

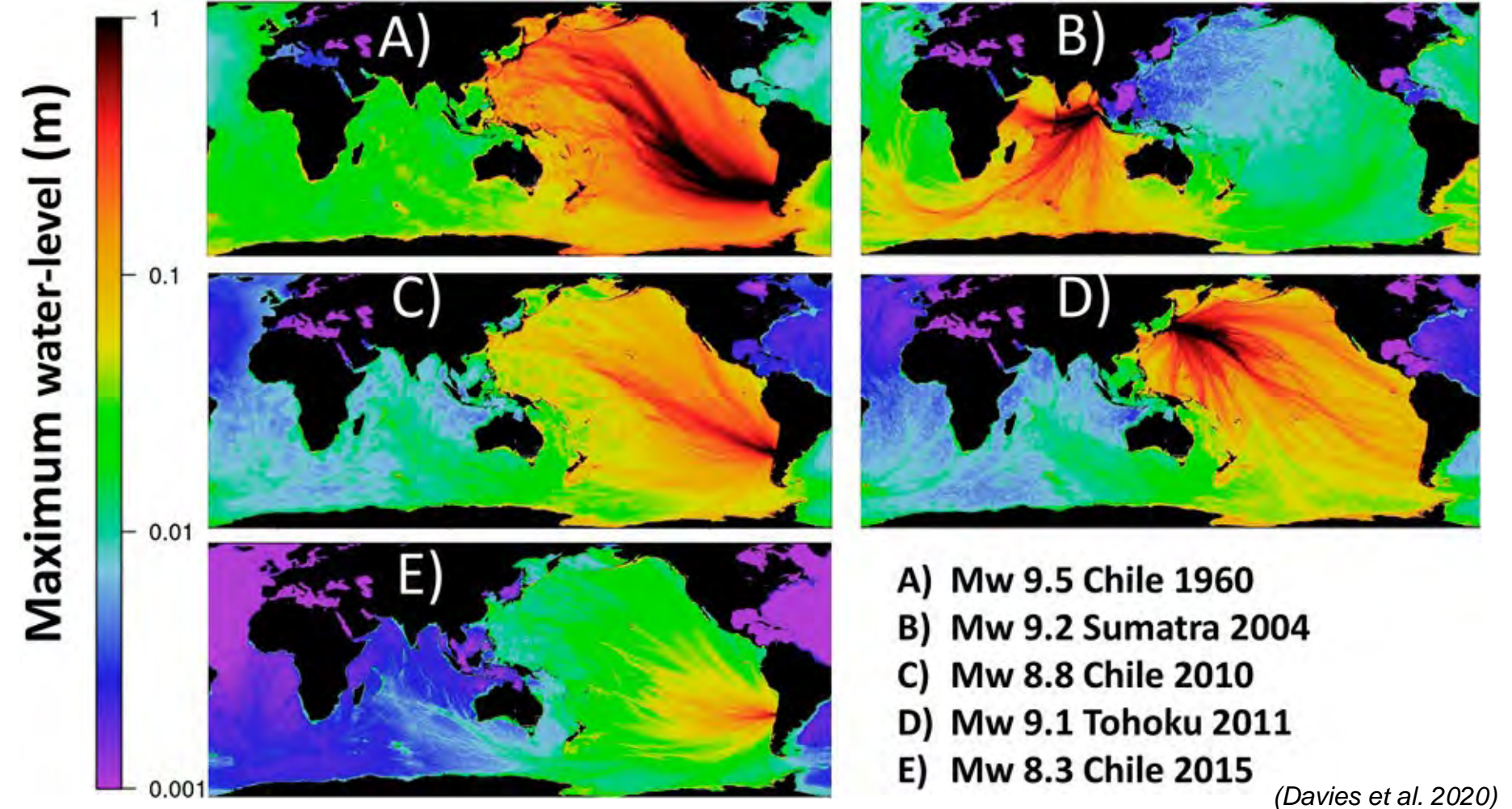


**Fondecyt**  
Fondo Nacional de Desarrollo Científico y Tecnológico

# Geoarchaeological records and social impact of a prehistoric Mw 9.5 tsunamigenic earthquake in northern Chile

**Diego Salazar,  
Gabriel Easton,  
James Goff et al.**

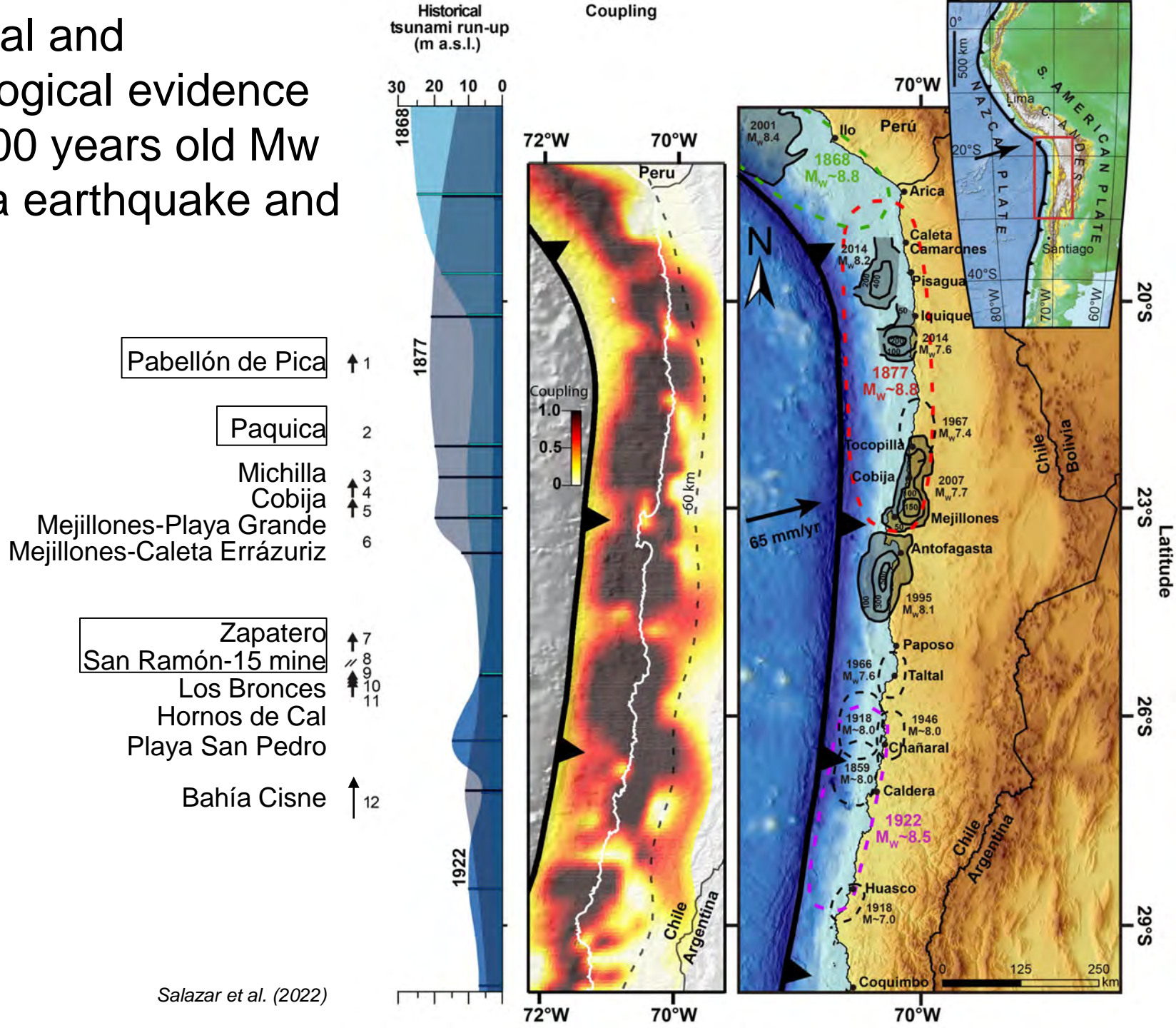




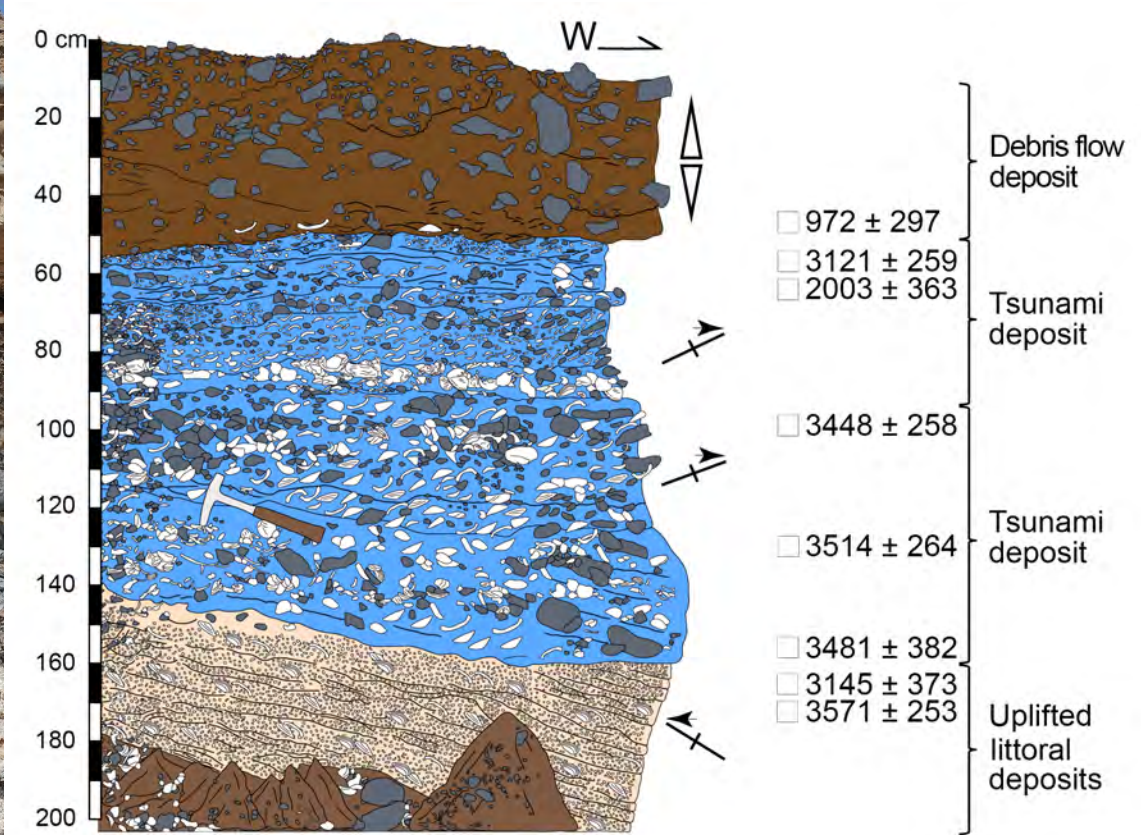
*“The official long-term forecast and most individual studies before the 2011 did not consider the occurrence of  $M \sim 9$  earthquakes offshore Tohoku, largely because of insufficient evidence for ruptures of that size and the slow spreading of the geologic and historical knowledge to the scientific community and the government.”*

*(Uchida and Bürgmann 2021)*

# Geological and archaeological evidence for a 3,800 years old Mw 9.5 mega earthquake and tsunami

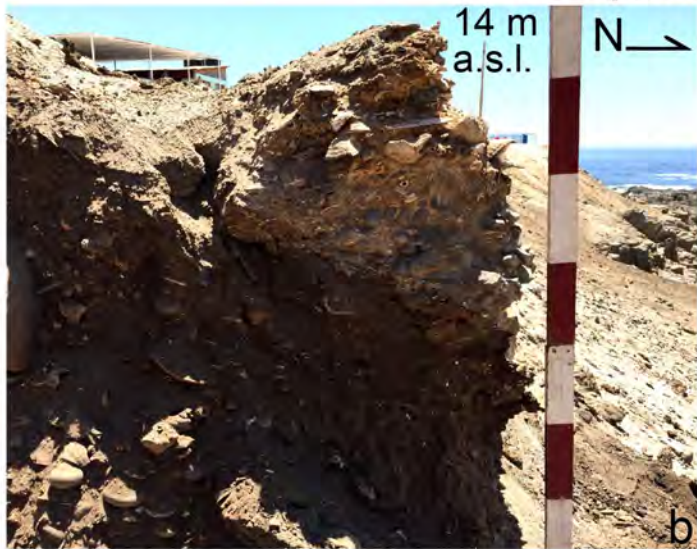


# 1. Uplifted littoral deposits (+6-7 m a.s.l.) and paleotsunami deposit *Pabellón de Pica site*

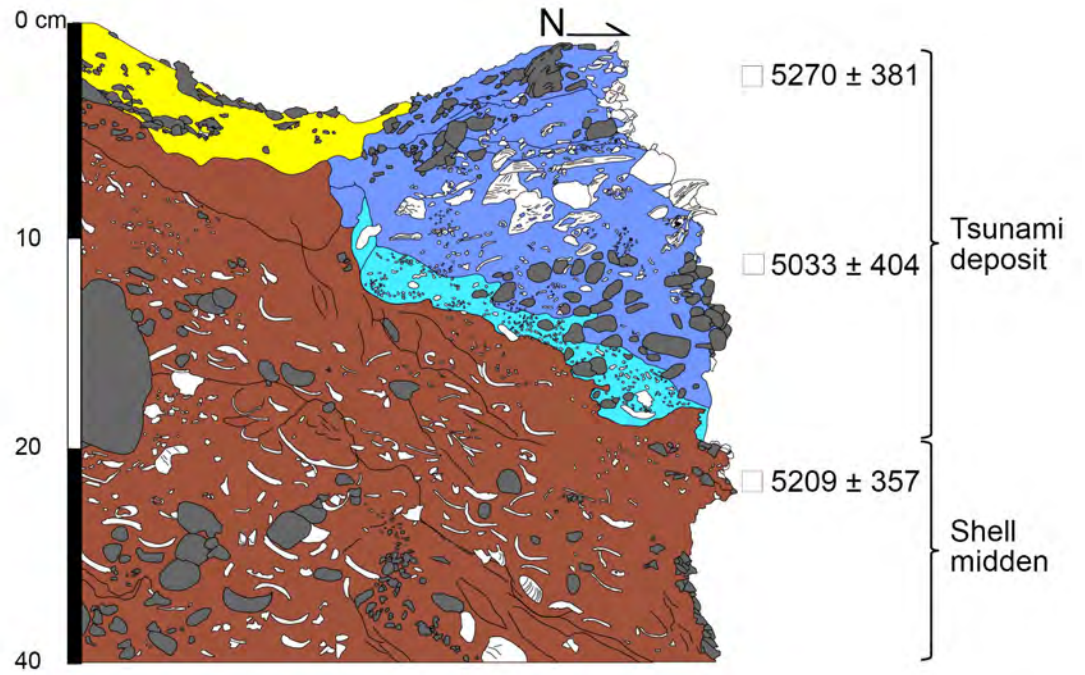


Salazar et al. (2022)

# Paquica



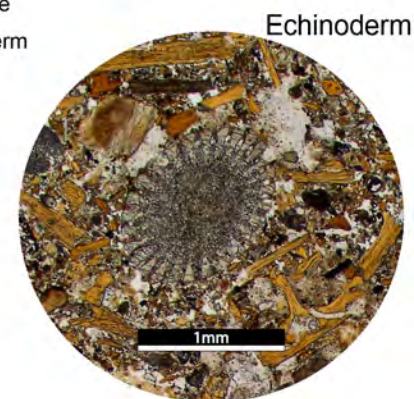
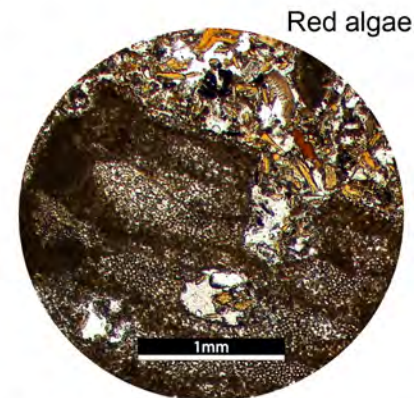
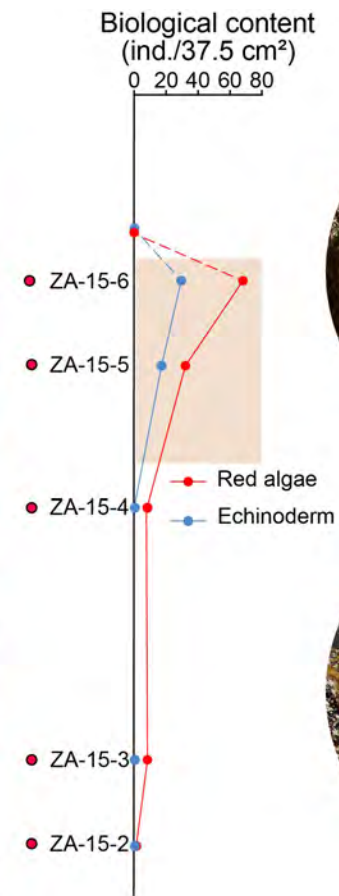
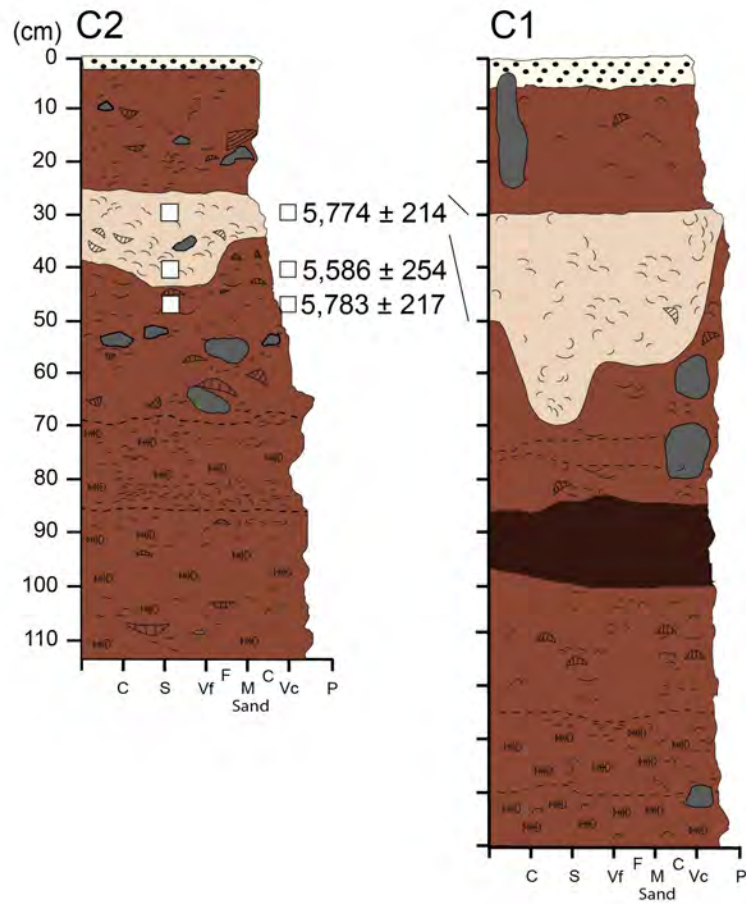
## 2. Paleotsunami deposits (+14-16 m a.s.l.) *Paquica Site*





+19 m a.s.l.

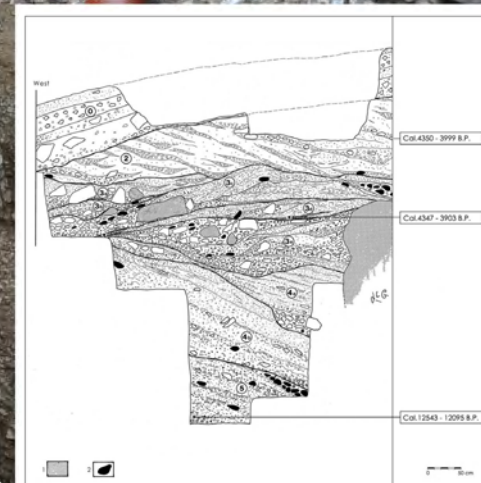
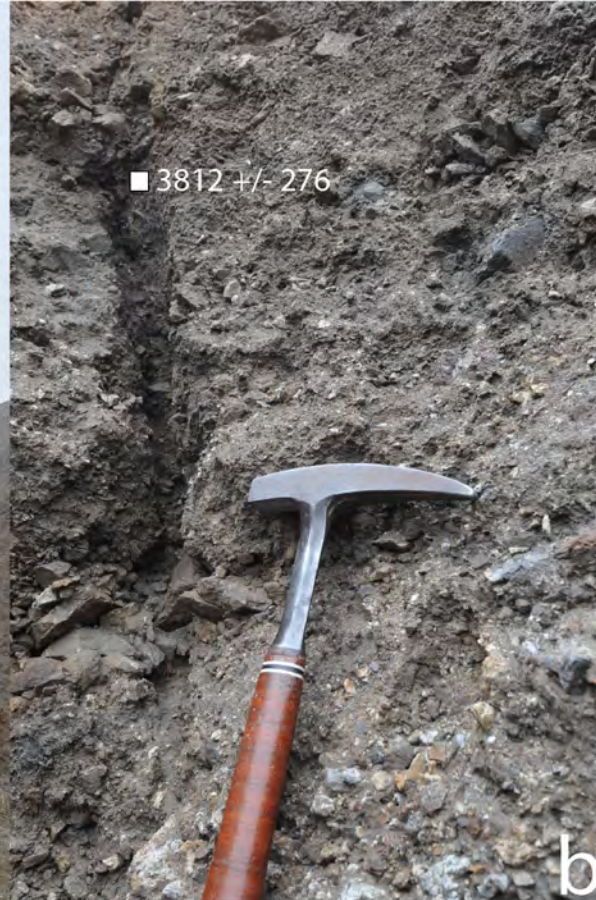




### 3. Fracture in archaeological sites San Ramón-15 mine



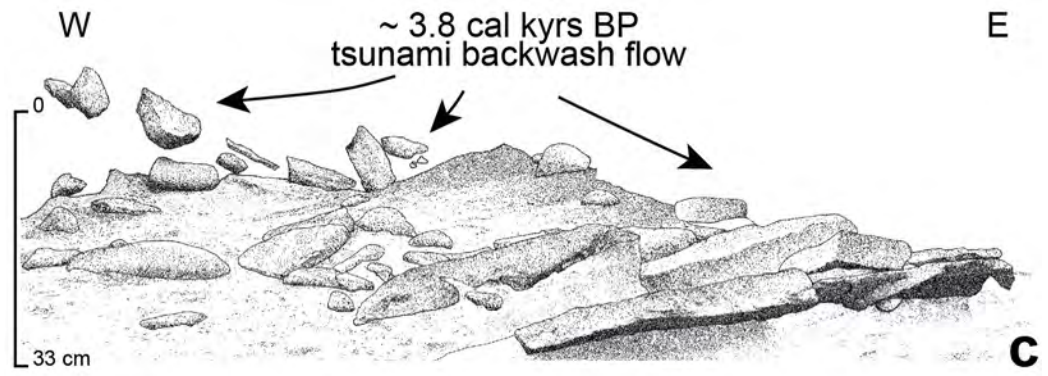
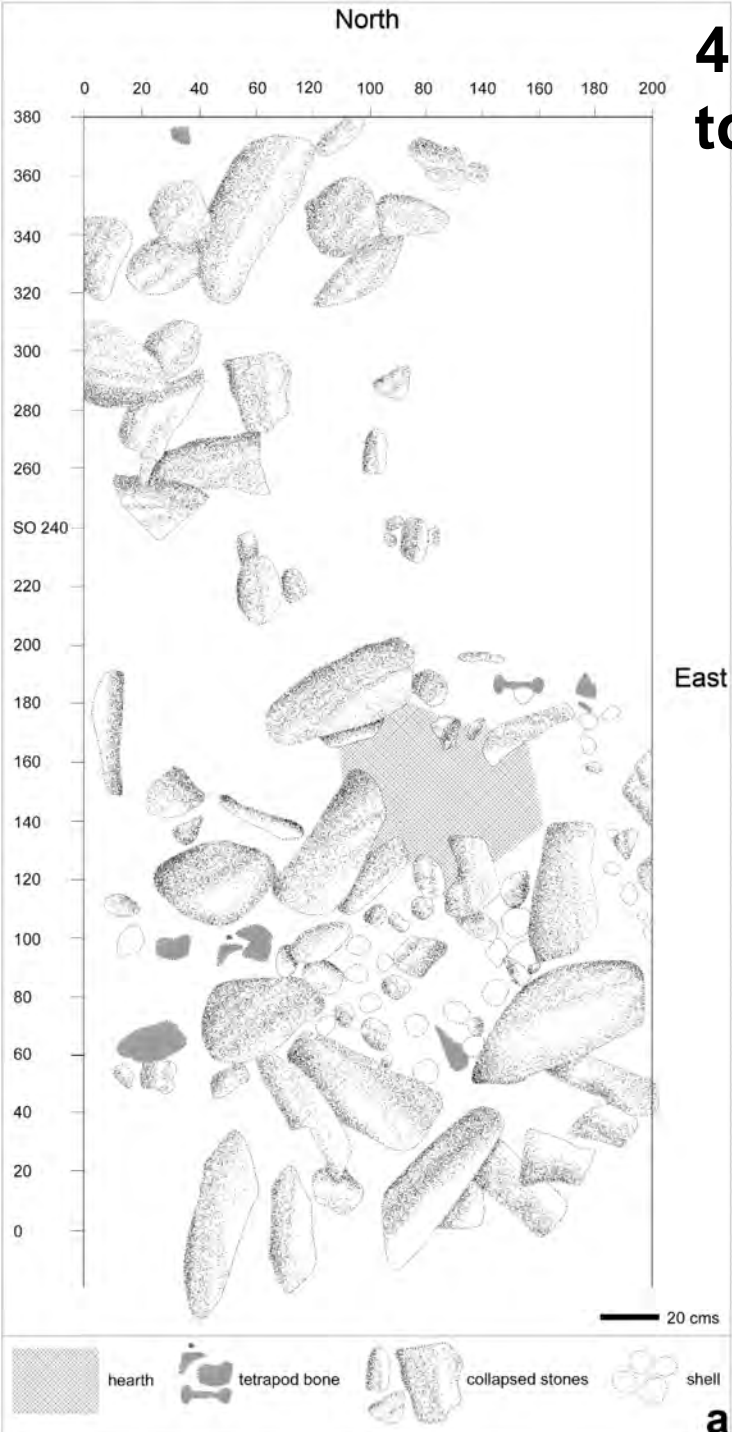
Salazar et al. (2022)



Salazar et al. (2011)



# 4. Destruction of structures and toppled stones at archaeological sites





**4645 ± 20 AP**  
**(Shell)**

**4188 ± 24  
AP**

FONDECYT 1110196  
SITIO ZAPATERO  
SECTOR SUR-ESTRUCTURA 1  
UNIDAD 3  
CAPA 2A - RASGO 2  
NIVEL 5-6 (50-60 cm)  
CIERRE  
FECHA 26/11/13

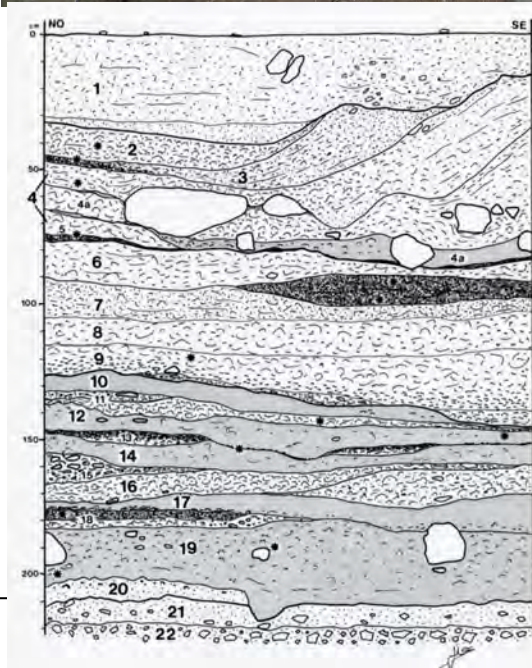


# 5. Evidence for Transpacific Tsunamis (and marine cores...)

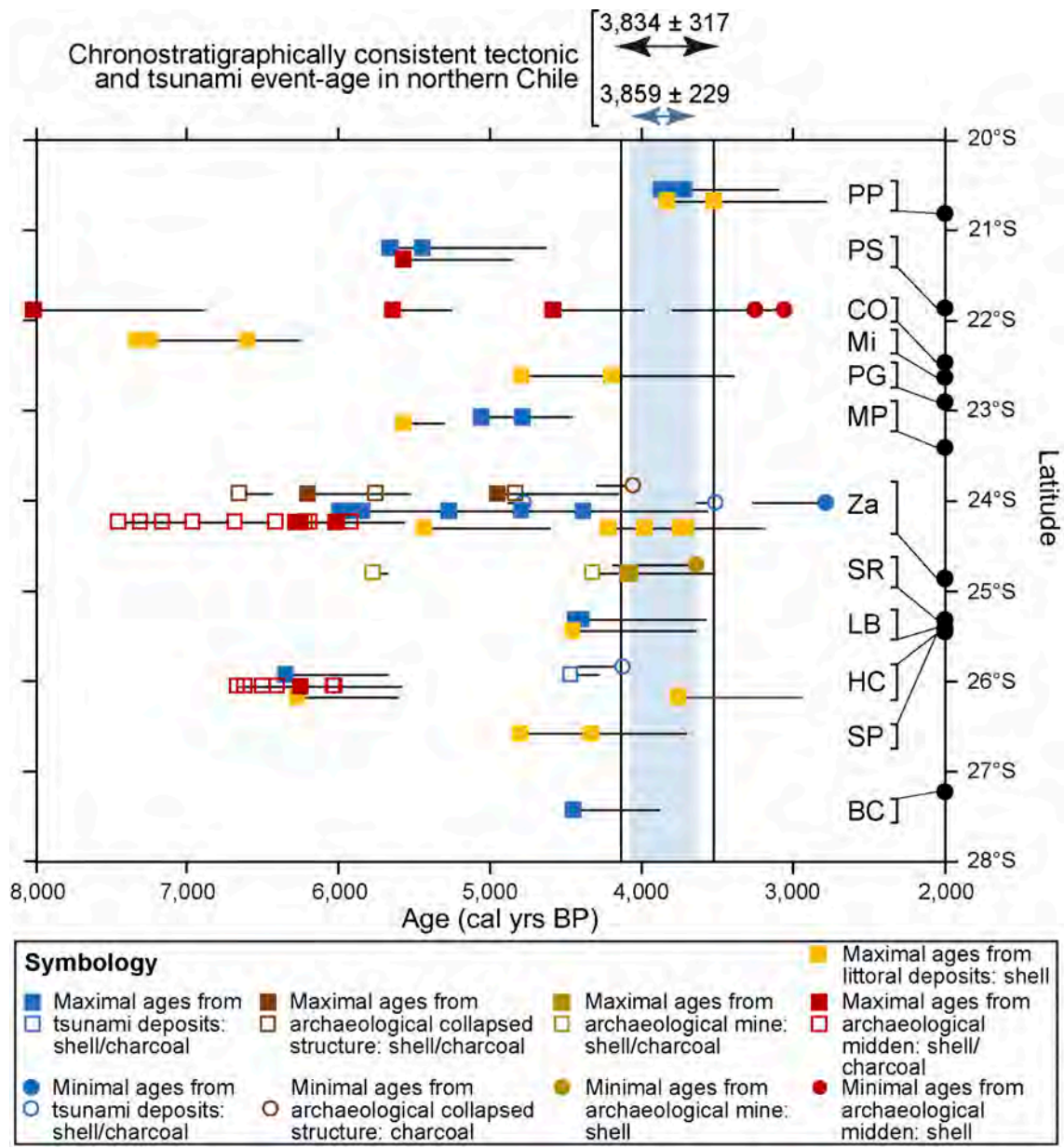
Okawa, Chatham Islands,  
New Zealand  
ca. 4 ka boulder deposits



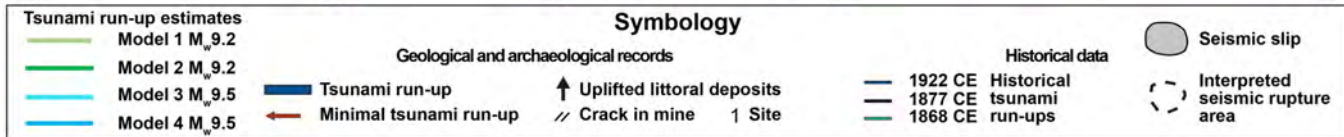
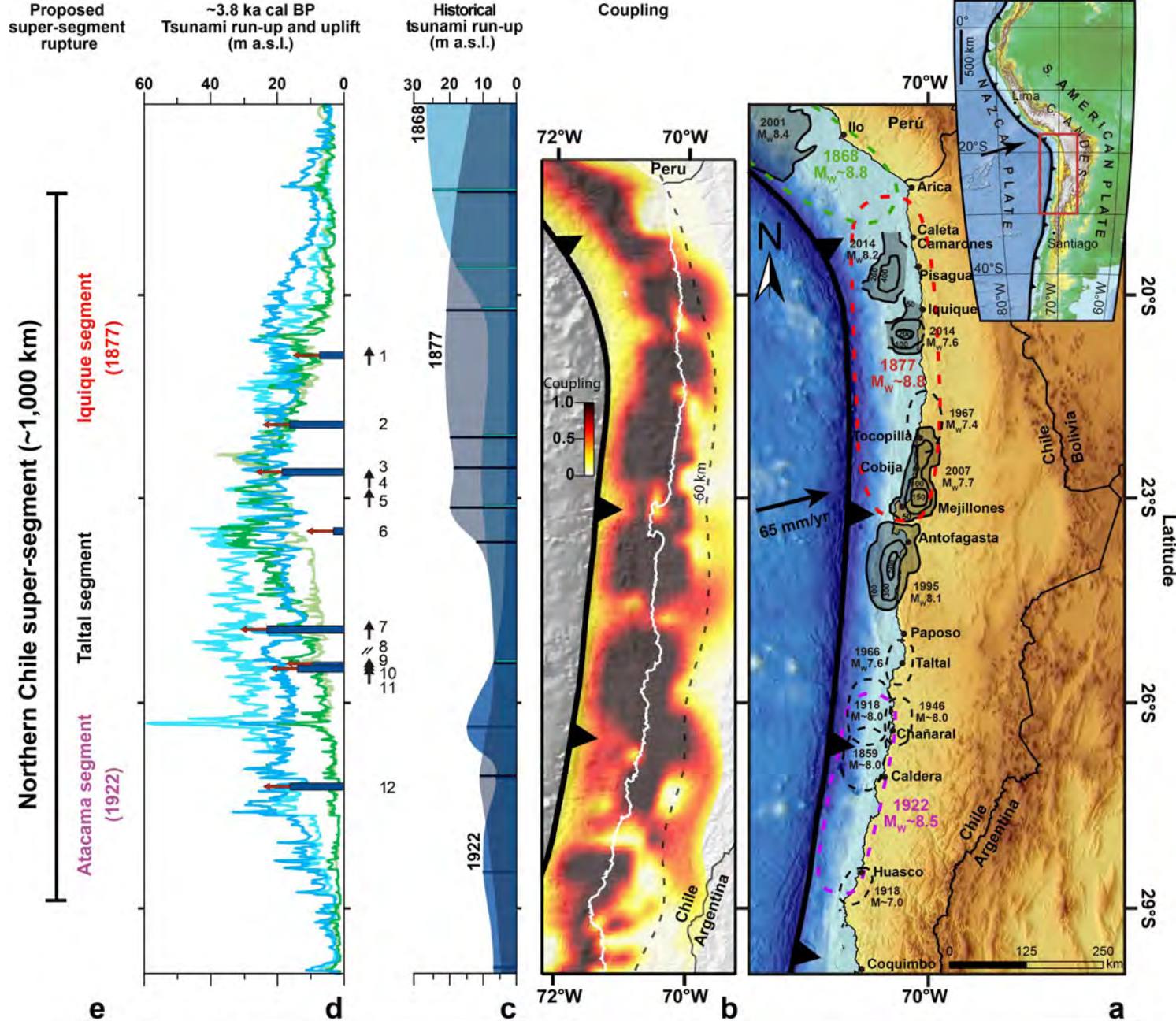
## 6. Transformations in the archaeological record



# Chronostratigraphic determination

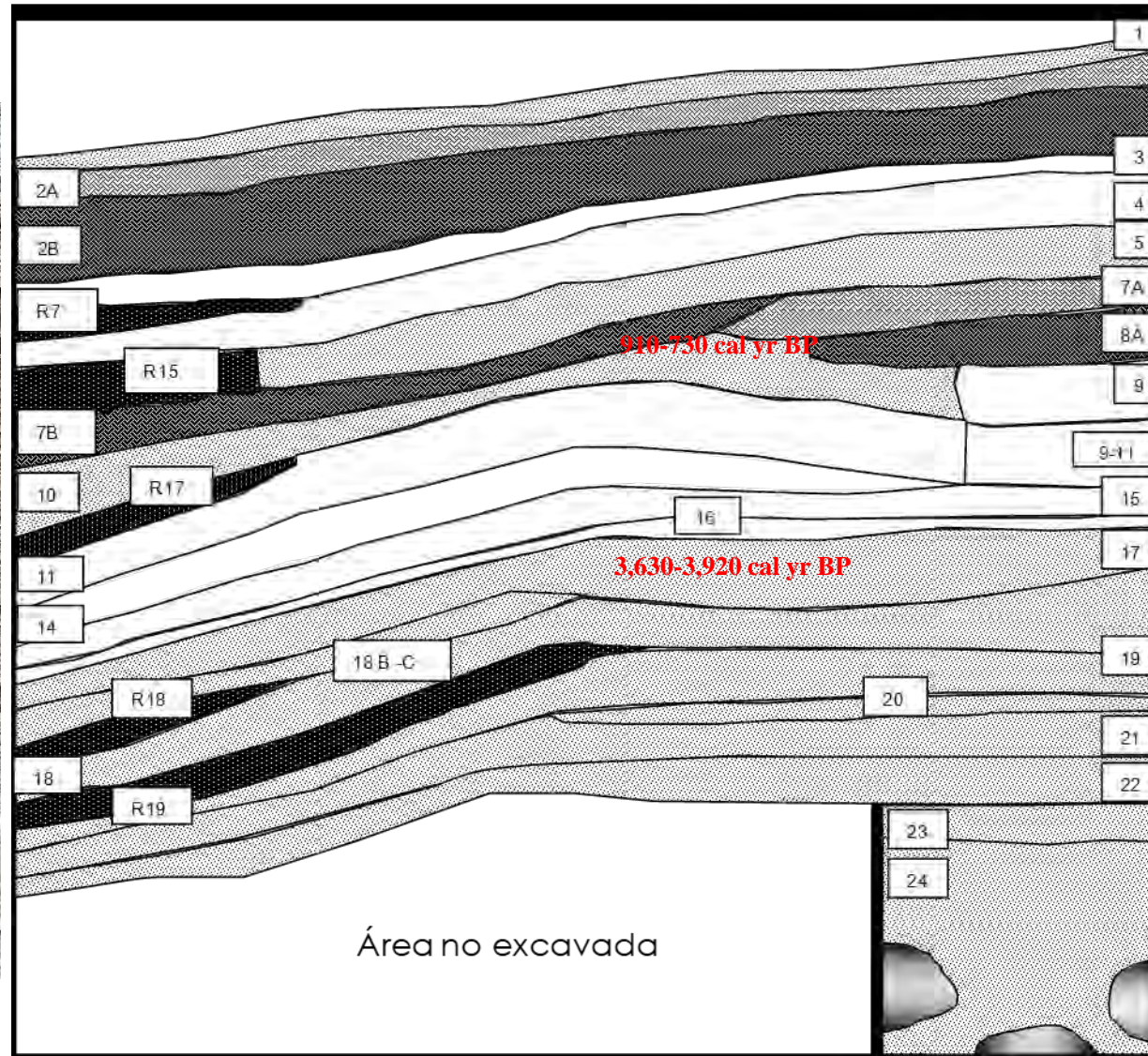


# M<sub>w</sub>9.5 Eq. and major tsunami



# Regional archaeological evidence

## *Mamilla 7*





# Regional archaeological evidence

## *Cobija 1N*



263 +/-230 □

339 +/-237 □

Late  
Holocene  
shell  
midden

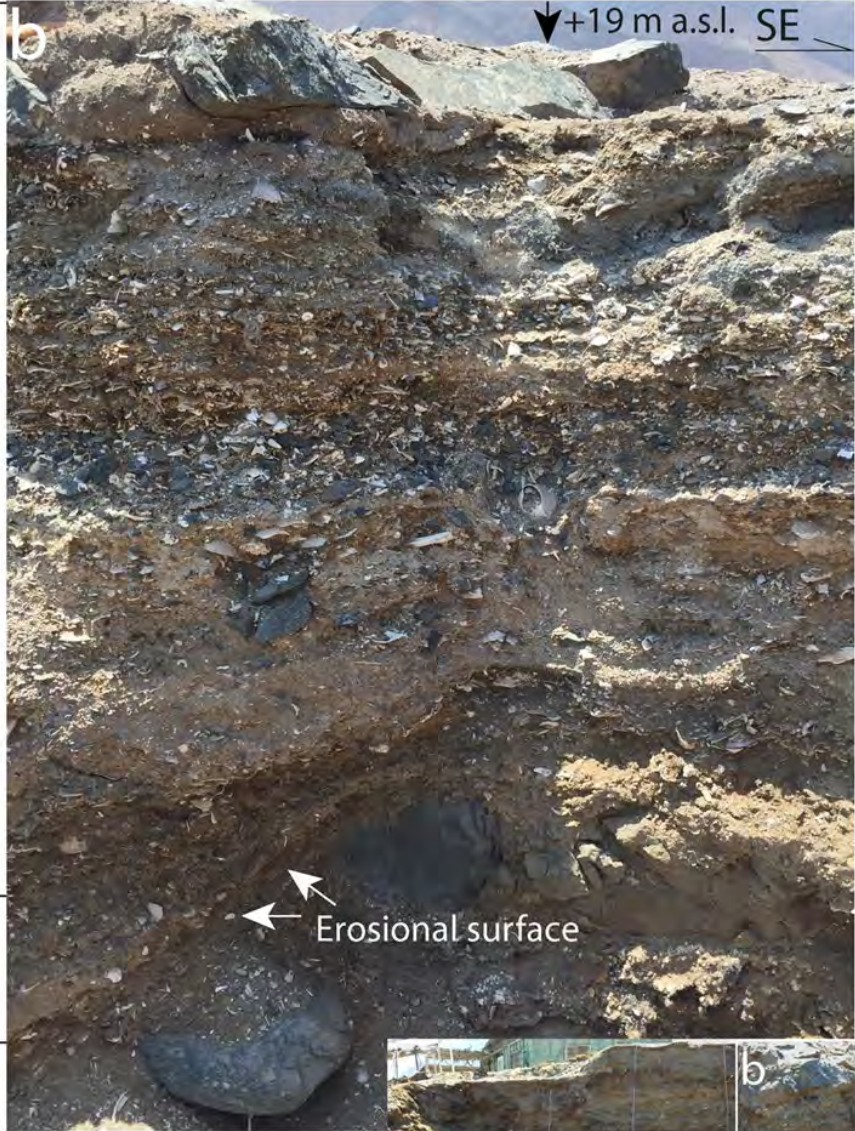
485 +/-212 □

3532 +/-288 □

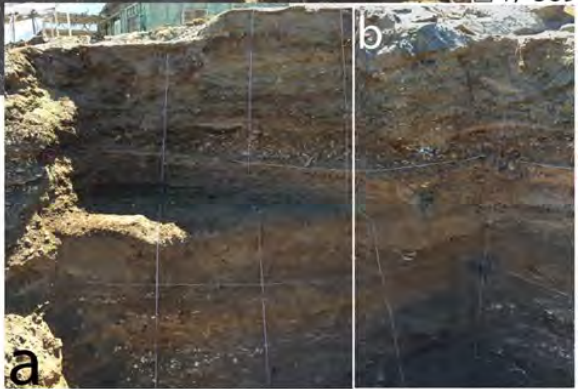
3334 +/-293 □

Reworked  
shell  
midden

4281 +/-315 □



5470  
□ +/-264  
7460  
□ +/-589



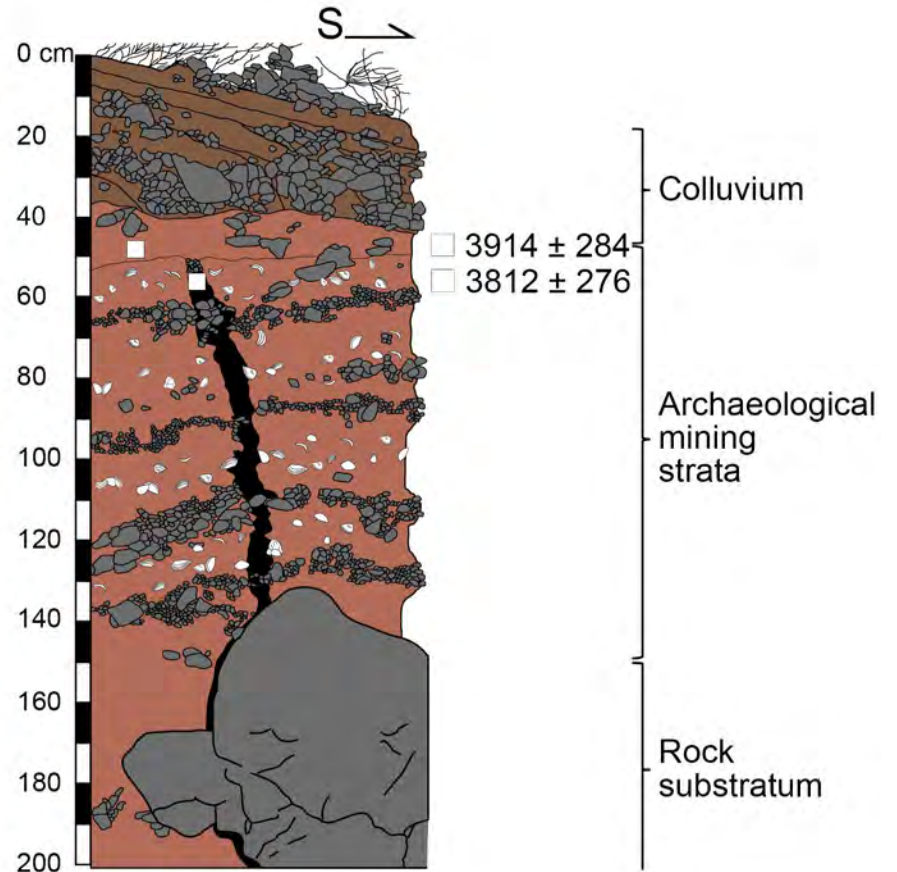
# San Ramón mine

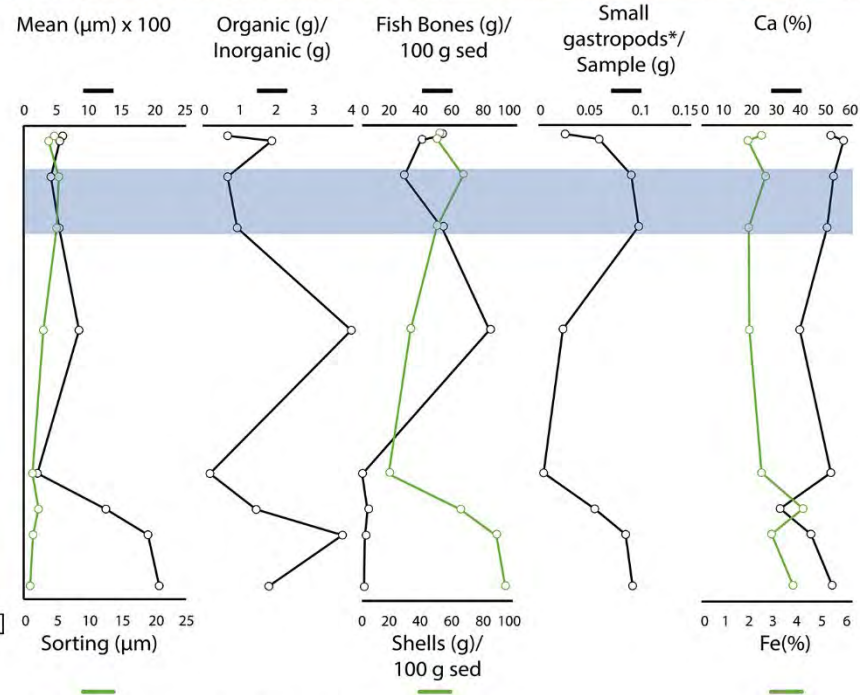
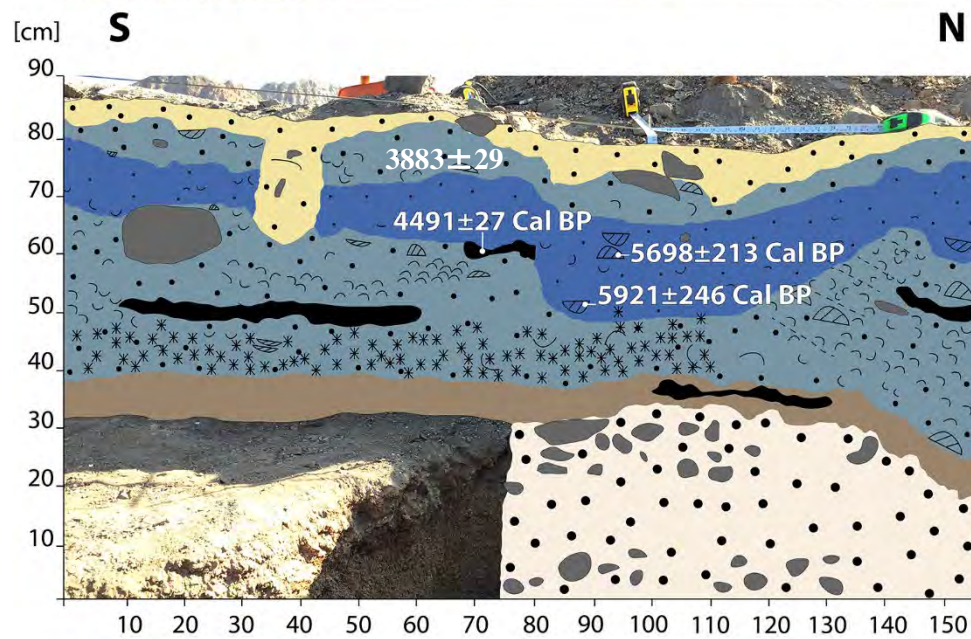
S →



# Regional archaeological evidence

SR-15





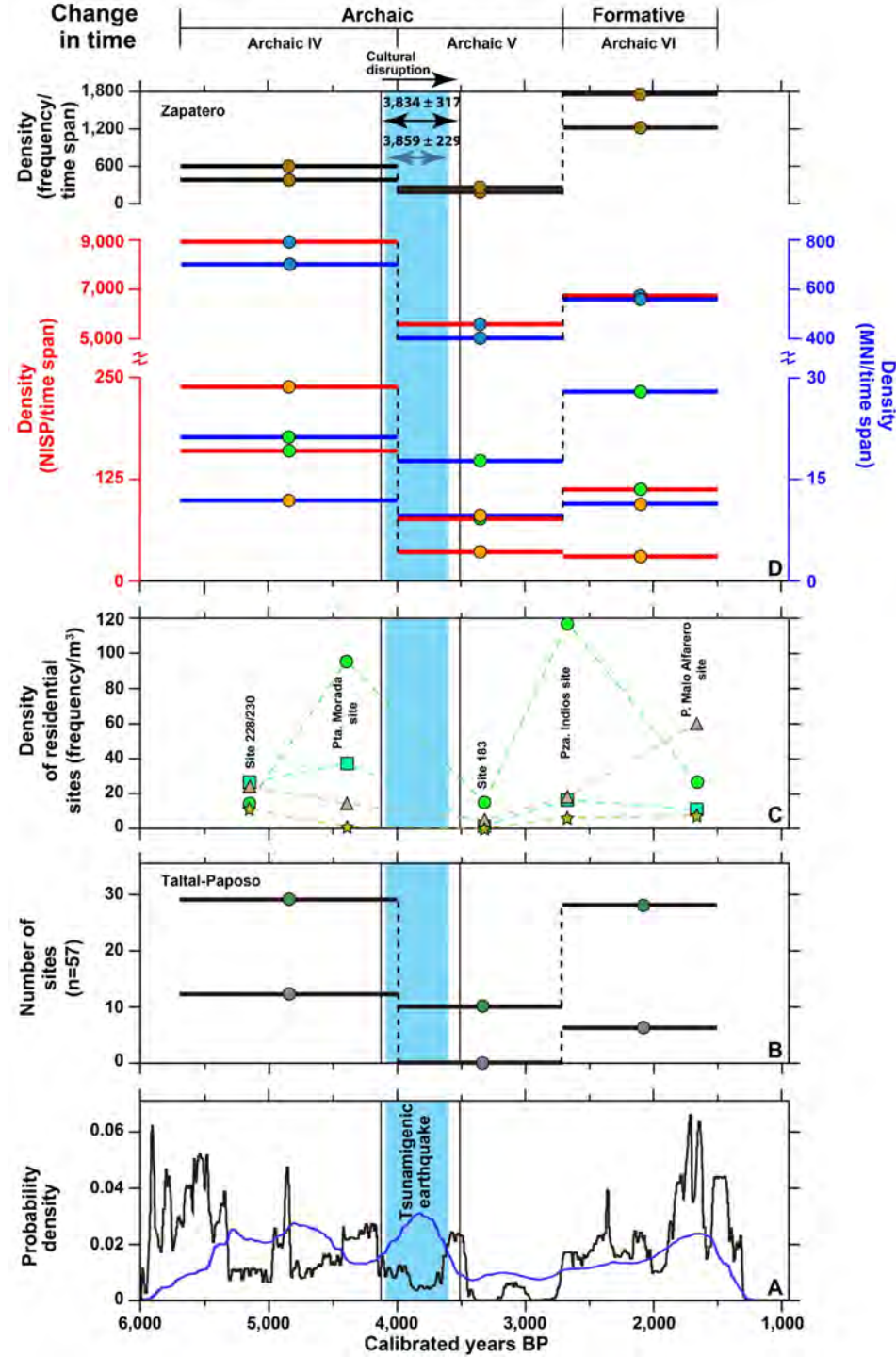
**Legend**

**León et al. 2019**

- |  |                                 |  |                              |  |                                |  |                 |  |            |  |               |
|--|---------------------------------|--|------------------------------|--|--------------------------------|--|-----------------|--|------------|--|---------------|
|  | Very coarse sand<br>Beach layer |  | Medium sand<br>Tsunami layer |  | Coarse sand<br>Reworked midden |  | Cobble          |  | Sea urchin |  | Broken shells |
|  | Coarse sand<br>Midden           |  | Fine sand<br>Eolian layer    |  | Charcoal                       |  | Complete shells |  |            |  |               |

\* Small gastropods analyzed in 2000, 1000 and 500 µm sieves.

# Regional archaeological evidence

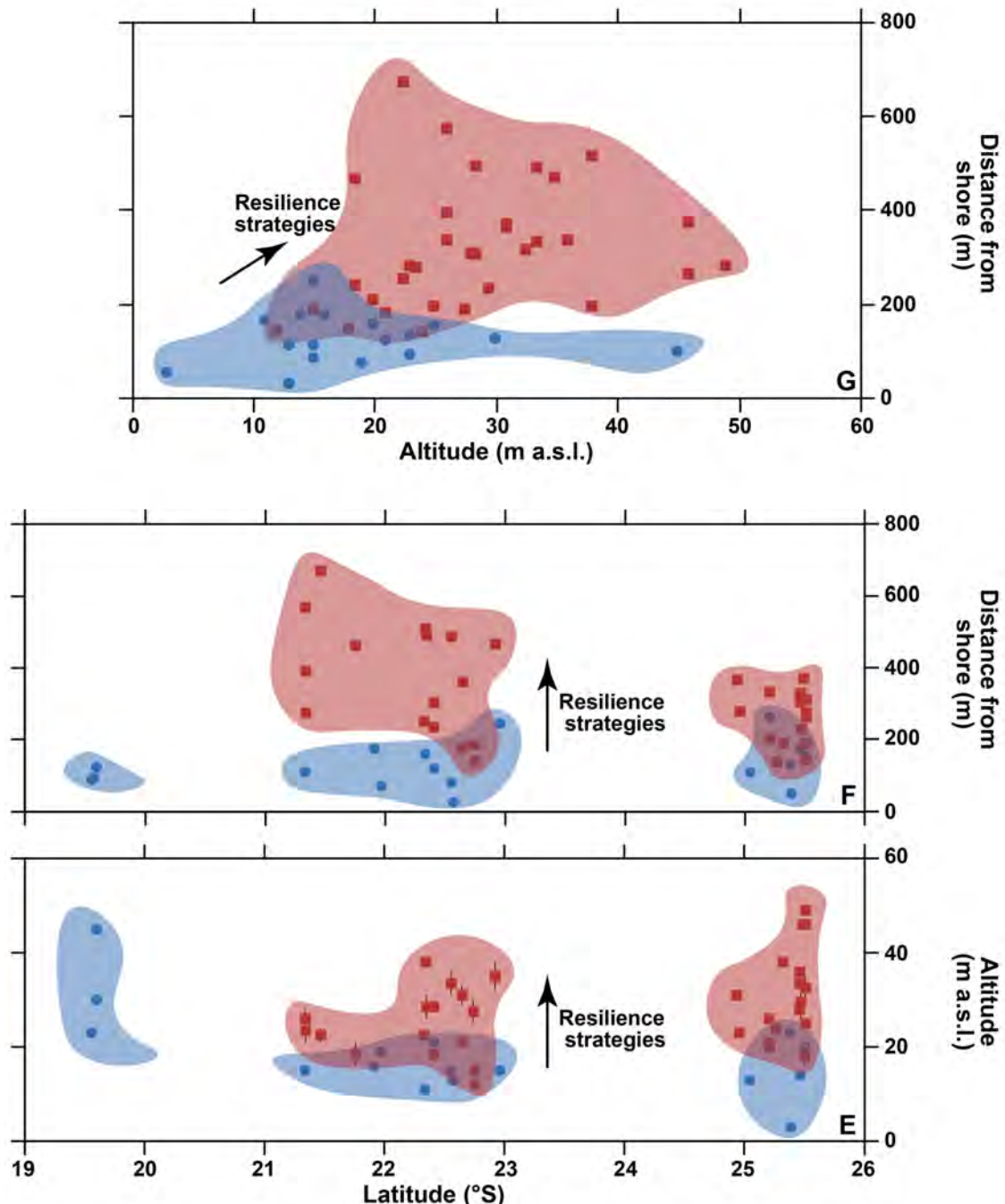


# Regional changes in location of cemeteries



Salazar et al. (2022)

## Change in spatial location of cemeteries



# Conclusions

Long time scales are essential to adequately assess the sources, characteristics, and recurrence of paleoearthquakes and paleotsunamis. However, hazard assessment in coastal northern Chile is currently based on information from historically documented earthquakes in the area, none of which has been stronger than Mw 8.8.

Results from our transdisciplinary geoarchaeological research provides evidence for the occurrence around 3800 cal BP of a Mw 9.5 mega-earthquake driven by a 1000 km length seismic rupture, which encompassed the entire northern Chile region and generated a large tsunami with a probable run up of up to 30-40 m.a.s.l. which had significant effects on local human populations.

These results suggest the need to consider a worst-case scenario of a Mw9.5 mega-earthquake producing 30m+ masl inundation in the northern Chile seismic gap. Such a scenario needs to be considered in tsunami hazard assessment in the whole Pacific basin region. We reinforce the necessity for continuous geoarchaeological research to assess seismic and tsunami risk, which should inform national hazard assessment policies and local communities in order to foster local resilience.



# Thank You Very Much...

Major challenge to integrate different types of scientific knowledge, public policy and social awareness.

Despite its difficulties would be most unfortunate if we still exclude specific sources of scientific knowledge or if we realize there is still “slow spreading of the geologic and historical knowledge to the scientific community and the government” (Urchida and Bürgmann 2021)