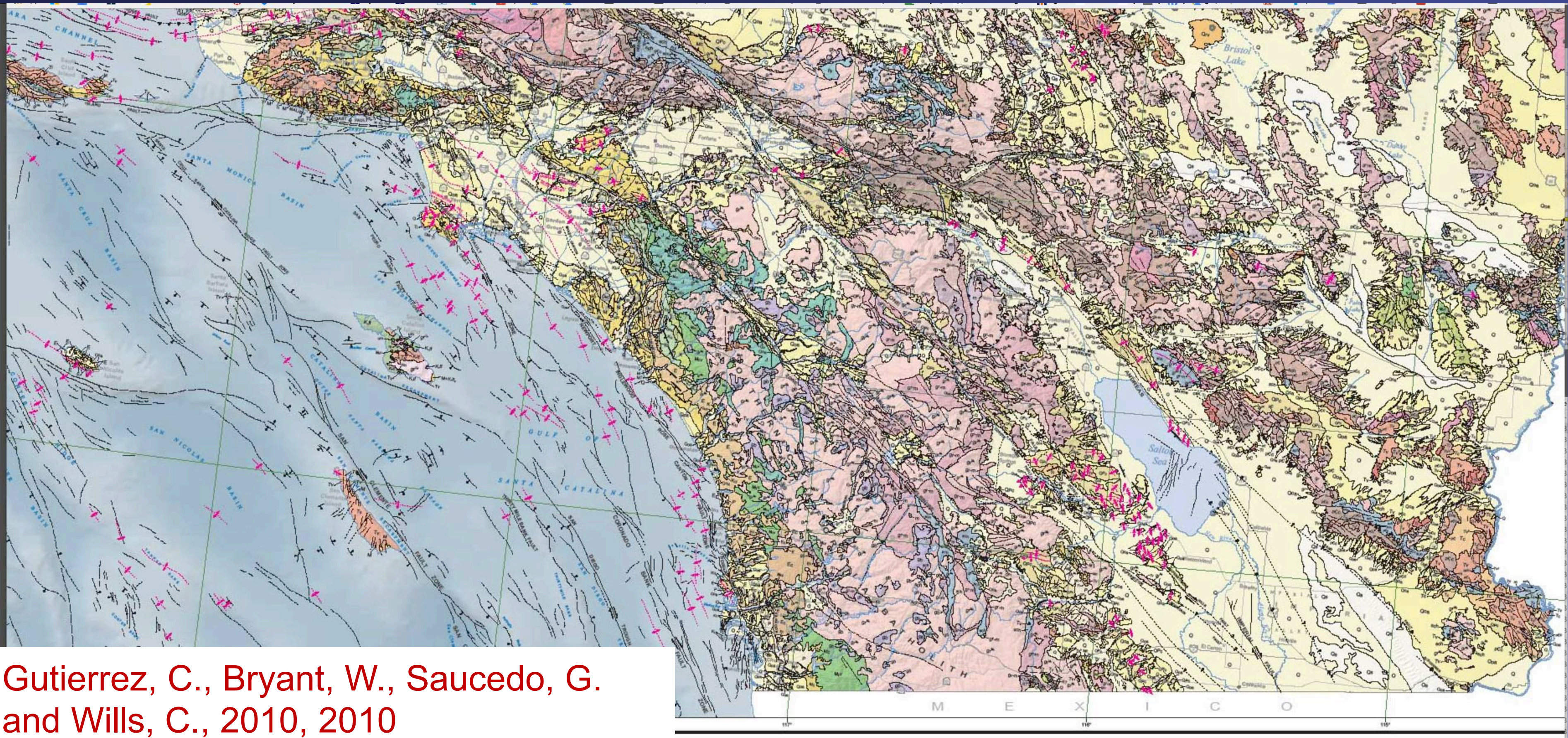
How complete is the database of active faults in southern California?

Susanne U. Janecke Utah State University



Gutierrez, C., Bryant, W., Saucedo, G. and Wills, C., 2010, 2010

Main points

Fault database is likely incomplete- especially in basins on land where agriculture, cities and Lake Cahuilla obscure

Fault zones are 100s m to >10 km wide

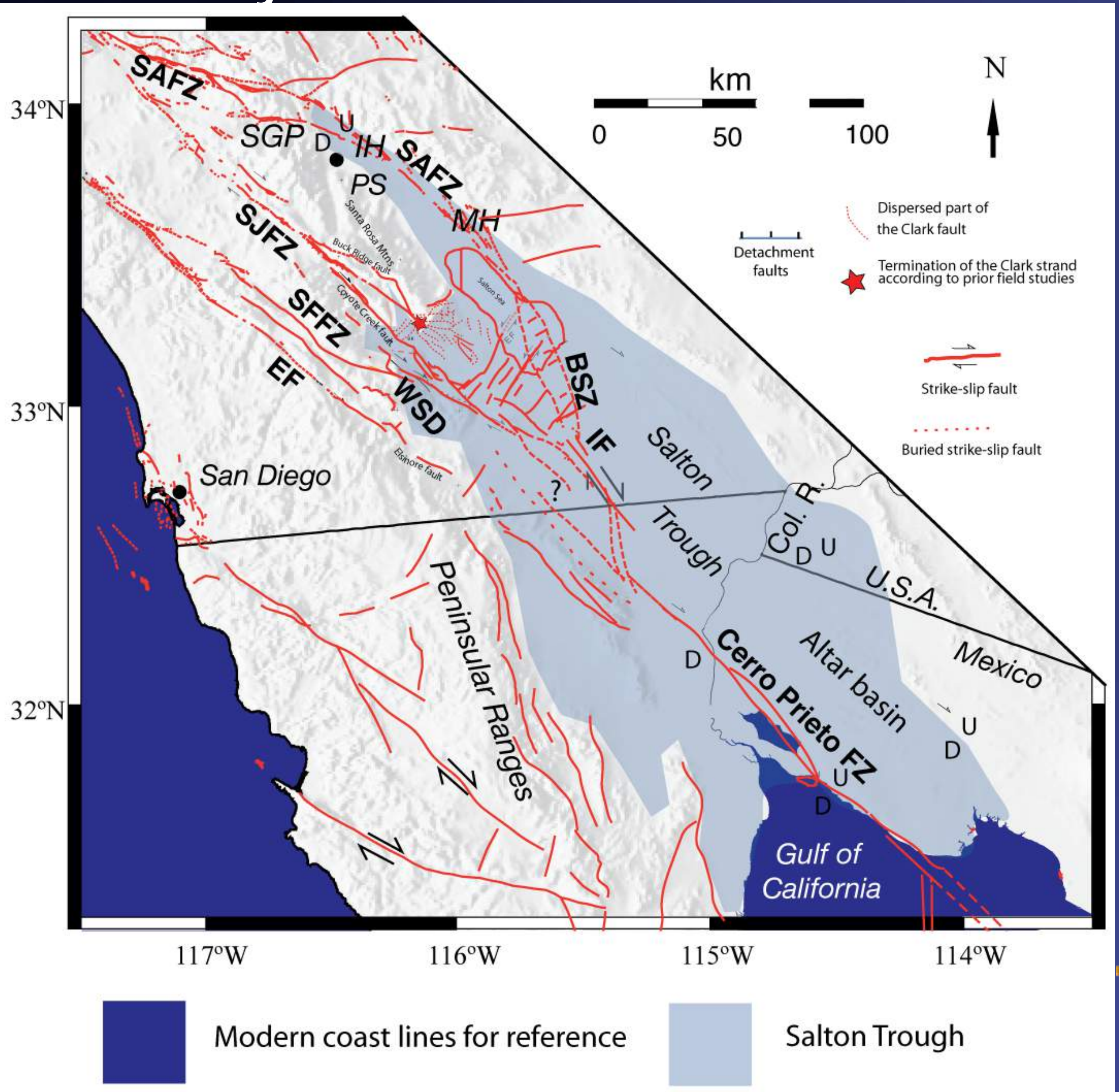
Many strike-slip faults are not vertical

More geologic mapping and subsurface analysis are needed in Gates. Esp. confirm main faults

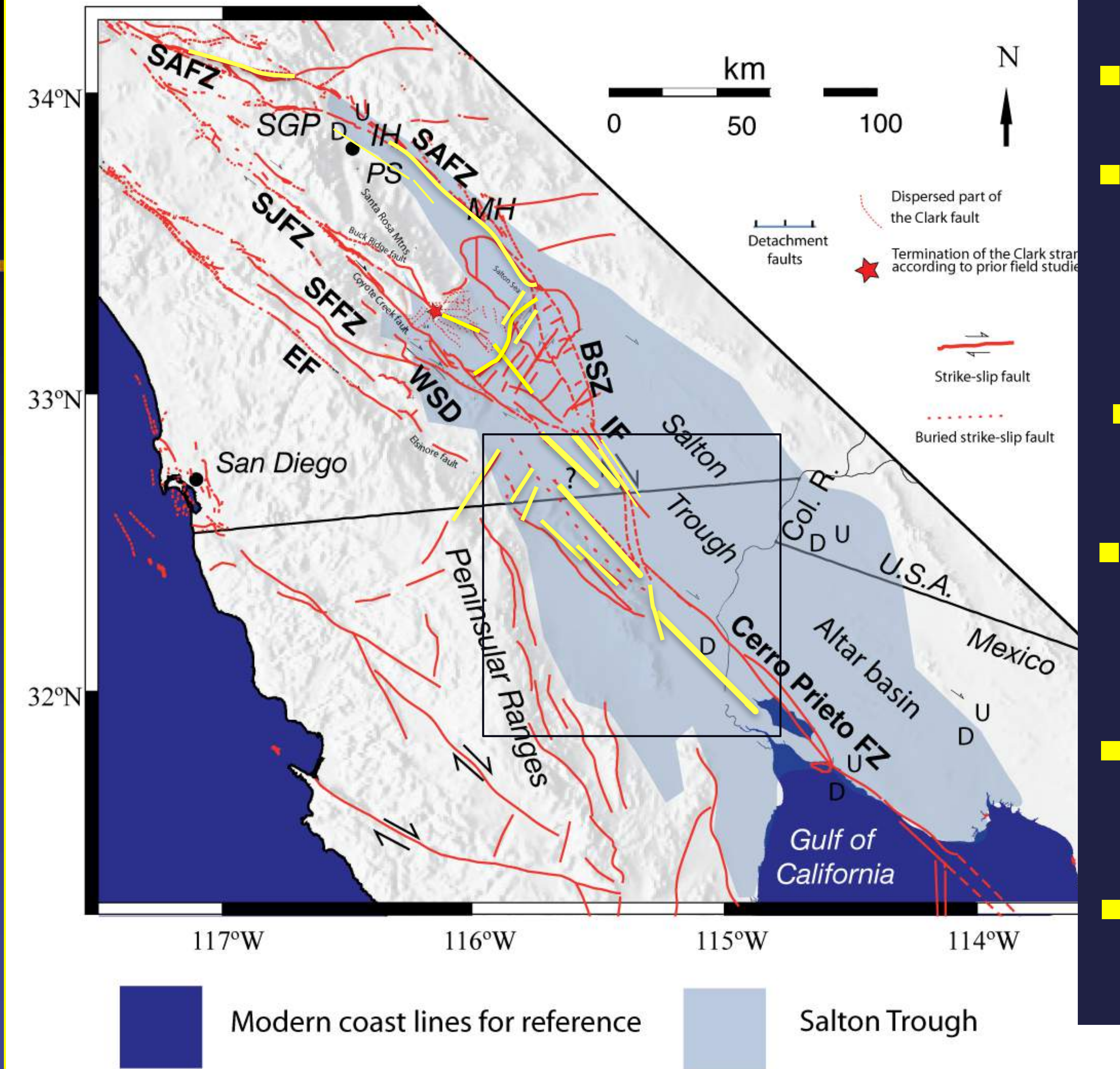
Necessary data:

- Locate all active faults correctly
- Geometry and kinematics (dip, steps, width, branches, tips, depth, slip sense)
- Properties (damage zone, strength, asperities, more)
- Actual and potential linkages

10-15 years revealed many "NEW" active faults

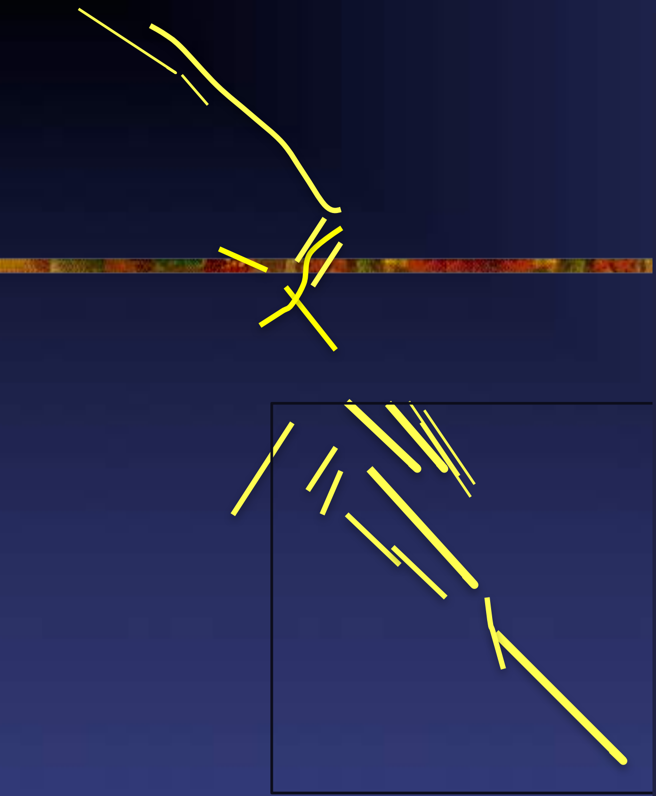


- Starting point is Janecke's 2007 compilation of active faults



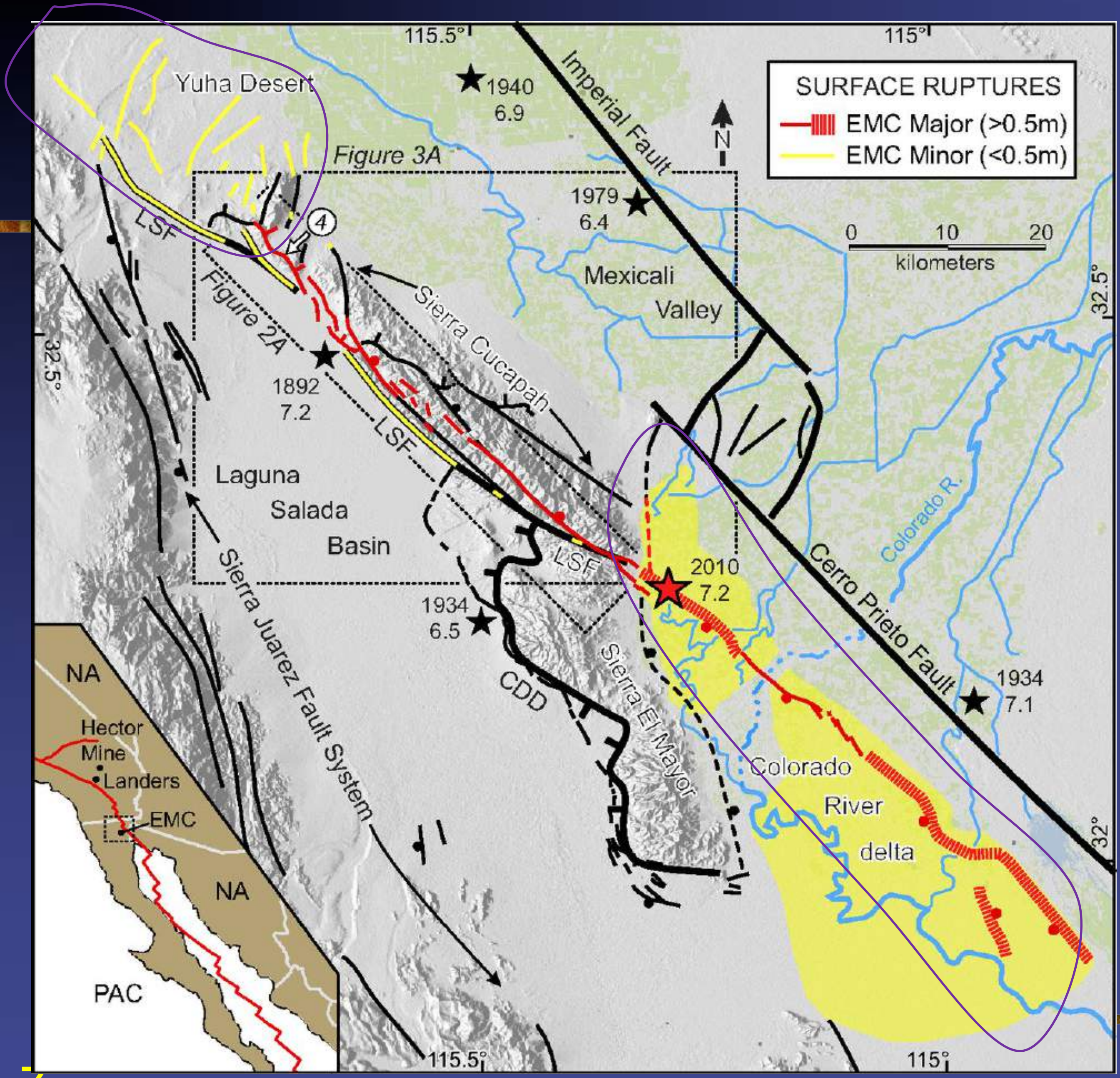
New insights: N to S

- East Shoreline strand of San Andreas fault
- (maybe Palm Springs fault is important)
- Extra fault array is widespread and bent by SJFZ
- Clark fault connects to Superstition Hills fault
- Brawley seismic zone
- Imperial fault has many strands at depth
- San Jacinto connects to Cerro Prieto flt
- El Mayor Eq ruptured unexpected and new faults



New insights in last 10-15 years about Salton Trough and its active faults: N to S

- East Shoreline strand of San Andreas fault (maybe Palm Springs fault is important)
  - Janecke and Markowski, 2013 2016, Sneed et al., many years; Nicholsen et al., 2013; 2015.
- Extra fault array is widespread and bent by SJFZ
  - Brothers et al. 2009, 2011; Thornock, 2013; Janecke, 2013.
- Clark fault connects to Superstition Hills fault
- Fialko 2006 proposed it, Thornock, 2013; Janecke, 2013 confirmed it.
- Brawley seismic zone-
  - Shearer et al 2005; Lin 2013, Meltzner et al., 2006, Meltzner and Rockwell, 20xx
- Imperial fault has many strands and is > 1 km wide at depth
  - Shearer et al. 2002
- San Jacinto connects to Cerro Prieto flt
  - Magistrale 2002; Lindsey and Fialko, 2016
- El Mayor Eq ruptured unexpected and new faults
  - Oskin et al 2012, Fletcher et al 2014, more



El Mayor earthquake:

About half of rupture was not known to exist or thought to be a concern before hand

Fletcher et al. 2014

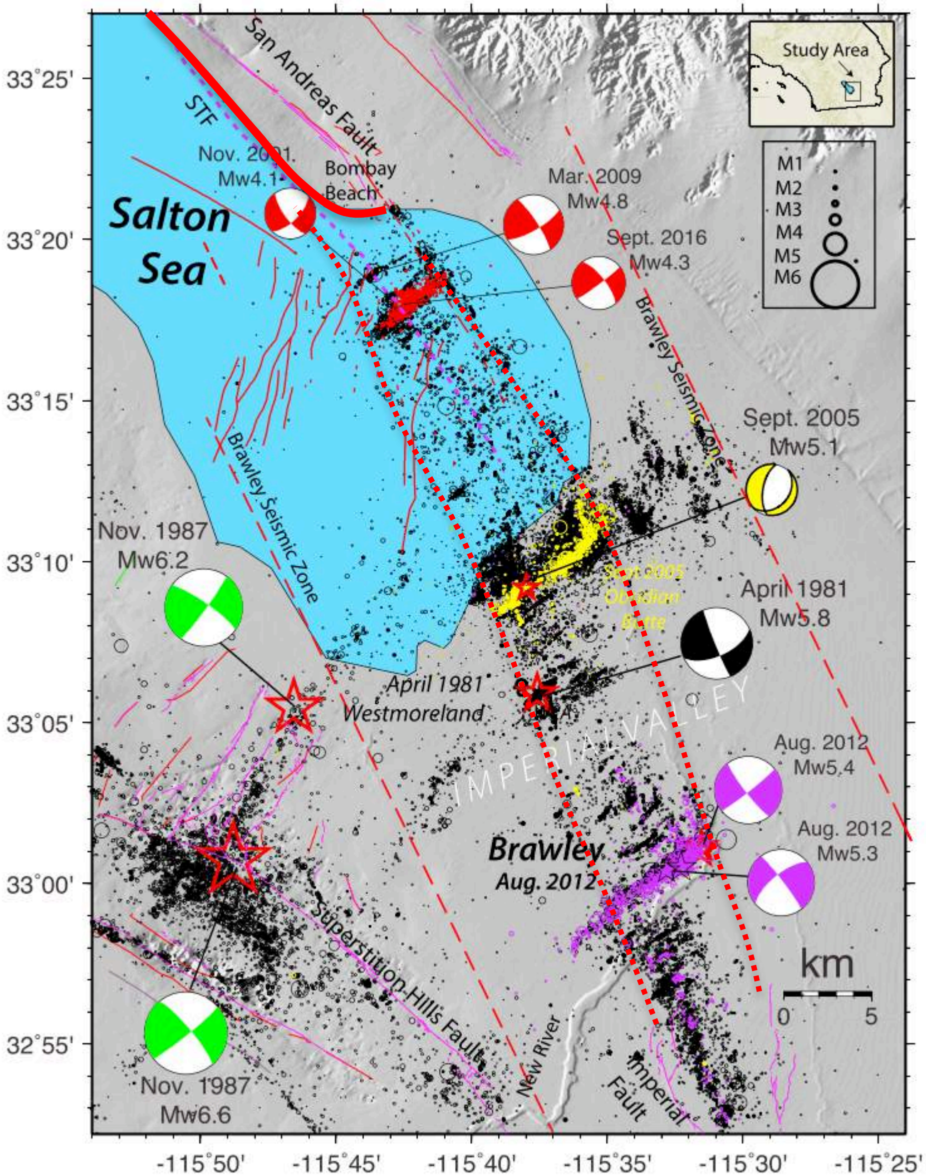


Figure 1. Map of 1981–2016 relocated seismicity of the BSZ shown as black circles. The lower hemisphere focal mechanisms for larger events that are labeled include 1981 Westmoreland, 1987 Elmore Ranch and Superstition Hills (green), Obsidian Butte 2005 (yellow), Brawley 2012 (purple), and the Bombay Beach 2001, 2009, and 2016 (red). Elmore Ranch and Superstition Hills moment tensors are from *Bent et al.* [1989] and *Yang et al.* [2012]. The late Quaternary faults are from *Jennings and Bryant* [2010]; normal faults beneath the Salton Sea and the offshore extension of the SAF are from *Brothers et al.* [2009]. The Salton Trough fault (STF) is from *Sahakian et al.* [2016].

Interpreted width of Brawley seismic zone varies by factor of almost 3?!

Narrow version is >5 km wide

Hauksson et al. 2017

Inner red dashes show traditional view

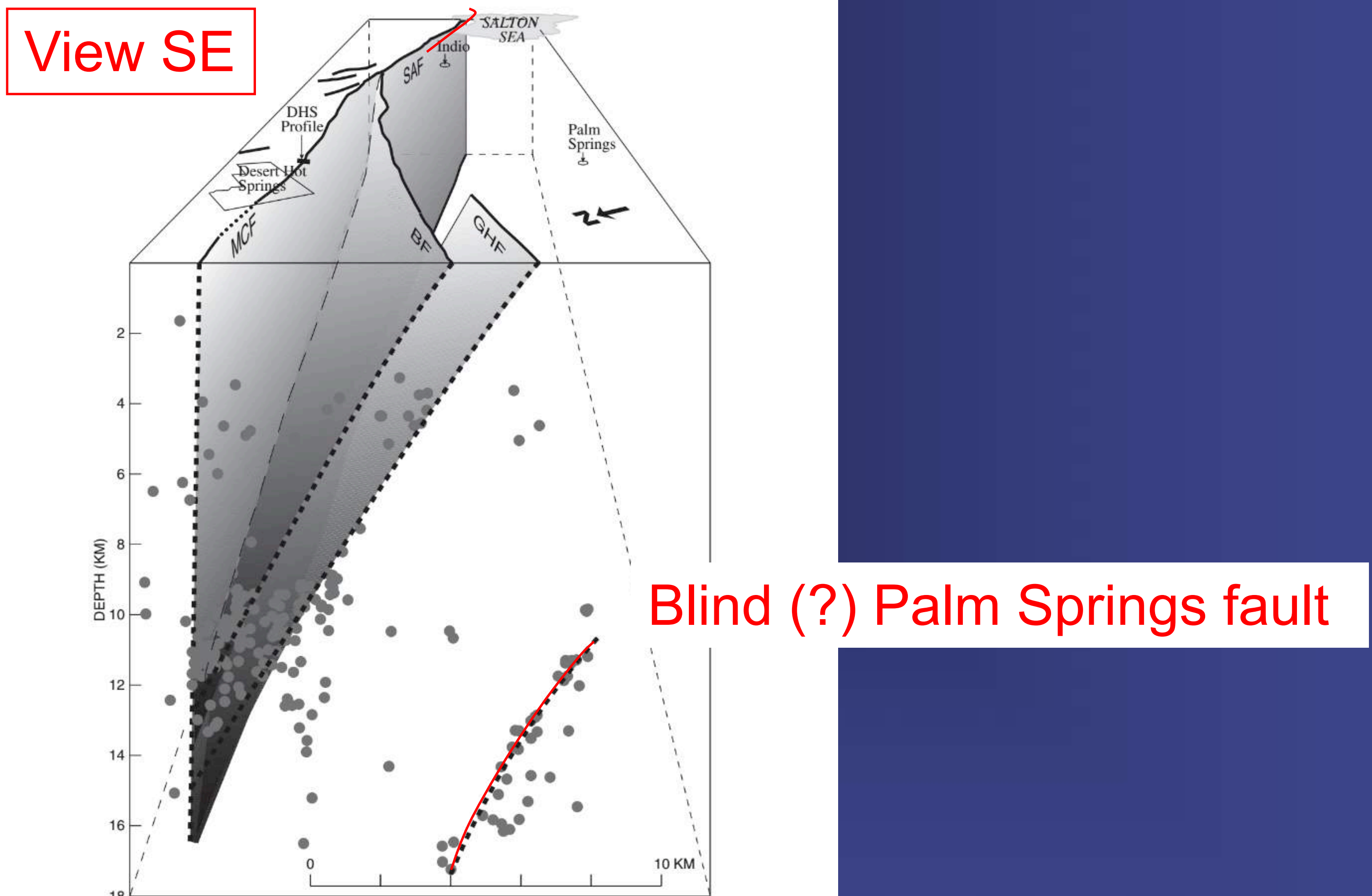
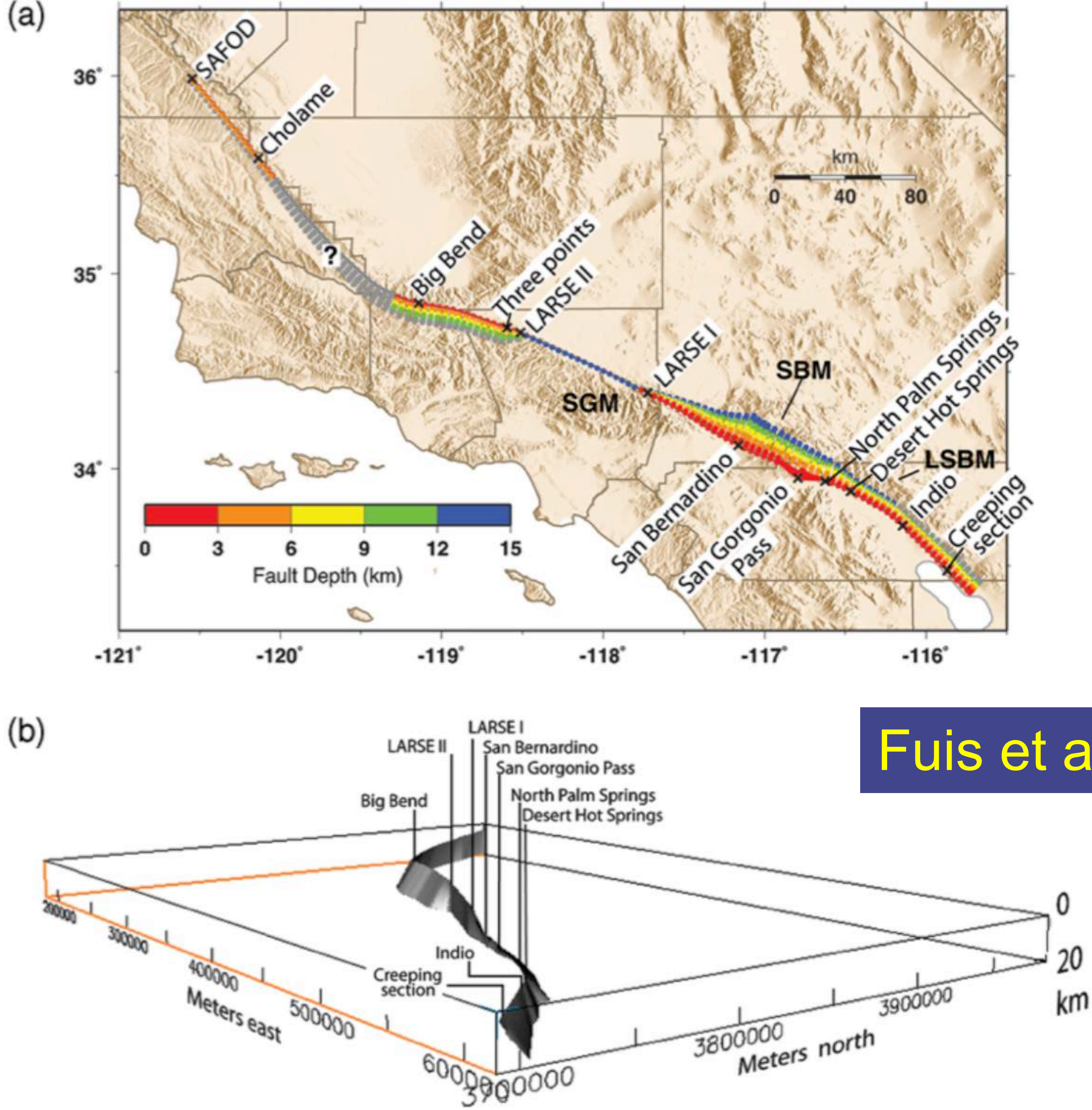


Figure 11. Interpretative 3D fault model (gray shading) of the northern Coachella Valley. In this model, the Mission Creek fault is near-vertical, and the Banning and Garnet Hill faults dip northward toward the Mission Creek fault; dip increases with depth. The model assumes that the Banning fault merges with the Mission Creek fault at progressively greater depths from southeast to northwest. Gray dots show earthquake hypocenters (from Hauksson, 2000) along profile BB′ (see Fig. 1).

Catchings et al 2006 BSSA



Fuis et al.,2012 BSSA

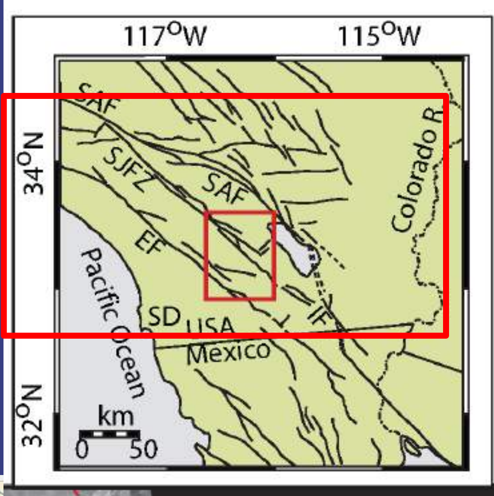
Figure 2. (a) Plan view of dipping SAF model surface colored by depth; gray colors, unconstrained projections. Mountain ranges within Transverse Ranges (see Fig. 1): SGM, San Gabriel Mountains; SBM, San Bernardino Mountains; LSBM, Little San Bernardino Mountains; SAFOD, San Andreas Fault Observatory at Depth. (b) Oblique view of SAF surface from southeast.

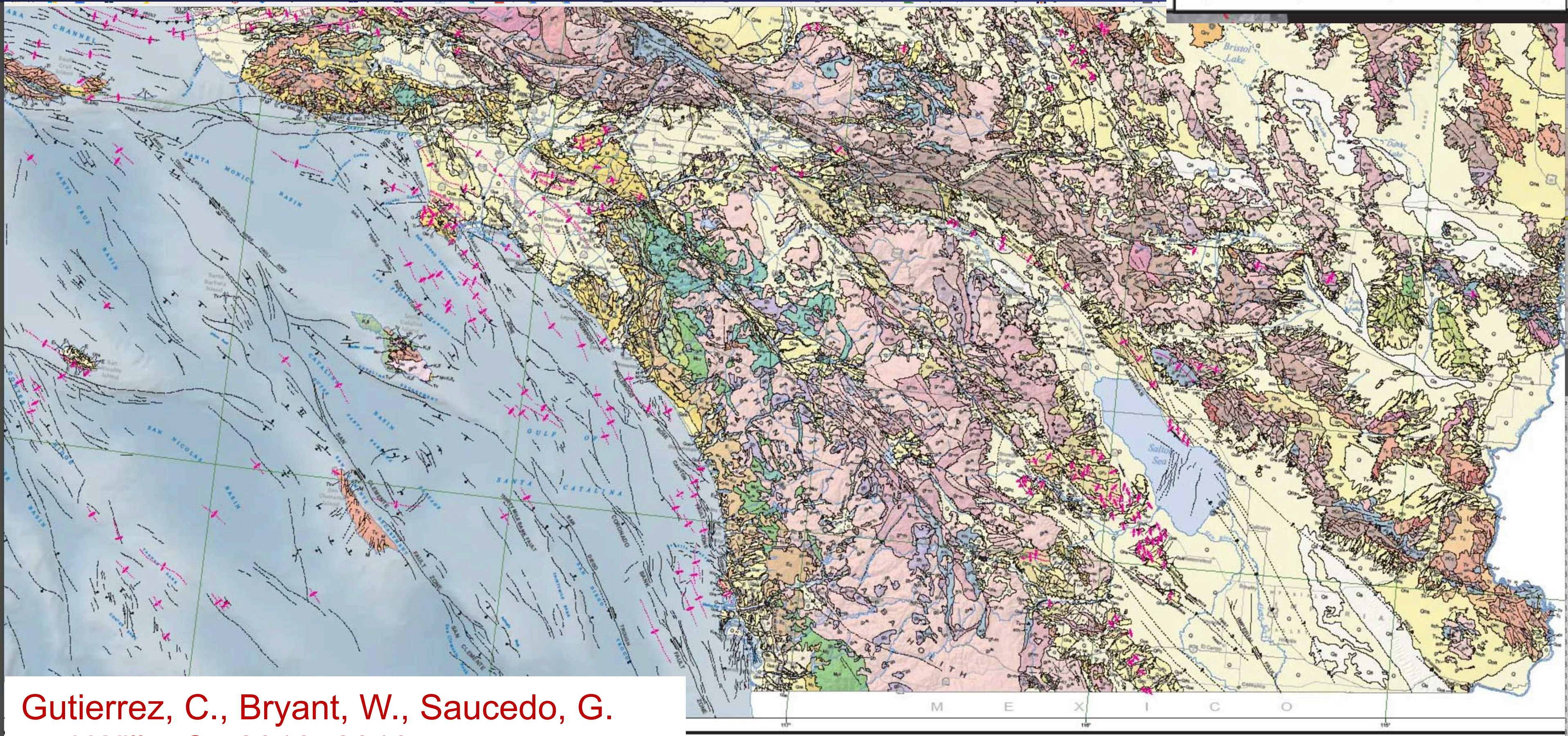
Small differences in stress and geometry have huge impact

- **Uncertainty in stress and predictability of results**
- It has long been known that rupture propagation and fault slip distribution depend on the applied stress field. However, it is perhaps unexpected how radically the rupture dynamics change for models in which the initial tectonic stress field is rotated only 10° clockwise. This finding is due to the range of fault orientations in this system; a small rotation of the stress field can bring some segments much closer to failure, whereas other segments are brought much farther from failure. This effect presents significant challenges to the prediction of earthquake size and ground motion for future events, as the local stress field is rarely known within a 10° precision. The problem is even more aggravated when considering other sources of stress heterogeneity. Our current models make a zeroth-order approximation: the stress field everywhere is simply a regional triaxial field, resolved into the different fault segments. However, natural stress fields are modulated by the effects of prior earthquakes on the fault system (e.g. Tse & Rice 1986; Rice 1993; Nielsen & Knopoff 1998; Lapusta *et al.* 2000; Duan & Oglesby 2005), which can lead to elevated stress levels near the corners of the segments (e.g. Fig. 3). Such stress build-up will be sensitive to the details of the loading history, any potential off-fault relaxation and the detailed geometry of the bend, each of which is estimated only with considerable uncertainty. Furthermore, the stress field near these geometrical discontinuities largely determines whether rupture may propagate through these obstacles or not. Thus, we find ourselves in the uncomfortable position in which the dynamics of the event, including its final size, may depend critically on the most uncertain aspects of the model.

Oglesby, D.D. and Mai, P.M., 2012. Fault geometry, rupture dynamics and ground motion from potential earthquakes on the North Anatolian Fault under the Sea of Marmara. *Geophysical Journal International*, *188*(3), pp.1071-1087.

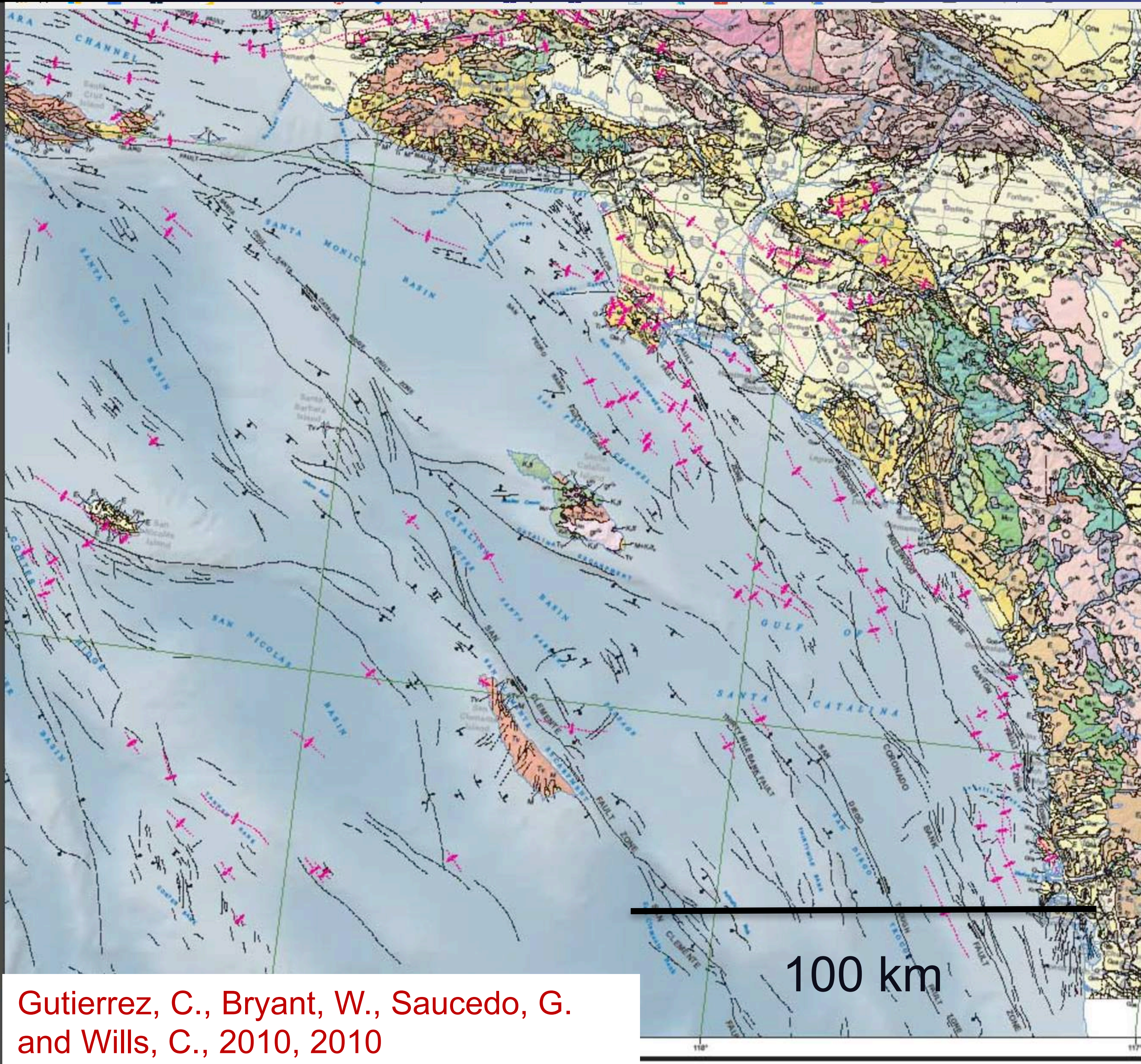
How dense are fault arrays?



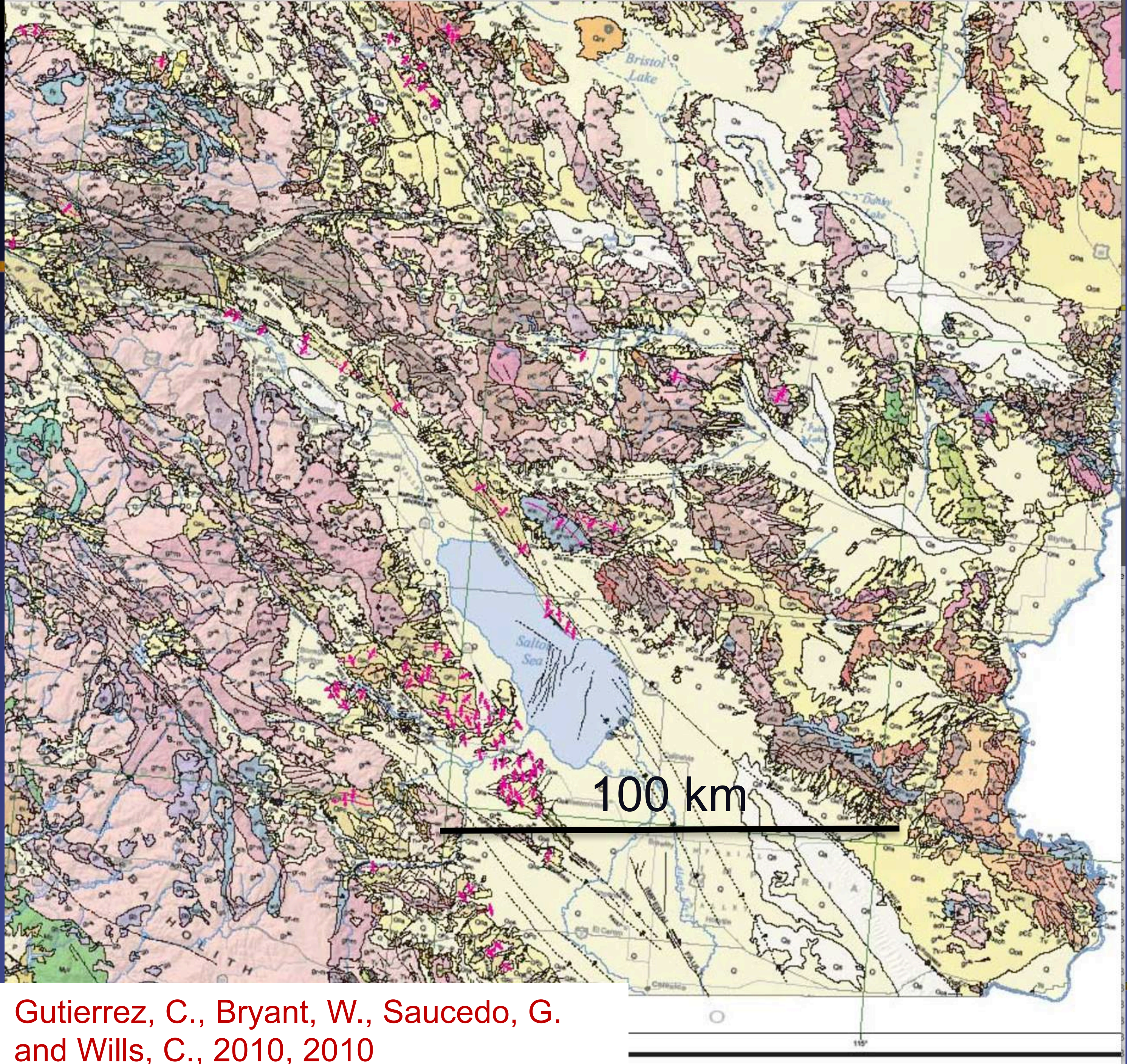


Gutierrez, C., Bryant, W., Saucedo, G. and Wills, C., 2010, 2010

Borderlands has 20-25 faults along a 100 km-wide traverse



Gutierrez, C., Bryant, W., Saucedo, G. and Wills, C., 2010, 2010



A typical 100 km long E-W line crosses only 8-12 faults in Salton Trough

Could offshore frequency be more representative in basins?

Gutierrez, C., Bryant, W., Saucedo, G. and Wills, C., 2010, 2010

Main points

Fault database is likely incomplete- especially in basins on land where agriculture, cities and Lake Cahuilla obscure

Fault zones are 100s m to >10 km wide

Many strike-slip faults are not vertical

More geologic mapping and subsurface analysis are needed in Gates. Esp. confirm main faults