DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

# GEOLOGIC MAP OF THE COVE FORT QUADRANGLE, WEST-CENTRAL UTAH

By

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This report is preliminary and has not been edited or reviewed for conformity with U.S. Geological Survey standards.

## DESCRIPTION OF MAP UNITS

QTa ALLUVIAL DEPOSITS (HOLOCENE TO MIOCENE)--Range from modern alluvium in channels of intermittent streams and local valley bottoms, to basin-fill fan and pediment deposits consisting of silt, sand, pebble and boulder gravel. Include some colluvium. Thickness unknown but may exceed 200 m in some basins

Qls LANDSLIDE DEPOSITS (HOLOCENE AND PLEISTOCENE)--Heterogeneous deposits of local origin. Commonly have hummocky surface

Qcg BASALTIC ANDESITE OF CEDAR GROVE (PLEISTOCENE)--Porphyritic, dark-gray to black lava flows with 30 to 45 percent phenocrysts of plagioclase, clinopyroxene, hypersthene, magnetite, and some olivine in a finely felted groundmass of microlites and glass. Flows contain about 60 percent $SiO_2$ and 3 percent $K_2O$ (Clark, 1977). Petrographic description modified from Clark (1977)

Qcgc BASALTIC ANDESITE CINDER CONE OF CEDAR GROVE (PLEISTOCENE)--Cinder cone marking the vent for the lava flows of the basaltic andesite of Cedar Grove (Qcg)

Qcf BASALTIC ANDESITE OF COVE FORT (PLEISTOCENE)--Dark-gray to black, vesicular to dense lava flows containing phenocrysts and microphenocrysts of plagioclase, pyroxene, magnetite, olivine, and sparse corroded quartz in a felted matrix of microlites and glass. Petrographic description modified from Clark (1977). K-Ar whole rock age is 0.5 m.y. (Best and others, 1980)

Qcfc BASALTIC ANDESITE CINDER CONE OF COVE FORT (PLEISTOCENE)--Cinder cone on crest of shield volcano marking vent of most lava flows comprising the basaltic andesite of Cove Fort (Qcf)

Qrk BASALTIC ANDESITE OF RED KNOLL (PLEISTOCENE)--Dark-gray to black, porphyritic basaltic andesite to latite lava flow with a blocky, scoriaceous surface underlain by dense to vesicular rock. Phenocrysts of labradorite and pyroxene (30-40 percent) are set in a glassy to very finely granular matrix. Petrographic description modified from Clark (1977)

Qck BASALTIC ANDESITE OF CRATER KNOLL (PLEISTOCENE)--Dark-gray to black, porphyritic basaltic andesite lava flow with a blocky, scoriaceous surface underlain by dense to vesicular rock. Phenocrysts are largely labradorite and pyroxene (40-45 percent); matrix is glassy to finely granular, with microlites of plagioclase, pyroxene, olivine(?), and opaque minerals. Petrographic description modified from Clark (1977). K-Ar whole rock age is 1.0 m.y. (Best and others, 1980)

Qbm BASALTIC ANDESITE OF BURNT MOUNTAIN (PLEISTOCENE?)--Includes Burnt Mountain Flows and Cove Creek Flows of Clark (1977). The lava flows erupted from the Burnt Mountain center consist of black to medium-gray, fine- to medium-grained, porphyritic rock with 20 percent phenocrysts of labradorite and lesser olivine, orthopyroxene, and clinopyroxene. Flow surfaces are marked by blocky aa lava. Individual lava flows are 10-20 m thick, and the entire assemblage is probably not more than 150 m thick. Lava flows from a center 2 mi north of Cove Creek (Cove Creek Flows of Clark, 1977), consist of dark-gray to black, dense to scoriaceous rocks generally containing less than 5 percent phenocrysts, mostly andesine with some hypersthene, in a glassy groundmass. The thickness of the Cove Creek Flows of Clark (1977) is not known but is probably more than 120 m. Petrographic description modified from Clark (1977)

Qbmc BASALTIC ANDESITE CINDER CONES OF BURNT MOUNTAIN (PLEISTOCENE?)--Two cinder cones marking vents of the lava flows of basaltic andesite of Burnt Mountain (Qbm)

QTl UNNAMED MARLY LIMESTONE (PLEISTOCENE? AND PLIOCENE)--White, yellowish-white, and buff, fine-grained, marly limestone and calcareous tufa. Contains lenses and tongues of clay, sandstone, and conglomerate and isolated pebbles of igneous and sedimentary rocks, all from nearby sources. Typical exposures are of rudely bedded limestone consisting of broken fragments of calcareous tufa enclosing many large and small openings, interlayered with finer-grained marly beds. Some beds are fossiliferous and contain remnants of ostracodes, charophytes, diatoms, gastropods, and fish (Zimmerman, 1961). Intertongues with basalt of Lava Ridge. Exposed thickness 80-100 m; maximum thickness unknown

QTlr BASALT OF LAVA RIDGE (PLEISTOCENE? AND PLIOCENE)--Black to dark-gray olivine tholeiite. Individual flows are generally widespread sheets as much as 30 km long and 5 km wide (Clark, 1977). A local volcano source marked by cinders, ash, and local flows is located along the northwest margin of the quadrangle. Most rocks contain few phenocrysts and range from scoriaceous to dense, black glassy to microcrystalline rocks in thin flows and near the margins of thicker flows, to finely crystalline diabasic to diktytaxitic rocks forming most of the thicker flows. Both the sparse phenocrysts and the more crystalline matrices consist largely of labradorite, olivine, clinopyroxene, and black opaque oxide minerals. Unit is equivalent to the Black Point Flows and part of the Black Rock Flows of Clark (1977). Intertongues laterally with unnamed marly limestone unit (QTl). Thickness unknown, but exceeds 150 m. K-Ar whole rock age is 2.5 m.y. (Best and others, 1980)

Tr RHYOLITE OF CUDAHY MINE (PLIOCENE)--Highly siliceous, crystal-poor rhyolite lava flows and pyroclastic rocks. Commonly glassy with abundant obsidian nodules ("apache tears") in a more hydrated glass matrix. Contains very sparse small phenocrysts of sanidine, sodic plagioclase, and magnetite. Petrography from Crecraft and others (1980). K-Ar whole rock ages range from 2.6 to 2.4 m.y. (Crecraft and others, 1980)

Trg RHYOLITE OF GILLIES HILL (MIOCENE)--Thick local lava flows and volcanic domes of light-gray to white, flow-layered rhyolite. Ranges from nearly aphyric to porphyritic with abundant phenocrysts. One series of flows, generally crystal poor, is characterized by quartz, sanidine, plagioclase, and very sparse biotite phenocrysts, whereas a major flow along the eastern margin of the accumulation has abundant plagioclase and biotite phenocrysts. Finely granular matrix ranges from dense to highly vesicular. K-Ar age on biotite is 9.1 m.y. (S. H. Evans, written commun., 1979)

MOUNT BELKNAP VOLCANICS (MIOCENE)

Tmr Felsitic rhyolite lava flows--Possibly part of the Mount Baldy Rhyolite Member (Steven and others, 1979, p. 29). Contorted flow layers common

Tmj Joe Lott Tuff Member--Light-gray, crystal-poor, slightly to moderately welded ash-flow tuff containing 1-2 percent phenocrysts of quartz, sodic plagioclase, sanidine, and traces of biotite. Age is bracketed between dated units as about 19 m.y. (Steven and others, 1979).

To OSIRIS TUFF (MIOCENE)--Gray to reddish-brown, densely welded, crystal-rich ash-flow tuff containing phenocrysts of andesine (25 percent), and lesser sanidine, biotite, clinopyroxene, and magnetite. K-Ar age on biotite is 22.4 m.y. (Fleck and others, 1975)

Tb BULLION CANYON VOLCANICS (MIOCENE AND OLIGOCENE)--Intermediate-composition lava flows along the southern border of the quadrangle. Toward the west, south of Cedar Grove, the rocks are strongly propylitized and hornfelsed from proximity to intrusive rocks Tis and Tig. East of Highway 15, the rock is a coarse porphyry continuous downward into intrusive latite (Til) and represents an extrusive lava flow-volcanic dome that spread out on the surface above a large volcanic neck

Tsc SCORIA FLOW (MIOCENE?)--Irregularly scoriaceous, dark-gray porphyry with prominent phenocrysts of plagioclase (30 percent), pyroxene (10 percent), and magnetite (2 percent). Closely similar to vesicular phases of nearby intrusive latite (Til), and locally grades into it. Equivalent to parts of nearby lava flows in Bullion Canyon Volcanics (Tb)

Til LATITE PORPHYRY (MIOCENE?)--Forms shallow plutons (volcanic necks) that cut unit Tbt and are overlain unconformably by unit To. Texture similar to that in nearby, intermediate-composition, porphyritic lava flows (Tb), with prominent phenocrysts of plagioclase, clinopyroxene, magnetite, and locally biotite set in a fine-grained, red to dark-gray matrix. Locally is highly vesicular, especially in higher parts of plutons, and in part is lithologically identical with nearby scoria flows (Tsc). To the south it is continuous upward from a crosscutting pluton into a thick, overlying lava flow (Tb). Is similar to nearby intrusive monzonite (Tim) in composition and age, but differs in having a finer grained texture similar to that in the overlying lava flow

Tim MONZONITE PORPHYRY (MIOCENE?)--Forms shallow intrusive plutons that cut units Tbt, Ta, and Tzt, and are overlain unconformably by unit To. Consists of phenocrysts of andesine-labradorite, clinopyroxene, and magnetite in a variable fine- to medium-grained matrix of alkali feldspar and magnetite. Contains little or no quartz. Border phases range widely in mineralogy and texture and locally are identical with rock in unit Til

Tis SYENITE (MONZONITE) (MIOCENE?)--Medium- to coarse-grained, leucocratic, porphyritic to hypidiomorphic-granular rock consisting of predominant orthoclase and plagioclase, and lesser hornblende, clinopyroxene, and sparse biotite. Sphene and magnetite are common accessory minerals. Feldspar ratios range from predominantly orthoclase to subequal orthoclase and plagioclase. Very sparse, highly resorbed grains of quartz are present locally. Cuts the gabbro porphyry (Tig) with which it is closely associated. May be related to monzonite-latite intrusions (Tim-Til) 8-12 km to the east and northeast

Tig GABBRO PORPHYRY (MIOCENE?)--Strongly porphyritic, dark-gray rock consisting of prominent phenocrysts of labradorite and clinopyroxene in a felted matrix of plagioclase microlites and Fe-Ti oxide granules. Cuts propylitically altered, intermediate-composition volcanics (Tb) and may be related to monzonite intrusions (Tim-Til) 8-12 km to the east and northeast

Tzt ZEOLITIC TUFF (MIOCENE?)--White, nonwelded, ash-flow tuff containing 10-30 percent lithic fragments and phenocrysts of sanidine and plagioclase with sparse quartz and biotite. Matrix has been almost completely converted to the zeolite mineral clinoptilolite

Ta TUFF OF ALBINUS CANYON (MIOCENE OR OLIGOCENE)--Red, densely welded, crystal-poor, ash-flow tuff (contains virtually no phenocrysts in the Cove Fort area). Characteristically is highly vesicular with many of the vesicles now filled with tridymite

Tbt THREE CREEKS TUFF MEMBER OF BULLION CANYON VOLCANICS (OLIGOCENE)--Densely welded, crystal-rich, ash-flow tuff with 40-60 percent phenocrysts of plagioclase (30 percent), hornblende (10 percent), biotite (5 percent), sanidine (tr), and magnetite (tr). K-Ar and fission-track ages indicate an approximate age of 27 m.y. (Steven and others, 1979)

Tw VOLCANICS OF WALES CANYON (OLIGOCENE)--Reddish, intermediate-composition lava flows and welded ash-flow tuffs containing moderately abundant phenocrysts of plagioclase and pyroxene, and sparse biotite. The welded tuffs were called Wales Canyon Tuff Member of the Bullion Canyon Volcanics by Caskey and Shuey (1975), but the name volcanics of Wales Canyon is here extended to cover the lithologically similar lava flows that overlie and underlie the tuffs

Tn NEEDLES RANGE FORMATION (OLIGOCENE)--Here probably consists only of the Wah Wah Springs Member of the Needles Range Formation. Reddish-brown to gray, medium-grained, welded ash-flow tuff containing approximately 40 percent phenocrysts of plagioclase, hornblende, and minor biotite and abundant flattened pumice fragments in a matrix of devitrified glass shards. Locally is interlayered with volcanics of Dog Valley (Tdv). Minimum thickness is about 120 m. A best-estimate K-Ar age of 28.9 m.y. was reported by Fleck and others (1975)

Tdv VOLCANICS OF DOG VALLEY (OLIGOCENE)--A heterogeneous assemblage of intermediate-composition lava flows, tuff breccias, and local and regional ash-flow tuffs, characterized by abundant phenocrysts of plagioclase, hornblende, biotite, and locally pyroxene. Includes a thick, coarsely porphyritic lava flow that Caskey and Shuey (1975) called the Sulphur Peak Member of the Bullion Canyon Volcanics. Is interlayered locally with the Needles Range Formation (Tn)

Kpr PRICE RIVER FORMATION (CRETACEOUS)--Massive, pebble to boulder conglomerate consisting of subrounded clasts of quartzite and limestone cemented by red- and brown-weathering sand, clay, and limy mudstone. Lenses of coarse sandstone and fine pebble conglomerate are common, and beds of brownish-gray shale and gray marly limestone also are present locally. Thickness is irregular due to character of underlying erosion surfac•, but locally is as much as 250 m thick

JT n NAVAJO SANDSTONE (JURASSIC AND TRIASSIC?)--Red-weathering, massive, fine- to medium-grained, friable, crossbedded sandstone, commonly with zones of white sandstone near thrust faults. Locally forms cliffs. Thickness about 500 m

CHINLE FORMATION (TRIASSIC)

T cp Petrified Forest Member--Mostly beds of variegated red, maroon, chocolate, and white mudstone overlying a layer of purple, coarse-grained sandstone at base. Some beds of friable, purple and tan, crossbedded sandstone in upper part. Unit commonly forms a slope above the more resistant Shinarump Conglomerate Member. The upper contact of Petrified Forest Member is an erosion surface; average thickness is about 85 m

T cs Shinarump Conglomerate Member--Mostly light-brownish-gray, coarse-grained sandstone or grit containing thin beds and lenses of chert-pebble conglomerate, some layers of greenish-gray shale near the middle of the member, and beds of friable purple sandstone near top. Silicified wood is abundant throughout. The base of the member overlies a widespread erosion surface. Thickness is about 150 m

T m MOENKOPI FORMATION, UNDIVIDED (TRIASSIC)--Mostly dark-red to chocolate-brown siltstone and shale with two prominent limestone units that divide the formation into 5 members not shown on present map. These are: (1) lower red member, (2) Virgin Limestone Member, (3) middle red member, (4) Schnabkaib Member, and (5) upper red member. The Virgin Limestone Member consists chiefly of dark-brownish-gray limestone interbedded with red siltstones and mudstones. The Schnabkaib Member consists of 5 beds of light-gray crystalline limestone each about 3-5 m thick and separated by red sandstone and siltstone 2-15 m thick. Some thin gypsum beds are present in the upper part of this member. The lower, middle, and upper red members commonly contain beds that are ripple marked and mudcracked, and locally also contain small nodules of hematite and ironstone. Total thickness of the Moenkopi is about 320 m

Pkt KAIBAB LIMESTONE AND TOROWEAP FORMATION, UNDIVIDED (PERMIAN)--A generally light-colored unit consisting of limestone, sandstone, and minor shale. Two prominent horizons, one near the base and the other near the middle of the unit, consist of massive, light-gray, coarsely crystalline limestone, commonly with scattered nodules of white to dark-red chert. The remainder of the unit consists of interstratified tan, fine-grained sandstone, tan and gray limestone, and some shale. Total thickness of the unit in the Dog Valley thrust plate is about 360 m; on Dog Valley Mountain in the allochthon it is only about 235 m

Pta TALISMAN QUARTZITE (PERMIAN)--Massive, yellowish-gray, crossbedded and cross-laminated, quartzitic sandstone. Beds within a meter or so of the base commonly are light red in color, as are thin horizons higher in the formation. In general, beds in the lower half of the Talisman are more friable and loosely cemented than the quartzitic beds in the upper half. The thickness ranges from 50-200 m

P o OQUIRRH FORMATION (PERMIAN AND PENNSYLVANIAN)--Interbedded gray to blue, fine- to coarse-grained, platy to massive, commonly cherty limestone and tan to brown, fine- to coarse-grained quartzite and sandstone. In general, the arenaceous beds make up about 20-25 percent of the formation. Total thickness is about 290 m in the Dog Valley thrust plate and more than 1,500 m thick in the allochthon exposed at Dog Valley Mountain

Mr REDWALL LIMESTONE (MISSISSIPPIAN)--Bluish-gray, medium-bedded, fossiliferous, locally cherty and oolitic limestone. Abundant well preserved brachiopods and corals are a characteristic feature of the formation. Thickness is about 175 m

Dcf COVE FORT QUARTZITE OF CROSBY (1959) (DEVONIAN)--White to light-gray, highly indurated, somewhat vuggy quartzite with some beds of limestone flat-pebble conglomerate near middle. This formation apparently overlies an extensive erosion surface that has been cut into the Simonson Dolomite. Average thickness about 25 m

Dsi SIMONSON DOLOMITE (DEVONIAN)--Massive, dark-brown, sugary-textured dolomite commonly with a striped appearance. In the Cove Fort quadrangle the top of formation is an erosion surface overlain by the Cove Fort Quartzite of Crosby (1959), but in other areas in western Utah the Simonson is succeeded by the Guilmette Formation. Thickness of Simonson Dolomite is 70-165 m

Dse SEVY DOLOMITE (DEVONIAN)--Massive, dense, fine-grained, light-brownish-gray, faintly laminated dolomite that commonly weathers light gray. Some beds contain scattered isolated clear quartz grains and some thin layers and lenses of quartzite. Average thickness about 200 m

SOlf LAKETOWN AND FISH HAVEN DOLOMITES, UNDIVIDED (SILURIAN AND ORDOVICIAN)--Massive, dark-gray, dense, apparently recrystallized dolomite containing a few beds of thinly laminated stromatolitic dolomite. Many beds also are cherty. Regionally, poorly preserved corals and other fossils indicate that the upper third or so of this unit is Silurian, but the contact between the Silurian Laketown Dolomite and the Ordovician Fish Haven Dolomite was not identified. The top of this map unit is an erosion surface. Average thickness is about 300 m

Oe EUREKA QUARTZITE (ORDOVICIAN)--Massive, fine- to medium-grained, faintly crossbedded, vitreous, white to tan quartzite with a few beds of sandy dolomite near the middle. Locally the surface of the light-colored quartzite is stained brown, red, and purple by iron oxides and clay. Thickness is about 55 m

Op POGONIP GROUP, UNDIVIDED (ORDOVICIAN)--Mostly light-blue-gray, thin-bedded, argillaceous limestone containing many thin beds of intraformational conglomerate. Upper part contains many beds of olive-drab-weathering shale, but no definite Kanosh Shale is recognized. Base of formation is concealed. Thickness of exposed section is 338 m

Ꞓls LIMESTONE, UNDIVIDED (MIDDLE CAMBRIAN)--Light-blue-gray, fine-grained, silt-streaked limestone. Occurs in a klippen of the Pavant thrust fault with no formational contacts preserved. This unfossiliferous limestone resembles the Teutonic and Herkimer Limestones of the East Tintic Mountains (Morris and Lovering, 1961)

Ꞓt TINTIC QUARTZITE (CAMBRIAN)--Isolated exposures of thin sequences of massive, dense, tan to buff vitreous quartzite in klippen and in the main Pavant thrust plate

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# Geology of the Cove Fort quadrangle, west-central Utah

by

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The Cove Fort quadrangle in west-central Utah has been the site of diverse structural, volcanic, and hydrothermal events that have taken place episodically since Late Cretaceous time. These events developed a wide variety of geologic environments, and many significant inter-relationships can be determined within the quadrangle. Prevolcanic structures consist of a sequence of easterly directed thrust-faults that formed during the Late Cretaceous Sevier orogeny and cut Paleozoic and Mesozoic sedimentary rocks. The Cove Fort quadrangle occurs in a part of the Sevier orogenic belt where dominantly south-trending structures in northern Utah abruptly turn west-southwestward from the southern part of the Pavant Range, cross the Cove Fort quadrangle to southwestern Utah, and there resume a more southerly orientation. The area containing this bend in the orogenic belt later was the site of igneous activity that formed part of the Pioche-Marysvale igneous and mineral belt in middle and late Cenozoic time. Volcanic and intrusive rocks emplaced in the Pioche-Marysvale belt in Oligocene and earliest Miocene time are mostly calc-alkalic andesites to low-silica rhyolites; these rocks formed during a period of tectonic quiescence, and the volcanic rocks were deposited on an erosion surface cut on deformed Paleozoic and Mesozoic sedimentary rocks, or on undeformed Late Cretaceous and early Tertiary fluvial and lacustrine sediments deposited in a basin in front of the eroded Sevier orogenic belt (Spieker, 1946; Rowley and others, 1979). In early Miocene time, about 22 m.y. ago, the composition of the eruptive rocks changed to a bimodal assemblage of high-silica alkali rhyolite and basalt, an assemblage which has been erupted episodically ever since. Basaltic lava flows were emplaced widely throughout southwestern Utah, but the rhyolitic rocks were for the most part confined to the Pioche-Marysvale belt where earlier calc-alkalic volcanoes had been active. The bimodal igneous activity was broadly coincident in time and space with extensional tectonism that caused widespread block faulting throughout the Basin-Range province in later Cenozoic time (Christiansen and Lipman, 1972).

Deformed Paleozoic and Mesozoic sedimentary rocks crop out in a narrow belt extending from the northeast corner of the Cove Fort quadrangle southwestward for about 20 km. These rocks make up three structural units: the regionally extensive Pavant thrust plate, the underlying subsidiary Red Ridge thrust plate, and rocks autochthonous relative to the thrust plates. Exposed autochthonous rocks below the thrust plates range from the Pennsylvanian and Permian Oquirrh Formation to the Triassic(?) and Jurassic Navajo Sandstone. Over much of central and southwestern Utah autochthonous rocks are relatively little deformed and throughout a large part of this area the Navajo Sandstone is the only formation exposed in the footwall of the Pavant and the correlative Blue Mountain thrust fault (Hintze, 1963). In the Cove Fort quadrangle, however, the autochthon in the general area of Dog Valley and southward was domed during the Sevier orogeny, and was eroded to expose units from the Navajo Sandstone downward to the Oquirrh Formation before post-orogenic sediments were deposited in Late Cretaceous time.

In the area north and east of the Cove Fort quadrangle, the Pavant plate, which rides on the Pavant thrust, consists of the Cambrian Tintic Quartzite, Ophir Formation, and Teutonic Limestone. This plate is only sparsely exposed within the Cove Fort quadrangle, however, where only a few small outcrops of Tintic Quartzite have been mapped along the northeastermmost boundary of the quadrangle. The trace of the Pavant thrust is not exposed in the Cove Fort quadrangle where it projects beneath the alluvial fill of White Sage Flat. A major easterly trending right-lateral tear fault in the northern part of the Cove Fort quadrangle has been proposed (Crosby, 1973) to account for the west-southwesterly swing in the Sevier orogenic belt. We see no evidence for such a tear fault, and think the moderately sharp turn in the trace of the thrust zone is more probably related to deflection of the plate of the Pavant thrust by the structural dome near Dog Valley. Although draping of the thrust plate over this dome largely accounts for the apparent easterly strike of the thrust trace in the Cove Fort quadrangle, the presence of a local tear or normal fault of relatively small displacement somewhere beneath the alluvial cover cannot be entirely disproven.

The Red Ridge thrust plate consists of overturned strata ranging from the Lower and Middle Ordovician Pogonip Group to the Lower and Middle(?) Triassic Moenkopi Formation. This inverted slab of sedimentary rocks between the Red Ridge and Pavant thrusts appears to be the detached upper limb of a nearly recumbent syncline which developed in the autochthon beneath the Pavant thrust, was later sheared off, and then dragged eastward beneath the moving plate. The nearly easterly strike of the overturned strata suggest that the plate was displaced eastward an unknown distance from its point of origin and then pivoted around the northern side of the Dog Valley dome causing the originally north-striking beds to assume east-northeastward bedding trends.

Exposures of thick, bouldery, wedge-shaped conglomerate masses of the Price River Formation of latest Cretaceous age in the eastern part of the Cove Fort quadrangle and the area to the northeast indicate that the orogenic zone was an area of high youthful mountains during and following the Sevier orogenic event. Locally these deposits are several kilometers thick and in some areas contain slabs and rounded clasts as much as several meters in diameter. Eastward and northeastward from the quadrangle the coarse clastic beds grade into sandstone tongues that ultimately terminate in flysch-like sedimentary rocks of marine origin that underlie parts of the Colorado Plateau.

Calc-alkalic volcanic and intrusive rocks of Oligocene and early Miocene age comprise two structural blocks within the Cove Fort quadrangle. These blocks are separated by a major, generally east-trending, fault that follows the valley of Cove Creek across the east-central part of the quadrangle. The block north of Cove Creek fault exposes the lower part of the volcanic section, which rests unconformably on an irregular erosion surface cut across deformed Paleozoic and Mesozoic sedimentary rocks. Most of these volcanic rocks consist of coarsely porphyritic rhyodacite lava flows and volcanic breccias of the volcanics of Dog Valley, which formed a local volcano centered near the quadrangle boundary east of Cove Fort. To the north, the volcanics of Dog Valley intertongue marginally with the Wah Wah Springs Member of the Needles Range Formation (30-29 m.y. old)[1/] (Caskey and Shuey, 1975), a regional ash-flow tuff sheet derived from a caldera source in the southern Needle Range pear the Utah-Nevada state line (Best and others, 1979), many kilometers to the west. Higher in the succession the volcanic rocks consist in turn of locally derived lava flows and welded ash-flow tuffs of the volcanics of Wales Canyon, and the crystal-rich Three Creeks Tuff Member of

[1/] Sources of age designations are given in Description of Map Units.

the Bullion Canyon Volcanics (27 m.y. old).

The structural block north of the Cove Creek fault is riven by numerous north- to northeast-trending Basin-Range block faults. The north-trending faults jostle numerous blocks up and down, but do not have major displacement. Some of the northeast-trending faults, on the other hand, have major displacement and deflect the major topographic mountain front from northward along the Tushar Mountains south of Cove Creek to northeastward along the Pavant Range to the north.

The structural block south of the Cove Creek fault exposes the upper part of the volcanic succession and related shallow monzonite-latite plutons. The upper parts of the volcanics of Dog Valley and volcanics of Wales Canyon are exposed in a few of the fault blocks, but most of the volcanic rocks in this structural block comprise the Three Creeks Tuff Member (27 m.y. old), the tuff of Albinus Canyon, a distinctive white zeolitic tuff of unknown affinities, the Osirus Tuff (22.4 m.y.) old, and the Joe Lott Tuff Member and Mount Baldy Rhyolite Member(?) of the Mount Belknap Volcanics (19 m.y. old). Monzonite-latite plutons cut all volcanic rocks up through the zeolitic tuff, but are overlain unconformably by the Osiris Tuff; this indicates that emplacement was sometime between 27 and 22 m.y. ago, and probably in the latter part of this interval. All rocks up through the Osiris Tuff belong to the calc-alkalic suite, but the Mount Belknap units are siliceous rhyolites of the bimodal suite.

The structural block south of the Cove Creek fault shows several styles of faulting, which reflect different responses to changing stress fields. The Cove Creek fault is old relative to other datable faults in the Cove Fort quadrangle. Major displacement took place shortly before the Osiris Tuff was deposited about 22 m.y. ago, inasmuch as the zeolitic tuff is clearly offset by the fault near the east margin of the Cove Fort quadrangle, but the Osiris Tuff covers the fault without offset few kilometers farther east. This early faulting was about concurrent with emplacement of the shallow monzonite-latite plutons, and the north margin of known intrusives is very close to the fault. This near coincidence in time and space, as well as the aberrant-eastward trend of the fault, implies that faulting either took place during emplacement of the plutons, or was localized later along the northern margin of the buttressing plutons.

The faults south of the Cove Creek fault fall into a regional pattern of generally north- to northwest-trending Basin-Range faults comparable to but only in part continuous with the block faults to the north, and a set of generally arcuate block faults just south of the Cove Creek fault that formed by gravitational sliding (Moore and Samberg, 1979). The two patterns appear to have formed in part concurrently with the regional faulting both preceding and following gravitational faulting. The regional faults are much more sparse south of the Cove Creek fault than they are to the north, and major displacement seems largely limited to the range-boundary fault at the western base of the Tushar Mountains. This is believed to reflect the buttressing effect of the monzonite-latite plutons south of the Cove Creek fault which inhibited the intricate fracturing that took place farther north.

Early regional faulting apparently uplifted the northwestern corner of the Tushar Mountains very strongly to cause the topographic imbalances that led to gravity sliding (section C-C′). The layered volcanic rocks north of the main shallow pluton (Tim) broke along a series of arcuate listric faults and the individual blocks moved northwestward toward the adjacent lowland. Similar gravity slide blocks formed in the southern Pavant Range to the north where the north end of Dog Valley Peak apparently slid westward toward Dog

Valley. As interpreted on section C-C′, later regional block faulting raised a horst across the toe of the gravity slide blocks south of Cove Creek; this interpretation is strongly supported by the map pattern, but age relations of the different faults could not be established firmly in the field. The main range-boundary fault at the base of the Tushar Mountains clearly had late movement, and gravity data presented by Cook and others (1979) indicate that a narrow alluvium-filled trough extends south into the adjacent Beaver quadrangle just west of this fault (section D-D′).

Beginning with eruption of the Mount Belknap Volcanics in early Miocene time, bimodal rhyolites and basalts were erupted often in later Cenozoic time in and near the Cove Fort quadrangle. The 9-m.y.-old rhyolite of Gillies Hill (S. H. Evans, written commun., 1979) in the southern part of the quadrangle is along the north margin of an area 50 km wide that contains many scattered rhyolite accumulations of about the same age. The rhyolite of Gillies Hill consists largely of a series of volcanic domes and lava flows with subordinate pyroclastic rocks that were erupted along a probable fault indicated by the steep gravity gradient (Cook and others, 1979) marking the west side of the narrow alluvium-filled trough that extends south from the Cove Fort quadrangle (section D-D′).

In late Pliocene to perhaps early Pleistocene time (3-2 m.y. ago), a mixed accumulation of flood basalt lava flows and more local rhyolite domes and flows developed along the margin of a shallow saline lake in and near the northwestern part of the Cove Fort quadrangle (Nash and Crecraft, 1979). Both the basalt and rhyolite flows are complexly interlayered with lacustrine limestone beds deposited within the lake. An equidimensional area about 10 miles across was broadly domed (section B-B′) and the dome was cut by northeasterly trending extensional faults. Renewed eruptions of basalt from vents along the faulted crest of the dome filled the crestal graben with lava flows identical with many of the earlier flood-basalt flows in the same area. The sequence of events suggests that upwarping resulted from intrusion of mafic magma beneath the dome, and that some of this magma escaped along overlying distentional fractures.

Basaltic volcanic activity shifted southward in Pleistocene time (Clark, 1977). Two cinder cones developed to the south in the adjacent Beaver quadrangle, along the east side of a graben that extends south from the southwestern part of the Cove Fort quadrangle. Lava flows from these vents, which flowed down the graben northward into the Cove Fort quadrangle, are the basaltic andesite of Crater Knoll and basaltic andesite of Red Knoll, both about 1.0 m.y. old. The broad shield volcano of the basaltic andesite of Cove Fort centered in the south-central part of the Cove Fort quadrangle at Cinder Crater formed about 0.5 m.y. ago. Flank eruptions from a cinder cone along the south side of the shield volcano erupted an elongate lava flow, the basaltic andesite of Cedar Grove, which flowed westward along the margin of the shield. The shield volcano and marginal flow are cut by numerous north-northeast-trending normal faults of small displacement. These faults parallel regional Basin-Range trends in adjacent areas, but were so closely limited to the then-recently formed basaltic volcanoes that they seem almost certainly to have formed from local distentional forces related to the basaltic eruptions, superimposed on a regional stress field.

Hydrothermal systems were active at several different times in the Cove Fort quadrangle during late Cenozoic time. Three main episodes of such activity have been detailed by Moore and Samberg (1979). Intrusion of monzonite-latite plutons in early Miocene time was accompanied by hydrothermal alteration and contact metamorphism of adjacent sedimentary and volcanic rocks; holes drilled by Union Oil Company to evaluate the geothermal energy potential of the area encountered occurrences of pyrite and base-metal sulfides in altered rocks and skarns at several places near the intrusive bodies (Moore and Samberg, 1979, p. 19). Later hydrothermal activity concurrent with Basin-Range faulting deposited fluorite at the Rainbow and Black mines along the northeast-trending fault that forms the northwest border of Dog Valley Peak, north and northeast of Cove Fort. The fluorite was highly broken by later fault movements and is cut by native sulfur deposited by still-active hydrothermal systems (Moore and Samberg, 1979, p. 22-23). Very young deposits of native sulfur occur at Sulphurdale, in an area 2-4 km east of Cove Fort, and in the vicinity of the fluorite deposits 2-4.5 km north and northeast of Cove Fort. All three of these sulfur-depositing hydrothermal systems are still active as indicated by the continued generation of hydrogen sulfide. The sulfur deposit at Sulphurdale is currently being exploited.

The area of still-active hydrothermal systems near Cove Fort and Sulphurdale shows abnormal heat flow and has been classified as a Known Geothermal Resource Area (KGRA) (Moore and Samberg, 1979, p. 23-30). Several test holes were drilled by Union Oil Company, but no discoveries of potentially economic energy resources had been reported by the middle of 1981.

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