Geology of the Dog Valley–Red Ridge Area, Southern Pavant Mountains, Millard County, Utah*

ROBERT L. DAVIS
Union Oil Company of California, Anchorage, Alaska 99502

ABSTRACT.–More than 4600 m of sedimentary rock, ranging in age from Cambrian through Jurassic, crop out in the Dog Valley–Red Ridge area. These rocks were structurally deformed to their present position by tectonic forces of the Sevier orogeny. Two major thrust faults together with minor imbricate thrusts resulted from the Sevier orogenic pulse. The eastward-directed Pavant plate contains allochthonous Cambrian Tintic Quartzite, Pioche Shale, and undifferentiated Cambrian units thrust over Jurassic Navajo Sandstone. The Pavant thrust has the larger displacement of the two major thrusts and has associated with it a well-expressed décollement. The Red Ridge plate contains overturned, allochthonous, undifferentiated Cambrian; Ordovician Pogonip Group, Eureka Quartzite, and Bluebell Formation; Devonian Sevy, Simonson, Guilmette Formations, and Cove Fort Quartzite; Mississippian Redwall Limestone; Pennsylvanian Callville Limestone; Permian Pakoon, Queantoweap, and Kaibab Formations; Triassic Moenkopi and Chinle Formations; and Jurassic Navajo Sandstone. Displacement of less than 2 km has occurred along the Red Ridge thrust fault. An autochthonous section contains Mississippian Redwall Limestone through Jurassic Navajo Sandstone. Associated folding and minor strike-slip faults occurred concurrently with Sevier thrusting.

The Pavant thrust and subsidiary Red Ridge thrust form an eastward-directed salient which rammed into buttresses to the north and south. The Emery High existed to the north, and the existence of the Tushar Buttress is proposed on the south.

Cretaceous–Tertiary clastic sediments were shed from the Sevier highland and deposited along its southern and eastern edge. Oligocene volcanic rocks covered this clastic wedge and older sedimentary units. Subsequent uplift and erosion have formed the present southern Pavant Mountains, depositing volcaniclastic fanglomerates on the northern edge of the Dog Valley–Red Ridge area. North-trending Miocene to Recent normal faults transect the range. Two fault-bounded structures in the area of White Sage Flat and Dog Valley may be the result of emplacement of blind igneous intrusions.

Hydrocarbon potential in the area is good; known source and reservoir rocks occur in the area with structural complexities creating possible traps.

INTRODUCTION

The Dog Valley–Red Ridge area is one of complex geology. Recent interest of the petroleum industry in the overthrust belt-hingeline area of central Utah has prompted this study. Its objectives are as follows: (1) Make a more accurate and detailed description of the sedimentary formational units utilizing recent stratigraphic nomenclature; (2) provide a geologic map of the area on a 1:24,000 scale; (3) make an interpretation of the geologic structure and history of the area; and (4) analyze the potential for hydrocarbons within the Dog Valley–Red Ridge area.

Location and Accessibility

The Dog Valley–Red Ridge area includes portions of two 7½-minute quadrangles located approximately 24 km south of Fillmore, Utah (fig. 1). The Dog Valley Quadrangle is located in the northeast quarter of the Cove Fort, Utah, 15-minute quadrangle, and the Red Ridge Quadrangle is located in the northwest quarter of the Sevier, Utah, 15-minute quadrangle.

Volcanic rocks, which cover approximately 10 percent of the southern part of the Dog Valley Quadrangle and the southern half of the Red Ridge Quadrangle, were not included in this study because they were recently mapped (Callaghan and Parker 1962, Steven and Morris 1981).

Field Methods

Fieldwork was accomplished between June and October 1981. Mapping was recorded in the field on aerial photographs at a scale of 1:24,000 and transferred to topographic base maps, using a Bausch and Lomb zoom transfer scope.

PREVIOUS WORK

Early reports that include the Pavant Mountains were made by Wheeler (1875) and Dutton (1880). Maxey (1946) mapped and discussed the general geology of the western side of the mountain range. Lautenschlager (1952) studied and mapped the eastern slope. Tucker (1954) mapped the northern end of

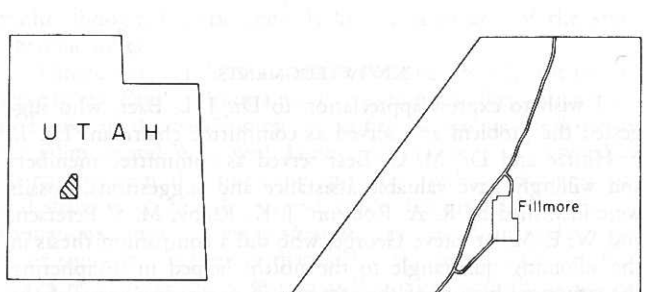

FIGURE 1.–Index map of the Dog Valley–Red Ridge area.

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the range. Crosby (1959) did a study of the southern end of the Pavant Mountains. His was a preliminary reconnaissance of the area, and his mapping was presented on a 1:62,500 scale. Geology of the Sevier Quadrangle, covering the southeast part of the range, was published by Callaghan and Parker (1962), at a scale of 1:62,500. Hintze (1963) made some minor changes to these two maps in his geologic map of southwestern Utah. The work of Hickcox (1971) overlapped that done by Maxey, Lautenschlager, Crosby, and Callaghan and Parker when he examined the Pavant Thrust sheet. A study of two klippen on the western flank of the Pavant Mountains was done by Feast (1979).

Moore and Samberg (1979) studied and mapped the volcanic rocks in the southernmost portion of the range. Their work has provided the only large-scale map (1:24,000) of the southern Pavant Mountains, but it includes only the Tertiary volcanic rocks and does not concern itself with the Paleozoic and Mesozoic sedimentary units. Steven and Morris (1981) completed the work to date when they studied the Cove Fort Quadrangle. Their study includes the Paleozoic and Mesozoic sedimentary units and a map on a scale of 1:62,500. Significant differences that exist in the interpretation of the sedimentary stratigraphy and structure of the area will be dealt with in this report.

ACKNOWLEDGMENTS

I wish to express appreciation to Dr. J. L. Baer, who suggested the problem and served as committee chairman. Dr. L. F. Hintze and Dr. M. G. Best served as committee members and willingly gave valuable assistance and suggestions. Fossils were identified by R. A. Robison, J. K. Rigby, M. S. Petersen, and W. E. Miller. Steve George, who did a companion thesis in the adjoining quadrangle to the north, helped in deciphering the structural history of the area and in measuring some of the stratigraphic sections. Special thanks go to Amoco Production Company who provided much-needed funds.

I am deeply grateful to my wife, Debbie, who typed the manuscript, and whose unending encouragement and support have made this project possible.

STRATIGRAPHY

Stratigraphic names (fig. 2) used herein for the southern Pavant Mountains are mostly of formations well known and established elsewhere in Utah. Recent work in central Utah has prompted some revision of nomenclature used by previous workers. Whenever stratigraphic terms are newly introduced, reference will be made to the original descriptions. In units where no change has taken place, the reader is referred to previous literature.

The rocks in the Dog Valley–Red Ridge area are exposed in both an overturned allochthonous section and a right-side-up autochthonous section. The rocks in the allochthon consist of a nearly complete section from undivided Middle Cambrian through Early Jurassic Navajo Sandstone. They are badly broken and sometimes thinned. Cambrian formations are exposed in a second allochthon that rests on the overturned allochthon.

The right-side-up autochthon consists of rocks which range in age from Mississippian through Jurassic. Pennsylvanian Callville Limestone through Jurassic Navajo Sandstone were measured in the autochthon. All other Paleozoic formations were measured in the allochthons. Location of all the measured sections can be found in figure 3.

Cambrian System

Tintic Quartzite

The Tintic Quartzite consists of a white to light pink and purple indurated quartzite. Cross-beds are frequent along with a few thin-bedded, coarse pebble conglomerates which are lens shaped and pinch out laterally. Glauconite is common in upper units of the formation, which is highly fractured and silicified. The top of the formation is drawn on the predominant occurrence of phyllitic shale interbeds. The Cambrian rocks in the northern section of the Dog Valley Quadrangle are right-side-up and in relatively good condition. An upside-down klippe of Tintic and younger Cambrian rocks occurs in sections 5 and 6, R. 4½ W, T. 24 S, of the Red Ridge Quadrangle and rests on Jurassic Navajo Sandstone. This section has been badly broken by thrusting and cannot be reliably measured. The Tintic Quartzite is 172 m thick in the section measured near the Interstate 15–Kanosh interchange.

Pioche Formation

Lower member of the Pioche Formation, best exposed near the Interstate 15–Kanosh interchange, consists of olive green phyllitic shales interbedded with thin quartzites. The quartzites contain *Skolithos* tubes and worm burrows (fucoidal trace fossil markings). The lower member is 59 m thick.

Tatow Member

The Tatow Member is marked by a basal limestone unit which contains unidentifiable trilobite fragments and *Chancelloria eros* sponge spicules (J. K. Rigby 1981 personal communication). *Chancelloria* places the Tatow Member in the Middle Cambrian. Above the limestone is a middle shaly unit containing phyllitic shales and thin-bedded quartzites. This unit is capped by a prominent dolomite 15 m thick. The dolomite is bluish gray and weathers light brown. The Tatow Member is 27.4 m thick.

Although the measured section (section 9, appendix) is not located in the study area, it is important because rocks from these formations are also found in the overturned Cambrian klippe which sits on the Navajo Sandstone in the Red Ridge Quadrangle.

Use of the Pioche nomenclature was suggested by Hintze (1981 personal communication). The Pioche Formation can be correlated with similar units in mountain ranges to the west (Hintze and Robison 1975), although it has thinned dramatically from its western counterparts. Higgins (1982) also measured a much thicker section of Pioche, along with younger Cambrian formations, in the Canyon Range. The Pioche Formation is 86.4 m thick.

Cambrian Rocks Undivided

The undivided Cambrian rocks exposed in the Dog Valley–Red Ridge area are of various lithologies including dolomite, limestone, and shale. Rock units above the Tatow Member of the Pioche Formation (measured section 9, appendix) consist of interbedded shale and limestone with abundant *Glossopleura* trilobite fragments (Robison 1981 personal communication). This fauna is equivalent to those found in the Middle Cambrian Chisholm Shale (Higgins 1982). However, the lithologies are different, and no equivalent to the Chisholm Shale or the underlying Howell Limestone was found.

Middle Cambrian rocks of the southern Pavant Mountains represent the edge of the miogeosyncline in which Cambrian sediments are not as thick as they are in western Utah.

Dolomite predominates above the interbedded limestone and shale. Some of the dolomites have distinctive light and dark gray bands. For the most part, the dolomites are nondescript medium gray units. The undivided Cambrian section exposed in Baker Canyon consists of these nondescript dolomites which have been highly fractured.

Pierson Cove Formation

The Pierson Cove Formation is located in a klippe in the northeast corner of the Dog Valley Quadrangle, just east of Widemouth Canyon. This section was previously mapped by Crosby (1959) and Steven and Morris (1981) as the Devonian Simonson Formation. Rocks from the klippe were identified by Hintze (1981 personal communication) as Pierson Cove Formation, which he and Robison (1975) first described as a series of light and dark dolomites and limestones found in the Wah Wah and Cricket Mountains and the House Range to the west. The age of the Pierson Cove Formation is Middle Cambrian, and it is equivalent to the lower Marjum Formation but does not contain the shale units found in the Marjum.

The lower portion of the formation consists of 203 m of very fine grained, dark gray, mottled dolomite. Some "twiggy" bodies are present in the upper 60 percent of the unit. The mottled rocks are composed of gray and brown dolomite.

The top portion of the unit consists of 90 m of a thinly laminated, very light gray, dolomitic boundstone. There is a 19-m-thick intraformational conglomerate separating the light and dark units. This top portion is probably near the Pierson Cove–Trippe Limestone boundary. Weaver (1980) described the contact between the two formations as a very light gray laminated boundstone in which an intraformational pebble conglomerate is common.

Hintze and Robison (1975) correlate the Pierson Cove Formation with the Bluebird Dolomite, the Herkimer Limestone, and the Dagmar Dolomite of the East Tintic Mountains, described by Loughlin (1919) and Morris and Lovering (1961).

Tucker (1954), Crosby (1959), and Hickcox (1971) used the stratigraphy of the Tintic district to describe the Middle Cambrian rocks of the Pavant Mountains. A quick reconnaissance into Hickcox's study area revealed rocks of Pierson Cove-type lithology. These units in the northern Pavant Mountains should be reexamined, because the stratigraphy of the adjacent Cricket Mountains may more aptly be applied.

No fossils were found in the outcrops east of Widemouth Canyon. The rocks in the klippe are highly fractured and rehealed with calcite vein fillings. The Pierson Cove Formation is 325 m thick.

Ordovician System

Pogonip Group

Sections of the Pogonip have been measured in Baker Canyon on two different occasions (Hintze 1951 and Crosby 1959). My section was measured 2 km east of Baker Canyon. Although the exposures are not as good as in the roadcut in Baker Canyon, these outcrops are more representative of those found in the study area. This section (measured section 7, units 1–7) can be used in addition to those by Hintze and Crosby.

Outcrops of Pogonip were found to be more extensive than previously mapped by Crosby (1959). Close examination of the low hills adjacent to the southern edge of White Sage Flat and west of Interstate 15 revealed rather continuous outcrops of both Pogonip Group and Eureka Quartzite. Steven and Morris (1981) also recognized these outcrops along the foot of the mountains as Pogonip.

The basal part of the Pogonip is composed of 316 m of fine-grained, medium gray limestone and limestone intraformational conglomerate. There are occasional cherty and sandy layers throughout this section. The limestones are medium bedded and form good ledgy outcrops. This section of the Pogonip is equivalent to the Juab and Wah Wah Limestones mentioned in Hintze's (1951) section in Baker Canyon.

The only fossils noted in this section were a few unidentifiable trilobite fragments and fossil ghosts. Hintze (1951) was able to find several Middle Ordovician species in the Juab Limestone and Wah Wah Limestone units in Baker Canyon.

The upper 27 m of the Pogonip is a series of thin interbedded shales and limestones. The limestones are dark purplish gray and weather brown to greenish brown. The shales are orange to yellowish orange, and the entire unit is easily eroded. This shaly section forms a prominent saddle in the ridge at the Pogonip–Eureka Quartzite boundary. This unit is very fossiliferous with at least two orthid brachiopod types, trilobite fragments, gastropods, crinoids, and worm trails. It correlates with the Kanosh Shale.

Steven and Morris (1981) mapped an imbricate thrust fault between the Pogonip and the Eureka Quartzite. This relationship is very likely because the interbedded shaly unit would make an excellent glide plane, and the unit is thin compared to other areas. Movement along this imbricate thrust would be slight, though, because there is little loss of any of the stratigraphic units.

Hintze's (1951) divisions of the Pogonip are difficult to observe in the Pavant Mountains. There are no marked differences or breaks in the basal limestone section which he breaks into the Fillmore and Wah Wah Limestones. There is an observable change between the limestone and the interbedded limestone and shale which he calls Kanosh Shale. Because the individual formations cannot be easily separated, and because the Kanosh Shale equivalent is thinner than at its type section, I have chosen to refer to the entire section as Pogonip Group; it is 343 m thick.

Eureka Quartzite

The Eureka Quartzite consists of a light-colored quartzite, generally white to light pink. It is highly fractured and silicified and forms a resistant ledge or quartzite rubble-covered slope between the Pogonip Group and Bluebell Formation. The formation is 45 m thick.

Tucker (1954), Crosby (1959), and Hickcox (1971) refer to these quartzites as possibly belonging to the Swan Peak Formation. I believe Hickcox (1971) has both Swan Peak and Eureka Quartzites exposed in his study area. The lower half of the formation is described by Hickcox (1971) as containing thin-bedded sandstones with fucoidal markings and interbedded shale. This section is equivalent to the Swan Peak Quartzite and represents the southernmost extent of the formation. This thin-bedded sequence is even thinner in the Dog Valley–Red Ridge area and has been included in the uppermost part of the Pogonip Group.

The massive quartzite which exists in the upper half of the formation (Hickcox 1971) closely resembles the quartzites in Baker Canyon in the Dog Valley Quadrangle. This unit correlates with the Eureka Quartzite.

Isopachous maps of the Eureka and Swan Peak (Webb 1956) show the southern extent of the Swan Peak to be north of the Dog Valley–Red Ridge area. Rapid thinning occurs in the Swan Peak to the south, and it becomes unmappable in the Dog Valley–Red Ridge area.

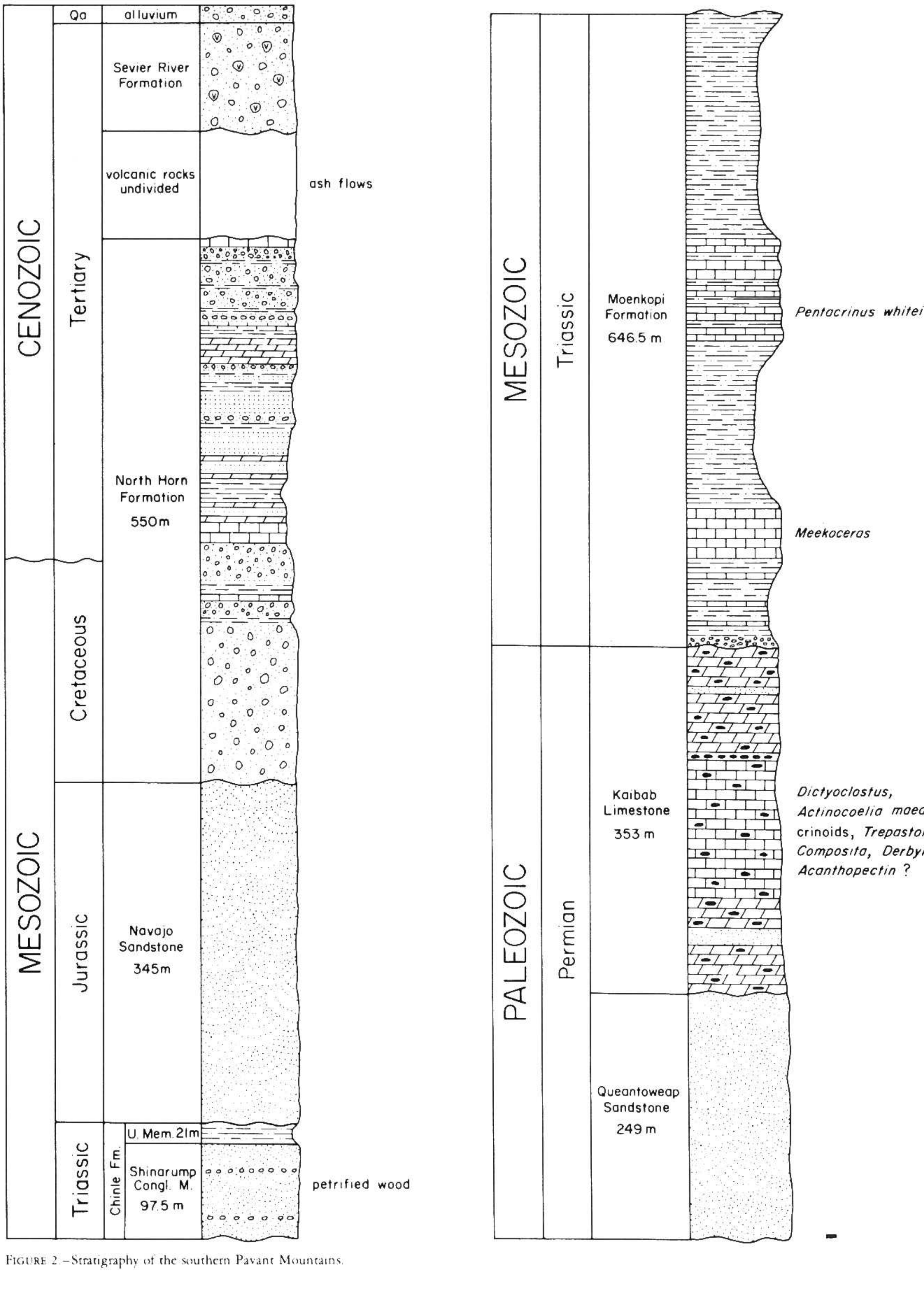
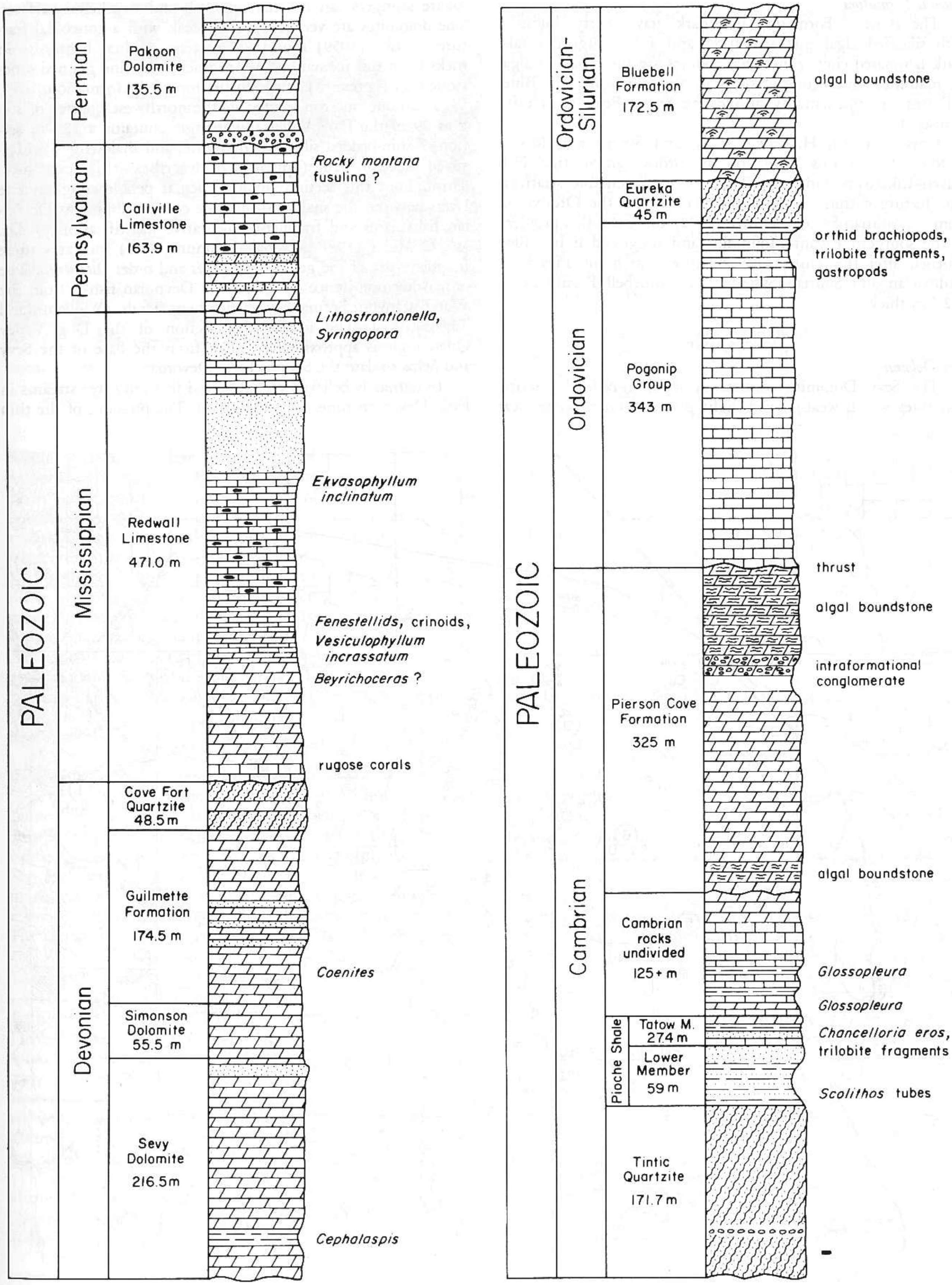


FIGURE 2.–Stratigraphy of the southern Pavant Mountains.


PALEOZOIC
Permian
Pakoon Dolomite 135.5 m
Pennsylvanian
Callville Limestone 163.9 m
Rocky montana fusulina ?
Mississippian
Redwall Limestone 471.0 m
Lithostrontionella, Syringopora
Ekvasophyllum inclinatum
Fenestellids, crinoids, Vesiculophyllum incrassatum
Beyrichoceras ?
rugose corals
Devonian
Cove Fort Quartzite 48.5 m
Guilmette Formation 174.5 m
Coenites
Simonson Dolomite 55.5 m
Sevy Dolomite 216.5 m
Cephalaspis
PALEOZOIC
Ordovician-Silurian
Bluebell Formation 172.5 m
algal boundstone
Ordovician
Eureka Quartzite 45 m
orthid brachiopods, trilobite fragments, gastropods
Pogonip Group 343 m
thrust
Cambrian
Pierson Cove Formation 325 m
algal boundstone
intraformational conglomerate
algal boundstone
Cambrian rocks undivided 125+ m
Glossopleura
Glossopleura
Pioche Shale
Tatow M. 27.4 m
Chancelloria eros, trilobite fragments
Lower Member 59 m
Scolithos tubes
Tintic Quartzite 171.7 m

Bluebell Formation

The Bluebell Formation is a dark gray, cherty dolomite with silicified algal mat structures and a few rugose corals. Dark laminated chert zones and nodules are the result of algal stromatolites which conspicuously identify this unit. The Bluebell lies uncomformably above the Swan Peak Quartzite (Crosby 1959).

Crosby (1959), Hickcox (1971), and Steven and Morris (1981) refer to this formation as Ordovician–Silurian Fish Haven–Laketown undivided. There is no discernable stratigraphic feature within the formation to separate the Ordovician from the Silurian System. Hintze (1972) addressed this problem in the southern Pavant Mountains and suggested it be called Bluebell after the Tintic nomenclature, which includes both Ordovician and Silurian Systems. The Bluebell Formation is 172.5 m thick.

Devonian System

Sevy Dolomite

The Sevy Dolomite consists of medium-bedded micritic dolomites which weather very light gray to white. Some clear calcite stringers can be seen on fresh and weathered surfaces. The dolomites are very dense and break with a concoidal fracture. Crosby (1959) found 8.7 percent residual bentonite in rocks from this formation. A 6-m-thick, very fine grained sandstone unit is present 12 m from the top of the formation.

A unique outcrop located in the northwest quarter of section 29 of the Dog Valley Quadrangle contains a 12.4-m section of thin-bedded siltstone, dolomite, and shale (fig. 4). Measured section 10 (appendix) describes this exposure. Throughout this section small lenticular pebble conglomerate layers between the shale and siltstone contain abundant Devonian fish plates and fragments. Tentative identification by Dr. W. E. Miller (1981 personal communication) indicates these fragments are of the genus *Cephalaspis* and order *Osteostraci*. The only other occurrence of these Early Devonian fish is from the Water Canyon Formation of northern Utah (Williams and Taylor 1964). The fossiliferous section of the Dog Valley Quadrangle is approximately 30 m from the base of the Sevy and helps to date the Sevy as Early Devonian.

Osteostraci is believed to have lived in freshwater streams in Early Devonian time (Denison 1956). The presence of the thin

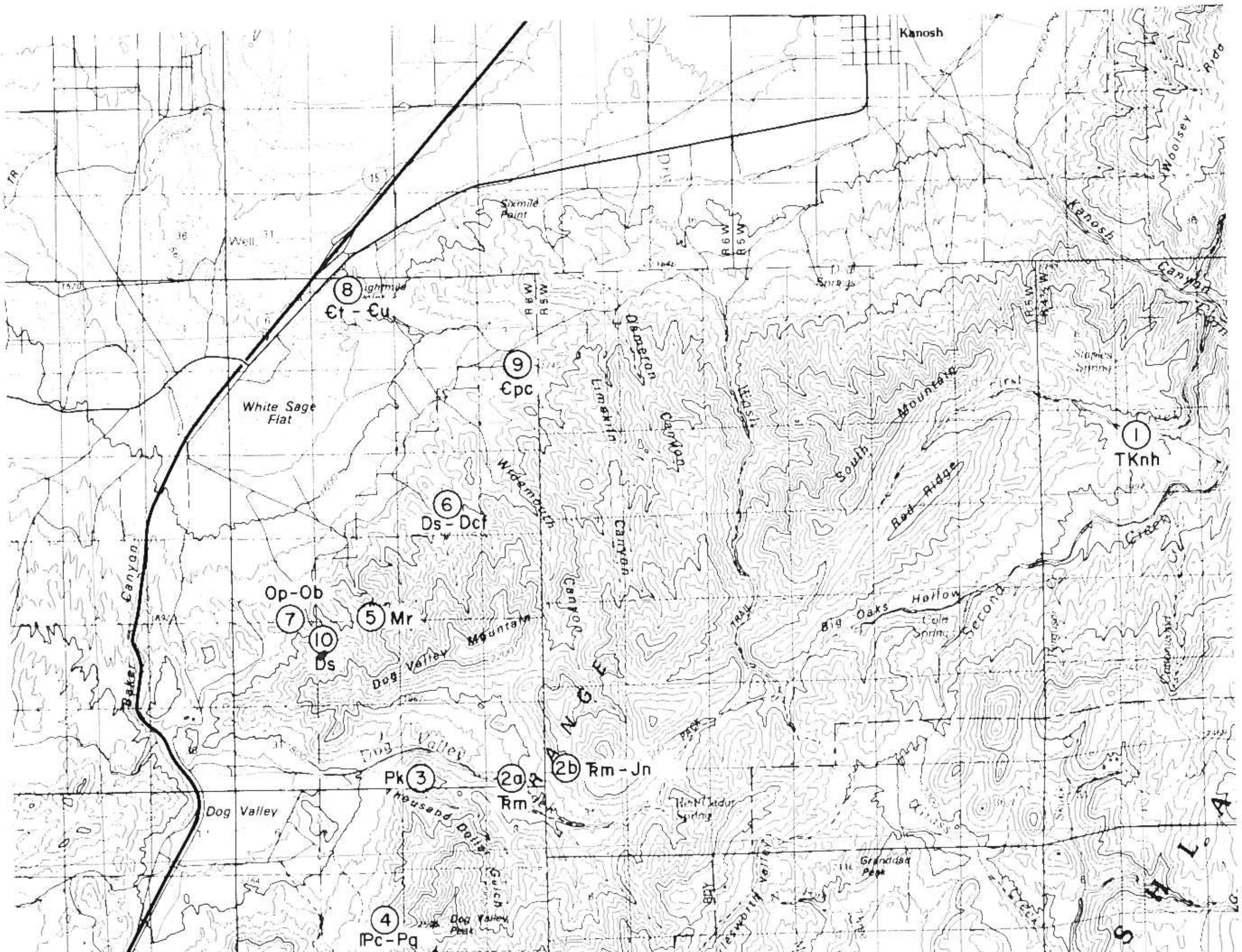


FIGURE 3. – Location map of measured stratigraphic sections.

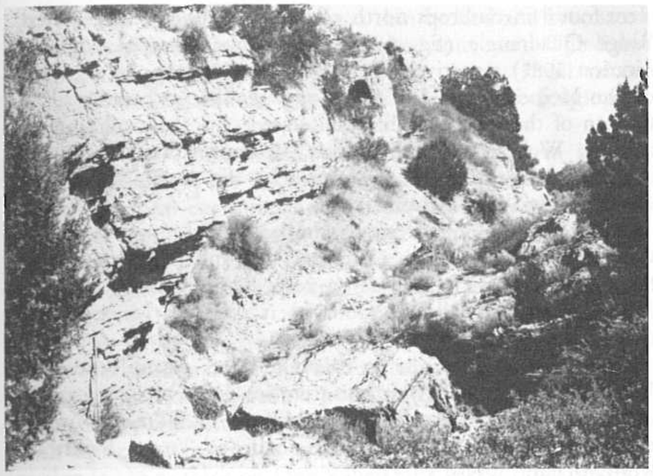


FIGURE 4.–Stream bed exposing unique occurrence of shale in the Devonian Sevy Dolomite. *Cephalaspis* fragments are found in this location. (Jacob staff is 1.5 m long.)

pebble conglomerate layer, siltstone, and shale could possibly represent an outlet area of a freshwater stream into the marine environment which represents the rest of the Sevy. All of the *Cephalaspis* material was fragmented, which also could represent a washing of the material out of a stream and into a shallow-water area.

Fossil fish debris occurs in several thin layers, and occasionally a fragment is found on the weathered surface of the surrounding dolomite. A characteristic bluish hue helps to identify the material as being phosphatic fish fragments. More detailed collecting and curating of specimens may reveal better preserved and identifiable material. This is the first reported occurrence of Devonian fish from the Sevy Dolomite in central Utah, and further work in this locality should prove worthwhile.

Simonson Dolomite

The Simonson Dolomite consists of a medium- to coarse-grained, sucrosic, light gray dolomite which weathers light brown. It is predominantly thin bedded and usually forms a saddle in the ridge between the Guilmette Formation and the Sevy Dolomite. Its texture and color make it an easy formation to identify and map. Crosby (1959) used its laminated nature as a key identifying characteristic, which at times can be useful. The Simonson Dolomite is only 55 m thick in the study area.

Guilmette Formation

The Guilmette Formation consists of predominantly medium-bedded dolomite with a few interbedded quartzite layers. Crosby (1959) noted these quartzites as being lenticular. The dolomite of the Guilmette is fine to medium grained, dark gray, and weathers brownish gray. Some of the dolomite appears to be very sandy, with sand grains visible with a handlens on weathered surfaces and the rock leaving scratches in a rock hammer when the two are rubbed together. The brownish weathered surface is probably due to this sand content.

Fossil corals were found in the measured section and were identified by J. K. Rigby (1981 personal communication) as *Coenites*. "Twiggy" bodies were also present in several of the units.

The Guilmette Formation is easily identifiable and is a prominent marker between the Cove Fort Quartzite and Simonson Dolomite. Steven and Morris (1981) did not include the Guilmette Formation in their stratigraphy but rather combined it into the Simonson and Cove Fort Formations. I choose to keep it as a separate formation because it is present in mountain ranges to the south and west of the Pavant Mountains (Baer 1962, Crosby 1959). The Guilmette Formation is 175 m thick.

Cove Fort Quartzite

The Cove Fort Quartzite was proposed by Crosby (1959) and rests conformably above the Guilmette Formation. It is 47.5 m thick at the point it was measured but thickens and thins laterally. The formation consists of medium-grained, massive quartzites at its top and base. The medial portion of the formation consists of interbedded dolomites and thin quartzites.

The quartzite units form prominent ledges and upon close examination appear highly fractured with numerous slickensides. The slickenside patches are relatively small and do not indicate a preferred orientation.

Sand grains in the quartzites are well rounded and can be seen on fresh and some weathered surfaces. The sands are clean and mature, and they prompted Crosby (1959) to postulate that the formation is probably the result of a beach or strand line deposit in a regressing sea.

The interbedded dolomites are fine grained and pinkish gray to gray. They are also highly fractured and rehealed. These dolomites have been referred to by Welsh (1972) as the Crystal Pass Formation. Welsh (1972) correlates the Cove Fort Formation with the Victoria Quartzite and Pinyon Peak Formations of the Tintic district.

Mississippian System

Redwall Limestone

The Redwall Limestone is the oldest formation exposed in the right-side-up autochthonous section on Dog Valley Peak. Only the upper part of the formation is exposed on Dog Valley Peak, but the complete section, overturned, is exposed north of Dog Valley. The presence of rugose corals and a pinkish hue, which permeates the rock, help to identify this formation. The Redwall Limestone has been divided into four main units by Welsh (1972). Three of these units have been identified in the southern Pavant Mountains. Unit A is a basal dolomite unit with a few limestone interbeds. Some sand is present in the massive bedded carbonates. These carbonates contain abundant *Vesiculophyllum incrassatum* rugose corals (McKee and Gutschick 1969) and crinoid ossicles. The dolomite is fine to medium grained and medium gray. Welsh (1972) correlates this unit with the Dawn Dolomite member. The unit is 118 m thick.

Unit B, which is an excellent marker bed, consists of thin-bedded fossiliferous limestone containing some chert. A silty residue is present on weathered surfaces of the limestone. The limestone in general is fine grained with abundant brachiopods, crinoids, and *Fenestellid* bryozoans. Organic content is high, and a very distinctive hydrocarbon odor is present on fresh fractured surfaces. The limestone is a dark gray on fresh surfaces but weathers to a light gray to light brown. Chert is usually brown to black with a pinkish tint. A small ammonoid found near the base of unit B was identified by M. S. Petersen (personal communication 1982) as *Beyrichoceras?* sp. of the *Pericyclus* zone and dates the rocks of unit B as Osagean. This unit correlates with the Anchor Limestone Member (Welsh 1972) and is consistent not only in the Redwall Limestone, but in the Joana and Monte Cristo Limestones as well. Unit B is 190 m thick.

Unit C is a calcareous sandstone with thinner interbeds of limestone and dolomite. The largest sandstone is 12 m thick and consists of a fine-grained, light to medium brown, cross-bedded sandstone. Other sandstones are medium to even coarse grained. Many sandstones are poorly cemented and very porous. Limestones which are interbedded with the sandstones contain abundant organic material as evidenced by a strong hydrocarbon odor on fresh surfaces. The very top of the unit contains an 8-m-thick limestone unit with an abundant *Lithostrontionella* and *Syringopora* fauna. One large *Lithostrontion* colony was found in growth position on Dog Valley Peak (fig. 5). It measured 30 × 45 cm with some coral strands 50 cm long and 1.5 cm in diameter. Rugose corals are also present in this limestone bed. *Ekvasophyllum inclinatum* (McKee and Gutschick 1969) was identified as coming from this horizon. Unit C is 163 m thick.

Unit C correlates with the Deseret Limestone (Welsh 1972), although the Deseret does not contain the sandstone which the Redwall contains. The Hunt Energy CHTE 15-30 geothermal well encountered a 15-m-thick phosphatic shale unit which correlates this section of the Mississippian Redwall with the Deseret Limestone. This phosphatic shale unit was never seen in surface outcrops although Sandberg and Gutschick (1977) note it on Dog Valley Peak. This unit is equivalent to the Bullion, Arrowhead, and Yellow Pine Limestone members to the south (Welsh 1972). The upper part of unit C also correlates with what has been called the Humbug Formation in the Shell Sunset Canyon well in section 21, T. 22 S, R. 4 W (Welsh 1972, 1976; Heylmun 1965). The Redwall Limestone is 471 m thick.

Pennsylvanian System

Callville Limestone

The Callville Limestone is composed of cherty, dolomitic limestone and dolomite. The carbonates are fine to medium grained and medium to light gray. Chert layers are abundant and characteristically white. The formation is medium to thick bedded, and good outcrops occur on Dog Valley Peak. In the allochthonous overturned section, the beds are brecciated and outcrops are not as good as in the autochthonous section on Dog Valley Peak.

Fusulinids were not found in the measured section but were found in outcrops north of South Mountain in the Red Ridge Quadrangle (fig. 6). J. K. Rigby (personal communication 1981) tentatively identified the specimens as *Fusulina* of Des Moinesian age. Identification was difficult because silicification of the specimens has obliterated critical morphological features. Welsh (1972) noted only Morrowan faunas occur in the area, although he did not eliminate the possibility of Des Moinesian and even Atokan faunas.

The Callville Limestone is similar in lithology from St. George to Fillmore, Utah (Welsh 1972), and represents a carbonate platform. The formation rests disconformably on the Mississippian Redwall Limestone as it does on Mississippian strata throughout the state (Welsh 1976).

The top of the Callville marks another disconformity as Late Pennsylvanian–Early Permian erosion has removed the older Pennsylvanian rocks from the Milford to Fillmore surface sections and from areas of the Kaibab and Emery Uplift of western Utah (Welsh 1972).

The Callville-Pakoon-Queantoweap Platform extended northward to the Oquirrh sag, and the lithologies of the Oquirrh Basin do not extend south of the Leamington-Nebo Fault (Welsh 1972, 1976, 1979). The Callville Limestone is 164 m thick.

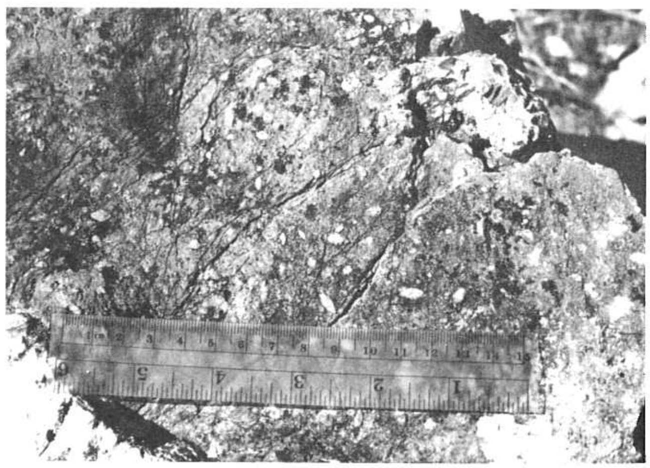


FIGURE 6.–Fusulinids in the Pennsylvanian Callville Limestone north of South Mountain.

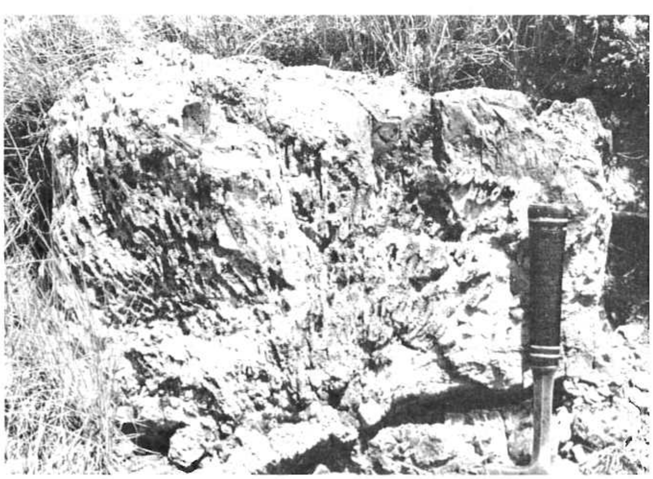


FIGURE 5.–*Lithostrontionella* colony in growth position, Mississippian Redwall Limestone on Dog Valley Peak.

Permian System

Pakoon Formation

The base of the Pakoon Formation is marked by a 15-m-thick conglomerate bed that forms a resistant cliff. Chert pebbles predominate, with some clasts containing coral genera of *Caninia* and *Chaetetes* (Welsh 1972, George 1981 personal communication). Coral-containing clasts were also found in the exposures north of South Mountain in the Red Ridge Quadrangle. The presence of this conglomerate represents an unconformable contact between the Permian and Pennsylvanian systems. *Caninia* and *Chaetetes* are both Pennsylvanian genera.

The remainder of the formation consists of predominantly sandy dolomite with an occasional limestone interbed. The dolomite is fine grained, with a silty to sandy residue on weathered surfaces. The dolomite is medium to light gray with occasional chert layers and nodules. Small clear to white calcite blebs on the fresh and weathered surfaces help to distinguish this formation.

The top of the formation has a thin-bedded and brecciated limestone with a basal, fine-grained sandstone unit. The limestone is fine grained and pinkish brown. Again, small calcite blebs on the surfaces help to identify the unit as belonging to the Pakoon.

Welsh (1972) dated the Pakoon as Wolfcampian in age. He concluded that the Pakoon Formation is the result of a restricted platform environment. Gypsum beds occur in the formation in southern Nevada, but they are not as common in Utah (Welsh 1976). The Pakoon Formation correlates with the Elephant Canyon Formation and the Riepe Springs Limestone (Welsh 1972, 1976).

Welsh (1972) noted the Pakoon would possibly make a good hydrocarbon reservoir because many of the dolomites have excellent intracrystalline porosity. Some organic material exists in the dolomites, as many have a strong fetid odor on fresh surfaces (measured section 4, unit 16). The Pakoon Formation is 136 m thick on Dog Valley Peak east of Dog Valley.

Queantoweap Sandstone

The Queantoweap Sandstone lies unconformably below the Kaibab Limestone and is exposed in both the overturned and the right-side-up sections in the Dog Valley Quadrangle. It is a fine-grained, cross-bedded sandstone, variegated pink to brown to white. Cementation of the unit varies throughout the study area, but in many areas it is poorly cemented. The Queantoweap Sandstone would make an excellent reservoir for hydrocarbons. It is upper Wolfcampian in age (Welsh 1972, Brill 1963).

The question as to what to call the formation, Talisman (Steven and Morris 1981) or Queantoweap, needs to be addressed. The Queantoweap Sandstone (Welsh 1979), in the earlier literature, was located in southern Nevada, northern Arizona, and southern Utah. Brill (1963) and Welsh (1972) suggest the Talisman Quartzite, Cedar Mesa Sandstone, and Queantoweap are equivalent. Welsh (1979) refers to this unit in the Pavant Mountains as the Queantoweap Sandstone which is a part of the Callville–Pakoon–Queantoweap Platform. This platform extended from southern Nevada to central Utah. Because this structural unit tends to be consistent through the area, and because his work in the Pennsylvanian and Permian strata of central Utah is extensive, I will follow Welsh's proposed stratigraphy.

Welsh (1979) believed the source for the Queantoweap was from the southeast. The Queantoweap Sandstone was measured on Dog Valley Peak and is 249 m thick.

Kaibab Limestone

The Kaibab Limestone has been subdivided (Welsh 1972; Welsh and others 1979) into three lithostratigraphic units: Toroweap, Fossil Mountain, and Plympton Formations. These units were not mapped individually in the Dog Valley–Red Ridge area because each of the units gradually grades into another. Therefore, distinct and mappable boundaries cannot be traced without detailed and meticulous work through the entire formation. Such work would have been particularly difficult in the allochthonous section where the rocks are badly broken, the units thinned, and the outcrops poor. However, the three units can be identified in the measured section (measured section 3, appendix).

The Toroweap is 100.5 m thick and is composed of units 1–5 of measured section 3. It consists of a fine-grained, cherty dolomite, medium to light gray. The dolomite is medium to thin bedded and has relatively few fossils. One probable shell fragment and a few crinoid ghosts were all that were found. A fine-grained sandstone is located in the upper third of the unit.

The Fossil Mountain unit is 138 m thick and grades into a limestone from the dolomitic Toroweap. It is represented by units 6–13 of measured section 3. This unit is a very fine to coarsely crystalline, fossiliferous, and cherty limestone, thin to medium bedded. Colors range from medium gray to brown.

Fossils are abundant in the Fossil Mountain unit, with brachiopods, bryozoans, sponges, and crinoids in evidence. Many of them are located in the silicious zones, although numerous brachiopods and crinoids can be found within the limestones themselves. Some, identified by J. K. Rigby (1981 personal communication), are as follows:

Dictyoclostus
Composita
Derbyia
Acanthopectin?
Trepastoma
Actinocoelia maeandrina

Crosby (1959) cites additional identified species which can also be found within the formation.

The Plympton can be correlated with units 14–25 of measured section 3. It is 114.5 m thick and is identified by sandy dolomite and dolomitic sandstone, both of which contain abundant chert. The sand and chert in this lithostratigraphic unit set it apart from the other two units.

The dolomite is fine grained, silty to sandy, medium gray to brown. No fossils were found in this unit. Chert in the Plympton is abundant and sometimes massive. Layers up to 3 m thick were found in the measured section.

The Kaibab of central Utah is Upper Permian Guadalupian in age (Welsh 1972). A regional unconformity exists between the Kaibab and the Queantoweap Sandstone. The Queantoweap, which represents a coastal dune and beach complex, was covered by the marine transgression of the Toroweap (Welsh 1976). Welsh also proposes at least six transgressive–regressive cycles which occurred in the Kaibab of southwest Utah after the Middle Permian hiatus between the Queantoweap and the Kaibab. The Kaibab Limestone is 353 m thick and was measured east of Dog Valley between Thousand Dollar Gulch and Dog Valley Canyon.

Triassic System

Moenkopi Formation

The Moenkopi Formation includes five members: (a) lower red member, (b) Virgin Limestone Member, (c) middle red member, (d) Shnabkaib Member, and (e) upper red member. Individual members were not mapped because of poor exposures, especially in the allochthonous overturned section. The Shnabkaib Limestone Member holds up resistant hills in the autochthon (right-side-up) and therefore is easily visible on aerial photographs. Fossil identification is the best way to recognize the Shnabkaib and Virgin Limestone Members.

The lower red member contains a basal pebble conglomerate with interbedded siltstone and sandstone. The boundary between the Triassic Moenkopi and Permian Kaibab was drawn on the last occurrence of cherty dolomite. The siltstone and shale of the lower red contain ripple marks, crossbeds, and mudcracks. Units are reddish brown near the base and olive green to olive brown near the top. Some thin limestones which contain oolites and fossil shell fragments occur near the top. Some limestones appear to be bioturbated. The lower red member is 86 m thick.

The Virgin Limestone Member is distinctive because it contains abundant *Meekoceras* (fig. 7). Nine distinct horizons containing ammonoids were found in the measured section (measured section 2b, unit 8). Ammonoids range in size from 3 cm up to 20 cm in diameter. Crosby (1959) noted *Meekoceras gracilitalis* as the dominant species found. The greenish brown shale and siltstone represented in this member, along with those in the top of the lower red member, indicate a shelf, possibly open shallow marine, environment. A subaerial environment is indicated for the lower and middle red members. The Virgin Limestone is 55 m thick.

The middle red member contains 169 m of thin-bedded sandstone, siltstone, and limestone. Shale is also present, but poorly exposed. Color is medium reddish brown to brownish red except for the limestone which is gray to brown and sandy. The contact between the Virgin and middle red members is gradational. Units within the middle red contain ripple marks, mudcracks, and cross-beds. Some gypsum has been noted by previous authors (Crosby 1959, Steven and Morris 1981).

The Shnabkaib Limestone Member has five major fossiliferous limestone units interbedded with thin sandstone and dolomite beds. The limestones form a resistant ridge easily observed on aerial photographs. Each is fine to medium grained and gray and contains *Pentacrinus whitei* and brachiopod shell fragments. The *Pentacrinus* ossicles were useful in identifying this member, especially in the overturned allochthonous section. The Shnabkaib Member is approximately 103 m thick.

The upper red member contains shale, siltstone, and sandstone in thin-bedded, poorly exposed units. Ripple marks are common in the platy slope debris. The contact between the upper red member and the Shinarump Conglomerate was drawn on a marked change in slope angle. The upper red member is approximately 234 m thick.

The Moenkopi section was measured in Dog Valley Canyon beginning in the Narrows. The overturned allochthonous sections are thinner because of attenuation of the shale units. Often the Shnabkaib and Virgin Limestone Members are juxtaposed. The thrusted units are much more broken with many of the ammonoids made indistinguishable. An occasional undestroyed ammonoid was found in the allochthon, but usually just fragments or ghosts were preserved. Because of their small size, *Pentacrinus* are well preserved in the allochthon. The Moenkopi Formation is 647 m thick.

Chinle Formation

The Chinle Formation is divided into two members, the Shinarump Conglomerate Member and the Upper Chinle Member. The Shinarump Conglomerate is 97.5 m thick and forms a resistant ridge (fig. 8). It contains medium- to coarse-grained sandstone, gritstone, and pebble conglomerate. Vitreous quartz grains are the predominant clast with minor amounts of quartzite and chert. Abundance of quartz and coarseness of texture help to identify this formation as Shinarump and eliminate the possibility that it could be the Moss Back Member, which has more chert and is finer grained (Stewart, Poole, and Wilson 1972; Stokes 1972).

Individual units within the Shinarump are cross-bedded and lens shaped, indicating a fluvatile deposition. Abundant fossil wood occurs throughout the formation. The largest petrified log segment seen was 50 cm in diameter and 46 cm long.

The Upper Chinle Member forms a slope on the Shinarump bench within the Dog Valley–Red Ridge area. The member is composed of thin-bedded mudstone, siltstone, and sandstone, dark red to dark purple. The common exposure of Upper Chinle is a red soil with thin plates of siltstone and sandstone occurring throughout. Abundant calcite concretions and nodules, up to 10 cm in diameter, weather from the red muddy matrix.

The Upper Chinle Member thickens northward as George (1981 personal communication) reports up to 58 m between Kanosh and Fillmore. Crosby (1959) noted 88 m in Second Creek Canyon. He indicated that the top of the Chinle is an erosional surface. The Upper Chinle Member is 21 m thick northeast of Dog Valley.

Jurassic System

Navajo Sandstone

The Navajo Sandstone forms prominent ledges, along with brownish red peaks and ridges. It is a fine-grained, clean, crossbedded sandstone; its quartz grains are well rounded and frosted. The formation is predominantly brownish red, although white bleached-out zones occur near the top. Previous investigators have suggested the bleached zones represent thrust fault planes where movement has occurred (Maxey 1946, Crosby 1959, Steven and Morris 1981). The suggestion is plausible because some bleaching was also noted by me along the thrust fault contact in section 19 of R. 5 W, T. 24 S.

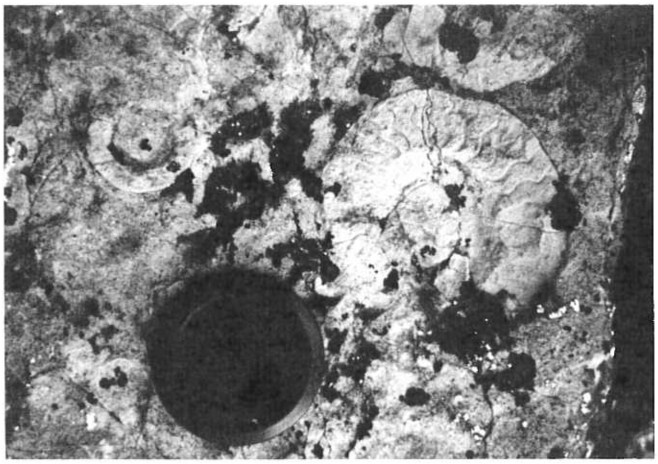


FIGURE 7 – *Meekoceras* in the Triassic Moenkopi Formation located in the Narrows northeast of Dog Valley.

FIGURE 8 – Prominent bench of Shinarump Conglomerate. Dashed line is Red Ridge thrust northeast of the Narrows.

The Navajo is the youngest formation exposed in the overturned allochthon. The right-side-up section is on the crest of an anticline which formed in front of the thrusting. The leading edge of the thrust fault broke out of the adjoining syncline.

The Navajo has been assigned to the Jurassic, although in southern Utah the Triassic-Jurassic boundary is believed to be somewhere within the formation. Steven and Morris (1981) suggest this could be the case in the Pavant Mountains as well. The Navajo Sandstone is approximately 345 m thick.

Cretaceous-Tertiary Systems

North Horn Formation

The North Horn Formation consists of conglomerate with interbedded limestone, dolomite, sandstone, and bentonitic shale. The conglomerate rests unconformably on Navajo Sandstone in the Red Ridge Quadrangle and on a variety of formations in the Dog Valley Quadrangle, including Moenkopi, Kaibab, Callville, and Redwall.

The base of the conglomerate is composed entirely of quartzite boulders and cobbles, some up to 1.5 m in diameter, all from the Tintic Quartzite and set in a brownish red matrix. Cambrian limestone and dolomite cobbles become more abundant upsection.

Interbedded with the conglomerate are freshwater limestones (fig. 9) which weather light gray to light pink. The limestones are micritic to very fine grained with tiny clear calcite blebs in the matrix and on the surface. Limestones near Big Oaks contain whitish gray chert layers.

Very fine grained, light pink sandstone layers occur with the limestone. Some sandstones noted in the Bull Valley area (Red Ridge Quadrangle) were "dirty," with 10 percent dark grains that may be volcanic debris.

Conglomerate that interbeds with the limestone contains clasts of fossiliferous and cherty limestone and yellow sandstone. These clasts were probably derived from upper Paleozoic and younger formations.

A fairly thick sequence of limestone, dolomite, sandstone, and shale was measured in section 1 (appendix). Bentonite is common in the weathered soils, giving them a light, fluffy appearance.

The North Horn conglomerates have been previously referred to as the Price River Formation, but the presence of the freshwater lacustrine units interbedded with bentonitic shale indicates the formation is likely younger than Price River (Callaghan and Parker 1962, Rowley and others 1979, Stanley and Collinson 1979).

Speiker (1946) originally defined the late Mesozoic and early Cenozoic stratigraphy of central Utah. He defined the Price River-North Horn boundary as the zone of greatest change between the sandstone and conglomerate of Price River and the variegated North Horn beds of various lithologies. The North Horn Formation includes lithologies of variegated shale, sandstone, conglomerate, and freshwater limestone.

Callaghan and Parker (1962) collected freshwater gastropods from these rocks in the Monroe Quadrangle. The Monroe Quadrangle rocks are similar in lithology and stratigraphic position to the Tertiary limestone in the Red Ridge Quadrangle. These gastropods were found to be representative of late Eocene-early Oligocene time. Callaghan and Parker (1962) suggested it could possibly place the boulder conglomerate as North Horn equivalent, the limestone and shale as Bald Knoll equivalent, and the sandstone and bentonite layers as Gray Gulch equivalent. However, no fossils were found in the outcrops of the Red Ridge Quadrangle.

FIGURE 9.–Steeply dipping limestones of the North Horn Formation located in section 8, R. 4 ½ W, T. 24 S, Red Ridge Quadrangle. (Staff is 1.5 m long.)

Rowley and others (1979) and Stanley and Collinson (1979) believe the conglomerates north of the Marysvale volcanic region correlate with the Upper Cretaceous-Paleocene North Horn Formation.

The conglomerates of the area are therefore probably no older than North Horn equivalent; however, a minimum age is more difficult to determine. The proposed Oligocene Gray Gulch Formation (Callaghan and Parker 1962, Schneider 1964) contains bentonite layers, but so does the Eocene Green River Formation. It is very likely the distal edge of Lake Green River is represented by the rocks south of Red Ridge. More stratigraphic evidence needs to be produced, and work on a regional scale needs to be completed before these rocks can be firmly assigned to any formation.

Sevier River Formation

The Sevier River Formation was described by Crosby (1959) as a fanglomerate deposit containing poorly sorted clastic material with a high percentage of volcanic clasts. Sevier River alluvial fans, exposed in the area, were shed northward from the high which existed in the southern Pavant Mountains. Recent faults have transected these deposits near Baker Canyon.

Clast size, as described by Crosby (1959), ranges from silt to boulders up to 2 m in diameter. Clasts from nearly all formations in the Pavant Mountains can be found in the Sevier River Formation. The presence of volcanic clasts distinguishes this formation from the North Horn conglomerates. The Sevier River Formation was not measured because of the poor exposures of bedding.

STRUCTURAL GEOLOGY

The most important structural elements in the Dog Valley-Red Ridge area are two major thrust blocks faulted by minor associated imbricate thrusts. Large-scale folds are associated with the autochthonous bodies of rock. All of these structures have been overprinted by basin-and-range high-angle faulting. Figure 10 is a generalized tectonic map.

Folds

An 8-km-wide anticlinal structure in the autochthonous upper Paleozoic and Mesozoic rocks is most visible east of Dog Valley and includes Dog Valley Peak (fig. 11). This anticline is faulted and plunges 25° in the S 80° E direction.

The anticlinal structures in the Pavant Mountains were formed in front of the thrust. Usually, as is the case in the Pavants, an anticline is formed ahead of the thrust, and the thrust breaks out of the trailing syncline behind the frontal anticline.

The Red Ridge and Pavant thrust faults have cut the recumbent syncline. Because of this syncline, overturned Paleozoic and Mesozoic rocks are juxtaposed on right-side-up Paleozoic and Mesozoic rocks.

Minor wrinkles occur in the autochthonous Moenkopi Formation in the Narrows (fig. 12), and minor folds in the allochthon. A small syncline, trending N 40° E, is exposed in the Red Ridge thrust plate just west of Dog Valley. A rootless anticline, trending N 35° E, is exposed in the imbricate thrust plate between Widemouth Canyon and Dry Wash. They represent minor folds cut by the thrust.

Thrust Faults

Two major thrust faults are exposed in the Dog Valley-Red Ridge area. Imbricate thrusts of smaller magnitude are also exposed (fig. 13).

The Pavant thrust is exposed in the klippe containing Cambrian Pierson Cove Formation which rests on the Ordovician Bluebell Formation in the northeast corner of Dog Valley Quadrangle. All the rocks in the thrust plate are Cambrian and in the right-side-up position. The rocks beneath the thrust are upside-down Cambrian through Jurassic.

In the Red Ridge Quadrangle however, the Pavant thrust is represented by an upside-down Cambrian klippe which rests on the Navajo Sandstone. Cambrian rocks at this location consist of Tintic Quartzite, Pioche Shale, and some undifferentiated dolomite. This small klippe correlates with the thick section of upside-down Cambrian rocks which are exposed north of the Red Ridge Quadrangle.

Strike of the thrust fault exposures indicate the Pavant thrust sheet moved toward the southeast. North of the Red Ridge Quadrangle however, movement was toward the east.

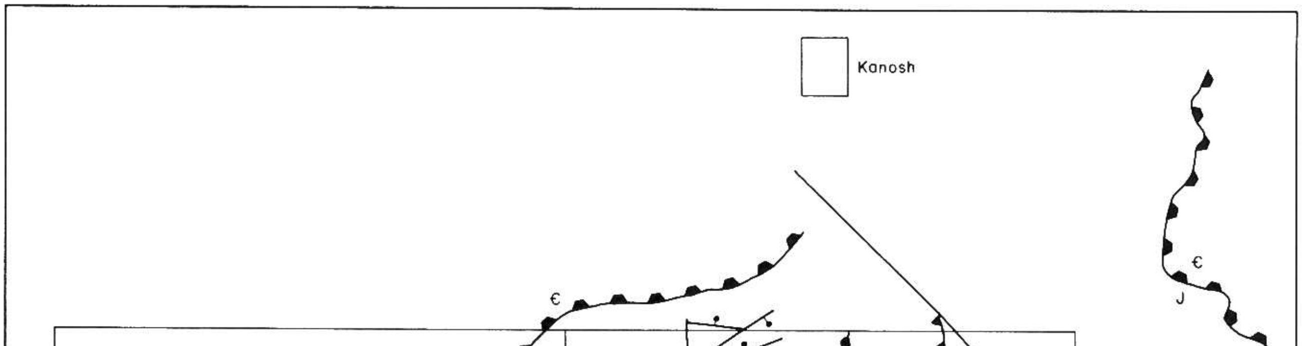


FIGURE 10.–Generalized tectonic map of the Dog Valley–Red Ridge area.

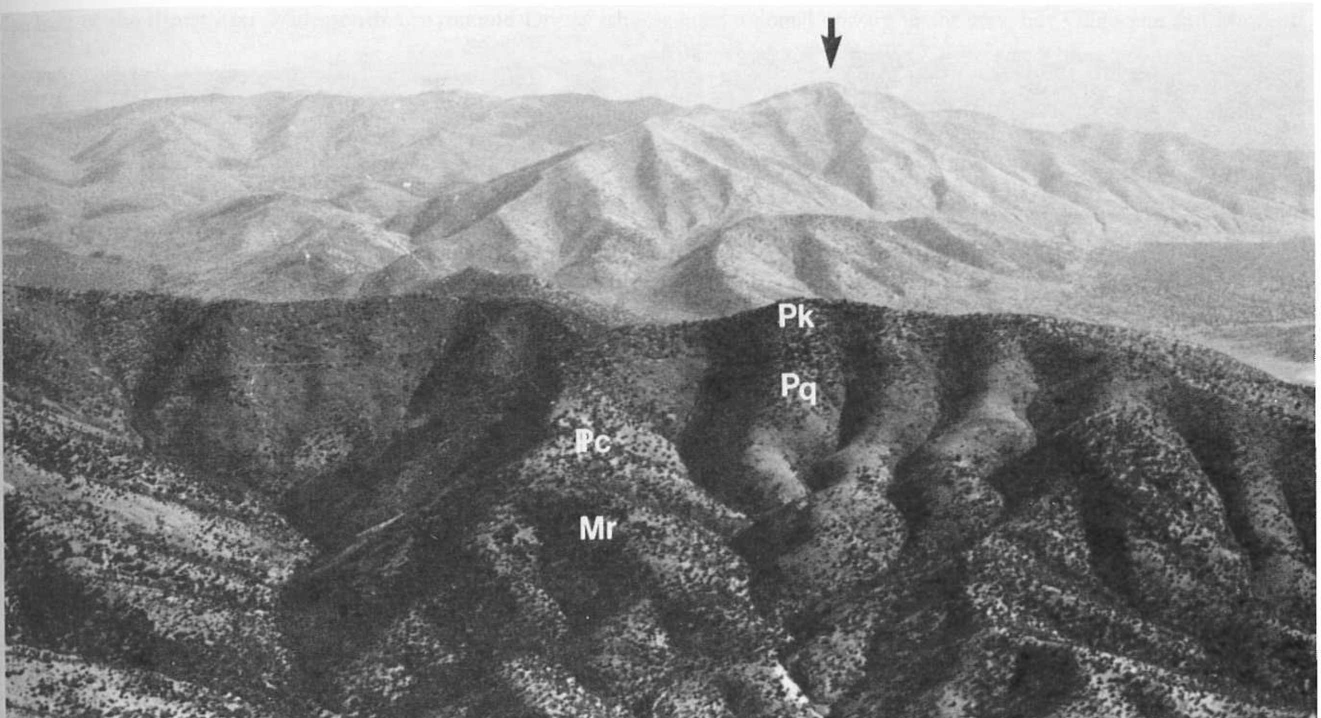


FIGURE 11.—Plunging anticline of autochthonous Paleozoic and Mesozoic strata on Dog Valley Peak (arrow). Foreground is overturned allochthonous section of Paleozoic strata.

An offset or bending has occurred in the Pavant thrust sheet at the point near the mouth of Kanosh Canyon (fig. 1) 1 km northeast of the Red Ridge Quadrangle. The change in geometry of the Pavant thrust fault, which includes this 60° bend, is believed by Crosby (1973) to be near the southernmost exposures of the thrust. He believes it does not continue southward beneath the overlapping Late Cretaceous and Tertiary rocks. Crosby (1973) recognized a right-lateral offset which he called the Black Rock Offset. I have found a left-lateral strike-slip zone trending southeast located north of First Creek in the Red Ridge Quadrangle.

The Pavant thrust is younger than and underlies the Canyon Range thrust (Millard 1983). The Canyon Range thrust places Precambrian rocks on top of Cambrian rocks. Movement of the Pavant thrust was probably along thin shaly zones at the base of the Tintic Quartzite (Crosby 1973).

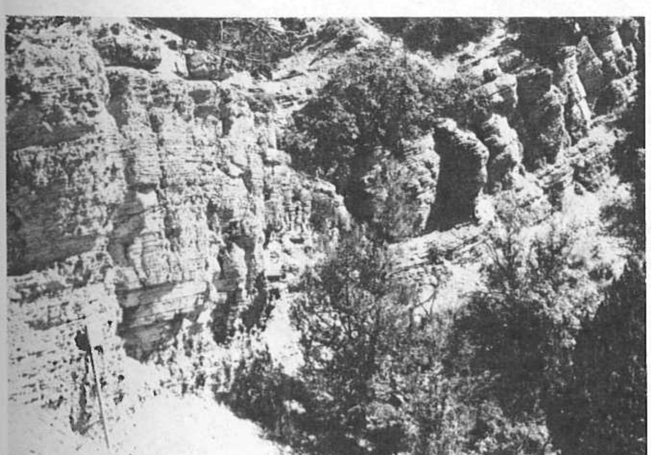


FIGURE 12.—Minor folds in the autochthonous Triassic Moenkopi Formation in the Narrows. (Staff is 1.5 m long.)

The Red Ridge thrust (Steven and Morris 1981) is exposed in both the Red Ridge and Dog Valley Quadrangles. The breakout zone for this thrust is in the axis of an asymmetrical syncline. Upside-down Paleozoic through Mesozoic rocks are placed on top of right-side-up Mississippian through Jurassic rocks (fig. 14). Extent of the movement of this thrust varies laterally. At the head of Widemouth Canyon, Triassic rocks are thrust against Triassic rocks. East of this point, in the area north of the Pyramids, Permian rocks are thrust against Jurassic. Farther east, between South Mountain and Red Ridge, Triassic rocks are thrust against Jurassic rocks.

Displacement along this thrust is less than 2 km, and therefore it is not as important a thrust. The Red Ridge thrust appears to be an imbricate thrust detached beneath the Pavant thrust.

Minor imbricate thrusts are also exposed in the Red Ridge allochthon. In the section west of Baker Canyon, these imbricate thrust relationships involve Devonian Guilmette Formation on Mississippian Redwall Limestone. The Dog Valley Mountain section, between Baker Canyon and Widemouth Canyon, also involves Devonian on Mississippian. However, various Devonian formations as early as Sevy Dolomite are emplaced on Mississippian Redwall.

In the section beneath Widemouth Canyon and Dry Wash, the imbricate thrust involves Mississippian Redwall Limestone on top of Permian Pakoon Formation through Permian Kaibab Limestone (fig. 10). In the center of this section, a small rootless anticline has been exposed by erosion. Pennsylvanian Callville Limestone is exposed in the center of this anticline. However, Mississippian Redwall Limestone is exposed at

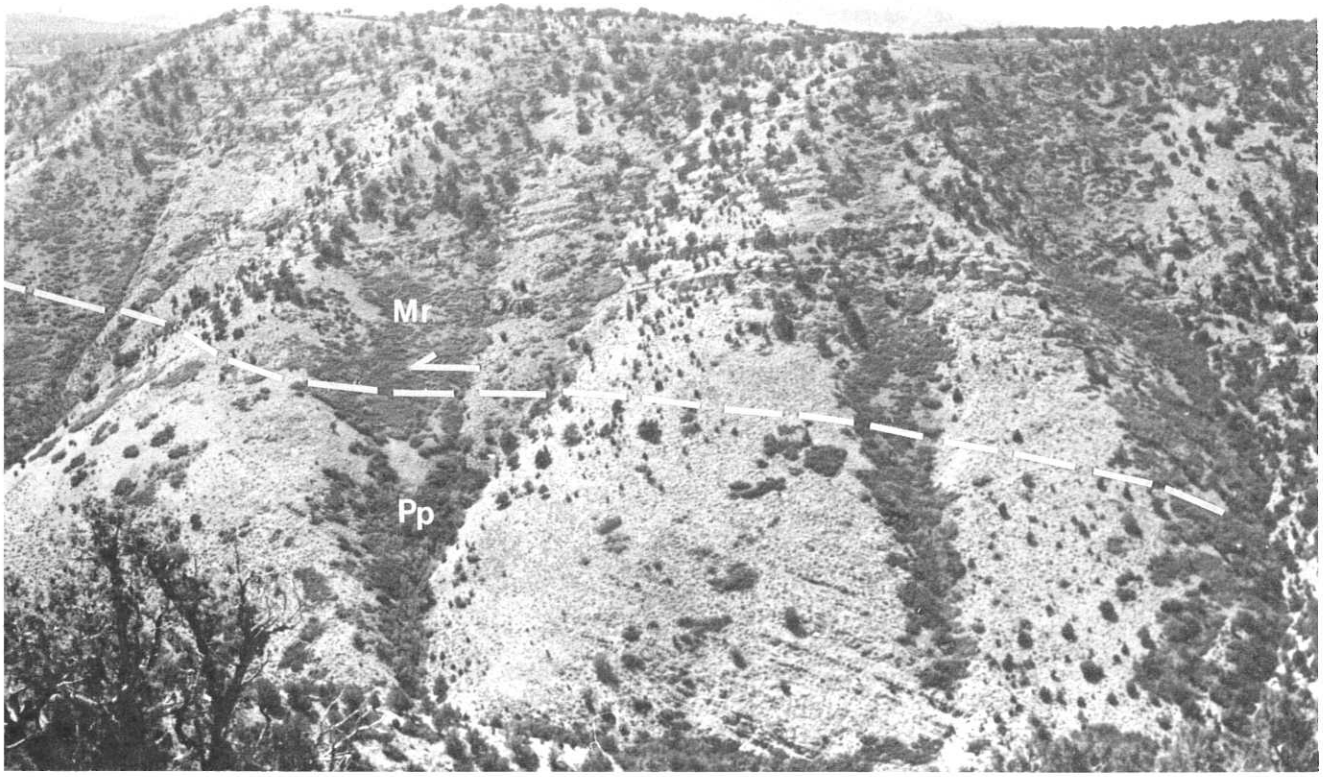


FIGURE 13.–Imbricate thrust within the Red Ridge Thrust plate. Exposure is west of Dry Wash in the Red Ridge Quadrangle.

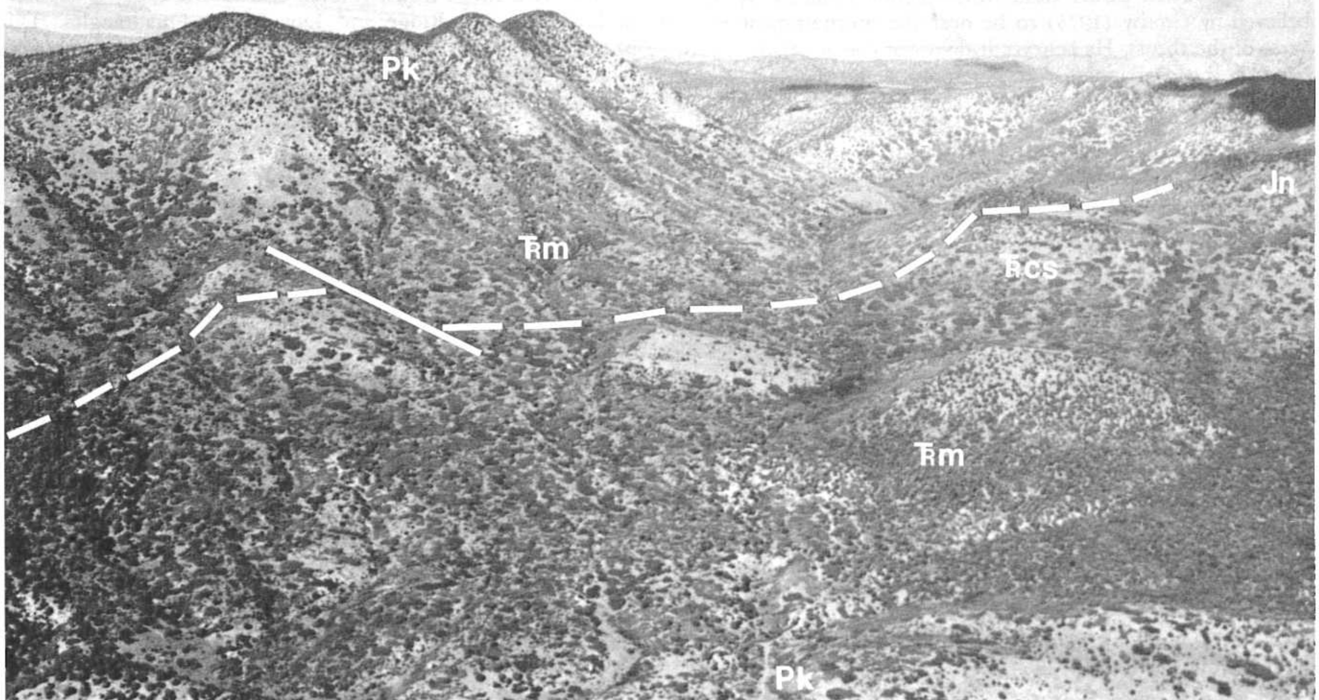


FIGURE 14.–Upside-down strata of Red Ridge allochthon resting on right side-up autochthon, northeast of Dog Valley. Dashed line is Red Ridge Thrust. Offset is small right-lateral strike slip fault.

the base of the thrust near Widemouth Canyon and Dry Wash (fig. 13).

In the South Mountain section, between Dry Wash and Kanosh Canyon, the Pennsylvanian Callville Limestone appears to be at the base of the thrust. In this location, the thrust overrode Permian Kaibab Limestone. Some Mississippian Redwall Limestone is involved at the frontal edge of the thrust in this area. The thrust contact moves downsection westward, an indication that the imbricate thrust fault plane is plunging northwestward. A southeast direction of movement is therefore very likely.

The trend of the major thrust faults changes northeast of the Red Ridge Quadrangle. Southward from the Canyon Range, the trend is due north. At Kanosh Canyon (fig. 1) it makes a 60° bend and trends northeast. This pattern appears lobate on a regional scale (fig. 15). The northern extent of this salient is near Leamington Canyon in the Canyon Range. Another salient occurs north of Leamington Canyon and includes the Nebo and Charleston thrusts. These lobate structures intersect at structural highs or buttresses known as the Emery High and the Uinta Axis. The southern end of the Pavant salient suggests there was a structural high or buttress south of the Pavant Mountains, which I am calling the Tushar Buttress. This structural high was much larger than the small local high near Dog Valley proposed by Steven and Morris (1981). Eastward-directed thrust sheets ramming into these buttresses produced the salient features which exist at present on a regional scale (fig. 15). Thick sequences of volcanic rocks, of large areal extent, presently exist in the Tushar Buttress region. The possible occurrence of this buttress suggests thermal activity caused a domal upwarp in the area, but Oligocene and Miocene volcanic rocks cover any evidence of it.

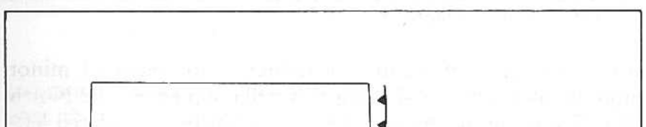


FIGURE 15.–Tectonic map of Utah showing thrust salients and buttresses.

The Tushar Buttress prevented the Pavant thrust from overriding the Jurassic Navajo Sandstone in the southern Pavant Mountains. The exposures of the Pavant thrust near White Sage Flat represent the base of the thrust fault, which did not extend much farther southward because of the buttress.

The mechanism for thrusting may involve one or more of the following. A structural or domal upwarp took place in western Utah during the Sevier orogeny (Burchfiel and Hickcox 1972, Crosby 1976). As this upwarping took place, segments of the crust broke out and slid eastward, producing the zone of duplication we see in the Pavant Mountains. Structural buttresses would tend to funnel the rocks into low areas. Possible dual motion on some of these thrusts could be due to the momentum of the sheet moving the rocks onto the sides of a buttress and then relaxing backwards.

These may be piston-driven thrusts, considering there are thick miogeosynclinal sediments thrust on top of the thinner platform sediments. The thickness of the miogeosynclinal sediments could lend strength to the block of material and therefore allow the rocks to be pushed into a thinner sequence. These compressional forces would allow breakout of some of the upper units causing overthrusting.

Movement of the thrusts occurred during Late Cretaceous and continued into the Paleocene (Stanley and Collinson 1979). In some locations Cretaceous conglomerates rest unconformably across thrusts. This configuration would place the major deformation before the close of the Cretaceous (Burchfiel and Hickcox 1972). In other locations, such as those in Second Creek, where Cretaceous and Tertiary conglomerates and lacustrine limestones rest at angles of up to 55° (fig. 9), subsequent thrusting may have occurred and pushed up these sediments. Therefore, the last impulse of thrusting occurred in the Paleocene and possibly even the Eocene.

High-Angle Faults

Dog Valley rests in a graben. On the eastern side, high-angle normal faults striking N 35° E are downdropped on the western side. Numerous fault line scarps can be seen on the western side of Dog Valley Peak (fig. 16). On the western edge of Dog Valley, faults striking N 20° W are downdropped to the east. Normal faults also enter the valley from the south and north.

I suggest two possible causes for the graben. It may be a result of basin-and-range block faulting, or it may possibly be related in some way to an intrusion below Dog Valley. A latite porphyry dike or sill was encountered in the Hunt Energy CHTE 15-30 geothermal well drilled south of White Sage Flat in section 30, T. 24 S, R. 6 W, and the Union well south of Cove Fort (Moore and Samberg 1979). Three wells were also drilled in 1981 around the perimeter of Dog Valley for geothermal exploration. Hydrothermal alteration exists in the Paleozoic rocks due west of Dog Valley, adjacent to the western boundary fault. Sulfurous springs and alteration occur along the eastern boundary fault south of Dog Valley Peak (Moore and Samberg 1979). Hot water has been encountered in the geothermal wells, although the exact temperature is classified information. Very little hydrothermal alteration can be seen in rocks other than those near the boundary faults. Moore and Samberg (1979) dated these particular faults as mid-Miocene to Recent. The Dog Valley area is presently seismically active (Olson and Smith 1976), and that activity might also suggest movement of an intrusive mass below the surface.

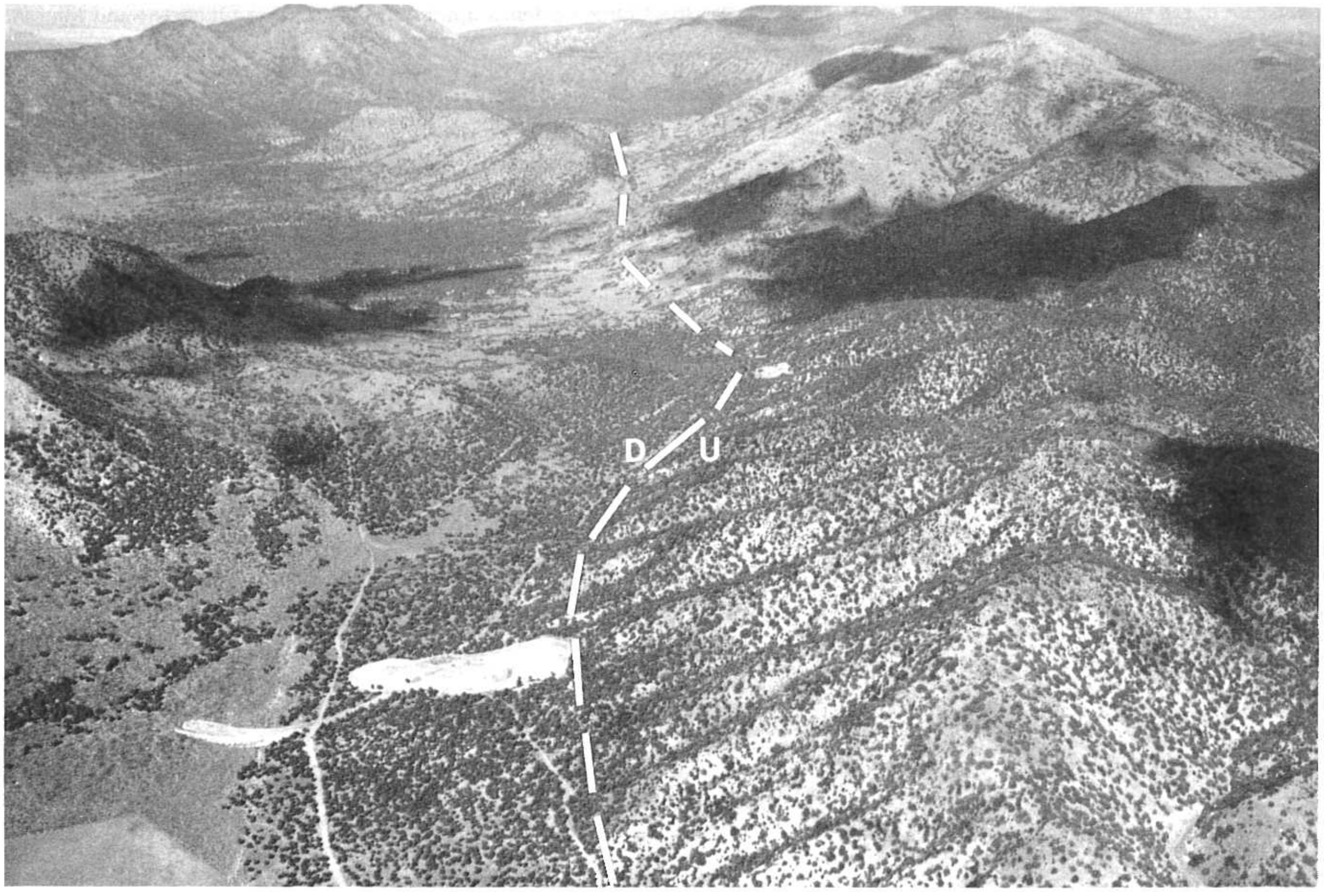


FIGURE 16.–Boundary fault zone–east side of Dog Valley–along which mineralized zones and sulfurous springs occur.

It is also possible that a small intrusive mass underlies White Sage Flat. Minor hydrothermal alteration occurs along fault zones south of the flat, which appears to be a grabenlike structure similar to Dog Valley. Radial drainage into the valley is very noticeable.

Some of the faults in the Dog Valley Quadrangle have cut Quaternary gravels and the Sevier River Formation. One such fault is present on the eastern side of Dog Valley in section 5, 0.8 km east of Baker Canyon. It can be traced almost 8 km and has approximately 90 m of displacement (Crosby 1959). Its prominent escarpment can be easily seen from the air (fig. 17) and on aerial photos.

A series of normal faults occurs within the imbricated thrust system of the Red Ridge thrust plate. These faults strike N 60° E and have faulted up and down a series of small blocks north of South Mountain. They may be the result of basin-and-range activity and represent a northeast-southwest component of faulting. They may also be listric faults due to the pushing and thrusting or relaxation of the rock bodies after thrusting.

Another series of normal faults striking N 50° W in the Bull Valley–Big Oaks area of the Red Ridge Quadrangle occurs through the Navajo Sandstone–North Horn contact and into the volcanic rocks. They could represent subsequent movement along zones of weakness from earlier faulting more closely related to thrusting.

Strike-Slip Faults

A strike-slip fault separates the Cambrian-on-Jurassic klippe of the Red Ridge Quadrangle from the Cambrian-on-Ordovician rocks south of Kanosh. Left-lateral movement of minor proportions has occurred along this strike-slip zone. The North Horn Formation in the First Creek area has been displaced left-laterally and has been pushed to a steep angle.

A minor left-lateral strike-slip fault occurs through Thousand Dollar Gulch east of Dog Valley. Minor evidence for a left-lateral strike-slip fault in Dry Wash is that formations have been displaced a few hundred meters. These faults strike N 50°–60° W. These may be shear fractures because Millard (1983) has encountered minor left-lateral fractures trending in the same direction in the Canyon Range. He has also noted a linear zone near Scipio Pass which strikes N 40° E which may possibly be a major right-lateral shear between the Pavant and Canyon Range Mountains. The 100° angles separating these fractures suggest shear forces.

These minor strike-slip faults indicate the thrust sheets broke up somewhat during their transport. However, no great displacement occurred, indicating the driving force for the thrust sheets was moderately uniform.

HYDROCARBON POTENTIAL

Possible petroleum source rocks include a 15-m phosphatic shale member in the Mississippian Redwall Limestone. This shale contains approximately 3 percent or more organic carbon (Sandberg and Gutschick 1977). It was noted on Dog Valley Peak and in the Hunt Energy CHTE 15-30 geothermal well near White Sage Flat.

Conodonts from Dog Valley Peak (Sandberg and Gutschick 1977) show color alteration index (CAI) values of 1½,

FIGURE 17.–Normal fault east of Baker Canyon displaces Sevier River Formation at bottom of photo. White patch in upper left is location of Hunt Energy CHTE 15-30 geothermal well.

indicating an optimum temperature for petroleum generation, even though the area is in close proximity to volcanic and hydrothermal activity.

Sandstone beds within the Mississippian Redwall Limestone and the Permian Queantoweap Sandstone and dolomites above the Mississippian would possibly make good reservoir rocks. Triassic and Jurassic rocks would make both hydrocarbon source and reservoir rocks.

Because fractured older Paleozoic formations are in fault contact with the younger Paleozoic and Mesozoic source rocks, they may also have good hydrocarbon potential (Moulton 1976).

SUMMARY AND CONTRIBUTIONS

From my study, the following was established:

1. Ordovician quartzite in the Dog Valley–Red Ridge area correlates with the Eureka Quartzite of eastern Nevada and not with Swan Peak Quartzite of northern Utah.

2. Fragments of *Osteostraci* have been found in the Sevy Dolomite in the first reported occurrence of fish from this formation in central Utah.

3. Upper Paleozoic map units in the Pavant Mountains include the Mississippian Redwall Limestone, Pennsylvanian Callville Limestone, Permian Pakoon Formation, and Permian Queantoweap Sandstone. These formations are easily identified and best correlated with rocks formed on the Callville-Pakoon-Queantoweap Platform of central and southwestern Utah. Nomenclature of the Pennsylvanian–Permian Oquirrh Formation should not be extended into the southern Pavant Mountains.

4. The major late Mesozoic–early Cenozoic Pavant thrust exposes Cambrian rocks sitting on top of younger Paleozoic and Mesozoic rocks.

5. The imbricate Red Ridge thrust broke beneath the Pavant thrust. Detachment occurred in the axis of an asymmetrical syncline. Other smaller imbricate thrusts, exposed in the Red Ridge thrust plate, involve Devonian through Permian strata.

6. The lobate nature of the Pavant thrust sheet, along with its apparent southern vector of motion, indicates a structural high existed south of the present Pavant Mountains. I call this high the Tushar Buttress.

7. Minor left-lateral strike-slip faults occur in the Dog Valley–Red Ridge area and indicate a possible major right-lateral shear between the Pavant and Canyon Range Mountains. I suggest this phenomenon be studied on a regional scale, including a study of the Scipio Pass area.

8. Numerous post-thrusting normal faults have complicated the structure of the southern Pavant Mountains. A graben in the Dog Valley area may be related in some way to a small intrusive body beneath Dog Valley. Shallow geothermal wells drilled in the perimeter of Dog Valley have encountered high temperature water and an intrusive sill or dike.

9. Potential for hydrocarbons is good because of source and reservoir rocks in the Pavant Mountains. Possible source rocks for hydrocarbons are in the Mississippian Redwall Limestone. Good reservoir rocks include the Mississippian Redwall Limestone, Permian Queantoweap Sandstone, and Triassic and

Jurassic sandstones. Fractured early Paleozoic rocks would also make excellent reservoirs when they are in fault contact with younger reservoir and source rocks.

The appendix to this paper, manuscript pages 51–123, measured stratigraphic sections, is on open file in the Geology Department, Brigham Young University, Provo, Utah 84602, where a Xerox copy may be obtained.

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