Stress Patterns in the San Jacinto Fault Zone and South Central Transverse Ranges

Niloufar Abolfathian[1]
Patricia Martínez-Garzón[2], Yehuda Ben-Zion[1]

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[1]University of Southern California, Los Angeles, USA
[2]GFZ German Research Centre for Geosciences, Potsdam, Germany

Introduction:

- Refining the methodology (Martínez-Garzón et al., 2016)
- Inverting focal mechanisms for the principal stress orientations and the stress ratio

Objectives:

- Obtaining a reliable, high-resolution information about stress parameters in Southern California near San Jacinto Fault Zone (SJFZ) and South Central Transverse Ranges (SCTR)
- Coming up with ingredients affecting the stress in the crust

Methods:

- MSATSI software (Martínez-Garzón et al., 2014), an updated version from SATSI (Hardebeck and Michael, 2006; Michael, 1984).
- A linear damped stress inversion on the earthquake focal mechanisms.
- Determines the orientation of the principal stresses and the stress ratio:

$$R = \frac{\sigma_1 - \sigma_2}{\sigma_1 - \sigma_3}$$

Refinement (Martínez-Garzón et al., 2016):

- Using declustered seismicity.
- Selecting the fault plane with the largest fault instability (Vavrycuk, 2014)
- Discretizing the focal mechanisms using an updated *k-means* technique.

Data:

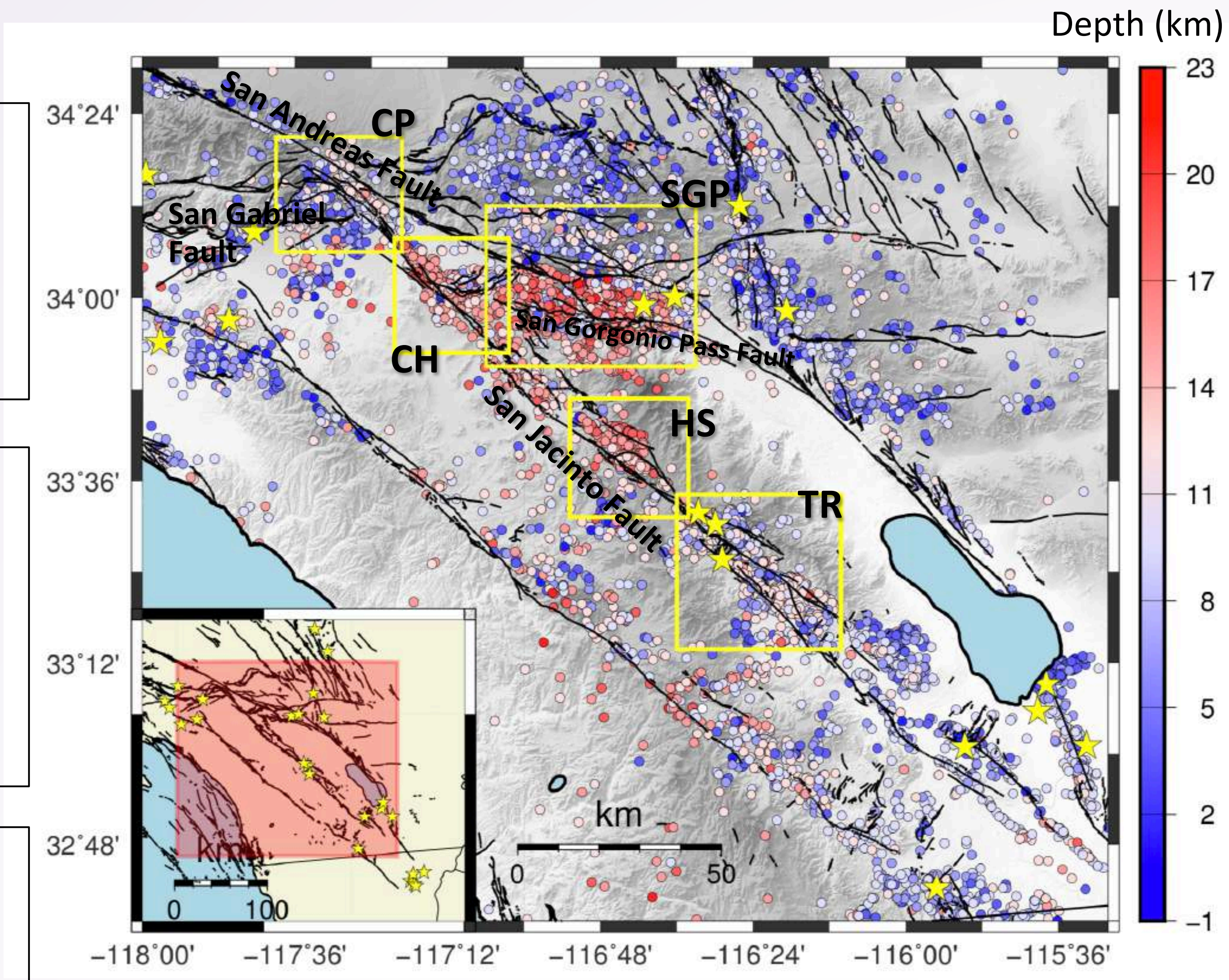
San Jacinto Region:
(CH, HS, TR)
Years: 2000 to 2009

10,829 focal mechanisms declustered catalog

South Central Transverse Ranges:
(CP, SGP)
Years: 1981 to 2017

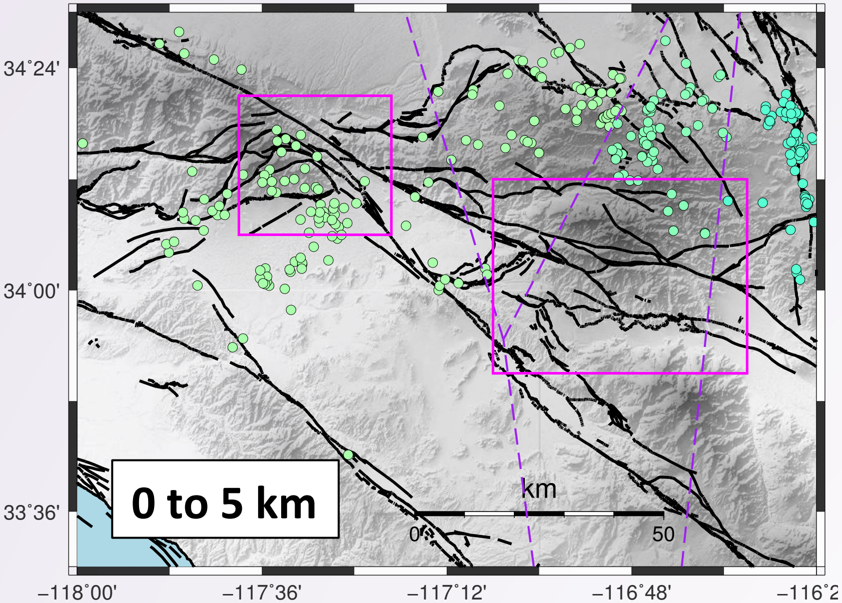
~3,200 focal mechanisms declustered catalog

CH: Crafton Hills
HS: Hot Springs
TR: Trifurcation area
CP: Cajon Pass
SGP: San Gorgonio Pass



- Seismicity catalog by Hauksson et al., (2012)
- Earthquake focal mechanisms catalog by Yang et al., (2012).
- Declustered following Zaliapin and Ben-Zion, (2013).

Stress Ratio (R) in SCTR



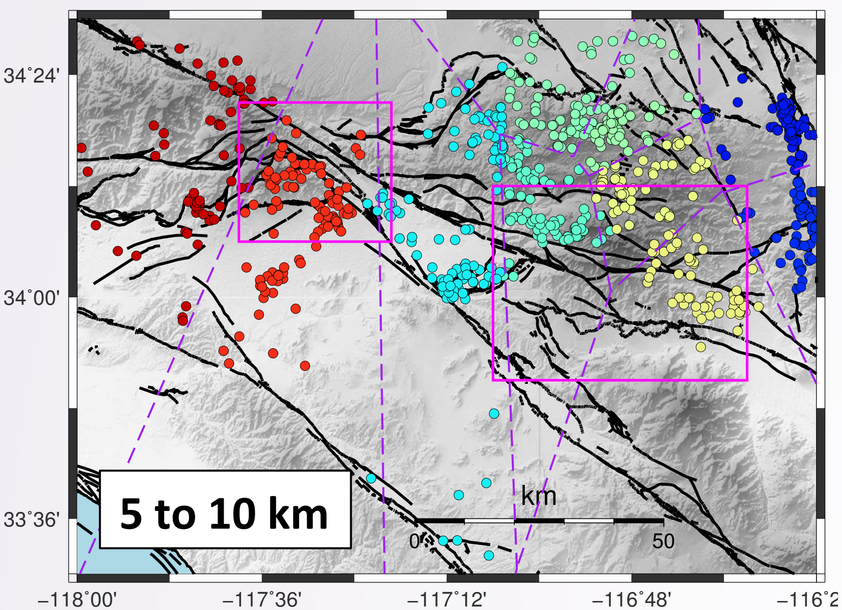
Key point:

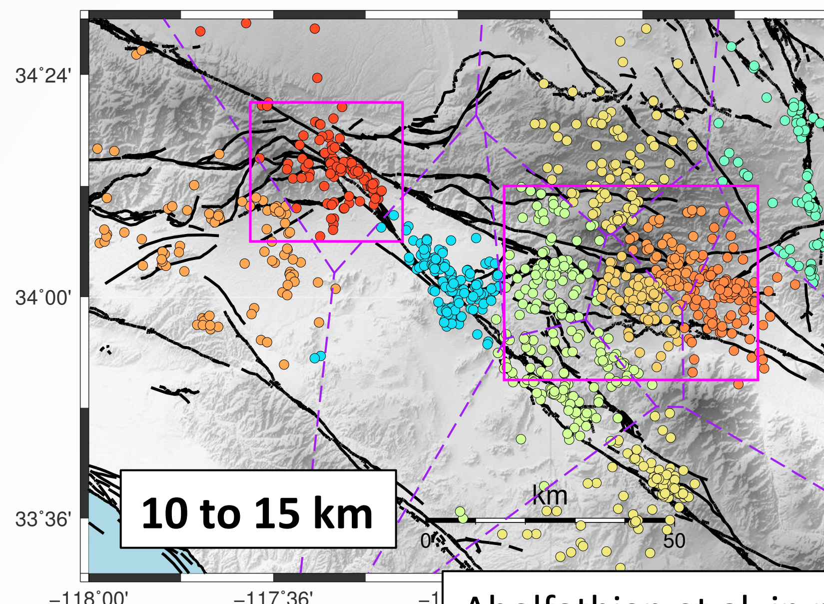
Transpressional stress regime adjacent to the highest topography.

In Strike-slip regime: $$R = \frac{\sigma_1 - \sigma_2}{\sigma_1 - \sigma_3}$$

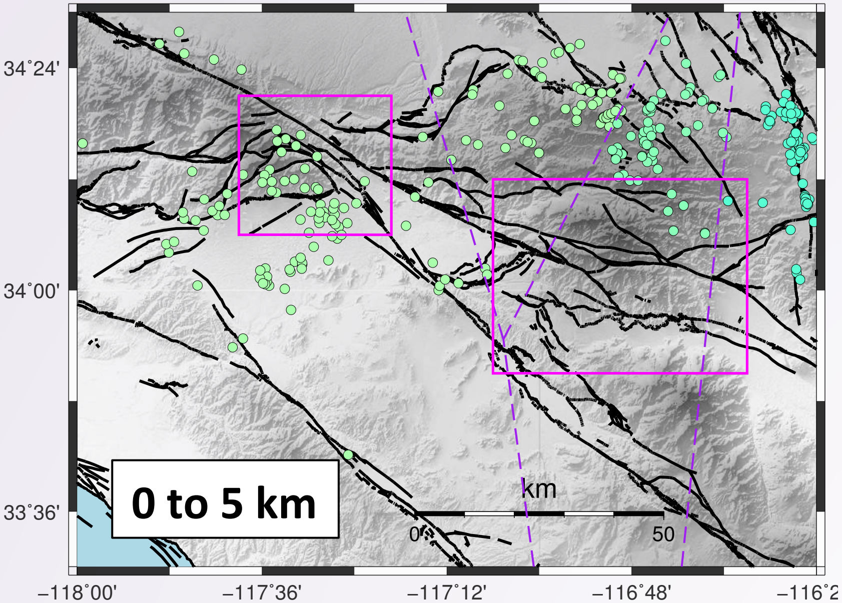
R increases (R → 1), stress regime towards transpressional.

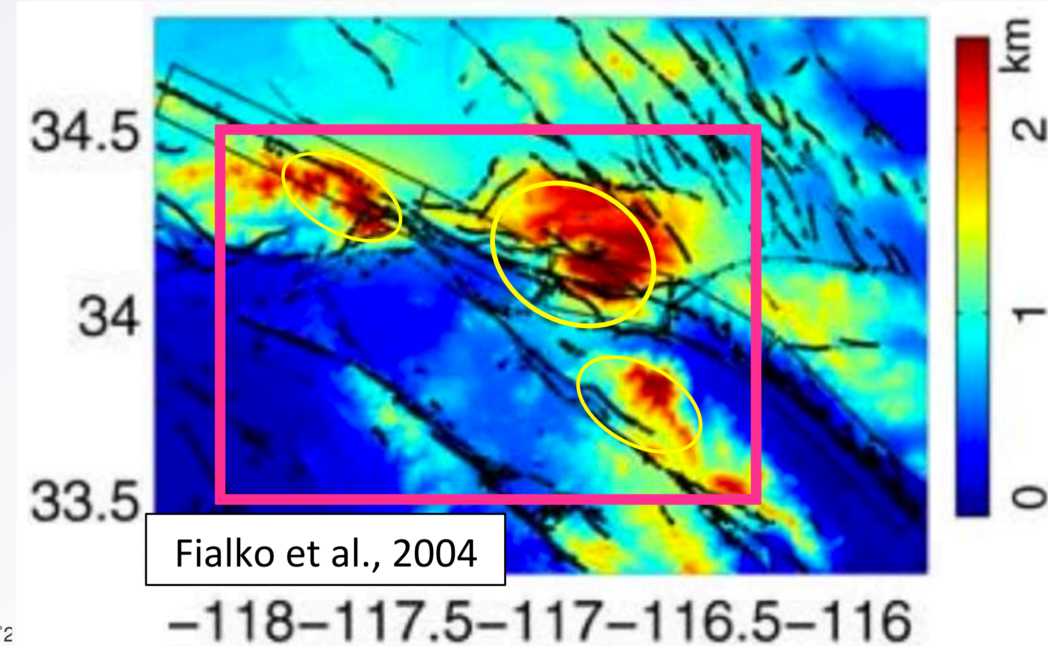
R decreases (R → 0), stress regime towards transtensional.

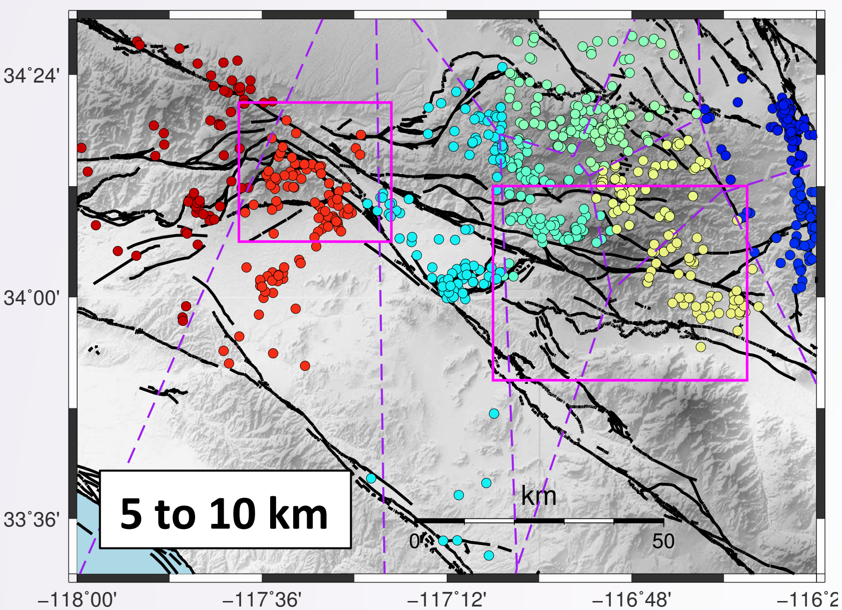


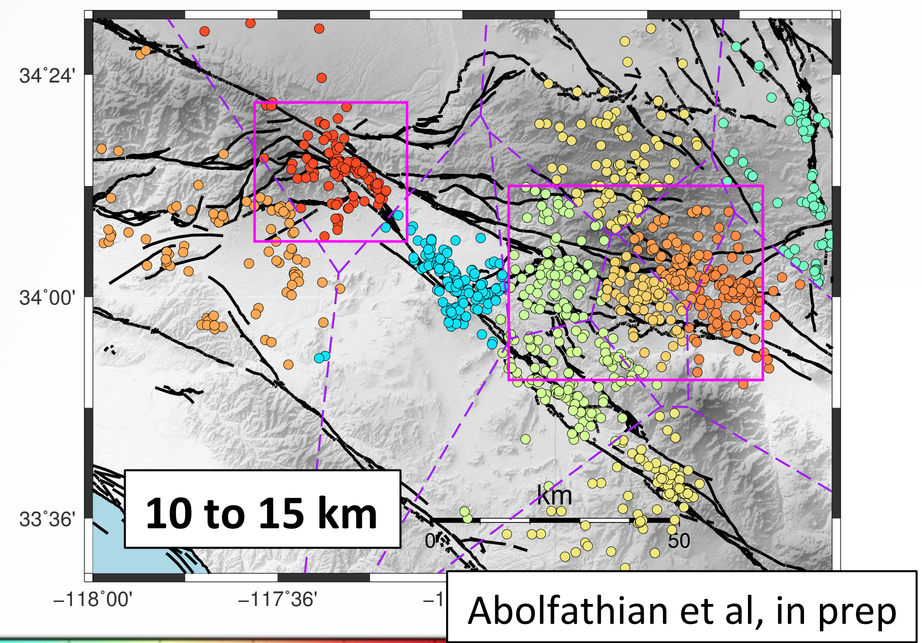


Abolfathian et al, in prep


34°24'
34°00'
33°36'
−118°00'
−117°36'
−117°12'
−116°48'
km
0
50
0 to 5 km

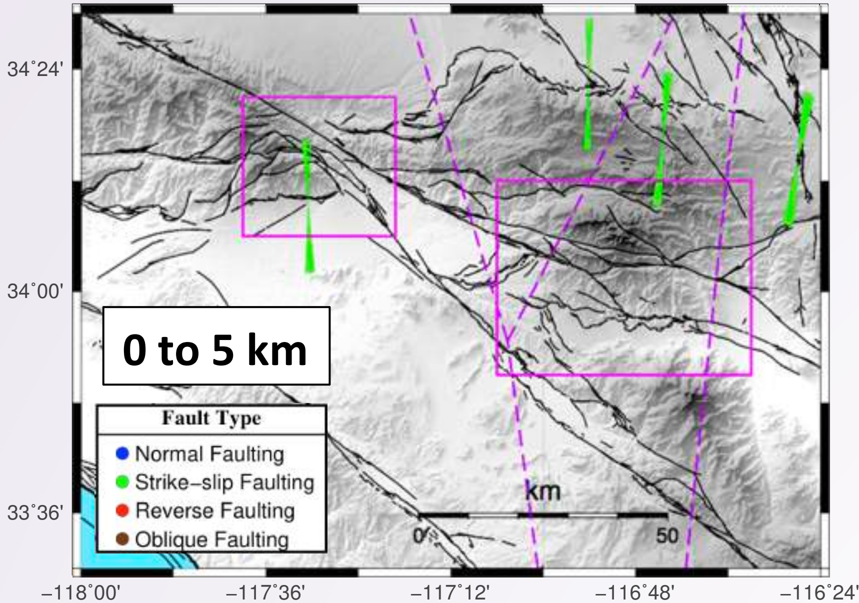

34.5
34
33.5
km
2
1
0
Fialko et al., 2004
−118−117.5−117−116.5−116


34°24'
34°00'
33°36'
−118°00'
−117°36'
−117°12'
−116°48'
km
0
50
5 to 10 km


34°24'
34°00'
33°36'
−118°00'
−117°36'
km
0
50
10 to 15 km
Abolfathian et al, in prep


Stress ratio (R)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0

Maximum Horizontal Compressional Stress (S_{Hmax}) in SCTR

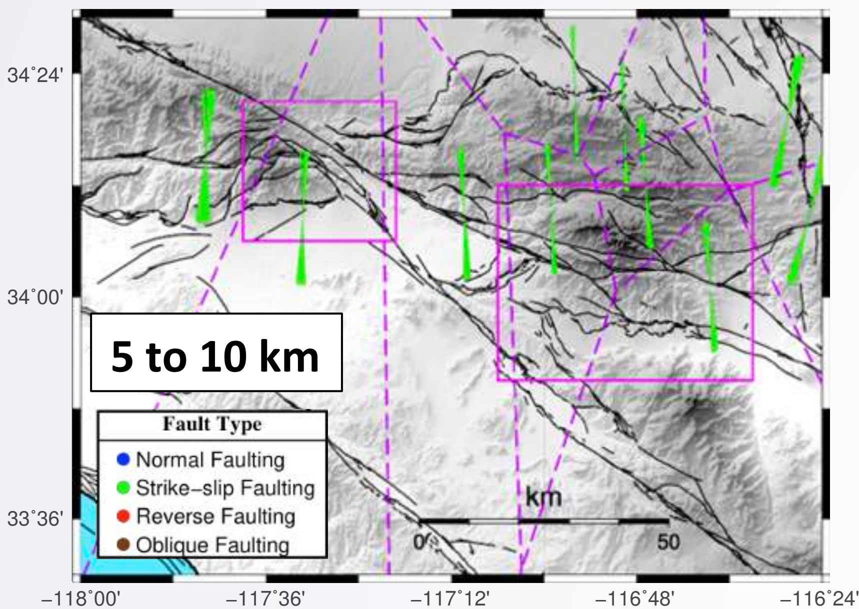


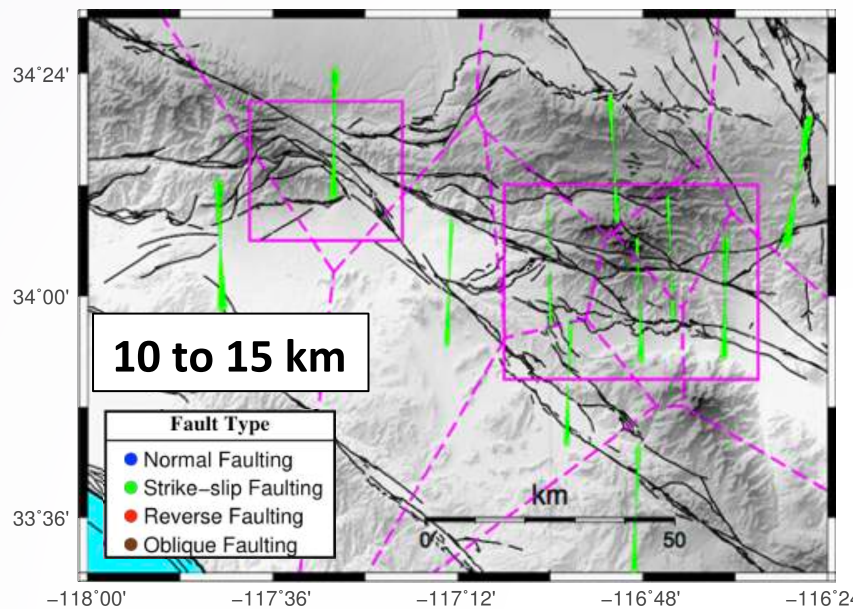
Key point:

No significant rotation in the S_{Hmax} direction.

-S_{Hmax} is estimated following Lund and Townend (2007)

-Faulting types following Zoback (1992).





Crafton Hills (CH):

Key point:

Extensional region adjacent to intersection of San Andreas and San Jacinto faults

Significant rotation of maximum horizontal compressional stress (SHmax) with depth

-S_{Hmax} is estimated following Lund and Townend,(2007)

-Faulting types following Zoback, (1992).

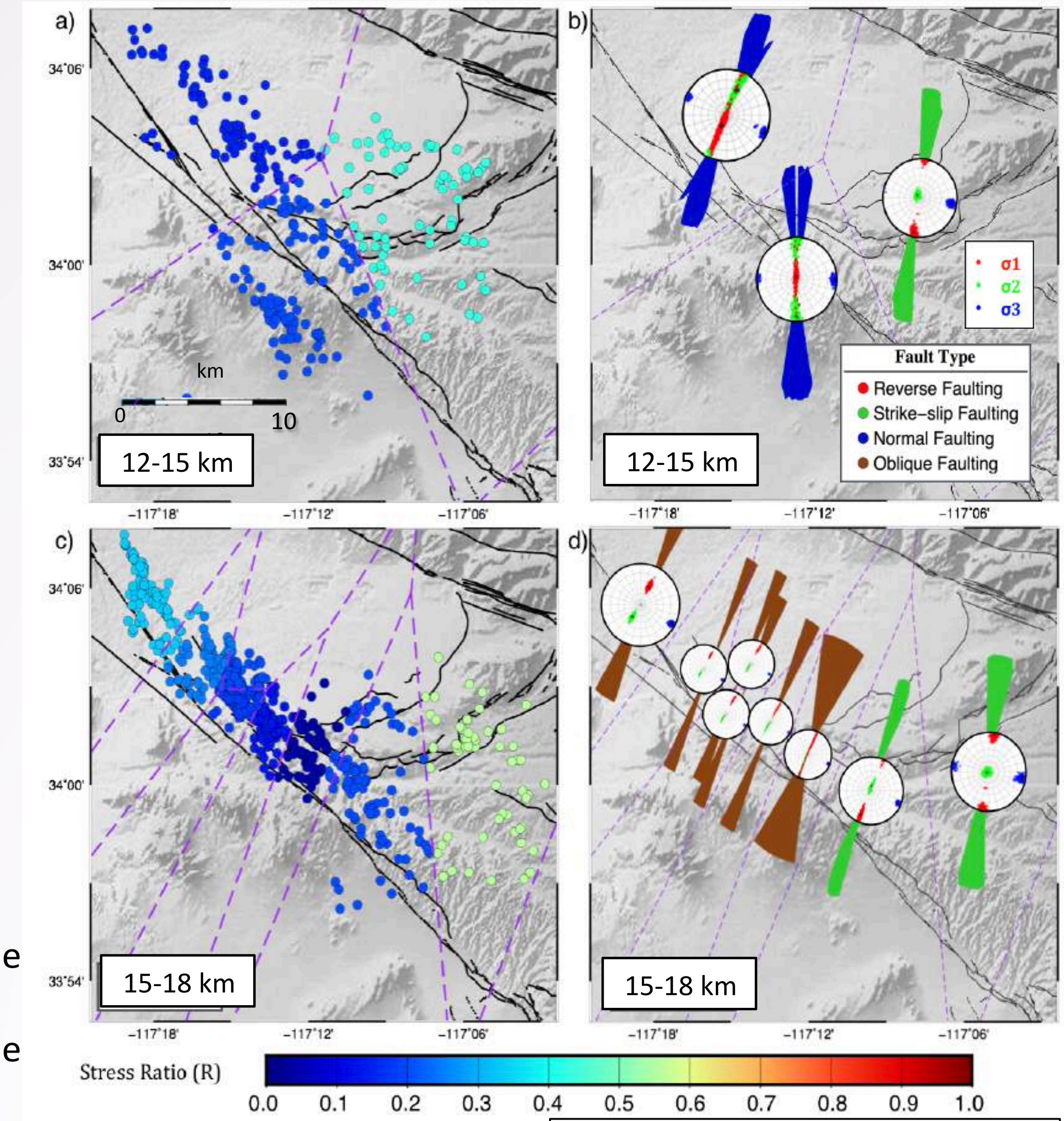
In Strike-slip regime:

R increases (R → 1), stress regime towards transpressional.

R decreases (R → 0), stress regime towards transtensional.

Stress Ratio (R)

Maximum Horizontal Compressional Stress (S_{Hmax})



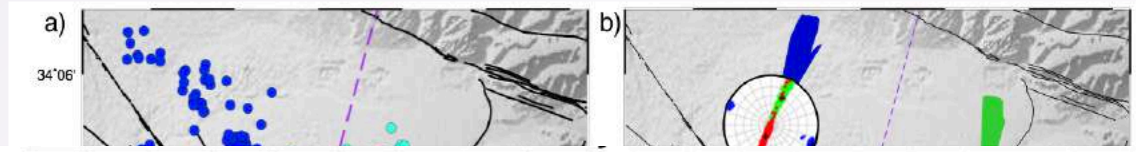
Abolfathian et al, PAAG, 2018

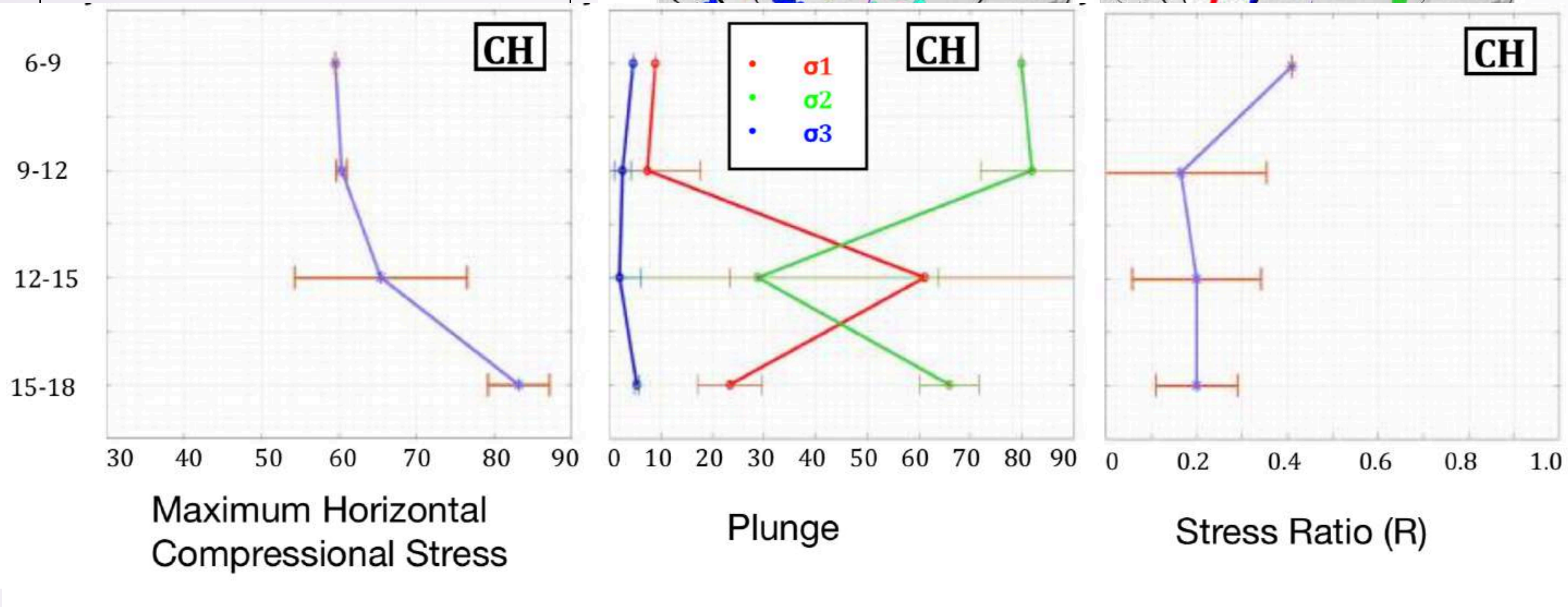
Crafton Hills (CH):

Stress Ratio (R)

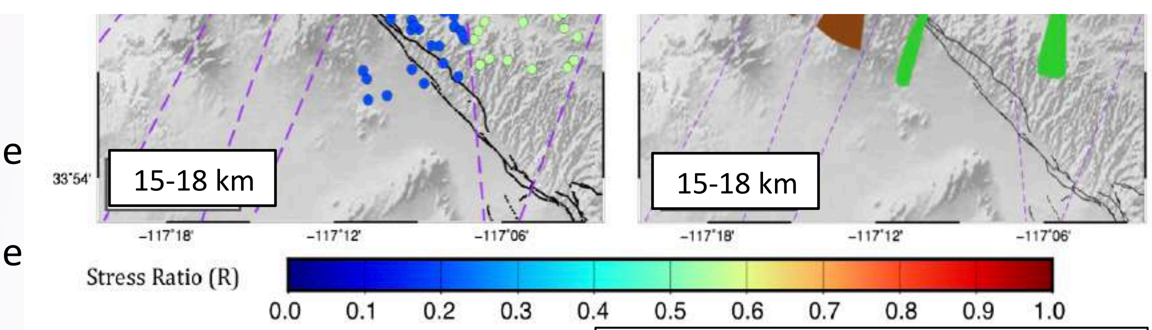
Maximum Horizontal Compressional Stress (S_{Hmax})

Key point:





(1992).



In Strike-slip regime:

R increases (R → 1), stress regime towards transpressional.

R decreases (R → 0), stress regime towards transtensional.

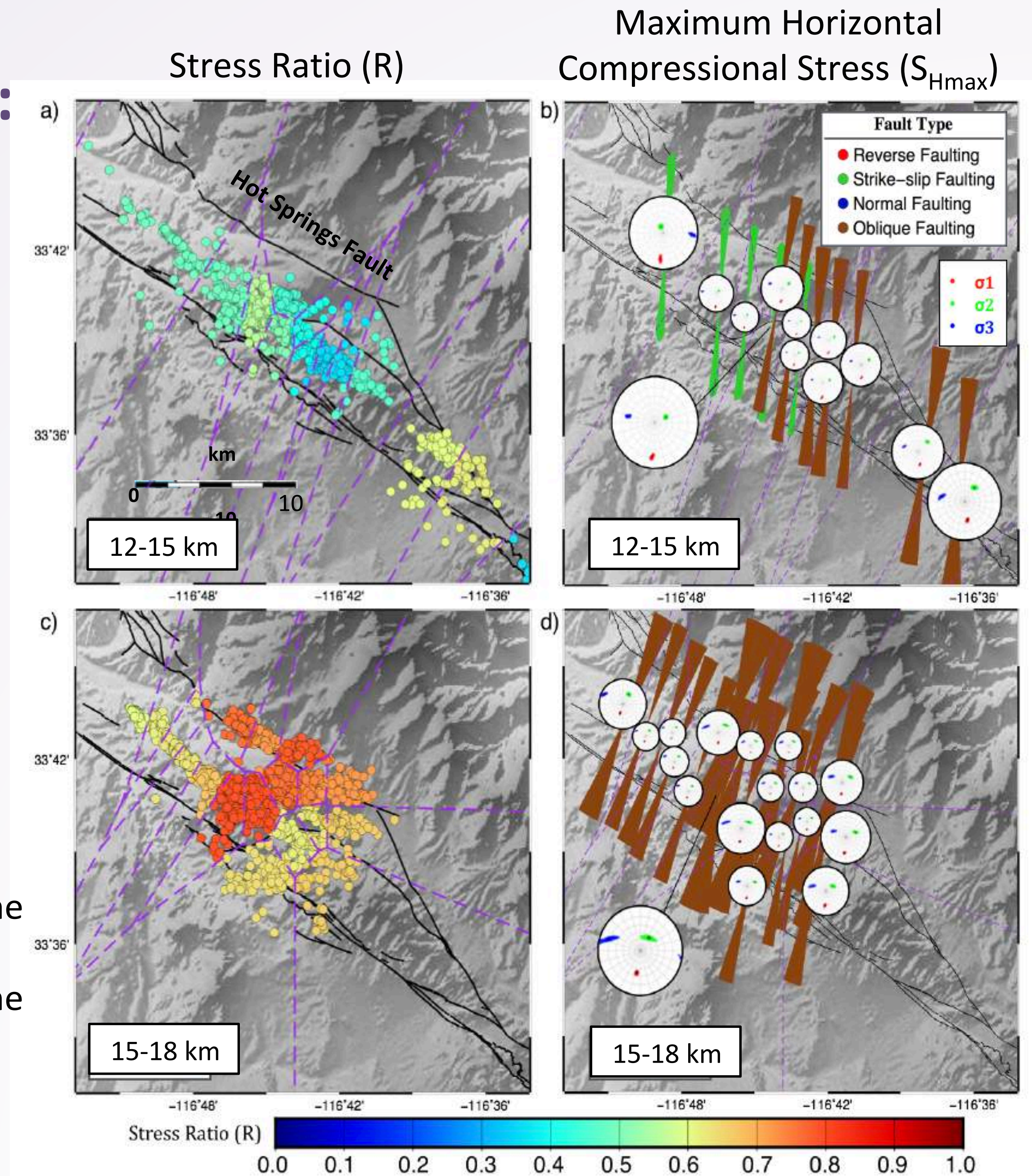
Abolfathian et al, PAAG, 2018

Hot Springs area (HS):

Key point:

Strike-slip at shallow depth, larger focal mechanism variety with depth.

Increased stress ratio in deeper area



In Strike-slip regime:

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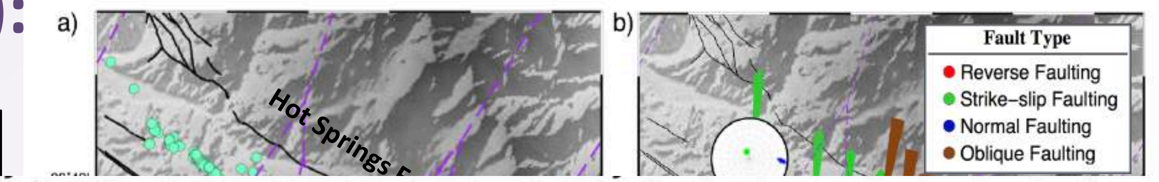
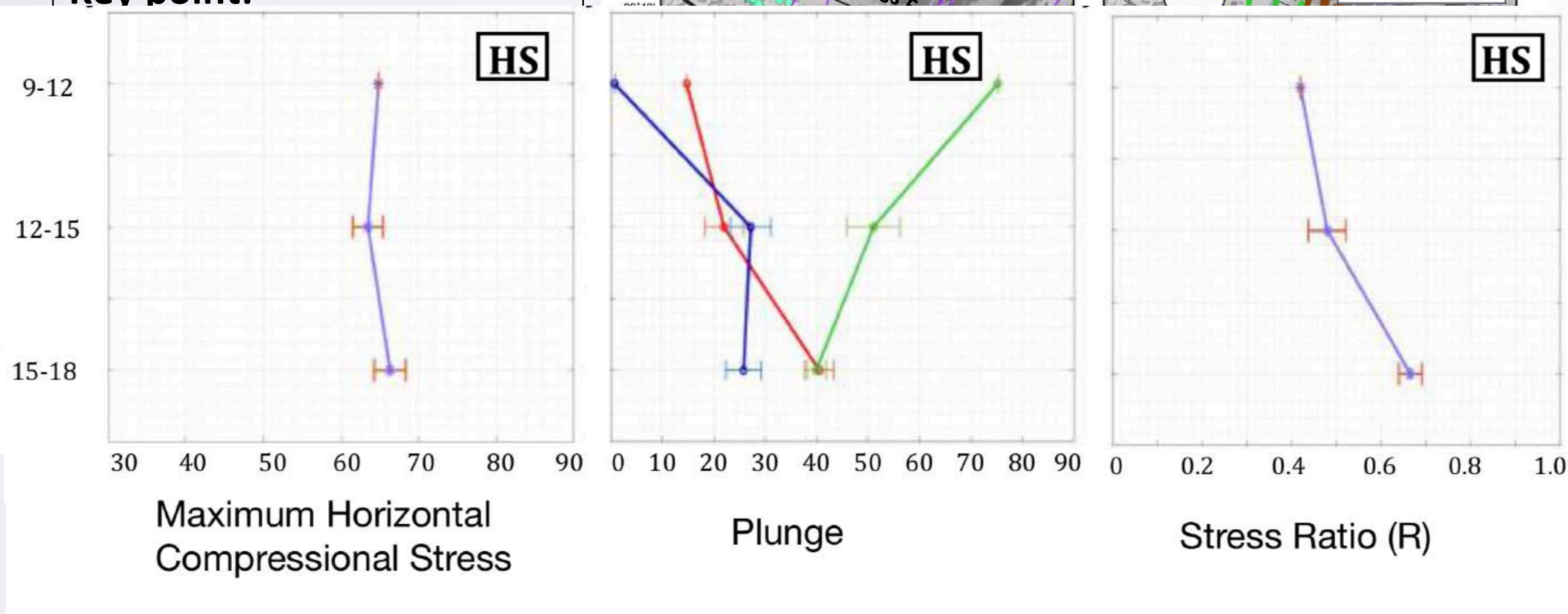
Hot Springs area (HS):

Stress Ratio (R)

Maximum Horizontal Compressional Stress (S_{Hmax})

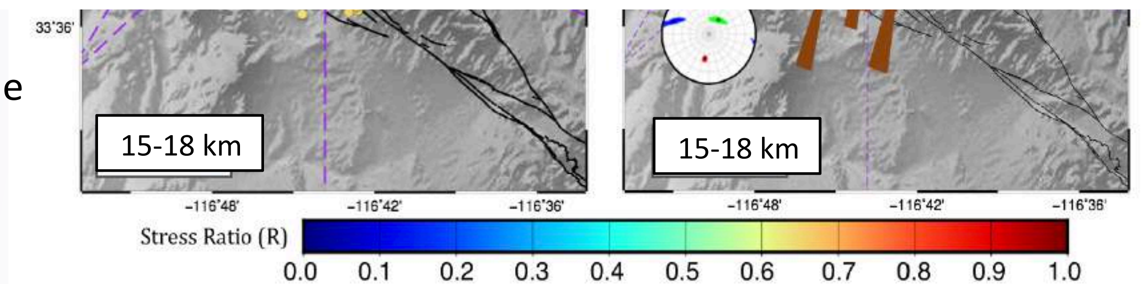


Key point:



towards transpressional.

R decreases (R → 0), stress regime towards transtensional.



Trifurcation area (TR):

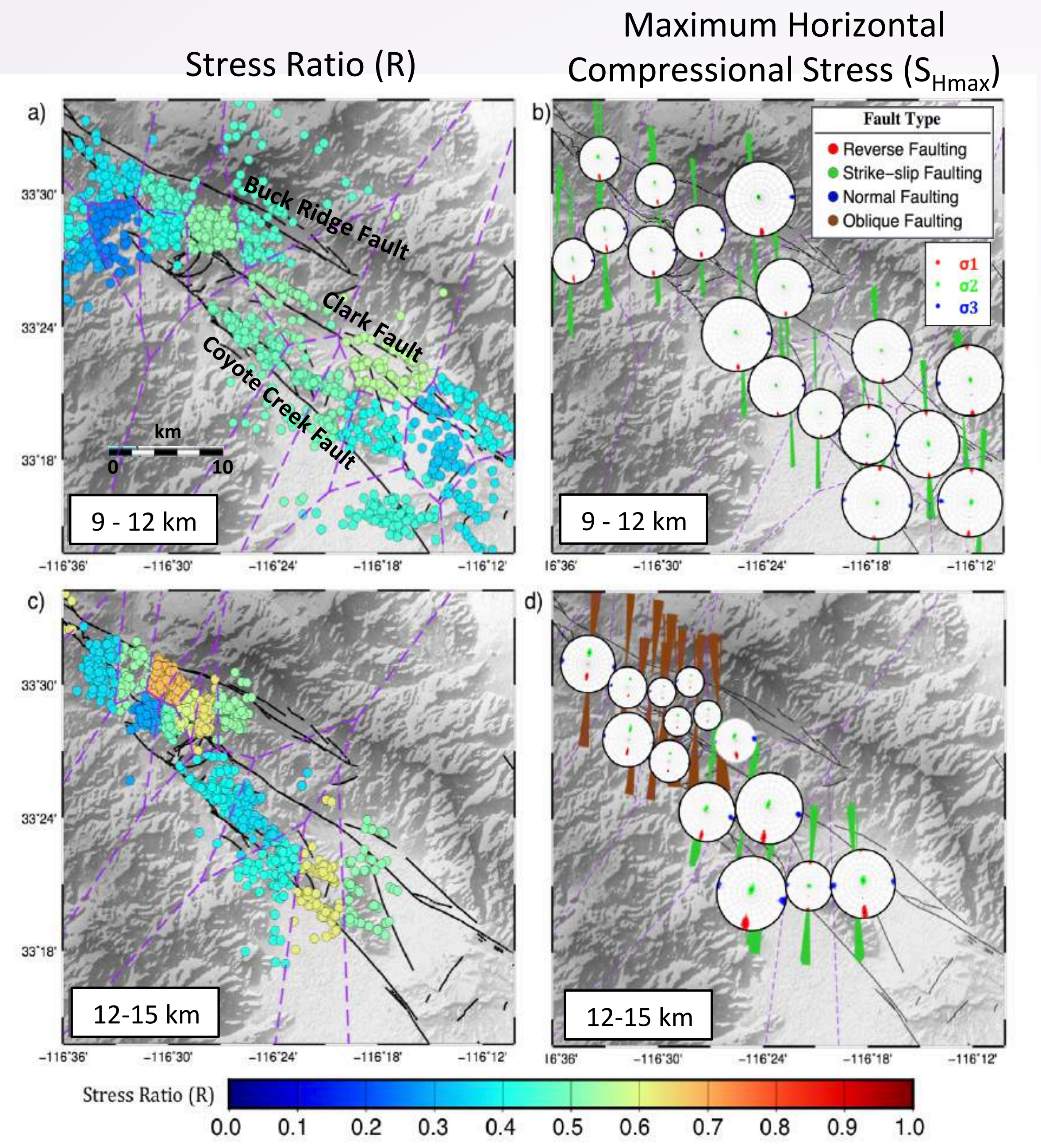
Key point:

- Strike-slip stress regime

- Rotation of the principal stress axes and S_{Hmax}

In Strike-slip regime:

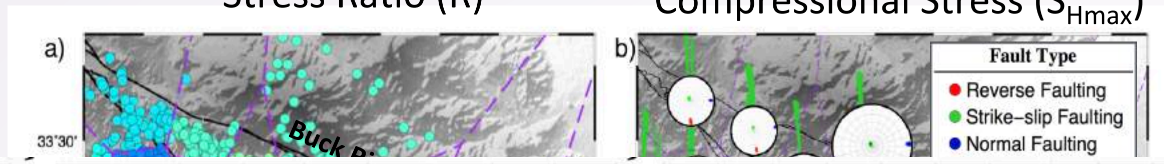
R increases (R → 1), stress regime towards transpressional.
R decreases (R → 0), stress regime towards transtensional.

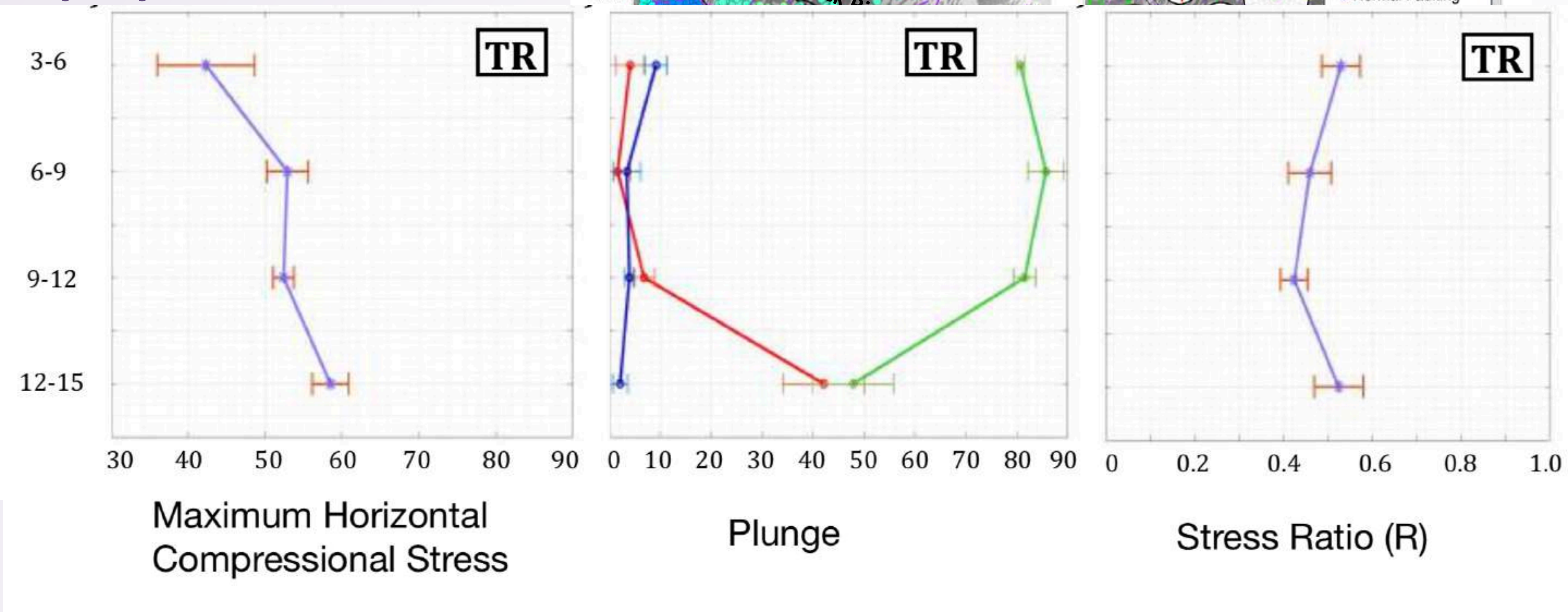


Trifurcation area (TR):

Stress Ratio (R)

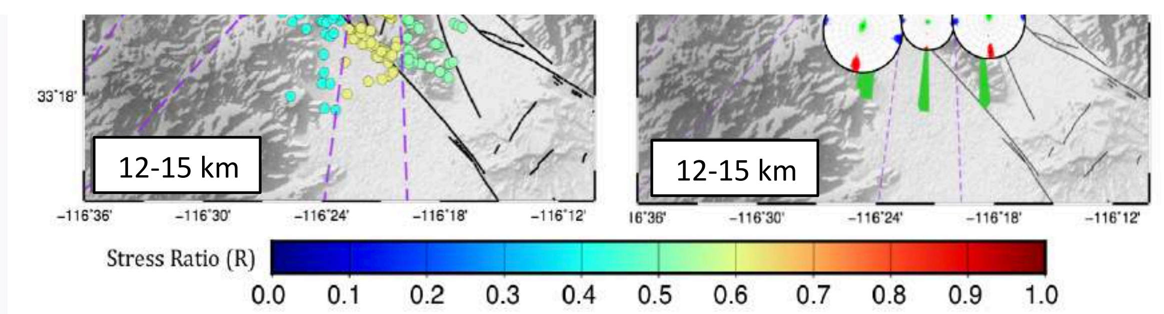
Maximum Horizontal Compressional Stress (S_{Hmax})





R increases (R → 1), stress regime towards transpressional.

R decreases (R → 0), stress regime towards transtensional.



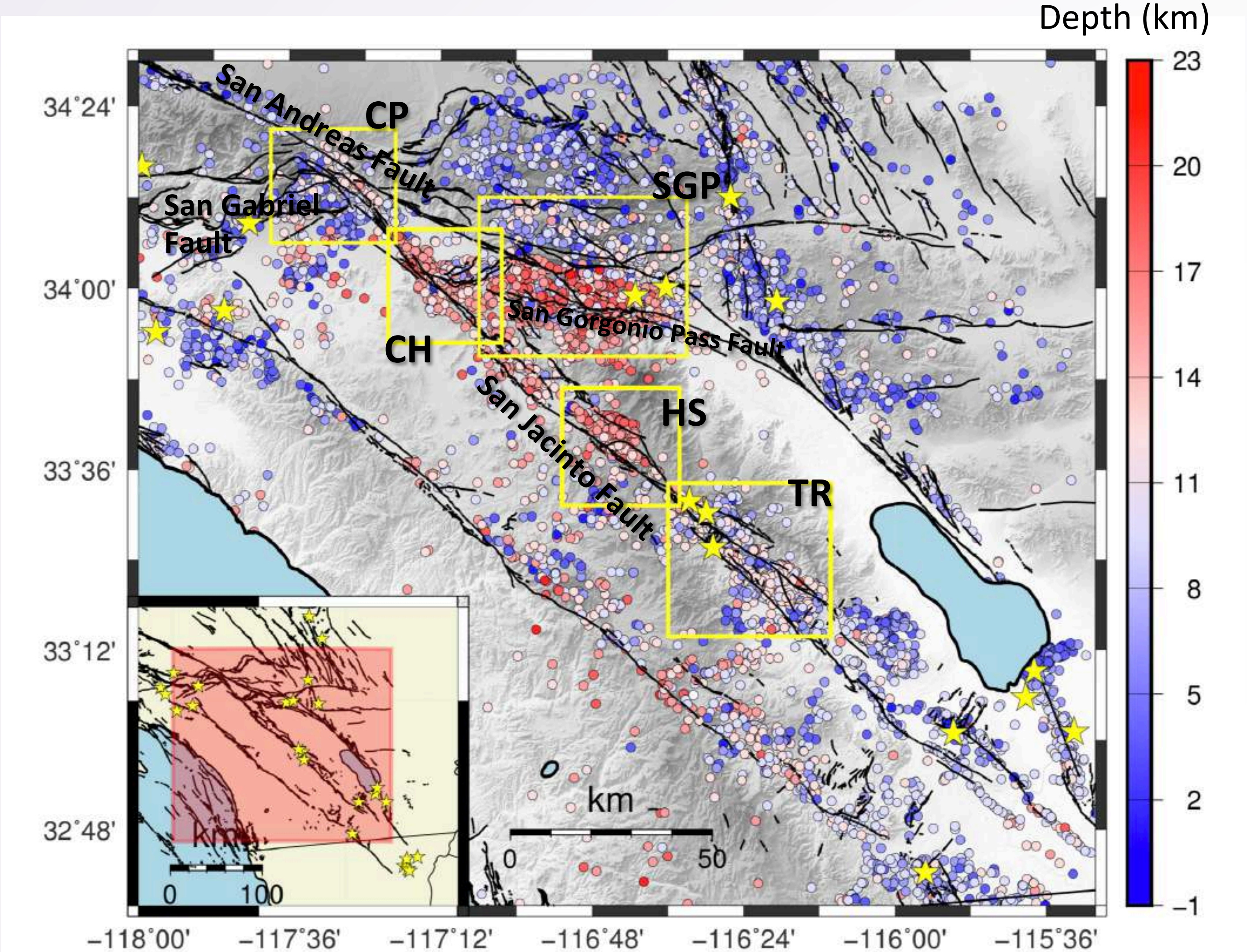
Summary:

- Significant variations of stress parameters with depth:
  - Transpressional stress components in regions with high topography, similar observed in CP, SGP and HS.
  - Transtensional components near Crafton Hills (CH)
  - Rotation of maximum horizontal compressional stress (S_{Hmax}) in CH
  - Rotation of the principal stress plunges is observed deeper than ~9 km at CH, HS and TR areas

- Abrupt variation in stress ratio near Cajon Pass!

Stress Distribution in SCTR:

Data separated in three different regions: between the SJF and SAF strands, western and eastern sections



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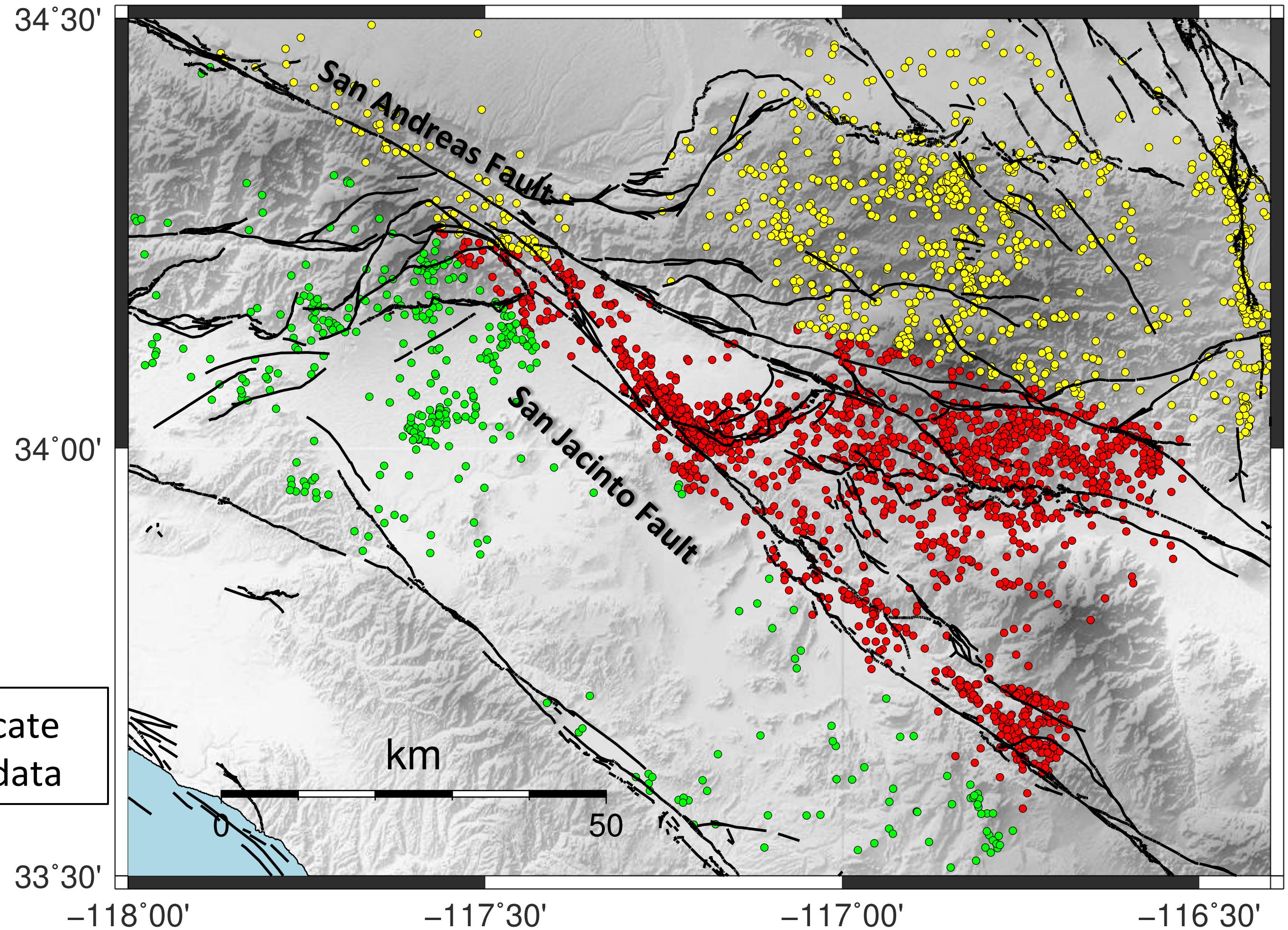
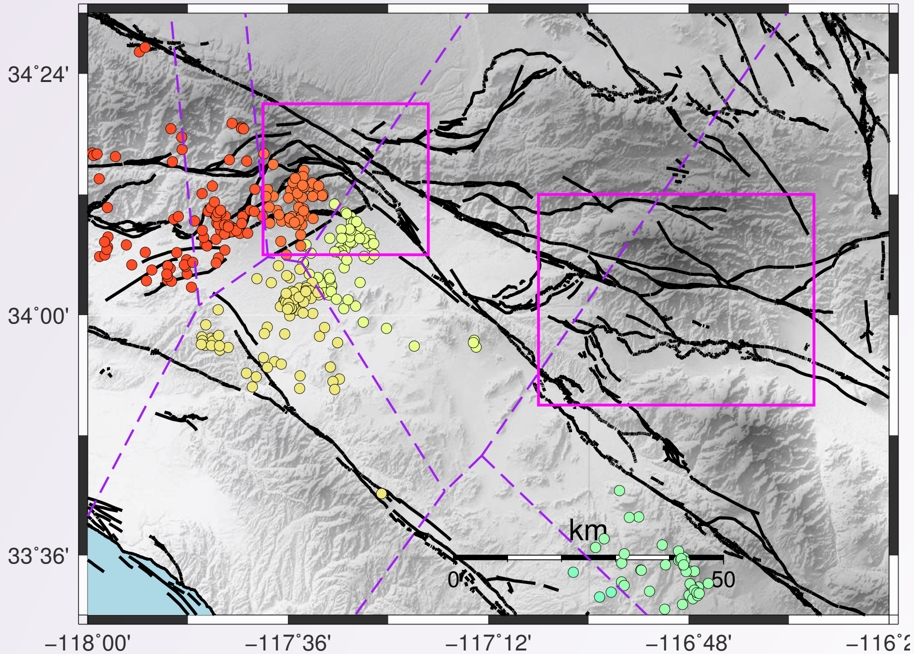
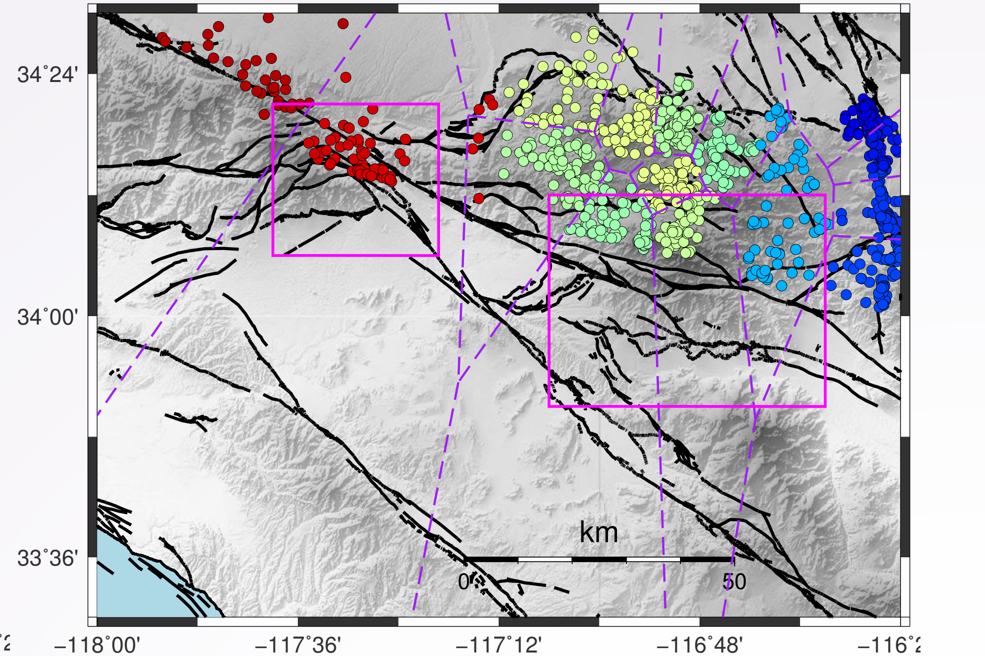


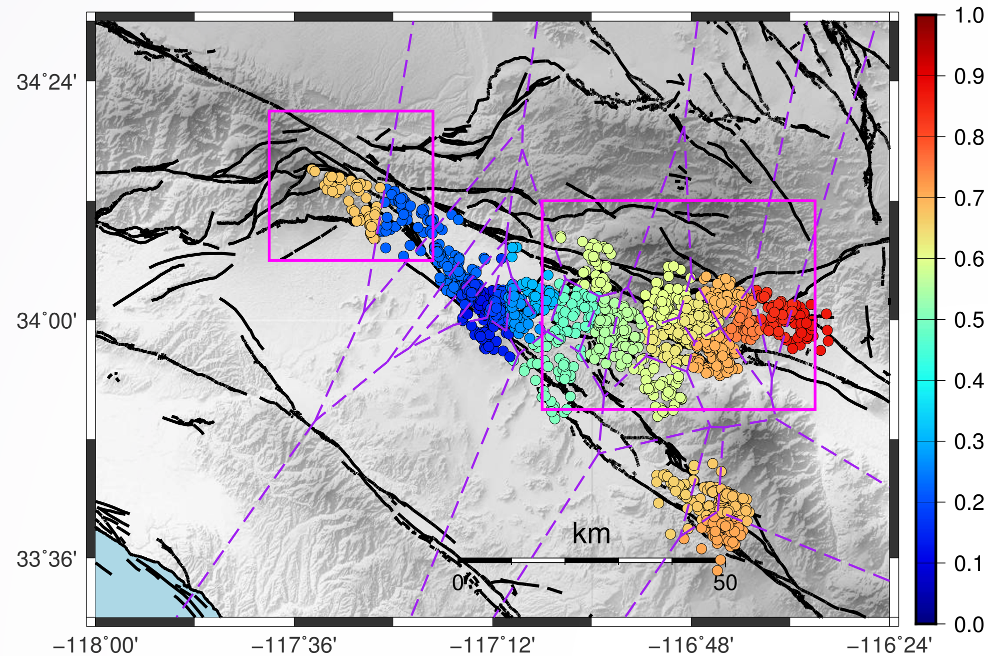
Colors indicate subsets of data





Stress ratio distribution in the SCTR:
Variations in the trend of stress patterns between the two main fault strands (SJFZ and SAF)

R increases (R → 1), stress regime towards transpressional.
R decreases (R → 0), stress regime towards transtensional.

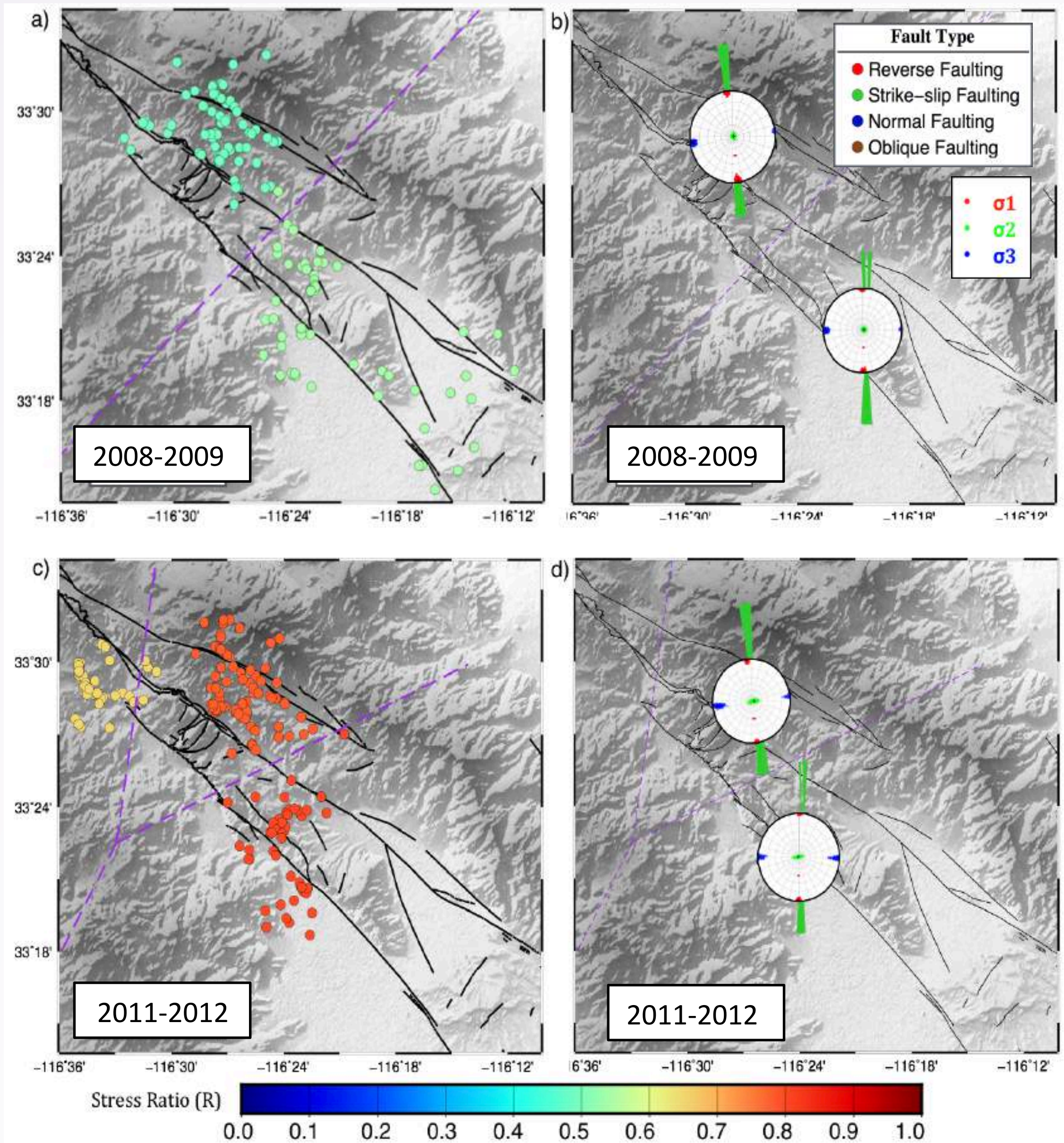


Temporal changes of the stress before and after El Mayor event:

Trifurcation area (Depth 6-9 km):

Year	Number of focal mechanisms
2008-2009	2901
Oct2010-2012	2429

- Consistency in S_{Hmax}
- Increase in stress ratios in Trifurcation area at 6-9 km (R-value: 0.52 → 0.79)



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  - Rotation of the principal stress plunges is observed deeper than ~9 km at CH, HS and TR areas

- Abrupt variation in stress ratio near Cajon Pass!

- Variation in stress ratios trend between main two fault strands of San Jacinto and San Andreas where hypocentral depth of seismicity also gets deeper

Discussion:

Ingredients affecting the spatial distribution of the stress in the crust:

Structure:

- Number and geometry (dip, junctions, etc) of the major faults
- Rheology (Moho depth/ brittle-ductile transition zone, topography)

Loading:

- Tectonic Loading (Partitioning of plate motion among main faults)
- Gravity (Depth dependent; effects of topography)

Focus on temporal changes of stress parameters!

Selected References:

- **Abolfathian, N.**, Martínez-Garzón, P., & Ben-Zion, Y. (*in preparation.*). Variations of stress parameters in Southern California Shear Zone from inversion of focal mechanisms.
- **Abolfathian, N.**, Martínez-Garzón, P., & Ben-Zion, Y. (2018). Spatiotemporal Variations of Stress and Strain Parameters in the San Jacinto Fault Zone. *Pure and Applied Geophysics*, 1-24, doi:10.1007/s00024-018-2055-y.
- Martínez-Garzón, P., Ben-Zion, Y., **Abolfathian**, N., Kwiatek G., & Bohnhoff M. (2016). A refined methodology for stress inversions of earthquake focal mechanisms, J. Geophys. Res., 121, 8666-8687, doi:10.1002/2016JB013493.