The Global Importance of Continental Seismic Sequences

1.

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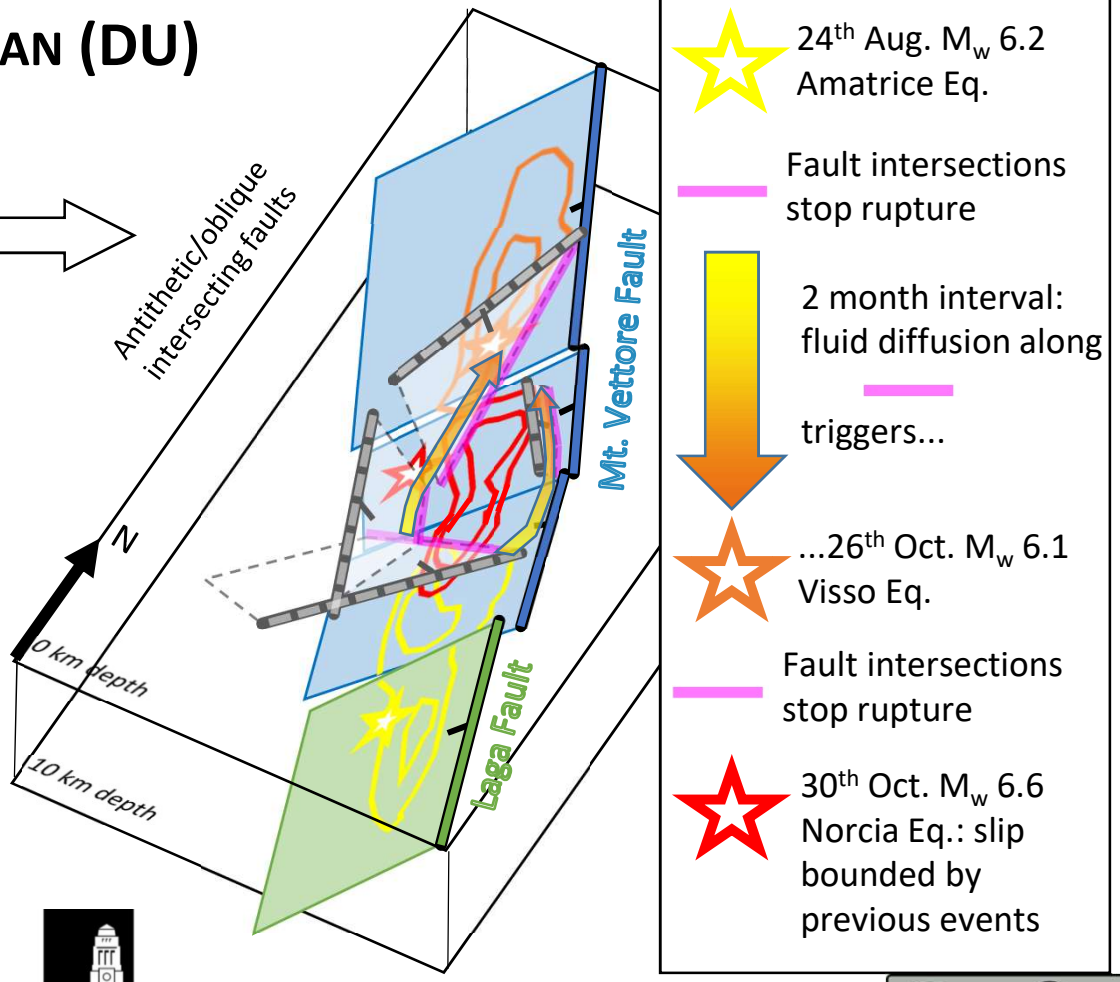
1. Motivated by our work on 2016 Central Italy Seismic Sequence **(Walters et al., 2018, EPSL)**

2. First seismic sequence to occur in 'modern-era' of earthquake seismology/geodesy

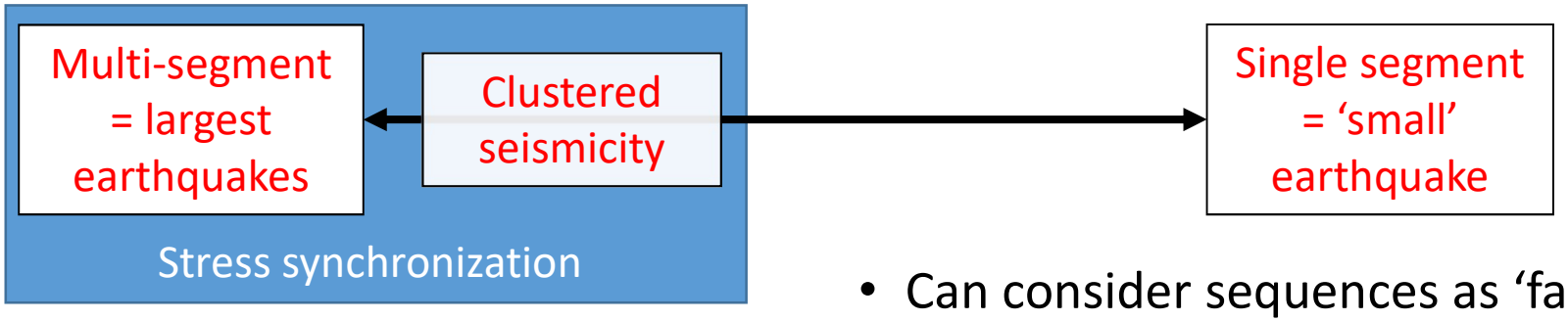
3. We found that structural complexity (intersecting faults) likely controlled size and timing of stop-start rupture in sequence

...but this is just one example, need global analysis....



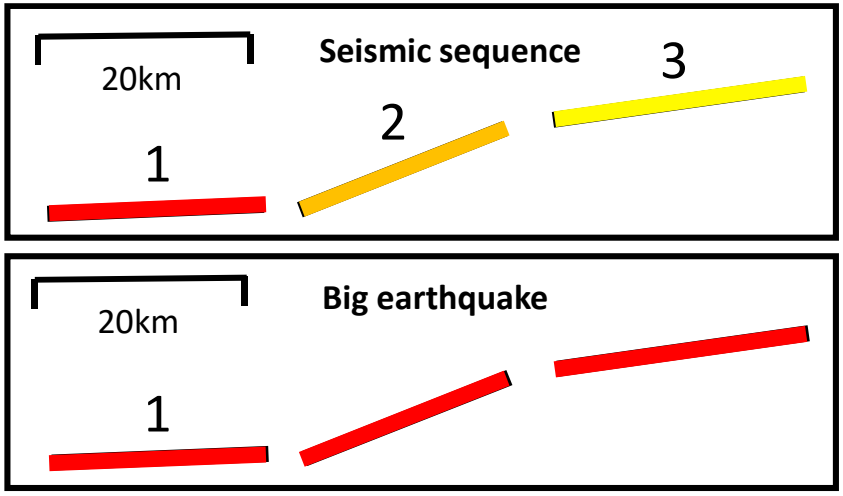
Failure of continental fault networks: Multi-segment Rupture

2.



- Continental faults are highly segmented
- Max segment length limited by thickness of seismogenic crust (< ~25 km, e.g. Scholz, 1998; Klinger, 2010)

- Can consider sequences as 'failed' big earthquakes- same initial conditions...
- ...stress-synchronization of faults is common (Scholz, 2010)



- Largest episodes of strain release (largest hazard) involve multi-segment rupture
- Two modes of failure for largest episodes of strain release
- **Major differences in hazard!**

Three main questions:

3.

1. How important are seismic sequences on a global scale? (i.e. for M_0 budget, hazard)

2. Are there variations between tectonic regions?

3. What controls likelihood of big multi-segment events vs. stop-start sequences?

Global analysis of clustering

4.

Previous work...

- Zaliapin & Ben-Zion (2016): global analysis **(incl. oceanic, subduction)** shows some control of tectonic style on clustering
- Stallone & Marzocchi (2019): No significant difference in clustering between **SoCal, Japan and Italy (specific regions only)**– in all cases clusters make up ~6-8% of seismicity **by number**

Our approach....

- **Global analysis**, comparison from global catalogues of R, S, N
- Focus specifically on **crustal continental events**
- Focus specifically on **seismic sequences**, not just clustered seismicity
- Focus on **importance to M_0 budget**, not just number of triggered events

What's needed for this analysis?

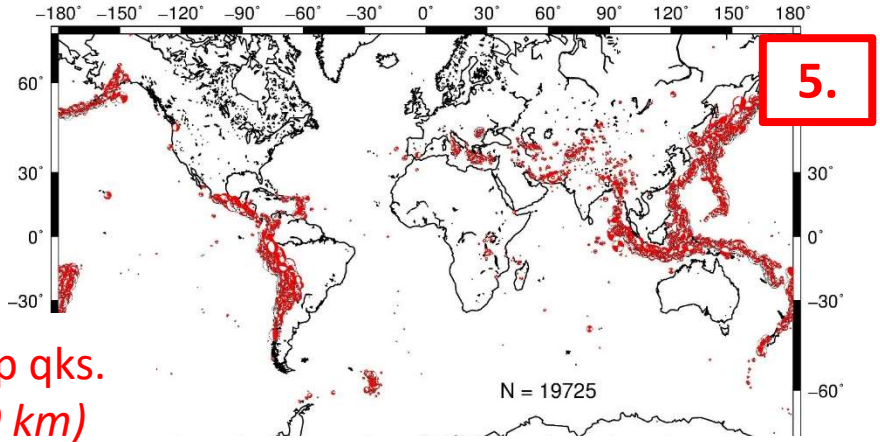
- Global dataset of continental qks with mechanism
- A method to identify seismic sequences

GCMT catalog (Dziewonski & Woodhouse, 2012)

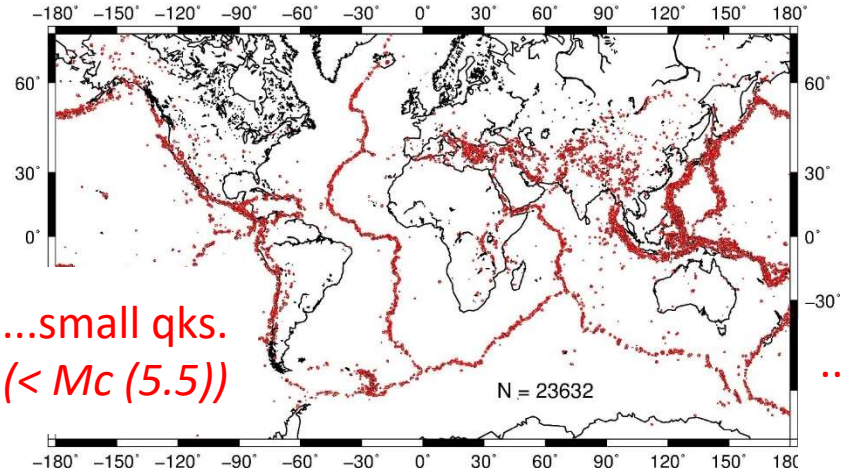
1976 – 2019:
~ 53,000 events

We remove....

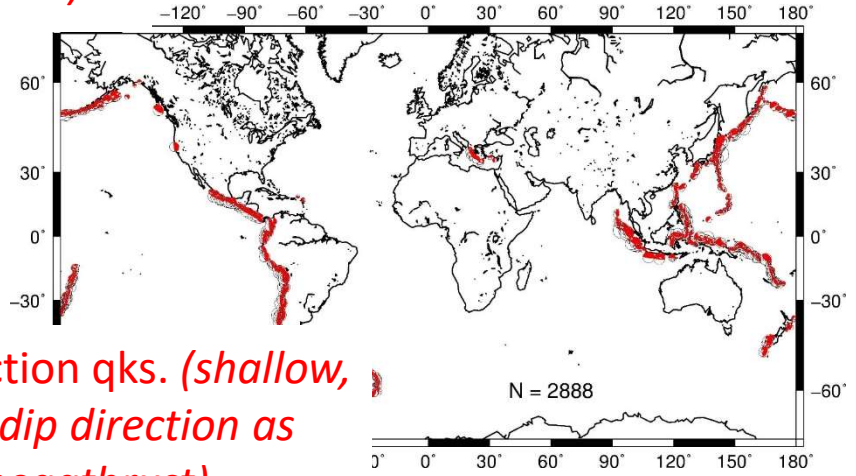
5.



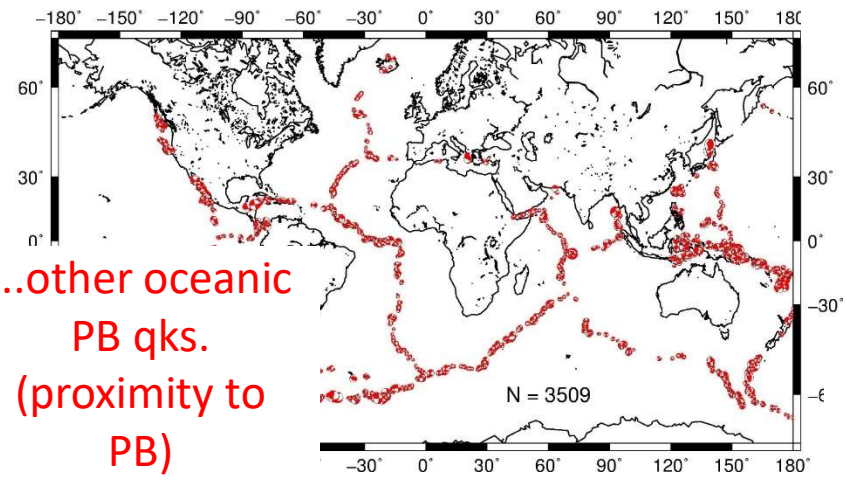
...deep qks. *(< 30 km)*



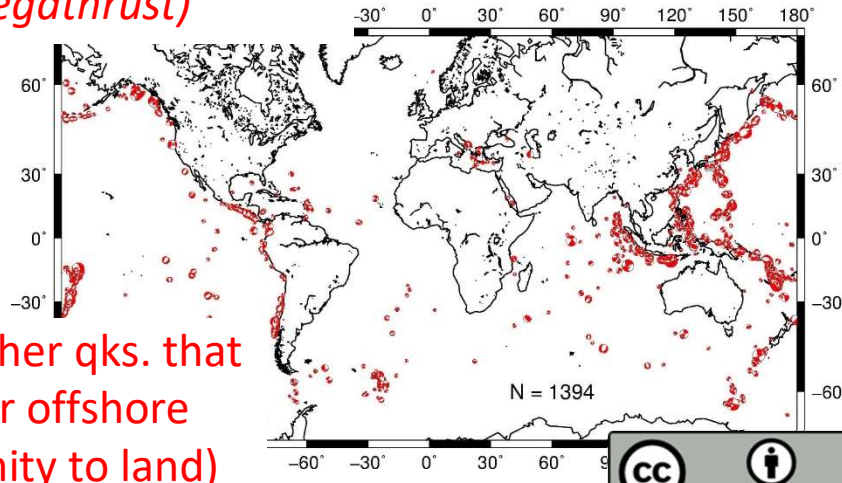
...small qks. *(< Mc (5.5))*



...subduction qks. *(shallow, same dip direction as megathrust)*



...other oceanic PB qks. (proximity to PB)



...and other qks. that are far offshore (proximity to land)

Sequence identification

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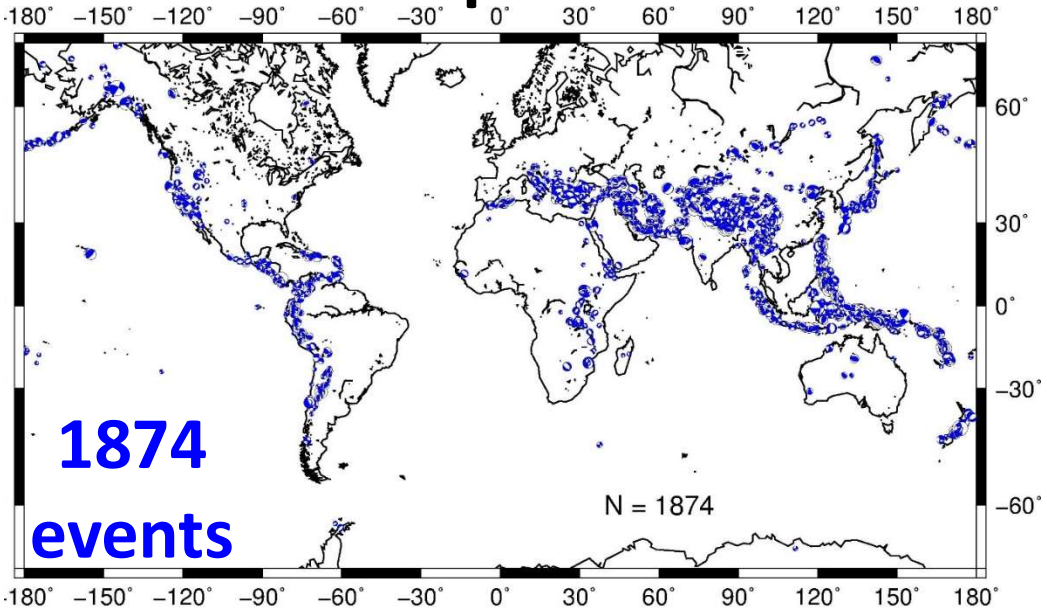
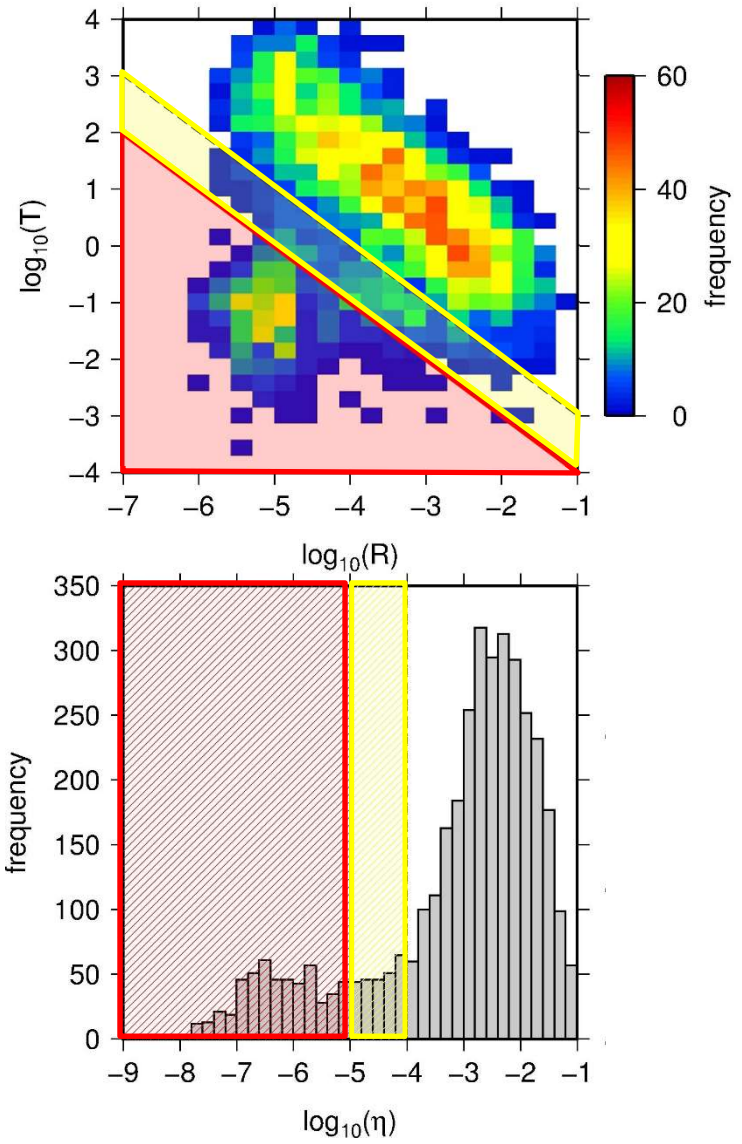


$$T_{ij} = t_{ij} 10^{-qbm_i}$$
$$R_{ij} = (r_{ij})^{d_f} 10^{-(1-q)bm_i}$$
$$\eta_{ij} = T_{ij} R_{ij}$$

$$\log_{10} \eta_{ij} = \log_{10} T_{ij} + \log_{10} R_{ij}$$

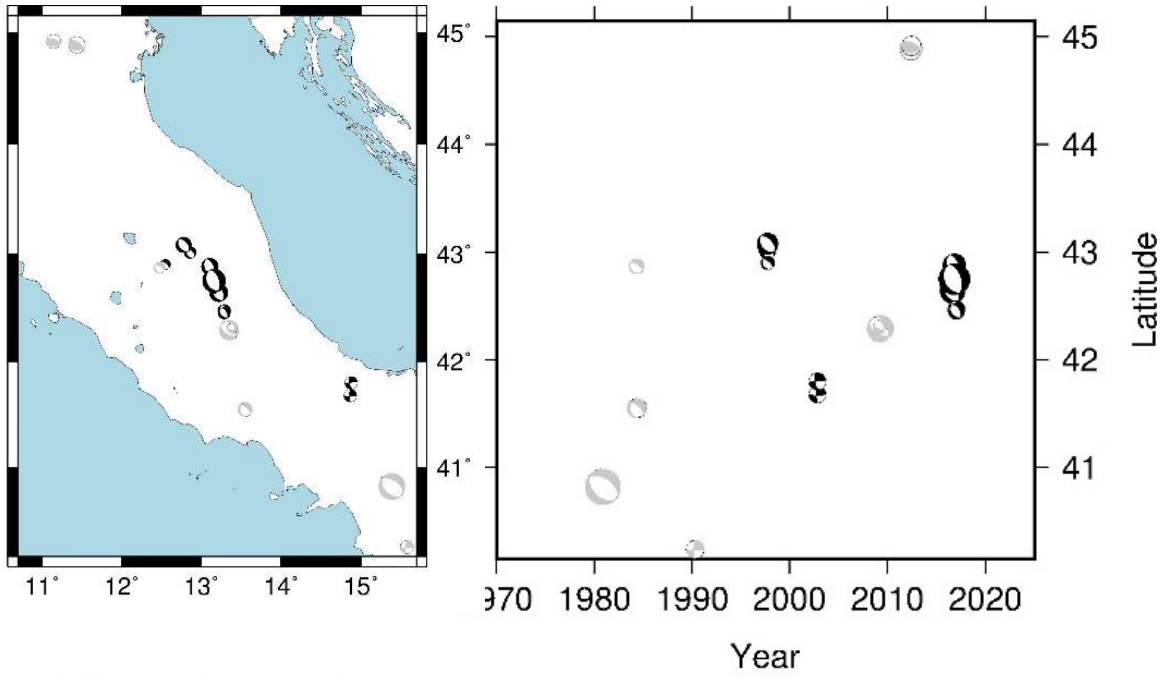
- Sequences are agglomerates of clustered pairs...
- ...containing at least one 'hard-link'...
- ... and where M_0 of all later events is > 50% M_0 of 1st event *(i.e. significant portion of available M_0 budget remained when rupture in 1st event halted)*

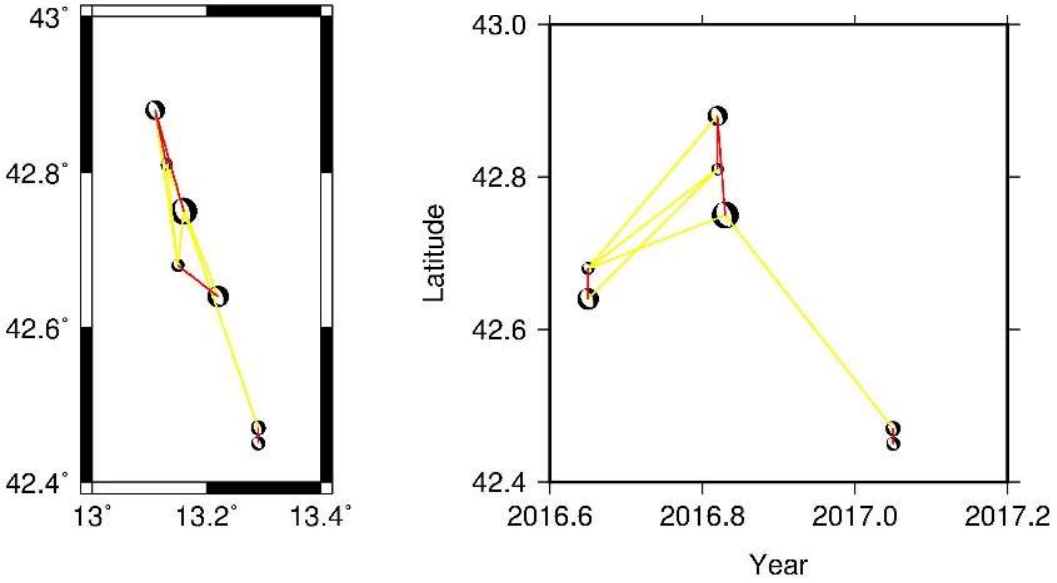


Zaliapin and Ben-Zion, 2013
Hicks 2011

The 2016 Central Italy sequence

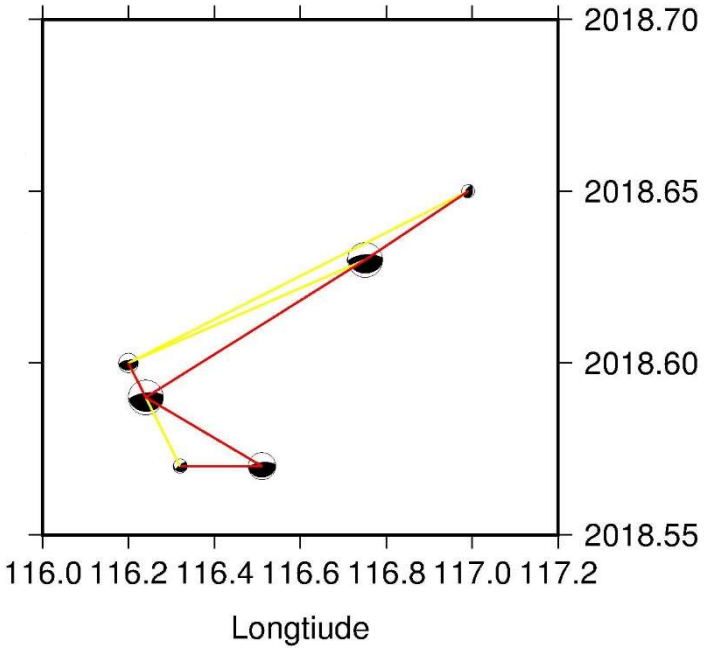
7.

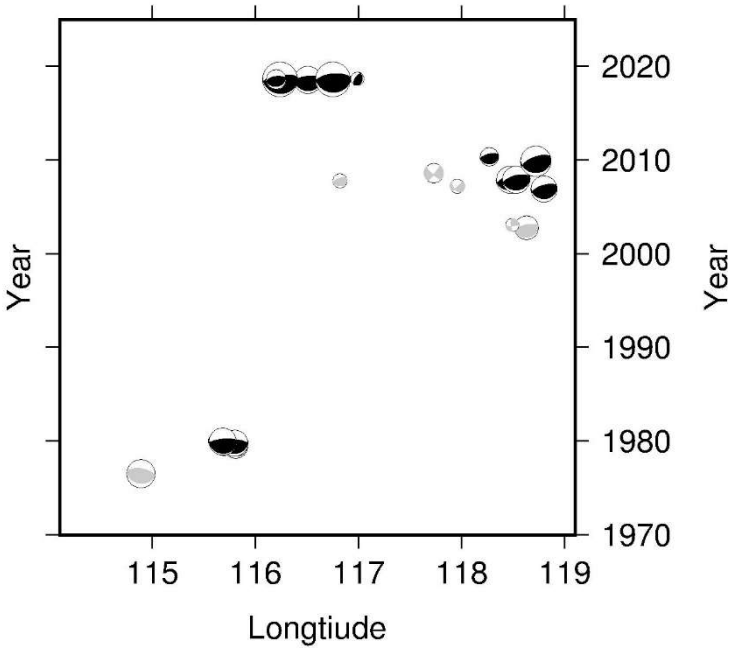


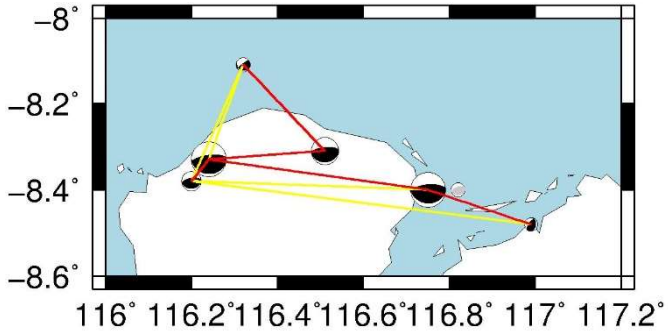


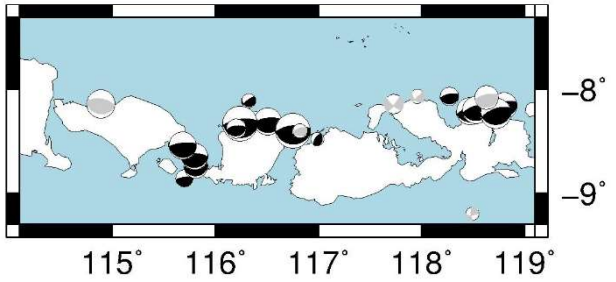
2018 Lombok (Bali) sequence

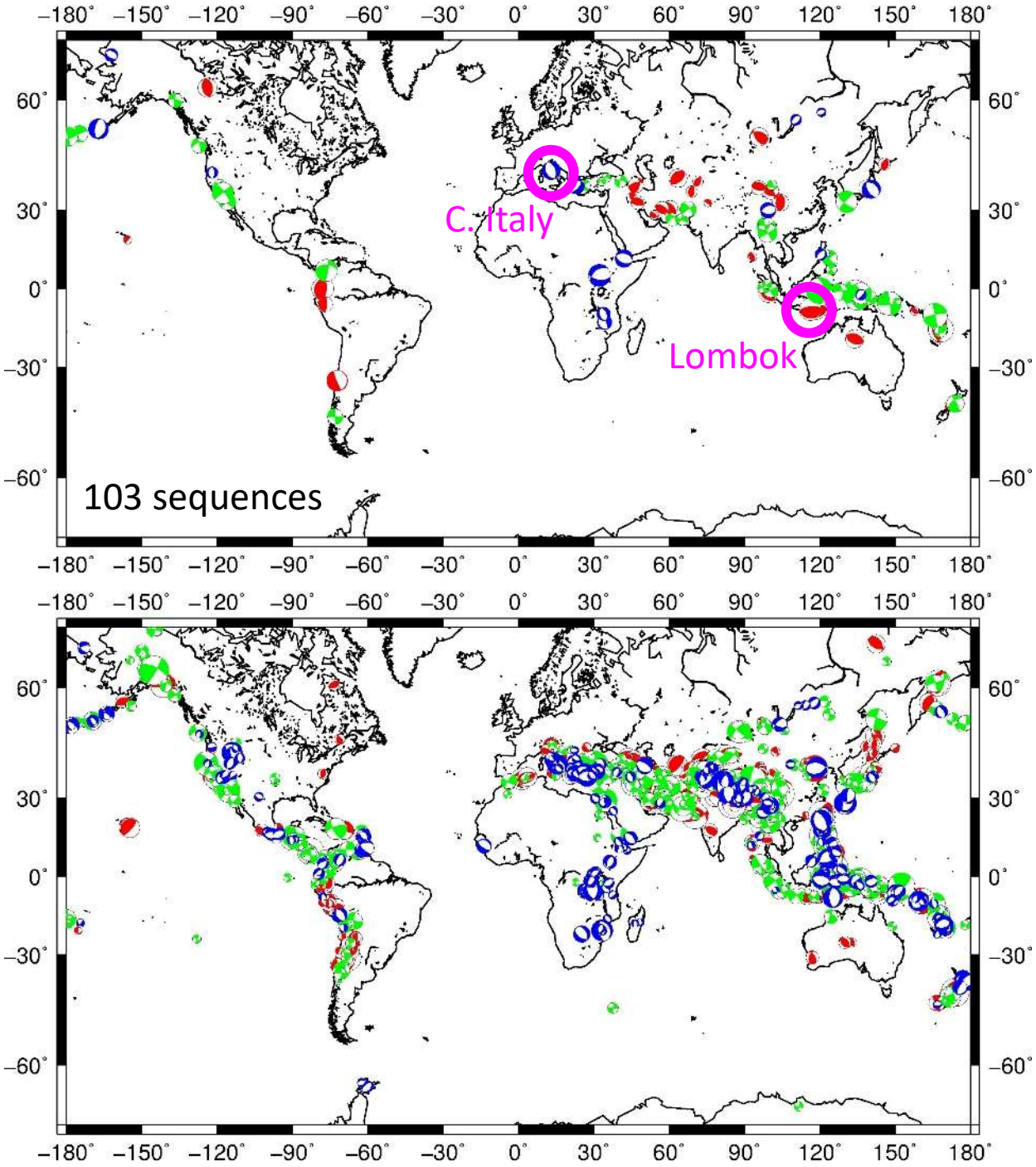
8.



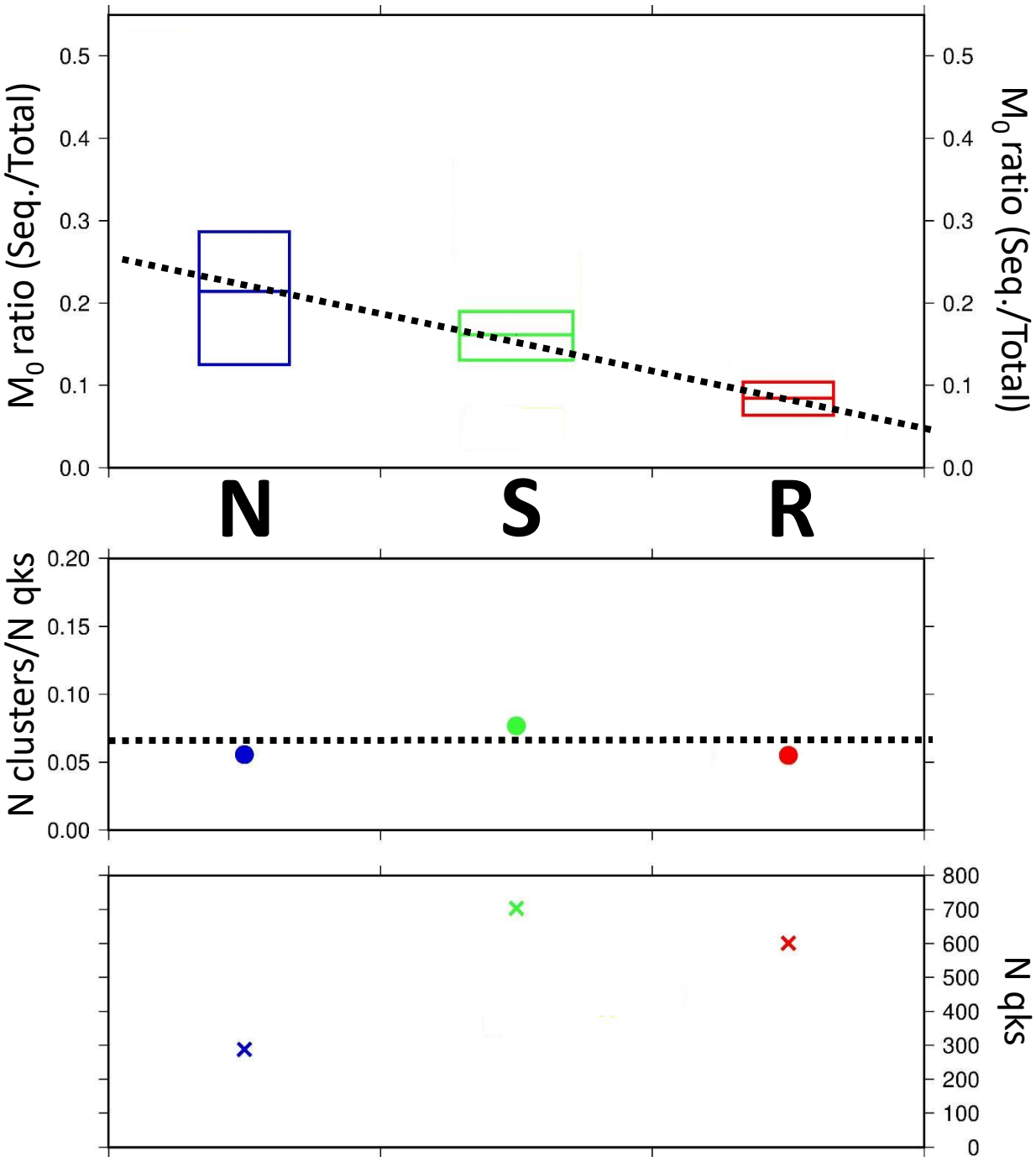








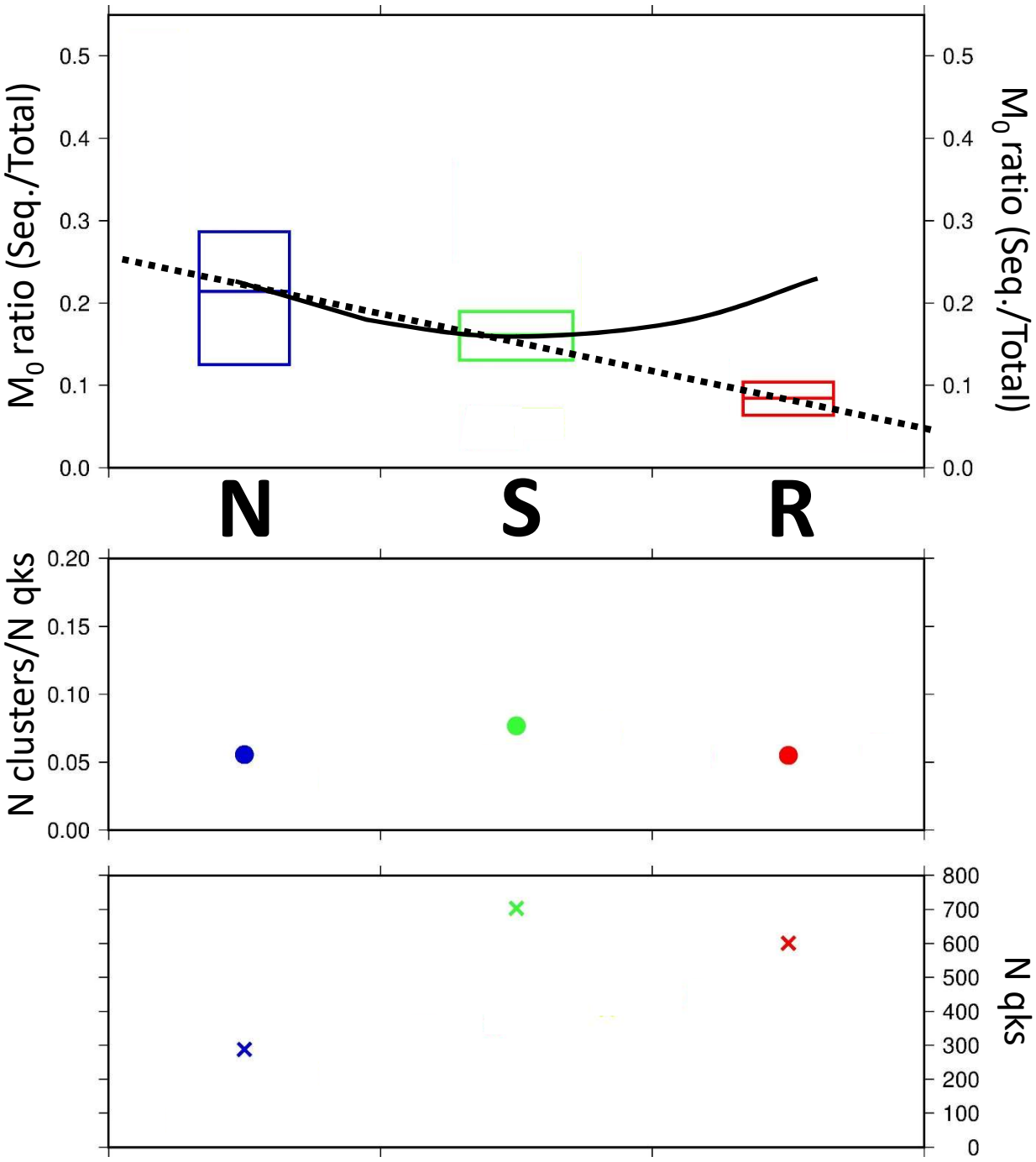
Global Sequences



2.... big differences in proportion of M_0 released by sequences in different tectonic settings...

1. Consistent with results from Stallone & Marzocchi (2019)... and yet.....

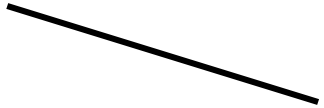
3. How can we reconcile these two results?



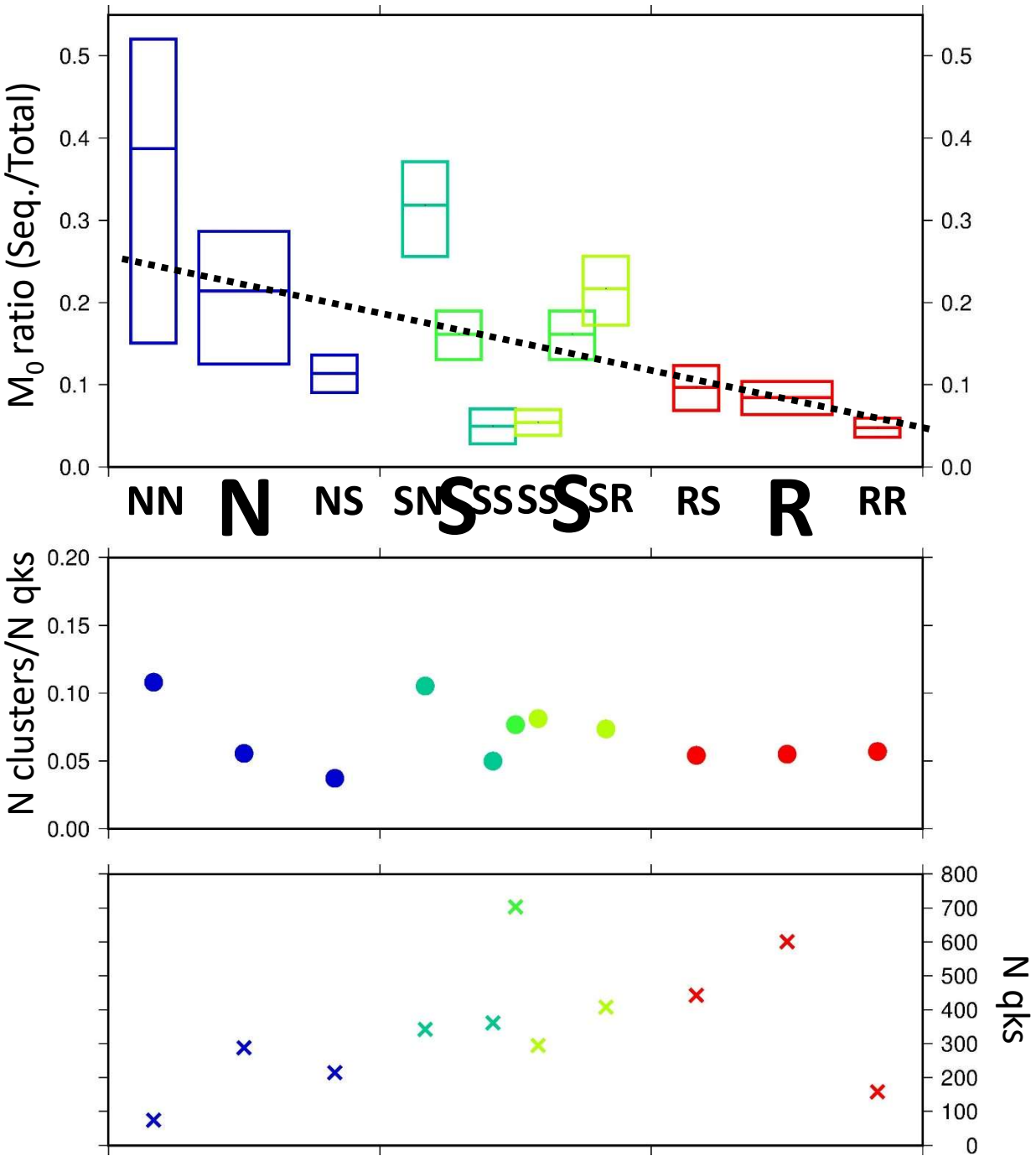
Insight into cause of seismic sequences. 3 possibilities....

- ~~Fault geometry (dip-slip vs. strike-slip)~~

- Stress regime (extensional vs. compressional, impact on differential stress etc.)



- Structural complexity (e.g. N > S > R in complexity of fault networks)



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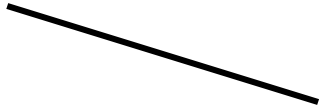

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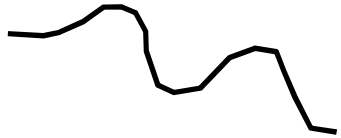

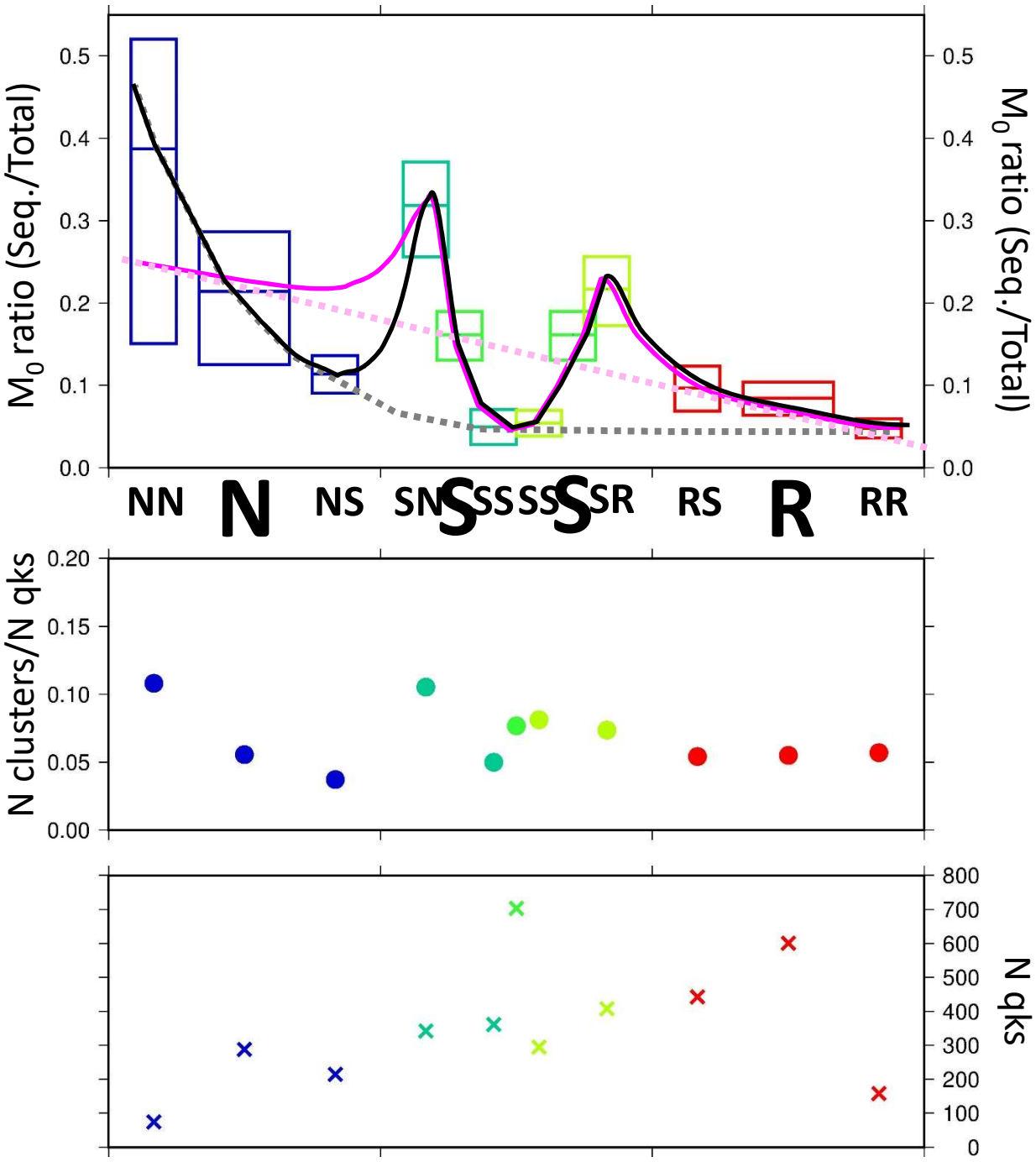

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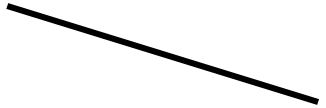

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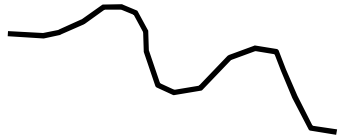

Summary:

1. How important are seismic sequences on a global scale?
2. Are there variations between tectonic regions?
3. What controls likelihood of big multi-segment events vs. stop-start sequences?

- For central Italy example – structural complexity key in determining both size of events and timing- i.e. the stop and the start **(Walters et al. 2018)**.
- Sequences make up 10-20% M_0 globally, common phenomena, important for hazard
- Equally common *by number* in all continental environments (agreement with but account for higher proportion of seismic M_0 in N > S > R, i.e. sequences at max magnitude are more common
- 'Mixed' tectonic regimes also higher M_0 release in sequences than 'pure' regimes
- Implies complexity of fault network controls frequency of large M_0 seismic sequences. More 'failed' big earthquakes and therefore seismic sequences in more complex fault networks **(Walters et al. in prep)**