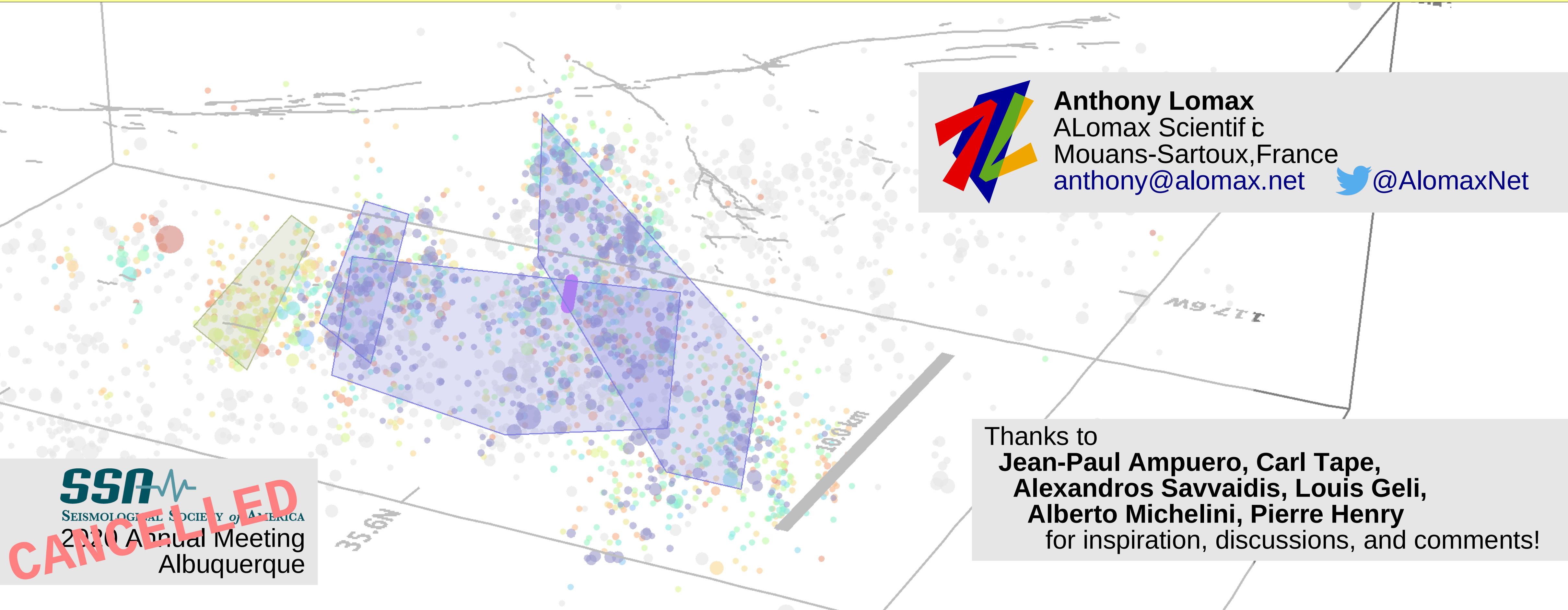
Absolute Location of 2019 Ridgecrest Seismicity:

Duplex Mw6.4 Ruptures,
Migrating and Pulsing Mw7.1 Foreshocks,
Unusually Shallow Mw7.1 Nucleation.

Did the Mw7.1 rupture *require* incitation by Mw6.4-like rupture?



Anthony Lomax
ALomax Scientific
Mouans-Sartoux,France
anthony@alomax.net @AlomaxNet

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SSA
Seismological Society of America
2020 Annual Meeting
Albuquerque
CANCELLED

Calibrated absolute location of M≥1.0 Ridgecrest events

Absolute earthquake location forms a foundation and framework for earthquake response and basic seismological studies.

Here we examine *calibrated* absolute relocation with:

- different 1D and 3D velocity models

1D
- SC1D - constant-velocity layered, 1-D, Southern California (Kanamori and Hadley, 1975)
- HK1D - smooth version of SC1D (Plesch et al., 2011)
- L1D - smooth, 1D model (Lin et al, 2007)

3D
- CVMH3D - SCEC CVM-H 3D: topological/bathymetric, basement, and Moho surfaces (Plesch et al., 2011)
- ZL3D - smooth, 3D, tomographic model for the Coso-Ridgecrest area (Zhang and Lin, 2014)

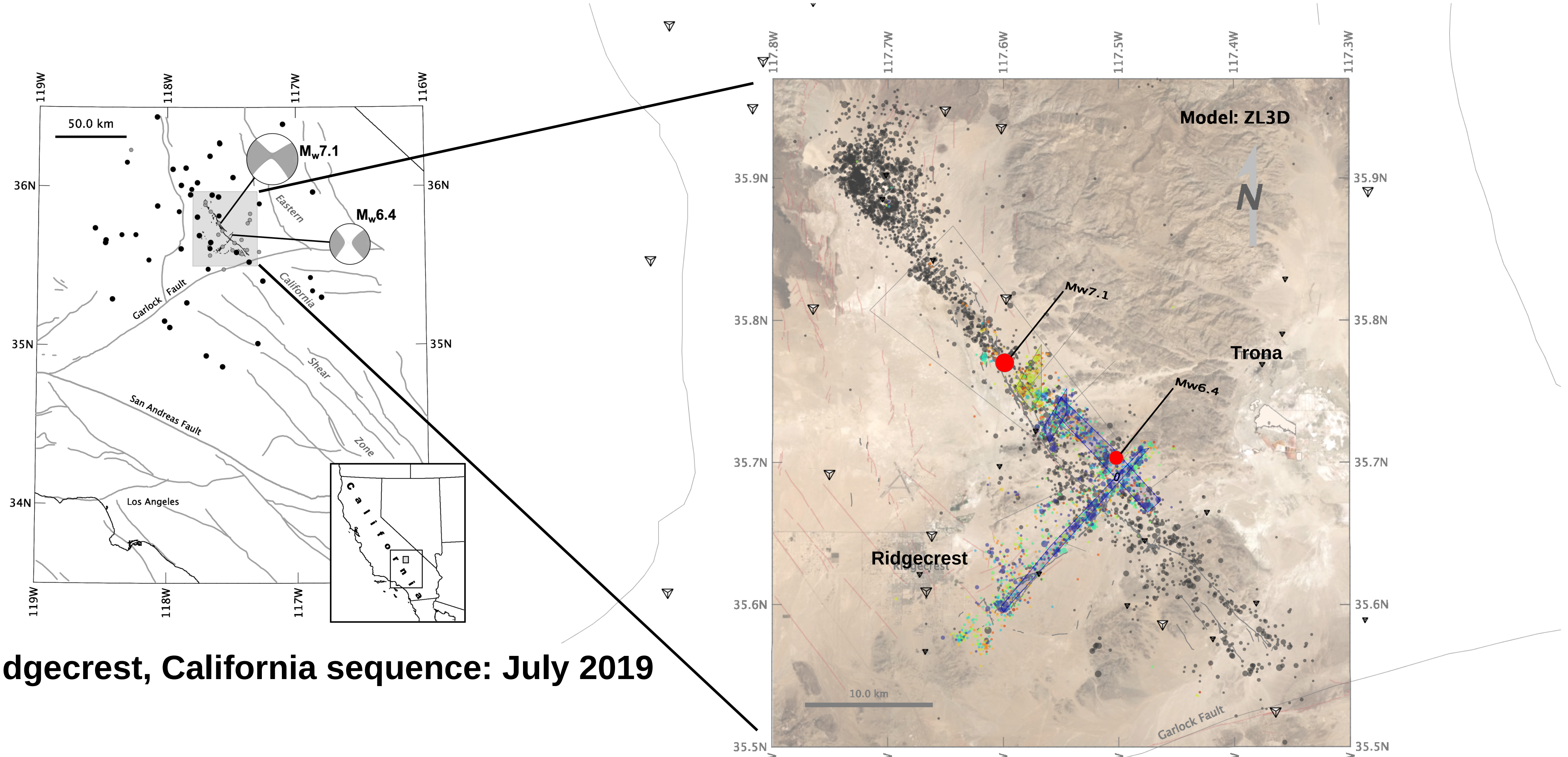
- probabilistic, global-search location algorithm: robust to model and arrival-time error

NonLinLoc algorithm (Lomax et al., 2000, 2005, 2008, 2014)

- station corrections

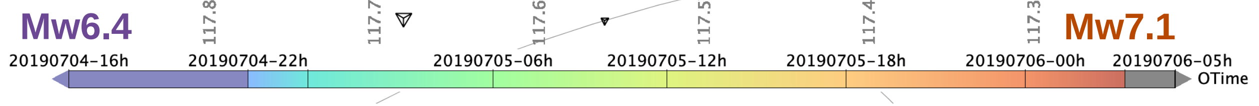
developed using 278 USGS M≥2.5 events after July 12, 2019, when nearby, temporary stations installed

Study area and relocated seismicity: post-Mw6.4 (color), post-Mw7.1 (dark gray)



Ridgecrest, California sequence: July 2019

Timeline of displayed seismicity →



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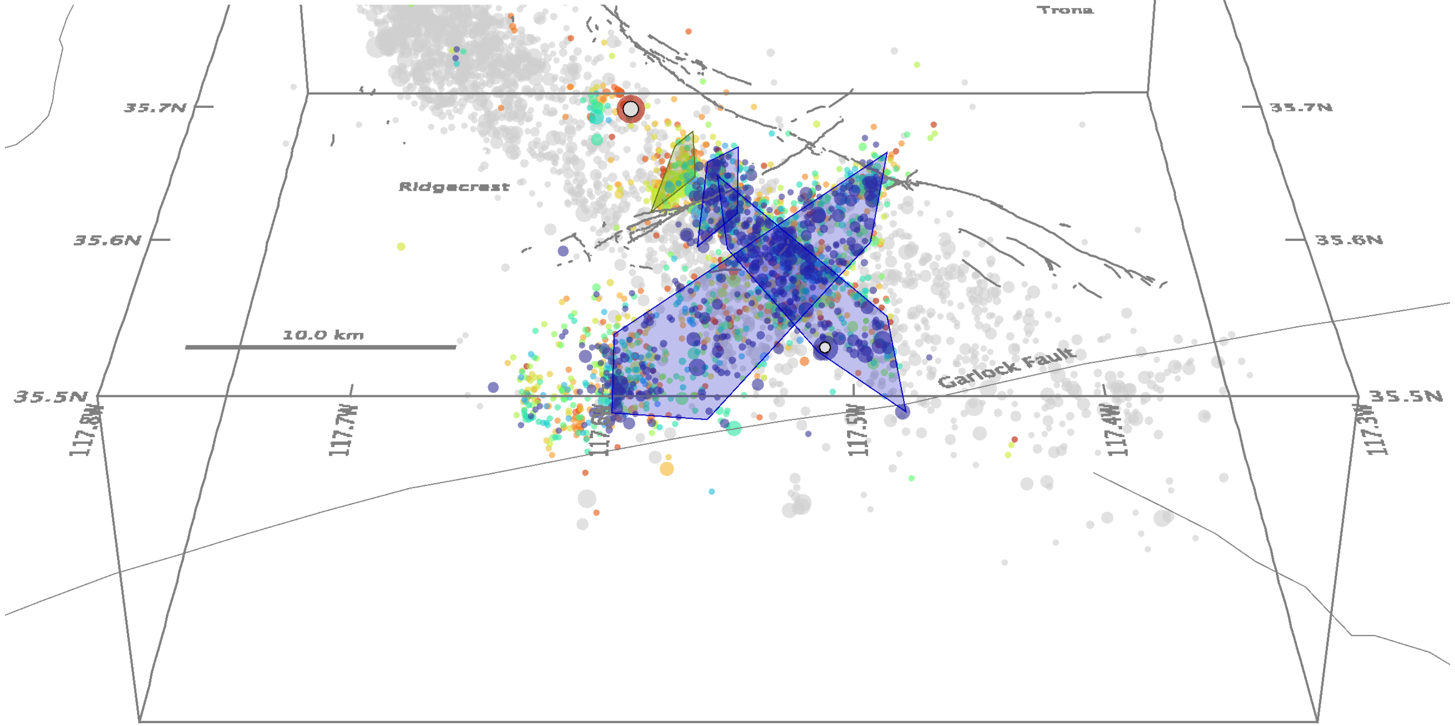
Relocated seismicity: post-Mw6.4 (color), post-Mw7.1 (light gray)

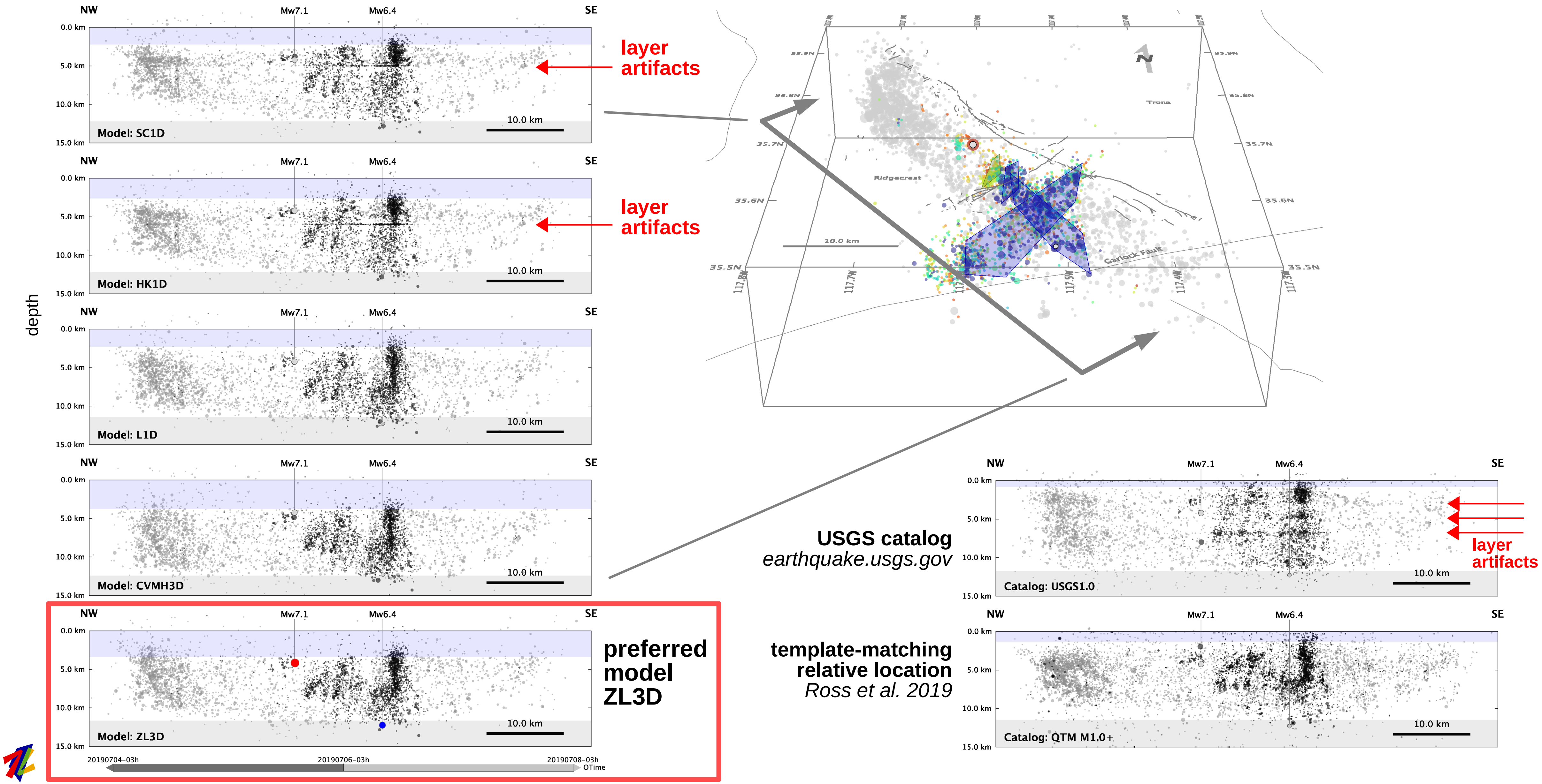
Understand the seismicity in 3D:

An animation of absolute relocations of M≥1.0 Ridgecrest seismicity with interpreted faulting structures:

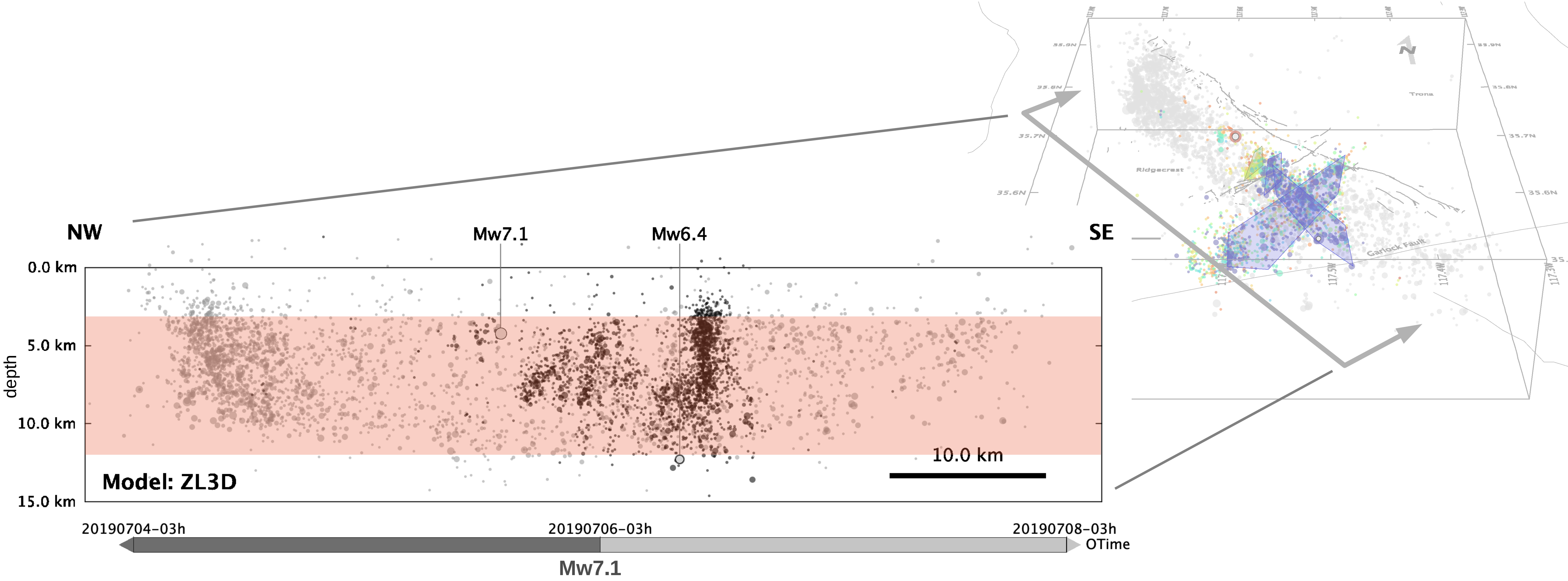
click here → Ridgecrest2019_ALomax_M1_Faulting_movie



Different seismic velocity models give different depth ranges for seismicity

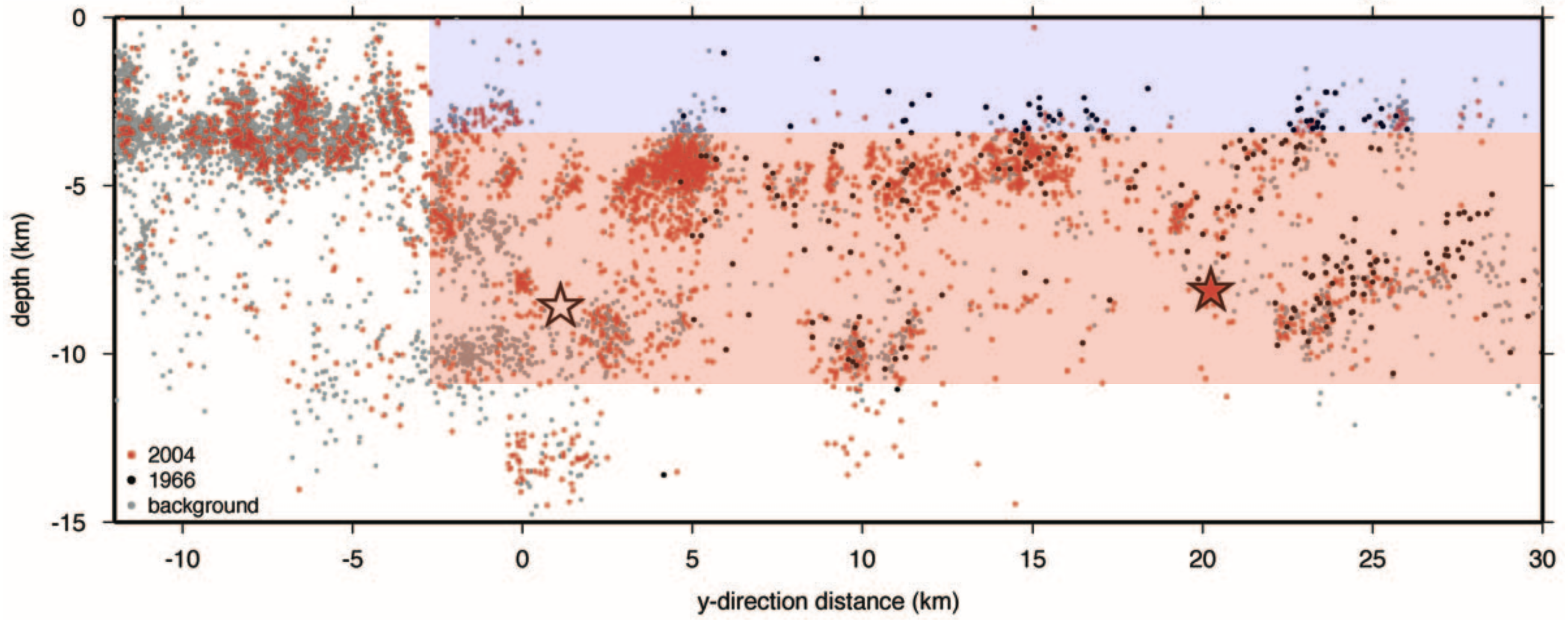


The seismicity is mainly ~3-12km deep, with few shallower events



The seismicity is mainly ~3-12km deep, with few shallower events

A similar depth range for seismicity is found elsewhere in California, for example:



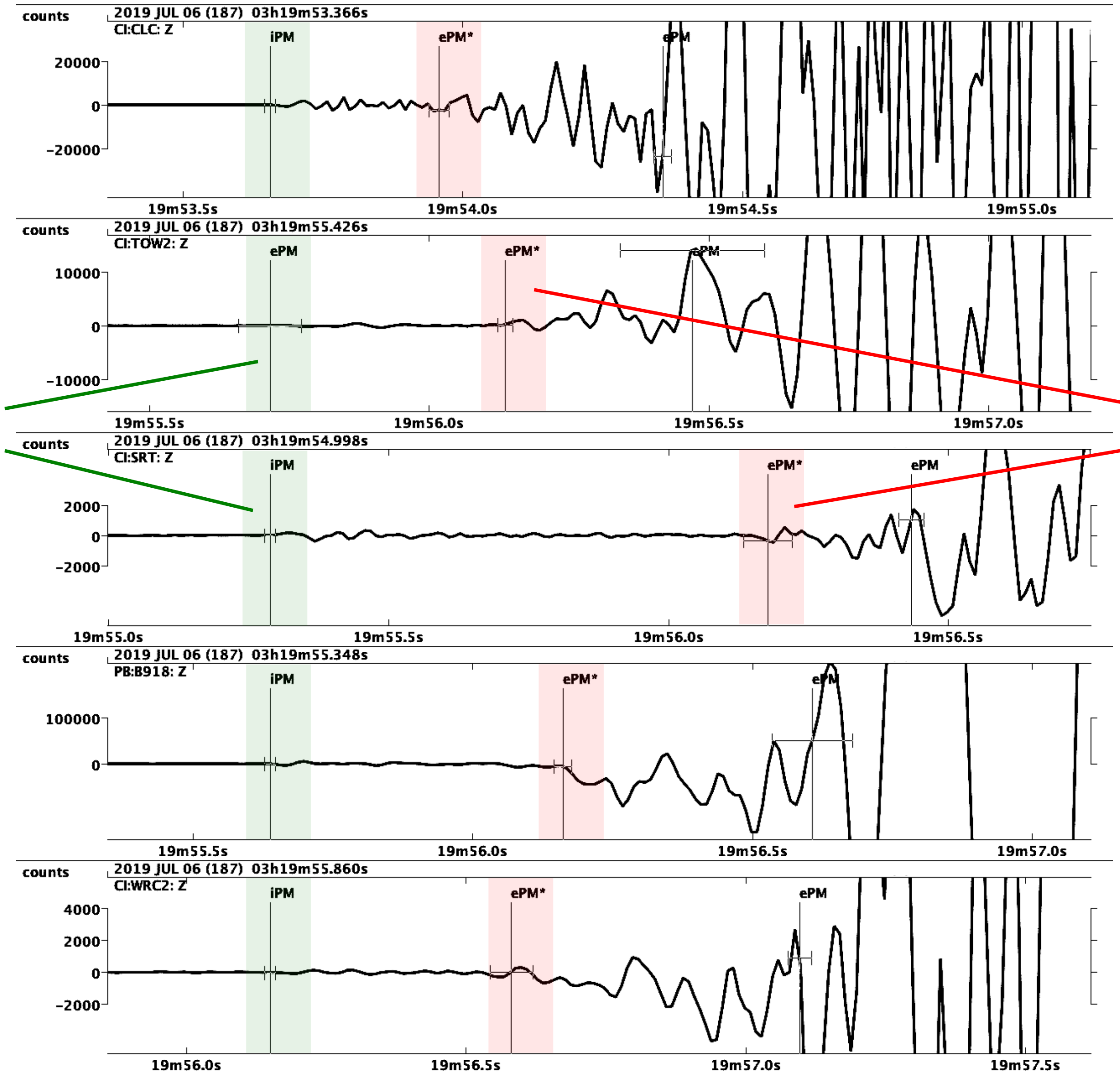
Calibrated relocations from 1966 to 2005 for the Parkf ield segment of the San Andreas Fault

Thurber et al., 2006

Mw7.1 location is complicated by overlapping waveforms from a small, M6.4 aftershock

re-picked stations closest to Mw7.1 epicenter

small aftershock of the Mw6.4 event



re-picked Mw7.1 mainshock

0.5 sec

vertical component seismograms

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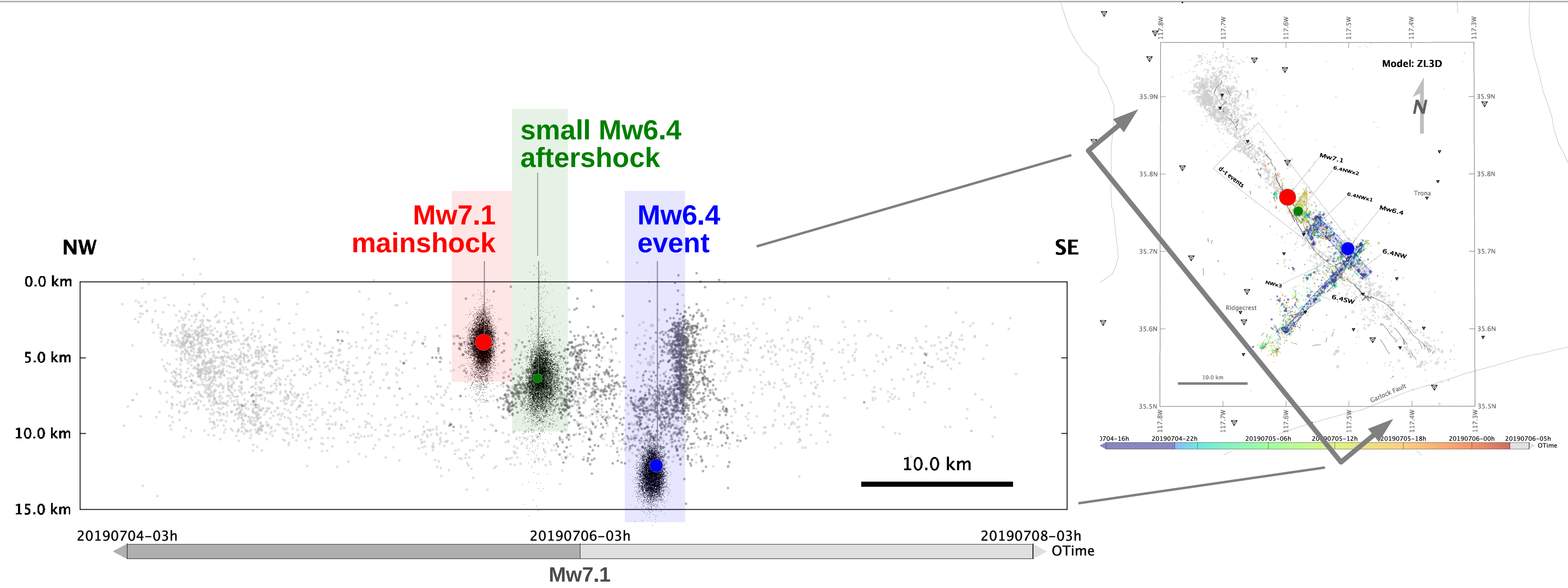
The Mw6.4 hypocenter is ~12km deep,
the relocated Mw7.1 hypocenter is unusually shallow at ~4km



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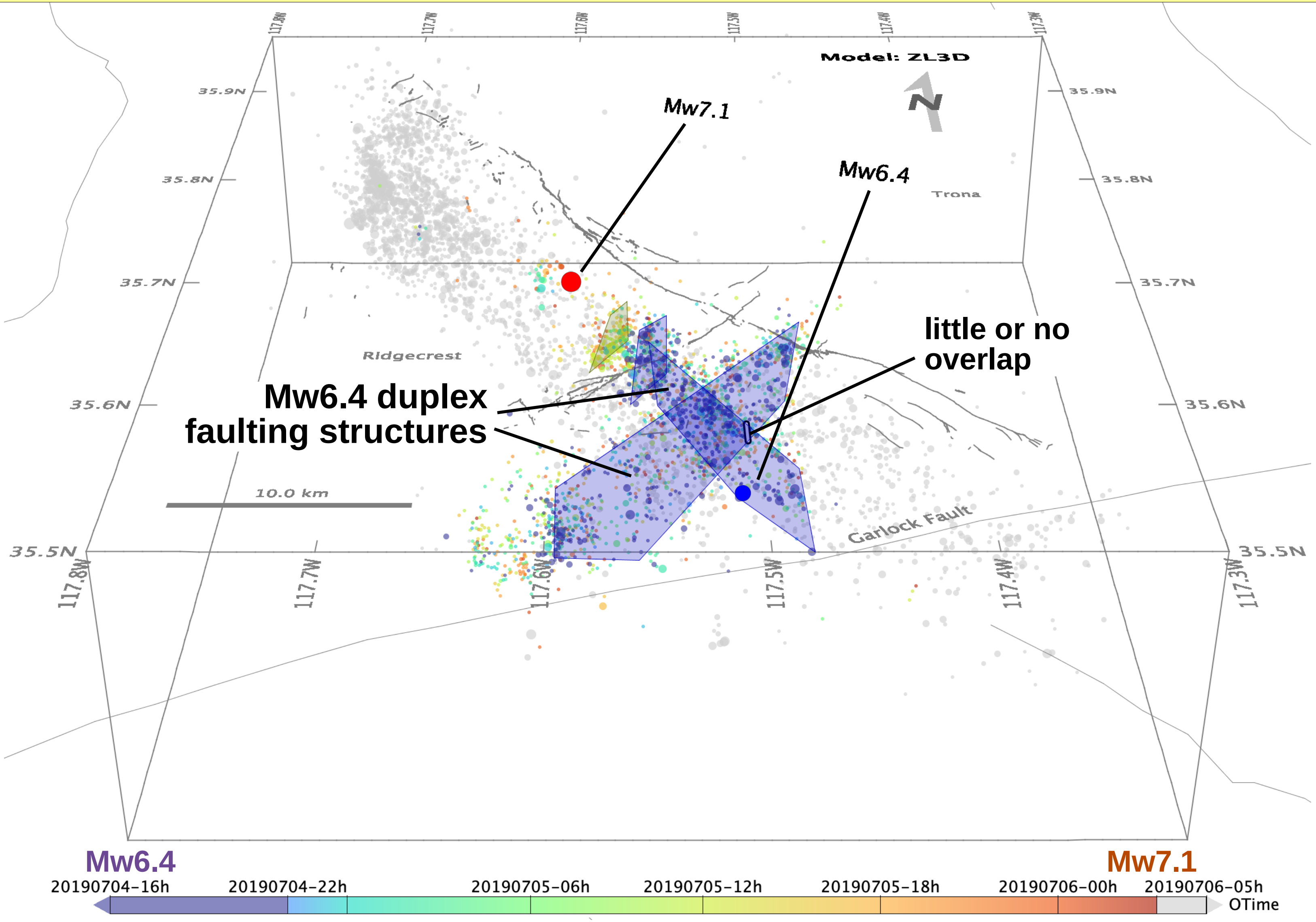
Post-Mw6.4 seismicity def hes orthogonal, duplex faulting structures
→ the Mw6.4 event is a double earthquake.



ALomax Scientific

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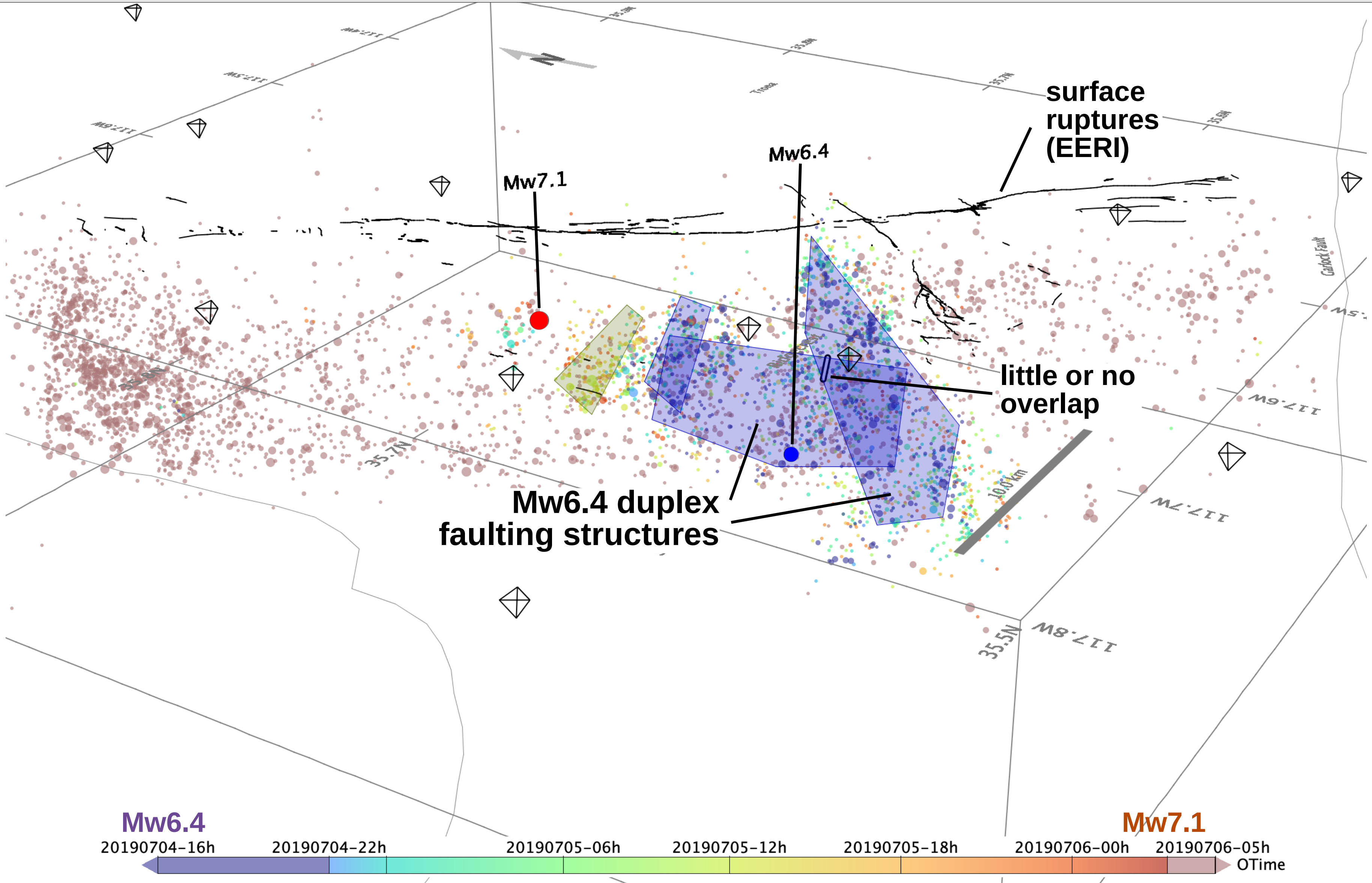

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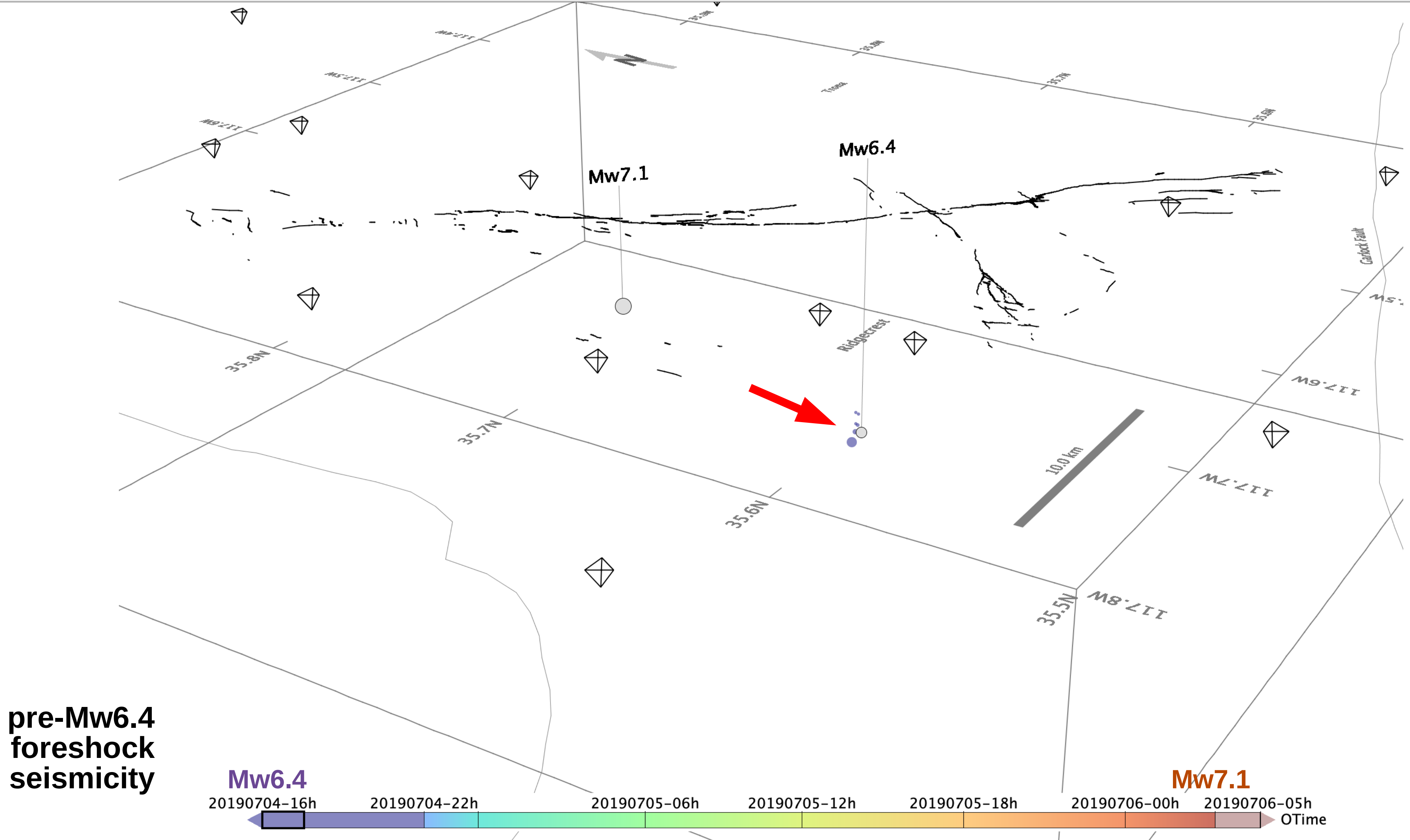
Timeline of seismicity: several hours of pre-Mw6.4 seismicity occurs at ~12km depth, near the future Mw6.4 hypocenter



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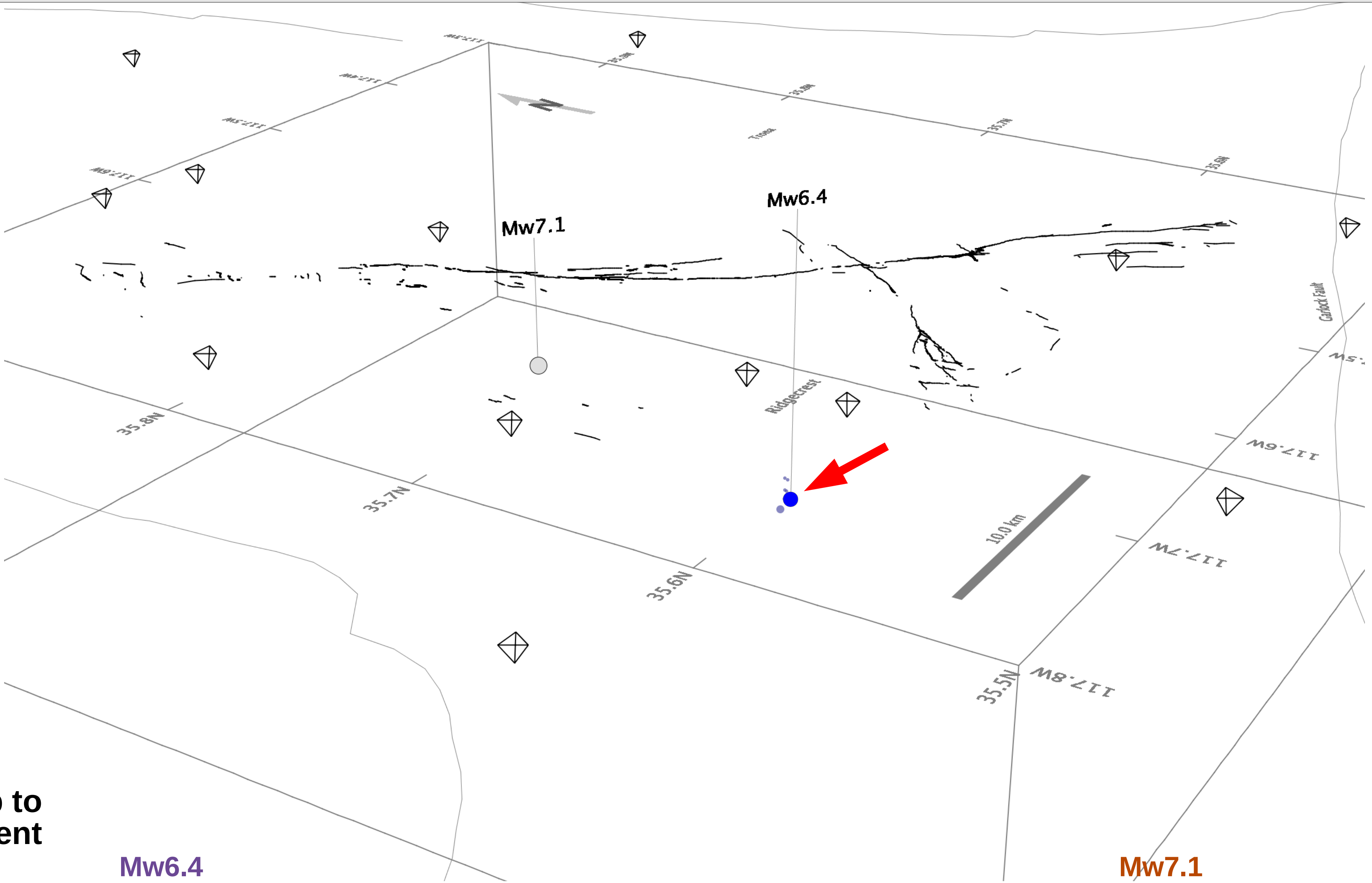
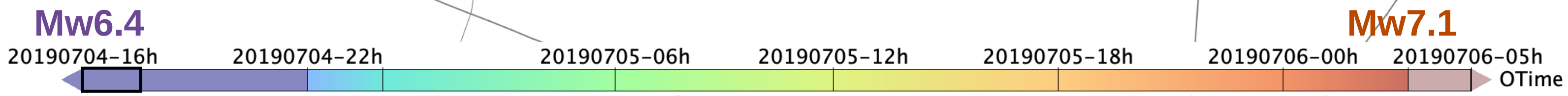
The Mw6.4 hypocenter and rupture initiation is at ~12km depth



seismicity up to the Mw6.4 event



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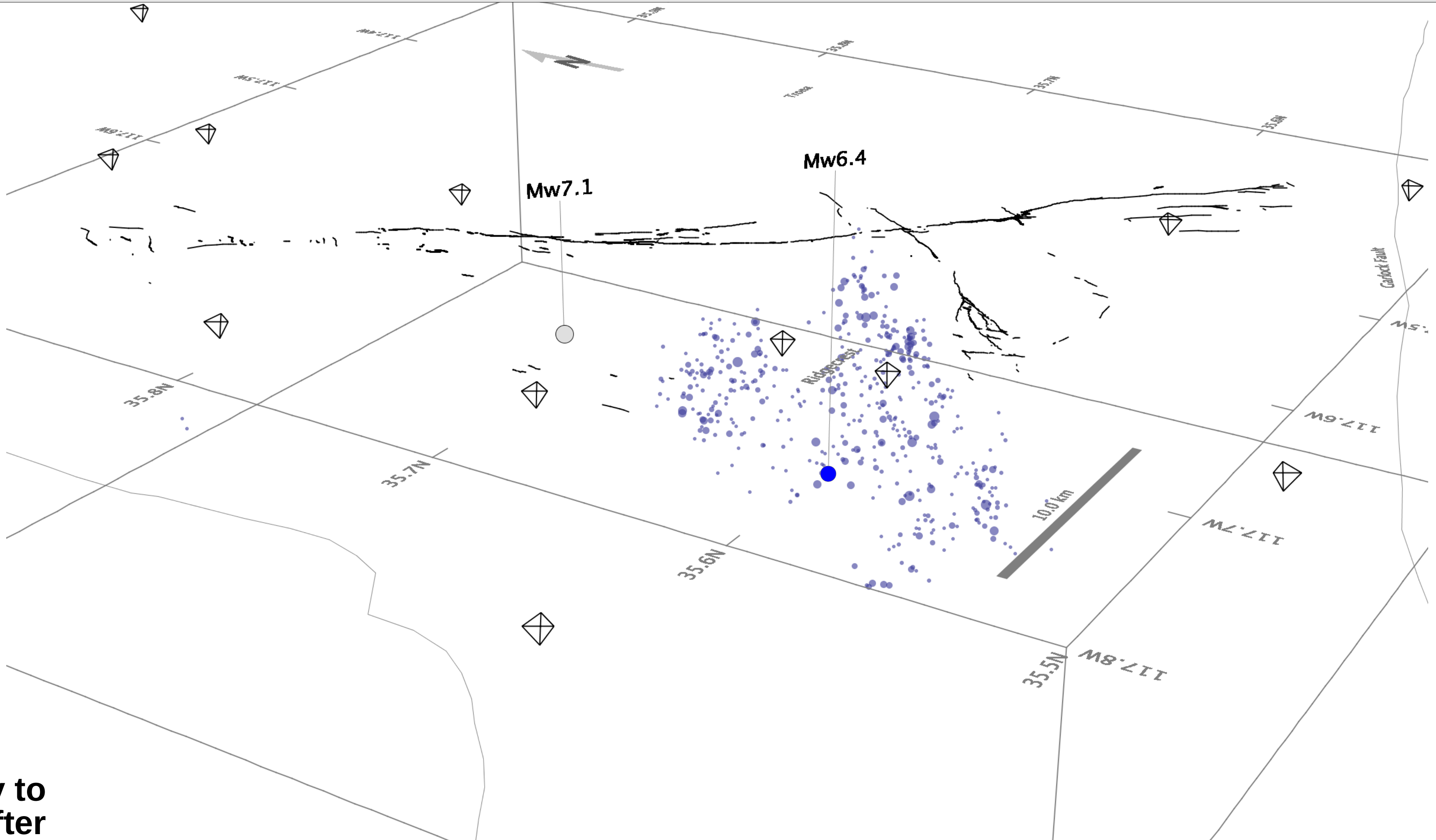
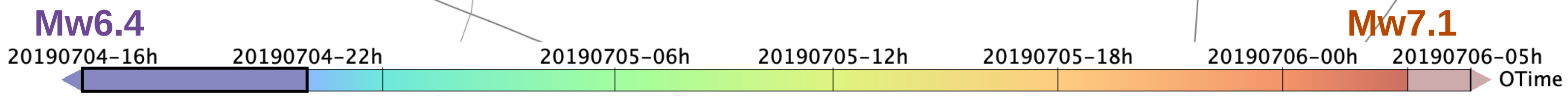
Post-Mw6.4 seismicity def ines duplex faulting structures
→ the Mw6.4 event is a double earthquake

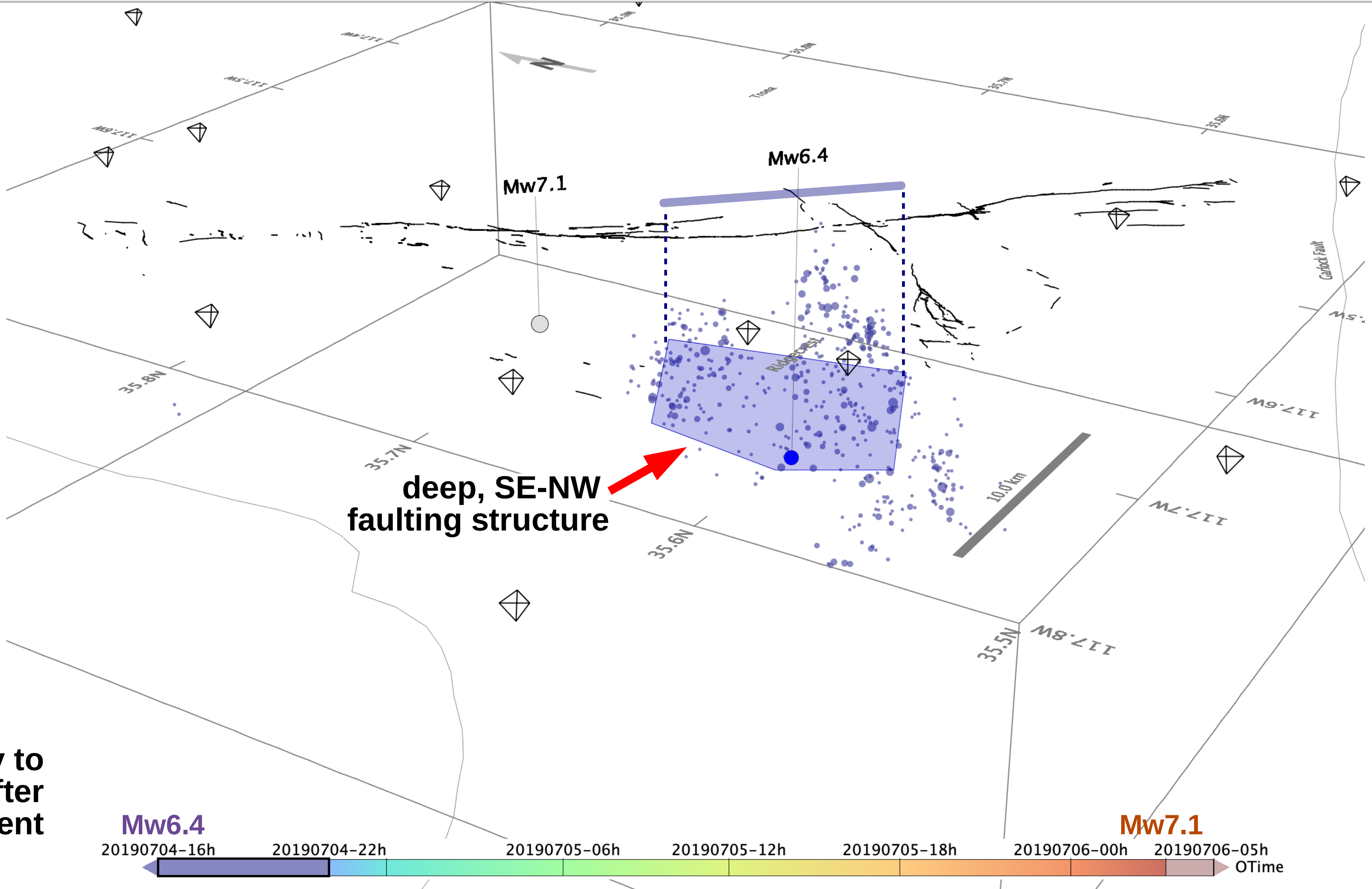


seismicity to 6 hours after Mw6.4 event



ALomax Scientific

Post-Mw6.4 seismicity def hes duplex Mw6.4 faulting structures:
rupturing f rst a deep, SE-NW faulting structure



seismicity to 6 hours after Mw6.4 event

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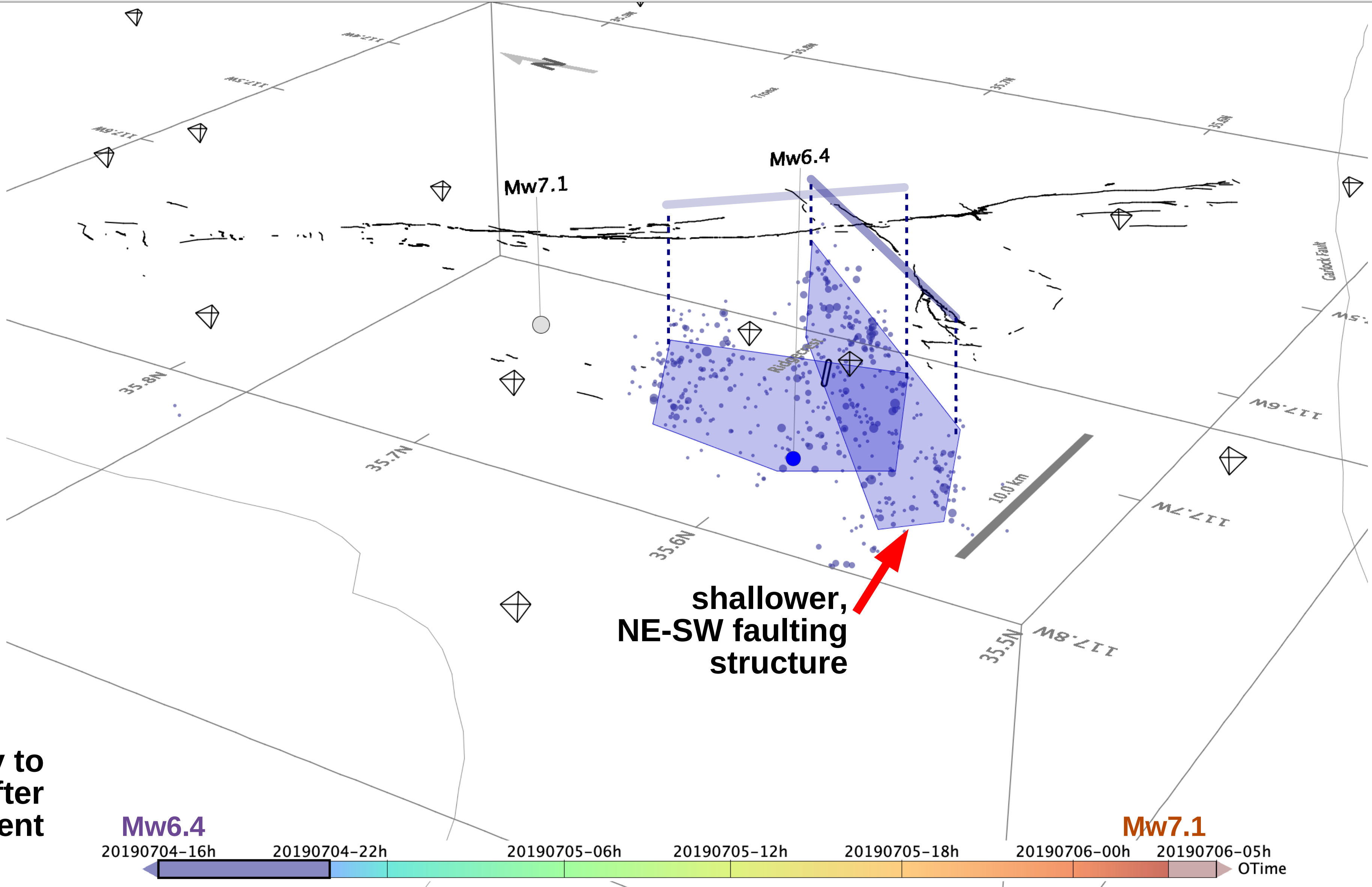
Post-Mw6.4 seismicity defines duplex Mw6.4 faulting structures: then rupturing a shallower, NE-SW faulting structure



seismicity to
6 hours after
Mw6.4 event

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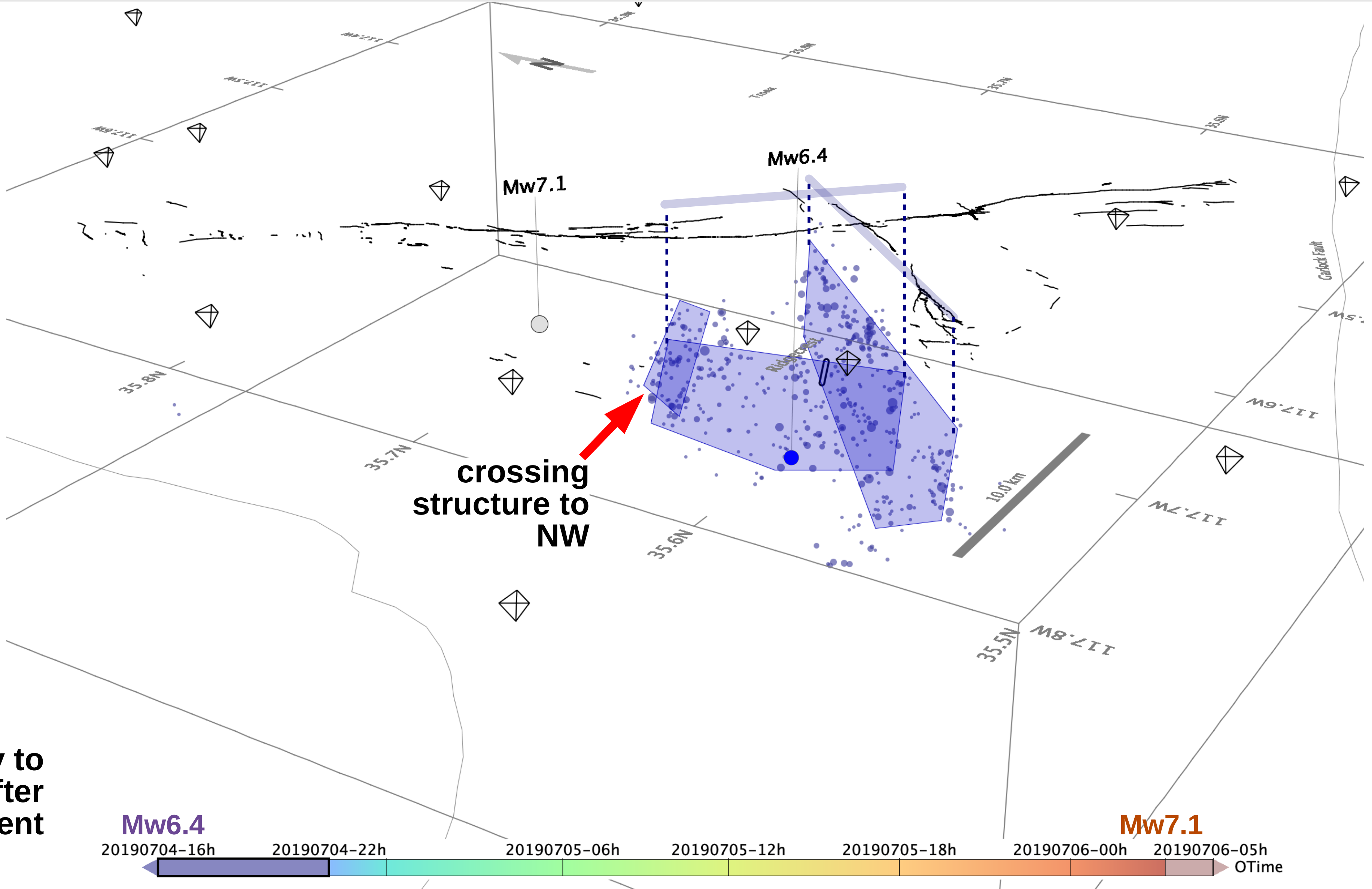
Post-Mw6.4 seismicity def hes duplex faulting structures:
and illuminating a crossing structure to the NW



seismicity to 6 hours after Mw6.4 event

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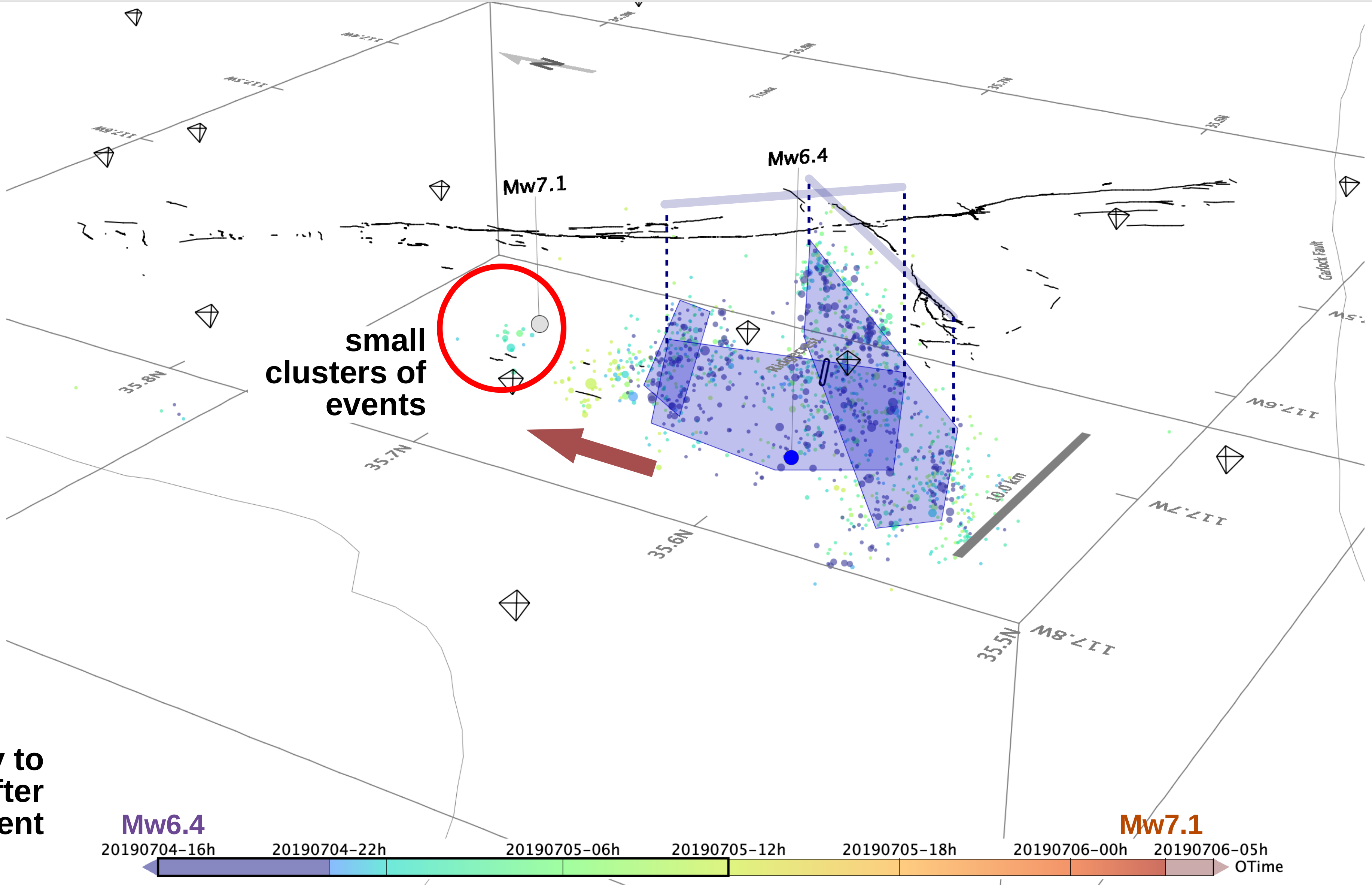
Post-Mw6.4 seismicity extends towards the Mw7.1 hypocenter, and small clusters of events activate near the future Mw7.1 hypocenter



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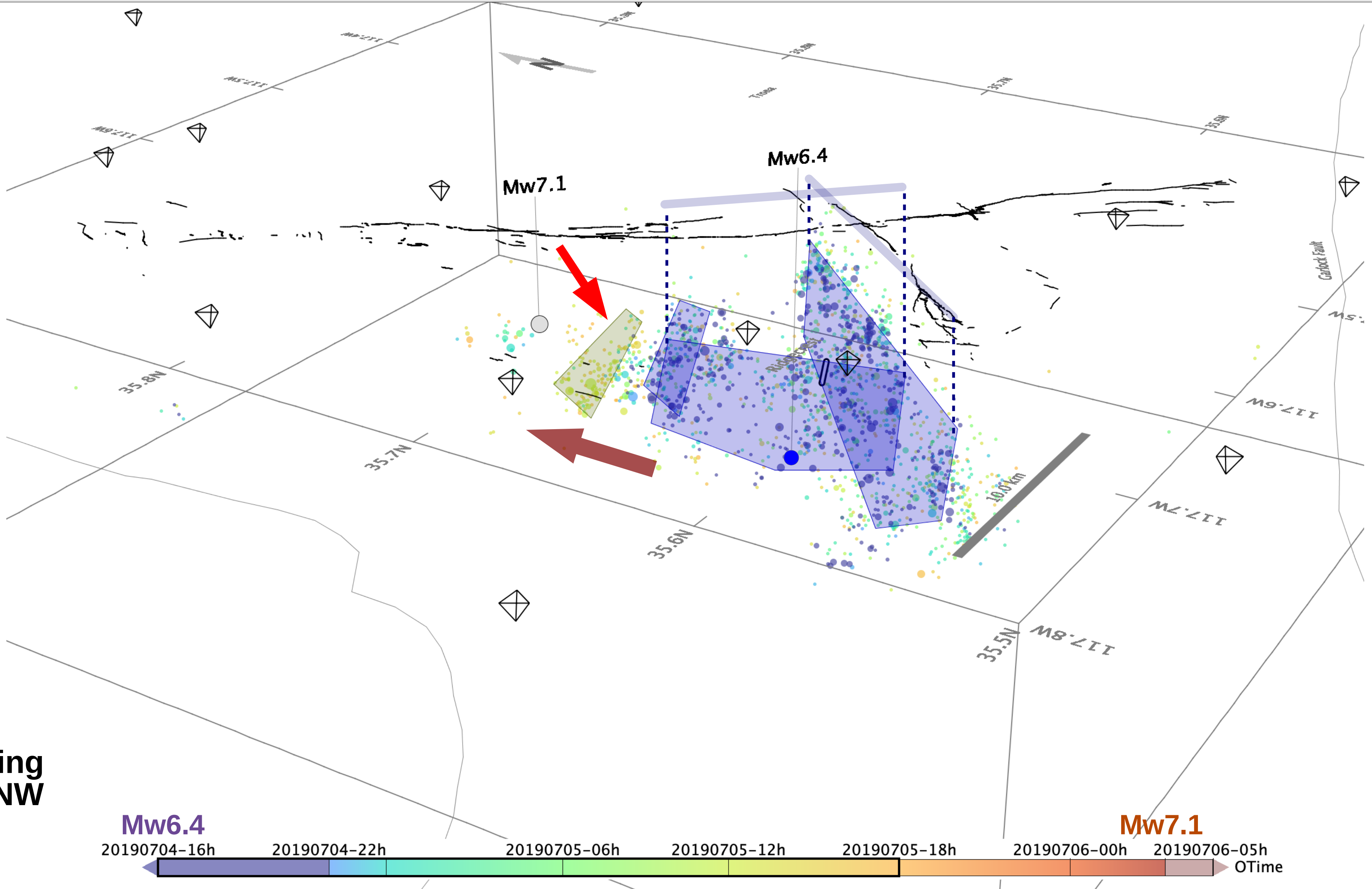
Post-Mw6.4 seismicity extends towards the Mw7.1 hypocenter, with an Mw5.4 event illuminating a new crossing structure



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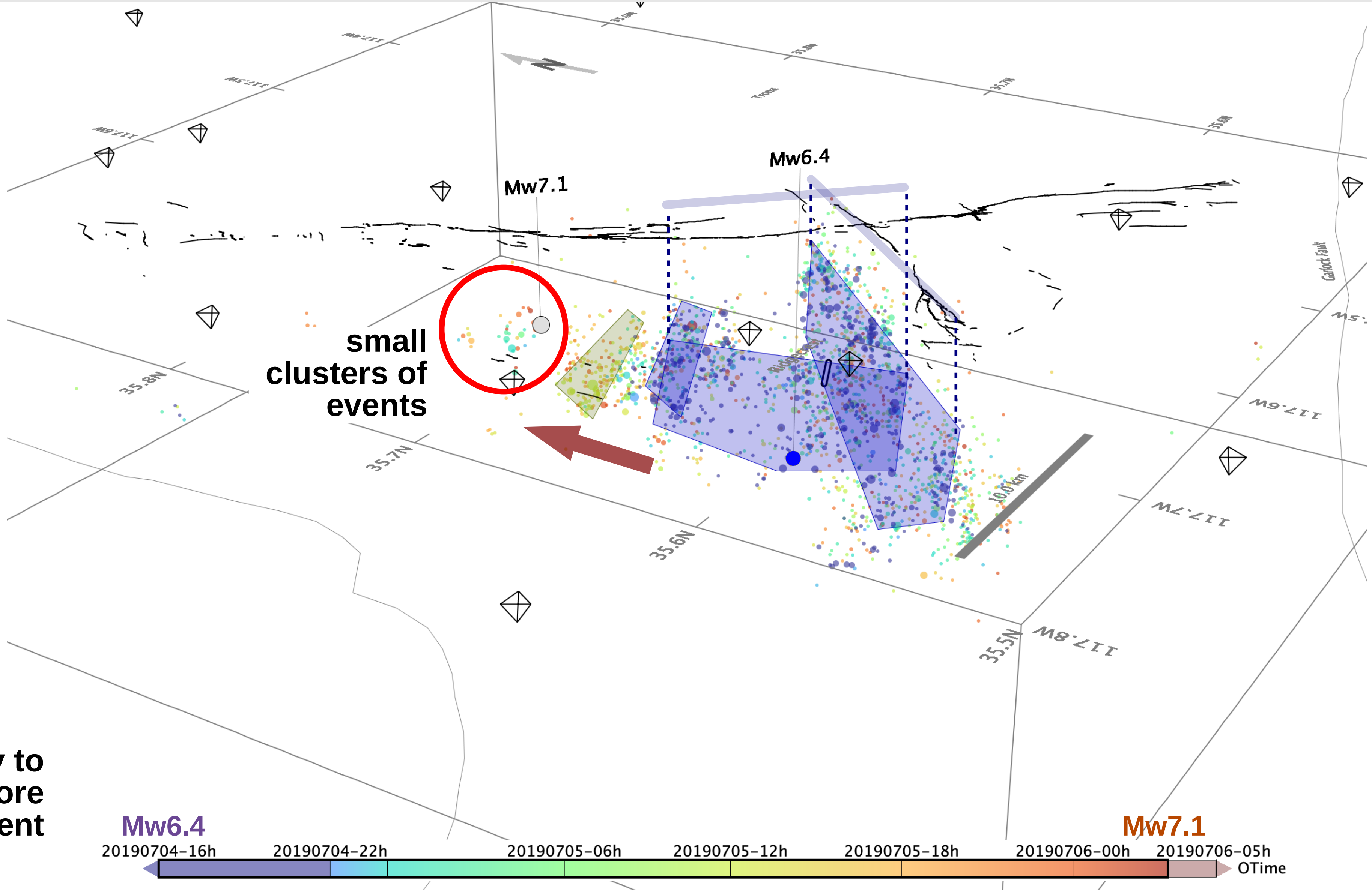
Small clusters of events near the future Mw7.1 hypocenter activate in pulses up to Mw7.1 initiation



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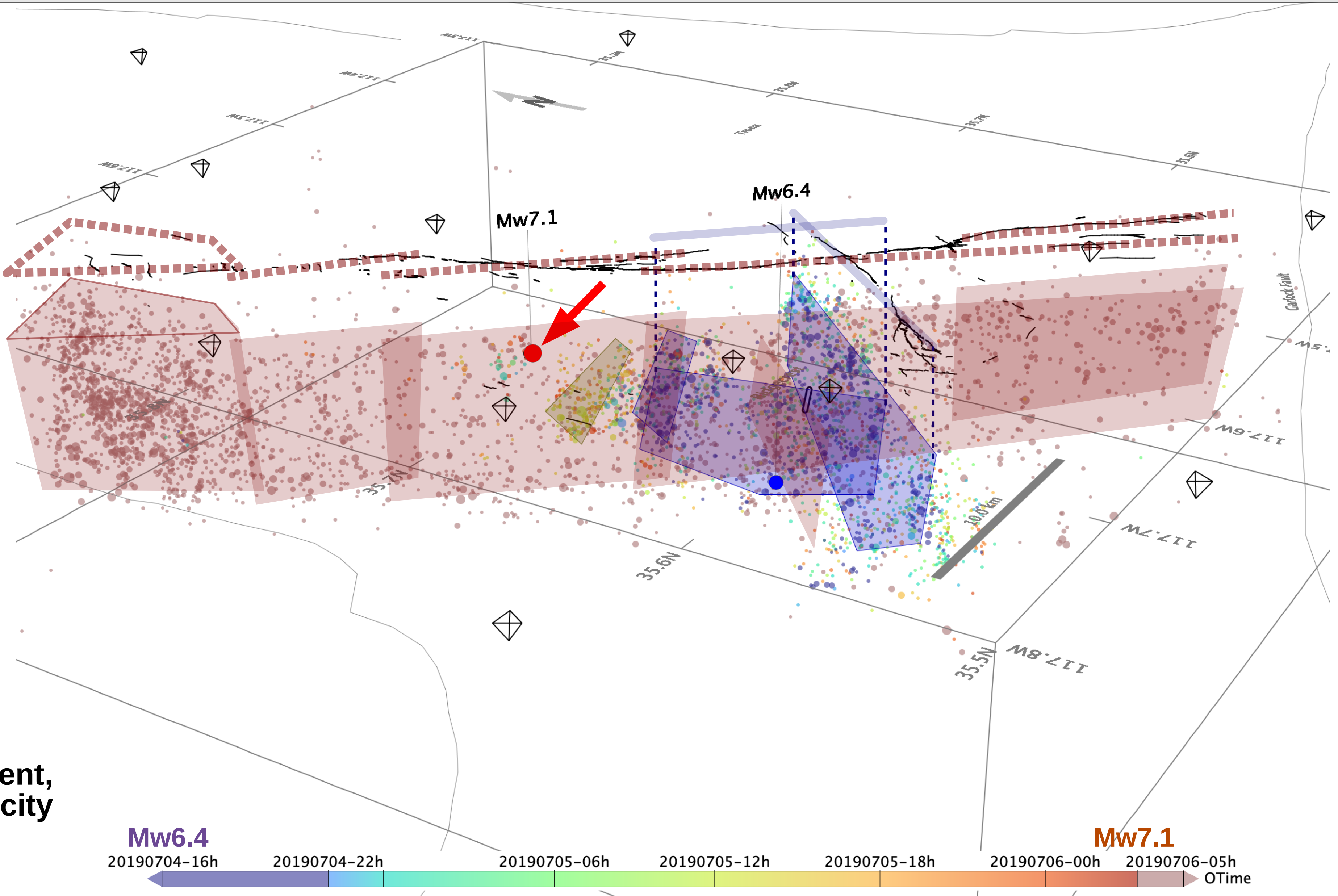
Post-Mw7.1 seismicity def hes ~55km long, near-vertical, SE-NW structures



Mw7.1 event, all seismicity

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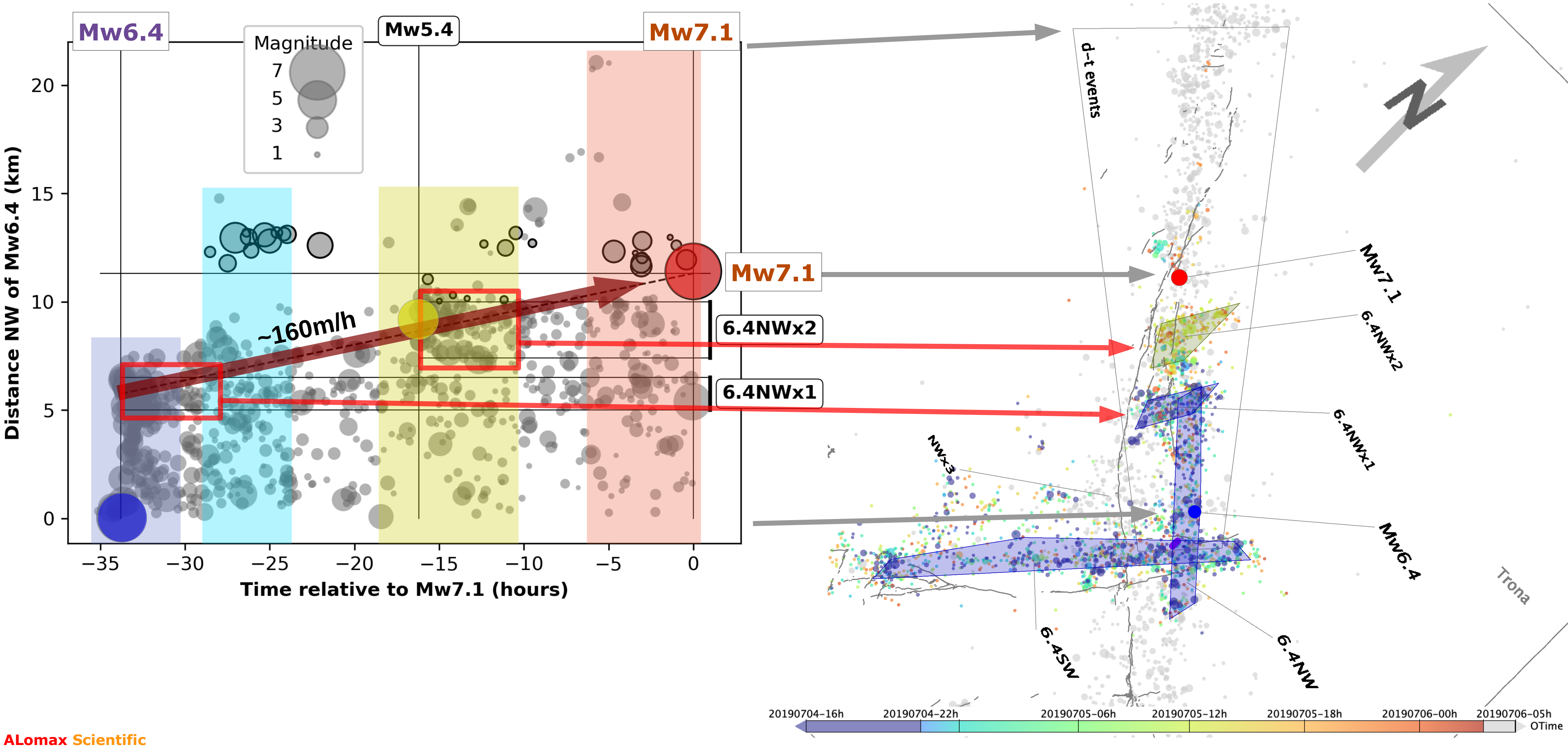
Pre-Mw7.1 seismicity extends towards the Mw7.1 hypocenter, with an Mw5.4 event illuminating a new crossing structure (6.4NWx2)



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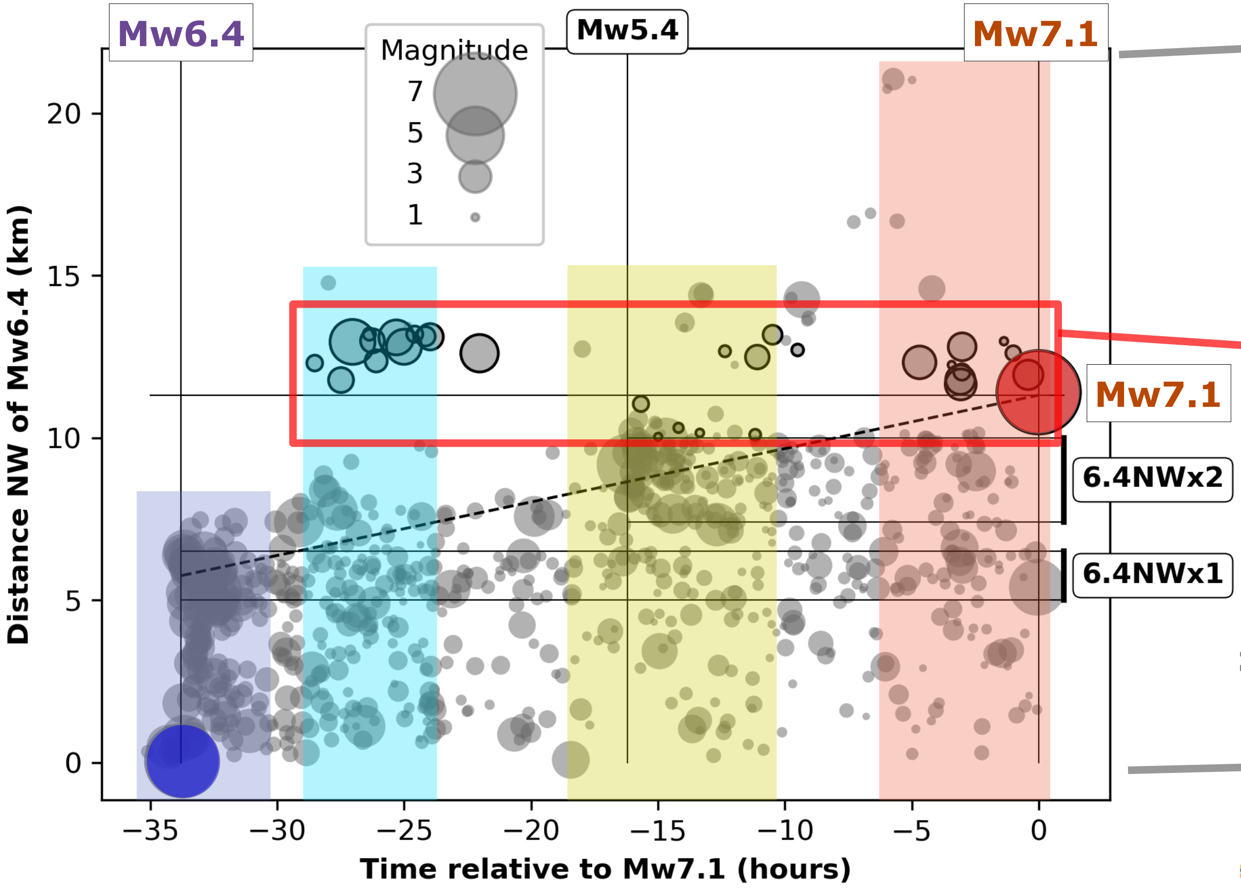
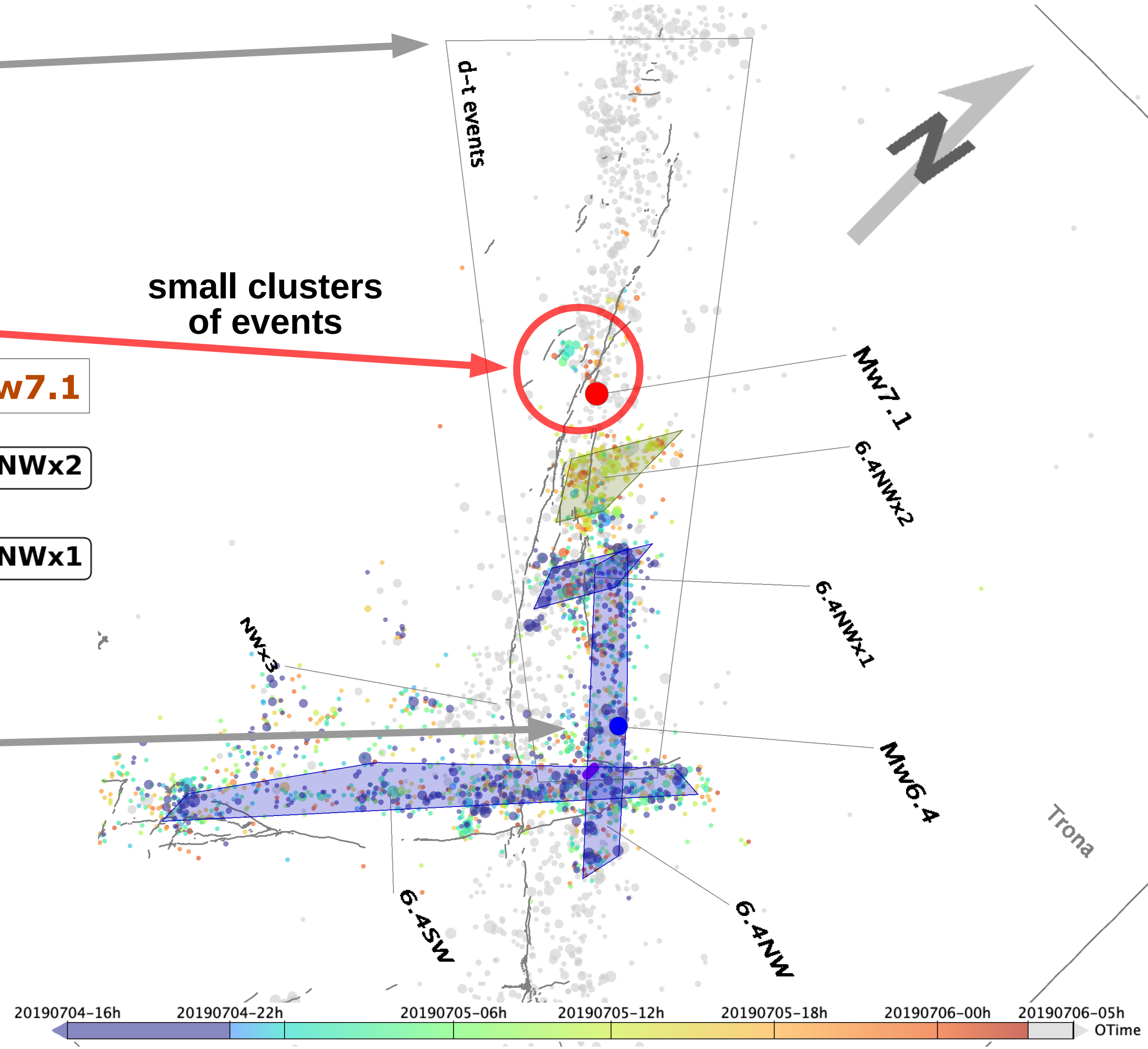
Small clusters of events near the future Mw7.1 hypocenter activate in pulses up to Mw7.1 initiation





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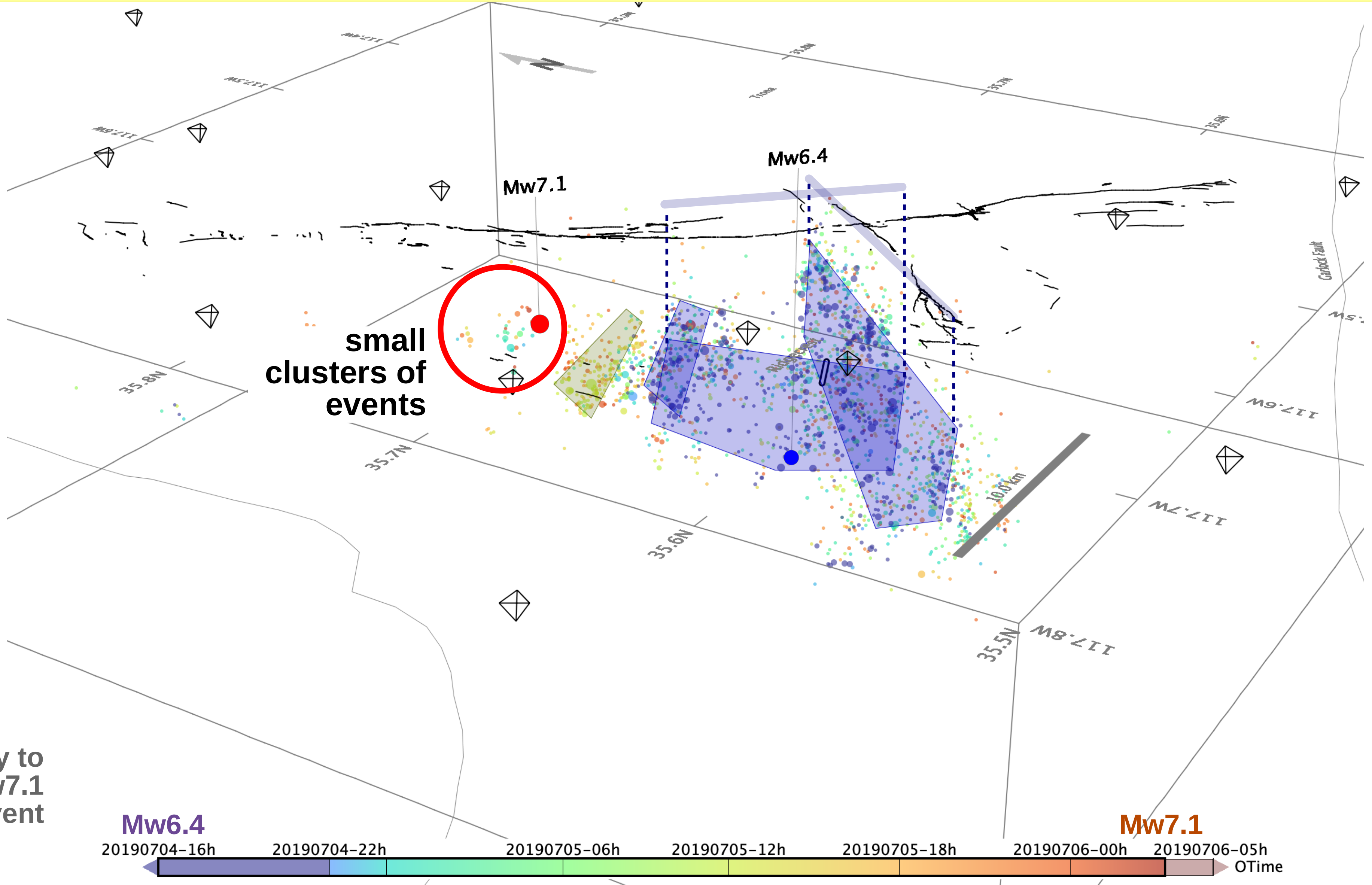
The seismicity suggests:
Mw7.1 rupture initiation activated as an event in the pulsing clusters, ...



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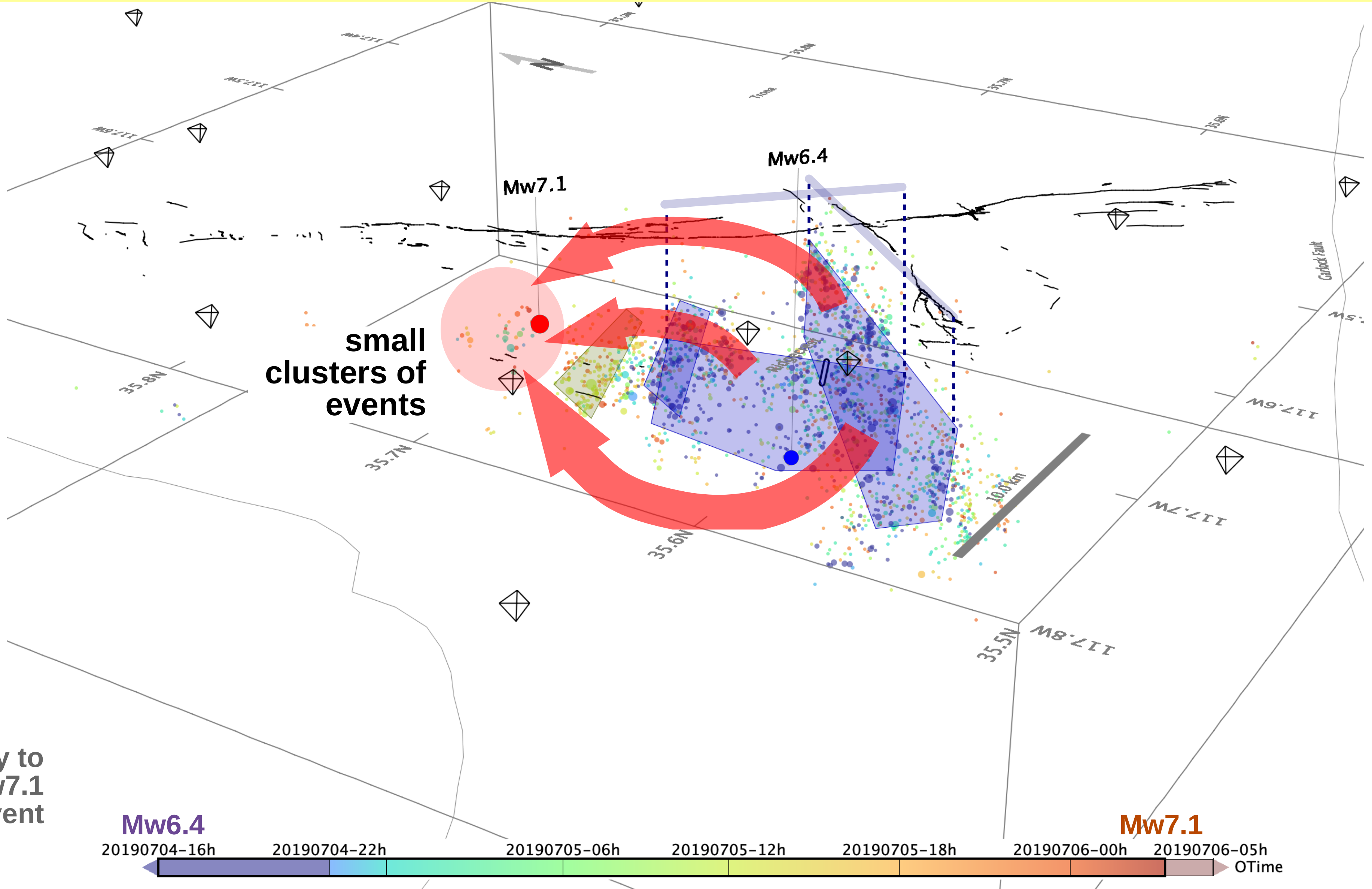
… early Mw7.1 rupture growth was *primed* by stress changes from Mw6.4 rupture and aftershocks, ...



ALomax Scientific

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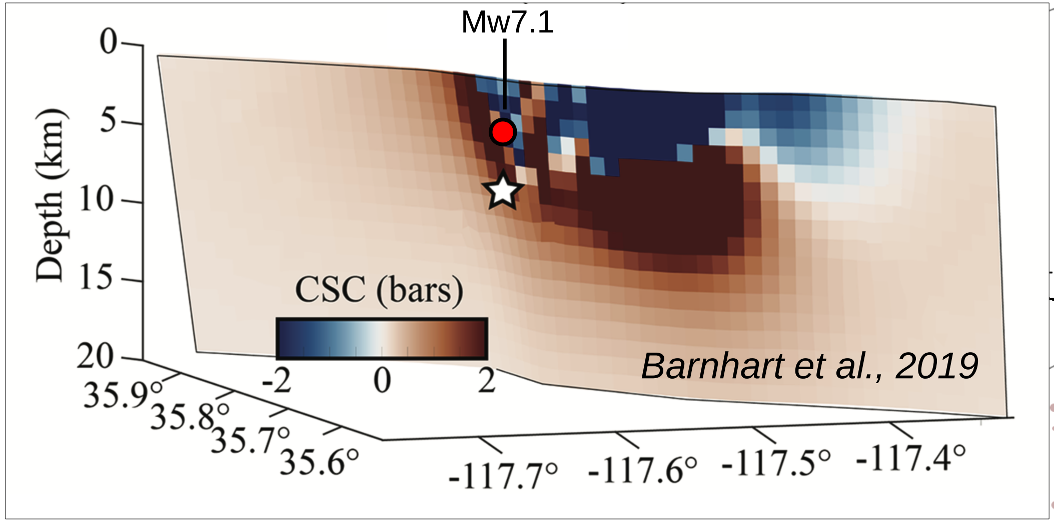
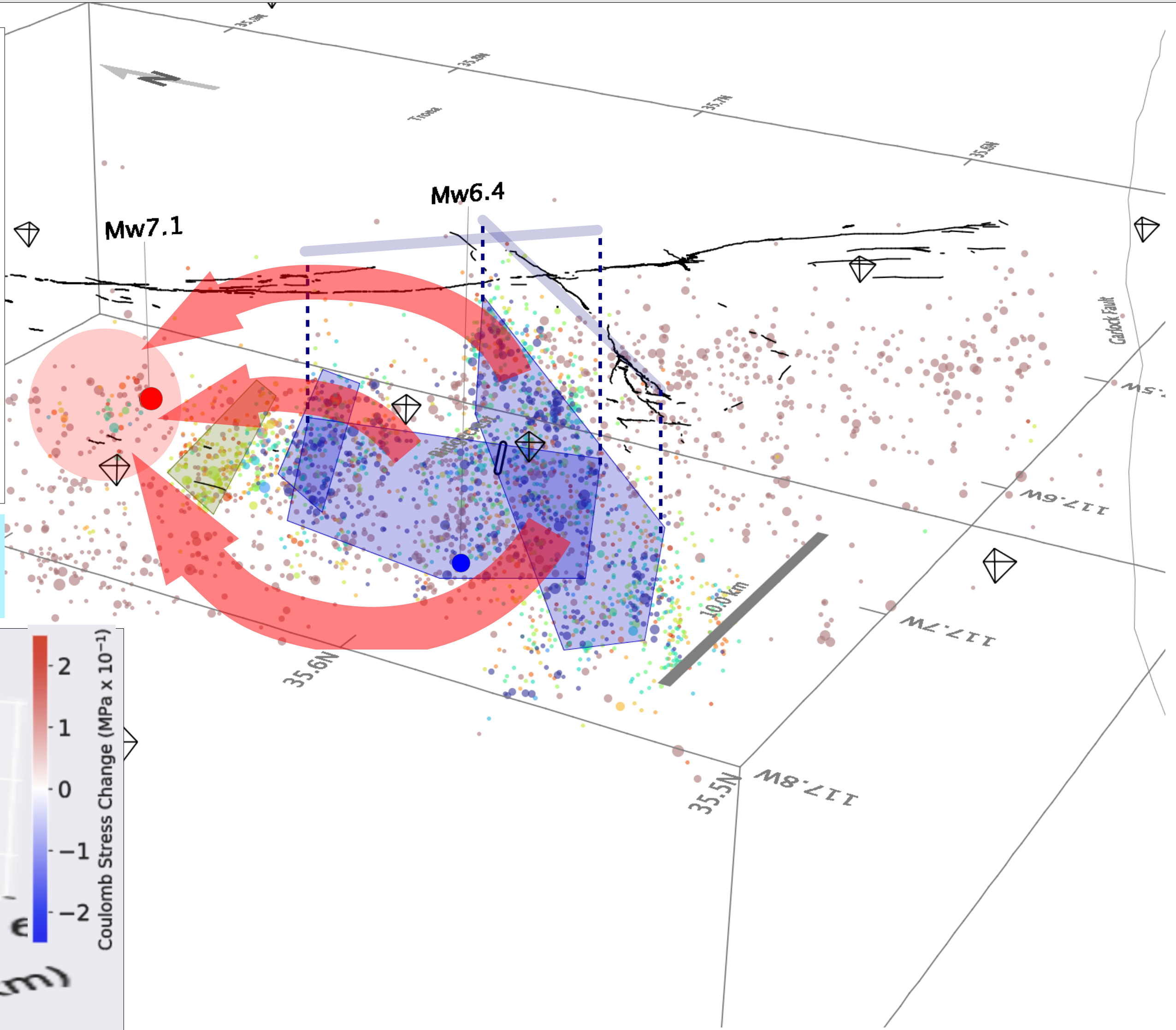
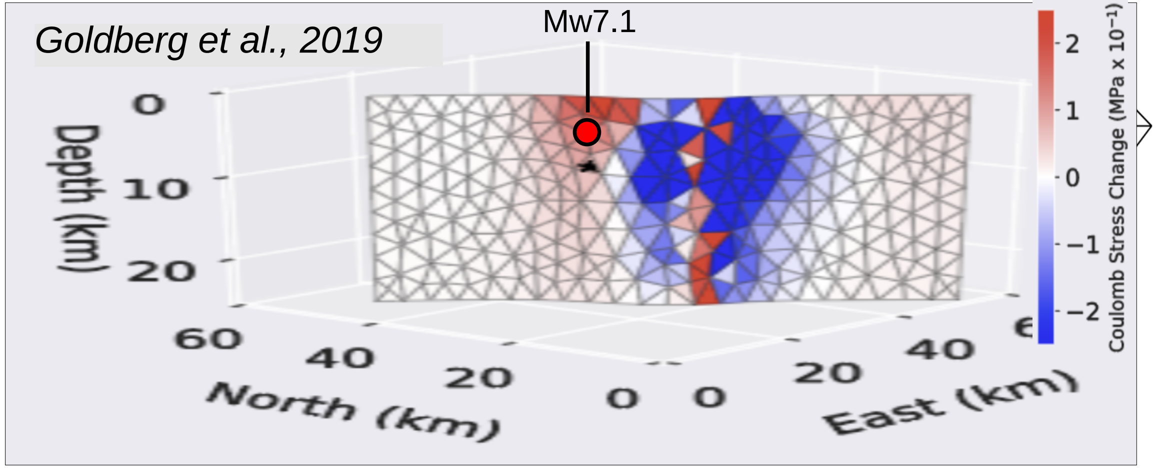


Coulomb stress change on Mw7.1 fault plane due to Mw6.4 rupture is *positive* near future M7.1 hypocenter





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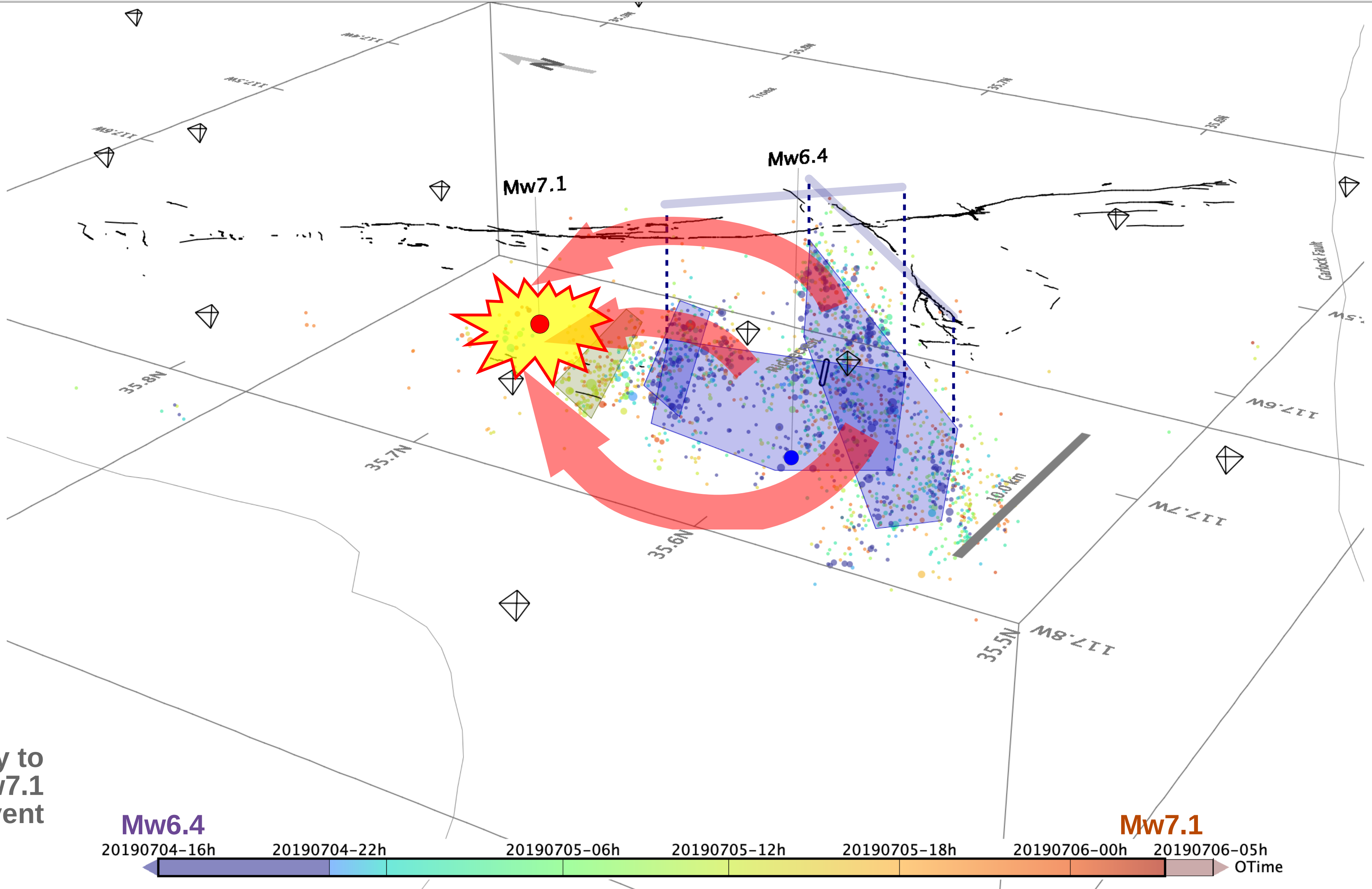

seismicity to just before Mw7.1 event

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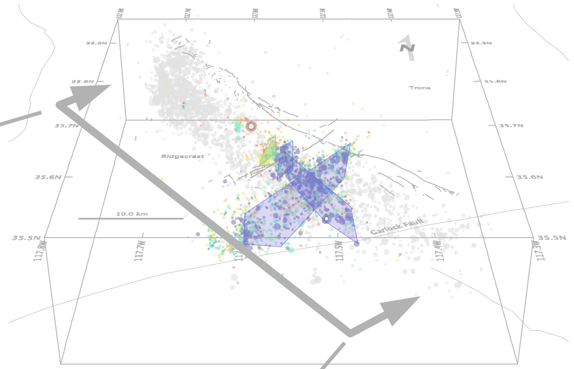
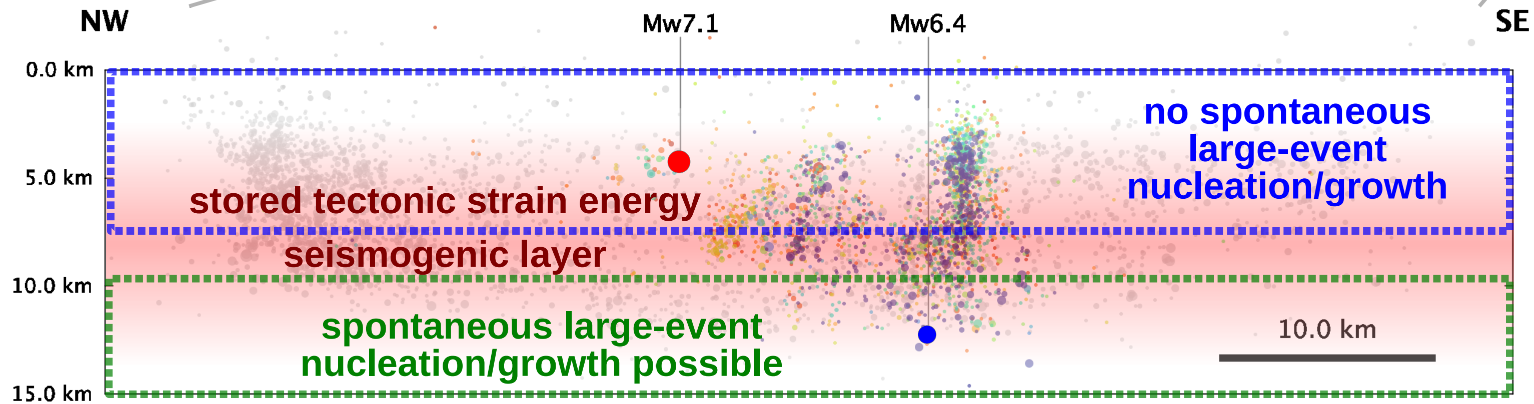
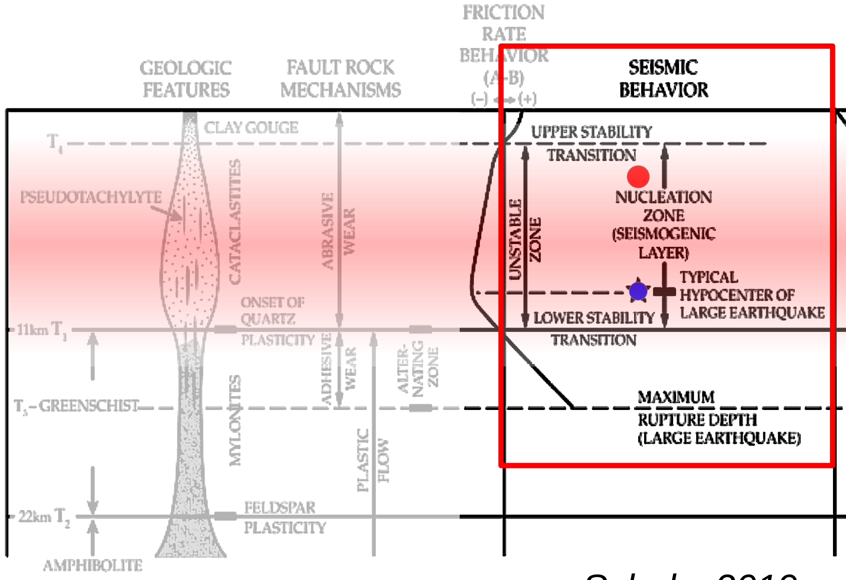
thus, Mw7.1 nucleation at shallow depth may have *required incitation* by the Mw6.4 event.





The Mw7.1 hypocenter falls in a shallow zone with physical properties not conducive to spontaneous rupture nucleation and growth of large earthquakes



Scholz, 2019

Synoptic model of a continental shear zone.

… otherwise, Mw7.1-like rupture might not have occurred until long in the future:

through incitation by another, deep, Mw6.4-like event,

or with nucleation at greater depth,

or perhaps rupture on a different, nearby fault
might relieve the tectonic strain energy.

… otherwise, Mw7.1-like rupture might not have occurred until long in the future:

through incitation by another, deep, Mw6.4-like event,

or with nucleation at greater depth,

or perhaps rupture on a different, nearby fault
might relieve the tectonic strain energy.

This scenario greatly complicates hazard assessment:

It implies that the occurrence of some large earthquakes depends
not only on rupture zone properties, state of stress,
and nearness to end of some “seismic cycle”,
but also on *incitement by a nearby, deeper, perhaps smaller event*.

Conclusions

Robust, absolute earthquake location for Ridgecrest defines faulting structures and evolution of seismicity.

The Mw6.4 event ruptured two, non-intersecting, duplex structures; the Mw7.1 hypocenter is unusually shallow.

Mw7.1 nucleation may have required incitation by the Mw6.4 event, which greatly complicating hazard assessment.

Further information, preprint and links:
http://alomax.net/projects/Ridgecrest_2019

This work is Accepted for publication in
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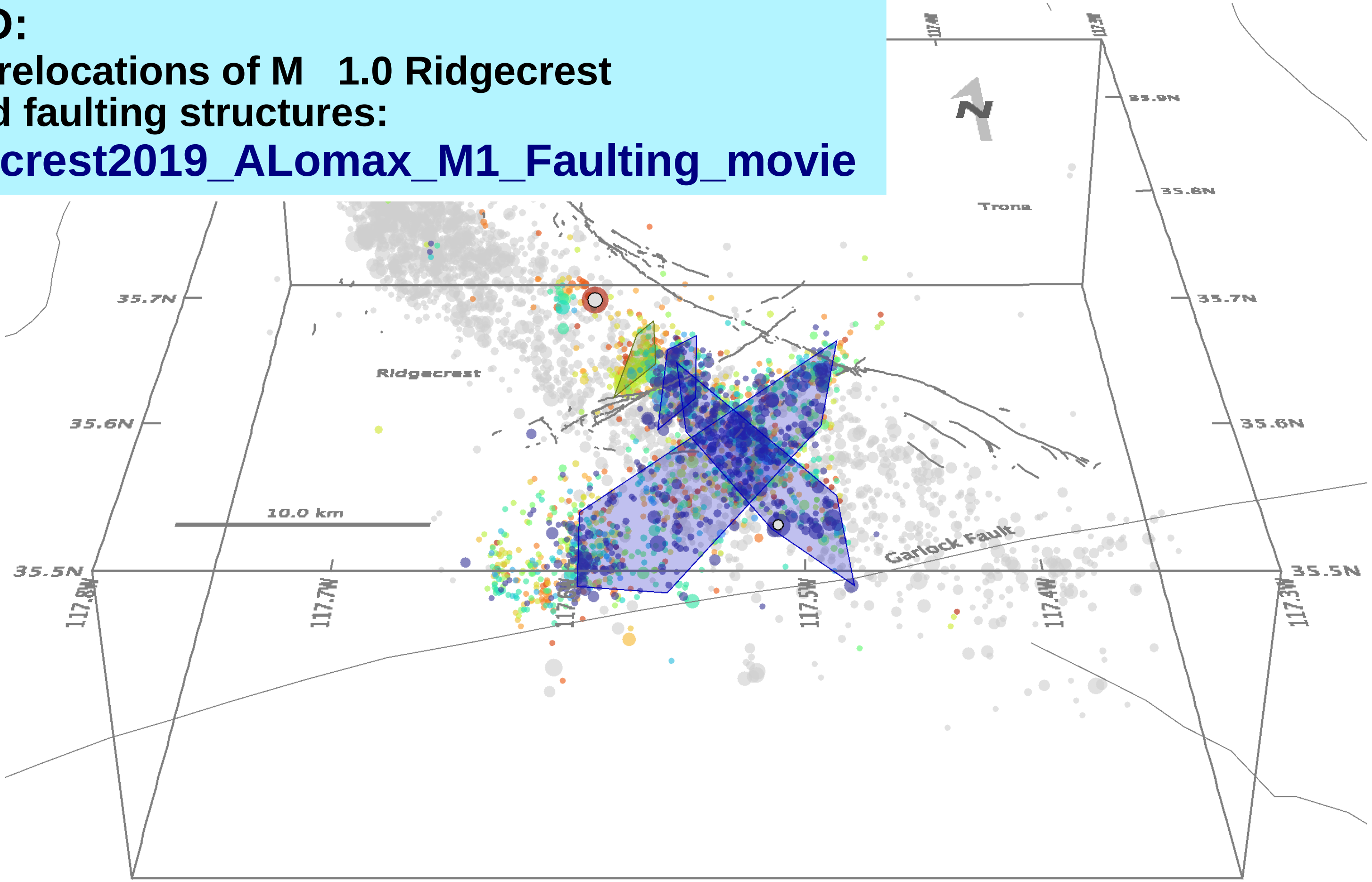
Anthony Lomax
ALomax Scientific
Mouans-Sartoux, France
anthony@alomax.net @AlomaxNet

Relocated seismicity: post-Mw6.4 (color), post-Mw7.1 (light gray)

Understand the seismicity in 3D:

An animation of absolute relocations of M 1.0 Ridgecrest seismicity with interpreted faulting structures:

click here → Ridgecrest2019_ALomax_M1_Faulting_movie



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