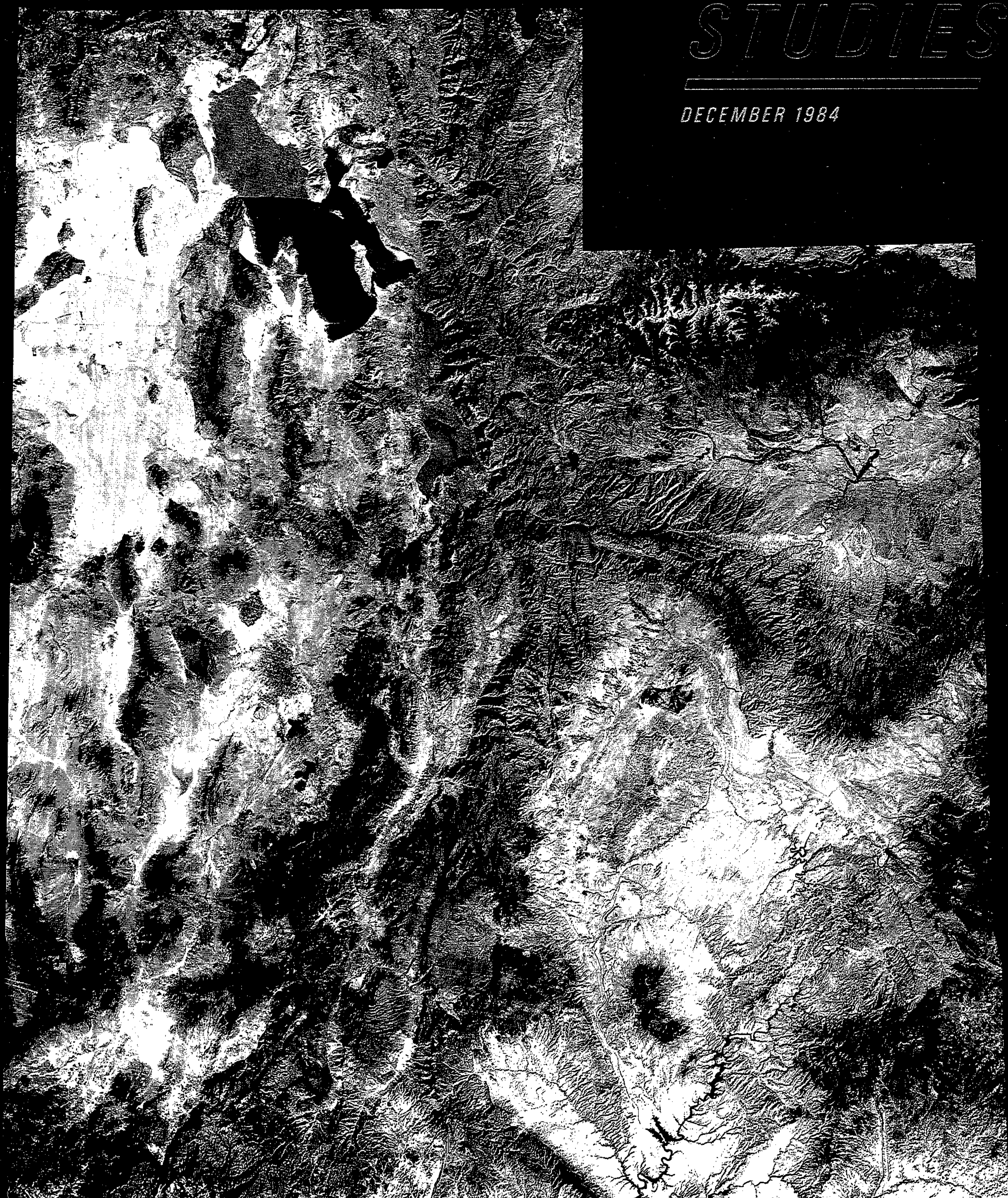
BRIGHAM
YOUNG
UNIVERSITY

GEOLOGY

STUDIES

DECEMBER 1984



VOLUME 31, PART 1

BRIGHAM YOUNG UNIVERSITY GEOLOGY STUDIES

VOLUME 31, PART 1

CONTENTS

A publication of the
Department of Geology
Brigham Young University
Provo, Utah 84602

Brigham Young University Geology Studies is published by the Department of Geology. This publication consists of graduate student and faculty research within the department as well as papers submitted by outside contributors. Each article submitted by BYU faculty and outside contributors is externally reviewed by at least two qualified persons.

Cover: LANDSAT Mosaic of the State of Utah. Fall 1976. U.S. Department of Agriculture, Agricultural Stabilization and Conservation Service. Salt Lake City, Utah: Aerial Photography Field Office.

ISSN 0068-1016
Distributed December 1984
12-84 600 74358

CONTENTS

Figures

Geology of the Northern Canyon Range, Millard and Juab Counties, Utah*

JOHN C. HOLLADAY
Provo, Utah 84602

Thesis chairman: LEHI F. HINTZE

ABSTRACT

Two thrust sheets are exposed in the Canyon Range, an upper one, the Canyon Range allochthon, and a lower allochthon. Comparison of Middle Cambrian stratigraphy of the Canyon Range allochthon with that of the lower allochthon of the Canyon Range, and the Pavant allochthon near Kanosh, 80 km to the south, showed differences in lithologic character, thicknesses, and paleontology between the first two, but close similarity of Cambrian strata of the lower allochthon of the Canyon Range and the Pavant allochthon. On the basis of this and other considerations, the lower allochthon of the Canyon Range is believed to be a northern extension of the Pavant allochthon.

The Canyon Range thrust initially moved in a southeasterly direction an estimated 21 km. Subsequent thrusting of the Pavant allochthon was in an easterly direction and of unknown magnitude. Folding of the range along a north-south axis coincided with movement of the Pavant thrust, and minor (1 km) recurrent movement of the Canyon Range thrust may have occurred during this later folding.

Stratigraphic units exposed in the area include late Precambrian, Cambrian, Ordovician, Cretaceous, and Tertiary rocks totaling more than 7,750 m. Precambrian strata included the Pocatello Formation, Blackrock Canyon Limestone, Caddy Canyon Quartzite, and Mutual Formation. Cambrian strata of the Canyon Range allochthon have been described in terms of House Range nomenclature and include all formations from the Tintic Quartzite through the Wheeler Shale, with an undivided carbonate unit above. Cambrian strata of the Pavant allochthon consist of Tintic Quartzite, Pioche Formation, and a 1,000-m-thick section of undivided carbonates that do not fit any established formational nomenclature in Utah. The thickness of Cambrian rocks in both sequences is approximately 2,000 m. A hundred meters of Ordovician Pogonip Group are exposed only on the Pavant allochthon. Cretaceous and Tertiary rocks are represented by 3,000 m of coarse synorogenic conglomerate and related postorogenic terrestrial sediments. They have been subdivided and mapped as the Canyon Range Formation, red beds of Wide Canyon, Fool Creek Conglomerate, and the Oak City Formation.

INTRODUCTION

The northern Canyon Range includes part of the fold and thrust belt of central Utah. It involves two folded, imbricate thrust sheets. The existence of the Canyon Range thrust was established by Christiansen (1952), but many parameters of thrusting including timing, direction, and magnitude have not been well defined. Particularly unclear is the relationship of the Canyon Range allochthon to the underlying Pavant allochthon, to the thick associated conglomerates, and to the folding of the range.

Detailed mapping of the northern Canyon Range has provided a clearer perspective on these matters. Both the footwall and headwall ramps of the Canyon Range thrust are recognized in this area, offering new data on the characteristics of the Canyon Range thrust. Mapping of subdivisions in the Precambrian stratigraphy has revealed a previously unknown exposure of the Canyon Range thrust east of Oak City and has shifted the position of the formerly recognized western thrust boundary of the Canyon Range klippe.

Comparison of the Lower and Middle Cambrian stratigraphy of the Canyon Range allochthon, Pavant allochthon of the Canyon Range, and the Pavant allochthon

*A thesis submitted to the Department of Geology, Brigham Young University, in partial fulfillment of the requirements for the degree of Master of Science, April 1983.

of the Pavant Range provide definitive evidence for extending the Pavant allochthon northward into the Canyon Range beneath the Canyon Range thrust. Subdivision and mapping of the 2,200+-m-thick section of the Cretaceous-Tertiary conglomerate on the east side of the range have provided data on basin-and-range fault trends, which defined the spatial relationship of the east limb of the Canyon Range syncline north of Wide Canyon.

LOCATION AND ACCESSIBILITY

The northern Canyon Range is located approximately 30 km east of Delta, Utah, and 50 km southwest of Nephi, Utah (fig. 1). Access within the area is provided by unimproved dirt roads and jeep trails. Relief is over 1,400 m, and many areas are accessible only on foot.

FIELD AND LABORATORY METHODS

Field mapping was recorded on 1:16,000 color aerial photographs and transferred to a 1:62,500 topographic map enlarged to 1:24,000. A Jacob's staff and compass were used to measure stratigraphic sections through selected exposures of strata that had not been previously examined in other areas of the Canyon Range.

Twelve palynological samples were prepared using standard techniques. Four samples yielded palynmorphs, and they were analyzed by Texaco Inc., but no definitive fossil forms were identified.

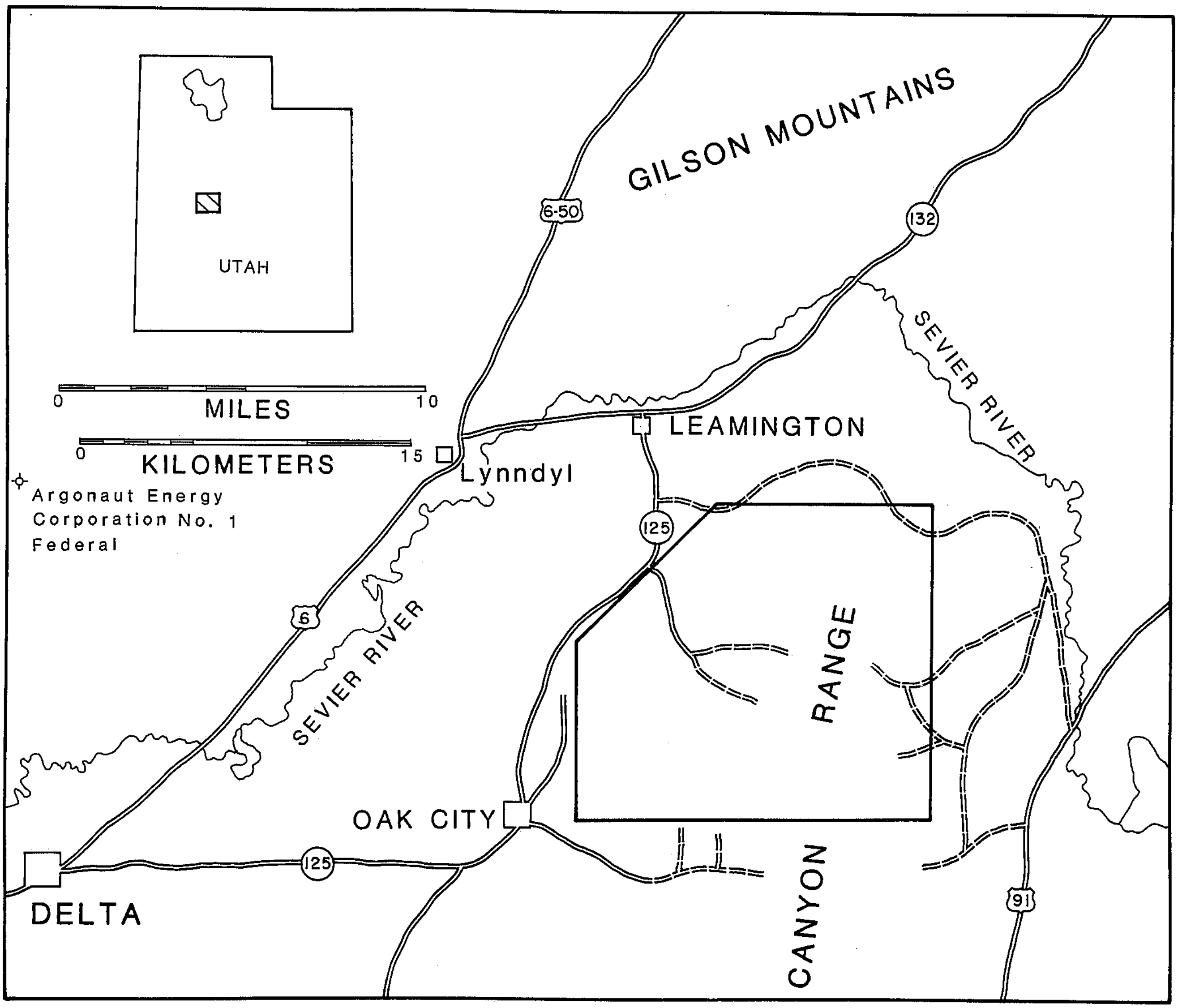


FIGURE 1.—*Index map of the northern Canyon Range.*

PREVIOUS WORK

Gilbert (1890) studied the Canyon Range in the Leamington Pass area but restricted his endeavors to Pleistocene Lake Bonneville geomorphic features. Loughlin (1914) conducted a reconnaissance study of the Canyon Range, concluding it contained Carboniferous limestone and quartzite uncomformably overlain by Cretaceous-Eocene conglomerate. Loughlin interpreted the regional structure as a north-trending anticline and syncline, bounded on the east by a strike-slip fault.

The first detailed study in the Canyon Range was by Christiansen (1952), who mapped the range on a scale of 1:62,500. He recognized basin-and-range normal faults on the east and west piedmonts, a major fold system, and the klippe of the Canyon Range thrust. Christiansen assigned the Canyon Range stratigraphy to upper Precambrian (undivided), Cambrian Tintic Quartzite, Ophir Formation, and undivided Upper Cambrian limestone and dolomite, Upper Cretaceous Indianola Group, Late Cretaceous to Paleocene North Horn Formation (?), Oligocene (?) Fool Creek Conglomerate, Pleistocene Pre-Bonneville sediments, and Recent Lake Bonneville sediments, alluvium, and sand dune deposits.

Armstrong (1968) placed the Canyon Range allochthon structurally above the Pavant Range allochthon, and recognized the importance of the Canyon Range conglomeratic sequence in dating thrusting of the Sevier orogeny. Armstrong disagreed with Christiansen's assigned ages of the conglomerates, and argued that they are equivalent to the Paleocene and early Eocene Flagstaff Limestone of the Colorado Plateau. Stolle (1978) measured stratigraphic sections in the lower part of the conglomerate and correlated them to the Cretaceous Price River, Cretaceous–Paleocene North Horn Formations, and the Paleocene Flagstaff Formation on the basis of trace fossils and lithological characteristics. Campbell (1979) detailed the late Cenozoic structure and stratigraphy of the Canyon Range, emphasizing the depositional and erosional history of the Miocene Fool Creek Conglomerate. He restricted the use of Fool Creek Conglomerate and defined a new unit, the Miocene–Pliocene Oak City Formation.

Higgins (1982) mapped the 7½-minute Champlin Peak Quadrangle of the southern Gilson Mountains and northern Canyon Range. She subdivided the Middle Cambrian stratigraphy of the Canyon Range allochthon as shown in figure 2, and examined the nature of the Leamington Canyon fault. Millard (1983) mapped the southwest quarter of the Scipio North 15-minute quadrangle, which includes the southeast part of the Canyon Range. He examined the western thrust fault of the Canyon Range klippe, and he subdivided Paleozoic strata on the east slope of the range.

STRATIGRAPHY

The stratigraphy in the northern Canyon Range is summarized in figures 2 and 3. Precambrian and Paleozoic rocks are common in both the Canyon Range and the Pavant allochthons, but the Middle Cambrian sections on the two thrusts are distinctly different. A thick synorogenic Cretaceous and Tertiary conglomerate rests unconformably on Cambrian rocks of the Canyon Range allochthon. These conglomerates are also found along the eastern piedmont of the range. The stratigraphy of both allochthons are treated together, except where measured stratigraphic sections of this study have demonstrated distinctions.

PRECAMBRIAN SYSTEM

Precambrian nomenclature follows the usage of Woodward (1972), who traced upper Precambrian units from Pocatello, Idaho, to the Beaver Mountains, Utah. These rocks were deposited in a basin described by Crittenden and others (1971) as having an axis trending from southern Deep Creek Range, Utah, northeast to Pocatello, with Precambrian units thinning southward. In the Canyon Range, Woodward identified the following units: Upper Pocatello Formation, Blackrock Canyon Limestone, Papoose Creek Formation, Caddy Canyon Quartzite, Inkom Formation, and the Mutual Formation. In the area of this study, all Precambrian units below the Caddy Canyon Quartzite are preserved only on the west limb of the syncline.

In the Sheeprock Mountains, 80 km to the north, Christie-Blick (1982) redefined the upper Precambrian stratigraphy and suggested that all rocks exposed in the Canyon Range stratigraphically below the Inkom Formation should be included within the Caddy Canyon Quartzite. Higgins (1982) followed Christie-Blick's usage in the Champlin Peak Quadrangle, but rocks older than Inkom Formation in the Champlin Peak area are poorly exposed, having been eroded and subsequently buried by Lake Bonneville and Sevier River alluvium. I reject Christie-Blick's nomenclature in the Canyon Range for the following reasons: (1) lithologies of Woodward's Pocatello Formation and Blackrock Canyon Limestone are atypical of those normally described as Caddy Canyon Quartzite; (2) the stratigraphic sequence below Inkom Formation is thick and easily subdivided according to characteristics typical of Upper Pocatello Formation and Blackrock Canyon Limestone lithologies; (3) this subdivision aided in understanding and describing the structural elements in the Canyon Range; (4) lithologies of the Sheeprock Mountains described by Christie-Blick are very different from that found in the Canyon Range; (5) stratigraphic sections described in both the Sheeprock Mountains and the Canyon Range are allochthonous with undefined pre-thrust-

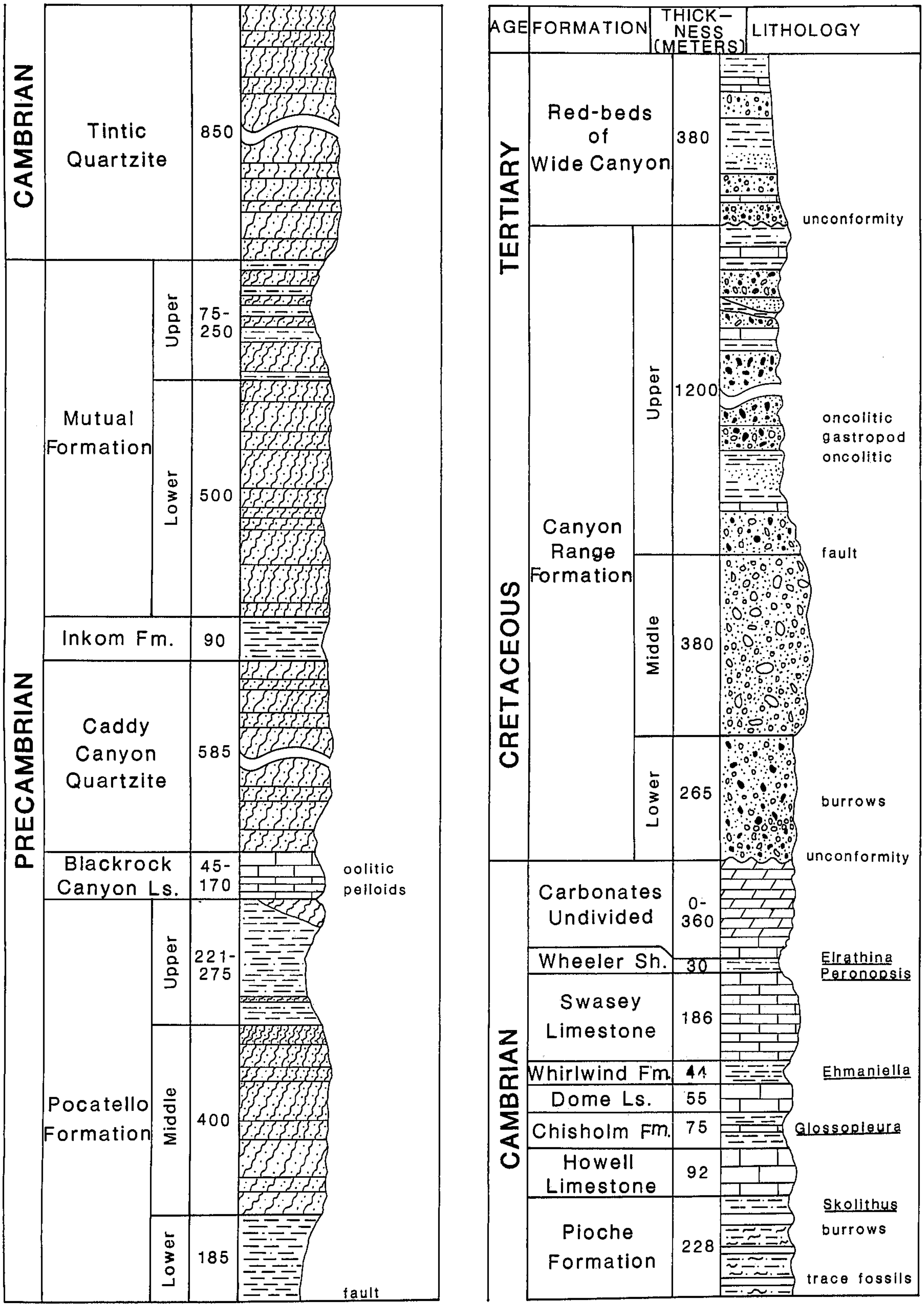


FIGURE 2.—*Stratigraphic column of the Canyon Range allochthon.*

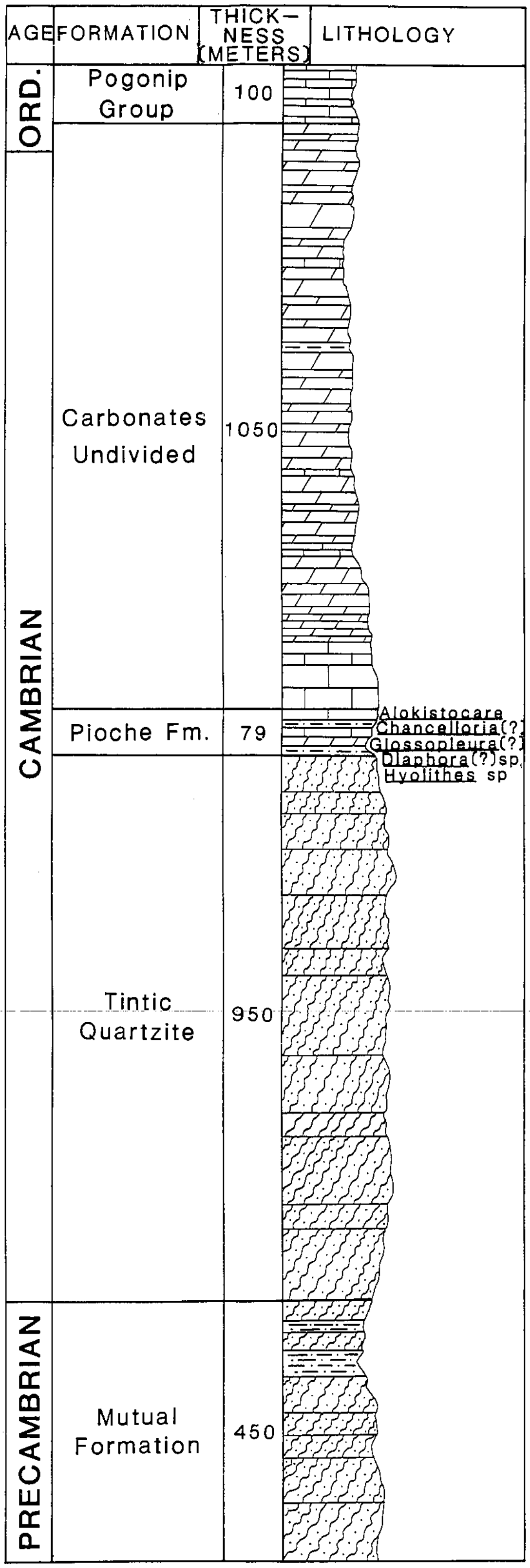


FIGURE 3.—*Stratigraphic column of the Pavant allochthon.*

ing relationships; (6) Christie-Blick's statements concerning Canyon Range stratigraphy are based upon prethrusting relationships. Millard (1983) also followed the nomenclature of Woodward in the southern Canyon Range.

Pocatello Formation

The Pocatello Formation is subdivided into three mappable units: a lower shale unit, a middle quartzite unit, and an upper shale and siltstone unit. Total exposed thickness of the Pocatello Formation is calculated to be approximately 800 m and represents only the upper member of the Pocatello Formation as described by Crittenden and others (1972). It is bounded below by the Canyon Range thrust fault, and the upper contact is drawn at the base of the lowest limestone ledge of the Blackrock Canyon Limestone (appendix A).

Lower Shale Member. The lower shale member is exposed only in Box Canyon where a strike valley has formed in the nonresistant shales. Exposures are poor and typically form a brownish gray to olive gray soil. This soil is locally covered by talus from adjacent quartzite cliffs. This unit is in fault contact with the Tintic Quartzite and Mutual Formation of the Pavant allochthon below. The upper contact is drawn at the first resistant ledge of the middle quartzite member. Exposed thickness of this unit is calculated to be 180 m.

Middle Quartzite Member. Between Wild Horse and Fool Creek Canyons, the middle quartzite member forms the first prominent ridge on the western edge of the range (fig. 4). Here the rocks are overturned to the west and dip 40°.

At the head of Limekiln Canyon, the rocks are nearly vertical before being truncated by the Canyon Range thrust. The rocks are white to bluish white, well-cemented, siliceous quartzite, which weathers grayish orange to moderate brown. This unit has cross-bed sets up to 20 cm thick and, near the base of the exposure, a conglomerate with 2-cm quartzite clasts in a poorly sorted quartzite matrix. This conglomerate correlates with the base of Higgins's (1982) Caddy Canyon Quartzite on the north slope of Leamington Canyon, where it is reported to be 100 m thick. This unit is easily confused with the Caddy Canyon and Tintic quartzites but is distinguished by its very light gray color and the presence of 1–4 mm angular cavities on weathered surfaces. These cavities are a function of weathering of limonite- and hematite-cemented quartz grains and are pervasive through the entire unit. The member is calculated to be approximately 400 m thick.

Upper Shale and Siltstone Member. The upper member ranges in thickness and lithology because of inter-

FIGURE 4.—*Outcrop of the middle member of the Pocatello Formation between Wild Horse Canyon and Dry Fork.*

fingering of sedimentary facies (fig. 5). A phyllitic shale unit thins from 221.5 m to 26 m, and a siltstone and quartzite wedge thickens from 2.5 m to 222 m, southward, over a distance of 25 km.

Millard (1983) described the rocks below the Blackrock Canyon Limestone as "a mixture of siltstone interbedded with quartzite, with a (26 m) thick bed of phyllitic shale near the middle." This section is 248 m thick at Whiskey Creek. Eleven kilometers north of Whiskey Creek, at the crest of the ridge north of Oak Creek, Christiansen (1952, p. 721) described these rocks as 195 m of micaceous shale and interbedded quartzite (unit 2), below 122 m of thin-

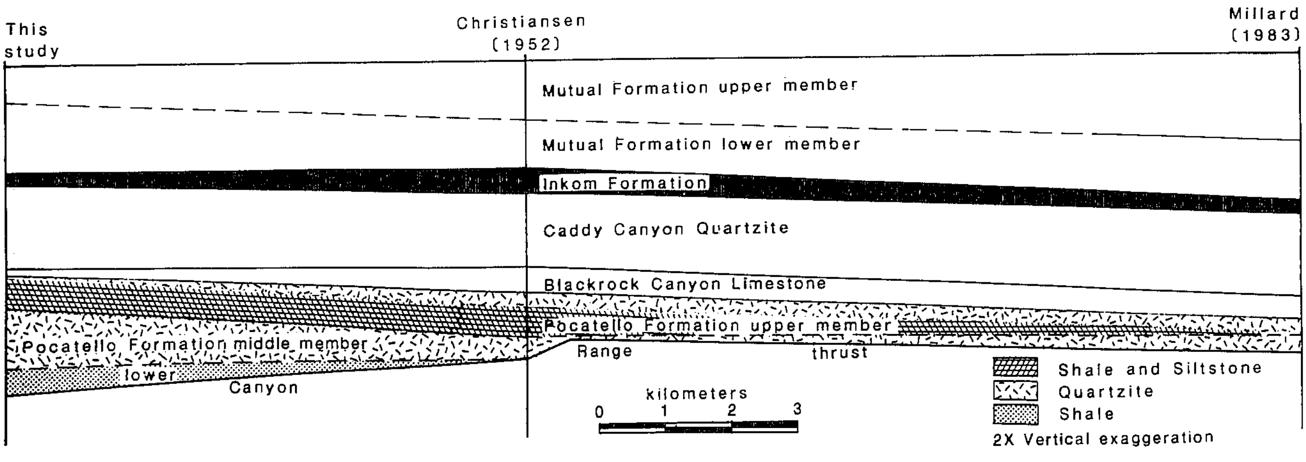


FIGURE 5.—*Precambrian facies cross section along a north-south line from Whiskey Creek (Millard 1983) to Oak Creek Canyon (Christiansen 1952) to Dry Fork.*

bedded, fine-grained quartzite (unit 3). Between Dry Fork and Wild Horse Canyon, 7½ km north of Christiansen's locality, the thin-bedded quartzite is replaced by a 221.5-m-thick shale unit. This shale contains only minor siltstone and quartzite interbeds (fig. 6).

Parts of Pole Canyon and an unnamed alluvium-filled strike valley north of Dry Fork are formed in the nonresistant shale. Where exposed, the shale is pale olive and weathers pale yellowish brown.

Blackrock Canyon Limestone

The Blackrock Canyon Limestone is a dark gray to medium dark gray ooidal and peloidal packstone and peloidal wackestone, that weathers medium bluish gray. The formation forms low hills and ridges on the west limb of the syncline. The upper part is mostly thick bedded, and the lower part is medium bedded.

The Blackrock Canyon Limestone thickens from 45 m south of Wild Horse Canyon to 169 m at Whiskey Creek Canyon (Millard 1983; see also fig. 5). It is uncertain whether this disparity is structural or stratigraphic, but on the basis of similar depositional wedging in the Pocatello Formation, it is likely stratigraphic. The upper contact with the Caddy Canyon Quartzite is at the top of the uppermost limestone (fig. 7).

Caddy Canyon Quartzite

This paper follows Millard (1983) by assigning the Papoose Creek Formation of Woodward (1972) to the Caddy Canyon Quartzite. The lower 100 m of this unit is a silty quartzite that may correlate to the Papoose Creek Formation, but lack of a distinct upper boundary and the absence of this lithology north of Dry Fork preclude its use. Where recognized, the silty quartzite is differentiated with a dashed contact on figure 8.

The Caddy Canyon Quartzite forms prominent ridges, massive cliffs, and broad dip slopes on its upper contact with the Inkom Formation. The upper part is a massively bedded, well-sorted quartzite, with cross-beds and minor interbedded pebble conglomerate. The lower section is silty and thin to medium bedded. The quartzite is very pale orange to grayish pink and weathers medium orange pink to light brown. The lower contact is at the uppermost limestone ledge of the Blackrock Canyon Limestone. The upper contact is placed at the appearance of phyllitic, pale olive shales of the Inkom Formation. Thickness of the Caddy Canyon Quartzite is approximately 585 m.

Inkom Formation

The Inkom Formation forms strike valleys and saddles that separate the massive quartzite cliffs of the Caddy Canyon Quartzite, below, from the cliffs of the Mutual Formation, above (fig. 9). The rocks are best exposed at the base of dip slopes of the Caddy Canyon Quartzite on the east limb of the syncline. Here they consist of phyllitic, light olive gray shale that weathers pale olive. Minor siltstone and quartzite are interbedded near the base and top of the formation. Exposures on the west limb of the syncline are poor, as they are commonly covered with a dark yellowish brown soil and talus alluvium. The Inkom Formation is approximately 90 m thick at Fool Creek.

FIGURE 6.—*Outcrop of the upper member of the Pocatello Formation between Wild Horse Canyon and Dry Fork. The rock is phyllitic shale and thin-bedded siltstone and quartzite.*

Mutual Formation

The Mutual Formation is divided in this study into two members: a lower quartzite unit and an upper siltstone and quartzite unit (fig. 2). The lower contact is drawn where quartzite beds dominate over the shales of the Inkom Formation, and the upper contact is at the base of the massive pale orange cliffs of the Tintic Quartzite. Total thickness of the Mutual Formation is calculated as approximately 750 m. Millard (1983) reports less than this

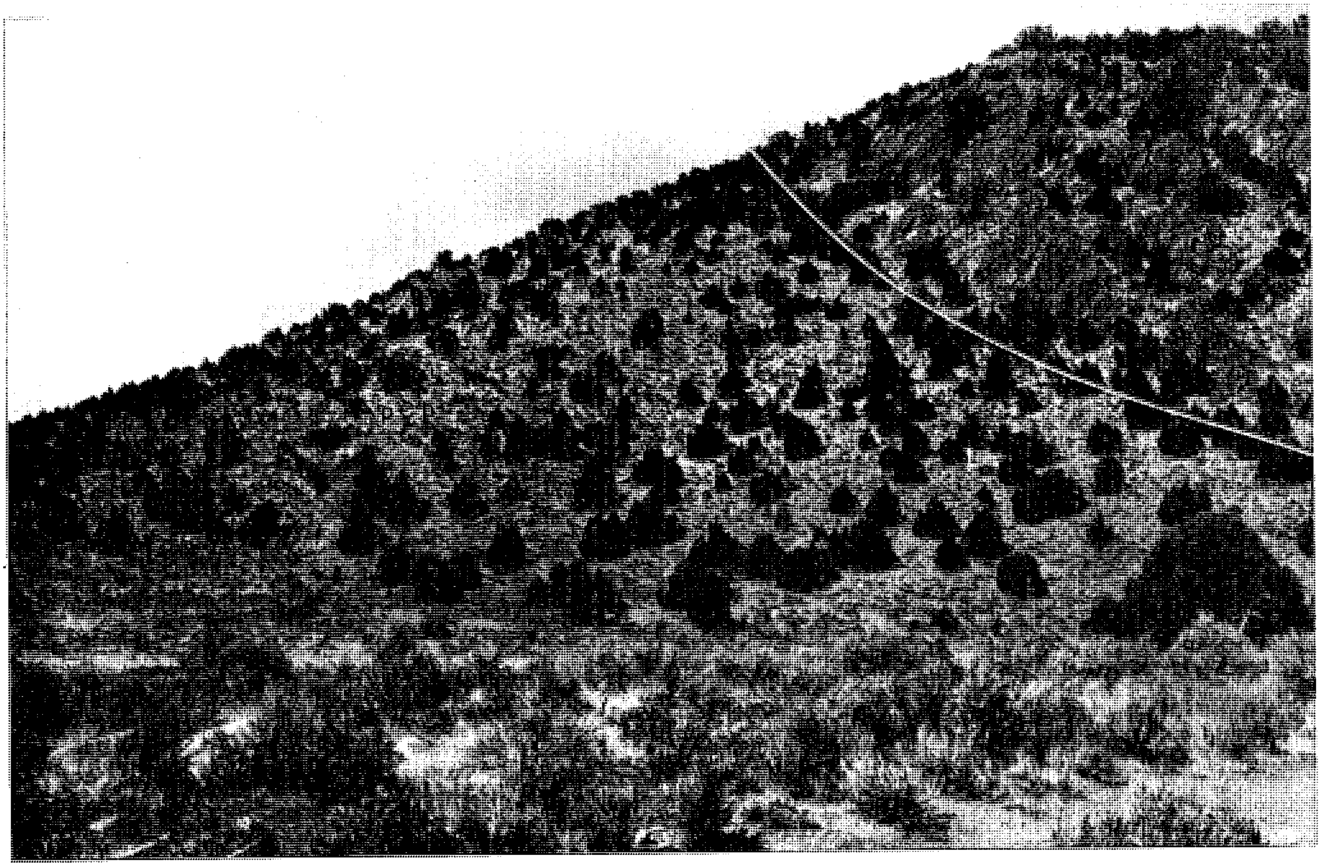


FIGURE 7.—*Contact between the Blackrock Canyon Limestone (left) and the Caddy Canyon Quartzite. View is north from Dry Fork.*

thickness in the southern Canyon Range because he has assigned parts of the upper Mutual Formation to the Tintic Quartzite.

Lower Member. The lower member is a medium red to pale reddish brown massive quartzite, which weathers pale red to dark reddish brown. It is thick to medium bedded, with cross-bed sets up to 30 cm. Conglomerate interbeds of quartzite pebbles and grit in a quartzite matrix comprise 5–10 percent of the unit. The upper contact with the siltstone and quartzite member is drawn where siltstone predominates over quartzite, with the subsequent change from cliffs to ledge and slope topography. Calculated thickness of this member is approximately 500 m.

Upper Member. The upper member is regionally lenticular, increasing in thickness from 75 m at Leamington Pass to 250 m south of Wild Horse Canyon. It forms a saddle between the massive, very pale orange Tintic Quartzite and the massive reddish quartzite member of the Mutual Formation. Often it forms prominent strike valleys. One such strike valley is found north of Morning Dove Spring in Dry Fork Canyon. This member consists of nearly equal amounts of thin-bedded, slope-forming siltstone and ledge-forming quartzite. The color is variegated red and pinkish gray and appears transitional from the dark reddish brown lower Mutual Formation to the very pale orange Tintic Quartzite.

CAMBRIAN SYSTEM

Cambrian rocks in the Canyon Range are represented by two distinctly different stratigraphic sections. They correspond to deposition in different areas of the western Utah miogeosyncline. These areas were subsequently juxtaposed by faulting of the Canyon Range and Pavant allochthons. Both sequences conform to a regional depositional regime of basal clastic sedimentation, followed by primarily carbonate deposition (Hintze 1972).

The basal unit of both allochthonous sections is the Tintic Quartzite. On the Canyon Range allochthon, rocks identified as Ophir Formation by Christiansen (1952) have been subdivided by Higgins (1982) using nomenclature from the House Range, Millard County, Utah (fig. 2). The following descriptions of these units are based in part on Higgins (1982), appendix B, and more complete descriptions may be obtained from that study.

Cambrian stratigraphy on the Pavant allochthon in-

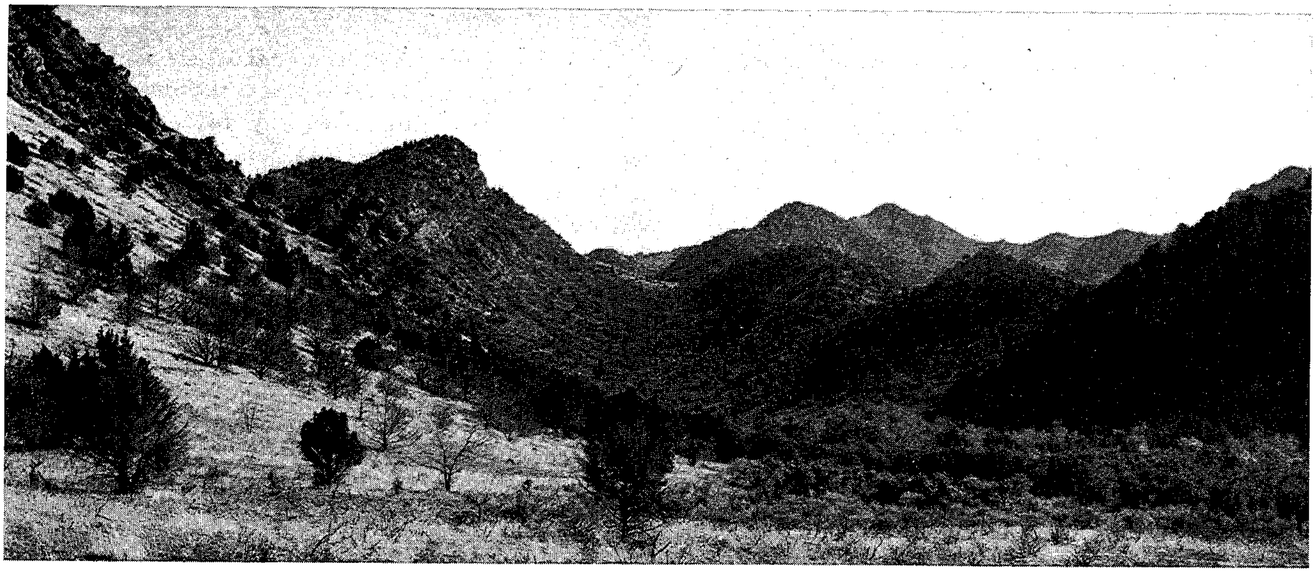


FIGURE 9.—*Strike valley eroded along the Inkom Formation. View is south from Dry Fork. Caddy Canyon Quartzite is on the right, and Mutual Formation is on the left.*

cludes Tintic Quartzite, Pioche Formation (?), and undivided Cambrian carbonates (fig. 3). In the Pavant Range, Cambrian strata have been partially subdivided using East Tintic mining district nomenclature (Lautenschlager 1953). These subdivisions are based on questionable lithologic similarities, without the benefit of biostratigraphic control, and use of this nomenclature above the Tintic Quartzite is probably tenuous (Davis 1983). Consequently, in this study, the use of Ophir Formation is abandoned. Undivided Cambrian carbonates are found on both allochthons, but they delineate lithologically different strata and represent partially different time intervals.

CAMBRIAN SYSTEM—CANYON RANGE ALLOCHTHON

Tintic Quartzite

The Tintic Quartzite is the most topographically prominent unit in the northern Canyon Range. It forms the highest peaks (including Fool Peak, elevation 2,962 m) and the most conspicuous ridges and cliffs. On the west limb of the syncline, the Tintic Quartzite is vertical to slightly overturned, and forms formidable cliffs that serve to make some areas almost inaccessible. South of Dry Fork, the Tintic Quartzite is the uppermost unit in the center of the syncline, and large, broad dip slopes shape the topography.

The Tintic Quartzite is the basal Cambrian unit in the Canyon Range, and is regionally disconformable with the Mutual Formation below. The lower contact is drawn at the base of the massive quartzite on the Tintic and above the siltstones of the upper Mutual Formation. Color transition at this boundary is gradational and does not have the significance that has been emphasized elsewhere in the Canyon Range. The upper contact is placed at the top of the uppermost massive quartzite, which coincides with the first significant occurrence of shale in the sequence.

The Tintic Quartzite is moderate orange pink to gray orange pink and weathers dark yellowish orange to pale reddish brown. Pebble conglomerate comprises up to 10 percent of the formation, and 10–30 cm cross-bed sets with alternating reddish brown and yellowish orange laminae are common. The Tintic Formation is typically very fractured and silicified. The Tintic Quartzite is approximately 850 m thick.

Pioche Formation

The Pioche Formation is found on both the Pavant and Canyon Range allochthons, but the two sections are dissimilar in both thickness and lithology. The Pioche Formation of the Canyon Range is typical of House Range lithology, consisting primarily of olive gray, phyllitic shale with interbedded ledges of grayish red purple to grayish orange quartzite. The shale weathers light olive gray, and the quartzite weathers moderate yellow brown to dark yellowish brown. In outcrop, the Pioche forms typical ledge-slope topography. In contrast with the Pioche Formation on the Pavant allochthon, no carbonate rocks are included within the Pioche Formation of the Canyon Range allochthon.

Higgins (1982) reported abundant trace fossils in the Pioche beds, including distinctive *Skolithus* burrows. She reported the thickness of the formation at 228 m. The lower contact is at the first appearance of thick shale in the sequence, and the upper contact is at the base of the massive limestone of the Howell Formation.

Howell Limestone

The initial appearance of Cambrian limestone in the Canyon Range allochthon marks the lower contact of the Howell Limestone. The Howell Limestone is a massively bedded unit that forms a prominent ridge between the ledge-and-slope topography of the Pioche Formation below and the slope of the Chisholm Formation above. The upper contact is gradational and drawn at the base of the lowest shale above the limestone cliffs of the Howell.

The lower part of the Howell Limestone is medium gray and weathers light gray. Solution pits are common on exposed surfaces, and limonite-stained oncolites are abundant. The upper part of this formation is medium dark gray and weathers medium gray. It is massively bedded and forms cliffs. The Howell Limestone is approximately 90 m thick.

Chisholm Formation

The Chisholm Formation is a recessive slope or valley forming olive gray, micaceous shale with interbedded oncolitic limestone. The thin-bedded limestone comprises approximately one-third of the formation and contains abundant pisolites, oncolites, and *Glossopleura* trilobite fragments. Both the upper and lower contacts are gradational but were mapped at the cliffs of the Howell and Dome Limestones. The formation is 75 m thick.

Dome Limestone

The Dome Limestone forms another resistant Cambrian limestone of the Canyon Range allochthon. The formation is medium dark gray to medium gray and weathers light gray. Approximately 5% of the unit is shale interbeds. The lower contact is drawn at the base of its massive limestone, and the upper contact is drawn at the appearance of shale of the Whirlwind Formation. The Dome Limestone is 55 m thick.

Whirlwind Formation

The Whirlwind Formation is an olive gray, calcareous silty shale, that forms a saddle between the Dome and Swasey Limestones. Seldom actually exposed, the shale weathers yellow gray and contains minor interbedded limestone ledges. *Ehmaniella* trilobite hash and trace fossils were reported in these limestones by Higgins, and R. A. Robison collected *Ehmaniella* from this interval in the Yellowstone Canyon area (Hintze 1972). The Whirlwind Formation is 44 m thick.

Swasey Limestone

The Swasey Limestone forms the third and most prominent Cambrian limestone ridge. Upper and lower contacts are often covered but are drawn at the top and base of the massive limestone. It is medium dark gray to dark gray and weathers medium gray to medium light gray. Brown, silty laminae comprise approximately 5 percent of the formation. The Swasey Limestone is 186 m thick.

Wheeler Shale

The Wheeler Shale is a slope-forming unit of light olive gray to olive gray shale and interbedded siltstone and limestone. The siltstone comprises about 10% of the formation, and the medium gray limestone about 20%. The Wheeler Shale is only 30 m thick in the Canyon Range. The lower contact is placed at the base of the shale interval.

Higgins reports a diverse fauna collected from the Wheeler Shale. These fossils include the conodont *Hertzina bisculata*; trilobites *Bathyuriscus rotundatus*, *Elrathina* sp., *Kootenia* sp., *Peronopsis segmenta*, and *Ptychagnostus intermedius*, all representative of the *Ptychagnostus gibbus* zone. In addition, Higgins collected the sponge *Kiwetinokia utahensis*, agnostid *Ptychagnostus seminula* (?), and disarticulated sclerites of *Modocia* and *Zacanthoides*.

Undivided Cambrian Carbonates

In the northern Canyon Range, Higgins attempted to subdivide the carbonate rocks above the Wheeler Shale using nomenclature of the East Tintic mining district. Because of nondistinct lithologies and a lack of fossils to substantiate a correlation, the attempt was abandoned. However, these carbonates are conformably above rocks of known Middle Cambrian age (*Ptychagnostus gibbus* zone), and are believed to be Middle and possibly Upper Cambrian in age. No rocks of Ordovician age are known to crop out on the Canyon Range allochthon.

The undivided carbonates are truncated above by angularly unconformable Tertiary conglomerates. At Leamington Pass, approximately 360 m of undivided carbonates have been mapped, but at Wild Horse Canyon these rocks have been totally removed by late Mesozoic (?) erosion, and the conglomerates rest on Swasey Limestone. The undivided carbonates are almost vertical near the axis of the syncline and form rounded, talus-covered ridges and ledgy slopes. The lower part of this unit is predominately limestone with dolomite interbeds, and the upper section is primarily dolomite.

CAMBRIAN SYSTEM—PAVANT ALLOCHTHON

Tintic Quartzite

The prominent ridge east of Oak City is an asymmetrical anticline comprised of Tintic Quartzite that has been downdropped on a basin-and-range fault within the folded Pavant allochthon. Immediately east, the Tintic also forms a conspicuous ridge at Limekiln Canyon, where the rocks are overturned on the west limb of the syncline. The Tintic strata of both sequences appear to be similar, although the Pavant section is calculated to be approximately 100 m thicker than the 850-m Canyon Range Tintic section. The Tintic Quartzite on the Pavant allochthon is mostly Lower Cambrian in age but may also include Middle Cambrian strata below the *Glossopleura* trilobite zone.

Pioche Formation (?)

Pioche Formation on the Pavant allochthon exhibits close affinity to rocks in the Pavant Mountains, 80 km to the south near Kanosh, Utah (Davis 1983). Here Davis subdivided the Pioche into a lower sandstone and shale member and an upper Tatow Member, consisting of dolomite, limestone, and interbedded sandstone and shale. The Pioche Formation of the Canyon Range is correlated, with modifications, to the Tatow Member of Davis (fig. 10).

The Pioche Formation of the Canyon Range consists of micaceous shale interbedded with dolomite, limestone, and siltstone. Exposures are poor but can be observed at the head of Limekiln Canyon, where the shale forms slopes of talus-covered brown soil (see appendix B). The interbedded medium light gray dolomite forms ledges in the slope. The siltstone is pale green and weathers grayish orange. The siltstone and limestone are very thin bedded and typically form a talus slope. The Pioche Formation of the Canyon Range also includes a shale and interbedded limestone containing fossils tentatively identified by R. A. Robison (written communication 1982) as representing the *Glossopleura* trilobite zone. These fossils include *Glossopleura* (?) sp. and *Alokistocare* sp. trilobite fragments, *Chancelloria* (?) sp., *Hyolithes* sp., and two undetermined genera of articulate brachiopods, one of which may be *Diaphora* sp. Equivalent *Glossopleura*-containing strata in the Pavant Mountains are included as a part of the undifferentiated Cambrian carbonates, as defined by Davis, and are found just above the Pioche Formation.

Thickness of the Pioche Formation on the Pavant allochthon is 79 m. The lower contact is at the top of the uppermost massive quartzite of the Tintic, and the upper contact is drawn at the top of the shale at the base of the first massive limestone above *Glossopleura*.

Undivided Cambrian Carbonates

The undivided carbonates of the Pavant thrust form a prominent ridge between Limekiln Canyon and Knoll Hollow. The rocks are predominantly medium dark gray to light olive dolomite and weather dark brown gray to light olive gray. Limestone predominates in the lower 100 m, but above this forms only minor interbeds in the dolomite. The unit is vertical to overturned in the Limekiln Canyon area, and forms cliffs, steep talus-covered slopes, and hogback ridges.

The strike of the western edge of the Canyon Range klippe is oblique to the undivided carbonates, and the thrust progressively covers these strata northward. At Oak Creek, a calculated 1,050-m thickness of Cambrian carbonate rocks is exposed, but 1 km north of Pauls Meadow, these rocks are totally covered. The lower contact is at the top of the shale of the Pioche Formation. The upper contact with the Ordovician Pogonip Group was mapped at the change in lithology from dolomite to limestone.

ORDOVICIAN SYSTEM

Pogonip Group

Ordovician rocks in the northern Canyon Range are located only on the Pavant allochthon at the east ridge of Knoll Hollow. They are covered to the east by the western edge of the Canyon Range klippe and truncated to the north by a strike-slip fault. Only the lower part of the Pogonip Group is exposed although Millard (1983) reported a more complete Ordovician section to the south.

Rocks of the Pogonip Group are primarily thin-bedded limestones with some chert nodules and layers. Where exposed, the strata are vertical to overturned and form slopes and hogback ridges. The Pogonip Group appears to be conformable with the undivided Cambrian carbonates below, and the lower contact is gradational from predominately dolomite of the Cambrian to the limestones of the Ordovician. No biostratigraphic control was available, so the contact was drawn at this change in lithology. Approximately 100 m of Pogonip Group rocks are exposed, but the strata are likely thicker below the Canyon Range thrust.

CRETACEOUS AND TERTIARY SYSTEMS

The Cretaceous and Tertiary strata of the northern Canyon Range include more than 2,600 m of synorogenic to postorogenic conglomerates and associated terrestrial sediments. Stratigraphic units include the Canyon Range Formation (modified after Stolle 1978), red beds of Wide Canyon, Oligocene Fool Creek Conglomerate, and Miocene Oak City Formation.

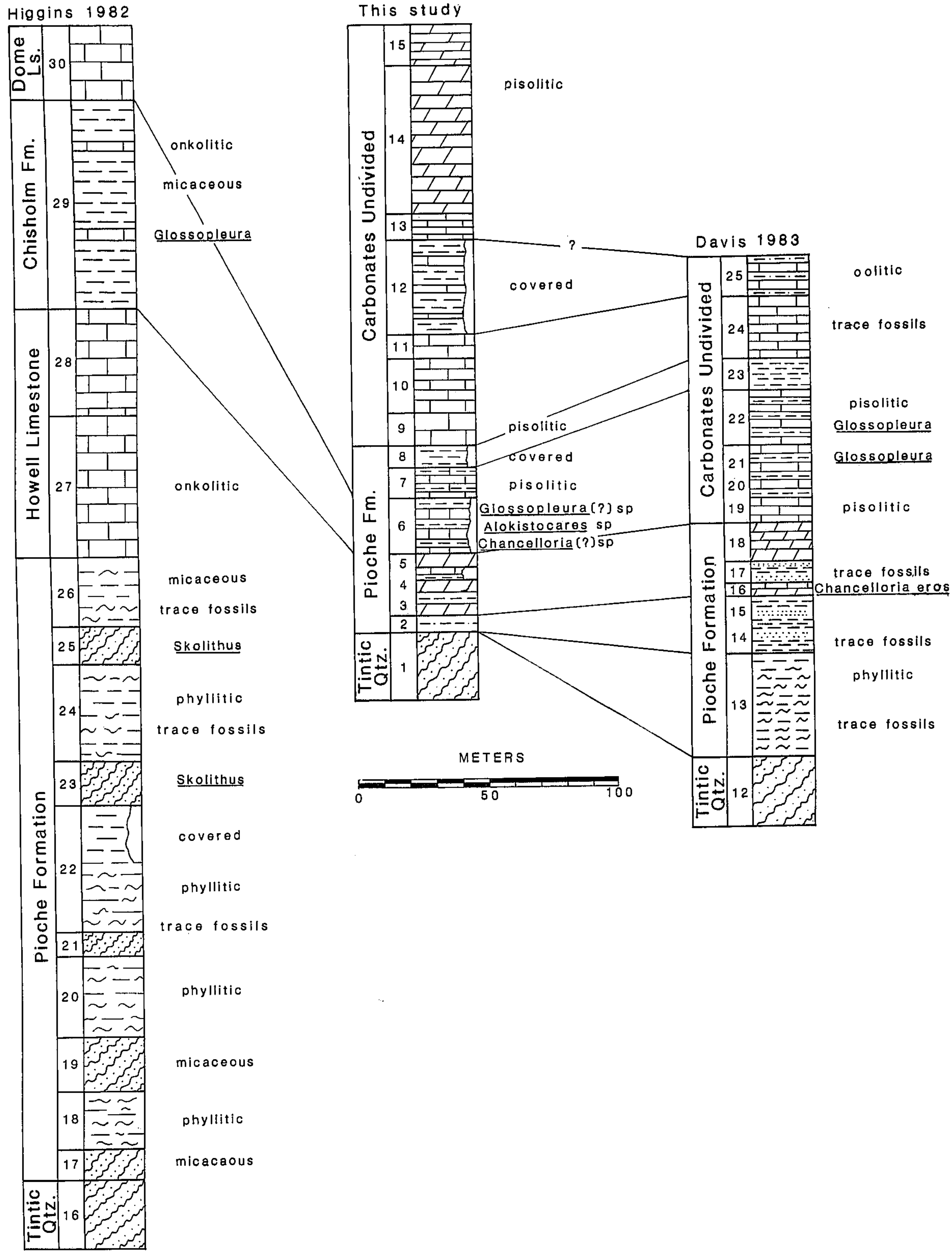


FIGURE 10.–*Middle Cambrian stratigraphy of the Canyon Range and Pavant allochthons, showing close affinity between the Pavant allochthon of the Pavant Range (Davis 1983) and the Pavant allochthon of the Canyon Range (this study). Equivalent rocks of the Canyon Range allochthon (Higgins 1982) are very dissimilar to the other sections.*

Canyon Range Formation

Christiansen (1952) described a sequence of thick synorogenic conglomerates north of Wide Canyon and along the eastern piedmont of the range, and tentatively assigned these rocks to the Cretaceous Indianola Group. He divided them into three mappable members: a lower conglomerate of predominately Paleozoic limestone fragments, a middle member of massively bedded quartzite cobble and boulder conglomerate, and an upper member of less coarse conglomerate and interbedded sandstone, siltstone, shale, and nonmarine limestone. Armstrong (1968) questioned the Indianola age assignment of Christiansen and argued that these rocks are a lateral equivalent of the Paleocene and early Eocene Flagstaff Formation of the Utah plateaus.

Stolle (1978) informally named these strata the Canyon Range Formation, and subdivided them into units A (older) and B (younger). Stolle correlated unit A with the Lower Cretaceous Price River and Cretaceous–Paleocene North Horn Formations and correlated unit B with the Cretaceous–Paleocene North Horn and Paleocene Flagstaff Formations. These correlations were based primarily on lithological characteristics, including a single oncolite cored with an unidentifiable genus of freshwater gastropod.

Christiansen's lower and middle members are equivalent to Stolle's unit A (stratigraphic units 1–20 and 21–25, respectively). Stolle reported that his unit B is equivalent to the North Horn (?) Formation of Christiansen, but this report is erroneous. Unit B represents part of the exposed section of the upper member of the Indianola (?) of Christiansen, and the North Horn (?) strata were not described by Stolle. The boundary between Stolle's unit A and B is a basin-and-range fault contact with vertical displacement greater than 1200 m, a relationship Stolle did not fully exploit. He briefly noted the possibility of a fault contact but described the boundary as depositional and likely conformable, or with slight angular unconformity. I propose that the Canyon Range Formation of Stolle be given formal status but modified according to Christiansen's parameters of three members. A type section is designated in the vicinity of Cow Canyon, as described by Stolle. The lower member is found on a spur north of Cow Canyon, beginning at N ½, SW ¼, section 24, T. 16 S, R. 2 W, and extending west into unsurveyed Fishlake National Forest. The upper and middle members are located on the slope south of Cow Canyon in unsurveyed Fishlake National Forest. The lower two members appear to have a local source of origin, and inverted lithologies from their source represent a deroofing of the Canyon Range allochthon (Armstrong 1968). North of Leamington Pass, Higgins (1982) mapped strata of the lower two members and informally named them Conglomerate of Leamington Pass. The upper member is finer in texture, with more rounded and sorted clasts, and may have had a sediment source to the west of the Canyon Range.

No reliable fossil data are available to precisely date these rocks. In this study, 12 samples of shale and freshwater limestone were obtained for palynological dating, but they yielded no fossil forms. Identifications of pollen forms were provided by R. K. Jain of Texaco Inc. and included only modern pollen of plants common to this area (*Chenopodiaceae*), which must be attributed to field-related contamination.

Lower Member. The lower member rests unconformably on the Upper (?) Cambrian carbonates of the Canyon Range allochthon at Leamington Pass and on the Tintic Quartzite at Wild Horse Canyon. The strata are folded and overturned in the axis of the syncline but dip homoclinally east of the Canyon Range thrust. Locally, rotation accompanying vertical movement on listric normal faults has increased the dip of these beds.

The lower member is a coarse conglomerate with clasts up to 50 cm of predominately limestone. The matrix is typically moderate red to light red and comprises 10–30 percent of the total rock. Locally, quartzite clasts form lenses in the medium gray limestone conglomerate. At Cow Canyon, a 75-m-thick quartzite lens is present but rapidly thins to the north and is not observed at Wide Canyon. Arenaceous nonmarine limestones also form lenses in the conglomerate. The lower member varies in thickness from 265 m at Wild Horse Canyon to 414 m north of Leamington Pass (Higgins 1982, appendix B, units 38–56). The upper contact is distinctive and was mapped at the change in clast composition from limestone to quartzite.

Middle Member. The middle member is a very resistant quartzite clast conglomerate and typically forms precipitous cliffs and steep, rugged topography (fig. 11). This unit occurs both on and below the Canyon Range allochthon. Above the thrust, the rocks are folded in the syncline or rest unconformably on the steep dip slopes near Fool Peak (fig. 12). Beneath the Canyon Range thrust, the strata have been folded and overturned to the west by movement of the Canyon Range allochthon.

The member is composed almost entirely of coarse, angular quartzite clasts within a bright hematite red sand, grit, and pebble matrix. Clasts commonly exceed 50 cm in diameter, and boulders over 2 m were observed. Exposed thicknesses range from 125 m at Cow Canyon to over 600 m north of Leamington Pass. The upper boundary is a fault contact with vertical displacement exceeding 1,200 m, and variability of thickness is likely a factor of tectonics rather than deposition or erosion.

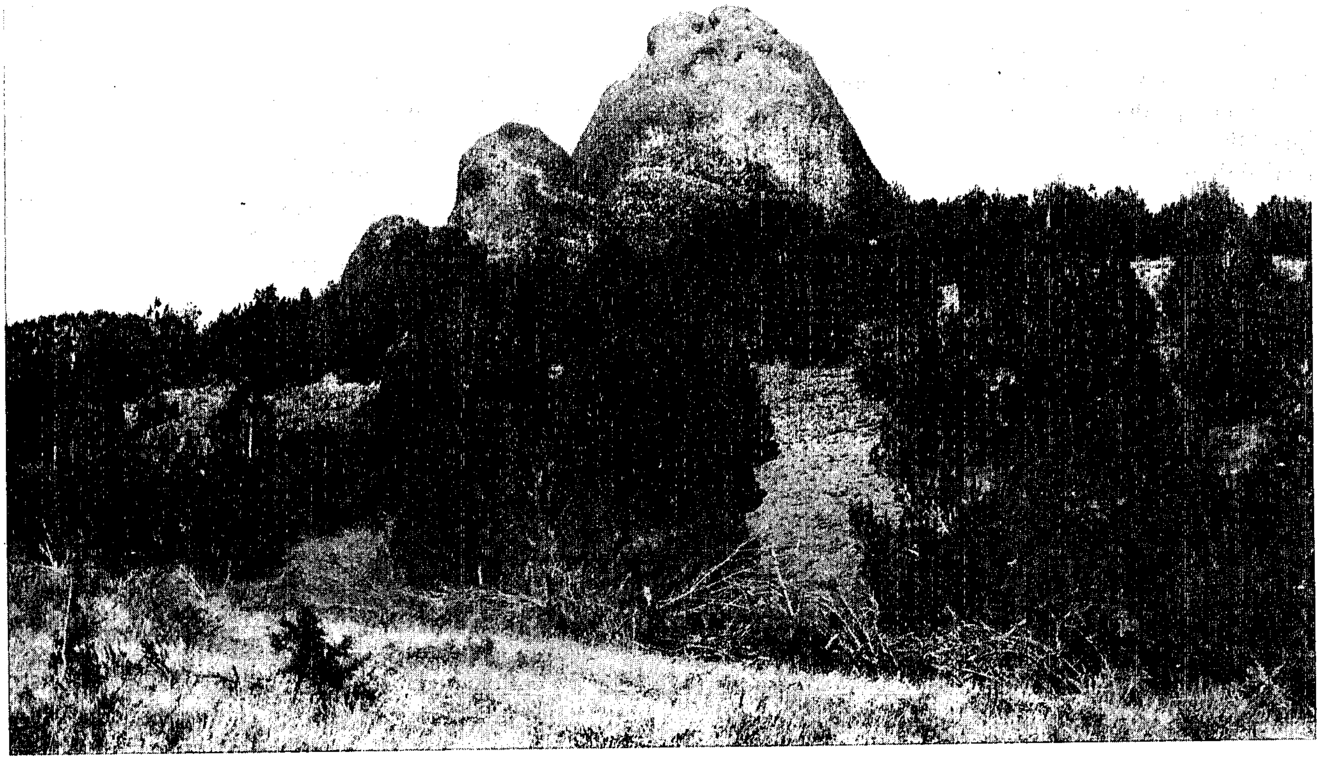


FIGURE 11.—*Outcrop of the middle member of the Cretaceous–Tertiary Canyon Range Formation north of Wide Canyon.*

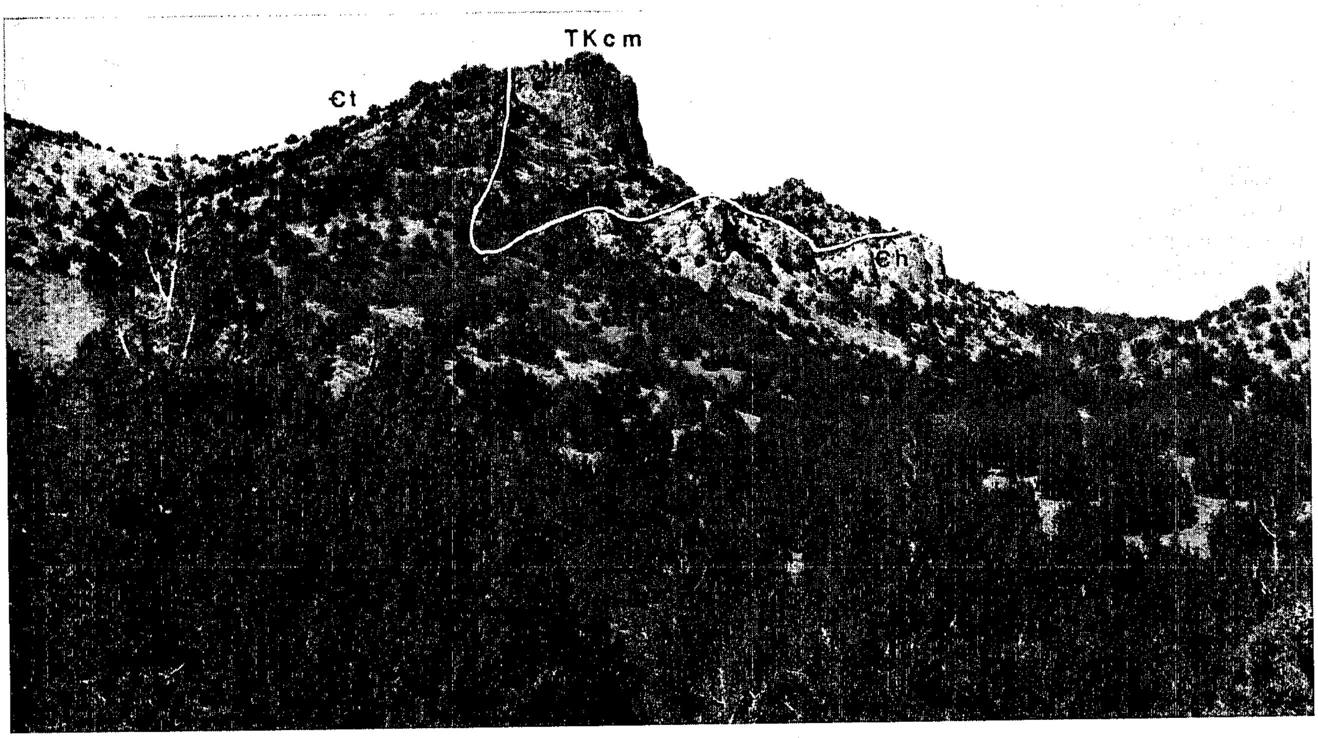


FIGURE 12.—*Middle member of the Cretaceous–Tertiary Canyon Range Formation folded in the center of the Canyon Range syncline. Tintic Quartzite is on the west, and undivided Cambrian carbonates are immediately to the east. View is north from Dry Fork.*

Upper Member. The upper member is comprised of finer, more rounded and sorted clastic material than the lower two members of the Canyon Range Formation. It consists of more than 1,200 m of cobble and pebble conglomerate, coarse sandstone, siltstone, shale, and nonmarine limestone. Conglomerate makeup ranges from almost total limestone clasts to clasts of nearly pure quartzite. The sandstone strata are comprised of poorly sorted, angular grains, ranging from grit-size to fine silt-size particles. The strata tend to be discontinuous or lenticular and typically have very limited lateral extent. For example, a 30-m-thick sandstone bed at Wringer Canyon lenses out within a distance of 1 km.

The lower boundary is a fault contact, and the 1,200 m of exposed thickness is a minimum value. The upper contact was mapped at the distinctive color change at the base of the overlying red beds.

Red Beds of Wide Canyon

In the Wide and Wringer Canyons area, there is a change in color, texture, and lithology of the rocks above the Canyon Range Formation. The strata tend to be finer grained, better sorted, and brighter colored. In this paper, these rocks are hereafter referred to as the red beds of Wide Canyon. They include, in part, strata mapped and described by Christiansen (1952) as North Horn Formation, and Christiansen's description of these rocks follows:

Shale and siltstone comprise 50 percent of the formation. The shale beds are dark red to light red and tan, and usually break down into dark-red soils. The siltstones and calcareous siltstones vary considerably in color. They are commonly light brownish red, light gray to pinkish, or light shades of lavender. The arenaceous and calcareous siltstones are usually mottled in pastel shades of lavender, red, and yellow. The interbedded sandstone is chiefly light gray to tan and yellowish brown, calcareous, medium- to coarse-grained and unsorted. The grains in the sandstone are angular to subangular. The thickest beds and lenses usually contain iron concretionary masses unevenly distributed through the sandstone. Conglomerate lenses occur commonly within the sandstone strata. Conglomerate units are generally less than 15 feet thick, although a few may be 30 feet thick. They are made up of subangular to rounded pebbles and cobbles.

Angular discordance between the red beds of Wide Canyon, and the underlying Canyon Range Formation amounts to approximately 10°. This unconformity is best observed at Flat Canyon. Campbell (1976) stated that the red beds of Wide Canyon once covered all or much of the Canyon Range on the basis of clasts typical of its lithologies found on the west slope of the range, in the Fool Creek and Oak City Formations. The exposed thickness of the red beds is calculated at approximately 750 m.

Fool Creek Conglomerate

At the head of Dry Fork and other west-flowing canyons, conglomerate rests unconformably on older stratigraphic units. These conglomerates and other similar strata were grouped by Christiansen (1952) and mapped as the Fool Creek Conglomerate. All these rocks are poorly exposed, as they are typically covered with a veneer of unconsolidated gravels.

Campbell (1976, 1979) redefined the Fool Creek Conglomerate, subdividing the strata into two formations: the Fool Creek Conglomerate and the Oak City Formation. He retained the name *Fool Creek Conglomerate* for Oligocene beds, and proposed the Oak Creek–Little Oak Canyon divide as the type section. Campbell described the Fool Creek Conglomerate as consisting predominately of clasts of Precambrian and Cambrian quartzite. Locally, cross-bedded sandstone occurs. Minor parts of the formation are comprised of clasts of older Cretaceous or Tertiary conglomerates. Clast size ranges from granules to large boulders (up to 1.2 m). The matrix is calcite-cemented, silty sandstone. At Dry Fork divide, where the Fool Creek Conglomerate was observed in this study, limestone cobble clasts predominate over quartzite. Much of the formation has been eroded, making estimates of original thickness difficult and subject to error. It is approximately 160 m thick at Dry Fork, but may have originally been deposited to a thickness of 1,100 m, equal to paleorelief.

Oak City Formation

Along the western edge of the range, between Dry Fork and Oak City, Miocene conglomerate forms low, dissected hills and spurs. These strata were originally included as Fool Creek Conglomerate by Christiansen (1952). This conglomerate has been described by Campbel (1979) and renamed the Oak City Formation. Campbell described the Oak City Formation as conglomerate with interbedded sandstone, siltstone, and shale. The conglomerate consists of rounded quartzite clasts, with limestone clasts near the mountain front. The matrix is pink, calcareous, silty sandstone. The conglomerate is less lithified than the Fool Creek and older conglomerates.

The Oak City Formation is poorly exposed because of a ubiquitous mantle of unconsolidated gravel. It rests unconformably on older strata. Campbell assigned a Miocene age to the Oak City Formation. At Bridge Canyon, the formation covers a basin-and-range fault with no apparent displacement in the conglomerates. If basin-and-range faulting was initiated in middle Miocene, this relationship may place late Miocene constraints on the formation. Campbell reported a minimum thickness of 490 m.

QUATERNARY SYSTEM

Quaternary rocks have not been subdivided on figure 8 but are represented by three types of deposits: older fanglomerate, Lake Bonneville sediments, and younger alluvium and colluvium. The older fanglomerate is found along the eastern border of the range as alluvial fans derived primarily from the Canyon Range Formation. Lake Bonneville sediments are laminated silts and clays found west of Utah 125. Recent alluvium and colluvium consist of stream rubble and angular talus adjacent to steep slopes and cliffs.

STRUCTURAL GEOLOGY

The northern Canyon Range has been shaped by two major structural events: Sevier orogenic folding and thrust-faulting and basin-and-range faulting (fig. 13). During Sevier orogenesis the Canyon Range and Pavant allochthons were thrust southeastward and eastward, respectively, and both allochthons were folded into a broad syncline and coupled overturned anticline. Basin-and-range faulting has downdropped the overturned anticline against the syncline and exhumed the range. Faulting of the anticline and subsequent erosion has served to isolate most of the exposed Canyon Range allochthon as a klippe.

In addition, a mid-Tertiary structural event, characterized by gentle, transverse folding appears to have been subtly overprinted on older Sevier structures.

THRUST FAULTS

Two imbricate allochthons are found in the Canyon Range: the upper thrust, or Canyon Range allochthon, and the lower thrust, herein called the Pavant allochthon. The basal thrust surface of the Pavant allochthon is not exposed in the Canyon Range. The Canyon Range thrust however, has major exposures in three areas: along the eastern face of the range, near the center of the range, and along the western border, east of Oak City. The first two exposures form the east and west boundaries of the Canyon Range klippe. The third is the western exposure of the Canyon Range allochthon which extends westward from the Canyon Range in the subsurface.

Canyon Range Thrust Fault (Eastern Exposure)

The eastern thrust fault of the Canyon Range klippe is exposed south of the head of Dry Fork, on the eastern edge of the range. At Dry Fork, the thrust fault is truncated by a normal fault (fig. 8). The thrust fault is believed to extend north of this area but is not exposed. The Dry Fork area also coincides with the lowest topographic exposure of the thrust surface. Southward the thrust climbs both topographically and stratigraphically, culminating adjacent to Fool Peak. At Cow Canyon, the thrust abruptly ramps upsection through the Caddy Canyon Quartzite to the Inkom Formation. The thrust remains in the Inkom Formation for approximately 2.5 km, before gradually ramping back through the Caddy Canyon Quartzite. South of this study, the thrust continues to cut downsection to the Blackrock Canyon Limestone (Millard 1983). The fault plane strikes N 5° E and dips approximately 40° to the west.

At its eastern exposure, the klippe is thrust over Cretaceous–Tertiary conglomerates (fig. 14). Deformation of rocks below the thrust is limited to immediately adjacent areas. Conglomerates adjacent to the thrust are overturned eastward and now dip to the west, but within 0.5 km the influence of thrusting is greatly diminished or absent. South of this study the klippe is thrust over Paleozoic rocks.

Canyon Range Thrust Fault (Western Exposure)

The western thrust fault of the Canyon Range klippe is found in the west central part of the range between Knoll Hollow and the mouth of Dry Fork. Here, erosion has removed a part of the Canyon Range allochthon and exposed the Pavant allochthon below. Rocks of the Pocatello Formation are thrust on Mutual Formation, Tintic Quartzite, undivided Cambrian carbonates, and Pogonip Group strata of the Pavant allochthon (fig. 15). The western fault of the Canyon Range klippe is located in the oldest rocks exposed in the range. At Dry Fork the thrust is in the lower shale member of the Pocatello Formation. East of Pauls Meadow, the thrust abruptly ramps upsection through the competent middle quartzite member to the incompetent shales and siltstones of the upper member. The thrust remains within this member through the southern Canyon Range.

Everywhere exposed, the upper surface of the Pavant allochthon is the footwall ramp of the Canyon Range thrust. The western exposure of the Canyon Range klippe is the hanging wall ramp of the same thrust fault. As exposed on the divide between the heads of Pole Canyon and Bridge Canyon, the stratigraphic displacement between the base of the Canyon Range allochthon and the top of the Pavant allochthon is more than 3 km.

The fault is believed to extend north to Dry Fork in the subsurface, possibly to Leamington Canyon fault. Relationships of this thrust and the Canyon Range thrust, east of Oak City, to the Leamington Canyon fault is uncertain, but all three faults form the border of the same allochthon.

Canyon Range Thrust Fault East of Oak City

Christiansen (1952) mapped the Canyon Range thrust fault east of Oak City as a normal fault of basin-and-range affinity (1952 map fig.). He defined the fault relationship

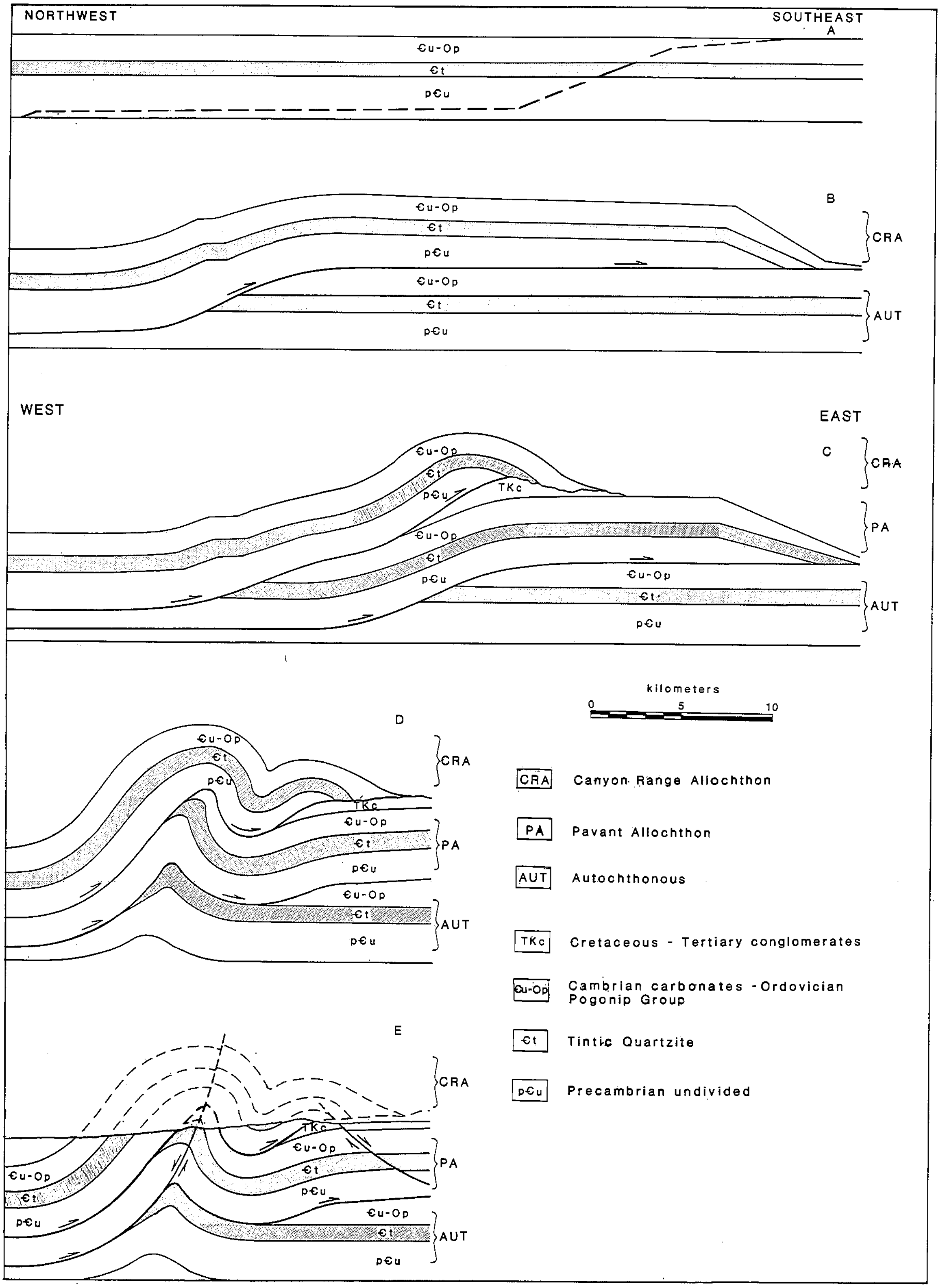


FIGURE 13.—*Structural evolution of the Canyon Range:* A, *detachment on the Canyon Range thrust;* B, *thrusting of the Canyon Range allochthon in a southeasterly direction 21 km;* C, *thrusting of the Pavant allochthon in an easterly direction, of unknown magnitude;* D, *folding of the range from continued movement on the Pavant thrust;* E, *normal faulting and erosion of the range. Note the change in perspective from northwest–southeast to west–east after* B.

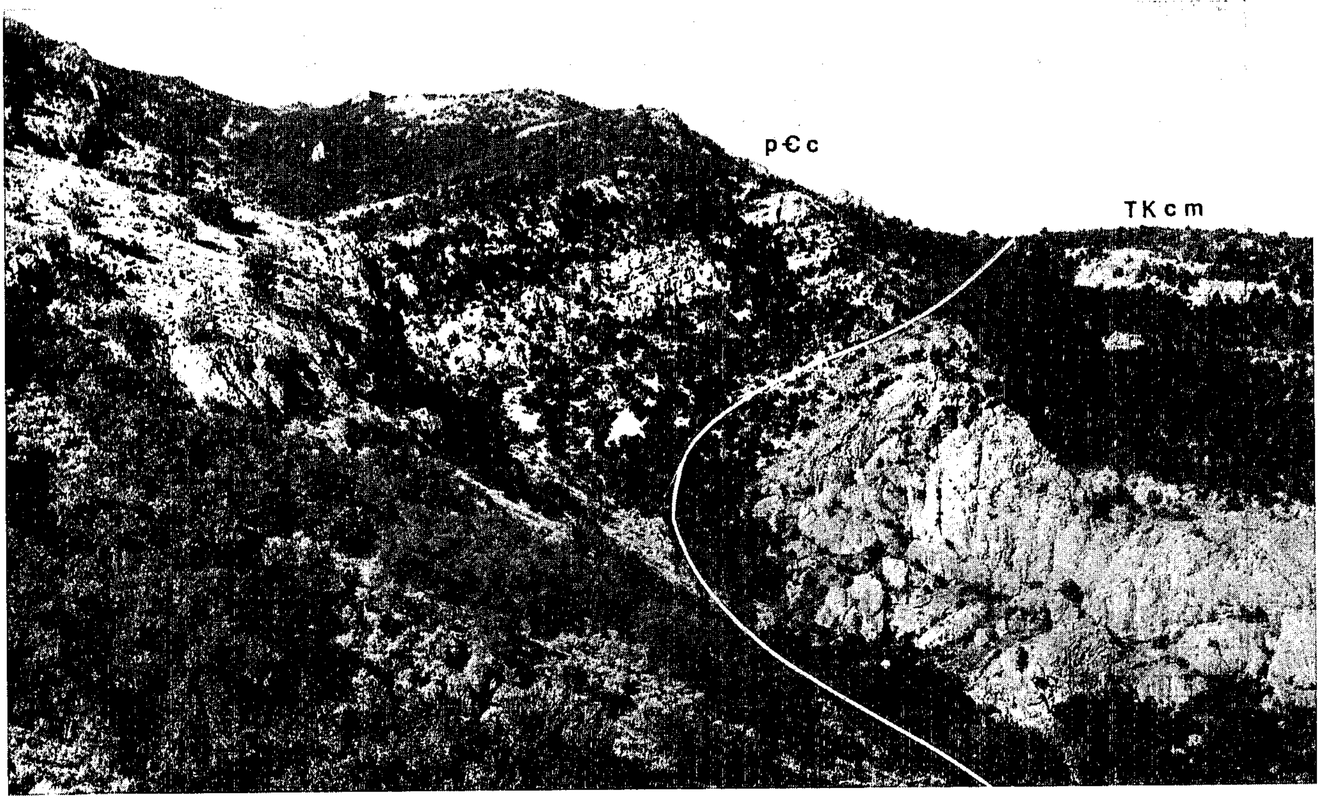


FIGURE 14.—*Eastern exposure of the Canyon Range klippe thrust fault showing Caddy Canyon Quartzite thrust on overturned Canyon Range Formation. View is north.*

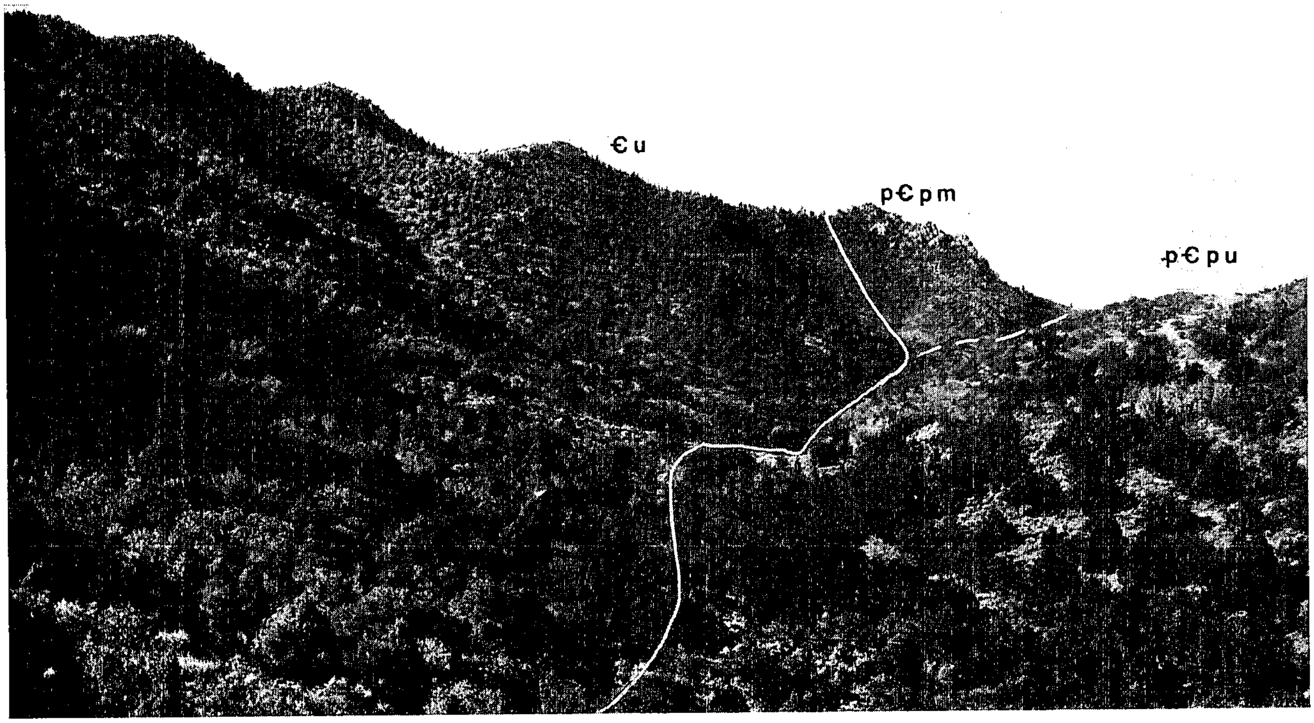


FIGURE 15.—*Western exposure of the Canyon Range klippe thrust fault at Knoll Hollow toward the north. Upper member of the Pocatello Formation is on the east, and undivided Cambrian carbonates are on the west. Note the thrust as it ramps abruptly through the middle member of the Pocatello Formation to the upper member at the right-center horizon.*

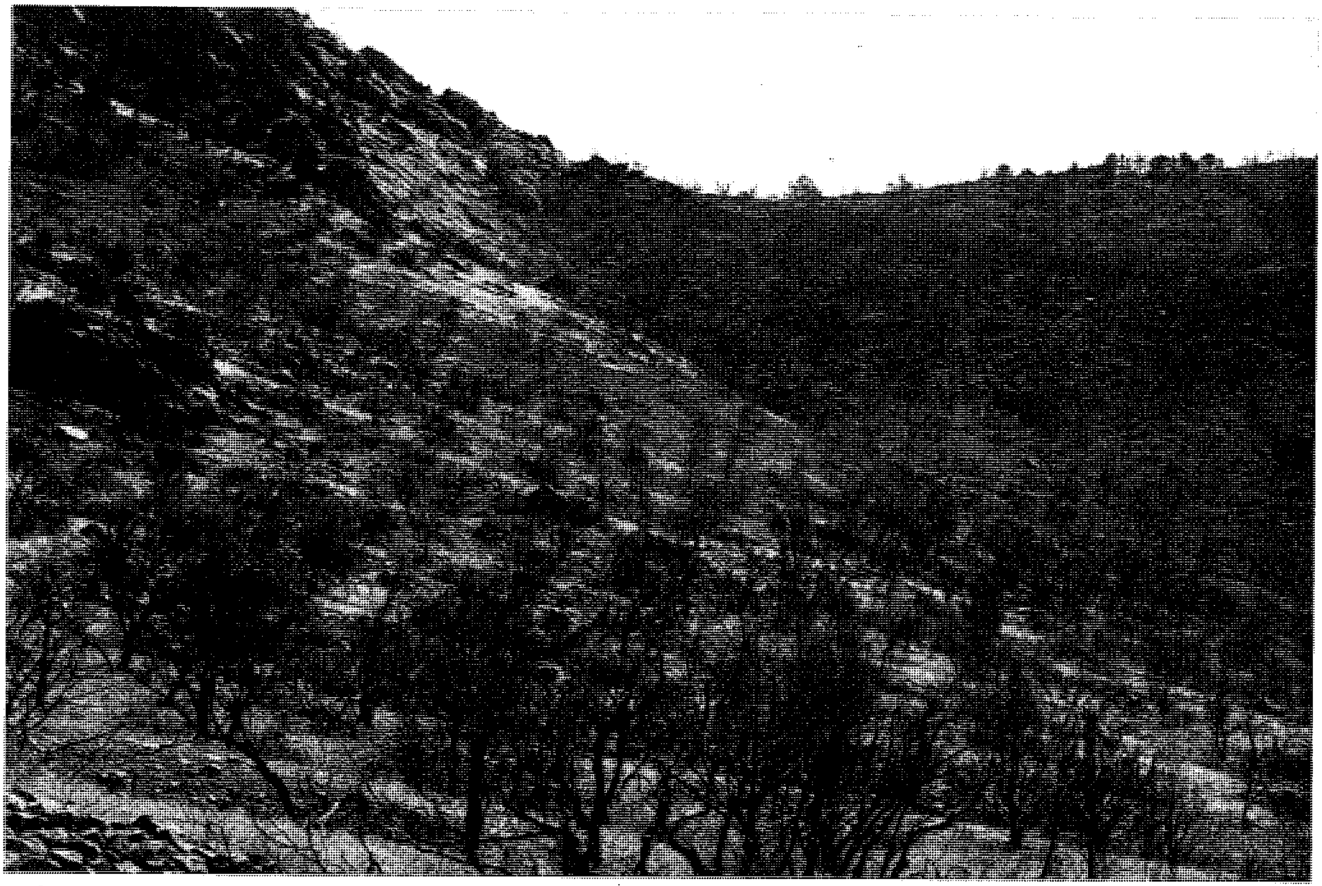


FIGURE 16.—*Oak City exposure of the Canyon Range thrust fault; view is to the southwest at the mouth of Mahogany Hollow. Rocks in the foreground and on the east (left) are Tintic Quartzite. Here they form a dip slope on the western limb of Canyon Range anticline. Dips shallow from 50° to the west near the top of the ridge to 30° in the foreground. Strata of the upper member of the Pocatello Formation are in the upper right third of the photograph.*

as Tintic Quartzite downdropped to the west against Precambrian strata. Confusion concerning this fault is rooted in poorly understood stratigraphy. Christiansen's assignment is reversed from actual stratigraphy. Shale and siltstone of the upper member of the Precambrian Pocatello Formation is faulted on the Tintic Quartzite. Figure 16 illustrates this relationship. The Pocatello Formation is less resistant and readily erodes, exposing the thrust plane. Near the top of the formation, a resistant quartzite ledge protrudes from the shales. This ledge dips 22° to the west, while the thrust plane dips 8° steeper than bedding.

The Canyon Range allochthon forms limited exposures east of Oak City. The thrust fault is buried by alluvium 1.4 km north of Mahogany Hollow, and the fault relationships south of Oak Creek Canyon are uncertain, as mapped by Christiansen. The Canyon Range thrust fault apparently continues to the west in the subsurface. Southwest of Oak City, Placid Oil Company's Henley #1 well (NW ¼, NW ¼, section 15, T. 18 S, R. 5 W) cut a thrust fault at a depth of approximately 2,250 m (Sprinkle and Baer 1982) that is probably the Canyon Range thrust fault.

Syncline Axis Thrust

West of Fool Peak, in the axis of the Canyon Range syncline, is a small, low-angle reverse fault. The thrust fault trace is contained within the Tintic Quartzite, making estimates of displacement tenuous. The fault is approximately 1 km long, and displacement is on the order of 100 m.

FOLDS

Canyon Range Syncline

The most prominent structural feature in the Canyon Range is the broad, north-trending Canyon Range syncline that extends the entire length of the range. The eastern limb is downfaulted in the subsurface north of Dry Fork. South of Dry Fork, the syncline is approximately 6 km wide. In the northern Canyon Range the syncline is doubly plunging, culminating near Fool Peak. Between Leamington Pass and Fool Peak, the syncline plunges approximately 11° north (fig. 17a,b).

The eastern limb dips between 40° and 50° to the west. The western limb is vertical to overturned, dipping to 27° to the west between Wild Horse and Dry Fork Canyons. The syncline is folded more tightly north of Wild Horse Canyon, and strike-slip faults have offset Cambrian strata in the axis of the fold.

Canyon Range Anticline

An overturned, doubly plunging anticline is present in the western third of the range. A normal fault separates this anticline from the Canyon Range syncline. It is almost entirely comprised of Tintic Quartzite of the Pavant allochthon (fig. 18), although south of the study area, east-trending normal faults have exposed Mutual Formation in the fold. On the western edge of the anticline, the Canyon Range allochthon is thrust on folded Tintic Quartzite. The anticline is buried north of Bridge Canyon by Quaternary alluvium and conglomerates of the Oak City Formation.

Tertiary Folds

A set of east-trending folds, with axes transverse to the earlier structures, is subtly imprinted on the Sevier folds of the Canyon Range (fig. 19). Cretaceous and Tertiary rocks are involved in the gentle folds. Meibos (1983) reported that this folding extends eastward to Long Ridge and that it occurred after deposition of the Sage Valley Limestone Member of the Goldens Ranch Formation (32 m.y.). He stated that salt movement or basin-and-range faulting may be responsible for the folding and favored the latter mechanism. Baer (personal communication 1983) has reported this same Tertiary folding in the Pavant Mountains, and I have observed what appears to be similar folding in the Wasatch Mountains east of Provo, Utah.

These folds have long wavelengths (approximately 6.5 km), and small amplitudes (on the order of 100 m). Tensional jointing occurs in the hinge of the folds, and erosion in these fractured, jointed zones is responsible for the transverse canyons of the range. The joint set is vertical and parallel to the axial plane. Major canyons occur at one-half wavelength of folding (approximately every 3 km). Leamington Pass, Dry Fork, and Cow Canyon delineate anticlinal axes. Wild Horse–Wringer Canyons, Bridge–Charlie Johnson Canyons, and Oak Creek Canyon are approximate locations of synclinal axes. Swank (1978)

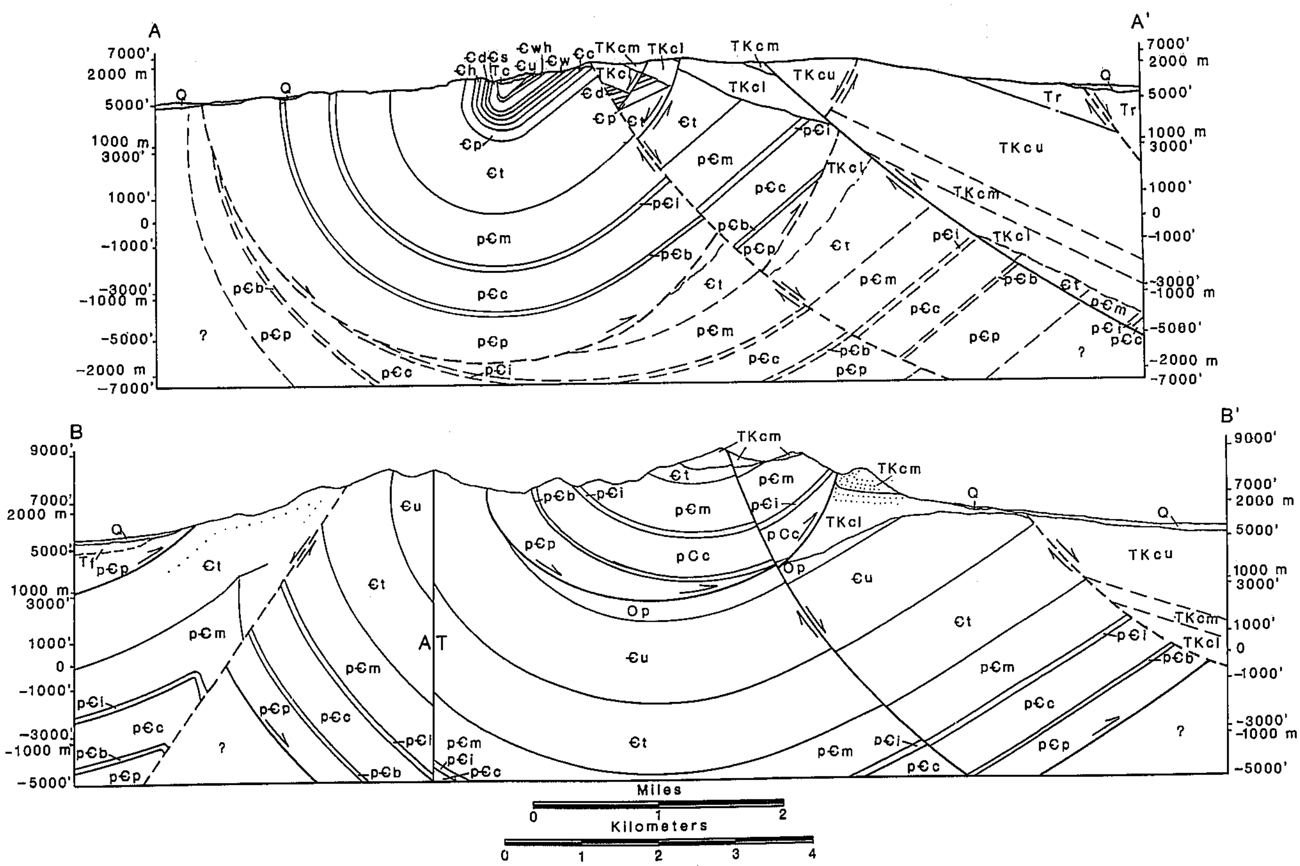


FIGURE 17.—*Structural cross sections.*

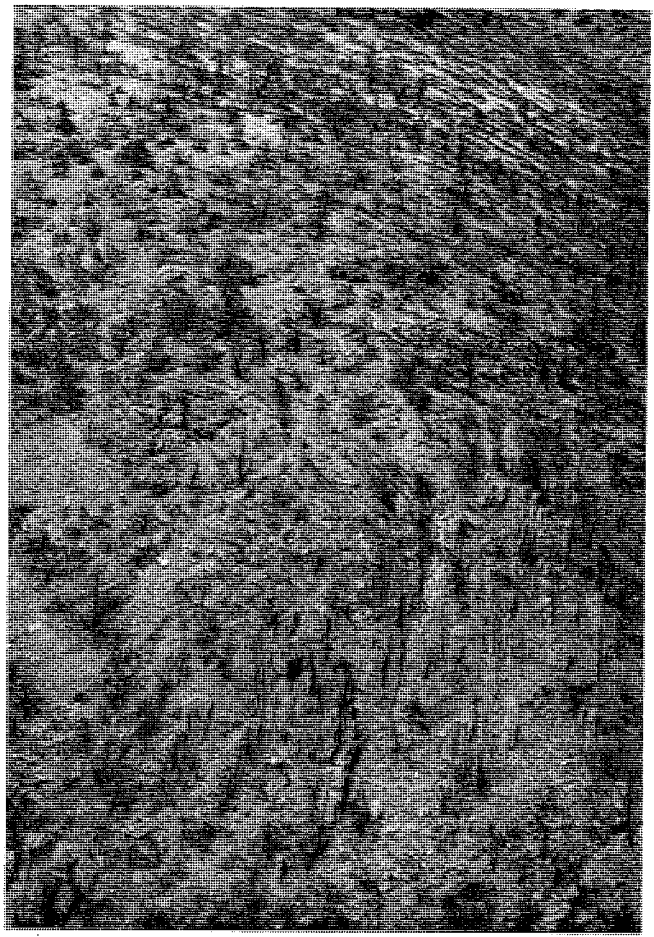


FIGURE 18.—*Overturned anticline in Tintic Quartzite at Mahogany Hollow. View is to the north.*

recognized this joint set south of this study in North Walker Canyon.

NORMAL FAULTS

All normal faults mapped in the northern Canyon Range are of basin-and-range affinity. South of Wide Canyon they have a north–south orientation. North of this area, they arc to the west, trending north–northwest.

Bridge Canyon Fault

South of Bridge Canyon, a north–south-trending fault has dropped the Canyon Range anticline down against the adjacent syncline. Between Mahogany Hollow and Bridge Canyon, the fault is confined to the Tintic Quartzite, making identification of the fault trace difficult. North of Bridge Canyon, the fault is buried by Quaternary alluvium and conglomerate of the Miocene Oak City Formation.

Displacement on the fault is estimated to be approximately 1800 m (fig. 17b). At depth, movement on this fault may have been recurrent on the Canyon Range thrust fault (fig. 13e). COCORP seismic reflection data of basin-and-range faults southwest of the Canyon Range have been interpreted by Allmendinger and others (1983) to represent listric faults, which reactivate and move on older thrust faults at depth. This phenomenon has also been reported by McDonald (1976) in basin-and-range features west of the Canyon Range.

Dry Fork Fault

At the head of Dry Fork Canyon, the eastern thrust fault of the Canyon Range klippe is truncated by Cretaceous conglomerates. Christiansen (1952) was uncertain of the exact nature of this change but concluded that it is a zone of "small tear faults and closely spaced joints." I postulate that the thrust fault is displaced by a normal fault downdropped on the northeast. The fault cuts across structure of the eastern limb of the syncline, placing Cretaceous conglomerates in fault contact with Fool Creek Conglomerate, Mutual Formation, and Tintic Quartzite. At the ridge between Dry Fork and Wild Horse Canyon, the fault arcs 120° and trends north–northeast. North of this point, the fault is difficult to trace because it is confined within rocks of the lower member of the Canyon Range Formation and Tertiary conglomerates derived from this member. At the Wild Horse Canyon–Wringer Canyon divide, the Dry Fork fault converges and joins with a second fault. This fault and a third fault subparallel and east of the second are antithetic to the Dry Fork fault. The dependent, antithetic nature of these last two faults lends credence to the normal fault nature of Dry Fork fault.

Wide Canyon-East Border Fault

The Wide Canyon fault is a major border fault on the east side of the range that may be a northern extension of the border fault of Millard (1983). It can be traced south of Leamington Pass, through Wide Canyon, to an east protruding spur north of Cow Canyon. South of Cow Canyon, the fault is buried by alluvium. Between Cow and Wide Canyons, the upper member of the Canyon Range Formation is downfaulted against its lower member. Displacement on the fault decreases northward. North of Wide Canyon the upper member is faulted against the middle member. Here, minimum throw on the fault is equal to the exposed thickness of the upper member of the Canyon Range Formation: approximately 1200 m. Dip on the fault is calculated at 40° to the east and is constant over its exposed length.

Recent Faults

Several recent faults crop out along the eastern edge of the range. At Wide Canyon, Tertiary red beds are faulted, but south of this area scarps are found only in alluvium. North of Wide Canyon, they form the border fault of the range and are buried by alluvium. These faults have been recognized and mapped by Bucknam and Anderson (1979), Campbell (1976), and Christiansen (1952).

TEAR FAULTS

Limekiln Canyon Fault

South of Pauls Meadow, in Limekiln Canyon, a strike-slip fault has displaced strata of the Pavant allochthon. Tintic Quartzite, Pioche Formation (?), undivided Cambrian carbonates, and strata of the Pogonip Group have been affected. The fault does not involve rocks of the Canyon Range allochthon. Apparent movement is right lateral, and displacement is approximately 125 m.

Syncline Axis Fault

At the ridge between Dry Fork and Wild Horse Canyon, in the axis of the Canyon Range syncline, two tear faults have formed at the transition from an open to a tight fold. The two faults have opposite directions of apparent movement, and they join nearly at right angles to one another. One fault, which is parallel to the synclinal axis, exhibits right lateral movement, and displaces Middle Cambrian and Cretaceous strata approximately 900 m. The second fault is transverse to the synclinal axis

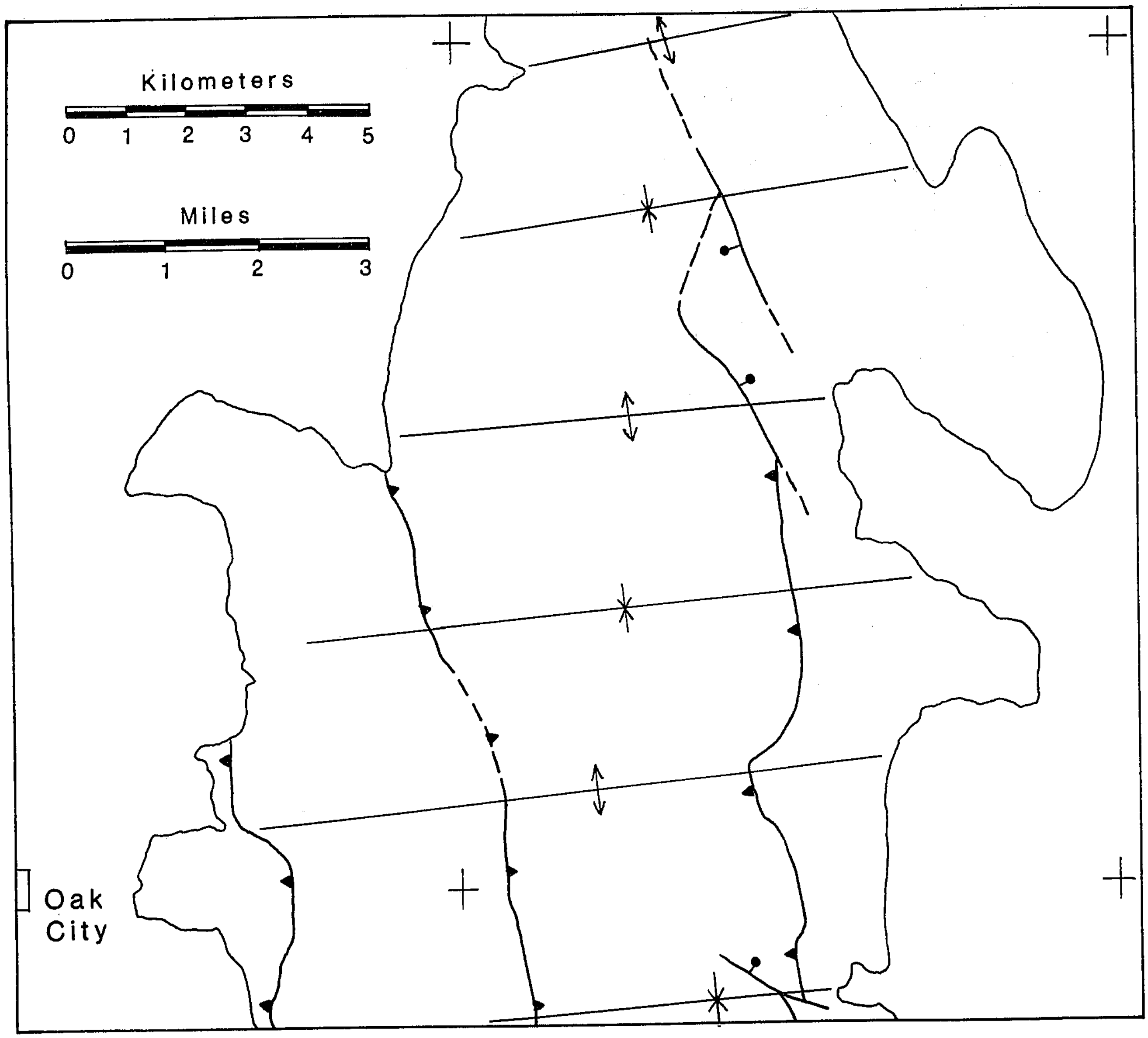


FIGURE 19.—*Tertiary folds in the northern Canyon Range.*

and has left lateral movement. Tintic Quartzite has been displaced 225 m against Middle Cambrian strata.

Cow Canyon Fault

Movement of the Canyon Range allochthon over conglomerates of the Canyon Range Formation has produced drag folds and tear faults in the subthrust strata. South of Cow Canyon and north of Wide Canyon, conglomerates are only locally deformed. Between these two canyons, and extending to the Wide Canyon-border fault, rocks of the lower member of the Canyon Range Formation dip steeply to the east. This area of extended deformation is bounded on the north and south by tear faults. Relative movement on the Cow Canyon fault is left lateral, and displacement is a minimum of 600 m.

PAVANT ALLOCHTHON

Correlation with Exposures in the Pavant Mountains

Many writers have recognized the structural position of the Pavant allochthon below the Canyon Range allochthon, and a few have projected the Pavant thrust into the Canyon Range (Millard 1983, Allmendinger and others 1983, Baer and others 1983, Burchfield and Hickcox 1972). Until recently, little evidence has been published to justify this projection.

The strongest evidence for the presence of the Pavant allochthon in the Canyon Range—and perhaps the most persuasive short of unbroken, exposed outcrop—is the character of the stratigraphy of the thrust sheets. The Pavant allochthon in the Pavant Range consists of Cambrian Tintic Quartzite through Ordovician Pogonip Group (Baer and others 1982). Older formations are not exposed but undoubtedly were involved in thrusting. Strata exposed below the Canyon Range thrust are Precambrian Mutual Formation through Ordovician Pogonip Group west of the Canyon Range klippe, and Ordovician Kanosh Shale through Devonian Cove Fort Quartzite east of the klippe. Precambrian strata are exposed only because of a unique set of circumstances, including the presence of the footwall ramp of the Canyon Range thrust, folding of the strata to a vertical attitude, and subsequent erosion.

The existence of the Pavant allochthon in the Canyon Range is convincingly demonstrated by comparison of Lower and Middle Cambrian strata between the two ranges. Although the Cambrian section measured near Kanosh, Millard County, by Davis (1983) is 80 km south of this study, the rocks are remarkably similar to strata at the head of Limekiln Canyon. In figure 10, a comparison is made of the Middle Cambrian stratigraphy of the Pavant allochthon in the Pavant and Canyon Ranges and the Lower and Middle Cambrian strata of the Canyon Range allochthon. The Pioche Formation is not subdivided in the Canyon Range. Davis subdivided the Pioche Formation of the Pavant Range into a lower member (measured section units 13–15), and an upper Tatow Member (units 16–18). The lower member is 59 m thick, and the Tatow Member is 27.4 m thick. In the Canyon Range, the lower member is absent or greatly reduced (unit 2?, this study, 6 m), and strata analogous to the Tatow Member are slightly expanded (79 m). Thicknesses of the Tatow Member are misleading, however, because I have mapped the Pioche Formation to include rocks containing the *Glossopleura* zone (unit 6), and Davis included equivalent strata as Cambrian undifferentiated (units 19–22). Combined thickness of the Tatow Member and the *Glossopleura* containing rocks of Cambrian undifferentiated is 74.4 m, which correlates well with the 79 m in the Canyon Range.

The lithologies of the two sections are similar, and a parallel pattern of facies is observed. In the Pavant Range, the Tatow Member contains a basal dolomitic limestone, a middle sandstone and shale, and an upper dolomite. In the Canyon Range, a basal shale and interbedded dolomite grade into poorly exposed limestone and then into dolomite and interbedded shale. Above these units in both ranges, strata are predominately thin-bedded limestone and interbedded shale, some of which contain *Glossopleura* zone fossils (Davis units 19–22, this study units 6–8). Massive limestone is found above the thin-bedded limestones, and dolomite is the principal lithology above the massive limestones.

Lower and Middle Cambrian strata of the Canyon Range allochthon are very different from those of the Pavant allochthon, even though the two areas in the Canyon Range are now only 8 km apart. The Pioche Formation of the Canyon Range allochthon is 230 m thick and consists of dark, phyllitic and micaceous shale and interbedded massive quartzite. The formation is devoid of carbonate rocks. *Skolithus* burrows and other trace fossils are common, but the diverse faunas of the Pavant sections are absent. The *Glossopleura* zone is found 100 m higher in the Chisholm Formation. A 500-m-thick sequence of alternating massive limestones and shales occurs above the Pioche Formation before dolomite is encountered in the section.

Canyon Range Thrust Footwall Ramp

In the northern Canyon Range, the exposed surface of the Pavant allochthon is the footwall ramp of the Canyon Range thrust. Between Box Canyon and Knoll Hollow, the thrust cuts steeply upsection from Mutual Formation to Pogonip Group strata. This represents ramping through 2,200 m of strata in a distance of 4,000 m for an average dip of 30°. South of Limekiln Canyon, the fault remains in the Pogonip Group for up to 5 km, averaging only 5° discordance with bedding.

On the west side of the klippe, the fault ramps upsection in the direction of movement (northwest to southeast). On the east side of the klippe, the Canyon Range thrust rests on Devonian strata in the north and on progressively older strata to the southeast (through Ordovician Kanosh Shale). This seesaw motion can be explained in two ways: (1) the thrust ramped upsection to the Devonian and then ramped downsection again; or (2) the thrust ramped upsection until it encountered the Upper Devonian unconformity and moved on this surface, at the base of the Mississippian. The latter alternative is the more likely, and figure 20 illustrates the Canyon Range subthrust surface based on this explanation. The upper surface of the Pavant allochthon beneath the klippe is dotted in figure 20. The Devonian unconformity has been described in much of central Utah (Rigby 1959), but not to date in the Canyon Range. The exposure on the east side of the klippe is the east limb of a pre-Mississippian syncline.

Beneath the Canyon Range allochthon, pre-Ordovician rocks of the footwall ramp trend northeast. Where exposed, the rocks of the footwall ramp appear to have a north–south component, but this is a function of the strata having been folded to a vertical attitude along the north–south axis of the Canyon Range syncline and subsequently eroded. Geometry of the Canyon Range allochthon, as it progressively covers the footwall ramp at Box Canyon, indicates the actual northeast trend in the subthrust.

STRUCTURAL EVOLUTION OF THE CANYON RANGE

Overview

Thrusting in the Canyon Range was initiated on the Canyon Range thrust fault, with movement in a southeasterly direction (fig. 13a,b). A second episode of thrusting occurred on the Pavant thrust in an easterly direction (fig. 13c), culminating in the development of the Canyon Range syncline and anticline (fig. 13d). Final structural development consisted of basin-and-range faulting, including the origin of the Bridge Canyon and Wide Canyon faults, and erosion to the present topography (fig. 13e). Thick conglomerates buried the range during the time between illustrated figures 13d and 13e.

Two alternatives to the mechanism for folding of the east limb of the syncline are possible. Instead of the Pavant thrust ramping on autochthonous strata, (1) a salt anticline in buried Mesozoic rocks may be present, or (2) recurrent movement on the Canyon Range thrust during folding of the Pavant allochthon may have resulted in a splay development, with consequent thrusting of the east klippe over a frontal, now buried, section of the Canyon Range allochthon. The latter alternative would provide a

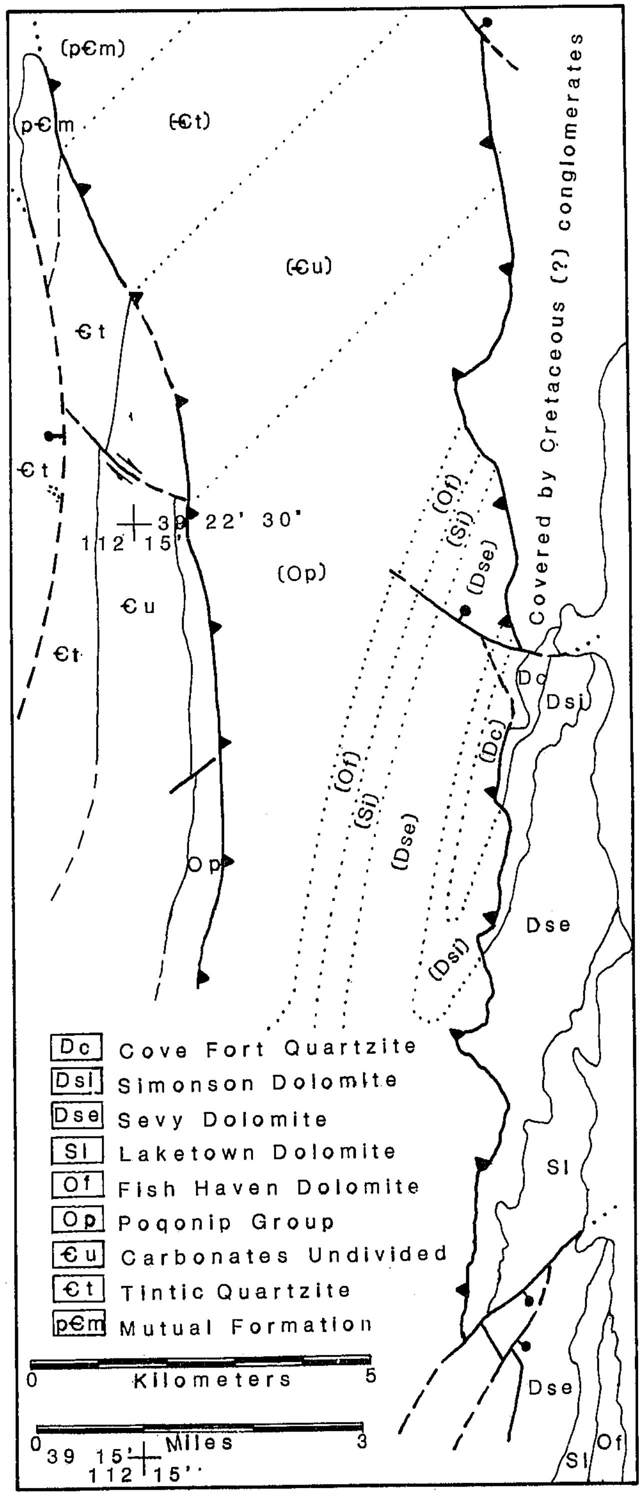


FIGURE 20.—*The Canyon Range allochthon subthrust surface showing exposed rocks in solid lines and inferred geology beneath the Canyon Range allochthon as dotted lines. A syncline of pre-Mississippian age is present in the southeast part of the range. The Canyon Range thrust ramped through older formations to the Upper Devonian unconformity and moved along this surface. Geology of the lower half of this figure is modified after Millard (1983).*

reasonable explanation for the north–south trend of the eastern edge of the Canyon Range thrust.

Directions of Thrust Movements

The direction of movement of the Canyon Range thrust is traditionally considered to be easterly, but evidence exists to support a southeasterly direction of transport. The following evidences are offered: (1) the strike of the Canyon Range footwall ramp trends northeasterly and typically is perpendicular to detachment; (2) the angle of the Cow Canyon reentrant is also perpendicular to movement; (3) geometry of the ramp in the middle member of the Pocatello Formation at Pauls Meadow implies a pronounced southerly movement; (4) the oldest rocks thrust are in the northernmost exposures, not to the west; (5) the thrust fault encountered in the Placid Oil Henley # 1 well placed undivided Cambrian carbonates over Ordovician Pogonip Group. If this fault is the Canyon Range thrust, a possibility substantiated by similarities to the exposure east of Oak City, then a strict easterly direction of movement is not possible. Easterly movement would require a thick Precambrian and Tintic Quartzite section below the undivided Cambrian carbonates. In addition, Higgins (1982) cited small folds with axes parallel to the Leamington Canyon fault, and slickenside orientations as evidences of a northwest–southeast direction of thrusting.

The north–south folded Canyon Range syncline is cited as an evidence of east–west movement of the Canyon Range thrust. Armstrong (1968) recognized that the Canyon Range thrust could have developed only prior to folding, and that after the fold developed, thrusting (on the scale that occurs in the Canyon Range) was no longer possible. By reason of the fact that the Pavant thrust is also folded, the folding did not result from movement of the Canyon Range thrust.

A more reasonable explanation is that folding coincided with movement on the underlying, subsequent Pavant thrust. Baer and others (1982) report that the Pavant thrust moved south–southeast in the southern Pavant Range and more easterly in the north. In the Canyon Range this trend is continued with movement from west to east.

Magnitudes of Thrust Displacement

A minimum value of displacement on the Canyon Range thrust can be obtained from the distance between the footwall and hanging-wall ramps. The stratigraphically lowest preserved part of the hanging-wall ramp is the upper member of the Pocatello Formation at the southeast edge of the range. The lowest exposed part of the footwall ramp is the Mutual Formation at Box Canyon. The distance between these two points measured along a northeasterly trending line is 18 km. A more realistic figure can be obtained by extrapolating the position of the Pocatello Formation on the footwall ramp in the subsurface. Using this method gives a probable displacement of 21 km. A maximum displacement on the thrust is more difficult to assess, but I would place an upper limit at about 30 km. This limit is dependent on the amount of erosion that has occurred on the leading edge at Scipio Pass.

Estimating movement on the Pavant thrust is more difficult because the thrust plane is not exposed. Baer and others (1982) reported a minimum displacement of 10 km on the Pavant thrust in the Pavant Range. In the Canyon Range, a minimum of 3 km of shortening has occurred during folding of the range, but the amount of thrusting cannot be estimated.

The Canyon Range thrust may have been reactivated during initial folding of the range. The direction of this secondary movement was eastward (Swank 1978). The magnitude can be estimated by measuring the vertical displacement of apparently equivalent conglomerates on opposite sides of the thrust and using an observed 40° dip for the thrust plane. On the south flank of Fool Peak the middle member of the Canyon Range Formation is 250 m above equivalent strata at Cow Canyon. If the 40° dip of the thrust plane is maintained at depth, the maximum displacement is 300 m. If 10° is used for the average dip, the maximum heave is 1,400 m.

Leamington Canyon Fault

The footwall ramp of the Canyon Range thrust rapidly descends downsection toward the northwest. This ramping can be extrapolated to the north in the subsurface to include the stratigraphically lowest observed strata of the Canyon Range allochthon (the Canyon Range allochthon detached from the Pavant allochthon in this area). The observed values of 30° to bedding for competent rocks and 5° for incompetent units can be used for the extrapolation, and the fault will be found to ramp through the 1,800 m of Mutual Formation through the lower member of the Pocatello Formation in less than 8 km. If the Pavant sole thrust is stratigraphically at or near the basal Pocatello Formation, the footwall cutoff would have truncated the Pavant allochthon in the area of the Leamington Canyon fault. The Leamington Canyon fault trends parallel to the footwall cutoff (perpendicular to movement on the Canyon Range thrust; fig. 21).

The Leamington fault was first mapped by Costain (1960), who interpreted it as a thrust fault dipping to the southeast. Morris and Shepard (1964) considered the feature to be a tear fault with right lateral displacement on the southern edge of the Nebo–Charleston thrust. Eardley (1969) considered the fault to be a shear on the Canyon Range thrust with left lateral movement. Birchfield and

Hickcox (1972) agreed with Morris and Shepard's interpretation. Higgins (1982) closely examined the exposed features of the fault and concluded that it is a thrust fault with northwest or southeast movement. Although it cannot be denied that the fault has characteristics on the surface of a thrust fault, if the premise of Canyon Range thrust movement preceding movement on the Pavant thrust is accepted, then the fault cannot be a thrust fault in a true sense. The Canyon Range allochthon has been transported to its present position "piggyback" on the Pavant allochthon, and the Pavant footwall cutoff coincides with a tear fault in the Canyon Range allochthon.

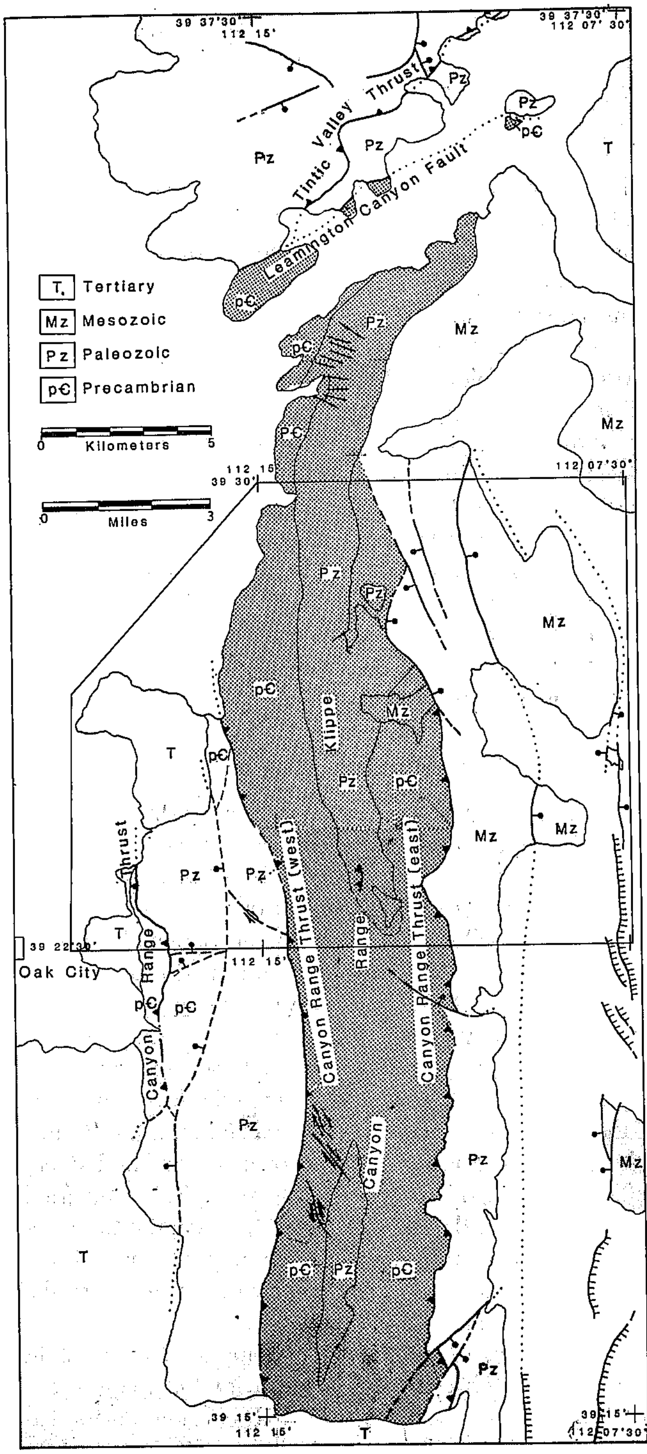


FIGURE 21.—*Geological map of the Canyon Range area. Geology modified after Christiansen (1952), Higgins (1982), and Millard (1983).*

The Leamington Canyon fault is aligned along the trend of the Nebo–Charleston thrust (Higgins 1982, fig. 6) and very likely moved with right lateral displacement as described by Morris and Shepard, and others. The most obvious structural feature between Leamington Pass and Leamington Canyon fault is the west limb of the Canyon Range syncline that is folded north 35° east. This folding is most easily explained as drag on a right lateral fault, and the high degree of deformation may be a function of large displacement. Drag has also placed Precambrian rocks over Paleozoic strata, lending the impression to some authors of thrusting as the principal mode of displacement.

Salt Tectonism

The Sanpete–Sevier Valley, east and south of the Canyon Range, is the site of an elongate anticline caused by salt diapirism in the Jurassic Arapien Shale (Witkind 1982). Stokes (1982) speculated that the synclinal nature of the Canyon Range may be a function of inverted topography caused by intrusion and subsequent erosion of salt anticlines. He cited the San Pitch and Valley Mountains as similar features. The Canyon Range lies beyond the known extent of the evaporite facies, but salt tectonics may be a possible alternative explanation for folding of the east limb of the syncline.

Salt diapirism has also been reported west of the range (fig. 1) in the Argonaut Energy Corporation No. 1 Federal well (CNW, section 23, T. 15 S, R. 7 W). The well penetrated 1,570.3 m of Tertiary age salt beginning at depth 777.2 m (Mitchell 1979). The Tertiary age of the salt precludes salt tectonics involving Sevier age structures.

No structures were observed in this study that could be reasonably attributed to salt movements.

ECONOMIC GEOLOGY

Potential for economic hydrocarbon recovery in the Canyon Range is probably low. In the Pavant Range, the Pavant allochthon is thrust over Mesozoic source rocks, and there is some tendency to extrapolate the same relationships northward to the Canyon Range. In the Canyon Range proper, two 4-km-thick (pre-erosional) thrust sheets are stacked on allochthonous strata below. During the Tertiary, another 1–2 km of conglomerates may have covered the range. Assuming the presence of possible source rocks, at these depths all oil would have been converted to gas less than 5 million years after thrusting (Angevine and Turcotte 1983). The greatest potential for recovery of hydrocarbons is east of the range, in the pre-Mississippian structures of the Pavant allochthon, or in Mesozoic strata beneath the thrust (assuming the Canyon Range thrust does not continue east of the range).

In the 1890s "Bishop" Peter Anderson prospected for lead-zinc-silver ores in the Canyon Range. Numerous small pits, holes, and tunnels are found north of Dry Fork. Diggings are restricted to the Pioche Formation, which Anderson called the "Black Jack." According to local lore, one profitable wagonload of ore was mined from the Yellowstone Canyon area. Galena and euhedral calcite can still be collected from his tunnel workings.

CONCLUSIONS

1. Strata below the Canyon Range thrust correlate with the Pavant allochthon of the Pavant Range.
2. Thrusting was initiated on the Canyon Range thrust which moved southeasterly approximately 21 km.
3. The Canyon Range thrust ramped upsection to the position of the Upper Devonian unconformity, and then stayed at this horizon.
4. The Canyon Range thrust fault on the east limb of the Canyon Range syncline at Cow Canyon is truncated by a basin-and-range normal fault, and not by strike-slip displacement.
5. Subsequent thrusting occurred on the Pavant thrust in an easterly direction with unknown magnitude.
6. Folding of the range along a north-trending axis coincided with thrusting on the Pavant thrust.
7. The Leamington Canyon fault is a tear fault in the Canyon Range allochthon above the Pavant thrust cutoff. Subsequent, large-scale, right-lateral movement may have occurred at this boundary associated with the Nebo thrust.

ACKNOWLEDGMENTS

Sincere thanks and appreciation are extended to members of my thesis committee: Dr. Lehi F. Hintze, Dr. J. Keith Rigby, and Dr. James L. Baer, for their help and direction during preparation of this thesis. Thanks are also extended to R. A. Robison, who willingly helped by providing fossil identification, and Raj K. Jain of Texaco for identification of palynological forms. I also thank Roger Anderson and his family for their friendship and hospitality while I was completing field research in the Canyon Range.

Funding for this project was provided by the American Association of Petroleum Geologists and the Utah Geological Association through their respective grant-in-aid programs. Aerial photographs were provided by Placid Oil Company.

Lastly, I am indebted to my loving wife, Janet, for her patience, help, and support throughout this study.

REFERENCES CITED

Allmendinger, R. W., Sharp, J. W., Tish, D. V., Serpa, L., Brown, L., Kaufman, S., Oliver, J., and Smith, R. B., 1983, Cenozoic and Mesozoic structure of the eastern Basin and Range from COCORP seismic reflection data: Geology, in press.

Angevine, C. L., and Turcotte, D. L., 1983, Oil generation in overthrust belts: American Association of Petroleum Geologists Bulletin, v. 67, no. 2, p. 235–41.

Armstrong, R. L., 1968, Sevier orogenic belt in Nevada and Utah: Geological Society of America Bulletin, v. 79, p. 429–58.

Baer, J. L., Davis, R. L., and George, S. E., 1982, Structure and stratigraphy of the Pavant Range, central Utah: Utah Geological Association Publication 10, p. 31–48.

Burchfield, B. C., and Hickcox, C. W., 1972, Structural development of central Utah: Utah Geological Association Publication 2, p. 55–67.

Bucknam, R. C., and Anderson, R. E., 1979, Map of fault scarps on unconsolidated sediments, Delta 1 × 2 quadrangle, Utah: U.S. Geological Survey Open-File Report 79-366, 23p.

Campbell, J. A., 1976, Cenozoic structural and geomorphic evolution of the Canyon Range, central Utah: Ph.D. dissertation, University of Utah, Salt Lake City, 145p.

————, 1979, Middle to late Cenozoic stratigraphy and structural development of the Canyon Range, central Utah: Utah Geology, v. 6, no. 1, p. 1–16.

Christiansen, F. W., 1952, Structure and stratigraphy of the Canyon Range, central Utah: Geological Society of America Bulletin, v. 63, no. 7, p. 717–40.

Christie-Blick, N., 1982, Upper Proterozoic and Lower Cambrian rocks of the Sheeprock Mountains, Utah: regional correlation and significance: Geological Society of America Bulletin, v. 93, no. 8, p. 735–50.

Costain, J. K., 1960, Geology of the Gilson Mountains and vicinity, Juab County, Utah: Ph.D. dissertation, University of Utah, Salt Lake City, 139p.

Crittenden, M. D., Jr., Schaeffer, F. E., Trimble, D. E., and Woodward, L. A., 1971, Nomenclature and correlation of some upper Precambrian and basal Cambrian sequences in western Utah and southeastern Idaho: Geological Society of America Bulletin, v. 82, p. 581–602.

Davis, R. L., 1983, Geology of the Dog Valley–Red Ridge area: southern Pavant Mountains, Millard County, Utah: Brigham Young University Geology Studies, v. 30, pt. 1, p. 19–36.

Eardley, A. J., 1969, Charting the Laramide structures of western Utah: Utah Geological and Mineralogical Survey Bulletin, v. 82, p. 51–70.

Gilbert, G. K., 1890, Lake Bonneville: U.S. Geological Survey, Monograph 1, p. 164–66.

Goddard, et al., 1975, Rock-color chart: Geological Society of America, 16p.

Higgins, J. M., 1982, Geology of the Champlin Peak Quadrangle, Juab and Millard Counties, Utah: Brigham Young University Geology Studies, v. 29, pt. 2, p. 40–58.

Hintze, L. F., 1972, Lower Paleozoic strata in central Utah: Utah Geological Association Publication 2, p. 7–11.

Hintze, L. F., and Robison, R. A., 1975, Middle Cambrian stratigraphy of the House, Wah Wah, and adjacent ranges in western Utah: Geological Society of America Bulletin, v. 86, p. 881–91.

Lautenschlager, H. K., 1952, The geology of the central part of the Pavant Range, Utah: Ph.D. dissertation, The Ohio State University, Columbus, 188p.

Loughlin, G. F., 1914, A reconnaissance in the Canyon Range, west-central Utah: U.S. Geological Survey Professional Paper 90-F, p. 51–60.

McDonald, R. E., 1976, Tertiary tectonics and sedimentary rocks along the transition: Basin and Range Province to Plateau and Thrust Belt Province, Utah: Rocky Mountain Association of Geologists, 1976 Symposium, p. 281–317.

Meibos, L. C., 1983, Structure and stratigraphy of the Nephi Northwest 7½-minute Quadrangle: Brigham Young University Geology Studies, v. 30, pt. 1, p. 37–58.

Millard, A. W., 1983, Geology of the southwest quarter of the Scipio North Quadrangle, Millard and Juab Counties, Utah: Brigham Young University Geology Studies, v. 30, pt. 1, p. 59–81.

Mitchell, G. C., 1979, Stratigraphy and regional implications of the Argonaut Energy No. 1 Federal, Millard County, Utah: p. 503–14.

Morris, H. T., and Shepard, W. M., 1964, Evidences for a concealed tear fault with large displacement in the central East Tintic Mountains, Utah: U.S. Geological Survey Professional Paper 501-C, p. 19–21.

Rigby, J. K., 1959, Upper Devonian unconformity in central Utah: Geological Society of America Bulletin, v. 70, p. 207–18.

Sprinkle, D. A., and Baer, J. L., 1982, Overthrusts in the Canyon and Pavant Ranges: Utah Geological Association Publication 10, p. 302–13.

Stokes, W. L., 1982, Geological comparisons and contrasts, Paradox and Arapien Basins: Utah Geological Association Publication 10, p. 1–11.

Stolle, J. M., 1978, Stratigraphy of the Lower Tertiary and Upper Cretaceous(?) continental strata in the Canyon Range, Juab County, Utah: Brigham Young University Geology Studies, v. 25, pt. 3, p. 117–39.

Swank, W. J., Jr., 1978, Structural history of the Canyon Range thrust, central Utah: Master's thesis, The Ohio State University, Columbus.

Witkind, I. J., 1982, Salt diapirism in central Utah: Utah Geological Association Publication 10, p. 13–30.

Woodward, L. A., 1972, Upper Precambrian stratigraphy of central Utah: Utah Geological Association Publication 2, p. 1–5.