MESOZOIC AND TERTIARY STRATIGRAPHY
OF THE BURDELL MOUNTAIN AREA
AND
IMPLICATIONS FOR SLIP ALONG THE EAST BAY
FAULT SYSTEM,
MARIN COUNTY CALIFORNIA

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SFSU Masters Thesis in Cooperation with
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INTRODUCTION

Estimates of long-term offset along the East Bay fault system (EBFS) have relied primarily on correlations of Miocene volcanic rocks. Fox et al. (1983) identified the northward-younging trend of volcanic rocks associated with northward migration of the Mendocino triple junction. Since approximately 12 Ma the EBFS has dissected and translated these volcanic rocks to the northwest resulting in the juxtaposition of older volcanic rocks to the west of younger volcanic rocks. Previous studies (McLaughlin et al., 1996; Graymer et al., 2002) estimated the net offset along the EBFS to be ~175 km based in part, on a correlation between the Quien Sabe volcanic field (QSV) and the Burdell Mountain volcanics (BMV) and general similarities in the Mesozoic basement (Great Valley Group) rocks in these two areas. However, previous K/Ar and Ar/Ar ages for the Burdell Mountain volcanics (11.8-13.6 ma) did not match those for the QSV (7.4-11.6 Ma), and few studies have focused on details of the Mesozoic basement rocks in either area.

This field trip will examine the stratigraphy and structural relations in the Burdell Mountain area (Figs. 1 and 2) and implications for net right-lateral displacement along the EBFS. We present new Ar/Ar ages for the BMV (~11 Ma) that now support the age correlation between the BMV and QSV (Table 1; Fig. 2). New detailed mapping at Burdell Mountain and field reconnaissance in the QSV have also revealed nearly identical stratigraphic relations between the volcanics and underlying Tertiary marine strata (Figs. 2 and 3). Additionally, submarine channel conglomerates of the Great Valley Group that form part of the basement rock in both the BMV and QSV areas have a Sierran provenance with essentially identical clast lithologies (Figs. 4 and 5). Current studies are focusing on establishing better paleontologic age constraints for these units and to evaluate better the previous correlations across the EBFS. We further suggest the conglomerates are offset right-laterally ~10 km across the Burdell Mountain fault zone (BMFZ), implying that the BMFZ is an important component of the EBFS. We will also examine youthful tectonic geomorphic features along the (unzoned) fault that suggest the fault is active, and may have produced a late Holocene surface rupture.
ACKNOWLEDGEMENTS

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REFERENCES


Figure 1. Road and topo map for stops 1 through 5.
Stop 1. *Intersection of San Antonio Road and I Street*

**Stratigraphic and structural relations across the Burdell Mountain fault zone (BMFZ).**

At this location (Fig. 2), the Cretaceous Novato Conglomerate (Kn) to the west is faulted against Franciscan sandstone (KJfm) to the east along the BMFZ. Both units and a thick gouge zone along the main trace of the fault are exposed in the road cut along San Antonio Road. The BMFZ is a northwest-striking, approximately 500 meter wide, subvertical shear zone that bounds the BMV block to the east. The fault can be traced northwestward from SF Bay for at least 14 km into Sonoma County across Chileno Valley Road.

The Novato Conglomerate has been identified as Great Valley Group strata (Berkland, 1969) and this unit appears to hold important clues for correlations between the BMV and QSV areas as well as for estimating right-lateral offset across the BMFZ. The conglomerate consists mostly of rounded, altered, porphyritic, felsic and intermediate volcanic rocks, quartzite, granitic rocks, and chert ranging in size from pebbles to boulders. Lower Cretaceous (?) *Buchia* (?) fossils (Figs. 6, 7, and 8) found in Kn shale and sandstone beds that underlie the conglomerate ~1 km to the west along San Antonio Road suggest the conglomerate is Lower Cretaceous or younger. The conglomerate closely resembles conglomerate (Figs. 3 and 5) mapped near QSV which has been correlated to the Upper Cretaceous Panoche Formation (Drinkwater, 1992). However, the age and hence, correlation of the conglomerates at QSV to the Panoche Formation is not yet supported by fossil evidence. A correlation between the conglomerates at this location and the type-Novato Conglomerate located ~10 km to the south and across the BMFZ is supported by several lines of evidence: 1) Clast counts for the two units (Fig. 9) show remarkably similar lithologies; 2) the conglomerate at both areas is several to many 10’s of meters thick indicating a submarine canyon depositional environment for both areas. Only minor conglomerate layers have been mapped west of the BMFZ to the south beneath the BMV; and 3) Lithologically similar, Lower Cretaceous sandstone and shale turbidites underly the conglomerates in both areas. The correlation of the submarine channel conglomerates across the BMFZ strongly suggests ~10 km of right-lateral offset on the fault. We will examine the type-Novato Conglomerate at Stop 4 (Fig. 1).
Figure 3. Location map showing the distribution of Miocene volcanic rocks in relation to the San Andreas fault system. Near Hollister, the San Andreas system branches northward into a series of sub-parallel active fault zones. The faults east of the San Francisco Bay consist of the Hayward-Rodgers Creek, Calaveras, Concord-Green Valley, and Greenville, and together comprise the East Bay fault system (EBFS) (McLaughlin et al., 1996). Figure modified after McLaughlin et al. (1996).
**Figure 4.** Schematic stratigraphic column of the Burdell Mountain area and the Quien Sabe volcanic field.
Figure 5. Upper Cretaceous (?) Panoche Formation (?) conglomerate (Kpc) near the Quien Sabe volcanic field east of Hollister. Clasts from this conglomerate are lithologically similar to those of the Novato Conglomerate.

Figures 6, 7, and 8. Buchia (?) fossils found in sandstone and shale beds underlying Kn along San Antonio Road. Buchia fauna range in age from Upper Jurassic to Lower Cretaceous.
Figure 9. Clast counts comparing the Novato Conglomerate at the Atherton Avenue and San Antonio Road sites. Based on 100 clasts from each locality.
Stop 2. Cooley's property near the northeast flank of Burdell Mountain

Recent(?) surface rupture along the Burdell Mountain fault

In this area, the BMFZ strikes northwest along the ridge to the northeast. The fault is here characterized as a broad, ~500 m wide zone consisting of several anastomosing (?) strands. The units northeast of the fault are Franciscan schist, phyllite, sandstone and serpentinite (Fig. 2). Rocks on the southwest side of the fault consist mostly of Great Valley sandstone and shale that is included with the Novato Conglomerate (Kn) in Fig. 2.

On the Cooley's property, the BMFZ exhibits tectonic geomorphology that is strongly suggestive of a Holocene surface rupture. The primary evidence for recent surface rupture consists of a well-preserved uphill-facing scarp and side-hill bench that is clearly expressed along the fault across several consecutive interfluvles (Fig. 9). Although these scarps are formed on serpentinite bedrock and regolith the fault also appears to offset modern stream channels and recent landslides locally. The scarps exhibit 0.5-1.0 m of down-to-the-east vertical separation of the hillslope surface. Similar scarps in bedrock can be traced discontinuously for ~5 km to the southeast and approximately 2 km to the northwest. Although we have not observed scarps in modern alluvium along this zone, we speculate that the youthful tectonic features may be late Holocene. Toppozada et al. (2002) located two earthquakes in the region with uncertain sources based on intensity reports and anecdotal information; the 1855 M 5.5 Petaluma and the 1898 M 6.5 Mare Island earthquakes. Although the locations of these earthquakes are not precisely known, they are large enough to produce surface rupture.

Figure 10. View north from the northeast flank of Burdell Mountain at an uphill-facing scarp (side hill bench) along the Burdell Mountain fault at Cooley's property.
Stop 3. Rancho Olompali Historic Reserve

BMFZ concealed by dip-slope style landsliding along faceted spurs

Approximately 1 km northwest of the Olompali parking lot, a ~3 m-high, down-to-the-northeast fault scarp along the BMFZ trends northwest along the southwest side of the small valley. Although the scarp is expressed in bedrock units and may be a fault-line scarp, it can be traced continuously for a distance of ~2 km. It also exhibits the same apparent sense of vertical offset as the recent-appearing scarps to the northwest at Cooley’s property. Previous workers (C. Wentworth, in Rice, 1973) noted the conspicuous nature and expression of fault scarps and suggested they might be young tectonic features. Alternatively, structural relations exposed in a drainage incised across the fault, 1.5 km northwest of Olompali, show that the resistant volcanics, which form the fault scarp are apparently down-dropped relative to Franciscan rock to the east, supporting a fault-line scarp interpretation.

In the Olompali Historic Reserve, landslides tend to exploit and break along foliation dip slopes within the volcanic rock, resulting in the formation of faceted slopes, clearly visible along the eastern escarpment of Burdell Mountain. The numerous landslides conceal much of the trace of the BMFZ as well as the contact between the volcanics and underlying Tertiary marine strata. However, Tertiary marine strata is exposed in the two largest northeast trending drainages to the west of the Miwok Village, and can be traced up to an elevation of ~200 m. It is unclear whether the Tertiary strata exposed in the drainages is intact or part of the landslide complex.

Due to logistics, we will not be viewing “intact” porphyritic andesite that comprises and caps the majority of Burdell Mountain (Figures 2a and 2b). However, there are abundant exposures of landslide deposits and blocks of porphyritic andesite, and volcanic breccia at this stop. Ar/Ar ages from a sample of the andesite near the summit quarry and on the northwest flank of the mountain, revealed dates of 11.18 ± 0.05 Ma and 10.99 ± 0.08 Ma respectively (Table 1; Fig. 2).

Stop 4. Bugeia Lane

Type location for the Lower (?) Cretaceous Novato Conglomerate

Shale beds underlying the conglomerate along Atherton Avenue yielded Lower Cretaceous mollusks (*Buchia*). *Buchia* were also collected from a clast within the Novato Conglomerate indicating a maximum Lower Cretaceous (Valanginian) age for the conglomerate (Berkland, 1969). In addition, a boulder of biotite-bearing, rhyolite porphyry in the conglomerate yielded a K/Ar age of 138 ± 4 Ma (Berkland, 1969) also indicating an Lower Cretaceous or younger age for the Novato Conglomerate. As discussed at Stop 1, sandstone and shale turbidites beneath thick submarine channel conglomerates north of Burdell Mountain also appear to contain Lower Cretaceous *Buchia*, lending strong support to the correlation of the Novato Conglomerate across the BMFZ and the interpretation of ~10 km of right-lateral offset on the fault.
Stop 5. San Andreas Drive

11.1 Ma Rhyolite and Landslides on the Southwest side of Burdell Mountain

Flow-banded rhyolite (Tvr) at this location yielded an Ar/Ar age of 11.07 ± 0.04 Ma (Table 1). The rhyolite lies nonconformably on metamorphic rocks of Franciscan Complex (KJfsch) (Fig. 2). The basal contact of the rhyolite is locally marked by perthitic glass that is exposed along the foot trail that trends northwest (?) across the ∼1 km² outcrop. The rhyolite locally exhibits columnar jointing. The rhyolite is very similar in age to the Northbrae Rhyolite in the Berkeley Hills (11.5 Ma) suggesting ∼25 km of cumulative right-lateral offset along the north bay portion of the EBFS (Hayward-Rogers Creek- Petaluma Valley- Burdell Mountain fault zones) (L. Murphy, personal communication). Detailed petrographic analyses and geochemistry are necessary to evaluate better this possible correlation.

Large landslides are visible to the northeast along the southwest slope of Burdell Mountain and have concealed the base of the rhyolite. A northwest-striking fault parallels the western escarpment of the mountain (Fig. 2). Structural relations across the fault are not well understood, although the fault is variably characterized by highly-sheared Franciscan rocks, gouge, and localized silicification where the fault cuts Tertiary units. Also visible high on the mountain, are large rotational slump blocks >1 km across. In contrast to most of the foliation-controlled landslide surfaces on the east side of the mountain, these rotational slumps cut layering within the Tertiary and Mesozoic rocks at a high angle. The landslides largely conceal underlying contacts between in-place units. However, pristine stratigraphic relations are preserved and exposed in deeply incised drainages around the west, north, and east slopes of the mountain (Fig. 2).

### Table 1

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<th>Isochron Age</th>
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