Interpretation of anomalous and previously unmapped Franciscan Complex from the Gualala Block, Northern California coast

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INTRODUCTION

The Franciscan Complex is a tectonic melange of blueschist facies metamorphic rocks that was deposited as sediments in the accretionary wedged formed during the subduction of the Farallon Plate beneath the north American Plate from the Late Jurassic until the end of the Cretaceous. Rocks belonging to the Franciscan Complex crop out along more than 650 km of the California coast and can be further subdivided into several tectonostratigraphic terranes (Blake et al., 1984). In northern California, the San Andreas Fault (SAF) separates the Franciscan-bearing terranes to the east from a terrane known as the Gualala Block to the west, which has been translated hundreds of kilometers to the north. However, near Point Arena, isolated anomalous exposures of rocks typical of the Franciscan Complex have been found west of the SAF in the Gualala Block. The stratigraphy of this area (Wentworth et al., 1998) consists of Cenozoic sedimentary units and does not include any lithologies similar to those typical of the Franciscan Complex. The purpose of this study is to: 1) investigate these anomalous outcrops and determine if their lithologic characteristics support their inclusion in the Franciscan Complex; 2) devise geologic models that could account for the presence of the Franciscan Complex west of the SAF and; 3) evaluate the proposed models in light of local and regional geology.

METHODS

During the summer of 1999, 21 samples of Franciscan Complex and inferred Franciscan Complex rocks were collected in the general Pt. Arena/Manchester vicinity from 11 different localities, 8 of which were west of the SAF (Figure 1). There is very limited bedrock exposure in the area due to the thick cover of Quaternary marine terrace deposits. A thorough search was made for all exposures of Franciscan-affinity rocks and all finds were sampled. Some outcrops could not be sampled because the private landowners refused permission. The samples were cut and ground into standard thin sections and stained with sodium cobalnitrate to aid in the identification of potassium feldspar. Analyses of these thin sections, together with general field and hand sample observations, were used to classify the rocks based on metamorphic texture, mineralogy, and shared characteristics.

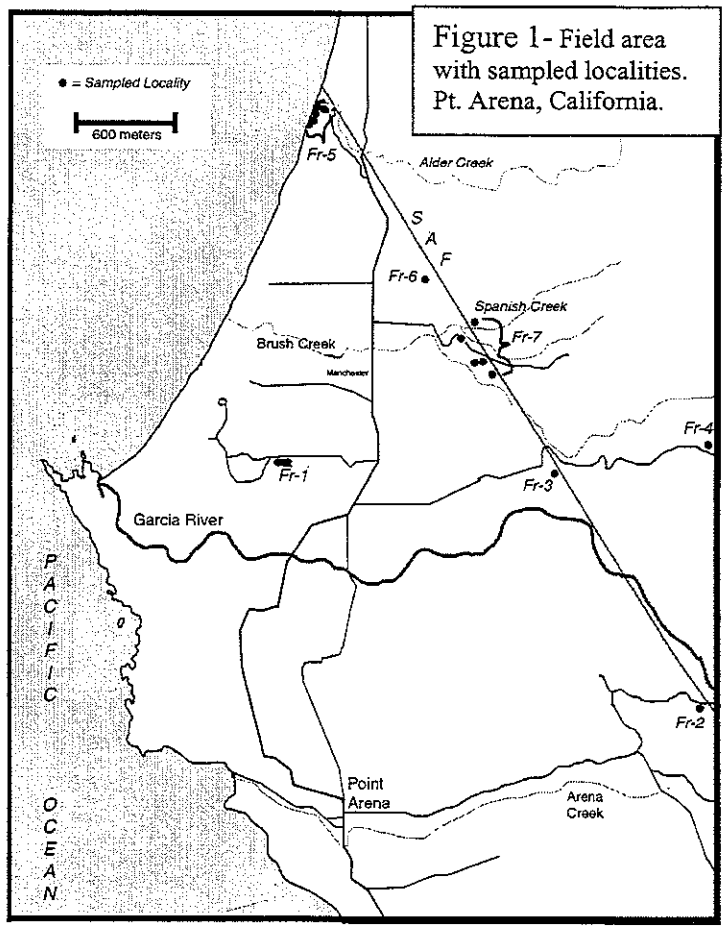


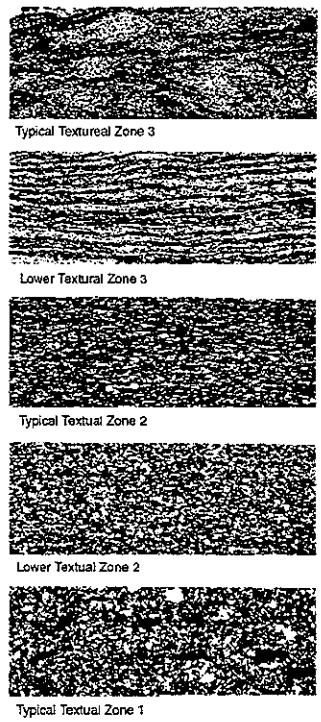
Figure 1- Field area with sampled localities. Pt. Arena, California.

RESULTS

All of the samples display a metamorphic fabric that is very weak when compared to the bulk of the Franciscan Complex (Blake et al., 1967). Quartz grains show some flattening and basalts display an altered ophitic texture. Under the classification of Franciscan metagreywacke metamorphism presented by Blake et al., (1967) all of the samples fall under textural zone 1 (Figure 2). This evidence supports their origin from the westernmost part of the Franciscan Complex because the metamorphic grade within the complex increases from west to east (Blake et al., 1967). The metamorphic mineral assemblage found in textural zone 1 coincides exactly with that observed in the samples. Chlorite, recrystallized quartz, and albite are common as is pumpellyite which is the most diagnostic mineral of low temperature, low pressure metamorphism (Blake et al., 1967).

The results of the cobalnitrate staining showed that most of the samples contained little or no potassium feldspar. The one locality that contained abundant potassium feldspar is also the most unusual and significant outcrop sampled (Figure 1, Fr-1), as it is the most isolated locality and farthest west of the SAF. The sampled outcrops can be directly correlated to specific terranes of the Franciscan complex. Two of the samples, one of which was from the east side of the SAF (as a comparison), showed approximately 2% potassium feldspar. Some is expected in the coastal belt to the east and such a small amount in any sample could come from many sources. All of the samples taken from the Stoneboro Road outcrops (Figure 1, Fr-1) yielded approximately 30% potassium feldspar. These greywackes appear very similar to the other samples in hand specimens but there is a clear difference in the amount of potassium feldspar.

Figure 2- Textural zones of Blake et al., 1984, p. C4.



MECHANISM OF EMPLACEMNET

Petrographic analysis indicates that the sampled lithologies have affinities with the westernmost exposures of the Franciscan Complex that crop out along the east side of the SAF. The fact that they lie west of the fault and are surrounded by the sedimentary rocks of the Gualala Block presents an interesting geologic problem. Three theories are suggested as the most probable methods for incorporation of Francsican Complex rocks into the Gualala Block.

The first hypothesis requires that the SAF has migrated eastward with time. The Franciscan Complex rocks would be incorporated into the Gualala Block as small slivers as the fault jumped progressively eastward. The exposures further inland would be the oldest and from the furthest south. For example, imagine a releasing bend as illustrated in Figure 3. As time progresses; 1) the SAF with a releasing bend in it; 2) the fault straightens itself and the more westerly portion moves to the east in a later rupture; 3) now rock from the Franciscan Complex is translated to the west of Gualala Block strata and 4) through time, more eastward jumps of the fault at releasing bends and continued strike slip movement can incorporate slivers of Franciscan complex into the relatively northward moving Gualala Block.

The second hypothesis considers the Franciscan exposures at locality Fr-1 to be part of a poorly understood and largely offshore terrane known as the Vizcaino Block. The Vizcaino Block is suspected of having Franciscan Complex as part of its stratigraphic assemblage and the southeast corner of the terrane has been projected to come ashore near the studied area (Figure 4). Thrust faults on the west side of the Vizcaino Block could have emplaced Franciscan Complex rocks west of the SAF. There are known lineations in the terrane that could possibly be such faults, but concrete evidence was not obtained. Without greater field evidence and further research, it is not possible to thoroughly evaluate this hypothesis.

The third hypothesis, which must be considered when dealing with a complex fault system such as the SAF, is that localized transpressional forces may have produced thrust faults, (flower structures) that have brought up material from the fault zone and thrust it to the west. This scenario is more likely for the outcrops that are closer to the fault trace. Quaternary faulting of the Gualala Block was observed, but nothing concretely relating he observed outcrops to flower structures was found.

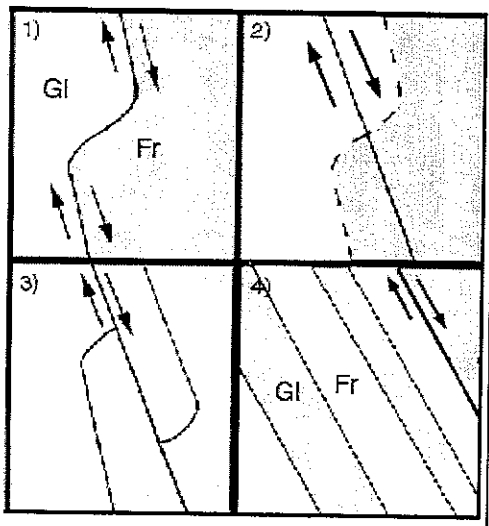


Figure 3- (left) Mechanism for the incorporation of Franciscan Complex into the Gualala Block along the SAF.

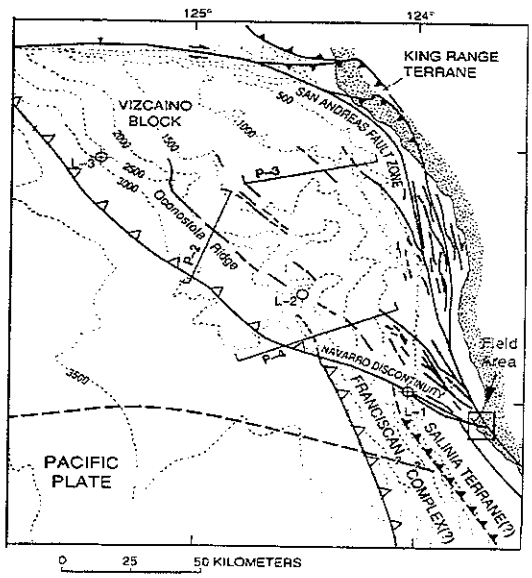


Figure 4- (right) Map of the Vizcaino Block in relation to Pt. Arena and the California Coast (After McLaughlin et al., 1998, p.38)

DISCUSSION

All of the sampled rocks correlate well with the typical lithologies of the Central Belt of the Franciscan Complex. The Central Belt is typically composed of blocks of greenstone, chert, greywacke, and sandstone in a sheared matrix of argillite (Blake et al., 1988). This is exactly the assemblage observed in the studied exposures. The typical mineral assemblage of the central belt (quartz+albite+chlorite+pumpellyite+calcite+white mica) directly correlates with the thin sections. This supports the idea that these rocks were incorporated further south and have been translated northward by motion of the SAF but does not rule out other theories of emplacement. The Coastal Belt of the Franciscan Complex found on the east side of the SAF in the field area has similar greywackes that are characterized by the presence of laumontite (Blake et al., 1988). This metamorphic mineral was not found in samples from either side of the fault in the vicinity of Point Arena. However, the argillite matrix typical of the Central Belt Franciscan complex was not observed on the east side of the fault, leaving open the question of the affinity of those rocks. The characteristics of the Vizcaino Block are not well known and could account for some of the inconsistencies observed.

The Central Belt has been subdivided into 12 smaller tectonostratigraphic terranes (Figure 5) using metamorphic grade and the the abundance of potassium feldspar (Blake et al., 1984), so an even more specific location for the origin of the Franciscan Complex rocks within the Gualala Block can be hypothesized. The samples from locality Fr-1 correlate remarkably well with the San Bruno Mountain terrane (Figure 5) which is south of Point Reyes and directly on the east side of the SAF. The San Bruno Mountain terrane is the only terrane of the Central Belt with abundant potassium feldspar. If the Fr-1 outcrop came from further south along the SAF, it must have originated as part of the San Bruno terrane.

Samples containing little or no potassium feldspar that were collected closer to the trace of the SAF can be readily correlated to other terranes of the Central Belt. The terranes north of the San Bruno Mountain including the Rio Nido and Novato Quarry terranes and the undifferentiated Central Belt along the coast all seem to be a relatively good match for the lithologies and mineralogies observed (Figure 5). The fact that the samples all belong to metamorphic textural zone 1 supports their derivation from the California coast south of the Gualala Block because the grade of metamorphism is lowest along the coast and increases inland. The Rio Nido and Novato Quarry terranes are some of the youngest and most coherent parts of the Franciscan Complex melange. The knockers sampled from within the Gualala Block close to the SAF were relatively unsheared and coherent, suggesting that they were incorporated as large discreet blocks. This suggests that the blocks were emplaced in the Gualala block along widely spaced faults, with little post lithification internal deformation.

CONCLUSIONS

Based on close similarities in lithology and low metamorphic grade, the anomalous outcrops of rocks within the Gualala Block can be confidently correlated with parts of the Franciscan Complex exposed south of the block and just east of the SAF. The westernmost outcrop correlates with the San Bruno Mountain terrane while the rest of the outcrops correlate with Franciscan Complex lithologies exposed in terranes further north. The patterns of Franciscan Complex affinities observed in the anomalous outcrops in the Gualala Block are exactly those that would be produced by a combination of a gradual northward translation of the Gualala Block and periodic eastward jumps of the SAF. If this scenario is indeed the correct one, the trace of the SAF at this latitude in northern California has shifted approximately 3.5 km to the east while strike-slip displacement has accumulated 130 km of right-lateral

offset. The mapped Cenozoic cover of terrace deposits and sandstones (Boyle, 1965) may obscure much of the Franciscan Complex outcrop that would have been incorporated by the eastward jumping SAF. The Vizcaino block hypothesis cannot be discounted, but there is presently not enough information on it and its relationship to the Point Arena area to properly evaluate it. The hypothesis of fault structures at depth seems unlikely due to the affinity of these rocks to Central Belt Franciscan rather than the Coastal belt Franciscan which is found directly east of the field area. All the evidence form this study supports the origin of these Franciscan rocks from the southern Central Belt terranes discussed, and from that, the nature of the movement of the San Andreas Fault can be better understood.

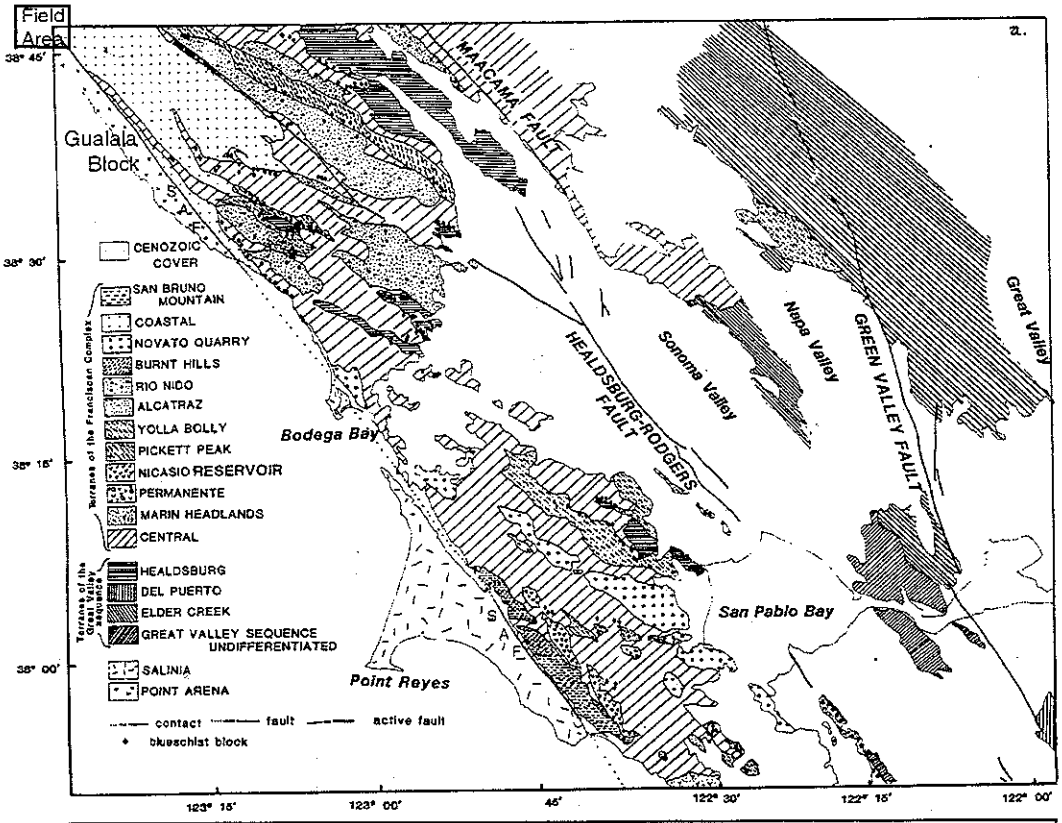


Figure 5- Tectonostratigraphic terranes of the Franciscan Complex and Great Valley Sequence, north of San Francisco Bay and south of Pt. Arena. (Blake et al., 1984, p. 6)

References

Bailey, Edgar H., Irwin, W. P., and David L. Jones, 1964, Franciscan and related rocks, and their significance in the geology of western California: California Division of Mines and Geology, Bulletin 183.

Blake, M. C. Jr., Howell, D. G., and Jayko, A. S., 1984, Tectonostratigraphic terranes of the San Francisco Bay region, in Franciscan Geology of Northern California: Pacific Section S.E.P.M., v. 43, p. 5-22.

Blake, M.C. Jr., Irwin, W. P., and Coleman, R. G., 1967, Upside-down metamorphic zonation, blueschist facies, along a regional thrust in California and Oregon, U.S. Geological Survey Professional Paper 575-C, p. C1-C9.

Blake, M.C. Jr., Jayko, A. S., McLaughlin, R. J., and Underwood, M. B., 1988, Metamorphic and tectonic evolution of the Franciscan Complex, northern California, in Ernst, W.G. ed., Metamorphic and Crustal Evolution of the Western United States, Ruby Vol. VII. p. 1035

Boyle, Michael W., 1965, Stratigraphy, Sedimentation and structure of an area near Point Arena, California. unpublished MS thesis, University of California, Berkeley, p. 64

McLaughlin, R. J, Sliter, W. V., Fredriksen, N. O., Harbert, W. P., and McCulloch, D. S., 1994, Plate motions recorded in tectonostratigraphic terranes of the Franciscan Complex and evolution of the Mendocino Triple Junction, northwestern California: U. S. Geological Survey Bulletin 1997.

Wentworth, Carl M., 1998, Geology and regional correlation of the Cretaceous and Paleogene rock of the Gualala Block, in Elder, W.P. ed., Geology and Tectonics of the Gualala Block, Northern California: Pacific Section, SEPM. p. 3-26.