Convergence rate versus brittle-ductile transition depth in compressional settings: considerations on seismogenic volume and potential earthquake magnitude

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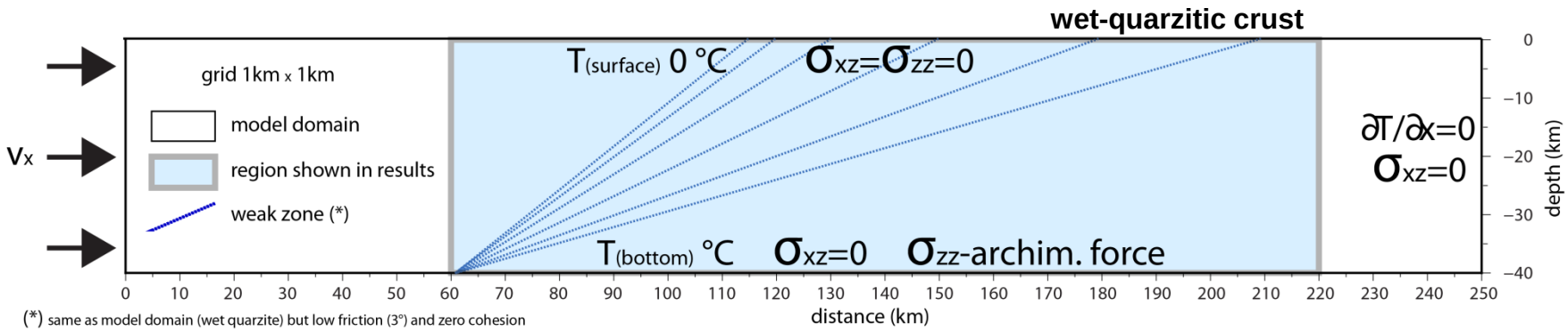
MODEL SETUP – predict the BDT location



VISCO-ELASTO-PLASTICITY

1. Non-Newtonian power-law viscosity

$$\eta = \left(\frac{1}{2}\right) B^{-1/n} (\varepsilon_{II})^{1/n-1} exp(Q/(nRT) d^m$$

2. Mohr-Coulomb elasto-plasticity

$$\frac{\partial p}{\partial t} = -K\frac{\partial v_i}{\partial x_i}, \quad \frac{\partial \varepsilon_{ij}}{\partial t} = \frac{1}{2G}\frac{\partial \tau_{ij}}{\partial t} + \frac{1}{2\eta}\tau_{ij}$$

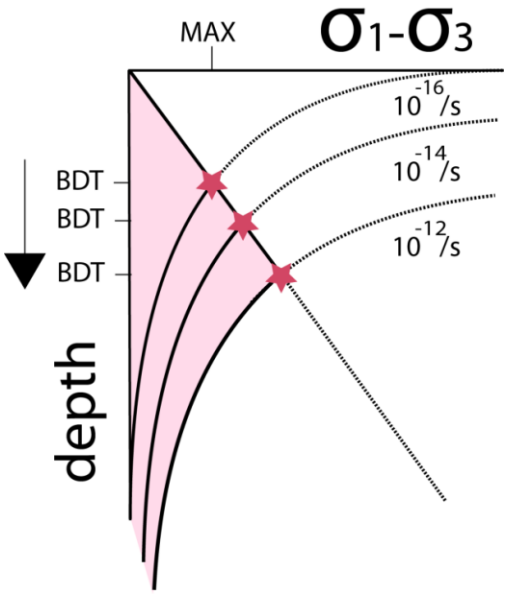
Parameters		Unit	Value
Density	ρ	Kg/m^3	2800
Thermal expansion	α	K^{-1}	3.7×10^{-5}
Bulk modulus	K	GPa	55
Shear modulus	G	Gpa	36
Heat capacity	Cp	J/kg/K	1200
Heat conductivity	λ	W/K/m	2.5
Heat productivity	A	$\mu W/m^3$	1.5
Creep activation energy	Q	KJ/mol	223
Power-law exponent	η		4

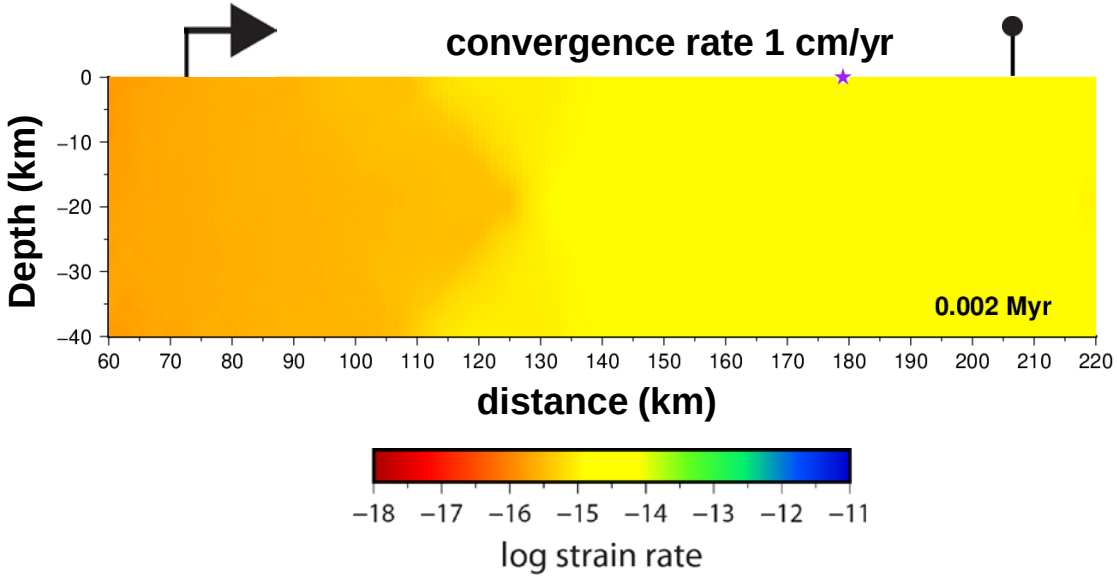
Petricca et al., 2018 - *PEPI*

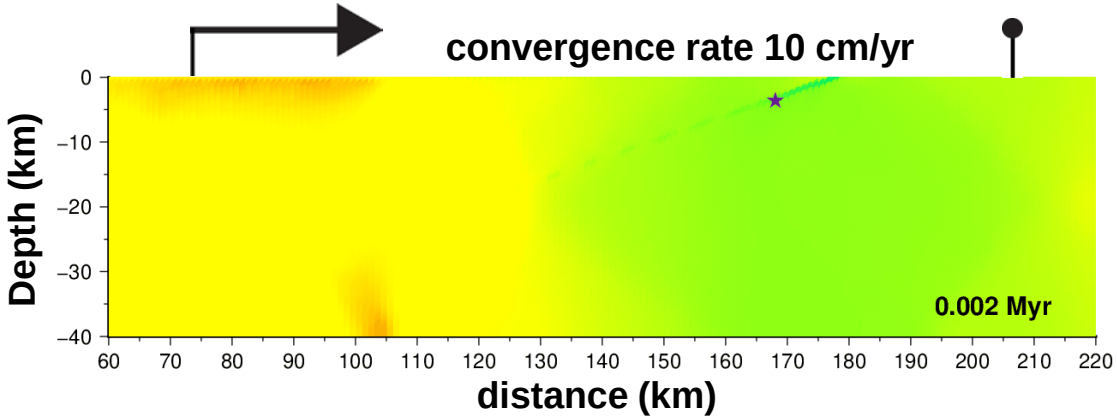
RESULTS – BDT depth depends on convergence rate

brittle-ductile transition

(POINT OF MAX σ diff)

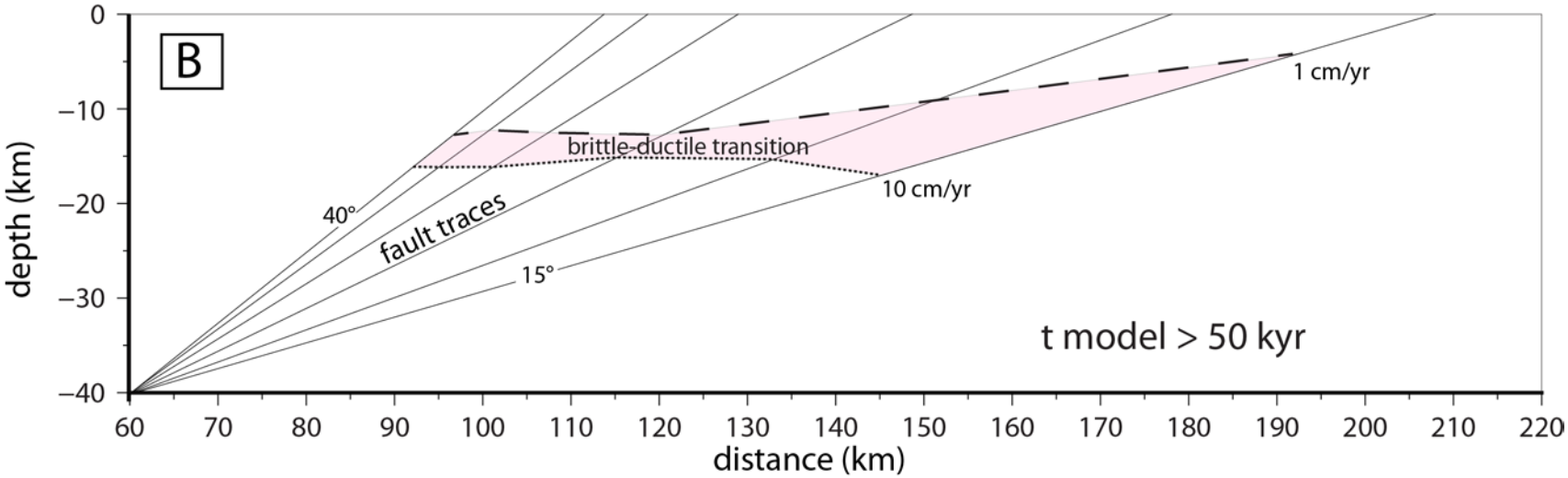






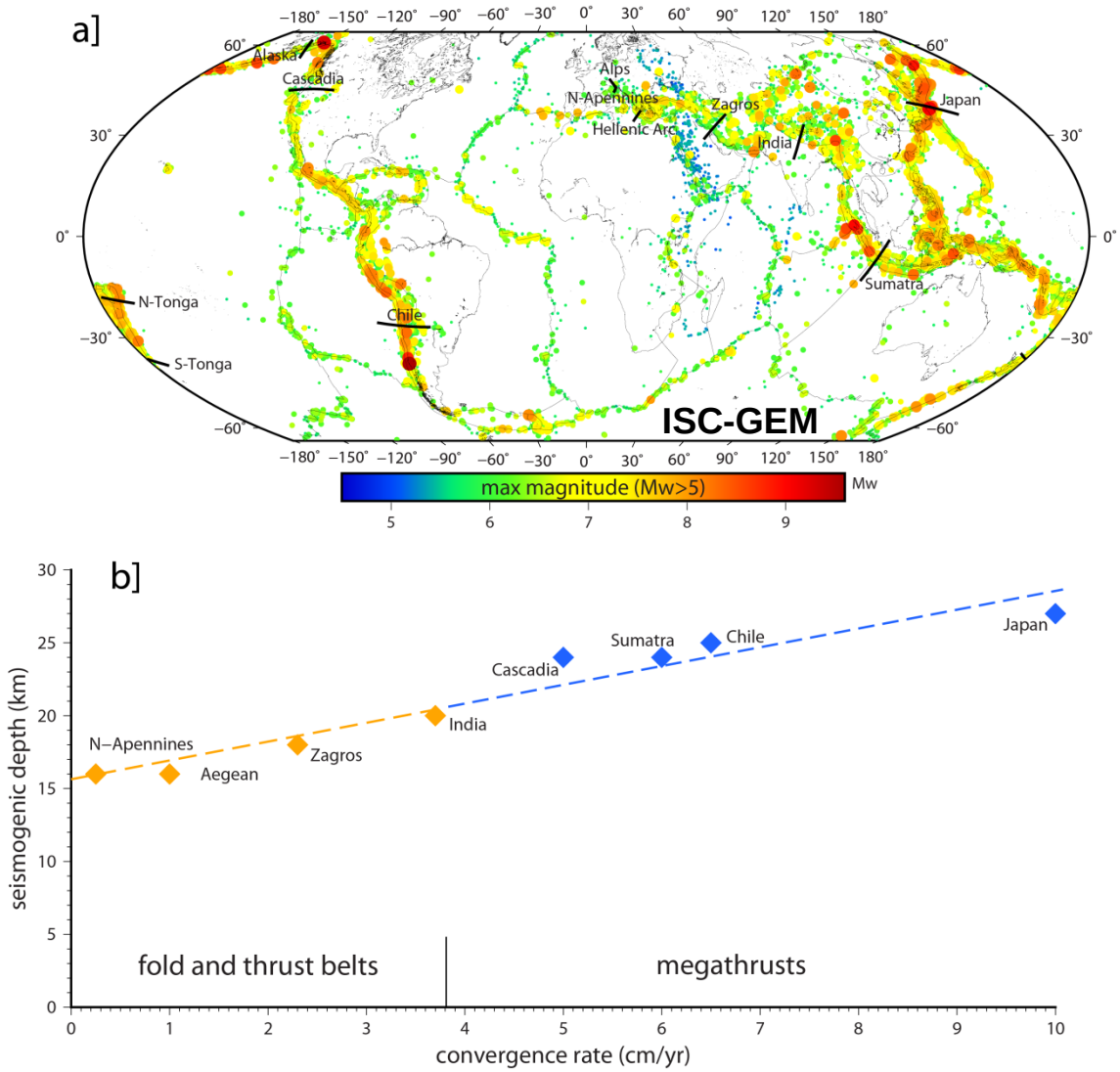
Petricca et al., 2018 - *PEPI*

RESULTS – slow vs fast convergence and fault dip



Petricca et al., 2018 - *PEPI*

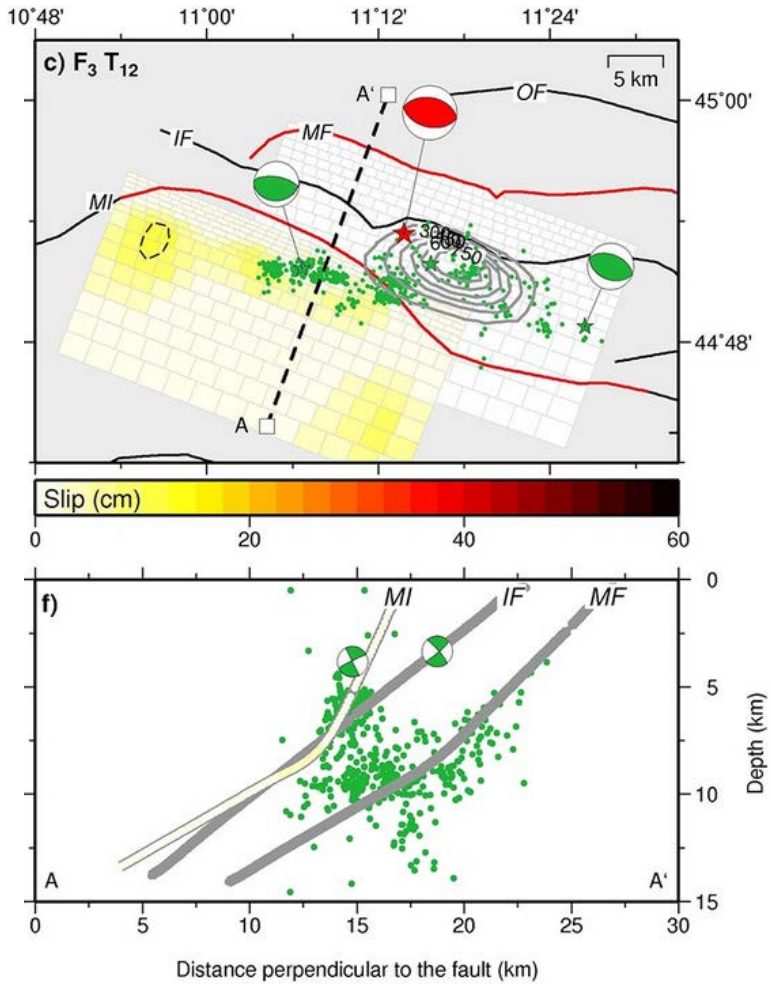
DATA – convergence rate vs seismicity depth



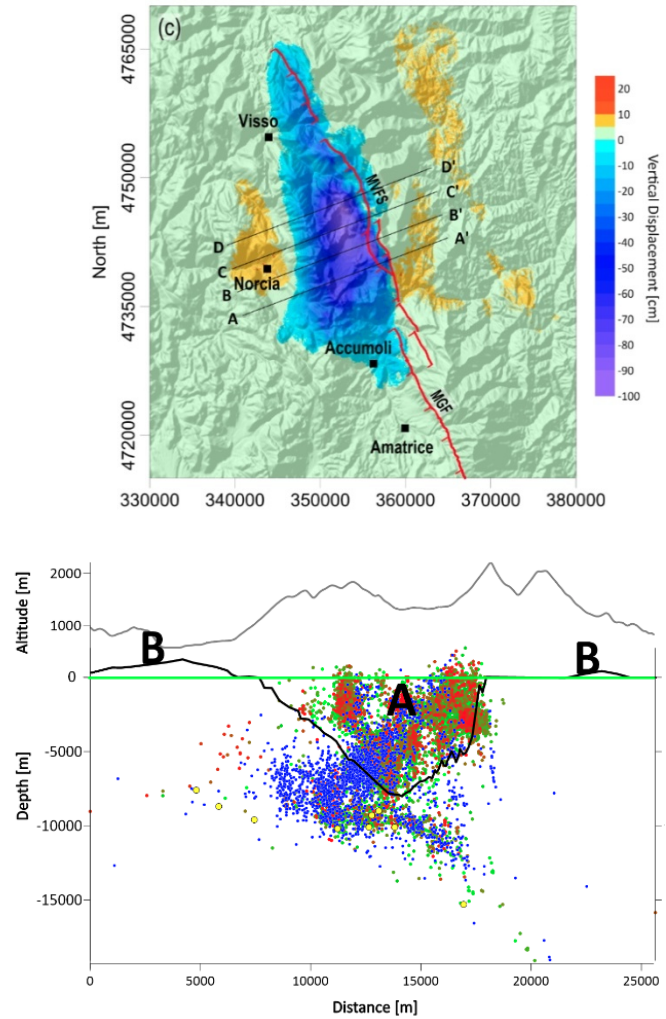
Petricca et al., 2018 - *PEPI*

CONSIDERATIONS ON… seismogenic volume

Emilia 2012



Visso-Amatrice 2016



Cheloni et al., 2014 – *JGR*

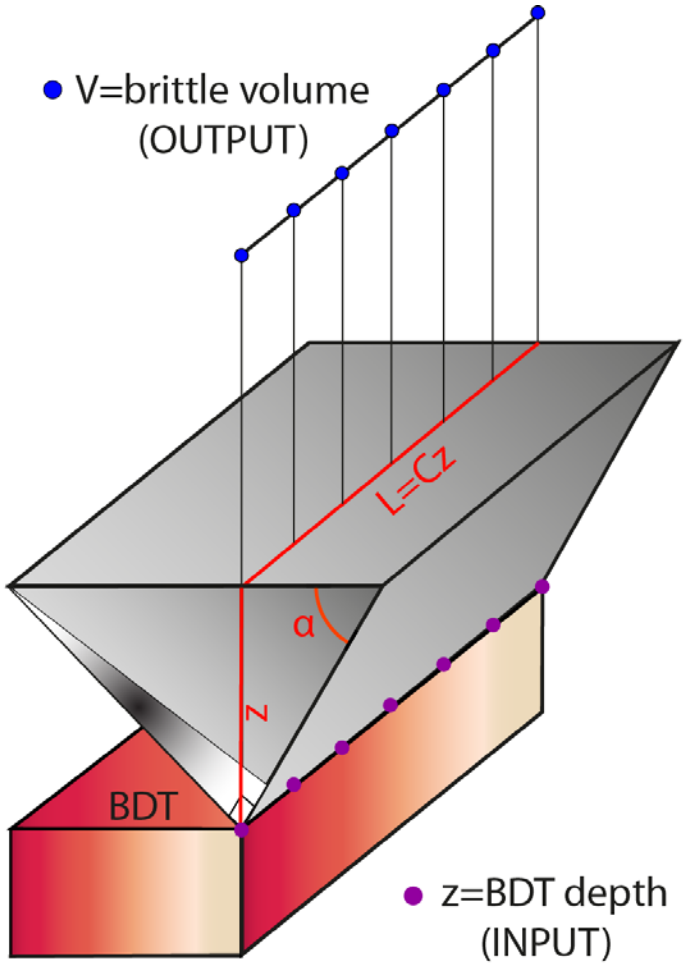
Valerio et al., 2018 – *Under review*

… controlling parameters

$$V_{(i,j)} = \frac{C}{2} z^3_{(i,j)} \left[\cot(\alpha)+\cot(90-\alpha)\right]$$

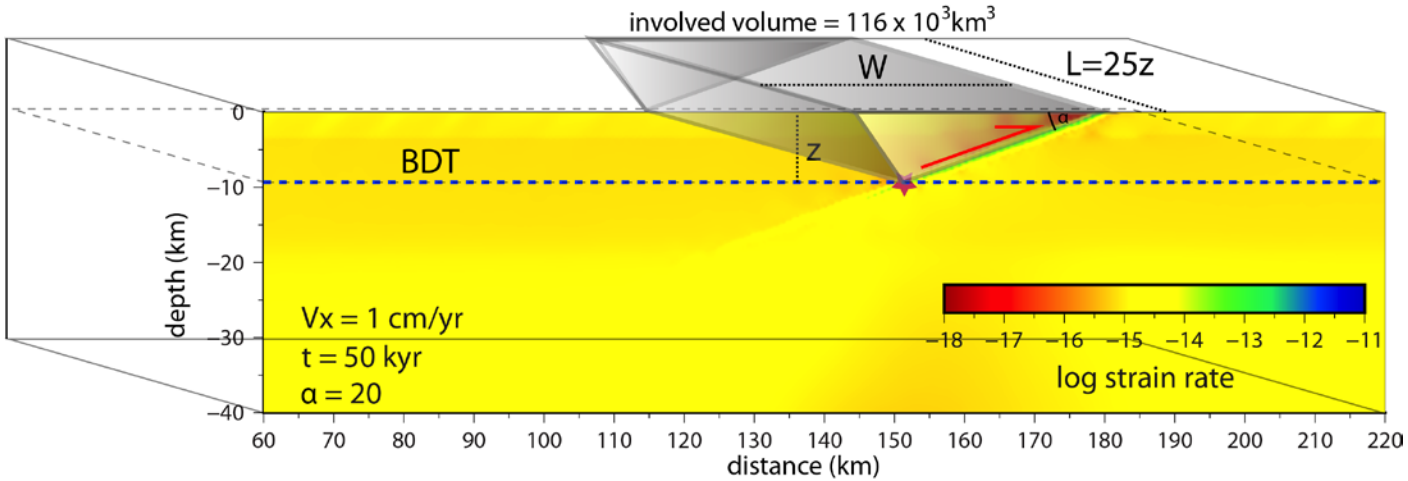
- z = BDT depth
- α = fault dip
- C = L/z {3<C<25}

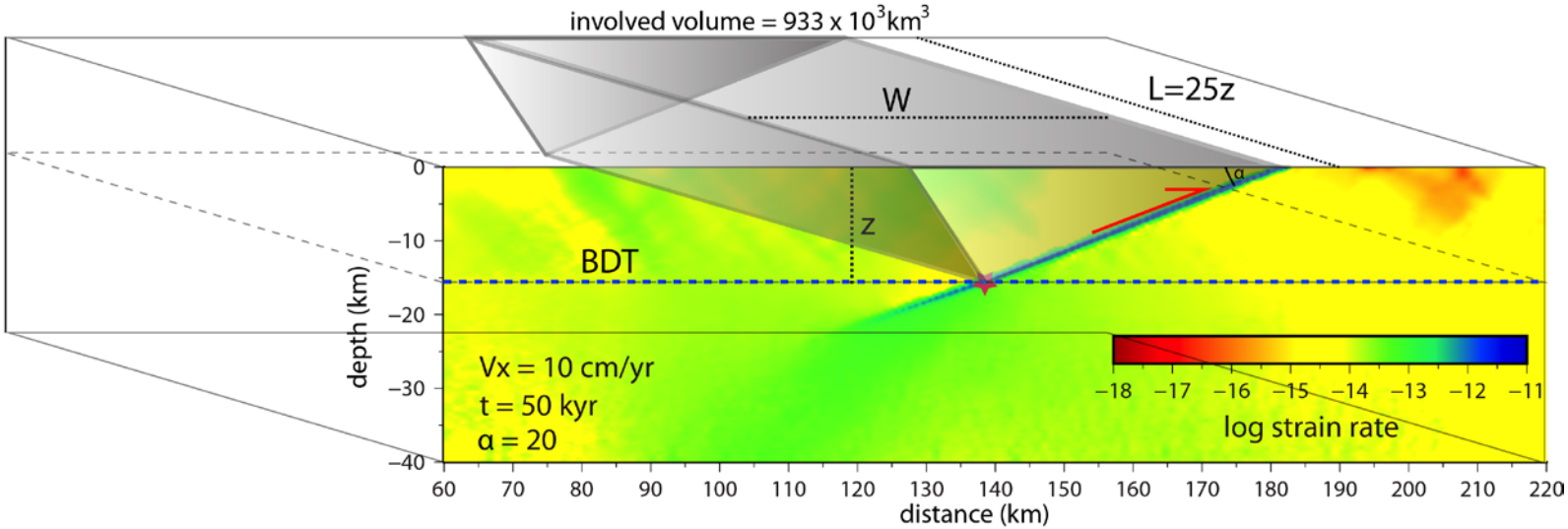
C≈25 for thrust faults
Doglioni et al., 2015 – *Sci. Rep.*



Petricca et al., 2015 – *Tectonophysics*

… volume increase



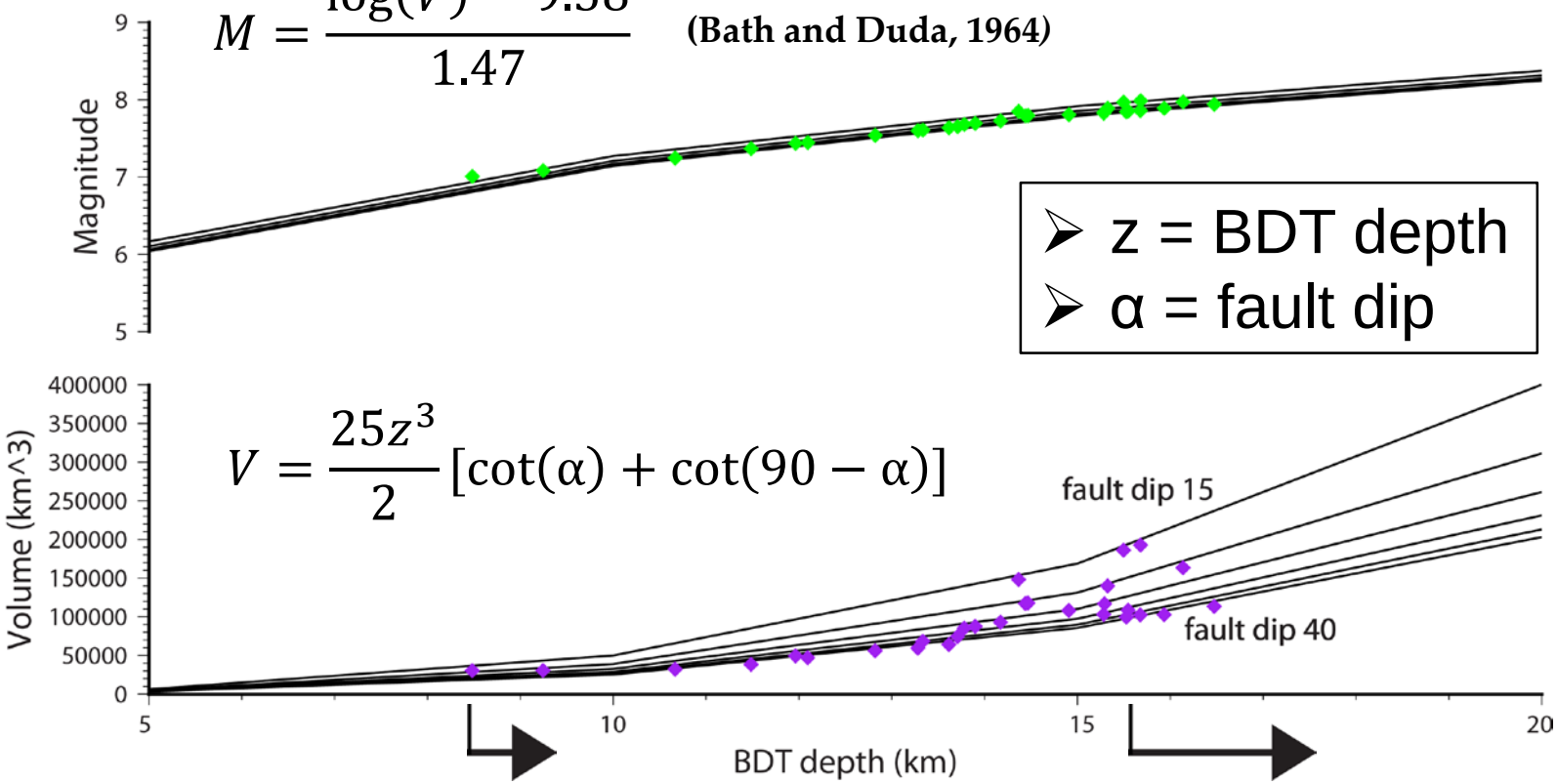


Petricca et al., 2018 - *PEPI*

… potential earthquake magnitude

$$M = \frac{\log(V) - 9.58}{1.47}$$

(Bath and Duda, 1964)



$$V = \frac{25z^3}{2}[\cot(\alpha) + \cot(90 - \alpha)]$$

- z = BDT depth
- α = fault dip

1 cm/yr **10 cm/yr**

Petricca et al., 2018 - *PEPI*

… conclusions

- **DATA**
- the seismogenic layer thickens with increasing convergence rate

- **MODEL**: increasing convergence rate (from 1 to 10 cm/yr)
- the **BDT depth** doubles
- the **brittle volume** more than quadruplicates

- **SURMISE**: increasing convergence rate (from 1 to 10 cm/yr)
- the **potential earthquake magnitude** increases up to 2

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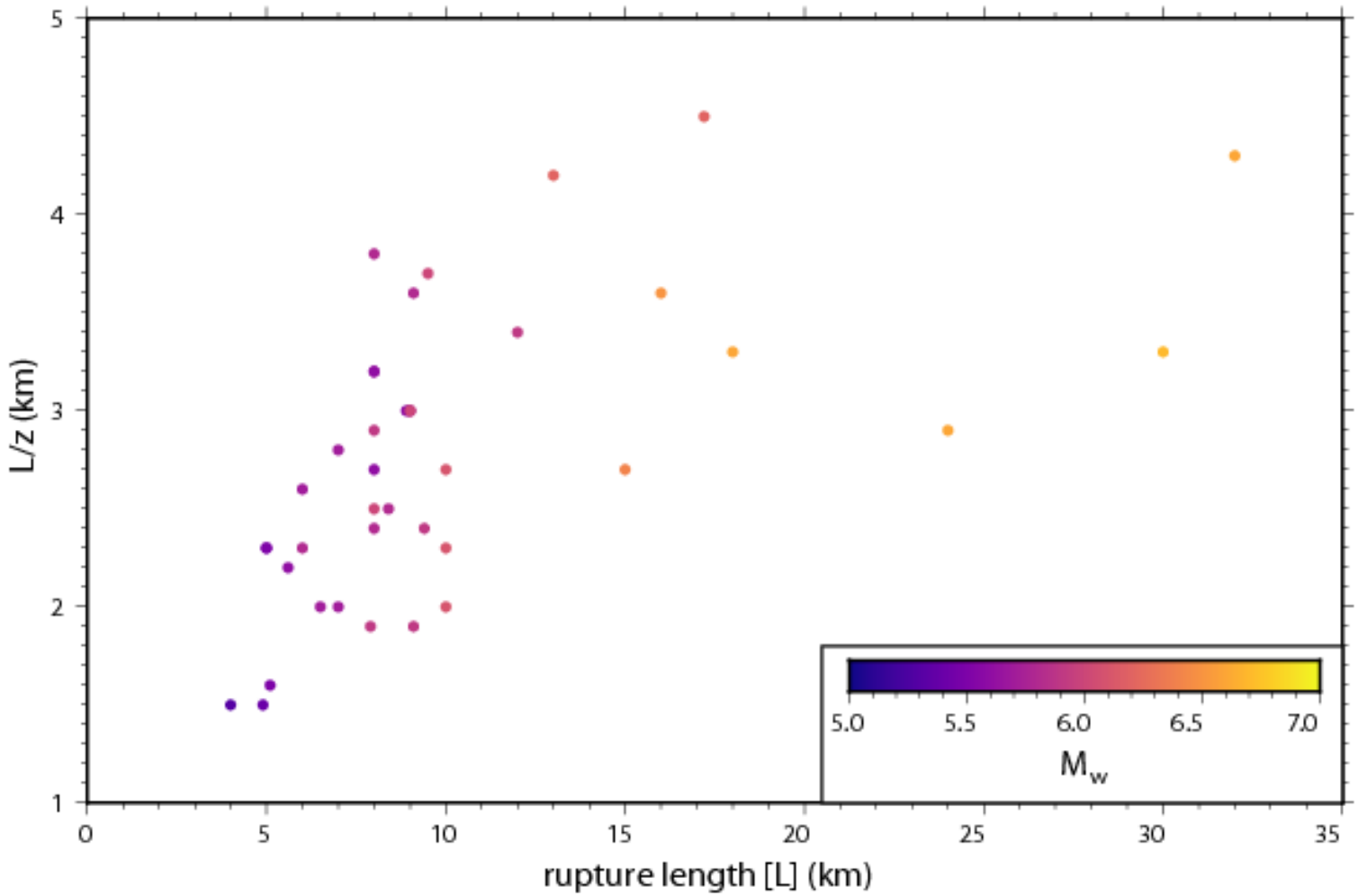
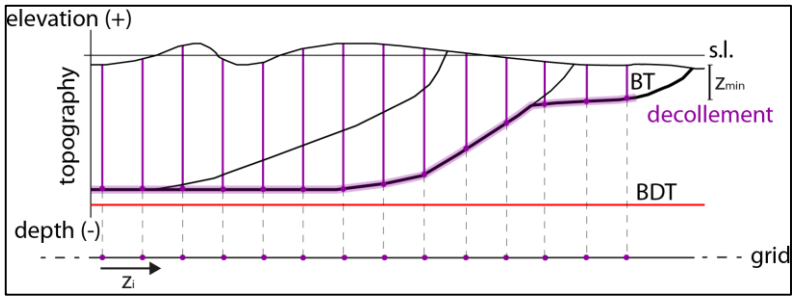
- **WATH DO WE NEED FOR VALIDATION?**
- L/z ratio
- maximum depth of faulting

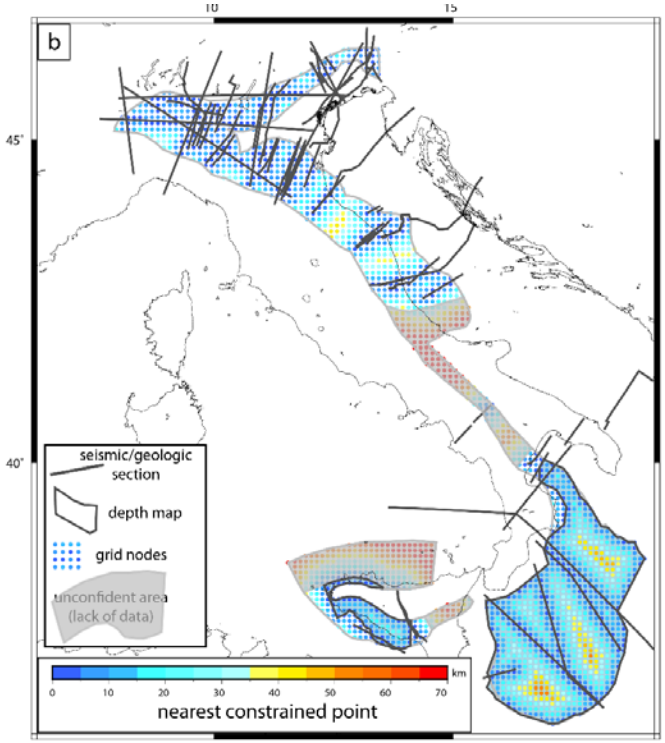
… L/z ratio of thrust faults in Italy

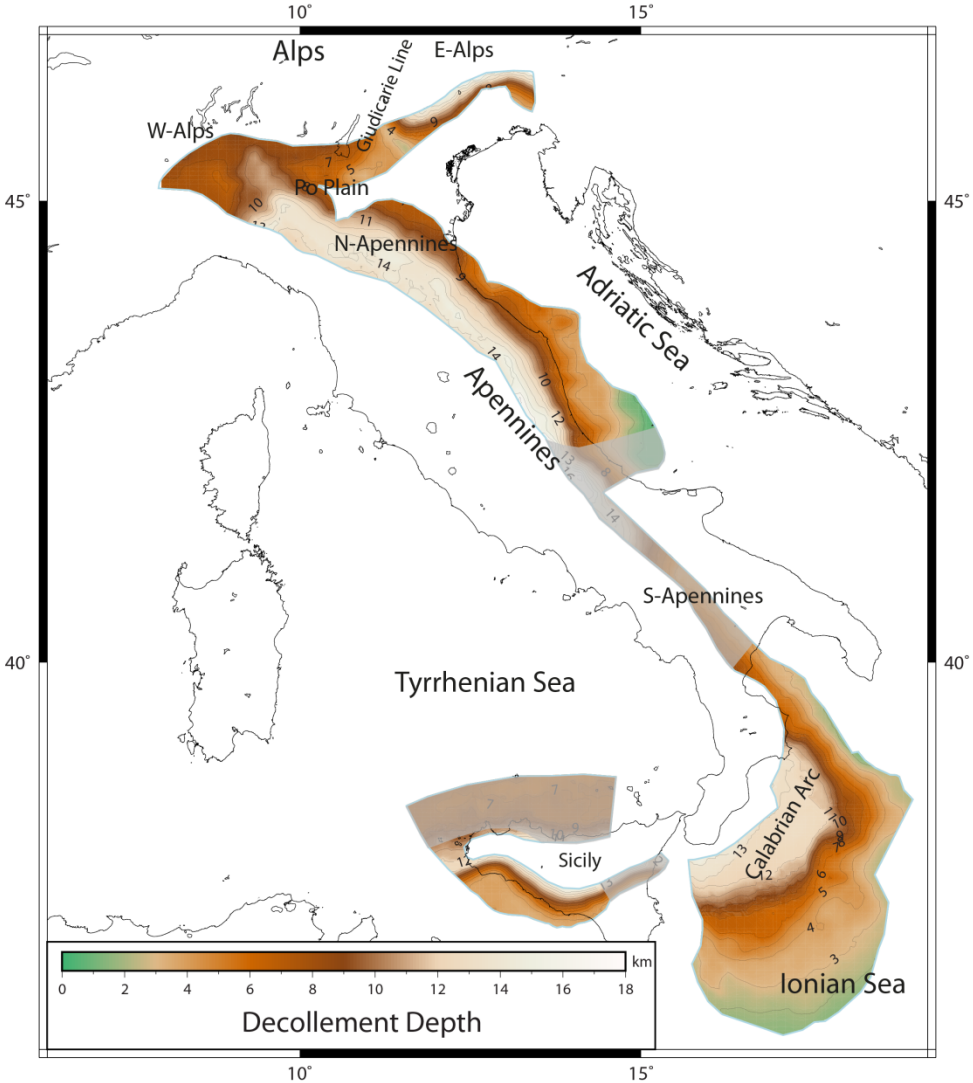


Petricca et al., 2018 – *Under review*

… thrust faulting depth in Italy

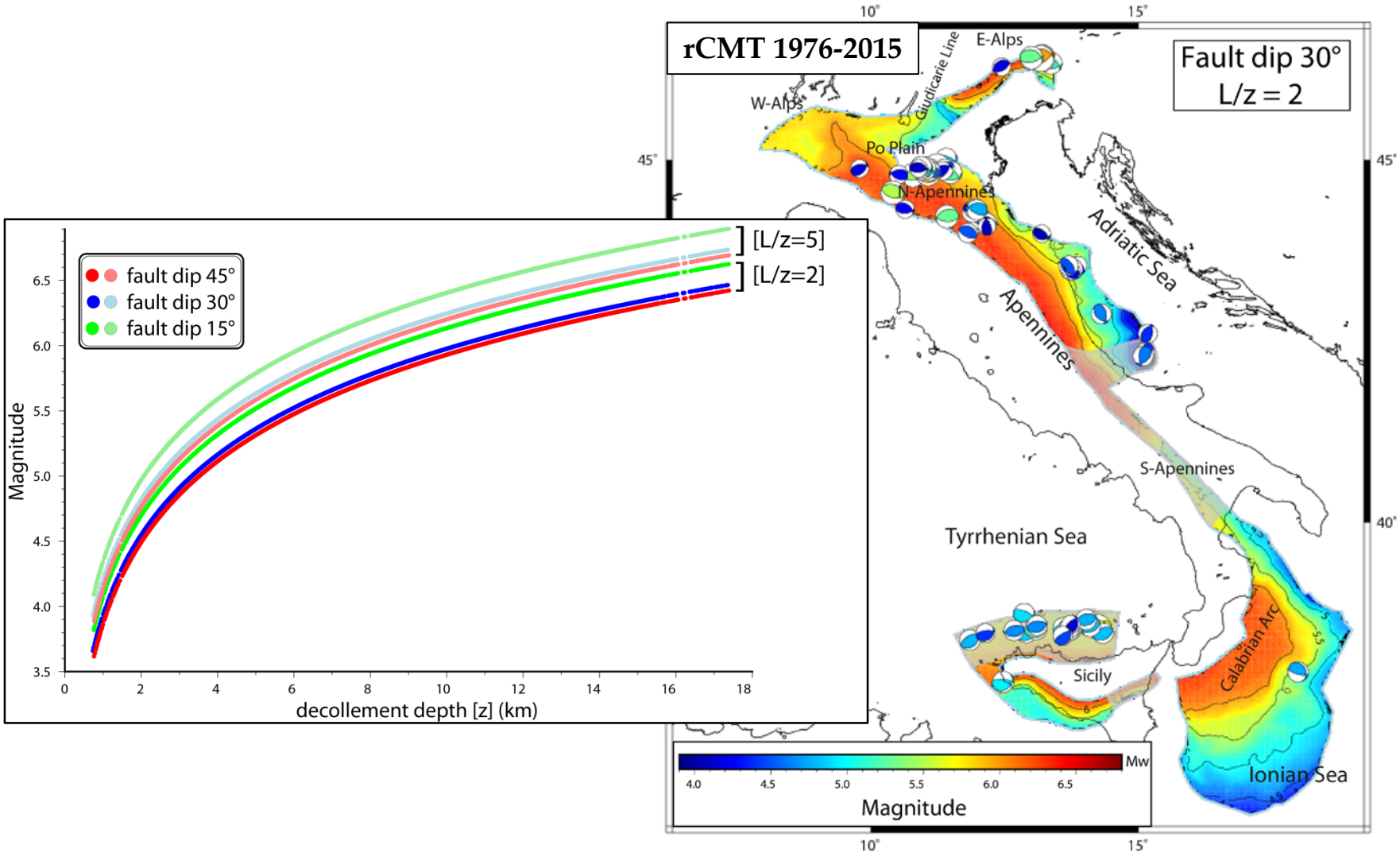






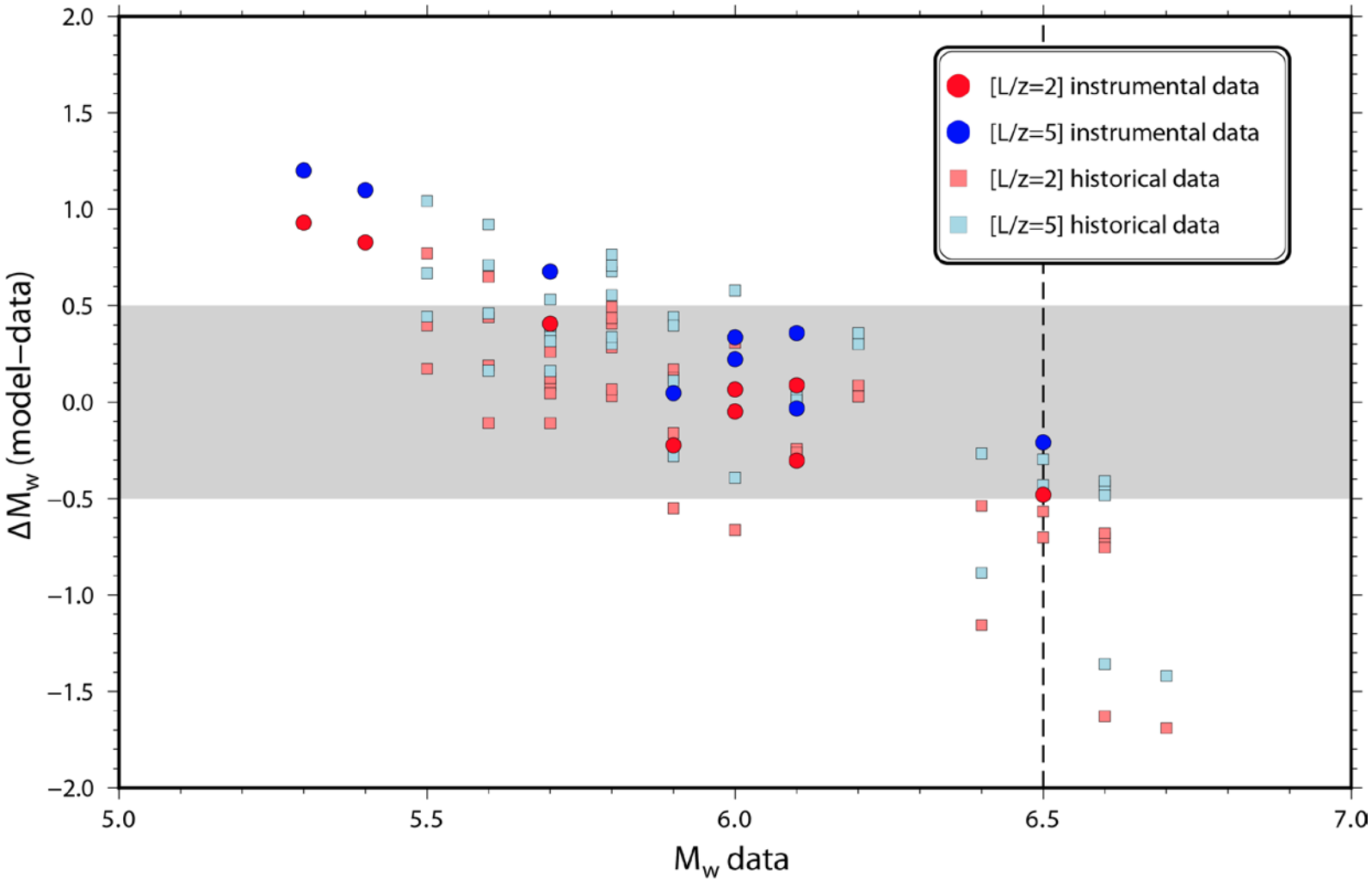
Petricca et al., 2018 – *Under review*

… MODEL vs DATA



Petricca et al., 2018 – *Under review*

… MODEL vs DATA



Petricca et al., 2018 – *Under review*

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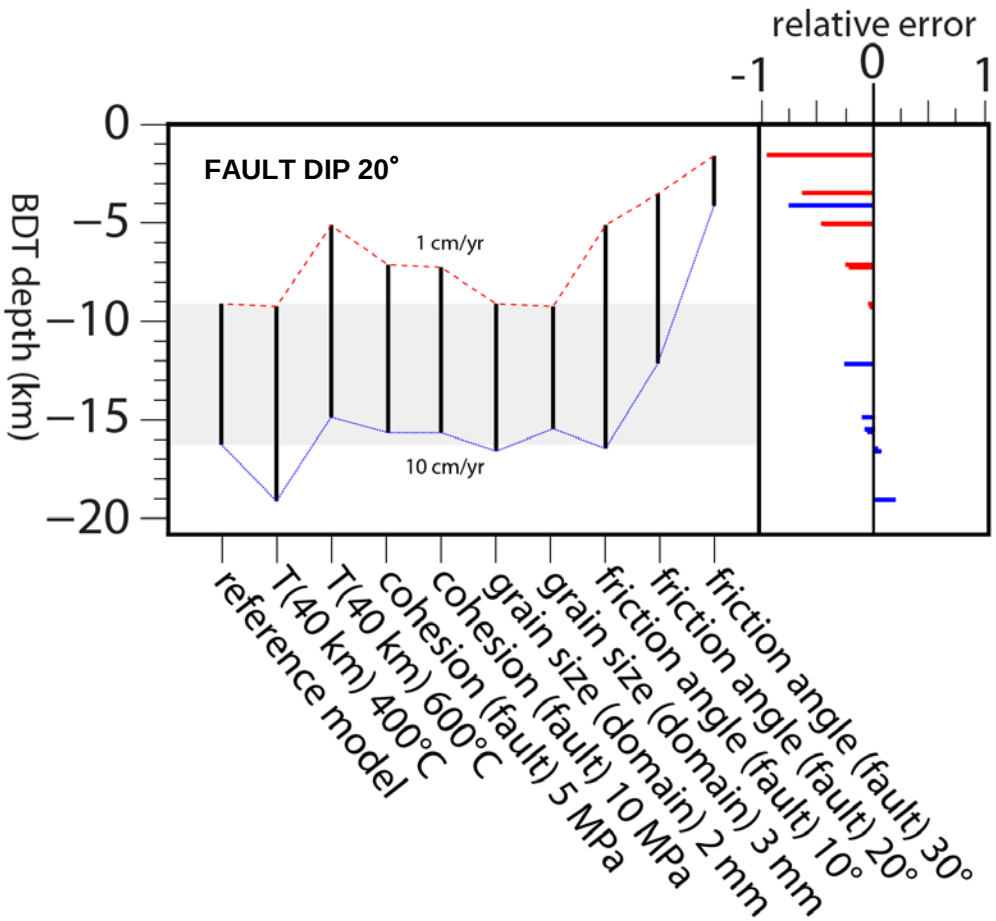
- **SURMISE**
- the **potential earthquake magnitude** increases up to 2

- **WATH DO WE NEED FOR VALIDATION?**
- L/z ratio
- maximum depth of faulting

- **WHAT'S NEXT?**
- integrate with normal and strike slip models
- well constrained empirical relationship $V \propto Mw$

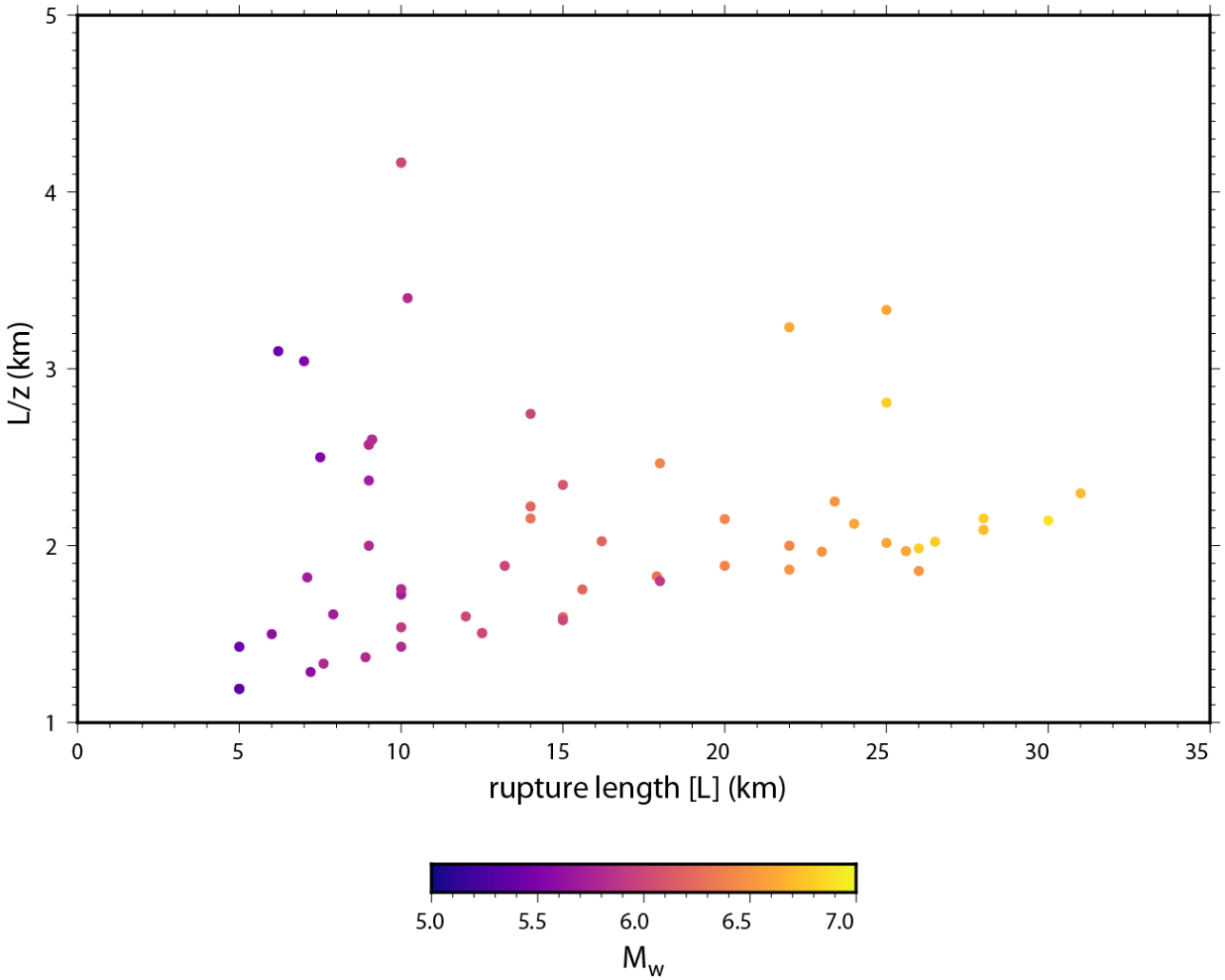
THANK YOU!

RESULTS – slow vs fast convergence and model parameters



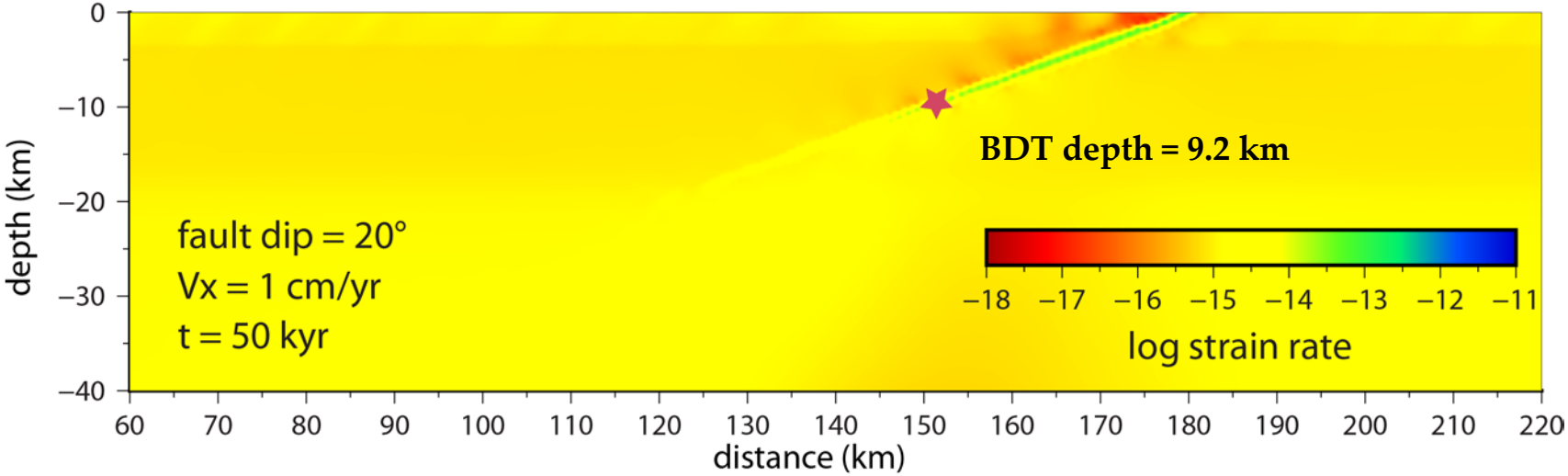
Petricca et al., 2018 - *PEPI*

COMPARISON – L/z ratio of normal faults in Italy

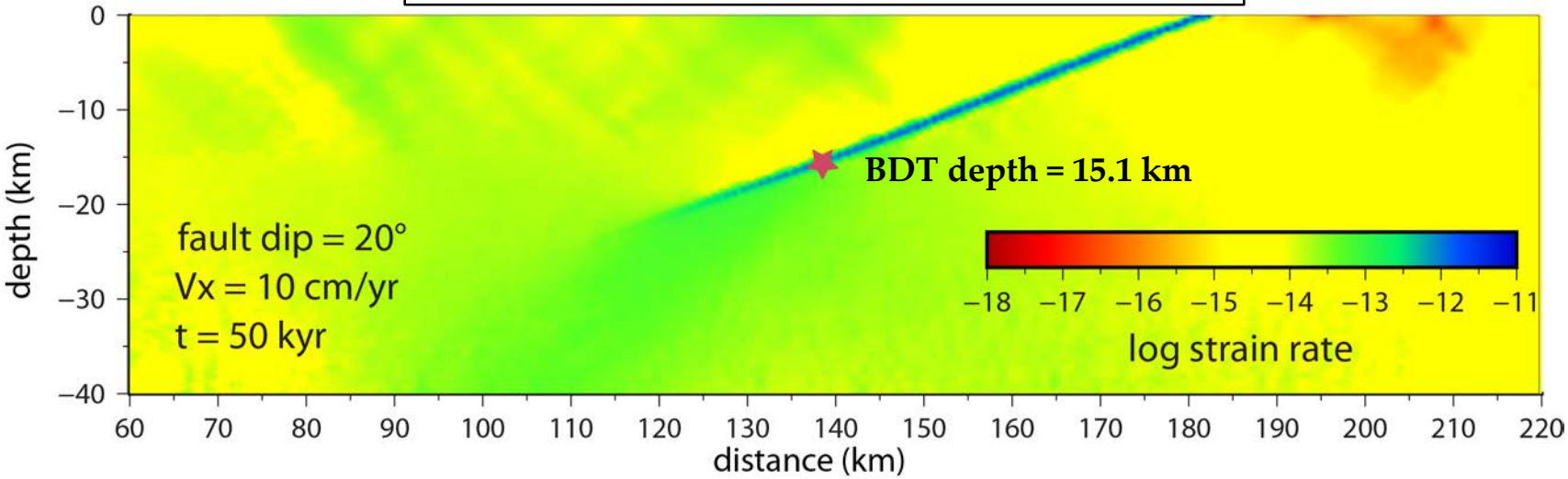


Petricca et al., ***in prep.***

RESULTS – slow vs fast convergence (thrust faults)

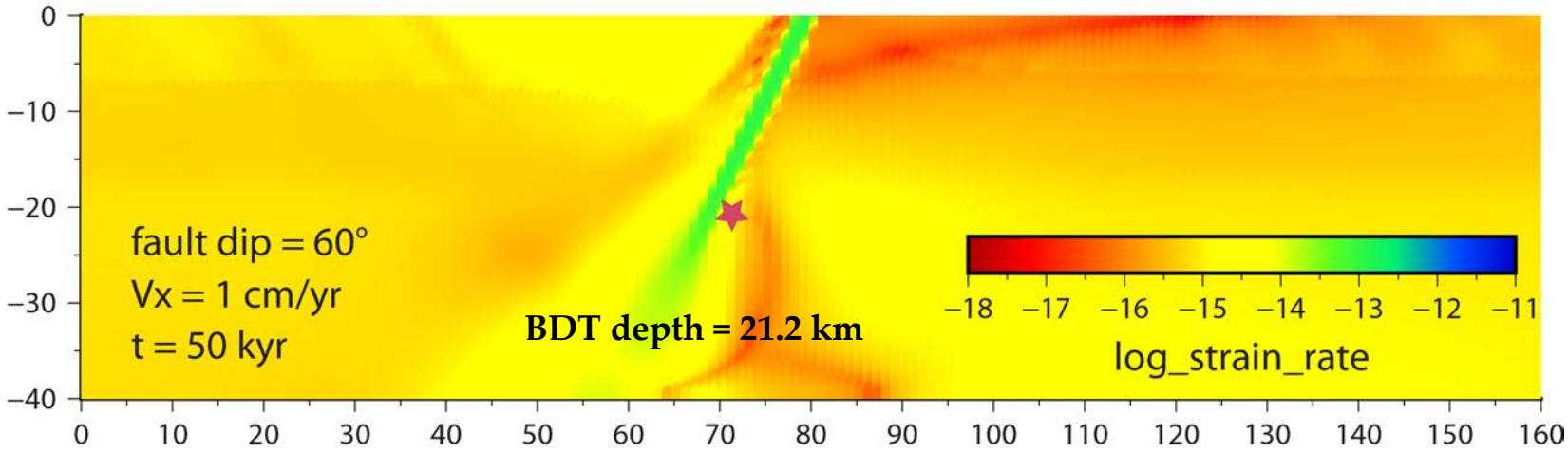


BDT = POINT OF MAX DIFFERENTIAL STRESS

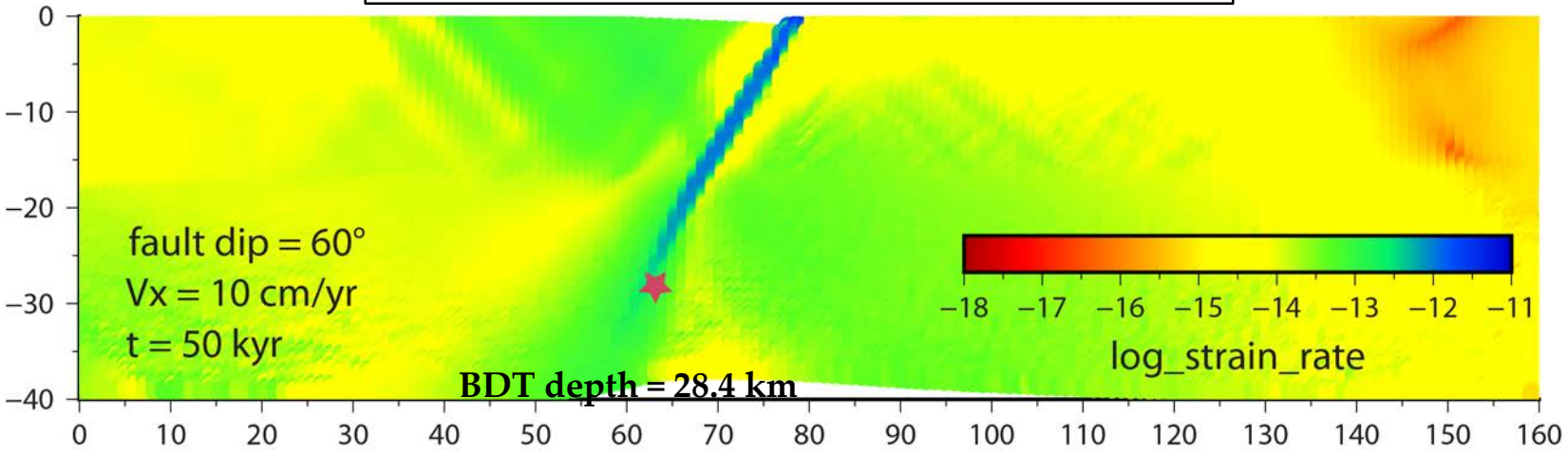


Petricca et al., 2018 - *PEPI*

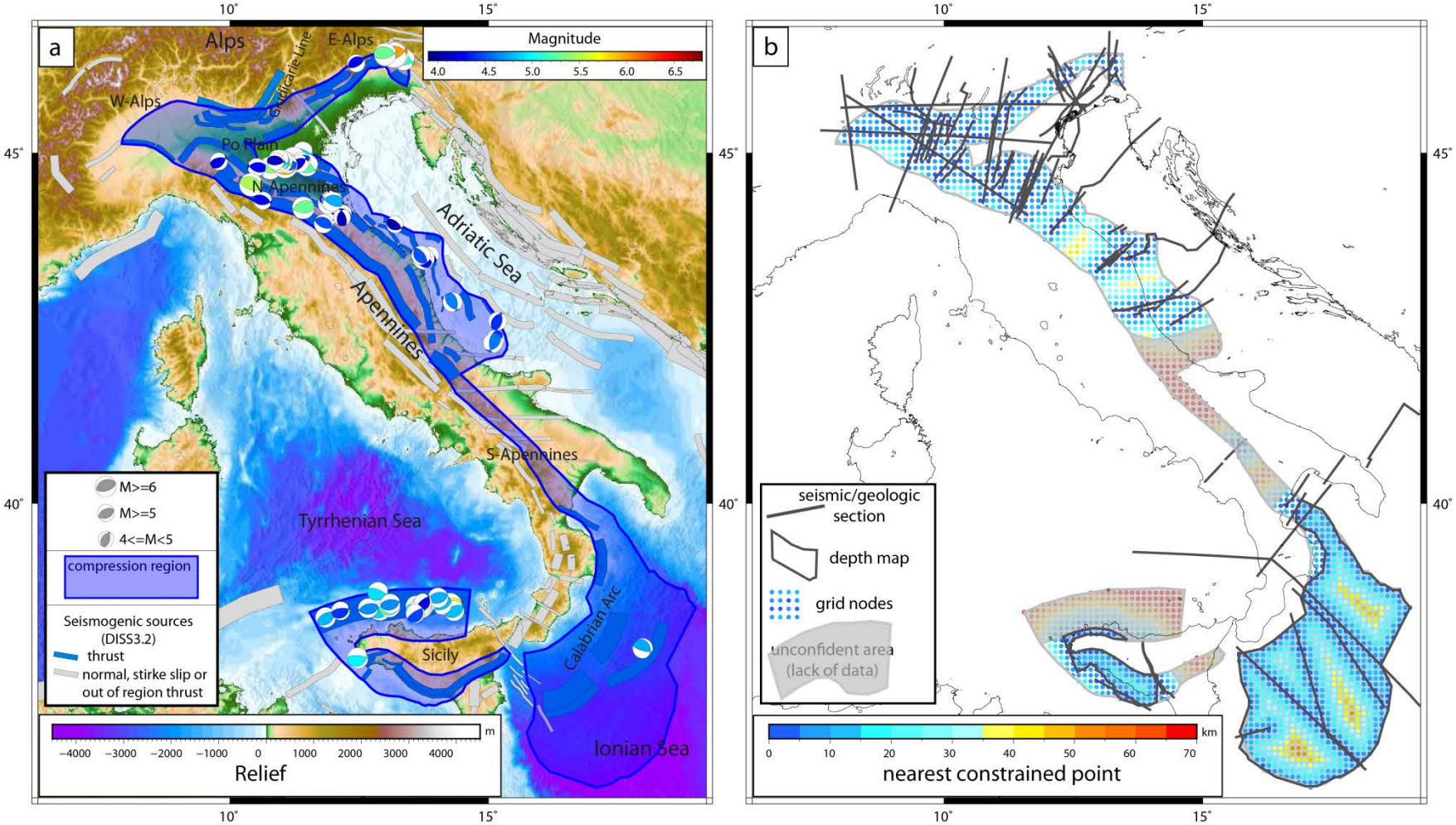
RESULTS – slow vs fast extension (normal faults)



BDT = POINT OF MAX DIFFERENTIAL STRESS



Petricca et al., ***in prep.***



Petricca et al., 2018 – *Under review*

Parameters		Unit	Value
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Bulk modulus	K	GPa	55
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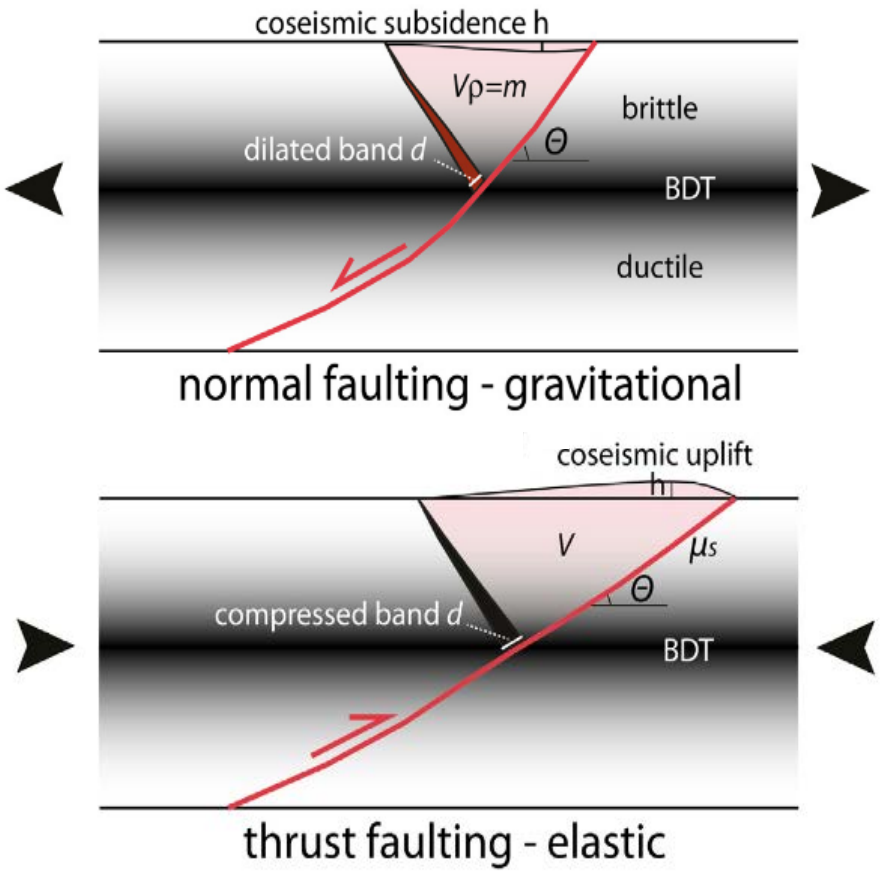
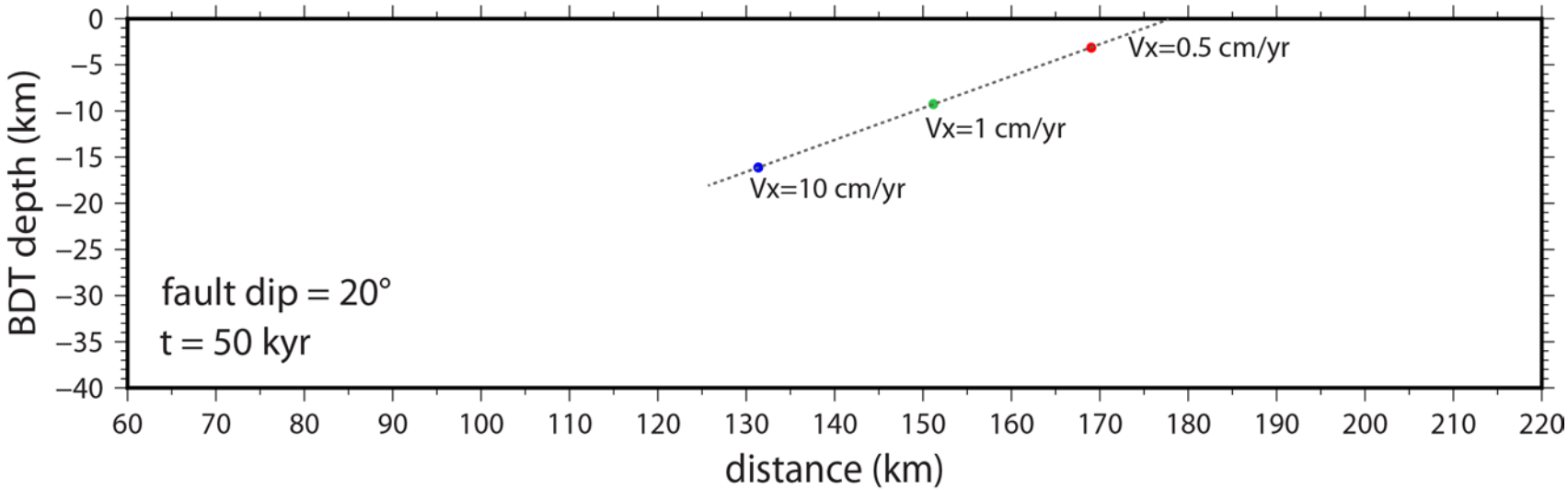
Heat productivity	A	$\mu W/m^3$	1.5
Creep activation energy	Q	KJ/mol	
Power-law exponent	η		4
Mohr-Coulomb elasto-plasticity			
Domain: friction angle		°	30
cohesion		MPa	10
Weak zone: friction angle		°	3
cohesion		MPa	0

Petricca et al., 2018 - *PEPI*

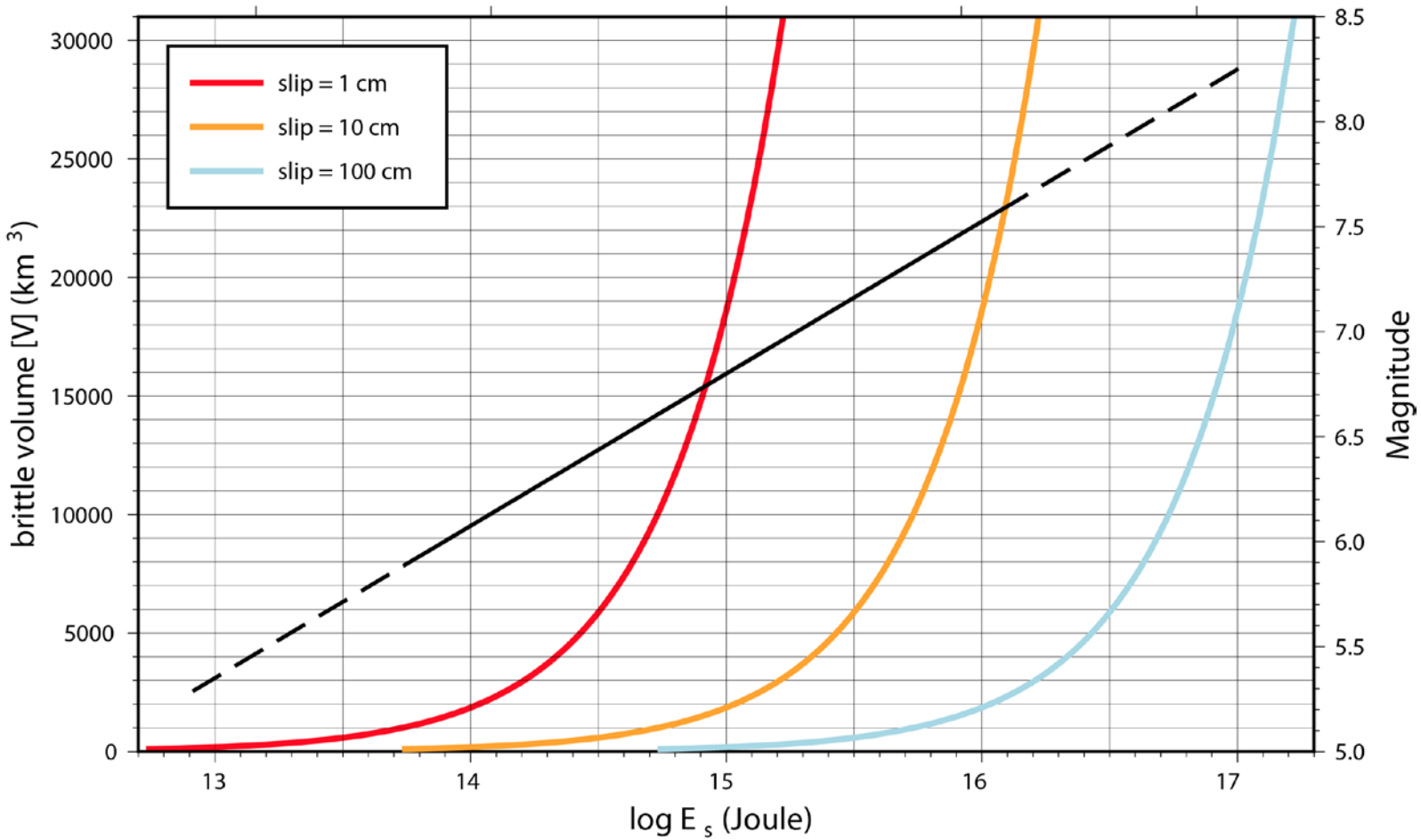
INTRODUCTION – earthquake energy



Doglioni et al., 2015 – *Geosc. Front.*



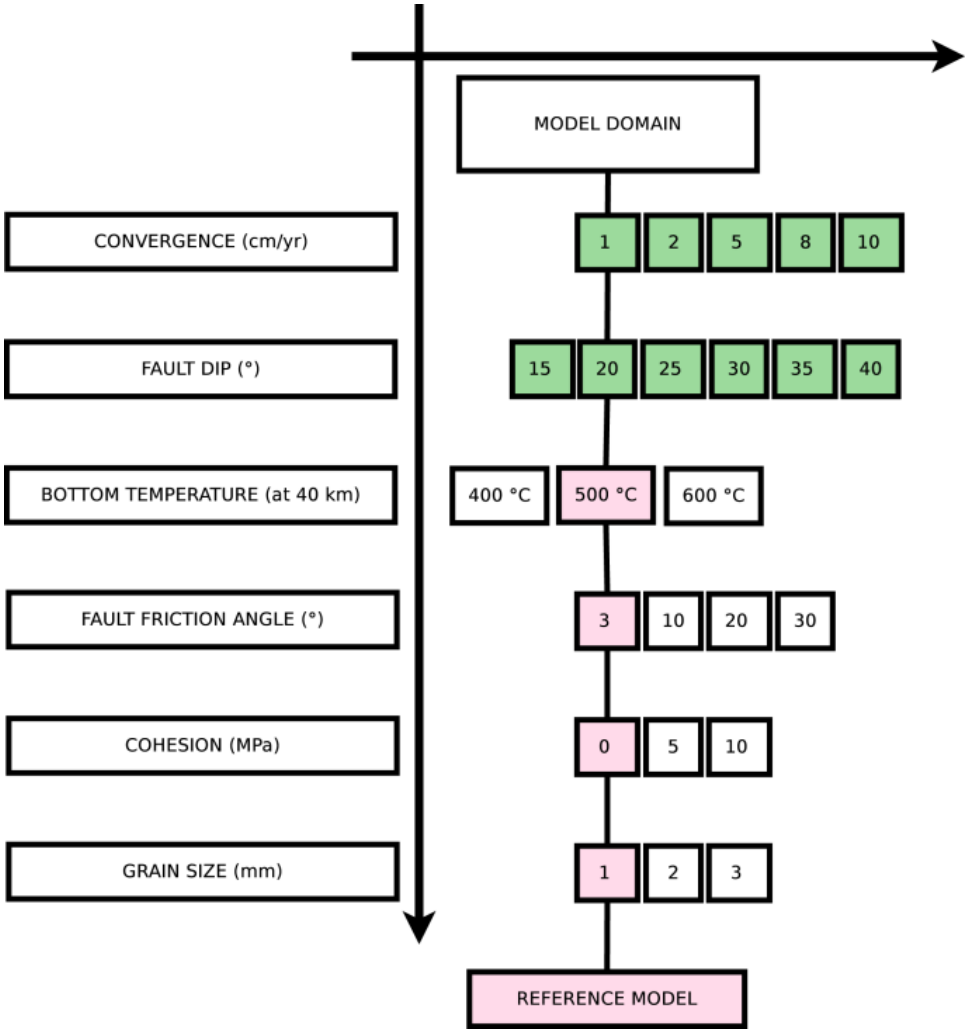
Petricca et al., 2018 - *PEPI*



Petricca et al., 2018 – *Under review*

Subduction	Rate (mm/yr)
Alps	2.0
N-Apennines	2.5
Calabrian Arc	5.0
Hellenic Arc	34.0
Zagros	23.0
India	37.0
Java-Sumatra	60.0
Tonga S	49.0
Tonga N	76.0
Japan	100.0
Alaska	58.0
Cascadia	50.0
Chile	65.0

Petricca et al., 2018 - *PEPI*



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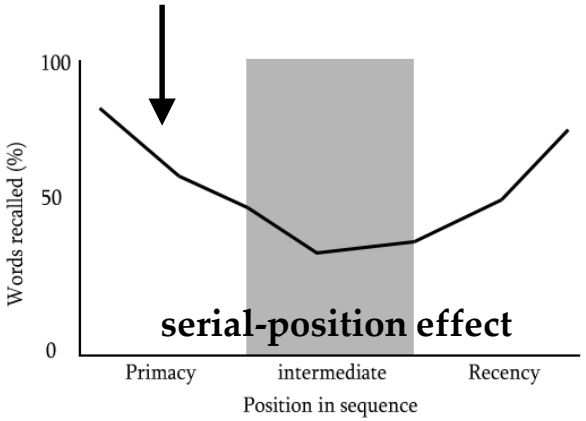
100
50
0
Words recalled (%)
serial-position effect
Primacy
intermediate
Recency
Position in sequence