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PRELIMINARY RESULTS OF GEOARCHAEOLOGIC INVESTIGATIONS ALONG THE NORTHERN SAN ANDREAS FAULT ZONE, FORT ROSS STATE HISTORIC PARK, CALIFORNIA

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ABSTRACT

We are studying the temporal and spatial distribution of pre-European-contact sites along the northern San Andreas fault in Fort Ross Sate Historic Park. The geologic and archaeologic contextual settings of the study sites present an opportunity to develop new techniques for investigating the timing and amount of surface ruptures related to large-magnitude earthquakes. Our research includes locating and documenting several occupation sites that are up to several thousand years old and are offset by the fault. The spatial match of temporally distinct occupation sites will provide quantification of fault offset and slip rate along the northern San Andreas fault.

PROJECT OVERVIEW

This paper describes an on-going project in the Fort Ross State Historic Park that evaluates the feasibility of employing archaeological data to estimate the magnitude and timing of past seismic events along the North Coast segment of the San Andreas fault (Figure 1). Direct information on the number and timing of large-magnitude events along this segment of the San Andreas fault prior to an earthquake in A.D. 1838 is lacking. Our paleoseismic project at Fort Ross uses archaeological data to estimate the recurrence intervals for large-magnitude earthquakes, including the 1906 San Francisco earthquake (M8) and those that occurred prior to Russian and Anglo-American occupation of the area. The research is significant because it may refine predictions on the timing and magnitude of future earthquakes by taking into account the long-term cycle of seismic events along the northern San Andreas fault.

Previous Paleoseismic Research

Estimates of the recurrence intervals of past earthquakes are usually based on information on slip rate, amount of lateral movement per event, and elapsed time since the last major earthquake. There are few paleoseismic data on earthquake recurrence for the North Coast segment of the San Andreas fault. Prentice (1989) suggests that the recurrence interval along this segment ranges from 188 to 340 years, and that the most recent, pre-1906 surface rupture in the Point Arena area occurred between A.D. 1530 and 1718. In a paleoseismic study located near Olema, Niemi and Hall (1992) interpret a recurrence interval of 210 ± 41 years. Additional data on the timing of paleoseismic events along the North Coast segment will considerably help in assessing seismic hazards along the northern San Andreas fault.

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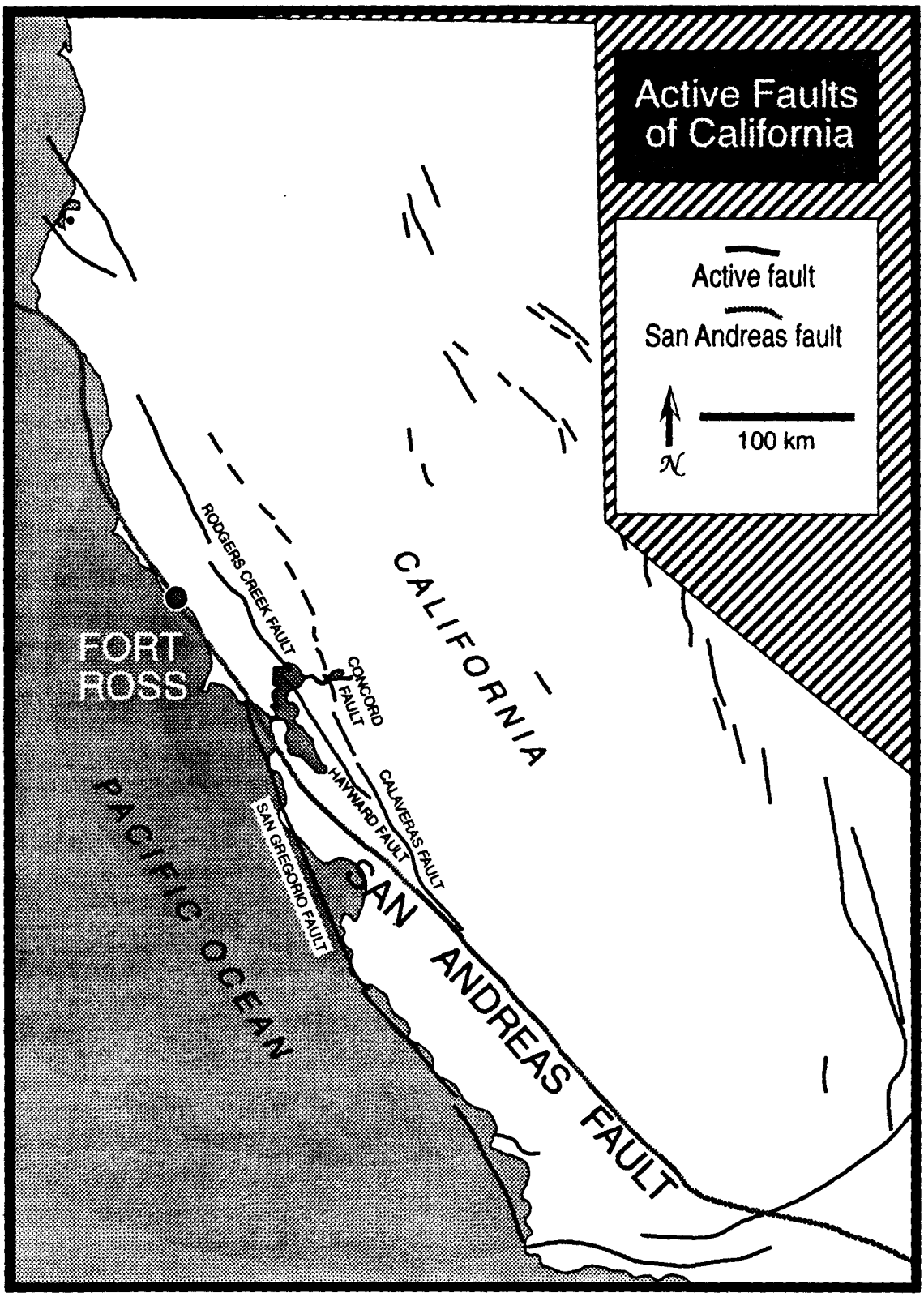

Figure 1. The Fort Ross study area is located on the northern segment of the San Andreas fault approximately 110 km northwest of San Francisco.

Primary data that are required to assess fault slip rates and earthquake recurrence intervals are the amount of displacement and age of displaced linear or planar features. Recent paleoseismic investigations have used geologic or geomorphic piercing lines, such as paleochannels or marine terrace back-edges, to assess fault displacements. These studies typically estimate ages of displaced and undisplaced features or strata via radiometric dating of charcoal fragments. In many cases, these techniques provide insufficient constraint on the amount and ages of displacements, and resultant uncertainties in slip rates and recurrence intervals are large.

New Role of Archaeology in Paleoseismic Research

One approach to better constrain these uncertainties is to assess the displacement and age of offset archaeological sites and features. This approach, which we are employing in this study, is significant for several reasons:

1. Age Control. Many archaeological deposits contain charcoal fragments and cultural artifacts that provide a means to estimate the age of strata. The archaeological chronology of the North Coast Ranges has been greatly refined by recent advances in our understanding of the hydration rates of local obsidian materials. The common occurrence of obsidian artifacts on prehistoric sites in the Fort Ross area allows us to assign dates to most archae-ological deposits. Thus, uncertainties concerning detrital redwood charcoal are avoided.

2. Ethnostratigraphic Piercing Lines. The spatial distribution of cultural features can be well-constrained. Many of those features are linear or have well-defined margins and therefore provide excellent strain gauges for evaluating fault displacement (Figure 2). One example along the northern San Andreas fault may be an offset linear brick feature (possibly a fallen chimney) from SON-1446 in the Fort Ross State Historic Park built sometime between A.D. 1812 and 1841. Displacements can also be estimated based on the distribution of offset occupational sites. Cultural artifacts provide another means to identify distinct stratigraphic intervals, which can then be used to obtain the amounts or number of displacements. For example, isopachs of discrete cultural strata provide excellent linear features.

3. Stratigraphic Record. The long-term stratigraphic record of some archaeological deposits may provide a diachronous record of paleoearthquakes. A few sites in the Fort Ross State Historic Park may be characterized by occupation episodes that span a period of several hundred to one or more thousand years. These sites may contain archaeological deposits that allow for reconstruction of the middle-to-late Holocene paleoseismic history of the northern San Andreas fault.

In short, the use of archaeological features in paleoseismic investigations is an approach that we believe provides excellent potential for assessing the timing, style, and amounts of surface ruptures. In addition, this approach has the potential to greatly improve the resolution of evaluations of slip rates and recurrence intervals based on geologic data. We anticipate that this project will contribute to understanding the recurrence interval and geologic slip rate along the northern San Andreas fault and will provide direct input for constraining time-dependent probabilities of large-magnitude earthquakes on the northern San Andreas fault.

Project Objectives

The primary objectives of this research are to constrain better the seismic character of the northern San Andreas fault and to develop new paleoseismic investigative techniques that incorporate archaeological features. In the Fort Ross area, the San Andreas fault is geomorphologically well expressed and there is on-site documentation of deformation associated with the 1906 earthquake (Lawson 1908). In addition, this area contains a rich and varied archaeological record that may span back to the mid-Holocene. Together these data provide an excellent opportunity to obtain the following information related to Holocene behavior of the northern San Andreas fault:
(1) Timing and Recurrence of Moderate-to Large-Magnitude Earthquakes. Based on stratigraphic relations exposed during geo-

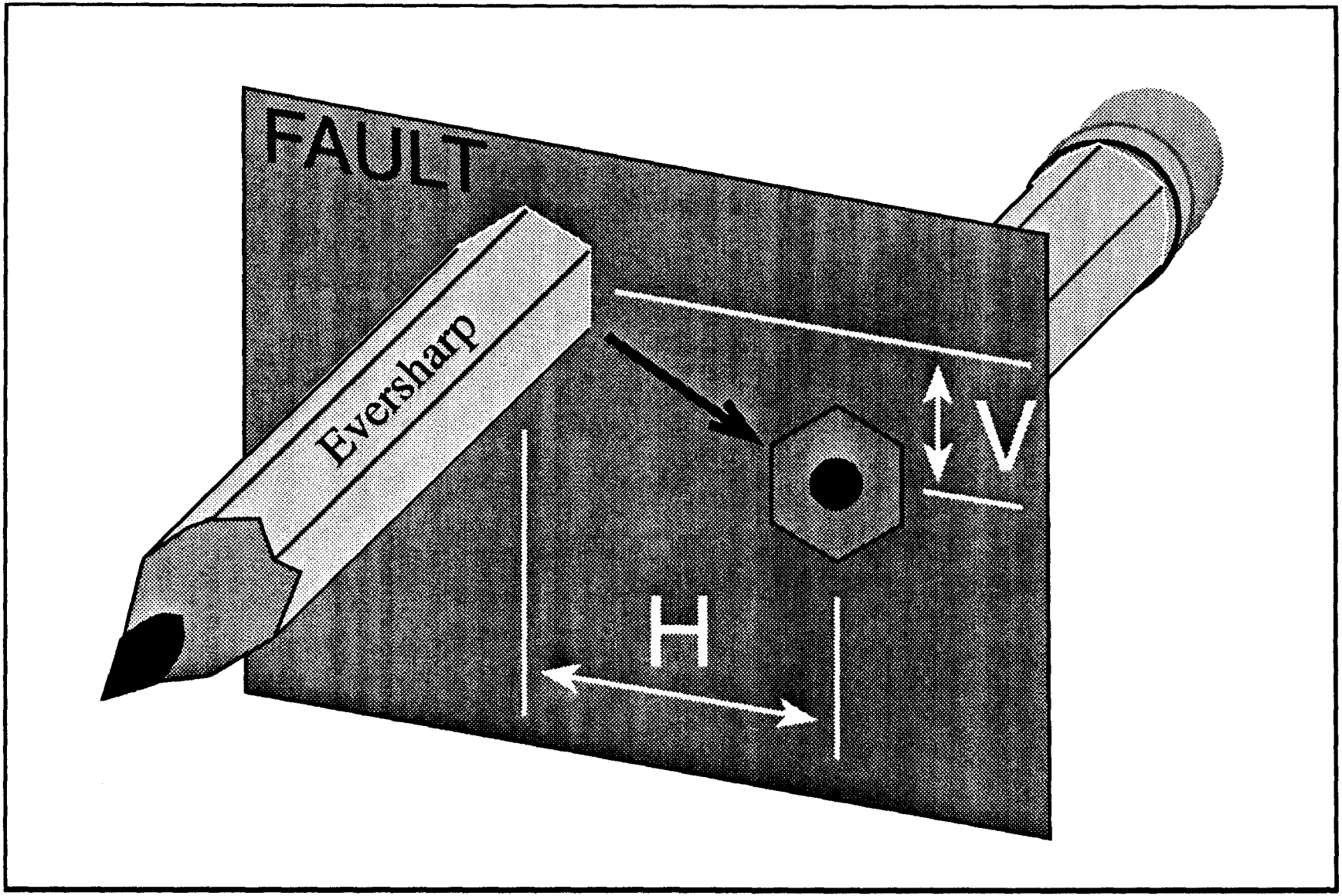

Figure 2. A cultural piercing line is represented here by a pencil that is split and offset along a fault. Using the pencil as a piercing line, one is able to determine the amount of horizontal (H) and vertical (V) displacement along the fault since the pencil was laid across the fault.

logic subsurface investigations, we are developing an event stratigraphy to assess the number and timing of paleoearthquakes.

(2) Holocene Slip Rate and Displacement Per Event Data. Based on offset cultural, geologic, and geomorphologic features, dated via radiometric, obsidian-hydration, and diagnostic artifacts, we are assessing middle-to-late Holocene displacements and slip rates.

(3) Development of New Approaches and Techniques for Paleoseismic Investigations. In addition to conventional geologic approaches, we are applying archaeological methods to assess the long-term cycle of seismic events along the northern San Andreas fault. These methods are examining the timing and magnitude of displacements of archaeological deposits along the fault.

(4) Fault Segmentation and Lengths of Paleo-Ruptures. Segmentation of the northern San Andreas fault may be elucidated through combination of the results of this study with existing estimates of the timing of paleo-ruptures to the north and south of Fort Ross (Prentice 1989; Niemi and Hall 1992).

Project Setting

Paleoseismic and geoarchaeologic research is currently focusing on SON-670, an areally extensive, multi-component archaeological deposit located 1 km east of Fort Ross. The site is transected by and offset along its western margin by the San Andreas fault. At this location, the fault is a single strand and is well-defined by linear troughs and ridges, scarps, and closed depressions. The archaeological deposit is located on a wide, sidehill bench between the San Andreas fault and Fort Ross Creek. The fault is defined by a west-facing escarpment adjacent to SON-670. West of this escarpment are a closed depression and several sidehill benches at about the same elevation. Surface rupture along this strand of the San Andreas fault was well documented following the 1906 earthquake (Lawson 1908). Local evidence of the surface rupture associated with the 1906 earthquake includes a fence that is offset by 3.7 m along a single fault strand (Lawson 1908).

Archaeological excavations of SON-670 have been conducted at 4 separate times (Lightfoot et al. 1991). The initial excavations were undertaken in 1971 to mitigate effects of the construction of a group campground on the site (Stillinger 1975). Excavations were also undertaken by the California Department of Parks and Recreation in 1979 and 1985. The 1985 excavation evaluated the impact of a proposed septic tank in the campground. In 1988, U.C. Berkeley field crews recorded a small locus 30 m south of the main site. Excavations were undertaken in 1990 by crews from Santa Rosa Junior College to mitigate further expansion of the camp.

The main area of the site includes approximately 3,750 m^2. Stillinger (1975) notes the foundations of buildings, probably built as part of a historic logging operation. The southern locus, recorded in 1988, is an elliptically-shaped midden, approximately 104 m^2 in area, close to Fort Ross Creek. A large quantity of lithic artifacts and some faunal remains were recovered during the above investigations. Stillinger's (1975) analysis of lithic materials from the 1971 excavation included 2 battered cobbles, 4 choppers,1 anvil, 5 large bifaces, 2 scraper planes, 6 handstones, 2 net weights, 1 pestle, 57 whole or fragments of projectile points, and a considerable quantity of chert and obsidian debitage. Historic materials include 15 glass beads, many nails, and 40 glass fragments from the 1971 excavation. Two projectile points are manufactured from glass.

Stillinger (1975) and Lightfoot et al. (1991) suggest a long use duration for SON-670, involving at least 3 major occupation episodes. The presence of shouldered lanceolate points in the lower levels of some excavation units dates the earliest occupation of the site to the Upper Archaic (1000 B.C - A.D. 500) or Lower Emergent (A.D. 500-1500) periods. The second phase of occupation appears to have occurred during the early historic period, due to the presence of glass trade beads, glass projectile points, and corner-notched projectile points. Farris (1986) suggests that this occupation occurred during Russian times (A.D. 1812-1841) and/or the early ranching phase (A.D.

1841-1867). The third phase of occupation is that of the logging operation established at Fort Ross by James Dixon and Charles Fairfax in A.D. 1867 (Lightfoot et al. 1991).

Our preliminary reconnaissance shows that additional loci of cultural materials are present west of the fault, i.e., across the fault from the main occupation site. We hypothesize that these loci were, in their own time, contiguous with the main occupation site but have since been offset along the fault. In essence, we expect the spatial patterning of these smaller sites to indicate progressively older ages to the north and, thus, that these sites represent a lateral or horizontal stratigraphy correlatable with the different occupations at the main occupation site. Piercing lines established from 3-dimensional analysis of the main site should be correlatable with piercing lines constrained in plan view on the sidehill bench sites.

Defining discrete stratigraphic horizons at the site is difficult given bioturbation created by burrowing rodents and other natural agents. However, the spatial distribution of artifact types (e.g., projectile points), faunal assemblages, specific kinds of debitage, and dated materials (via obsidian hydration) can be employed to reconstruct the formation processes of the site over time.

METHODS OF INVESTIGATION

We are characterizing the paleoseismic and geoarchaeologic history of SON-670 via several interrelated tasks. These tasks, described below, are being conducted within both geologic and archaeologic contexts.

Task 1: Characterization of Surficial Geology and Archaeology

We are mapping surficial geology and archaeology at a scale of 1:200 using a TOPCON total station on a topographic base map (0.2 m contour interval) of our own construction. The topographic map consists of the delineation of fault-related geomorphic features and surficial deposits, and surface distribution of SON-670. It is expected that this mapping will delineate surface geological piercing lines (e.g., ridges, channels, etc.) and archaeological piercing lines (e.g., site boundaries, trails, roads) for use in slip-rate determinations.

Task 2: Characterization of Near-Surface Geology and Archaeology

To establish additional geologic and archaeological piercing lines to be used in deriving slip rate, we are excavating hand-auger borings, archaeological test units, and exploratory trenches.

Hand-auger borings are being drilled to assess the three-dimensional distribution of ethnostratigraphic units. Boring holes are excavated on 1, 2, and 5 m grids laid out on both sides of the fault within the boundaries of SON-670, with the smaller grid size adjacent to the fault. Tops of the holes have been surveyed to ensure precision of our 3-dimensional reconstructions. Soil samples are taken at 10 to 20 cm depth intervals from each boring. The soil samples are being analyzed in the laboratory for various chemical, geological, and archaeological constituents, as described below. Results from these investigations will be plotted and contoured to provide preliminary piercing lines. Along the locations of these piercing lines, additional hand-auger borings may be placed at shorter intervals.

Archaeological test units are being excavated to provide context and chronostratigraphic control for hand-auger borings. Well-placed test units may better define the piercing lines defined by hand-auger boring and help establish the chronology of these features.

Exploratory trench excavations across the San Andreas fault are used to develop an event stratigraphy based on displaced and undisplaced lithostratigraphic and ethnostratigraphic horizons. We have excavated 2 backhoe trenches, to a depth of almost 5 m, across a closed depression located directly west of the main site of SON-670. The trenches are providing site-specific, three-dimensional stratigraphic and archaeological information to establish correlations across the fault. The event stratigraphy, combined with the estimate of slip rate based on offset archaeological deposits, provides an excellent opportunity to establish recurrence in-

tervals and estimates of slip per event for the northern segment of the San Andreas fault.

Task 3: Document, Analyze, and Date Field Samples

Field samples are analyzed to document and quantify the characteristics of lithostratigraphic, pedostratigraphic, and ethnostratigraphic horizons that may not be apparent based on field observation. Laboratory characterization of litho- and pedostratigraphic units include analyses of particle size, organic carbon, and pH. Data pertinent to the definition of ethnostratigraphic units include: lithic artifact classes (formal tools, flakes and debitage), raw material types (obsidian, chert, etc.), faunal remains (mollusks, animal bones), and historic artifacts (ceramic, metal, glass). To aid in the detection of small artifacts and faunal remains, all soil samples were wet screened through 1 mm mesh, dried, sorted, and bagged. Obsidian recovered in the samples were analyzed by the Obsidian Hydration Laboratory at Sonoma State University. Carbon recovered from some soil samples is being submitted for radiometric dating.

Piercing lines across the fault will be defined by offset archaeological deposits. For example, isoratio lines of chert/(chert + obsidian) debitage are piercing lines. Based on data from one of the previous excavations, we have made preliminary plots of the ratio of chert/(chert + obsidian) debitage in the near surface layer and contoured these to produce isoratio lines. Even with minimal data, the plot shows 2 isoratio lines at high angle to the fault. Because these data include quantity and age of obsidian, these isoratio lines are excellent dated piercing lines across the fault.

Similar spatial trend analyses will be undertaken with the archaeological materials recovered from auger-holes, test units, and trenches. Cryptic trends in the chemistry of the soil samples, including phosphorus, iron, and organic carbon, are being plotted as functions of location, depth, and host stratigraphic horizon. Plotted in plan view for any given stratigraphic horizon, isoconcentration lines of these chemical tracers that cross the fault zone may also be used as piercing lines to estimate amounts of fault displacement.

Summary

The project described in this paper is employing archaeological data to estimate the recurrence intervals for large-magnitude earthquakes on the northern San Andreas fault. We believe that archaeological sites, such as SON-670, located along fault segments may be offset by previous seismic events. We are attempting to define piercing lines across the fault that represent displaced archaeological deposits. We will define isoratio contours, based on the spatial distribution of archeological materials, as piercing lines. Archaeological materials that define these piercing lines will be dated by obsidian hydration and radiometric methods. By measuring the amount of displacement along the fault, and defining the chronology of these seismic movements, we may be able to define the slip rate and amount of lateral movement per event as part of the long-term cycle of seismic activity along the North Coast segment of the San Andreas fault.

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