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# GEOLOGY STUDIES

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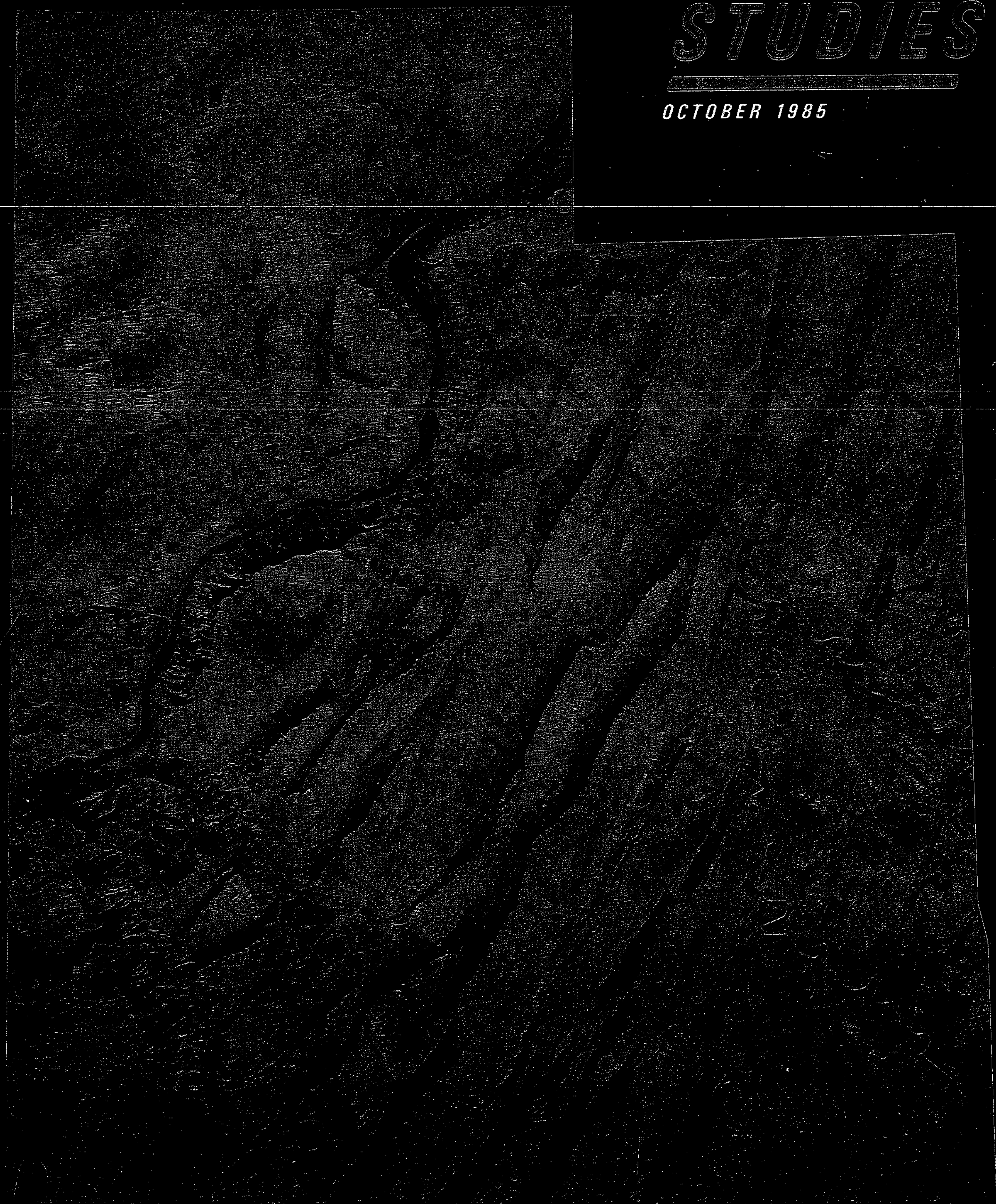

VOLUME 32, PART 1

# BRIGHAM YOUNG UNIVERSITY
# GEOLOGY STUDIES

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CONTENTS



THE GLORY OF GOD IS INTELLIGENCE

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# Structural Geology of the Pavant Mountain Front in the Fillmore and Kanosh Quadrangles, Millard County, Utah*

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## ABSTRACT

The Fillmore and Kanosh Quadrangles are located on the west flank of the Pavant Range in the Utah thrust belt. Partial sections of approximately 5,830 m of Cambrian-through-Jurassic strata are exposed. Approximately 1,300 m of right-side-up, allochthonous Cambrian Tintic Quartzite, Pioche Formation, and Cambrian carbonates overlie the Pavant thrust. Scattered exposures of the North Horn Formation overlie allochthonous rocks with angular discordance. Overturned parautochthonous exposures of Ordovician Pogonip Group through Triassic Moenkopi Formation lie beneath the Pavant thrust. Approximately 1,300 m of autochthonous Permian Kaibab Limestone through Jurassic Navajo Sandstone form a northwest-dipping, overturned syncline that parallels the mountain front. Tertiary and Quaternary rocks include the Sevier River Formation, Lake Bonneville sediments, basaltic igneous rocks, tufa deposits, and alluvium.

The Pavant thrust shows an apparent horizontal displacement of approximately 12 to 14 km in a southeasterly direction. Thrust faults in the footwall and hanging wall of the Pavant thrust show maximum displacements of 3,000 m in the same direction. Major displacement of rocks along normal faults probably occurs at the western edge of the quadrangles and not along the mountain front.

Folding and thrust faulting took place during latest Cretaceous through Paleocene. Normal faulting took place during the Miocene to Recent.

## INTRODUCTION

The Fillmore and Kanosh $7\frac{1}{2}$-minute Quadrangles are located on the west flank of the Pavant Range and include the Utah thrust belt. Both thrust- and normal-fault tectonics, combined with the effects of Cenozoic erosion and deposition, have produced a series of geographically isolated but structurally related outcrops. Study of this area has put constraints on estimates of direction and amount of movement of Paleozoic strata in the Pavant thrust.

## LOCATION

The Fillmore and Kanosh Quadrangles are located in south central Utah, approximately 235 km south of Salt Lake City, encompassing the towns of Fillmore and Kanosh (fig. 1). The Pavant Mountain Range occupies the southeastern third of each quadrangle. Interstate 15 runs through the northwestern quarter of each quadrangle, and dirt roads provide access to most of the area within the quadrangles.

## PREVIOUS WORK

The first geologists to mention the Pavant Mountains were Wheeler (1875) and Dutton (1880), who did reconnaissance work in the area. Gilbert (1890) described the Lake Bonneville and volcanic deposits of the Pavant Valley.

The first detailed mapping of the area was done by Maxey (1946) and Dennis and others (1946). The mapping used a planimetric base at a scale of 1:64,500. Maxey (1946) studied the geology of the central Pavant Mountains, and Dennis and others (1946) described the groundwater resources of the Pavant Valley. Lautenschlager (1952) mapped the geology of the central Pavant Range east of the Fillmore and Kanosh Quadrangles. Tucker (1954) mapped the geology of the Scipio Quadrangle to the north, and Crosby (1959) mapped the geology of the southern Pavant Range. Other works pertaining to the geology of the area include a study by Schneider (1963) on part of the central Pavant Range of the thesis

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area and a study by Feast (1979) on two klippen located in the Fillmore Quadrangle.

## FIELD METHODS

Field mapping of both of the quadrangles was done on aerial photographs (approximate scale 1:20,000) between the months of June and November 1981. Later, a Bausch and Lomb Stereo Zoom Transfer Scope was used to transfer the geology to topographic base maps (scale 1:24,000). A Brunton compass and a Jacob's staff were used in the field to measure and describe stratigraphic units.

## STRATIGRAPHY

Stratigraphic units exposed in the Fillmore and Kanosh Quadrangles range from Cambrian to Quaternary in age (fig. 2). All exposed Cambrian rocks are right side up. The remainder of the exposed Paleozoic formations are overturned. Mesozoic rocks are exposed in both normal and overturned sequences. Cenozoic rocks consist of Tertiary conglomerates and fanglomerates, basaltic rocks, hot spring deposits, lake sediments, and recent alluvial deposits. The stratigraphic units used in this report are similar to ones used by Hintze (1972) and Welsh (1972).

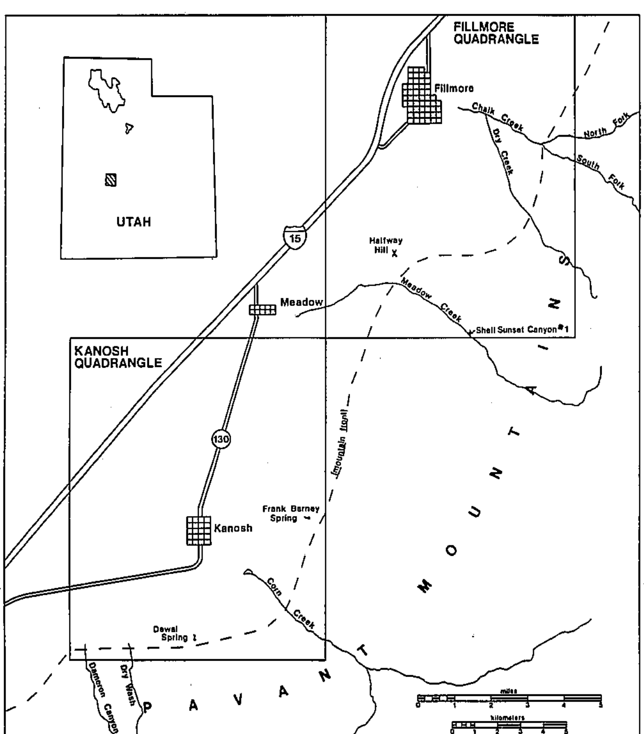


FIGURE 1.—*Index map showing the location of the Fillmore and Kanosh Quadrangles.*

## CAMBRIAN SYSTEM

### *Tintic Quartzite*

The Tintic Quartzite is a fine- to coarse-grained, white to brownish-orange-weathering quartzite. It is well indurated and contains a few layers of pebble conglomerate. Abundant slickensides and fractures are present, making it difficult to discern the attitude of bedding.

In both quadrangles this formation is exposed as the basal unit overlying various thrust faults. Because of erosion, cover, and proximity to thrust faults, the true thickness of the Tintic Quartzite is not known. I estimate a maximum of about 1,000 m is exposed east of Meadow Canyon overlying Navajo Sandstone.

### *Pioche Formation*

The Pioche Formation overlies Tintic Quartzite conformably and consists of interbedded quartzite, argillaceous siltstone, and shale and an upper unit of interbedded shale and limestone. The quartzite beds are brownish orange, green, or purple. They are fine to medium grained, medium bedded, and cross-bedded, and they contain vertical burrows (skolithus) and glauconite (up to 50% of rock). The argillaceous siltstone and shale beds are brownish green to olive green and phylitic. The upper part of the formation contains some thin-bedded, dark bluish gray limestone beds. Many of these beds have abundant oncolites that give the rock an orange, spotted appearance when weathered (fig. 3). In addition, limestone layers containing intraformational conglomerate, oolites, pisolites, and trilobite fragments (*Glossopleura*) are abundant. At the top of the Pioche Formation a thick-bedded, brown-weathering dolomitic limestone unit persists throughout both quadrangles.

Outcrops of Pioche Formation too small to be mapped occur as basal units of thrust sheets in exposures southwest of Dewal Spring (NW $\frac{1}{4}$, section 3, T. 24 S, R. 5 W) in the Kanosh Quadrangle, and on a hill about 2 km east of Halfway Hill (SE $\frac{1}{4}$, section 9, T. 22 S, R. 4 W) in the Fillmore Quadrangle. The base of the Pioche Formation was mapped at the first appearance of shale beds above Tintic Quartzite. The Pioche Formation at Halfway Hill was found to measure 138.5 m (appendix). Hickcox (1971) measured a minimum of 130 m of comparable rock above the Pavant thrust to the east.

### *Cambrian Limestone*

Two informal units have been mapped in this report to divide Cambrian carbonate rocks. They are called Cambrian limestone and Cambrian dolomite.

The Cambrian limestone map unit consists of limestone with interbedded sandstone, siltstone, and shale beds that resemble those in the Pioche Formation but are less micaceous (appendix). Beds in the lower part of the Cambrian limestone unit also resemble those of the Pioche Formation; they are, however, sandier and more thinly bedded. Like the Pioche Formation these limestone beds contain abundant oolites, oncolites (*Glossopleura*), trilobite fragments, and layers of intraformational conglomerate. The upper part of the Cambrian limestone unit contains two thick-bedded, bluish-gray-weathering limestone beds. These beds have light gray, horizontal, silty layers that give the outcrop a characteristic banded or striped appearance (fig. 4).

The base of the Cambrian limestone unit was mapped at the top of the brown-weathering, thick-bedded dolomitic limestone bed in the Pioche Formation. The Cambrian limestone unit is 120 m thick as measured at Halfway Hill (appendix). This unit appears to be the same as the lower limestone unit of Hickcox (1971). The combined thickness of Pioche Formation and Cambrian limestone herein is 258.5 m as compared to 261.5 m reported by Hickcox (1971).

### *Cambrian Dolomite*

The Cambrian dolomite map unit consists of three basic lithologies. The rock directly overlying the Cambrian limestone unit is a light gray, medium crystalline, sucrosic dolomite that often weathers with a slight pinkish

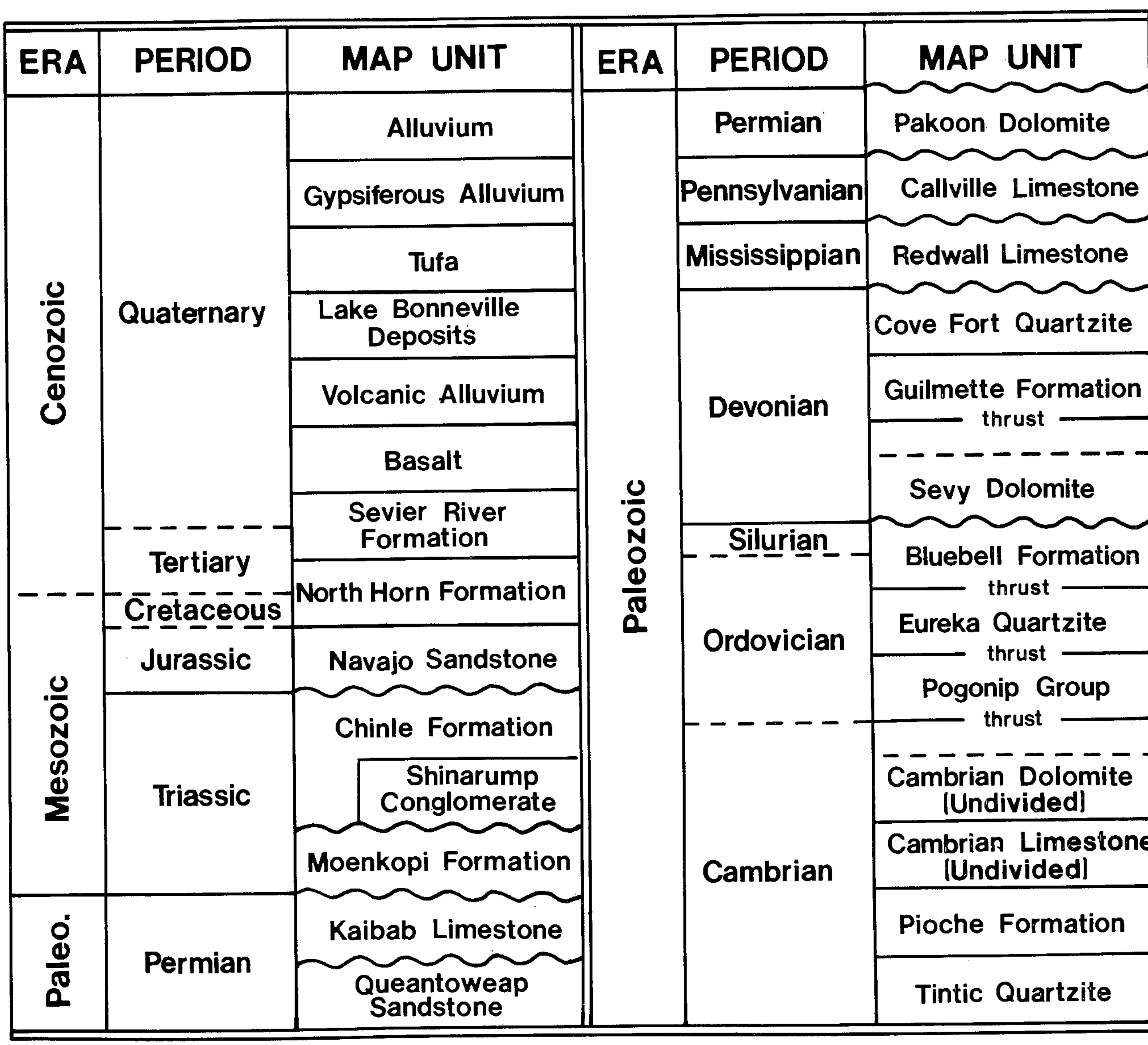


FIGURE 2.—*Rock units used in mapping the Fillmore and Kanosh Quadrangles.*

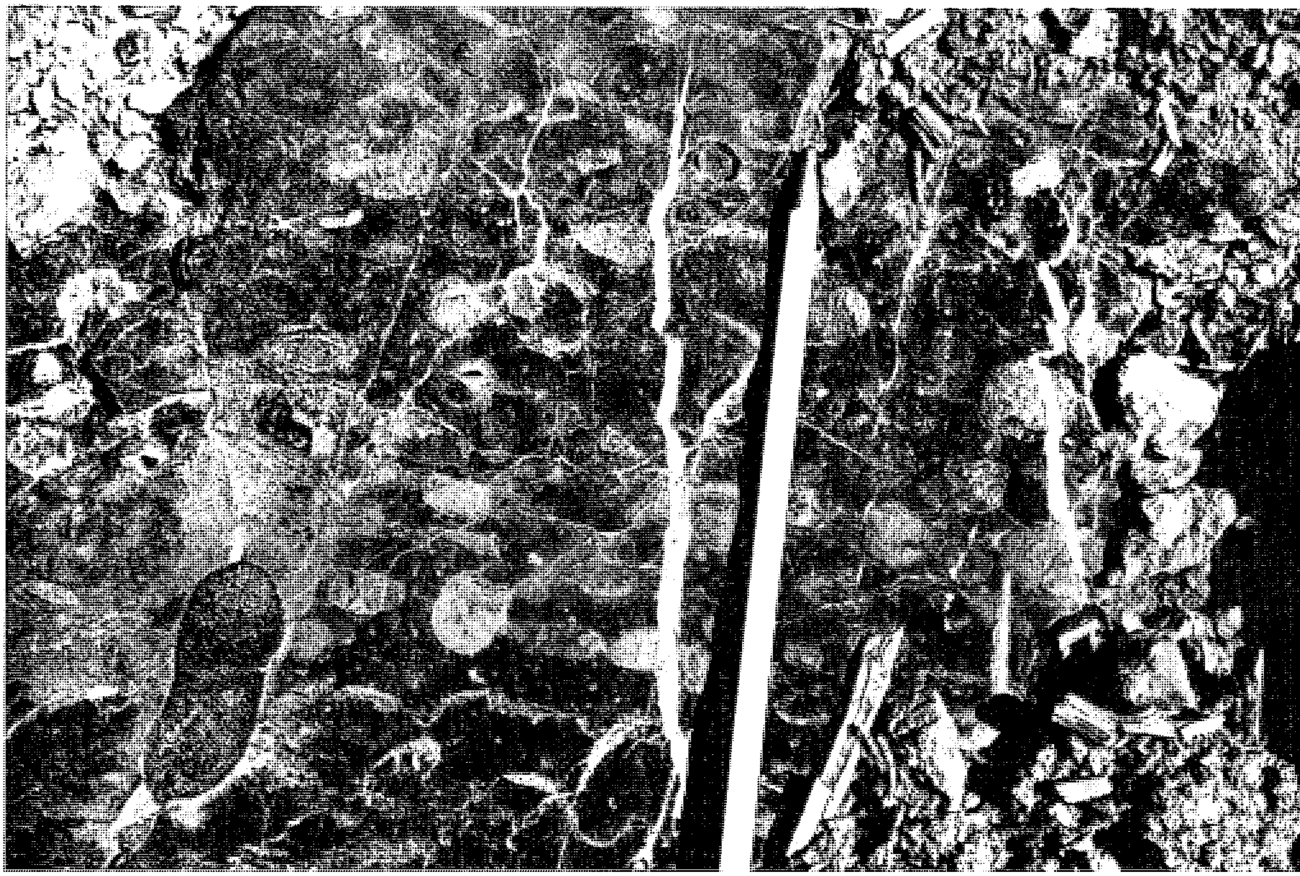

FIGURE 3.—*Oncolitic limestone unit in the Pioche Formation (from outcrop at Halfway Hill).*

hue. Commonly it forms a steep ledge or cliff and is highly fractured and rough looking. The other lithologies are a dark gray to black, medium crystalline dolomite, and a dark gray, banded dolomitic limestone similar to the upper beds of the Cambrian limestone unit. In most cases these three lithologic types contain abundant calcite and dolomite "twiggy bodies" (fig. 5).

The lower contact of the Cambrian dolomite unit was mapped in the middle of a gradational boundary between the bluish gray, banded beds of the Cambrian limestone unit and light gray, sucrosic beds of the overlying Cambrian dolomite unit. This gradational boundary is usually about 1–2 m wide and can be recognized throughout both quadrangles. Only 22.5 m of the Cambrian dolomite unit were measured at Halfway Hill (appendix); however, thicker exposures occur in the hills to the east where up to 150 m are exposed.

## ORDOVICIAN SYSTEM

### *Pogonip Group*

Division of the Pogonip Group into the established mappable formations was impossible in the area because of faulting and limited, poor exposures. The Pogonip Group as exposed consists of bluish gray to brownish gray, thin- to medium-bedded crystalline limestone. Beds in the lower part of the section are medium bedded and contain few fossils. In the upper part of the section, the beds contain much more silt and have layers of shale and intraformational conglomerate. In addition, some layers contain abundant trilobite, crinoid, gastropod, and brachiopod fragments.

The Pogonip Group is exposed in only two places in the Kanosh Quadrangle. The largest exposure occurs just west of Dameron Canyon (section 6, T. 24 S, R. 5 W). The other exposure occurs along a roadcut just east of Dameron Canyon (section 4, T. 24 S, R. 5 W). It is highly altered and brecciated and is characterized by its dark red appearance.

As with all exposures of Paleozoic rocks in the quadrangles except Cambrian rocks, the Pogonip Group is overturned. In both exposures the upper and lower contacts are faulted. Only 103.5 m of the Pogonip Group are exposed as compared to a thickness of 343 m just a few kilometers to the southwest as reported by Davis (1983).

FIGURE 4.—*Banded limestone unit in the Cambrian limestone unit (from outcrop at Halfway Hill).*

### *Eureka Quartzite*

The Eureka Quartzite is a fine-grained, white- to light-red-weathering quartzite. It is highly fractured and typically forms rounded irregular outcrops.

The Eureka Quartzite is overturned and exposed in only two areas in the Kanosh Quadrangle. Both exposures occur overlying the previously discussed Pogonip Group outcrops. The thickness of Eureka Quartzite ranges greatly because its upper and lower contacts are faulted. A maximum of 30 m is exposed.

## ORDOVICIAN–SILURIAN SYSTEMS

### *Bluebell Formation*

The Bluebell Formation is a fine- to medium-crystalline, light creamy gray to dark-gray-weathering dolomite. It contains both bedded and nodular chert sometimes comprising 50% of the rock. Some beds contain layered algal structures that are horizontal or concentric resembling convolute bedding. Poorly preserved rugose corals and brachiopod fragments were observed, but they are not abundant and are very difficult to recognize.

The Bluebell Formation is overturned and exposed along the foot of the mountain west of Dry Wash only in the Kanosh Quadrangle. The maximum exposed thickness of the Bluebell Formation is 110 m.

## DEVONIAN SYSTEM

### *Sevy Dolomite*

The Sevy Dolomite overlies the Bluebell Formation conformably and consists of fine to microcrystalline, creamy light gray to light brown dolomite. It is commonly laminated and contains minor amounts of chert, some sandy layers, and a few recrystallized unidentifiable fossils.

The Sevy Dolomite is overturned and is exposed only in the Kanosh Quadrangle just west of Dry Wash (sections 4 and 5, T. 24 S, R. 5 W), where it underlies the Bluebell Formation. The upper contact of the Sevy Dolomite is faulted. Only about 25 m are exposed.

### *Guilmette Formation*

The Guilmette Formation consists of interbedded layers of dark gray, medium crystalline, sandy dolomite and creamy light gray, microcrystalline dolomite. This formation is overturned and exposed in only one outcrop 2 km east of Halfway Hill (SE $\frac{1}{4}$, section 9, T. 22 S, R. 4 W) in the Fillmore Quadrangle. The Guilmette Formation underlies Cambrian limestone with a faulted contact. The formation is highly fractured and poorly exposed with a maximum thickness of 20 m.

### *Cove Fort Quartzite*

The Cove Fort Quartzite overlies the Guilmette Formation conformably and consists of interbedded quartzite and fine- to coarse-grained sandy dolomite. The quartzite in the lower part of the formation is coarse grained, weathers brownish orange, and is crumbly. The quartzite in the upper part of the formation is well indurated, fine grained, white to light pink, and vitreous.

Only two exposures of Cove Fort Quartzite occur in the quadrangles. In the Fillmore Quadrangle, Cove Fort Quartzite is overturned and underlies the Guilmette Formation 2 km east of Halfway Hill. In the Kanosh Quadrangle a questionable outcrop of this formation occurs overlying the Redwall Limestone (section 4, T. 24 S, R. 5 W). At the most, 30 m of this formation are exposed.

## MISSISSIPPIAN SYSTEM

### *Redwall Limestone*

The Redwall Limestone overlies Cove Fort Quartzite unconformably and consists of three basic lithologies. The lower part of the section is made up of finely crystalline, medium gray, dolomitic limestone typically thin bedded and nonfossiliferous. The middle part consists of medium crystalline, light to dark gray, sparsely cherty, fossiliferous limestone. Fossils include many types of bryozoans, crinoid stems (up to 1 cm in diameter), some rugose corals, and a few brachiopods (fig. 6). The upper part consists of interbedded layers of limestone and sandstone. The limestone is medium gray, fine crystalline and contains abundant black and brown chert. Abundant rugose corals, with only a few crinoid and bryozoan fossils, characterize these upper layers. The sandstone layers in the upper unit are calcareous, medium gray, and fine to medium grained. At the very top of the Redwall Limestone, limestone layers contain many *Lithostrontionella* and *Syringopora* fossils. Throughout the entire formation, many beds give off a hydrocarbon odor when broken.

A partial section of Redwall Limestone was measured south of Meadow Creek in the Fillmore Quadrangle, where 58.5 m are exposed (appendix). Because most of

FIGURE 5.—*Twiggy bodies in the Cambrian dolomite unit (from outcrop at Halfway Hill).*

the exposures are limited and faulted, it is difficult to tell the original thickness of the formation in the area. I estimate that no more than 150 m of Redwall Limestone are exposed in any given outcrop. The thickness of Redwall Limestone as measured by Davis (1983) in the southern Pavant Range is 471 m. In the Shell Sunset Canyon #1 well in the Fillmore Quadrangle (SE $\frac{1}{4}$, section 21, T. 22 S, R. 4 W; fig. 7), a thickness of 427 m was recorded as interpreted by Welsh (1976). Most of the exposures of Redwall Limestone appear to represent the upper two-thirds of Davis's (1983) section.

## PENNSYLVANIAN SYSTEM

### *Callville Limestone*

The Callville Limestone overlies Redwall Limestone unconformably and consists of interbedded sandstone and dolomite. The sandstone beds are fine to coarse grained, calcareous, brownish gray to light gray, and thin bedded. Some crinoid stems less than 2 mm in diameter and poorly preserved brachiopods are present. Layered and nodular white chert is also present, sometimes forming beds up to 1 m thick. Some of the sandy dolomite beds have a hydrocarbon odor.

The Callville Limestone is exposed in only two places in the quadrangles, both in overturned sections. In the Fillmore Quadrangle it is exposed underlying Redwall Limestone in the hills south of Meadow Creek (fig. 8), and in the Kanosh Quadrangle it is exposed 1 km southwest of Dewal Spring (section 3, T. 24 S, R. 5 W).

The contact between Redwall Limestone and Callville Limestone is gradational. The boundary was mapped between the black chert and coral-bearing beds of upper Redwall Limestone and the crinoid- and white chert-bearing sandy dolomite beds of lower Callville Limestone. The total thickness of Callville Limestone as mea-

FIGURE 6.—*Fossiliferous unit in the Redwall Limestone (from outcrop south of Meadow Creek).*

sured in the Fillmore Quadrangle is 52.5 m (appendix). This formation seems to thicken to the east and south.

## PERMIAN SYSTEM

### *Pakoon Dolomite*

The Pakoon Dolomite overlies Callville Limestone unconformably and consists of interbedded sandstone and dolomite beds with a basal conglomerate unit. The sandstone beds are similar to those in the Callville Limestone. The dolomite beds are light gray to light brownish gray, thin bedded, and fine crystalline. They contain characteristic calcite blotches and fibrous masses (fig. 9). The basal conglomerate unit is composed of angular chert and rounded limestone and dolomite clasts in a matrix of coarse-grained, sandy dolomite (fig. 10). The unit weathers medium gray, shows faint bedding of the clasts, and has some sandy layers that are roughly cross-bedded. Some silicified coral fragments are also present.

The Pakoon Dolomite is overturned and exposed in only three places in the quadrangles. In the Fillmore Quadrangle it is exposed overlying Kaibab Limestone just south of Meadow Creek (fig. 8). In the Kanosh Quadrangle it is exposed in outcrops along the southern edge of the quadrangle. One is located 2 km southeast and the other 1 km southwest of Dewal Spring (sections 1 and 3, T. 24 S, R. 5 W).

The contact between Pakoon Dolomite and Callville Limestone was mapped at the base of the conglomerate unit in the Pakoon Dolomite. I estimate a maximum thickness of 50 m is exposed, with the basal conglomerate at times up to 9 m thick (appendix).

### *Queantoweap Sandstone*

The Queantoweap Sandstone is a fine- to medium-grained sandstone that overlies Pakoon Dolomite unconformably. It is usually white, light brown, or reddish orange.

The Queantoweap Sandstone is overturned and exposed only in the Kanosh Quadrangle. The contact between Queantoweap Sandstone and Pakoon Dolomite was mapped at the top of the last dolomite unit in Pakoon Dolomite. No more than 50 m of Queantoweap Sandstone are exposed.

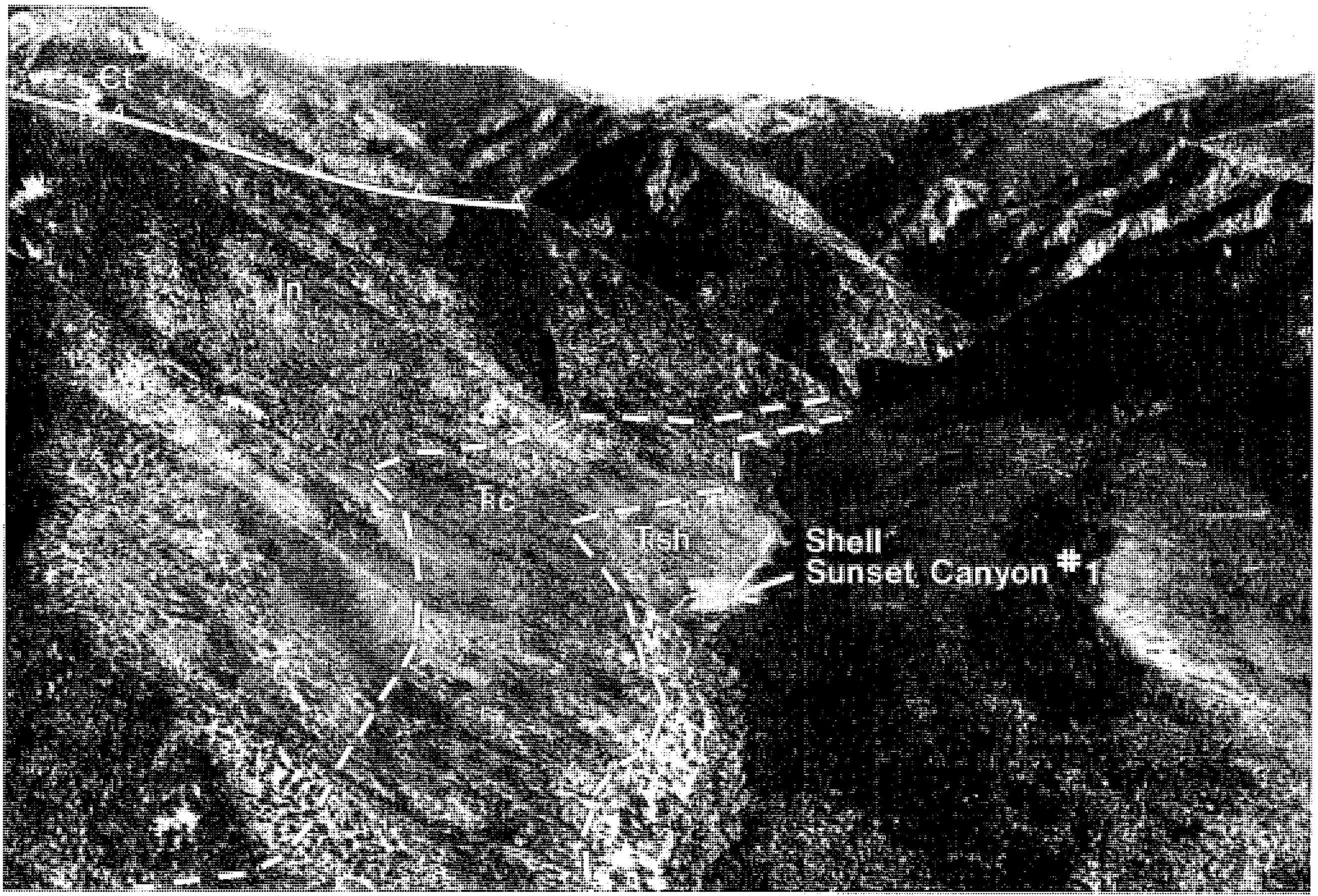


FIGURE 7.—*Meadow Canyon. View is southeast, showing the Pavant thrust on the south-facing slope. Shell Sunset Canyon #1 well was drilled to a depth of 8,962 feet in 1960 (sections 17, 20, 21, T. 22 S, R. 4 W, Fillmore Quadrangle).*

### *Kaibab Limestone*

Upper Permian Toroweap and Kaibab Limestones identified in the area by Welsh (1976) have been mapped in the Fillmore and Kanosh Quadrangles as Kaibab Limestone. The Kaibab Limestone overlies Queantoweap Sandstone unconformably and consists of many different types of lithologies. The dominant rock type is a medium-crystalline, medium-bedded, gray dolomitic limestone. It is often sandy and contains abundant brown to reddish brown fossiliferous chert. Some beds are highly fossiliferous, containing numerous crinoids, brachiopods, and bryozoans. In addition to limestone beds, there are numerous layers of sandstone within the formation. The sandstone is gray to reddish brown, fine grained, calcareous, thin to medium bedded, and well indurated, often resembling quartzite. Some of the sandstone beds are cross-bedded and have fossil burrows.

As mentioned before, many exposures previously mapped as Kaibab Limestone are actually exposures of Redwall Limestone. The lithologic differences between the two formations are subtle. Generally the Kaibab Limestone beds are sandier, more dolomitic, and thicker bedded, and they do not contain the abundant coral fauna that the Redwall Limestone does.

The base of Kaibab Limestone was mapped at the first appearance of limestone beds at the top of Queantoweap Sandstone. No complete section of Kaibab Limestone is exposed in the quadrangle because of thrust faulting and erosion. Just south of Meadow Creek, 151.5 m were measured (appendix)—probably the maximum thickness of exposure in both quadrangles.

## TRIASSIC SYSTEM

### *Moenkopi Formation*

The Moenkopi Formation overlies Kaibab Limestone unconformably and consists of interbedded sandstone, siltstone, shale, and limestone beds. The sandstone and siltstone beds are thin to medium bedded and red. Some layers are cross-bedded and some contain ripple marks,

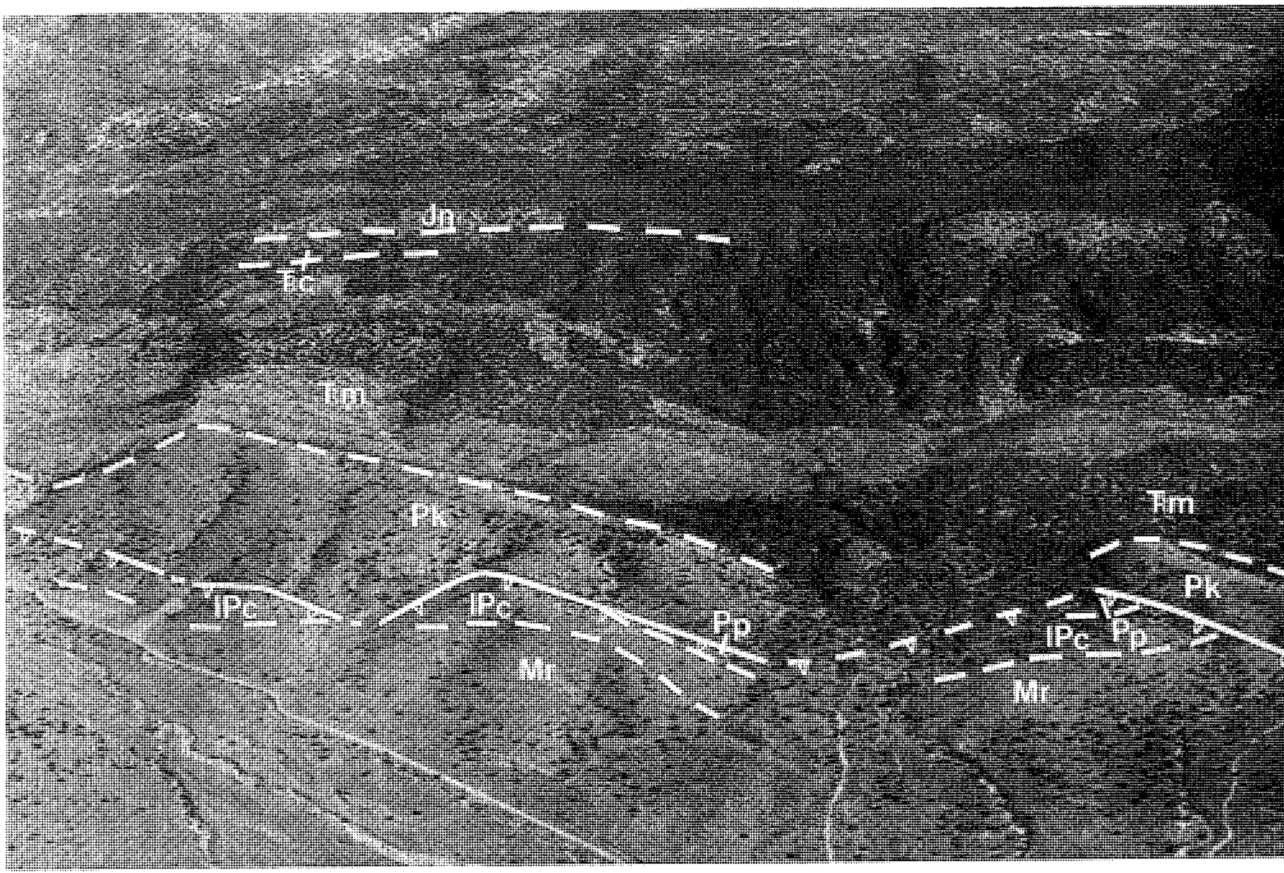


FIGURE 8.—*Hills south of Meadow Creek. View is east toward Pennsylvanian and Permian rocks thrust over Permian strata (sections 13, 24, T. 22 S, R. 5 W, Fillmore Quadrangle).*

mudcracks and current scour marks. The shale beds are usually dark red and fissile. The limestone beds in the lower part of the Moenkopi Formation are light brownish gray to greenish gray and contain abundant fossil brachiopods and ammonoids (*Meekoceras*). The limestone beds in the upper part of the formation are similar in color and contain abundant crinoid (*Pentacrinus*) stem fragments and brachiopods.

The Moenkopi Formation is overturned and exposed intermittently along much of the mountain in both quadrangles. Much of Halfway Hill that was previously mapped by Maxey (1946) and Feast (1979) as Kaibab Limestone is actually exposures of limestone beds in the Moenkopi Formation (fig. 11). In partial sections measured in the Moenkopi Formation on Halfway Hill and south of Meadow Creek, a total thickness of 612.5 m was found (appendix), comparable to the 646.5 m measured in the southern Pavant Range by Davis (1983) and substantially thinner than the 1,000 m that Welsh (1976) identified in the Shell Sunset Canyon #1 well (fig. 8) just 4 km to the east. This difference may be the result of tectonic thinning in the overturned beds or the possible inclusion of older beds in the formation in the well log interpretation.

### *Chinle Formation*

The Chinle Formation overlies the Moenkopi Formation unconformably. Its lower half is the Shinarump Conglomerate Member, which consists of a basal pebble conglomerate grading upward into sandstone. The pebble conglomerate is made up of well-rounded quartzite pebbles (1 to 20 cm in diameter) in a matrix of coarse sand. The conglomerate is bedded and contains abundant petrified wood. The sandstone in the upper part of the Shinarump Conglomerate is white to brown, medium to thick bedded, and cross-bedded and contains some pieces of petrified wood.

The Shinarump Conglomerate varies in thickness throughout both quadrangles. In a measured section on the southeast side of Halfway Hill, 54 m of the Shinarump Conglomerate are exposed (appendix). Although the base of the Shinarump Conglomerate is poorly exposed in Meadow Creek Canyon, the thickness appears to be about 50 to 70 m. The upper contact of this unit was

FIGURE 9.—*Crystalline calcite blotches in the Pakoon Dolomite.*

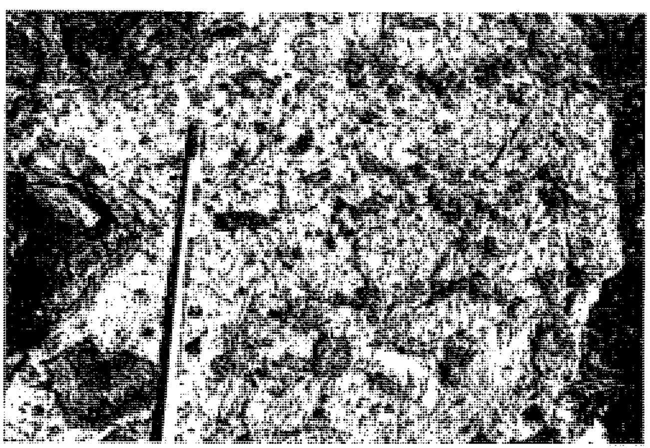

FIGURE 10.—*Chert and limestone pebble conglomerate at the base of the Pakoon Dolomite.*

mapped at the base of the lowest appearance of shale beds.

The remainder of the Chinle Formation consists of interbedded sandstone, siltstone, mudstone, and shale. These beds are dark reddish brown to reddish purple and form a slope between the resistant sands of Shinarump Conglomerate and Navajo Sandstone. The sandstone beds are cross-bedded and medium to coarse grained. The mudstone units usually contain green blotches of clay. Layers containing abundant calcareous septarian nodules, hematite nodules, and petrified wood are also present.

Like the Shinarump Conglomerate Member, the upper Chinle Formation varies in thickness throughout both quadrangles. In measured sections on the southeast side of Halfway Hill and in Meadow Creek Canyon, the thicknesses of the upper part of the Chinle Formation are 58.5 and 55.5 m, respectively (appendix). The upper contact of the Chinle Formation was mapped at the top of the last appearance of shale and mudstone beds.

## JURASSIC SYSTEM

### *Navajo Sandstone*

The Navajo Sandstone overlies the Chinle Formation conformably and consists of fine- to medium-grained, massively cross-bedded sandstone. Most exposures are red and somewhat friable; however, outcrops of white Navajo Sandstone also occur. Some of these white outcrops near thrust faults are well indurated and almost quartzitic. Hickcox (1971) estimated about 550 m of the Navajo Sandstone are exposed in the Pavant Range.

## CRETACEOUS–TERTIARY SYSTEMS

### *North Horn Formation*

The North Horn Formation is made up of a series of interbedded conglomerate, sandstone, siltstone, shale, and limestone beds. The conglomerate beds contain rounded quartzite pebbles, rounded carbonate pebbles, and oncolites in a matrix of fine- to coarse-grained, calcareous sandstone. Most of the clasts are from 1 to 10 cm in size and appear to have been eroded from Cambrian units. Some of the purple quartzite pebbles may have originated from Precambrian formations not exposed in the area. In addition, some conglomerate beds contain sandstone and siltstone clasts. The sandstone units are reddish gray to dark red, well indurated, fine to coarse grained, calcareous, and cross-bedded. Depending on the bed, some of the sandstone layers are silty, contain exclusively rounded quartz grains, exclusively angular grains, or a high percentage of lithic grains. The siltstone and shale beds are poorly exposed and form dark red to reddish purple soil. The limestone beds are medium crystalline, dull gray, and oncolitic. Oncolites range in size from 1 to 10 cm in diameter and are spheroidal to ellipsoidal (fig. 12); often red coarse sandstone fills the spaces between them.

In both quadrangles this formation rests on Cambrian limestone and dolomite beds with angular discordance. In the Fillmore Quadrangle the North Horn Formation is exposed on the north side of Halfway Hill (fig. 11) and on the hills to the east (sections 7, 8, and 9, T. 22 S, R. 5 W). In the Kanosh Quadrangle this formation is exposed 500 m southwest of Dewal Spring (section 3, T. 24 S, R. 5 W). Remnants of the North Horn Formation were observed overlying Cambrian limestone in the northwest part of Halfway Hill and on Cambrian dolomite west and north of Dameron Canyon (section 35, T. 23 S, R. 6 W).

The thickness of the North Horn Formation is unknown in the area because of poor exposure; however, it is

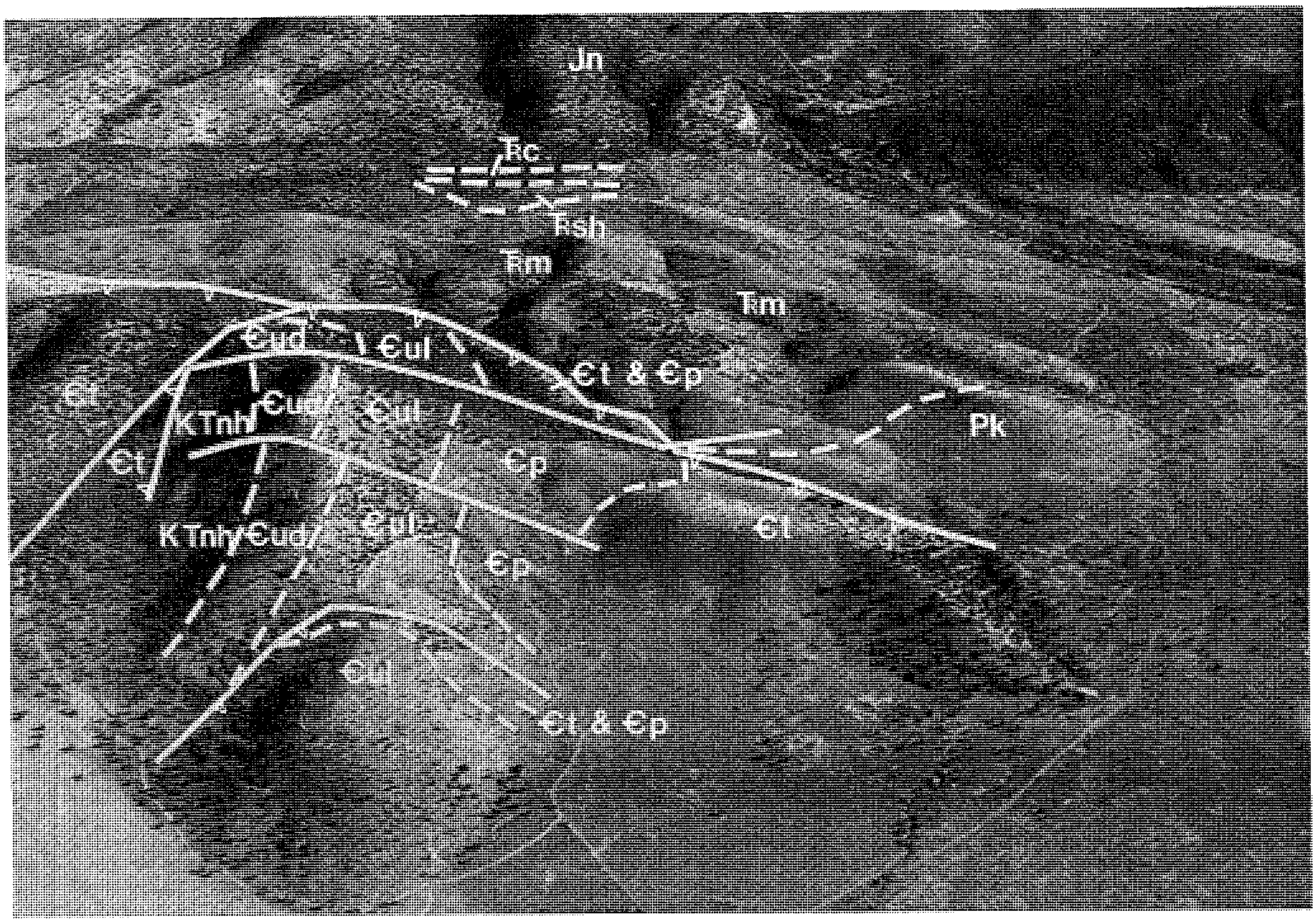


FIGURE 11.—*Halfway Hill. View is southeast, showing Cambrian strata thrust over Permian and Triassic units (sections 7, 8, 17, 18, T. 22 S, R. 4 W, Fillmore Quadrangle).*

estimated that a maximum of 75 m is exposed. Because of the dinosaur and mammal fossils found in it in other areas, Spieker (1946) suggested a Cretaceous–Tertiary age for the formation. Stolle (1978) indicated that oncolites provide a good lithologic marker in distinguishing lower Tertiary from Upper Cretaceous strata.

## TERTIARY–QUATERNARY SYSTEMS

### *Sevier River Formation*

In the Fillmore and Kanosh Quadrangles the Sevier River Formation consists of three basic lithologies. The lowest is a white to light gray unit of interbedded conglomerate, sandstone, and siltstone beds. The middle contains alternating sandstone, siltstone, and limestone beds with abundant volcanic debris. The upper is red, coarse-grained sandstone and conglomerate.

The lowest unit is a light gray sequence of interbedded conglomerate, sandstone, and siltstone beds. This sequence is thin bedded (maximum bed thickness observed: 50 cm) and repetitive. The conglomerate and sandstone layers contain about 40% lithic fragments. The grains and pebbles are angular, and the matrix is composed of clay and volcanic ash. Thin ash beds occur interbedded in this sequence and contain abundant angular quartz fragments and biotite.

The middle unit is very similar to the lowest. It is very poorly exposed and is recognized by light gray to light grayish purple slopes covered with limestone and volcanic float. The material making up the slope is probably eroded, thin-bedded sandstone, siltstone, shale, and volcanic ash beds. The limestone beds are numerous and no more than 50 cm thick. They are light brown, micritic, contain algal laminations, and abundant small gastropods (less than 3 mm). Dark brown, translucent chert deposits are associated with these limestone beds. Appearing in the slopes of this middle unit are extrusive volcanic clasts up to 70 cm in diameter, including rounded fragments of andesite, latite, and tuff similar to the rocks of the Marysvale area.

The upper unit is a light to dark red conglomerate

FIGURE 12.—*Oncolites in the North Horn Formation.*

composed of rounded lithic fragments in a matrix of medium- to coarse-grained, cross-bedded sandstone. Most of the clasts are quartzite and carbonate pebbles and cobbles; however, some volcanic clasts and some clasts of red sandstone and oncolitic limestone (probably from the North Horn Formation) occur.

The Sevier River Formation is exposed as an old pediment surface that has been subject to faulting and erosion. It is typically very poorly exposed. The best exposures occur in the Fillmore Quadrangle along the north side of Chalk Creek, in a streambed in the northeast corner of the quadrangle (NW $\frac{1}{4}$, section 11, T. 21 S, R. 4 W), and in a small pit dug in the north side of a hill in the northeast corner of the quadrangle (SW $\frac{1}{4}$, section 11, T. 21 S, R. 4 W). For the most part, the Sevier River Formation occurs as a series of dissected, low-relief, rounded ridges in the northeastern half of the Fillmore Quadrangle and in the Kanosh Quadrangle south of Corn Creek.

The thickness of the Sevier River Formation is unknown. In a well drilled in the northern Pavant Valley, more than 600 m of the formation was encountered (McDonald 1976). It is difficult to estimate the actual thickness in the Fillmore and Kanosh Quadrangles because of poor exposure, erosion and fault repetition and deletion of beds. The formation is considered to be Pliocene to Pleistocene in age (Callaghan 1938).

## QUATERNARY SYSTEM

### *Basaltic Volcanic Rocks*

On the western edge of the Kanosh Quadrangle is a series of volcanic deposits known as the Kanosh volcanic field, consisting of cones, flows, and unconsolidated water-deposited cinders (fig. 13). Subsurface layers of basalt have also been encountered in a number of water wells drilled in the area (Dennis and others 1946). These volcanic rocks are composed of basalt with phenocrysts of plagioclase, olivine, and augite (Hoover 1974).

The volcanic deposits follow a linear trend that is nearly north-south, starting from a small outcrop just south of county road 130 (section 26, T. 23 S, R. 6 W) to a large exposure 2 km north of Black Rock Volcano (section 11, T. 23 S, R. 6 W).

Well-developed Lake Bonneville terraces can be seen on the slopes of the cones. Hoover (1974) has radiometrically dated the Kanosh Volcanics at 670,000 B.P.

### *Tufa Deposits*

North of the volcanic exposures, following the same trend, is a large tufa deposit. The tufa is calcareous and forms banded and porous deposits that are very crumbly when weathered (fig. 14). They appear to have been formed by mineralized waters issuing from a long linear fracture system (with some local radial features) that appears to be aligned with the volcanic trend. The main fracture is about 2 km long and trends 23° northeast. From the valley floor to the top of the deposit relief is approximately 30 m.

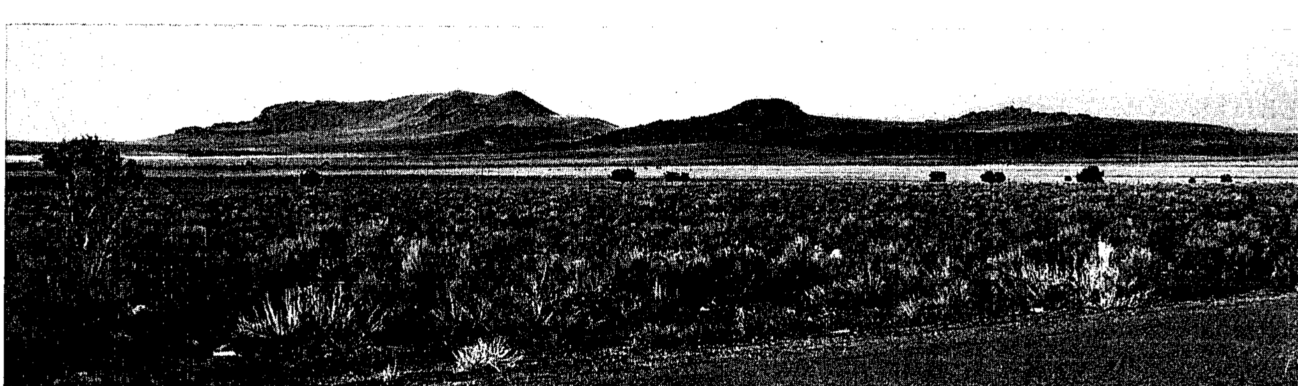

FIGURE 13.—*Kanosh volcanic field from the south (sections 13, 14, 23, 24, 26, T. 23 S, R. 6 W, Kanosh Quadrangle).*

*Lake Bonneville Deposits*

Lake Bonneville deposits can be seen most strikingly as numerous terraces on the flanks of Black Rock Volcano west of Kanosh. The most prominent of them is between 1,560 and 1,566 m (5,120 and 5,140 ft) in elevation. A terrace at this level is also persistent south of Kanosh and continues intermittently along the west flank of the Pavant Range through both quadrangles. These terraces are composed of rounded, cross-bedded, unconsolidated cobbles, pebbles, sand, and silt. Water wells drilled in Pavant Valley have encountered similar unconsolidated deposits along with clay beds (Dennis and others 1946). Near the volcanic cones the lake deposits are composed mostly of volcanic detritus. Although deposits of many stages of Lake Bonneville are present, the terraces between 1,560 and 1,566 m probably represent Bonneville level deposits (Bissell 1968).

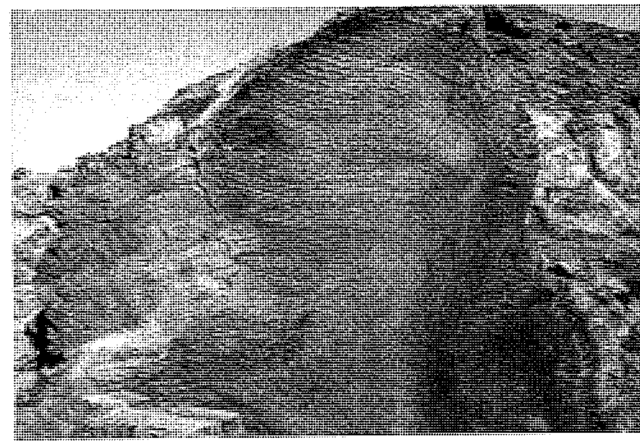

FIGURE 14.—*Vertical cut through tufa deposit (from outcrop northwest of Kanosh, sections 25, 26, 35, 36, T. 22 S, R. 6 W, Kanosh Quadrangle, height approximately 5 m).*

*Quaternary Alluvium*

Recent alluvial deposits cover many outcrops and fill most stream valleys. They consist of unconsolidated boulder, gravel, sand, and silt deposits.

## STRUCTURE

### GENERAL STATEMENT

The Fillmore and Kanosh Quadrangles are located in the Utah thrust belt. The late Mesozoic Pavant thrust and associated folding are the dominant structural features. Many minor thrust faults add to the structural complexity of the area. Cenozoic normal faults are also present.

### THRUST FAULTS

*Pavant Thrust*

The dominant structural feature of the Pavant Range is the Pavant thrust. Its eastern trace crosses through the southeastern corner of the Fillmore Quadrangle (fig. 15). From its northernmost exposure in the quadrangle, the surface trace increases in elevation 760 m to a high point 2,680 m above sea level just north of Meadow Creek (fig. 7), where the Tintic Quartzite rests on Navajo Sandstone. From a distance the fault can be seen as a bench on top of the Navajo Sandstone above which the Tintic Quartzite cliffs arise. Because of heavy vegetation and soil cover, the actual fault plane is poorly exposed. Local fracturing, discoloration of beds, and alteration of the Navajo Sandstone to a quartzite help to define the fault plane. In addition, most canyons contain springs where they intersect the fault line.

At its eastern exposure, the plane of the Pavant thrust is nearly horizontal, however, at the eastern boundary of the Fillmore Quadrangle the plane of the fault dips about 15° in an easterly direction. Lautenschlager (1952) states that this dip is a result of postthrust tilting of the range.

Although the eastern position of the Pavant thrust is well established, its position west of the mountain front is less clear. Erosion has removed the Pavant thrust and associated allochthonous rocks from much of the western part of the range. Deposition of post mid-Tertiary deposits and structural complications, resulting from multiple episodes and styles of faulting, have further masked its western position. Remaining are about a dozen geographically isolated exposures of Cambrian rocks cropping out west and north of the mountain front (fig. 15). For the purpose of distinguishing these outcrops as allochthonous, the western trace of the Pavant thrust has been placed at the contact between them and the overturned exposures of Paleozoic and Mesozoic rocks to the east and south (fig. 15).

Nowhere in the quadrangles west of the mountain front is the plane of the Pavant thrust exposed. For this reason its dip cannot be directly observed. Most of the beds directly above the thrust dip about 20° to 40° away from the mountain front. This dip seems to provide a reasonable estimate for the attitude of the plane of the Pavant thrust west of the mountain front.

The geometry of the Pavant thrust is shown in a generalized cross section drawn through the western part of the Pavant Range in figure 16. The Fillmore and Kanosh Quadrangles are located in the area where the Pavant thrust cuts up through the Paleozoic and lower Mesozoic section to override Jurassic rocks. Because so much of the Tintic Quartzite is exposed at the base of the thrust to the east, it is possible that the basal décollement may have occurred within the upper part of the Precambrian Mutual Formation, west of the quadrangles.

The direction of movement of rocks along the Pavant

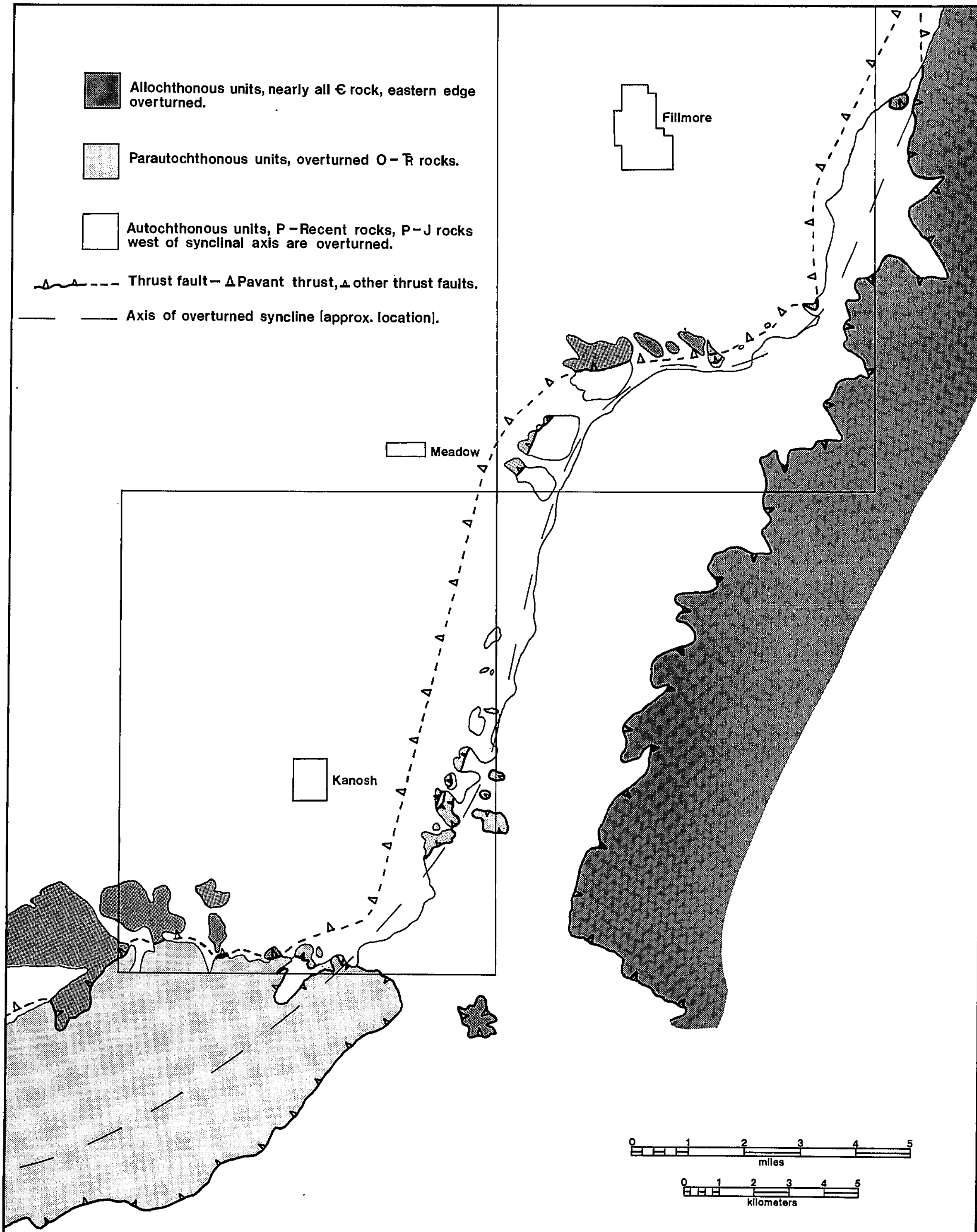


FIGURE 15.—*Generalized geologic map of the Pavant Range near Fillmore and Kanosh.*

thrust is obvious in the Fillmore and Kanosh Quadrangles. Extending the full length of the mountain range in the quadrangles is a west-dipping overturned syncline (discussed in detail later) that formed during the thrusting event. The axis of the fold is horizontal, and its average trend is about 30° northeast (fig. 15). Figure 17 is a rose diagram showing the strike of beds taken on exposures of the western overturned limb of the syncline. The dominant strike direction confirms the estimate for the trend. Assuming that the principle stress or thrust direction is perpendicular to the axis of the synclinal fold, the rocks moved along an azimuth of 120° to the southeast.

However, localized changes in the direction of thrusting occur. Just north of Meadow Creek in the Fillmore Quadrangle and south of Corn Creek in the Kanosh Quadrangle, the trend of the axis of the principal syncline shifts to the west. Data collected to determine the direction of thrust movement in these areas follow:

1. In figure 17 a small cluster of measured strikes between 50° and 70° northeast represents the strike of beds in the areas where the synclinal fold axis changes its trend.
2. A conjugate fracture pattern was observed on aerial photos in Navajo Sandstone near Corn Creek. The principal strike of the conjugate pair was 0° north and 300° northwest.
3. In outcrops of the Tintic Quartzite, near the fault trace of the Pavant thrust north of Dameron Canyon, a conjugate fracture pattern was observed. Figure 18 shows a rose diagram of the strike of major fractures with slickensides. The dominant pair of fractures strikes 25° northeast and 325° northwest.

From these data it is seen that, where the axis of the overturned syncline deflects to the west, the local direction of apparent thrusting deflects 30° to 55° to the south. This deflection may have been caused by the movement of the Pavant thrust sheet against some type of stable foreland irregularity. Beuther (1977) has observed similar phenomena throughout much of the Wyoming-Utah thrust belt. Figure 19, adapted from Beuther (1977), shows his model of the deflection of the principle stress ($\sigma_1$) for a deformable slab compressed against an irregular foreland. Note that as the boundary between the stable foreland and the deformable slab shifts to the west, the principle stress or direction of thrusting is deflected to the south. Davis (1983) referred to the "Tushar Buttress" as the agent of deflection of the Pavant thrust south of Kanosh.

The previous estimate for the magnitude of displacement of rocks along the Pavant thrust was a minimum of 19 km and a minimum total shortening of 32 km (Hickcox 1971). I think that the actual displacement is less. In cross sections made from west to east across parts of the Pavant Range, using an approximate thickness of 5,832 m of Paleozoic and Mesozoic rocks involved in tectonism and projecting the structure of the beds westward, I estimate a horizontal displacement along the Pavant thrust of 12 to 14 km. This estimate is supported by good surface data for the eastern position of allochthonous rocks and the subsurface structural configuration inferred from overturned autochthonous rocks on the west flank of the range.

### *Thrust Faults in the Hanging Wall*

Thrust faults within allochthonous Cambrian units occur north of Dameron Canyon in the Kanosh Quadrangle (fig. 20), on Halfway Hill, and on a small hill 1 km to the east in the Fillmore Quadrangle. These thrust faults cause surface repetition of Tintic Quartzite through Cambrian dolomite units as well as the North Horn Formation which overlies them. Dahlstrom (1977) and Seria (1977)

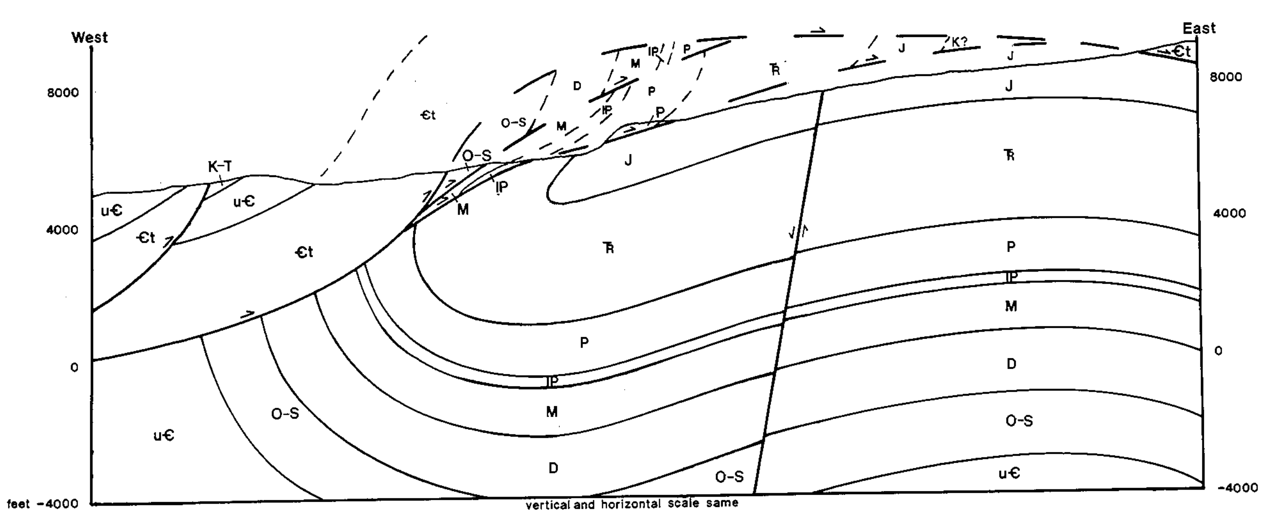


FIGURE 16.—*Idealized cross section through the eastern edge of the Pavant Valley and western edge of the Pavant Range.*

have described imbricate thrust faults in frontal and ramp areas, respectively, as subsidiary to the major fault. I think the thrust faults in allochthonous Cambrian units west of the mountain front are imbricate thrust faults intersecting the Pavant thrust at depth (fig. 16).

Previous workers in the area did not describe these Cambrian exposures as thrust-repeated units. Crosby (1959) and Feast (1979) postulated that these repetitious, en echelon outcrops are separated by tear faults. I found no evidence for this in the field; only thrust faults that have been offset by minor normal faults occur. Anomalous stratigraphic relationships occur along dip, as one would expect with multiple thrust faults, and not along strike. The geographically separated en echelon pattern of the outcrops appears to have been caused by deposition of alluvium in strike valleys formed in the Pioche Formation.

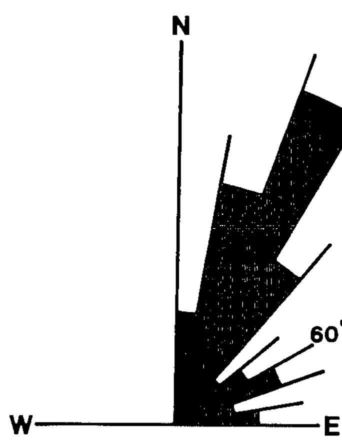


FIGURE 17.—*Rose diagram showing the dominant strike of beds in 40 exposures of overturned, west- and north-dipping autochthonous units.*

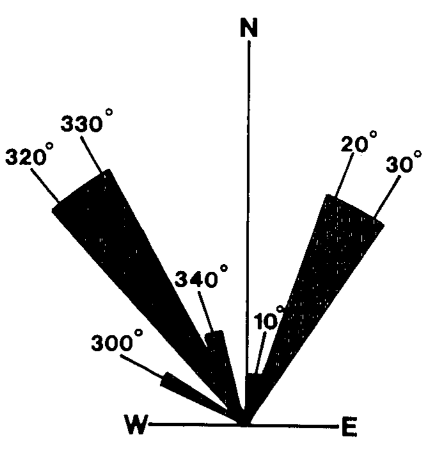


FIGURE 18.—*Rose diagram showing the dominant strike of 16 fractures with slickensides taken from exposures of the Tintic Quartzite north of Dameron Canyon (section 5, T. 24 S, R. 5 W, and section 35, T. 23 S, R. 6 W, Kanosh Quadrangle).*

### *Thrust Faults in the Footwall*

Imbricate thrust faults cut the footwall of the Pavant thrust in both quadrangles. These faults commonly dip between 15° and 25°. They are characterized by relatively small displacements of overturned Paleozoic and Mesozoic units (fig. 16). Structural and stratigraphic relationships in many small outcrops have previously been misinterpreted because little deformation occurs along the fault plane, and formations that are similar in lithology are brought in contact with each other.

In the Fillmore Quadrangle three of these thrust faults are exposed. One is 3 km east of Halfway Hill where overturned Cove Fort Quartzite rests on a section of overturned Moenkopi Formation. Another is at Halfway Hill where overturned Kaibab Limestone overlies overturned Moenkopi Formation (fig. 21). The last is exposed south of Meadow Creek where overturned Callville Limestone and Pakoon Dolomite are in thrust contact with the Kaibab Limestone (fig. 8).

Numerous exposures of these thrust faults also occur in the Kanosh Quadrangle. Erosional remnants of two such faults are exposed 4 km east of Kanosh in a series of outcrops near the mountain front. One fault places overturned Kaibab Limestone and Moenkopi Formations over Triassic-through-Jurassic rocks. The other fault places overturned Redwall Limestone on Permian formations (fig. 22). Thrust faults similar in relationship to those

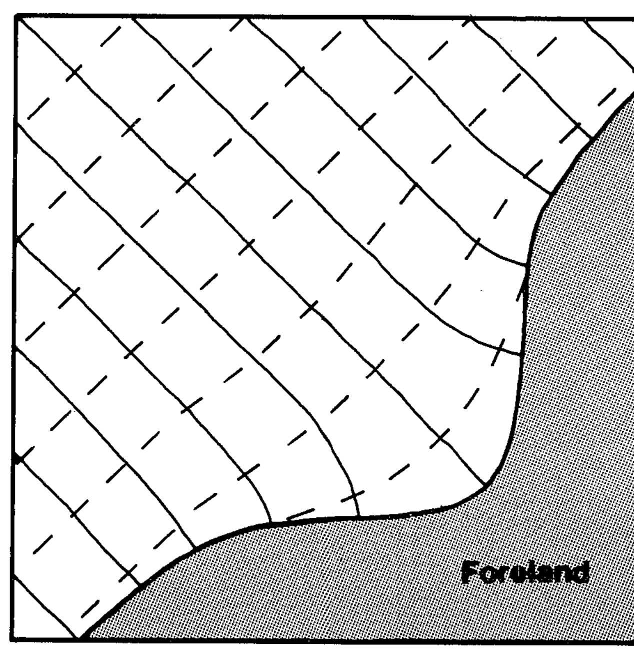


FIGURE 19.—*Diagram showing a deformable slab compressed against an irregularly shaped foreland (adapted from Beuther 1977). Diagonal solid lines represent the principal stress ($\sigma_1$) or direction of thrust movement.*

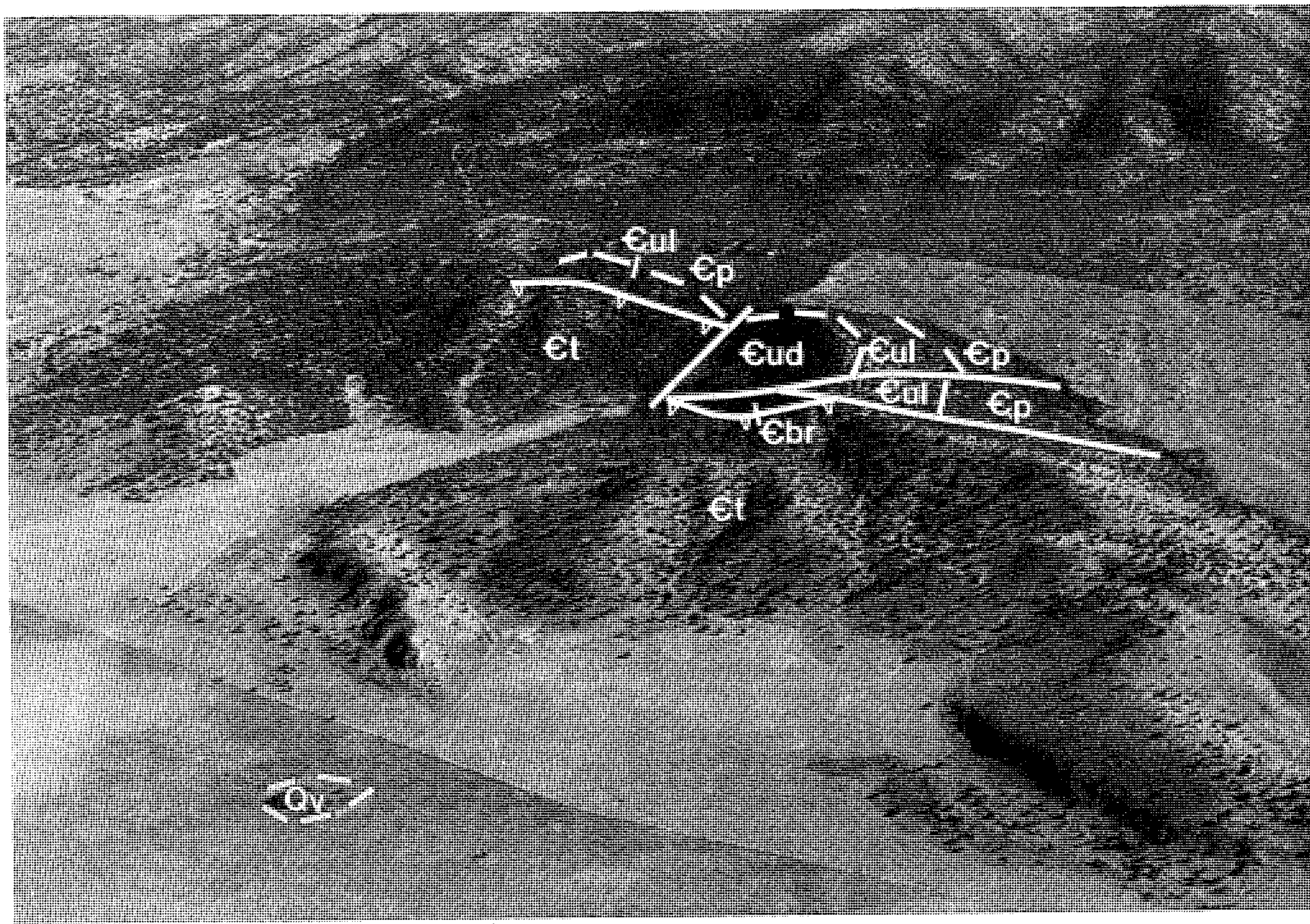


FIGURE 20.—*View southeast toward thrust fault in Cambrian rocks in the hills southwest of Kanosh (sections 35, 36, T. 23 S, R. 6 W, Kanosh Quadrangle).*

east of Kanosh are exposed 5 km south of Kanosh along the mountain front. Near Dameron Canyon other thrust faults place overturned Pogonip Group over Eureka Quartzite, and Eureka Quartzite over Bluebell Formation.

Because these thrust faults are so poorly exposed, it is difficult to discern the direction of offset. One outcrop immediately south of Dewal Spring exposes the plane of the thrust fault dipping 25° to the northwest (fig. 23). Another thrust fault that places overturned Kaibab Limestone over overturned Moenkopi Formation can be seen at Halfway Hill, where a prospect pit has been dug along the fault plane (fig. 21). The fault plane dips to the northwest at about 18°. Everywhere the dip of these faults follows the same trend as that of the Pavant thrust.

One striking feature that distinguishes these thrust faults from the Pavant thrust, aside from the different lithologies involved in the thrusting, is the magnitude of displacement of rocks along the fault. From cross sections drawn through various areas, the maximum displacement on any one of these faults is approximately 3,000 meters. As these faults continue beyond the Kanosh Quadrangle to the southwest, the maximum displacement along any one of them is approximately the same (Davis 1983).

## FOLDS

One of the main structural features of the Fillmore and Kanosh Quadrangles is an asymmetric, northwest-dipping, overturned syncline that extends along much of the mountain front in both quadrangles. The axis of the syncline is horizontal and is located approximately at the boundary between the Pavant Range to the east, and the foothills to the west (fig. 15). The eastern limb of the syncline forms the mountain front and is characterized by outcrops of Navajo Sandstone dipping 10° to 20° to the west. The western limb of the syncline forms foothills west of the mountain front. It is characterized by exposures of overturned Kaibab, Moenkopi, and Chinle formations dipping between 20° and 60° to the west and northwest. This limb has been sheared off by thrust faults and overlain by allochthonous and parautochthonous rocks.

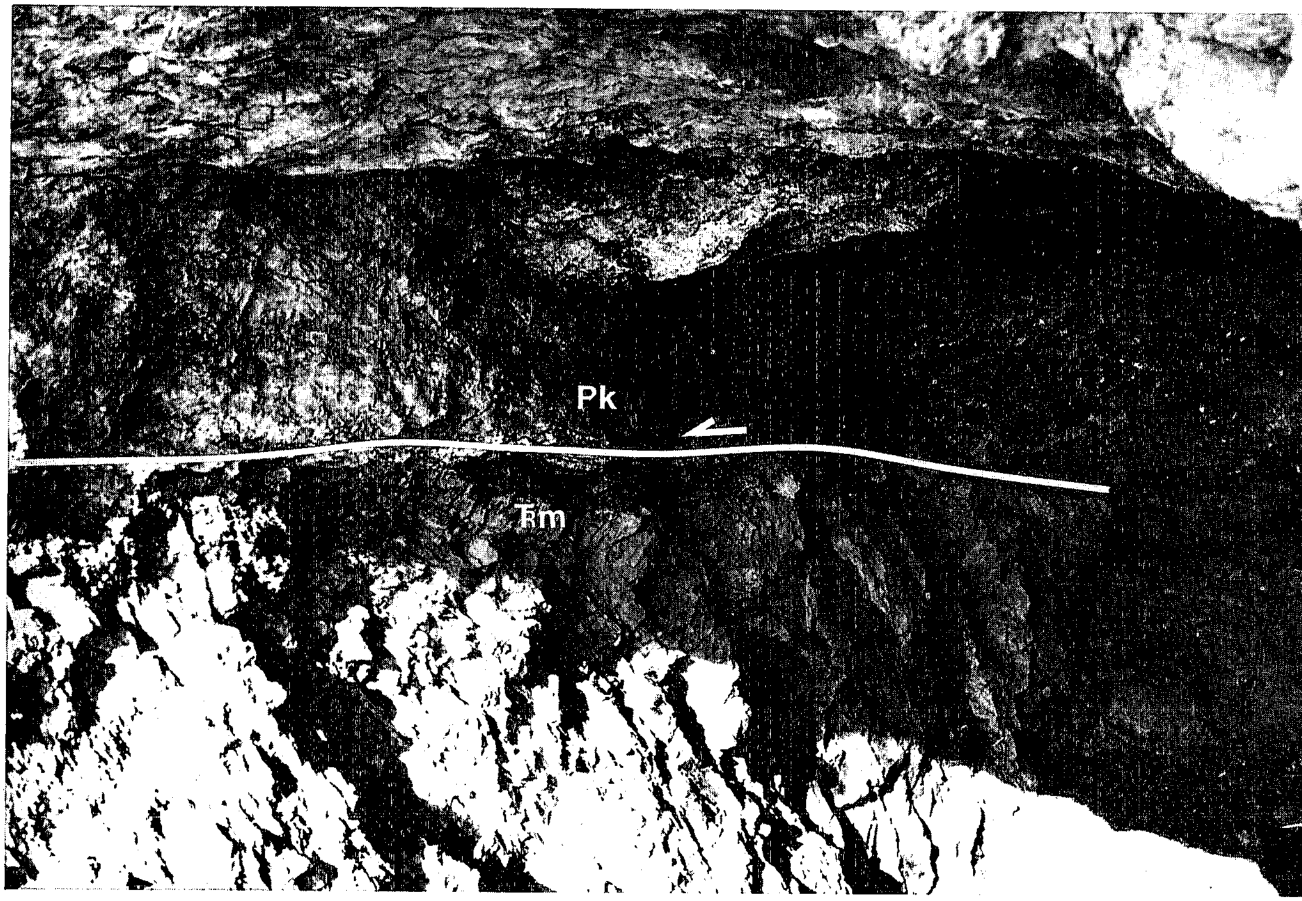


FIGURE 21.—*Thrust fault exposed in a prospect pit at Halfway Hill (section 7, T. 22 S, R. 4 W, Fillmore Quadrangle).*

Figure 16 shows the geometry of the fold. Surface exposures of the fold occur near its center where the folding is very tight. In many places overturned Permian and Triassic formations are exposed only tens of meters west of Navajo Sandstone, which forms the mountain front and is not overturned. Because of this exposure, the asymmetry of the fold, and the discontinuous nature of exposures west of the mountain front, previous workers have inferred the existence of a major normal fault which separates rocks in normal sequence to the east from overturned rocks to the west. I think this inference is a misinterpretation. Some observations that support my conclusion are as follows:

1. Cross sections drawn at several locations along the western front of the Pavant Range imply that the positioning of the exposures and thickness of the units is consistent with the structural model.
2. Outcrops of overturned, west-dipping Triassic rocks are consistently exposed (except where covered by Tertiary and Quaternary deposits) at the same horizontal distance from rocks in normal sequence to the east, even when the mountain front changes trend. It is unlikely that displacement of rocks by normal faulting would produce such an outcrop pattern along a sinuous course across the length of both quadrangles.
3. In the Fillmore Quadrangle just east of where the north and south forks of Chalk Creek join (SW $\frac{1}{4}$, section 25, NW $\frac{1}{4}$, section 26, T. 21 S, R. 4 W), the east limb of the syncline is cut by a high-angle fault which displaces rocks about 150 m down to the east. West of the fault the interior of the syncline has been exposed, showing tightly folded Navajo Sandstone at the center (fig. 24), surrounded on both sides by exposures of the Chinle Formation. Maxey (1946) and others have previously interpreted this fault as down to the west, having major vertical displacement.
4. Just north of Meadow Creek on the southeast side of Halfway Hill (fig. 11), a good exposure of the Shinarump Conglomerate can be observed, yet just south of Meadow Creek (W $\frac{1}{2}$, section 19, T. 22 S, R. 4 W) the Shinarump Conglomerate appears to be missing (fig. 8). Both Feast (1979) and Maxey (1946)

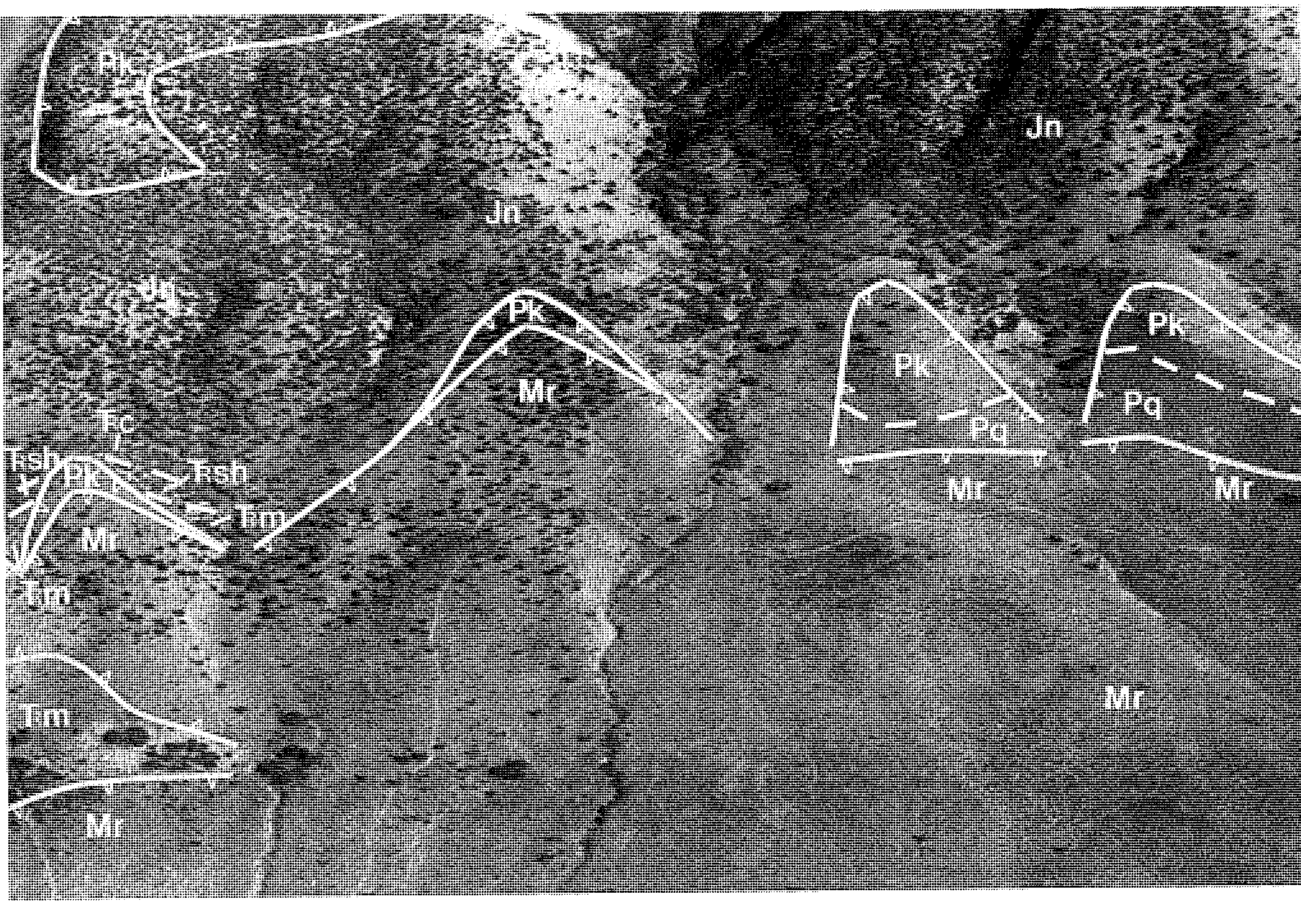


FIGURE 22.—*Hills east of Kanosh. View is east toward Paleozoic units thrust over Paleozoic and Mesozoic units (sections 22, 23, 26, 27, T. 23 S, R. 5 W, Kanosh Quadrangle).*

resolved this problem by inferring the existence of a west-dipping normal fault running along the mountain front. This fault is not evident in the field. South of Meadow Creek bits of petrified wood, smooth rounded quartzite pebbles, and boulders from the Shinarump Conglomerate were found immediately downslope from its normal place of exposure. I think that no normal fault exists there and that the Shinarump Conglomerate has been covered by slope wash from the easily eroded shales of the Chinle Formation.

5. Deep V-shaped canyons and the abrupt western termination of the erosion-resistant Navajo Sandstone have been used as evidence implying the presence of high-angle faults bordering the western mountain front. I think westward termination of the Navajo Sandstone has been caused by folding and thrust faulting. The V-shaped canyons have been produced by erosion due to the subsequent uplift of the range and abrupt westward termination of the erosion-resistant Navajo Sandstone.
6. Feast (1979) showed a normal fault bordering the mountain front because he said it would be highly unlikely to fold a thick, resistant unit like the Navajo Sandstone so tightly. At many places along the mountain front, I have observed fracturing, slickensides, folding, and thrust faults in the Navajo Sandstone. I think that this type of deformation could have accommodated the tight folding present.

Parallel to and east of the synclinal fold, an anticlinal fold occurs in the Fillmore Quadrangle. It is best seen by the change in the dip of the Navajo Sandstone at the western part of the range (17° west) to its shallow eastward (15° to 20°) dip several kilometers to the east. Forethrust anticlinal folds in autochthonous rocks are common along the western thrust belt in northern Utah, Idaho, and Wyoming. The axis of the fold is parallel to the synclinal fold and seems to plunge slightly at both ends, reaching a high point just north of Meadow Creek Canyon (fig. 7).

Minor folds in overturned Triassic rocks at Halfway Hill and in Mississippian-through-Permian rocks east and south of Kanosh were also observed. Determination of

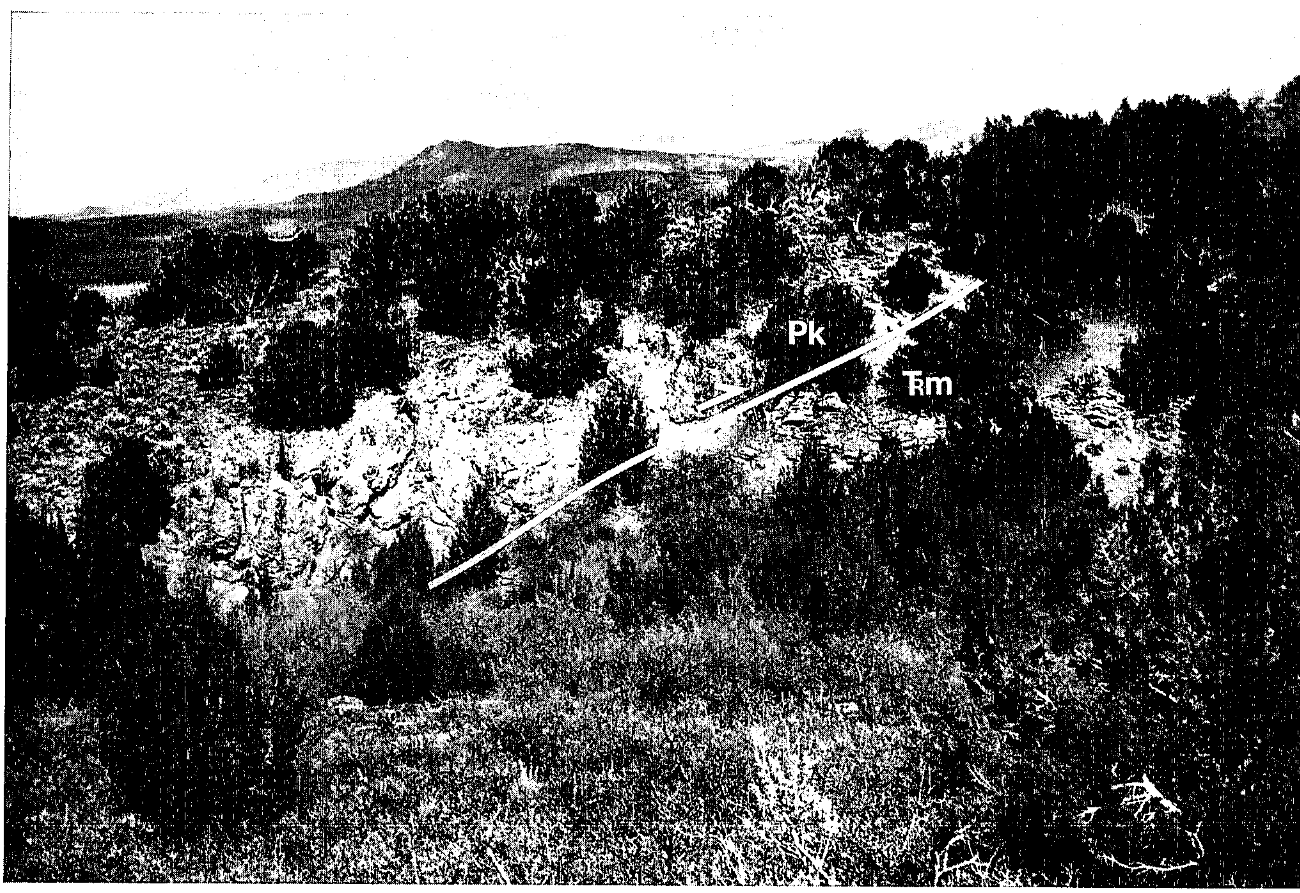


FIGURE 23.—*Thrust fault exposed about 1 km south of Dewal Spring (section 3, T. 24 S, R. 5 W, Kanosh Quadrangle).*

the trend of their fold axis was impossible because of poor exposure. I think that these minor folds are related structurally to the thrusting event and are probably drag folds.

## NORMAL FAULTS

Numerous normal faults occur in the Fillmore and Kanosh Quadrangles. Most of these faults exhibit less than 200 m of stratigraphic displacement. Most trend north-northeast or north-northwest. They appear to cut all formations in the quadrangles except alluvium. No major high-angle-fault offset has been observed between the mountain front and outcrops immediately west, as previously mentioned. The major basin-and-range faults probably occur along the western edge or west of the quadrangles. In a gravity survey of the area, Isherwood (1967) reports a major zone of normal faulting 12 to 19 km west of the Pavant Range. High-angle faults may occur along the west edge of the Kanosh Quadrangle as indicated by the linear trend of the volcanic and hot spring deposits (Hoover 1974).

In the Fillmore Quadrangle one normal fault of special interest trends northeast and intersects Chalk Creek approximately 800 m west of the boundary of the Fishlake National Forest. In roadcuts south of Chalk Creek and in outcrops to the north, beds can be seen dipping east into the fault. Farther west the beds flatten. Royce and others (1975) described a type of normal fault in thrust-faulted regions whose fault plane flattens at depth and soles into a thrust fault. This kind of fault occurs in areas where thrust faults ramp up through the stratigraphic section. Because the Pavant thrust cups up through the stratigraphic section in this area in the subsurface (cross section A, Fillmore map, plate 1), it is likely that the plane of the normal fault soles into the Pavant thrust.

Recognition of this type of normal fault in the area may also help to explain a structural problem at Halfway Hill. A north-striking fault separates a large section of Tintic Quartzite in the northeastern part of the hill from younger Cambrian rocks to the west. This fault occurs in the area where the Pavant thrust cuts rapidly upward through the stratigraphic section. I think the fault is a normal fault that soles into the Pavant thrust (cross section A, Fillmore map, plate 1). This would explain why younger rocks crop out west of the large exposure of Tintic Quartzite. It would also explain the anomalously thin Tintic Quartzite section at the base of the Pavant thrust west of the fault.

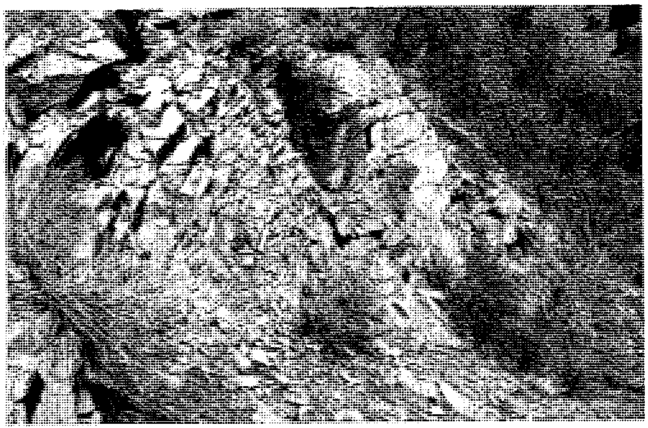

FIGURE 24.—*Folded Navajo Sandstone exposed in the canyon of the south fork of Chalk Creek (section 36, T. 21 S, R. 4 W, Fillmore Quadrangle).*

## STRUCTURAL HISTORY

The first major structural event affecting the quadrangles was the formation of the Pavant thrust. During this event, rocks were folded and thrust to the southeast. The Pavant thrust, the large asymmetric overturned syncline, and most of the other folds and thrust faults were formed during this event. The age of this folding and thrusting is latest Cretaceous.

Contemporaneous with and following the Pavant thrust episode, the area experienced a period of erosion. Debris shed from this tectonic highland was deposited in the area as the Price River and North Horn Formations.

Following deposition of the North Horn Formation, another episode of deformation occurred. West and north of the mountain front is a series of thrust-repeated Cambrian outcrops mentioned previously. Discordantly overlying Cambrian dolomite and limestone units on each of these thrust slices are outcrops of the North Horn Formation (interpreted as Sevier River Formation by previous workers). These exposures show dips of 40° to 75° to the northeast, while the North Horn Formation east of the Pavant thrust dips uniformly 15° to the east. Figure 25 shows the plot of poles to bedding planes of the North Horn Formation and the underlying Cambrian dolomite for four geographically separated outcrops. Assuming that the North Horn Formation was deposited horizontally over the Cambrian rocks, the clustering of the rotated Cambrian dolomite poles indicates uniform orientation of Cambrian beds throughout both quadrangles during the deposition of the North Horn Formation. The clustering of the North Horn Formation poles indicates that the outcrops of conglomerate were probably brought to their present orientation by the same structural event or by similar structural events having similar directional components. I think that the event that produced this deformation was an additional thrust-faulting episode affecting rocks west of the present mountain front. Because the North Horn Formation is deformed, this faulting occurred during the Paleocene.

The next structural deformation began with Miocene basin-and-range faulting. Major displacement along basin-and-range faults probably occurred along faults at the western edge of the quadrangles, now covered by lake sediments and alluvium. There is evidence in the quadrangles that basin-and-range-type faulting continued through at least early Pleistocene. Several faults cutting the Sevier River Formation have been observed. Also numerous conglomerate layers in the Sevier River Formation imply periods of uplift and erosion during the Pliocene-Pleistocene. No fault scarps have been observed in Lake Bonneville sediments or alluvium. The most recent tectonic activity appears to be an episode of basaltic volcanism in the Kanosh Quadrangle dated at 670,000 B.P. (Hoover 1974).

## SUMMARY

The following is a summary of observations about the geology of the Fillmore and Kanosh Quadrangles.

A. Surface exposures of rocks can be placed into four groups:
   1. Allochthonous, right-side-up Cambrian rocks, some overlain by Cretaceous-Tertiary strata.
   2. Parautochthonous, overturned Paleozoic and Mesozoic rocks.
   3. Autochthonous, right-side-up and overturned Paleozoic and Mesozoic rocks.
   4. Cenozoic sedimentary deposits and igneous rocks.

B. Previously unmapped exposures of Devonian, Mississippian-through-Permian, and Cretaceous-through-Quaternary formations occur within the quadrangles.

C. Overturned Paleozoic rocks on the west and north flanks of the Pavant Range within the quadrangles, previously thought to be downfaulted, make up the western limb of an overturned syncline that has not been downfaulted.

D. Horizontal displacement on the Pavant thrust is approximately 12 to 14 km in the quadrangles.

E. Movement of rocks along the Pavant thrust and associated imbricate thrust faults was to the southwest.

F. Local changes in the direction of thrusting were probably caused by multiple episodes of thrusting and deflection of the thrusting due to the compression of rocks against an irregular foreland.

G. Deformation by folding and thrusting occurred in two events, one in latest Cretaceous and one in the Paleocene.

H. Outcrops previously thought to be offset by "shear" faults are proposed to be a series of imbricate thrust slices that are offset by normal faults and geographically separated by subsequent erosion and deposition.

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## APPENDIX

Locations of outcrops plotted on figure 25.

Outcrop 1—1 km southwest of Dewal Spring (Kanosh Quadrangle), SE $\frac{1}{4}$, NW $\frac{1}{4}$, section 3, T. 24 S, R. 5 W.
Cambrian dolomite—strike 290°, dip 40° NE
North Horn Formation—strike 310°, dip 75° NE

Outcrop 2—Halfway Hill (Fillmore Quadrangle), NW $\frac{1}{4}$, SE $\frac{1}{4}$, section 7, T. 22 S, R. 4 W.
Cambrian dolomite—strike 310°, dip 35° NE
North Horn Formation—strike 330°, dip 65° NE

Outcrop 3—First hill east of Halfway Hill (Fillmore Quadrangle), SE $\frac{1}{4}$, NW $\frac{1}{4}$, section 8, T. 22 S, R. 4 W.
Cambrian dolomite—strike 313°, dip 42° NE
North Horn Formation—strike 325°, dip 65° NE

Outcrop 4—Third hill, (2 km) east of Halfway Hill, SE $\frac{1}{4}$, NW $\frac{1}{4}$, section 9, T. 22 S, R. 4 W.
Cambrian dolomite—strike 282°, dip 25° NE
North Horn Formation—strike 320°, dip 40° NE

*The measured sections for this paper, on manuscript pages 43–66, are on file at the Department of Geology, Brigham Young University, where a copy may be obtained.*

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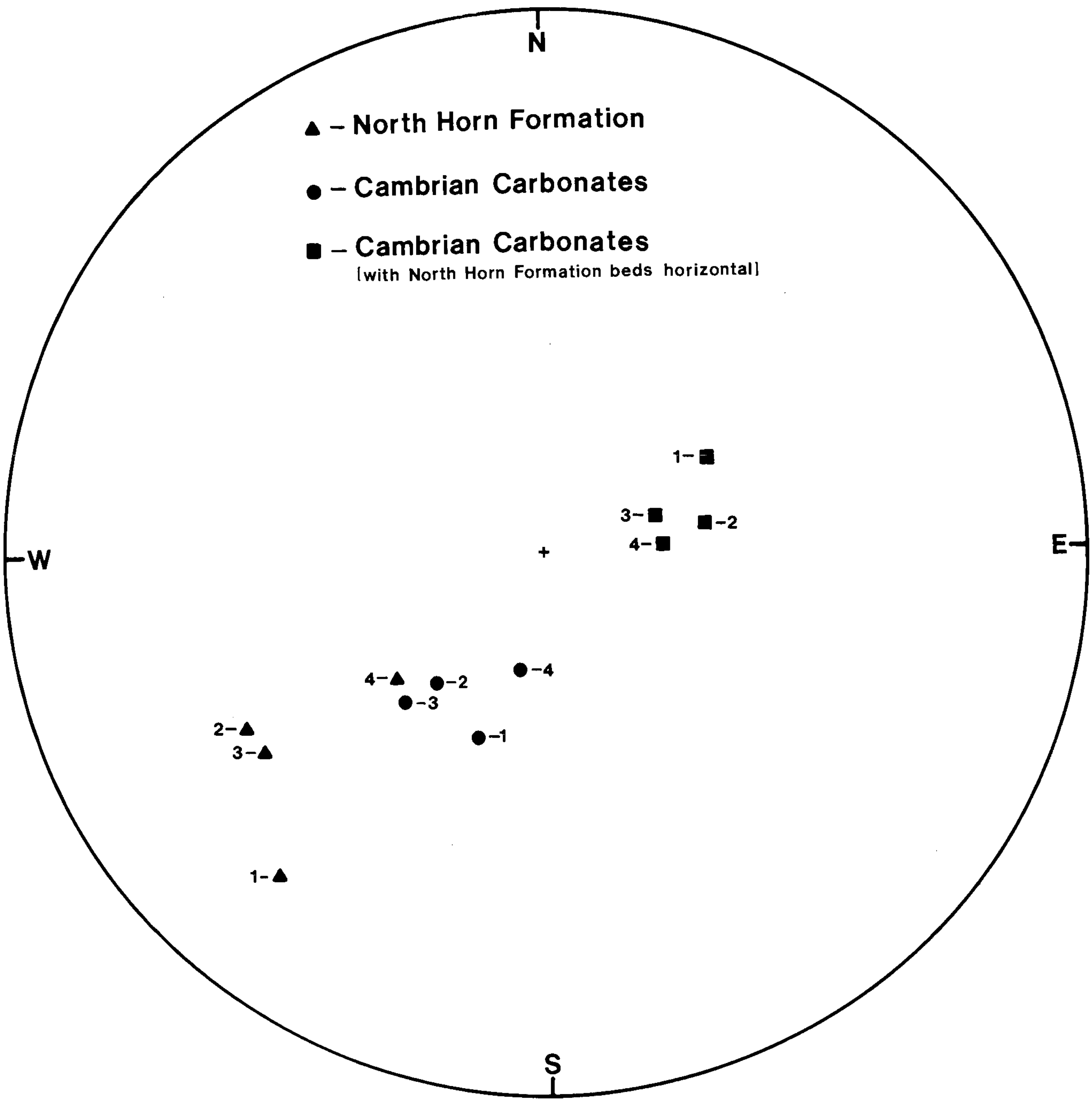


FIGURE 25.—*Poles of Cambrian carbonate and overlying North Horn Formation beds in four geographically separated outcrops (see appendix for location of outcrops).*