

Annual Report, 1998
Historic and Paleoseismic Behavior of the Southcentral San Andreas Fault
Between Cholame and the Carrizo

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Collaborative project with Ramon Arrowsmith of Arizona State University

The goal of this project is to measure displacement along the Cholame segment of the San Andreas fault from the 1857 earthquake by using historic surveys and analysis of geomorphic offsets. This project is part of a larger collaborative investigation of the historic and paleoseismic behavior of the southcentral San Andreas fault between Cholame and the Carrizo Plain with Ramon Arrowsmith, Elizabeth Stone (both of ASU) and Dallas Rhodes (of Southern Georgia Univ.). The objectives of the larger project are to

- ✱ measure the amount of slip along the Cholame earthquake from the 1857 earthquake
- ✱ date the penultimate rupture by paleoseismic excavation.
- ✱ determine the magnitude and extent of past ruptures along the San Andreas fault between the northwestern Carrizo Plain and Cholame
- ✱ test the Cholame segmentation model, as defined by the Working Group on California Earthquake Probabilities (1988).

To accomplish these goals we have coordinated efforts to map structures and offsets along the fault, analyze historic surveys and plan a paleoseismic excavation. Arrowsmith, Stone and Rhodes conducted field reconnaissance of geomorphic offsets, potential paleoseismic sites and survey monuments. I compiled and reviewed records of original cadastral surveys across the San Andreas fault between Cholame and the Carrizo Plain in San Luis Obispo County, and Kern County. I also analyzed the survey data. Portions of the analysis were peer reviewed by Arrowsmith. This report summarizes analysis of the historic survey data.

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Using Cadastral Surveys to Measure Displacement

In 1855 and early 1856 James E. Freeman surveyed numerous lines across the San Andreas fault and established monuments in Townships 26 through 30 south of Mount Diablo baseline. At least 26 section lines were established across the San Andreas fault between Highways 46 and 58 prior to the 1857 Fort Tejon earthquake (see **Figure 1**).

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The purpose of the surveys was to establish a permanent legal system for measuring and identifying lands in the new western states (White, 1983). Grant and Donnellan (1994) recovered two of Freeman's original monuments spanning the San Andreas fault in the Carrizo Plain. By measuring the distance between the monuments and comparing it with the pre-1857 distance, they were able to calculate 11.0 ± 2.5 m of right-lateral displacement from the 1857 earthquake near Wallace Creek. We are applying Grant and Donnellan's methods to try to measure the amount of displacement from the 1857 earthquake along the Cholame segment of the San Andreas fault. This involves

- ✱ searching records of surveys to verify that monuments are still in their original locations

- ✧ field checking monuments for verification
- ✧ comparing the original surveys with post-1857 measurements of the same lines
- ✧ analysis of errors and uncertainties
- ✧ conversion of line lengths to co-seismic displacement

Search of Survey Records and Monuments - Field notes and plattes of original surveys were transcribed by the General Land Office and then microfiched by the Cadastral Survey Office of the U.S. Bureau of Land Management (BLM). These government surveys established the legal definition of property and have been referenced in nearly all subsequent surveys by licensed surveyors. Each time an area is resurveyed, the condition of monuments and the measured distances between them are recorded. Records of resurveys are filed with the BLM, Kern County and San Luis Obispo County.

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✧ review of all known official and recorded resurveys across the fault zone was required to establish the authenticity of each monument. From records of resurveys, it appears that many monuments were “lost” after the 1857 earthquakes. Surveying regulations require that lost monuments be replaced and reset proportionally from existing monuments. Reset monuments might not be in their original location and therefore have to be identified and eliminated from our study. **Figure 2** shows the history of monuments that were established near the fault zone prior to 1857. Most of Freeman’s original monuments along the Cholame segment have been replaced by subsequent surveyors because they were decaying. Original monuments were constructed of wooden posts in mounds of dirt or stone, overlying a pint of charcoal. Newer monuments are made of notched stone or steel pipe with a scribed brass cap. We field checked as many monuments as possible (see Figure 2) and compared the condition and description of the monuments with records of resurveys.

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Reliability of Surveys - The quality and reliability of early surveys varied greatly. Original General Land Office surveys were conducted on a contract basis, and many were fraudulent or poorly executed. The contract system was eventually eliminated for these reasons (Moffit and Bossler, 1998). Fortunately, Freeman’s surveys were conscientiously done and very reliable. Numerous resurveys by professional surveyors, field checks by us and research by Grant and Donnellan (1994) established the reliability of Freeman’s notes, monuments and measurements. In contrast, some early resurveys of Freeman’s original surveys were found to be problematic or fraudulent and were rejected by the BLM.

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✧ **Accuracy and Precision of Chained Surveys** -Freeman’s original surveys were conducted with chains and poles according to rules published in the 1855 Manual of Surveying Instructions. The chains were held taught and a hand level was used to keep them horizontal. The accuracy of a chained survey depended greatly on the skill of the surveying party, the condition of the equipment and the terrain. On relatively flat ground with little vegetation, errors of 1 part in 1000 could be achieved. The accuracy of chained surveys can be estimated by comparing with results of resurveys using modern equipment. Grant and Donnellan (1994) calculated combined errors of 1 part in 950 for Freeman’s surveys in the relatively flat Carrizo Plain and adjacent portions of the more rugged Temblor Range. The terrain along the Cholame segment is more rugged than in the Carrizo Plain, but less rugged than the Temblor Range.

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Error Analysis and Results of Resurveys

Resurveys of some of Freeman's section lines across the San Andreas fault were conducted in 1873, 1893, 1896, 1917, 1942, 1979 and 1997. The most recent survey was conducted by Arrowsmith and Rhodes using a Total Station. Results of the resurveys are summarized on Figure 2 as changes in line lengths and date of record of resurvey. After removal of systematic errors, the line length changes can be converted to fault-parallel displacement.

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The quality of some surveys is so poor that they should not be used. For example, the 1942 surveyors could not find one of the monuments, so they reset it proportionally. The 1979 survey retraced portions of the 1942 survey, found the original monument and replaced it with a more durable one. Therefore, we conclude that the 1942 surveyors did not measure the true line length and their measurement is not shown on Figure 2. The 1893 and 1896 surveys were seriously flawed and were initially rejected by the U.S. government. Both surveys were repeated and amended, with dubious accuracy. Although the measurements of the 1893 and 1896 surveyors do not appear to be very accurate, they were conscientious about reporting the condition of Freeman's monuments and they replaced many decaying monuments. The field notes of a 1917 survey by A. J. Nielson are lost and the existing platte is nearly illegible. Nielson replaced many decaying monuments with durable scribed sandstone but it is difficult to tell from the platte which monuments were proportionally reset and which were replaced.

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The most extensive and accurate resurvey was conducted by Kern County Surveyors Office in 1979 with average accuracy of 1 part in 10,000. The 1979 survey by Kloepper remeasured several of Freeman's original lines across the fault and outside the fault zone. Arrowsmith and Rhodes resurveyed one of Kloepper's lines and verified the length within a few centimeters. All of Kloepper's surveyed lines across the fault zone increased in length. This suggests that we need to apply a correction to convert between Freeman's 1855 surveys, and Kloepper's. The question is how to determine the correction factor and its accuracy. In theory, we should be able to compare Kloepper's surveys of lines outside the fault zone to Freeman's and determine the difference in length for lines which should not have changed. Ideally, we should be able to obtain an average correction factor from several measurements. In practice, there is only ONE measurement which was made by both Freeman and Kloepper outside the fault zone, using the same monuments AND in similar terrain. (The terrain correlates with the accuracy of chained surveys, so it is important to compare similar terrain). The northern boundary of sec. 6, T27S R17E was 6.7m shorter when measured by Kloepper than it was recorded in Freeman's notes. This suggests that we can subtract 6.7m per 1.0-mile section. This correction should be valid for the immediately adjoining 1.5 mile line (not 1.0 mile) that crosses the fault between the NW corner of sec. 5 and the N1/4 of sec. 4. Scaling the error by multiplying it by 1.5, we get a correction of -10.05m. The 1979 measurement was 15.04m longer than the 1855 measurement. If we subtract the "error", then the "true" length change should be 4.99m. This can be converted to displacement. Assuming the strike of the fault is N40W, and the survey line strikes N 88-90 E, we calculate fault parallel displacement of 7.8 – 8.1 m. Preliminary calculations by Stone and Arrowsmith suggest that interseismic strain accumulation is 0.2 – 0.4 m. Therefore, **coseismic displacement was 7.4 – 7.9 m.**

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It is difficult to evaluate the uncertainty in this measurement because statistical methods cannot be applied. The uncertainty is similar to the unquantifiable uncertainty inherent in most

paleoseismic data sets (e.g. interpretation of the number of ruptures exposed in a trench or measurement of offset streams, etc.). Future work will include final calculation of post-seismic strain accumulation; comparison of measured displacement with offsets measured in the field by us and by others; analysis of the structure of the fault zone; and implications for seismic hazard.

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References

Grant, L. B. and A. Donnellan, *1855 and 1991 Surveys of the San Andreas Fault: Implications for Fault Mechanics*, **Bull. Seism. Soc. Amer.**, Vol. 84, No. 2, p.241-246, 1994.

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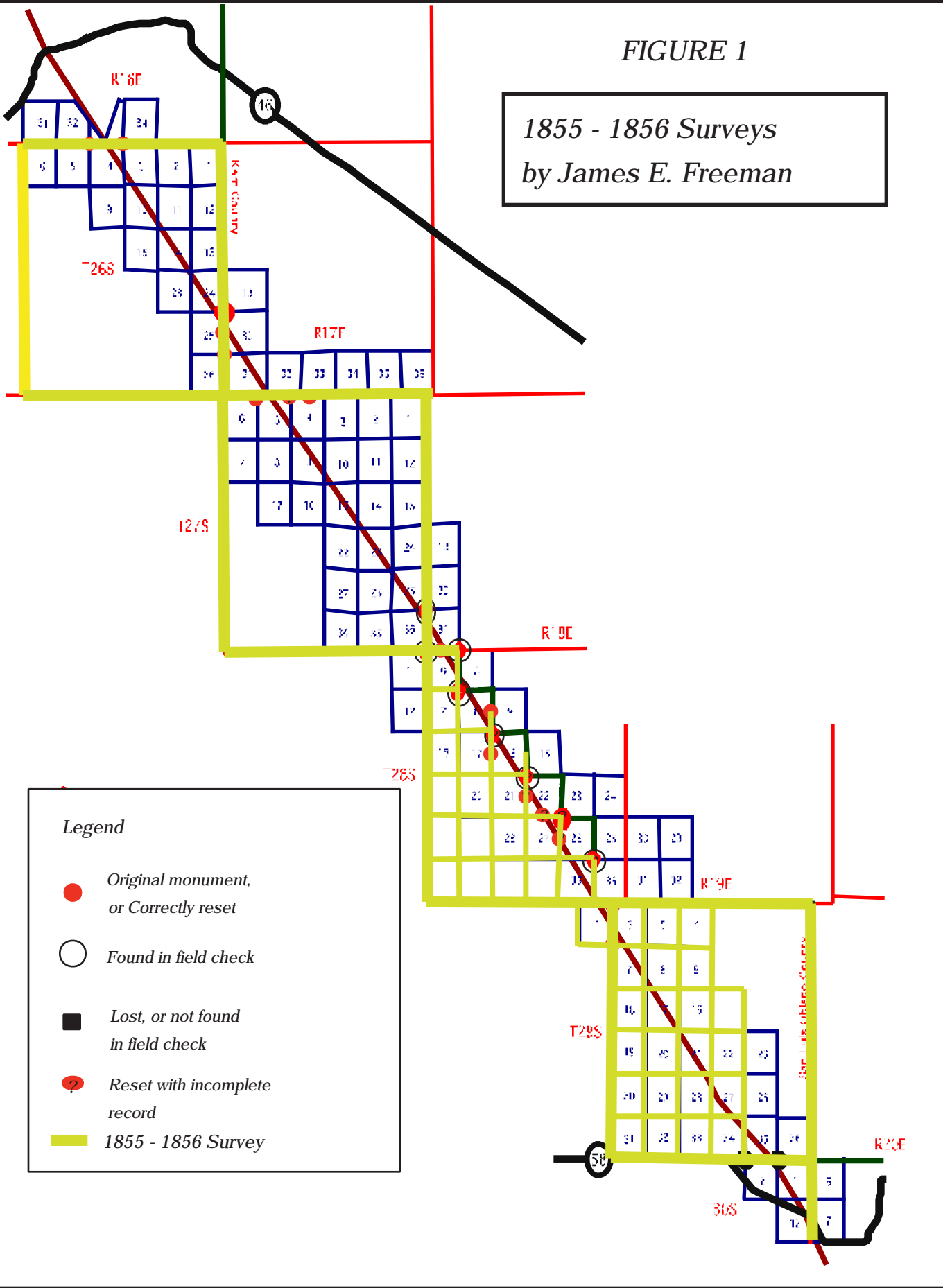
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Publications and Products – Included in Annual Report on Request for Use of Residual Funds to Support Earthquake Geology Research.

FIGURE 1

1855 - 1856 Surveys
by James E. Freeman



Legend

- Original monument, or Correctly reset
- Found in field check
- Lost, or not found in field check
- ⊗ Reset with incomplete record
- 1855 - 1856 Survey

FIGURE 2

Changes in Line Lengths Following the 1857 Earthquake

