Evidence for recent change in strain on the Gualala Block, Northern California

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INTRODUCTION

A compressional fault near the town of Point Arena records a sense of shortening opposite to the regional direction of shortening, suggesting a recent change in strain on the northern tip of the Gualala Block. The Gualala block in northern California is bounded by the San Andreas Fault to the east, the inactive Pilarcitos/Montara Fault to the west, and a remnant of the Farallon plate, known as the Vizcaino block, to the north. A curviplanar, low-angle thrust fault dipping southeast and cutting the youngest marine terrace deposits indicates a change in orientation for the shortening direction on the Gualala block. NW-SE trending folds in the local bedrock record a previous compressional event which does not penetrate the Quaternary terrace. This suggests that the direction of shortening near Point Arena has shifted since the Pleistocene Epoch. The dynamic tectonic relationship between the Gualala block and the Vizcaino block may explain the presence of this thrust fault (Fig. 2).

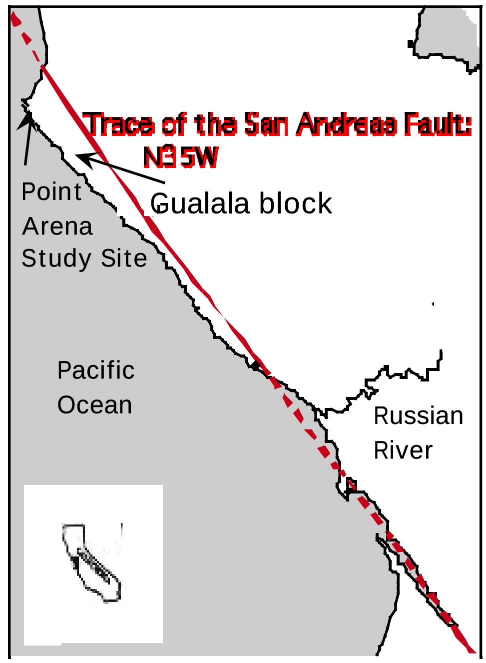

Fig 1. Location of Gualala Block and Point Arena, California

Fig 2. Tectonic Setting of Gualala block and Vizcaino block (modified from McCullough, 1989).

The San Andreas Fault severely deforms rocks in northern California, including those on the Gualala block, as they are translated along the oblique transform fault boundary. The Neogene structural development of the Gualala block and the Vizcaino block are closely tied to the northward migration of the Mendocino Triple Junction and the instabilities created at the geologic boundaries (Castillo and Ellsworth, 1993). Jones et al. (1998) reported “at least three distinct deformations….recorded by the structures within the Gualala block.” The oldest structures are extensional faults down-dropping younger strata onto the oldest rock on the Gualala block. Younger north-south compressional folds and faults crop out near the Black Point ophiolite. The youngest deformation features are also compressional and include northwest-trending, tightly folded Miocene strata; and northeast-dipping thrust faults near Point Arena (Jones et al., 1998). The thrust fault examined in this study is evidence for a subsequent deformational event because it disturbs a Pleistocene age terrace deposit and has an opposite orientation.

The San Andreas Fault came into notoriety following the 1906 San Francisco earthquake. Offset fences and displaced streams recorded rupture due to this event along the San Andreas Fault trace as far north as the Gualala Block. While there have been many studies on the Gualala block, only two have focused on the Point Arena area. In 1971, the Pacific Gas and Electric Power Company sent two geologists to map the area just north of the town to determine whether the area was structurally stable to support a nuclear power plant (Jahns and Hamilton, 1971). The thrust faults examined in this study were not included on this map. Dr. Carol Prentice mentioned multiple thrust faults at this site in her Ph.D. in 1989. In a field guide compiled for the Gualala Block in 1998, she is quoted as saying, “These relations indicate recent compression along the [San Andreas] plate boundary in this area” (Anderson and Stanley, 1998).

METHODS

Terracing and uplift of the folded Miocene strata of the Point Arena Formation occurred during the 80,000 year high sea level stand (Muhs, et al., 1994). Terrace deposits overlie the Point Arena Formation, but do not show evidence of folding. A structural map of the field area was compiled from bedding attitudes of the local bedrock of the Point Arena Formation along a 7 kilometer stretch of sea cliffs from the town of Point Arena, north to the lighthouse. Bedding strikes NW-SE and dips either NE or SW. The structural map designates the location of the anticline and syncline axes. Stereonet analysis shows the axial plane strikes 315° and dips 83° east. The fold axis plunges 13° toward 316° (Fig. 3).

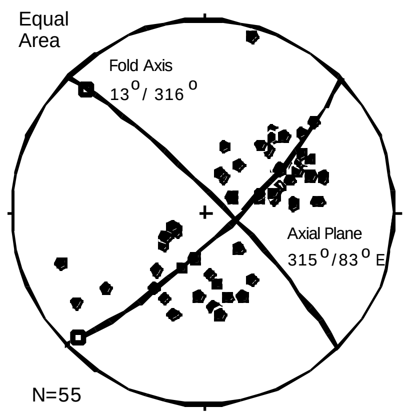

Fig. 3. π-solution for fold axis in the Point Arena Formation.

The fault exposures were studied in outcrops and trench profiles. Exposures of the thrust fault crop out along the sea cliffs and in collapse pits structurally underneath a Quaternary terrace deposit. Each exposure revealed the nature of the faulted relationships once cleaned off with shovels. In all five exposures the Miocene Point Arena Formation is thrust onto Quaternary-age terrace deposits. Measured stratigraphic sections of each individual outcrop describe the exposures. Similar clay gouge is present in each shear zone. Attitudes of the fault surface change along the trace of the fault. Only 15-40 meters, as measured in the field, separates each fault exposure. In one exposure, soil thickness changes between the hanging wall and the foot wall of the thrust fault. Small-scale fabrics in an oriented sample collected from the fault zone reveal a direction of transport, which is slightly west of north. Minimum displacement along the fault plane, measured from offset terrace markers, is 9 meters.

Total station data were collected to create a detailed topographic base map of the field area (Fig 4). The topographic map includes the coastline, topographical features of the terrace surface, and the location of the thrust fault. This map contains the entirety of the fault trace interrupting the terrace surface

RESULTS

The five exposures appear to form part of a single fault system rather than a multiplicity of fault systems as Prentice (1989) proposed. The changes in strike orientation imply a curviplanar geometry for a near-surface, low-angle thrust sheet. The topographic map reveals a small riser developed in the soil horizons, parallel to the trend of the fault plane, linking two of the exposures (Fig. 4).

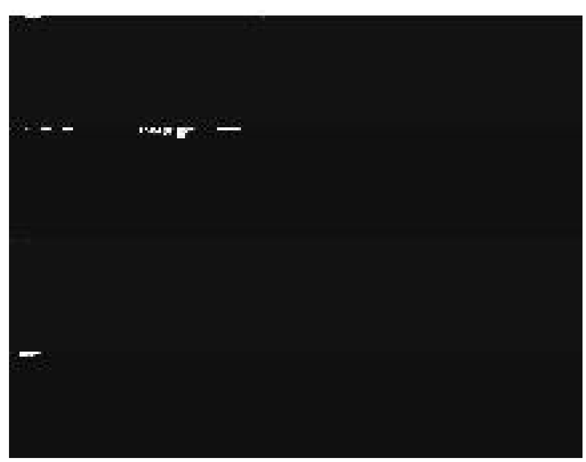

Fig. 4. Topographic map created with Total Station data

The detailed topographic map created from the total station data also shows a shallow seaward dip of 3 degrees on the western margin of the terrace surface, while otherwise it is a relatively planar surface. The topographic contours drop noticeably by 24 cm along the riser connecting two of the exposures from the hanging wall to the foot wall of the thrust sheet (see Fig 4). This conforms with the general scenario for near surface faulting in unconsolidated deposits where “The hanging wall is thrust up and over the footwall to form a hump (pressure ridge) or moletrack scarp” (quoted from Weber and Cotton, cited in Carver and McCalpin, 1980). Because the overlying terrace deposits have been disturbed, faulting must have occurred after the terrace was formed. The characteristic of the terrace surface riser agrees with Weber and Cotton’s description of a near surface thrust system. In addition, soil is thicker on the foot wall than on the hanging wall, due to erosion of soils from the hanging wall and deposition on the foot wall (Fig. 5). The soil is only broken near extensional fractures on the small anticlinal hanging wall fold. This suggests the fault has been active since development of soil on the terrace.

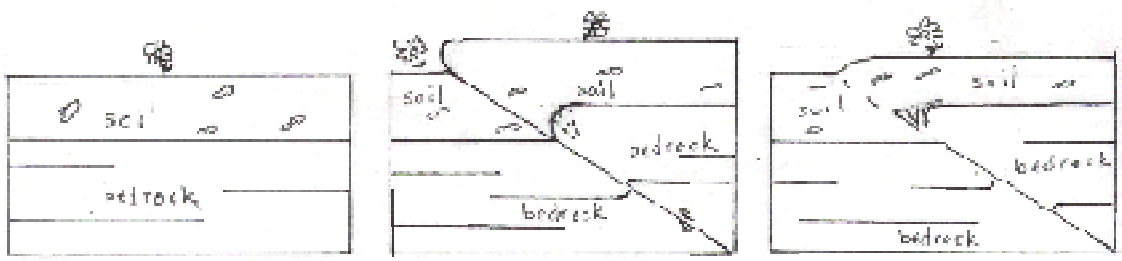

Fig 5. Cartoon showing the development of soil on a near-surface thrust fault. The soil is thicker on the foot wall after the fault has propagated the surface. A “hump or moletrack scarp” forms at where the fault intersects the surface. Soil fills extensional cracks on the hanging wall.

The terrace affected by the faulting is the youngest terrace surface on the Gualala block. The shoreline angle elevation (the best representation of mean sea level at the time the wave-cut platform formed) on the terrace surface is approximately 23 meters above sea level and corresponds to the 80,000 year high sea-level stand (Muhs, et al., 1994). *Balanophyllia* coral fossils from two localities on the terrace surface yielded U-series ages of 76,000+/- 4,000 (Muhs, et al., 1990) and 88,000 +/- 2,000 (Muhs, et al., 1994). These ages provide a maximum age for the faulting.

The 80,000 year old terrace surface truncates a pair of folds in the Point Arena Formation trending NW-SE. The folds within the Point Arena Formation record different strain than the fault of the Point Arena Formation into the Pleistocene marine terrace. NW-SE folds in the Point Arena bedrock resulted from NE-SW shortening, while the thrust fault strikes across the bedding and records NW-SE contraction. The low angle thrust fault crosscuts the folds which are not seen to penetrate the terrace surface throughout the field area. Thus, the orientation of the maximum principal stress near the town of Point Arena must have changed from NE-SW, approximately orthogonal to the Gualala block, to NW-SE, parallel to the long axis of the Gualala block.

CONCLUSIONS

The thrust fault north of Point Arena, California is important because it cuts the youngest deposits on the Gualala block, dated at around 80,000 years. The previous structural deformation in the area, folding of the Point Arena Formation, did not involve these Pleistocene-age deposits. The change in the direction of the maximum principal stress, responsible for earlier folding followed by Pleistocene thrust faulting, may be related to the ongoing northward migration of the Mendocino Triple Junction (Atwater, 1989). Instabilities exist between various tectonic blocks associated with the triple junction (Castillo and Ellsworth, 1993). One such unstable tectonographic boundary lies between the Vizcaino block and the Gualala block. The Vizcaino block is considered part of the Pacific plate and is being translated north relative to the North American plate along the San Andreas Fault (Atwater, 1989). Because most of the motion along the San Andreas Fault system is currently compensated along the Maacama and Bartlett Springs faults, and the Vizcaino block does not extend east to these faults, the block has become a rigid part of the Pacific plate (Castillo and Ellsworth, 1993). The northern edge of the Vizcaino block lies along the 1500 meter high Gorda Escarpment (McCullough, 1987). Stratigraphy interpreted from multichannel seismic data implies that the escarpment is a recent “pop-up feature caused by north-south compression” (Leitner, et al., 1998). As the Gualala Block continues to migrate north with the Mendocino Triple Junction, the Vizcaino block may act as a rigid barrier to this northward migration.

This study suggests that the Gualala block has buckled near its boundary to the Vizcaino block, since it is moving northward relative to a “stable” Vizcaino block. One possible model suggests that the north-south compression on the Vizcaino block may be transferred to the Gualala block at the boundary between the two tectono-specific blocks. Another possibility includes that the motion of the Gualala block is simply hindered by the rigidity of the Vizcaino block. The boundary between the two blocks is just north of Point Arena where the thrust fault occurs. It is the conclusion of this study that the Vizcaino block is impeding the northward migration of the Gualala block. As the block has moved north, it has accumulated strain. The thrust fault indicates that the brittle limit of the near-surface materials was exceeded on the Gualala block during its transport northward into the more rigid Vizcaino block.

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