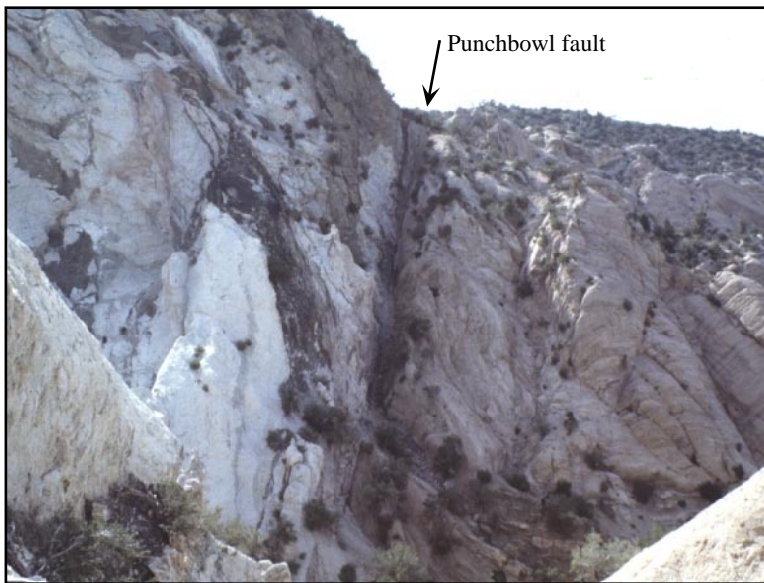


Field Guide to the Punchbowl Fault Zone at Devil's Punchbowl Los Angeles County Park, California

Frederick M. Chester

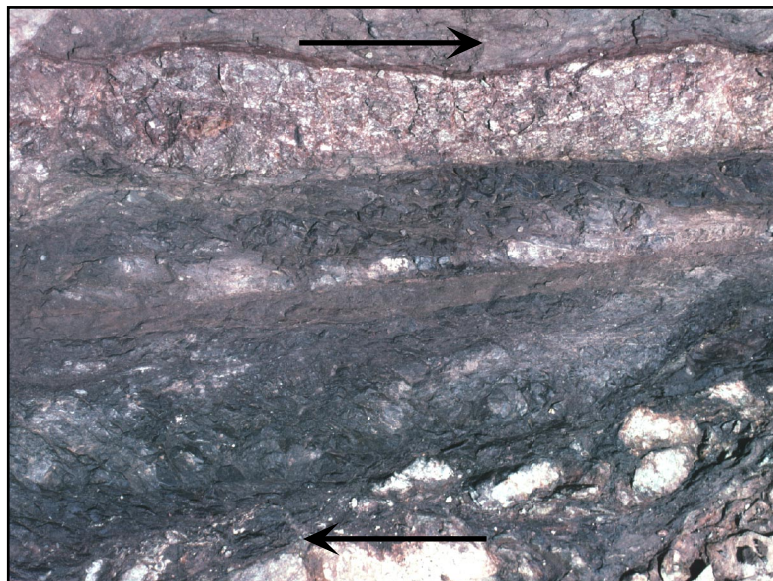
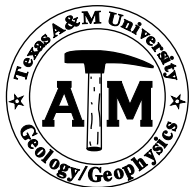
Center for Tectonophysics
Dept. of Geology & Geophysics
Texas A&M University
College Station, TX

v. 2.1, January, 1999



↑ View to the northwest from
Devil's Chair

Ultracataclasite layer in the
core of the Punchbowl fault.



Introduction

The Punchbowl fault in the Devil's Punchbowl County Park, California, provides an unequaled view of the internal structure of a large-displacement fault of the San Andreas system. The Devil's Punchbowl is an area of moderate relief between the San Gabriel Mountains and Mojave Desert. The area was eroded to low relief in Pleistocene time and covered by piedmont alluvial fans after the Punchbowl fault became inactive. Recent uplift has rejuvenated the erosion that has dissected the piedmont and exposed the Punchbowl fault and associated folds. As a result, the Devil's Punchbowl provides an excellent exposure of the Punchbowl fault and subsidiary faults and folds associated with strike-slip faulting adjacent to uplifted blocks of basement as might occur in a flower structure or at the margins of a strike-slip basin. The Punchbowl fault accommodates more than 40 km of right-lateral strike-slip displacement. Microstructures and mineral assemblages of the fault rocks from the Punchbowl fault are consistent with faulting at 2 to 4 km depth. By analogy with nearby active faults, we assume that the Punchbowl fault was seismogenic and that the structure of the fault records the passage of numerous earthquake ruptures. In the Devil's Punchbowl, the fault consists of a broad zone of damaged rock bounding a continuous ultracataclasite layer along which the Punchbowl Formation sandstone and an igneous and metamorphic basement complex are juxtaposed. Structures at all scales record the localization of fault displacement not only to the ultracataclasite layer, but to discrete slip surfaces within the layer as well. A walk through the Devil's Punchbowl park along the Burkhart Trail provides the opportunity to inspect the internal structure of the large displacement Punchbowl fault.

Geology of the Punchbowl Fault, Devil's Punchbowl Area

The Punchbowl fault is an inactive, exhumed fault of the San Andreas transform system in the central Transverse Ranges of southern California (Fig. 1). It is located approximately 5 km southwest of and is parallel to the active strand of the San Andreas fault. The Punchbowl fault is truncated to the northwest and to the southeast by the San Andreas, and can be considered an abandoned strand of the San Andreas System (Dibblee, 1968, 1987; Weldon et al., 1993). The fault has a somewhat sinuous trace and is often steeply dipping to the southwest. The fault cuts crystalline rock of the San Gabriel basement complex and Paleocene and younger sedimentary rocks, and is overlain by Quaternary alluvial deposits (Noble, 1954).

In the Devil's Punchbowl area, the San Andreas and Punchbowl faults bound a slice of exotic crustal rock, referred to as the Punchbowl block. Within the block, the Paleocene San Francisquito Formation unconformably overlies the crystalline basement, and is unconformably overlain by the Miocene-Pliocene Punchbowl Formation. The Punchbowl Formation is restricted to the Punchbowl block, and was deposited in an elongate basin referred to as the Punchbowl basin. Stratigraphic and structural relations indicate that the Punchbowl block was located between the Soledad and Orocopia regions prior to dissection by the Punchbowl and San Andreas faults (Dibblee, 1968; Farley and Ehlig, 1977; Weldon et al., 1993). This reconstruction is based partly on the correlation of the San Francisquito fault in the Sierra Pelona Mountains on the southwest side of the Punchbowl fault, the Fenner fault in the Punchbowl block (Fig. 1), and the Clemens Well fault in the Orocopia Mountain region on the eastern side of the San Andreas fault (Dibblee, 1968). These correlations indicate 44 km and approximately 210 km of right-lateral slip on the Punchbowl and San Andreas faults, respectively.

The Punchbowl basin is a small, elongate basin that was filled with a >1 km thick sequence of the Punchbowl Formation (Noble, 1954; Woodburne, 1975). The basin probably originated as a pull-apart basin during the early phases of Punchbowl faulting in the Middle Miocene. The Punchbowl Formation consists of a cobbly to pebbly arkosic sandstone with interbeds of siltstone and a basal breccia. The Punchbowl Formation

overlaps the angular unconformity with the Paleocene San Francisquito Formation along the northeastern edge of the basin showing that the sediments onlapped relief to the east (Weldon et al., 1993). The southwestern side of the basin is truncated by the Punchbowl fault and the marginal sedimentary deposits are not preserved. A less than 0.5 km wide outcrop of the basal breccia extends approximately 11 km to the southeast of the basin along the Punchbowl fault (Fig. 1). This basal breccia may record sedimentation associated with the fault-controlled margin of the Devil's Punchbowl basin (Weldon et al., 1993). The basal breccia both overlies and is cut by subsidiary faults of the Punchbowl system suggesting contemporaneous deposition and fault movement (Chester, unpublished mapping, 1995).

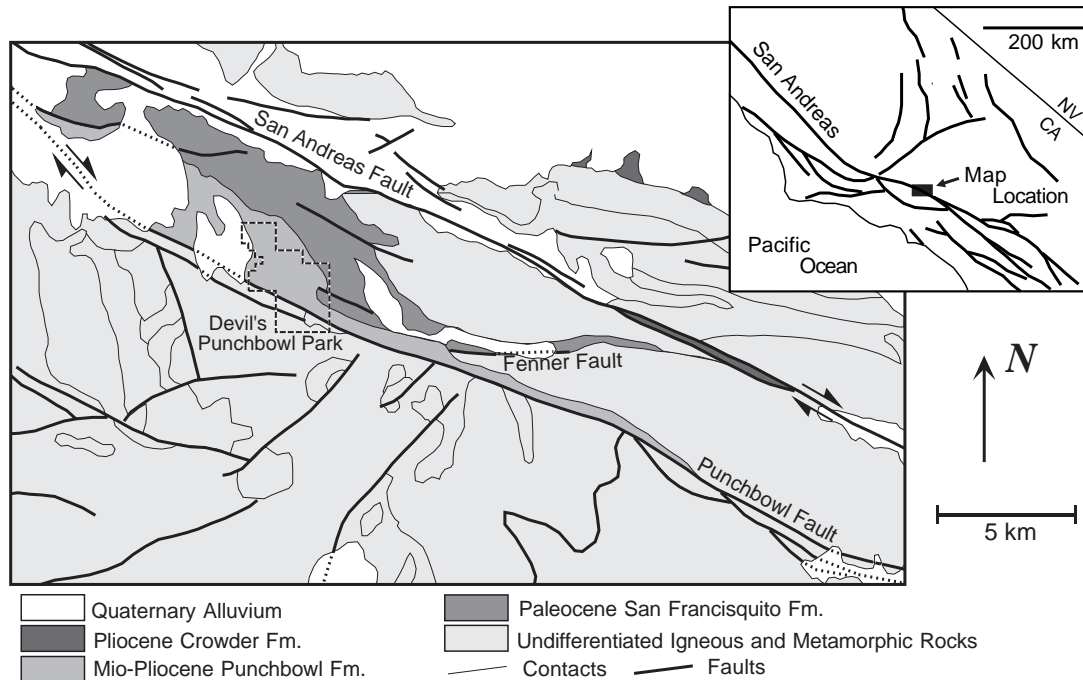


Figure 1. Geologic map of the Punchbowl fault on the northeast side of the San Gabriel Mountains, southern California. The location of the Devil's Punchbowl Los Angeles County Park is shown.

The timing of movement on the Punchbowl fault system is uncertain. Although the fault appears to have been active during the formation of the Devil's Punchbowl basin, at least half of the total displacement occurred during the Pliocene and Pleistocene, after the deposition of the Punchbowl Formation was complete (Barrows et al., 1985; Matti et al., 1985; Weldon et al., 1993). The folding and faulting in the Punchbowl block is largely related to strike-slip displacement on the Punchbowl fault. Angular unconformities and the geometry of folds suggest that several episodes of deformation are represented within the block.

In the Devil's Punchbowl Los Angeles County Park, which covers the eastern portion of the Devil's Punchbowl basin, the Punchbowl fault system is composed of two fault strands that bound a slice of fractured and faulted basement up to 0.5 km in thickness (Fig. 2). The slice of fractured basement between the northern and southern fault strands contains a heterogeneous assemblage of Precambrian biotite gneiss and quartzofeldspathic gneiss with alternating leucocratic and melanocratic bands, and massive to foliated Cretaceous plutonic rocks including quartz diorite, tonalite, granodiorite, and biotite monzogranite (Cox et al., 1983). Locally, within the Devil's Punchbowl Park, the monzogranite is a brilliant white aplite that complexly intrudes melanocratic rocks. The southernmost fault strand, referred to informally as the Cocktail fault, juxtaposes similar

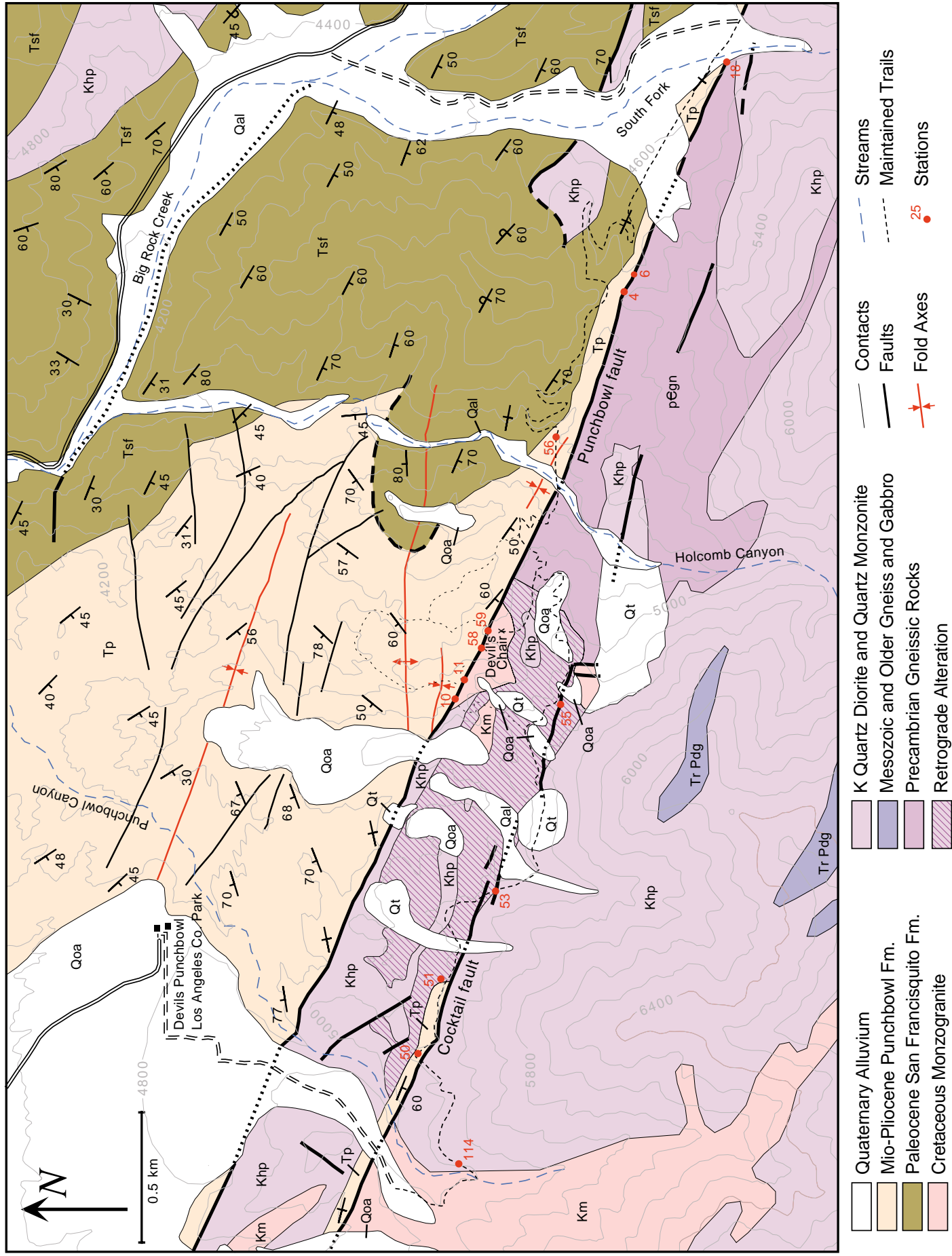


Fig. 2. Geologic map of the Punchbowl fault zone in the Devil's Punchbowl Los Angeles County Park, CA.

rock types (Cox et al., 1983), is not always well developed, and is segmented and discontinuous (Chester, unpublished mapping, 1995). It probably accounts for only a few kilometers of right-lateral separation. The northernmost fault strand, referred to as the Punchbowl fault, is much better developed and places the cataclastically deformed basement rock against arkosic sedimentary rocks of the Punchbowl Formation along a single, continuous ultracataclasite layer approximately 0.5 m thick (photos on cover page of field guide). Previous structural studies indicate that nearly all of the displacement on the Punchbowl Fault zone was localized to the ultracataclasite layer of the northernmost trace (Chester and Chester, 1998). Mineralogical alteration associated with cataclastic deformation is common in the Punchbowl fault zone (Chester & Logan, 1986). Alteration products include chlorite, illite, smectite, and several zeolites. Generally, the higher-grade alteration products (e.g. chlorite) are found in the faulted basement rocks and the very low-grade alteration products (e.g., smectite) occur in the Punchbowl fault ultracataclasite (Chester & Chester, 1998). We interpret the petrologic and structural relationships as indicating that the deformation and alteration in the Punchbowl ultracataclasite records the shallowest conditions and the last stages of fault movement. The Cocktail fault appears to record early deformation at the deepest conditions with some later deformation at shallower conditions.

The partitioning of total displacement between the northern and southern fault strands is unknown. The distribution of rock types along the Punchbowl fault in the Devil's Punchbowl suggests that at least 10 km of separation occurred on the northern strand. Less than 10 km of separation would require an offset extension of the Fenner fault and associated Pelona Schist to occur in the slice between the northern and southern strands (Figure 1). On the basis of internal structure and continuous character, we think that the northern strand accommodated >90% of the total displacement.

Internal Structure of the Punchbowl Fault

The general structure of the Punchbowl fault is that of a reverse-oblique, strike-slip fault dipping to the southwest towards the mountains and placing crystalline basement above folded Tertiary sedimentary rocks (Fig. 2, photo on cover page of field guide). The folds in the Punchbowl Formation are asymmetric, imperfect-cylindrical folds with axial surfaces that are subparallel to the Punchbowl fault and fold axes that plunge steeply (60°) to the northeast (see fig. 2 in Chester and Logan, 1987). Overall, the amplitude and wavelength of the folds decrease with proximity to the Punchbowl fault and minor folds occur within the damaged zone of the fault, indicating that the folding of the Punchbowl Formation was directly related to movement on the Punchbowl fault. It is obvious by inspection of lithologic contacts and bedding within the fault zone that the displacements on the fault were largely localized to the ultracataclasite layer.

The intensity of deformation as measured by folding, subsidiary faulting, and microfracturing, increases progressively towards the ultracataclasite layer in the core of the fault. Measurements of mesoscopic scale fracture density along traverses from the ultracataclasite layer of the Punchbowl fault into the Punchbowl Formation indicate a high density of fractures and faults near the layer and a decrease to background levels at about 20 m from the layer (Fig. 3). Locally high fracture densities, even far from the main fault, appear to correlate with large subsidiary faults. Microfracture density also is greatest near the ultracataclasite layer, but appears to display a higher density to greater distances as compared to the mesoscopic scale fractures and faults (Fig. 4). Microfracture density decreases to background levels at about 100 m from the layer.

Subsidiary Fault Fabric

Small subsidiary faults are present throughout the Punchbowl block, but are particularly numerous near the Punchbowl fault. It is relatively easy to determine offset sense and slip directions for subsidiary faults in the Punchbowl Formation. Slip and

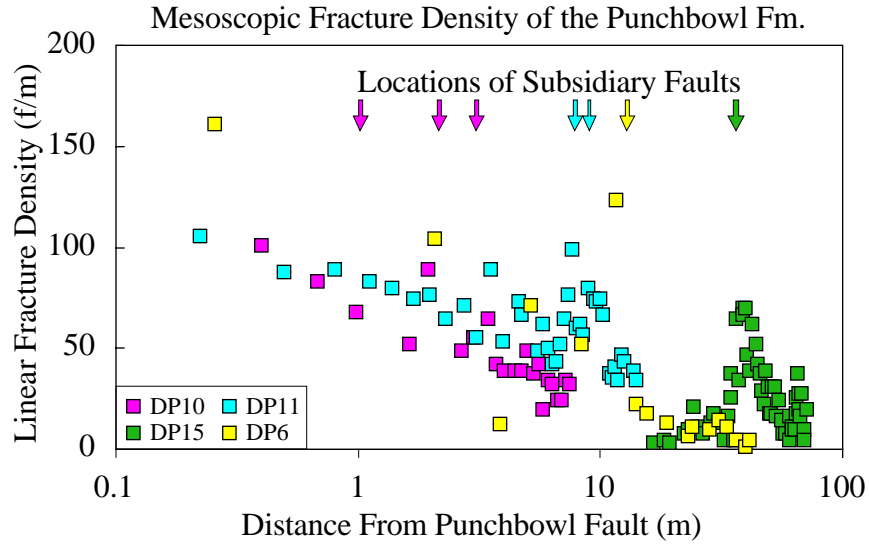


Fig. 3. Density of mesoscopic scale fractures and subsidiary faults in the Punchbowl Formation sandstone as a function of distance from the Punchbowl fault. Linear density determined from the total number of fracture intercepts with two perpendicular line segments along four different traverses. Fracture density decreases with distance from the fault except locally near large subsidiary faults (shown by arrows coded to traverse by color).

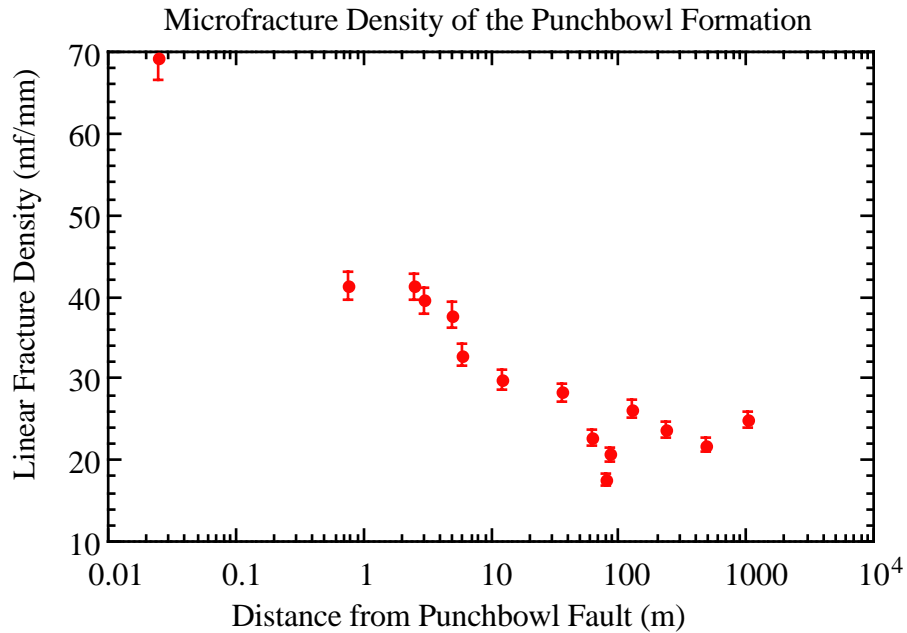


Fig. 4. Density of microfractures in the Punchbowl Formation sandstone as a function of distance from the Punchbowl fault. Density determined from the total number of fracture intercepts along ninety (90) randomly oriented line segments from 3 mutually perpendicular petrographic sections for each sample (Wilson, 1998).

orientation measurements of numerous subsidiary faults located within the damaged rock of the fault zone indicate that the slip-direction during latest stages of Punchbowl faulting was oriented with a plunge of 20 to 30° to the southeast, which is consistent with the reverse geometry of the Punchbowl fault (Chester and Logan, 1987). The orientation of fold axes coincides with the b-axes of the subsidiary faults indicating that both are compatible with the same displacement field (see fig. 4 in Chester and Logan, 1987). Comparison of the slip data from various locations on folds indicates that the subsidiary fault slip-data record displacement conditions subsequent to most of the folding. Overall, the subsidiary faults define a quasi-conjugate geometry with a bisector oriented approximately 70° to the plane of the Punchbowl fault (Fig. 5). Such an orientation is consistent with nearly fault-normal contraction and suggests that the Punchbowl fault had a low frictional strength. Thus it appears that the Punchbowl fault was mechanically similar to modern faults of the San Andreas system (e.g., Zoback et al., 1987; Chester et al., 1993).

Microfracture Fabric

Study of microfractures along traverses across the Punchbowl fault zone have revealed systematic preferred orientations of fractures relative to position in the fault zone (Wilson, 1998). The microfracture fabric within the damage zone is relatively homogeneous, whereas outside the damage zone the preferred orientations are more variable (Fig. 6). In the damage zone and within 2.5 m of the fault surface (inner damage zone), microfractures display preferred orientations that are parallel and perpendicular to the fault surface. Between 2.5 and approximately 100 m from the fault surface, microfractures display a single preferred orientation that is perpendicular to the fault surface and to the slip direction of the fault. The microfracture fabrics are inconsistent with models of fracture formation during the initial stages of fault growth and localization. Fabrics are, however, consistent with prolonged fracturing and wear during accumulation of large displacement.

Structure of the Fault Core

We have mapped the fault core at four localities along the Punchbowl fault at scales of 1:10 and 1:1 (Fig. 7; Chester & Chester, 1998). Several important features of the fault core are common to all of the mapped segments even though the map locations are spaced up to two kilometers apart. Most displacement on the fault occurred within a < 1-m wide zone of ultracataclasite. The boundaries between the ultracataclasite and surrounding (proto)cataclasite are extremely sharp, but not parallel or planar on the meter-scale (Fig. 7). On the basis of color, cohesion, fracture and vein fabric, and porphyroclast lithology, two main types of ultracataclasite are distinguished in the layer: an olive-black ultracataclasite in contact with the basement, and a dark yellow-brown ultracataclasite in contact with the sandstone (Fig. 8). The two are juxtaposed along a continuous contact that is often coincident with a single, continuous, nearly planar, prominent fracture surface (pfs) that extends the length of the ultracataclasite layer in all exposures (Figs. 7 and 8). No significant mixing of the brown and black ultracataclasites occurred by offset on anastomosing shear surfaces that cut the contact or by mobilization and injection of one ultracataclasite into the other. The ultracataclasites are cohesive throughout except for thin accumulations of less cohesive, reworked ultracataclasite along the pfs. Structural relations suggest that: 1) the black and brown ultracataclasites were derived from the basement and sandstone, respectively; 2) the black and brown ultracataclasites were juxtaposed along the pfs; 3) the subsequent, final several kilometers of slip on the Punchbowl fault occurred along the pfs; 4) earthquake ruptures followed the pfs without significant branching or jumping to other locations in the ultracataclasite.

Geochemistry of the Fault Rocks

XRD, XRF, and stable isotope analyses of the fault rocks and surrounding protoliths have been used to characterize the chemistry of the fault zone (Kirschner & Chester, 1998). Quartz, potassium feldspar, plagioclase, micas, amphiboles, laumontite, and calcite are the

Fabric of Subsidiary Faults, Punchbowl Fault Zone

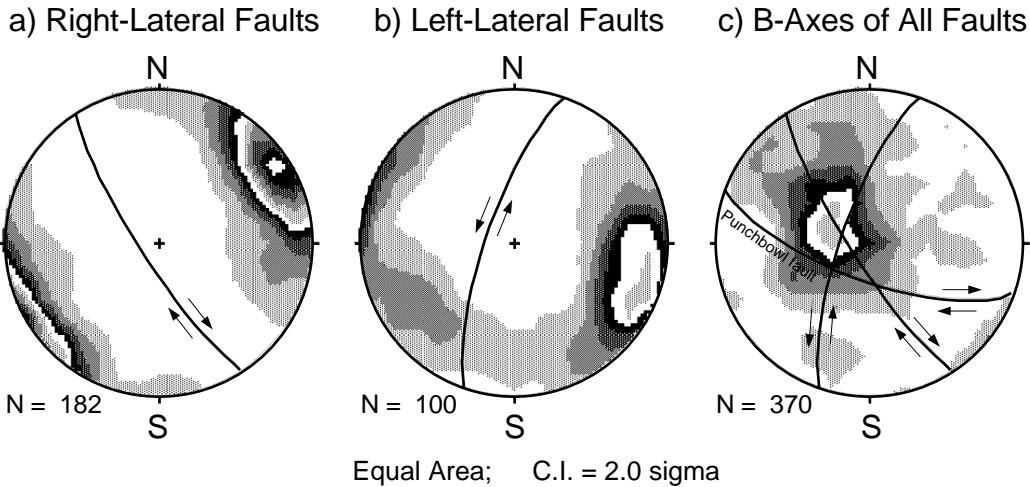


Fig. 5. Fabric of subsidiary faults in the Punchbowl Formation and basement complex along the Punchbowl fault. Plots are lower hemisphere equal area projections onto the horizontal plane with north at the top. Preferred orientation and sense of shear of faults are shown by great circles and arrows. (a) Orientation of poles to all faults with known right-lateral sense of shear. (b) Orientation of poles to all faults with known left-lateral sense of shear. (c) Orientation of b-axes to all faults with known direction of shear. Single preferred orientation of b-axes for the quasi-conjugate set of left-lateral and right-lateral faults indicates oblique reverse strike slip faulting with axis of maximum shortening at high angles to the Punchbowl fault.

Microfracture Fabric, Punchbowl Fault Zone

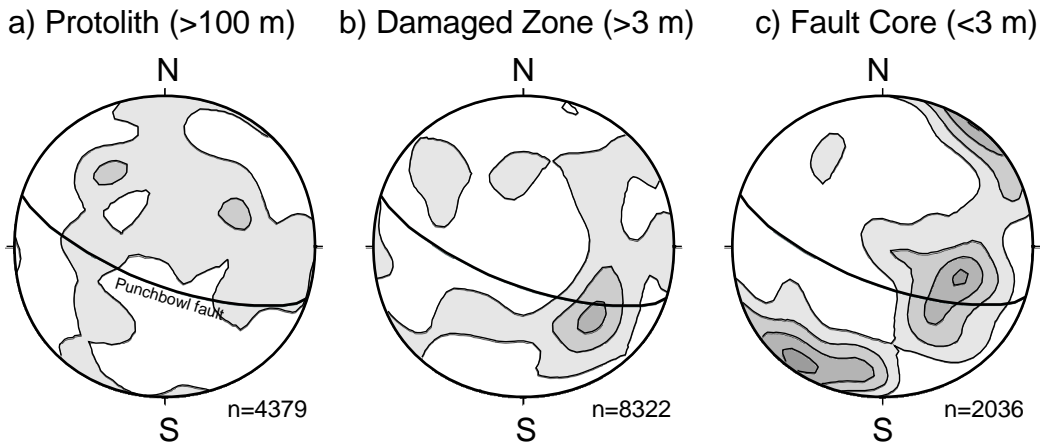


Fig. 6. Microfracture fabric of the Punchbowl Formation sandstone along the Punchbowl fault. Plots are lower hemisphere equal area projections onto the horizontal plane with north at the top. Kamb contour intervals at 3, 4, 5, and 6 σ . (a) Microfracture fabric outside the damage zone of the fault. Grouped data of four samples from greater than 100 m from the fault surface. Fabric is essentially random. (b) Microfracture fabric of the outer damage zone of the fault. Grouped data of eight samples from between 2.5 m and 100m from the fault surface. Microfractures display a preferred orientation approximately perpendicular to the fault surface. (c) Microfracture fabric of the inner damage zone of the fault. Grouped data of four samples from less than 2m from the fault surface. Microfractures display a preferred orientation approximately parallel and perpendicular to the fault surface. From Wilson (1998).

Ultracataclasite Layer, Punchbowl Fault, Devil's Punchbowl, CA

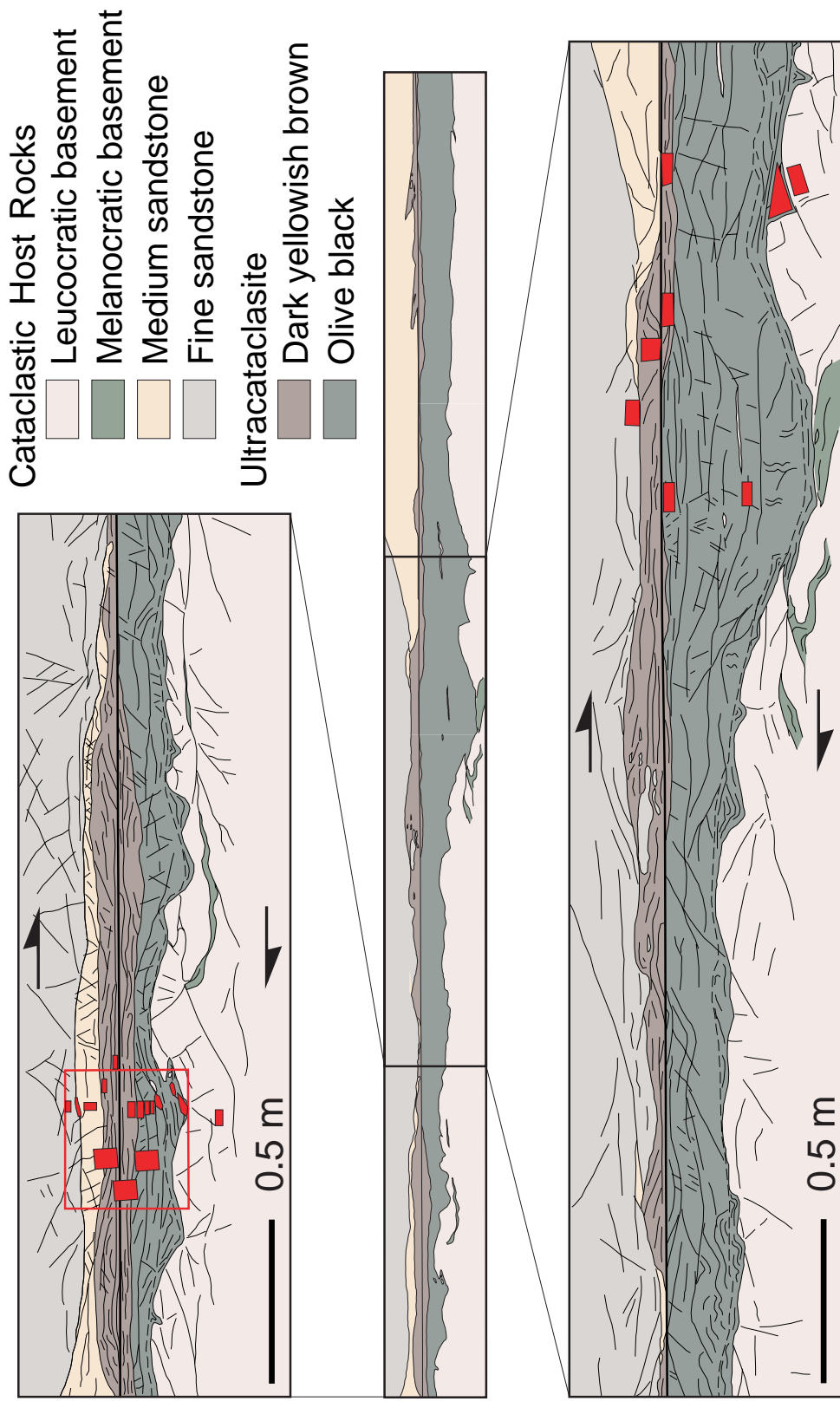


Fig. 7. Portions of one of the four strip maps made of the ultracataclasite layer in the Punchbowl fault core. The orientation of the map is perpendicular to the layer and parallel to the slip direction. Thin black lines represent the location of contacts and fractures. Thick black line through the center of the layer is the prominent fracture surface. The location of the photograph in Figure 8 is indicated by the red box. Size and location of the samples collected are shown by red filled areas. The maps document that the general structure of the ultracataclasite layer is similar along a strike distance of 2 km.

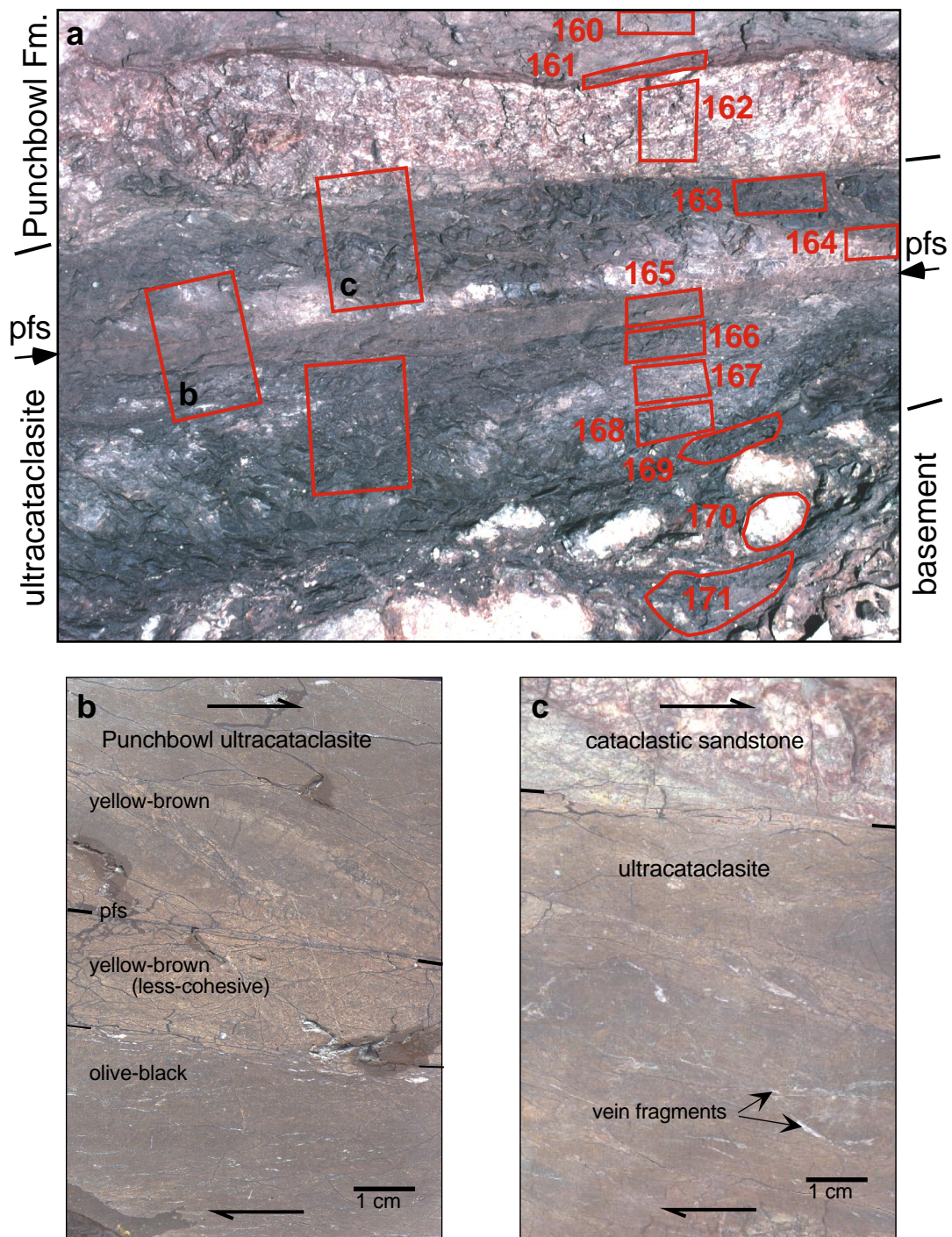


Fig. 8. Photographs of the ultracataclasite . a) Structure and sampling traverse of the ultracataclasite layer with basement at the bottom and sandstone at the top. Note the porphyroclasts of basement rock in the ultracataclasite layer and the subsidiary fault in the sandstone. The prominent fracture surface is located in the center of the layer and identified by arrows. The less cohesive brown ultracataclasite occurs in a layer along the basement side of the pfs. The location of the photo is indicated in Fig. 7. b) Polished hand sample of the ultracataclasite across the prominent fracture surface. Location of sample shown in (a). c) Polished hand sample of the ultracataclasite across the contact with the bounding cataclastic sandstone. Location of sample shown in (a).

dominant minerals in the host rock. The largest variations in mineralogy and element concentrations occur in the (proto)cataclasite and surrounding damaged zone rocks. Quartz, intermediate plagioclase, and clays (smectite) are the dominant mineral components in the ultracataclasite. Overall, the mineralogy and major and trace element concentrations are similar along and across the ultracataclasite layer, but do show a systematic variation across the ultracataclasite layer and between the ultracataclasite and surrounding rocks.

Comparison of host rock and fault rock geochemistry indicate that the ultracataclasite is the product of mechanical mixing of the host lithologies, hydration reactions, mass transfer and possible volume loss, and chemical exchange with pore fluids. Very preliminary oxygen isotope data from along one traverse across the fault core indicate that the system was not fluid-starved and that some exchange and fractionation occurred during alteration of the ultracataclasite (Fig. 9). The stable isotope data will be used to identify the origin of the volatiles in the ultracataclasite and distinguish between open and semi-open system behavior. Veins, secondary cement, and mineralogic alteration is concentrated in the fault zone (Chester and Logan, 1986, 1987). The structure of veins records repeated fracture and sealing, and suggests that vein opening was quick relative to sealing.

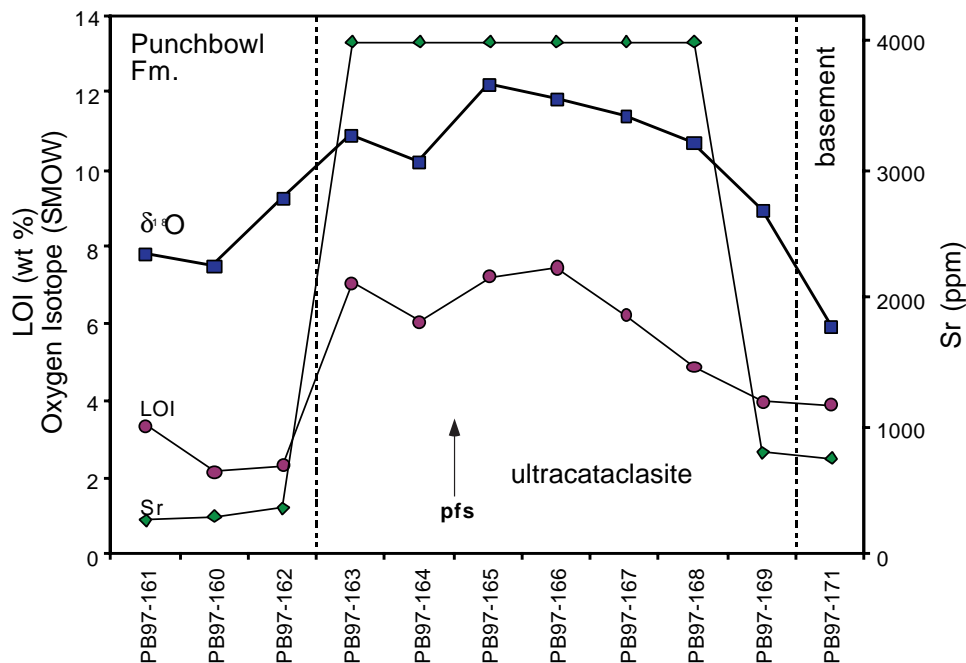


Figure 9. Example of variation in geochemistry across the Punchbowl fault core. The location of samples is shown in Figure 8a. Amount of volatiles shown by loss on ignition (LOI) is increased in the ultracataclasite relative to surrounding fault rocks and host rocks. $\delta^{18}\text{O}$ correlates with LOI in the ultracataclasites suggesting exchange and fractionation occurred during hydration reactions. Concentrations of several minor and trace elements in the ultracataclasite are either increased or decreased markedly from those of the surrounding cataclastic and host rock (Kirschner & Chester, 1998).

Faulting Mechanisms

Structural and geochemical relations indicate that slip was extremely localized to the principal slip surface within the ultracataclasite layer during the final stages of faulting. Although structural evidence indicates that the ultracataclasite layer must have formed early in the fault history, the timing of formation of the localized slip surface is uncertain. Two possible models for ultracataclasite evolution are envisioned, either progressive localization of strain to develop a single slip surface late in the faulting history or formation of the slip surface early with subsequent migration of the surface and repeated reworking of the

ultracataclasite. The fact that different types of ultracataclasite occur in the fault and are in sharp contact along the slip surface imply that earthquake ruptures repeatedly followed the surface without significant branching or jumping to other locations in the ultracataclasite. In addition, the structure and geochemistry imply that fluid-assisted chemical exchange and mass transfer were restricted, consistent with fluid compartmentalization and fluid flow at the outcrop scale. The geochemical data are most consistent with somewhat accelerated alteration and dissolution of the finely comminuted rocks in the fault core and fluid-assisted transfer of mass from the ultracataclasite to the surrounding fault rocks. Stable isotope data ultimately will help determine the source of fluids and whether the fault zone was an open or semi-open system. Of the various mechanisms proposed to explain the low strength of the San Andreas system and to produce dynamic weakening of faults, those that assume extreme localization of slip and restricted fluid flow appear most compatible with our observations.

Acknowledgments

This version of the field guide was prepared on the occasion of a field trip in association with the Fault Zone Guided Wave Workshop organized by John Vidale and Tom McEvelly and supported by the Southern California Earthquake Center. My research on the Punchbowl fault zone has benefited from collaboration with John Logan, Judi Chester, Jim Evans, David Kirschner, Steve Schulz, Jen Wilson, and Gang Li. Access to the fault has been simplified over the years by the ever friendly and helpful Park Naturalists at the Devil's Punchbowl Park, David Numer and Jack Farley. Most of this research has been supported through contracts from the U.S. Geological Survey Earthquake Hazards Reduction Program and by grants from the National Science Foundation.

References

- Barrows, A.G., Kahle, J.E. and Beeby, D.J., 1985. Earthquake hazards and tectonic history of the San Andreas fault zone, Los Angeles County, California, California Division of Mines and Geology Open File Report, 85-10LA, pp. 139.
- Chester, F. M., and J. S. Chester, Ultracataclasite structure and friction processes of the Punchbowl fault, San Andreas system, California, *Tectonophysics*, in press, 1998.
- Chester, F.M., J.P. Evans, and R.L. Biegel, Internal Structure and Weakening Mechanisms of the San Andreas Fault, *J. Geophys. Res.*, 98, 771-786, 1993.
- Chester, F. M., and J. M. Logan, Implications for mechanical properties of brittle faults from observations of the Punchbowl fault zone, California, in *Internal Structure of Fault Zones*, edited by C.-Y. Wang, *Pure Appl. Geophys.*, 124, 79-106, 1986.
- Chester, F. M., and J. M. Logan, Composite planar fabric of gouge from the Punchbowl fault, California, in *Shear Criteria in Rocks*, edited by P. R. Cobbold et al., *J. Struct. Geol.*, 9, 621-634, 1987.
- Cox, B.F., Powell, R.E., Hinkle, M.E. and Lipton, D.A., 1983. Mineral resource potential map of the Pleasant View Roadless Area, Los Angeles County, California, U.S. Geological Survey Miscellaneous Field Studies Map, MF-1649-A, scale 1:62,500.
- Dibblee, T.W., Jr., Displacements on the San Andreas fault system in the San Gabriel, San Bernardino, and San Jacinto Mountains, southern California, in *Proc. Conf. on Geologic Problems of San Andreas Fault System*, *Stanford Univ. Pubs. Geol. Sci.*, 11, 260-276, 1968.
- Dibblee, T.W., Jr., *Geology of the Devil's Punchbowl, Los Angeles County Park, California*, Geological Society of America Centennial Field Guide - Cordilleran Section, 207-210, 1987..
- Farley, T., and P.L. Ehlig, Displacement on the Punchbowl fault based on the occurrence of "polka-dot" granite clasts, *Geol. Soc. Am. Abstr. w. Prog.*, 9, 419, 1977.

- Kirschner, D.L., and F.M. Chester, Structural and geochemical investigation of fault rocks in the core of the Punchbowl fault, San Andreas system, California, *Geol. Soc. Am. Abstr. w. Prog.*, 30, A-324, 1998
- Matti, J.C., Morton, D.M., and Cox, B.F., Distribution and geologic relations of fault systems in the vicinity of the central Transverse Ranges, southern California, USGS Open File Report, 1985.
- Noble, L.F., Geology of the Valyermo Quadrangle and vicinity, Map GQ-50, USGS, 1954.
- Weldon, R.J., II, Meisling, K.E. and Alexander, J., 1993. A speculative history of the San Andreas fault in the central Transverse Ranges, California. In: R.E. Powell, R.J. Weldon, II and J.C. Matti (Editors), *The San Andreas Fault System: Displacement, Palinspastic Reconstruction, and Geologic Evolution*. Geological Society of America Memoir 178, pp. 161-198.
- Wilson, Jennifer, Microfracture fabric of the Punchbowl fault zone, San Andreas system, California, M.S. Thesis, Texas A&M University, in prep., 1998.
- Woodburne, M.O., Cenozoic stratigraphy of the Transverse Ranges and adjacent areas, southern California, *GSA. Special Paper*, 1975.
- Zoback, M.D., M.L. Zoback, V.S. Mount, J. Suppe, J.P. Eaton, J.H. Healy, D. Oppenheimer, P. Reasenber, L. Jones, C.B. Raleigh, I.G. Wong, O. Scotti, and C. Wentworth, New evidence on the state of stress of the San Andreas fault system, *Science*, 238, 1105-1111, 1987.

v. 2.1; January, 1999.

Road and Trail Log

The following describes a field excursion to the Punchbowl fault approaching the Devil's Punchbowl Los Angeles County Park from the southeast side. Another possible approach is from the northwest side, hiking along the trail from the main headquarters of the County Park. Also from the headquarters there is a short nature trail passing along outcrops of the Punchbowl Formation in the Punchbowl Canyon.

From the Los Angeles area, proceed north on Hwy 14
towards Palmdale

En Route: Shortly after the Lamont-Odett overlook you drive across the San Andreas fault. Extremely folded and faulted Pliocene nonmarine strata of the Anaverde Formation are exposed along a large roadcut just north of the San Andreas fault. These rocks were probably deposited in sag ponds along the San Andreas fault. Deformation in this roadcut records local contraction between two traces of the San Andreas system on the north and south ends of the road-cut.

Exit Hwy 14 at Hwy 138 and head southeast to
Pearblossom. At Pearblossom turn right (south) on
Longview avenue and left (east) on Avenue W. Proceed east
on Avenue W (which changes to Valyermo Road). Continue
east, and shortly after joining Big Pines highway turn right
(south) on Big Rock Creek Road. Follow the road to the
end of pavement at Fenner Camp.

En Route: Between Valyermo and Big Rock Creek Roads is a large south-facing fault scarp produced during the great 1857 Fort Tejon earthquake. Surface rupture occurred from north of Tejon Pass to just north of Cajon Pass, and slip magnitudes up to 6 m were observed. No movement has occurred along this segment of the San Andreas since 1857.

On the drive up Big Rock Creek Road we see the San Francisquito Formation, which consists of marine turbidite deposits of Paleocene and Eocene age that unconformably overlay crystalline basement. Relatively few Paleocene-Eocene deposits are exposed in southern California. This is a distinctive formation that was caught up within and displaced along the San Andreas fault system. Note the conglomerate channel fill deposits one mile up Big Rock Creek road from the turn-off, and the general change from sandstone-dominated to shale-dominated deposits as we drive south.

The Fenner fault is located in Fenner canyon and places the San Francisquito Formation against the Pelona Schist. The Fenner fault has been correlated with the San Francisquito fault on the southern side of the Punchbowl-Nadeau fault and north of the Sierra Pelona, which records approximately 44 km of right-lateral separation along the younger Punchbowl fault. Before and after turning around at Fenner Camp, note the large outcrops of the basal Punchbowl Formation, obvious from the deep red-brown color to the south of the road.

Turn around at Fenner Camp and return to the dirt road
leading to the South Fork Big Rock Creek Campground.
Head south on dirt road to gate or to trail head and park.

Stop: Punchbowl fault at South Fork Big Rock Creek.

The trail to the Devil's Punchbowl is fairly obvious; it takes off from the stream bed near the campground just before the canyon narrows and heads west-northwest up into the

mountains. The trail to the first saddle between the South Fork and Holcomb Creek, which takes approximately 1.5 hours round trip, permits examination of the localized deformation associated with the Punchbowl fault in outcrop and the off-fault folding. The 3.5 hour round trip hike to the Devil's Chair provides a spectacular view of the Punchbowl fault and of the fold geometries in the Punchbowl Formation. In addition, the trail will take you past exposures of the damaged crystalline basement rocks and of subsidiary faults in the Punchbowl Formation. The basement rocks are both fractured and mineralogically altered from passage of hydrothermal fluids during faulting. If you can arrange a drop-off at South Fork and pick-up at the Devil's Punchbowl County Park headquarters, you can hike the entire trail through the park in about 4 to 5 hours. The following is a list of stops identified by station numbers (Fig. 2) along the trail from the South Fork Big Rock Creek northwest to the trail head at the Devil's Punchbowl Los Angeles County Park.

Station 18: The rocks exposed along South Fork Big Rock Creek represent the main components of a crustal block that is bounded by the Punchbowl fault to the south and the San Andreas fault to the north as well as the San Gabriel basement complex to the south of the Punchbowl fault. A short walk up South Fork Big Rock Creek south from the trail crosses the Punchbowl fault zone. Inspect the canyon walls to the west of the creek you can see the transition from the damaged crystalline rock in the Punchbowl fault zone to the relatively undeformed crystalline rock of the San Gabriel basement complex.

Stations 4 and 6: The trail to the first saddle passes through a thin but normal succession of rocks, from crystalline basement through the San Francisquito Formation and into the red-beds of the basal Punchbowl Formation. A short side excursion up the gully from the first switchback in the trail will cross the Punchbowl fault near station 6 and allow inspection of the deformation of the crystalline basement. Mesoscopic structures near small subsidiary faults in the basement display the Riedel geometry and foliations produced by cataclastic flow. Depending on the amount of rock debris present, the ultracataclasite of the Punchbowl fault may be exposed. After the most northerly switchback, the trail passes from basement rocks in the core of an anticline, up through the folded strata, and to the Punchbowl fault near the saddle. Note the facing directions of strata in the San Francisquito and Punchbowl Formations along the trail. Just past the saddle the San Francisquito beds are overturned but the Punchbowl beds are not, which shows an angular unconformity exists locally between these units. Structural relations suggest that the folds in the area existed prior to deposition of the Punchbowl Formation, but were accentuated and amplified by another phase of deformation after deposition as well, probably associated with motion on the Punchbowl fault. The two splays of the Punchbowl fault and their reverse geometry can be seen from the saddle, as well as the large Punchbowl syncline. A short scramble to the southeast from the saddle will lead to station 4 where the discrete layer of ultracataclasite that forms the contact between the brecciated crystalline basement rocks and the Punchbowl Formation is usually well exposed. It is obvious from the exposures that subsidiary faulting, fracturing and brecciation directly associated with fault slip was extremely localized (Fig. 3).

Station 56: Large exposures of the Punchbowl Formation are present along the trail just prior to reaching Holcomb Creek. This is an excellent location to view subsidiary faults. Because of the prominent bedding in the Punchbowl Formation, the sense of shear on the faults often can be determined. Most fault surfaces also display slickenlines that record dominant strike slip movement. Both the right lateral and left lateral fault sets that form the quasi-conjugate fault fabric (Fig. 5) are present.

Station 56 to 114: Trail log incomplete at this time.