Accurate Earthquake Locations of the Adriatic Thrust Fault of the 2021 Seismic Sequence with sP Depth Phases.

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What makes earthquake's location unstable?

a-priori issues (network geometry)

Closest station epicentral distance > 30km
Azimuthal gap > 180°

a-posteriori issues (modeling)

misidentification of arrivals, ray-tracing, seismic velocity model

Distance of the closest station is proved to be the worst issue especially against the hypocenter's depth

Standard solution to mitigate: installing as many stations as possible to always have a station "on top" of the event.
In off-shore conditions, this is a hard-to-achieve result.

Depth Phases

later arrivals pP, sP, sS upgoing--> reflected --> downgoing

From Zhao et al., 2015

The use of a depth-phase datum in earthquake location is just like installing a new seismic station close to the epicenter (at the bouncing point (BP, Fig. 1a,b) on the Earth's surface or seafloor)
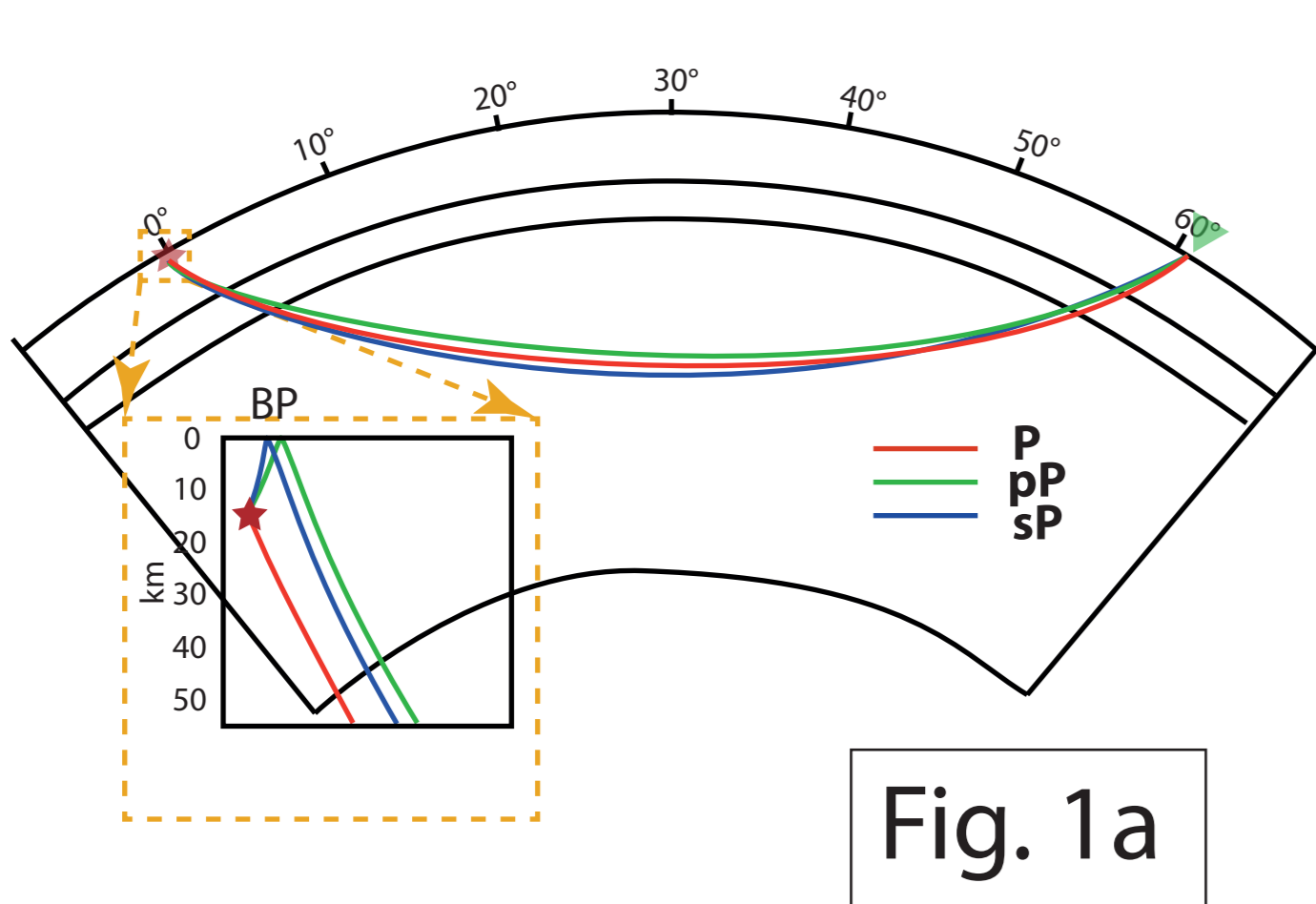

Fig. 1a

Fig. 1b

sP Depth Phase at local distance key-points

sP-onset Identification points

- found and/or better visible at Δ ≥ 90-150km
- stronger signal on vertical-component
- sP–P δt ~constant independent of station Δ or azimuth
- particle motion is quite comparable to a P-wave

Modeling points

s to P conversion at the BP is influenced by:
- *sediments' thickness and velocity*
- *surface topography/bathymetry*

sP peculiar ray-path must be accurately modeled

The 2021 Seismic Sequence

An earthquake sequence occurred in the Central Adriatic region (Italy-Croatia) starting on 27th March 2021 with a mainshock of Mw 5.2.
No foreshock was observed before this mainshock.

The epicenters occurred in the open sea, approximately 80 km from the Gargano promontory and 40 km from the Croatian island of Lastovo, between the 2003 Jabuka seismic sequence (northwest), and the 1988 Palagruza seismic sequence (southeast).
This mainshock was felt in many central–southern Italian regions, from Ancona to Foggia, and in Central Dalmatia.
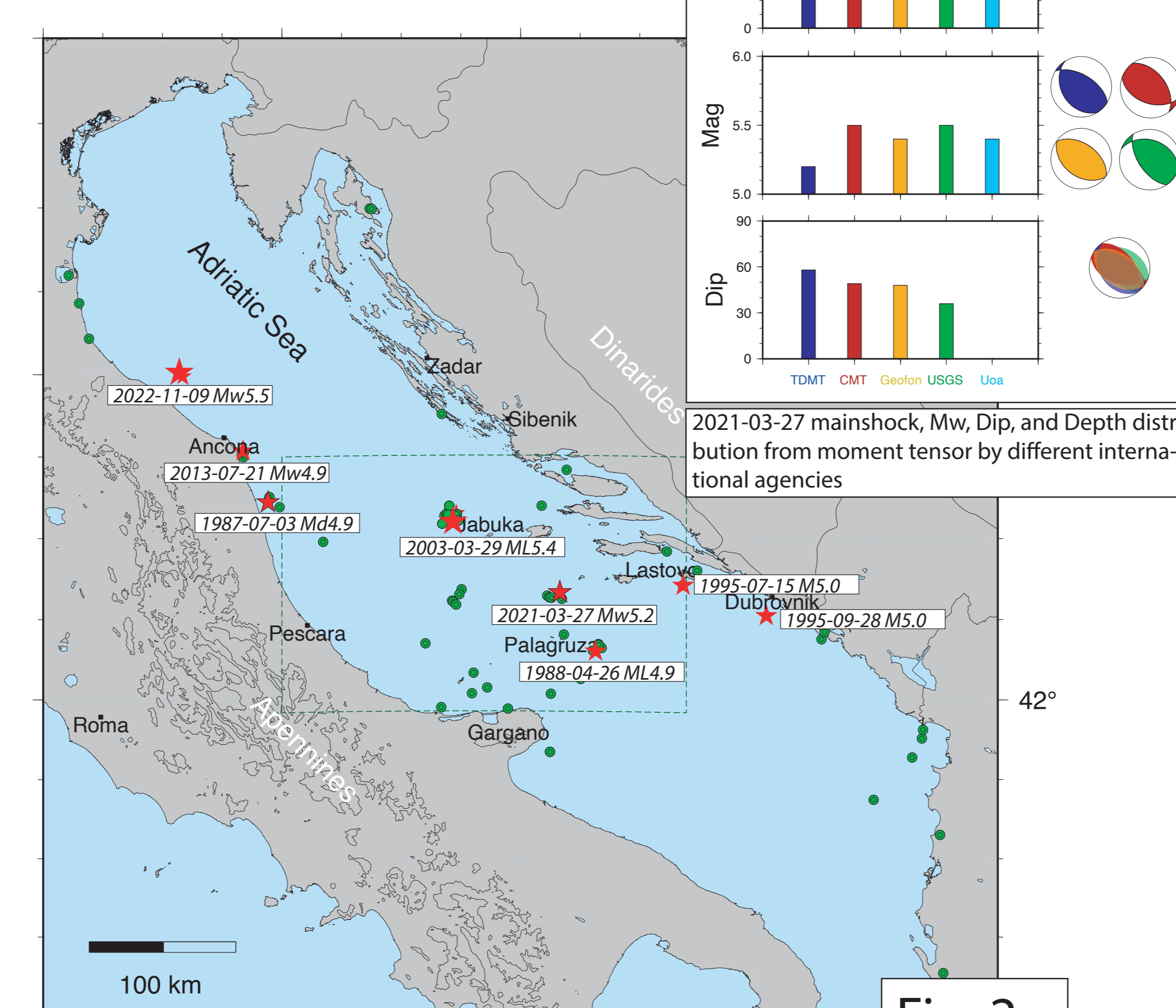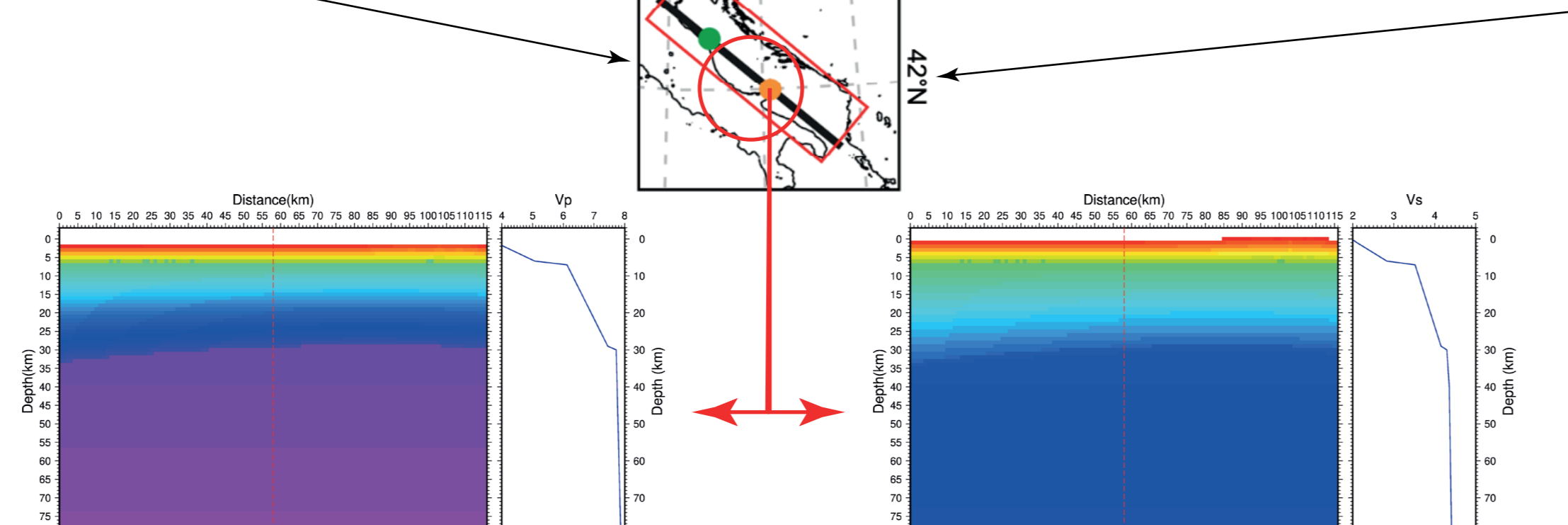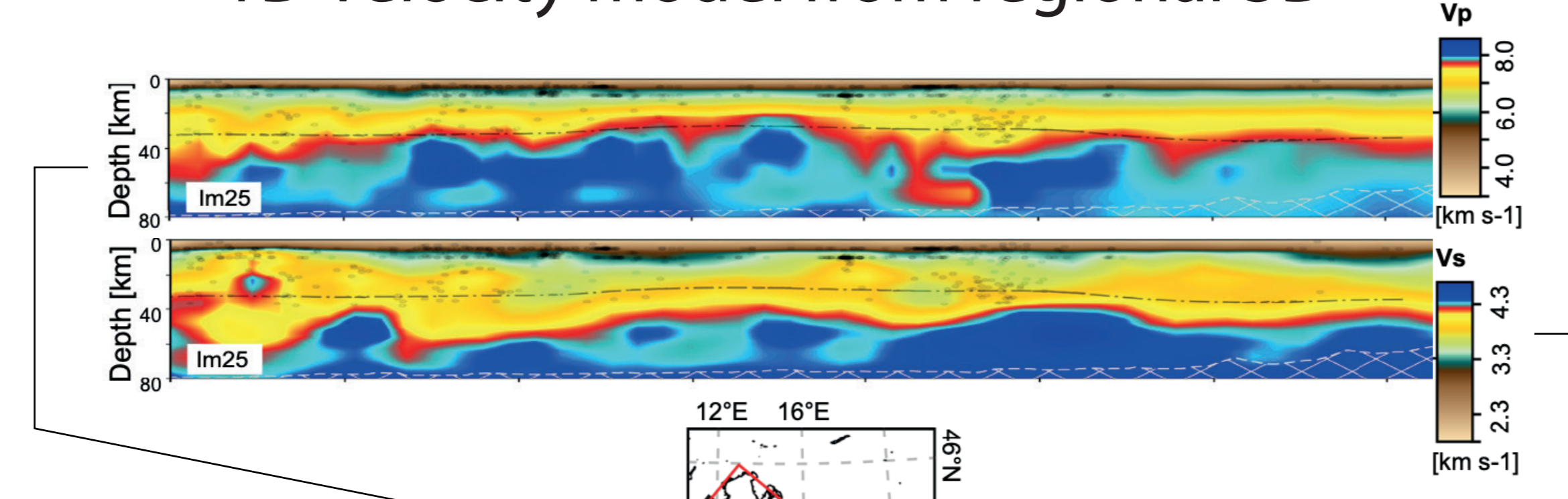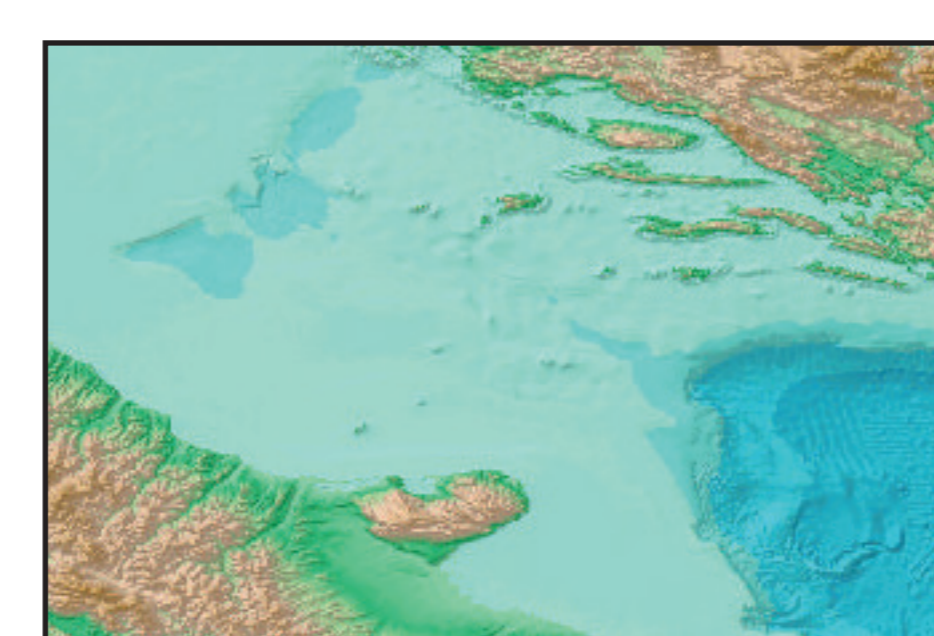

2021-03-27 mainshock, Mw, Dip, and Depth distribution from moment tensor by different international agencies

Fig. 2a

1D velocity model from regional 3D

Magnoni et al., 2022
https://doi.org/10.1038/s43247-022-00397-7

Fig. 2b

topography / sediments (thickness/velocity)

https://download.gebco.net/
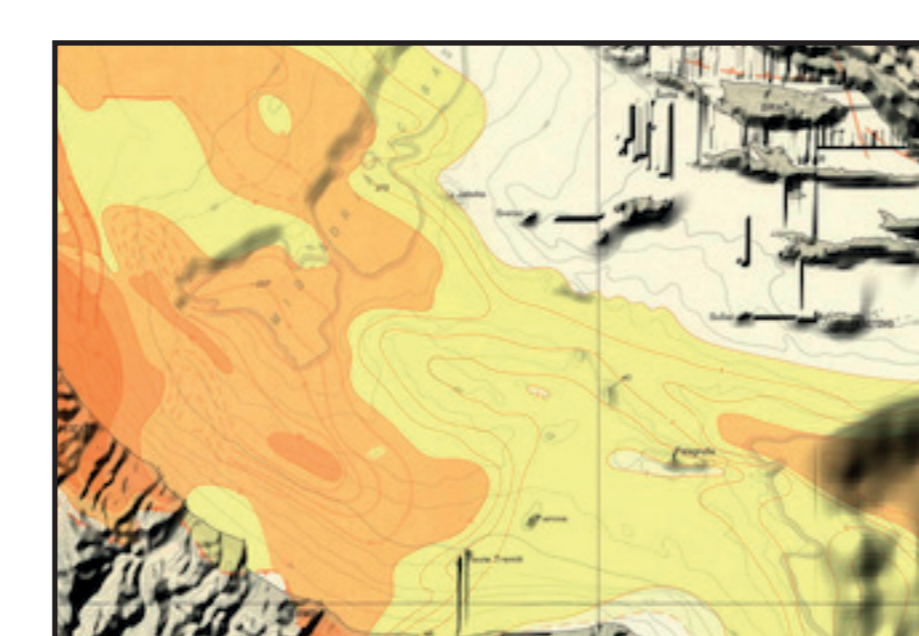
from literature

sP Depth Phase in the Adriatic Sea: a-priori setup

Moho 2d geometry

Di Stefano et al., 2011
https://doi.org/10.1029/2011-GC003649

Workflow for off-shore earthquakes locations with sP

- Waveforms download within 300km distance from INGV location
- Picking P- and S-onsets on three components and "stacking" visualization of vertical components only, aligned along P-onsets (Fig. 3a)
- sP possible identification on 1 to 3 (only best signals)
- final check with particle motion (Fig. 3b)

For each event, P-, S-, and sP-arrivals are inverted with the on-purpose designed code by Zhao et al. (2007, 2011), in the a-priori detailed setup (Fig. 2b) for a new location (Fig. 3c).

Fig. 3a

Fig. 3c

Fig. 3b

Results: the Mid Adriatic Fault

Fig. 3d
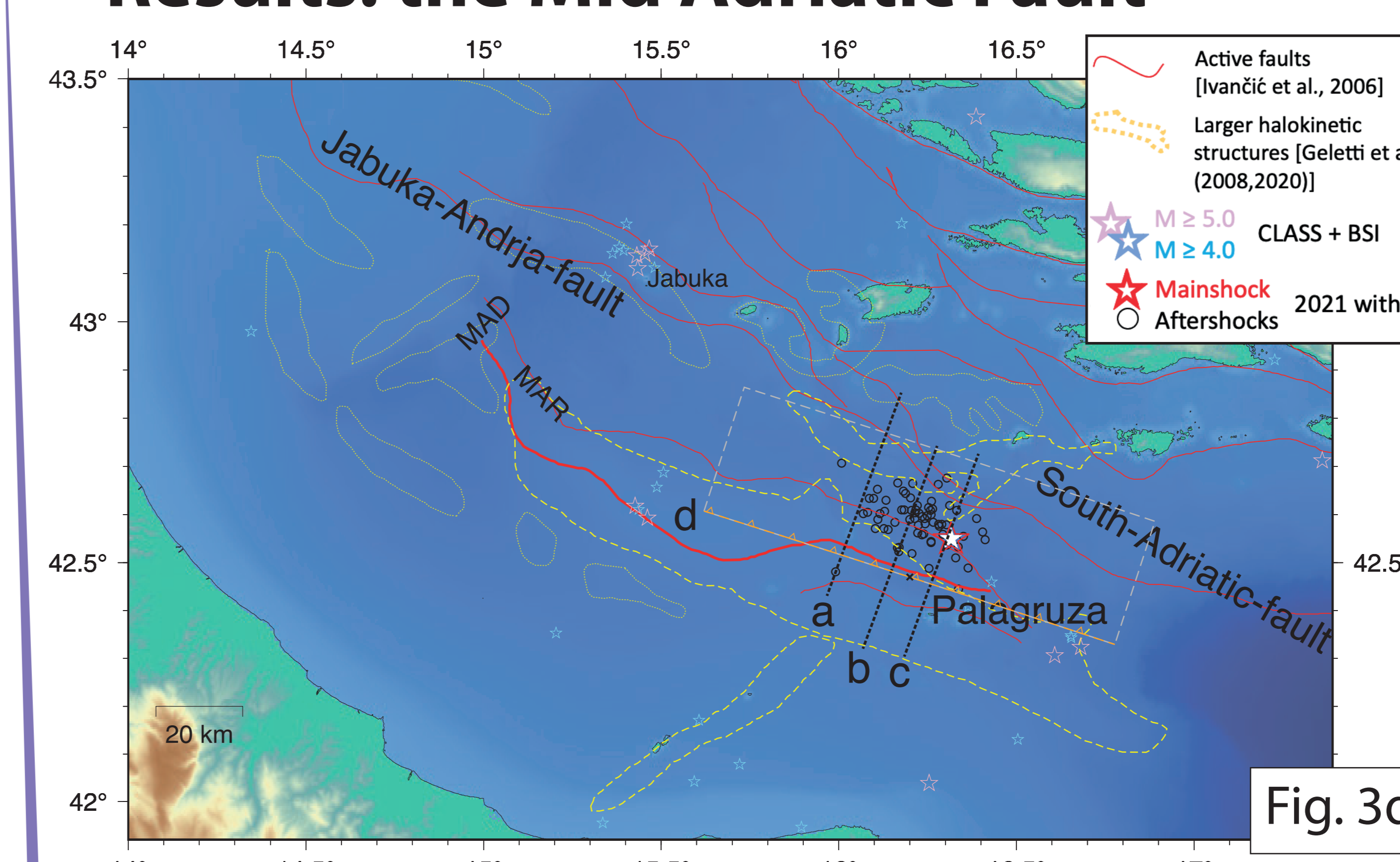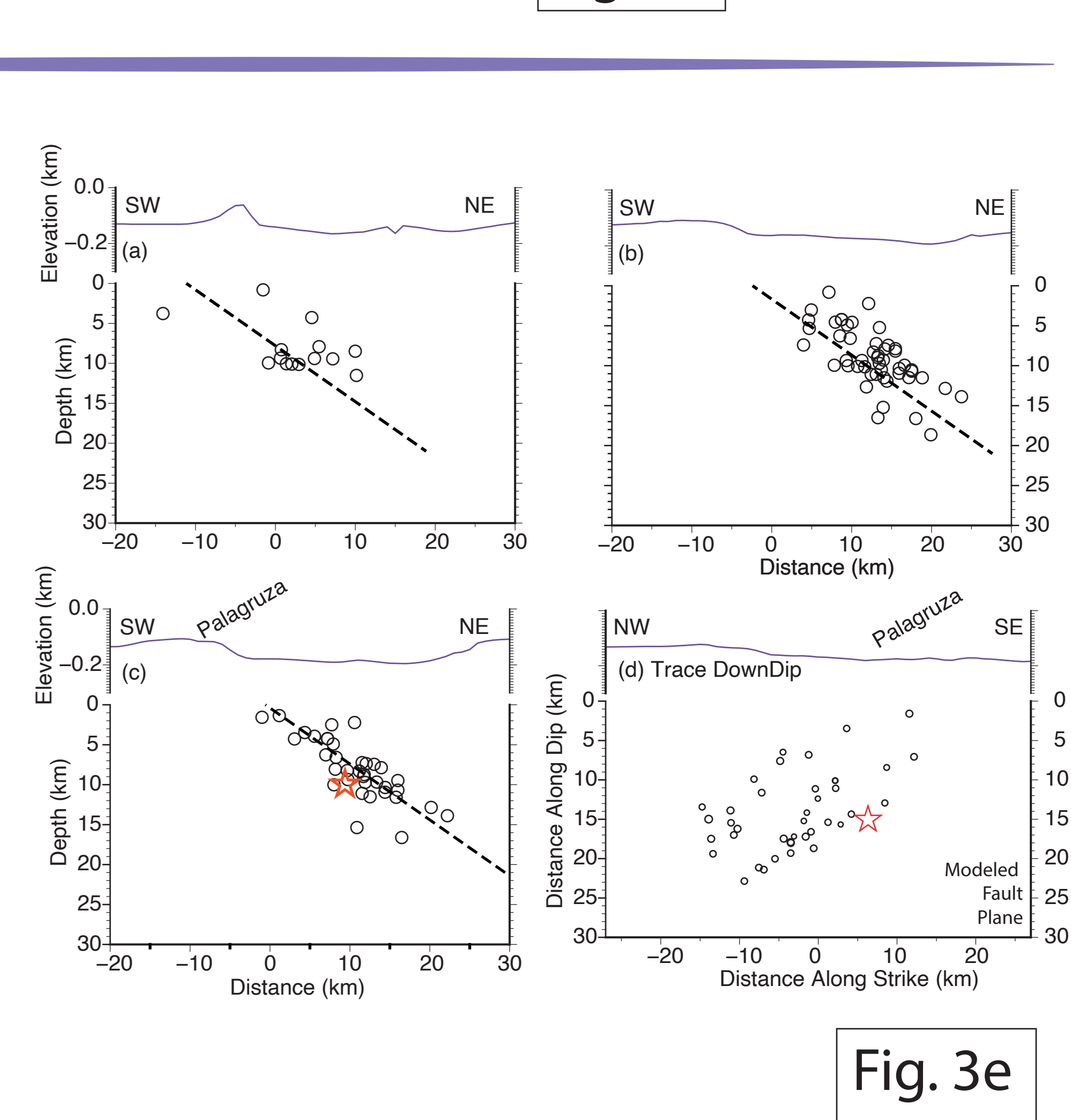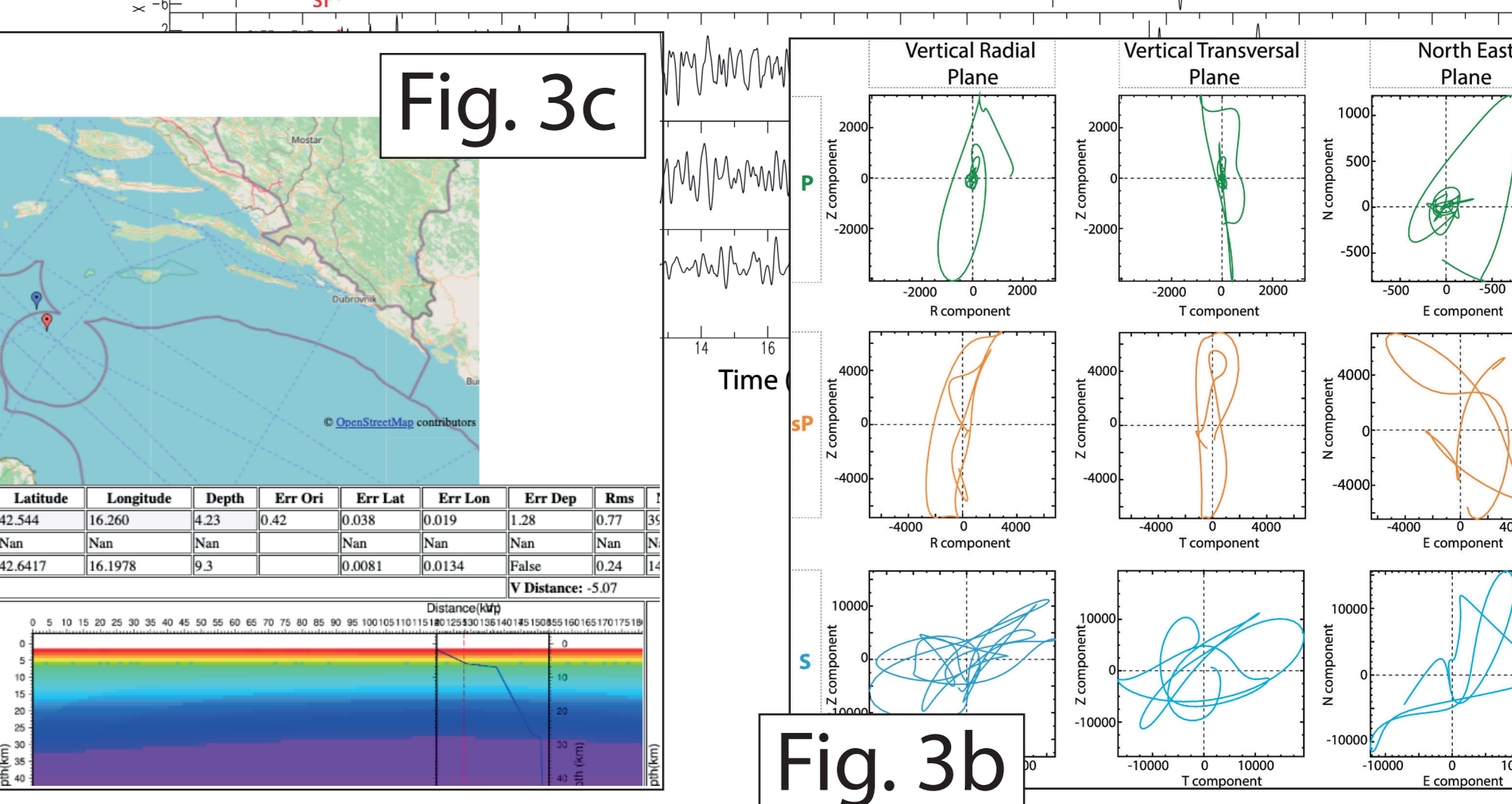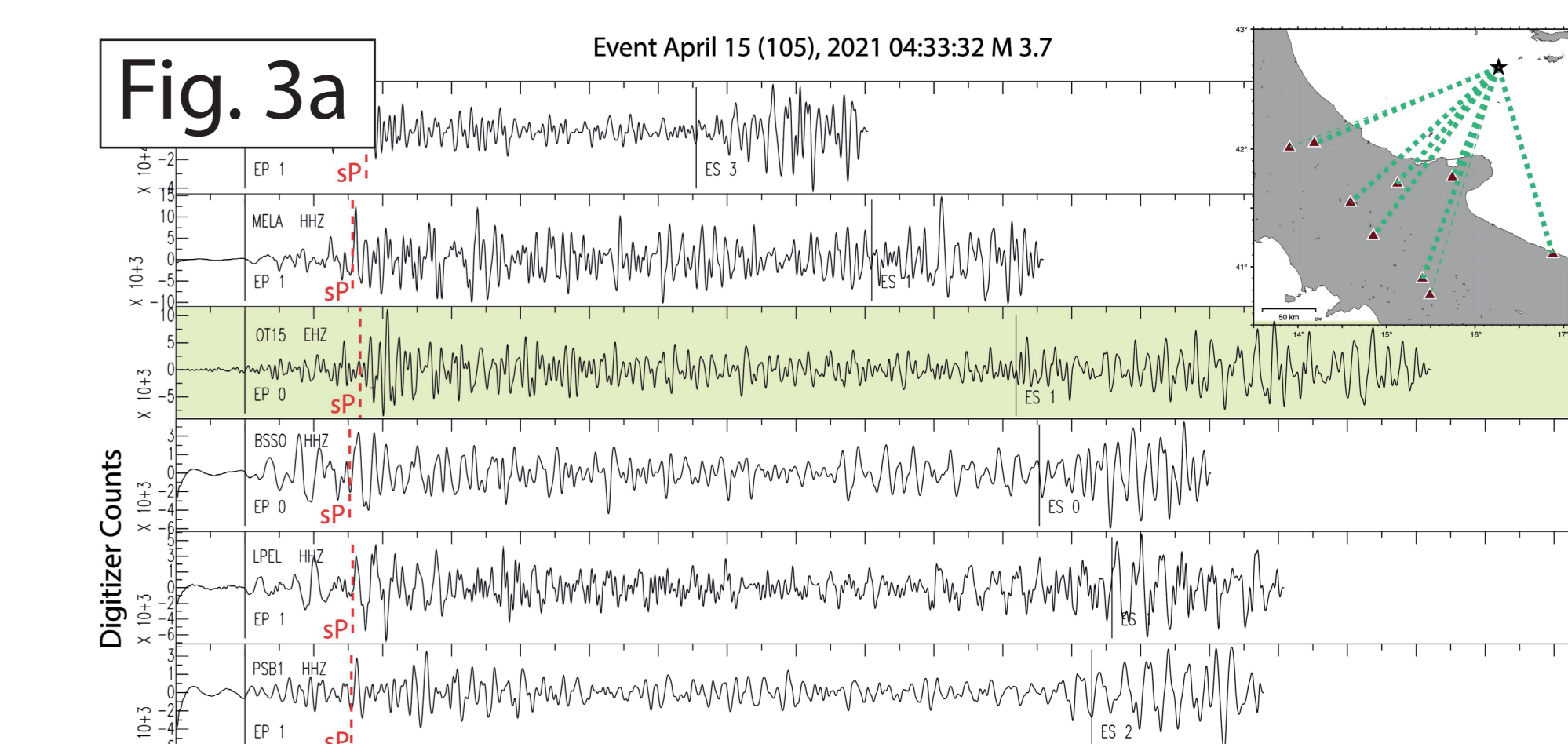

Fig. 3e

According to our locations (70 earthquakes with, M ≥ 2.9, hypocenters constrained with P, S, and sP stations D ≤ 300 km (Independent from the GAP):

☼ the 2021 central Adriatic seismic sequence occurred along the Mid Adriatic Fault (MAF)
☼ the MAF is northeast-dipping thrust fault of the Dinaric front
☼ its dip is between 35° and 45° (comparable to moment tensors's dispersion, Fig. 2a)
☼ it is ocated parallel to, and between the, 2003 Jabuka and 1988 Palagruza seismic sequences
☼ the fault plane was ctivated from near-surface depths to a depth of approximately 20 km
☼ the mainshock is located approximately in the middle of the fault
☼ the MAF is urrounded by uprising halokinetic structures thus confirming the correlation between such structures and the tectonic regime of this area

Poster References
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