Laboratory exercise:

Mapping landforms with applications to geomorphology and earthquake geology

J R. Arrowsmith
School of Earth and Space Exploration
Arizona State University
Tempe, AZ 85287
ramon.arrowsmith@asu.edu
http://www.public.asu.edu/∼arrows

Introduction

The geomorphic expression of the San Andreas Fault (SAF) system dominates the landscape of western California. It is approximately 1100 km long and stretches from Cape Mendocino in the northwest to the Salton Sea and on into Mexico in the southeast.

The *first* purpose of these laboratory exercises is to expose you to the spectacular tectonic geomorphology that records the motion along the SAF over the last hundreds to thousands of years. By mapping the major landforms and applying simple geologic principles of cross-cutting relationships, you will interpret their history with respect to motion along the SAF. That interpretation, when coupled with ages for the landforms, will permit us to determine a slip rate along the fault. *Secondly* (and if there is time), you will interpret the stratigraphic record of earthquakes as exposed on the walls of an excavation across the fault. That interpretation will be combined with an analysis of the ages of layers that bound the timing of earthquakes in the laboratory exercises by Dr. George Hilley.

Knowing a slip rate, slip-per-event in prior earthquakes, and their timing are essential inputs to models of faulting and earthquake hazard. Hopefully you can apply this approach in your own research.

Part I–Mapping the San Andreas Fault near Wallace Creek California

Rarely are tectonic landforms as well expressed and dated as they are at Wallace Creek in south-central California (Figure 1). In the area surrounding Wallace Creek are examples of most of the classic geomorphic features of strike-slip faults. These landforms were noted by numerous geologists through the early and mid 1900s as indicating horizontal motion along the SAF. The seminal work at the site, however, was by Sieh and Jahns, 1984.

Goals–Part I

After completing this part of this exercise, you should have these basic skills:

- Use large scale aerial photography, topographic maps, and other topographic data to delineate landforms.
- Identify tectonic landforms along a strike-slip fault system and estimate offsets if appropriate.
- Interpret simple logs of excavations (trenches) to determine the ages of landforms.
- Estimate the slip rate along the San Andreas Fault and consider the implications for earthquake timing.

Tasks–Part I

Using the aerial photographs, topographic maps, and trench logs provided, please do the following (best done in pairs). Do the mapping on the large plate provided:

1. Familiarize yourself with the major landforms of the area and discuss them with your colleague. [10 minutes]

2. Using the suggested mapping symbology (and others you might need to supplement–Figure 2), delineate the major geomorphic elements of the area. Try to keep the delination as descriptive as possible without interpreting history. Don't put the fault(s) in yet–do it after you mapped the features (next step). Emphasize the area shown in Figure 3–note that it has a 0.5 m contour interval. [20 minutes]

3. Looking at Figure 4, neatly label the major features that you have mapped and discuss with your colleague. Feel free to label other features of interest and map the SAF. It does not have to be a single line. [10 minutes]

   Look for landforms and structures such as

   - Beheaded drainages
   - Offset drainages
   - Sags
   - Shutter ridges
   - Scarps
   - Different terrace levels (hint: look for terraces preserved near deeply incises channels)
   - Fault traces

4. Looking at Figure 3 and your mapping, measure several offsets, including the one for the main Wallace Creek channel and record your measurements in the table. Using the trench logs from Figure 5, determine the age of the two surfaces that were cut by the trenches. If you assume they date the last deposition in the beheaded channel, how do they constrain the age of the active channel? [20 minutes]

Upstream feature	Downstream feature	Offset measurement (m)	Age (Years BP)	Slip rate

5. What sources of error must be considered in the offset channel measurements you made and in the estimates of offset rate? [10 minutes total]

6. If you look to the southeast of the main Wallace Creek offset, there are some small offsets that hopefully you noticed (?). How much are they offset? They are inferred to have formed in the last major earthquake here which was 1857. Given the slip rate you calculated, how long would it take to accumulate the slip that was released in 1857 here?

   If you assume that the next earthquake might recur after the same amount of slip has accumulated as was released in the last earthquake, when would you expect the next to occur? How valid is that estimate for earthquake hazard assessment?

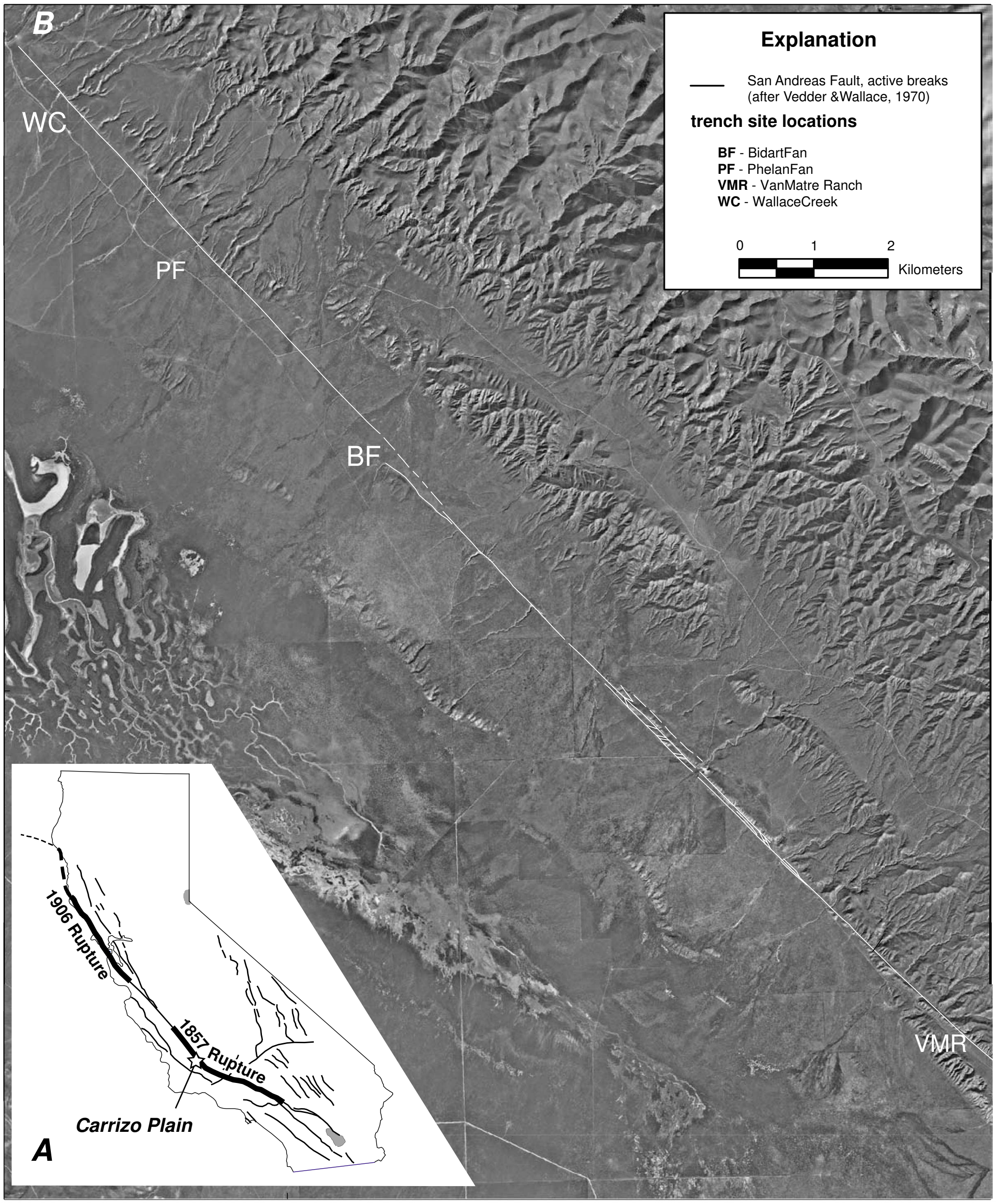

Figure 1: Location of study area. A) Location of the Carrizo Plain along the San Andreas Fault in south-central California. It last ruptured here in 1857. B) The major sites along the SAF in the Carrizo Plain. Our exercise will emphasize the area near Wallace Creek (WC–part I) and Bidart Fan (BF–part II).

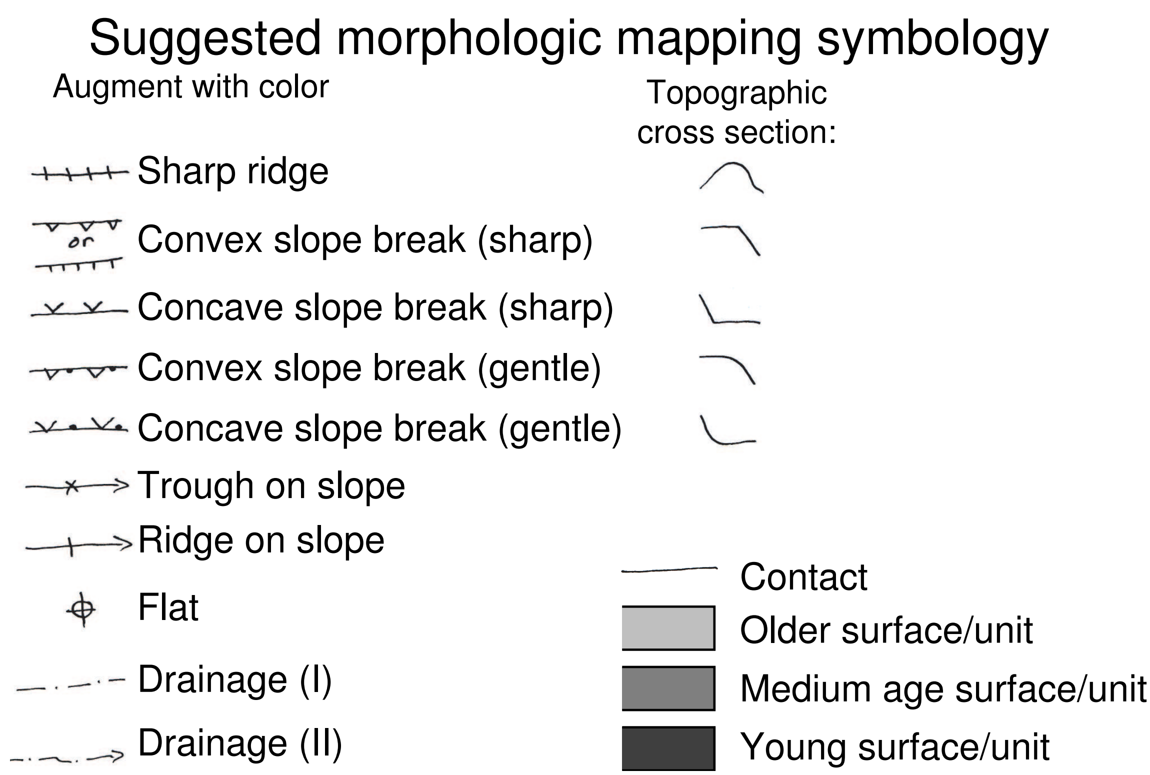

Figure 2: Suggested morphologic mapping symbology. Use this mapping "language" to indicate the positions and extents of the morphologic elements that comprise the landforms. Feel free to create new ones as you need; just be consistent and put it on an explanation for the map. Use colors where you can for emphasis.

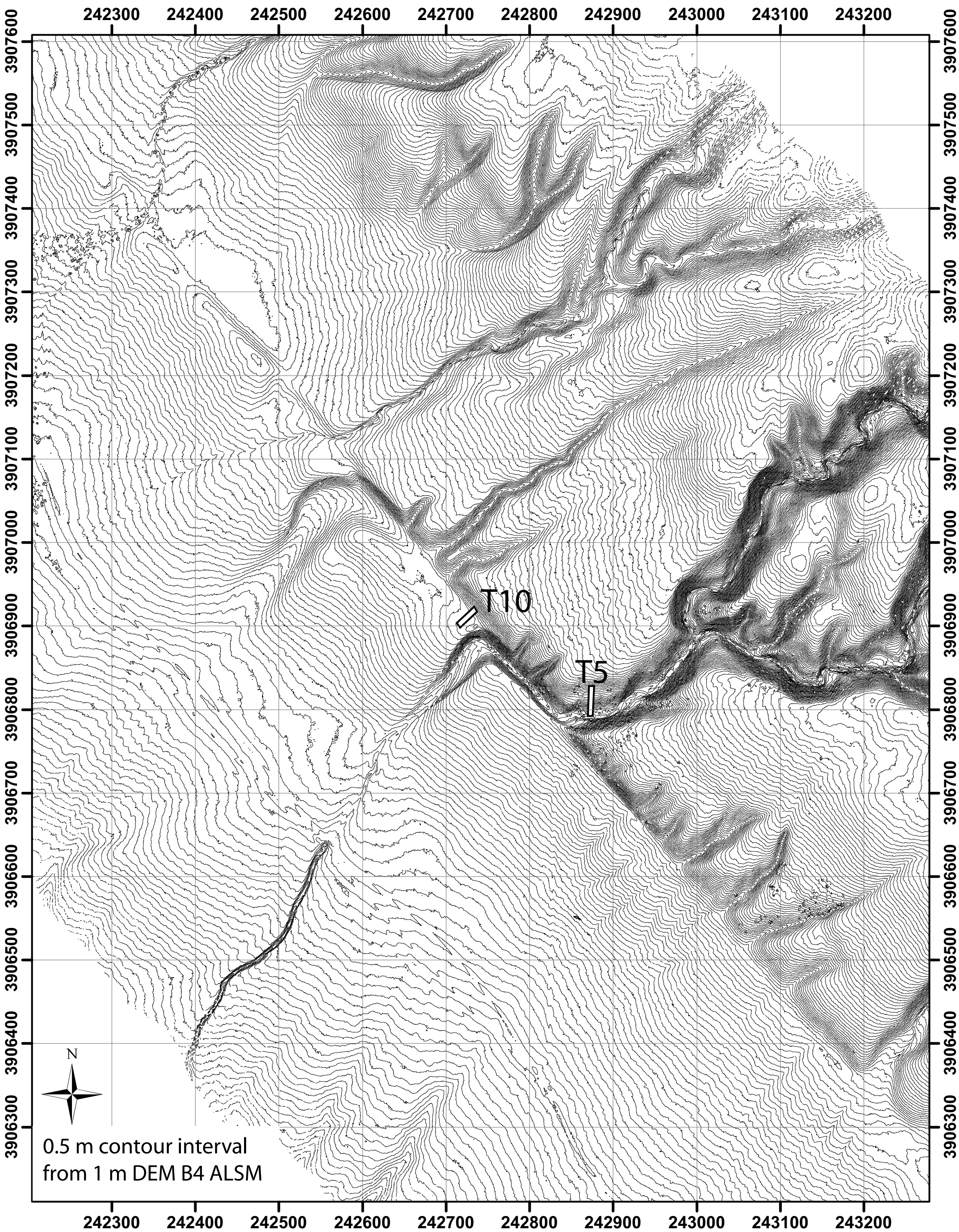

Figure 3: 0.5 m contour interval topographic map of the area around Wallace Creek. Note the larger offsets (∼100s m) and the small ones (to the southeast–∼10s m). The locations of T5 and T10 (Figure 5) are indicated. The surrounding grid is 100 m UTM WGS84.

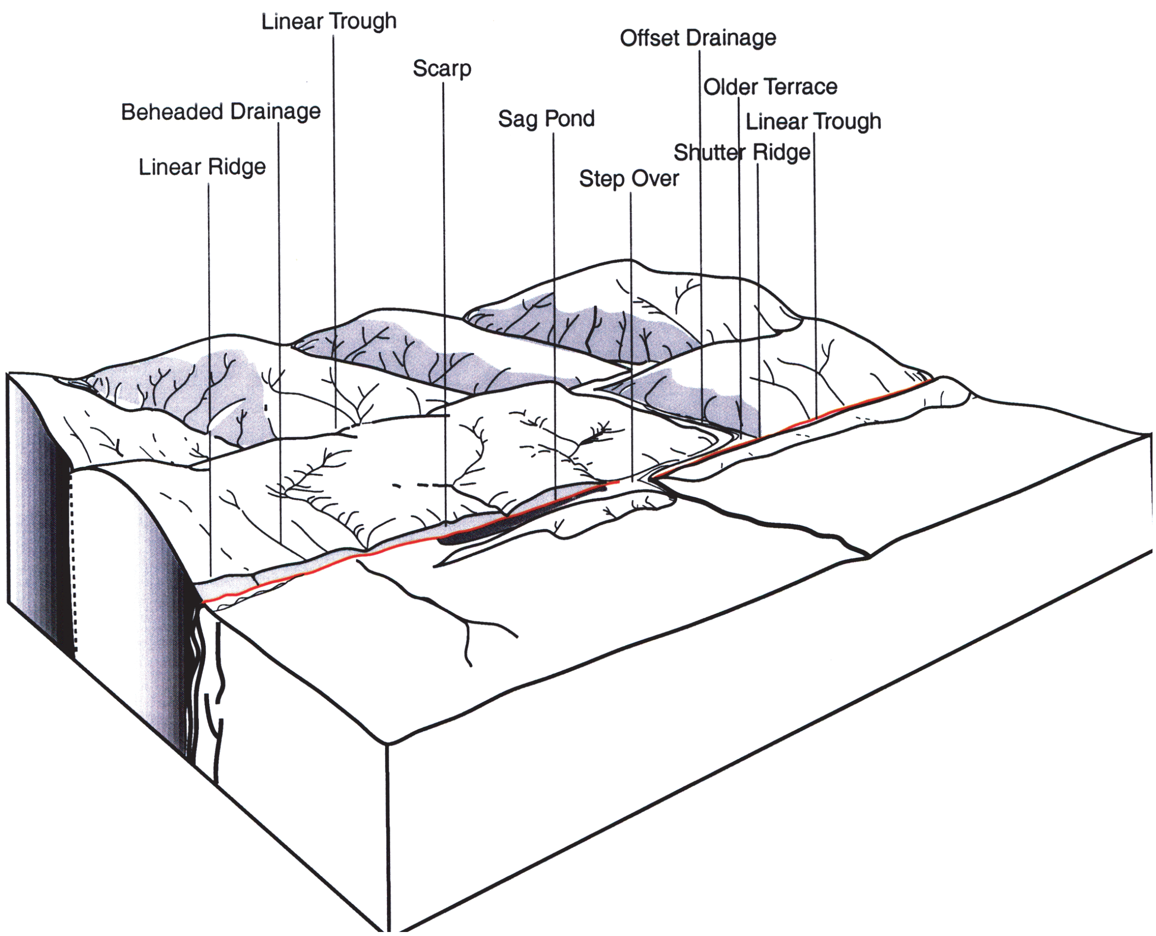

Figure 4: Block diagram showing landforms produced along recently active strike-slip faults (modified from Vedder and Wallace, 1970 by Jeri Young).

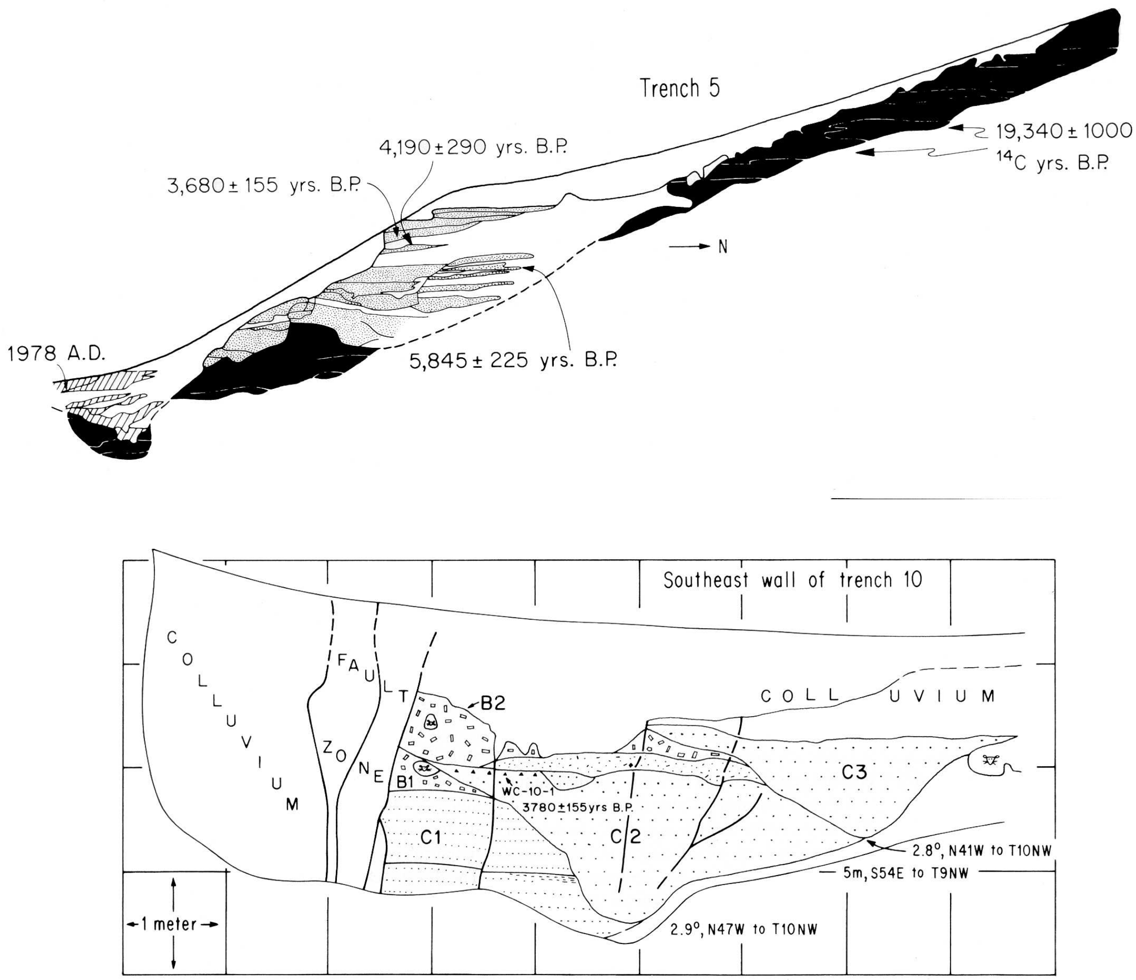

Figure 5: Logs from trenches 5 and 10 from Sieh and Jahns 1984. Use these ages to estimate the time of last deposition of these materials and hence the ages of the surfaces they are associated with. Note their locations on Figure 3. *Hint: look closely at the bench into which T5 is cut. Note that it is a couple meters higher than the level in the channel where T10 was cut. These are correlative surfaces.*

Part II–Estimating the time of earthquake ruptures along the San Andreas Fault at Bidart Fan

Just a few km southeast of Wallace Creek is Bidart Fan (Figure 1), where a sustained effort to expose dateable, ruptured stratigraphy yielded an important earthquake history for this portion of the SAF (Grant and Sieh, 1994). Recent work at the site with new trenches and further ^{14}C dating of samples from Grant and Sieh, 1994 has yielded a revised set of dates (e.g., Ackiz, et al., 2006).

Goals–Part II

After completing this part of this exercise, you should have these basic skills:

- Appreciate the significance of the local geomorphology for the trench stratigraphy.
- Identify and qualify evidence for earthquakes in trench stratigraphy.
- Provide simple age estimates for those earthquakes

Tasks–Part II

Using the trench logs provided, please do the following (best done in pairs):

1. Look at Figure 1, 6, and 7. Note the trench locations from Grant and Sieh, 1994 on Figure 6. We will work with the data from T2. Its location is shown with the yellow dots on the historic (1933) aerial photos (Figure 7). Note the geomorphic setting. Why do you think the trenches were located where they are? [20 minutes]

   Based on the geomorphology of the site, what kinds of sediments are expected?

2. Look at the trench logs and familiarize yourself with the main features. Emphasizing the parts of the trenches highlighted with rectangles in Figure 8, identify the main geologic units and number them (use the numbers in Figure 8 as a start). Then, identify evidence for earthquakes and provide a rating: *good, fair, poor.* [30 minutes]

Wall	Approx. location	Paleo-earthquake evidence	Quality	Possible bounding ages (Use calibrated (green) dates

3. How many earthquakes do you identify in this trench (synthesize results from above). Over how much time did they occur (recognize that the last earthquake was in 1857 here)? [10 minutes]

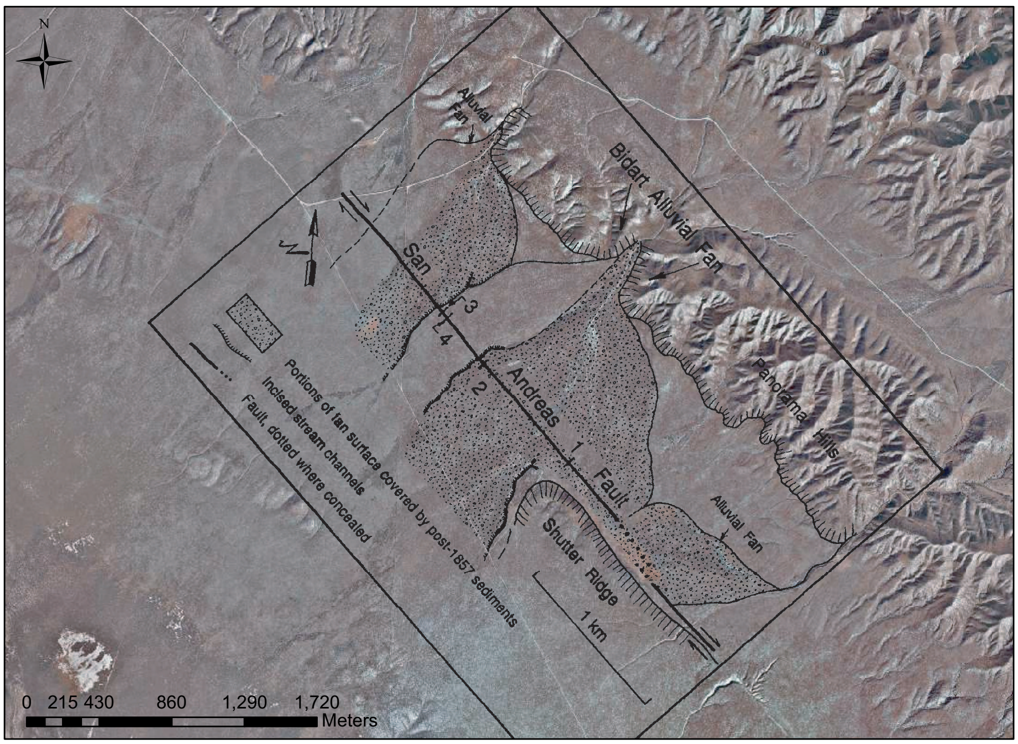

Figure 6: Geomorphic setting of the Bidart Fan site (see Figure 1 for location). Map of main landforms and trenches is from Grant and Sieh, 1994. This exercise emphasizes Trench 2.

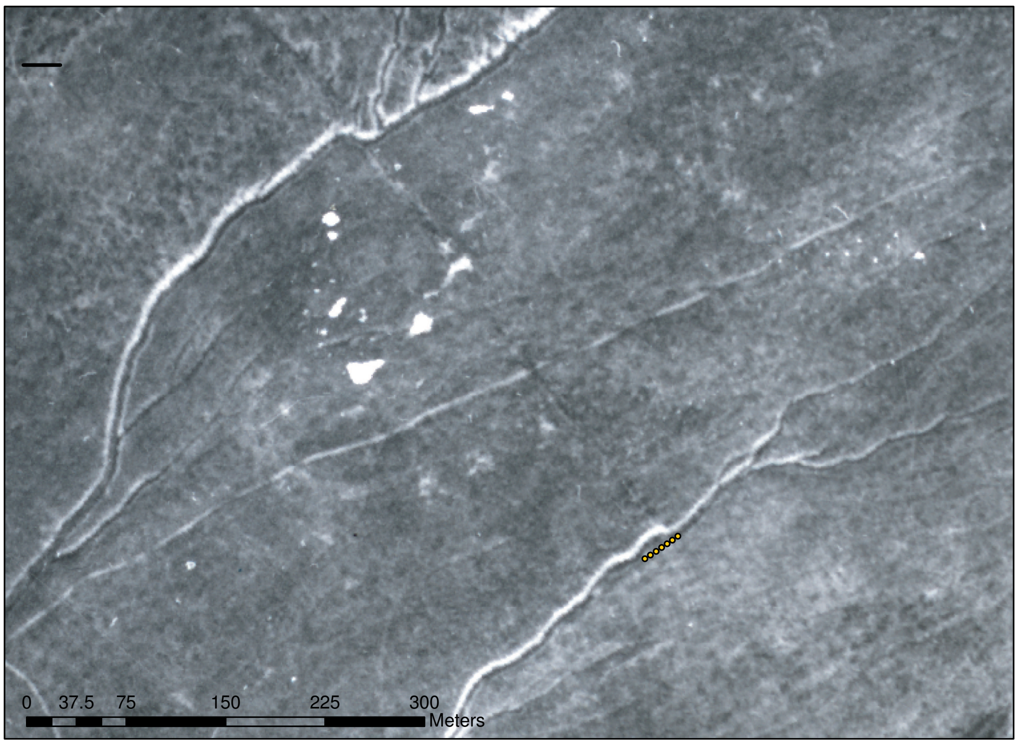

Figure 7: Aerial photograph of Bidart Site (from Fairchild Aerial Photography Collection at Whittier College). Photograph was taken in 1932–only 75 years after the 1857 earthquake. Dots show location of Trench 2. Where is the SAF?

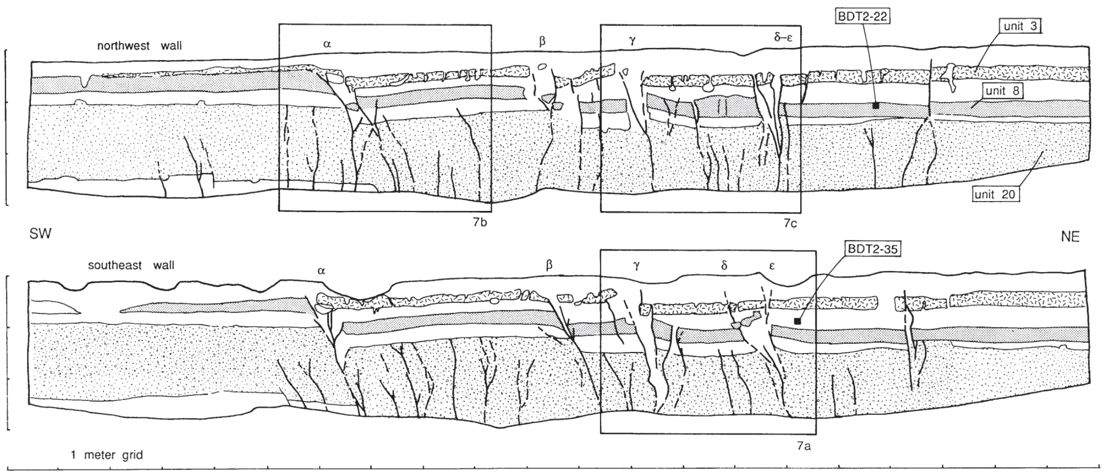

Figure 8: Cross section through sediments in the walls of trench 2 shows fault traces and original radiocarbon sample locations. Boxes outline stratigraphic sections to emphasize in exercise interpretations. View is towards the northwest. From Grant and Sieh, 1994

Acknowledgements and References

These exercises build on similar ones produced by Dr. Jeri Young in 2003, and also draw heavily from material available from the Southern California Earthquake Center: `http://www.scec.org/wallacecreek`. Lisa Grant and Sinan Akciz shared the T2 logs for Bidart.

The topographic data for this project came from Airborne Laser Swath Mapping data from the B4 project processed using the GEON LiDAR Workflow (see `http://lidar.asu.edu/` for more information).

Sinan Akciz, Sue Selkirk, and Ken Jones helped with the production and duplication of the graphics.

References

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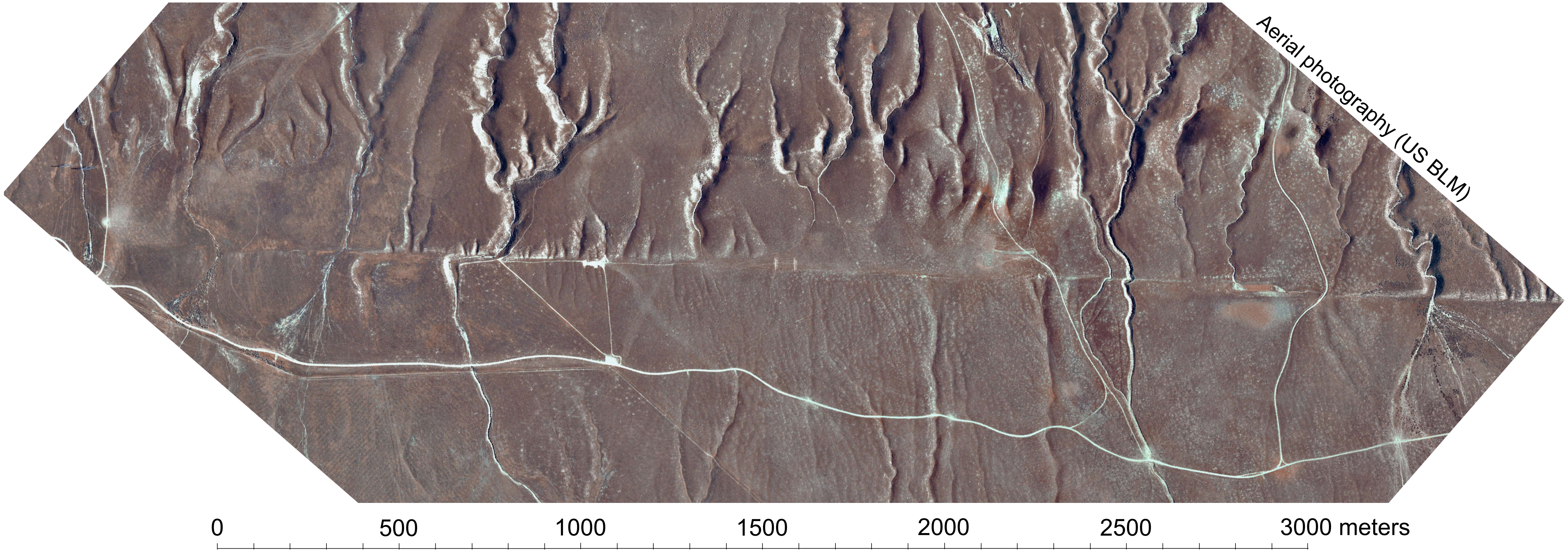
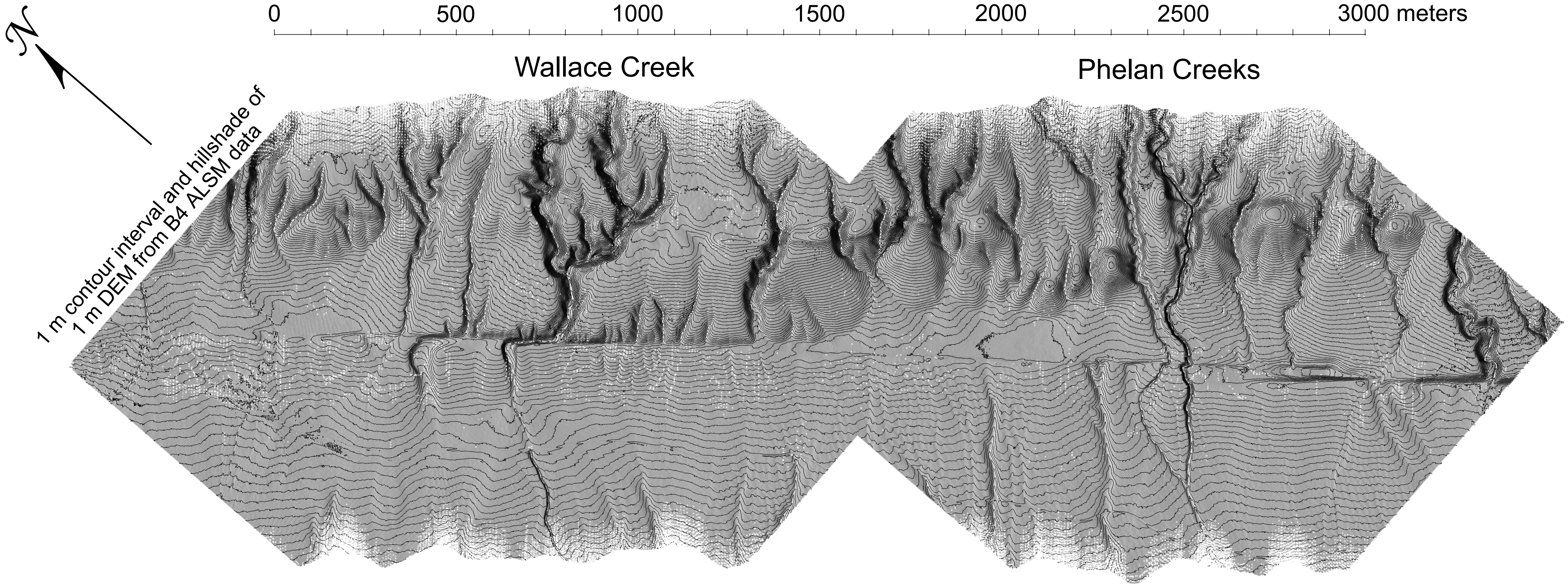
Vedder, J. G., and Wallace, R. E., Map showing recently active breaks along the San Andreas Fault and related faults between Cholame Valley and Tejon Pass, California, US Geological Survey Miscellaneous Investigations Map I-574, 1970.

Wallace Creeks to Phelan Creeks Topographic and Aerial Photographic data

Prepared by Ramón Arrowsmith (SESE, ASU)

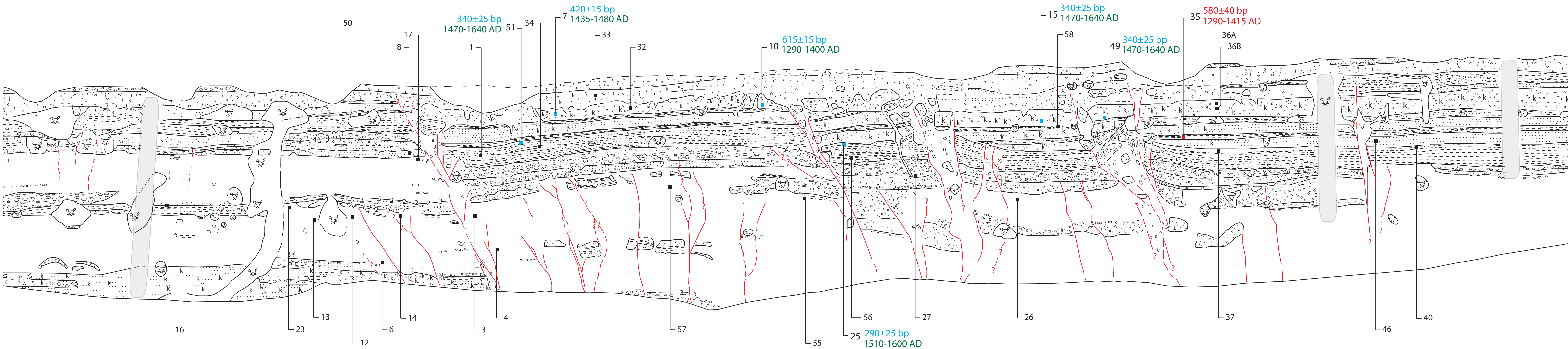




T2 SE

Bidart site, San Andreas Fault

Grant & Sieh, 1994 (redrafted)



C14 sample

new analyzed C14 sample

C14 sample analyzed and reported in Grant and Sieh (1994)

255±45 bp — new C14 results

11 — C14 sample number

1480-1690 AD — OxCal Calibrated new C14 results in calendar years

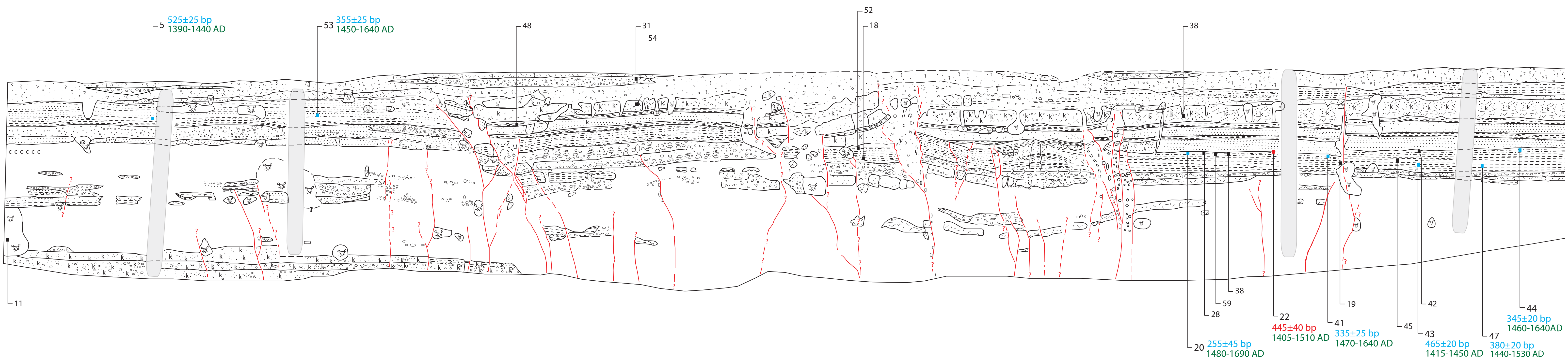
580±40 bp — C14 result reported in Grant and Sieh (1994)

1290-1415 AD — Calibrated C14 results in calendar years (Grant & Sieh, 1994)

T2 NW

Bidart site, San Andreas Fault

Grant & Sieh, 1994 (redrafted)



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