Revealing the earthquake history during the last 200 ka on a large submarine strike-slip fault: The Yusuf Fault System (Alboran Sea)

Hector Perea[1], Eulàlia Gràcia[2], Stefanie Almeida[2], Laura Gómez de la Peña[3], Sara Martínez-Loriente[2] and Rafael Bartolomé[2]

(1) Fac. Ciencias Geológicas, Universidad Complutense de Madrid, 28040 – Madrid, Spain
(2) B-CSI, Institut de Ciències del Mar - CSIC, 08003 Barcelona, Spain
(3) GEOMAR - Helmholtz Centre for Ocean Research Kiel, 24148 Kiel, Germany

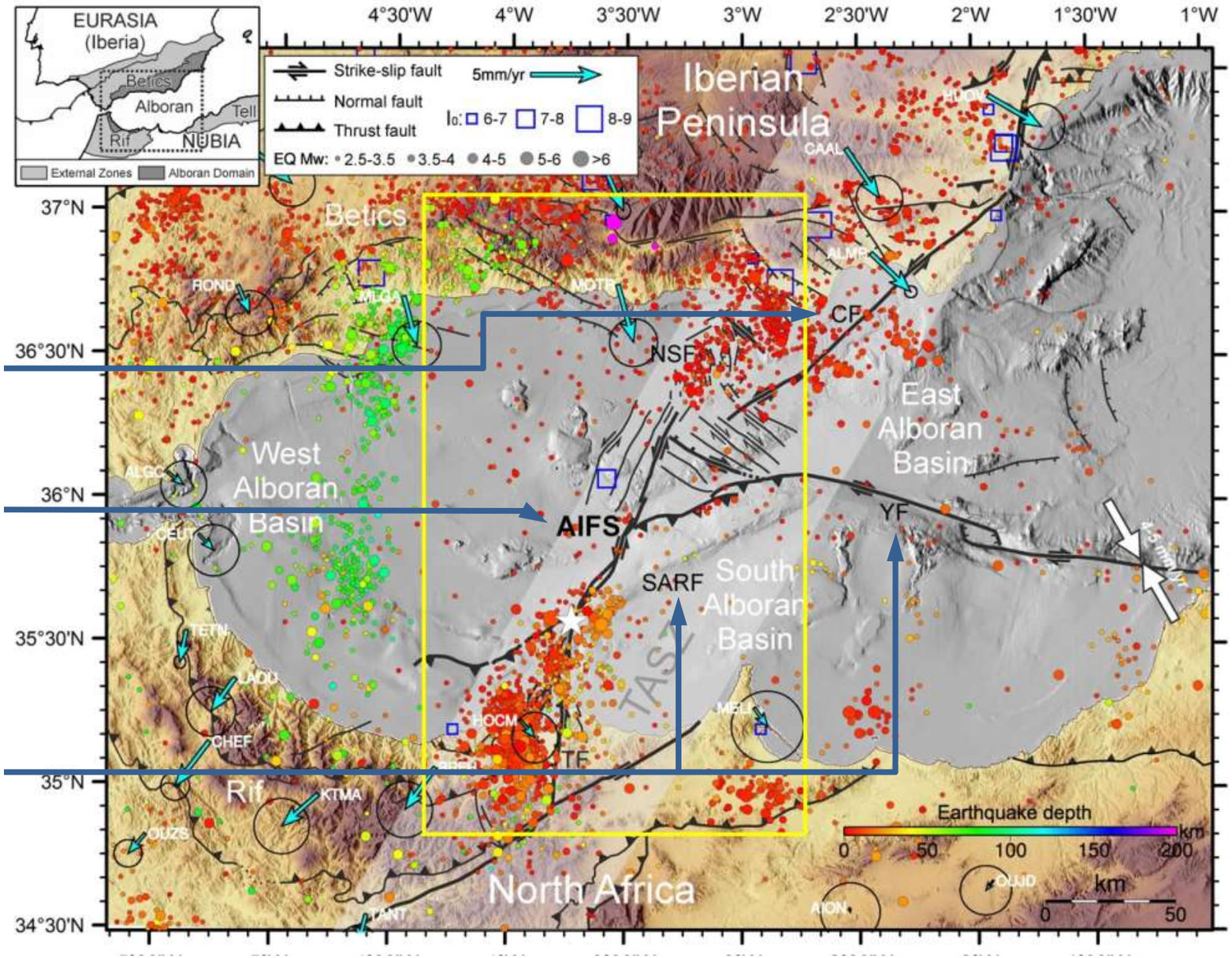
CC BY

The Alboran Sea – Main geological structures

Gràcia et al. (Nature Comm., 2019)

- Three main sedimentary basins: Western, Eastern and Southern Alboran basins

- Three major fault systems bound the basins:
  - **Carboneras Fault** (CAF; LLSS fault)
  - **Al-Idrissi Fault** (AIFS; LLSS fault) (focus presentation by Gràcia et al. EGU2020-3125 / SM2.2/NH4.16/TS5.12)
  - **Yusuf and Alboran Ridge faults** (YF and SARF; RLSS and reverse faults)



CC BY

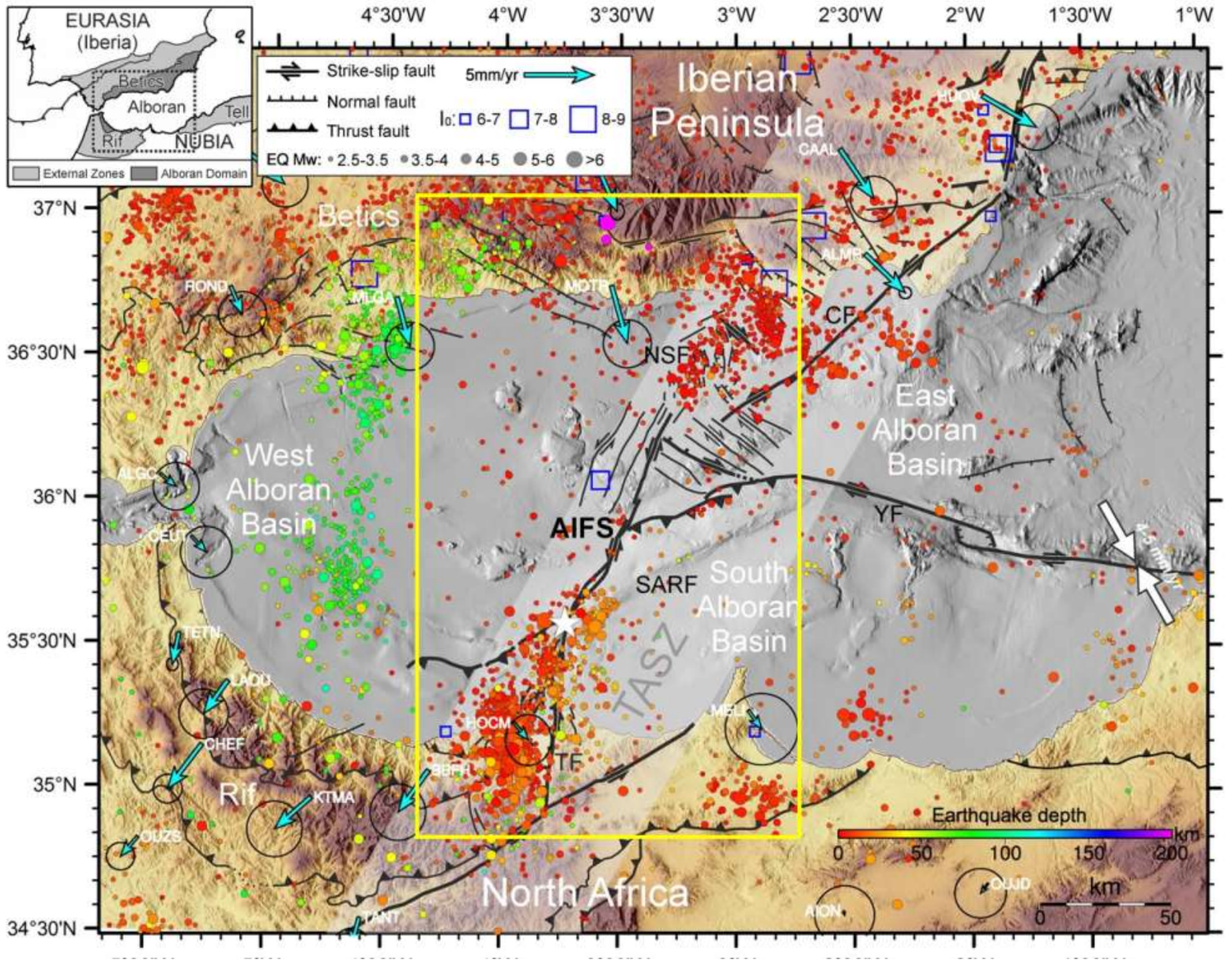
The Alboran Sea – Seismicity and GNSS

Gràcia et al. (Nature Comm., 2019)

- Moderate instrumental seismic activity with low to moderate magnitude → Some large Earthquakes: 2016 Al-Idrissi EQ (Mw 6.4; white star), 1994 and 2004 Al-Hoceima EQs (Mw 6.0 and 6.3; N Morocco)

- Moderate and large historical earthquakes (I > IX): 1522 Almeria, 1790 Oran or 1910 Adra

- GNSS → Iberia moving to SSE to ESE respect to Africa (fixed; light blue arrows)



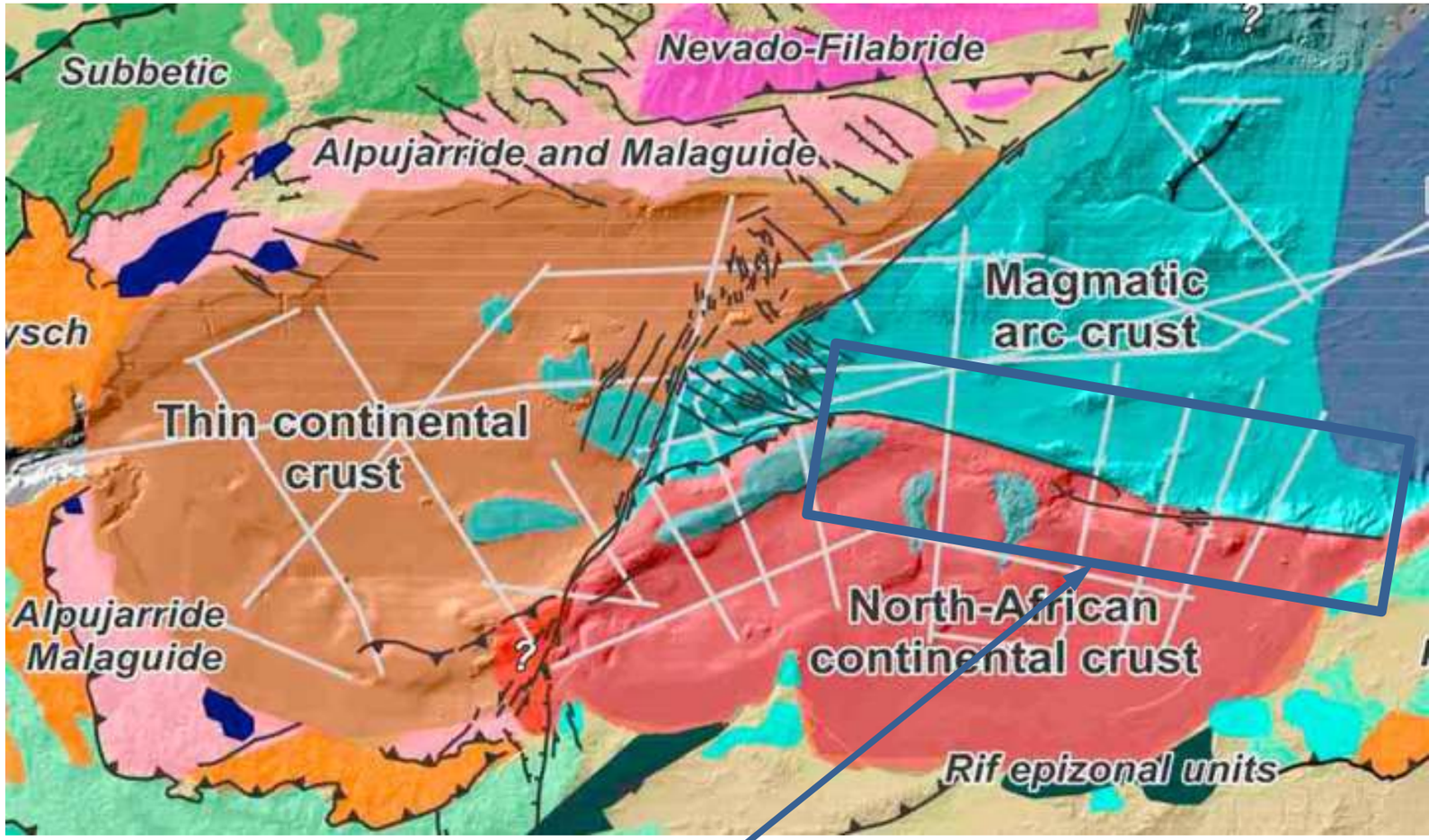
CC BY

The Alboran Sea – Main geological structures

- The Alboran basin is bounded to the north east and south by the Betic and Rif mountains related to the Gibraltar arched orogen.

- Different crustal zones have been described across the Alboran basin:
  - Thin continental crust in the West Alboran basin → Sedimentary infilling of up to 4 km.
  - North-African continental crust intruded by arc magmatism and corresponding to the South Alboran basin
  - The magmatic arc crust forming the east Alboran basin

Gómez de la Peña et al. (Tectonics, 2018)

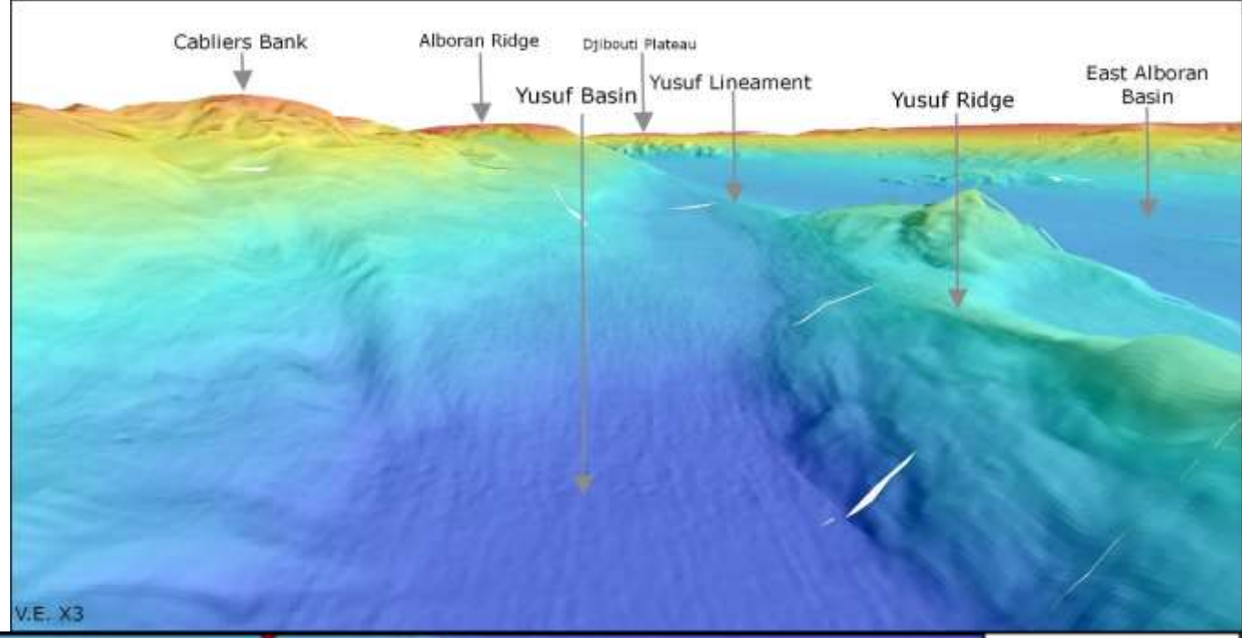


One of the main crustal boundaries is the one separating the South and East Alboran basins and corresponds to the **Yusuf fault**

CC BY

The Yusuf fault system

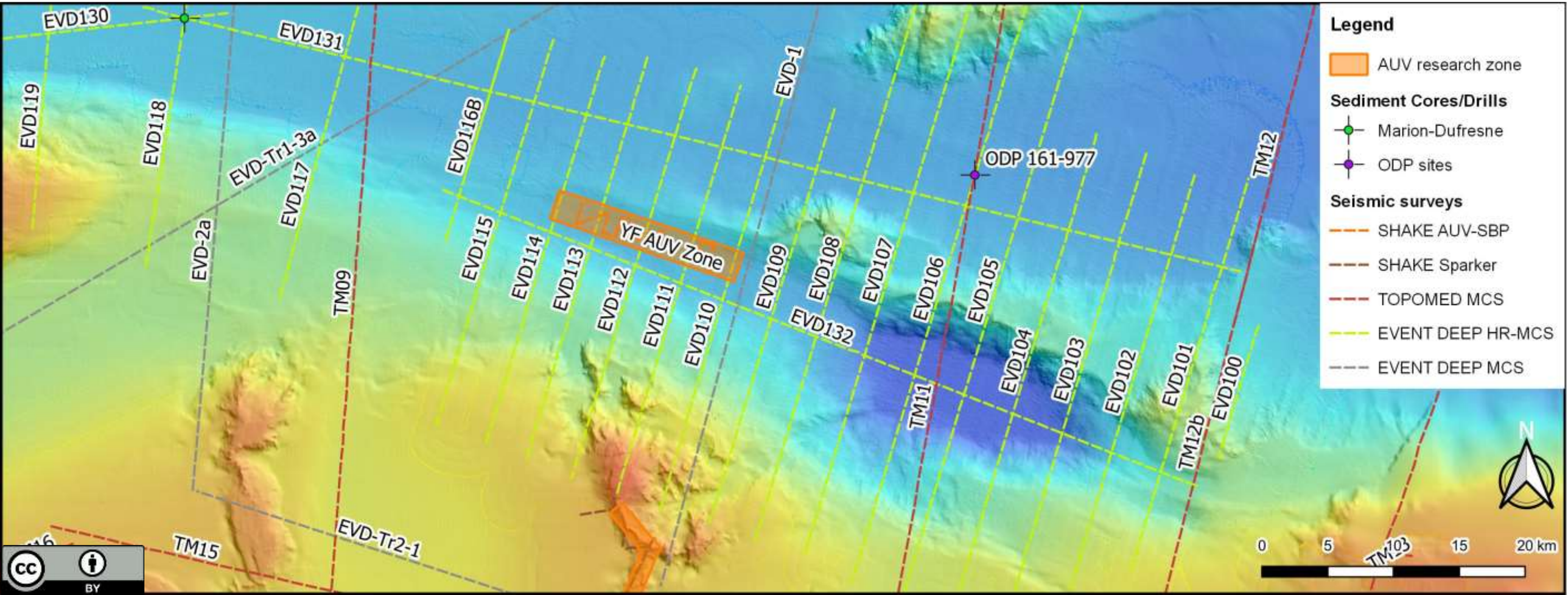
- Right-lateral strike-slip fault system
- Trends WNW-ESE
- Length: 150 km → Two segments
- Pull-apart basin



East Alboran Basin
Al-Mansour Seamount
Algero-Balearic Basin
Alboran Ridge
Yusuf Lineament
Yusuf Ridge
Yusuf Basin
Catifas Bank
Cabliers Bank
Habibas Scarpment
Pytheas Basin
Habibas Basin
Bathymetry (m)
0
-833.25
-1666.75
-2500
0
10
20
30 km
N
CC BY

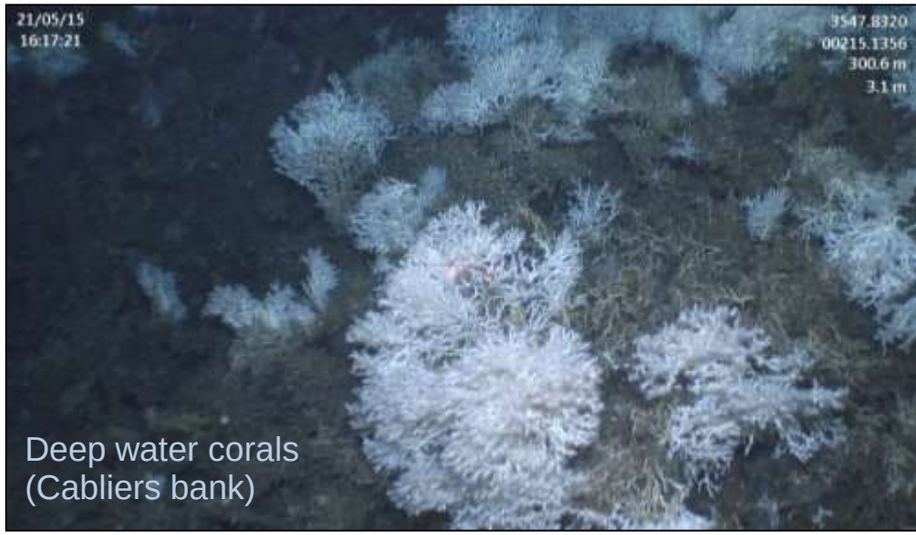
The Yusuf fault system – Oceanographic surveys

- MCS profiles → HR, medium penetration (3.5 km streamer) and high penetration (5.4 km streamer)
- AUV-SBP profiles → 13 UHR
- AUV Micro-bathymetry

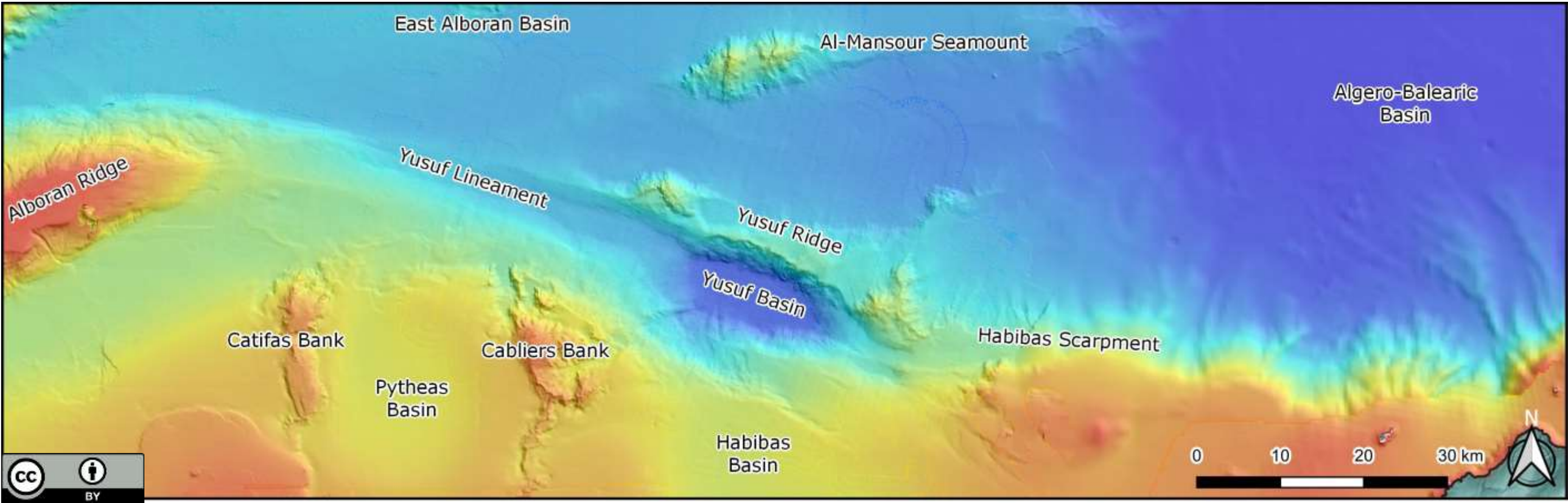


The Yusuf fault system - Geomorphology

- Deep oval pull-apart basin → Yusuf basin
- Ridges and seamounts → Yusuf or Alboran ridges
- Different lineaments → Yusuf lineament
- Deep water coral mounds → Cabliers bank

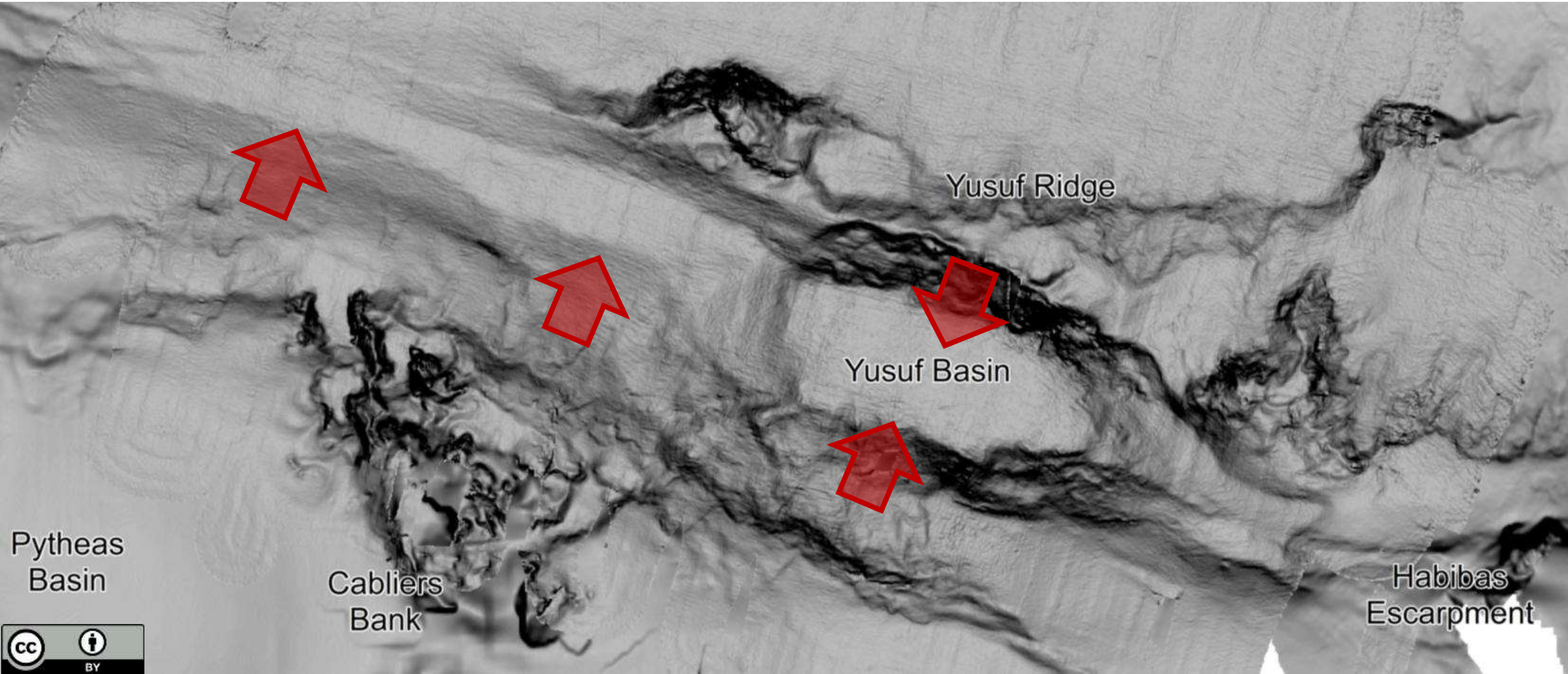


Deep water corals
(Cabliers bank)



The Yusuf fault system - Geomorphology

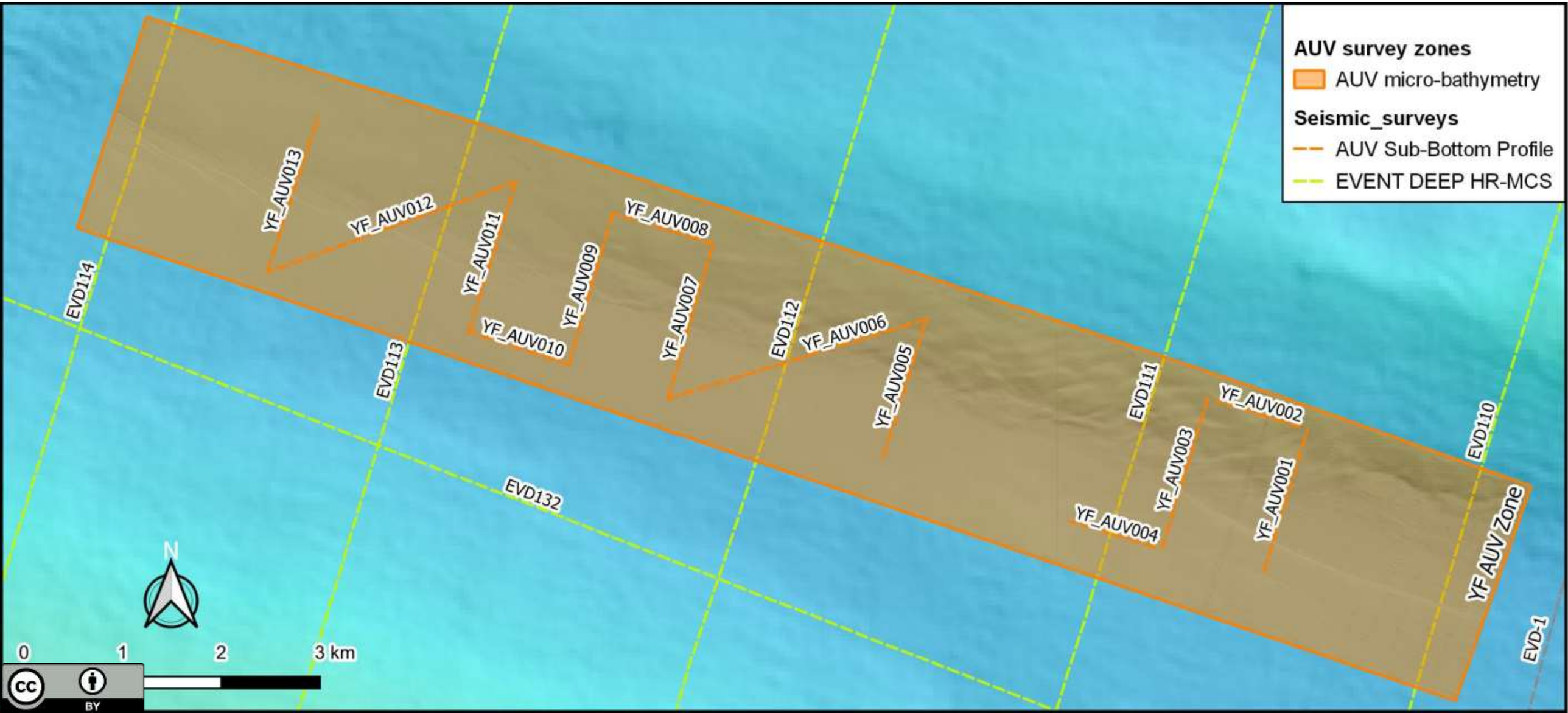
- Landslide scars → Relation to earthquakes?



CC BY

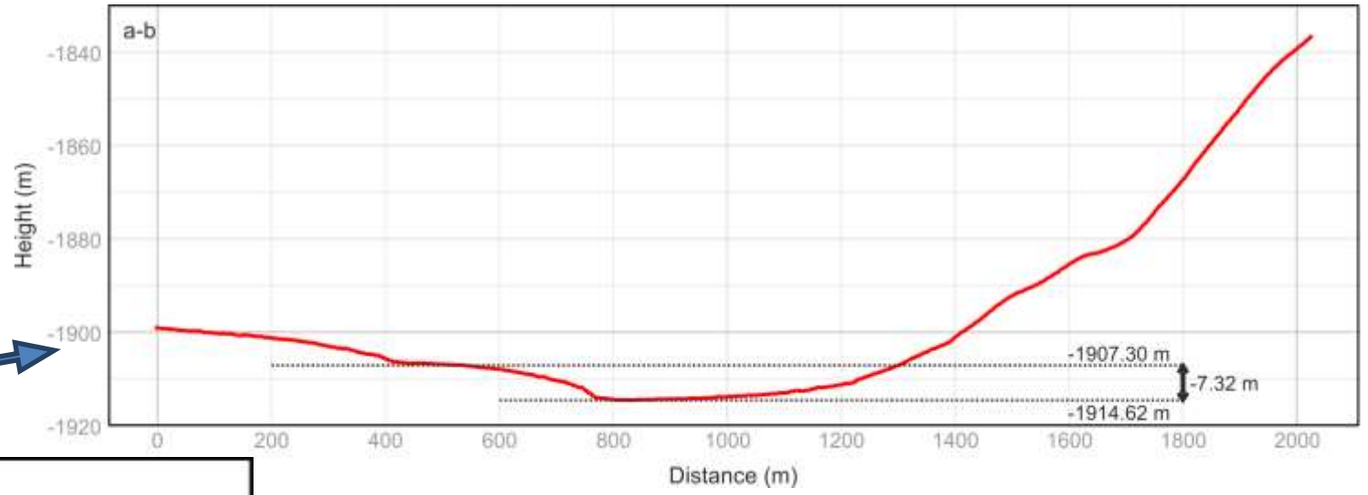
The Yusuf fault system

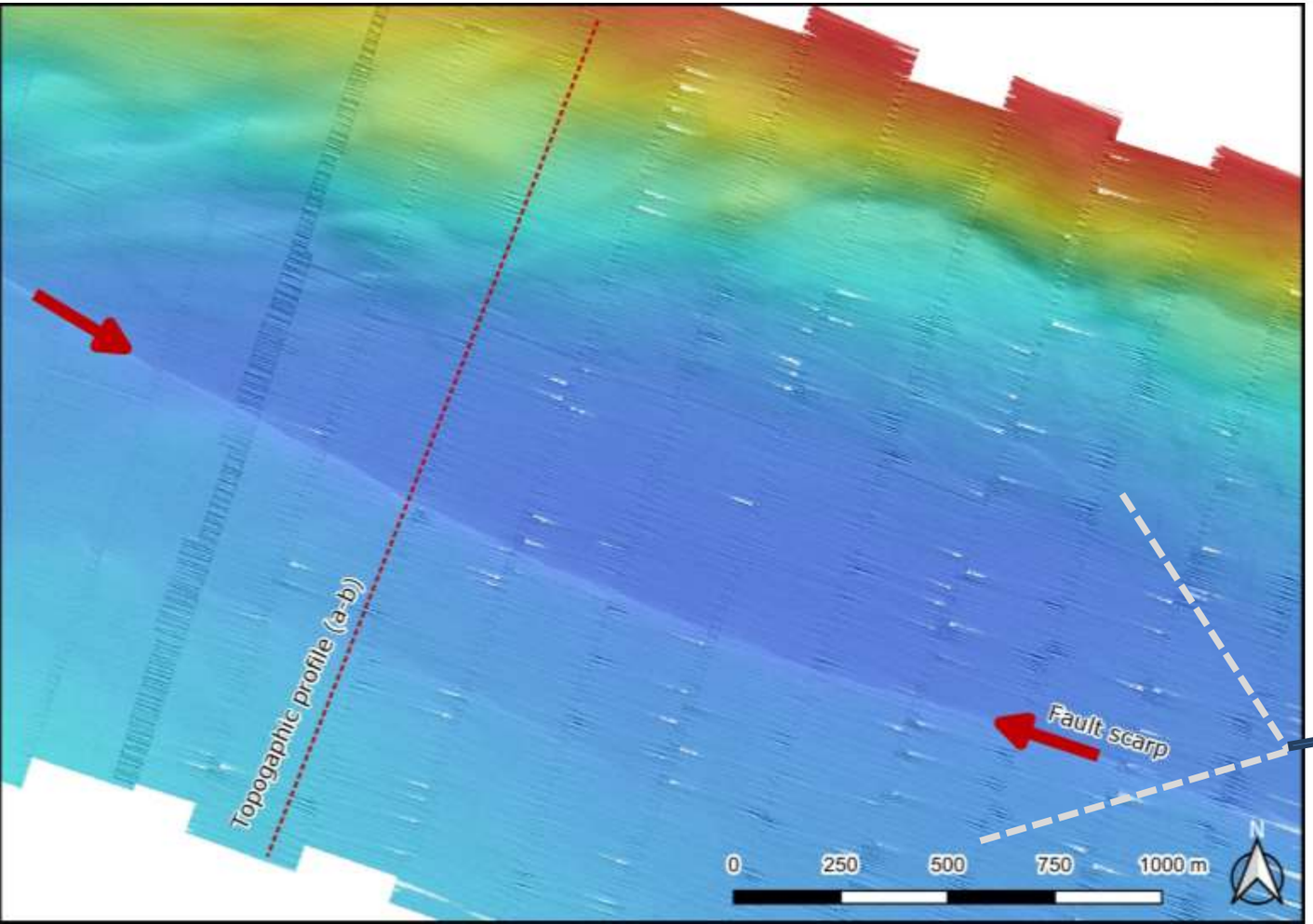
AUV micro-bathymetry

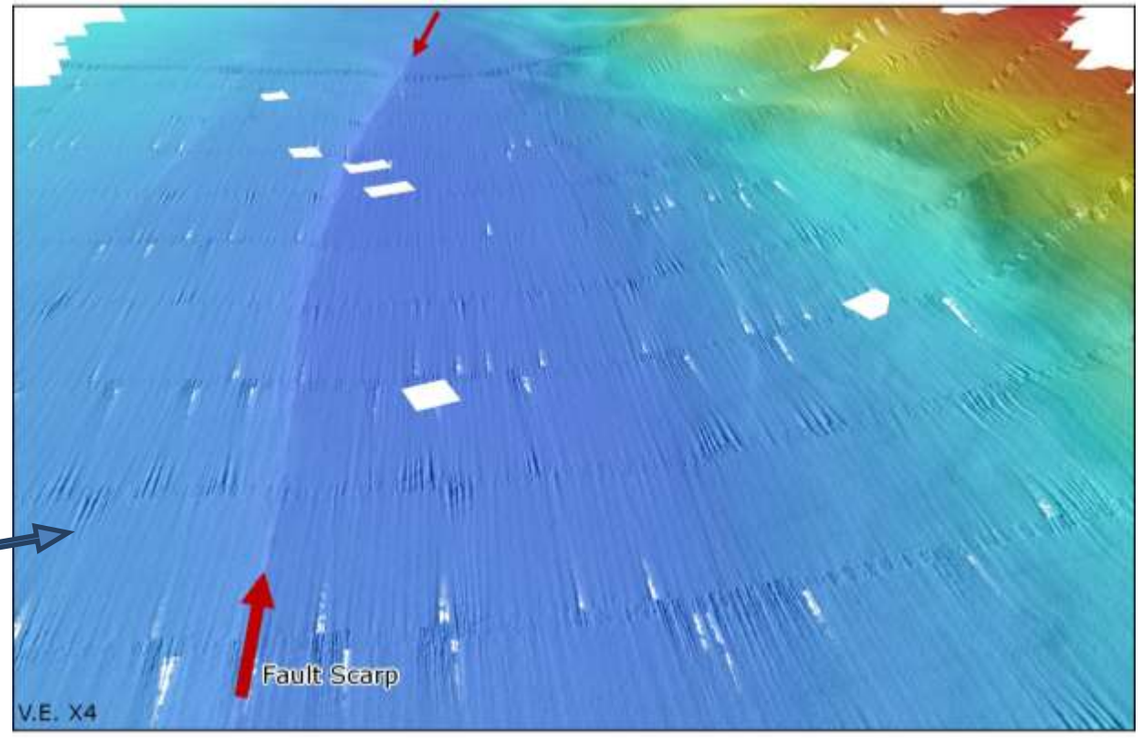


The Yusuf fault system

AUV micro-bathymetry – Fault scarps



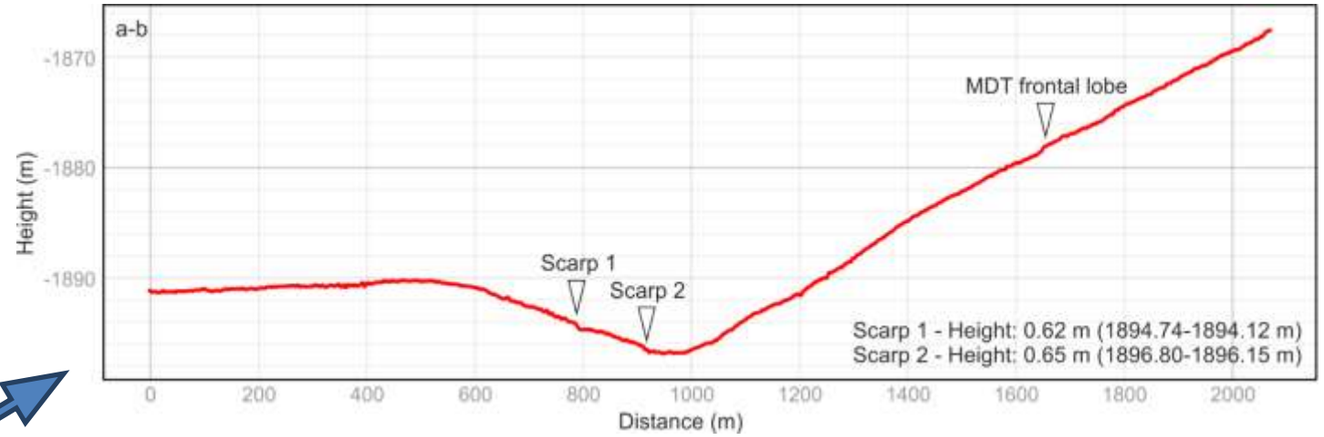


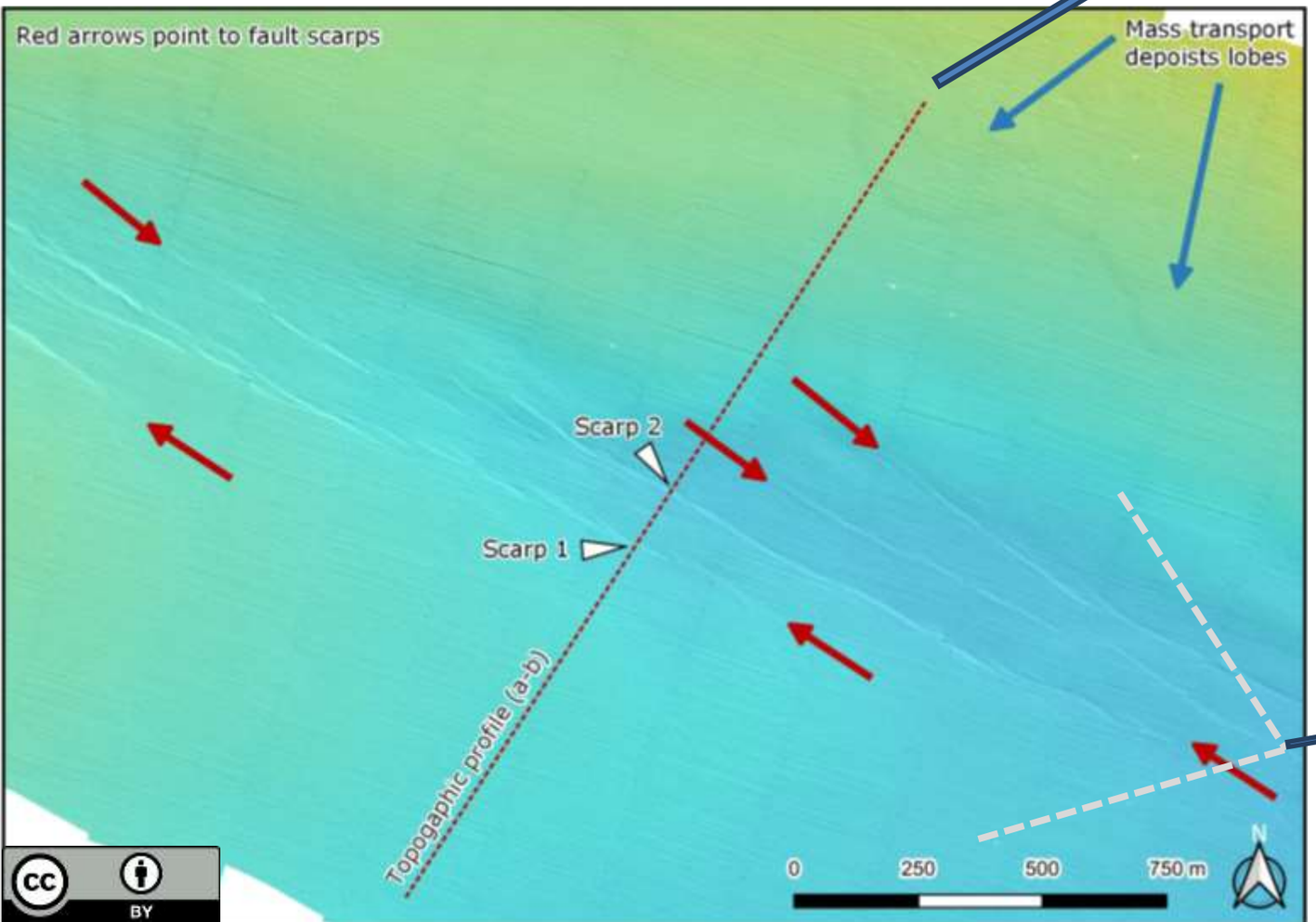


The Yusuf fault system

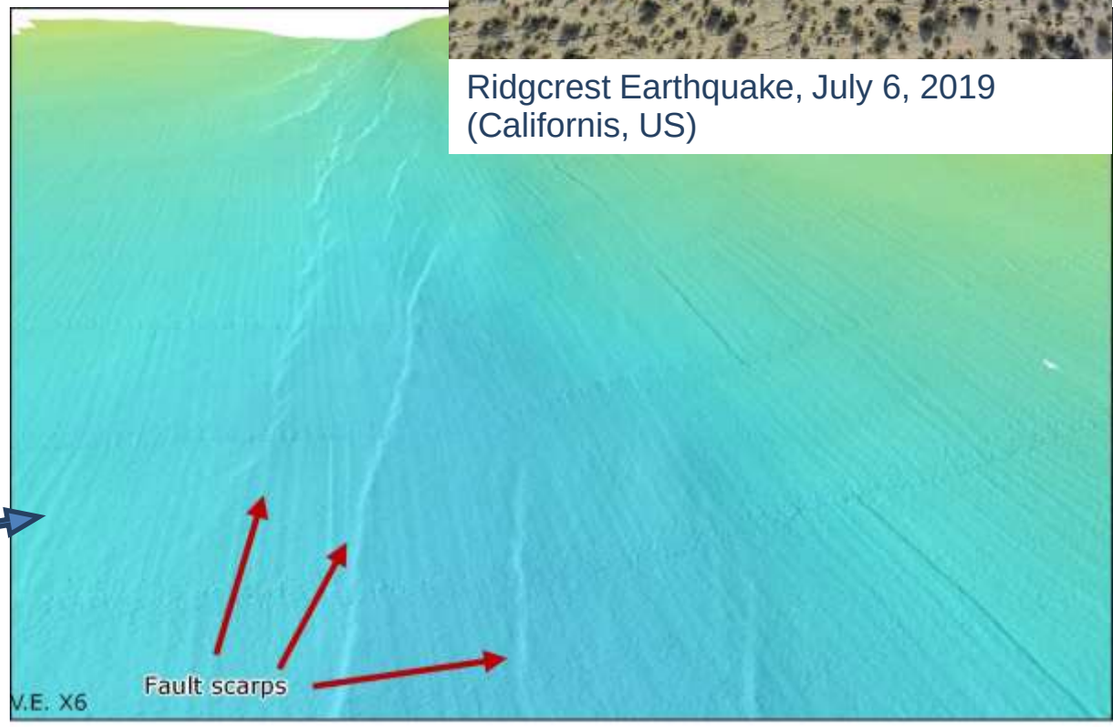
AUV micro-bathymetry – Fault scarps

- Recent surface rupture? → Historical EQ?





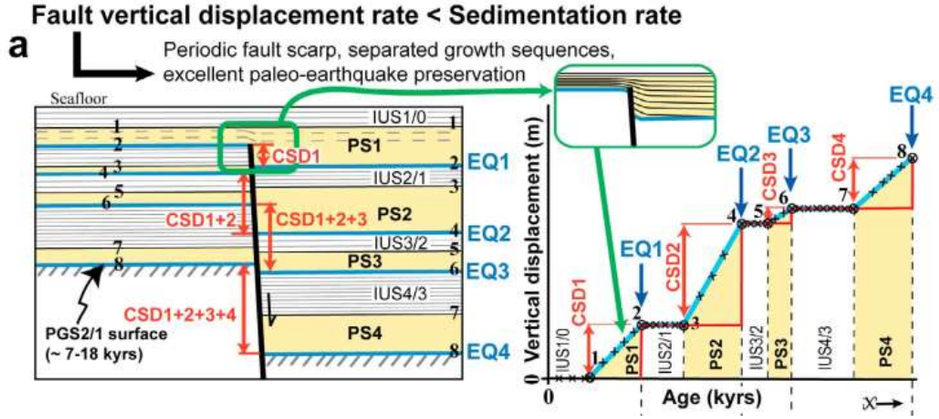
Ridgcrest Earthquake, July 6, 2019 (Californis, US)



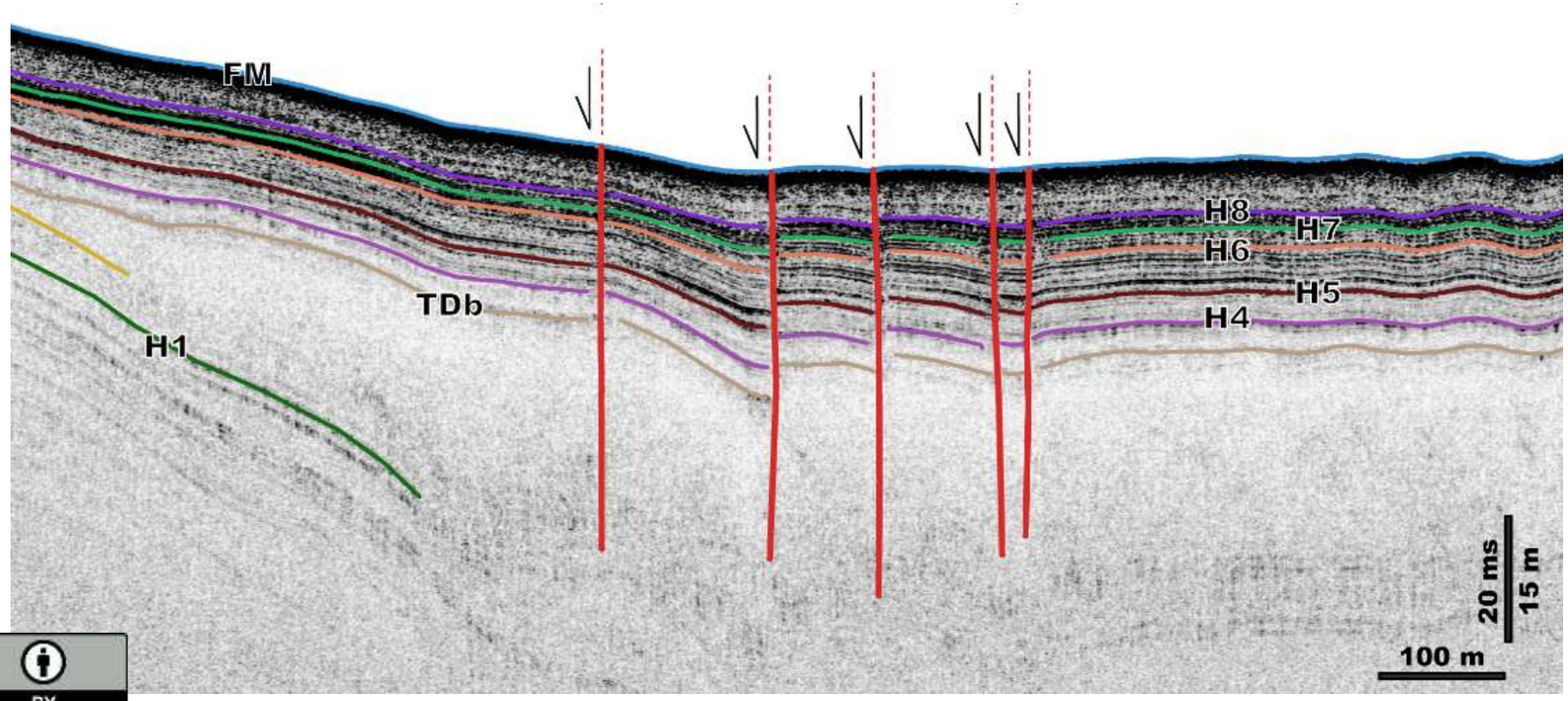
The Yusuf fault system

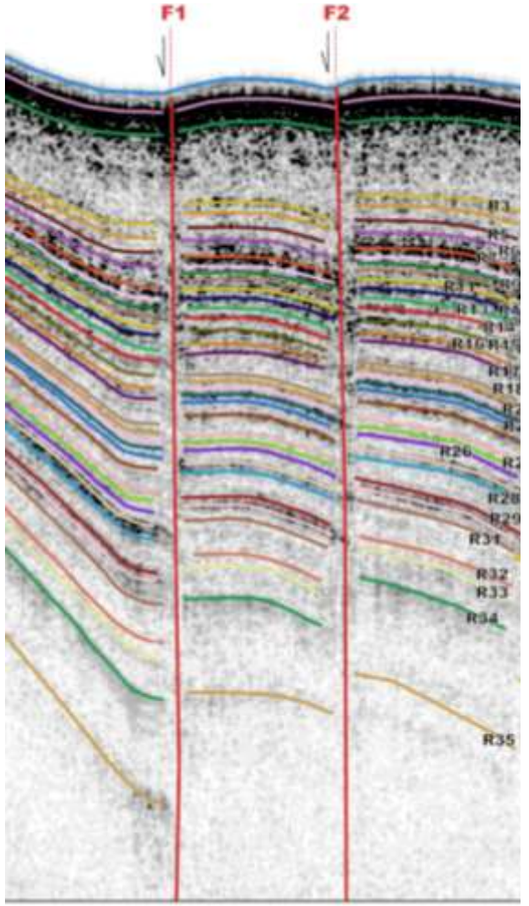
AUV sub-bottom profiles

- Seismostratigraphic units:
  - Hemipelagic → Unconformities
  - MTD → Transparent facies
- Faults offset the seismostratigraphic units and the seafloor
- On-fault paleoseismological study



Barnes and Pondard (JGR, 2010)

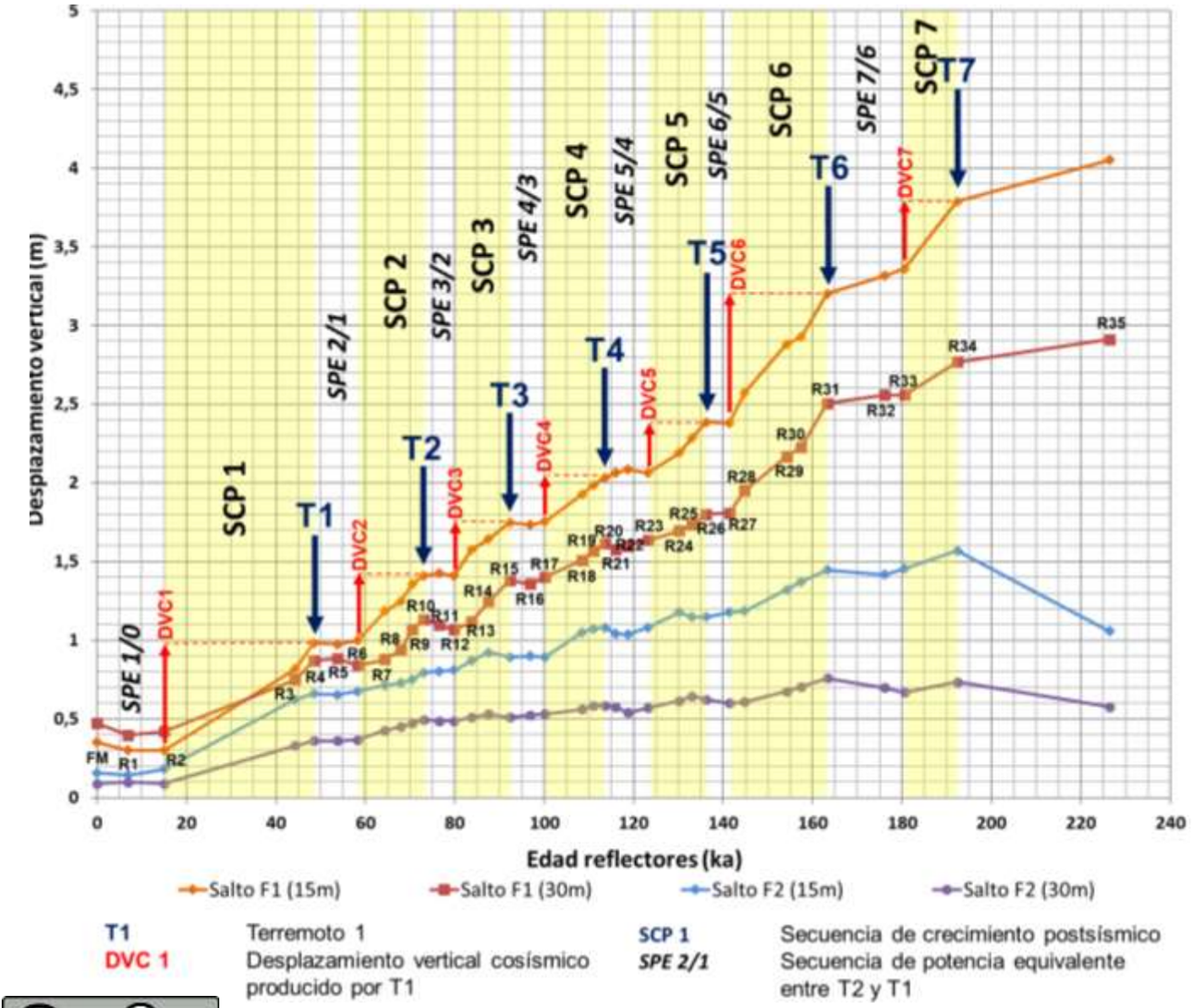




CC BY

The Yusuf fault system

AUV sub-bottom profiles – Paleoseismology → **PRELIMINARY RESULTS**



T1	Terremoto 1	SCP 1	Secuencia de crecimiento postsísmico
DVC 1	Desplazamiento vertical cosísmico producido por T1	*SPE 2/1*	Secuencia de potencia equivalente entre T2 y T1

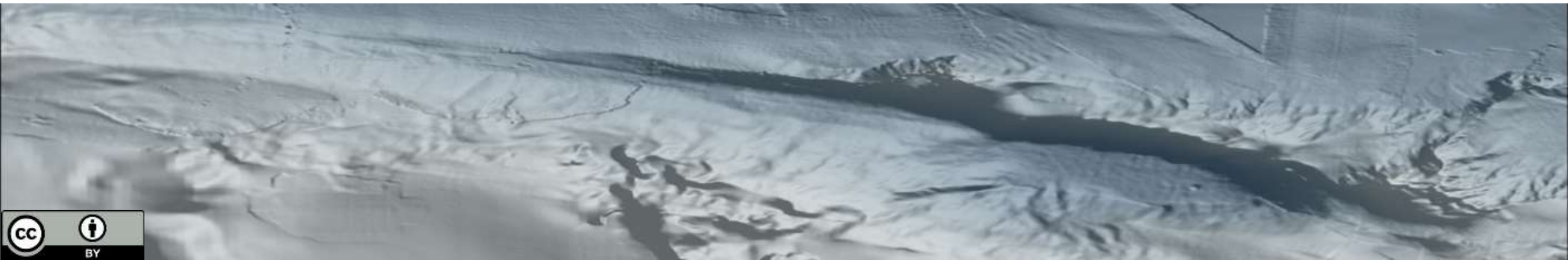
Paleoseismological results:

- Events → 8 in the last ~200 ka (0.1 mm/yr)
  - Last event very recent →Surface rupture
- Recurrence interval :
  - Range → ~19.29 to ~48.43 ka
  - Average ~27.48 ka
- Vertical displacements:
  - F1: 0.16-0.83 m
  - F2: 0.02-0.48 m
- EQ magnitude:
  - Max. vertical displacement → Mw 6.9
  - Strike slip fault → 4x vert. displ.? → Mw7.5

CC BY

Conclusions

- The Yusuf fault is a complex fault system → Composed by several faults
- Some faults offset the seafloor → Quaternary activity on the fault system
- Paleoseismology (**PRELIMINARY RESULTS**):
    - At least 8 EQs in the last 200 ka → Average recurrence interval of 27.5 ka → Needed to improve sediment geochronology information
    - Average vertical offset 0.64 m → Vertical slip rate 0.03 mm/yr →Minimum rate
    - EQ larger than Mw 7.0
- Even with some uncertainties, the results show that detailed geomorphological, structural and paleoseismological studies are essential to reveal present activity in active faults and to characterize their seismic behaviour and, thus, improve the seismic hazard assessment



Thank you

Acknowledgements:

National and international research projects:

EVENT (CGL 2006-12861-C02-02)

SHAKE (CGL 2011-30005-C02-02)

ESF TopoEurope TOPOMED project (CGL 2008-03474-E/BTE)

PALEOSEISQUAKE (657769 H2020-MSCA-IF-2014)

UNdERSEA (2018-T1/AMB-11039)

The captain, crew and science party onboard the RV Sarmiento de Gamboa cruises

Hector Perea is an **"Atracción de Talento Investigador" Postdoctoral Research Fellow** at the UCM funded by the Comunidad de Madrid (2018-T1/AMB-11039)