Final Technical Report for USGS/NEHRP #04HQGR0042 (UO #238600)

Project Title: Filling the Gap: Completion of a 5,000 year Paleoearthquake record on the San Andreas fault at Wrightwood California

PI: Ray Weldon, University of Oregon (contact: ray@uoregon.edu or 541-346-4584)
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SUMMARY

This project attempted to build a complete record of earthquakes at the Wrightwood paleoseismic site on the San Andreas fault in Southern California. The site preserves a record of ~5000 years of sedimentation and deformation associated with ~50 earthquakes (given the average recurrence of ~100 years). Prior to this project approximately 30 earthquakes had been characterized in two time intervals from ~3000 BC to 1500 BC (Scharer *et al.*, 2007) and from 500 AD to the present (Biasi *et al.*, 2002; Fumal, *et al.*, 2002; Weldon, *et al.*, 2002, 2004, 2005). We were able to document at least 5 and up to 12 additional earthquakes within the "gap" (or Middle section) in between the published sections (that we call the "Young" and "Old" sections; Figures 3 and 6 below). As discussed below, some of the earthquakes recognized in poorly resolved sedimentary sections from separate trenches probably overlap, so the exact number and timing of earthquakes within the gap cannot be established without significantly more dating to better correlate these physically unconnected sections, or the discovery of a complete section spanning the gap with good evidence for earthquakes.

We do not feel that we have documented a complete record of the earthquakes that occurred during this time period because we were unable to locate a place within the site that contained both a thick enough sedimentary section to separate the events from each other and contemporaneous faulting and folding to characterize the events. Because we do know that the required section exists in a relatively undeformed parts of the site, we believe that it remains possible to fill the gap and build a complete record for the past 5,000 years, but it will take at least one more season of field work and logistically difficult deep excavations to expose the required section where it is involved in the faulting and folding produced by the San Andreas fault, because we have exhausted the possibilities of finding the combination of section and deformation near the surface.

Report:

The Wrightwood paleoseismic site (location, Figure 1; site map, Figure 2; stratigraphic section, Figure 3) has been one of the most successful paleoseismic sites in the world, with more than 35 prehistoric earthquakes recognized to date. Because only about 3000 years of the documented 5000 year stratigraphic record (Figure 5) has been adequately exposed to work out a complete record of earthquakes, the potential exists to establish a 5000 year long record. This project was our first attempt to fill in the ~2000 year "gap" between about 1500 BC and 500 AD, that we call the "Middle" section. We excavated trenches 37 to 46, re-evaluated the evidence for earthquakes in the middle section in previous trenches (esp. T8-10, T31&T35), and explored the site with pits and ground penetrating radar in an attempt to find the "sweet spot" where adequate section

and clear evidence for deformation related to earthquakes occur together. Unfortunately, evidence for earthquakes was only found in the key middle section where it was highly attenuated (T8-10; green section in composite trench log in Figure 7; see Weldon et al., 2002 for detailed trench logs), or in isolated pockets of section formed in structural depressions that could not be directly connected (*i.e.* by physically tracing individual layers) to the more extensive exposures of the middle section (Figures 4, 5). While it would be possible to directly date these isolated pockets of section and thus build a complete record, the uncertainties in radiocarbon dating make it very difficult to exactly correlate the sections and we might double count some earthquakes that have slightly different age constraints in two places but are actually the same event. Thus we decided to summarize our results (Figure 6) by trench and have not attempted to establish a chronology within the middle interval until additional data are available.

Radar work:

One approach we have used to extend our understanding of the spatial distribution of the stratigraphy at the site was ground penetrating radar. Figure 7 shows some of the results from an unpublished University of Oregon MS Thesis by Reina Foxx. Radar lines were run parallel to previously excavated trenches and compared to the trench logs of the pre-existing trenches. As shown in the upper 3 panels of Figure 7, Radar lines 5 (C and D were multiple runs parallel to trenches 1, 6, 7, 8, 9, 10), the radar was quite successful in imaging the offset and tilted blocks in the "Secondary Zone" (left side) and the onlap of sediments in the "Main Zone" (right side). Based on this success, we conducted a series of radar lines across the site, including line 12 shown at the bottom of Figure 7, parallel to the main trace, where trench 41 on Figure 2 was subsequently excavated.

Unfortunately, most of the truncated reflectors and folds interpreted in the radar line (red lines in the lowermost Figure 5) turned out to be undisturbed bedding when Trench 41 was subsequently excavated. Only the onlap relationship, seen on the eastern (right) side of the line, contained useful paleoseismic information (see T41 in Figure 5).

Biasi, G.P., Weldon, R.J.II, Fumal, T.E., and Seitz, G.G., 2002, Paleoseismic event dating and the conditional probability of large earthquakes on the Southern San Andreas fault, California, *Bulletin of the Seismological Society of America*, v. 92, p. 2761-2781.

Fumal, T.E., Weldon, R.J.II, Biasi, G.P., Dawson, T.E., Seitz, G.G., Frost, W.T., and Schwartz, D.P., 2002, Evidence for large earthquakes on the San Andreas fault at the Wrightwood, California paleoseismic site: A.D. 500 to Present, *Bulletin of the Seismological Society of America*, v. 92, p. 2726-2760.

Scharer, K.M., Weldon, R.J.II, Fumal, T.E., and Biasi, G.P., 2007, Paleoearthquakes on the southern San Andreas Fault, Wrightwood CA, 3000 to 1500 BC, *Bulletin of the Seismological Society of America,* v. 97, p. 1054-1093.

Weldon, R.J.II, Fumal, T.E., Biasi, G.P., and Scharer, K.M., 2005, Past and future earthquakes on the San Andreas fault, *Science*, v.308, p. 966-967.

Weldon, R.J.II, Scharer, K.M., Fumal, T.E., and Biasi, G.P., 2004, Wrightwood and the earthquake cycle: what a long recurrence record tells us about how faults work, *GSA Today,* v. 14, 4-10.

Weldon, R.J.II, Fumal, T.E., Powers, T.J., Pezzopane, S.K., Scharer, K.M., and Hamilton, J.C., 2002, Structure and earthquake offsets on the San Andreas fault at the Wrightwood, California paleoseismic site, *Bulletin of the Seismological Society of America,* v. 92, 2704-2725.

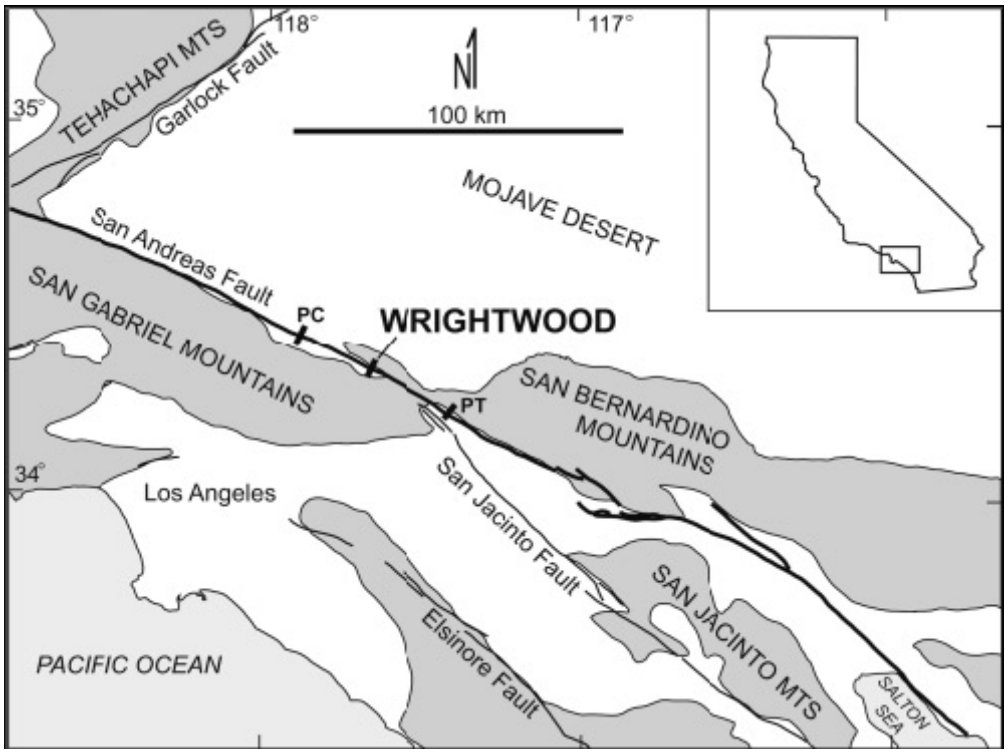


Figure 1 - Location of the Wrightwood site. It is immediately NW of a possible segment boundary at the junction of the San Andreas and San Jacinto faults, but appears to preserve records of most of the earthquakes recognized to the north (*e.g.* the Pallett Creek-PC-site), and south (*e.g.* the Pitman Canyon-PT-site). From Scharer *et al.*, 2007).

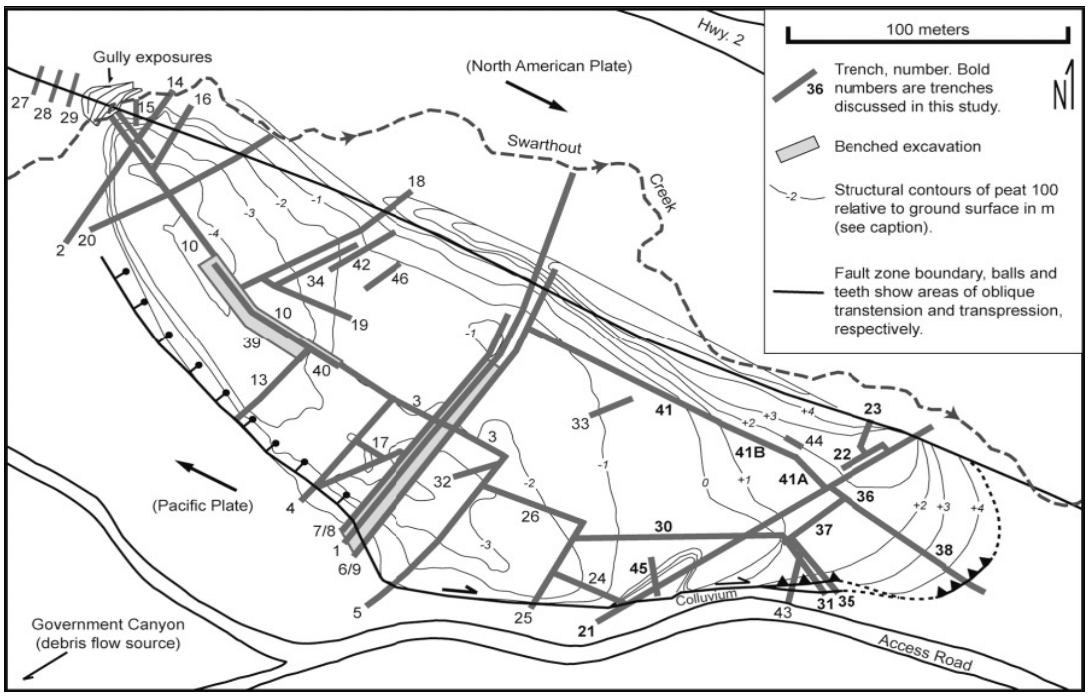


Figure 2 – Site map of the Wrightwood paleoseismic site. Trenches 37-46 were excavated during the time period of this grant. From Scharer *et al.*, 2007).

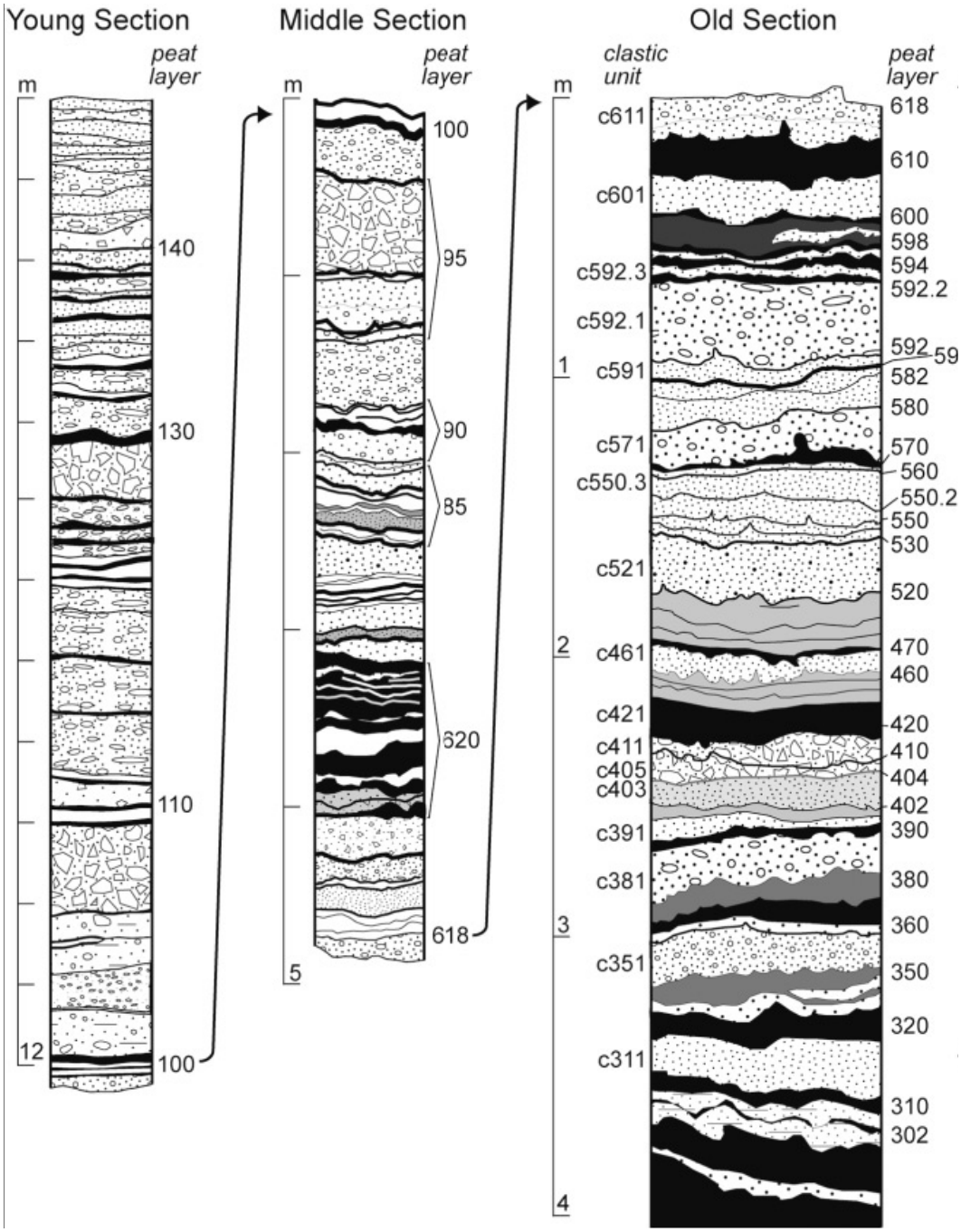


Figure 3 - Complete stratigraphic section of the Wrightwood paleoseismic site. The target of this proposal was the Middle section, below peat 100 in the upper section nomenclature and above peat 620 in the lower section. From Scharer *et al.*, 2007).

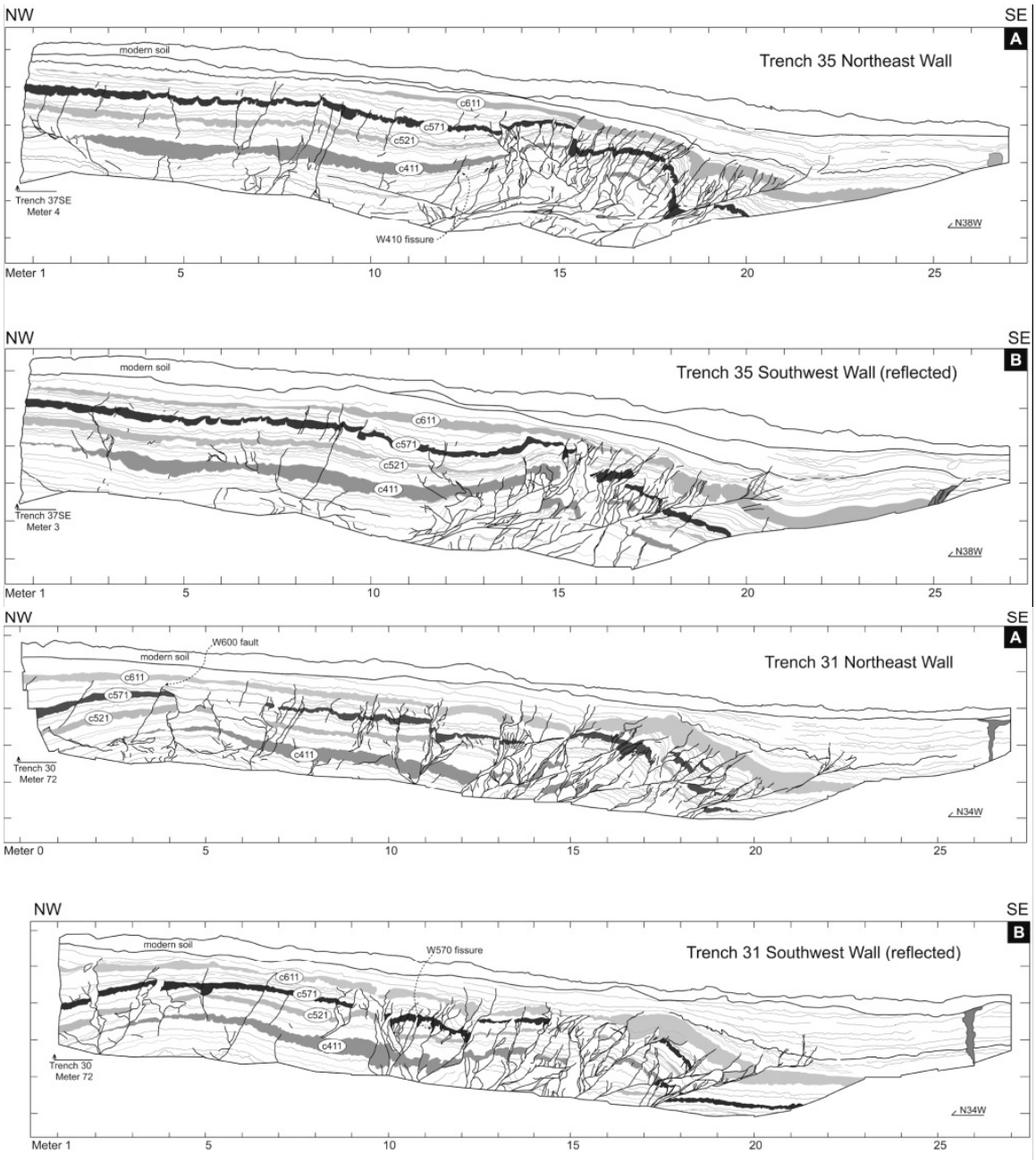


Figure 4 - Evidence for earthquakes above unit c611 (~ top of the lower section) in trenches T31 and 35. Faulting propagates into growth strata above c611, where sequential offset, discrete growth of section, and a subsequent large fissure (extreme right edge of figures) can be interpreted as being produced by up to 5 earthquakes. because this section pinches out onto the anticline to the NW, the individual units cannot be directly connected (*i.e.* by physical tracing of layers) to our master section. Radiocarbon dating of these growth strata would provide some constraint on the ages of the earthquakes, our experience suggests that it is impossible to distinguish earthquakes separated by only decades without direct stratigraphic control. From Scharer *et al.*, 2007).

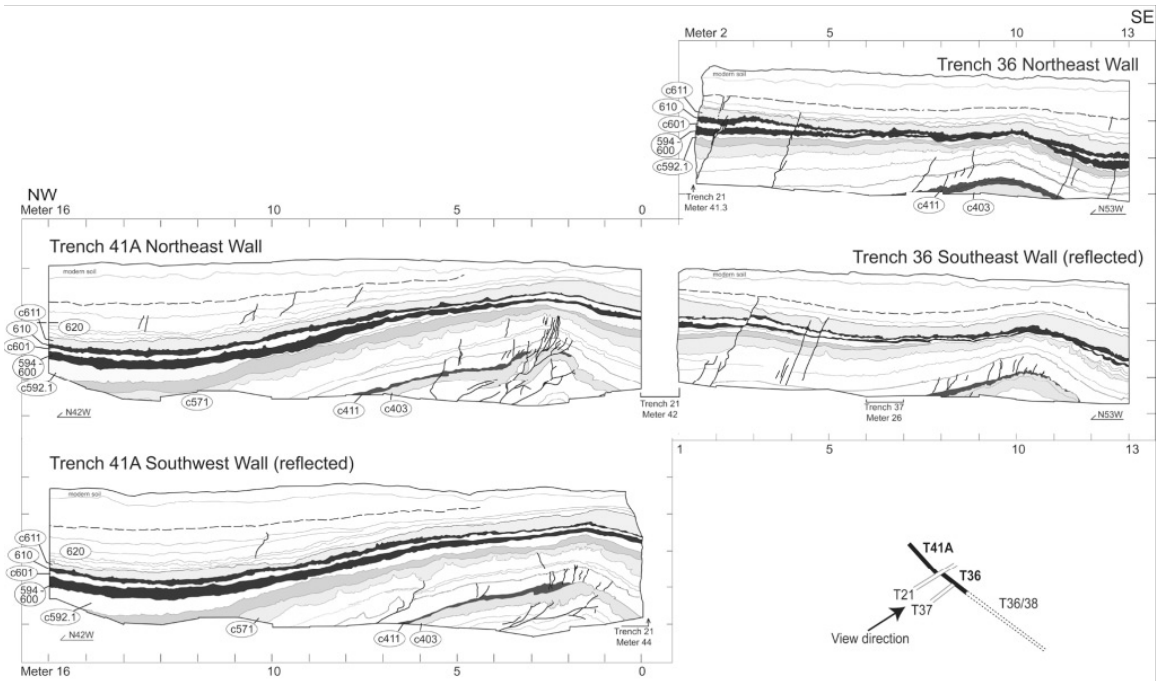


Figure 5 – Growth strata above peat 620 can be interpreted as at least two earthquakes. From Scharer *et al.*, 2007).

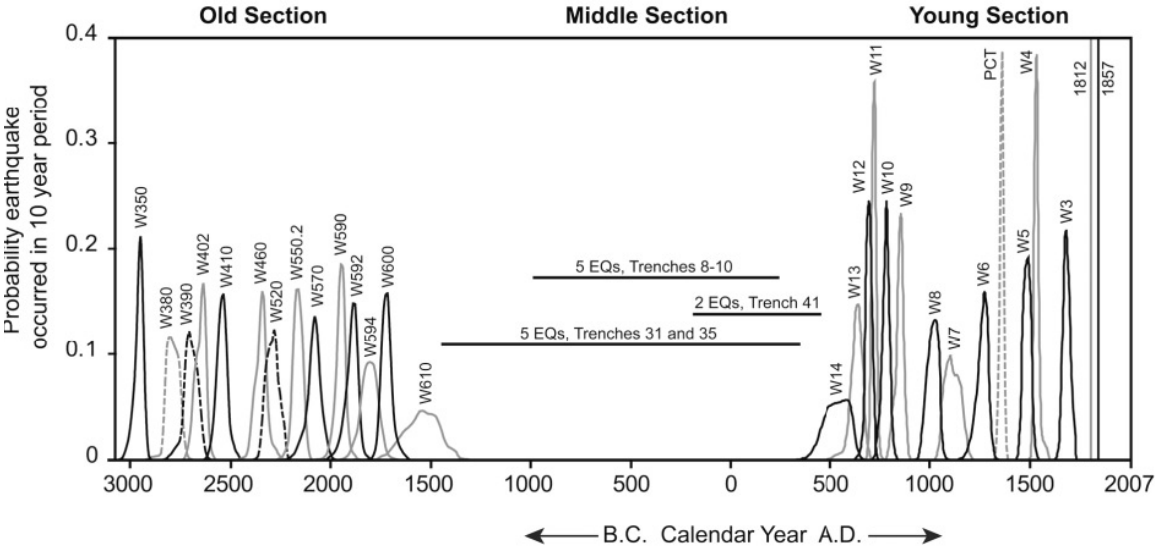
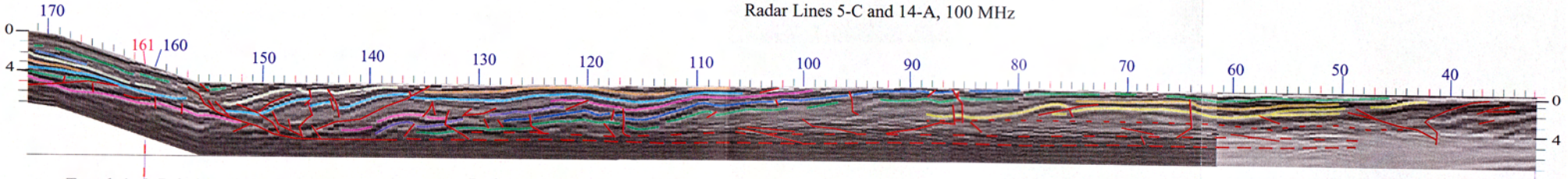


Figure 6 - Summary of our current understanding of the timing of earthquakes at the Wrightwood site. Because the record in the Middle section is almost certainly incomplete, and the places where the evidence was interpreted are not physically connected we have shown them as overlapping bars representing the time span of each of the 3 areas we see evidence for earthquakes in the Middle Section. Based on the current evidence there could be as few as 5 events that we have seen in multiple places and as many as 12 if the actual events don't overlap between sections. In either case we do believe that we have a complete record of this section yet. From Scharer *et al.*, 2007).

N20E

1.0 m.

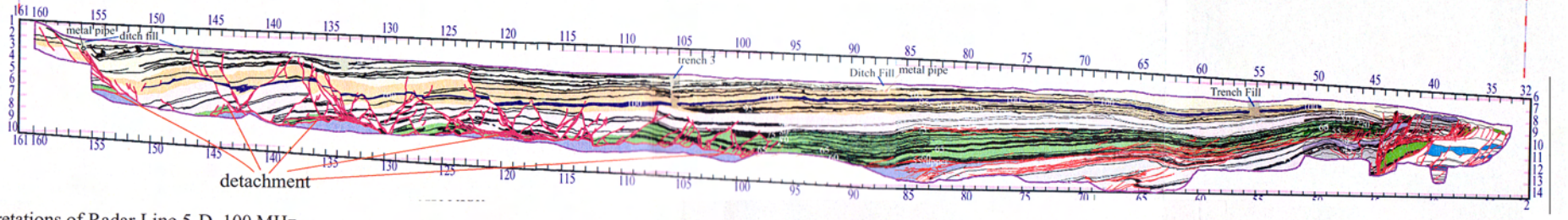
Radar Lines 5-C and 14-A, 100 MHz



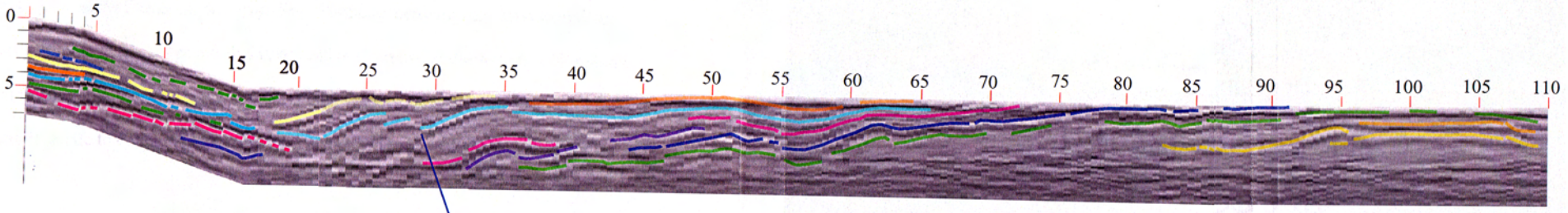
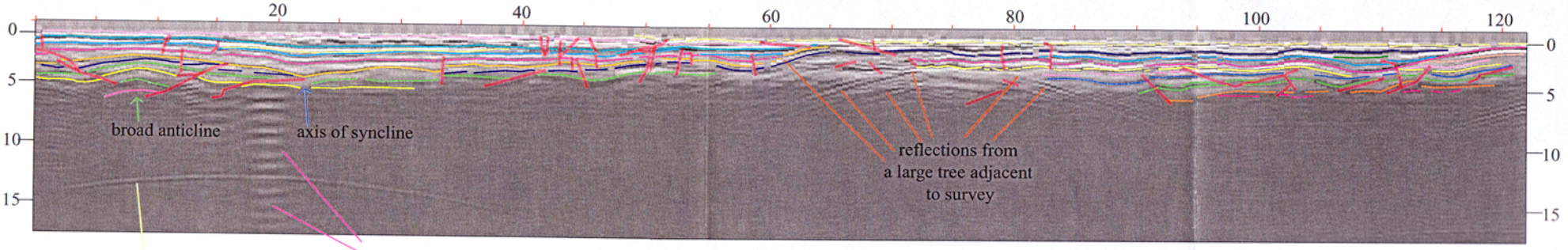
Trench 1, 6, 7, 8, 9, and 11

Radar Line 5-C

Radar Line 14-A



Interpretations of Radar Line 5-D, 100 MHz



Radar Line 12, represented by data set 12-A, 100 MHz