Surface and Bedrock Geology of the Stebbins Cold Canyon Reserve Area, Vaca Mountains, Solano County, California

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Stebbins Cold Canyon Reserve, part of the University of California Davis Natural Reserve System, is located immediately southeast of Lake Berryessa in the Coast Ranges of northern California. The reserve is 50 kilometers west of Davis along California State Highway 128. The trail extending southward up Cold Canyon to the Old Homestead begins at a hairpin bend in Route one kilometer east of Monticello Dam. The area is densely vegetated, and exposure is limited to the streambeds and to the surrounding ridge tops (Plate I). Several small east-west trending intermittent streams flow into Cold Canyon Creek in a trellis style drainage pattern. Coarse gravels and large boulders are present in the streambeds of Cold Canyon, and the creek flows through the reserve and into Putah Creek downstream from the dam.

This paper summarizes a field study of the geology of the Cold Canyon and Wild Horse Canyon portion of the Vaca Mountains in the Eastern California Coast Ranges. The purpose of the study was to map the surface geologic features and to describe the stratigraphy, geomorphology and structure of the area within Stebbins Cold Canyon Reserve. The mapping involved photogeologic interpretation of NAPP (National Aerial Photograph Project) aerial photographs and field mapping on a topographic base consisting of parts of the Monticello Dam and the Mt. Vaca USGS (United States Geological Survey) 7 1/2 minute quadrangles enlarged to an approximate scale of 1:15300. A structural cross-section of the subsurface geology through an area of particular interest was constructed to gain an understanding of the near-surface geologic relations in three dimensions.

Geologic Setting

Cold Canyon lies along the eastern front of the Northern California Coast Ranges, within an uplifted and east-tilted homoclinal sequence of Cretaceous and Tertiary strata. Cretaceous and lower Tertiary rocks are interbedded marine sandstone and shale of the Great Valley Group. Figure 1 is a stratigraphic column of the southwestern Sacramento Valley showing stratigraphic units, benthic foraminifera zones, and petrofacies units. Kirby (1943) defined six formations in the Upper Cretaceous sediments, including from oldest to youngest, the Fiske Creek, Venado, Yolo, Sites, Funks, Guinda, and Forbes Formations. The units strike approximately north with local variations and typically dip steeply to the east. Tertiary rocks of the Eocene Capay Formation, the Miocene Neroly Formation and Putnam Peak basalt, the Pliocene-Pleistocene Tehama Formation, and the Pleistocene Putah Tuff overly the Great Valley strata to the east (Fig. 1). West of the Great Valley Group, the Jurassic-Cretaceous Franciscan Complex is juxtaposed against lower Cretaceous strata by the Coast Range Fault, and the Pliocene Sonoma Volcanics crops out east of Napa Valley. The Franciscan consists of deformed and metamorphosed rocks ascribed to formation in an east-dipping subduction zone along the western North American plate margin.

Stratigraphy

Principal rock types in the Cold Canyon area are Upper Cretaceous interbedded marine sandstones and shales of the Fiske Creek, Venado, Yolo, and Sites Formations (Kirby 1943). Ingersoll (1976), compiled schematic stratigraphic sections of the Great Valley Group within the Sacramento Basin. Resistant sandstones of the Venado Formation form the crest of the Blue Ridge west of Cold Canyon. The slope material between Cold Canyon and the Blue Ridge consists mostly of landslide deposits derived from the Venado Formation. Shales and sandstones of the Yolo Formation are exposed in the streambed of Cold Canyon Creek. The interbedded sandstones and shales of the Sites Formation comprise the ridge and spurs on the east slope of Cold Canyon. Stream terraces in Quaternary landslide deposits and stream gravels occur within Cold Canyon and along Wild Horse Canyon.

The Cenomanian (95 Ma) Fiske Creek Formation is not present within Cold Canyon Reserve, but is exposed in the eastern shorebanks of Lake Beryessa along Route 128. The formation is approximately 1200 meters thick and is dominantly mudstone with thinly-interbedded sandstones (Ingersoll, 1976). The mudstones are poorly to moderately indurated grey to black shales. Iron oxide stains, calcite vein precipitates, and concretions are present in several exposures. Other exposures display irregular, anastamosing clastic dykes that crosscut shales without disrupting the continuity of bedding. Fining upward sequences in the sandstone beds, load structures, and erosional features, such as flute casts and scoured bedding surfaces, indicate stratigraphic top is to the east. The top of the Fiske Creek Formation is defined by an abrupt contact between a black, moderately indurated shale below and an overlying resistant sandstone.

The Cenomanian (91 Ma) Venado Formation is made up of over 1000 feet of sandstone, shale and conglomerate, spectacularly exposed in the roadcut at Monticello Dam. This formation dips steeply to the east and contains massive, thick-bedded sandstone sequences, packages of thin-bedded mudstone and sandstones, and conglomeratic beds. Conglomerates at the base of the Venado Formation contain pebbles, cobbles and subordinate boulders of volcanic, plutonic and metasedimentary rocks in grey sandstones. The sandstones are mostly coarse-medium grained with clasts of potassium feldspar, quartz, volcanic lithic fragments and rare plagioclase. The conglomeratic layer contains several olistrolithic blocks of thinly- to thickly-bedded sandstone and shale and is unconformably overlain on top by recent cobble conglomerates. Bed thickness and grain size decreases up-section.

Exposures of the Turonian (90 Ma) Yolo Formation are present 500 meters south of Highway 128 and extend for approximately one kilometer along strike in the streambanks of Cold Canyon. The Yolo Formation is composed mainly of shales and subordinate sandstones and is approximately 200-300 meters in thickness. Poor exposure of upper and lower Yolo contacts in Cold Canyon preclude a precise determination of thickness. The Yolo Formation contains alternating sandstones and shales with micro-fossil (foraminifera) bearing concretions in the shales. A fossil Turridea shell was collected, 150 meters south of the point where the trail crosses Cold Canyon Creek, in a moderately indurated, chalky gray shale bed with oblate concretions. Bouma sequences in this formation exhibit planar bedding and fining upward sequences of sand, silt and shale with sharp contacts between shales and overlying sandstones (Plate II). The sandstones deform underlying shale beds and contain rip-up clasts and organic fragments. Erosional structures such as flute casts and scour and fill channels are also present within this unit and indicate that the stratigraphic top is to the east.

The Coniacian (88 Ma) Sites Formation comprises sandstone and shale stratigraphically above and to the east of the Yolo Formation. The formation is exposed in the roadcut immediately northeast of the entrance to Cold Canyon, in east-west trending drainages on the east slope of Cold Canyon, and in along the east-facing streambanks of Wild Horse Canyon. Total thickness of this formation is approximately 1200 meters. A very resistant unit within the Sites is traceable across the topography for approximately 2000 meters from Route 128 south to Wild Horse Canyon (Plate III). Beds within this resistant unit contain discrete lenses of pebble-size clasts of sub-angular to sub-rounded quartz, lithic fragments, and mafic minerals and grade upward into a coarse to medium grain reddish-brown sandstone. Southeast of the trailhead to Cold Canyon, half-way up the first east -west drainage, a small spring emerges from the surface of a three meter thick massive grey sandstone bed. A silty sandstone, with concretions approximately one meter in diameter, crops out in a bend along Wild Horse Creek and in isolated hillside exposures along strike for approximately 2000 meters. In several exposures along the streambanks of Wild Horse Canyon, clastic dykes crosscut and envelope beds of shale and siltstone. Fining upward sequences, flame structures, convolute bedding, and erosional structures are present within the beds of the Sites Formation and indicate stratigraphic top to the east. (Plate IV). The 500 meter thick Coniacian (87 Ma) Funks Formation (Ingersoll, 1976) is stratigraphically above the Sites and dominantly consists of shales. The stream erodes less resistant shale beds at the upper contact of the Sites Formation and define the north striking portion of Wild Horse Canyon.

Recent landslide deposits are exposed in the roadcut two hundred meters east of the dam. They extend from there to the Stebbins Cold Canyon trailhead and south to the Old Homestead near the sign marked: "High Erosion Area." The landslide deposits, derived from the Venado Formation, contain large angular blocks of sandstone and shale in a muddy matrix. The blocks are fine to medium grained, well-sorted sands composed of sub-rounded grains of quartz, plagioclase, and lithic fragments and subordinate micas and oxidized mafic minerals. No trace of bedrock in place is present in the roadcut, or along the trail between Cold Canyon and the Blue Ridge. This massive landslide deposit runs the length of the west slope of Cold Canyon and overlies bedrock of the Yolo Formation (?) on the east and west banks Cold Canyon Creek. The landslide deposit, and the contact between the resistant Blue Ridge and the unconsolidated slope material (Plate V) is visible on the aerial photographs as a distinct break in slope that can be traced for several kilometers southward to the headwaters of Cold Canyon Creek. A second aerial photograph lineament can be traced through the middle of the landslide deposit for two kilometers from Route 128 just beyond the site of the Old Homestead. The trail winds through this material from the trailhead, along the flanks of the spurs on the east slope of Cold Canyon, and to the site of the Old Homestead.

Structure

The regional structure of Cold Canyon is generally an uplifted homocline along the eastern front of the northern California Coast Ranges that is bounded on the east by the Sacramento Valley. The Rumsey Hills and Dunnigan Hills to the north 25 kilometers are prominent areas of Quaternary uplift and folding (Unruh and Moores, 1992). Seismic analysis by Unruh and Moores (1992) and Ramirez (1992) reveals that east dipping thrust faults are rooted in a west dipping detachment zone. At 4-7 kilometers depth an east-tapering tectonic wedge system (Fig. 2) that, along with underthrusting of the Franciscan complex, accommodated Latest Cretaceous and Cenozoic shortening of the Coast Ranges and the western Sacramento Valley (see Wentworth et. al., 1984. p. 163-173, for a complete explanation of the model).

Several structural features in roadcuts along Highway 128 and in streambeds through Cold Canyon and Wild Horse Canyon are present and may help to constrain the number and timing of deformational events that have affected the area. None of these structures have been identified north of Lake Berryessa or Putah Creek.

One kilometer west of the dam, an outcrop-scale anticline-syncline fold of approximately two meters wavelength is present in sandstone and shale beds of the Fiske Creek Formation. The eastern limb of this chevron-style fold is overturned to the east. The fold axis plunges eight degrees to the north and the axial surface is gently inclined to the east. In the roadcut two hundred meters east of the dam, an outcrop-scale anticline is present in the uppermost beds of sandstone and shale of Venado Formation (Plate VI). The fold is nearly upright; its limbs define a fold hinge with a plunge and trend of 35 degrees to the south and an axial surface striking approximately north and dipping 85 degrees to the east.

Near the Cold Canyon trailhead, a roadcut exposes alternating beds of sandstone and shale of the Sites Formation (Plate VII). The beds dip 20 degrees to the east near the north end of the exposure and progressively steepen to the south. Large sandstone blocks are present within the shale and talus cones rim base of the exposure. Approximately five meters above the road a 30 centimeter thick sandstone bed has a step-like, segmented appearance as it extends southward and upslope along the exposure. On the bottom of this sandstone, elongate slickenlines mark the underside of the bedding surface. The structural lineations plunge 15 degrees to the north 50 degrees east and indicate the presence of a fault along which relative east- west movement has occurred. The fault plane strikes north 30 degrees west and dips 30 degrees to the east. Six kilometers due south of the Cold Canyon trailhead, a fault occurs in a roadcut of sandstone and shale beds at the far southern end of Wild Horse Canyon (not included on field map). The fault has not yet been characterized, but bears similarity to the thrust fault in the Sites Formation (Plate VII).

500 meters south of Route 128 along the trail through Cold Canyon, the hillside to the west is scarred by a recent debris flow (Plate VIII). About fifty meters upslope are two adjacent scarps where clay-rich material is overlain by angular blocks of sandstone. Several small springs emerge from the base of the scarps (Plate IX). Just down slope from the scarps a small spring emerges from an outcrop of thinly-bedded gray sandstone and siltstone which fines upward to the west and dips to the west. A crust of calcium carbonate (Plate X) covers the surface of the outcrop. No attempt was made to analyze the spring deposits or spring waters within the Cold Canyon area, but Davisson et.al. (1994) have reported on the chemical and isotopic characteristics of perennial saline springs in the Rumsey Hills area, and discuss their source and geochemical evolution. The springs of Cold Canyon may be reasonable analogs to these springs which typically emerge at high elevtions, along tectonic structures within the eastern margin of the northern California Coast ranges.

West of the spring, bedding in the streambank is exposed in the debris flow scar and dips to the west about 45 degrees. Original bedding is difficult to detect immediately east and down slope of the spring. Approximately 30 meters east of the spring, beds of thinly bedded sandstone and shale fine eastward and dip 70 degrees to the west; thus the beds in this exposure are overturned (Plate XI and Plate XII).

Discussion

The upper Cretaceous Fiske Creek, Venado, Yolo, and Sites Formations of the Great Valley group are interpreted as submarine fan deposits (Ingersoll, 1978) formed within a forearc basin between the Sierran -Klamath magmatic arc and the Franciscan subduction complex (Dickinson & Seely, 1979). The Fiske Creek Formation is composed of low density basinal turbidites. The Venado Formation is interpreted as a retrogradational sequence of inner-mid fan channelized deposits. The decrease in grain size and bed thickness in sandstone and conglomerate beds of the Venado Formation indicates a gradual rise in sea-level during deposition . The Yolo Formation is dominantly shale, interpreted as outer- to distal-fan deposits that may have been deposited during a rapid rise in relative sea-level (Ghosh & Lowe, 1992). The Sites Formation is interpreted as channelized mid fan and outer-fan lobe deposits also associated with a relative rise in sea-level (Ingersoll, 1976).

Sedimentary structures such as load casts, erosional marks, and graded beds within sandstone and shale are characteristic of soft-sediment deformation associated with submarine turbidite deposits. Slump structures typically occur in environments where rapid deposition and oversteepened slopes lead to instability of unconsolidated or semiconsolidated sediments usually under the influence of gravity. Discordant sandstone layers within overlying shale beds may be a result of increased fluid pressure and clastic dike injection owing to the compaction and deformation of incompletely lithified sediments.

The geometry of observed structures in the Cold Canyon area may be a result of more than one deformational event. The chevron fold in the shale beds of the Fiske Creek Formation has a completely different geometry from the anticlinal fold in the sandstone beds of the Venado Formation, and the fold axes of each fold trend in widely divergent directions. If these structures were related through a single-deformational event, the observed fold geometries should be consistent with one another. The lack of fractures along the hinge of the tight fold in the sandstone bed of the Venado Formation (Plate VI), suggests a role for soft sediment deformation in the development of the fold. The timing of the deformation is difficult to constrain, but it may have taken place in the upper Cretaceous, while the sediments were still soft.

Overturned beds (Plates XI and XII) exposed in the stream bank of Cold Canyon are anomalous. The origin of these overturned beds may be explained by a few possibilities. The first suggests that the beds were broken and overturned by recent slumping of strata by downslope movement. The Venado Formation is dominantly sandstone and conglomerate, but thin-bedded mudstone and sandstone beds at the tops of fourth-order depositional packages are also recognized in the formation (Ghosh & Lowe, 1992). The fine-grained sandstones grade upward into mudstones which in turn are in sharp contact with the overlying sandstone beds.

Slope stability is dependent on such variables as type of earth materials, topography, climate, vegetation, water, and time. If the driving forces overcome the resisting forces, downslope movement occurs. The weight of the slope material is the most common driving force and the shear strength acting along potential slip planes of the slope material is the most common resisting force. The steep eastward dip of beds in the Venado Formation, in combination with abrupt contacts between sandstone beds and underlying shales, may have produced bedding plane failure. Downslope movement of beds within the Venado Formation may have caused rotational slumping and consequent breakage and overturn of an otherwise coherent package of sediments. Another similar possibility for the presence of overturned beds in Cold Canyon is downhill creep. Creep results in deformation of rocks at the base of a slope under the influence of gravity. In this case, no slip plane is required for the gradual downhill movement of earth materials.

A second possible explanation is that the overturned beds are a result of folds in the hanging walls of west-directed backthrusts within the Yolo Formation, similar to those described in the Capay Valley area by Unruh et al. (1992). The thrust fault in the Sites Formation may be a related structure, but it has not been traced south of the Cold Canyon trailhead. A lineament on the aerial photograph roughly coincides with the southward projection of the fault, but it has not been verified in the field. The fault that crops out in the roadcut at the southern end of Wild Horse Canyon may also be structurally related to the overturned beds within Cold Canyon. The presence of such faults, or other exposures of overturned beds, through Cold Canyon south to Wild Horse Canyon, would support the hypothesis that west-directed backthrusts and associated fold propagation layers occur along lithologic boundaries of major formational units within an east dipping homoclinal sequence of Great Valley strata in the eastern Coast Ranges and the western Sacramento Valley (Fig. 2).

Twenty kilometers north of Cold Canyon in the Dunnigan and Rumsey Hills, Unruh (1992) and Ramirez (1992) have characterized low-angle backthrusts or bedding-parallel thrust faults in the Funks, Sites, Yolo, and Cortina Formations by overturned or steeply dipping beds, anastomosing shear zones, abrupt changes in the dip of bedding, and slickensided shear planes near the base of beds. The thrusts typically occur in mudrocks and ramp upward along more resistant sandstones. Fault bend and fault propagation folds occur in the hanging wall of the thrusts and produce the anticlinal structures within upper Cretaceous, lower Tertiary, and Quaternary sediments. The Rumsey Hills and Dunnigan Hills are prominent areas of Quaternary uplift and folding (Fig. 2), and similar styles of deformation may continue to the south into the Cold Canyon.

If the overturned beds in Cold Canyon were related to larger-scale features, then such beds should extend north and south beneath the landslide deposits along the length of Cold Canyon. Beds exposed in Cold Canyon typically conform to the regional attitude of the area. However, the northernmost exposure of any bedding along the stream banks of Cold Canyon is at the site of the overturned beds. The beds at this location lie farther to the west than any other exposures along the west banks of Cold Canyon, and are uncovered due to a recent debris flow scar (Plate VIII). North of this exposure, all rocks, including any overturned sequences, are completely covered by landslide debris derived from the Venado Formation. The aerial photograph lineament through the middle of the landslide deposit may represent a buried feature related to the overturned beds.

Figure II (not shown) is an unbalanced geologic cross section of the Cold Canyon area constructed through the site of the overturned beds. Surface data are limited to only a few bedding attitude measurements along the line of section, and thus the geometry of the subsurface is highly interpretative. Following the work of Unruh et al. (1992), the model suggests that the overturned beds result from the development of a fault bend anticlinal fold within the Yolo Formation. The model further suggests that Quaternary sliding and slumping has disrupted, and obscured the surface expression of these large-scale structures in the Cold Canyon area. Given the relationship of saline perennial springs to tectonic features determined by Davisson et. al. (1994), and assuming that the springs at Cold Canyon are sufficiently similar to the ones in the Rumsey Hills, the occurrence of the spring near the location of the overturned beds supports the possibility that a large-scale tectonic feature, such as a fold or a thrust fault, is present at this location. West-directed, bedding-parallel backthrusts and associated anticlinal structures in the upper Cretaceous strata, such as the Yolo Formation, are associated with renewed crustal shortening during latest Cretaceous-early-Tertiary times (Unruh, et al., 1992). The field observations that beds in the Venado and Yolo Formation dip more steeply to the east than do beds in the Sites Formation and the presence of the anticlinal fold in the uppermost beds of the Venado Formation (Plate VI) together suggest that fault bend propagation folds may have developed prior to, or during, the deposition of the Sites Formation in the Upper Cretaceous.

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References

Davisson, M. L., Presser, T. S., Criss, R. E., 1994, Geochemistry of tectonically expelled fluids from the northern Coast ranges, Rumsey Hills, California, USA: Geochimica et Cosmochimica Acta., v. 58, p. 1687-1669.

Dickinson, W. R., and Seeley, D. R., 1979, Structure and stratigraphy of the fore-arc regions: American Association of Petroleum Geologists Bulletin, v. 63, p. 2-31.

Ghosh, B., and Lowe, D. R., 1992, Architecture of deep-water channel complexes, Cretaceous Venado sandstone member, Sacramento Valley, California, in Graham S. A., and Lowe, D. R., 1993, Pacific Section Society of Economic Paleontologists and Mineralogists, p. 51-95.

Kirby, J. M., 1943, Upper Cretaceous stratigraphy of the west side of Sacramento Valley south of Willows, Glenn County, California: AAPG Bulletin, V27, p.279-305.

Ingersoll, R. V., 1978, Petrofacies and petrologic evolution of the Late Cretaceous fore-arc basin, northern and central California: Journal of Geology, v. 86, p.335-352.

Ingersoll, R. V., 1976, Evolution of the Late Cretaceous forearc basin of northern and central California: Palo Alto, California, Stanford University, Ph.D. dissertation p. 200.

National Aerial Photography Project Photographs, 8/16/93, photo nos. 6358-102-105.

Unruh, J. R., Ramirez, V. R., Phipps, S. P., and Moores, E. M., 1991, Tectonic wedging beneath fore-arc basins: ancient and modern examples from California and the Lesser Antilles: GSA Today, v. 1, p. 185-190.

Unruh, J. R., and Moores, E. M., 1992, Quaternary blind thrusting in the southwestern Sacramento Valley, California: Tectonics, Vol. 11, no.2, p. 192-203.

Unruh, J. R., Loewen, B. A., and Moores, E. M., 1994, Progressive arcward contraction of a Mesozoic-Tertiary fore-arc basin, southwestern Sacramento Valley, California: Geological Society of America Bulletin, v. 107, p. 38-53.

Wagner D. L., Bortugno, J. J., 1982, Geologic map of the Santa Rosa quadrangle, California, 1:250,000.

Wentworth, C. M., Blake, M. C. Jr., Jones, S. L., Walter, A. W., and Zoback, M. D., 1984, Tectonic wedging associated with emplacement of the Franciscan assemblage, California Coast Ranges, in Blake, M. C. Jr., ed., Franciscan Geology of Northern California: Pacific Section, Society of Economic Paleontologists and Mineralogists, v. 43, p.163-173.