



**The Abdus Salam
International Centre for Theoretical Physics**



2060-37

**Advanced School on Non-linear Dynamics and Earthquake
Prediction**

28 September - 10 October, 2009

Archaeoseism: Past Earthquakes Recorder by Man-made structure

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ARCHAEOSEISM: PAST EARTHQUAKES RECORDED BY MAN-MADE STRUCTURE

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THE HEBREW UNIVERSITY,
JERUSALEM

Advanced School on Non-Linear Dynamics & Earthquake Prediction
ICTP 28 September - 10 October 2008.

AGENDA

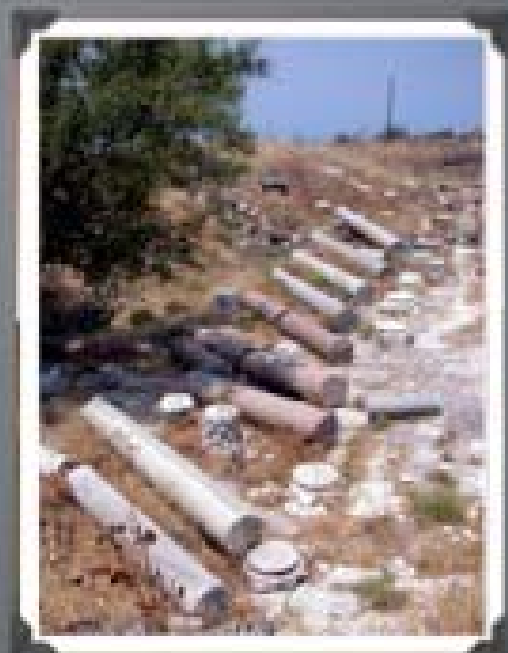
- Radiation - shock: fallen (originally) vertical elements (columns, walls)
- Radiation - shaking: Dynamic trajectories
 - keystones, fractures, asperities
- Source: dislocated reference lines:
 - walls, floors, sea level
- Timing

RADIATION - SHOCK

- fallen (originally) vertical elements
 - columns
 - monoliths: impact, fracture, footings
 - fragmental
 - walls
 - unidirectional collapse

MONOLITH COLUMNS

DIRECTIONAL
FALLING;
OFFSET FROM
DAMAGED
PEDESTALS



Marco, Hartal, Hazan, Lev, Stein
2003

Susita/Hippos



Petra:
Temple of Winged Lions



Destroyed
late 4th century AD

fragmental columns



Great Temple
destroyed 5th
century AD



tilting ($\sim 10^\circ$), damaged pedestal

RADIATION - SHOCK

- fallen (originally) vertical elements
 - columns
 - monoliths: impact, fracture, footings
 - fragments
 - walls
 - unidirectional collapse

Montfort, Crusader



quake or war?

Tel Safi, Late Bronze Age



bricks, fallen northward - quake or deterioration?

Vadum Iacob
constructed and demolished 1179, hit by quake 1202



ashlars cast in order, collapsed vault



Qadesh
Hellenistic

E-W walls fallen

*N-S walls standing
and extended*



**MEGIDDO
IRON AGE**

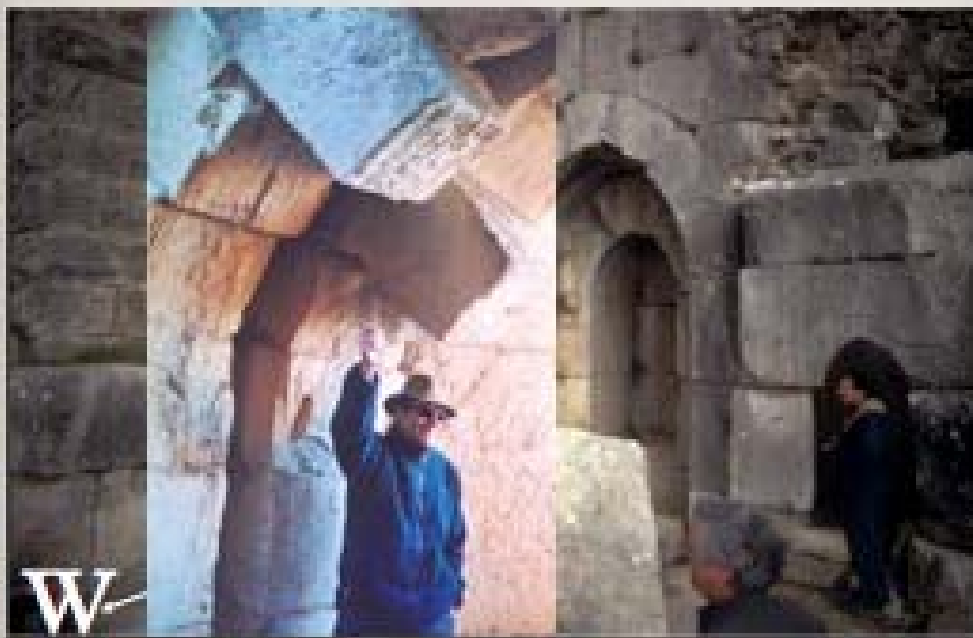
*tilted wavy walls;
cracked building stones*

Marco, Agnon, Finkelstein,
Ussishkin, 2006

AGENDA

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QAL'AT SUBEIBA (NIMROD)



*E-W keystones
shifted
NS arches
keystones
intact*

*inverted in some
towers*

*shaking or
multiple shocks?*

Monfort, Crusaders



cracked corners





through-going cracks

El Hazneh, Petra,
Jordan



cracks through bedrock

Minia, Ummaid (748 AD)



asperity - dynamic trajectory

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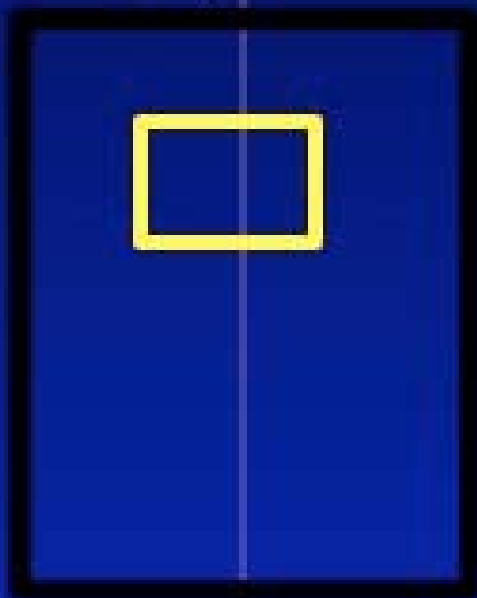
Vadum Iacob: 3 millennia history of ruptures

Ellenblum, Agnon, Marco,
Rockwell, Boas, 1998



Archaeology+History:

1.6 m offset



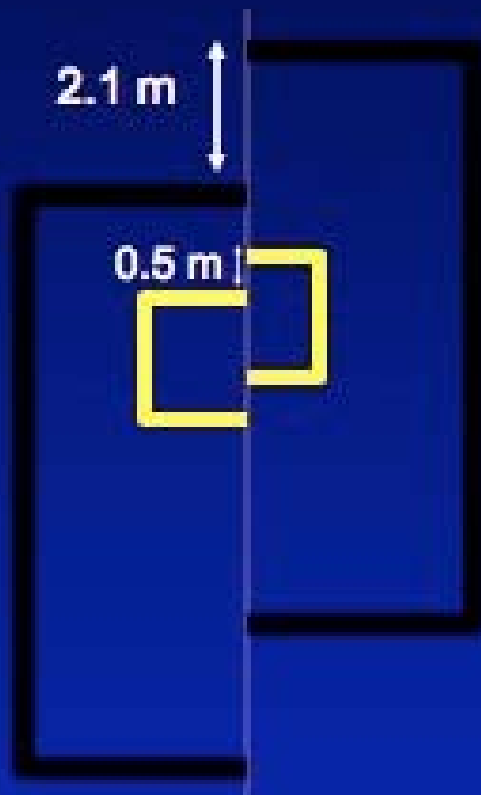
20.5.1202 "at dawn"

1.6 m offset

16-17th century
Mosque was built

Ellenblum, Agnon, Marco,
Rockwell, Boas, 1998

Archaeology+History:



20.5.1202 "at dawn"

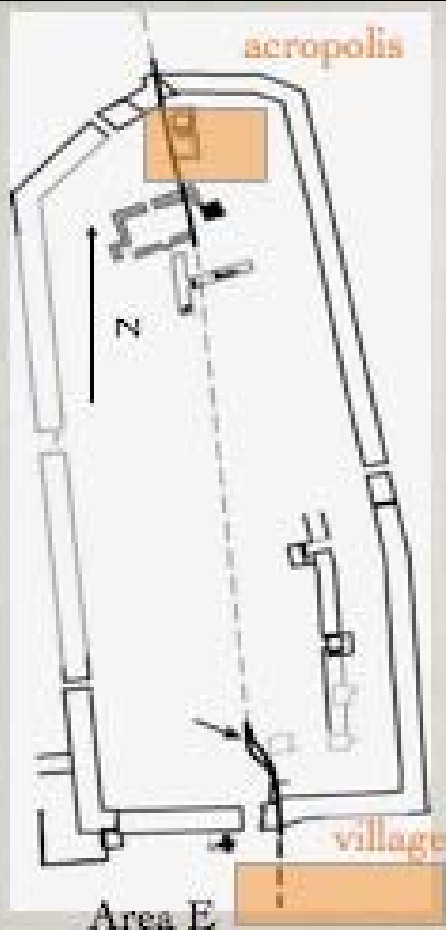
1.6 m offset

16-17th century

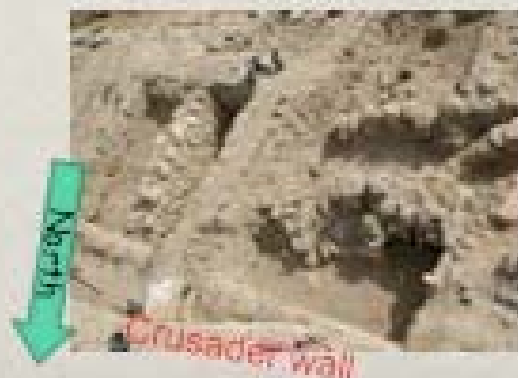
Mosque was built

30.10.1759

0.5 m offset



HELLENISTIC LOCII AT VADUM IACOB



Two construction phases in the Hellenistic period, Ateret



New findings

2006 excavations:
Hellenistic complex

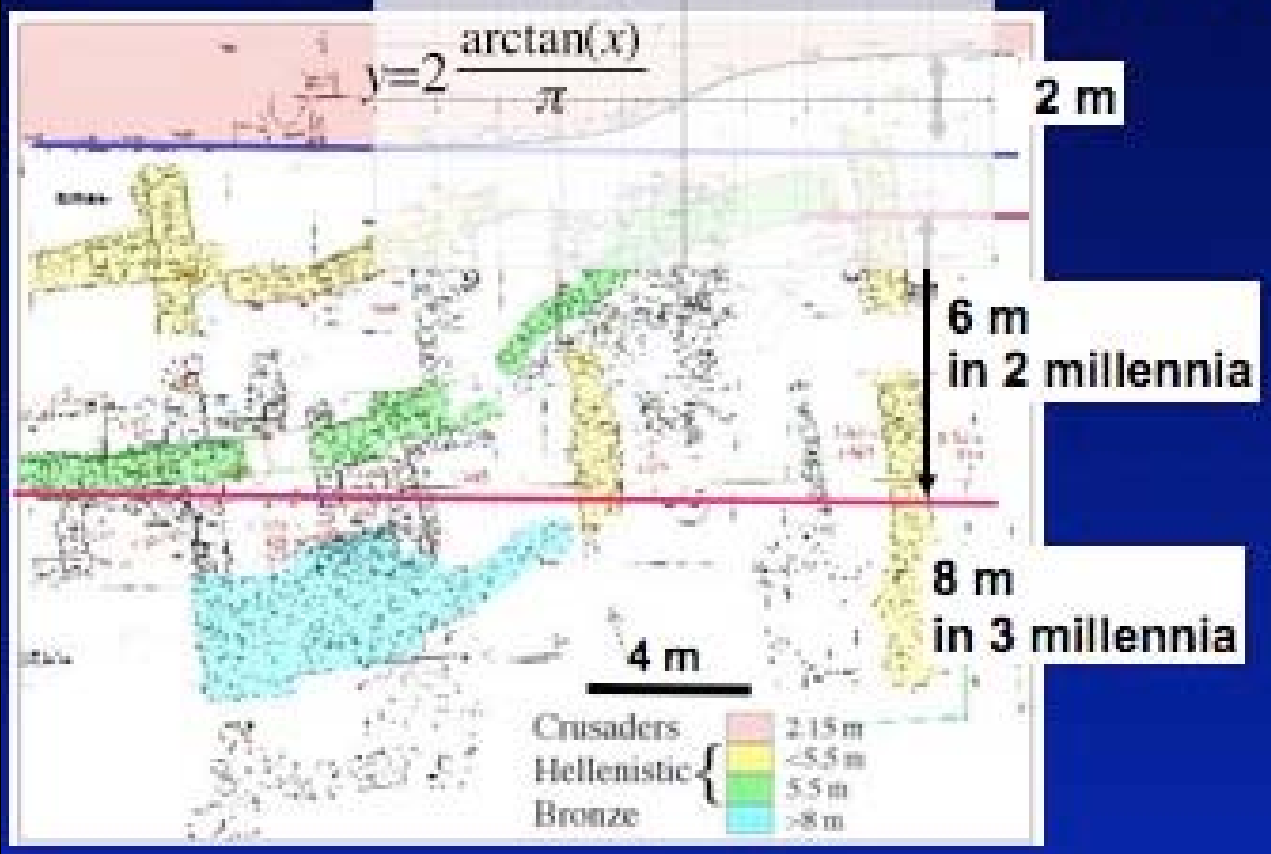


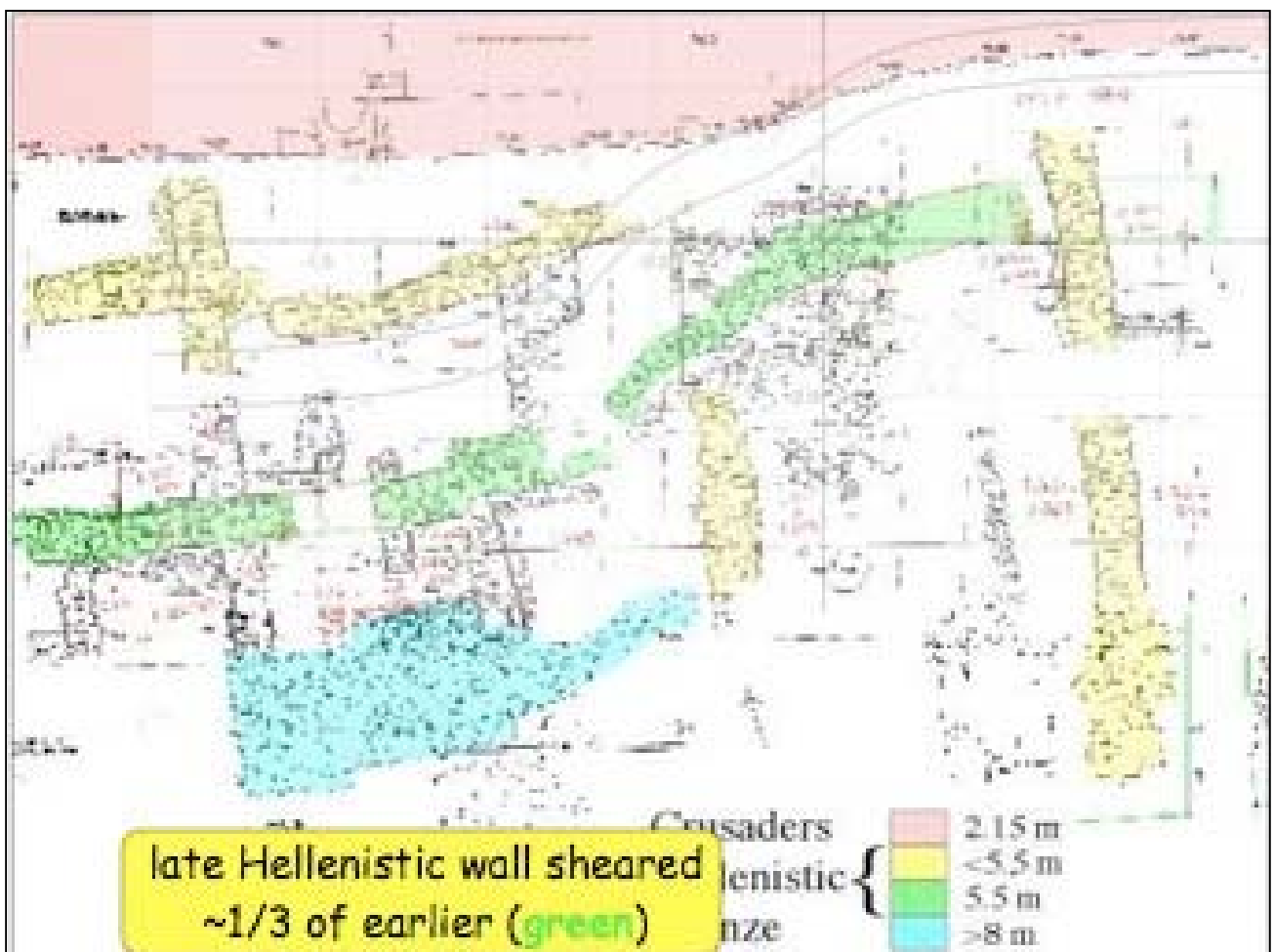
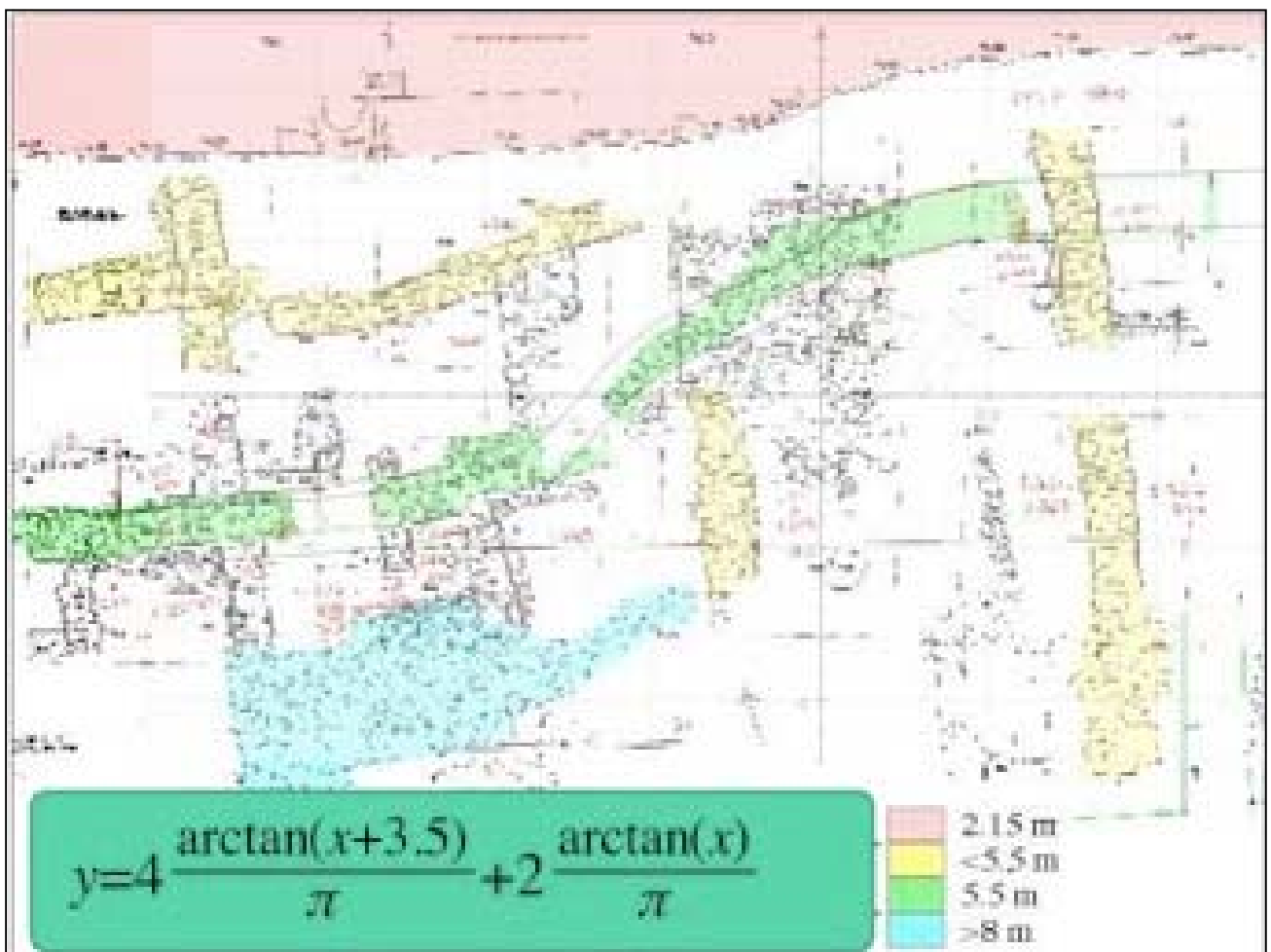
2006 excavations: Hellenistic complex

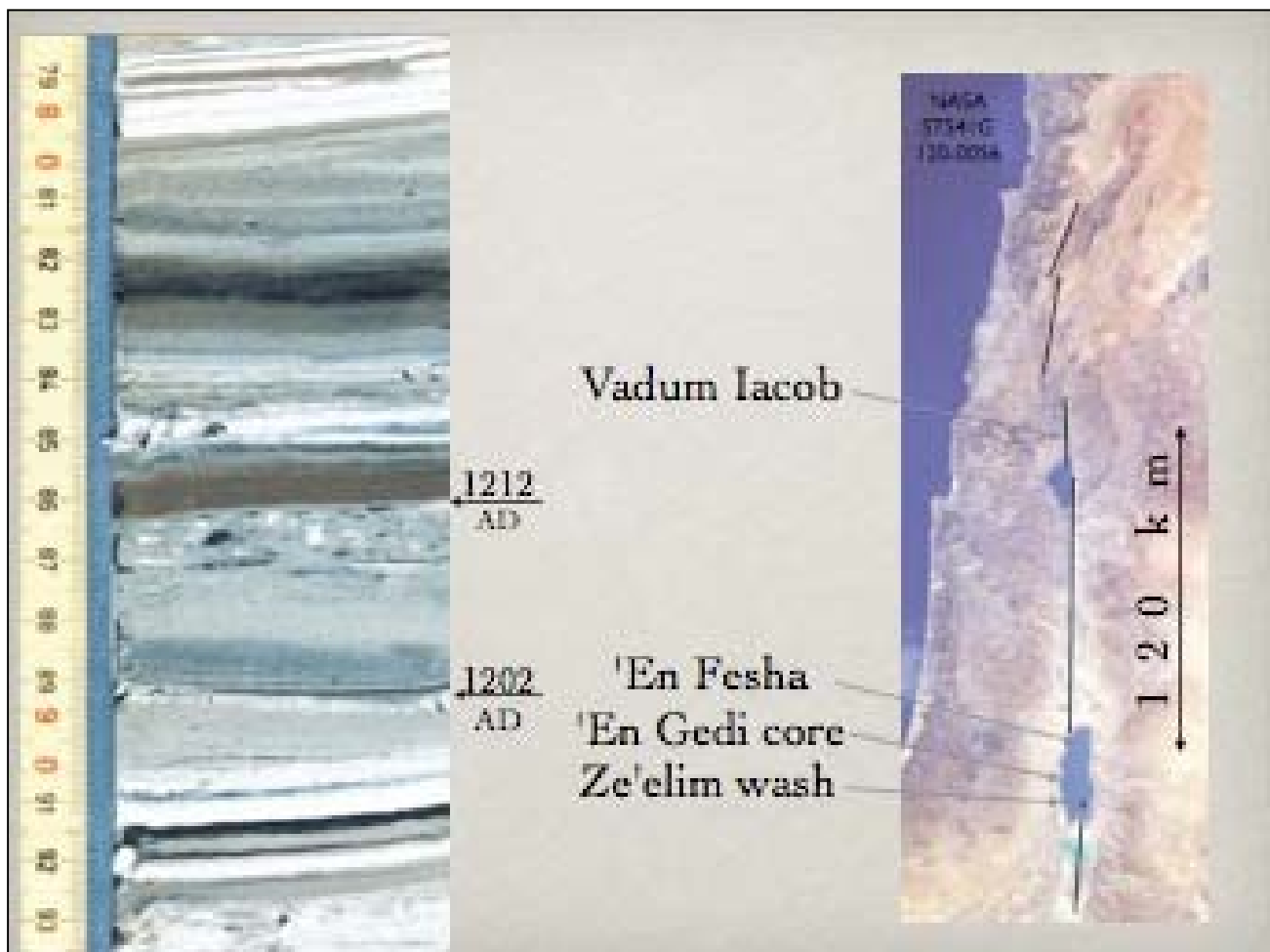


Hellenistic Period Earthquake !?

SEQUENCE OF DEFORMATION EVENTS



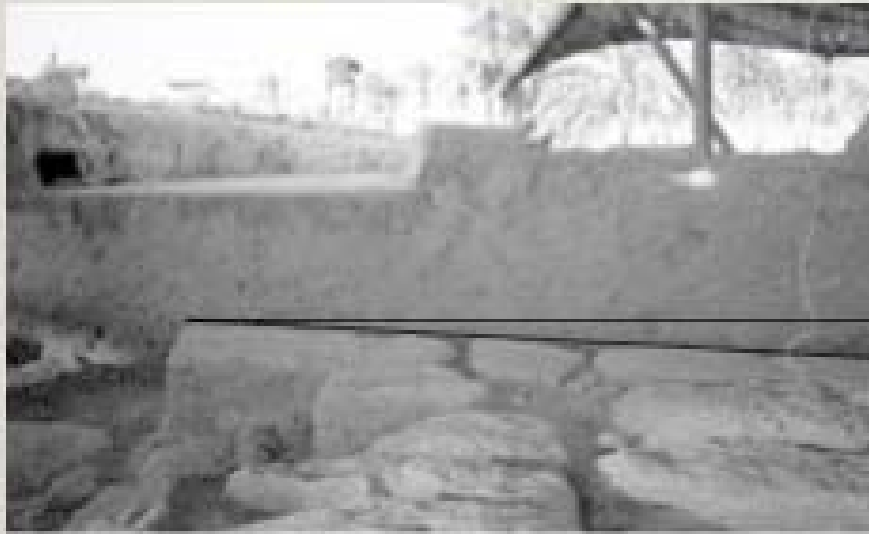




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Megiddo, Iron Age



Marco,
Agnon,
Finkelstein,
Ussishkin,
2006

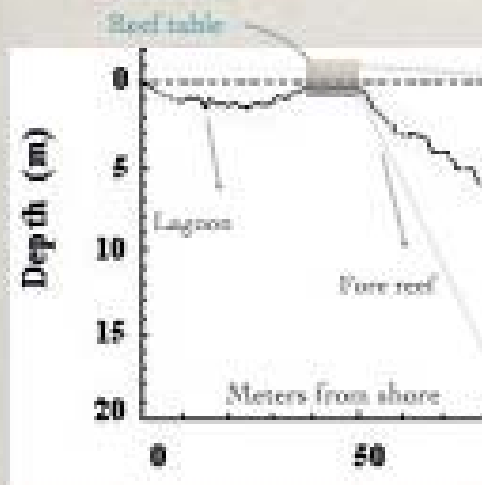
tilted floor, repair during occupation

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The Elat Reef

Profile of the modern reef at Elat



Sea level



Shaked, Marco, Stein,
Lazar, Avner, Agnon
2004

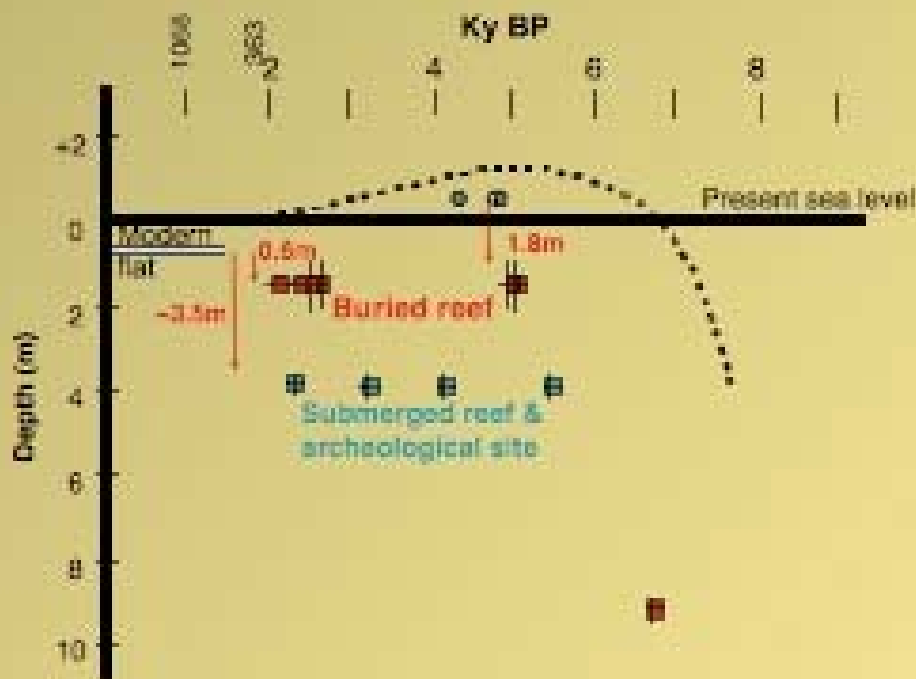
any time in the last 8 millennia
archaeological site on an
abraded fossil reef table



*building stones not cemented
depth: 4-5 m
southern storm action limit:
2 m*

Hence - foundation was displaced fast

Age vs. Elevation



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*reconstruction
close to demolition:
continuous occupation*

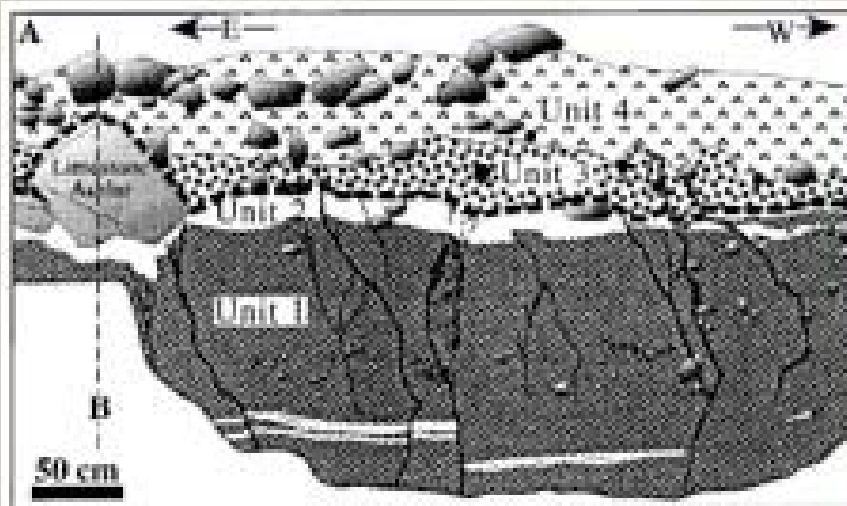
Megiddo, Iron Age



Marco,
Agnon,
Finkelstein,
Ussishkin,
2006

clean floor under fallen stones

Vadum Iacob, Crusaders



- Legend
- 1 August 1179 datum - - - -
 - Beetle nests ●
 - Cobble ○
 - Fault/bear crack [V]
 - Pebble-rich soil [dots] Unit 4
 - Colluvium [dots] Unit 3
 - Lime surfaces [horizontal lines] Unit 2
 - Crusader infill [solid black] Unit 1
- Unit 4 } Post A.D. 1179
Unit 3 }
Unit 2 } Pre A.D. 1179
Unit 1 }



tripod dating:
archaeology, history,
geology

Ellenblum, Agnon, Marco,
Rockwell, Boas, 1998

CONCLUSIONS

- Archaeology can supplement our record
- Not yet standalone
- Robust when agrees with history and geology
- Neither geology nor history standalone



Marco, 2008, *Tectonophys.*

