Holocene geologic characterization of the northern San Andreas fault, Gualala, California

NEHRP External Grant Award Number 03HQGR0045

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Program Element II: Determine paleoearthquake chronologies and refine slip rate and recurrence estimates and evaluate segmentation models for the San Andreas fault

Key Words: San Andreas Fault, LIDAR, geomorphic mapping, paleoseismology

December 1, 2003

Investigations undertaken

The northern San Andreas fault is the most prominent tectonic feature along the western boundary of the North American plate and extends approximately 330-km from the San Francisco Bay Area to Shelter Cove within the California Coast Range geomorphic province. Although the fault has been relatively aseismic for much of the recent past, it was the source of the devastating great San Francisco earthquake of 1906, and remains a threat for future large magnitude events. Recently, the Working Group on California Earthquake Probabilities (WGCEP, 1999) recognized the possibility that the northern San Andreas fault may consist of separate rupture segments. To test rupture segmentation models it is necessary to compare earthquake recurrence and timing data from multiple sites along the fault. Data collection of turbidite event stratigraphy is presently in progress offshore of the entire northern San Andreas fault (Goldfinger, 2000; 2001; in progress). Despite paleoseismic efforts in the study region (Prentice, 1989; Baldwin, 1996; Simpson et al., 1996; Noller et al., 1993; Prentice et al., 2000; Kelson et al., 2003) data on the recurrence and timing of events on the fault remain poorly constrained and no paleoseismic data exists within the Gualala River valley.

In collaboration with Dr. Carol Prentice of the U.S. Geological Survey, we commenced a one-year program to refine existing mapping of the fault and characterize active fault strands and surficial deposits along the portion of the fault between Valley Crossing (~6-km north of Stewarts Point) and Voorhees Grove (~8-km southeast of Point Arena) (Figure 1). Our results will be used to evaluate potential paleoseismic research sites that may contain information of earthquake recurrence and timing. The identification of these sites and future assessments of earthquake history at these sites will provide a means to compare the offshore and onshore event record. These data will help evaluate potential earthquake rupture segmentation models and will contribute to estimating the magnitude and probability of future earthquakes in the San Francisco Bay area and North Coast region.

Previous attempts to map the fault by aerial photograph interpretation have been difficult, and next to impossible in some localities due to the dense forest canopy. New high resolution LIDAR (Light Distance and Ranging) topographic surveys were acquired from USGS and NASA in September, 2003. By removing the vegetative cover, these images provide a high degree of clarity and excellent depiction of fault-related features. Prior to this study, LIDAR has not been used to document the location of faults in northern California.

The LIDAR images were uploaded to an ARCGIS program and used to interpret and compile fault related features. We also acquired various base layers including digital 1:24,000 scale USGS topographic quadrangles, and 30-m and 90-m digital elevation models (DEMs). Digital maps depicting geomorphic features in the Gualala River watershed and maps of Alquist-Priolo fault traces were acquired from the California Geological Survey. We were provided a digital database including streams and dirt roads from Gualala Redwood Company. Additionally, Justin Pearce of William Lettis & Associates assisted us in digitizing fault-related geomorphic features and interpreted locations of fault strands associated with the 1906 rupture from maps completed by Brown and Wolfe (1972). We have begun compiling these digital products into ARCGIS in order to compare lineaments interpreted on LIDAR to previously published fault location maps in an effort to more accurately map the fault. Ultimately, we will produce a digital detailed late Quaternary strip map of the fault, surficial deposits, and fault-related geomorphic features that can be viewed on a variety of base layers. This map will document the location of active strands of the northern San Andreas fault and evaluate the potential of future paleoseismic research sites.

In October 2003 we began to field check our LIDAR lineament interpretation by systematically walking the fault from south to north. Accurate field locating has always been a problem in the densely vegetated rugged slopes along this reach of the fault. The LIDAR data proved to be invaluable (far superior to aerial photographs) for accurately locating fault strands and other geomorphic features. In the field, we used two versions of the LIDAR data at a scale of 1:6,000 including a "full-feature" model that shows the distribution of vegetation and a "bald-earth" model that shows detailed topography and no vegetation. By cross comparing the LIDAR data to aerial photographs and topographic maps we were able to confidently locate and document tectonic features on the map. To date we have completed approximately 3 km of our field reconnaissance, and, in the coming months, plan to complete the entire 24-km reach of the fault between Valley Crossing and Voorhees Grove.

Preliminary Results

Within the study area the fault is characterized by short overlapping fault splays and parallel ridges and swales in the topography. The ridges are oriented along fault traces that alternate between a single main trace and two prominent parallel fault traces. Uphill-facing ridges are often associated with linear valleys and large sag ponds (Figure 2). From south to north, the fault traverses the southwestern valley wall of the linear South Fork Gualala River, extends along the channel of the North Fork and Little North Fork Gualala Rivers, and projects along the channel and southwest valley wall of the linear Garcia River. Because of its location along the southwest valley walls, numerous east draining tributary streams have been offset by fault displacement.

We mapped numerous notches and abandoned channels that cut through uphill-facing ridges. At a few of these localities, paleodrainages are partially filled with colluvial and alluvial sediment and are traceable across the topography. We noted a thick accumulation of organic rich fine grained marsh deposits at the northern end of a prominent sag pond. At this locality, the fault is constrained within a narrow (~10-m-wide) linear valley. Additionally, we identified two sites in which small ephemeral drainages have deposited fine and coarse grained alluvial fans against traces of the fault. These localities are drainage divides between ephemeral streams that flow to the east and are diverted north and south at the fault. All of these sites possess site conditions and stratigraphy that may have potential to reveal timing and recurrence information from future paleoseismic investigations.

Preliminary results of the investigation indicate that mapping on LIDAR images in the office prior to field reconnaissance provides an excellent first cut interpretation of the location of fault strands. We have used the printed LIDAR lineament interpretation as a field base map to accurately locate and document geomorphic observations and fault strands along the southern 3 km of the study reach. A few lineaments interpreted as potential faults strands were determined in the field to be of cultural origin (roads, powerlines, skid trails) and not tectonic origin. These were noted in the field and removed from the digital dataset. In the coming months we will complete our field reconnaissance and develop digital map products.

Non-technical summary

This research on the northern San Andreas fault is being conducted to refine existing mapping of fault strands and fault-related geomorphology along a 24 km long reach of the fault between Valley Crossing and Voorhees Grove in the Gualala and Garcia River valleys. New high resolution LIDAR topographic data is being used to more accurately map the fault and evalutate the potential of future paleoseismic research sites. Earthquake timing and recurrence investigations at these sites will help evaluate segmentation models along the northern San Andreas fault and refine earthquake probability estimates for northern California. The new fault map will be produced in a digital format that can be viewed on a variety of base maps.

Reports published

An abstract was presented by Prentice at the 2003 AGU meeting in San Francisco.

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Data availability

Data generated by this research will ultimately be available electronically in GIS format. Additional detailed information on the investigation is available from the Principal Investigator listed above.

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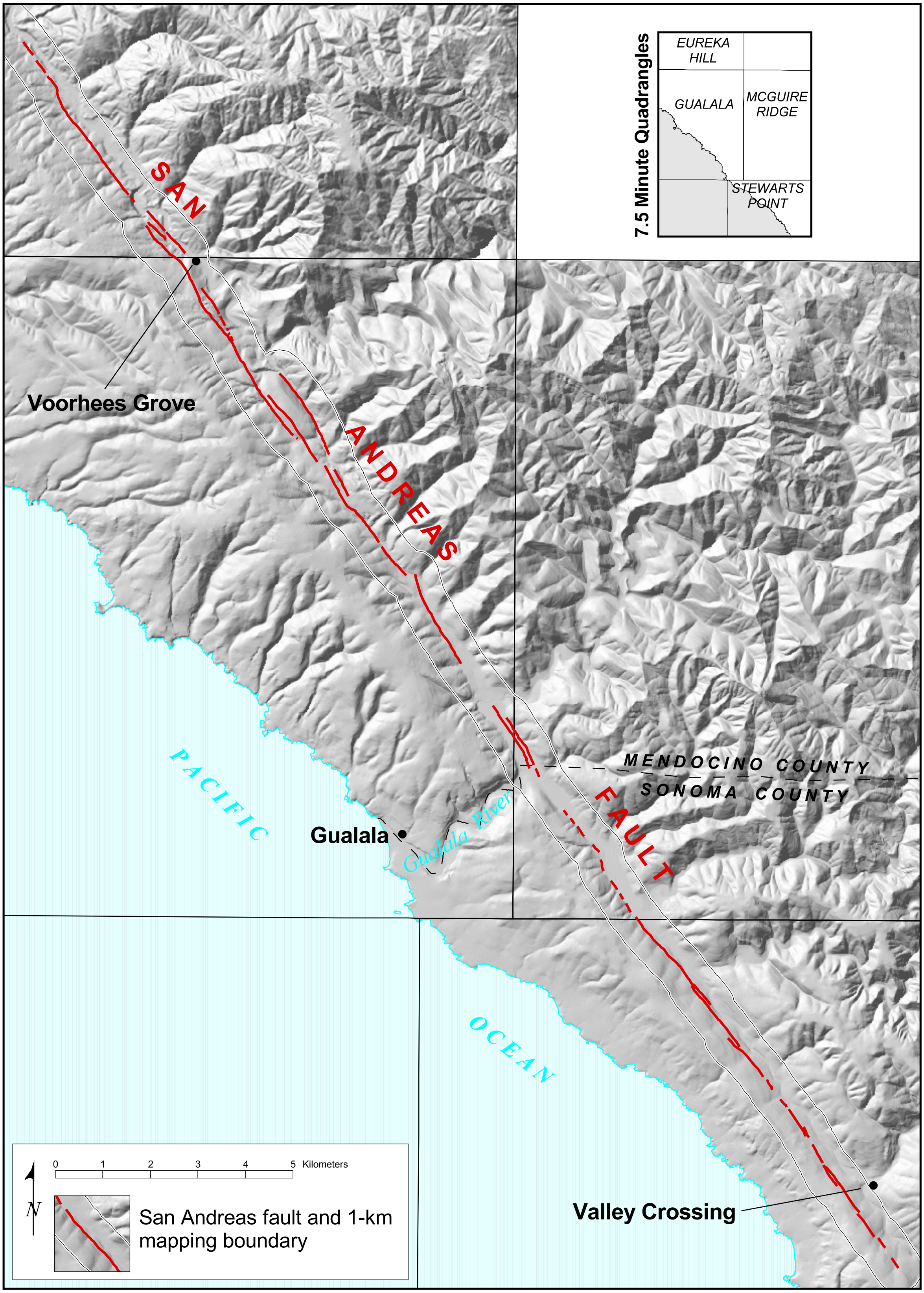

Figure 1. Shaded relief map of the North Coast segment of the San Andreas fault between Valley Crossing in the Gualala River valley and Voorhees Grove in the Garcia River valley. Generalized faults from Brown and Wolfe (1972), shown within our 1-km wide mapping boundary. (Map compiled by Andrew Barron, Center for Neotectonic Studies, University of Nevada, Reno.)

Figure 2. Photo shows San Andreas fault at base of scarp on right adjacent to sag pond. Numerous large sag ponds exist along the fault in the Gualala River valley. A linear valley extends to the north.