Magmatic Rifting and Active Volcanism Conference 2012, January 11-13, Addis Ababa.

Dallol Volcano and Danakil Depression, Ethiopia

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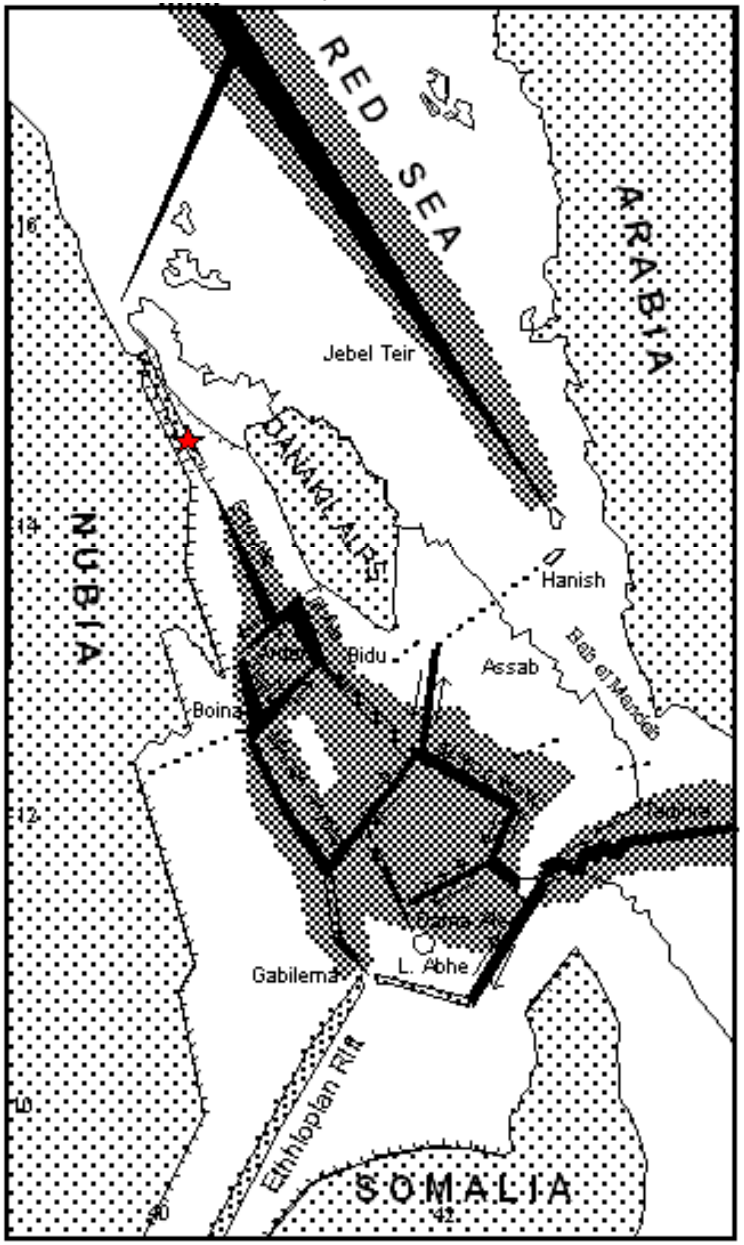
Location and Tectonic Setting

(From Barberi and Varet, 1977)



Continetal Basement

Continental Rift Infill

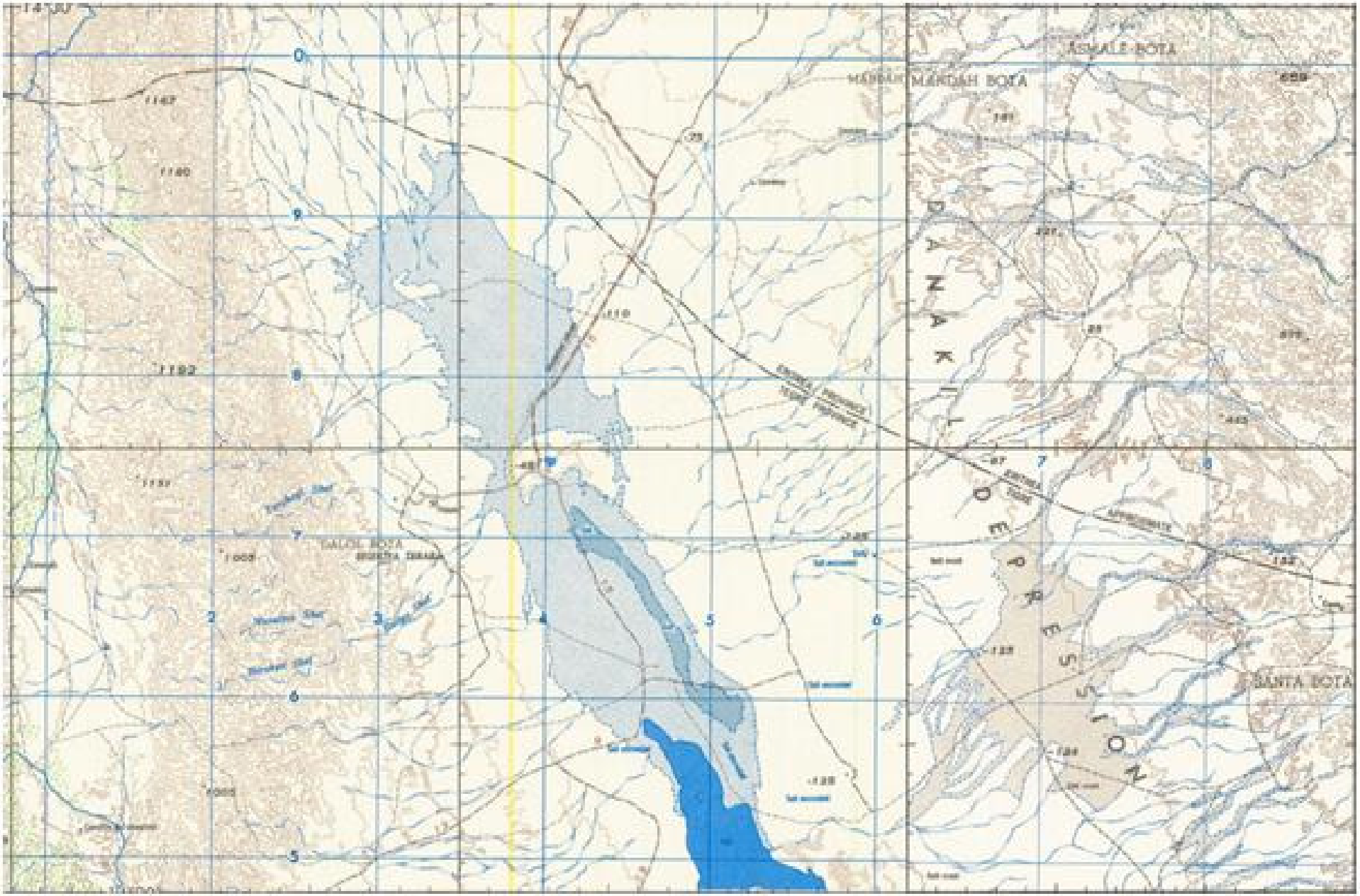
Oceanic Crust formed during last 3-4 Ma

Spreading axis (Axial Ranges)

Transverse Volcanic Ranges

50km

Physiography - An island in an intermittent shallow brine lake.

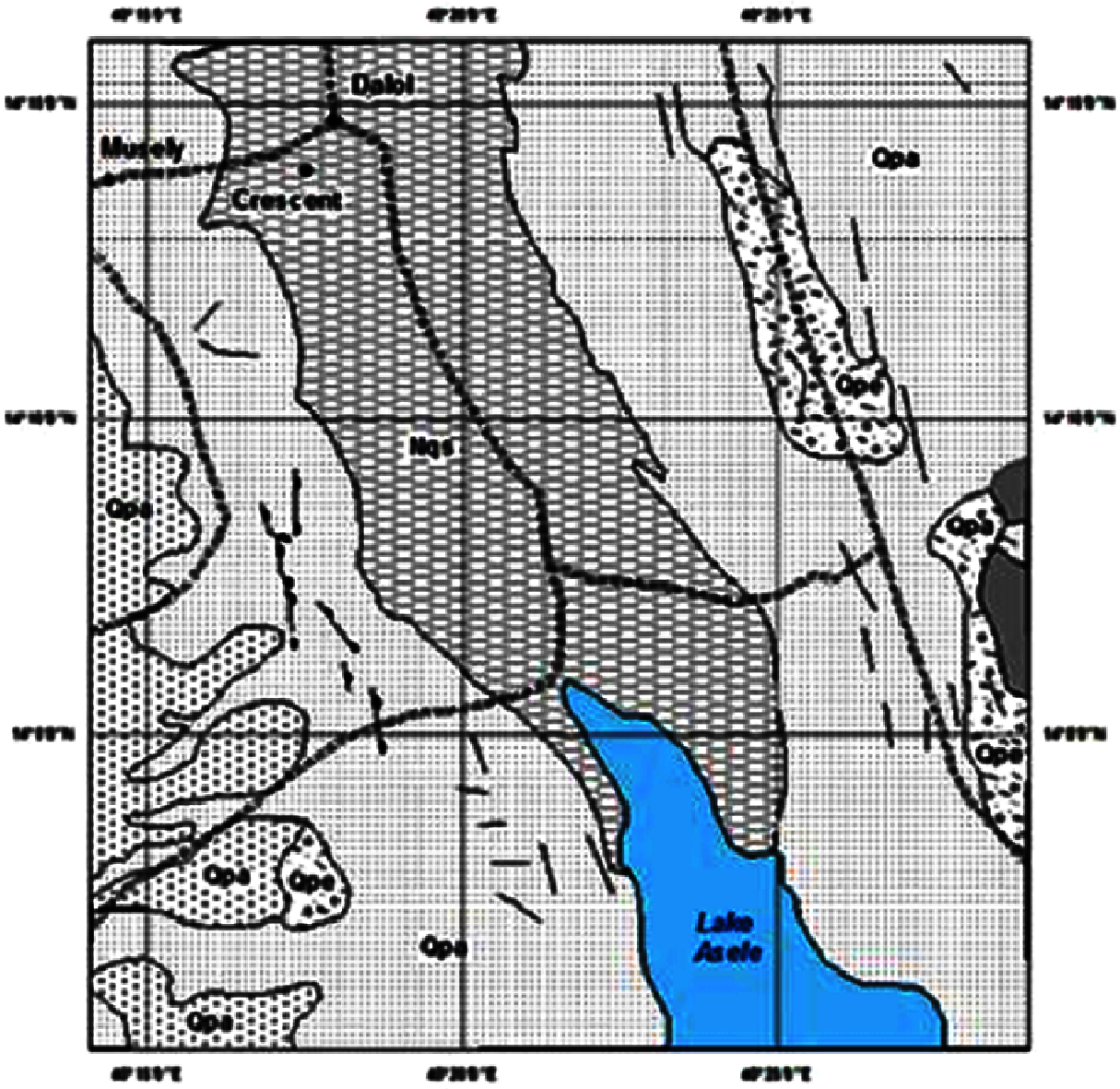


Geology

- Precambrian Basement (crops out near Berhale) and below ca. 5km in DD
- Phanerzoic cover rocks –Paleozoic and Mesozoic Sediments
- Tertiary Development of Danakil Depression
  - ✓ Basaltic flows
  - ✓ Danakil Fm - Red Series (continental) ~ 500m (25-3.4 Ma)
  - ✓ Enkafla Fm -White Series (marine) ~ 35m thick (200-80 Ka)
  - ✓ Evaporite Succession -1000m + (200-25 Ka)
  - ✓ Afdera Fm <15m thick, (8 Ka)

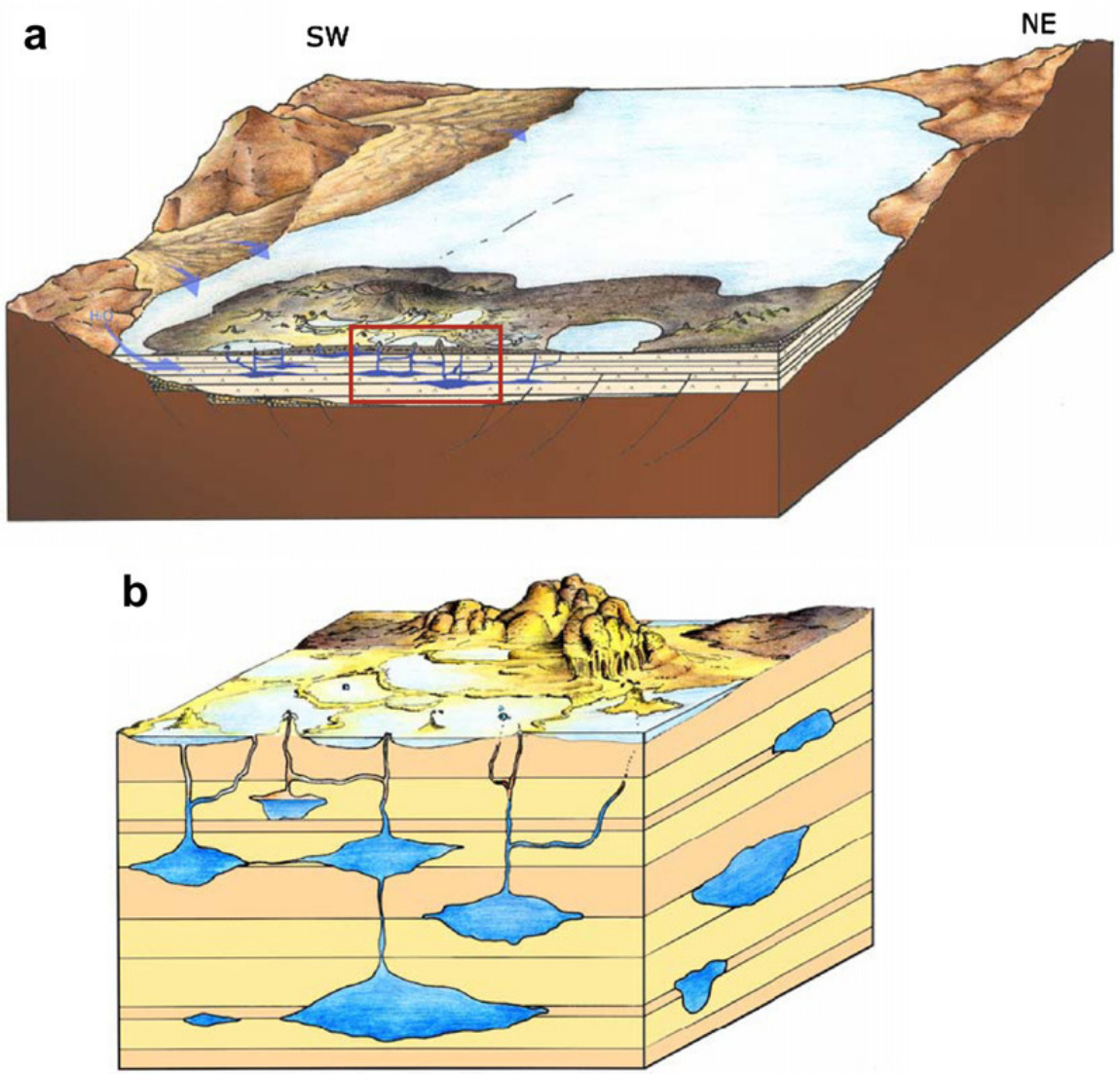
Local Geology –

Recent salt beds, Alluvium, Gravel and Sand stone, Enkafla Fm, Basalt



Hypothetical 3D block Diagram of Dallol (Carniel et al. , 2010)

Detail on the sub-basement below the evaporite succession is not given



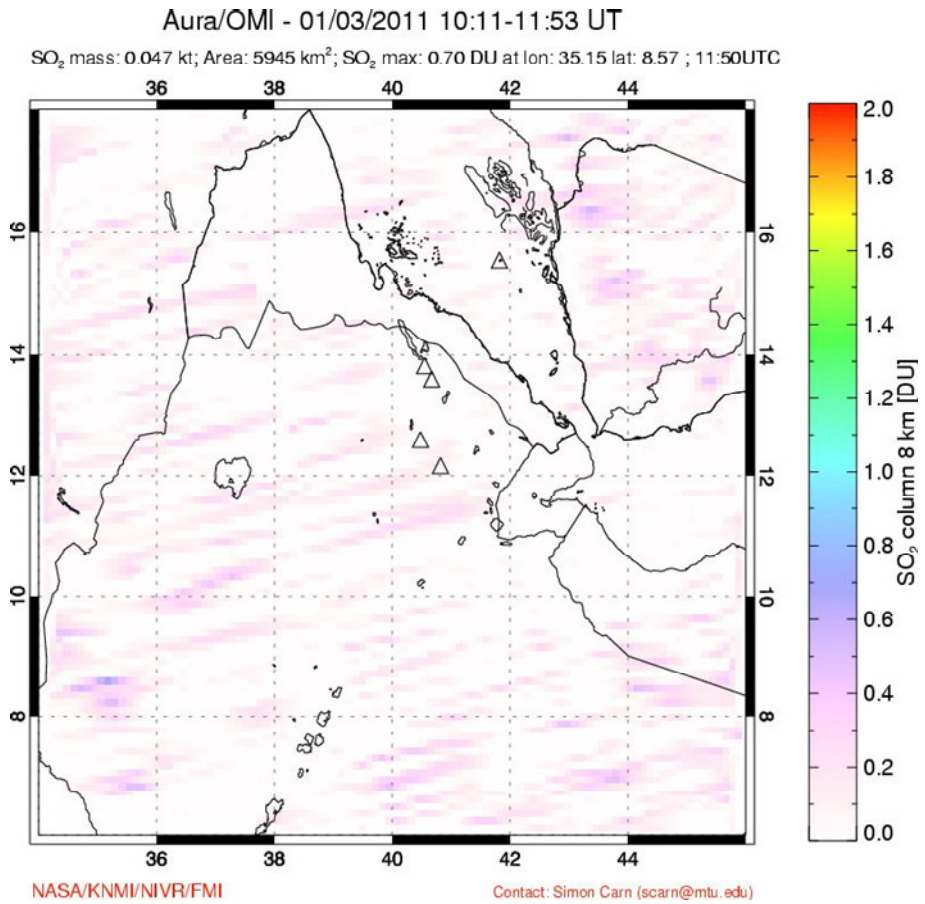
Economic Activities around Dallol

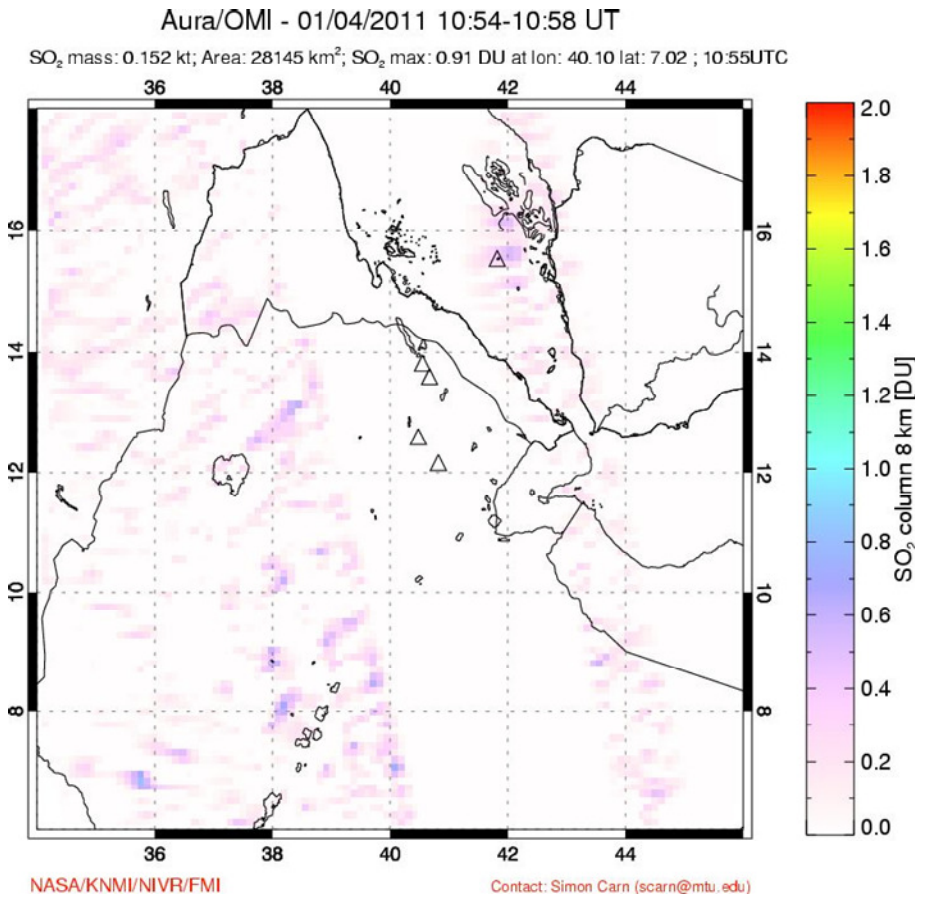
- Artisanal Mining for Rock salt
- Modern mining
  - ✓Started around 1911 for Potash and Sulphur .
  - ✓Notable works include Parsons Comp. (1954-1968)
  - ✓Exploration and re-evaluation of resources is being conducted by a number of companies with production due to begin in the near future.
- Seasonal eco-tourism

Unusual Smoke from Dallol Crater January 2011

- Smoking from Dallol Crater was reported by residents of Ahmedela in the first week of January, 2011.
- January is among the coolest months at Dallol and smoke becomes more visible than other times in the year.
- All indications are that smoking was a result of volcanic degassing (CO2) than fusion / burning of sulphur within the crater. (Crystalline Sulphur has a melting point of 115˚C)
  - Atmospheric SO2 data
  - IR hot spot data

Atmospheric SO2 plume sensor image for January 3 and 4, 2011. (from: http: //SO2.umbc.edu/omi/ (2011).

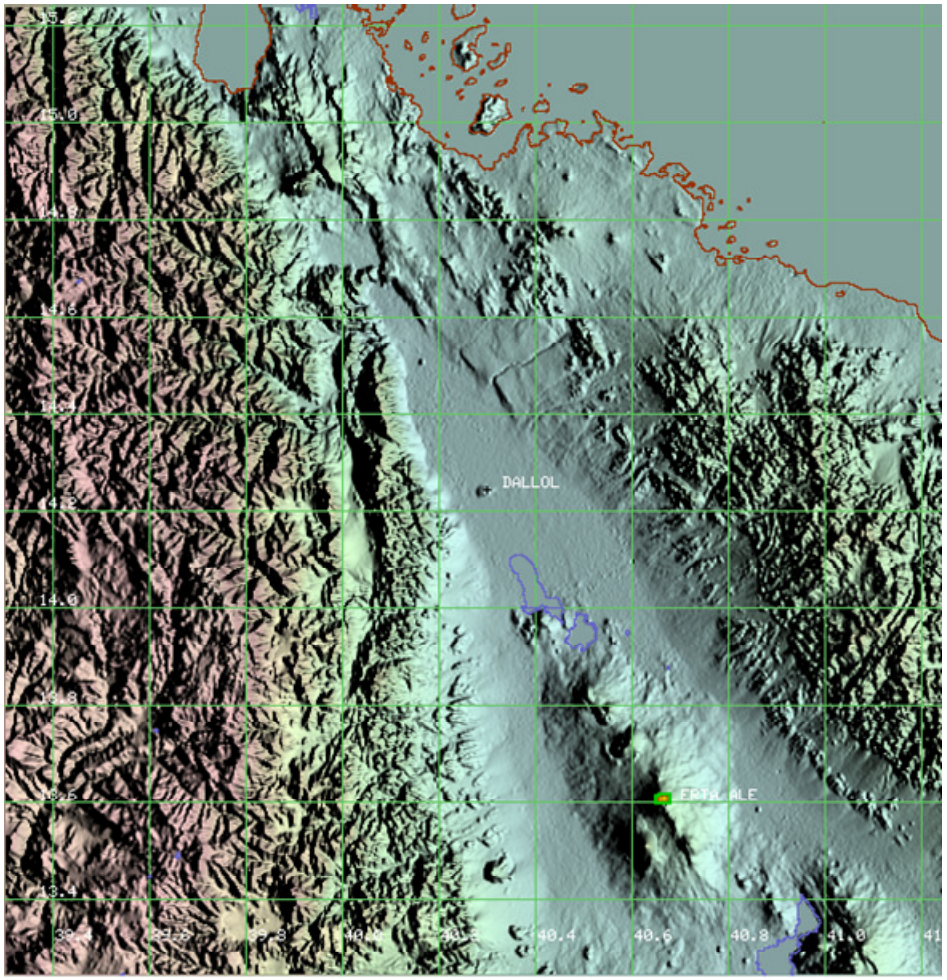




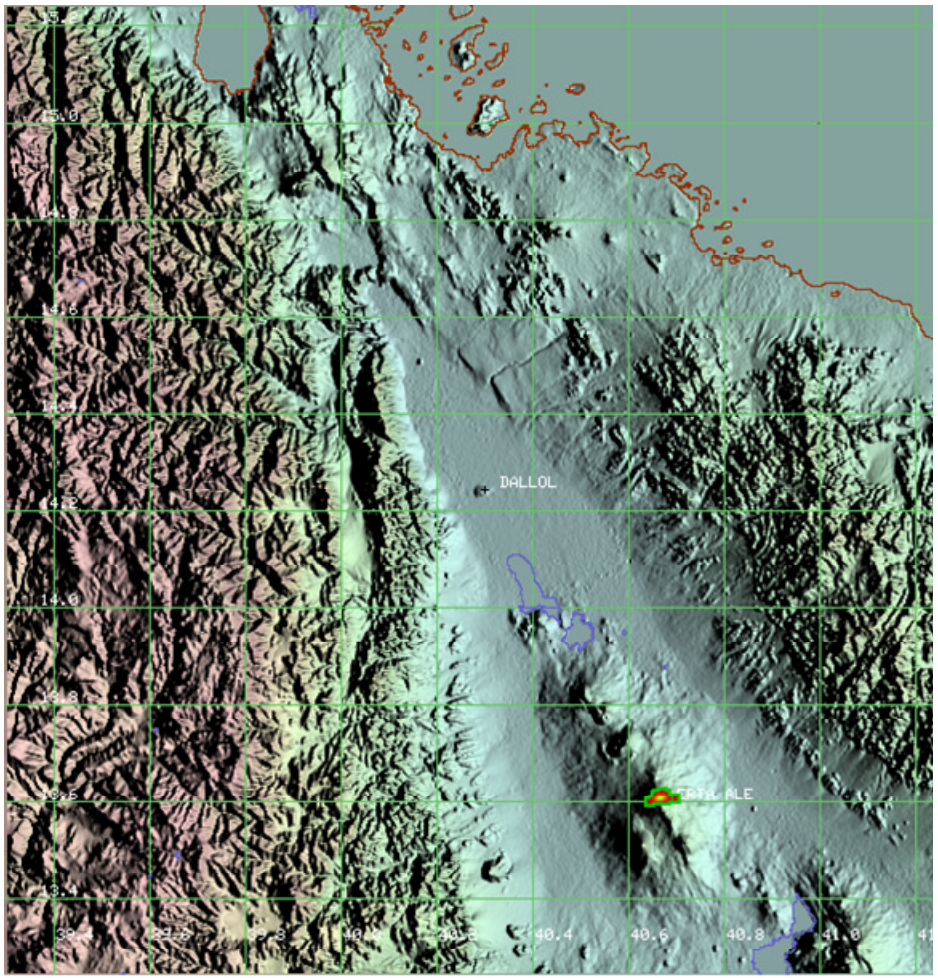
Satellite based hot spot image for Dallol

Note hot spots on Erta Ale lava lake on the images.

(from http: //modis.higp.hawaii.edu)



Week 1 – January, 2011



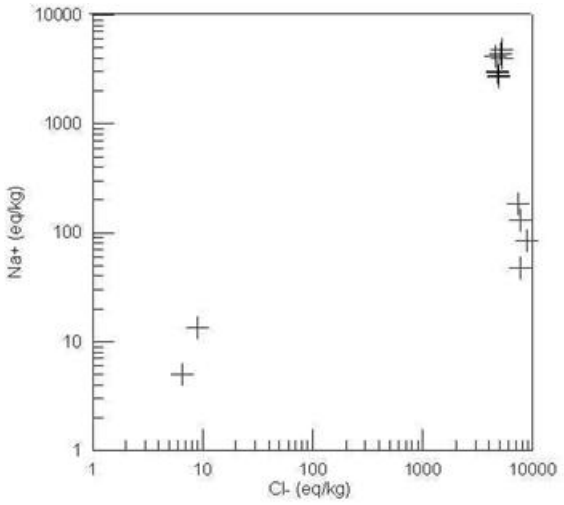
Monthly average December, 2010

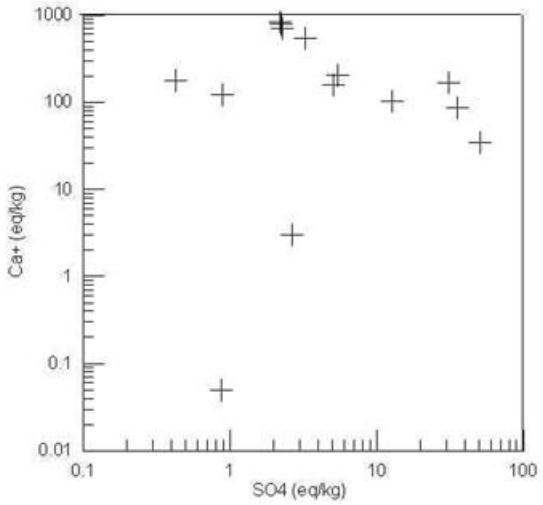
Geochemistry of Dallol thermal brine

- A thermal brine reservoir is formed from evaporated sea-water and later interactions within an evaporite aquifer.
- Hot spring and geysers discharge acid brine TDS > 300g/l
- Some of the thermal brine discharges have boiling point temperatures. ($\geq$ 100°C)
- Li and K are more concentrated than Na as compared to their relative concentrations in sea water.

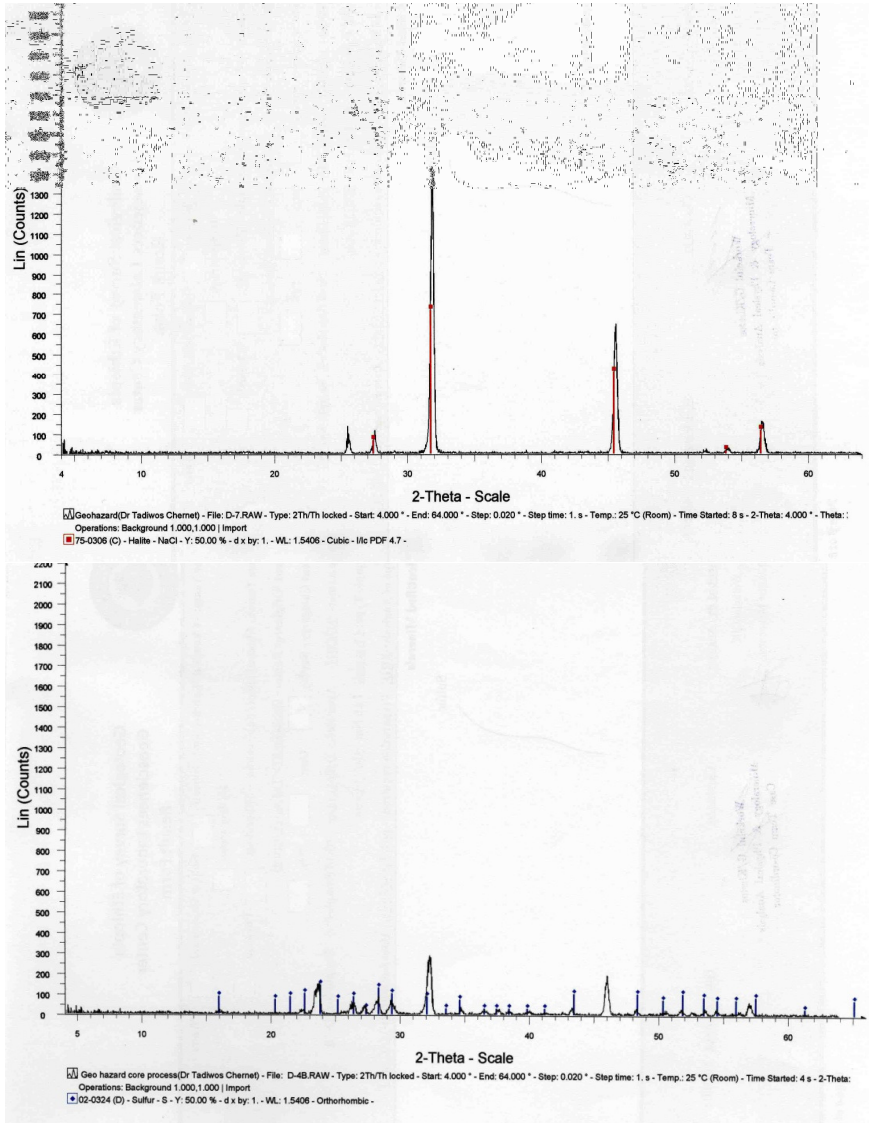
Geochemistry of Dallol thermal brine

Processes - Evaporation, Boiling & Geochemical rxns. in an evaporite reservoir





(Data from UNDP, 1973)



Geochemistry of Dallol thermal brine

- Chemical Reactions affecting pH

  Hot water in contact with native sulfur forms sulfates.

  $S + H_2O \leftrightarrow 3H_2S + H_2SO_4$

  Near surface Oxidation H_2S

  $H_2S + 2O_2 \leftrightarrow 2H^{2+} + SO_4^{2-}$

- Equilibrium Thermodynamics – $\log_{10} K = -\frac{\Delta H}{2.3\,RT} + c$

  Temperature dependence of pH – for pure water at 300°C, pH = 5.5 and 4.9 for 1m salt solution ; compare to 7 at 25°C

  Temperature dependence of Solubility product (K) of Halides, carbonates and sulfates

Geochemistry of Dallol thermal brine

- Collegative properties of solutes result Boiling point elevation / vapour pressure reduction - $\Delta T_b = K_b m$

  ΔT_b - increase in boiling point

  K_b - molal boiling point elevation constant

  m - molility

  K_b for H2O is 0.52 (°C/m) and is twice for an ionic solute e.g. NaCl

- Pressure @ 1000m depth is over 1 Kb - Can the critical PT condition of 221 bars and 374°C for pure water be achieved without heat from a magmatic system?

- Can a hyper-saline solution boil without contribution from volcanic degassing?

Geothermal System

- In volcanic gases $H_2O > CO_2 > SO_2 > H_2 > CO > H_2S > HCl$
- Dallol is a volcanic geothermal system *vis a vis* volcanic hydrothermal or non-volcanic hydrothermal geothermal systems.
- The thermal manifestations are of a perched / stagnant hyper-saline system *vis a vis* advective hydrothermal system (Hochstein , 2005)
- Geothermal reservoirs of economic significance can only be found below the stagnant system and the evaporite succession (Varet, 2010).

Geo-hazards

- Phreatic and Phreato-magmatic eruptions.
- EQ – evident as fissures on salt beds
- Flooding – Dallol volcano is an island in an intermittent lake
- Formation of sinkholes / caving

Conclusions

- The scarcity of fresh water has made the area unsuitable for permanent settlement and may keep the area as low volcanic risk area but capital investment risks are potentially high in modern mining.
- Flooding control mechanisms are necessary – (e.g. digging trenches around camps.)
- Public awareness (e.g. Hazard sign posts, Proper rest area and tracks for visitors who are always escorted to the volcano).
  - ✓ Conservation of natural conditions
- Long term volcanologic monitoring of a hidden basaltic maar field.

Acknowledgments to
Organizational Sponsors

- Ministry of Mines
- Geological Survey of Ethiopia
- IGSSA (Addis Ababa University)
- Department of Earth Sciences of (Mekelle University)

Thank you