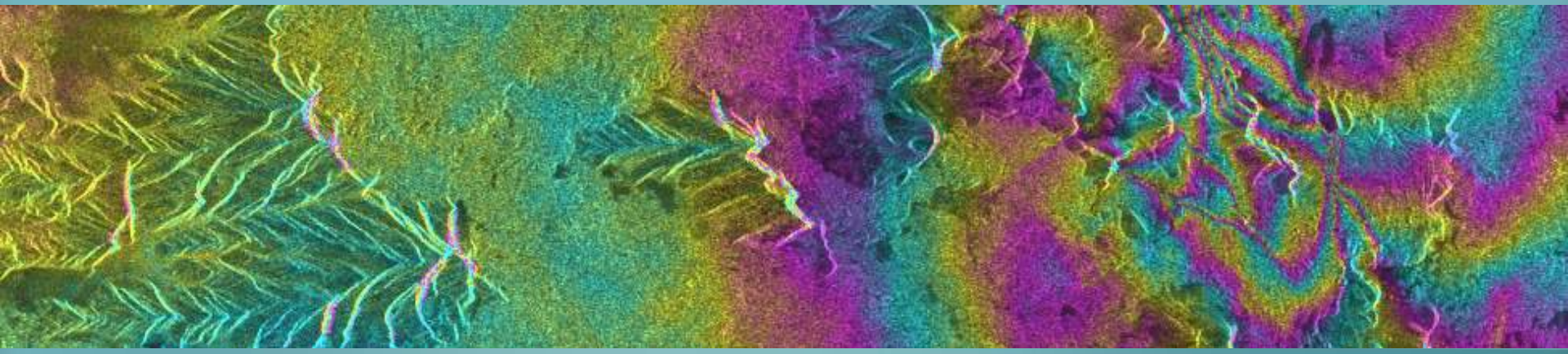
University of Strasbourg, 19 October, 2015

King Abdullah University of Science and Technology

KAUST

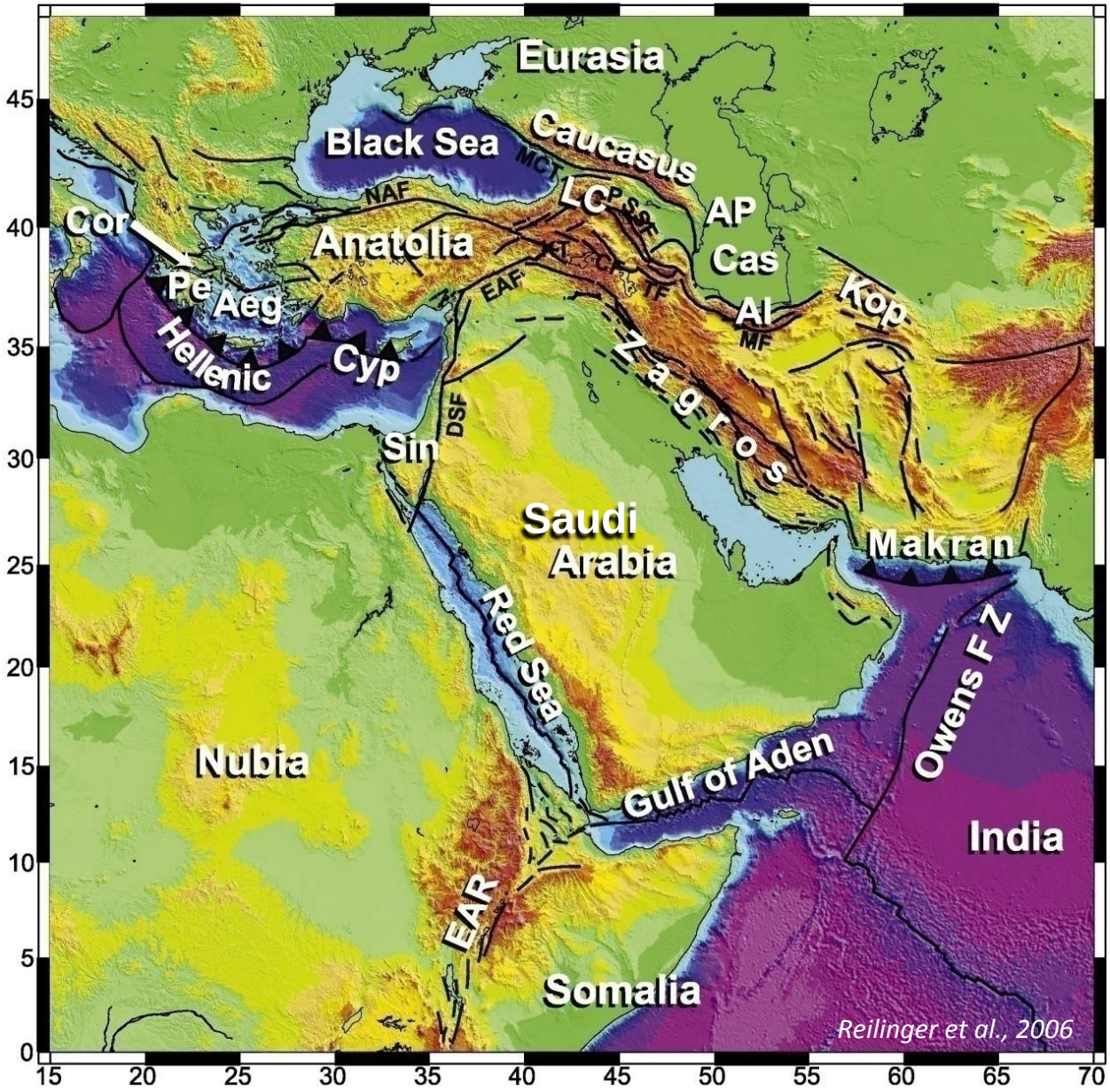
Extensional Tectonics and Volcanism in the Red Sea Region observed by InSAR



Sigurjón Jónsson, Wenbin Xu, Joël Ruch, and Rishabh Dutta

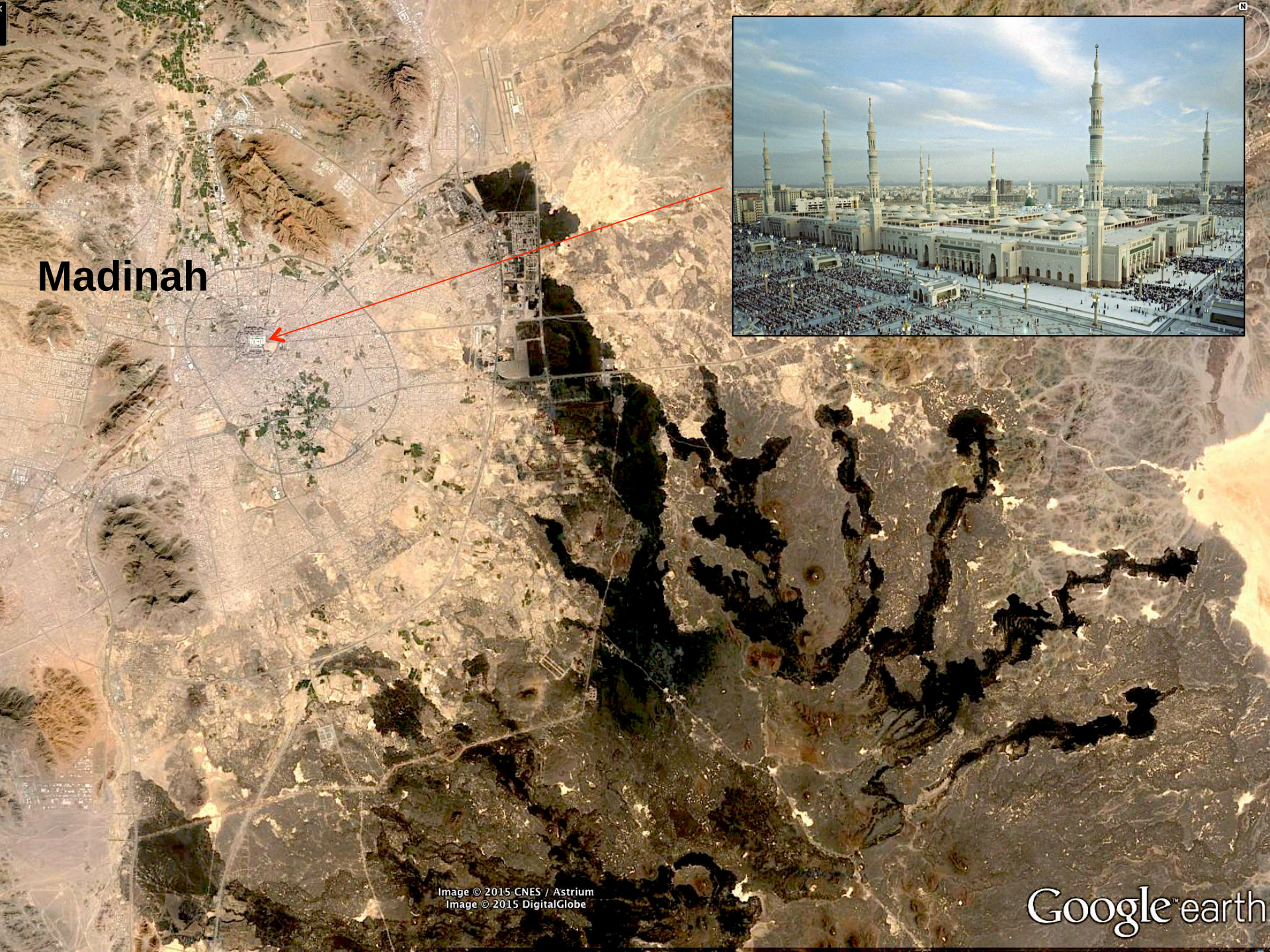
King Abdullah University of Science and Technology (KAUST), Saudi Arabia

Saudi Arabia

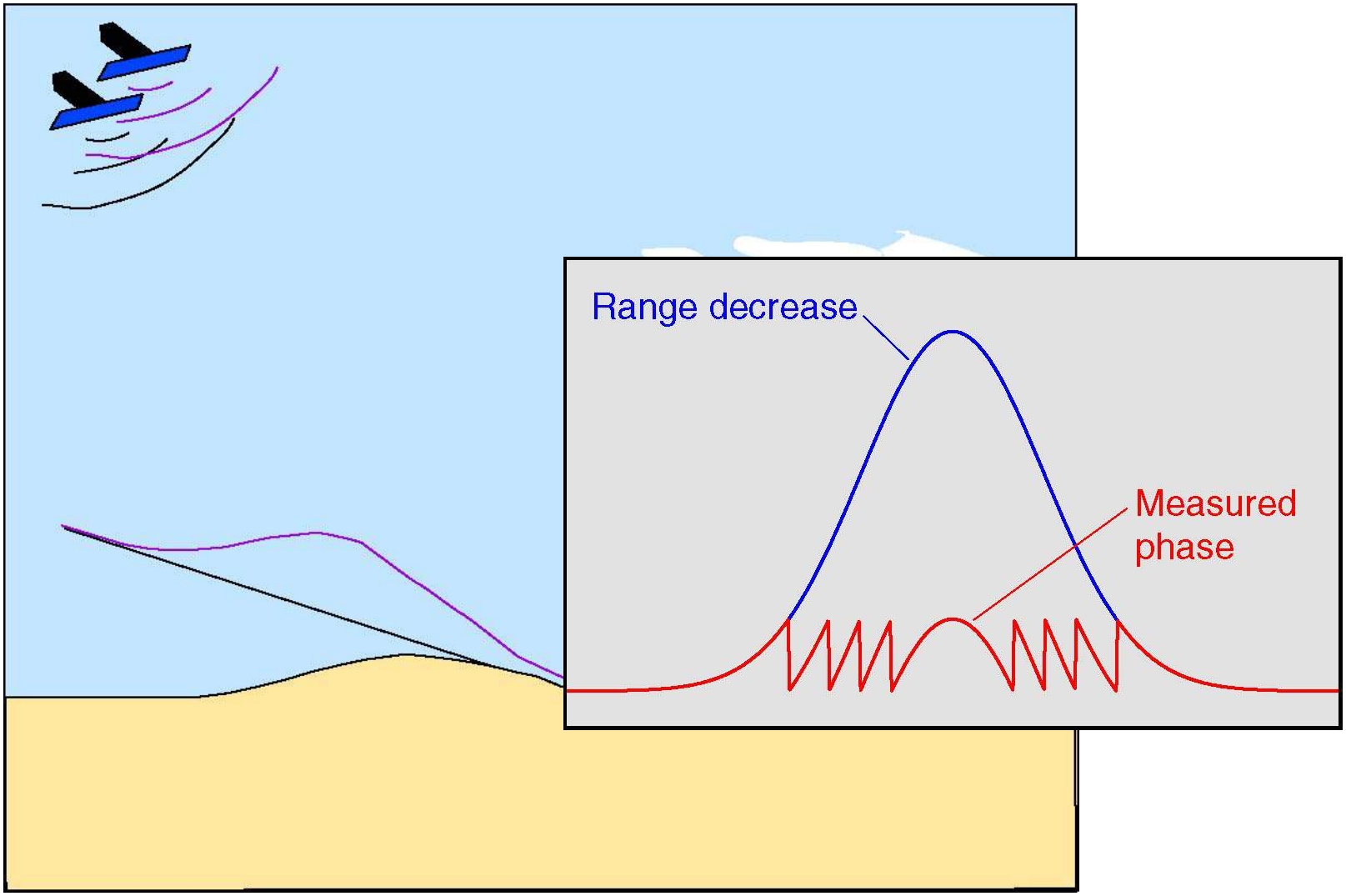


Yes, Saudi Arabia has volcanoes!

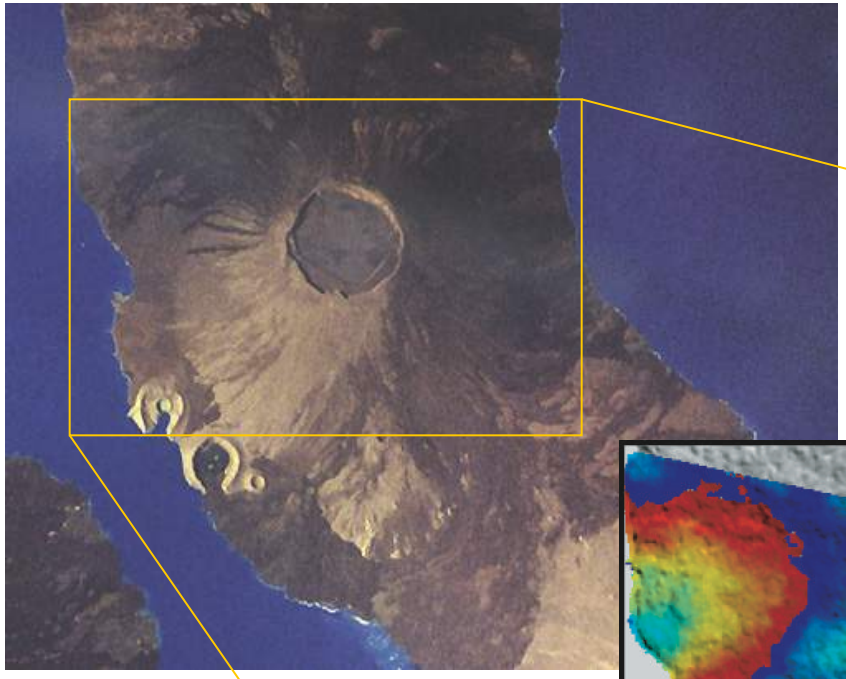
NASA image


Madinah
Image © 2015 CNES / Astrium
Image © 2015 DigitalGlobe
Google earth

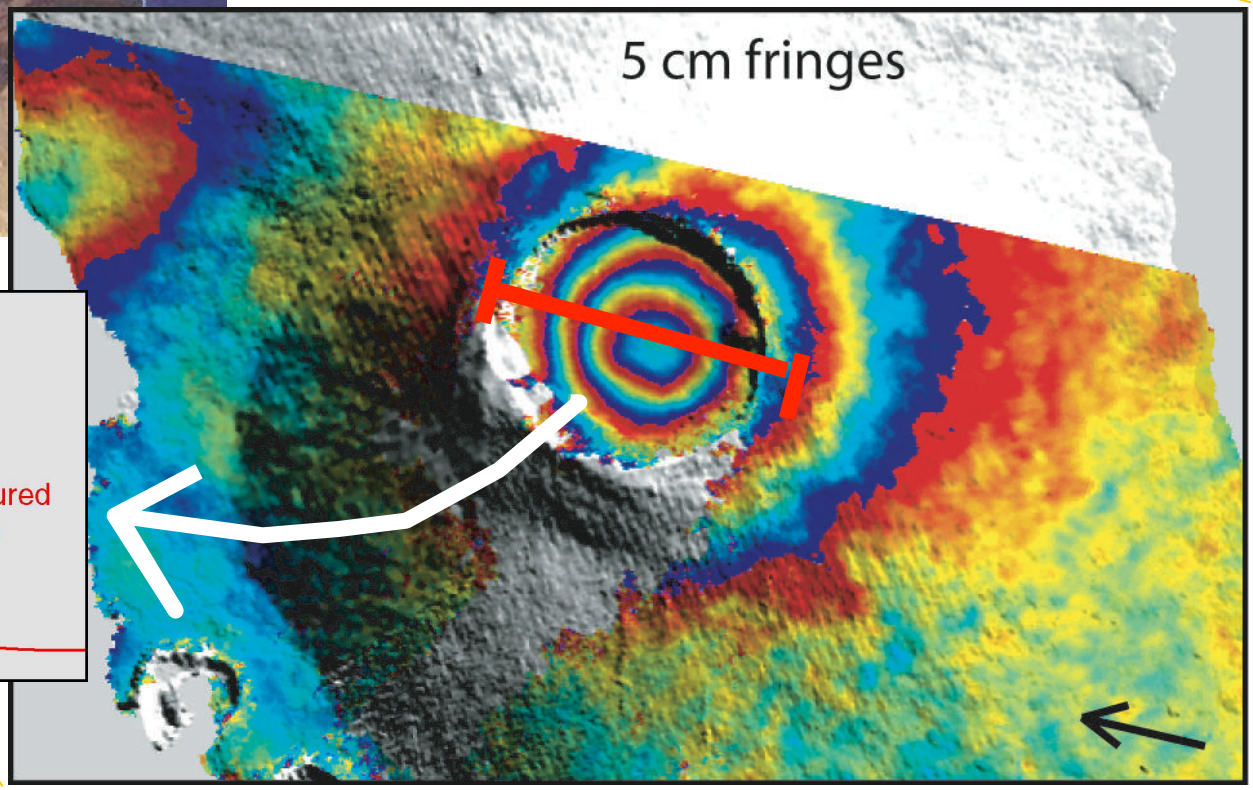
InSAR Phase Difference due to Deformation

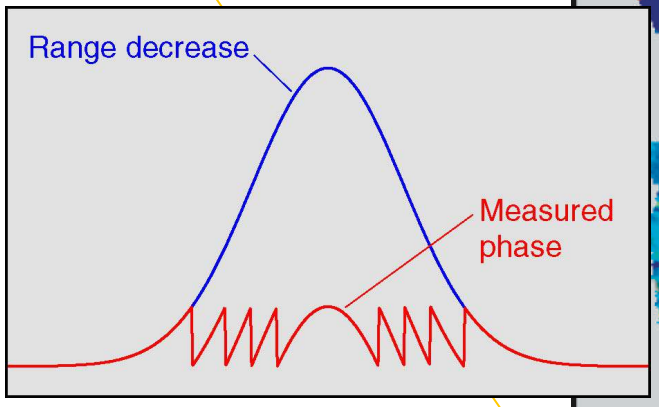


InSAR Phase Difference due to Deformation



Example: Uplift of Darwin Volcano, Galapagos

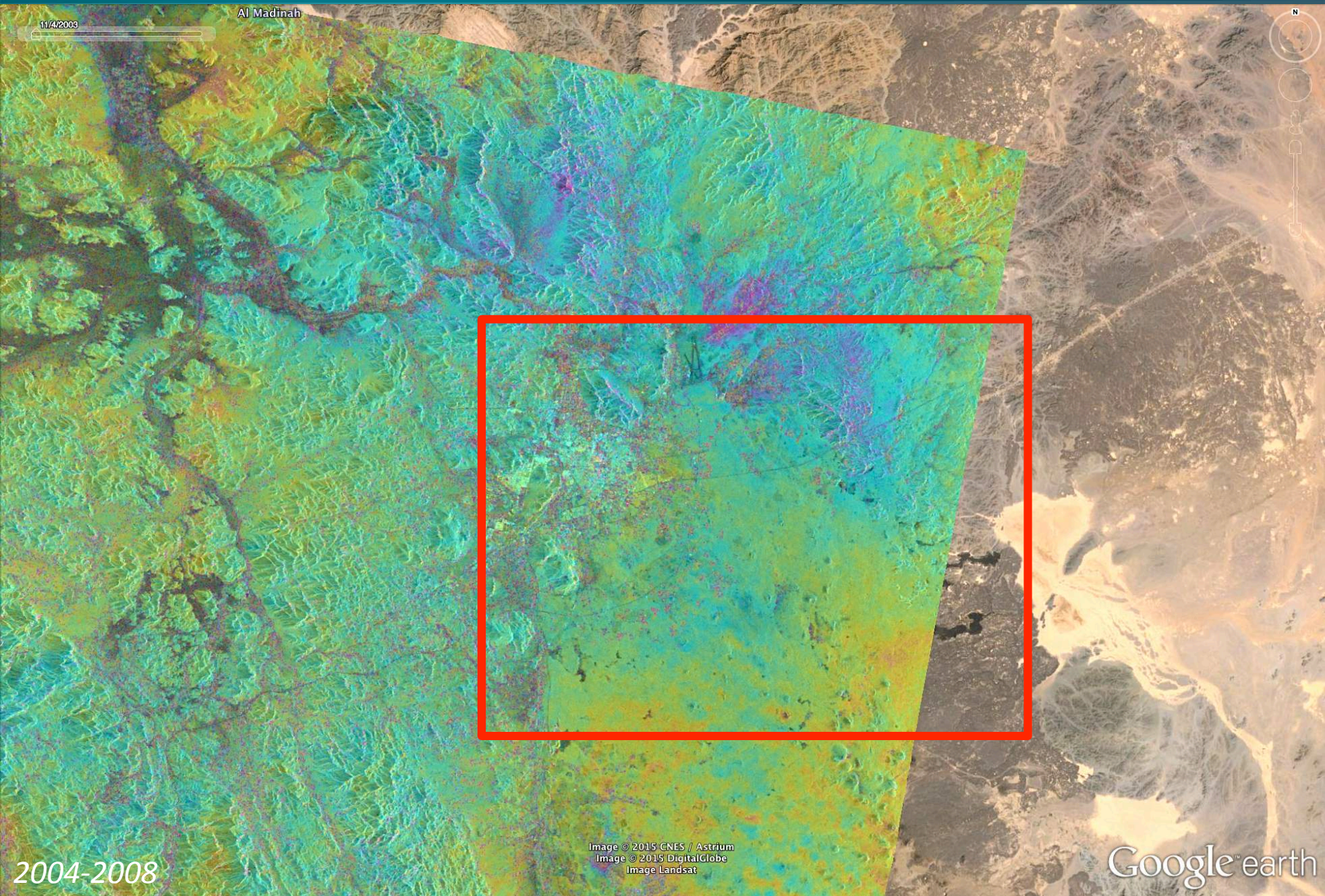




Madinah

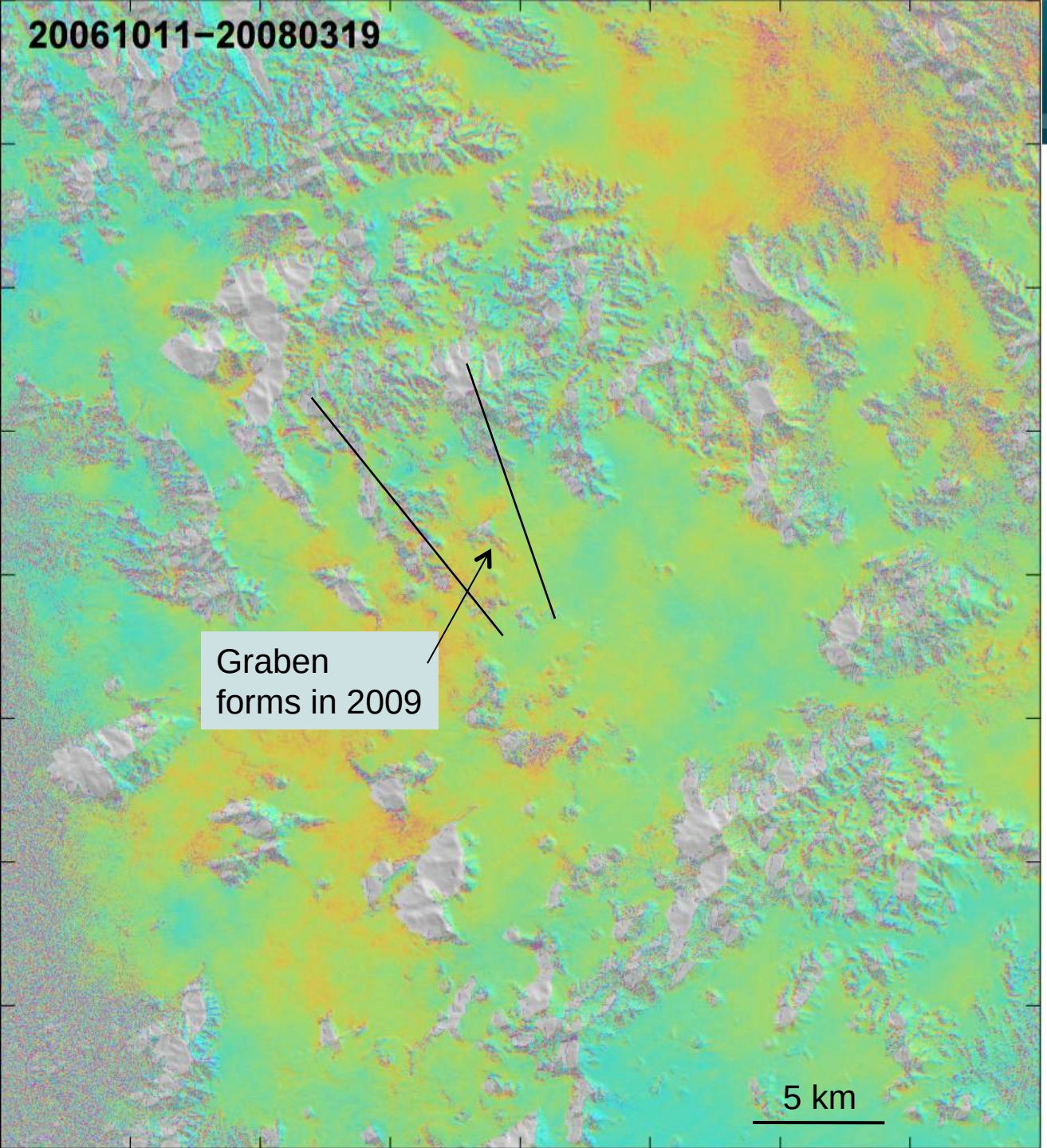

Al Madinah
11/4/2003
Image © 2015 CNES / Astrium
Image © 2015 DigitalGlobe
Image Landsat
Google earth

No deformation in Madinah!



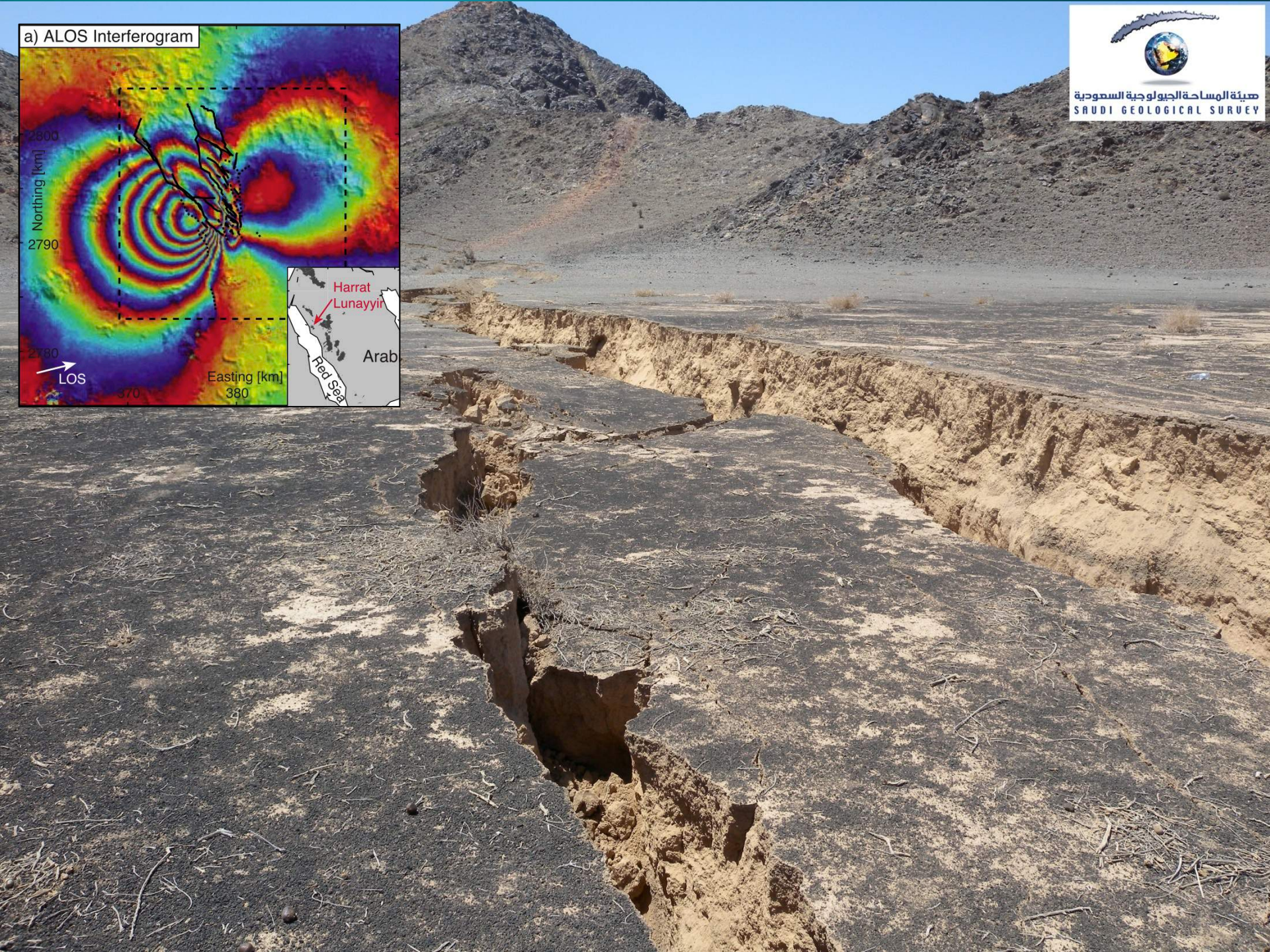
2004-2008

Lessons to learn from Harrat Lunayyir?

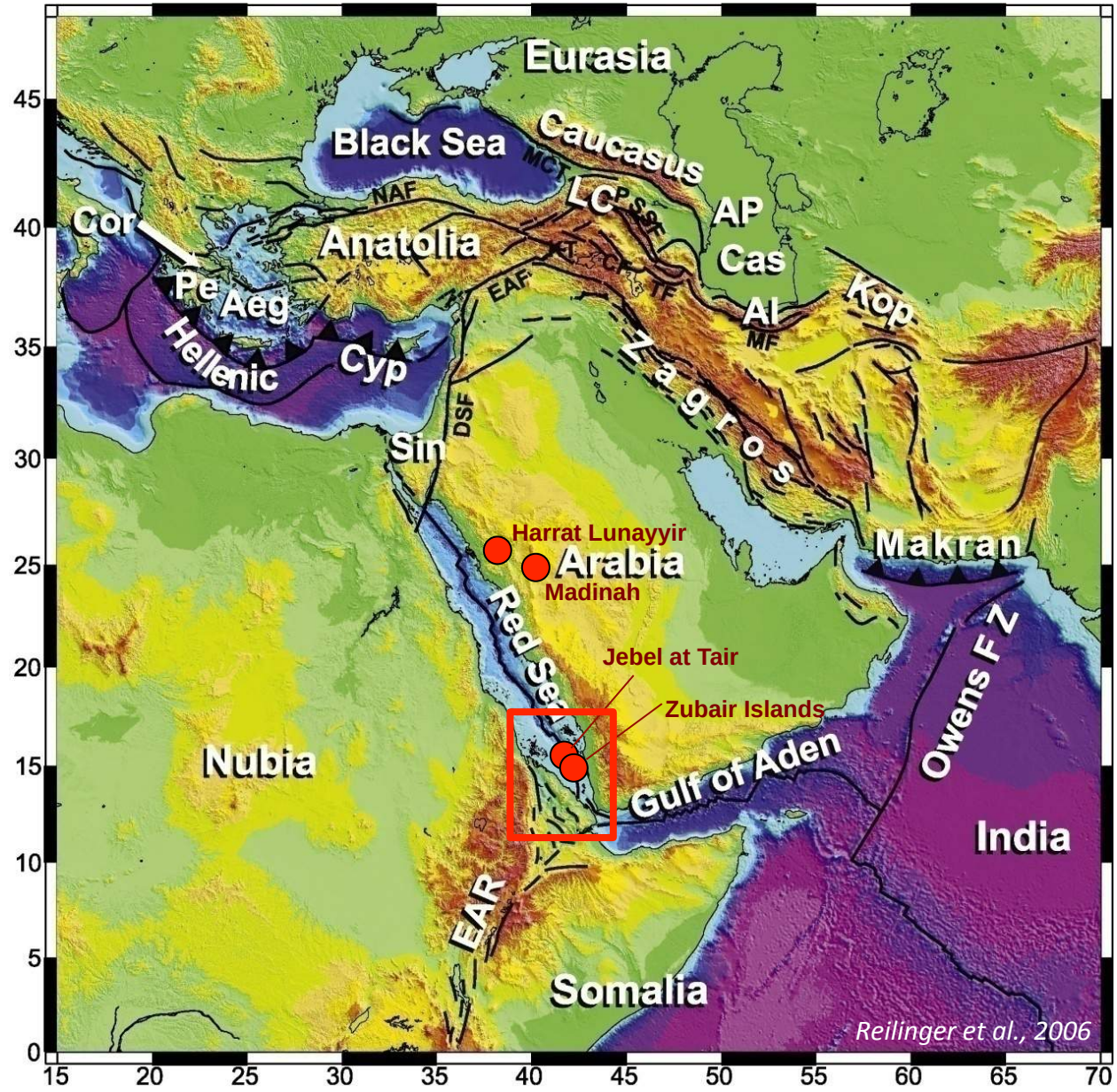


Envisat Data Example
Oct 2006 – Mar 2008

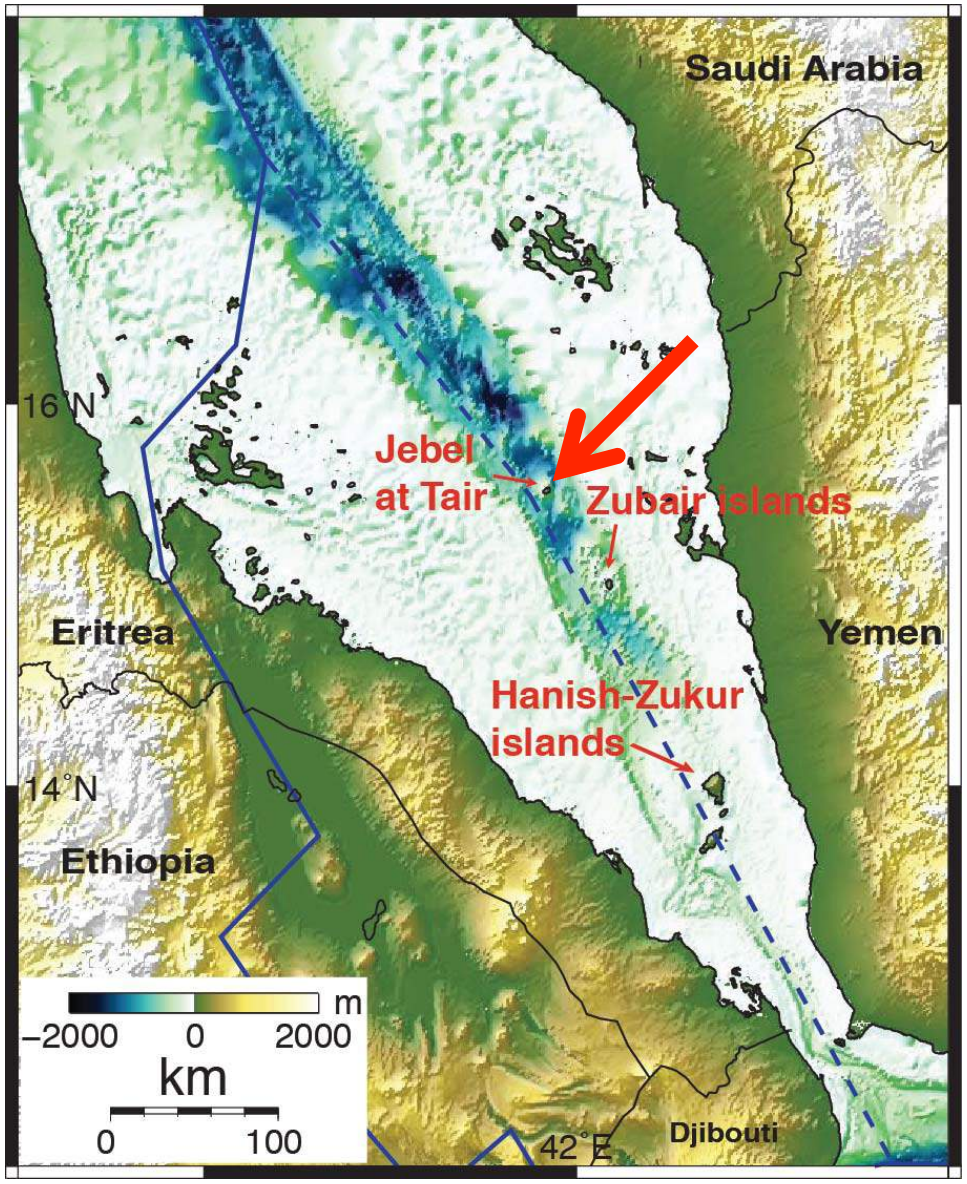
No precursory deformation!!


a) ALOS Interferogram
2800
Northing [km]
2790
2780
LOS
370
Easting [km]
380
Harrat
Lunayyir
Arab
Red Sea
هيئة المساحة الجيولوجية السعودية
SAUDI GEOLOGICAL SURVEY

Volcanic Activity in the southern Red Sea

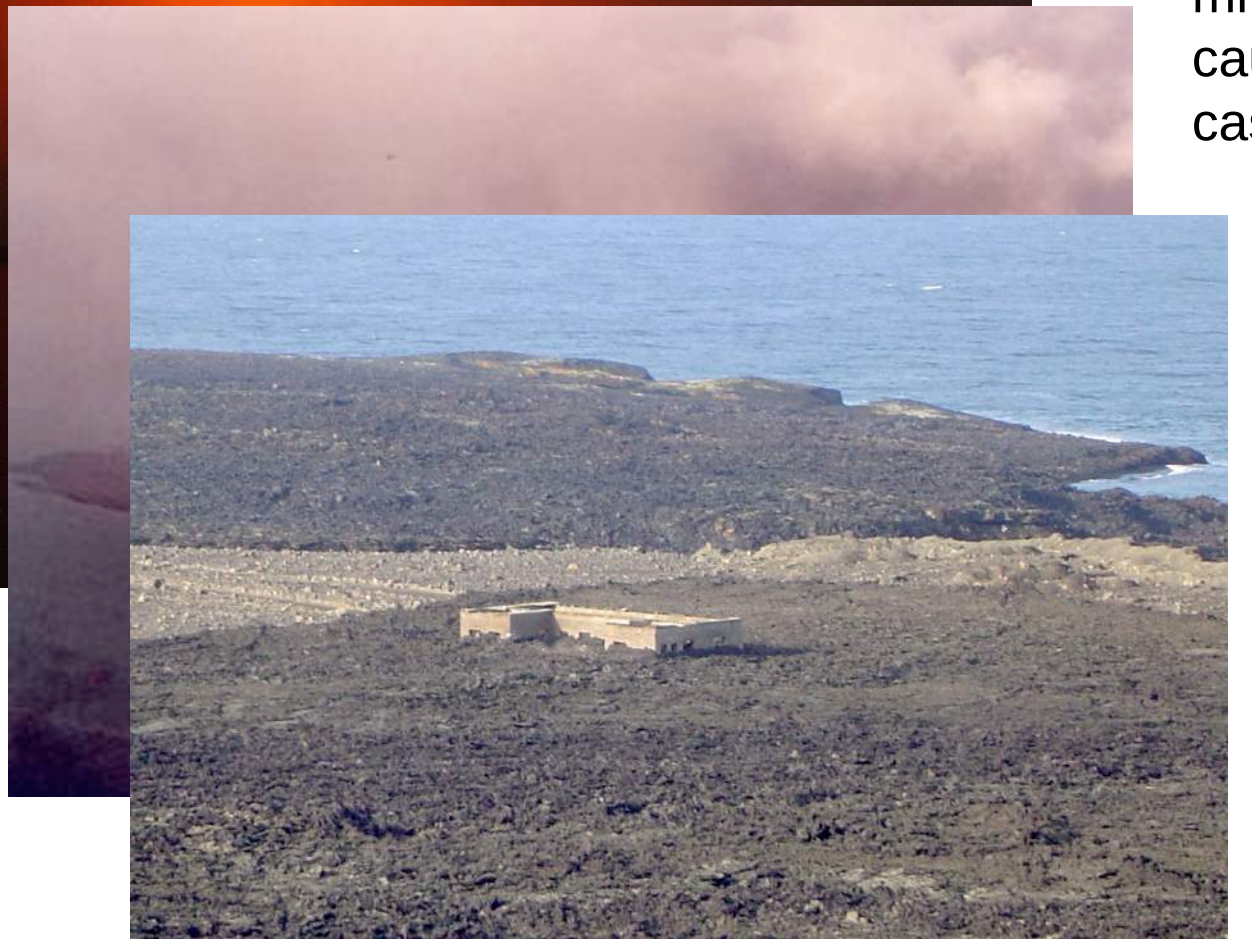


Three recent volcanic eruptions



- Jebel at Tair (2007-8)
- Within Zubair islands in 2011-12 and 2013
- First volcanic activity in over a century

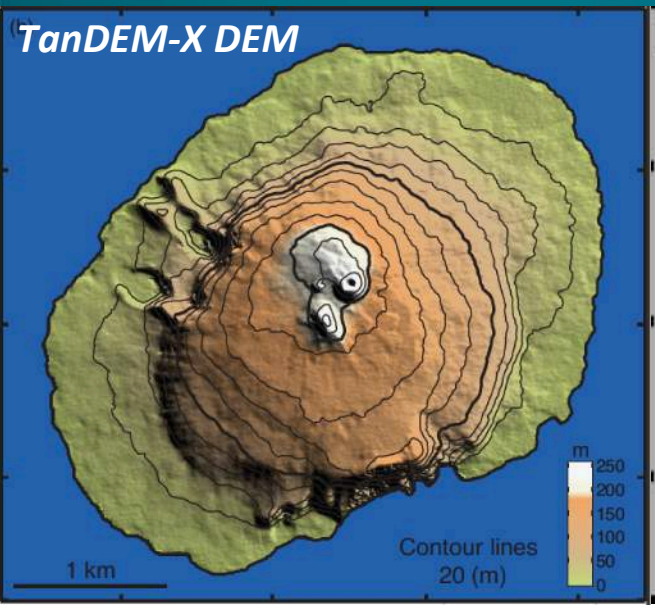
The 2007-8 Tair Island eruption

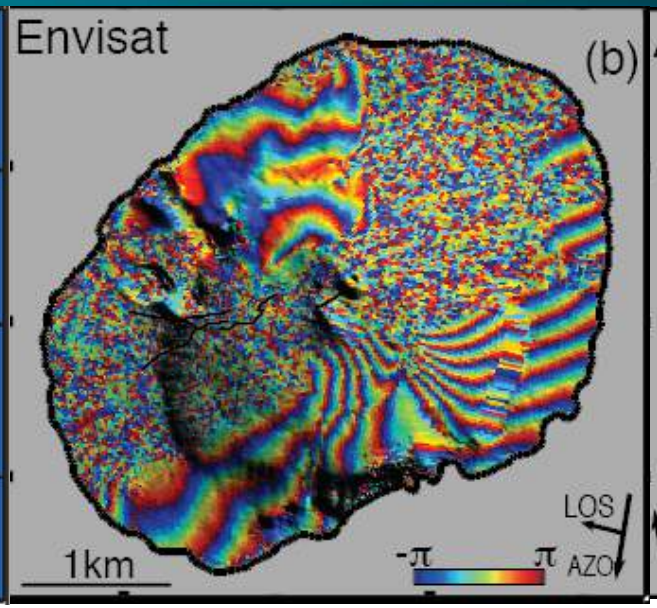


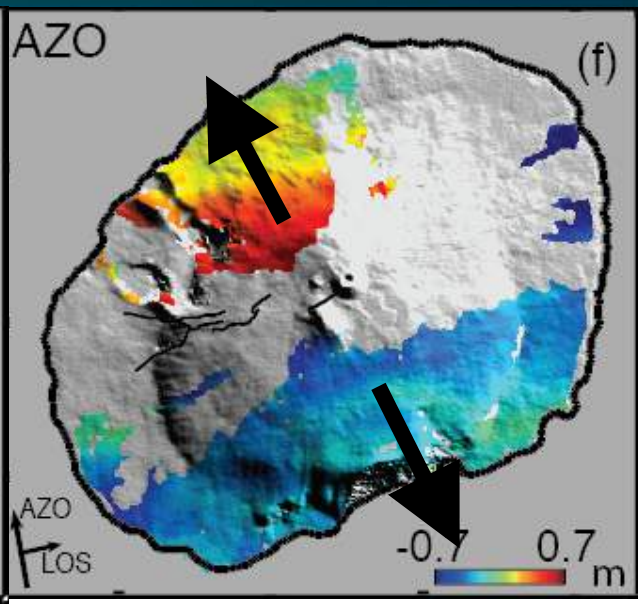
- Eruption destroyed the military outpost and caused several casualties

Photos from Jamal Sholan, Seismological and Volcano observatory, Yemen

Co-eruption Ground Deformation

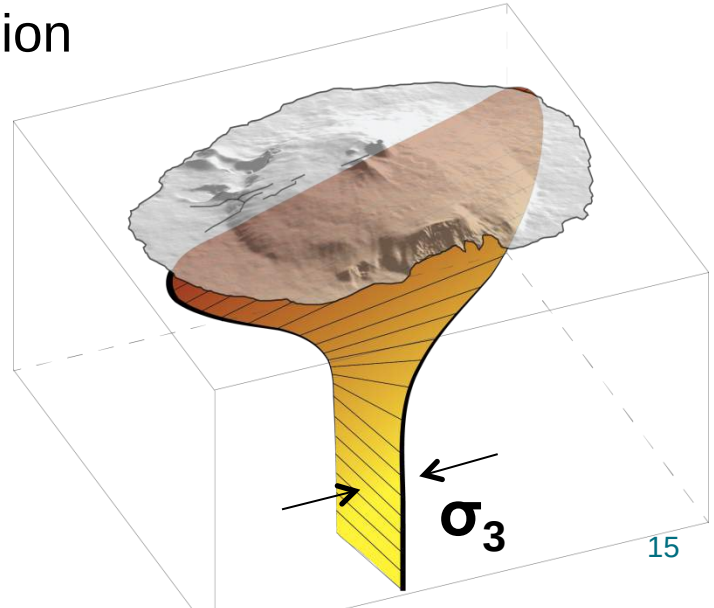


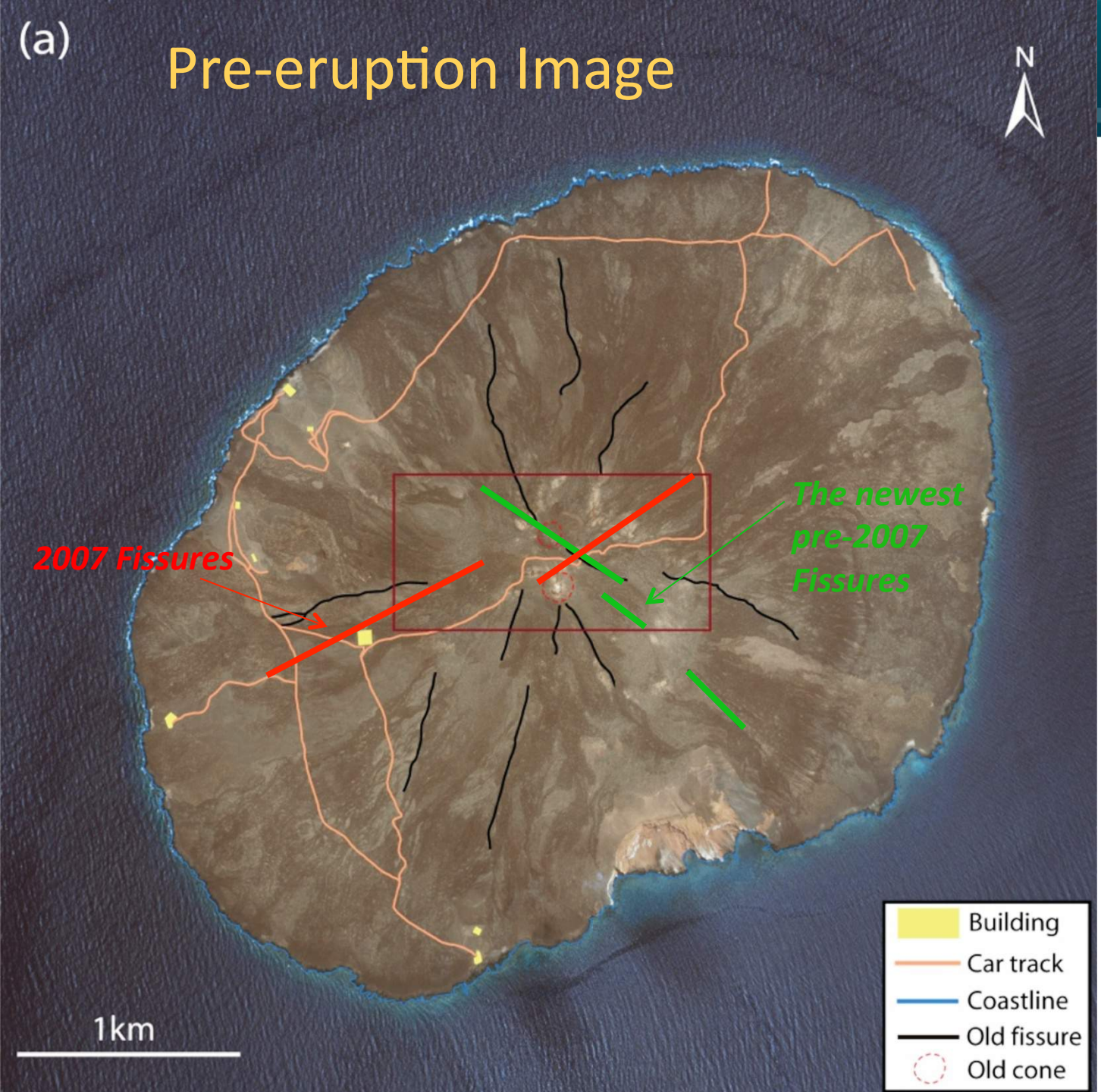




Xu and Jónsson, Bull. Volc. 2014

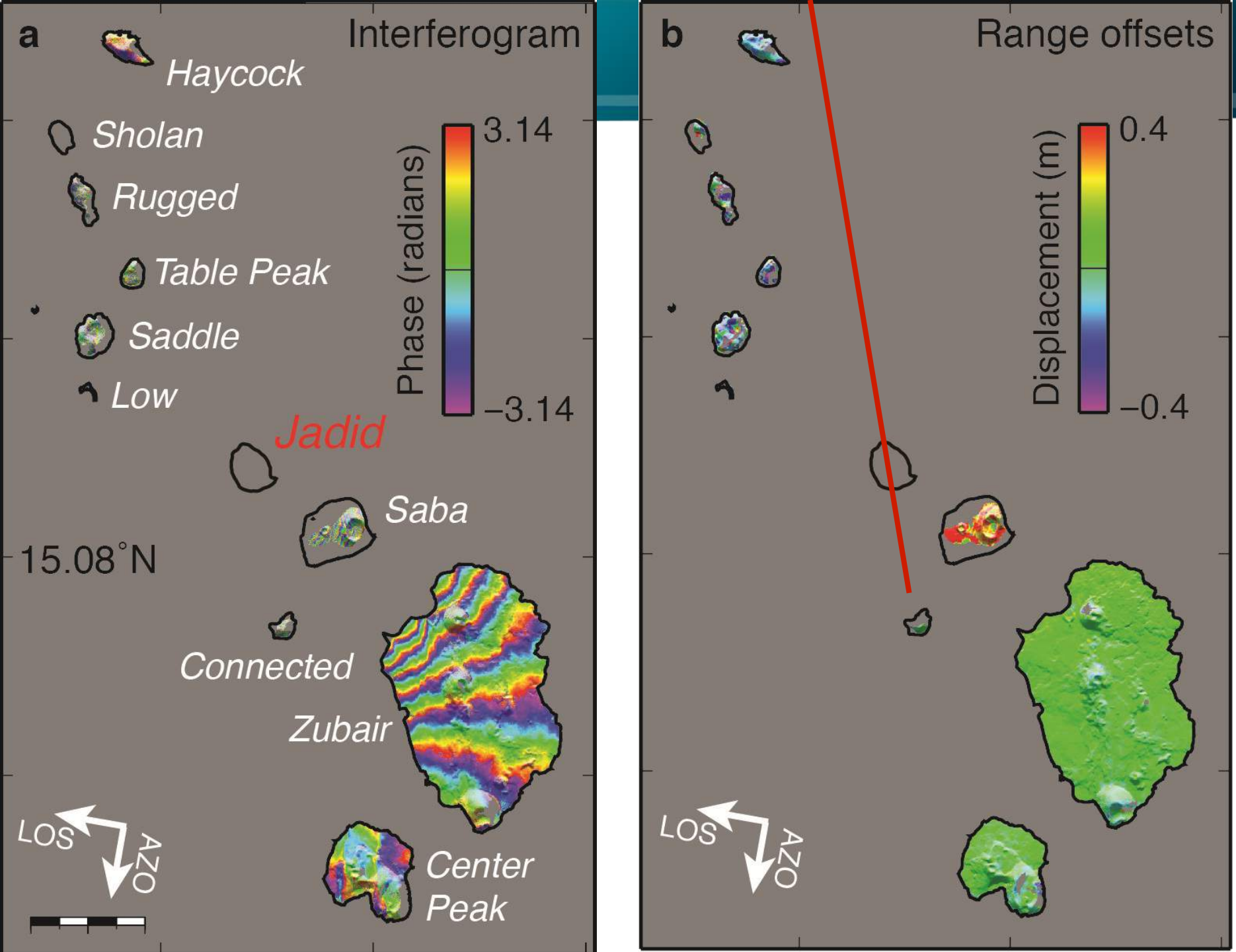
- Azimuth offsets show about 1 m of extension across eruptive fissure at the summit
- Edifice stress-field decoupled from the regional stress-field

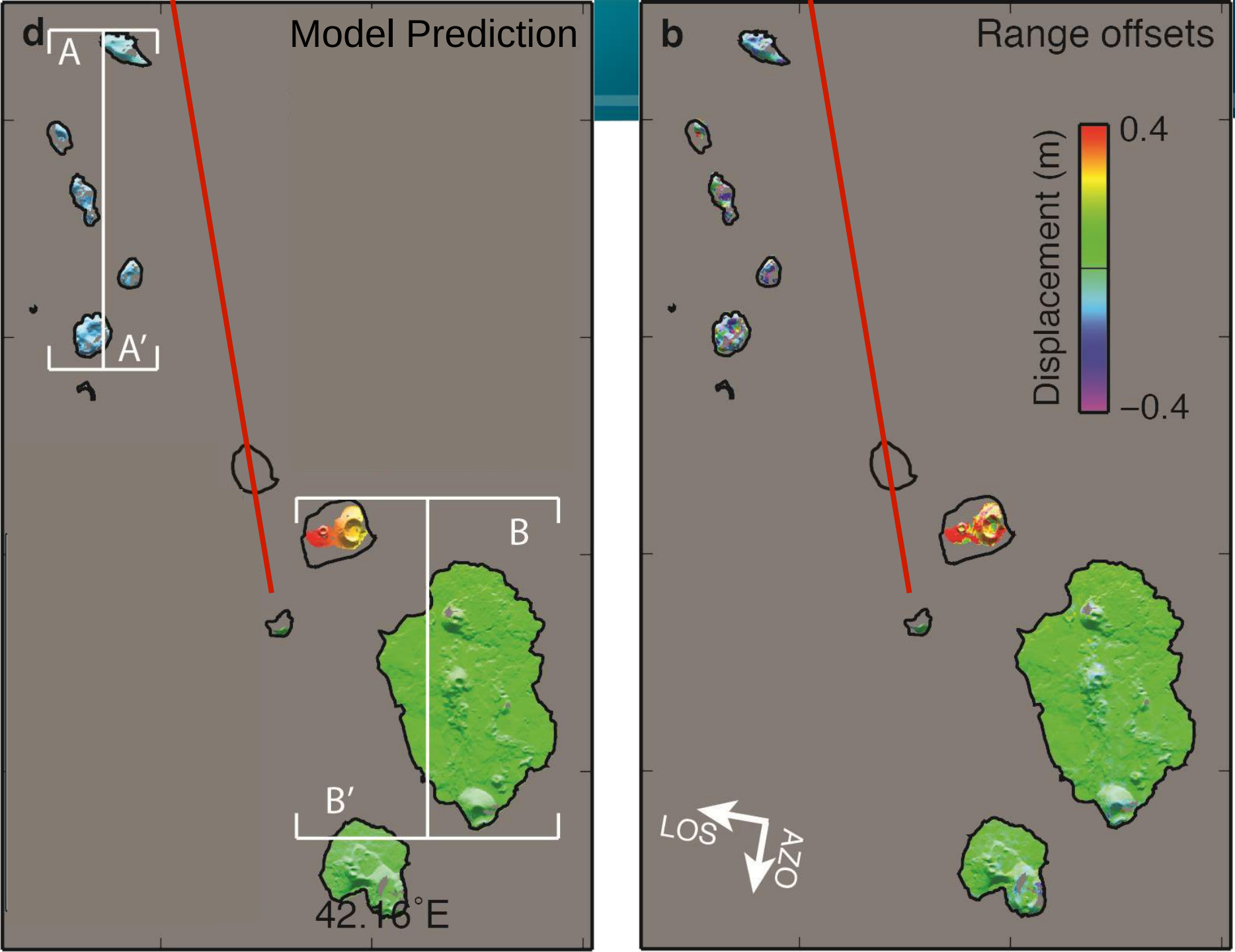




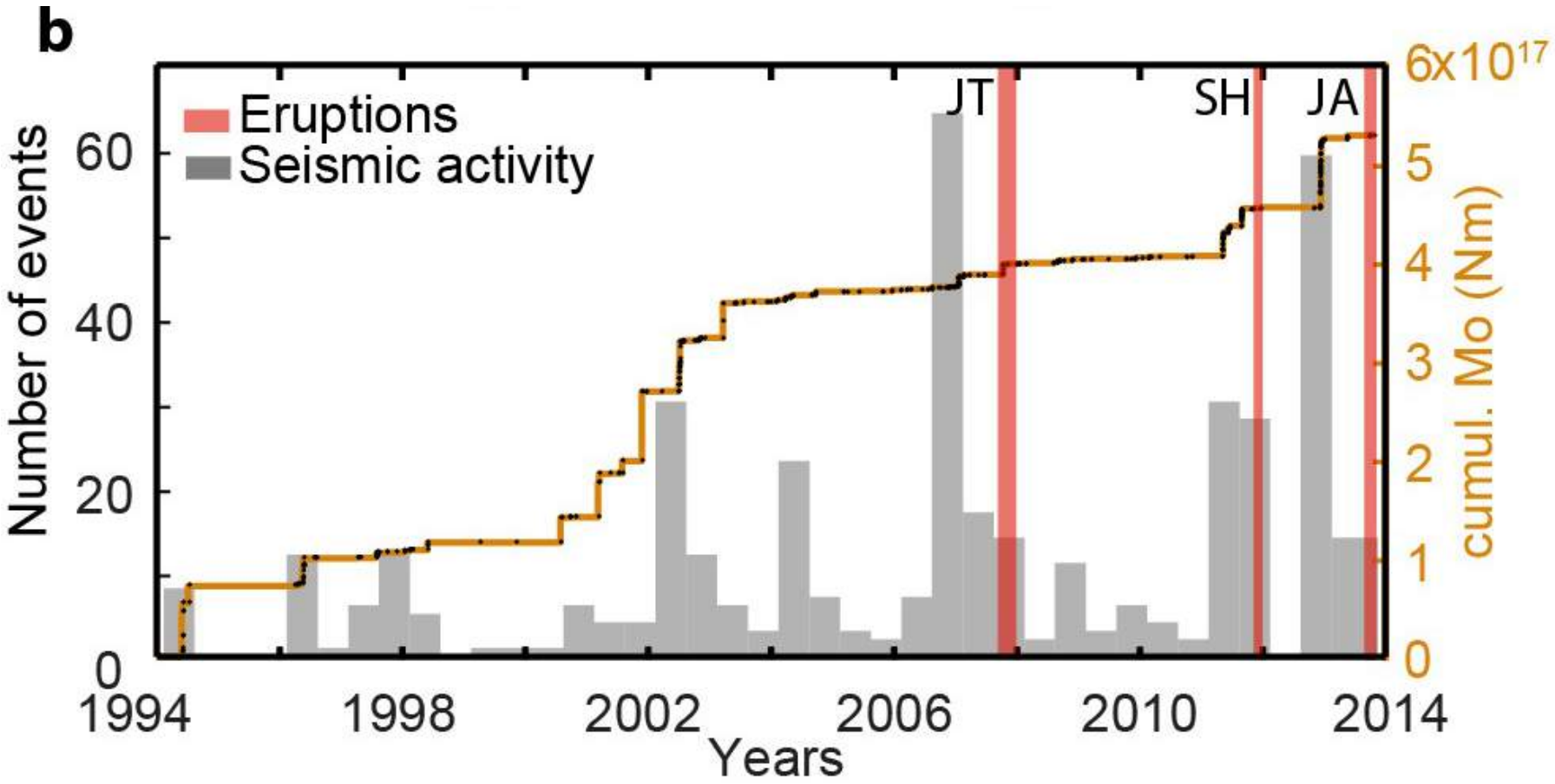
- Quickbird, res-olution 60 cm
- Old surface fissures with variable orientations

Xu and Jónsson, Bull. Volcanol. 2014


a
Interferogram
Haycock
Sholan
Rugged
Table Peak
Saddle
Low
Jadid
Saba
15.08°N
Connected
Zubair
Center
Peak
Phase (radians)
3.14
−3.14
LOS
AZO
b
Range offsets
Displacement (m)
0.4
−0.4
LOS
AZO

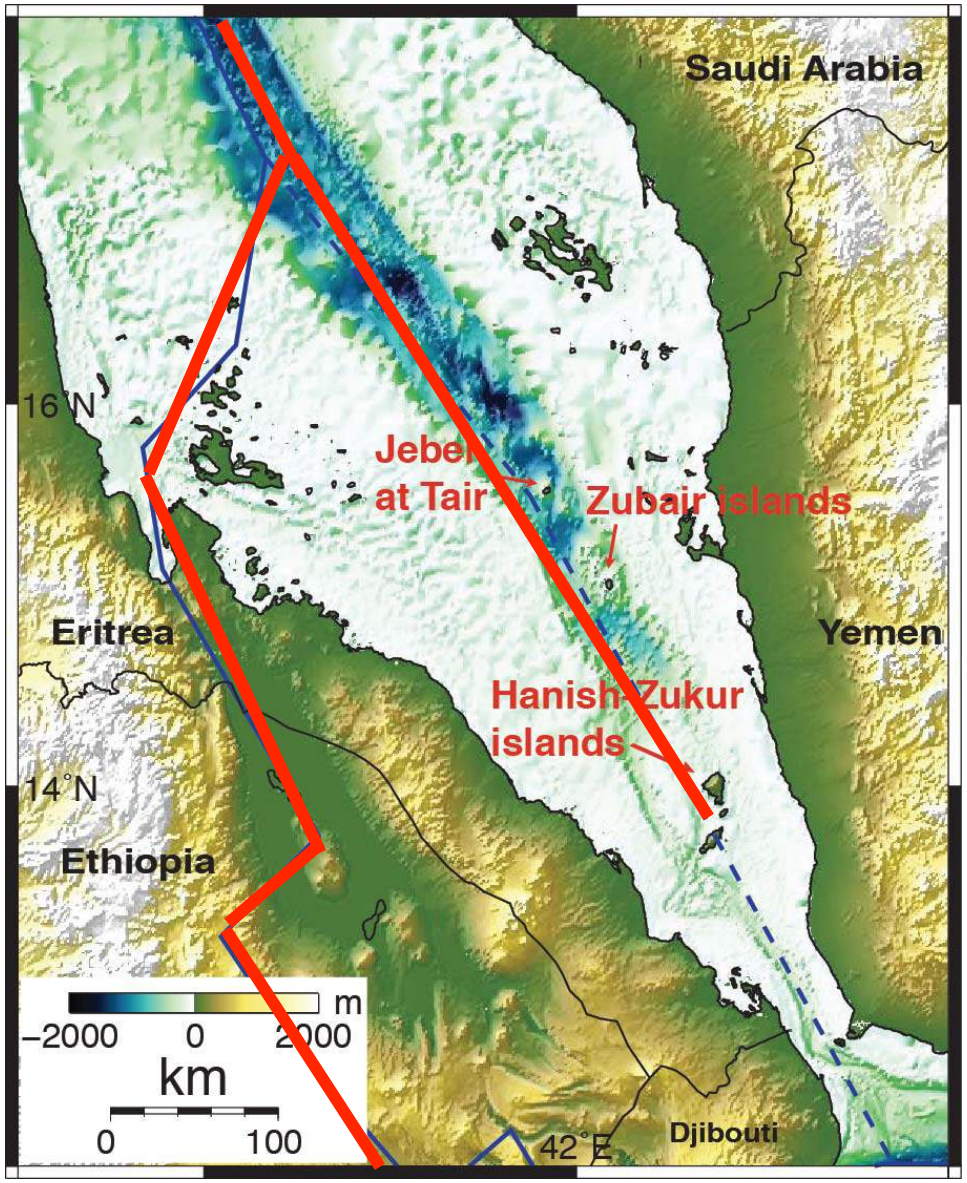

d
Model Prediction
A
A′
B
B′
42.16°E
b
Range offsets
Displacement (m)
0.4
−0.4
LOS
AZO

Rifting episode?

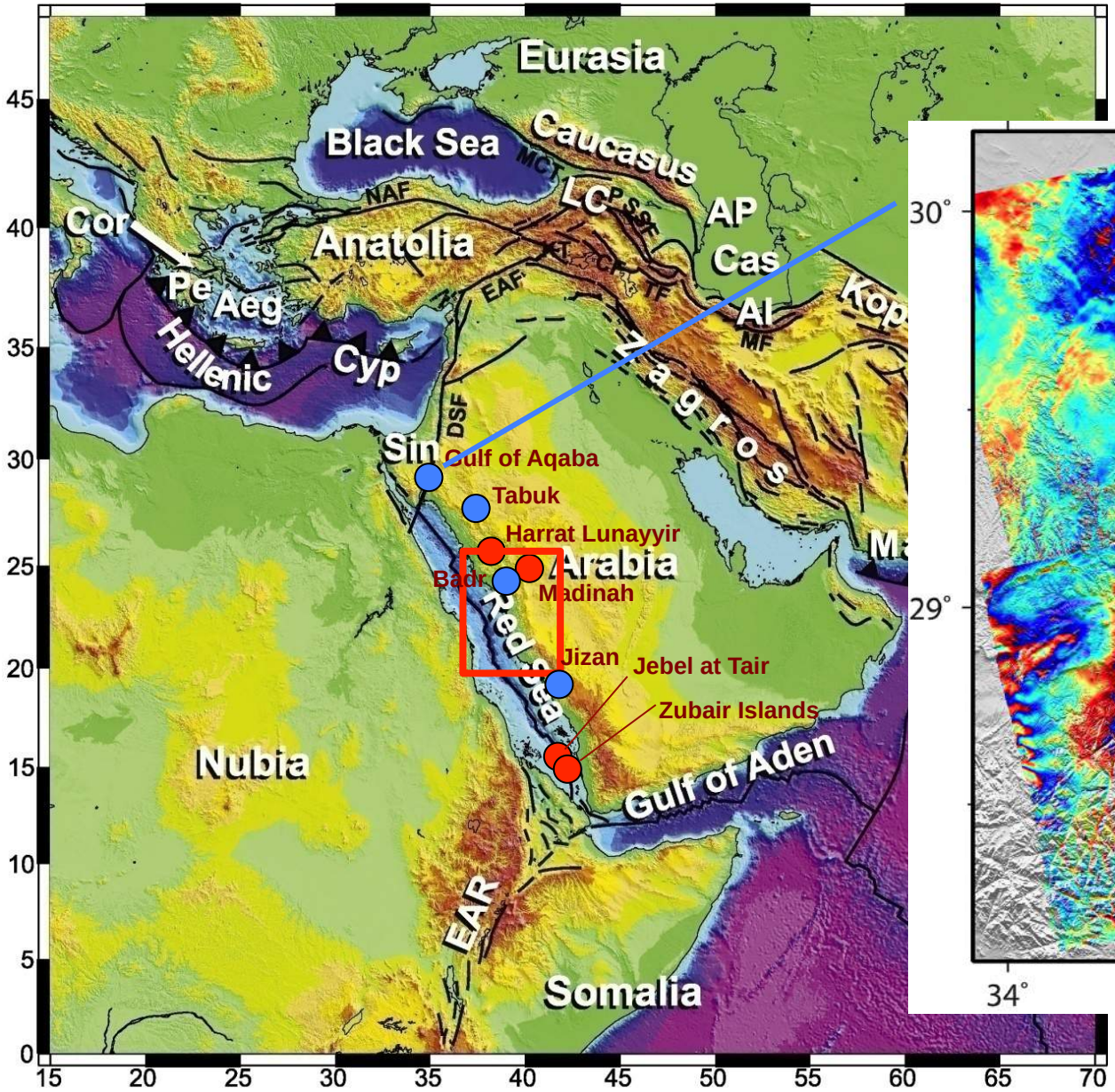


Xu, Ruch & Jónsson, Nature Communications, 2015

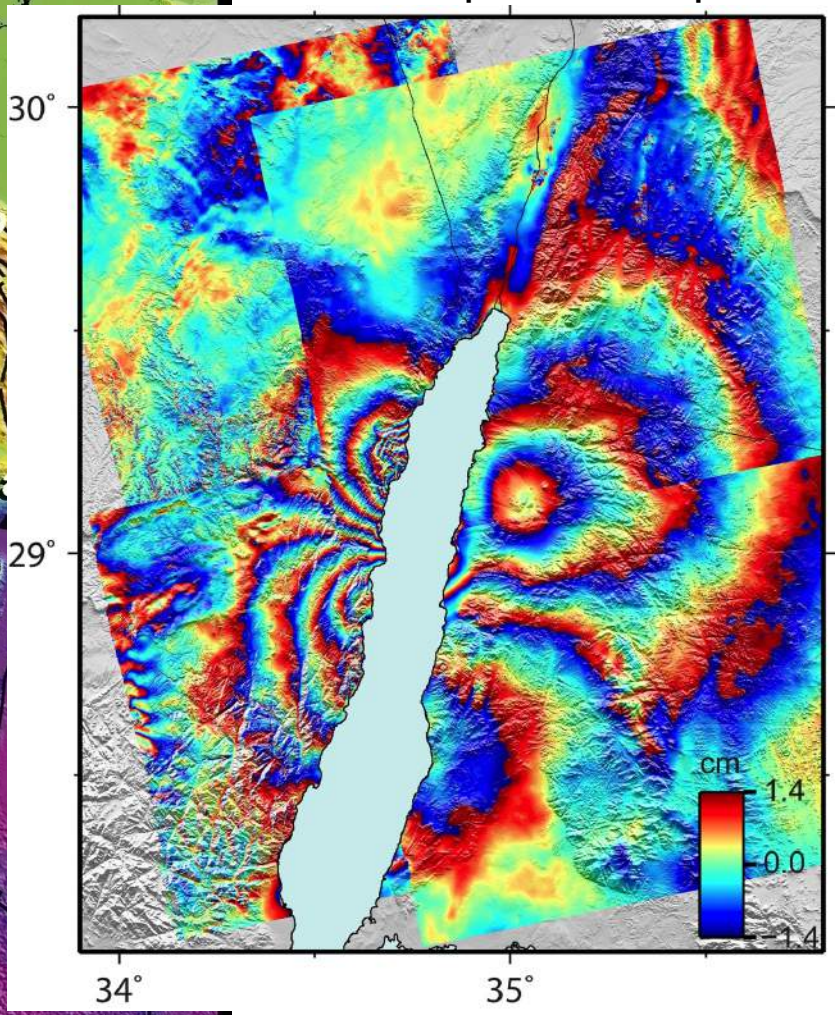
Southern Red Sea is still an active rift



Earthquakes?



The 1995 M7.2 Gulf of Aqaba earthquake



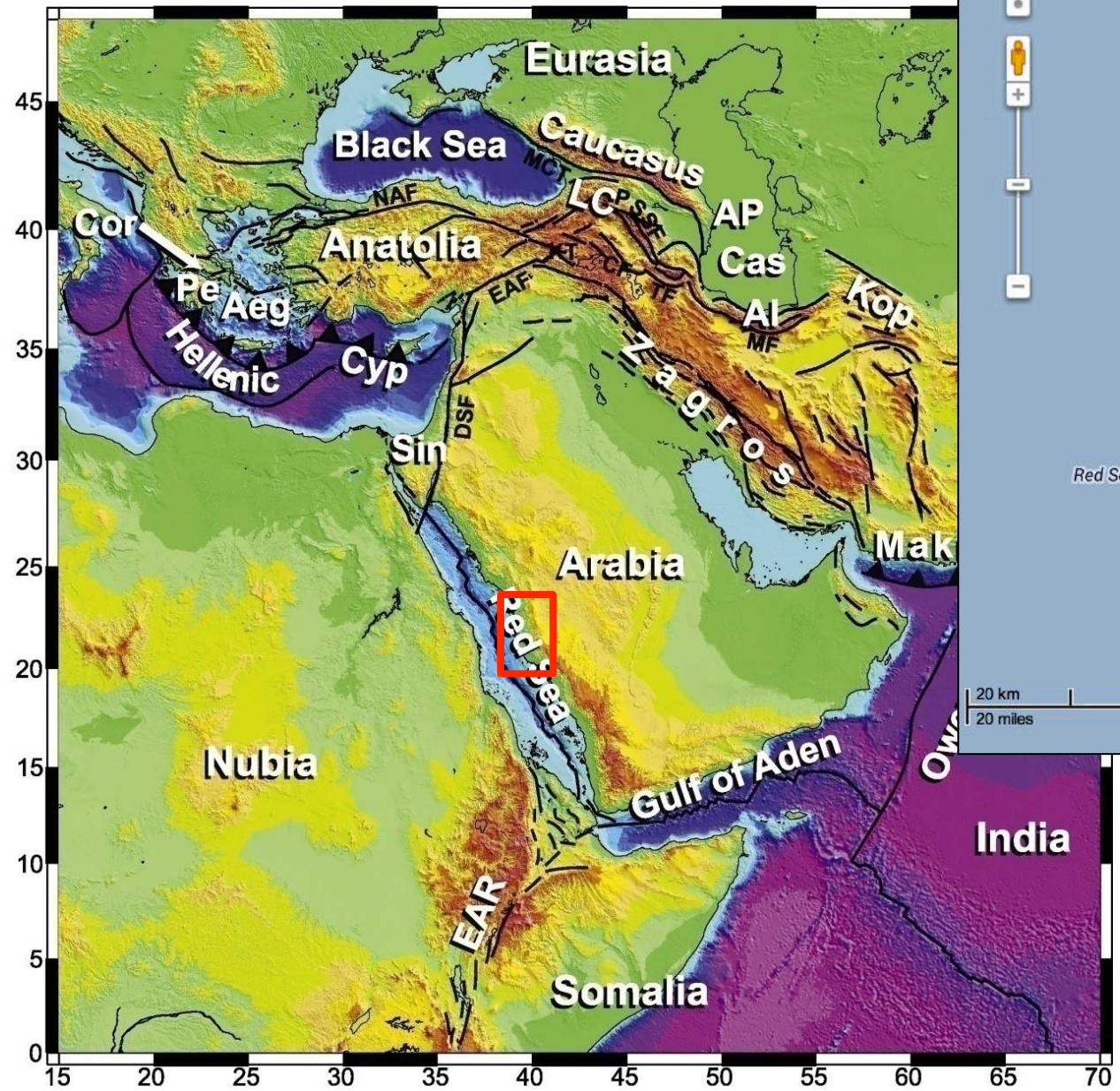
Bathke et al. (in prep. 2015)

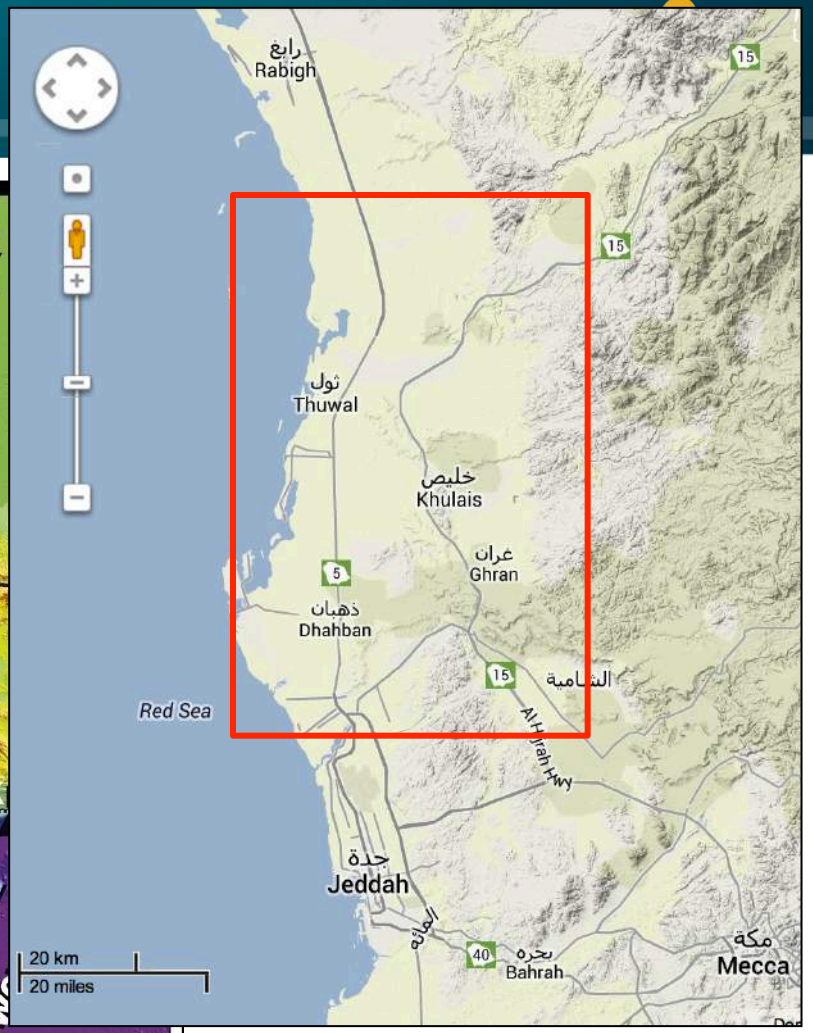
What is this?

www.kingdomtowerskyscraper.com

King Abdullah Economic City (KAEC)

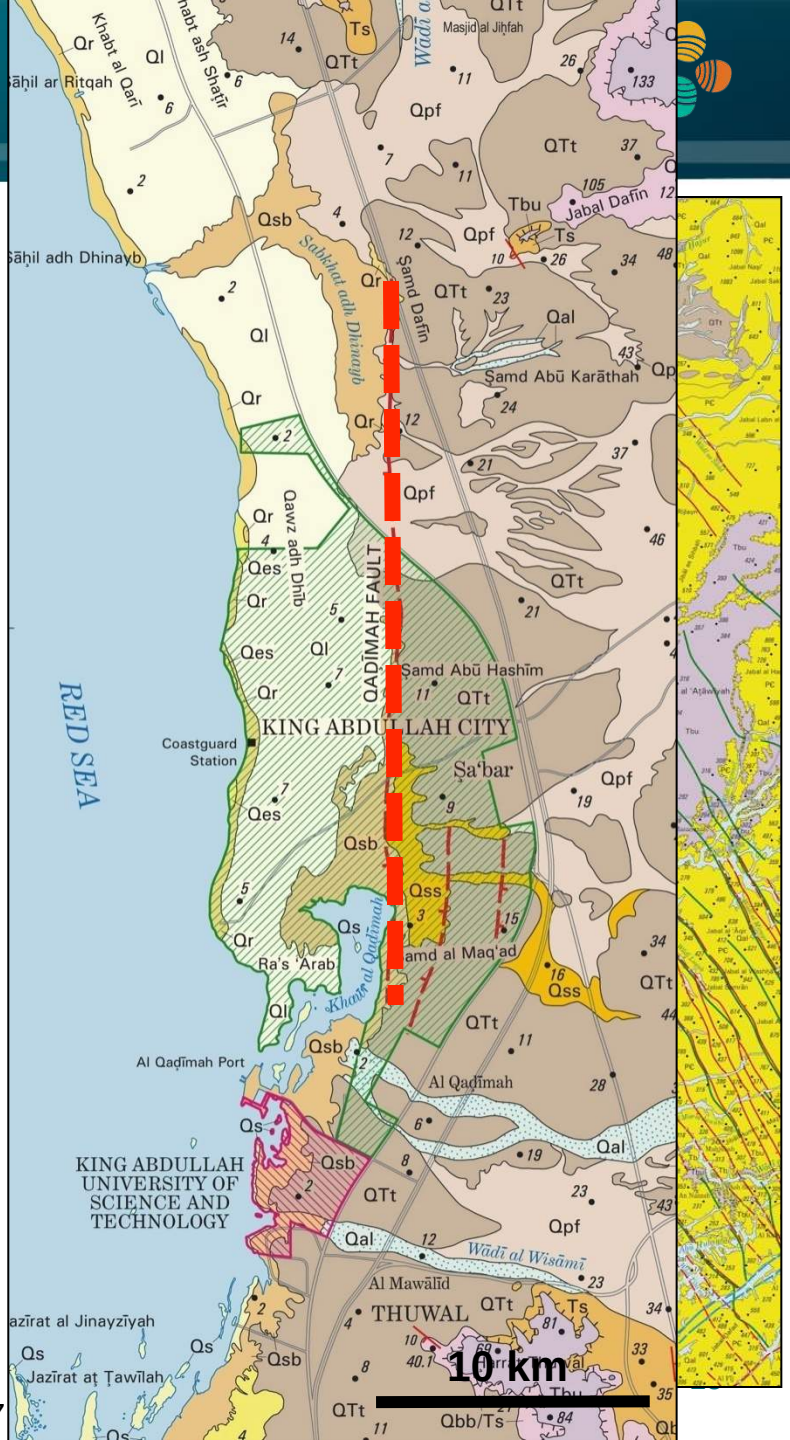
Central Western Coast





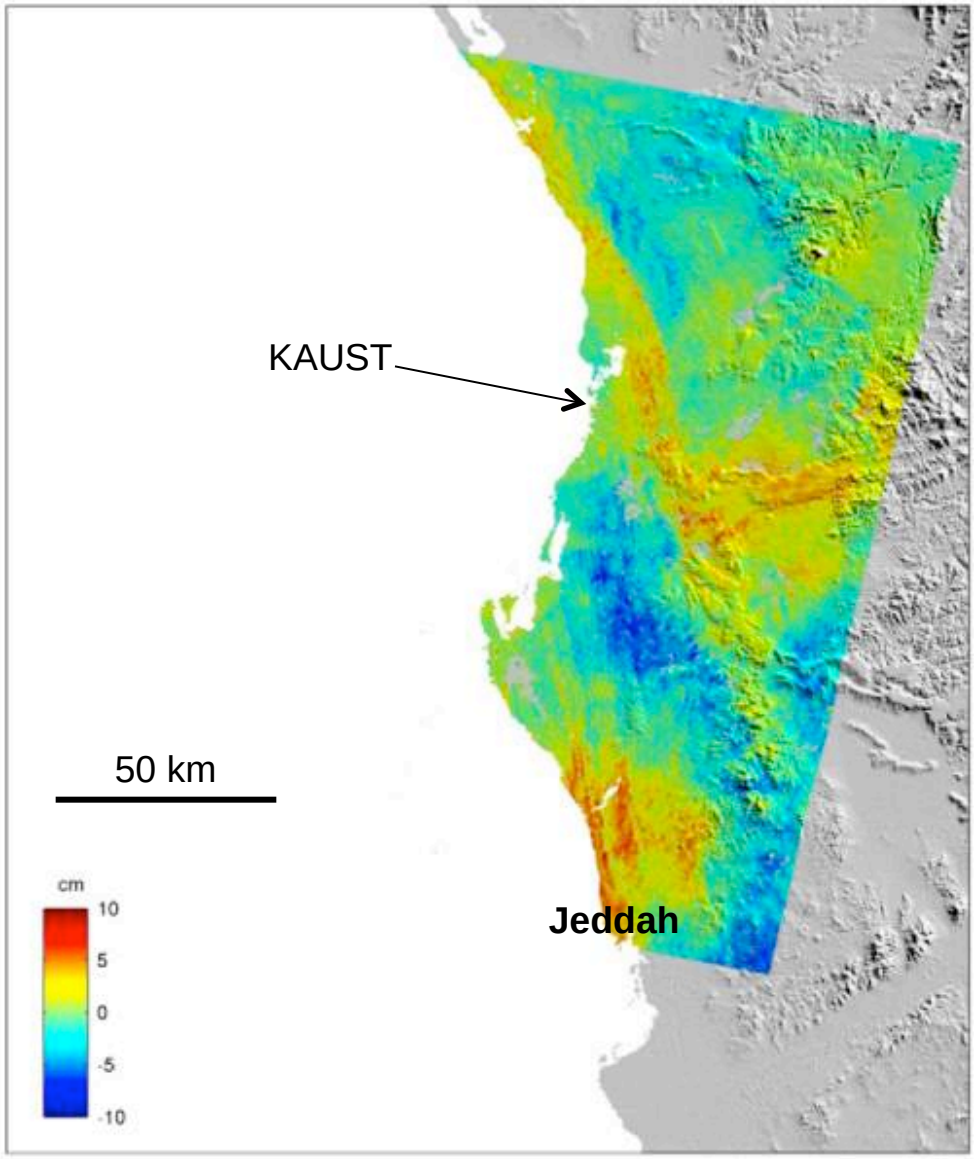
Active faults?

- Precambrian shield (yellow)
- 30-50 km wide coastal plain
- The Qadimah “fault”
- Active?
- Can InSAR help?



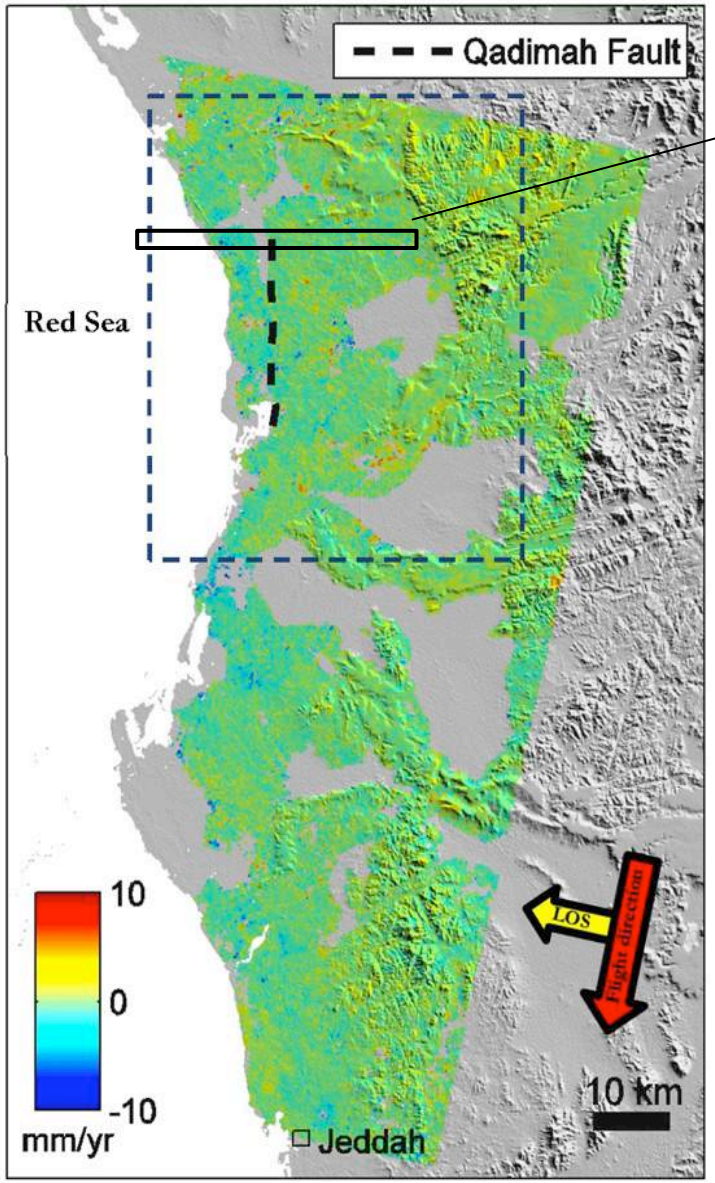
Roobol and Kadi, 2007

InSAR along Red Sea coast

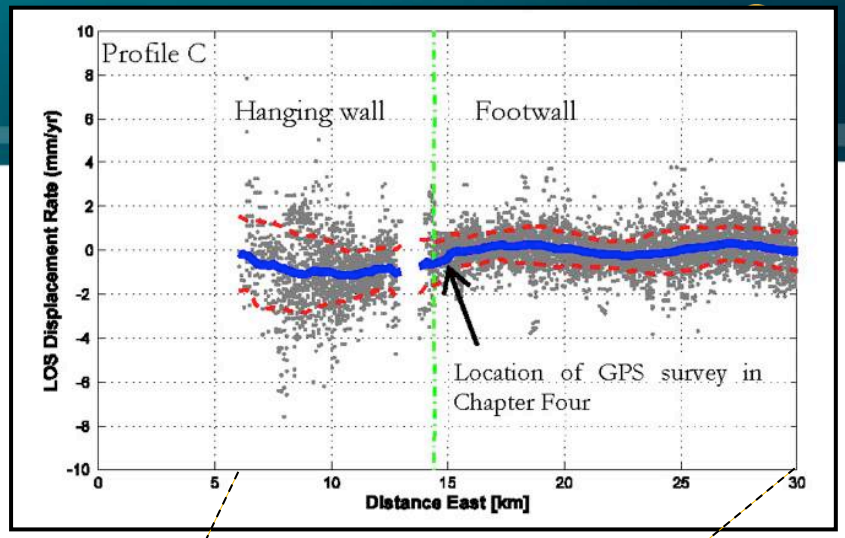


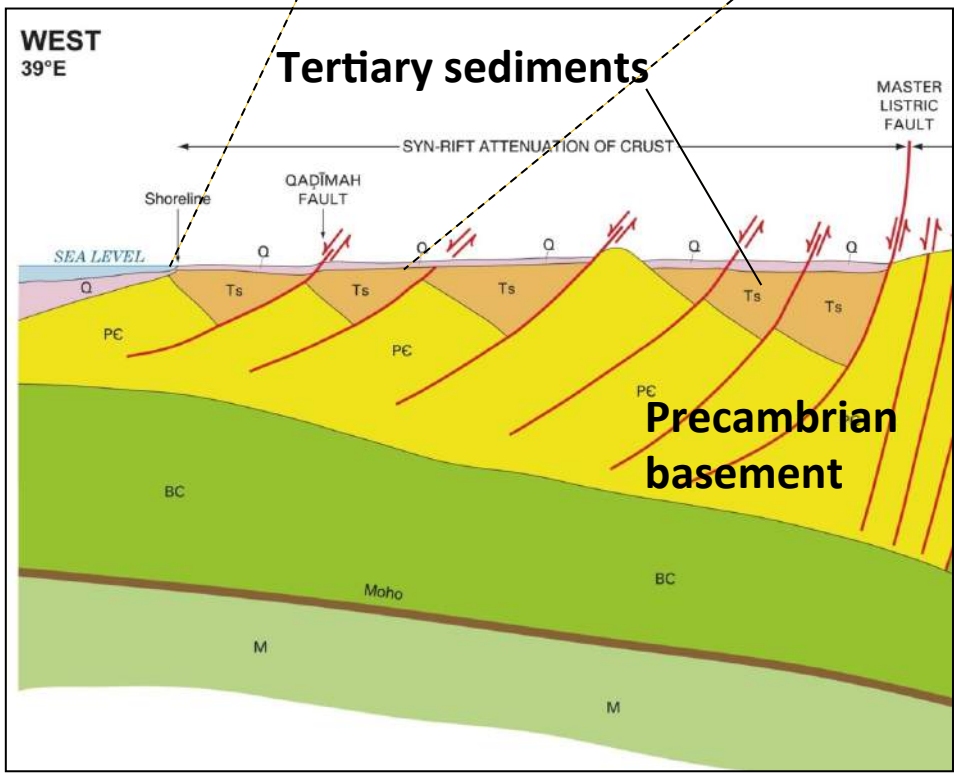
+/- 10 cm atmospheric signals!

InSAR Time-Series Results

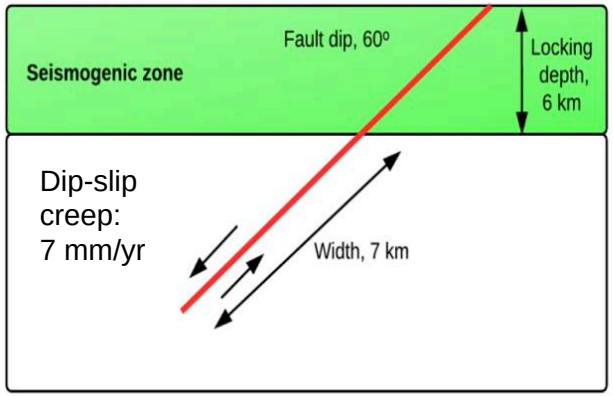


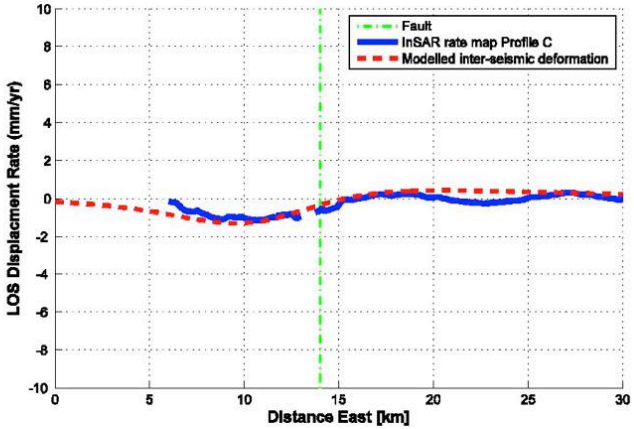
With MERIS corrections





Possible model for observed deformation

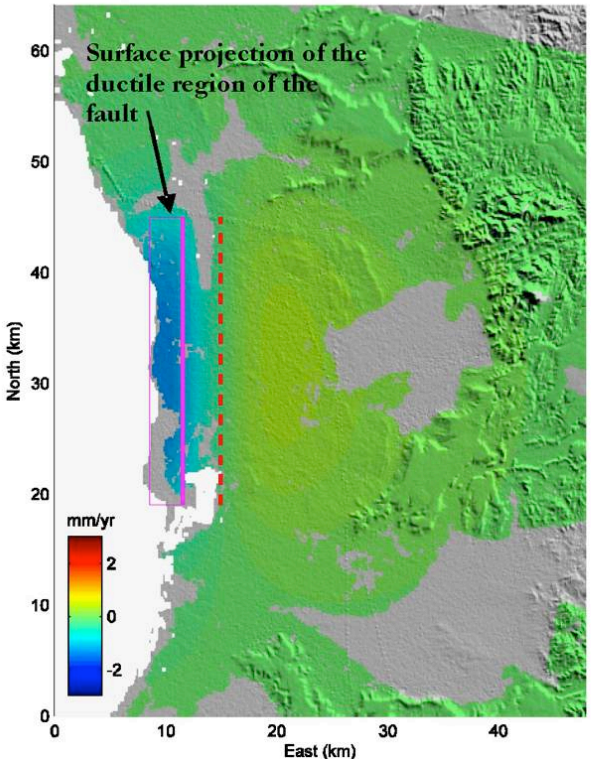




(d)

R. Smith (MS Thesis)

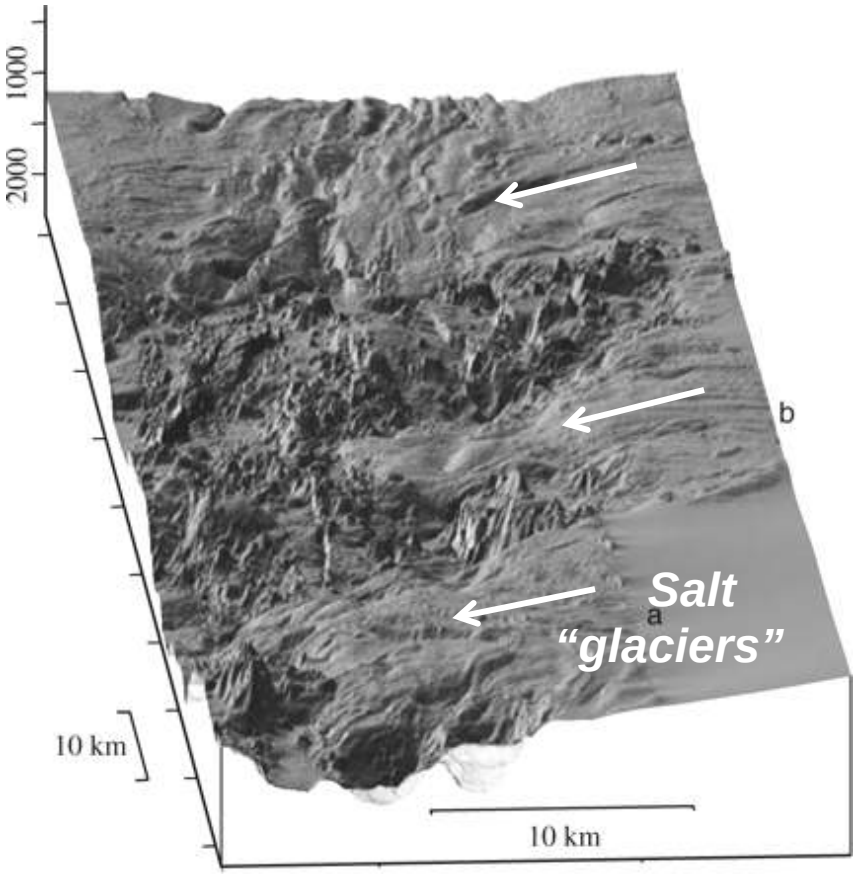
(c)



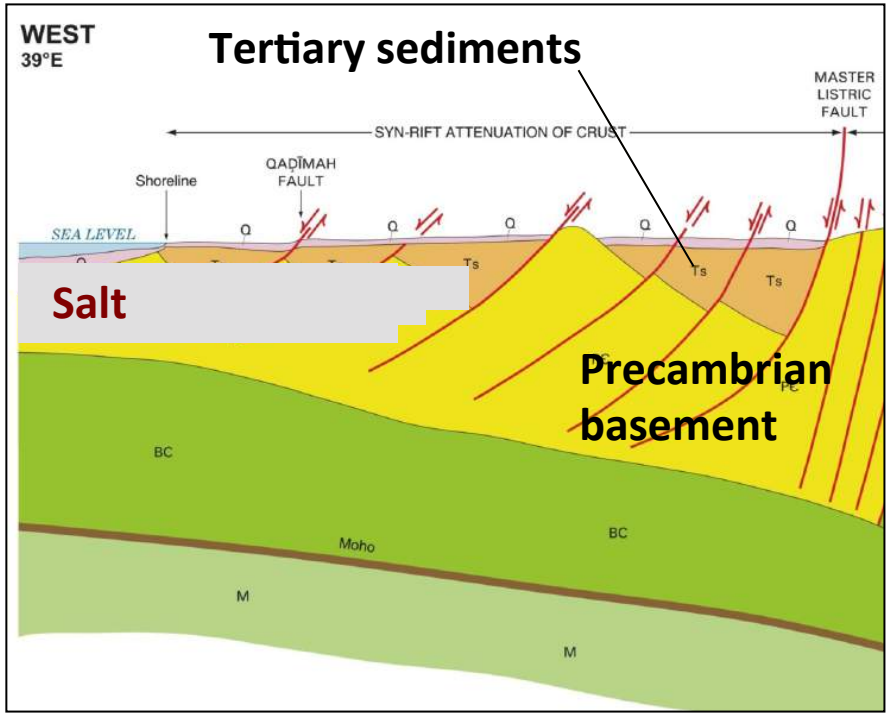
- A simple model with normal-slip creep of 7 mm/yr below 6 km
- Can reproduce the observed signal of 1 ± 2 mm/yr

Salt “glaciers” in the Red Sea

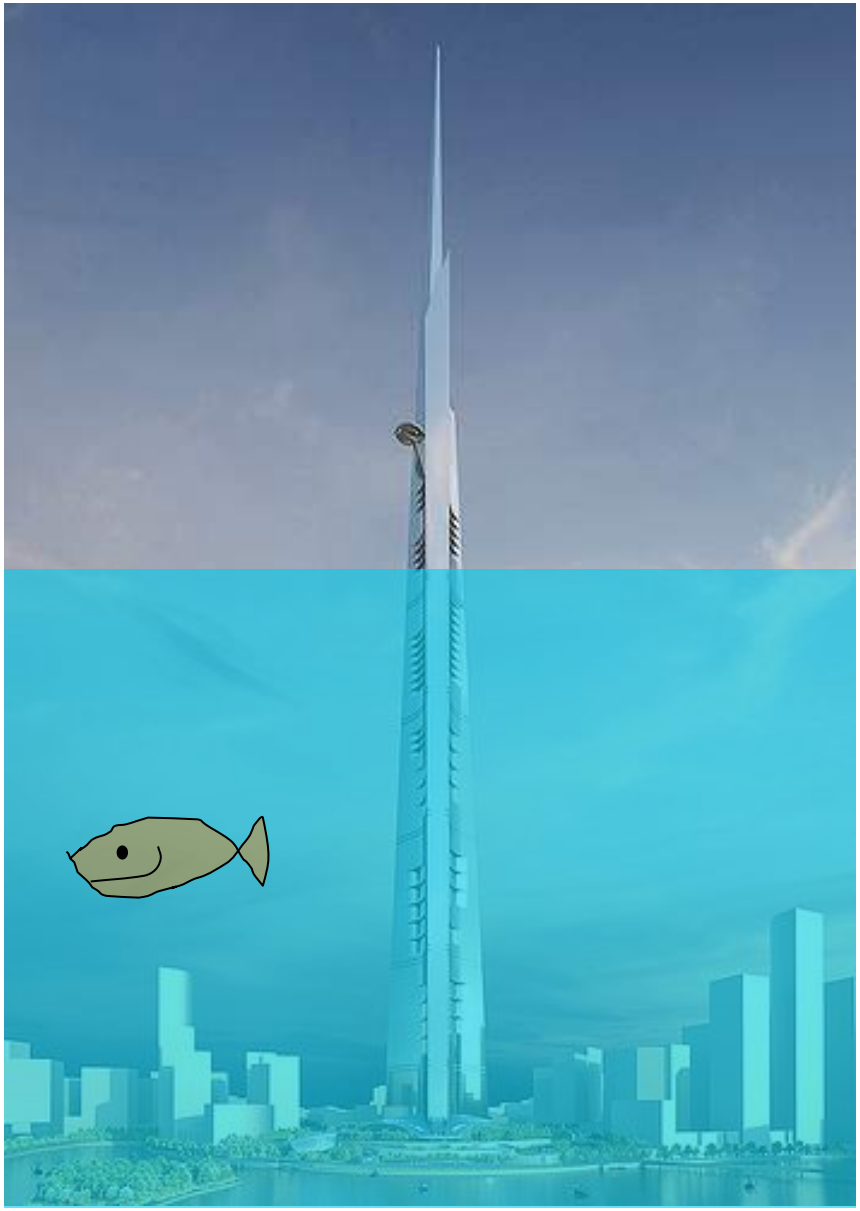
At the Red Sea central trough

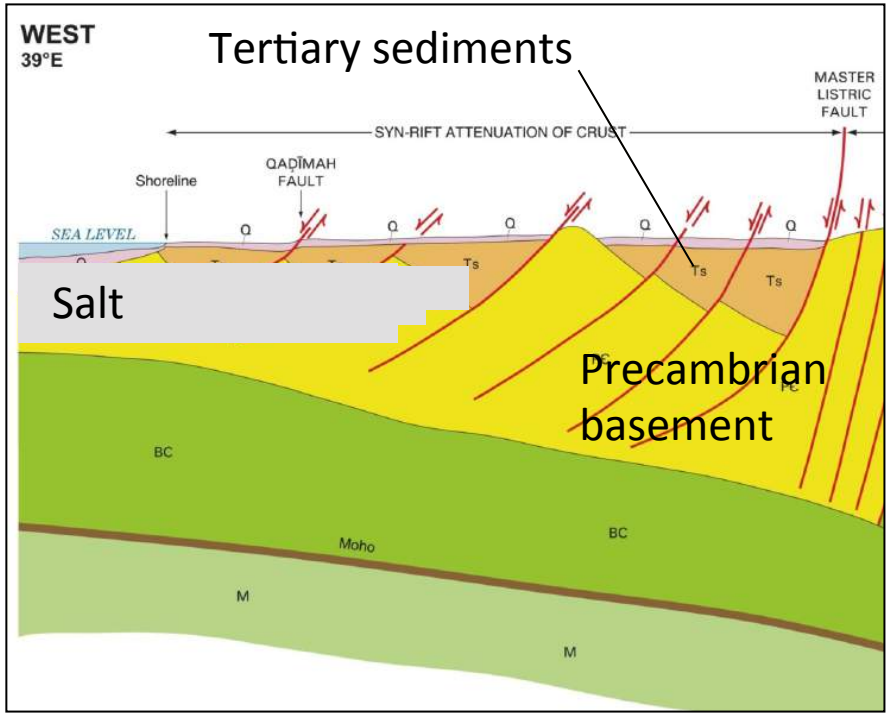


Mitchell et al. GSA Bull. 2010



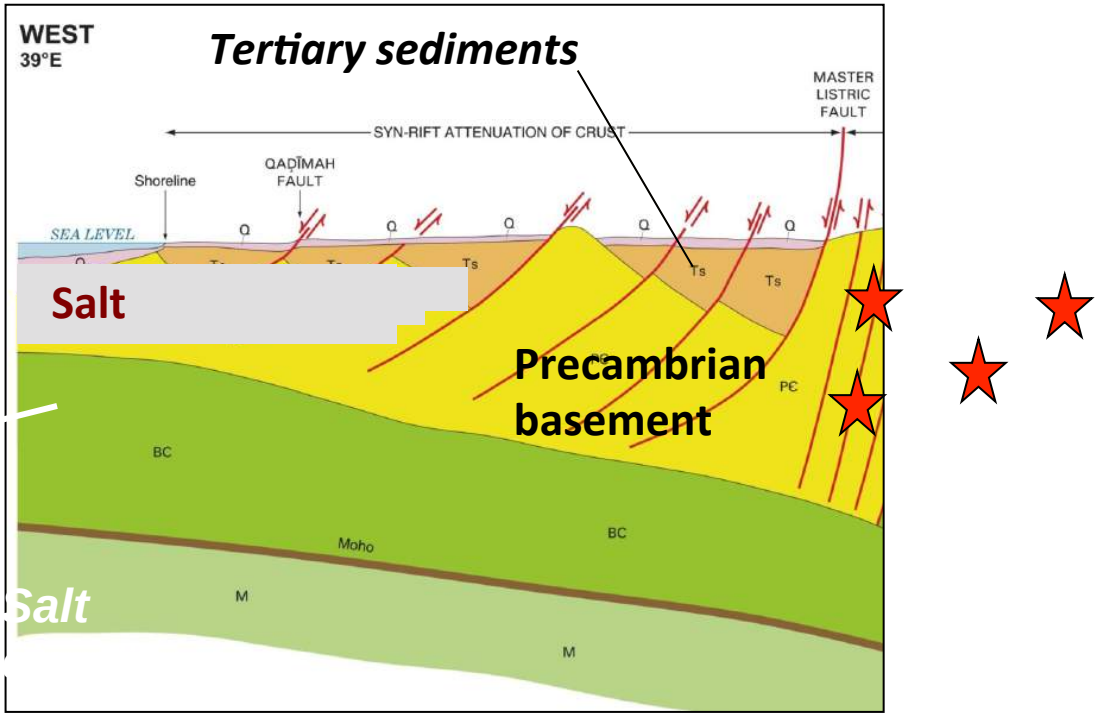
Salt “glaciers” in the Red Sea





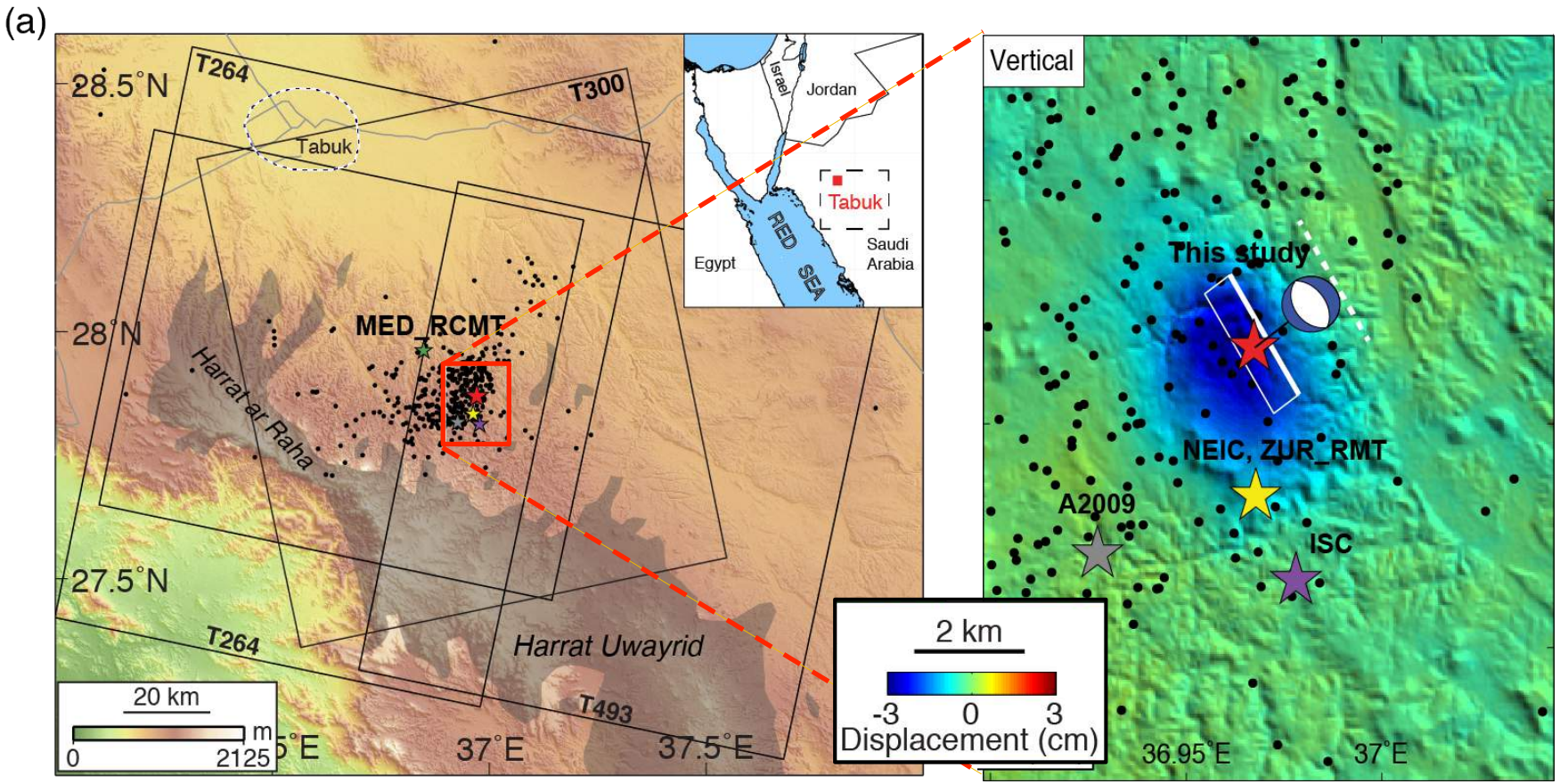
Situation after 0.5 million years at 1 mm/yr subsidence rate

Observed earthquakes in the shield



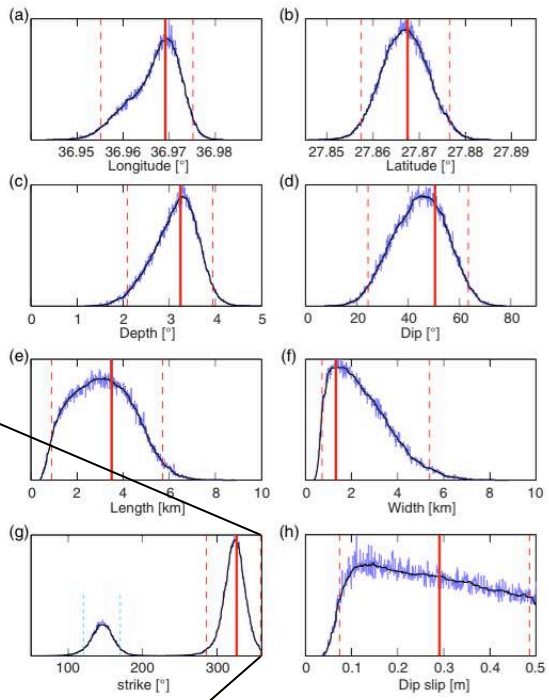
Important to identify active faults

- The 2004 M_w5.1 Tabuk earthquake, locations inaccurate
- Only 3 cm of subsidence, no surface rupture

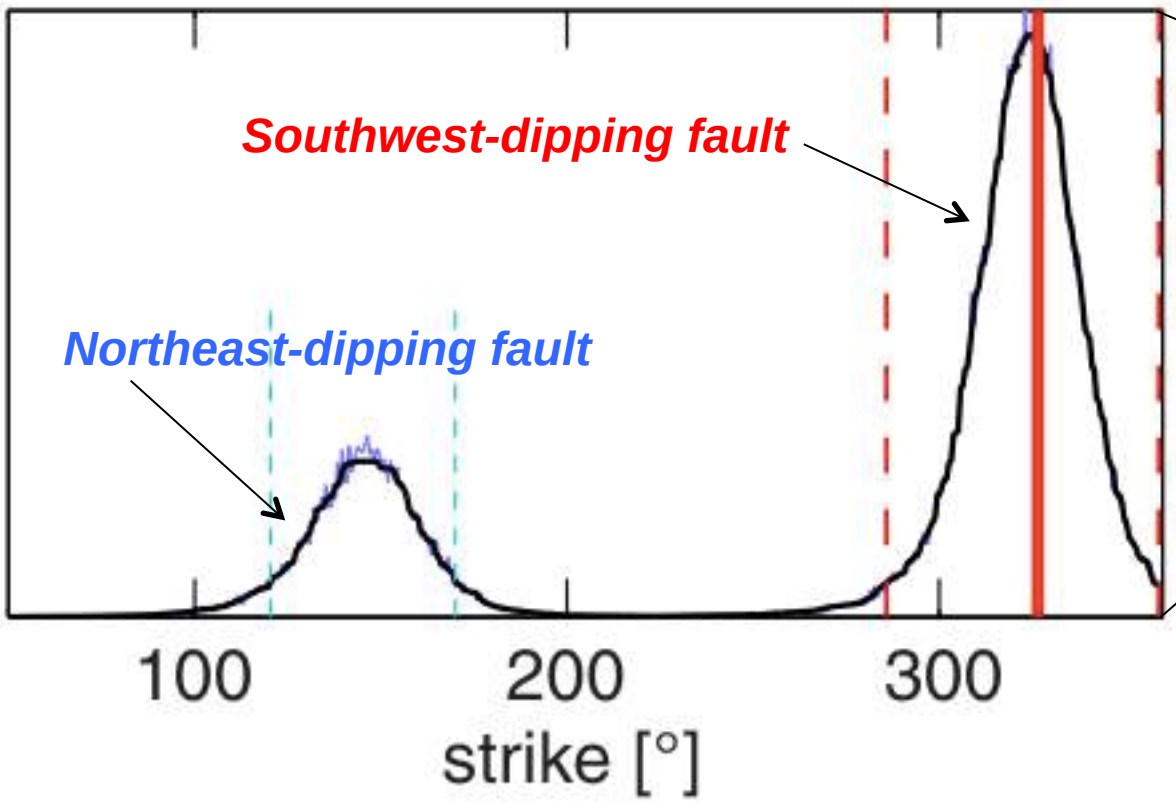


Xu, Dutta, and Jónsson, BSSA, 2015

Southwest or Northeast-dipping fault?

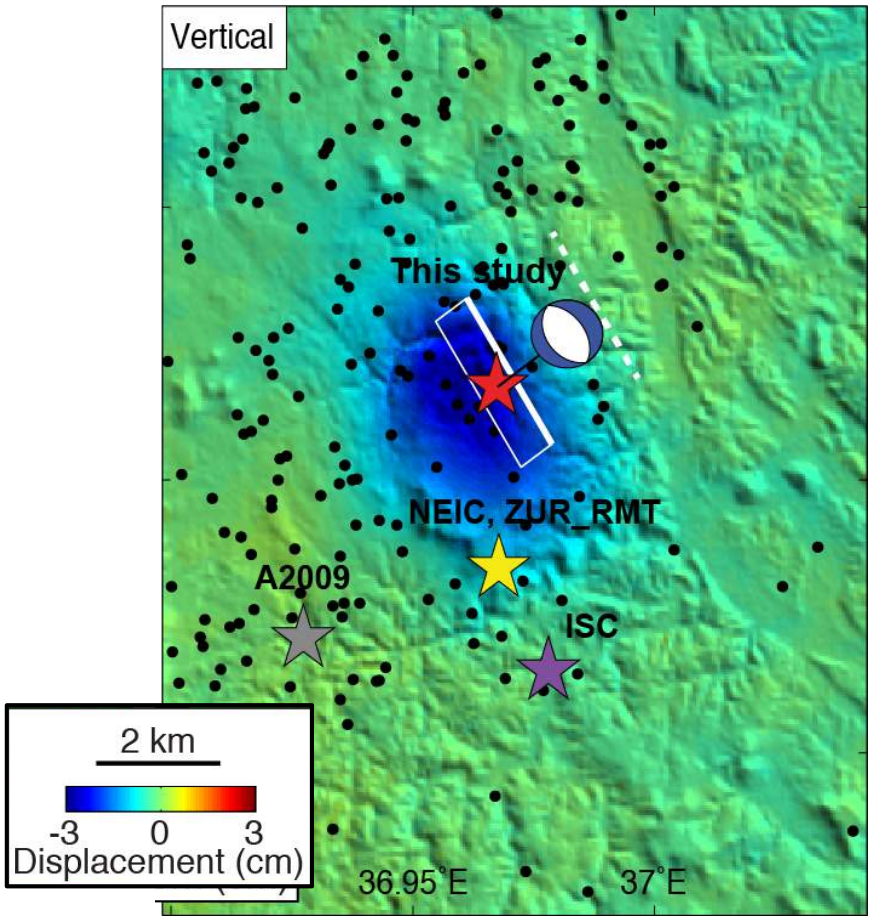


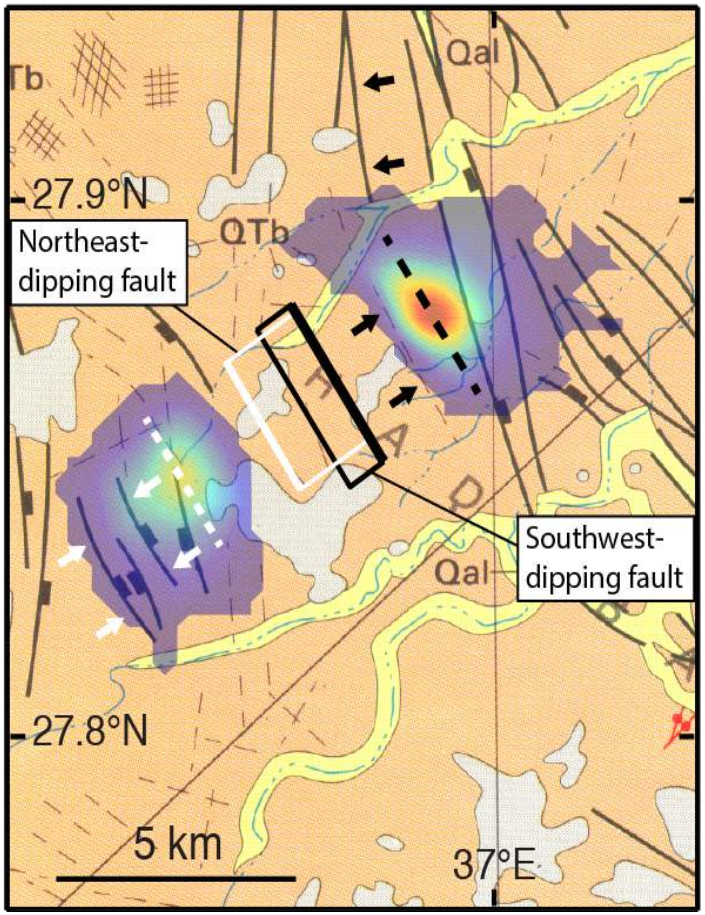
Marginal PDF for fault strike



Find which of the mapped faults is active

- Much improved hypocenter location
- Extrapolate uncertain fault solution to the surface





Xu, Dutta, Jónsson, BSSA, 2015

Take-home points

- Limited precursory deformation
- Volcanic edifices have their own stress
- Southern Red Sea rifting episode
- Coastline may be unstable due to salt
- InSAR helpful to identify active faults