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GEOLOGICAL SURVEY

# GEOLOGIC MAP OF THE CASTLE CLIFF AND JARVIS PEAK QUADRANGLES WASHINGTON COUNTY, UTAH

By

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# GEOLOGIC MAP OF THE CASTLE CLIFF AND JARVIS PEAK QUADRANGLES WASHINGTON COUNTY, UTAH

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## DESCRIPTION OF MAP UNITS

Qya YOUNGER ALLUVIUM (Holocene and Pleistocene)--Sand, gravel and boulders along present stream channels

Qc COLLUVIUM (Holocene and Pleistocene)--Talus and slope-wash consisting of angular debris of all sizes; forms a cover more than 20 m thick in places

Qoa OLDER ALLUVIUM (Holocene? and Pleistocene)--Sand, gravel, and bouldery deposits that form benches and terraces above present stream channels; 20 m thick in places

QTa ALLUVIUM (Pleistocene and Pliocene?)--Exhumed alluvial pediment deposits that form extensive surfaces that slope towards Beaver Dam Wash. Deposits consist of silt, sand, gravel, and boulders derived mostly from Precambrian metamorphic and Paleozoic sedimentary rocks of the Beaver Dam Mountains but also include a variety of clasts of volcanic rocks derived from the Bull Valley Mountains to the north. Deposits are more than 100 m thick along Beaver Dam Wash

QTl LANDSLIDE BLOCKS AND RUBBLE (Pleistocene and Pliocene?)--Detached masses of Paleozoic rocks that have moved downslope retaining various degrees of coherence. Identity of source Paleozoic formations is shown on map in parentheses where blocks are mostly coherent. A large mass of Queantoweap Sandstone in the north central part of the Jarvis Peak quadrangle has tilted slightly as it moved downslope; Callville and Redwall strata in the central part of the same quadrangle are similar except that Callville rocks have been considerably broken up. The largest area of landslide blocks is in the north half of the Castle Cliff quadrangle where huge masses of Redwall Limestone rest on Tertiary Muddy Creek Formation along the western base of the range. Cook (1960a) described these deposits near Welcome Spring as "breccia blocks". The largest of these blocks forms Sheep Horn Knoll which consists of an almost unbroken mass of Redwall Limestone that rests on highly brecciated and attenuated Cambrian and Devonian rocks. The relationship is somewhat similar to that exposed 4 km to the south at castle Cliff where a large sheet of Callville strata rest on a much attenuated and brecciated Mississippian and Cambrian sequence. The relationship at Castle Cliff has long been considered to be a younger-on-older thrust (Dobbin, 1939, p. 129-131)

Tm MUDDY CREEK FORMATION (Pliocene?)--Pale pinkish-brown, calcareous mudstone, siltstone, and sandstone exposed in patches in the central part of the Castle Cliff quadrangle beneath a cover of QTa and QTl. Bohannon (1983) noted that the Muddy creek Formation is overlain by a

5.9-my-old basalt and overlies a 10.6-my-old sandstone near Lake Mead. Total thickness of the formation cannot be ascertained in the Castle Cliff area; individual outcrops show no more than 30 m of beds

CHINLE FORMATION (Upper Triassic)--Members as mapped follow subdivisions used by Stewart and others (1972a)

₨cp PETRIFIED FOREST MEMBER--Variegated colored mudstone, siltstone, and some sandstone ranging from white to purplish-red and orangish-red. Chips of fossil wood not uncommon on weathered slopes. Exposure of member in map area is limited to narrow belt beneath thrust in northeast corner of Jarvis Peak quadrangle where beds no more than 30 m thick are found

₨cs SHINARUMP CONGLOMERATE MEMBER--Ranges from cobble conglomerate to coarse sandstone and has an overall orangish-brown color. Exposed only in narrow belt in northeast part of Jarvis Peak quadrangle where it is about 40 m thick

MOENKOPI FORMATION (Lower Triassic)--Members as mapped follow subdivisions discussed by Stewart and others (1972b)

₨mu UPPER RED MEMBER--Grayish-red to moderate brown siltstone, mostly evenly and thinly bedded and with about 30 percent of the layers showing laminated ripple marks. Light brown to yellowish- or orangish-brown sandstone that forms ledges makes up about 10 percent of the member and thin gypsum beds and stringers make up less than one percent. This map unit is found only in a narrow faulted belt in the northeast part of the Jarvis Peak quadrangle. In better exposed sections a few km north and east from there, the member is 150-200 m thick

₨ms SHNABKAIB MEMBER--Banded white and pale red gypsiferous mudstone and siltstone with lesser dolomite and limestone. The conspicuous broad white bands, largely containing the gypsum, set this member apart from the red members bounding it. Primary gypsum is laminated to thin-bedded, very light gray to bluish gray; secondary gypsum stringers occur throughout the member. Fossils are absent except in one thin bed of limestone that bears gastropods and echinoderm fragments. The limited exposures in the northeast corner of the Jarvis Peak quadrangle adjoin more extensive exposures in adjacent quadrangles where the Shnabkaib is about 250 m thick

₨mm MIDDLE RED MEMBER--Pale reddish-brown laminated or thinly bedded siltstone and mudstone with very thin interbeds and stringers of white or greenish-gray gypsum. Upper contact with Shnabkaib Member is gradational in some places; the lowest gypsum bed thicker than 1 m was taken as basal Shnabkaib. This member is well exposed in the northeast corner of the Jarvis Peak quadrangle where it is 100-125 m thick

Ꞧmv VIRGIN LIMESTONE MEMBER--Limestone comprises only 20 percent of this member, but it forms three distinctive sharp ledges or low cliffs near the base, middle, and top that make the member easily identifiable in the field and on aerial photographs. The basal limestone is 2-5 m thick and contains abundant five-sided echinoderm fragments. The upper limestone caprock is 3-7 m thick and is underlain by a conspicuous light colored siltstone and mudstone that makes it readily identifiable on aerial photographs. The middle limestone is variable in thickness and position within the member. The limestones are yellowish-brown to medium gray and composed of pelloids, ooids, intraclasts, and shell fragments usually in a micritic matrix. Lenticular chert occurs here and there in the limestone but is not consistent in distribution. Fossils include echinoid debris, pelecypods, gastropods, brachiopods, and ostracodes. Eighty percent of the member is made up of yellowish-brown weathering mudstone and siltstone that form slopes. Its drab color readily sets the Virgin apart from adjacent members of the Moenkopi Formation, but where the lower red member is missing and the Virgin Limestone Member rests directly on the Harrisburg Member of the Kaibab Formation the color change is sometimes less evident. In the northeast corner of the Jarvis Peak Quadrangle the Virgin Limestone Member is 50-60 m thick

Ꞧml LOWER RED MEMBER--Reddish-brown siltstone and mudstone with thin interbeds of gypsum and dolomite. Gypsum makes up much of the middle third of the member in places. Small-scale crossbeds and ripple marks are common. This member pinches out abruptly on the flanks of hills on the paleotopography developed on the Harrisburg Member of the Kaibab Formation. Thickness ranges from zero to 70 m

KAIBAB FORMATION (Lower Permian)--Members as mapped follow subdivisions proposed by Reeside and Bassler (1922), modified by Sorauf (1962), and adopted by Cheevers and Rawson (1979) and Nielson (1981)

Pkh HARRISBURG MEMBER--The lower half of this member is laminated gypsum with thin beds and lenses of dolomite limestone and siltstone; the middle 40 m is thin-bedded cherty limestone and dolomite interbedded with gypsum; the upper 40 m is silty gypsum with thin interbeds of dolomite and limestone including one 10 cm bed of very fossiliferous limestone bearing crinoid fragments and brachiopods. Gypsum in the Harrisburg is light gray and weathers to a powdery or clinkery surface. The thin bedded limestone and dolomite beds are seldom seen in place but commonly form a residual surface covered with reddish-orange cherty chips. Large solution collapse folds and breccias are common and the member usually forms rounded hummocky topography. Detailed measured sections of the Harrisburg Member in the Jarvis Peak quadrangle may be found in Nielson (1981) and Jenson (1984). Welsh and others (1979, p. 147) correlate this member with the Plympton Formation of western Utah. Considerable relief developed on the Harrisburg Member prior to deposition of the overlying Moenkopi Formation, consequently the Harrisburg in the map area ranges in thickness from 40 to 170 m

Pkf FOSSIL MOUNTAIN MEMBER--This member stands out by forming prominent ledges and cliffs bounded by the slope-forming gypsiferous units above and below. The member is composed entirely of yellowish-brown limestone that commonly is fossiliferous; brachiopods, often silicified, are the most common fossils, followed by bryozoans, corals and mollusca. Disarticulated rounded crinoid debris make up much of the rock. This member has been measured and described in detail by Nielson (1981). His average thickness for the member in the Jarvis Peak quadrangle is 75 m

TOROWEAP FORMATION (Lower Permian)--Map unit nomenclature follows that defined by Sorauf (1962) and Rawson and Turner-Peterson (1979, 1980) and used by Nielson (1981) in his detailed studies within the present quadrangles.

Ptw WOODS RANCH MEMBER--Grayish-orange gypsiferous siltstone with thin interbeds of white gypsum and pale orange limestone and dolomite. Member is topographically weak and generally covered or very poorly exposed. Nielson (1981) measured five sections of this member within the Jarvis Peak quadrangle. He reported that thickness of the member ranges from 40-70 m and averages about 65 m

Ptb BRADY CANYON AND SELIGMAN MEMBERS, UNDIVIDED--The Brady Canyon Member is a cliff-forming fossiliferous limestone that resembles the Fossil Mountain Member and is underlain by the recessive gypsiferous siltstone that makes up the Seligman Member. The Brady Canyon Member is about 80 m thick, as reported by Nielson (1980) for five sections measured within the Jarvis Peak quadrangle, whereas the Seligman Member averages only 25 m in thickness. Because of the thinness and recessive character of the Seligman Member it was not feasible to map it separately

Pq QUEANTOWEAP SANDSTONE (Lower Permian)--Very-pale-orange to grayish-orange-pink, thin- to thick-bedded, fine-to medium-grained, variably cemented sandstone. McNair (1951, p. 525-526) named the formation for exposures in Queantoweap (Whitmore) Canyon near the Grand Canyon and noted that in tracing it into southwestern Utah it should replace the term "Supai" previously used (Reeside and Bassler, 1922) because it has neither the color nor the lithology of typical Supai. The change in color and lithology occurs along the southern margin of the present quadrangle so that it is appropriate that Steed (1980) in mapping an adjacent quadrangle used different names for this interval. Within the Jarvis Peak and Castle Cliff quadrangles the Queantoweap Sandstone ranges in thickness from 350 to 550 m

Pp PAKOON DOLOMITE (Lower Permian)--Light gray fine-grained dolomite that weathers to light-brownish-gray ledges and low cliffs. Formation is often cherty but rarely fossiliferous, most fossils occurring in thin limestone beds in its upper third. The uppermost 15 m is mostly gypsum with minor limestone and sandstone. Thickness here ranges between 200 and 250 m

IPc CALLVILLE LIMESTONE (Pennsylvanian)--Medium-gray limestone, medium- to thick-bedded, commonly cherty and fossiliferous, with cyclic interbeds of orange-weathering sandstone and light gray dolomite increasing in the upper third. Lithostrotionella (hair coral) common in upper part, other corals, brachiopods and bryozoans common in limestone beds throughout. Poorly preserved fusulinids occur in some thin limestone beds. Forms step-ledge topography with few ledges greater than 2 m high. A Callville section measured 3 km southeast of the Utah Hill summit on the west side of Jarvis Peak was 500 m thick

Mr REDWALL LIMESTONE (Mississippian)--Cliff-forming, massive, medium- to dark-gray limestone, divided by McKee and Gutschick (1969) into four members which were traced into the Virgin Gorge area just south of this map area by Steed (1980) but which are not differentiated on the present maps, although one member, the very cherty Thunder Springs Member forms a conspicuous marker interval from 20 to 45 m above the base of the formation. Steed (1980, p. 112) presented a detailed measured section of the formation that applies to the sequence in this map area as well. Basal Redwall is coarse-grained and dolomitic and about 20 m thick. The Thunder Springs Member is cherty bioclastic limestone that weathers to a conspicuous dark brownish band about 25 m thick. The upper part of the Redwall is bioclastic and fossiliferous containing horn corals, colonial corals, and braciopods and is about 140 m thick. The entire formation is about 185 m thick

Dm MUDDY PEAK DOLOMITE (Devonian)--Two informal members described below were mapped where structure and exposure permitted. Muddy Peak beds are distinguished from adjacent formations principally by their color and topographic expression. A few layers contain distinctive pelletoidal structures and partly silicified stromatoporoidal fossils are sometimes prescut. More rarely gastropods and brachiopods occur within local crinoidal mounds. Steed (1980, p. 99) reported that conodonts, corals, and stromatoporoids from this formation in the Virgin Gorge just south of the quadrangle boundary indicate a Late Devonian age. Steed (1980) assigned 109 m of beds to the formation; in the present map area the formation is 150-220 m thick

Dmp PINNACLE MEMBER--The name of this informal member describes one of characteristics: it weathers to form light-gray hoodoos or pinnacles just below the massive dark-gray Redwall cliffs. It is composed of medium-gray medium-crystalline massive dolomite that contains scattered chert nodules and sandy laminae. The base was taken at the top of the ledge-forming sandstone beds in the upper part of the slope member. The pinnacle member is about 50 m thick

Dms SLOPE MEMBER--Silty fine-grained light olive-gray to pale yellowish gray thin- to medium-bedded dolomite. A variety of features occur locally within this member: reddish-brown weathering sandy dolomite beds form a few ledges 1-2 m thick; a few thin beds near the top include pelletoidal structures; small stromatoporoidal hemispherical structures, usually grossly silicified, occur in several layers; sparse biohermal mounds include crinoid debris and scattered coral, gastropod and brachiopod fragments; some units appear to be bioturbated. This member forms a ledgy slope between more resistant adjacent units; it is 100-150 m thick

€n NOPAH DOLOMITE (Upper Cambrian)--Medium- to fine-grained, thick-bedded, light-brownish-gray dolomite that generally forms cliffs and steep slopes. A few beds contain algal stromatolites 20 cm in diameter and up to 50 cm tall; more commonly, dolomitized twiggy bodies or small tubular structures suggest bioturbation. Steed (1980, p. 98) reported a fossiliferous shaly horizon near the base of this formation but this unit was not seen in the present map area. Widespread faulting and brecciation of the Nopah in the Jarvis Peak quadrangle has prevented accurate measurement of the unit here. Steed (1980) reported its thickness at 145 m just south of the map area; our measurement in the adjacent West Mountain Peak quadrangle to the north gave a thickness of 420 m

€bk BONANZA KING FORMATION (Upper and Middle Cambrian)--Mostly medium- to light-brownish-gray fine- to medium-grained, medium- to thick-bedded dolomite. Many beds are mottled light- to medium-gray and other beds contain abundant light gray to white "twiggy bodies" or short thin irregular tubular structures. The lowest 100 m includes some bluish-gray silty limestone beds, and an olive-gray slope-forming shaly limestone, about 7 m thick, occurs 15 m above the base and may correspond to part of the Chisholm Shale of the Pioche area, Nevada. The upper half of the formation includes numerous thin beds of light-gray laminated boundstone typical of upper Middle Cambrian rocks in western Utah and eastern Nevada. No fossils have been obtained from any part of the formation in this area, but Steed (1980, p. 113) reported a Late Cambrian trilobite, *Crepicephalus* sp. from the top of this formation in the Virgin Gorge just to the south of this area. The formation is so commonly faulted and brecciated within the Jarvis Peak quadrangle that accurate section measurement was not possible; measurement along the north side of Horse Canyon in the adjacent West Mountain Peak quadrangle gave a thickness of 800 m

€ba BRIGHT ANGEL SHALE (Middle Cambrian)--Recessive thin bedded micaceous siltstone, shale, and quartzite; includes a pale-brown-weathering ledge-forming dolomite 3 m thick about 40 m above the base; above this dolomite the strata are mostly yellowish-gray micaceous sandstone and siltstone with a 15 cm limestone bed 15 m below the top. Unfossiliferous. Bright Angel Shale is best exposed along its strike-valley just north of U.S. Highway 91 on the Castle Cliff quadrangle where it is 80 m thick. In other locations it is tectonically thinned or absent due to younger-on-older attenuation faulting

€t TAPEATS QUARTZITE (Middle? and/or Lower? Cambrian)--Reddish-orange to orange quartzite with a few thin layers of pebble conglomerate and sandstone; thin-bedded to very-thick-bedded; generally forms ledges and dip-slopes; upper contact is gradational. Formation is about 400 m thick except where thinned by attenuation faulting

p€ PRECAMBRIAN GNEISS, SCHIST AND PEGMATITE (Middle Proterozoic?)--Dark-gray gneissic diorite consisting mostly of amphibole with about 10 percent each of feldspar, quartz, and pyroxene. Gneissic diorite is the most resistant and most extensively exposed Precambrian rock type and is intimately interrelated with schist, amphibolite, pegmatite, and other lithologies so that no separation of rock types was mappable on the 1:24,000 scale. Schists range in composition with mica or amphibole as the principal mineral with lesser feldspar, quartz, garnet, and sillimanite. Pink granitic pegmatite dikes invade both gneissic diorite and schist and probably also intrude the white pegmatite dikes but this relationship is rarely seen. Pink pegmatites are composed mostly of K-feldspar with lesser orthoclase, quartz, and mica. White pegmatite, the least common rock type, is 60 percent orthoclase, 25 percent quartz, with lesser mica, plagioclase and garnet; graphic granite textures are common in this rock type. Detailed coverage of Precambrian rocks exposed in the Castle Cliff and Jarvis Peak quadrangles did not reveal any discrete mappable intrusive body such as shown on recent state map compilations (Hintze, 1980). Age of Precambrian rocks in the Beaver Dam Mountains has not been determined specifically but the rocks are comparable to the Vishnu and Brahma schists of the Grand Canyon area which are assigned a Middle Proterozoic age as discussed by King (1976, p. 63). Olmore (1971, p. 57) reported a 1.7 billion-year K-Ar date (mineral not specified) on a pegmatite in similar Precambrian rocks in the East Mormon Mountains, Nevada, some 30 km southwest of the Beaver Dam outcrops.

# EXPLANATION

| | | |
|---|---|---|
| Qya, Qc, Qoa | Pleistocene and Holocene | QUATERNARY |
| QTa, QTl | Pliocene and Pleistocene | TERTIARY |
| Tm | Miocene | TERTIARY |
| TRcp, TRcs, TRmu, TRms, TRmm, TRmv, TRml | Triassic | MESOZOIC |
| Pkh, Pkf, Ptw, Ptb, Pq, Pp | Permian | PALEOZOIC |
| IPc | Pennsylvanian | PALEOZOIC |
| Mr | Mississippian | PALEOZOIC |
| Dm, Dmp, Dms | Devonian | PALEOZOIC |
| Єn, Єbk, Єba | Cambrian | PALEOZOIC |

| | |
|---|---|
| Ꞓt | |
| pꞒ | PRECAMBRIAN |

## EXPLANATION OF MAP SYMBOLS

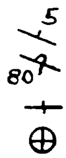
——— – – CONTACT--Dashed where approximately located or inferred

HIGH-ANGLE NORMAL FAULT--Dashed where approximately located or inferred; dotted where concealed. Bar and ball on relatively downdropped side

LOW-ANGLE ATTENUATION FAULT--Dashed where approximately located; dotted where covered. Barbs on upper plate which places younger strata on older rocks

THRUST FAULT--Dashed where approximately located; dotted where covered. Barbs on upper plate which places older rocks over younger

GRAVITY SLIDE BLOCK--Tertiary or Quaternary age




ORIENTATION OF BEDDING
- Inclined
- Overturned
- Vertical
- Horizontal

TRACE OF AXIAL SURFACE OF FOLD

ooo SURFACE TRACE OF STRONG CHANGE IN GRAVITY METER READINGS--The dots are centered over a zone about 1 km wide in which readings drop westward at the rate of about 8 mgal/km as compared to a drop of 2-4 mgal/km east of this zone and 1-2 mgal/km west of this zone

## STRUCTURE

Structures in the Castle Cliff and Jarvis Peak quadrangles are continuous with those described in adjacent quadrangles to the north as shown in Figure 2. Steed (1980) and Moore (1972) mapped and described the geology in adjacent areas to the south. Hintze (1983) briefly summarized structure of the Beaver Dam Mountains. Reber (1951, 1952) described the structure of parts of the area. Cook (1960b) summarized regional structures of southwestern Utah.

With the possible exception of the detached Paleozoic rocks along the west flank of the range discussed below, all rocks in this part of the Beaver Dam Mountains are clearly autochthonous. That is, these strata can be traced directly eastward onto the Colorado Plateau. They have been subjected to two principal deformations: a late Mesozoic compressional phase and a late Cenozoic extensional phase.

The Mesozoic compressional phase produced the southeastward-trending Beaver Dam Mountains anticline, the Shivwits syncline, the Reef Reservoir reverse fault and associated smaller folds and faults in the northeast corner of the Jarvis Peak quadrangle. Moore (1972) mapped a southwestward-trending anticline similar to the Beaver Dam Mountains anticline about 20 km to the south in the Virgin Mountains. Variation in the trend of the anticlinal axis and sinuosity of the Shivwits syncline as shown in Figure 2 suggests that compression from the west may have been deflected locally by pre-existing buttresses.

The Cenozoic extensional phase is reflected most clearly in the Grand Wash fault which can be traced southwards from the quadrangle edge for 130 km. It forms the western boundary of the Colorado Plateau as usually recognized in northwestern Arizona. At the Utah-Arizona line along the southern margin of the map the Grand Wash fault has a stratigraphic displacement of about 300 m, down to the west. This diminishes abruptly when followed northwards along Cedar Pockets Wash and is less than 50 m near Mine Valley Reservoir. Strata west of the fault dip 30 degrees or more eastward into the fault plane. This could be ascribed to "reverse-drag", but is more likely the normal dip on the flank of the Beaver Dam Mountains anticline. Considerable slumping attends the upthrown block along Cedar Pockets Wash. Another important extensional feature is the Hell Hole graben which extends into the northern edge of the map area as shown on Figure 2. The graben-bounding faults may extend farther south than shown but are masked by extensive cover around the summit of Utah Hill and extensive brecciation of the Bonanza King Formation within the Jarvis Peak quadrangle.

A basin-and-range normal fault of great displacement presumably bounds the western flank of the Beaver Dam Mountains, but it is nowhere exposed, nor do any of the late Cenozoic surficial deposits show any fault offset, although surface faulting has been reported by Moore (1972) along the base of the Virgin Mountains nearby to the southwest. Gravity profiles made in 1981 and 1982 by Brigham Young University students working under the direction of Dr. James L. Baer showed a substantial drop along the trend indicated on the Castle Cliff quadrangle. This is shown on the geologic maps by dots centered over a zone about 1 km wide in which readings drop westward at the rate of about 8 mgal/km as compared to 2-4 mgal/km east of this zone and 1-2 mgal/km in the valley west of this zone. The gravity break trends directly beneath Permian strata in the southeast corner of the Castle Cliffs quadrangle suggesting that they may be rootless as discussed below.

The Reef Reservoir fault is a reverse fault that extends northwards from where the Grand Wash normal fault dies out in Mine Valley. Reber (1951, 1952) called it the Shebit fault (apparently a local spelling of Shivwits) but his tracing of the fault was different enough from the present mapping that a new name may help avoid confusing his interpretation with that herein. The Reef Reservoir fault transects the Shivwits syncline at a low angle in the northeast corner of the Jarvis Peak quadrangle. Dip-slip slickensides are abundant along the trace of the fault directly east of Reef Reservoir where the steeply dipping Fossil Mountain Member of the Kaibab Formation has ridden eastwards over the Chinle Formation. Perhaps the most puzzling aspect of this reverse fault is its coincidence in trend with that of the Grand Wash normal fault. No beds of appropriate age to demonstrate unequivocal dating of the two faults are available within the Jarvis Peak quadrangle. But Hamblin(1970, p. 4-5) notes that major normal displacement apparently occurred on the Grand Wash fault prior to Late Miocene time and that lesser later normal movement has offset Pliocene basalt flows. The reverse nature of displacement on the Reef Reservoir fault seems to identify it as primarily a compressive structure and hence of the same age as the Shivwits syncline the west limb of which can be shown in the Motoqua and Gunlock quadrangles (Hintze and Anderson, 1985) to be post-Cretaceous and pre-Oligocene in age. It would thus seem that, although they are aligned, they are of different ages. Hence the alignment may be merely coincidental, or the later extensional faults may have followed an earlier established trend. Cook (1960, p. 65, 68) first discussed the unusual reversal of relationships along the Gunlock-Reef Reservoir-Grand Wash fault trend.

## DETACHED PALEOZOIC ROCKS

Interpretation of the emplacement mechanism of the sheets and blocks of Paleozoic rocks along the southwestern flank of the Beaver Dam Mountains has been discussed by several previous observers (Dobbin, 1939; Reber, 1952; Cook, 1960; Jones, 1963). Dobbin and Reber interpreted the blocks as remnants of a post-Miocene eastward-moving thrust sheet. Cook argued that most of the breccia blocks of Mississippian limestone are westward-moving slide blocks and were emplaced differently than the larger, more coherent masses at Sheep Horn Knoll and Castle Cliff. Jones agreed with Cook's interpretation of the smaller slide blocks but also included the larger Sheep Horn Knoll and Castle Cliff outcrops as part of the westward-moving slide masses. Jones (1963, p. 94) argued that small-scale structures which he described in the Castle Cliff block supported westward movement and hence gravity gliding. Mississippian Redwall Limestone on Precambrian rock (he overlooked the attenuated rubble in-between, but it does not affect his argument) poses a geometric problem to a thrusting hypothesis which generally emplaces older rocks on younger in a compressive regime.

Exposures at Castle Cliff and Sheep Horn Knoll have been incompletely identified on earlier mapping by Cook (1960). Beneath the coherent Callville Limestone sheet at Castle Cliff there are severely attenuated remnants of Redwall Limestone and Devonian and Cambrian formations, all brecciated but occurring in their normal stratigraphic sequence. All are smeared out, as it were, along the sole of the glide or fault surface. Some 1400 m of strata are now reduced to an attenuated zone 200-300 m thick. A similar relationship is found at Sheep Horn Knoll. Here the Redwall Limestone forms the coherent upper sheet and the Devonian and Cambrian strata form the attenuated rubble on which it has moved. Regardless of the mode or direction of transport of these blocks, they cannot have moved more than a few kms from their points of detachment. If they were derived from the east their probable source is the belt of Cambrian-Mississippian strata along the high part of the range. If they were derived from the west, they represent the easternmost remnants of a detachment. Wernicke (1982) indicated the extensive occurrence of a westward-moved sheet in the central Mormon Mountains some 50 kms west of here which he called the Mormon Peak detachment. No connection of the Beaver Dam and Mormon Mountains detachments is inferred, but the similarity of structures is noted.

Mapping in adjacent quadrangles to the north (Hintze, 1984 and Hintze and Anderson, 1985) as outlined on Figure 2 shows that the Jackson Wash-Pahcoon Flat fault and the related cluster of northwest-trending faults in the southeast corner of the Motoqua quadrangle are all low-angle, probably listric, normal faults, down to the southwest. Their net aspect is that of blocks calving off the main Beaver Dam Mountains block into the large structural depression of the

Beaver Dam Wash valley. The Sheep Horn Knoll-Castle Cliff sheets can be regarded as similar low-angle down-to-the-southwest blocks actuated by gravity rather than thrusting. Although there is no post-folding pre-block-faulting datum within the quadrangles on which to judge, it seems likely that the Beaver Dam Mountain block has been tilted eastwards because the principal range-bounding fault is on its west base. If eastward tilting has, in fact, occurred the presently observed westward dip of the surfaces on which the detached blocks moved downslope westward is less than the originally steeper dips of those surfaces.

Geologic mapping has traced detached upper Paleozoic rocks southward from Castle Cliff to a point in the southeasternmost corner of the Castle Cliff quadrangle where gravity data obtained by Dr. James L. Baer and students in connection with this mapping seems to indicate that these upper Paleozoic rock masses are rootless. That is, they seem to rest in part on higher density bedrock and, in part, on lower density valley fill. It is difficult to trace the detached upper Paleozoic masses southward into Arizona. Geologic maps of Moore (1972) and Steed (1980) show upper Paleozoic strata emplaced on rocks of the same age along a long tear fault and a kilometer-long exposure of a thrust.

## ECONOMIC GEOLOGY - METALS

Although there are a number of prospect pits in the Beaver Dam Mountains, the only property that has produced significantly is the Apex, or Dixie, mine located near the center of the Jarvis Peak quadrangle. Butler (1920, p. 595-597) reviewed the production (chiefly high-grade copper ores composed of secondary minerals) of the district through the early part of this century. In 1981, the mine was reactivated by Musto Explorations Ltd. of Vancouver British Columbia with the object of extracting copper, gallium, germanium, and zinc from the Apex ore. Development work continued in progress throughout 1983. The company's 1981 annual report summarized the geology of the Apex mine as follows:

> Callville Limestone is the host rock. Structural control of ore is the Apex fault, a reverse fault which strikes northwesterly and dips 60 to 80 degrees to the southwest. The hanging-wall on the fault appears to have moved upwards about 80 m relative to the footwall. The Apex vein contains leached and oxidized residual iron oxides, secondary copper minerals, and germanium and gallium. The vein follows the Apex fault near the surface but diverges slightly from it at depth. Copper ore bodies are located in the carbonate host rock nearby the Apex vein and were formed by leaching from the vein and redeposition in the host rock as malachite, azurite, and cuprite.

## ECONOMIC GEOLOGY - GYPSUM

Bedded gypsum occurs at several stratigraphic horizons. The lowest is in the upper part of the Pakoon Dolomite where variable thicknesses up to as much as 10 m are found. Good exposures of this interval are found in road cuts along the Bulldog Canyon road in the northeast corner of section 18, T. 43 S., R. 17 W., just south of Mine Valley. The gypsum is interbeded with thin beds of dolomite and sandstone. Gypsiferous beds occur locally within the Seligman and Woods Ranch members of the Toroweap Formation. These have been best documented by Nielson (1981) who reported that greatest thickness of gypsum (more than 10 m ) as occurring in the Woods Ranch Member in the general vicinity of Bulldog Pass on the Jarvis Peak quadrangle. The most extensively prospected gypsum deposits are those in the Harrisburg Member of the Kaibab Formation. Bulldozer cuts scar numerous knobby outcrops along the eastern edge of the Jarvis Peak quadrangle.

Gypsum is found in thin beds and stringers in many horizons in the Moenkopi Formation. The thickest gypsum beds, up to one or two meters, occur in the Shnabkaib Member and the numerous thinner beds of gypsum in that member help give it its overall very light gray aspect. Notwithstanding the abundance of gypsum in the Permian-Triassic part of the stratigraphic column here, there has been no commercial production of gypsum in the quadrangles.

Figure 1. Summary stratigraphic erosional column for the Castle Cliff and Jarvis Peak quadrangles showing relative resistance and other characteristics of rock units.

| Map Symbol | Age | Formations and Members | | Thickness meters | Remarks |
|---|---|---|---|---|---|
| Qya, Qc | QUATERNARY | Qya-younger alluvium Qc-colluvium | | 0-30 | surficial deposits |
| Qoa | | older alluvium | | 0-20 | above present stream courses |
| QTa | QUATERNARY -TERTIARY | high-level alluvium | | 0-35 | exhumed deposits |
| QTl | | landslide blocks and rubble | | 0-100? | parent bedrock identified on large blocks |
| Tm | TERTIARY Miocene | Muddy Creek Formation | | 30+ | only patches exposed |
| TRcp | TRIASSIC | Chinle Formation | Petrified Forest Member | 350 | variegated colors; mostly light shades on aerial photos |
| TRcs | | | Shinarump Cg Member | 40 | petrified wood common |
| TRmu | | Moenkopi Formation | Upper red member | 150-200 | |
| TRms | | | Shnabkaib Member | 250 | gypsum<br>pelecypods |
| TRmm | | | Middle red member | 100-125 | ripple marks; gypsum |
| TRmv | | | Virgin Limestone Member | 50-60 | 7 m basal ls; 2 m middle ls; top 3 m ls cross-bedded grainy ls |
| TRml | | | Lower red member | 0-70 | |
| Pkh | PERMIAN | Kaibab Formation | Harrisburg Member | 40-170 | gypsum; red rubbly chert; red beds |
| Pkf | | | Fossil Mountain Member | 75 | cherty ledges; fossiliferous |
| Ptw | | Toroweap Formation | Woods Ranch Member | 65 | gypsum |
| Ptb | | | Brady Canyon and Seligman Members, undivided | 100 | cherty |
| Pq | | Queantoweap Sandstone | | 350-550 | medium to small scale crossbedding inclined in many directions in lower part |
| Pp | | Pakoon Dolomite | | 200-250 | |
| IPc | PENNSYLVANIAN | Callville Limestone | | 500 | cyclic<br>Lithostrotionella (hair coral) beds in upper part<br>cherty |
| Mr | MISSISSIPPIAN | Redwall Limestone | | 185 | Thunder Springs Chert Member |
| Dm: Dmp | DEVONIAN | Muddy Peak Dolomite | Pinnacle member | 50 | stromatoporoids |
| Dm: Dms | | | Slope member | 100-150 | includes pebbly dolomite beds |
| €n | CAMBRIAN | Nopah Dolomite | | 420 | stromatolites<br>forms cliffs |
| €bk | | Bonanza King Formation | | 800 | laminated white boundstone in upper part<br>thin-bedded shaly limestone at base |
| €ba | | Bright Angel Shale | | 80 | green micaceous shale, siltst, qtzt |
| €t | | Tapeats Quartzite | | 400 | often attenuated |
| pC | PRECAMBRIAN | gneiss, schist, pegmatite | | | probably Vishnu Schist |

Lithology

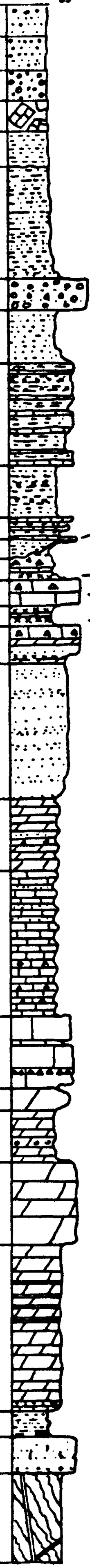


Figure 2. Summary structural map of the Beaver Dam Mountains area showing area covered by adjacent geologic maps.

A. Motoqua and Gunlock quadrangles (Hintze and Anderson, 1985)

B. West Mountain Peak and Shivwits quadrangles (Hintze, 1984)

C. Castle Cliff and Jarvis Peak quadrangles (this map)

Bold letters on map: G-Gunlock, M-Motoqua, S-Shivwits

Map units:

| | |
|---|---|
| Qs | Surficial deposits undivided |
| Qb | Basalt |
| Tm | Muddy Creek Formation |
| Tv | Volcanic rocks (mostly Quichapa Group) |
| Tn | Needles Range Formation |
| Tc | Claron Formation |
| Ki | Iron Springs Formation |
| Jc | Carmel and Temple Cap formations |
| JŦn | Navajo Sandstone |
| Ŧk | Kayenta and Moenave formations |
| Ŧc | Chinle Formation |
| Ŧm | Moenkopi Formation |
| Pk | Kaibab and Toroweap formations |
| Pq | Queantoweap Sandstone |
| PP | Pakoon Dolomite and Callville Limestone |
| MD | Redwall Limestone and Muddy Peak Dolomite |
| Ꞓn | Nopah Dolomite and Bonanza King Formation |
| Ꞓt | Tapeats Quartzite and Bright Angel Shale |
| pꞒ | gneiss, schist, pegmatite |

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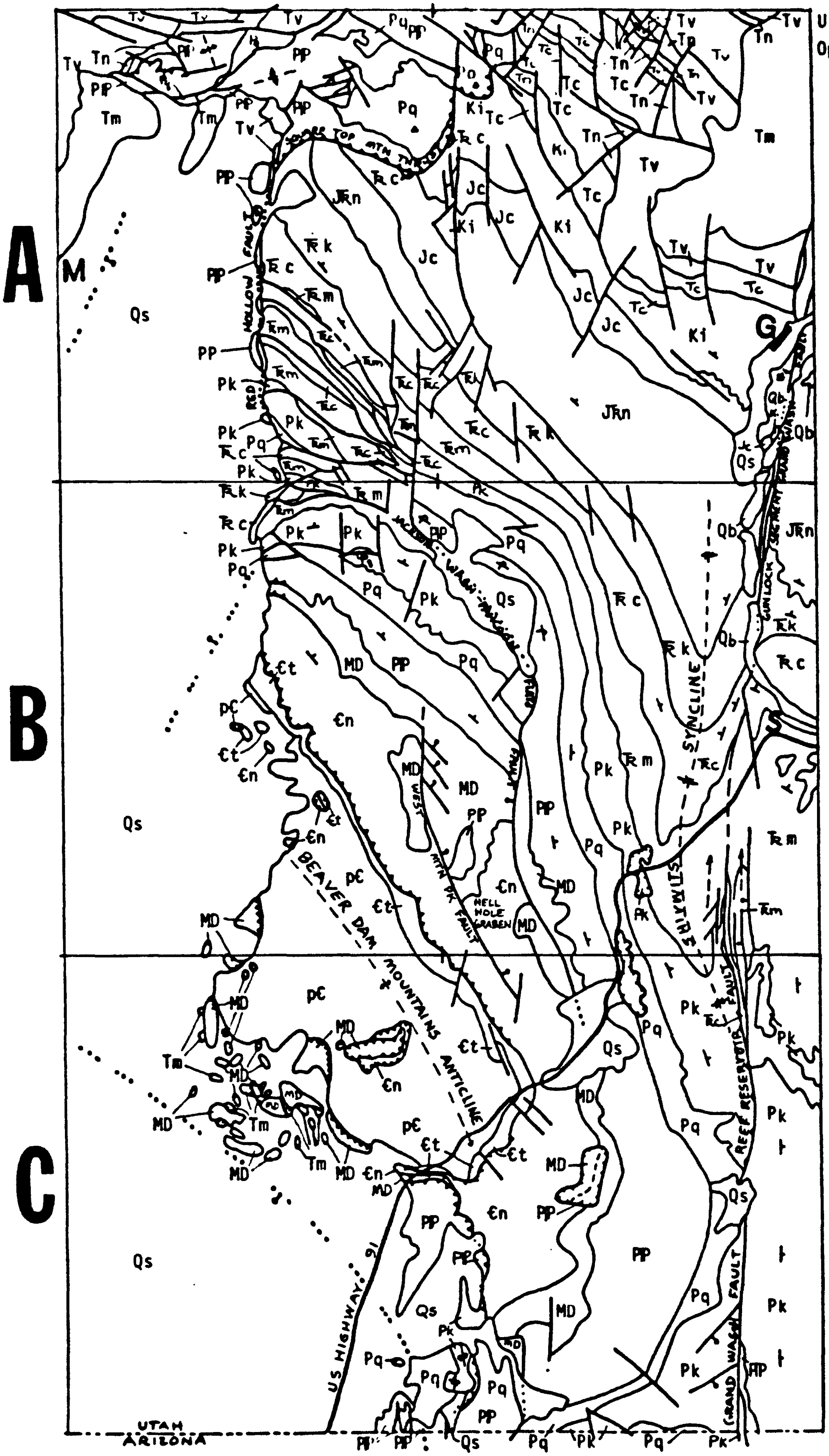
Figure 2



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