Tectonic-geomorphic mapping along the northernmost San Jacinto fault zone and implications for slip distribution

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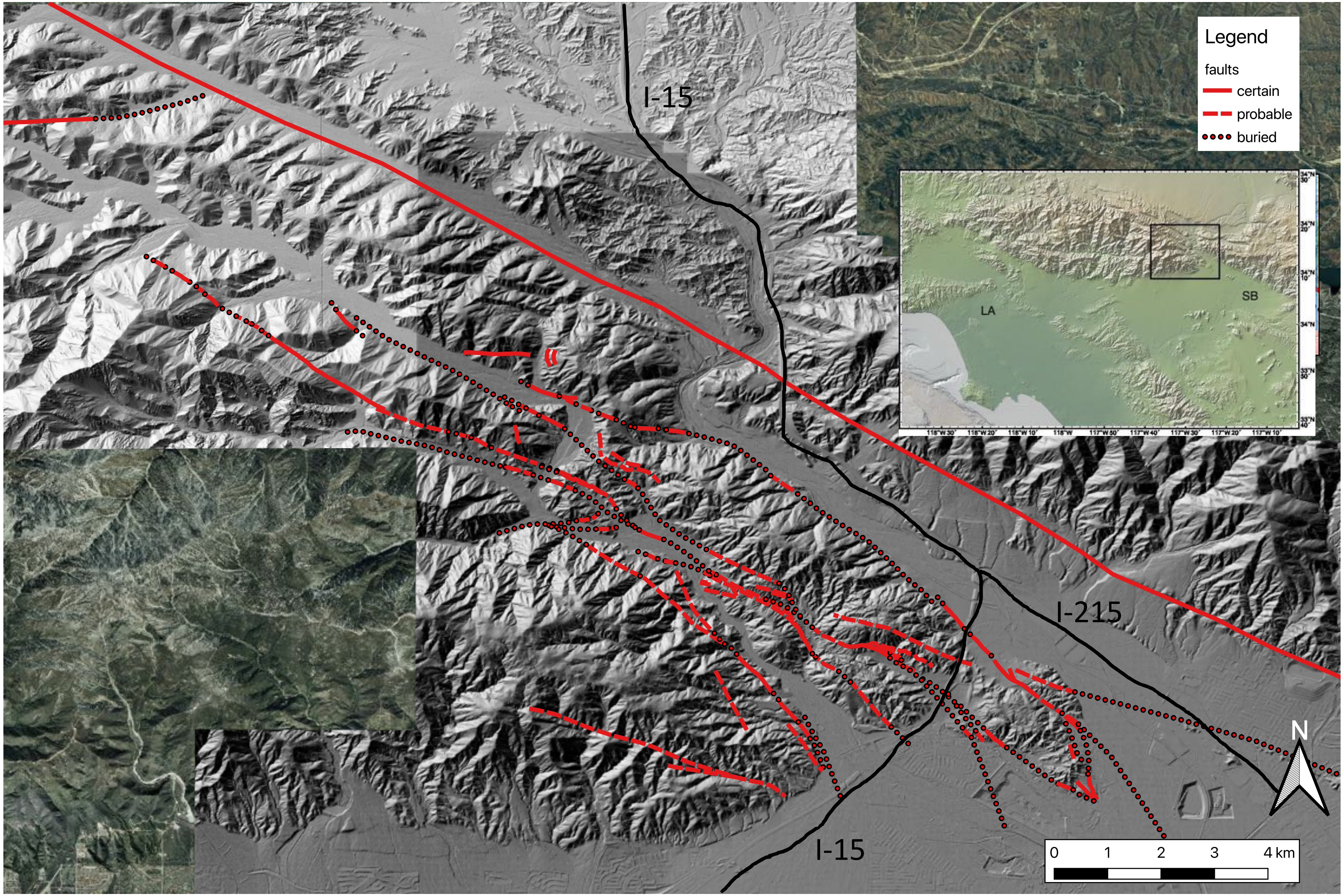
Northernmost San Jacinto fault zone (SJFZ)

Glen Helen fault

Middle San Jacinto fault

Lytle Creek fault

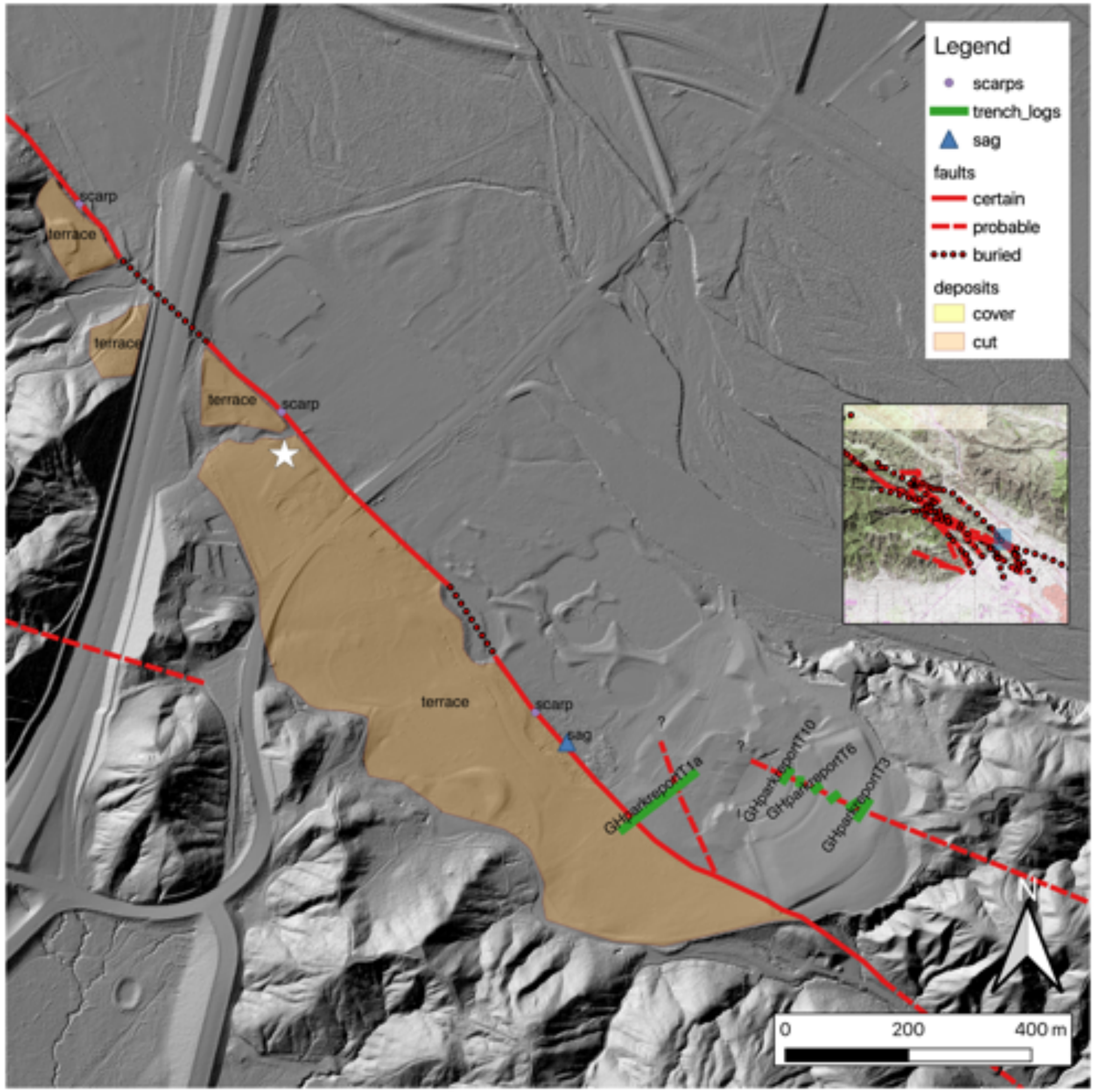


Methods

- Map geomorphic features related to tectonic activity
  - Aided by B4 and San Bernardino County LiDAR surveys
- Use existing consultant trench logs to locate faults in subsurface
- Identify potential paleoseismic and slip rate sites

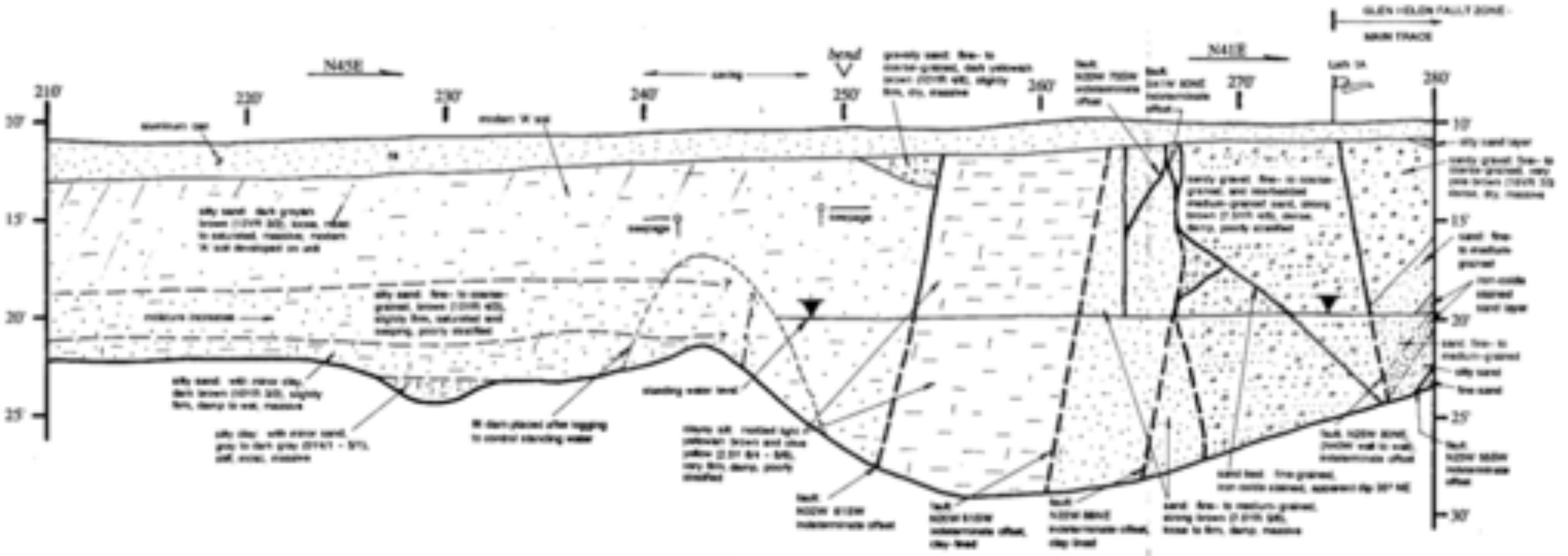
Glen Helen fault

- 5m high scarp (southwest side up) can be followed for over 1km
- Potential slip rate site (starred location)
    - Stream channel crosses scarp
- Trenching exposed the Glen Helen fault, as well as an older, inactive fault zone



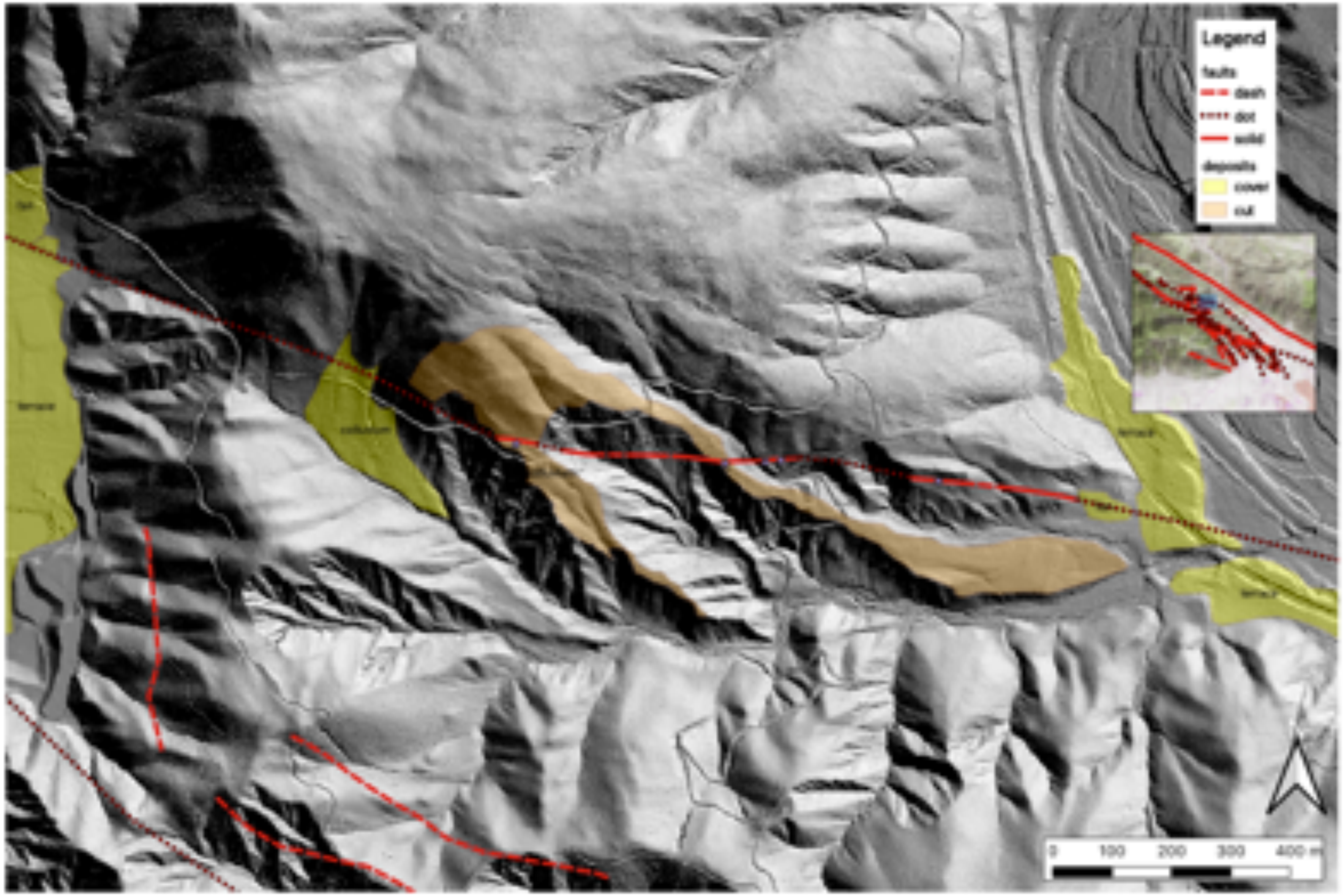
Glen Helen fault

- Offset of Holocene alluvium and modern “A” soil observed in trench 1 (Gary S. Rasmusen & Associates Inc., 1992)



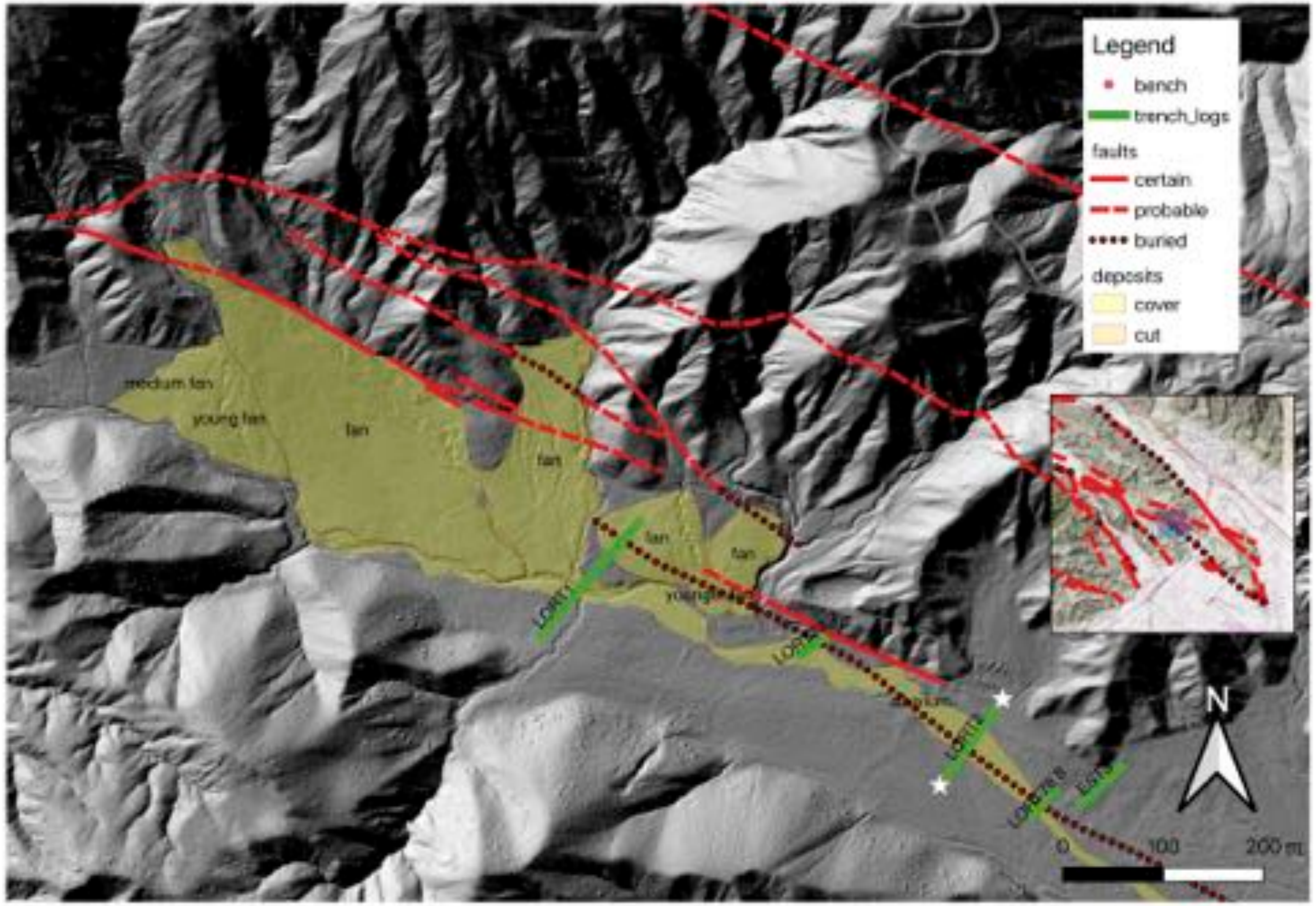
Glen Helen fault

- Linear mountain front along Cajon Creek where fault is buried under alluvial fans
- Buried under terrace deposits in Cajon Creek
- 1m high uphill-facing scarps (south side up) in colluvium
- Fault is buried under terrace deposits to northwest



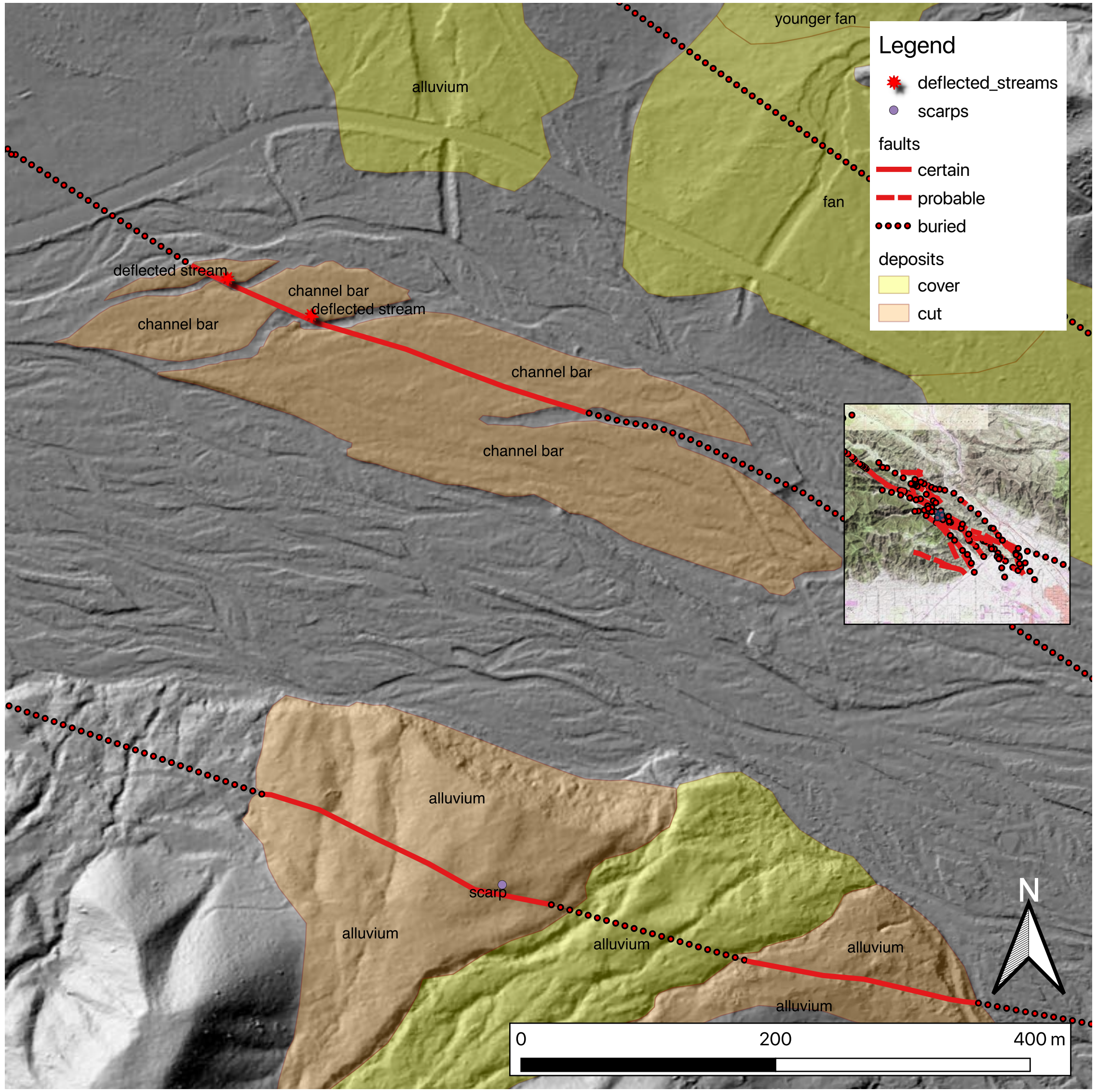
Middle San Jacinto fault

- Main trace is buried under recent alluvium
- Other traces are expressed as linear mountain fronts and benches
- Fault study by LOR Geotechnical Group Inc. (1994)
    - Trench 2 exposed cut layers of recent alluvium within 9.5 feet (2.9m) of the surface.
    - Detrital charcoal ages place the last surface rupture between calendar years 1380 and 1810 CE



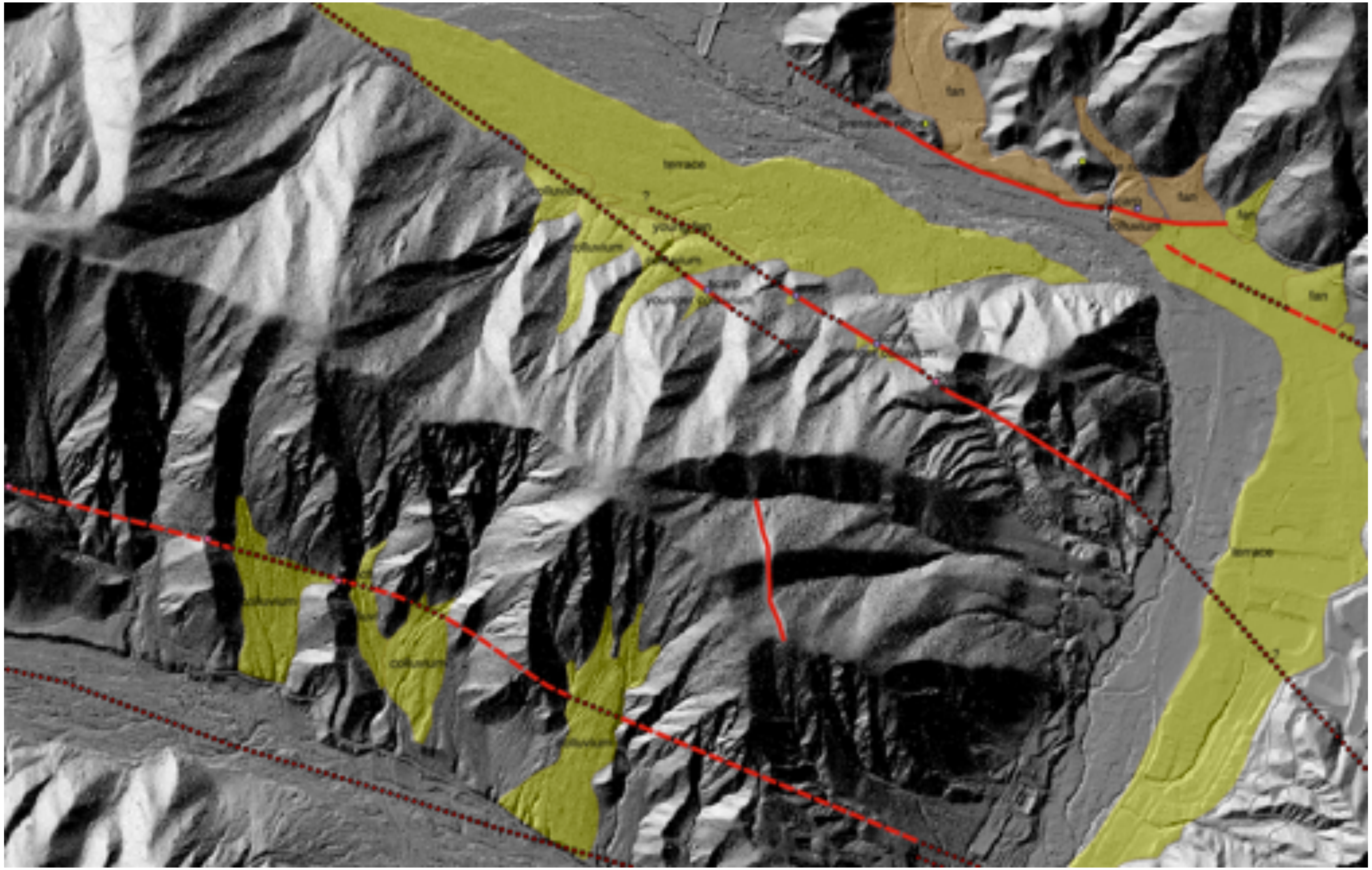
Middle San Jacinto fault

- Splits into 3 strands
- North strand is buried under recent alluvium
- Middle strand deflects channels in old channel bar
  - 15-25m right-lateral displacement
  - Attempts to date channel bar were unsuccessful
- South strand deforms older lobes of an alluvial fan
  - Scarp is 3m high (NE side up)
  - No evidence of lateral displacement



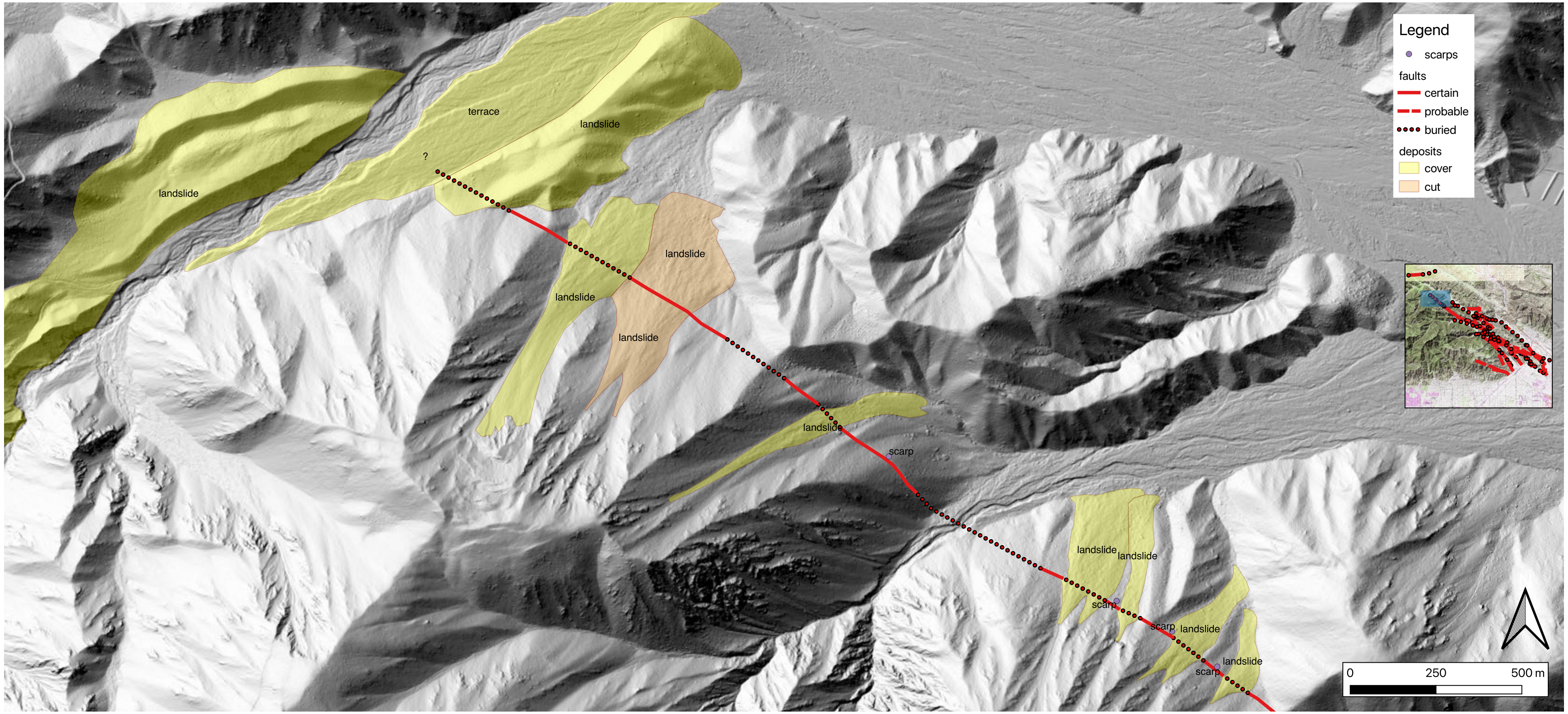
Middle strand of SJF shows northeast side up component

- Uphill-facing scarps on northeast side of ridge
- Erosion fronts on southwest side of ridge
  - Likely initiated when northeast side up fault motion over-steepened slope
  - Erosion fronts propagate upslope



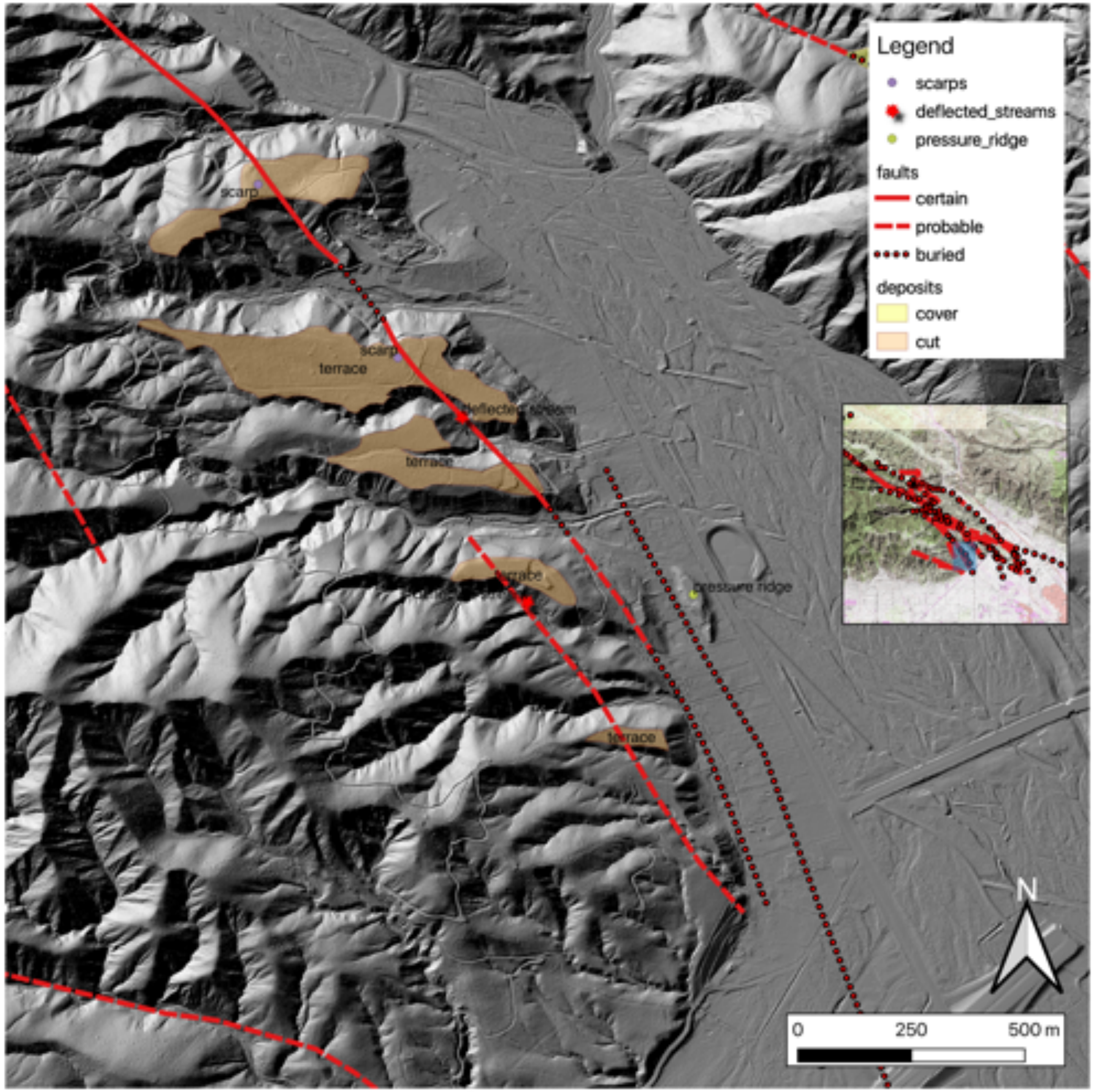
Middle San Jacinto fault

- Uphill facing scarp cuts one landslide, and is covered by several younger landslides
- Scarp extends semi continuously for 4.5 km
- Furthest NW extent of SJFZ

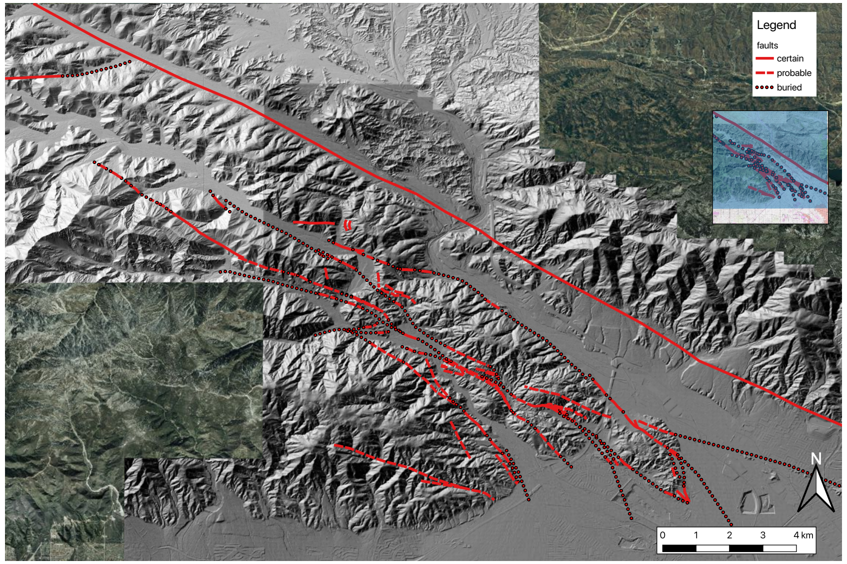


Lytle Creek fault

- Slip rate study by Mezger and Weldon (1983) yielded result of 2.5mm/yr
- Deflected streams in terrace deposits
- Lytle Creek fault is mostly expressed as fault benches



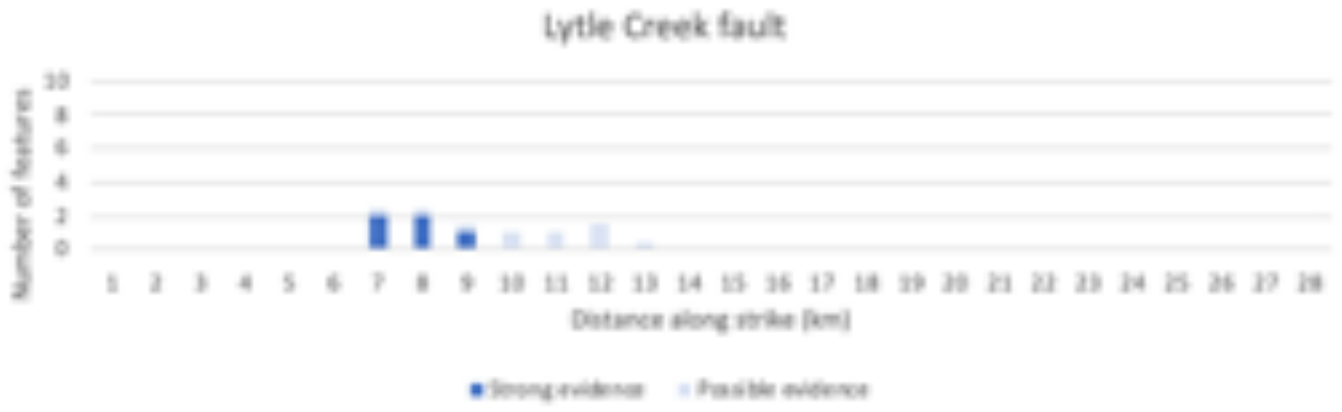
Analyzing distribution of geomorphic evidence

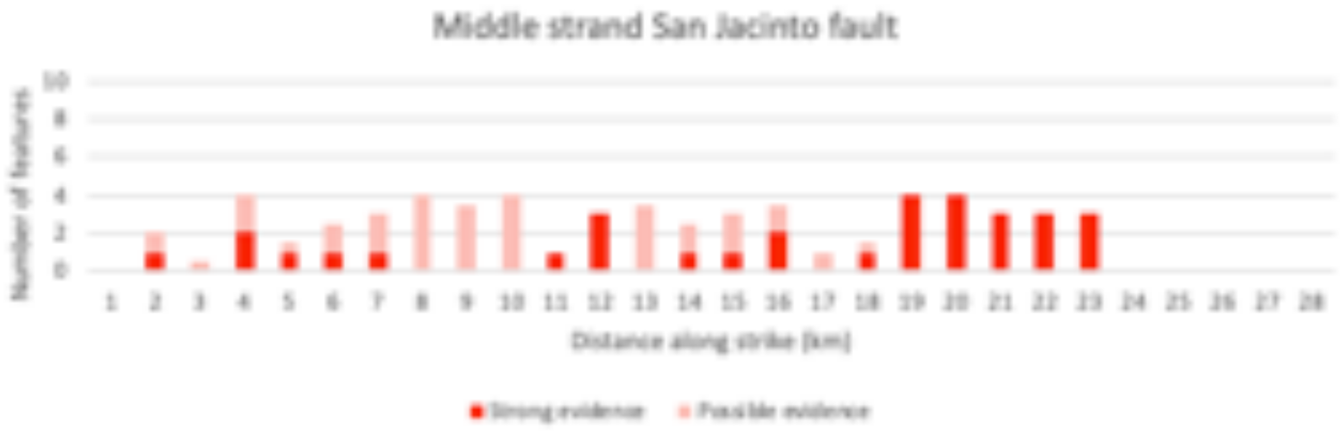


- Divide field area into 1km blocks along strike
- Count features per km block
- Classify strong vs possible evidence
  - Strong evidence: fault scarp, cut Quaternary deposit, offset stream, trench log, sag, shutter ridge
  - Possible evidence: bench, saddle, deflected stream, bedrock offset, linear mountain front
  - Count strong evidence as 1, and possible evidence as 0.5

Discussion

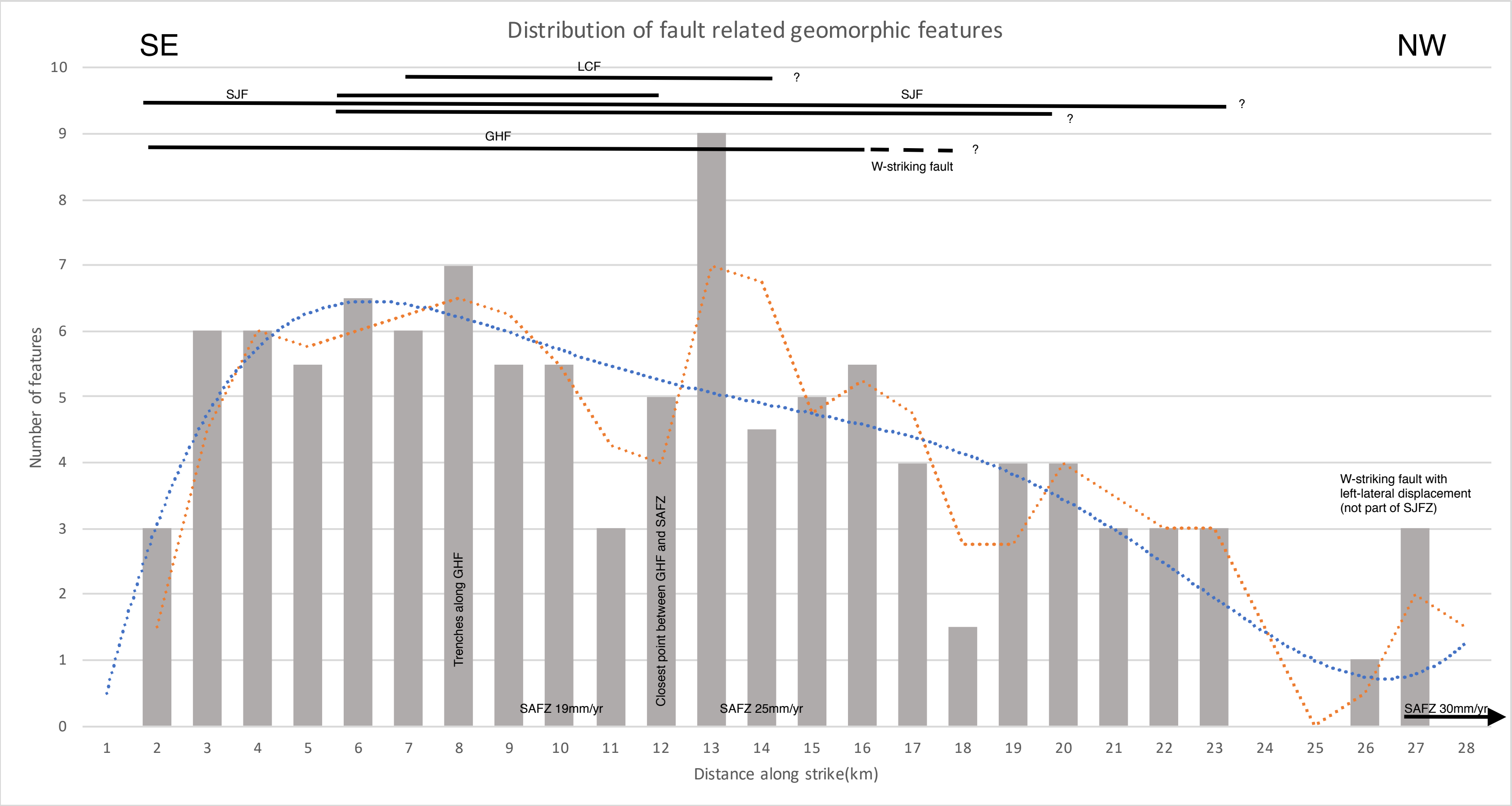
- Middle strand San Jacinto fault displays the most geomorphic evidence of being recently active





Discussion

- Geomorphic expression across the 3 strands of the SJFZ steadily increases to the southeast over a zone at least 20km long
- If geomorphic expression is a proxy for fault slip, this suggests slip is transferred to SJFZ gradually



Conclusions

- Geomorphic expression across the 3 strands of the SJFZ steadily increases to the southeast over a zone at least 20km long
- Middle strand SJF displays the strongest geomorphic evidence of being recently active
- Middle strand SJF had a ground rupturing earthquake between calendar years 1380 and 1810 CE (LOR Geotechnical Group Inc., 1994)
- Middle strand SJF displays northeast-side up component

Thank you!

References

Clopine, G.A., 1987, Geologic/seismic report for parcel #5, parcel map no. 6983, 9.9 acres, a portion of the northeast quarter of section 22, township 2 north, range 6 west, S.B.B. & M. Lytle Creek Area, San Bernardino County, California:

DeMets, C., and Dixon, T.H., 1999, New kinematic models for Pacific-North America motion from 3 Ma to present, I: Evidence for steady motion and biases in the NUVEL-1A model: Geophysical Research Letters, v. 26, p. 1921–1924.

Dibblee Jr, T.W., 2003, Geologic map of the Telegraph Peak and Phelan quadrangles: San Bernardino County, California: Dibblee Geological Foundation, Map DF-107, v. 1, p. 24000.

Johnston, J.J., and Leuer, J.P., 1994, Geologic fault investigation Sycamore Flats area San Bernardino County, California:

Jordan, F.F., and Martin, J.J., 1992, Subsurface engineering geology investigation proposed ampitheater approximately 45 acres Glen Helen Regional Park Devore, California:

Kaiser, A., Balfour, N., Fry, B., Holden, C., Litchfield, N., Gerstenberger, M., D'anastasio, E., Horspool, N., McVerry, G., and Ristau, J., 2017, The 2016 Kaikōura, New Zealand, earthquake: preliminary seismological report: Seismological Research Letters, v. 88, p. 727–739.

Kenyon, S., 2014, Using offset geomorphic features to estimate paleoearthquake slip distribution on the Claremont Fault, northern San Jacinto fault zone [M.S.]: California State University, Long Beach, 77 p., https://search.proquest.com/docview/1530205242/abstract/32394743935F4DABPQ/1 (accessed February 2019).

Lozos, J.C., 2016, A case for historic joint rupture of the San Andreas and San Jacinto faults: Science advances, v. 2, p. e1500621.

Matmon, A., Schwartz, D.P., Finkel, R., Clemmens, S., and Hanks, T., 2005, Dating offset fans along the Mojave section of the San Andreas fault using cosmogenic 26Al and 10Be: Geological Society of America Bulletin, v. 117, p. 795–807.

Matti, D.M.M.J.C., 2001, Geologic Map of the Devore 7.5'quadrangle, San Bernardino County, California:

McGill, S.F., Owen, L.A., Weldon, R.J., and Kendrick, K.J., 2013, Latest Pleistocene and Holocene slip rate for the San Bernardino strand of the San Andreas fault, Plunge Creek, Southern California: Implications for strain partitioning within the southern San Andreas fault system for the last ~35 k.y.: GSA Bulletin, v. 125, p. 48–72, doi:10.1130/B30647.1.

McGill, S.F., Owen, L.A., Weldon, R.J., Kendrick, K.J., and Burgette, R.J., 2019, Latest Quaternary slip rates of the San Bernardino Strand of the San Andreas Fault, southern California, from Cajon Creek to Badger Canyon | Southern California Earthquake Center: Southern California Earthquake Center, https://www.scec.org/publication/10001 (accessed May 2020).

McPhillips, D., and Scharer, K.M., 2018, Quantifying uncertainty in cumulative surface slip along the Cucamonga Fault, a crustal thrust fault in southern California: Journal of Geophysical Research: Solid Earth, v. 123, p. 9063–9083.

Mezger, L.L., and Weldon, R.J., 1983, Tectonic implications of the Quaternary history of lower Lytle Creek, southeast San Gabriel Mountains, *in* Geological Society of America Abstracts with Programs, v. 15, p. 418.

Morton, D.M., Matti, J.C., Digital preparation by Koukladas, C., and Cossette, P.M., 2001a, Geologic map of the Cucamonga Peak 7.5' quadrangle, San Bernardino County, California: U.S. Geological Survey Open-File Report USGS Numbered Series 2001–311, 22 p., http://pubs.er.usgs.gov/publication/ofr01311 (accessed March 2019).

References

Morton, D.M., Matti, J.C., Powell, R.E., and Weldon, R.J., 1993, Extension and contraction within an evolving divergent strike-slip fault complex: The San Andreas and San Jacinto fault zones at their convergence in southern California: The San Andreas fault system: Displacement, palinspastic reconstruction, and geologic evolution, v. 178, p. 217–230.

Morton, D.M., Woodburne, M.O., Foster, J.H., Morton, G., and Cossette, P.M., 2001b, Geologic map of the Telegraph Peak 7.5'quadrangle, San Bernardino County, California: US Geological Survey.

Onderdonk, N., McGill, S., and Rockwell, T., 2018, A 3700 yr paleoseismic record from the northern San Jacinto fault and implications for joint rupture of the San Jacinto and San Andreas faults: Geosphere, v. 14, p. 2447–2468.

Onderdonk, N.W., McGill, S.F., and Rockwell, T.K., 2015, Short-term variations in slip rate and size of prehistoric earthquakes during the past 2000 years on the northern San Jacinto fault zone, a major plate-boundary structure in southern California: Lithosphere, v. 7, p. 211–234.

Rockwell, T.K., Dawson, T.E., Ben-Horin, J.Y., and Seitz, G., 2015, A 21-event, 4,000-year history of surface ruptures in the Anza seismic gap, San Jacinto Fault, and implications for long-term earthquake production on a major plate boundary fault: Pure and Applied Geophysics, v. 172, p. 1143–1165.

Rockwell, T., Loughman, C., and Merifield, P., 1990, Late Quaternary rate of slip along the San Jacinto fault zone near Anza, southern California: Journal of Geophysical Research: Solid Earth, v. 95, p. 8593–8605.

Salyards, S.L., Sieh, K.E., and Kirschvink, J.L., 1992, Paleomagnetic measurement of nonbrittle coseismic deformation across the San Andreas fault at Pallett Creek: Journal of Geophysical Research: Solid Earth, v. 97, p. 12457–12470.

Sedki, Z., 2013, LiDAR and field investigation along the San Andreas Fault, San Bernardino/Cajon Pass area, Southern California: California State University, Long Beach.

Seitz, G., Weldon II, R., and Biasi, G.P., 1997, The Pitman Canyon paleoseismic record: A re-evaluation of southern San Andreas fault segmentation: Journal of Geodynamics, v. 24, p. 129–138.

Sieh, K.E., 1978, Prehistoric large earthquakes produced by slip on the San Andreas fault at Pallett Creek, California: Journal of Geophysical Research: Solid Earth, v. 83, p. 3907–3939.

Spotila, J.A., House, M.A., Blythe, A.E., Niemi, N.A., Bank, G.C., and Barth, A., 2002, Controls on the erosion and geomorphic evolution of the San Bernardino and San Gabriel Mountains, southern California: SPECIAL PAPERS-GEOLOGICAL SOCIETY OF AMERICA, p. 205–230.

Weldon, R.J., and Sieh, K.E., 1985, Holocene rate of slip and tentative recurrence interval for large earthquakes on the San Andreas fault, Cajon Pass, southern California: Geological Society of America Bulletin, v. 96, p. 793–812.