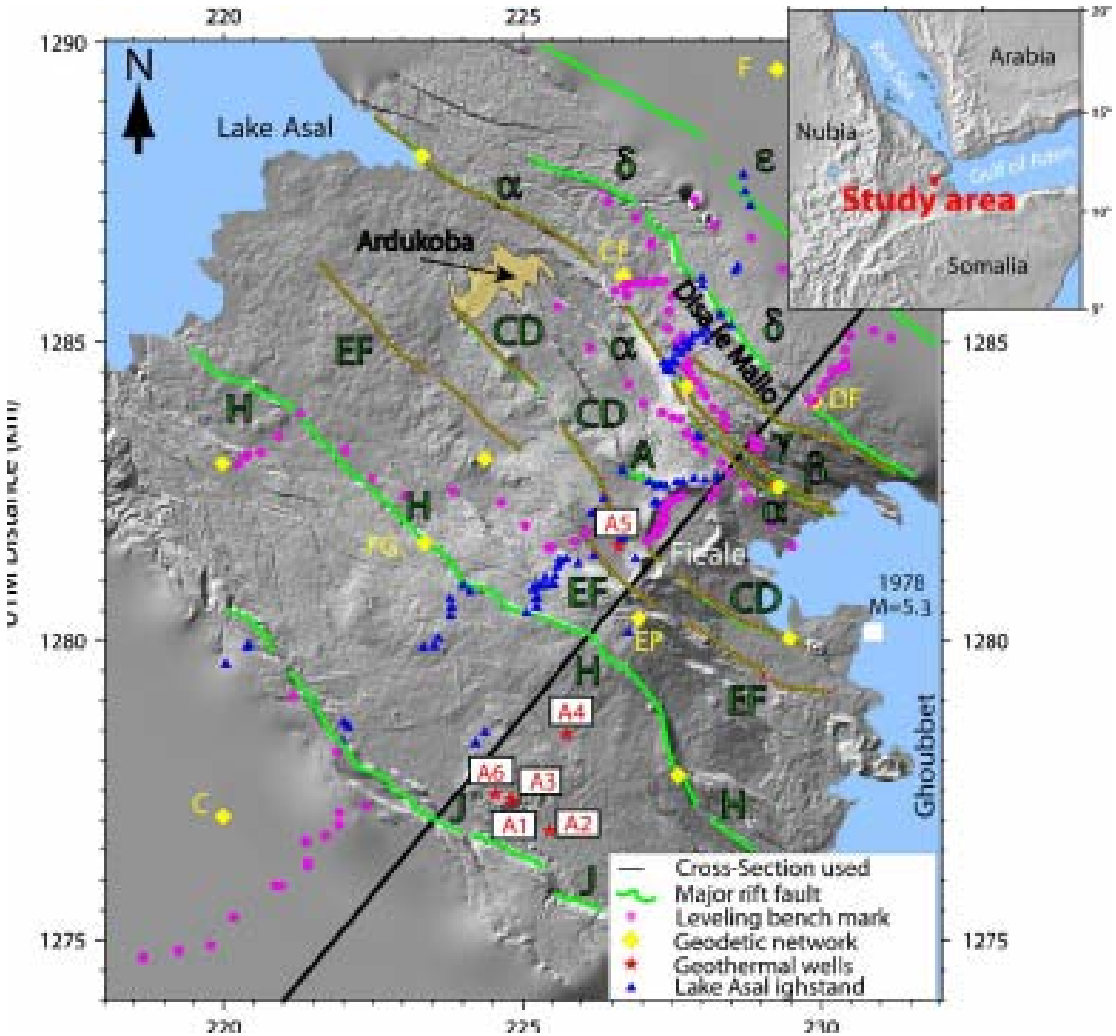
Asal rift, first emerged segment of Aden MOR



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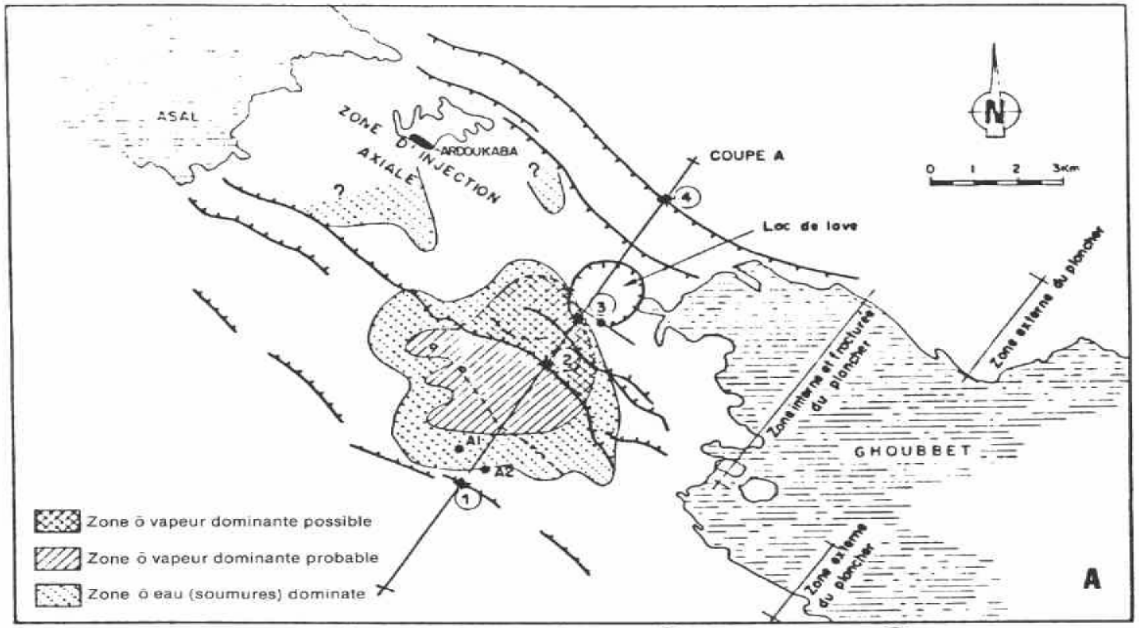
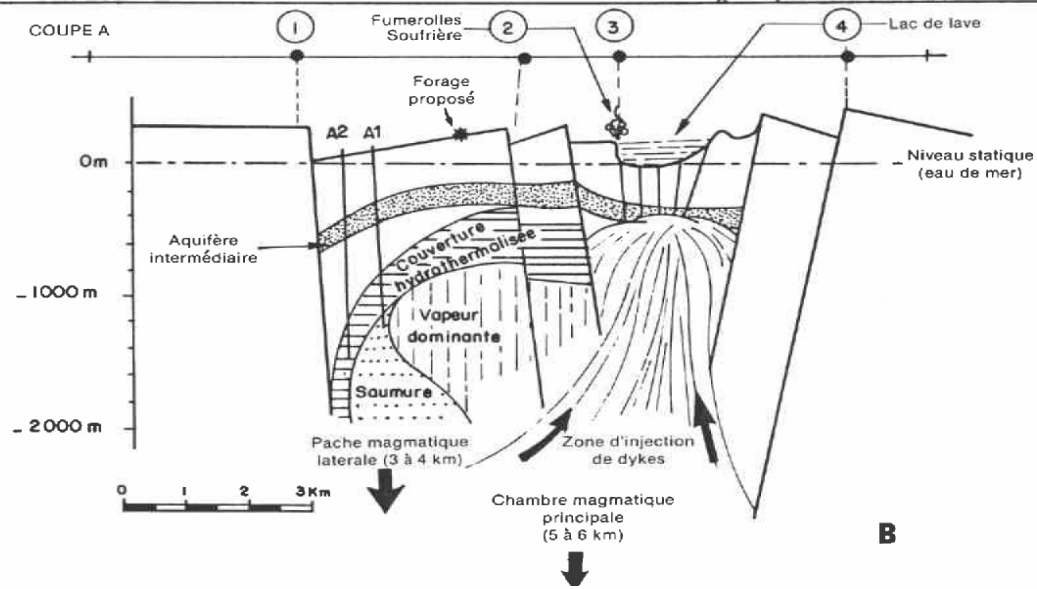
Exploration at Asal :

also look at N Goubet





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Afar suffers from a few constrains, quite different from Iceland

- **the scarcity of meteoritic water, and hence of re-filling natural geothermal systems;**
- **the composition of fluids, more salty and hence corrosive and depositing minerals;**
- **the cultural context, with lack of earth science specialists, and generally the present education level of the local population;**
- **an economic context presently less favourable, with a lack of communication, industrial, and financial infrastructures.**

Afar geothermal development : conclusion, propositions

- **Apparent difficulties can be solved with :**
  - appropriate technical measures
  - local cultural changes trough education
  - favourable regional and international decisions.
- **In the future, the world economy will rely upon :**
  - the most favourable renewable energy sources
  - As electricity has to be used near the site of production
  - the world industry will relocate on the best spots.
- **Afar region – just like Iceland – can offer several sites suitable for the development of significant geothermal plants of first world importance.**
- **A subject for a wide and long-lasting Euro - African cooperation including :**
  - Education (general culture, technicians, engineers, researchers)
  - R&D (volcanology, geophysics, geochemistry, metallogeny…)
  - transfer of know-how and technologies
  - and industrial & financial investments.
- **The humanity was born in Afar, and it may well be that is also there that, after having exhausted oil and gas reserves, she will find its future.**
  - Just let's do it !

Afar meetings 1967 – 2007 : future geothermal engineers

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Global tectonics should serve global economy

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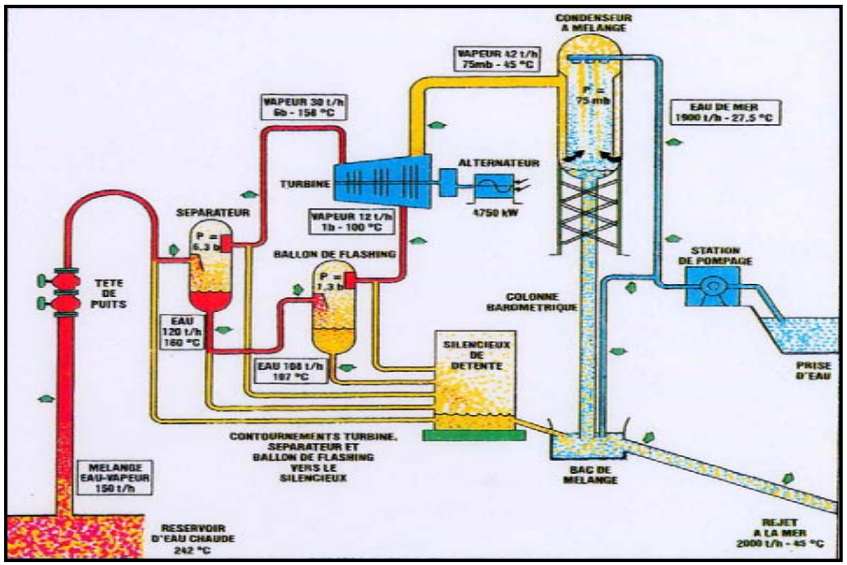
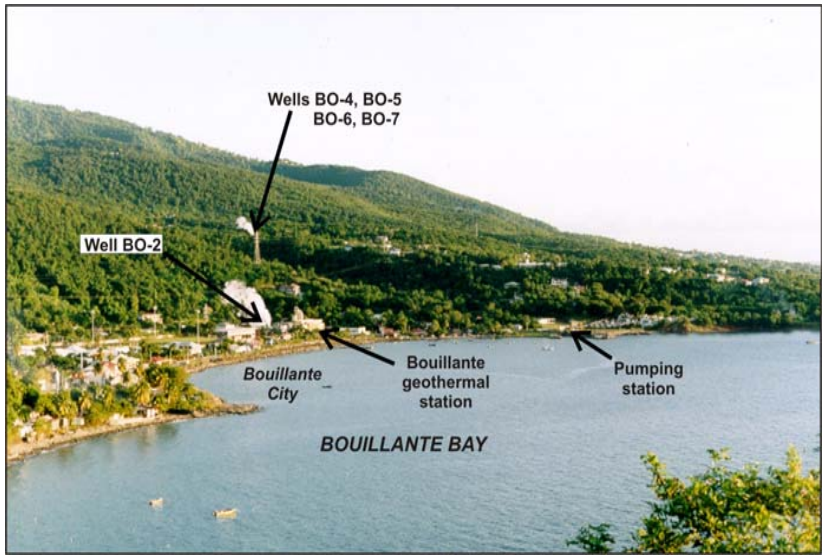
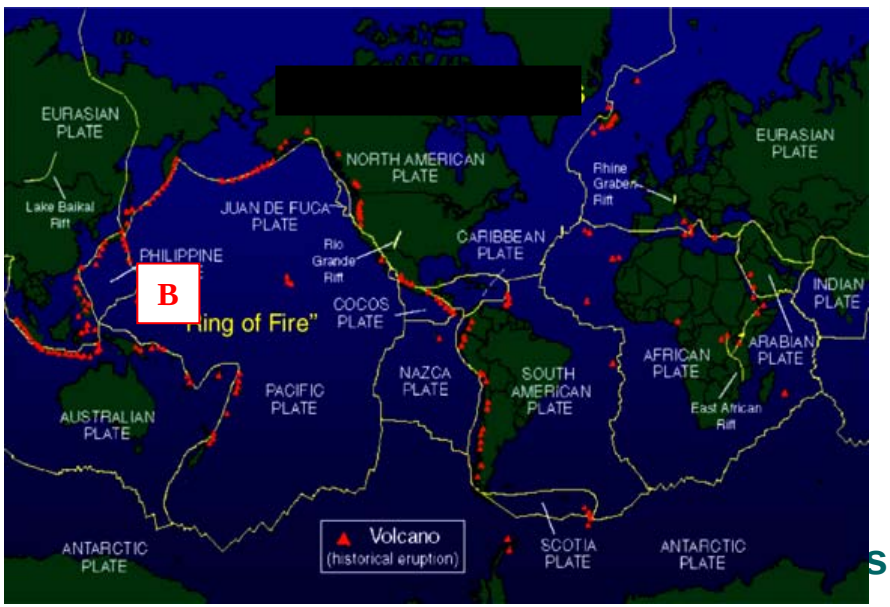
Tank you !
Erta Ale, J.Varet, 1972

A French expérience : Bouillante plant (10 + 5 MW)







Bouillante geothermal plant include two units :

10 + 5 MW

Covers nearly 10% of the electricity needs of Guadeloupe Island (FWI)

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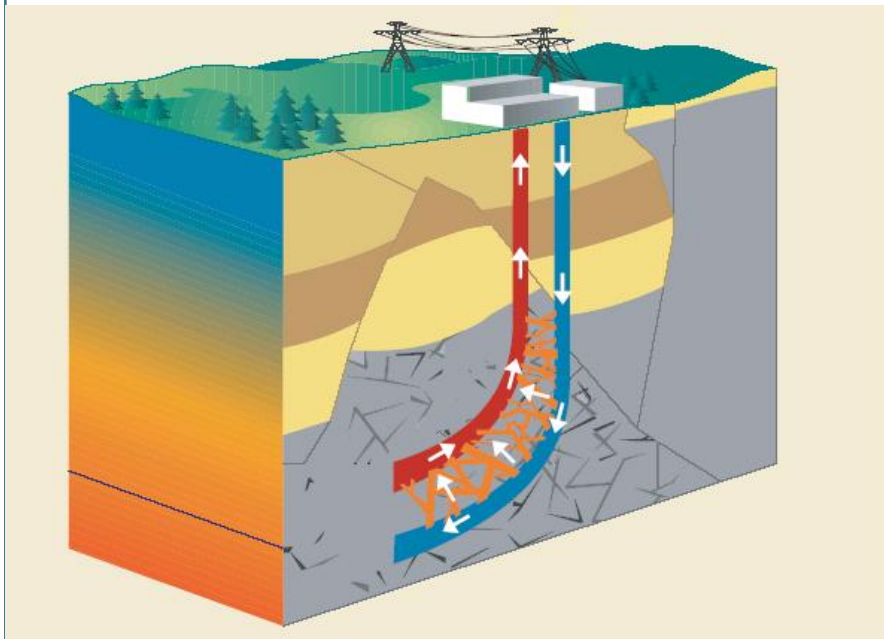
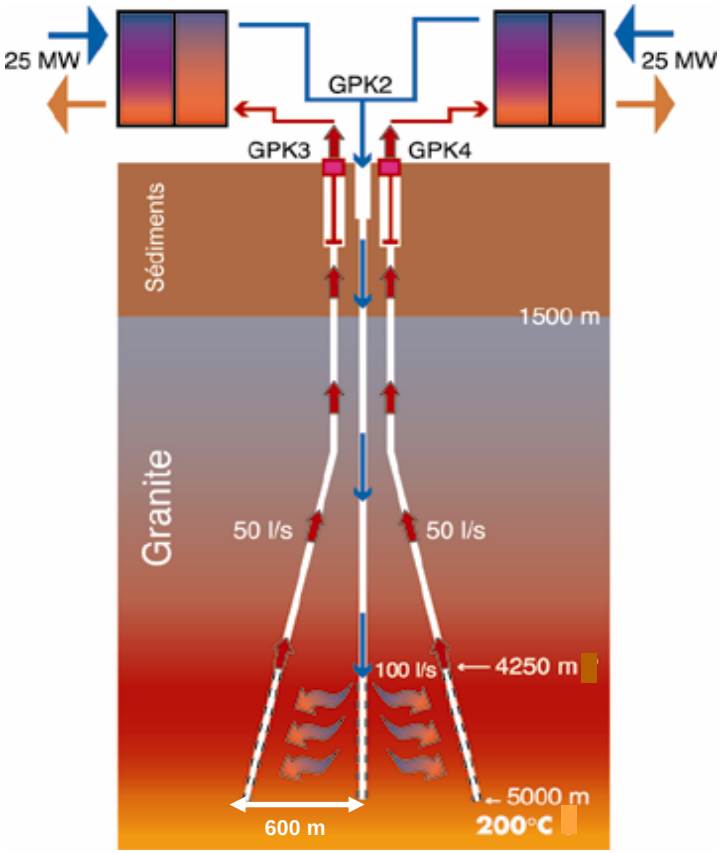
Progessing through EU research :

Soultz-sous-Forêts Project





tests de l'échangeur profond :2005, pilote : 2006

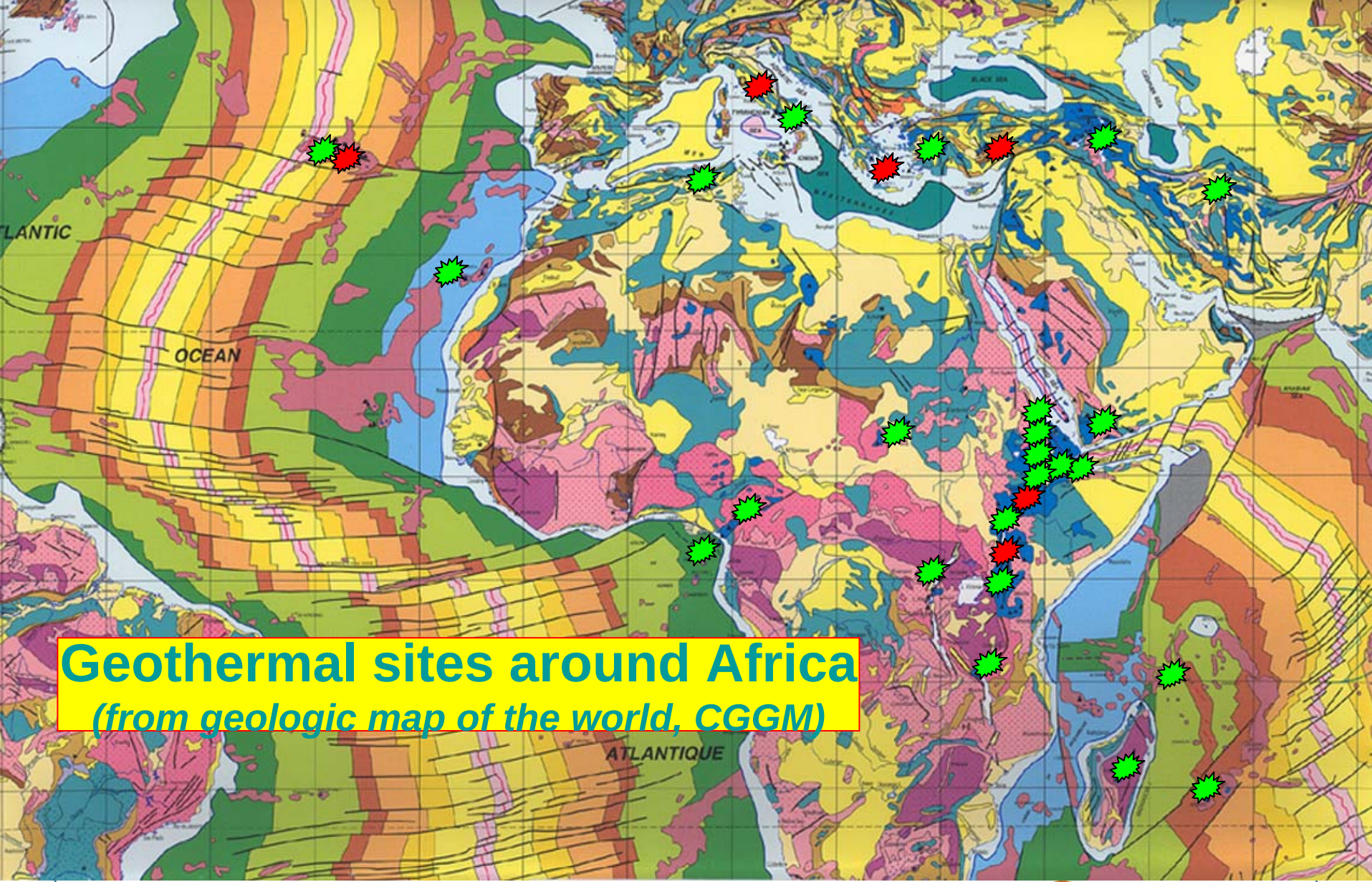
Soultz Projects aims at extracting heat from deep rocks (3000-6000m) by creation of a heat exchanger of large capacity (around 1Km3) by hydraulic stimulation of natural fractures.

The triplet under construction aims at production of 15 MW for 20 years.

The project is also aimed for progressing in stimulation of geothermal fields in general.

BRGM geothermal expertise

- geoscientific assessment of geothermal resources
- pre-feasibility studies
- advice on technical realisation of measurements
- ranking of prospects
- training in geothermal issues („on the job“; courses)
- ecological evaluation (environmental impact assessment)
- economic and socio-economic analyses
- advice on financing options



Geothermal sites around Africa

(from geologic map of the world, CGGM)

Exploited sites

Potentials sites