

“Ceux qui n'apprennent pas de l'histoire,
sont condamnés à la répéter”

Winston Churchill

Dead Sea Fault earthquake history revealed in Vadum Iacob (A French Crusaders castle)

History & Archaeology:

Ronnie Ellenblum

Geology:

Amotz Agnon, Shmulik Marco

Dead Sea Fault: transfers the opening of the Red Sea to the Eurasia-Arabia collision



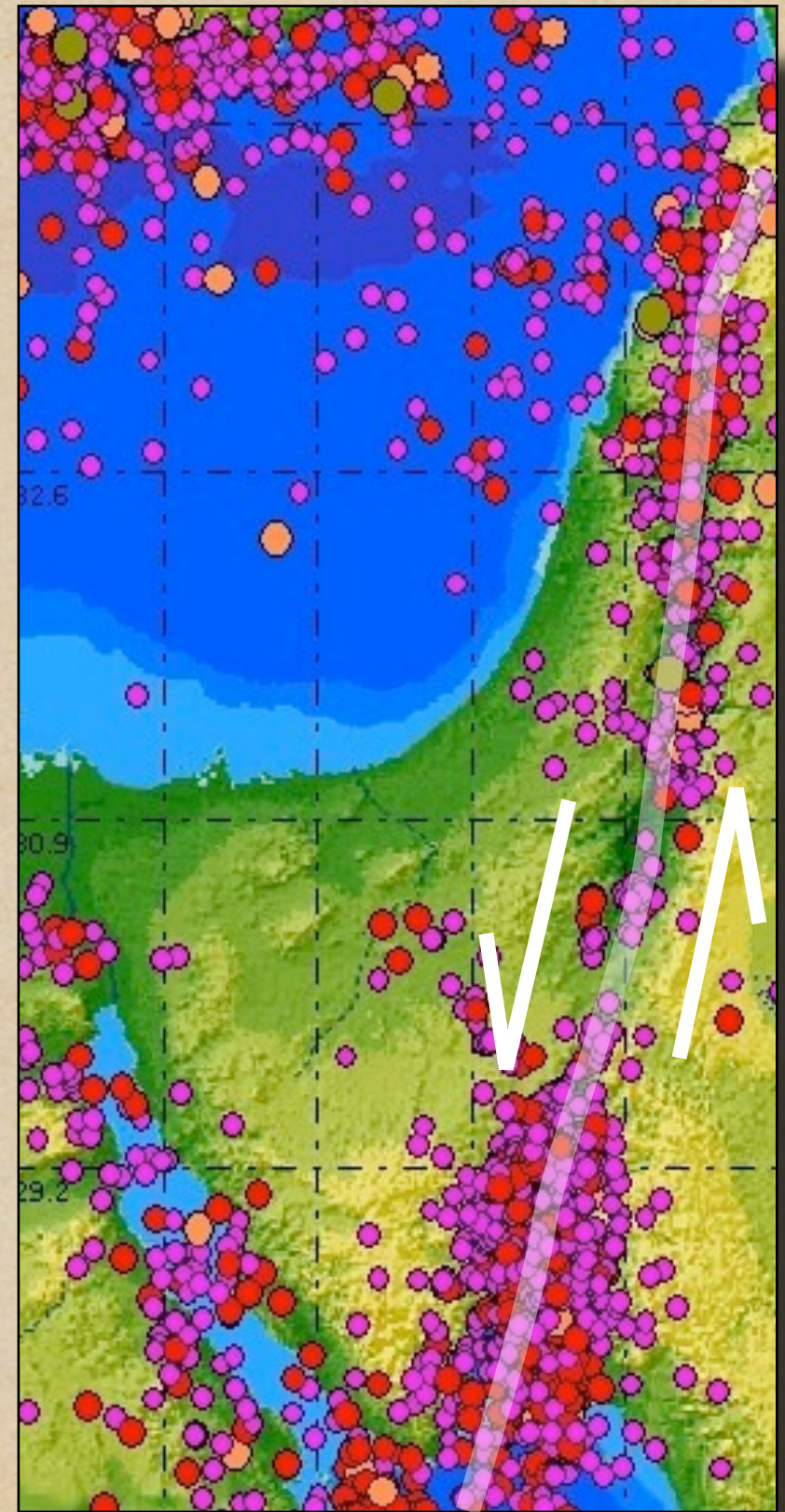
Modern seismographs
recorded only one
strong earthquake



1900-2009 Epicenters: Geophys. Inst. Israel

But we'd love to know...

- Strong eq chronology
- Fault types
- Slip per event
- Mean slip rate
- Earthquake sizes
- Recurrence pattern



Epicenters: Geophys. Inst. Israel

We need pre-instrumental sources

| Seismographs - 100 years

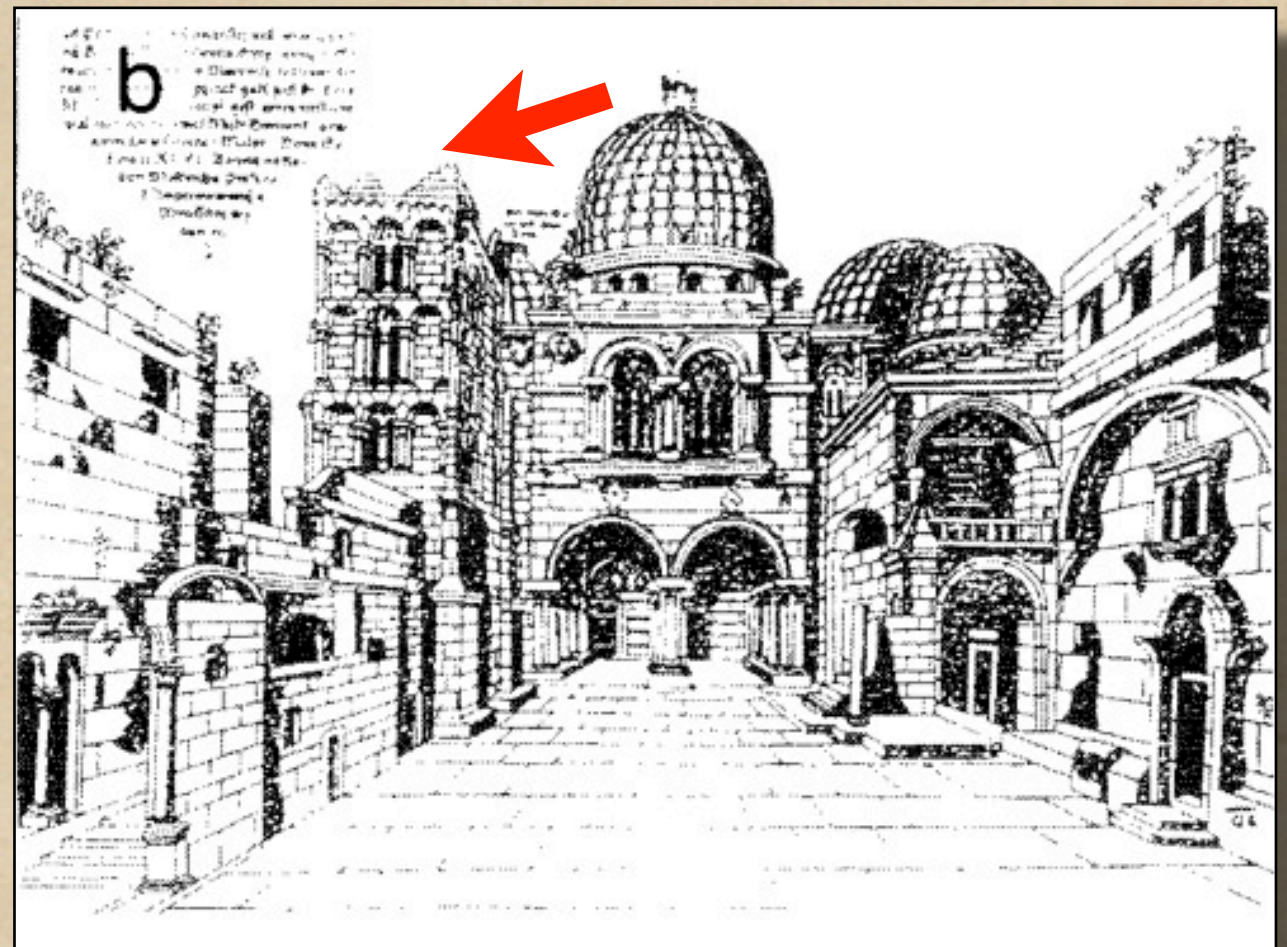
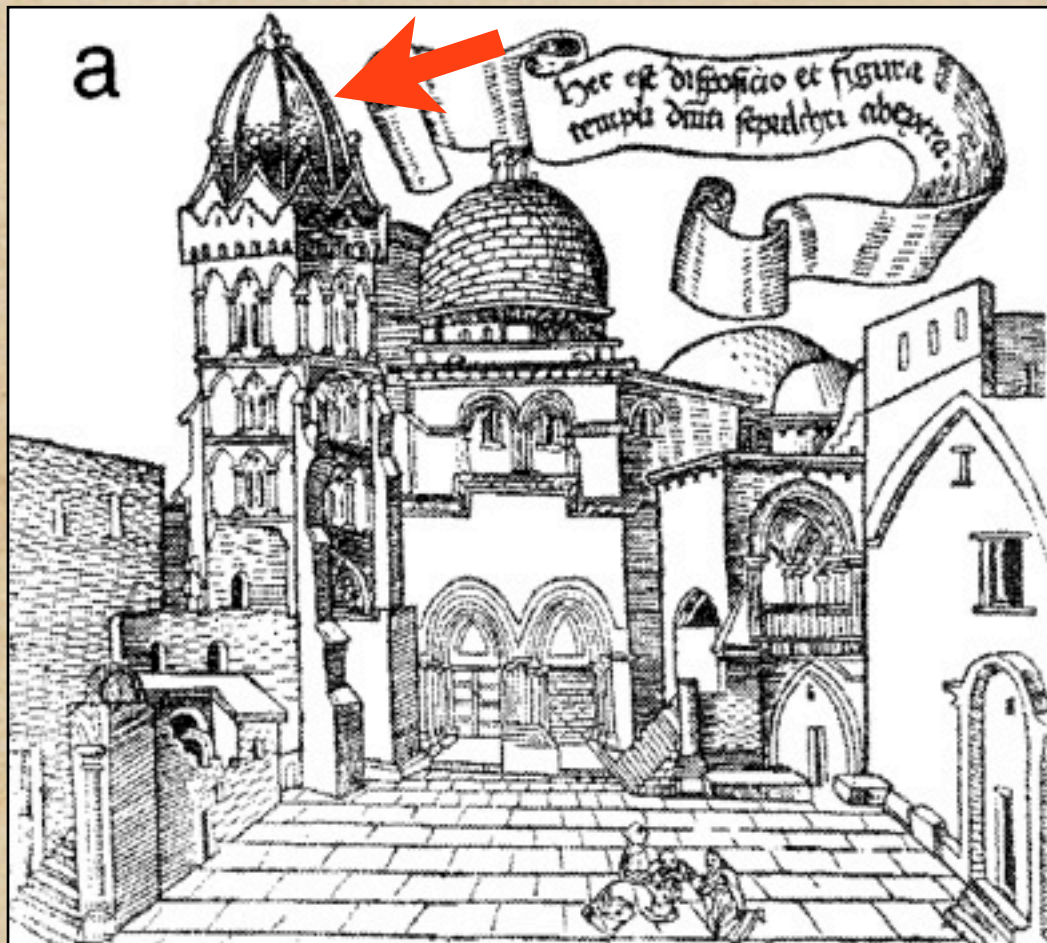
■ History ~3000 years

Geology ~280,000 years

Questions:

- Can we trust historical accounts of earthquakes?
- Are the historical earthquake catalogues complete?
- How can we reconcile different records?
- How can we use the data to better understand tectonics and earthquake occurrence?

Example: The Holy Sepulchre was reported as
“totally destroyed” after the 1546 earthquake



Before ... andThree months after the earthquake

Seismosleuthing: Ambraseys and Karcz 1992

Off-Fault earthquake damage

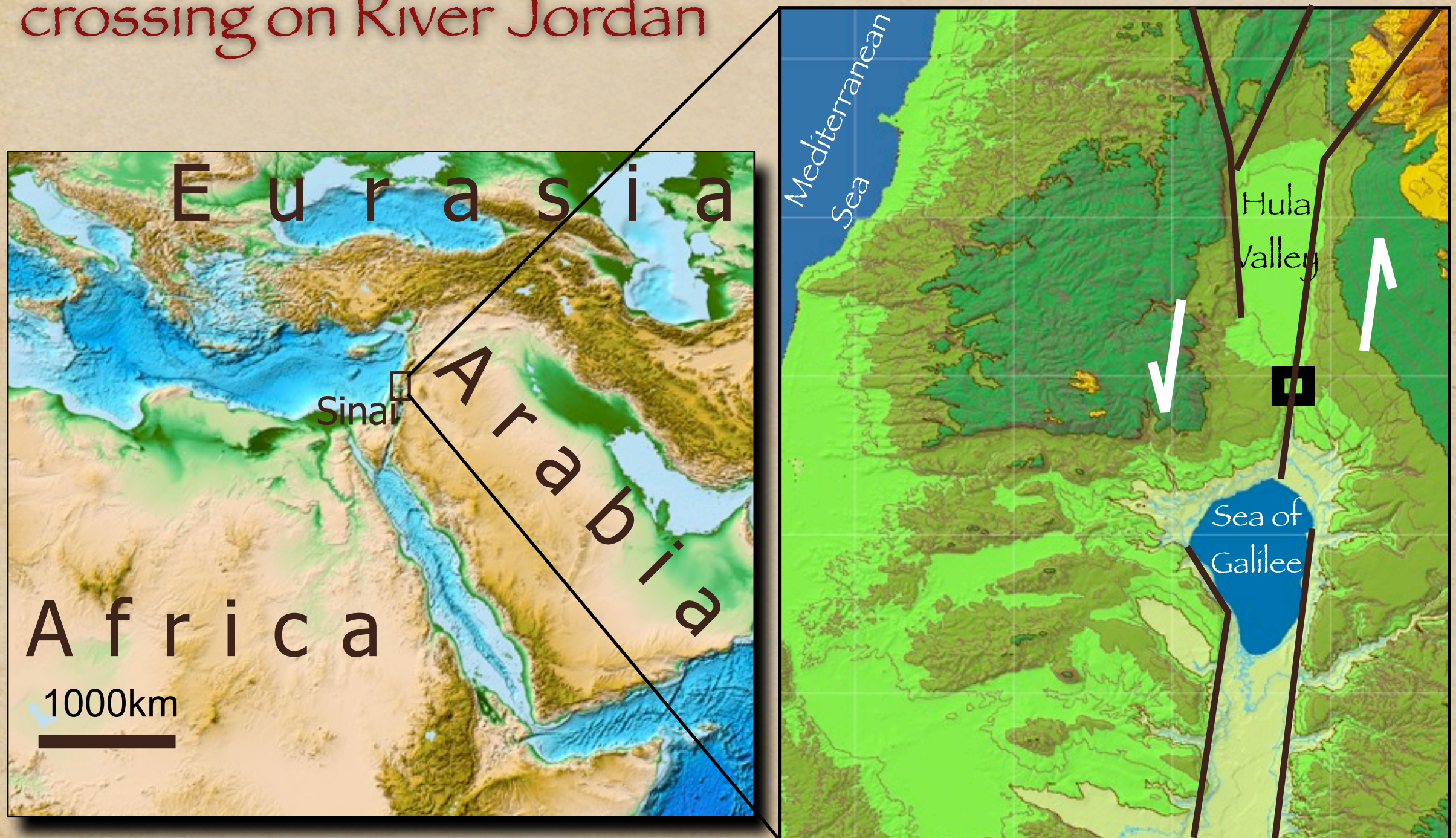


Crusader castle of Vadum Iacob (=Jacob's Fords):
Overlooking the King's Highway,
between the Hula swamps and
the Jordan Gorge



■ Crusader castle of Vadum Iacob (=Jacob's Fords):

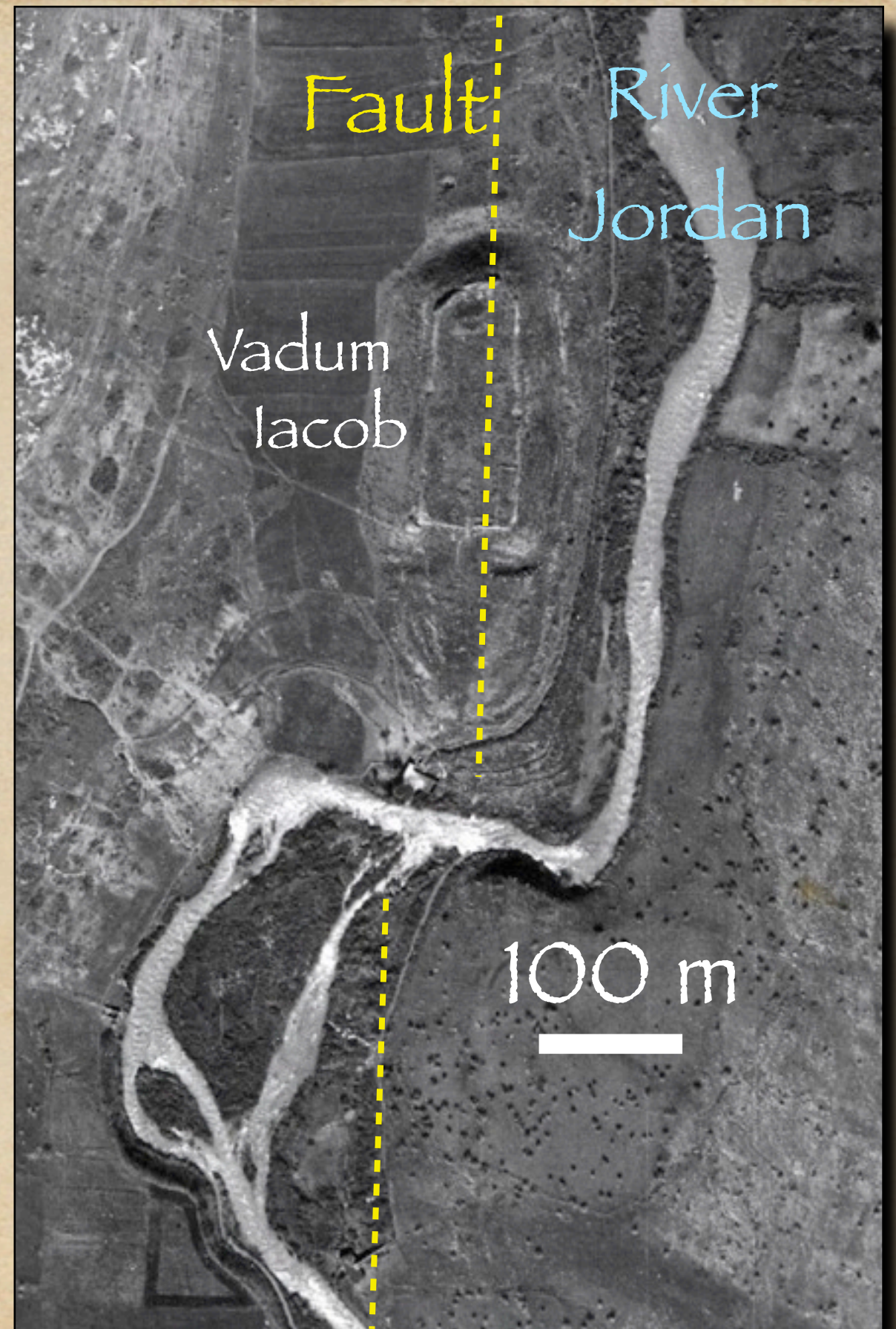
The fortress controlled strategic crossing on River Jordan



(strain gauge)

Construction began on
October 30, 1178,

Salah Al Din put siege
on 23.8.1179, conquered
and destroyed in 3 days



Vadum Iacob, 1178-1179

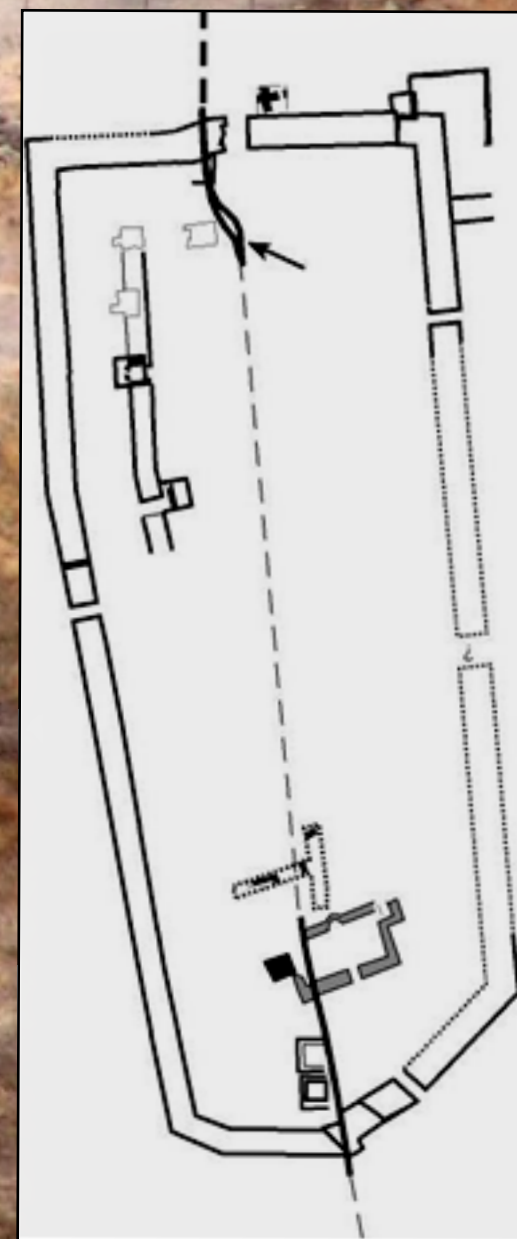
(now called Ateret)

River Jordan

South



Next



Construction ramp, outer wall



Fault - northern wall

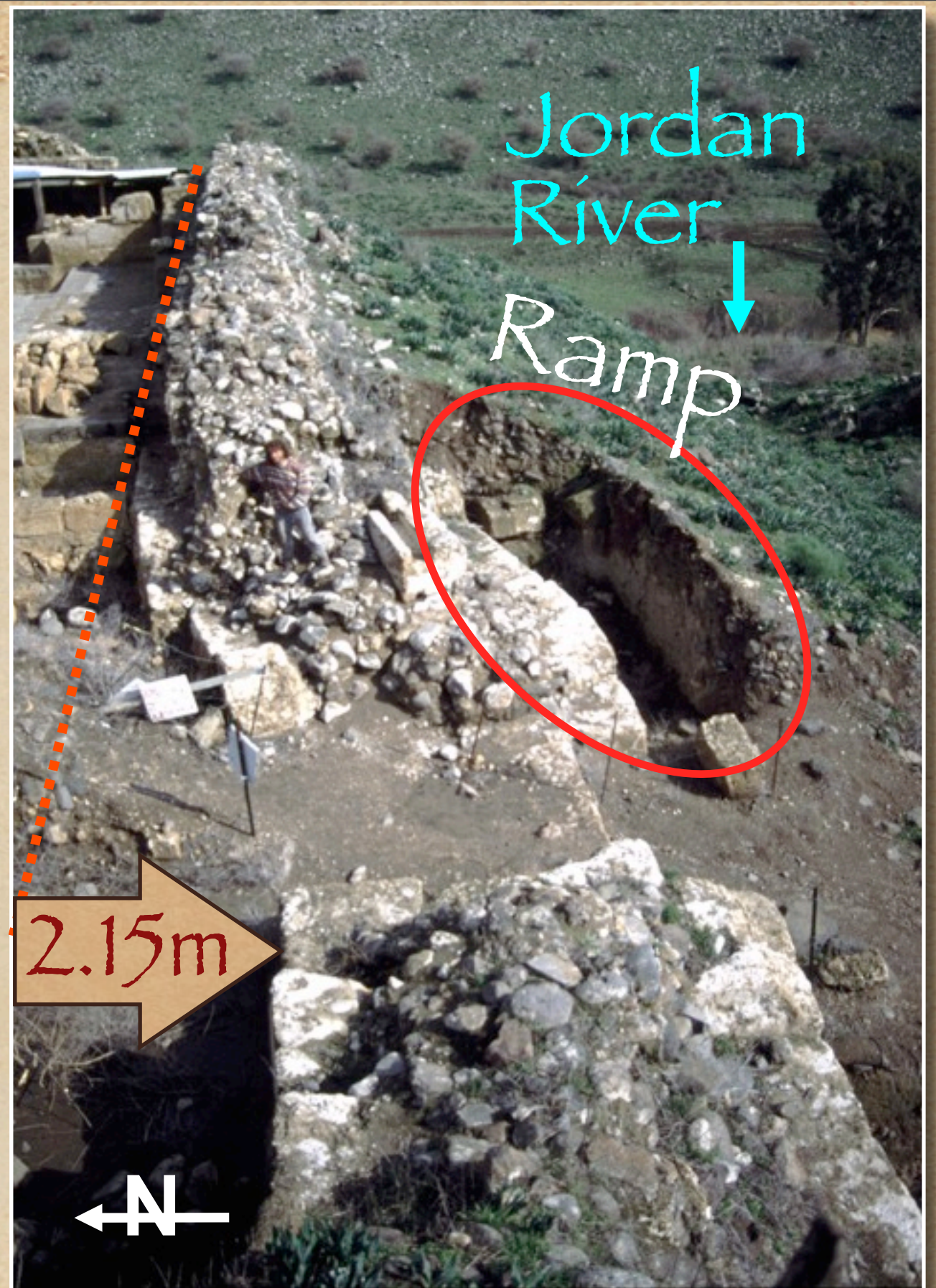


Fault - Ottoman mosque



0.5 m

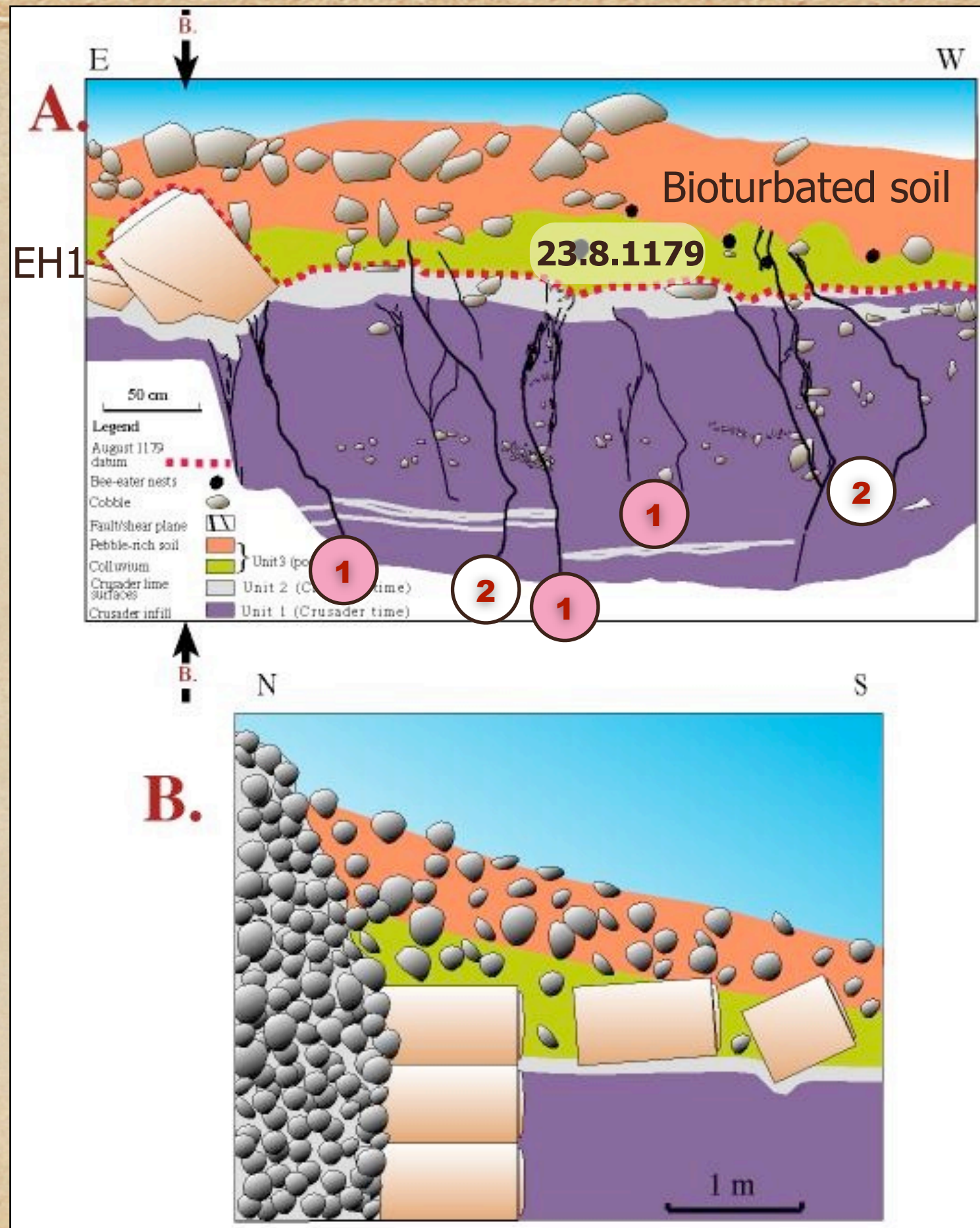
Southern wall offset



Adding history

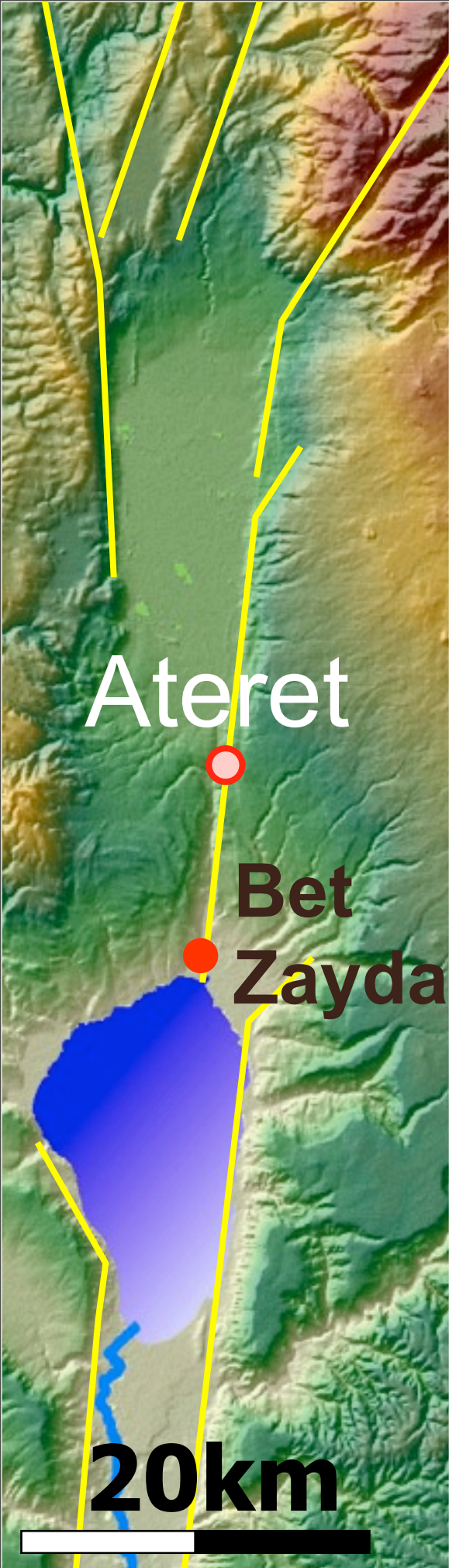
1 Event Horizon 1 (EH1),
20.5.1202

2 After deterioration of
the wall infill and
building of the Ottoman
mosque,
30.10.1759



Fault at Bet Zayda

(the site of The Miracles of the Loaves and Fishes)



Bet Zayda Buried Streams

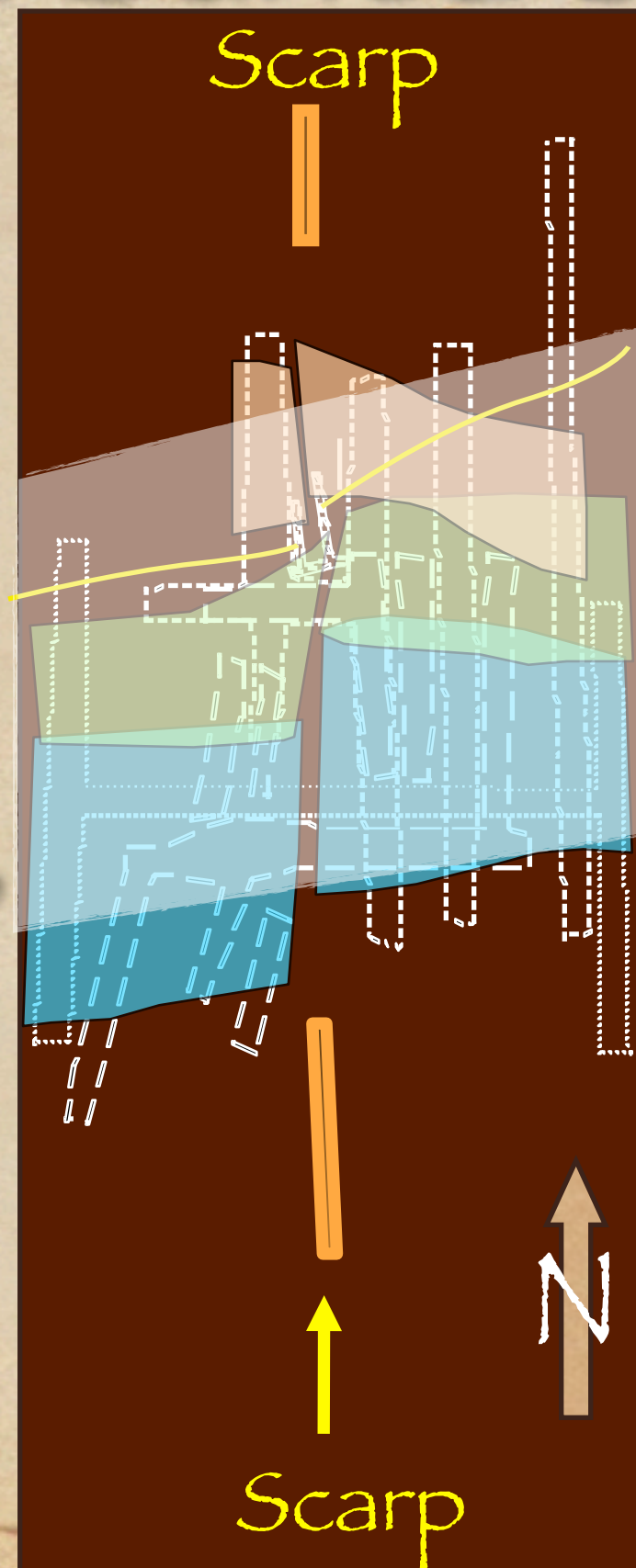
Left-lateral offsets:

2.7 m and 0.5 m.

2.2 m in the 13th
century and 0.5 m
after 1400 AD

Conform with Ateret,

Only 0.5 m
since 1202
0.06 mm/yr

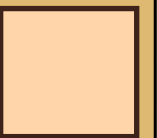


C14 ages

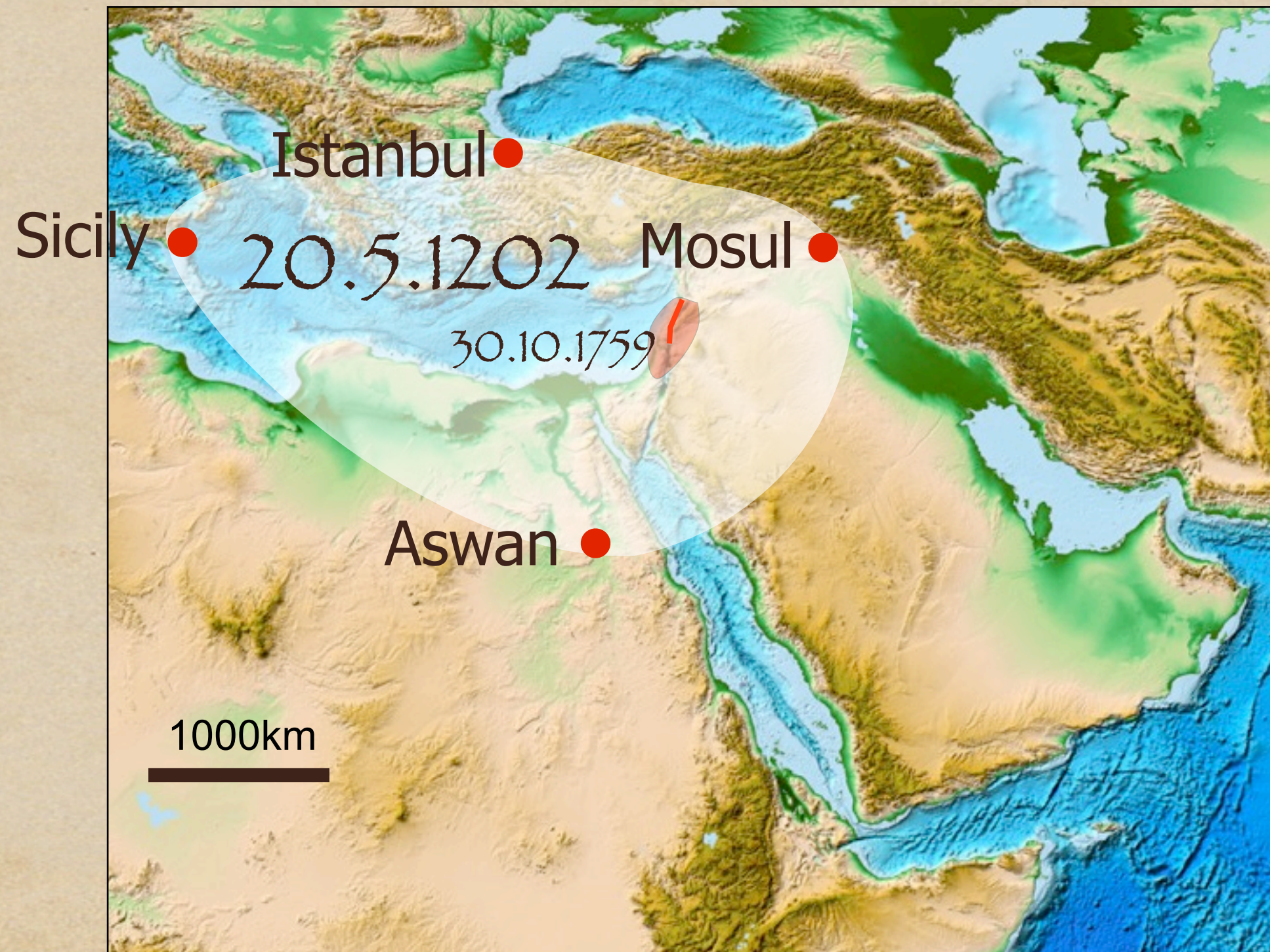
Post 1400

Pre 1700

Pre 1200



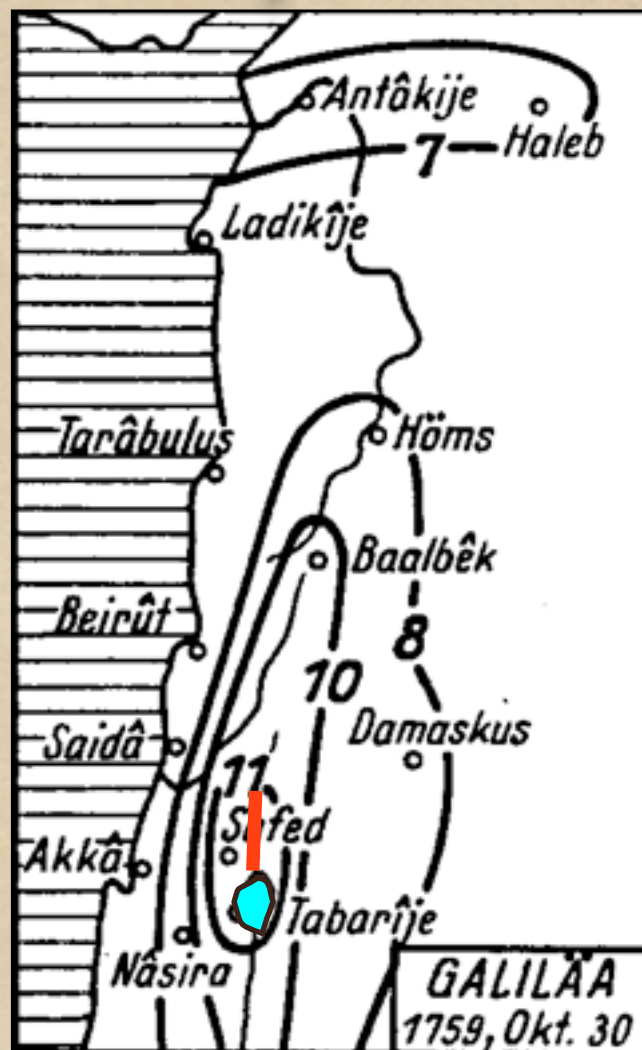
Reported zones



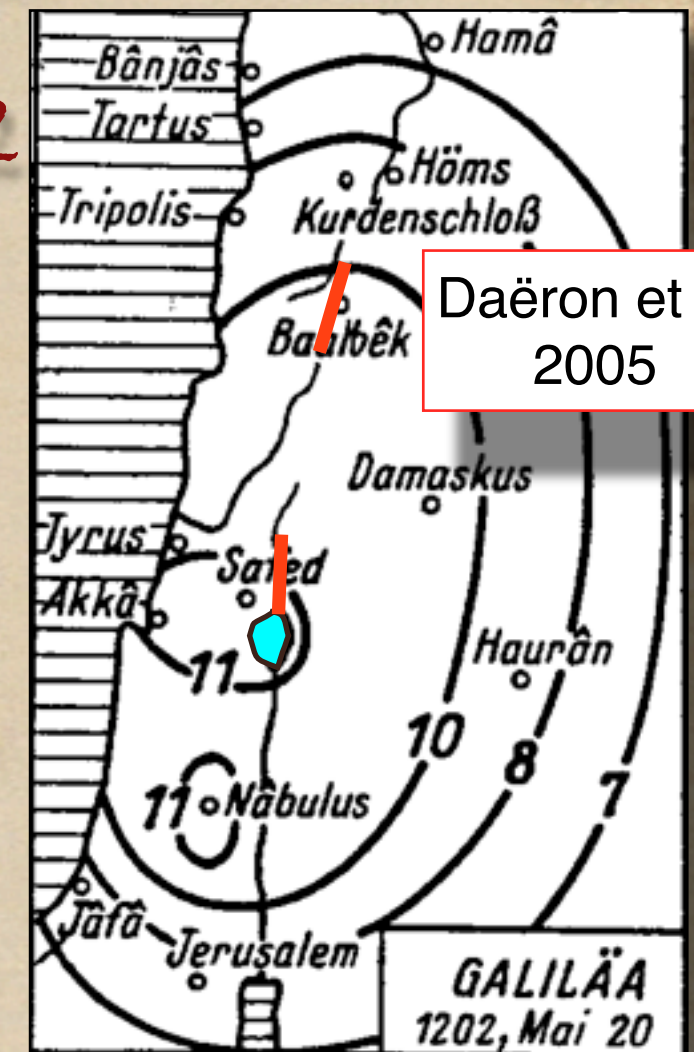
Isoseismals by Sieberg 1932

Historical data conform with paleoseismology & archaeology

10/1759



1202



Daëron et al
2005

Historical data
(Ambraseys 1988, 1989)

M6.2

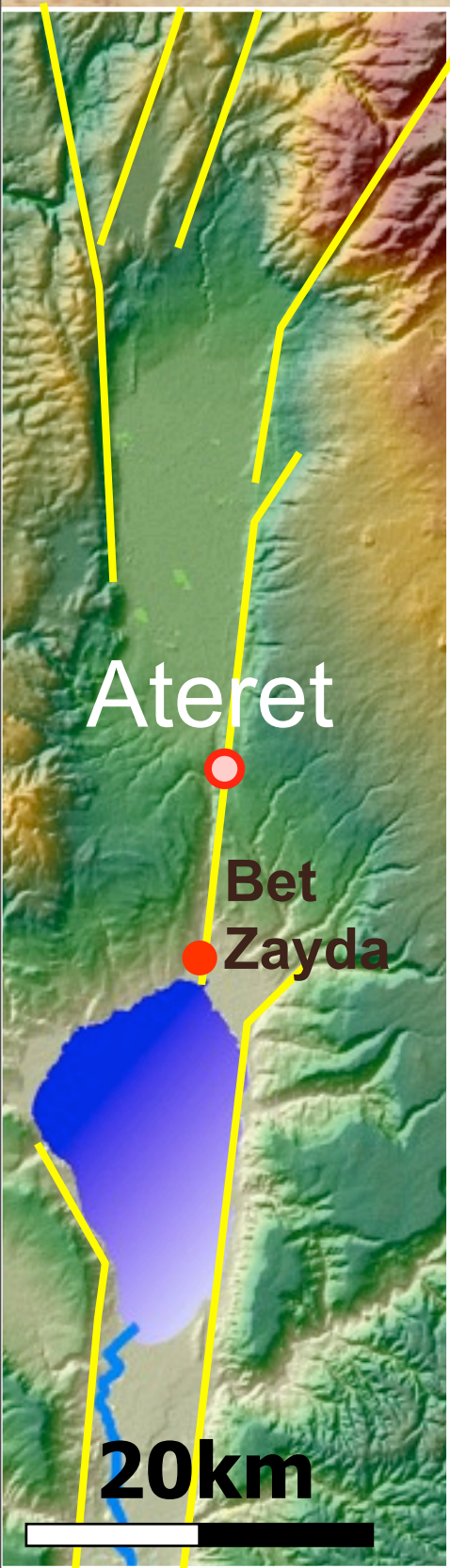
M7.6, 2m

Paleoseismic study

0.5 m

1.6m-2.2m

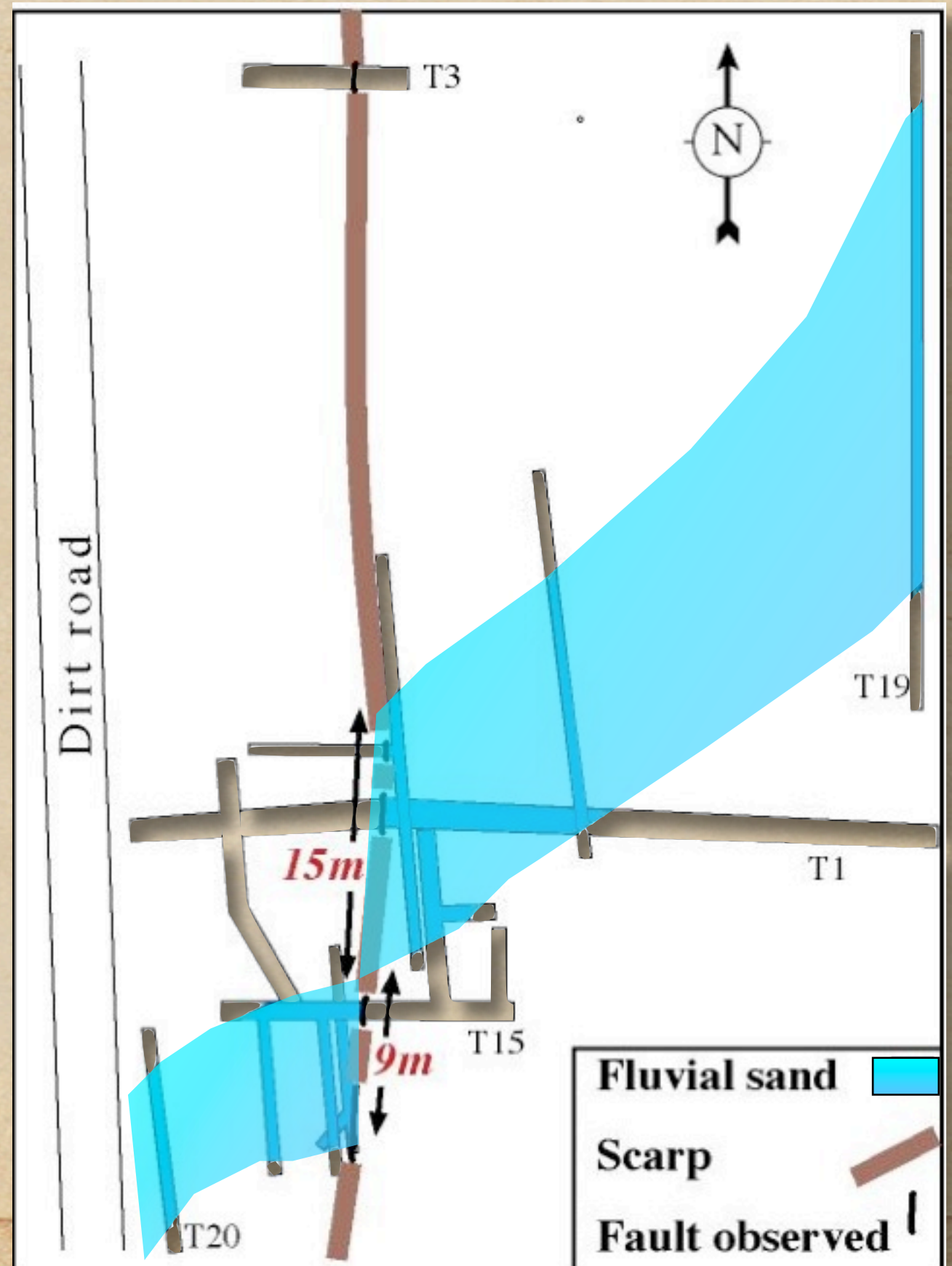
Bet Zayda Buried Streams



A stream channel
offset 15 m

^{14}C age:
 $5 \pm 0.1 \text{ ka}$ (calib.)

Mean slip rate:
 3 mm/yr



Slip rates

Long-term: ~5 mm/yr
105 km in ~20 Ma

GPS: 4-5 mm/yr

Pe'eri et al., 2002
Wdowinski et al., 2004
McClusky et al., 2003
Le Beon 2008

Westaway 2003

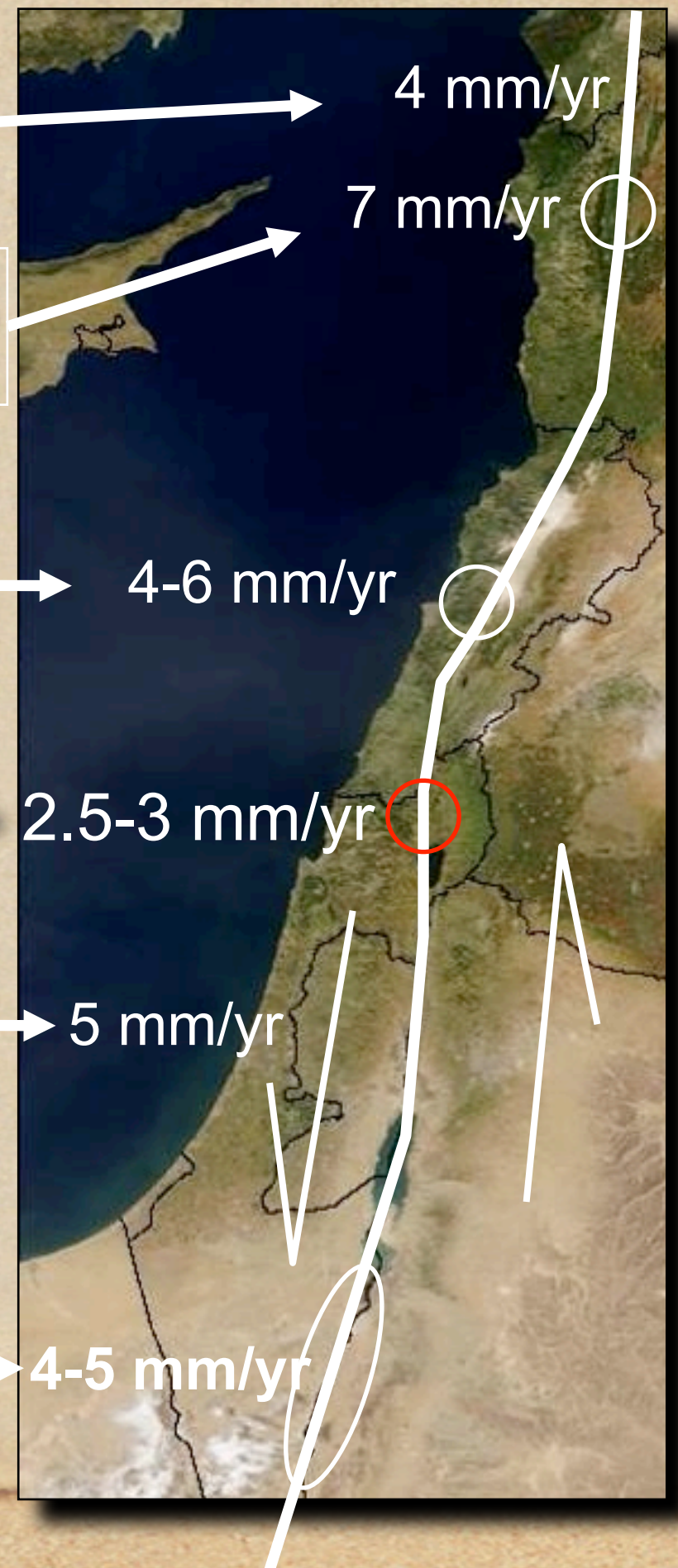
Meghraoui et al.,
2003

Daëron et al.,
2004

This study

Ferry et al., 2007

Niemi et al. 2001
Klinger et al. 2000
Le Beon 2008



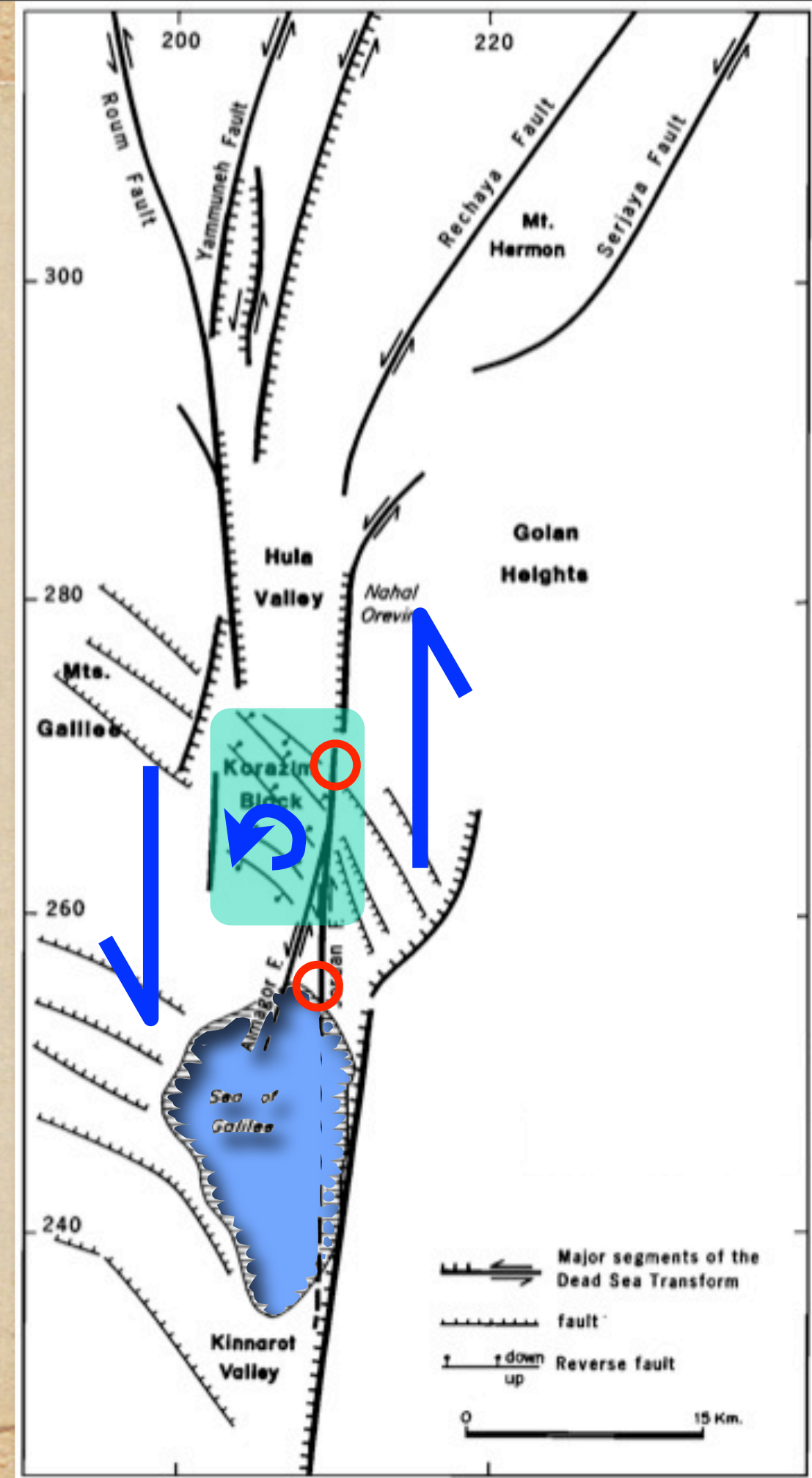
Where is the missing slip?

The missing 1-2 mm/yr
amount to 2-4 m
in the last 2 ka

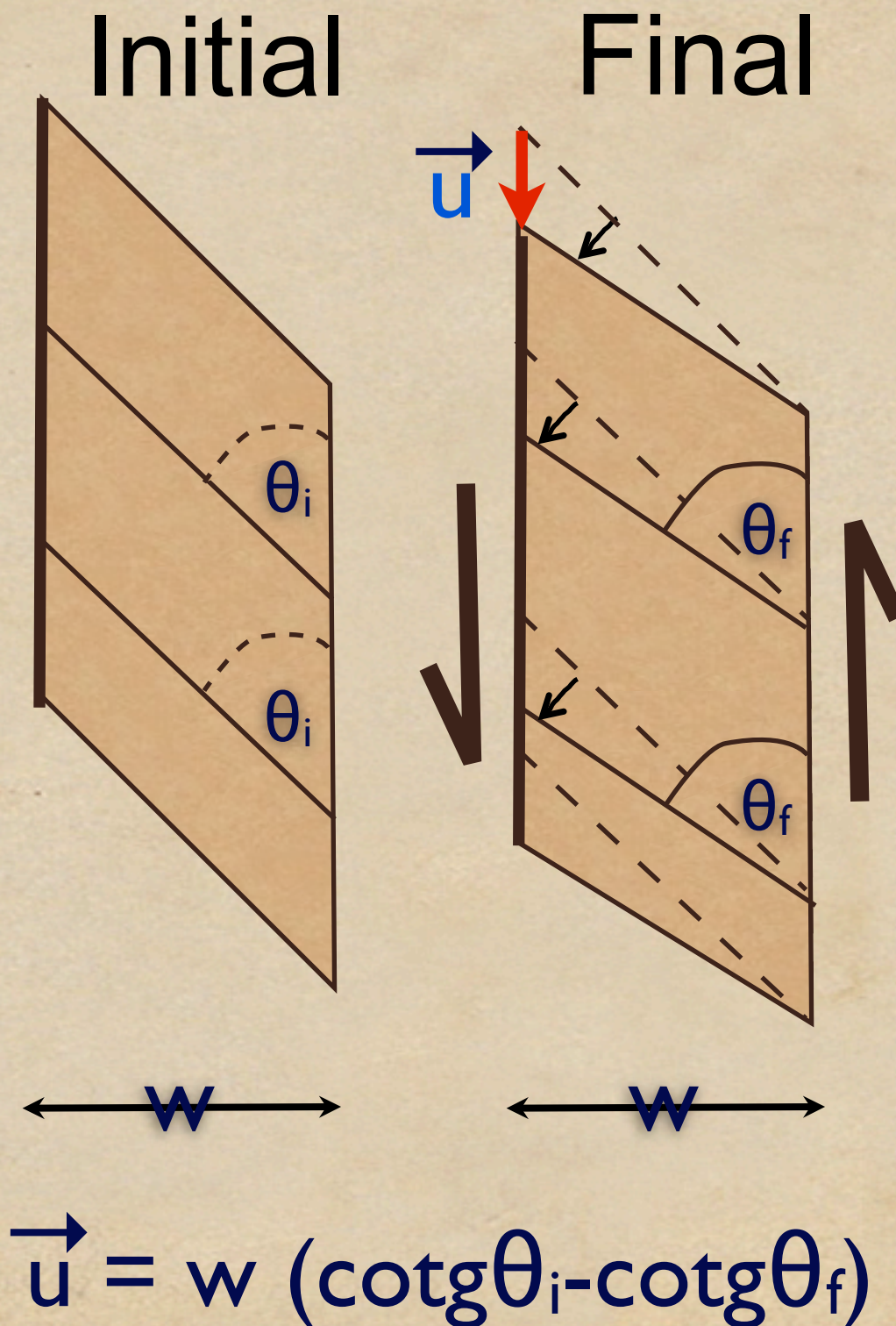
Rotations of rigid blocks about vertical axes

Heimann & Ron (1993)
paleomagnetic results:

$11.4^\circ \pm 4.0^\circ$ Counterclockwise rot.
K-Ar age of youngest basalt: ~ 1 Ma

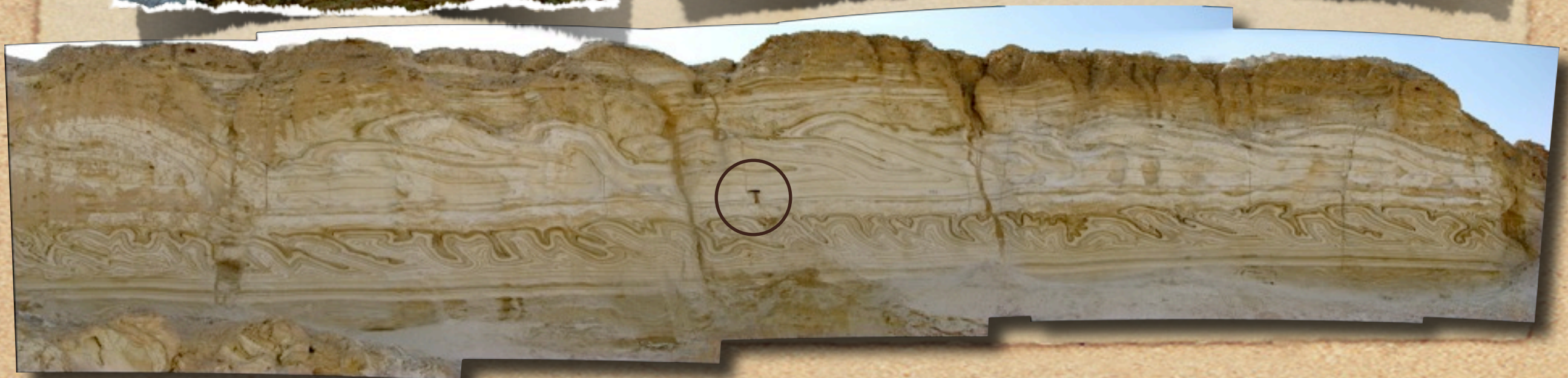


The contribution of block rotations



$w \sim 7 \text{ km}$
 $\theta_f \sim 45^\circ$
 $\theta_i \sim 34^\circ \pm 4^\circ$
 $5 \text{ km} \geq \vec{u} \geq 3 \text{ km}$
 in 1 Ma,
 corresponding to
 $10 \text{ m} \geq \vec{u} \geq 4 \text{ m}$
 in 2 ka

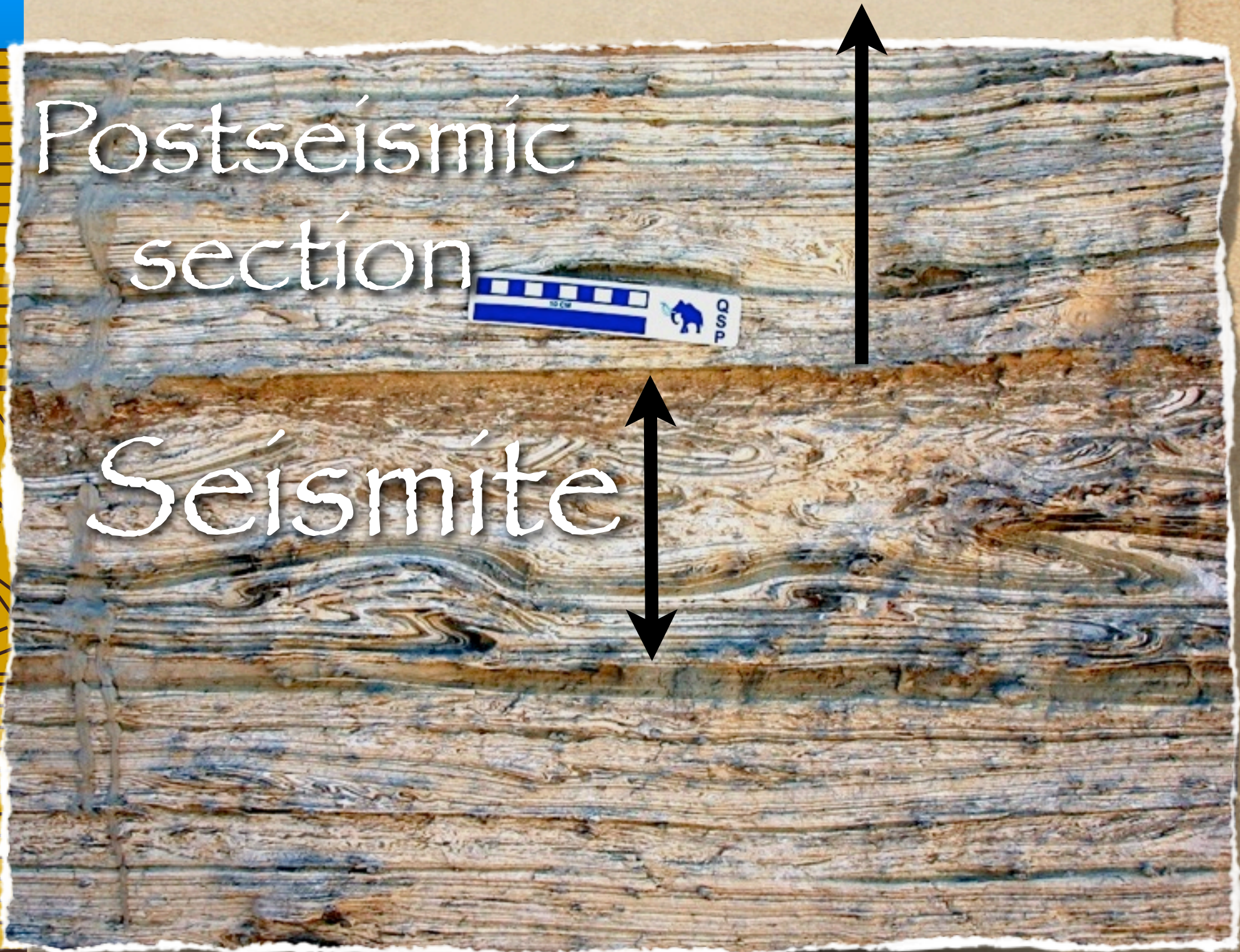
...and now we add Late Pleistocene seismites



Breccia layers - the interpretation

Postseismic
section

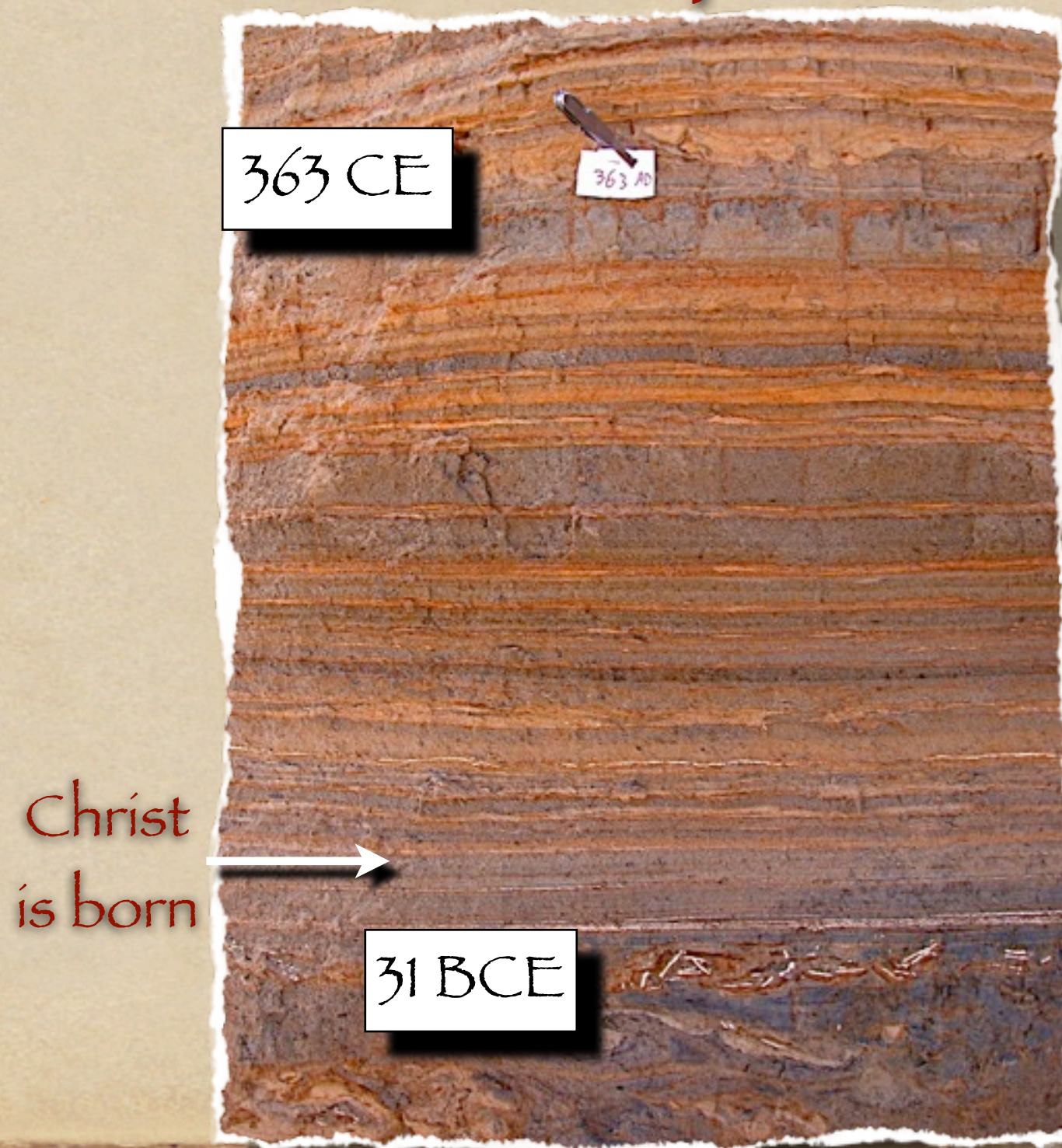
Seismite



Seismites associated with surface ruptures $M \geq 6$ earthquakes

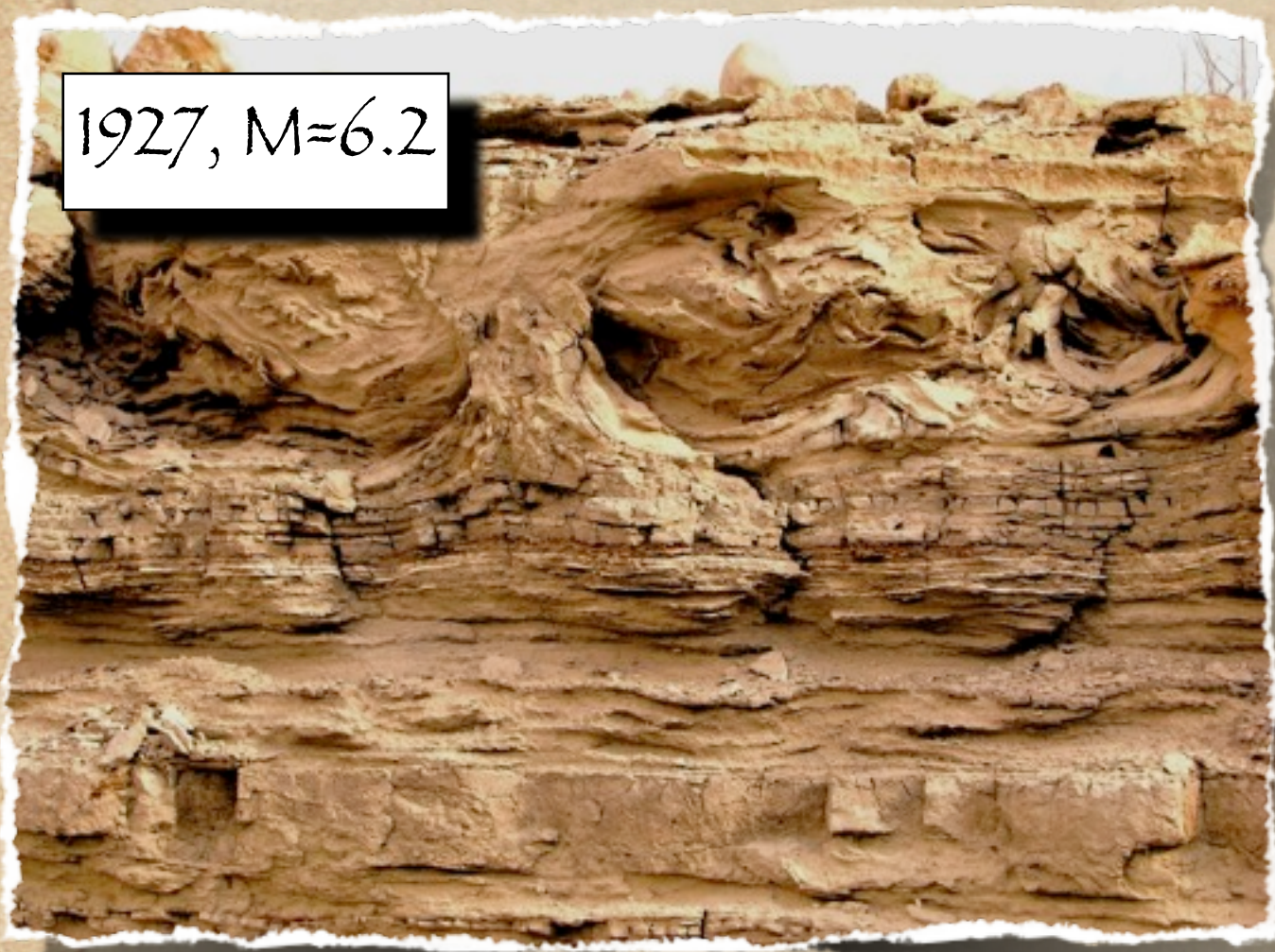


Last 3 millennia-seismite ages correlate with historical earthquakes

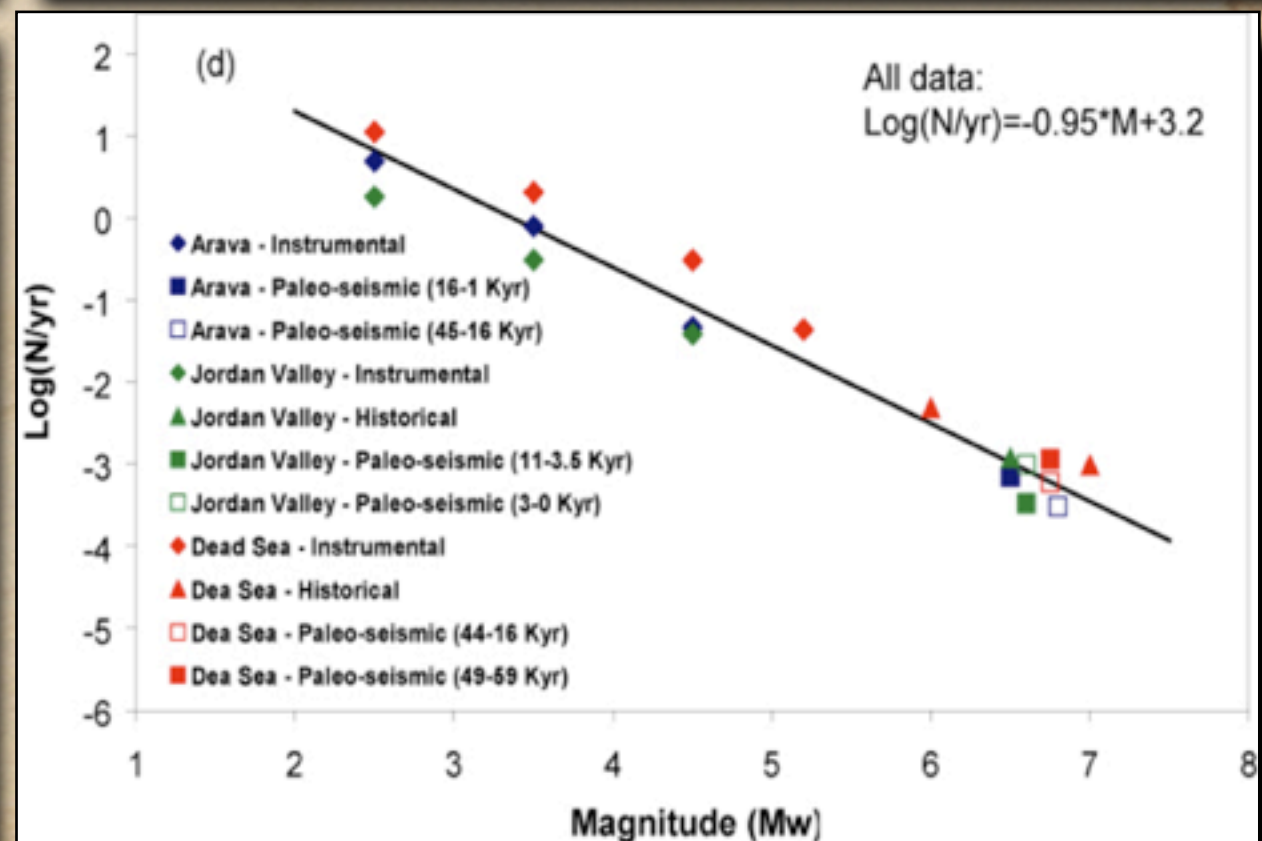
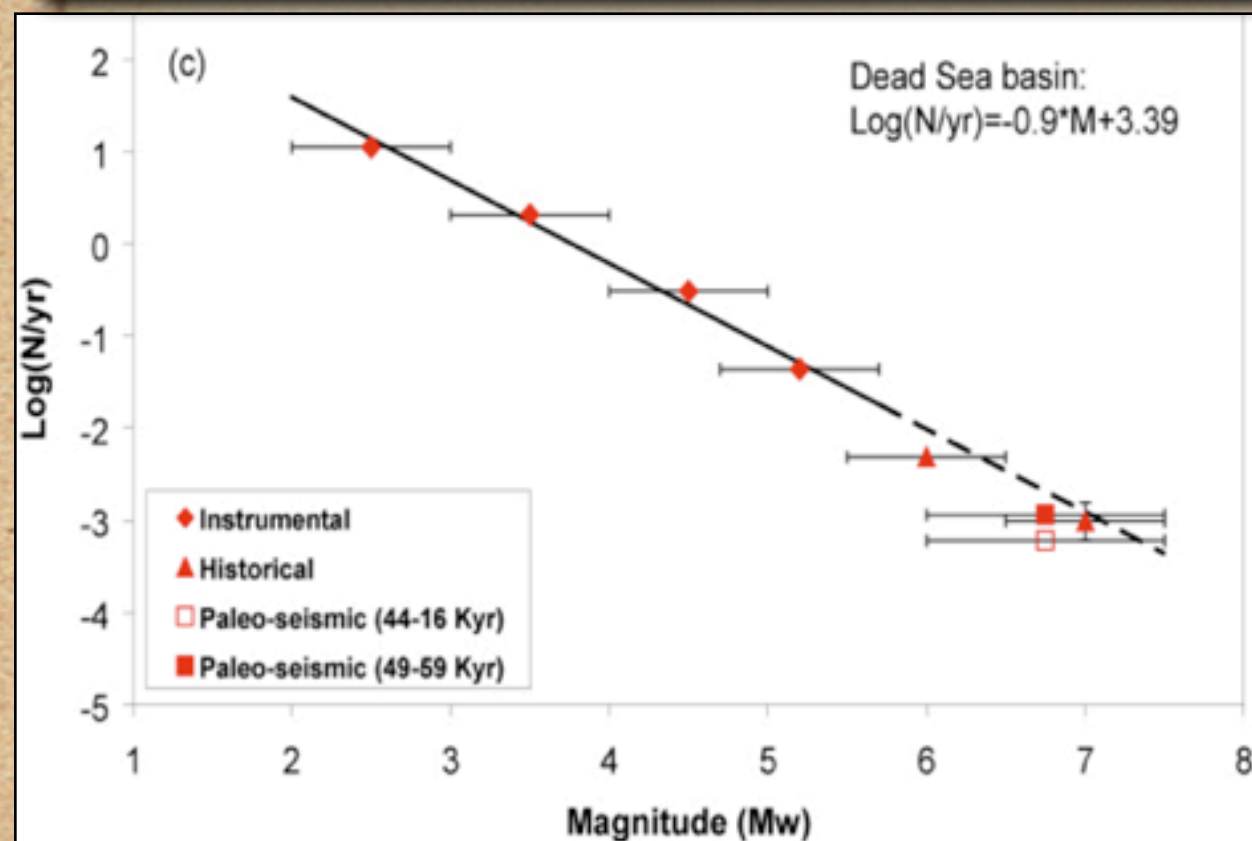
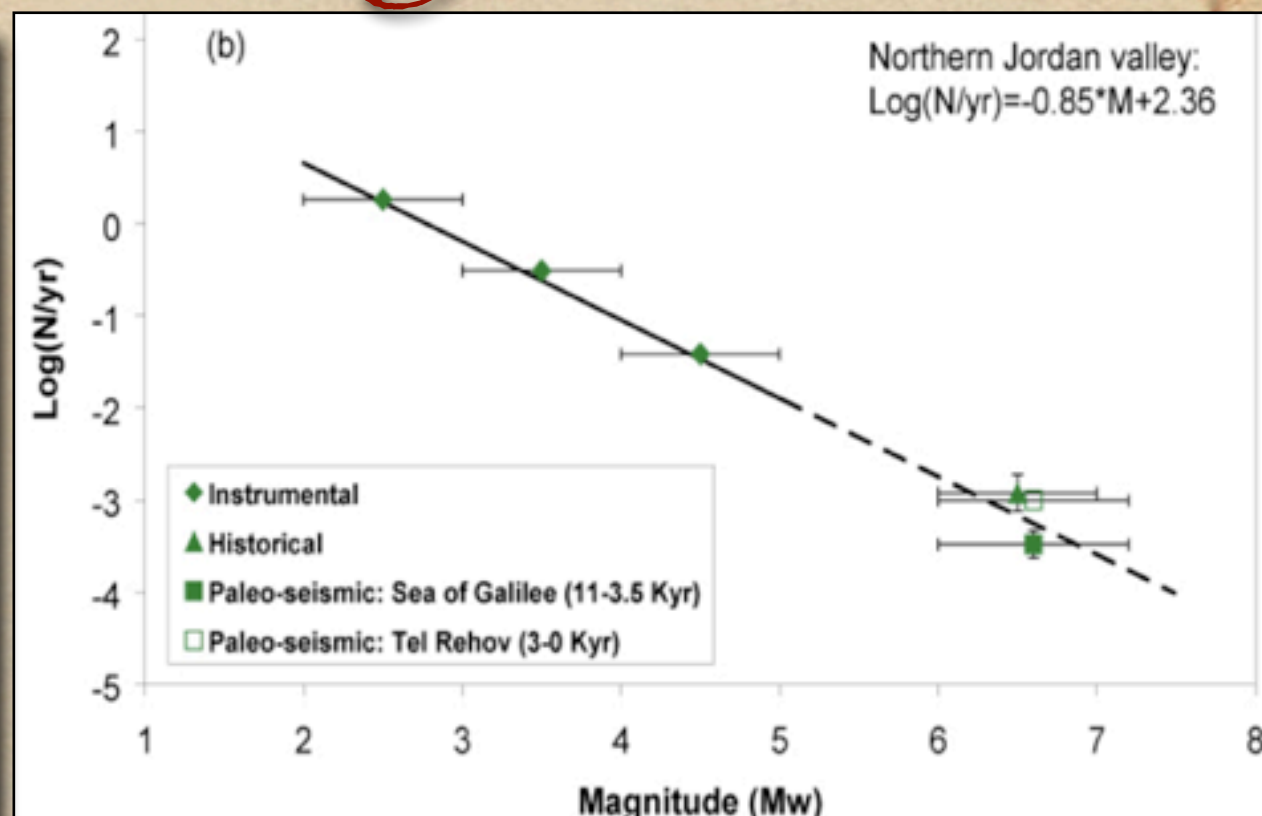
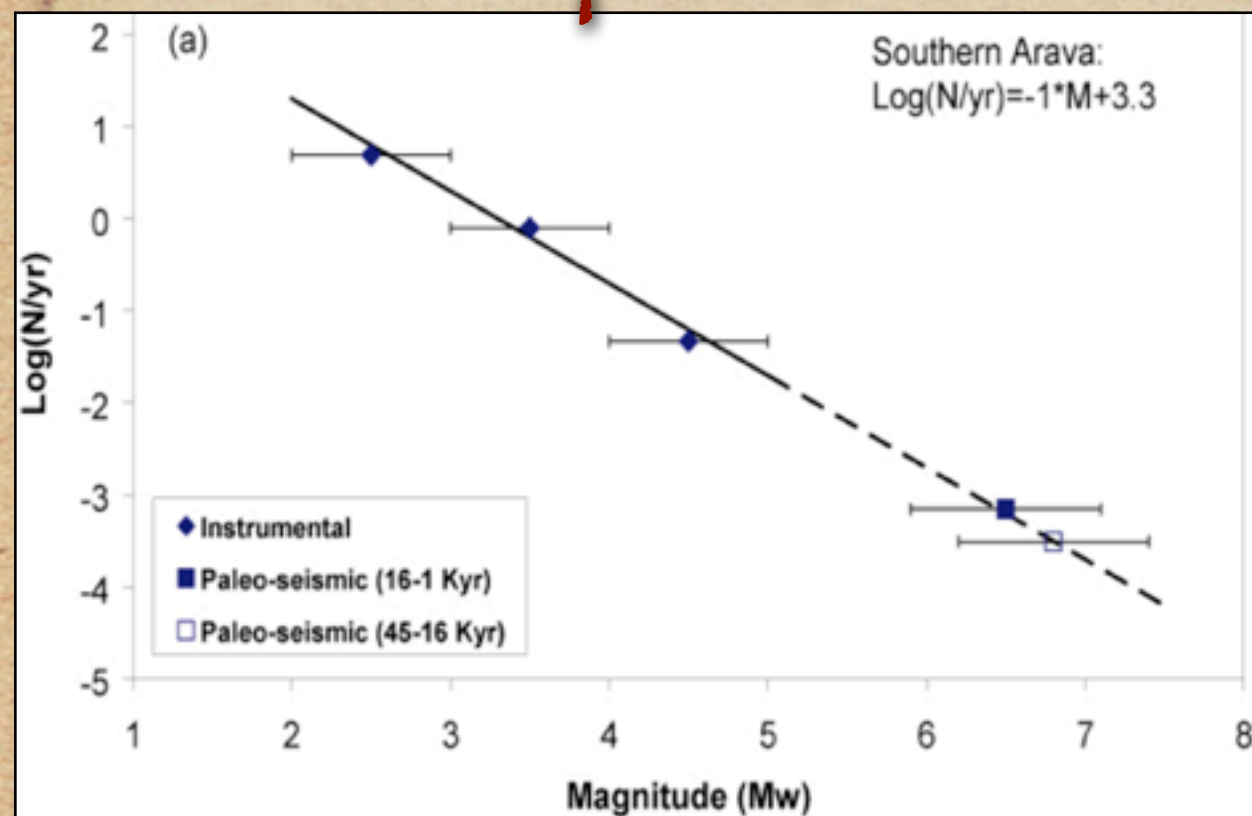


July 11, 1927, M6.2: photos, reports, seismogram, and seismites

1927, M=6.2



...put all the data together



Hamiel et al. 2009, BSSA

Conclusions - Earthquakes

- ★ The earthquakes of 1202 and 1759 displaced the Jordan Gorge segment by 2.1-2.7 m.
- ★ Observations are largely in agreement with interpretations of historical accounts.
However,
An Hellenistic period earthquake with surface rupture is poorly recorded in history.
- ★ Gutenberg-Richter magnitude frequency has been the typical earthquake behavior in the past 70 ka.

Conclusions - Tectonics

- ★ A localized total of 6 m of displacement in the last 2100 yrs accounts for ~60% of the long-term rate. The rest may be accounted for by distributed deformation (e.g., block rotations).

Merci beaucoup!

