NON-CHARACTERISTIC SLIP AND EARTHQUAKE CLUSTERING ON THE IMPERIAL FAULT, MESQUITE BASIN, IMPERIAL VALLEY, CALIFORNIA

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ABSTRACT

We excavated a series of trenches across the Mesquite Basin section of the Imperial fault, the primary plate-boundary fault in the southern Imperial Valley, to explore its late Holocene rupture history and to document slip per event. We identified several channels that cross the fault at a high angle and are displaced in the subsurface by the fault. These channels are incised into or embedded within lacustrine strata that are associated with major filling events of Lake Cahuilla. Three-dimensional excavation of these channels has yielded information on slip in the past six surface ruptures. Displacement is well documented for the 1979 and 1940 events, with 15–20 cm of coseismic lateral slip occurring in each event; creep and afterslip following these events are not well documented, however, but may be comparable in amount. A small rill, which also corresponds to the feeder channel for older beheaded channels, is deflected by about 60 cm, which we attribute to the 1979 and 1940 events plus creep and afterslip. This rill, which incises the lake sediments from the ca. AD 1700 lake, appears to record slip from only these two historical earthquakes, which is consistent with earlier paleoseismic studies farther south.

Three subsurface channels, which each measure ~50 cm in width, are completely beheaded by slip on the fault, with no evidence for rounding of the channels or flow along the fault. This relationship argues that displacement in each of these prehistorical events—the third, fifth, and sixth events back—was at least 50 cm, and the channel spacing suggests displacements of 1.4–1.5 m for each of the these past events. The fourth event back—which occurred during a channel-filling episode—produced very little slip, as the channel then re-incised in the same location, without any apparent flow along the fault. These observations suggest that the amount of slip per event at this site varies by as much as a factor of 10, and that the behavior of the fault in the historical period is not typical of the long-term average.

The ages of these past surface ruptures are constrained by their stratigraphic relationship to lacustrine intervals, by local ^{14}C dating, and by analysis of the regional late Holocene lacustrine stratigraphy. The youngest pre-1940 event (Event 3) displaces a channel that is embedded between lakes 1a and 1b, which date to the late 17th and earliest 18th centuries, and occurred during or just prior to the last lake highstand. We attribute the additional 1.4 m of offset on this channel (in addition to the 60-cm deflection of the modern rill) to the event recognized at the International Border that occurred during the highstand of the last lake at ca. AD 1700. Event 4 produced very little displacement at the site (possibly an amount similar to that which occurred in 1940 or 1979) but is clearly recognized as a unique event horizon. Both Events 5 and 6 occurred between lakes 1b and 2—most likely the interval between about AD 1500 and 1600—and produced an additional 1.4 m and 1.5 m of slip, respectively. Thus, the northern Imperial fault has sustained about 5.0 m of slip in the past 500 years with the majority (~4.4 m) occurring in the four earlier events between about AD 1500 and 1700.

These observations suggest that: (1) the 1940 and 1979 events were not "characteristic" for the northern Imperial fault, but rather, that the 1940 event sustained an incomplete rupture which was followed by the 1979 "make-up" event, perhaps due to stress loading by high slip in the border region; (2) the Imperial fault appears to be more typified by end-to-end ruptures, assuming that the larger displacements represent more complete and evenly distributed stress release; (3) the slip rate for the Imperial fault in the Mesquite Basin is about 1 cm/yr for the past five centuries; (4) slip per event ranges from about 0.15 to 1.5 m; and (5) scaling slip per event in Mesquite Basin with maximum slip near the International Border, and assuming that most end-to-end ruptures sustain 5–6 m along the central portion of the fault, suggests that the Imperial fault accommodates a slip rate of about 3–4 cm/yr, close to that estimated by GPS.

Fault-Parallel Trenches

SE — T6 SW Wall — NW

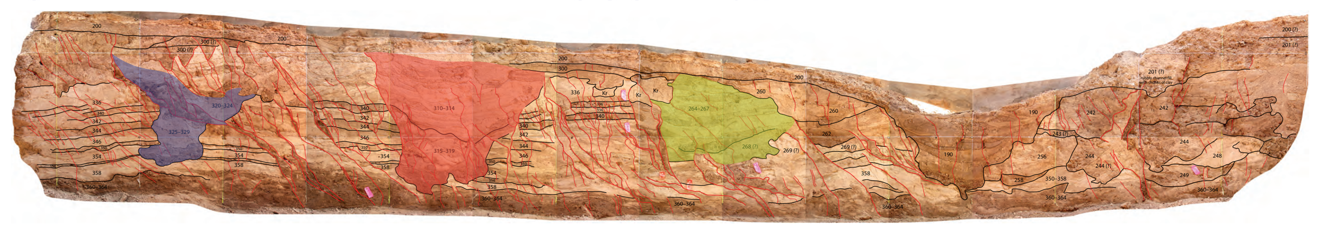
SE — T6 NE Wall (reflected) — NW

Footwall — SW of fault

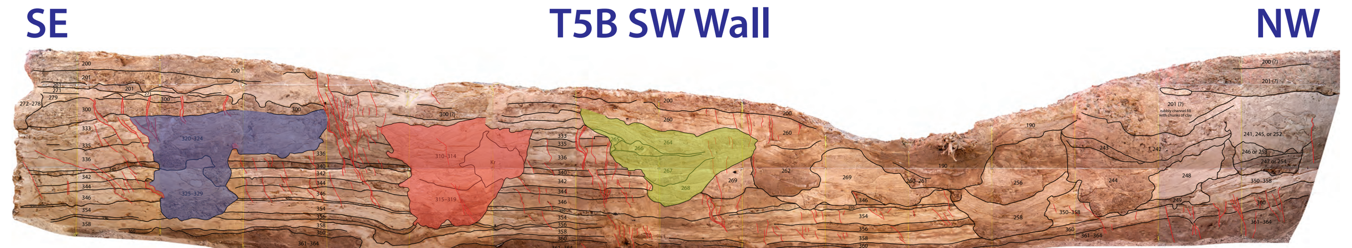
Hangingwall — NE of fault

Scale for all logs:
(no vertical exaggeration)
0 — 1 m

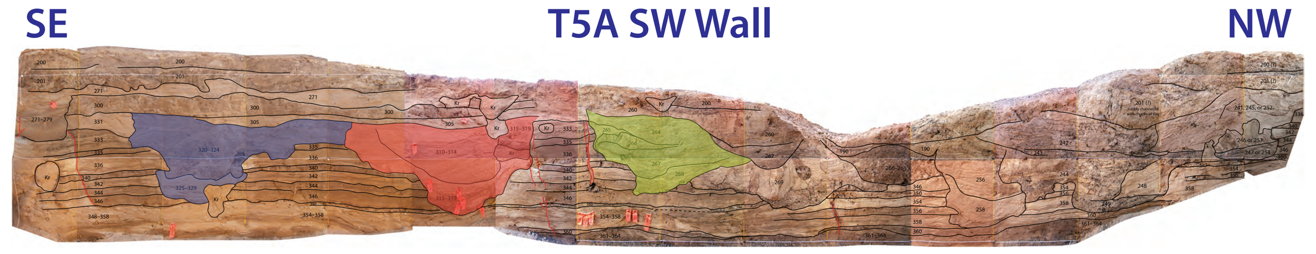
SE — T5C SW Wall — NW



SE — T5B SW Wall — NW

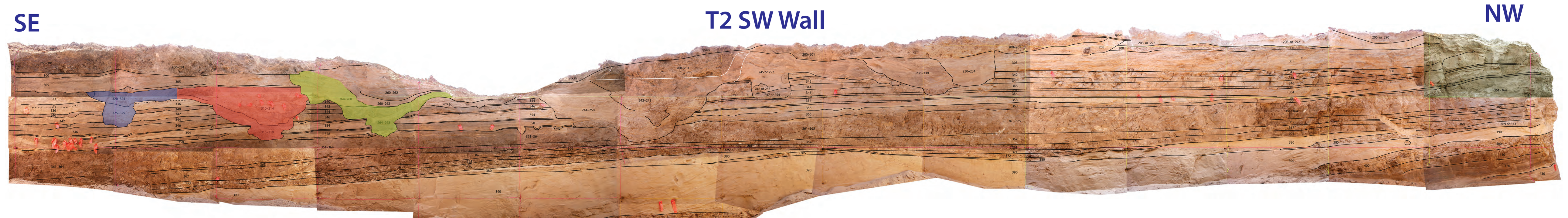


SE — T5A SW Wall — NW



SE — T5A NE Wall (reflected) — NW

SE — T2 SW Wall — NW



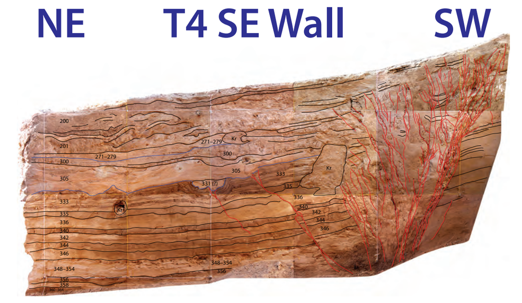
^{14}C Dating Results

Sample ID	Unit #	^{14}C Age (yrs BP)	Calibrated Calendric Age Range (2σ)
IFD-T2-C61	205	130 ± 15	AD 1681-1953
IFD-T5-C78	271-279	3095 ± 15	
IFD-T3-C66	305-367	1200 ± 15	
IFD-T2-C67	306	320 ± 15	AD 1495-1642
IFD-T2-C30	310-314	795 ± 50	
IFD-T2-C25	310-314	670 ± 15	
IFD-T2-C24	310-314	670 ± 15	
IFD-T2-C23	310-314	655 ± 15	
IFD-T5-C72	315-319	825 ± 15	
IFD-T5-C73	315-319	630 ± 15	
IFD-T5-C75	315-319	605 ± 15	
IFD-T5-C86	315-319	615 ± 25	
IFD-T5-C87	315-319	680 ± 15	
IFD-T5-C68	331/333	650 ± 15	
IFD-T2-C21	336	640 ± 15	
IFD-T2-C36	342	380 ± 15	AD 1449-1617
IFD-T2-C37	342	2265 ± 15	
IFD-T2-C44	342/344	655 ± 15	
IFD-T2-C20	342/344	630 ± 15	
IFD-T2-C49	346	655 ± 15	
IFD-T5-C79	348-358	630 ± 15	
IFD-T5-C80	348-358	615 ± 15	
IFD-T5-C84	348-358	625 ± 15	
IFD-T2-C14	349-358 ?	1125 ± 15	
IFD-T2-C11	349-358 ?	610 ± 15	
IFD-T2-C45	354/356	625 ± 15	
IFD-T2-C47	356	605 ± 15	AD 1301-1400
IFD-T3-C51	366/367	2545 ± 15	
IFD-T3-C50	368-385	2715 ± 25	
IFD-T3-C42	390	1515 ± 15	
IFD-T3-C41	400	1180 ± 15	AD 779-891
IFD-T3-C40	400	2570 ± 15	

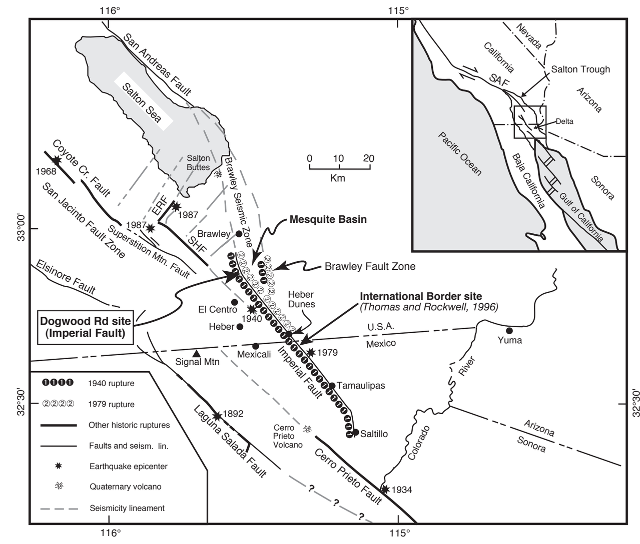
Fault-Normal Trenches

SW — T4 NW Wall — NE

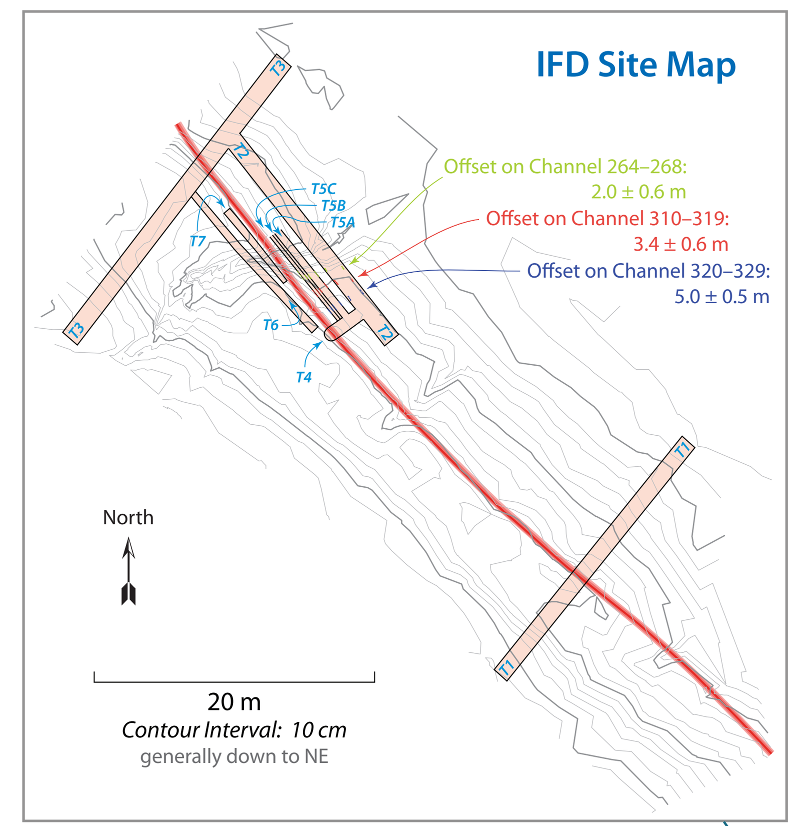
NE — T4 SE Wall — SW



Maps & Overview Photos



IFD Site Map



Slip Observed in 1979