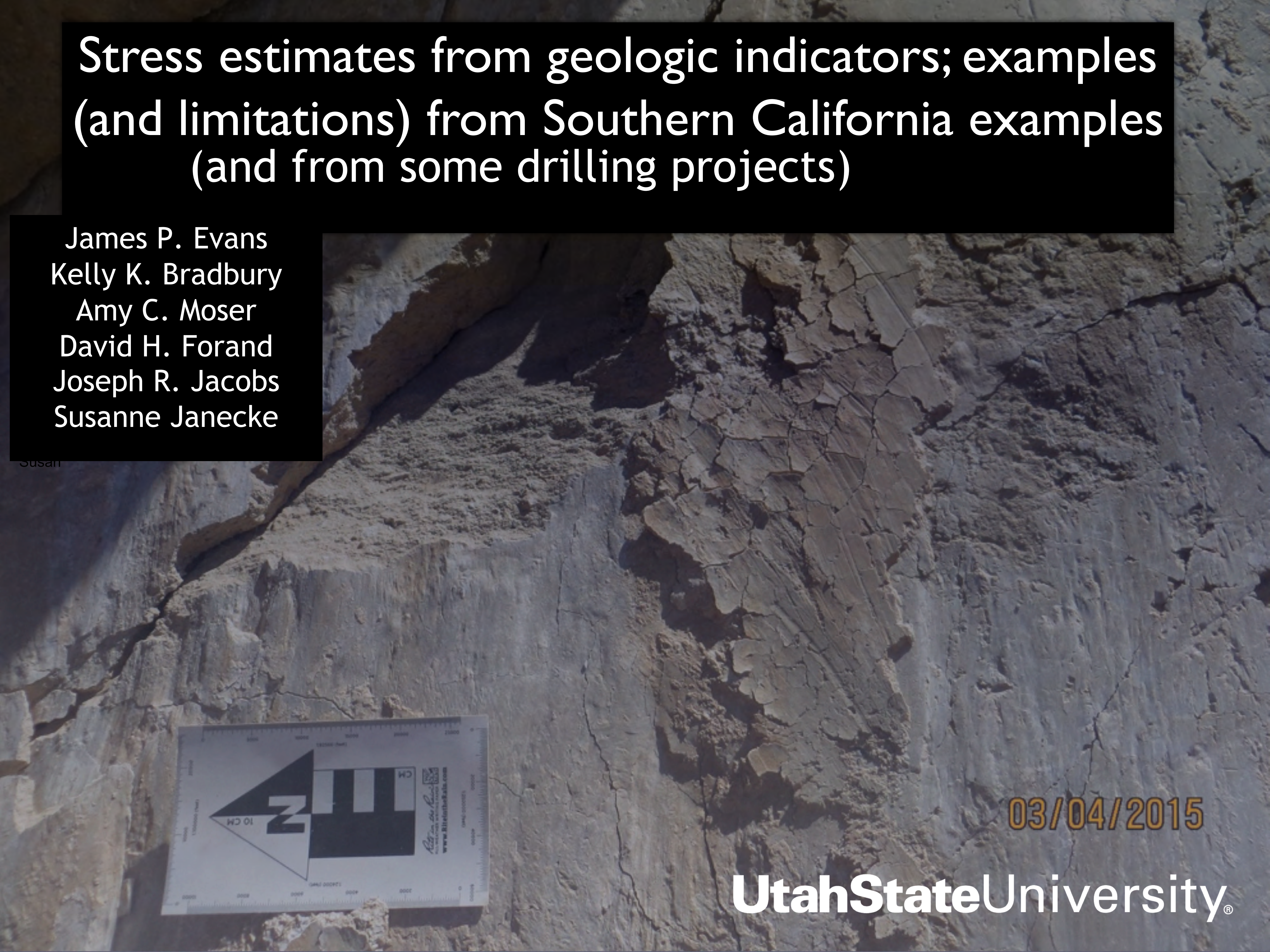
Stress estimates from geologic indicators; examples (and limitations) from Southern California examples (and from some drilling projects)

James P. Evans
Kelly K. Bradbury
Amy C. Moser
David H. Forand
Joseph R. Jacobs
Susanne Janecke
Susan



UtahStateUniversity

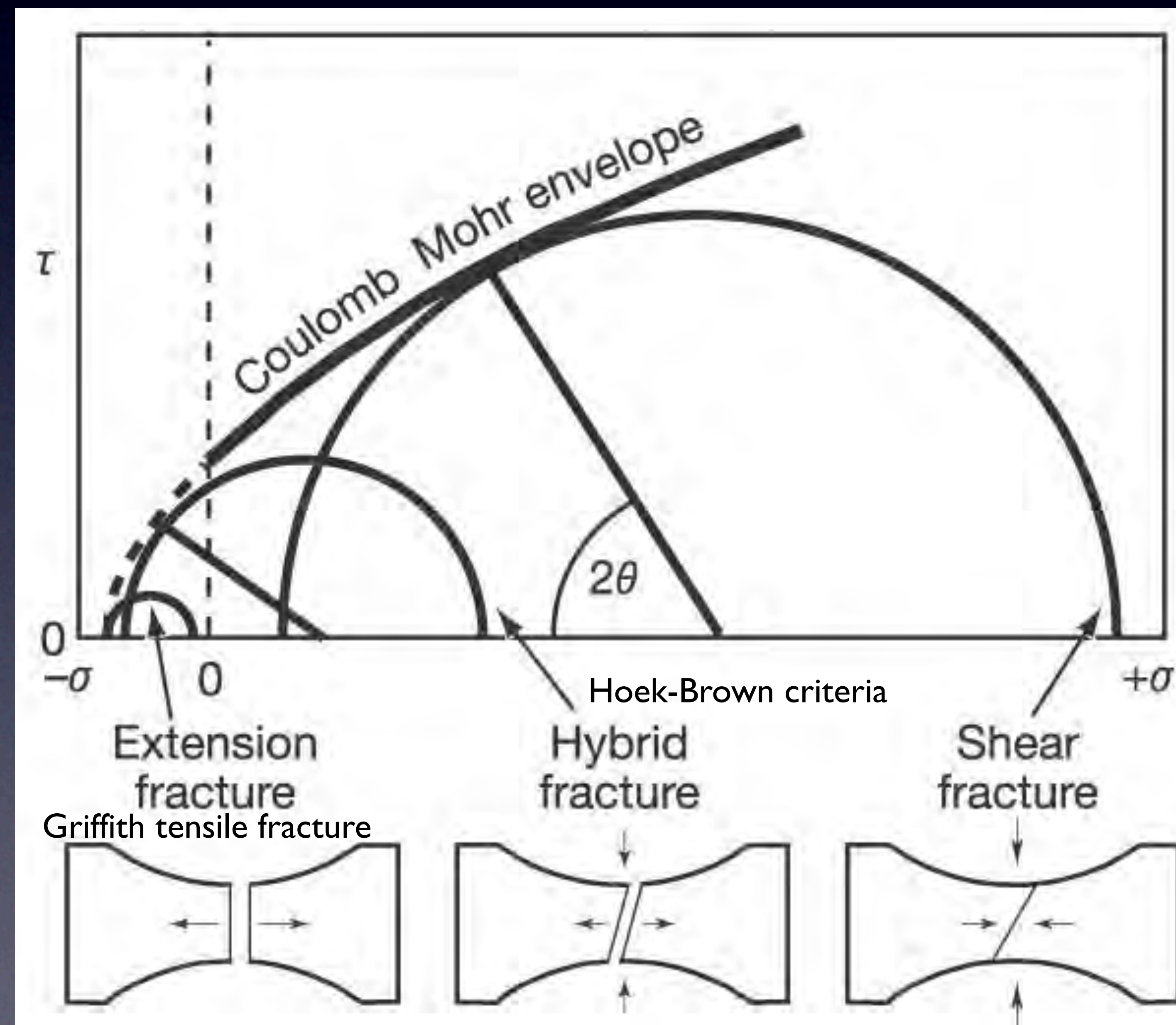
Geologic indicators of stress orientation and magnitude

Indicator	Result
Fault surfaces with slip direction and offset indicators	Kinematic indicator; Stress orientations; stress magnitudes*
Dikes, Veins, Joints	Principal stress orientations, magnitudes*
Conjugate faults	Approximate stress orienatiations
Microfractures	Stress orientations and magnitudes
Calcite twin orientations	Stress orientations and magnitudes; strains
Crystal plastic indicators: dislocation densities, subgrain sizes, recrystallized grain sizes	Stress magnitudes: Typically used for ductile / lower crustal conditions

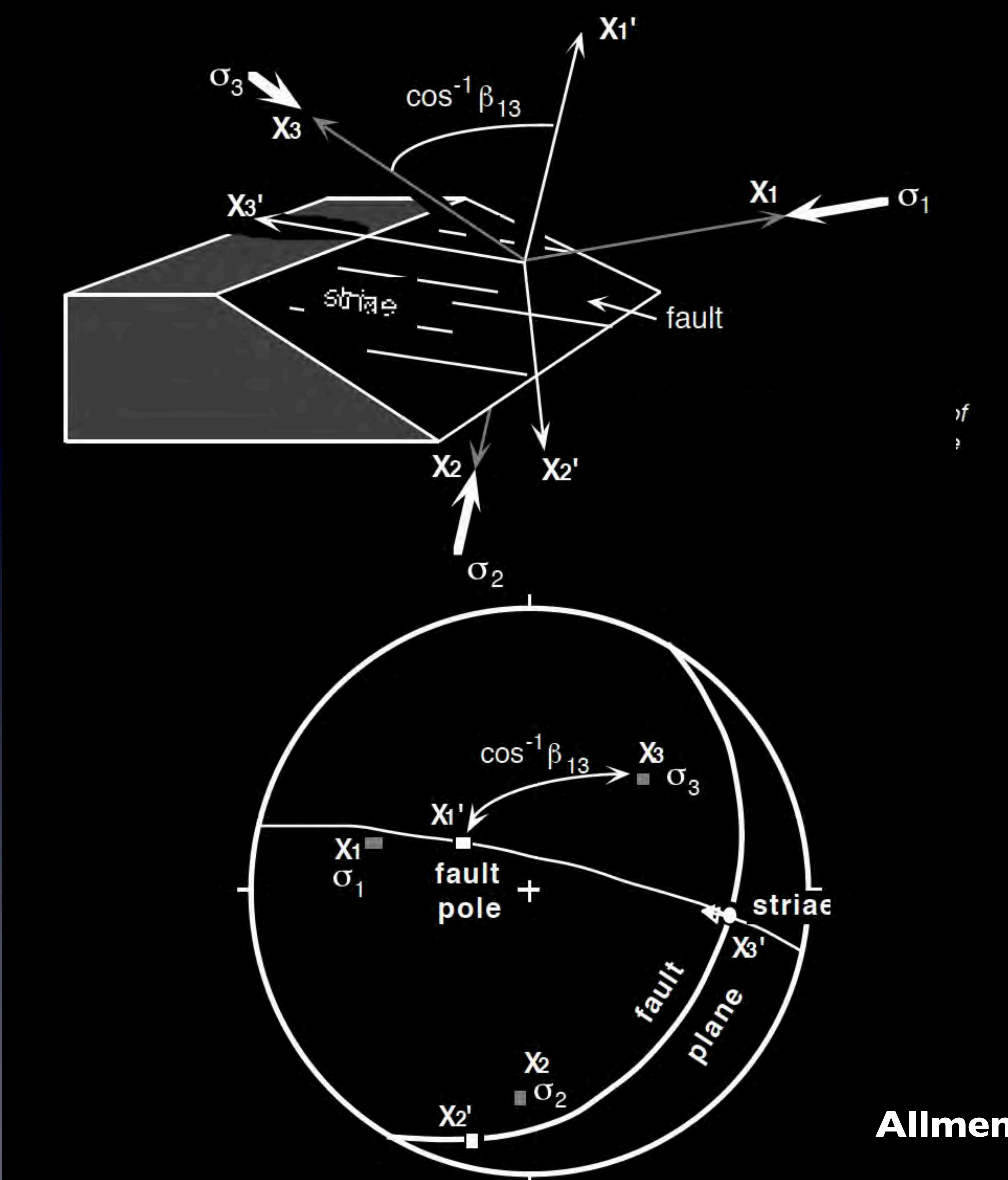
* Magnitudes can be determined with some assumptions

Assumptions / conditions

1. Basic Mohr-Coulomb-Griffith behavior: Slip on a fault plane occurs in the direction of resolved shear stress (assume that heterogeneities that might inhibit free slip of each fault plane – including interactions with other fault planes -- are relatively insignificant).
2. Uniform stress field (spatially and temporally) —no post-slip deformation/ overprinting - or use the overprinting to work out stress history
3. Geologic context, spatial setting, and timing are important to resolve in order to interpret the stress indicators



Ramsey and Chester, 2004

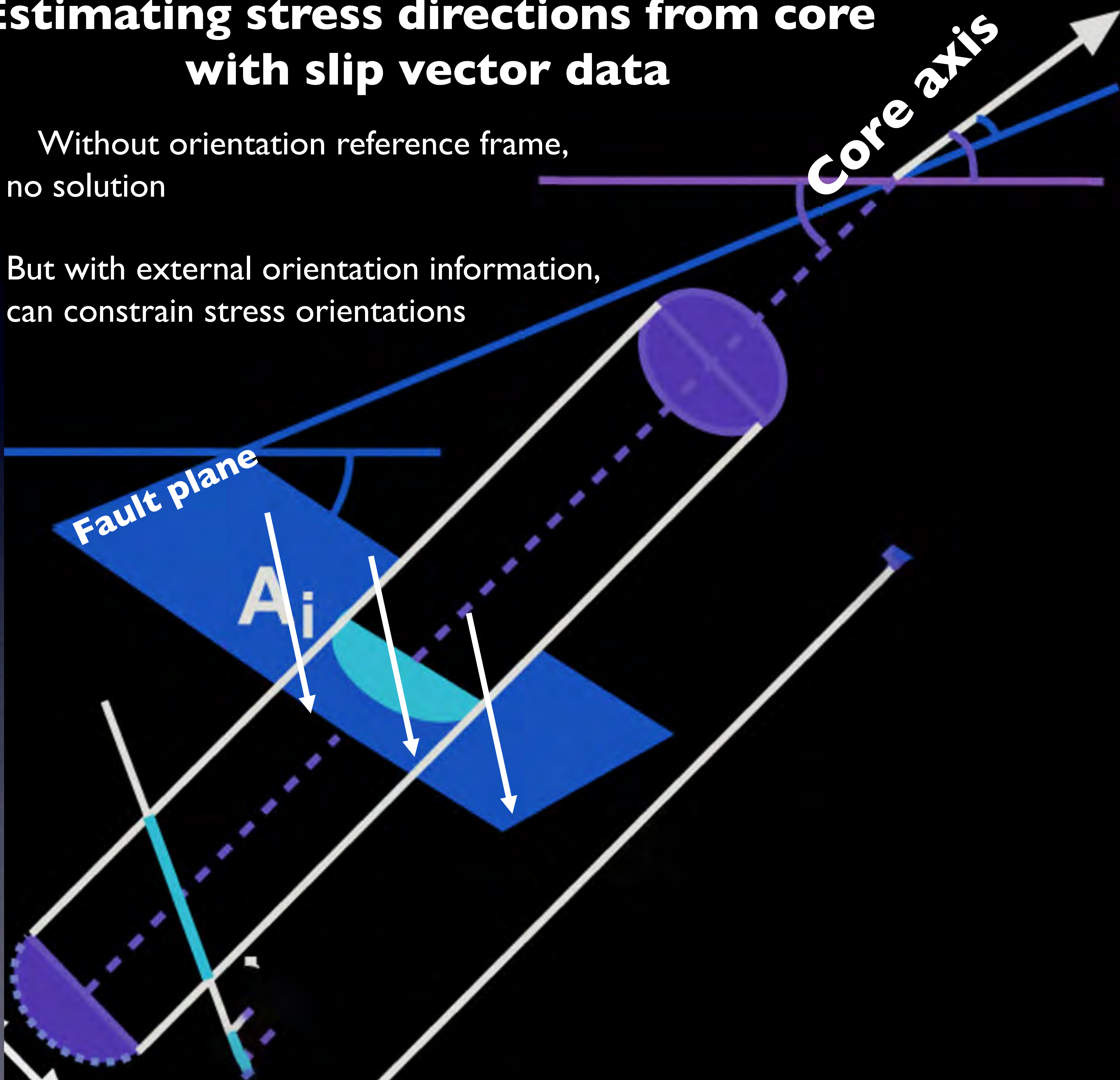


Allmendinger and Marrett, 1989

Estimating stress directions from core with slip vector data

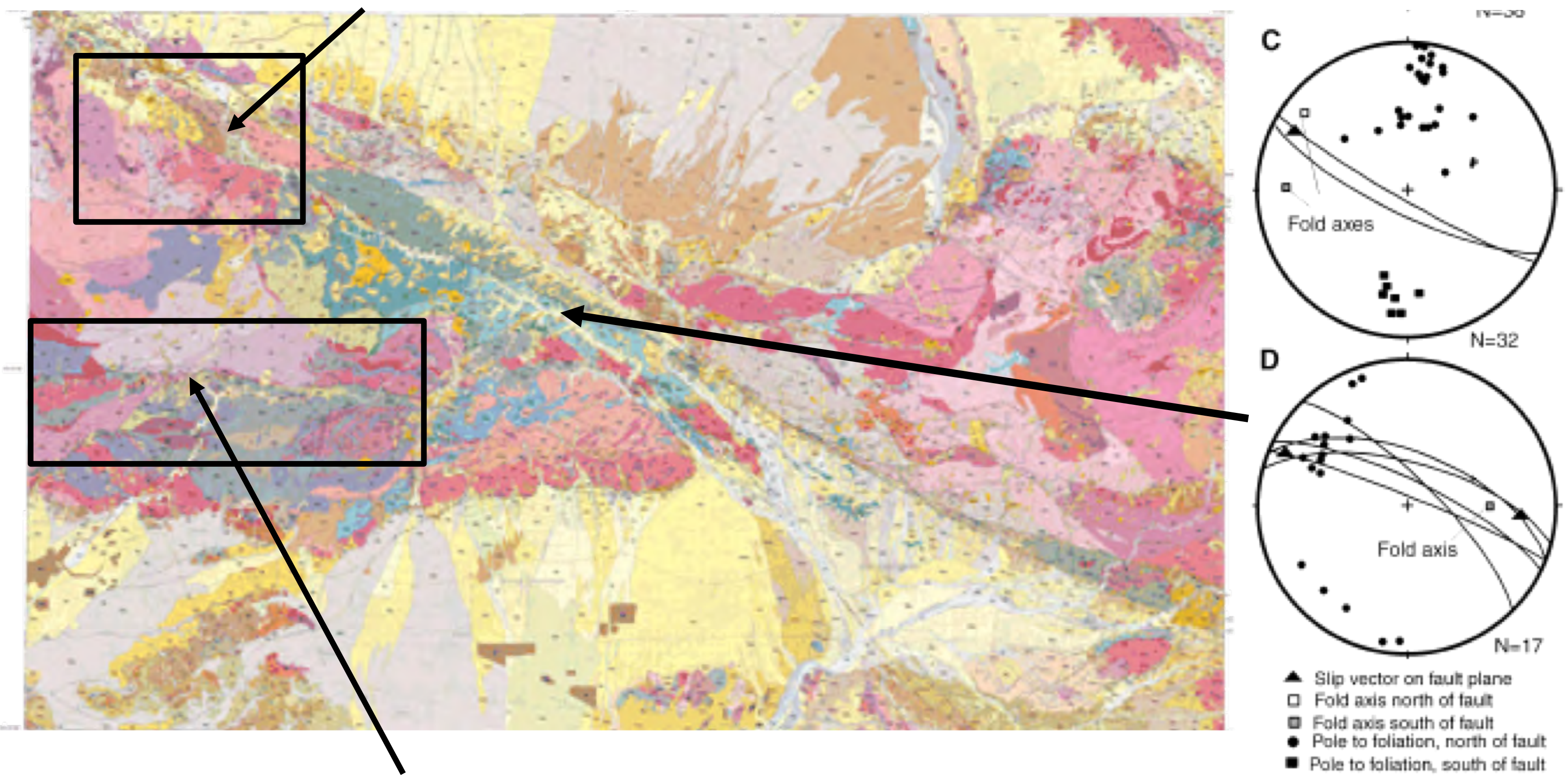
Without orientation reference frame, no solution

But with external orientation information, can constrain stress orientations



Off fault structure and stresses

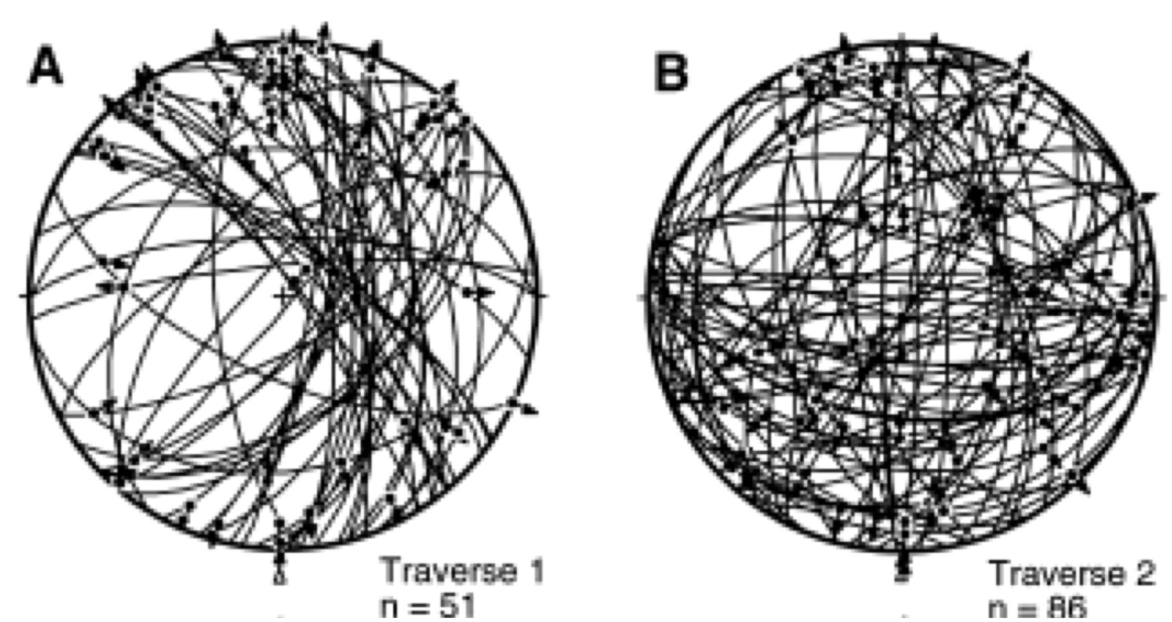
Punchbowl fault, Chester and Logan, 1986; Chester et al., 2000



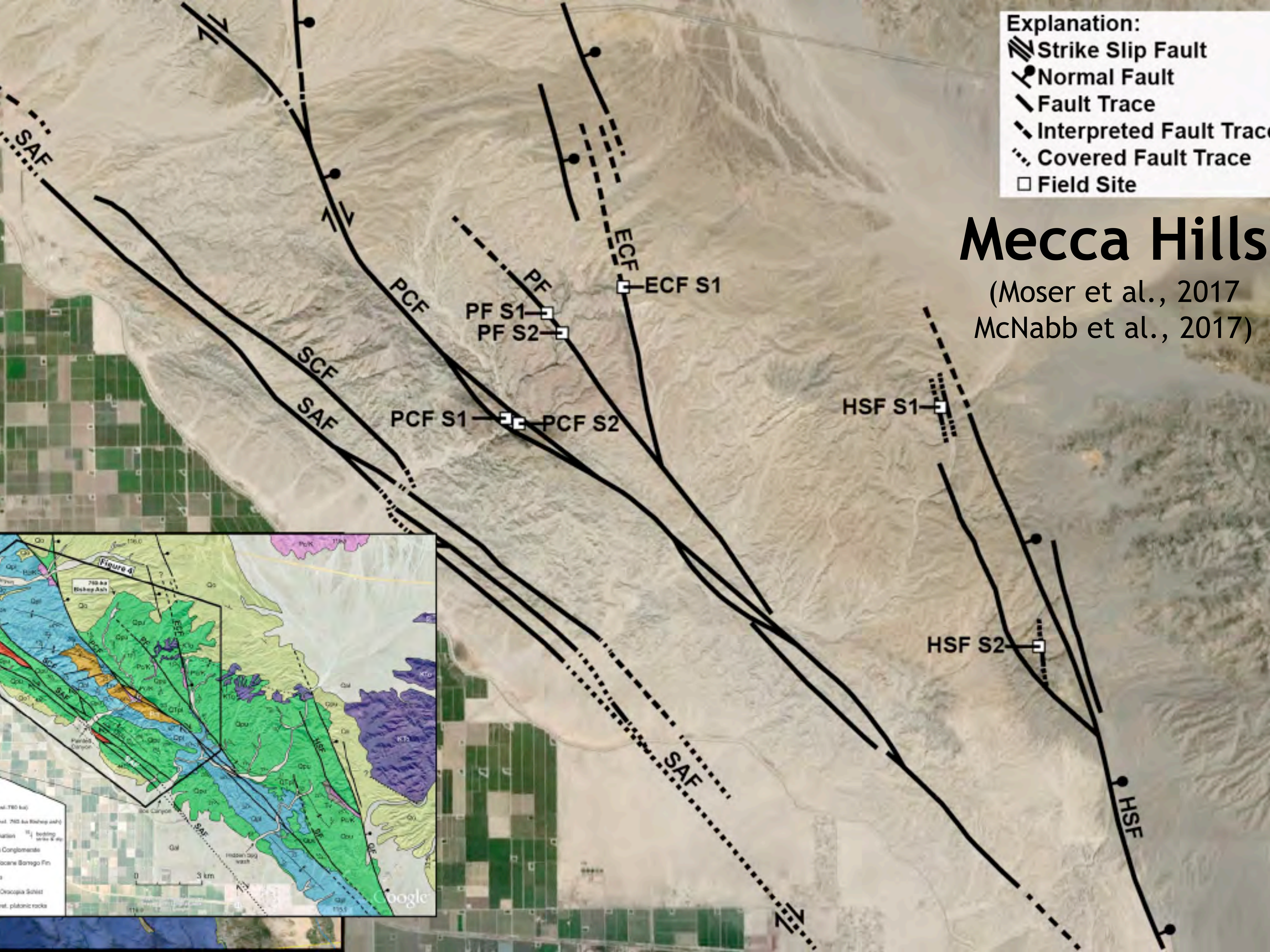
Punchbowl Fault

Schulz and Evans 2000

San Gabriel fault:
Chester et al., 1993;
Chester and Chester, 1998

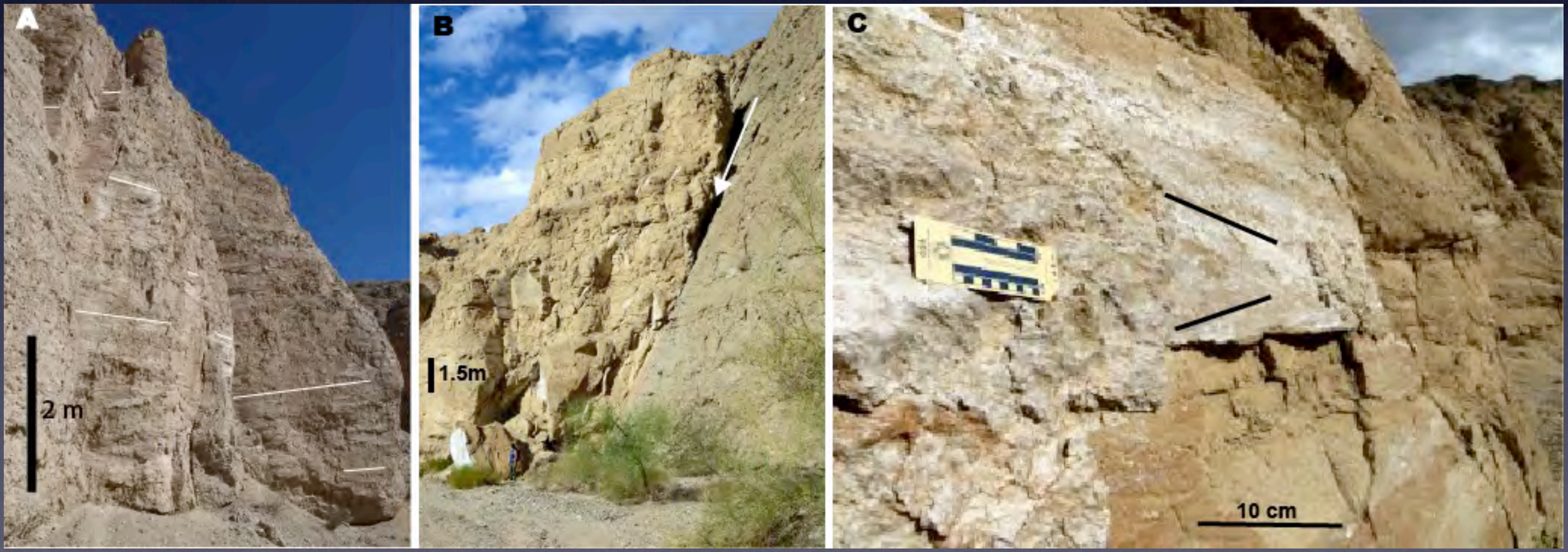


These (and other) data sets show that on major exhumed faults, **off-fault** structures are typically at very different orientations than the main slip surfaces: Stress inversions suggested right-lateral shear within a compressive regime

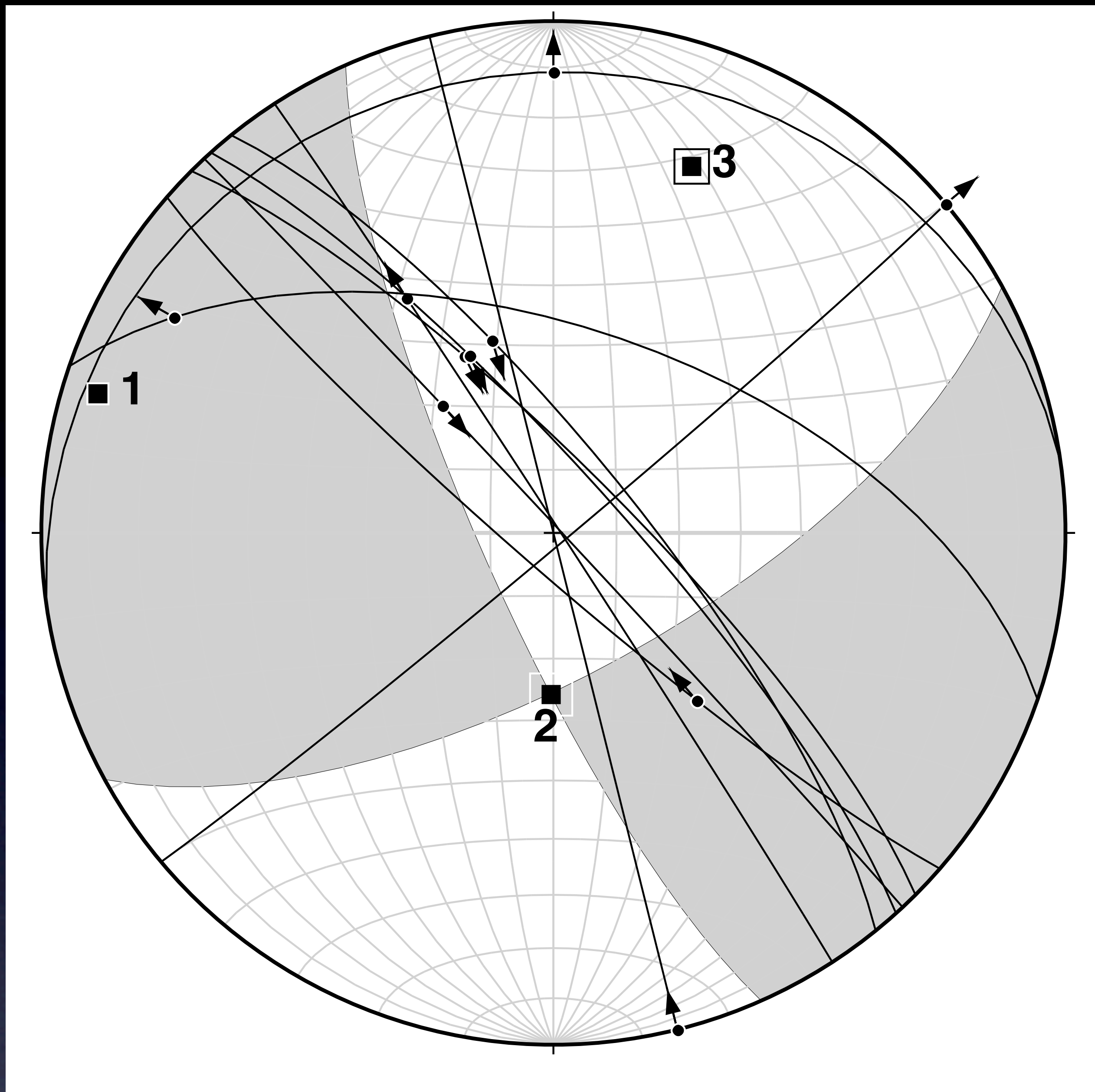


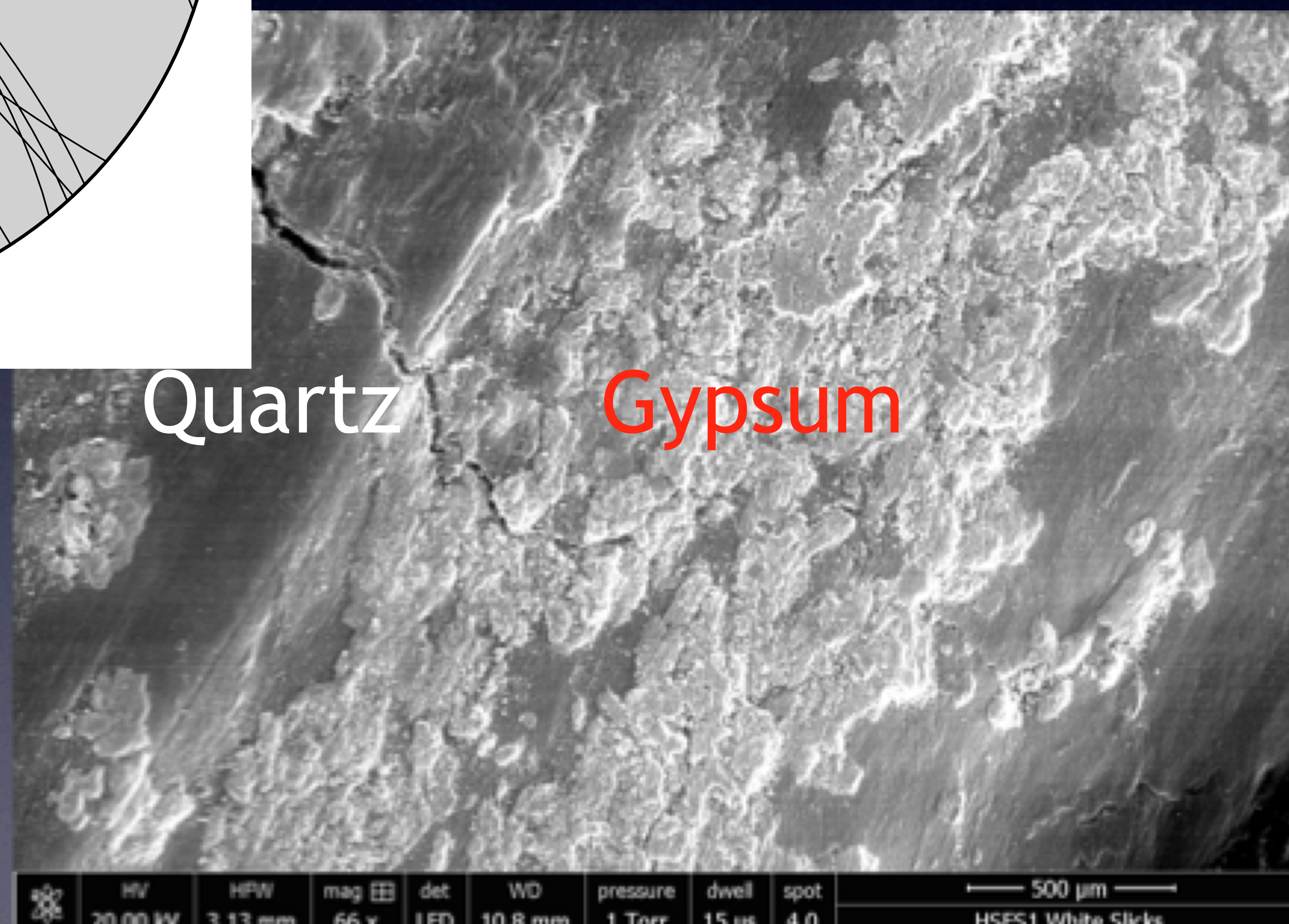
Mecca Hills
(Moser et al., 2017
McNabb et al., 2017)
Explanation:
Strike Slip Fault
Normal Fault
Fault Trace
Interpreted Fault Trace
Covered Fault Trace
Field Site
SAF
SCF
PCF
PF
ECF
HSF
PF S1
PF S2
ECF S1
PCF S1
PCF S2
HSF S1
HSF S2
Figure 4
3 km

Hidden Spring Fault, Mecca Hills



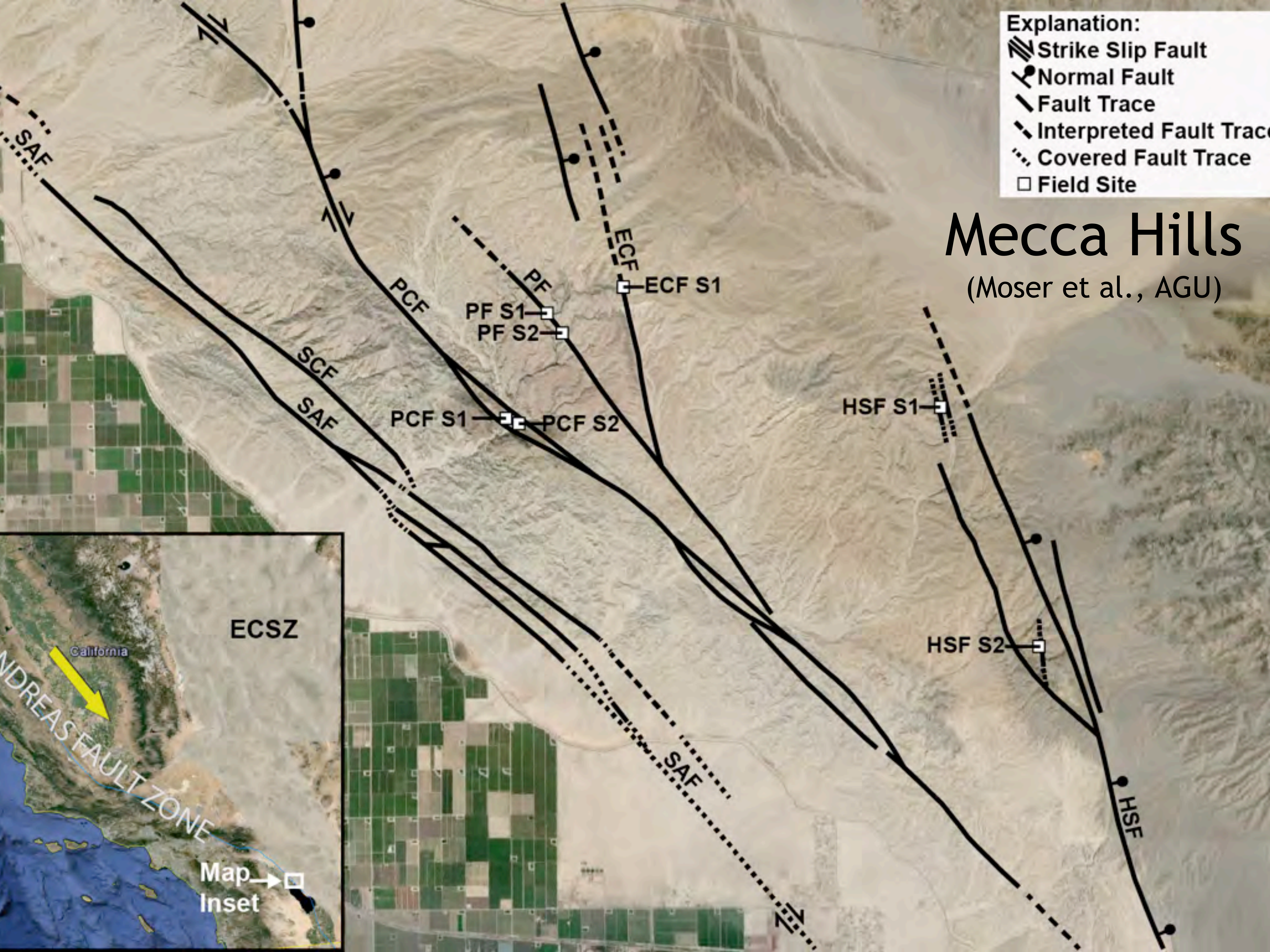
Hidden Spring fault



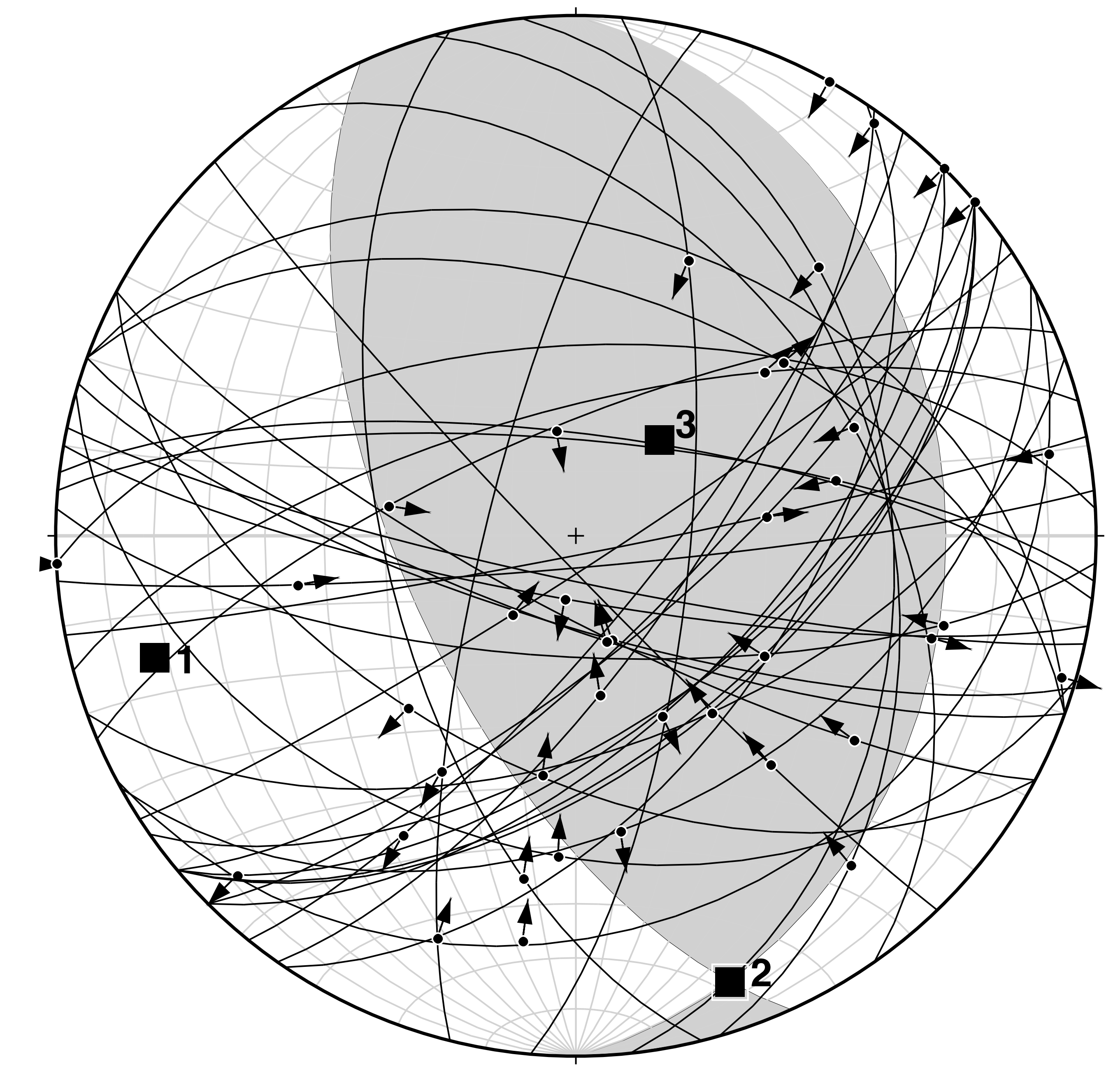


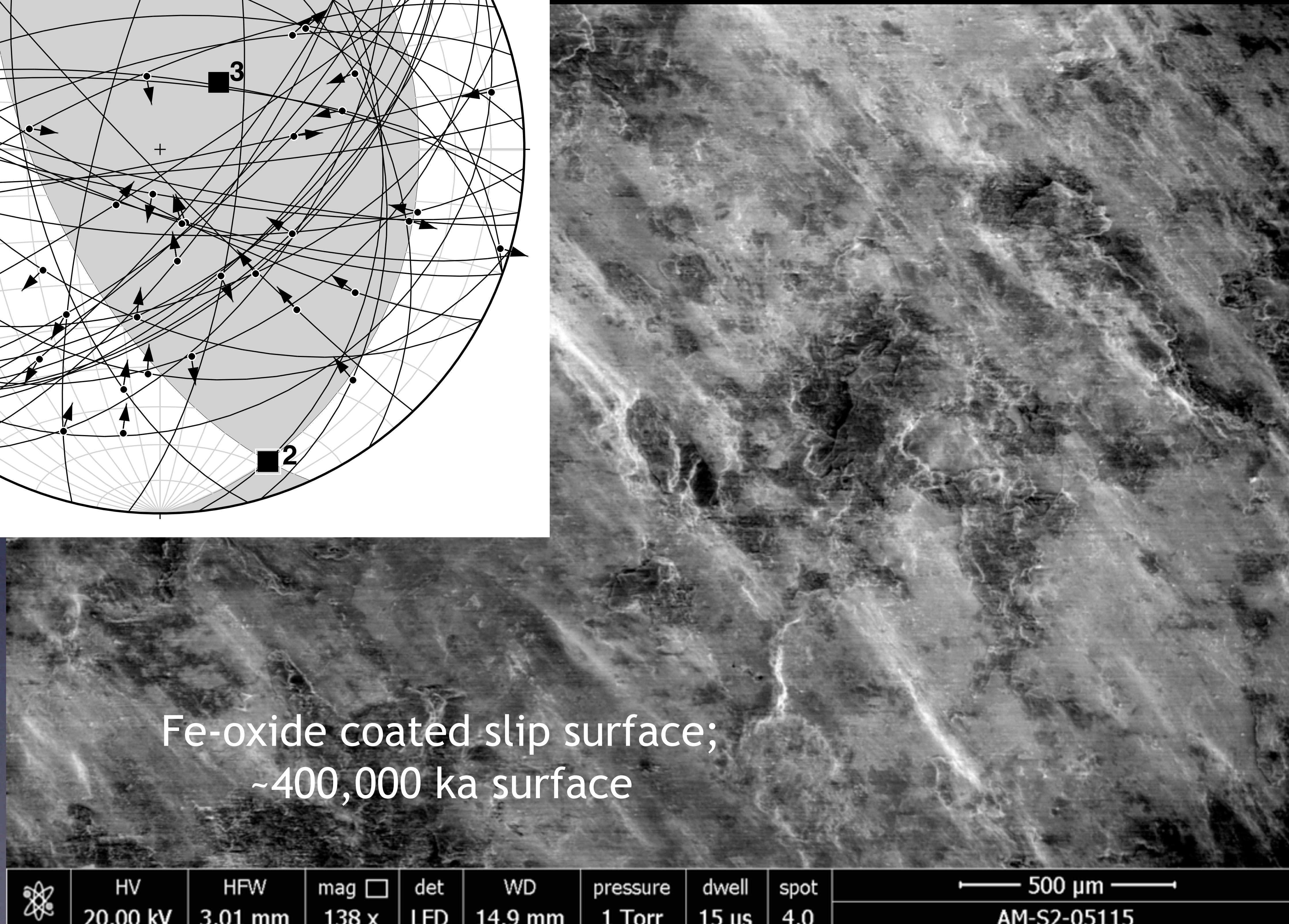
Mecca Hills

(Moser et al., AGU)



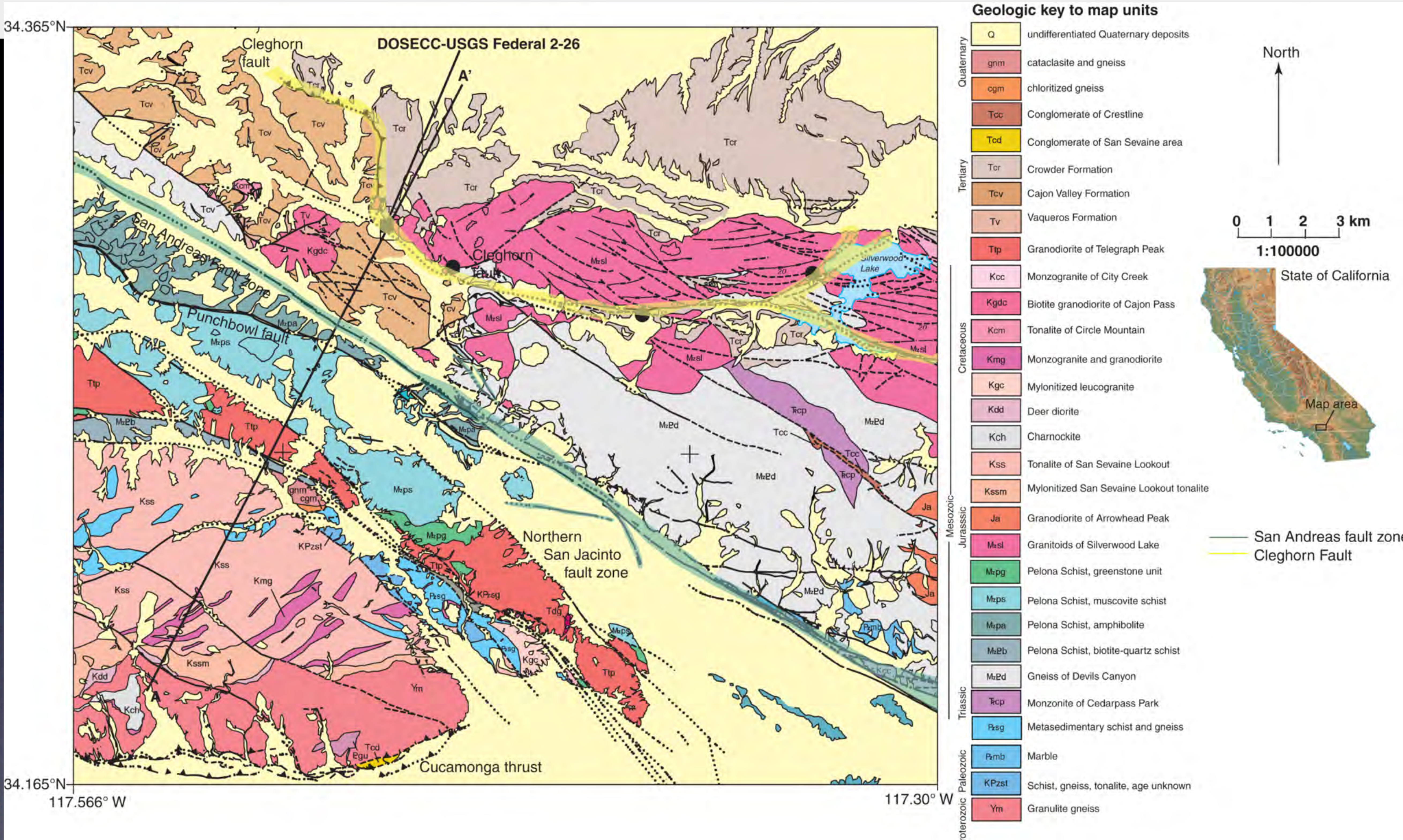
Platform Fault,Mecca Hills

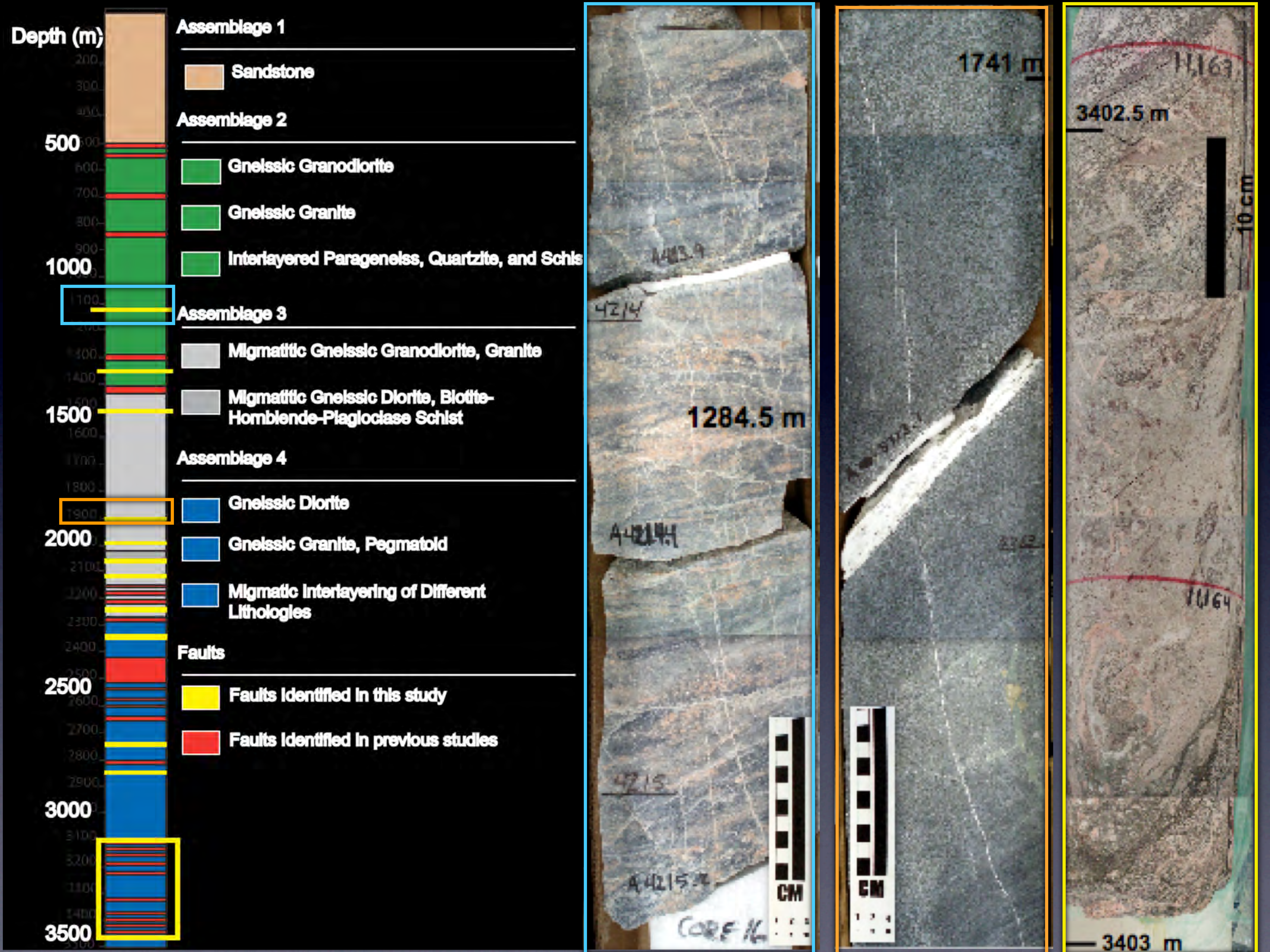




deep drill hole at Cajon Pass, California

Forand et al, GSA Bulletin.

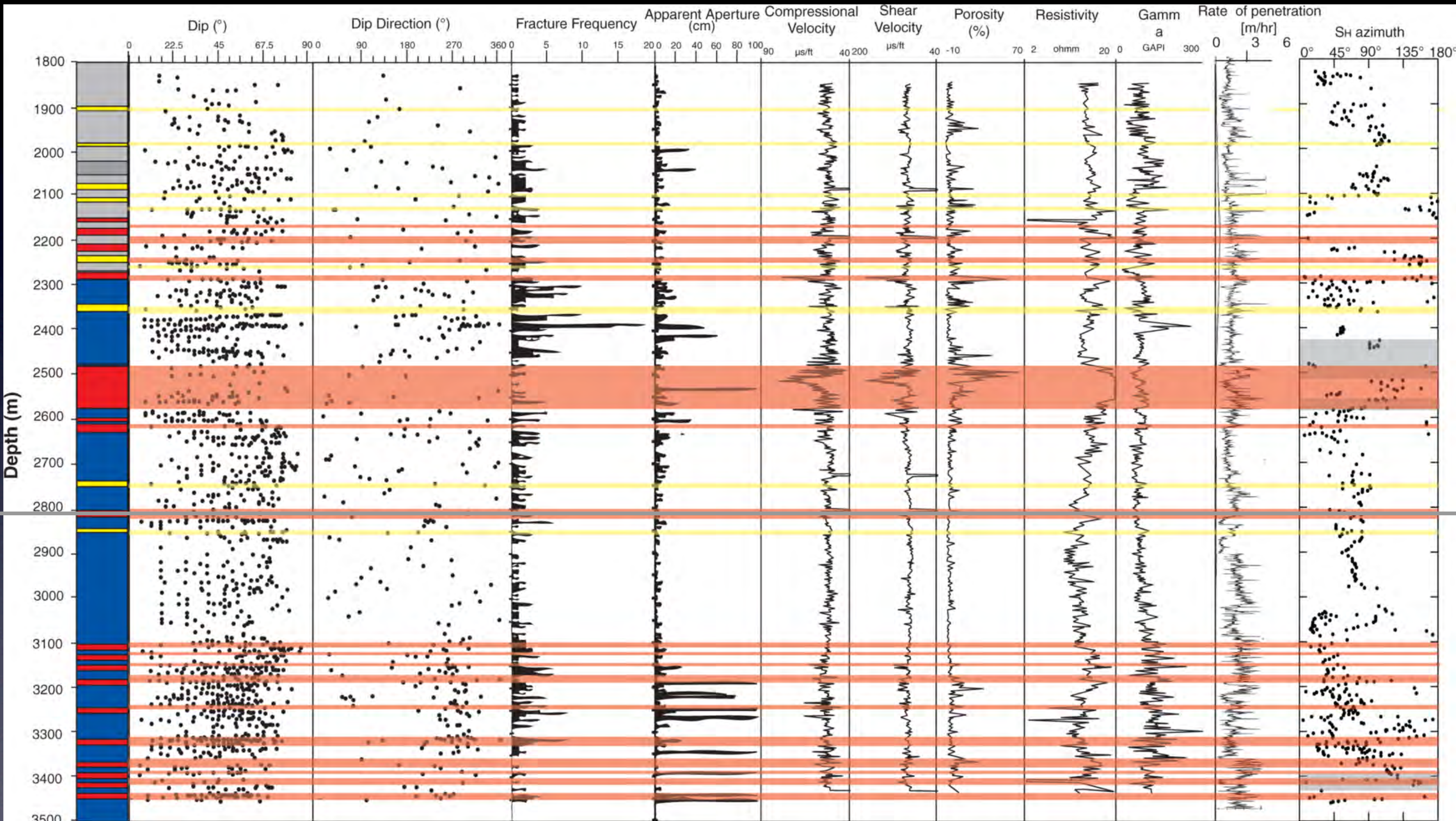




Depth (m)
500
1000
1500
2000
2500
3000
3500
Assemblage 1
Sandstone
Assemblage 2
Gneissic Granodiorite
Gneissic Granite
Interlayered Paragneiss, Quartzite, and Schis
Assemblage 3
Migmatitic Gneissic Granodiorite, Granite
Migmatitic Gneissic Diorite, Biotite-Hornblende-Plagioclase Schist
Assemblage 4
Gneissic Diorite
Gneissic Granite, Pegmatoid
Migmatic Interlayering of Different Lithologies
Faults
Faults Identified in this study
Faults Identified in previous studies
1284.5 m
CM
1741 m
CM
3402.5 m
10 cm
3403 m

From: **Insights into fault processes and the geometry of the San Andreas fault system: Analysis of core from the deep drill hole at Cajon Pass, California**

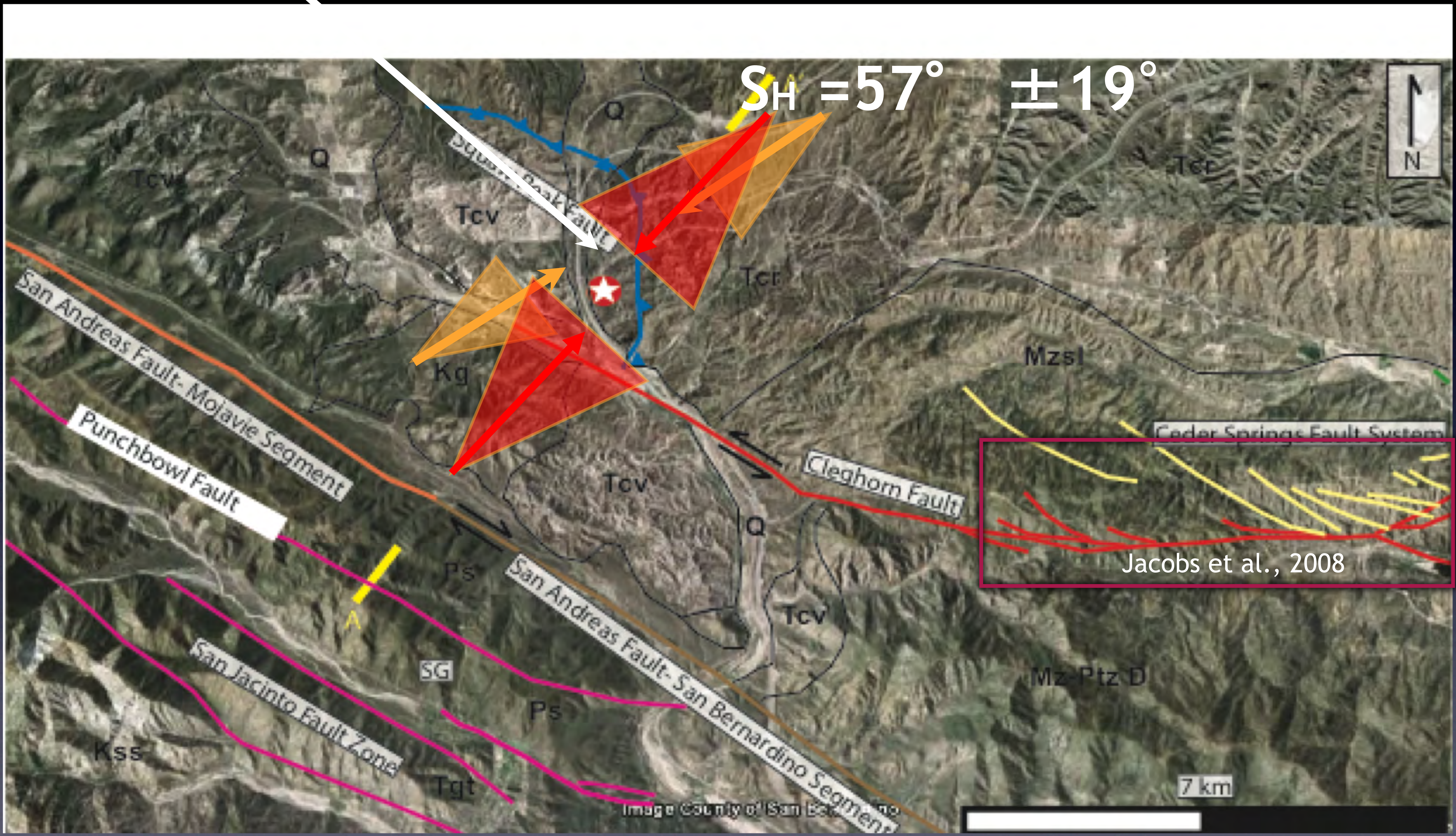
Forand et al., GSA Bulletin



Date of download: 1/13/2019

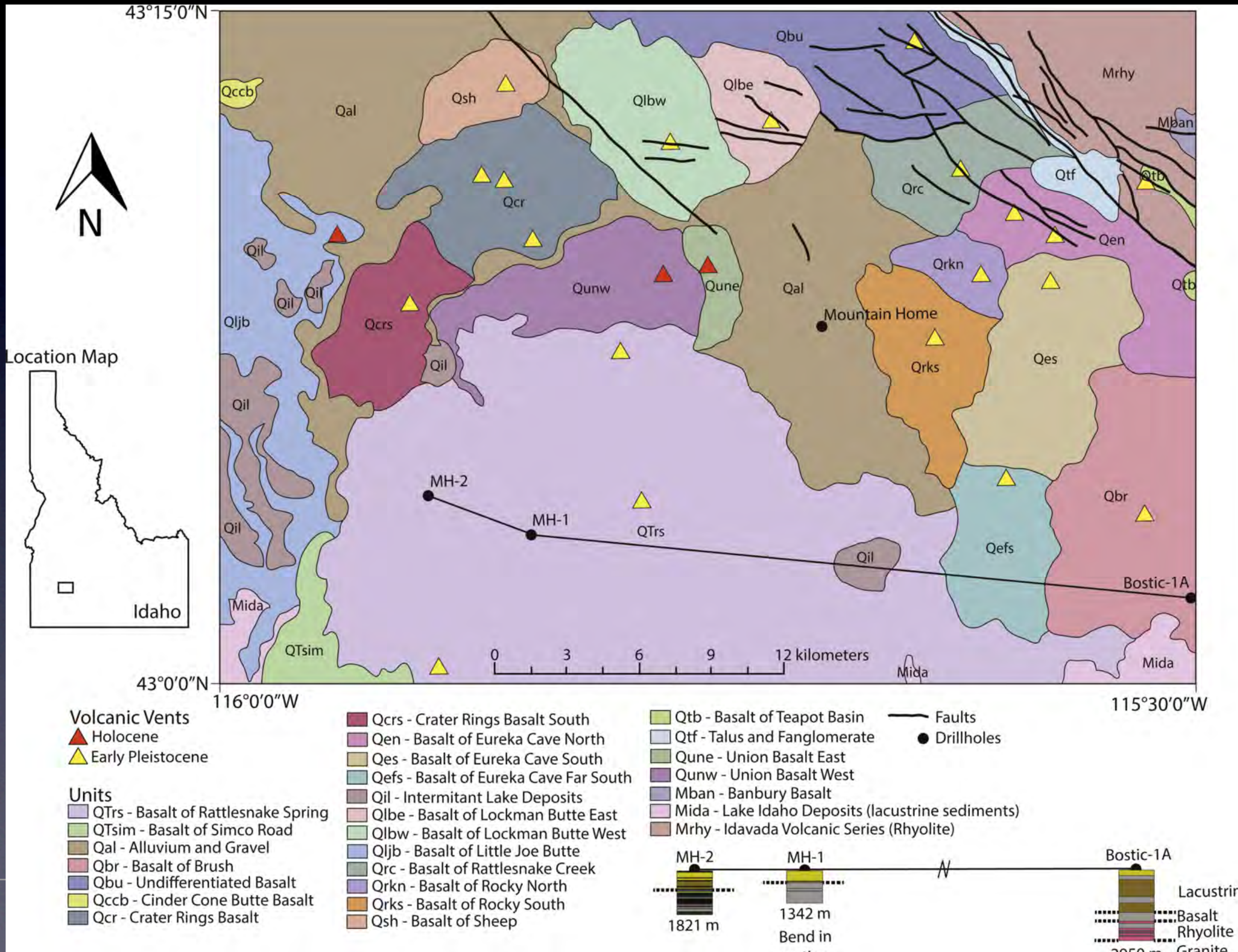
Cajon Pass

~ 5 km of structural relief from surface to TD



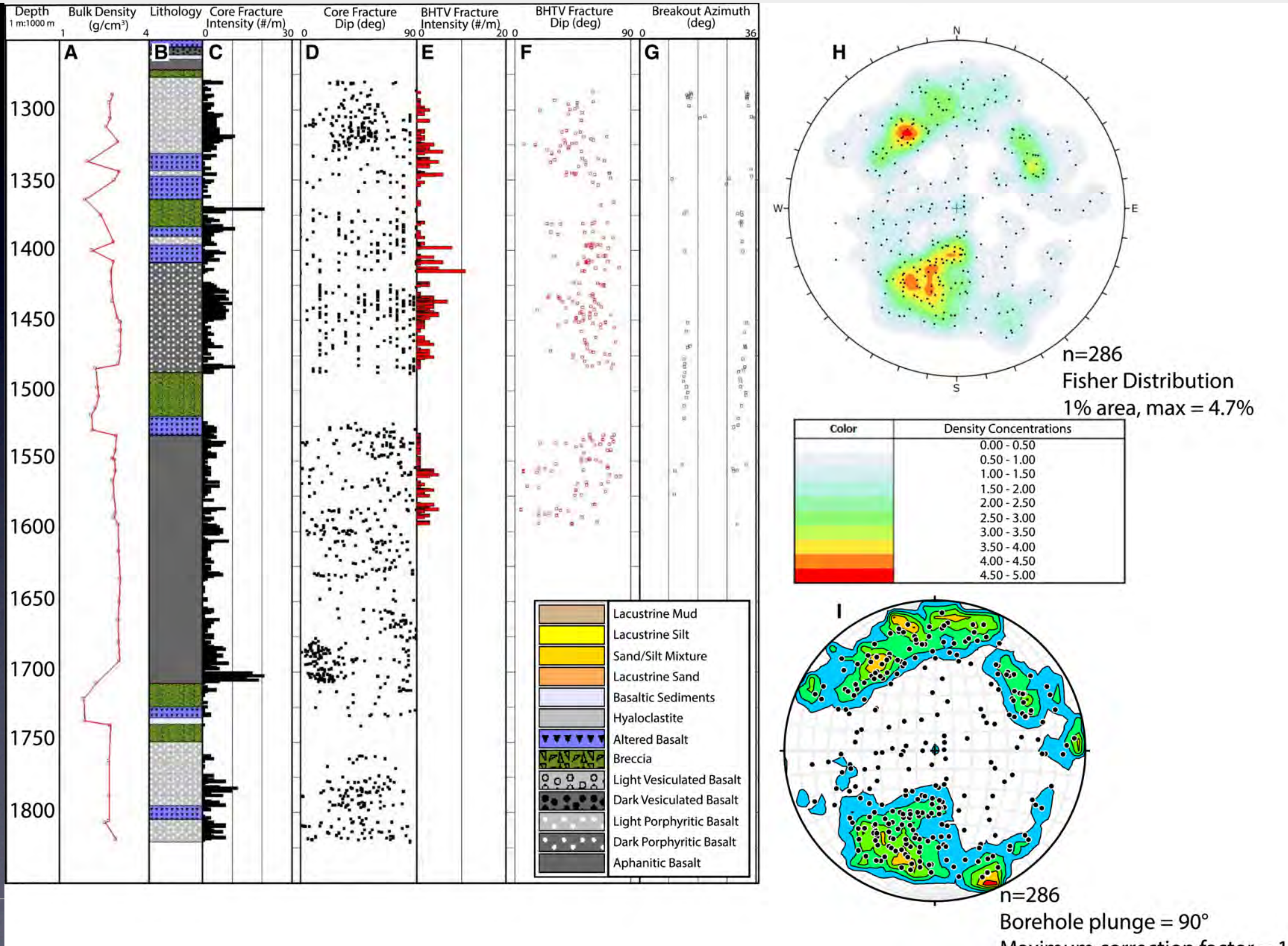
From: Geology and in situ stress of the MH-2 borehole, Idaho, USA: Insights into western Snake River Plain structure from geothermal exploration drilling

Lithosphere. 2017;9(3):476-498. doi:10.1130/L609.1



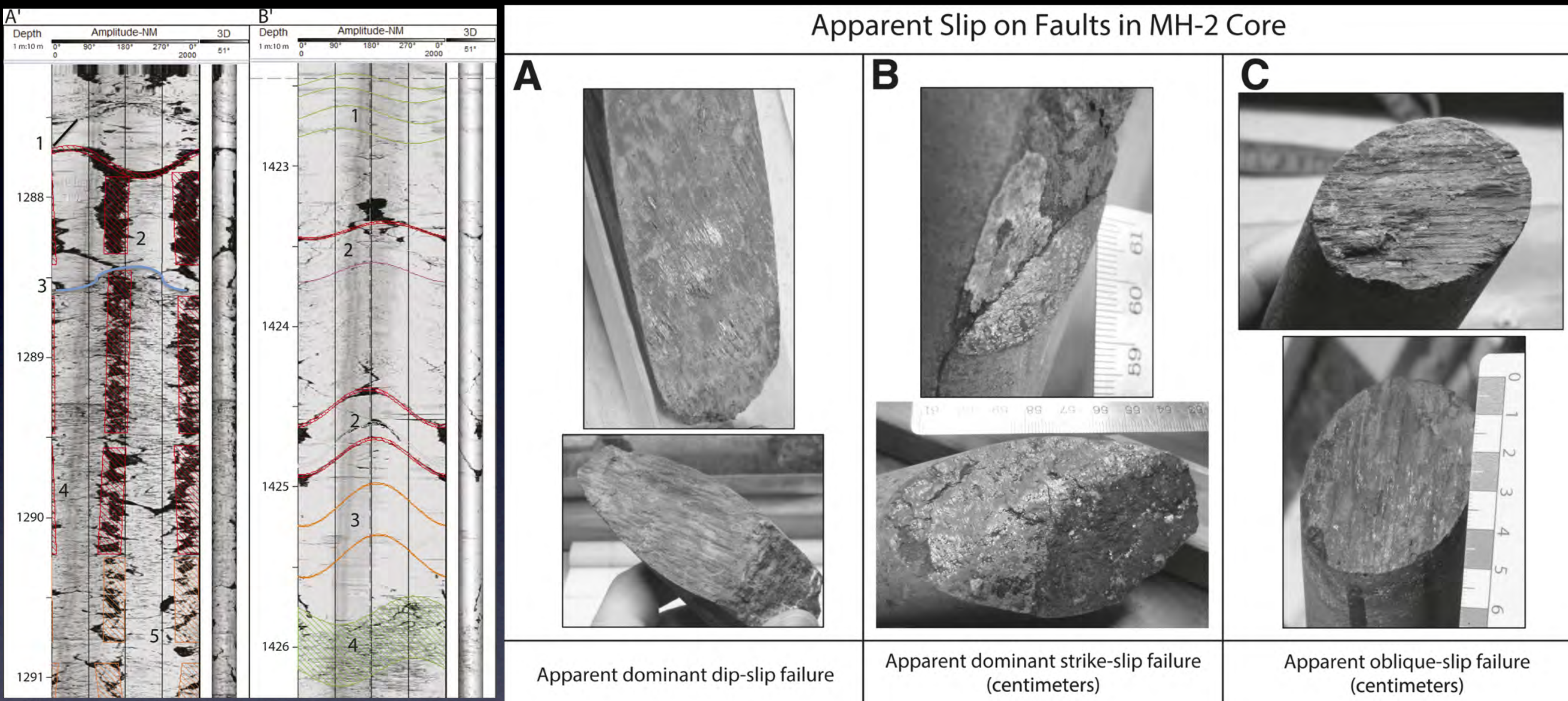
From: Geology and in situ stress of the MH-2 borehole, Idaho, USA: Insights into western Snake River Plain structure from geothermal exploration drilling

Kessler et al,, Lithosphere. 2017;9(3):476-498. doi:10.1130/L609.1



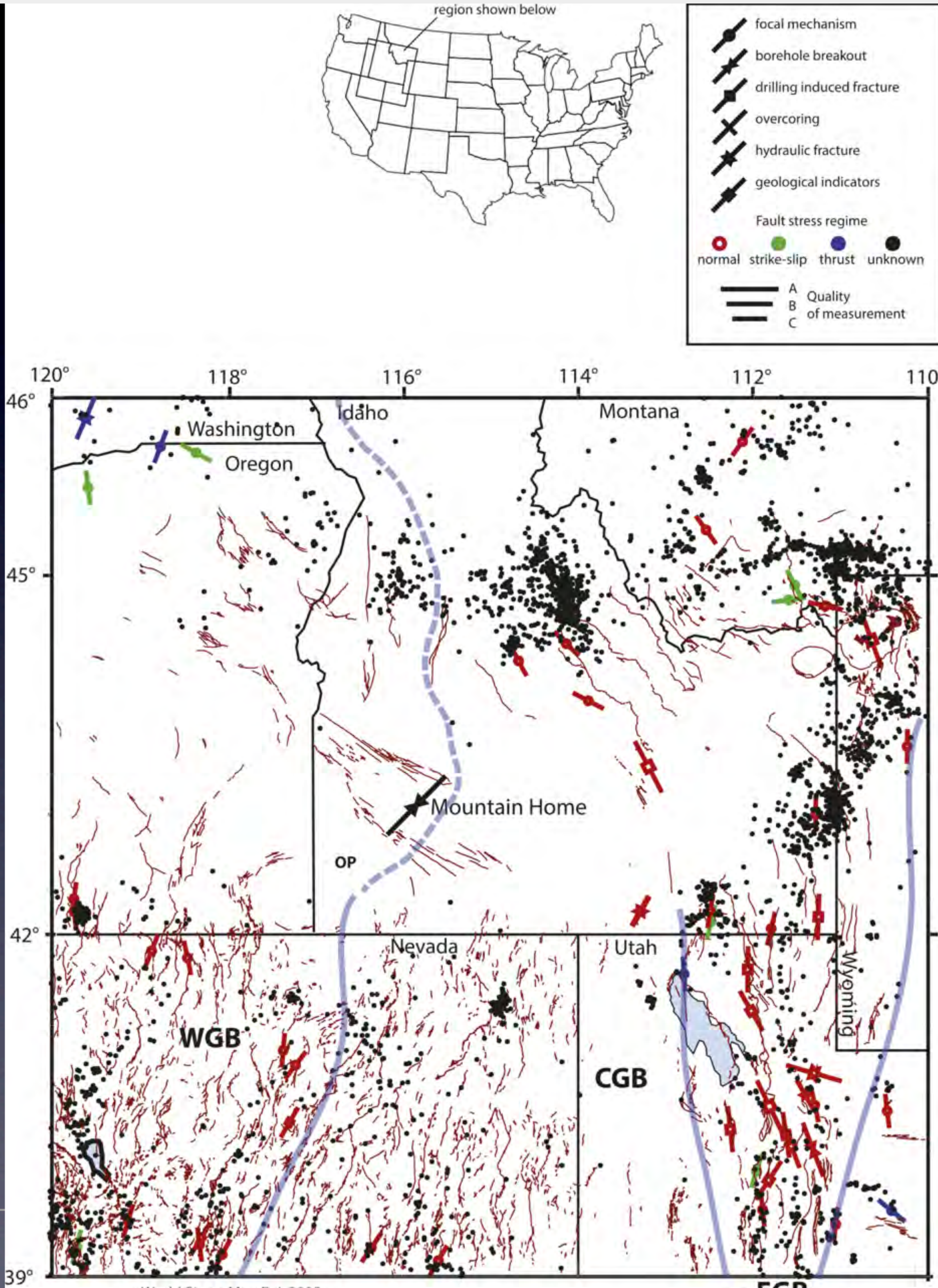
From: Geology and in situ stress of the MH-2 borehole, Idaho, USA: Insights into western Snake River Plain structure from geothermal exploration drilling

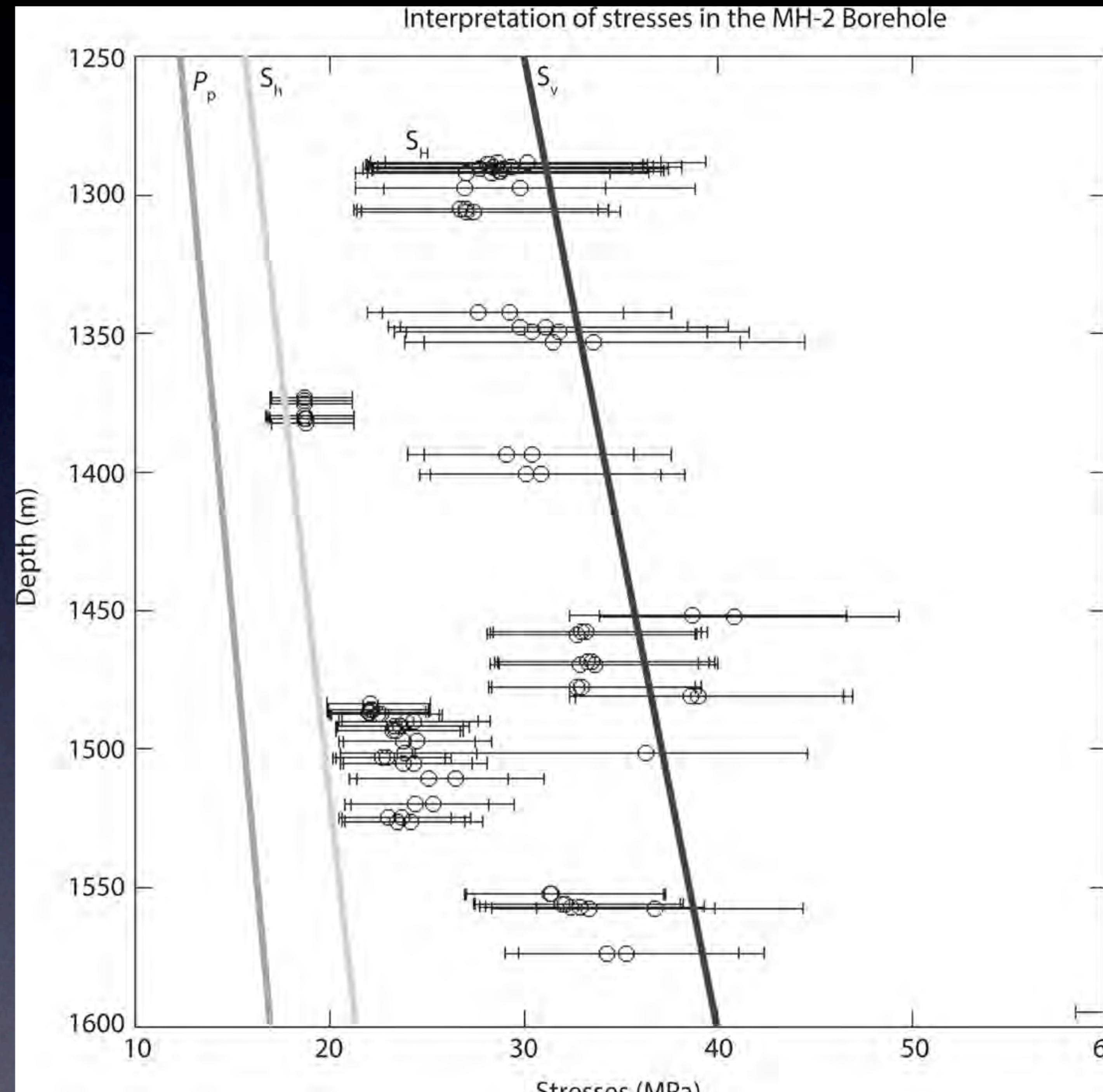
Kessler et al., Lithosphere. 2017;9(3):476-498. doi:10.1130/L609.1



From: Geology and in situ stress of the MH-2 borehole, Idaho, USA: Insights into western Snake River Plain structure from geothermal exploration drilling

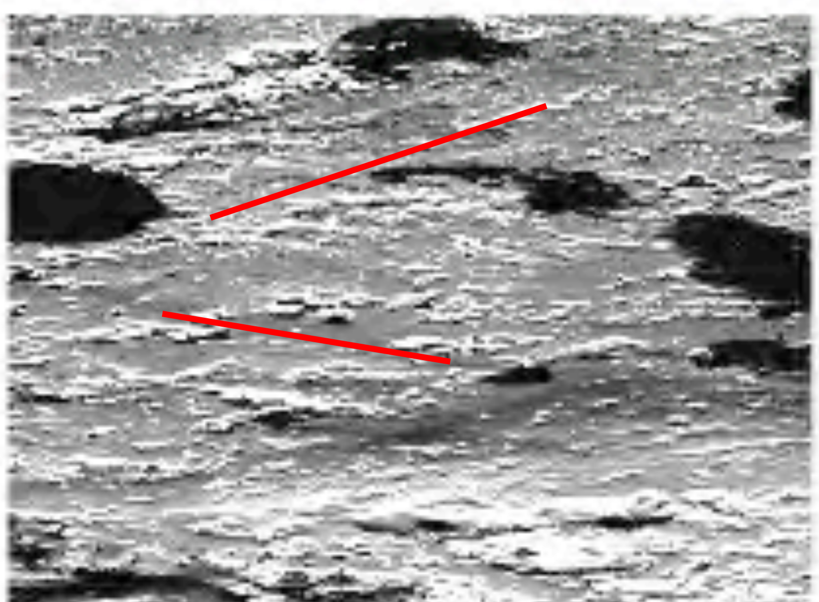
Lithosphere. 2017;9(3):476-498. doi:10.1130/L609.1

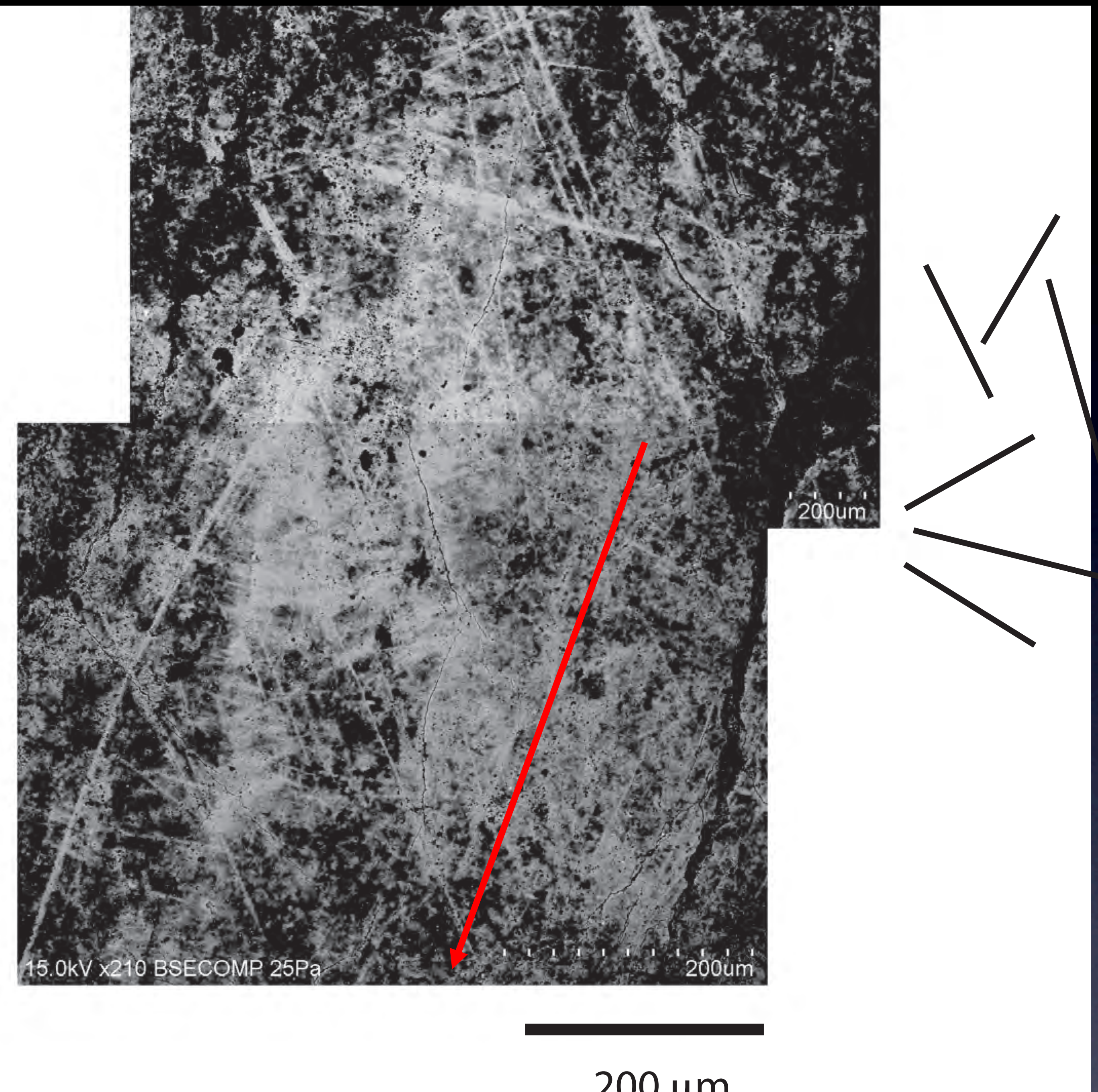




Caveats. “Simple” features can be complex

Evans and Langrock, 1994



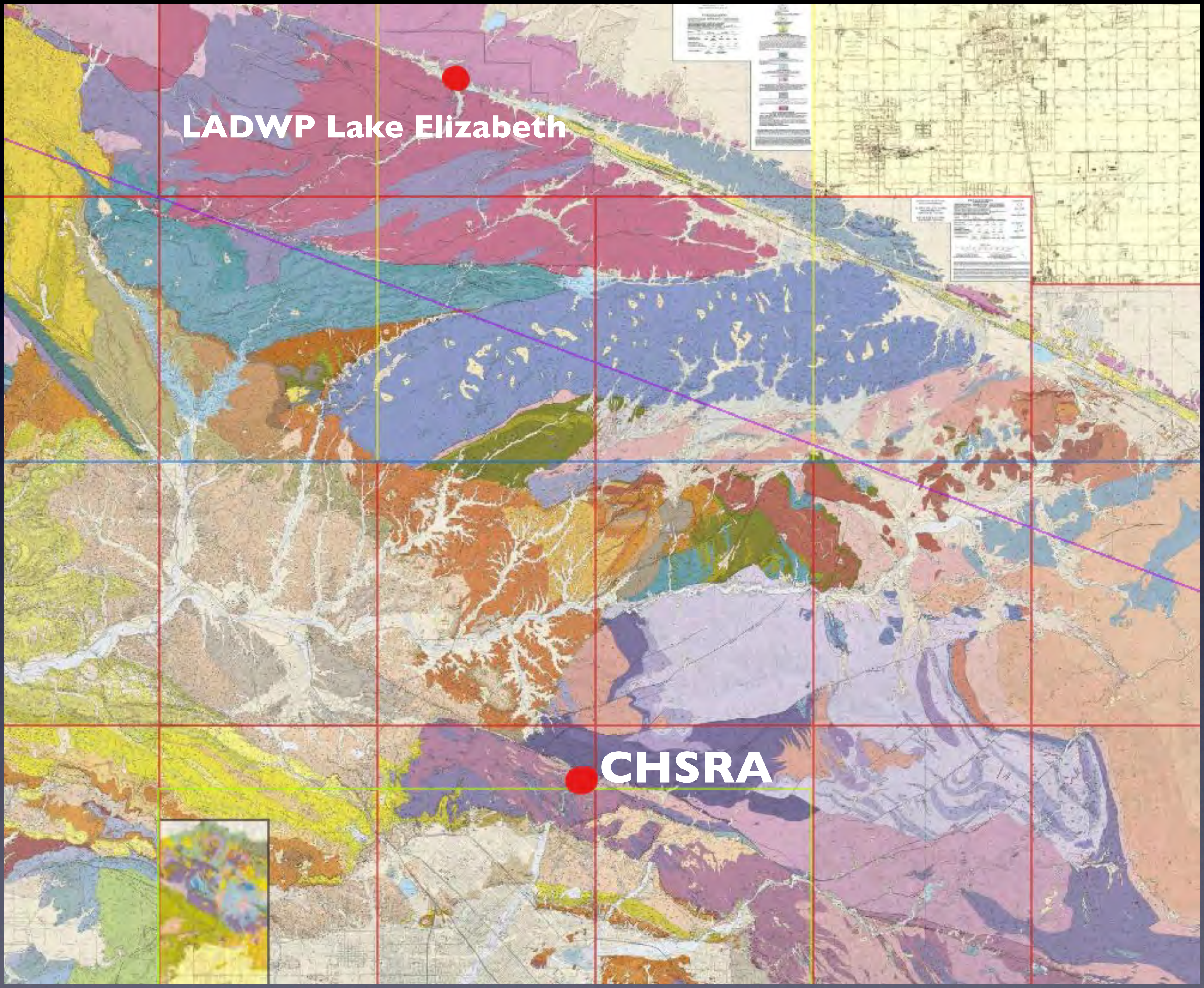


Dominate down-dip slip direction

Calozari et al, Ault et al., can date individual slip layers

Evans et al, 2014
Ault et al., 2015

Holes of opportunity



Geologic indicators of stress

- Add to our repertoire of stress orientation and magnitude indicators
- Feature, not a bug– issues of overprinting and slip complexity can in some cases be deciphered and used to our advantage
- Can get at stress histories
- How to determine/express uncertainties and precisions