Stratigraphy of Paleozoic Rocks in the Carlin-Pinon Range Area, Nevada

GEOLOGICAL SURVEY PROFESSIONAL PAPER 867-A

Prepared in cooperation with
Nevada Bureau of Mines and Geology

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By J. FRED SMITH, JR., *and* KEITH B. KETNER

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STRATIGRAPHY OF PALEOZOIC ROCKS IN THE CARLIN-PINON RANGE AREA, NEVADA

By J. FRED SMITH, JR., and KEITH B. KETNER

ABSTRACT

Paleozoic rocks are exposed over slightly more than one-quarter of the region here designated as the Carlin-Pinon Range area, which includes four 15-minute quadrangles that cover about 925 square miles in northeastern Nevada. Paleozoic rocks crop out mostly along the Pinon Range, trending north through the central part of the area, in the northeastern part of the area, and in isolated ridges and hills.

Strata ranging in age from Ordovician through Permian make up the stratigraphic section of Paleozoic units. Two prominent unconformities separate these units into three major sequences: (1) Ordovician to upper Upper Devonian, (2) Lower Mississippian to Middle Pennsylvanian, and (3) Upper Pennsylvanian to Upper Permian. Rocks forming sequence 1 consist essentially of two different facies and differ strikingly from the other two sequences. Sequences 2 and 3 are somewhat similar lithologically; the older parts of both are composed in part of sedimentary rocks deposited during major uplift of the source areas of the sediments.

Formations in sequence 1 consist of an autochthonous carbonate assemblage deposited in a miogeosyncline, an allochthonous siliceous assemblage deposited in a eugeosyncline to the west, and an allochthonous transitional assemblage. The oldest strata in the carbonate assemblage are of Ordovician age, consist of gray dolomite with interbeds of shale in the upper part, and are assigned to the Pogonip Group; these beds, incompletely exposed in a very small area, are about 350 feet thick with their base unexposed. Overlying the Pogonip and also exposed over only a small area is the Eureka Quartzite, which consists of 70 feet of obscurely stratified, thin- and thick-bedded white quartzite. Regionally, the basal contact of the Eureka is an uncomformity; in the area of this report it is poorly exposed but seems conformable.

The Hanson Creek Formation overlies the Eureka on what appears to be a conformable contact; regionally, however, this contact also is an unconformity. The Hanson Creek is composed of 150 feet of thin- to thick-bedded black and gray dolomite; a persistent yellowish-weathering limy siltstone and silty limestone unit marks the top of the formation. Poorly preserved fossils from this formation suggest that it is both Middle and Late Ordovician in age.

Ordovician units of the siliceous (western) assemblage in the mapped area are the Valmy and Vinini Formations. These two formations are time-equivalent and are similar lithologically in containing black shale and chert. The Valmy west of the area of the present report, however, also contains much quartzite and greenstone. On the basis of quartzite and greenstone content along with shale and chert, about 150 feet of strata at the northern end of the Sulphur Spring Range is placed in the Valmy Formation. Graptolites date these beds as Middle Ordovician. The dominantly black chert, shale, and mudstone that make up the Vinini Formation in this area are probably several thousand feet thick; bedding attitudes differ greatly in scattered exposures, however, and no reliable thickness can be measured. Fossil zones do not occur in the correct stratigraphic order locally and indicate that the Vinini is broken by numerous faults. Graptolite collections from the Vinini indicate that it includes Lower, Middle, and Upper Ordovician beds. In the northern part of the area, the Vinini is overlain by the Mississippian Webb Formation; Vinini contacts with other stratigraphic units are faults.

An Ordovician unit composed of claystone, shale, chert, limestone, sandy limestone, and quartzite has a minimum thickness of 1,600 feet on Marys Mountain in the northwest corner of the mapped area. It is considered as transitional between the carbonate and siliceous assemblages because it contains rock types characteristic of each of the other two assemblages. This unit is Early, Middle, and Late Ordovician in age. Positions of diagnostic fossils in this unit indicate that the beds do not occur in a normal stratigraphic succession and suggest that they are cut by numerous thrust faults.

Silurian carbonate-assemblage strata are assigned to the Lone Mountain Dolomite which is not completely exposed in the Carlin-Pinon Range area. The lower 350 feet of the formation in the center of the mapped area is mostly thick-bedded gray dolomite. The upper 775 feet of the formation in the southern part of the area consists largely of alternating brown and gray dolomite beds that range in thickness from 2 to 12 feet. On the basis of sparse fossil collections from the lower part, the Lone Mountain is considered to be mostly Late Silurian. This age indicates a hiatus between it and the underlying Hanson Creek Formation, although no physical break was discernible on the rubble-strewn slopes. The upper part of the Lone Mountain may be Devonian. The upper contact with the overlying Devonian Nevada Formation is poorly exposed but appears to be conformable at a change from alternating gray and brown dolomite beds in the Lone Mountain to dolomitic sandstone or quartzose dolomite at the base of the Nevada.

Siliceous assemblage rocks of Silurian age crop out over about one-half square mile on Marys Mountain in the northwest corner of the mapped area. Gray, tan, brown, and green chert in knobby beds and lesser amounts of white to gray siltstone compose these strata that may be 400-500 feet thick. This possible thickness is only an estimate, as both the lower and upper contacts of the unit are probably thrust faults and unrecognized internal faults probably cut the unit. A late Early or early Middle Silurian age of part of these beds is established from diagnostic graptolites. These strata may be correlative with the Fourmile Canyon Formation of the Cortez area.

Carbonate-assemblage rocks of Devonian age include the Nevada Formation and the Devils Gate Limestone. Three members are recognized in the Nevada Formation; the lower two are correlated with established members in the Eureka area to the south. The maximum

thickness of the Nevada may be as much as 3,200 feet in the southern quarter of the area. The Beacon Peak Dolomite Member, the lowest member of the Nevada, consists chiefly of thin- to thick-bedded gray to brown dolomite, which has a grainy texture observable on moistened surfaces and which characteristically contains thin red stylolites. Quartz grains occur in the basal part and are scattered through some upper beds. In the Carlin-Pinon Range area the Beacon Peak is overlain gradationally by the Oxyoke Canyon Sandstone Member which is composed of white, pink, gray, and light-brown quartzite and sandstone containing different amounts of dolomite. It has been suggested that the contact is an unconformity regionally. The upper member of the Nevada lies in gradational contact on the Oxyoke Canyon and is made up mostly of brown and gray dolomite in alternating layers with distinct to indistinct bedding. The Nevada Formation is Early and Middle Devonian in age.

Lower Paleozoic rocks, beginning at least with those as old as Hanson Creek Formation, change westward from dolomite to limestone across a north-south belt that passes near the western margin of the Carlin-Pinon Range area. The Nevada Formation in the mapped area is just on the east side of this belt.

The upper member of the Nevada both grades and interfingers into the overlying Devils Gate Limestone which is composed mostly of medium- to thick-bedded light- and dark-gray limestone. Coral-rich "spaghetti" beds are scattered through the formation. The maximum measured thickness of the Devils Gate is 940 feet. Faunas from this formation indicate an early Late and possibly a late Middle Devonian age. The upper contact of the Devils Gate is an unconformity along which the limestone is overlain by beds of Mississippian age.

Siliceous assemblage strata of Devonian age are assigned to the Woodruff Formation, named for exposures in this area. The Woodruff consists principally of dark-gray to black siliceous mudstone and chert and also contains shale, siltstone, dolomitic siltstone, and dolomite, and a few beds of limestone, sandy limestone, and calcareous sandstone. Because exposures where bedding attitudes may be seen are scattered and, very commonly, attitudes are irregular where they are seen, no accurate thickness of the Woodruff was determined; it must be about 3,000 feet in the southern part of the area and is probably several thousand feet more than that in the entire area. The Woodruff Formation ranges in age from Early Devonian to late Late (though not latest) Devonian. The oldest beds are dated on graptolites and the youngest, on goniatites. This Late Devonian age is important in the geologic history of the region, as it marks the age of the youngest rocks transported into the area on the Roberts Mountains thrust.

The Roberts Mountains Formation in this area is assigned to the transitional assemblage and is of earliest Devonian age as dated on graptolites. It is exposed only in a thrust slice on Willow Creek, where it consists of very dark brown and mostly black shaly and platy laminated silty dolomite and dolomitic marl.

An unnamed Devonian unit of limestone, sandy limestone, and chert, which crops out in a small area in the Sulphur Spring Range, is interpreted to be transitional between carbonate- and siliceous-assemblage rocks. These beds are dated on conodonts as Middle and perhaps early Late Devonian. Contacts between this unit and other Paleozoic units are faults.

Devonian strata in this area are overlain unconformably by beds of early Early Mississippian age. The time interval between deposition of Devonian and Mississippian units was the time of the Antler orogeny in this mapped area and of the movement of rocks of the siliceous and transitional assemblages into the area on the Roberts Mountains thrust. The orogeny and the associated thrust in the Carlin-Pinon Range area are dated as post-early Late Devonian, but not latest Late Devonian, and pre-early, but not earliest, Early Mississippian.

Mississippian and younger beds of sequence 2 deposited across lower Paleozoic allochthonous, siliceous, and transitional assemblage rocks and autochthounous carbonate assemblage ones juxtaposed by the Roberts Mountains thrust are called the overlap assemblage. The oldest Mississippian rocks in the area consist chiefly of siliceous mudstone and claystone and of some sandstone and limestone in lenticular beds. The limestone is a distinctive black to gray, tan-weathering, dense rock. These strata make up the Webb Formation which has a maximum thickness of at least 800 feet in the northern part of the area and wedges out southward. In the southern part of the area, where the Webb is lacking, the Chainman Shale rests on Devonian rocks, and this formation probably is partly equivalent to the Webb. The Webb is dated as Early Mississippian (early but not earliest Kinderhookian).

Black siliceous argillite, some black chert, and minor conglomerate and quartzite compose a unit about 5,000 feet thick centering at Lee Canyon in the middle of the mapped area. This argillite is presumed to be of Early Mississippian age because it is lithologically similar to some parts of the Webb Formation and the Chainman Shale. The basal contact of the argillite unit appears to be a thrust fault along which this unit was moved into the area from the east. Chainman Shale rests on the argillite unit on what seems to be a conformable contact.

The Chainman Shale and Diamond Peak Formation make up a sequence of clastic rocks that reflects a source area of continuing uplift to the west. Rocks making up this sequence are principally gray shale, sandstone composed of quartz and chert grains, and conglomerate composed of chert, quartzite, and sandstone pebbles to boulders. Limestone, sandy limestone, and calcareous sandstone occur locally. Pebbly mudstone is common locally, particularly in the lower part. In a general way the texture of the sequence becomes coarser upward, but conglomerates occur low as well as high in the section. This second sequence is mapped as three units: (1) Chainman Shale, where the rocks are mainly shale and sandstone, (2) Diamond Peak Formation, where the rocks are essentially conglomerate and sandstone, and (3) Chainman Shale and Diamond Peak Formation undivided, where shale, conglomerate, and sandstone seem about equally prominent. The thickness of the entire sequence ranges from 6,000 to 7,000 feet. Many fossil assemblages confirm an age range of these strata from Early Mississippian (late Kinderhookian) to Early Pennsylvanian.

The Moleen Formation and the undivided Moleen and Tomera Formations of Pennsylvanian age of the second sequence rest conformably on the Diamond Peak Formation. The Moleen consists of ledge-forming gray limestone and contains thin-bedded sandy and silty limestone which commonly form slopes between the ledges. Characteristically, chert occurs in pods and irregular layers in the gray limestone. Lenses of mostly chert pebble conglomerate are scattered through the formation. The Moleen ranges in thickness from about 1,200 to about 1,600 feet.

The Tomera Formation, which is transitional with the underlying Moleen, consists of interbedded and interfingering limestone and conglomerate. Chert pebble conglomerate makes up a prominent part of the formation, and is one of its distinguishing features. The thickness of the Tomera is 1,700-2,000 feet.

The amount of conglomerate in that part of the section equivalent to the Moleen increases westward or northwestward in the mapped area, and in one place the entire section is mostly conglomerate and sandstone. Where the entire sequence of Pennsylvanian strata has a relatively high percentage of conglomerate to other rock types, the Moleen and Tomera are mapped as an undivided unit. These two formations range in age from early Early Pennsylvanian to late Middle Pennsylvanian.

Deformation and erosion of the Tomera and older units resulted in a pronounced unconformity that is bracketed by fossiliferous beds of Missourian age resting on beds of early Des Moinesian age. The sea in which the postunconformity beds were deposited spread slowly over the area as erosion continued on land, and, so, in places strata of Late Permian age rest on strata of Early Mississippian age.

Rocks of Late Pennsylvanian and Early and early Late Permian age have a maximum exposed thickness of about 5,000 feet, but their top is eroded and the original thickness is unknown. Rock units are composed mainly of carbonate and siliceous fragments that range in size from clay to boulders. Thin-bedded calcareous fine-grained sandstone to siltstone and fine-grained sandy or silty limestone, which weather to form yellow, tan, and reddish-tan platy fragments, are characteristic rock types in the sequence. Conglomerate beds and lenses and conglomeratic limestone are prominent in parts of the area. As much as 2,000 feet of the lower part of these strata in the northern part of the area are mapped as the Strathearn Formation. Gray limestone in thin- to thick-bedded units is a prominent part of the Strathearn, which also contains platy silty and sandy limestone and conglomerate. Beds above the Strathearn and all the Upper Pennsylvanian and Permian rocks south of the area of recognized Strathearn are not divided. This third sequence of strata ranges in age from Late Pennsylvanian (equivalent to Missourian and Virgilian) to Late Permian (Guadalupian).

INTRODUCTION

Rocks ranging in age from Ordovician through Permian make up the stratigraphic section of Paleozoic units exposed in the Carlin-Pinon Range area. Two prominent unconformities separate these units into three major sequences: (1) Ordovician to upper Upper Devonian, (2) Lower Mississippian to Middle Pennsylvanian, and (3) Upper Pennsylvanian to Upper Permian. Rocks forming sequence 1 are composed of different facies and contrast strikingly in lithology from the other two sequences. Sequences 2 and 3 generally are more similar lithologically to each other than to sequence 1; the older sedimentary units of sequences 2 and 3 were deposited following orogenic episodes in the mapped area and generally east of a belt of rising land. The rocks of sequence 2 represent a more orderly development of synorogenic and possibly late orogenic deposition than rocks of sequence 3.

Units of sequence 1 were deposited in a miogeosyncline on the east and an eugeosyncline on the west, the Millard and Fraser belts, respectively, of Kay (1947, p. 1290). The miogeosynclinal deposits are chiefly carbonate rocks and are autochthonous in the area of this report, and the eugeosynclinal deposits are chiefly fine grained siliceous clastic rocks and chert and are allochthonous. In addition, some units of Ordovician, Silurian, and Devonian ages contain lithologic types similar to both the carbonate and the siliceous sections and evidently represent deposits transitional between them; these transitional deposits also are allochthonous in the mapped area. The Ordovician and Devonian rocks, then, consist of eastern-, transitional-, and western-assemblage units. (See Roberts and others, 1958, p. 2816-2820.) Deposition of this eugeosynlincal-miogeosynclinal dual sequence was brought to a close in late Late Devonian or early Early Mississippian by orogenic movements along a positive area, west of the mapped area, first identified by Nolan (1928, p. 158, fig. 1). These deformational movements constituted the Antler orogeny and the associated Roberts Mountains thrust (Roberts and others, 1958, p. 2817-2820; Merriam and Anderson, 1942), along which the allochthonous rocks moved eastward into the mapped area.

Sedimentary rocks that make up sequence 2 were deposited following movement along the Roberts Mountains thrust that took place during the Antler deformation. Beds of this sequence depositionally overlap the siliceous and carbonate assemblages of sequence 1 and form the overlap assemblage (Roberts and Lehner, 1955; Roberts and others, 1958, p. 2838-2846). In the report area, these overlap rocks range in age from Early Mississippian through Middle Pennsylvanian, and in general grade upward from very fine grained clastic rocks to coarse conglomerates and to limestone and conglomerate. Coarse-grained rocks also occur low as well as high in the section. The increase in coarseness upward through the Mississippian deposits reflects derivation of detritus from the rising land of the Antler belt to the west. The Pennsylvanian rocks also are composed mostly of detrital sediments and consist of limestone and interbedded sandstone and conglomerate; in general, the coarser beds are on the west and the finer ones on the east. Both lateral and vertical gradations between coarse- and fine-grained rocks are abrupt. Following deposition of sequence 2 the area was deformed and eroded before depositon of sequence 3; the break between the two sequences constitutes the sub-Strathearn unconformity (Dott, 1955, p. 2255).

Rocks of sequence 3 are largely detrital and range in age from Late Pennsylvanian to Late Permian. They consist of limestone and some dolomite and of siliceous clastic rocks ranging from siltstone to conglomerate. Lithologic types differ widely over the mapped area, and both lateral and vertical changes in lithology are common and are abrupt in places. These changes indicate intermittently unstable conditions in the source areas and may indicate local sources for some units. In the northern part of the area the upper part of this sequence consists of chert and fine-grained clastic rocks. Mesozoic and Cenozoic rocks unconformably overlie sequence 3 beds. Descriptions of post-Paleozoic units will be presented in another report.

THE CARLIN-PINON RANGE AREA

The country here designated the Carlin-Pinon Range area comprises four 15-minute quadrangles—the Dixie Flats, Carlin, Pine Valley, and Robinson Mountain quadrangles—in northeast Nevada (fig. 1). The north-trending Pinon Range forms the central backbone of the area and contains most of the outcrops of Paleozoic rocks. The north end of the Sulphur Spring Range, also underlain by Paleozoic rocks, extends into the southern margin of the area. Along the west side is the northern part of the Cortez Mountains in which post-Paleozoic rocks are exposed.

Drainage is all to the Humboldt River, the principal river in this part of Nevada, which crosses the northern part of the mapped area from east to west through the

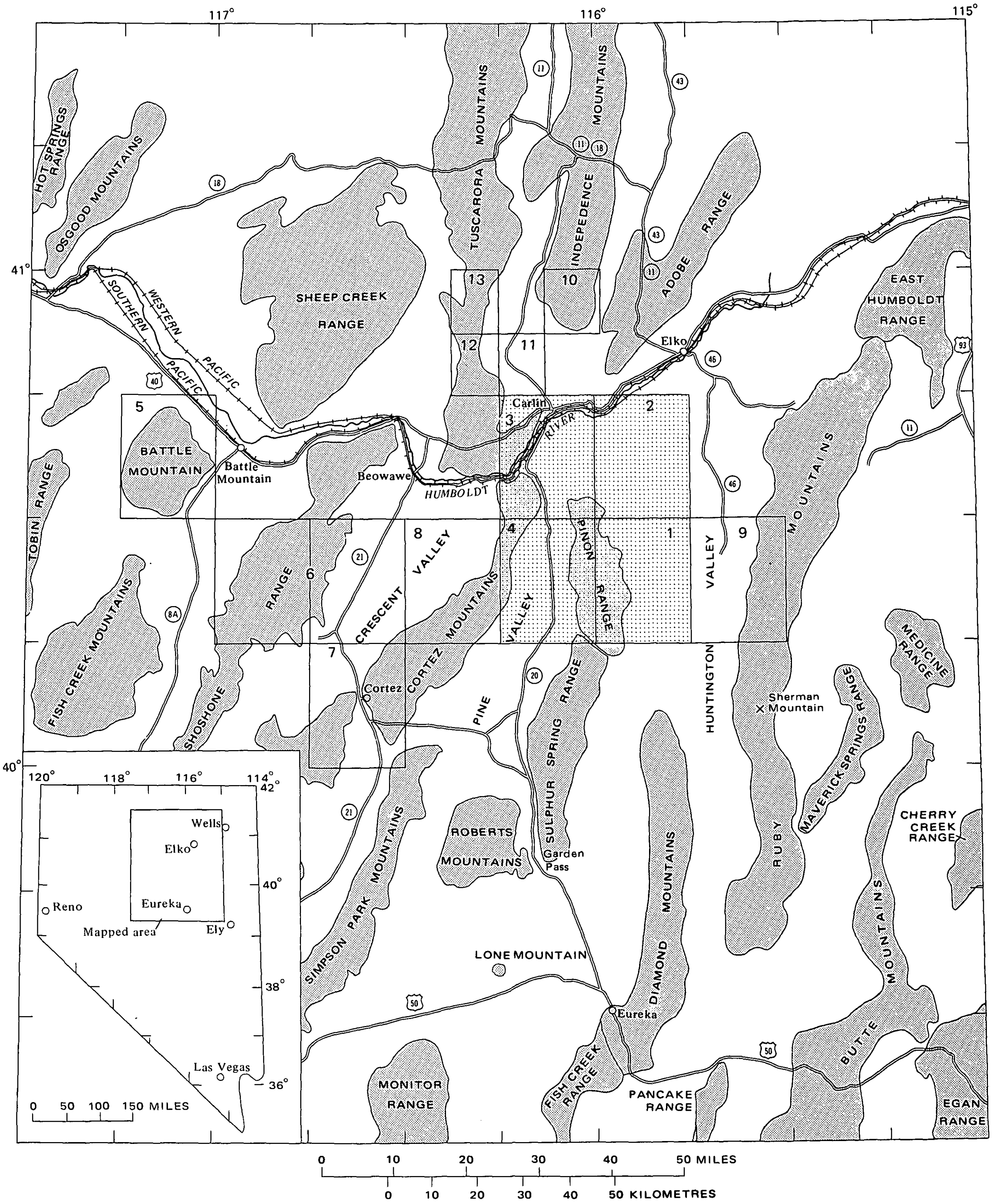


FIGURE 1.—Index map of part of northeast Nevada, showing the locations of the mapped quadrangles—(1) Robinson Mountain, (2) Dixie Flats, (3) Carlin, and (4) Pine Valley—that make up the Carlin-Pinon Range area (shaded area), and the locations of nearby quadrangles covered by recently published maps—(5) Antler Peak (Roberts, 1964), (6) Mount Lewis and Crescent Valley (Gilluly and Gates, 1965), (7) Cortez (Gilluly and Masursky, 1965), (8) Frenchie Creek (Muffler, 1964), (9) Jiggs (Wilden and Kistler, 1969), (10) Swales Mountain and part of Adobe Summit (Evans and Ketner, 1971), (11) Schroeder Mountain (Evans and Cress, 1972), (12) Welches Canyon (Evans, 1972a), and (13) Rodeo Creek NE (Evans, 1972b).

narrow Carlin Canyon, along a broad valley, and through the narrow Palisade Canyon. The South Fork Humboldt River also flows through a meandering canyon before it enters the flood plain of the main river about 8 miles southwest of Elko. The valleys on each side of the Pinon Range are occupied by permanent streams. Huntington Creek east of the range flows north into the South Fork Humboldt River; Pine Creek west of the range flows north into the Humboldt River in Palisade Canyon.

U.S. Highway 40 across the northern part of the area, State Highway 20 in Pine Valley, and ranch roads, jeep trails, and many hills that are traversable with four-wheel-drive vehicles make most of the area reasonably accessible. Cross-country travel by four-wheel-drive vehicle is possible across many areas underlain by fine-grained clastic rocks but not across areas underlain by coarse clastic rocks or carbonate rocks.

FIELDWORK AND ACKNOWLEDGMENTS

Field studies upon which this report is based were made from August 1955 to August 1965. The map was made essentialy in two phases: the first phase consisted of mapping the Paleozoic rocks, and the second phase, of mapping the post-Paleozoic ones. There was, of course, overlap in the two phases. Results of the stratigraphic parts of the studies are also reported in two parts: this report on the Paleozoic rocks and a separate one on the post-Paleozoic rocks.

The geologic map (pl. 1) accompanying this report is a composite of the four 15-minute quadrangles reduced to 1:125,000 scale. Reduction from a 1:62,500 scale necessitated generalization of the map units and omission of most bedding attitudes.

We were fortunate in having able assistance in the field from a number of people whose field sessions with us ranged from 1 to 5 months. Those who assisted primarily in studies of the Paleozoic rocks include Robert N. Diffenbach in 1956, Richard S. Kopp in 1956 and 1957, Lucian B. Platt in 1957, John Corliss and George Ditsworth in 1958, Pedro A. Gelabert and Jack A. Wolfe in 1959, William M. Briggs in 1960, and José B. Alarcon, from Chile, in 1961. Those who assisted primarily in mapping the post-Paleozoic units include Robert S. Crosson in 1960 and John C. Young and John R. Algor in 1962. Those who assisted in work on both Paleozoic and post-Paleozoic units include David D. Blackwell in 1961 and 1962, William L. Lehmbeck in 1963, and Robert K. Smith in 1964. To all these people we extend our thanks.

Many man-days were spent in the search for fossils, particularly in the lower Paleozoic siliceous-assemblage units and the Lower Mississippian rocks, and, without the conscientious reporting by numerous paleontologists on the collection, the stratigraphic succession could not have been established. Our thanks go to the 21 paleontologists who studied these fossil collections. Credit is given for fossil and age determinations at appropriate places in the text, and special mention is made of those who spent several days collecting with us in the field: Reuben J. Ross collected from several lower Paleozoic units and particularly from the Ordovician siliceous beds; Mackenzie Gordon, Jr., and Helen Duncan collected from the upper Paleozoic formations and particularly from the Mississippian ones; and Raymond C. Douglass collected fusulinids from the Pennsylvanian and Permian units.

Discussions with many colleagues in the U.S. Geological Survey have contributed to our understanding and interpretation of the geology. In particular, we have benefited from exchanges with James Gilluly, T. B. Nolan, R. J. Roberts, C. W. Merriam, and Harold Masursky.

All the local ranchers kindly granted us permission to work on their property and offered any assistance we needed.

PREVIOUS WORK

Paleozoic rocks of this area were first examined by members of the 40th Parallel Survey (Hague, 1877, 1883, 1892). In 1908 Emmons (1910, p. 88-95) visited the Railroad mining district west of Bullion and reported briefly on the geology of the Pinon Range and in more detail on the mining district. More recent work includes that of Dott (1955), who did an excellent job particularly on the Pennsylvanian and Permian rocks in Carlin Canyon and adjacent areas south and east; that of Carlisle (1957) on the Devonian rocks in the Sulphur Spring and Pinon Ranges; and that of Fails (1960) on the Permian rocks north of Carlin Canyon. Localities in the Carlin-Pinon Range area are referred to in a number of other reports; these are cited at appropriate places in the text.

ROCK FORMATIONS

ORDOVICIAN SYSTEM

CARBONATE (EASTERN) ASSEMBLAGE

POGONIP GROUP (PART)

The oldest exposed rocks of the carbonate or eastern assemblage in the Carlin-Pinon Range area belong to the Pogonip Group, a unit whose history and usage have been discussed by Nolan, Merriam, and Williams (1956, p. 23-29). In the mapped area the unit crops out only in an area of less than one-eighth square mile, southwest of Bullion, where exposures are poor and the exposed thickness is about 350 feet.

The lower part of the Pogonip here is uniformly dark gray dolomite in beds ranging in thickness from about 1 to 12 inches and containing many poorly preserved fossils. The upper part consists of dark-gray dolomite beds a few inches thick and alternating thinner yellow or brown shale partings and beds. The dolomite is medium grained and, where partially recrystallized, is whitened. In places both shale and dolomite are silicified; in other places only the shale is silicified. Fossils commonly are silicified.

In the Eureka area the Pogonip Group consists of three formations, the uppermost of which is the Antelope Valley Limestone (Nolan and others, 1956, p. 24-29). In general appearance and fauna, beds of the Pogonip Group in the Carlin-Pinon Range area resemble those in the Antelope Valley Limestone, although they are chiefly dolomite rather than limestone. Of several faunal zones in the Antelope Valley Limestone in the Eureka area, the youngest is the *Anomalorthis* zone. A fossil collection (USGS D575 (CO); No. 1 on pl. 1) made in the NW. cor. sec. 3, T. 30 N., R. 53 E., contains "small (3 mm in diameter) subspherical, hollow fossils, common in the Garden City and Pogonip beds, *Orthambonites* sp., and *Anomalorthis* cf. *A. utahensis* Ulrich and Cooper" and probably is equivalent to the *Anomalorthis* zone of the Antelope Valley according to R. J. Ross, Jr. (written commun., 1959); these beds, then, are Middle Ordovician (Nolan and others, 1956, p. 25, 29).

The contact between the Pogonip Group and the overlying Eureka Quartzite is not exposed but appears to be sharp and conformable. Regionally, the Eureka rests disconformably on older units (Nolan and others, 1956, p. 30-31; Roberts and others, 1958, p. 2830-2831; Gilluly and Gates, 1965, p. 14-15).

EUREKA QUARTZITE

The Eureka Quartzite, a widespread quartzite unit named by Hague (1883, p. 262; 1892, p. 54-57) for exposures near Eureka, Nev. (Nolan and others, 1956, p. 29), crops out as a distinctive band that forms a prominent low ridge and dip slope in places west of Bullion, where it is 70 feet thick. This formation is thicker northwest and west of the mapped area (Roberts and others, 1958, p. 2830) and to the south (Nolan and others, 1956, p. 31).

To the east and southeast in the Ruby Mountains, the Eureka is absent as far south as about lat. 40°9′ N. (Willden and Kistler, 1967, p. D65-D66; 1969), but occurs south of that latitude as a unit a few feet thick (Willden and Kistler, 1967, p. D65; Ross, 1961, p. 333; Webb, 1958, p. 2365). The Eureka Quartzite in the Carlin-Pinon Range area is near the west end of the Tooele arch of Webb (1958, p. 2350), the Cortez Uinta axis of Roberts and others (1965, p. 1928).

In the mapped area the Eureka Quartzite generally is similar to equivalent quartzite in the type locality and consists of white quartz sandstone and quartzite, which weather white mainly and light tan in places. It is massive to thin bedded, but bedding is obscure in most exposures; many beds are 2-3 feet thick, and in a few places beds one-half inch or less thick are visible. Grain size averages medium, and larger grains are scattered locally through the rock. In thin sections the rock is seen to be similar from base to top. Grains are 99 percent quartz in sizes mostly from 0.1 to 0.4 mm. Grains are well rounded and generally well sorted. Overgrowths of secondary quartz are common on many grains and impart a mosaic or intergrown texture to the rock. Some grains are moderately stained with iron oxide. Interstitial clay(?) makes up about 1 percent of the thin sections examined. The three-fold division of the Eureka recognized by Kirk (1933, p. 27-28) is not apparent in the Carlin-Pinon Range area.

In places the Eureka is cut by many joints spaced from less than an inch to several inches apart and with random trends. Weathering along these small joints produces slightly bumpy areas on bedding surfaces.

As no fossils were found in the Eureka in the mapped area, no direct evidence is available for dating the formation. Diagnostic fossils in the Middle Ordovician upper part of the Pogonip Group below and in the Hanson Creek Formation above, however, bracket the Eureka. On the basis of a possible late Middle Ordovician age for the lower part of the overlying Hanson Creek, the Eureka in this area can be no younger than Middle Ordovician. Elsewhere in central Nevada, it is considered to be of Middle Ordovician age (Ross, 1964, p. 1533).

The contact between the Eureka Quartzite and the overlying Hanson Creek Formation seems to be sharp, but it is mostly concealed by rubble and is difficult to examine. In one valley the contact appears to be gradational from quartzite into dolomite through a thickness of about 2 feet. Although this contact appears to be conformable in the mapped area, it is disconformable regionally (Nolan and others, 1956, p. 30-31).

HANSON CREEK FORMATION

The Hanson Creek Formation is chiefly limestone in the type section according to Merriam (1940, p. 10-11) but is mainly dark-gray to black dolomite in the Carlin-Pinon Range area and similar to exposures near Eureka (Nolan and others, 1956, p. 32-33). The only outcrops of the Hanson Creek in the mapped area are just west of Bullion, where the formation is 150 feet thick. Black boulders of dolomite commonly litter the slopes, and the formation makes a prominent dark band along the hillsides. Like the Eureka Quartzite, the Hanson Creek is thicker to the northwest and west (Roberts and others, 1958, p. 2830) and to the south (Nolan and others, 1956, p. 33). Southeast of the report area in the southern Ruby Mountains, Middle or Upper Ordovician brown dolomite is assigned to the Ely Springs Dolomite (Willden and Kistler, 1967, p. D65) correlative with the Hanson Creek, but the thickness is not reported. The Hanson Creek may thin eastward onto the Tooele arch as does the Eureka Quartzite.

In the Carlin-Pinon Range area the Hanson Creek Formation consists mostly of thin-bedded to massive fine-grained crystalline dolomite and a very few thin limestone beds. It is commonly dark gray to black but is light gray in places. Locally, light-gray and black bands alternate in distinct beds ¼-4 inches thick, although generally the bedding is obscure. The lighter colored parts are commonly more coarsely crystalline than the darker parts. In thin section, grain sizes are seen to range from 0.05 mm in the dark bands to 0.2 mm in the light ones. White coarsely crystalline dolomite in prominent pods, stringers, and veinlets contrasts sharply with the dark-gray to black dolomite. Coarsely crystalline dolomite with a pink tint occurs in patches. Some units are brecciated in fragments that are commonly less than one-half inch across. Corals and brachiopods are abundant in some beds but are poorly preserved; they rarely weather free but appear as white sections in a dark matrix. As seen in thin section, ghosts of fossil fragments about 0.5 mm across are abundant in the dark areas and are scarce in the light areas; the fossil fragments are more coarsely crystalline than the matrix in which they lie.

The top unit of the Hanson Creek as mapped is about 20 feet in maximum thickness and consists mostly of dolomitic and limy siltstone, silty limestone, and very fine grained sandstone that weather yellow and form a good marker in most places. In thin section, dolomite in this unit is seen to consist of abundant rhombohedron crystals, mostly 0.02 to 0.04 mm across, in a mosaic texture. Some dolomite grains are slightly rounded and fragmented, probably detrital, but because the rock has a mosaic texture it seems to have been largely recrystallized. Trace amounts of detrital quartz were partly replaced by carbonate minerals. Silty limestone from this same upper unit consists of calcite grains mostly less than 0.008 mm across and a few that average about 0.01 mm and of scattered quartz grains in the same size range. Iron oxide is abundant as a stain. The rock is finely laminated. A carbonate analysis of one sample of this silty limestone shows that it contains 64.4 percent calculated carbonate, 25.8 percent calcium, a trace of magnesium, and that the Ca/Mg molal ratio is 100. In figuring the molal ratio, a trace of magnesium was taken as zero.

This top unit differs from dolomite beds above and below it and could be mapped separately, were it not so thin. We originally placed it in the Lone Mountain Dolomite but now include it in the upper part of the Hanson Creek Formation inasmuch as Ordovician fossils were collected from it in the report area by David R. Budge and Peter M. Sheehan (oral commun., 1971)

Regionally, the Hanson Creek Formation and equivalent units of the eastern assemblage change from dolomite to limestone from east to west (Nolan and others, 1956, p. 32-33; Merriam, 1963, p. 31) (fig. 2). This directional change in the dominant type of carbonate rock occurs also in Silurian and Devonian units, but the dolomite sequence of the Hanson Creek has a prominent bulge westward that is not evident with the Silurian and Devonian units. (Compare fig. 2 with fig. 6.) This bulge may reflect the continuing influences of the Tooele arch on regional sedimentation patterns.

AGE AND CORRELATION

As first described by Merriam (1940, p. 10-11), the Hanson Creek Formation was considered Middle and Late Ordovician in age. More recently it has been dated only as Late Ordovician (Richmond Stage in the type section, Nolan and others, 1956, p. 34; Merriam, 1963, p. 30, 32-33), and both as Middle and Late Ordovician (Ross, 1964, p. 1533). Fossils in the formation in the mapped area generally are poorly preserved, but a collection (field No. SF-100; No. 2 on pl. 1) from the east edge of sec. 4, T. 30 N., R. 53 E., contains one specimen of a common Ordovician coral, *Catenipora* sp., identified by W. A. Oliver, Jr. (written commun., 1959). Fragmentary specimens of cephalopods were identified by R. H. Flower (written commun., 1959) as "*Actinoceras* sp.—undescribed; septal necks obscured by dolomitization; even the species group is doubtful; *Actinoceras*—of the species group *A. simplicem*; and *Armenoceras* sp.—extremely fragmentary, suggests *A. vesperale.*" Of this collection Dr. Flower stated: "The association is certainly one of later Ordovician, Red River or overlying Richmond in age, as western Richmond beds with actinoceroids are almost unknown (the Richmond of New Mexico has yielded one specimen, the type of *Armenoceras lenticontractum*). Red River age is strongly indicated, but not proved." According to Flower (1956, p. 1794) Red River age is correlated with late Trenton. On this basis the Hanson Creek may be in part at least late Middle Ordovician and the underlying Eureka Quartzite, therefore, entirely Middle Ordovician. Duncan (1956, p. 219-220) compared Red River corals with those of the Bighorn Dolomite and equivalent units and considered the Bighorn as probably early Late Ordovician. The Hanson Creek in the area of the present report, then, is considered to be of Middle and Late Ordovician age.

The contact between the Hanson Creek Formation and the overlying Lone Mountain Dolomite is sharp and seems to be conformable. Platy fragments of the yellow and tan siltstone and silty limestone at the top of the Hanson Creek cover the slope along a narrow band that contrasts with the beds both above and below, although exposures are poor in many places and exact location of the contact is difficult. In a few places for short distances the platy fragments were not found, either because this unit is lacking or because the small fragments tend to be

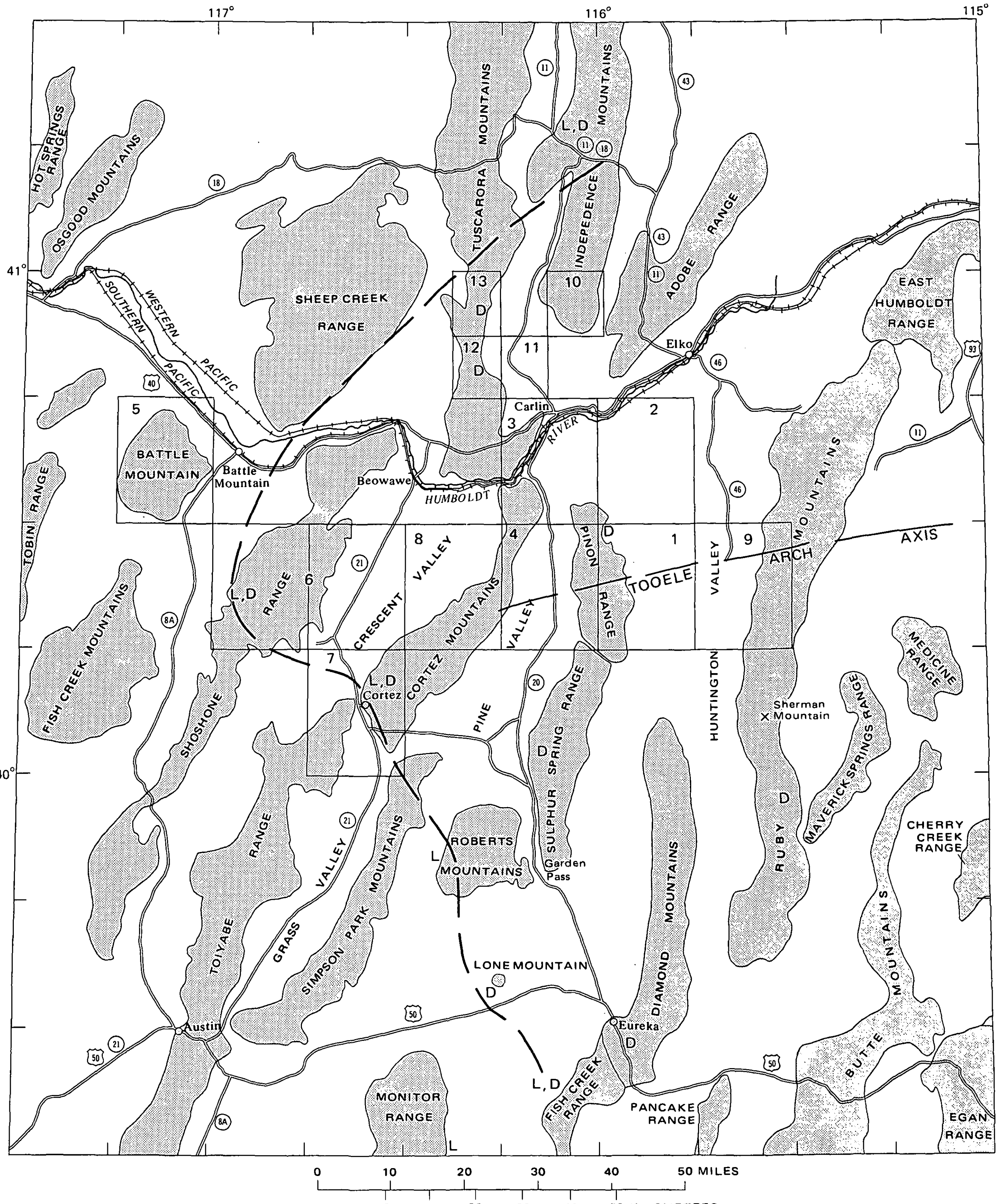


FIGURE 2.—Localities where Hanson Creek Formation and equivalent carbonate-assemblage rocks are exposed in the region, indicating whether the rock is dominantly calcitic (L) or dominantly dolomitic (D) or a combination of the two (LD). The broad dashed line marks the approximate west edge of dominantly dolomite lithology. Sources of data, other than the present study, are Kerr (1962, p. 446), Merriam (1963, p. 28, 31), Nolan, Merriam, and Williams (1956, p. 32-34), Rigby (1960, p. 174), Roberts, Hotz, Gilluly, and Ferguson (1958, p. 2830), Gilluly and Gates (1965, p. 16-17), Gilluly and Masursky (1965, p. 22-24), and Evans (1972a, b). Tooele arch axis from Webb (1958, fig. 5).

obscured on the steep rubble-covered slopes. Possibly a few feet or a few tens of feet of beds are missing along strike faults, but we do not believe that there are any significant faults near the contact.

Although the contact between the Hanson Creek and the overlying Lone Mountain appears conformable, a Late Silurian age of beds near the base of the Lone Mountain (p. A17) indicates that the Ordovician-Silurian contact may mark a considerable hiatus.

SILICEOUS (WESTERN) ASSEMBLAGE

Ordovician units of the siliceous (western) assemblage in the Carlin-Pinon Range area are mapped as two formations, the Valmy and Vinini. This division is based on the presence or absence of quartzite and greenstone with shale and chert; as mapped, the Valmy contains quartzite and greenstone, the Vinini does not. It has been suggested that the thick quartzite beds in the Valmy grade eastward into thinner and finer grained rocks in the Vinini (Roberts and others, 1958, p. 2833); this concept seems to be generally correct if the Vinini, which makes up most of the siliceous-assemblage Ordovician rocks in the Carlin-Pinon Range area, is compared with the Valmy in the Shoshone Range to the west (Roberts and others, 1958, p. 2832; Gilluly and Gates, 1965, p. 23-28). Both of these formations are allochthonous, however, and their present relative positions do not necessarily reflect their prefaulting relative positions.

VALMY FORMATION

The Valmy Formation, named by Roberts (1951) for exposures in the Antler Peak quadrangle about 45 miles west of the Carlin-Pinon Range area, crops out only in the small part of the Sulphur Spring Range that extends into the mapped area. Exposures are generally poor and are near the crest and along the northeastern part of the range in sec. 1, T. 27 N., R. 52 E., and sec. 36, T. 28 N., R. 52 E. The estimated thickness of the Valmy here is about 150 feet, but this figure is minimal and means little, as the base is not exposed and the upper contact is a fault; in addition, the beds probably are contorted.

Shale, quartzite, and greenstone compose the Valmy Formation. The strata occur in two units that consist of about 50 feet of shale in the lower part and about 100 feet of chiefly interbedded quartzite and greenstone in the upper part. The shale does not crop out but occurs as platy pieces ⅛-1 inch across. It is black to gray, quartz silty, and poorly fissile, and contains graptolites and small brachiopods. The quartzite consists of fine-size quartz grains which are moderately to well rounded. It ranges from black to white, weathers brown, and occurs in beds generally 6-12 inches thick and in units as much as 10 feet thick. Layers about 1 inch thick are faintly visible in places. Many cavities ¼-½ inch in diameter are on weathered surfaces, though none were observed in fresh rock. The greenstone seems to be interlayered with the quartzite but forms a smaller percentage of the rock unit. It does not crop out and occurs only as small blocks and pieces scattered on the slopes. It is olive green, contains no quartz, and is made up of equigranular phenocrysts; the rock has been recrystallized and albitized but evidently was a submarine mafic lava flow or tuff.

Three graptolite collections (USGS D360 (CO), D389 (CO), and D443 (CO); Nos. 4, 5, and 6, respectively, on pl. 1) from the Valmy Formation probably represent the Middle Ordovician *Climacograptus bicornis* faunal zone (Ross and Berry, 1963, p. 40-41, pl. 1), zone 10 of Elles and Wood (1914). The Valmy here is too thin and the age span too restricted for any meaningful comparisons with sections of the Valmy elsewhere.

The contact between the Valmy Formation and overlying rocks of Devonian age in the Sulphur Spring Range is interpreted as a fault and not an unconformity, although virtually the same beds appear to be at the base of the Devonian throughout the area of exposure. This Devonian unit above the Valmy has been recognized only in the Sulpher Spring Range (pl.1) and, conceivably, may represent a sequence of upper plate rocks in which Devonian strata were deposited unconformably on the Valmy. However, elsewhere in the area of this report and in nearby areas to the west and southwest (Gilluly and Gates, 1965; Gilluly and Masursky, 1965), the presence of Silurian rocks in the upper plate of the Roberts Mountains thrust suggests that an unconformity of such magnitude as to have the Silurian rocks missing below the Devonian does not exist in this region. Complex but undeciphered internal structure of the Devonian unit indicates the intense deformation to which these formations have been subjected and makes a fault between the Devonian limestone and the Valmy shale a reasonable possibility.

VININI FORMATION

The Vinini Formation was named by Merriam and Anderson (1942, p. 1693-1698) for exposures on Vinini Creek on the east side of the Roberts Mountains south of the Carlin-Pinon Range area. In the area of the present report the formation is exposed along Willow Creek, in a band north and south of the creek, and north and south of the Humboldt River about 3 miles east of Carlin. Outcrops generally are poor, and the hills and slopes are covered with small pieces of chert, shale, siltstone, and mudstone. No thickness of the Vinini can be determined, because the beds are distorted (fig. 3) and are repeated in probable thrust slices as indicated by juxtaposed age zones of graptolite collections. For example, table 1 shows the graptolite zones represented by 10 collections made over a lateral distance of about 460 feet along the north side of Willow Creek; the lithology is uniform, and the fossil zones occur in no orderly stratigraphic succession.

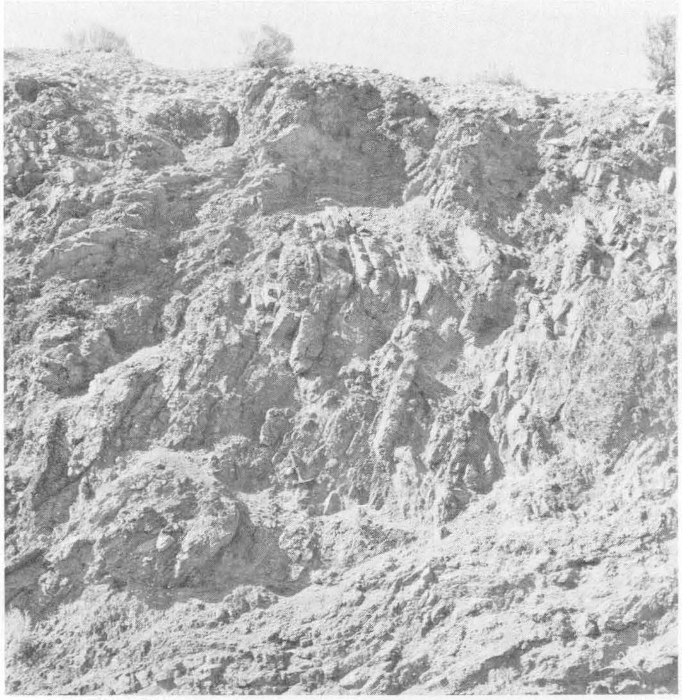


FIGURE 3.—Chert and some shale in Vinini Formation exposed in Western Pacific Railroad cut east of Vivian about 3 miles east of Carlin. These beds are in upper plate of Roberts Mountains thrust and are structurally complex on both large and small scales. Different bedding attitudes shown in photograph illustrate why thickness measurements based on scattered outcrops cannot be reliable.

LITHOLOGY

The Vinini Formation north and south of the Humboldt River east of Carlin is composed of chert, mudstone, shale, and a minor amount of calcareous siltstone. Chert, the dominant rock type, is black and weathers tan, brown, gray, or black. It occurs in beds generally 2-6 inches thick with laminations about 1 mm thick in places. Bedding surfaces appear to be argillaceous and are commonly gray or tan and coated with mudstone that resembles the thicker mudstone units. The chert has conchoidal fracture and is cut by many closely spaced joints, and so it breaks into pieces ¼-3 inches across. Outcrops are sparse. The mudstone is gray, and it weathers white to brown. It is shaly in some beds. It does not crop out but forms equidimensional to platy chips ¼-2 inches in maximum dimension. Stylolites having pits and pinnacles with a relief of 2-3 mm occur in the rock in places. Some of the mudstone is siliceous, and weathered slopes developed on it are bare of soil and are covered with hard loose fragments. Other mudstone is argillaceous and weathers to form a thin soft gray soil. A very small amount of calcareous siltstone is interbedded with the chert and mudstone; the siltstone is light gray, is poorly consolidated, and weathers to form a thin soft soil.

Exposures of the Vinini that form the band crossing Willow Creek consist chiefly of chert, shale, and siltstone. Here, too, chert is abundant, although much black and gray shale covers the north valley wall of the creek. Secondary gypsum is scattered along the slopes. The chert is mostly gray and black and weathers black and shades of gray and brown. Outcrops are sparse, and small chunky pieces of chert are prominent on the hillsides. On weathered surfaces of some fragments thin beds, and laminations of alternating black and tan or gray are visible. The siltstone is siliceous and light gray to black and weathers the same colors. It actually crops out in very few places but covers the slopes locally with either shaly and platy or small blocky fragments. One bed of brownish-gray siltstone noted contains many short sponge spicules. In thin section the siltstone and shale are seen to consist of argillaceous material and of detrital quartz grains 0.01-0.05 mm across, which may form 10 percent of the rock. Some sections have microscopic breccia, and some contain minute unidentified fossils. Much of the silica is too fine grained to permit determination of the type. A carbonate mineral, probably dolomite, fills some voids and is scattered through the rock. The siltstone and shale units probably are lenticular in the chert, although the irregular occurrence of chert and siltstone fragments on a slope may be the result of structural complexities rather than original sedimentary relations.

Uncommon rock types in the Vinini north of Willow Creek include a gray clastic rock and limestone. The gray clastic rock forms one bed composed of very coarse sand to granule-size angular fragments of mostly gray chert and scattered medium sand-size rounded grains of quartz in a chert matrix; this clastic rock weathers tan or pale green. The limestone is dark gray, dense to finely crystalline, weathers light gray to tannish gray, and has a strong bituminous odor on a freshly broken surface; it occurs as 2 to 5-inch-thick lenses in chert in the NE¼ sec. 24, T. 29 N., R. 52 E.

AGE AND CORRELATION

Graptolite collections, identified by R. J. Ross, Jr., and W. B. N. Berry, from the Vinini Formation indicate that Lower, Middle, and Upper Ordovician beds are represented, although not all the zones of Elles and Wood (1914) are recognized. These collections USGS D453 (CO), (No. 8 on pl. 1), D454 (CO) (No. 9 on pl. 1), D501 (CO) (No. 10 on pl. 1), and D502 (CO) (No. 11 on pl. 1) (Ross and Berry, 1963, p. 41-42), and USGS D568 (CO) (No. 12 on pl. 1), D783 (CO) (No. 13 on pl. 1), and D784 (CO) (No. 14 on pl. 1) (table 2) from the area about 3 miles east of Carlin, range from zone 10-13 and probably to 14, from upper Middle through lower Upper Ordovician. The 10 collections along Willow Creek (table

TABLE 1.—*Graptolite collections from the Vinini Formation along the north side of Willow Creek, showing zones of Elles and Wood (1914)*
[Graptolite identifications and zone determinations by Ross and Berry (1963, p. 38-40)]

USGS locality No. (No. 7 on pl. 1; sec. 36, T. 29 N., R. 52 E.)	D442i (CO)	D442h (CO)	D442g (CO)	D442f (CO)	D442e (CO)	D442d (CO)	D442c (CO)	D442b (CO)	D442a (CO)	D442 (CO)
A. Genus and species of each collection										
Trichograptus immotus Harris & Thomas			×							
Dichograptus n. sp.				×						
sp. (probably new)						×				
Tetragraptus approximatus (Nicholson)			×				×			
aff. *T. quadribrachiatus* (J. Hall)							×			
Ramulograptus surcularis Ross and Berry				×						
Didymograptus n. sp.			×							
n. sp.				×						
sp.		×		×		×				
Isograptus caduceus var. *divergens* Harris				×		×				
maxima Harris		×		×		×				
nanus Ruedemann										×
mut. *nanus*? Ruedemann						×				
? sp.						×				
Glossograptus hincksii (Hopkinson)									×	×
n. sp.				×						
? sp.			×							
Leptograptus sp.								×		
A nemagraptid?								×		
Climacograptus aff. *C. scharenbergi* Lapworth								×		
cf. *C. styloideus* Lapworth		×			×					
sp.		×	×					×		
? sp.					×					
Diplograptus decoratus? Harris and Thomas										×
Amplexograptus? sp.								×	×	
Glyptograptus cf. *G. intersitus* Harris and Thomas									×	
sp.	×								×	
sp.								×		
Orthograptus quadrimucronatus (J. Hall)		×								
sp.					×					
? sp.	×									
Tristichograptus ensiformis (J. Hall)						×				
cf. *T. martellii* (Ross and Berry)						×				
An archiretiolitid		×								
?					×					

B. Lateral distances between collections, and zones represented

[Zones indicate that the beds are not in an orderly stratigraphic succession]

Ordovician	Zones of Elles and Wood	D442i (CO)	D442h (CO)	D442g (CO)	D442f (CO)	D442e (CO)	D442d (CO)	D442c (CO)	D442b (CO)	D442a (CO)	D442 (CO)
Upper	14-15										
Upper	13	?↑	↑ [1]×			↑ ×?					
Upper	12	×	↓			↓					
Middle	11	↓									
Middle	10	?							[2]×		
Middle	9										
Middle	8										
Middle	7			[3]×						×?	×
Middle	([4])		[1]×		×		×				
Middle	6										
Lower	5										
Lower	4										
Lower	3							×			
Lower	2										
Lower	1										
Cumulative lateral distances of localities, in feet, from D442 (CO)		West 460	260	210	150	120	95	45	30	15	East 0

[1]Mixed.
[2]May be zone 9 *approximatus* (Nicholson).
[3]Contains one zone 3 form-*Tetragraptus*.
[4]This is zone 8 of Berry (1960) and between zones 6 and 7 of Elles and Wood (1914). (See Ross and Berry, 1963, table 1.)

1) range from zone 3 to zone 13 of Elles and Wood, from Lower to Upper Ordovician, although zones 4, 5, 6, 8, and 11 are not recognized. Zone 8 is represented in collection USGS D785 (CO) (No. 15 on pl. 1) made about 2.2 miles north of Willow Creek; according to R. J. Ross, Jr. (written commun., 1960), this collection is almost the same as collections from the Vinini Formation at Garden Pass in the Roberts Mountains area (Merriam and Anderson, 1942, p. 1698).

In general, the shale and mudstone in the Vinini Formation in the Carlin-Pinon Range area are similar to the Vinini shale and mudstone in the type locality (Merriam and Anderson, 1942, p. 1693-1698), but the formation does not have as much limestone or quartzite and, as we have mapped it in this area, contains no lava flows or tuffs. Although the Vinini in the Carlin-Pinon Range area covers the same age span as the Vinini in the type locality, it seems likely that original depositional conditions were slightly different in the two areas.

CONTACTS

Contacts between the Vinini Formation and other rock units are interpreted as faults or as unconformities. Along Willow Creek, Devonian rocks seem to overlie the Vinini along a thrust. North of Willow Creek, Devonian siliceous-assemblage rocks overlie the Vinini on an apparent thrust contact. These contacts are not exposed but are inferred to be thrust contacts chiefly on the regional relations of similar units and, also, north of Willow Creek on the lack of Silurian rocks between the Ordovician and Devonian. In the area east of Carlin, the Vinini is overlain unconformably by the Webb Formation of Early Mississippian age.

TABLE 2.—*Graptolites from the Vinini Formation*

[Identifications by R. J. Ross, Jr., and W. B. N. Berry, 1959 to 1963. For lists of collections D453(CO), D454(CO), D501(CO), and D502(CO), see Ross and Berry (1963, p. 41-42)]

Locality No. on pl. 1	15	16	12	13	14
USGS fossil collection No. (secs. 24 and 25, T. 29 N., R. 52 E.; secs. 30 and 31, T. 33 N., R. 53 E.)	D785 (CO)	D786 (CO)	D568 (CO)	D783 (CO)	D784 (CO)
Pterograptus sp.	×				
Didymograptus sp.	×				
Cardiograptus cf. *C. crawfordi* Harris	×				
Corynoides calicularis Nicholson				×	
? sp.				×	
Cryptograptus tricornis (Carruthers)?				×	
sp.				×	
n. sp.				×	
Glossograptus horridus Ruedemann	×				
cf. *G. horridus* Ruedemann	×				
sp.	×				
Dicranograptus nicholsoni cf. var. *geniculatus* Ruedemann and Decker				×	
nicholsoni cf. var. *parvangulus* Gurley				×	
nicholsoni n. var.				×	
n. sp.				×	
Climacograptus bicornis cf. *C. b.* var. *longispina* T. S. Hall			×		
hastatus n. var.				×	
aff. *C. hvalross* Ross and Berry					×
cf. *C. mississippiensis* Ruedemann			×		
phyllophorous Gurley					×
cf. *C. riddellensis* Harris	×				
scharenbergi Lapworth				×	
tubuliferus Lapworth					×
sp.		×			×
Diplograptus n. sp.	×				
Amplexograptus sp.	×				
Glyptograptus euglyphus var. *pygmaeus* Ruedemann					×
hypniformis (White)	×				
sp.	×	×		×	×
spp.			×		
Orthograptus aff. *O. calcaratus* Lapworth				×	
truncatus var.?				×	
? n. sp. (aff. *O. calcaratus tenuicornis* Elles and Wood)				×	
n. sp. (aff. *O. pageanus micracanthus*)				×	
n. sp. (aff. *O. quadrimucronatus*)				×	
sp. (*quadrimucronatus* type)			×		
sp.			×		
Lasiograptus sp.				×	

TRANSITIONAL ASSEMBLAGE

ORDOVICIAN ROCKS OF MARYS MOUNTAIN

The rocks of Ordovician age on the east side of Marys Mountain are here considered to be transitional between western- and eastern- assemblage strata because they contain lithologic types similar to both assemblages; they contain no greenstone, however. No formal name is applied to these transitional beds; more extensive and complete exposures of them probably are farther north and west in the Tuscarora Mountains, and studies there should afford better control for applying a name for the unit. These beds previously have been included in the Vinini Formation (Roberts and others, 1958, p. 2832; Roberts and others, 1967, pl. 3). Exposures of the Ordovician on Marys Mountain are generally poor on the steep slopes but are fairly good in saddles and on some ridges; the limestone makes good outcrops in places and forms ledges.

Near the northern part of Marys Mountain in the mapped area, we measured 1,600 feet of Ordovician strata (fig. 4). This appears to be a simple homoclinal section, but graptolite zones reveal that the beds are not in a simple stratigraphic succession. This sequence probably is cut by several thrust faults, although we did not map thrusts within this small area of exposure.

Claystone, shale, sandy limestone and chert, limestone, and quartzite compose the Ordovician rocks on Marys Mountain. Near the north edge of the mapped area, claystone and shale constitute about 80 percent of the exposed rocks, limestone and chert about 15 percent, and quartzite about 5 percent.

The claystone on the lower slopes of the mountain does not crop out in most places but occurs as irregular loose fragments. These pieces are either relatively soft or hard and siliceous, are light gray on both fresh and weathered surfaces, and are graptolite bearing. Poorly fissile shale above the claystone occurs mostly in chips about 1 inch across. The shale is black, dark gray, or brown and weathers black to light gray; it is partly silty and soft and, in places, is very siliceous and hard. Some of these fine-grained clastic rocks are seen in thin section to consist of detrital quartz grains about 0.01 mm in diameter set in a finer-grained matrix of possibly chert and micaceous or clayey material.

Interbedded sandy limestone and chert overlie the shale on the slope for a thickness of 235 feet. The limestone is gray with a brown tint in places, weathers gray, and contains coarse- to medium-size mainly angular grains of chert, most of which are almost white to gray although some scattered grains are green or pink. Some beds consist dominantly of clastic chert and are calcareous chert sandstone rather than sandy limestone. Bedding in the limestone ranges from slightly less than one-tenth of an inch to 1 foot in thickness. The chert interbeds are brown to gray, irregular, knobby, and podlike. The lower part of this 235-foot-thick unit is mostly limestone, and the upper part may be mostly chert, but exposures of the upper part are so poor that accurate measurements cannot be made. Three collections of conodonts from these limy beds were studied by John W. Huddle, who identified the following forms: (Collection numbers in fig. 4) Collection USGS D910 (CO), *Scolopodus* cf. *giganteus* Sweet and Bergstrom, *Ligonodina tortilis* Sweet and Bergstrom, *Prioniodina macrodentata* Graves and Ellison; collection USGS D911 (CO), *Periodon aculeatus* Hadding, *Falcodus prodentatus* (Graves and Ellison), *Oistodus venustus* Stauffer, *Ligonodina tortilis* Sweet and Bergstrom, and *Belodina* sp.; collection D912 (CO), *Prioniodina macrodentata* (Graves and Ellison), *Ligonodina tortilis* Sweet and Bergstrom, *Periodon aculeatus* Hadding, *Oistodus parallelus* Pander, *Oistodus venustus* Stauffer, *Oistodus forceps*? Lindstrom, *Falodus prodentatus* (Graves and Ellison), *Scolopodus varicostatus* Sweet and Bergstrom, *Acontiodus cooperi* Sweet and Bergstrom, *Acontiodus robustus* (Hadding), *Cordylodus*? sp., *Scandodus* sp., *Chirognathus*? sp., *Ligonodina* sp., and *Acodus* sp. Huddle reported (written commun., 1963) that these collections are Middle Ordovician, possibly Llandeilian (essentially zone 8 of Elles and Wood). About 1 mile farther south, chert, limestone, and claystone are interbedded through a

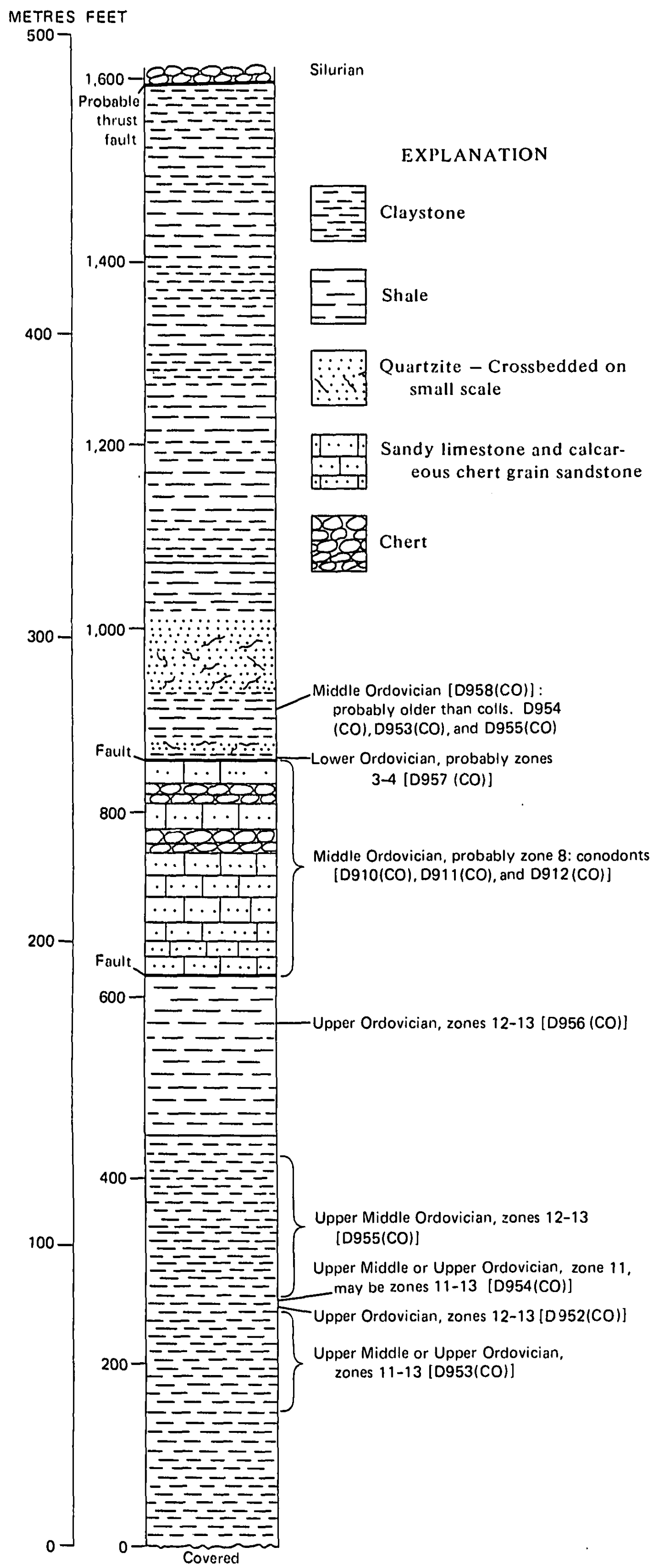


FIGURE 4.—Columnar section of Ordovician rocks on east side of Marys Mountain in N ½ sec. 16, T. 33 N., R. 51 E. Fossil collections bearing USGS numbers contain graptolites except for three [D910 (CO), D911 (CO), and D912 (CO)] that contain conodonts. Graptolites were identified by R. J. Ross, Jr., and W. B. N. Berry, and conodonts by J. W. Huddle. Fossil zones are those of Elles and Wood (1914). For lists of graptolites see table 3. Faults are inserted to satisfy relative ages of beds assuming upright attitude; other faults may cut the sequence also.

thickness of 65 feet; the chert is black, the limestone brown to black, and the claystone brown, and all weather yellowish brown.

Near the north edge of the mapped area, poorly exposed quartzite and claystone that overlie the limestone and chert, at least in part, are low in the Ordovician according to graptolite determinations. Most of the quartzite, however, is somewhat higher in the section and may be Middle Ordovician, possibly correlative with the quartzite unit shown in figure 4. The quartzite is fine grained, mostly well sorted, thin bedded and crossbedded on a small scale in places; it is chiefly tan and weathers tan to brown, but some fragments show alternating beds.

Claystone and shale, slightly more than 500 feet thick, form much of the upper exposed part of the Ordovician rocks at Marys Mountain. These rocks, too, are poorly exposed and break into pieces ¼-2 inches across with a hackly fracture. They are gray to dark brown, weather light gray to brown, and are mainly soft but are hard and siliceous in places; the hard siliceous beds form the best exposures. Graptolite collection D960 (CO) (No. 17 on pl. 1) about 100 feet below the top of the Ordovician section dates this claystone and shale unit as Late Ordovician.

Pale-brown tan-weathering dense limestone crops out near the base of the mountain in the NE¼ sec. 21, T. 33 N., R. 51 E., south of the line of our measured section. This limestone is in beds mostly ¾-1½ inches thick and seems to form a lens as much as about 40 feet thick and 1,000 feet long between graptolite-bearing black shale units. Both graptolites and trilobites occur in this limestone, an interesting fossil association not found elsewhere in the report area. According to R. J. Ross, Jr. (written commun., 1962), the graptolites (SF-272, table 3; No. 20 on pl. 1) are of Late Ordovician age. No well-preserved trilobite cranidia were found; hence, identification of them is inconclusive. A graptolite collection (D1423 (CO), table 3) from shale just below SF-272 is Late Ordovician, but another [D1422 (CO)] about 50 feet below is probably Middle Ordovician (zones 8-9 of Elles and Wood). A graptolite collection [D1424 (CO)] from shale just above the trilobite-bearing rocks is late Middle to early Late Ordovician (zones 11-13 of Elles and Wood).

Adjustment of the lithologic types to fit the age zones indicated by the fossils suggests the following general stratigraphic sequence, in ascending order: Lower Ordovician, claystone, shale, and minor quartzite; Middle Ordovician, chert-sandy limestone, calcareous sandstone, chert, and quartzite; upper Middle to Upper Ordovician, claystone and shale; upper Upper Ordovician, shale, and dense limestone lenses. No attempt is made to give thicknesses on any part, as they would mean little in this faulted section.

AGE

Ordovician rocks at Marys Mountain are of Early, Middle, and Late Ordovician age, although not all zones of Elles and Wood (1914) are recognized (fig. 4); fossil lists are given in table 3. As discussed previously, we consider this Ordovician section to be transitional between the eastern and western assemblages because it contains lithologic types similar to those in each of the other assemblages. A similar suggestion has been made for the lower part of the Vinini in the type locality (Roberts and others, 1958, p. 2832).

UPPER CONTACT

Rocks of Silurian age rest on rocks of Ordovician age at Marys Mountain, where the base of the Silurian is essentially along one chert bed or group of chert beds. This contact is mapped as a thrust fault for several reasons: (1) The contact as drawn does not seem to conform to the attitude of the beds, though, admittedly, good attitudes are difficult to obtain; (2) thrusts do occur on the mountain, as indicated by repetition or omission of beds in the Ordovician below; (3) the Ordovician beds below the contact may be truncated irregularly; (4) the base of the Silurian as mapped, although it is along outcrops of chert, may not be along a single bed or even a thin chert unit and, thus, may be truncated below; (5) the basal Silurian chert is a breccia in places; (6) a graptolite collection (D188-SD) 110 feet above the base of the Silurian is high Lower or low Middle Silurian, suggesting that the lowest Silurian may be lacking. An unconformity could account for all these relations except the possible basal truncation of the Silurian strata. Imbricate thrusts are characteristic of the upper plate of the Roberts Mountains thrust in this region, and a thrust contact seems likely. By our interpretation, the Ordovician rocks are of the transitional assemblage, and the Silurian rocks are of the siliceous assemblage at Marys Mountain. We cannot, however, reconstruct the prethrusting position of these units; they may have been deposited in essentially the same sequence or in far-separated sequences.

SILURIAN SYSTEM

CARBONATE (EASTERN) ASSEMBLAGE

LONE MOUNTAIN DOLOMITE

The Lone Mountain Dolomite named by Hague (1883, p. 262-263; 1892, p. 57-60) was formally redefined by Merriam (1940, p. 10, 13-14); further description and history of nomenclature of the formation are presented by Nolan, Merriam, and Williams (1956, p. 37-40). In the

TABLE 3.—*Graptolites from the Ordovician rocks on Marys Mountain*

[Identifications by R. J. Ross, Jr., and W. B. N. Berry]

Locality No. on pl. 1	18	21	22	(1)	(1)	(1)	(1)	(1)	(1)	(1)	19	17	23	24	25	20
USGS fossil collection No., except as noted (secs. 16 and 21, T. 33 N., R. 51 E.)	D951(CO)	D566 (CO)	D567 (CO)	D952 (CO)	D953 (CO)	D954 (CO)	D955 (CO)	D956 (CO)	D957 (CO)	D958 (CO)	D959 (CO)	D960 (CO)	D1422 (CO)	D1423 (CO)	D1424 (CO)	2SF-272
Dendrograptus n. sp.									×							
Olonograptus cf. *C. flexilis* (Hall)									×							
Dichograptids									×							
Cryptograptus tricornis (Carruthers)	×															
Glossograptus? sp.			×													
Dicellograptus cf. *D. complanatus* Lapworth?			×													
cf. *D. sextans* var. *exilis* Elles and Wood													×			
sextans Hall													×			
cf. *D. divaricatus* Hall													×			
intortus Lapworth	×															
sp.		×						×								×
Dicranograptus nicholsoni Hopkinson			×													
kirki Ruedemann															×	
nicholsoni var. *whitianus* (Miller)															×	
cf. *D. nicholsoni* var. *whitanus* (Miller)							×				×					
ramosus var. *longicaulis* Lapworth		×														
spinifer Elles and Wood		×														
sp.											×	×				
Climacograptus cf. *C. bicornis* Hall		×														
cf. *C. caudatus* Lapworth			×			×						×				
hastatus var.?											×					
cf. *C. hualross* Ross and Berry				×												
aff. *C. hualross* Ross and Berry					×											
innotatus Elles and Wood																×
cf. *C. minimus* (Carruthers)										×						
cf. *C. mississippiensis* Ruedemann			×													
peltifer (actually a variety between *peltifer* and *C. bicornis longispina*)			×													
cf. *C. raricaudatus* Ross and Berry		×														
cf. *C. riddellensis* Harris			×													
scharenbergi Lapworth													×			
spiniferus Ruedemann		×														
cf. *C. spiniferus* Ruedemann			×											×		
cf. *C. styloideus* Lapworth			×													
tubuliferus Lapworth															×	×
cf. *C. tubuliferus* Lapworth								×								
sp.	×					×						×		×	×	
spp.											×					
n. sp.								×								
C.? sp.													×			
Diplograptus sp.													×			
Amplexograptus arctus Elles and Wood													×			
confertus Lapworth													×			
cf. *A. differtus* Harris and Thomas			×													
modicellus Harris and Thomas?										×						
sp.	×															
Glyptograptus altus Ross and Berry														×		
cf. *G. altus* Ross and Berry			×					×			×					
euglyphus (Lapworth)?										×						
cf. *G. euglyphus* var. *pygmaeus* (Ruedemann)										×						
spp.	×		×			×					×	×	×		×	
cf. *G. serratus* Elles and Wood																×
n. sp.								×								
Orthograptus calcaratus var		×														
calcaratus var. *grandis* Ruedemann			×													
cf. *O. calcaratus* var. *acutus* Elles and Wood			×													
cf. *O. calcaratus* var. *vulgatus* (Lapworth)					×											
quadrimucronatus (Hall)		×		×												
quadrimucronatus var. *angustus* Ruedemann															×	
cf. *O. quadrimucronatus* (Hall)												×			×	
quadrimucronatus cf. var. *inequispinosus* (Ruedemann)								×								
aff. *O. quadrimucronatus* (Hall)				×	×			×			×					
quadrimucronatus var.?								×								
quadrimucronatus new var. (like var. *inequispinosus* Ruedemann)												×				
cf. *quadrimucronatus* n. var.							×					×				
truncatus var. *intermedius* Elles and Wood			×													
truncatus cf. var. *pauperatus* (Elles and Wood)											×					
whitfieldi Hall			×													
sp.				×	×							×				
Hallograptus bimucronatus (Nicholson)													×			
sp.													×			
H. ? sp.	×															
Retiograptus sp.													×			

1On columnar section, fig. 4. 2Field No.

Carlin-Pinon Range area, the Lone Mountain forms slopes broken by low ledges on the flanks of Coffin Mountain and rough dip slopes, largely of bare rock, along the east side of the northern part of the Pinon Range. No complete section of the Lone Mountain is exposed in the mapped area. Northeast of Bunker Hill the lower 330 feet of the formation crops out, and on the northwest flank of Coffin Mountain the upper 775 feet is exposed. About one-half mile south of Ravens Nest, the thickness, as determined from measurement on the map, is about 1,400 feet, but this figure cannot be accurate because reliable attitudes are difficult to determine in the obscurely bedded dolomite; also, this block of Lone Mountain is bounded by faults.

LITHOLOGY

Most of the lower part of the Lone Mountain Dolomite as exposed in the mapped area is obscurely thick bedded gray dolomite. Locally, the rock is black and coarsely crystalline, similar to the Hanson Creek Formation, in irregularly shaped blotches several feet to several tens of feet across. The upper part of the formation near Coffin Mountain consists largely of alternating brown and gray dolomite beds that range in thickness from 2 to 12 feet. The following stratigraphic sections are typical of the Lone Mountain Dolomite exposed in the Carlin-Pinon Range area.

The Lone Mountain east of Bunker Hill as seen in thin section consists chiefly of crystalline dolomite mainly with a mosaic texture with crystals ranging from 0.04 to 0.15 mm across. Silica is lacking in some sections and occurs as cement and void fillings in others; some silica is chalcedonic quartz. In one section, silica has partially replaced dolomite and, in turn, has been partially replaced by a carbonate mineral. On the basis of examination of 6 thin sections, the upper 775 feet of Lone Mountain Dolomite at Coffin Mountain is composed mostly of dolomite crystals ranging in size from 0.01 to 0.3 mm that form a mosaic texture. In general, the range in size increases upward from 0.01-0.05 mm near the base to 0.01-0.3 mm near the top. Scattered knots of more coarsely crystalline dolomite, some of which are recrystallized fossil fragments, occur throughout the sequence; in these, the crystal size ranges from 0.1 to 0.4 mm. Sparse quartz grains are scattered through the upper part of the formation. Calcium and magnesium analyses of 8 samples from the upper 775 feet of the Lone Mountain along stratigraphic section 2 were made by James A. Thomas. These rocks contain 92.6-96.9 percent total calculated carbonate, 20.4-21.5 percent calcium, 12.0-12.5 percent magnesium, and have Ca/Mg molal ratios of 1.02-1.07. They are dolomite and slightly marly dolomite according to the classification of Guerrero and Kenner (1955, p. 46).

SECTION S1.—*Partial stratigraphic section of Lone Mountain Dolomite northeast of Bunker Hill in W½ sec. 3, T. 30 N., R. 53 E.*

[Measured with Abney level. Location of section is shown by number on pl. 1]

	Feet
Quaternary System:	
Colluvium; fault near edge of bedrock.	
Silurian System:	
Lone Mountain Dolomite (lower part):	
7. Dolomite, light-gray; weathers light gray with rough to smooth surfaces; finely crystalline but slightly coarser than units below; massive on whole; bedding generally poor, faint thin bedding in lower part. Tan-weathering irregular bands 1-4 in. thick and as much as 4 ft long occur along bedding and along fractures in places; most bands are of slightly coarser dolomite, some of silica, and scarce ones of crystalline calcite; weathers to form slight indentations along some fractures. Some vugs, 1 in. or less across, and small stringers contain quartz crystals. In places, irregular patches, several feet to several tens of feet across, are dark gray and are similar to Hanson Creek Formation. About upper 50 ft are mottled light and dark gray like unit 2. Forms rough dip slope down spur. Base forms prominent jagged outcrop here and on next ridge to south	140
6. Dolomite, similar to unit 4; irregular projections on surface as much as 12 in. long are of slightly coarser crystalline dolomite and weather brown; near dike below, secondary silica also forms hard patches that project from weathered surfaces	29
5. Porphyry dike; narrow sag across spur and down slopes	12
4. Dolomite, like unit 3 but with irregular surface projections of slightly coarser crystalline dolomite that weathers brown; projections are 1-3 in. across	34
3. Dolomite, medium-gray; weathers medium light gray; very finely crystalline; massive, no distinct bedding; weathers with smoother surfaces than unit 2	98
2. Dolomite, medium-gray; weathers medium light gray; very finely crystalline; massive, no distinct bedding; in places weathers dark gray and also to a mottled light- and dark-gray surface with circles 1 in. across and irregular bands 1 in. wide and 2-4 in. long; surface roughened by 1/16 in. grooves that cross at random angles. Forms slight knoll on ridge	29
Thickness of exposed Lone Mountain Dolomite	330
Ordovician System:	
Hanson Creek Formation (incomplete):	
1. Siltstone, both dolomitic and limy, and very fine-grained sand-size fragments, light-olive-gray; weathers grayish yellow; does not crop out here, surface covered with platy fragments 2-5 in. across and blocky fragments 3-4 in. across. Forms low saddle on ridge	20

AGE AND CORRELATION

Fossils are sparse and poorly preserved in the Lone Mountain Dolomite in the area. Chain corals are visible on weathered surfaces in that part of the formation exposed in the northern part of the Pinon Range; this is the lower part of the formation in the mapped area. Two collections of these corals made on the crest of the range at Ravens Nest were examined by W. A. Oliver, Jr., who

SECTION S2.—*Partial stratigraphic section of Lone Mountain Dolomite on the northwest side of Coffin Mountain in sec. 29, T. 28 N., R. 53 E.*

[Location of section shown by number on pl. 1]

	Feet
Devonian System:	
Nevada Formation	
Contact appears to be conformable.	
Silurian System:	
Lone Mountain Dolomite (upper part, incomplete):	
3. Dolomite; alternating brown and gray beds 2-3 ft thick; brown beds have petroliferous odor and contain large numbers of crinoid columnal fragments; both brown and gray beds are vuggy; some thin quartz-sandy lenses	45
2. Dolomite; alternating brown and gray beds, 2-12 ft thick; thin laminations within some beds; brown beds have petroliferous odor; both brown and gray beds are vuggy; grain size of carbonate fragments 0.05-0.2 mm; 1 percent scattered quartz grains 0.1 mm in diameter near top of unit	120
1. Dolomite; brownish gray to yellowish gray in beds generally about 2 ft thick; thin laminations within some beds; grain size 0.01-0.3 mm; coarse stylolites about 340 ft above base; 10-ft-thick sedimentary breccia zone 540 ft above base of section	610
Base not exposed.	
Thickness of exposed Lone Mountain Dolomite	775

reported (written commun., 1957 and 1959) that they are poorly preserved in both collections, but that one (477; No. 28 on pl. 1) contains *Catenipora* sp. that is more like Silurian than Ordovician types and that the other (SF-99; No. 26 on pl. 1) contains *Halysites*? sp. indeterminate, horn corals, and crinoid columnals. *Halysites*? indicates a Silurian age. A third collection (SF-102; No. 27 on pl. 1) also form the crest of the range and about 1,800 feet south of Ravens Nest contain corals and brachiopods; this collection is very near the base of the formation. Of the corals, Oliver (written commun., 1959) stated that they "are very poorly preserved, having almost entirely recrystallized interiors," and listed them as including one favositoid coral, one ramose favositoid coral, one indeterminate phacelloid rugose coral, two specimens of an indeterminate horn coral, and a solitary coral *Amplexoides*? sp. He considered the *Amplexoides*? as being very close to and perhaps identical to a Silurian species. From this same collection (SF-102; No. 27 on pl. 1) silicified specimens of brachiopods were identified by A. J. Boucot (written commun., 1960) as *Protathyris* and fragments of a coarsely costellate rhynchonellid. Regarding the age of this fauna, Boucot stated: "In North America *Protathyris* has not been found outside strata of Ludlovian age. However, in Europe the genus is known from the Wenlockian to the lower Gedinnian. In Utah, Waite (1956) has found the genus in the Laketown Dolomite together with other forms, all of which he concluded to be of Late Silurian age. Until more information is forthcoming it seems best to conclude that the containing beds in the Elko area are of Ludlovian age."

We found no identifiable fossils in the upper 775 feet of the Lone Mountain at Coffin Mountain, although some beds between 45 and 165 feet below the top of the formation contain many fragments of crinoid columnals and a few recrystallized fragments of other fossils that can be seen in thin sections.

The Late Silurian age of the lower part of the Lone Mountain here suggests a major hiatus between the underlying Hanson Creek and the Lone Mountain. Lack of diagnostic fossils in the upper part of the Lone Mountain in this area prevents direct dating of the upper part. A Late Silurian age for the higher part of the Lone Mountain is indicated from fossils collected north of Wood Cone about 12 miles southwest of Eureka (Nolan and others, 1956, p. 36), but the formation may be of Silurian or Early Devonian age near Eureka (Nolan and others, 1956, p. 39). An Early Devonian age was indicated for the upper part or all of Lone Mountain at Lone Mountain, in the Roberts Mountains, and in the Sulphur Spring Range south of the area of this report. (See Poole and others, 1967, p. 883; Berry and Boucot, 1970, p. 179-180; Johnson and others, 1973, p. 4.) The Lone Mountain in the mapped area is considered as Late Silurian and, in our opinion as based on determinations farther south, may also include beds of Devonian age.

The Silurian age and the lithologic similarities to the Lone Mountain in the type locality (Merriam, 1940, p. 13-14) and elsewhere (Nolan and others, 1956, p. 37-40; Winterer and Murphy, 1960) south of the mapped area confirm the correlation with the Lone Mountain Dolomite.

UPPER CONTACT

The contact between the Lone Mountain Dolomite and the overlying Nevada Formation appears to be conformable at a change from alternating gray and brown beds, some of which contain many crinoid columnals, in the Lone Mountain to dolomitic sandstone or quartzose dolomite in the basal part of the Nevada. As the slopes are rubble-covered in many places, the actual contact is poorly exposed, but no evidence of an unconformity, such as that noted in the Eureka area (Nolan and others, 1956, p. 38), has been observed. The contact and lack of an unconformity are like the relations noted by Carlisle and others (1957, p. 2179-2180) in the Pinon Range and farther south in the Sulphur Spring Range.

SILICEOUS (WESTERN) ASSEMBLAGE

SILURIAN ROCKS OF MARYS MOUNTAIN

The Silurian rocks in the small part of Marys Mountain within the mapped area crop out over about one-half square mile. No formal name is applied here to these beds because we believe that studies of more extensive outcrops just to the west and perhaps to the north will provide a more substantial basis for making correlations with other siliceous-assemblage formations or for establishing a new formation. Exposures are poor over most of the area, although the base as drawn on the geologic map is along an almost continuous ledge of chert. The thickness of Silurian rocks on the east side of Marys Mountain is between 400 and 500 feet, but these figures may be meaningless, as the base and top may be faults; in addition, the exposed section may have deletions or repetitions of beds on faults.

Chert and lesser amounts of siltstone compose these Silurian rocks. Chert occurs on the lower 20-40 feet of the slope, siltstone in angular fragments and blocks on the next 80-100 feet, and chert on most of the upper slope. The chert is gray, tan, brown, and green and in places occurs in knobby beds ½-2 inches thick. These beds appear to be warped gently but not contorted, and the rock is brecciated locally. The siltstone is white to light yellowish gray and weathers tan and commonly forms angular fragments on the slopes. Locally, faint thin laminations are visible on the weathered surfaces. Some of the fragments have prominent brown iron-oxide concentrations along joint surfaces.

The Silurian age of these strata is based on graptolite collection USGS D188-SD, No. 34 on pl. 1, taken about 110 feet above the base of the unit. The graptolites were identified as *Cyrtograptus murchisoni* cf. var. *bohemicus* Boucek, *Monograptus* cf. *M. priodon* (Brongniart), *Monograptus pandus* Lapworth?, *Monograptus* sp., and *Retiolites geinitzianus* (Barrande) by R. J. Ross, Jr., and W. B. N. Berry (written commun., 1961) who date them as very late Early or early Middle Silurian. These beds may be correlative with the Fourmile Canyon Formation in the Cortez quadrangle (Gilluly and Masurky, 1965, p. 54-57). Lower Silurian graptolites also have been reported from the Seetoya sequence of Kerr (1962, p. 449) in the Seetoya Mountains about 45 miles north and from the Noh Formation of Riva (1970, p. 2698, 2713) in the HD Range almost 100 miles northeast of the Carlin-Pinon Range area. Regional correlation must await study of the more extensive areas of Silurian rocks exposed in the nearby Tuscarora Mountains.

Silurian rocks at Marys Mountain are in fault contact with Lower Devonian beds in the mapped area and are overlain by Lower Devonian beds on a contact that may well be a thrust fault just to the west, although poor exposures make exact relations at the contact inconclusive. The apparently highest beds in the Devonian unit seem to dip to the southeast into the Silurian rocks, suggesting a mechanical contact relation.

DEVONIAN SYSTEM

Devonian units in the mapped area belong to all three assemblages—carbonate, siliceous, and transitional—and may be seen close together along an east-west traverse near the southern margin of the area.

CARBONATE (EASTERN) ASSEMBLAGE

Carbonate-assemblage rocks of Devonian age form the core of the Pinon Range in the southern quarter and for about 5 miles in the center of the area. In addition, they are exposed at Pine Mountain and the hill southeast of Spring Canyon Mountain. In nearly all places these rocks suppport growths of trees—pinon pines and junipers—and in this respect differ from the clastic rocks of early Paleozoic age and of Mississippian age. The Nevada Formation and the Devils Gate Limestone compose the carbonate-assemblage units of Devonian age.

NEVADA FORMATION

As a stratigraphic term, Nevada was used in the early reports on the region (King, 1878, atlas, map 4; Hague, 1883, p. 264-267; 1892, p. 63-84), was redefined by Merriam (1940, p. 14-16), and has been discussed in more detail and divided into five members in the Eureka area by Nolan, Merriam, and Williams (1956, p. 40-48). In a report on Devonian stratigraphy of the Sulphur Spring and Pinon Ranges, Carlisle and others (1957) divided the Nevada into three members. In both the Nolan and Carlisle papers the formation is divided into a lower carbonate unit, a middle unit containing much quartz sand, and an upper carbonate unit. Figure 5 shows the correlation of Devonian strata in the Eureka district and the Sulphur Spring and Pinon Ranges, as presented by Carlisle and others (1957, p. 2181) and as modified by Johnson (1962, p. 545). In the Carlin-Pinon Range area, where we also have separated the Nevada into three units, the basal McColley Canyon Member of Carlisle and others is chiefly dolomite. This marks a northward change to dolomite from mostly limestone and dolomite in the Sulphur Spring Range. This and the north end of the limestone tongue in the Telegraph Canyon Member of Carlisle and others reflect a north or northeastward gradation and intertonguing of dolomite and limestone to dolomite.

Our map units are essentially the same as those defined by Carlisle and others (1957), although our boundaries do not coincide exactly with theirs. As the rock descriptions are adequately presented by them, our lithologic descriptions are shortened accordingly.

In our opinion, the two lower units of the Nevada Formation in this area are enough like the Beacon Peak Dolomite Member and the Oxyoke Canyon Sandstone Member of the Eureka area (Nolan and others, 1956, p. 42-43) to warrant use of those names in the Carlin-Pinon

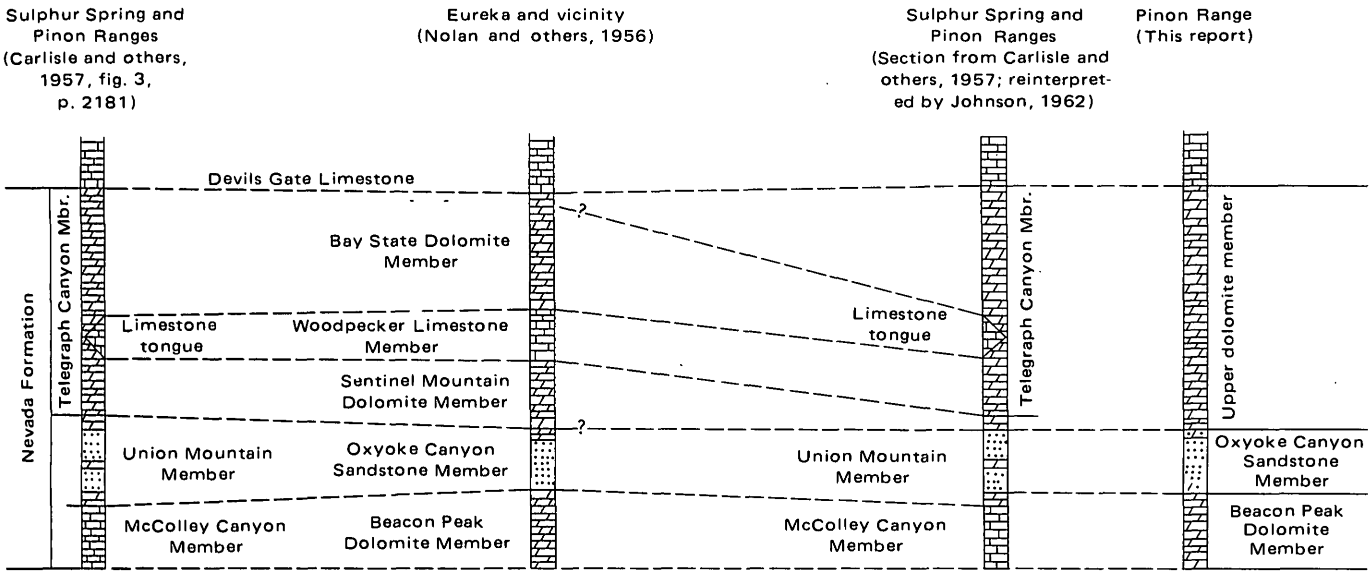


FIGURE 5.—Correlation diagram of Devonian strata in the Eureka district and the Sulphur Spring and Pinon Ranges by Carlisle and others (1957, p. 2181) and as modified by Johnson (1962, p. 545), and in the Pinon Range as used in the present report.

Range area rather than the names introduced later by Carlisle and others (1957, p. 2178-2183). Inasmuch as the three upper members in the Eureka area (Nolan and others, 1956, p. 43-46) form the same interval between the Oxyoke Canyon Sandstone Member and the Devils Gate Limestone as does our upper dolomite in the Carlin-Pinon Range area, no formal name is here applied to this upper unit. It is essentially the same as the Telegraph Canyon Member of Carlisle and others (1957 p. 2179, 2183-2184). We refer to it as the upper dolomite member.

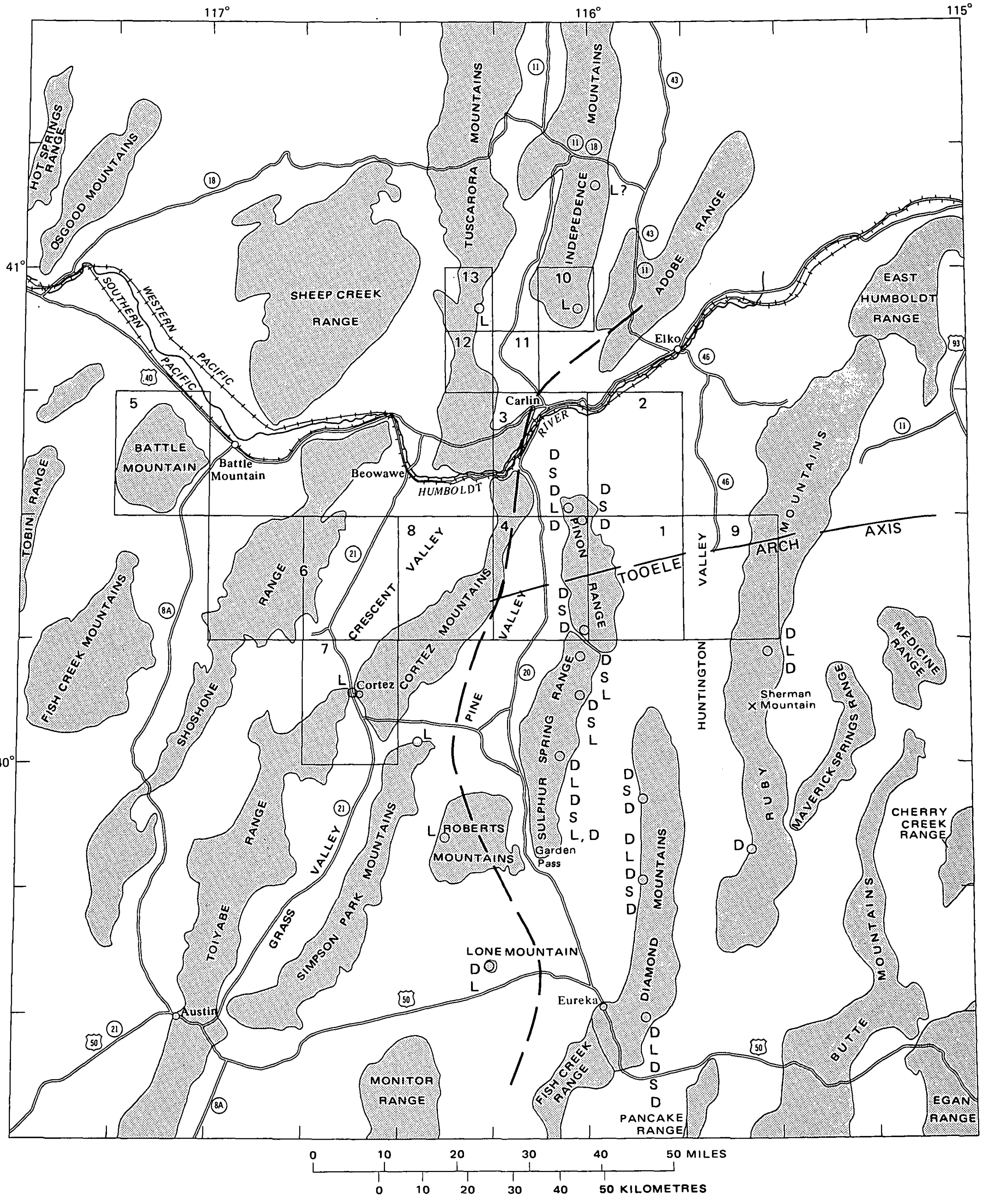
AGE AND CORRELATION

Fossils are scarce and poorly preserved in the Nevada Formation in the mapped area; this fits the regional pattern, as they become more scarce and more poorly preserved northward along the Sulphur Spring and Pinon Ranges (Carlisle and others, 1957, p. 2185). Of the faunal zones recognized in the vicinity of Eureka (Nolan and others, 1956, p. 46-47) we found only the *Eurekaspirifer pinyonensis* zone, Merriam's (1940, p. 53-56) third faunal zone above the base of the formation, about 385 feet above the base near Coffin Mountain. The rocks in the fossiliferous zone are chiefly yellow weathering silty dolomite. Three collections (USGS 4492-SD, 4493-SD, and 4494-SD; Nos. 50, 49, and 51, respectively, on pl. 1) of brachiopods from this zone contain Lower Devonian *Acrospirifer* cf. *A. pinyonensis* (Meek), *Eurekaspirifer pinyonensis* (Meek, 1870) (Johnson, 1970, p. 207-208), and *Atrypa* sp. These were identified in 1958 by Jean M. Berdan, although preservation of the shells was not very good because partial silicification had largely destroyed the external ornamentation. Carlisle and others (1957, p. 2179, 2187) collected the Middle Devonian coral *Heliolites* from our upper part of the Oxyoke Canyon Sandstone Member and lower part of the upper dolomite member, in the Dry Creek–Coffin Mountain area. The coral "spaghetti" beds occur in the Nevada Formation throughout the area. R. S. Boardman in 1956 identified stromatoporoid corals *Amphipora* sp. and *Stachyodes* of Middle and Late Devonian age from a collection (229; No. 52 on pl. 1) in the upper dolomite member near Dry Creek, and Helen Duncan identified *Syringopora* from a collection (USGS 1653-PC; No. 53 on pl. 1) from this same member on the southwest side of Coffin Mountain.

The Early and Middle Devonian age of the Nevada Formation is established from studies south of the mapped area (Merriam, 1940, p. 50-59; Nolan and others, 1956, p. 46-47; Carlisle and others, 1957, p. 2185-2188; Johnson, 1962). Correlation of the Nevada Formation with the Sevy and Simonson Dolomites that occur farther east has been discussed previously (Nolan and others, 1956, p. 47-48; Carlisle and others, 1957, p. 2189-2190; Langenheim and others, 1960, p. 66-67; Johnson, 1962; Poole and others, 1967, p. 883-884.

No complete section of the Nevada Formation is exposed along any one line in the mapped area, so its total thickness must be pieced together from fragmentary sections. In the southern quarter of the area, the maximum thickness can be as much as 3,200 feet. In the central part, where its base is not exposed, the minimum thickness is about 1,600 feet.

The area of the present report is just east of a zone of very marked change in lithology in the Devonian carbonate sequence, a change from dolomite and sandstone on the east to limestone on the west (fig. 6). This change is similar to that recorded in the Hanson Creek Formation and its equivalent strata, suggesting that similar



depositional conditions existed from Late Ordovician to Middle Devonian time, during which the belt of facies change shifted only slightly. At Pine Mountain the zone of facies change in the Nevada Formation is prominantly displayed. Thin limestone beds occur in the dolomite in the lower part of the formation there but do not occur farther southeast; limestone tongues evidently extend into this area from the west. The Oxyoke Canyon Sandstone Member at Pine Mountain is thinner and more lenticular than it is farther east and south in the Pinon Range and evidently marks a westward decrease in sand content. Johnson's (1962) correlation of the Sulphur Spring and Pinon Ranges sequence with that at Eureka (fig. 5) is based on faunal zones and indicates that a comparable succession of dolomite and limestone does not necessarily indicate that the same lithologic types are equivalent above the Oxyoke Canyon Member. Such a condition would be expected in this marginal area of westward change from dolomite to limestone by gradational and interfingering relations.

Beacon Peak Dolomite Member

The full thickness of the Beacon Peak Dolomite Member is exposed only in the southern part of the mapped area, where it is 675 feet. This thickness is about twice that shown by Carlisle and others (1957, p. 2179) for this same part of the section and area and reflects the fact that we placed the contact between the Beacon Peak and the overlying Oxyoke Canyon Sandstone Member higher in the section, at the position where sandstone or quartzite is dominant over dolomite. This unit also crops out near the center of the area, but its base is not exposed.

Lithology

The Beacon Peak consists chiefly of thin- to thick-bedded gray to brown dolomite. A characteristic feature of this dolomite in places is a peculiar grainy-appearing texture that may be observed on a moistened fresh surface. Also characteristic are thin red stylolites. Sandstone made up of quartz grains in dolomite cement forms the basal unit of the member, and quartz grains also are scattered through the dolomite in some higher beds. A described stratigraphic section (No. S3) measured on the northwest flank of Coffin Mountain follows.

Section S3.—*Stratigraphic section of Beacon Peak Dolomite and Oxyoke Canyon Sandstone Members of Nevada Formation on northwest side of Coffin Mountain in E½ sec. 29 and NW¼ sec. 33, T. 28 N., R. 53 E.*

[Measured with Abney level. Location of section shown by number on pl. 1]

	Feet
Top of formation eroded.	
Nevada Formation:	
Oxyoke Canyon Sandstone Member:	
7. Quartzite, brown to white, thin to massive-bedded; indistinct molds of fossils; quartz grains 0.1-1.0 mm in diameter showing sutured boundaries, cemented with dolomite in places; sandy dolomite	245
Total thickness of Oxyoke Canyon Sandstone Member	245
Beacon Peak Dolomite Member:	
6. Dolomite; alternating beds of quartz-sandy dolomite and pure dolomite, yellowish white or pinkish white to brown; beds range from a few inches to several feet thick, some brown beds very finely laminated; quartz grains are 0.1-0.3 mm in diameter, detrital carbonate grains are 0.01-0.1 mm in diameter; the topmost bed is similar to unit 4	220
5. Dolomite, gray to brown, thick-bedded; nearly free of quartz grains; contains rounded dolomite grains as in unit 3; red stylolites prominent	45
4. Dolomite, yellow; argillaceous in part; irregular laminae; grain diameter about 0.03 mm; contains numerous silicified brachiopods, mainly *Acrospirifer* cf. *A. pinyonensis* (Meek) (USGS 4492-SD identified by J. M. Berdan); *Eurekaspirifer pinyonensis* zone	25
3. Dolomite, gray to brown, thick-bedded; contains sparse quartz grains; abundant well-rounded pinkish grains 0.1-1.0 mm in diameter composed of extremely fine-grained dolomite are set in a matrix of irregular crystals of dolomite 0.01-0.3 mm in diameter; red stylolites; the outstanding feature of this interval is the grainy texture visible on a moistened fresh surface	285
2. Dolomite, gray to brown, thick-bedded; quartz sandy in places; contains rounded dolomite grains as in unit above; red stylolites	75
1. Sandstone, light-brown; thin low-angle crossbedding; dolomitic cement; quartz grains well rounded to angular, 0.05-0.2 mm in diameter; dolomite grains 0.05-0.3 mm in diameter, some rounded dolomite grains as in beds above	25
Total thickness of Beacon Peak Dolomite Member	675
Contact appears conformable.	
Lone Mountain Dolomite.	

Eleven samples of Beacon Peak from measured section S3 were analyzed for calcium and magnesium by James A. Thomas. Eight of these samples from units 2, 3, and 5 have total calculated carbonate percentages ranging from 91.4 to 97.2, calcium percentages ranging from 20.3 to 21.8, magnesium percentages ranging from 11.7 to 12.6, and Ca/Mg molal ratios ranging from 1.02 to 1.07. These rocks, then, are all dolomite except for those specimens with less than 95 percent total carbonate which are marly dolomite according to the classification of Guerrero

◀ Figure 6.—Principal localities where Nevada Formation and probable equivalent carbonate-assemblage rocks are exposed in the region, indicating the principal lithologic types represented; D, dolomite; L, limestone; S, sandstone; LD, limestone and dolomite. Vertical sequence of lithologic types is stratigraphic sequence. The broad dashed line marks the approximate west edge of sandy beds of the Oxyoke Canyon Sandstone Member and equivalent strata. Sources of data, other than from the present study, are Carlisle and others (1957), Johnson (1962), Larson and Riva (1963), Lovejoy (1959) Merriam (1940, 1963), Merriam and Anderson (1942), Nolan, Merriam, and Williams (1956), Rigby (1960), Sharp (1942), Gilluly and Masursky (1965), Ketner, Evans, and Hessin (1968), and Evans (1972b).

and Kenner (1955, p. 46). A specimen from the basal sandy unit contains 59 percent total calculated carbonate, 12.9 percent calcium, 7.7 percent magnesium, and has a Ca/Mg molal ratio of 1.01; this rock is dolomitic sandstone. A sample of quartz-sandy dolomite from the top unit (No. 6) contains 80.7 percent total calculated carbonate, 17.7 percent calcium, 10.5 percent magnesium, and has a Ca/Mg molal ratio of 1.02. One sample from unit 4, the *Eurekaspirifer pinyonensis* zone, has 76.5 percent calculated carbonate, 18.1 percent calcium, 9.0 percent magnesium, and Ca/Mg molal ratio of 1.22; it is a marly calcitic dolomite.

The Beacon Peak Member on the east side of Pine Mountain is mostly white crystalline dolomite that was recrystallized probably accompanying intrusion of a pluton below. (See p. A39–A40.) Quartz grains are scattered through the dolomite in the upper 200 feet of the member.

Two bands of limestone form part of the member on Pine Mountain. The stratigraphically lower limestone extends the full length of the mountain and is about 50 feet thick. It is a gray to bluish-gray dense limestone in beds mostly 1-4 feet thick but with thin laminations within some beds. The south end of the band near the fault on the east side of Pine Mountain is white coarsely crystalline limestone. This limestone contains poorly preserved brachiopods and corals. The stratigraphically higher band is 30-50 feet thick and pinches out on the south slope of the high part of the mountain. These two units probably are tongues of limestone extending eastward or northeastward from Devonian sequences that are entirely limestone.

The *Eurekaspirifer pinyonensis* zone, about 285 feet above the base of the Beacon Peak Member on Coffin Mountain, consists of yellow and tan argillaceous dolomitic and limy beds which differ from beds composing the rest of the member. These yellowish rocks are much thinner bedded than most of the Beacon Peak and weather to form a distinctive zone about 25 feet thick. Murphy and Gronberg (1970) have named this zone at Lone Mountain, northwest of Eureka, the Bartine Member of the McColley Canyon Formation. They (Murphy and Gronberg, 1970, p. 131) stated that their Bartine Member "will probably eventually be recognized as the most widespread and persistent lithologic unit of the entire Nevada Group in the area west and north of Eureka."

Upper Contact

The contact between the Beacon Peak Dolomite Member and the overlying Oxyoke Canyon Sandstone Member is gradational at most places; it is placed at the change from dolomite containing quartz sandy dolomite beds to dominantly sandstone or quartzite beds. Ranges of quartz grain sizes differ in the two members; those in the Beacon Peak range from very fine to medium, and those in the Oxyoke Canyon from very fine to coarse. This difference in maximum grain size may be useful in distinguishing the two members, but the contact is drawn on the basis of preponderance of quartz grains rather than on maximum grain size. Because of the gradual change, the contact probably would not be put at exactly the same stratigraphic position along any two traverses across it. On Pine Mountain, this contact is mostly an abrupt change from dolomite to quartzite, although sandy dolomite occurs as much as 200 feet below the contact.

Johnson (1962, p. 543-544) suggested that this contact at the base of the Oxyoke Canyon Member and correlative beds is a regional unconformity. His conclusion was based mainly on three factors: (1) the presence of a faunal break above the *Eurekaspirifer pinyonesis* zone in the Roberts Mountains and the northern part of the Simpson Park Mountains, (2) the eastward thinning and disappearance of the argillaceous unit of the *Eurekaspirifer pinonyensis* zone, and (3) the deposition of sandy beds above the unconformity in an eastward transgressing sea. We found no physical evidence of an unconformity in the Carlin-Pinon Range area and consider the contact as gradational, although it is abrupt in some places.

Oxyoke Canyon Sandstone Member

The Oxyoke Canyon Sandstone Member crops out prominently in the southern and central parts of the area; it caps Coffin Mountain, forms part of the cap and prominent ledges and cliffs along the Pinon Range northeast of the head of Trout Creek and forms a thin band along Pine Mountain. This member ranges in measured thickness from zero to 415 feet and probably is at least 600 feet in places. The unit is lacking, probably owing to nondeposition, for a distance of a few feet on the south slope of hill 7072 in sec. 18, T. 28 N., R. 53 E.; the thickness increases rapidly north and south from the zero locality. The maximum measured thickness of 415 feet is east of the head of Trout Creek (stratigraphic section S4A). A thickness of 600-700 feet is suggested by the map relations several miles north of Coffin Mountain.

Lithology

Quartzite and sandstone containing different amounts of dolomite compose the Oxyoke Canyon Member. The rock is white, pink, gray, and light brown and weathers to shades of the same colors. It is thin to thick bedded and crossbedded on a small scale in places; crossbedding shows most prominently on weathered surfaces. Beds of gray vitreous quartzite that weathers gray and pink are prominent locally and form ledges and cliffs. In thin section the quartz grains are seen to be 0.1-1.0 mm in diameter and to be generally well rounded, but original boundaries of many grains are indistinct and commonly are sutured and partly replaced by carbonate cement.

Many quartz grains are frosted. Some beds are chiefly dolomite which is largely recrystallized but which probably originally consisted of clastic grains. In the Railroad mining district, west of Bullion, the Oxyoke Canyon Member is closely jointed and obscurely bedded, and the original dolomite matrix has been altered to diopside (Ketner and Smith, 1963a, p. B9).

The Oxyoke Canyon Sandstone Member is described in stratigraphic sections S3, S4A and S5A.

SECTION S4A.—*Stratigraphic section of Oxyoke Canyon Sandstone Member and upper dolomite member of Nevada Formation in SE¼ sec. 16 and E½ sec. 21, T. 30 N., R. 53 E.*

[Measured with Abney level on Jacob staff and with Brunton compass and steel tape. Location of section shown by number on pl. 1]

	Feet
Devonian System:	
Devils Gate Limestone:	
Limestone.	
Contact between upper dolomite member of Nevada Formation and Devils Gate Limestone is gradational.	
Nevada Formation:	
Upper dolomite member:	
12. Dolomite, light-gray; weathers gray; thin bedded, laminated in places. Some gray limestone in upper 40 ft; yellow platy limestone in 1-ft bed at base of unit	110
11. Dolomite, light-gray; weathers gray and light tannish gray; some dark-gray dolomite; veinlets of secondary white dolomite	90
10. Dolomite, gray- and brownish-gray; weathers same with checkered and brecciated surface in places; laminated in beds 1/16 in. or less thick; petroliferous odor on fresh break; veinlets of white dolomite trend in random directions and show most clearly in dark-brownish-gray beds	190
9. Dolomite, grayish-brown and gray; weathers same with checkered and brecciated surface; fine grained; laminated in beds 1/16 in. or less thick, most beds regular, some wavy; petroliferous odor on fresh break; becomes darker toward top	365
8. Dolomite, gray; weathers gray with checkered surface in places; finely to moderately crystalline. The rock becomes somewhat darker upward and weathers to brownish tint; darker rock more finely crystalline	90
Total thickness of upper dolomite member	845
Contact between upper dolomite member and Oxyoke Canyon Sandstone Member is gradational.	
Oxyoke Canyon Sandstone Member:	
7. Quartzite and sandstone, dolomitic, gray; weathers gray; quartz grains here and below through unit 3 are mostly well rounded and very fine to coarse	30
6. Sandstone and quartzite, gray; weathers gray and pink; in beds generally about ¼ in. thick; small-scale crossbedding in places; local surface coatings of shiny pink secondary quartz. Forms a ledge	12
5. Quartzite and sandstone, dolomitic, gray; weathers gray; where bedding is visible it is thin, ¼-½ in.	70
4. Quartzite and sandstone; slightly dolomitic in places, light gray to white; weathers light pink. Some beds are gray and are more dolomitic than the pink ones. Secondary overgrowths of silica on some of the quartz. (Unit is much fractured and brecciated in places, so thickness measured may	

SECTION S4A.—*Stratigraphic section of Oxyoke Canyon Sandstone Member and upper dolomite member of Nevada Formation in SE¼ sec. 16 and E½ sec. 21, T. 30 N., R. 53 E.*—Continued

	Feet
Devonian System—Continued	
Nevada Formation—Continued	
Oxyoke Canyon Sandstone Member—Con.	
4. Quartzite and sandstone—Con. be incorrect.)	85
3. Sandstone, dolomitic, and sandy dolomite, gray; weathers gray; thin bedded; some dolomite in upper 30 ft. (Poorly exposed across a small syncline, so thickness measured may be incorrect by 10-20 ft.)	120
2. Quartzite, dolomitic, gray; weathers gray with brown tint; rounded medium grains of quartz; well bedded in places with layers ¼-2 in. thick; some beds almost completely dolomite, but fewer than in unit 1 below. Forms cliff locally	35
1. Dolomite, sandy containing scattered rounded medium and coarse quartz grains, and dolomite containing no quartz grains; beds generally 1-3 ft thick; quartz veinlets crisscross rock in places	63
Total thickness of Oxyoke Canyon Sandstone Member (brecciated in places and folded slightly, so thickness measured may be off slightly)	415
Beacon Peak Dolomite Member:	
Contact between Beacon Peak Dolomite Member and Oxyoke Canyon Sandstone Member is gradational. It is placed as near as possible at the first occurrence of prominent rounded medium and coarse quartz grains in the dolomite, but this first occurrence is at somewhat different positions along the strike.	
Beacon Peak Dolomite Member:	
Dolomite, gray with red tint in places, weathers very light-gray with brecciated surface.	

SECTION S5A.—*Stratigraphic section of upper dolomite member of Nevada Formation in NW¼ sec. 4 and N½ sec. 5, T. 28 N., R. 53 E.*

[Measured with Brunton Compass and steel tape and with Abney level on Jacob staff. Location of section shown by number on pl. 1]

	Feet
Devonian System:	
Devils Gate Limestone:	
Limestone.	
Contact between upper dolomite member of Nevada Formation and overlying Devils Gate Limestone is gradational, and intertonguing.	
Nevada Formation:	
Upper dolomite member:	
7. Limestone, massive, gray; weathers gray; interbedded thin-bedded light-gray dolomite; top as mapped grades into overlying Devils Gate Limestone	100
6. Dolomite, chiefly brown or brownish-gray; weathers brown; some gray dolomite, weathers gray; dense to moderately crystalline; well bedded with laminae locally, some contorted laminae on a scale of a few inches to a few feet; some beds cross-laminated on a small scale; some well-bedded massive outcrops; many pink and white dolomite veinlets; contains much "spaghetti" rock made up of coral *Amphipora*; brown beds have strong petroliferous odor on fresh break. Upper 100 ft is chiefly light gray moderately crystalline sugary dolomite in thin beds and in 2 to 5-ft-thick units, weathering light gray	850

SECTION S5A.—*Stratigraphic section of upper dolomite member of Nevada Formation in NW¼ sec. 4 and N½ sec. 5, T. 28 N., R. 53 E.*—Continued

	Feet
Devonian System—Continued	
Nevada Formation—Continued	
Upper dolomite member—Continued	
5. Mostly covered; float of dark-gray dolomite with brown tint and grayish-brown dolomite that weathers brown; dense to finely crystalline bedding generally indistinct, but some blocks are well laminated in 1/16-in. or less alternating light- and dark-brown layers that show particularly well on weathered surfaces; in some blocks, dolomite veinlets about 1/32 in. wide give the rock a honeycomb look; brown checkered weathered surface on some blocks; also brecciated float pieces. (Measured across anticline and corrected to avoid repetition; if any, error is probably less than 50 ft.)	490
4. Covered; probably similar to unit 2	165
3. Dolomite, fine-grained; gray with brown tint; weathers light-brown; thin bedded, generally laminated light gray and brown, mottled with light-colored finer grained dolomite blebs 1 in. or less across	60
2. Covered, float pieces suggest bedrock is similar to unit 1 below	140
1. Dolomite, light-gray; weathers light gray with pink cast along some fresh surfaces and along fracture surfaces in places; finely to coarsely crystalline, mostly fine with slightly rough surface; beds mostly 6 in. or less thick, some about 1/16 in.; a few beds are brown finely crystalline dolomite that weather brown and yield a strong petroliferous odor on a fresh break. Some float pieces appear brecciated on the weathered surface; veinlets of white dolomite show in some blocks but are not abundant	260
Total thickness of upper dolomite member	2,065

Contact between upper dolomite member and underlying Oxyoke Canyon Sandstone Member is gradational; the contact is taken as the top of the underlying sandy beds.

Oxyoke Canyon Sandstone Member:

Dolomite, sandy, light-gray to almost white, finely crystalline; scattered quartz grains are fine to medium size, well rounded, and frosted on some; top of member is top of an interbedded unit of dolomitic sandstone, sandy dolomite, and dolomite.

The Oxyoke Canyon Member as mapped on Pine Mountain consists of quartzite and dolomite lenses in a unit having a maximum thickness of 100 feet. Quartzite lenses as much as 15 feet thick appear to continue along strike for hundreds of feet, although it is difficult to trace a single lens along the rubble-covered slopes. The quartzite is white and is made of well-sorted and well-rounded fine grains of quartz; weathered surfaces commonly are white and shiny. Mostly gray finely to medium crystalline dolomite makes up the carbonate lenses. Contacts between quartzite and dolomite lenses are surprisingly sharp, and along most of them the dolomite next to the quartzite contains no quartz grains. The Oxyoke Canyon Member here marks a westward decrease in the amount of quartz sand in the Nevada Formation and indicates that much of this decrease is by interfingering of quartzite and dolomite.

The boundary between the Oxyoke Canyon Sandstone Member and the overlying upper dolomite member is gradational, and we place the contact at the top of the highest bed containing appreciable numbers of quartz grains.

UPPER DOLOMITE MEMBER

The upper dolomite member of the Nevada Formation crops out along the Pinon Range in the southern quarter of the mapped area, in the central part, and on the hills southeast of Spring Canyon Mountain. It is exposed in small windows in the Roberts Mountains thrust plate near Dry Creek. Smooth slopes broken by ledges and low cliffs develop on this member, and commonly the slopes are darker than those developed on adjacent units. Measured thicknesses of this member are 2,065 feet (stratigraphic section S5A) in the area about 5 miles north of Coffin Mountain and 845 feet (stratigraphic section S4A) on the range crest east of Trout Creek. Rocks of this member are not exposed for the 9 miles between the two measurements, so the nature of northward thinning is unknown. Carlisle and others (1957, p. 2179) show a similar northward decrease in thickness in this part of the Nevada Formation.

Lithology

This member consists of brown and gray dolomite in alternating layers. Bedding is distinct to indistinct and in many outcrops of brown dolomite fine laminations are clearly visible; locally, the laminations are contorted on a scale of a few inches to a few feet and also are cross laminated on a small scale. Well-bedded massive outcrops occur in places, particularly in the upper part of the member. Much of the brown dolomite has a strong petroliferous odor on a fresh break, and much of it weathers to form a characteristic checkered surface. The checkered surfaces, fine laminations, and petroliferous odor of the brown dolomite and the alternating gray and brown beds are characteristic features of this member. Also, the dolomite is mottled in many places. In the Railroad mining district west of Bullion, the dolomite was altered during intrusion of the stock and dikes so that most of the characteristic features no longer remain (Ketner and Smith, 1963a, p. B8-B9). There, it is closely jointed, finely to medium crystalline, creamy white, and, less commonly, gray. In places the altered dolomite is now coarsely crystalline white marble and skarn composed principally of garnet and diopside. Typical exposures of the upper dolomite member are described in stratigraphic sections S4A and S5A.

The upper dolomite has been altered on Pine Mountain and is mainly a white medium crystalline dolomite that weathers light gray to white and contains some fibrous crystals of tremolite. In places it is dark gray and fine grained and weathers bluish gray; very locally it is almost black. A characteristic rock type on the northern slopes of the mountain consists of prominent alternating thin beds, ½-5 inches thick, of brown and white to gray dolomite. Crossbeds occur locally. Quartz grains are scattered through some beds in the lower part and one band of quartzite about three-fourths mile long on the north end of the mountain is similar to the quartzite in the Oxyoke Canyon Sandstone Member.

Upper Contact

The contact between the upper dolomite member of the Nevada Formation and the overlying Devils Gate Limestone is gradational and interfingering through a thickness of 50-100 feet. The top of this gradational interval was generally mapped as the upper contact, although in places lenses and thin beds of dolomite are included in the lower part of the Devils Gate. The intertonguing relation is so pronounced north of hill 6979, about 6 miles north of the south edge of the mapped area, that the tongues were mapped (pl. 1); dolomite is shown as the upper dolomite member and limestone as the Devils Gate.

DEVILS GATE LIMESTONE

The Devils Gate was named as a formation by Merriam (1940, p. 16-17) on strictly a faunal basis and used as the rock-stratigraphic unit Devils Gate Limestone by Nolan, Merriam, and Williams (1956, p. 48) on a lithologic basis that is also consistent with the earlier paleontologic definition of the unit. In the Pinon Range the Devils Gate is exposed between Pony Creek and Willow Creek, in the Railroad mining district and east of Trout Creek, at Pine Mountain, southeast of Spring Canyon Mountain, and in scattered small isolated localities. Although exposed in a large number of localities, the total area of exposure of Devils Gate is relatively small. It has been recognized in the Sulphur Spring Range to the south (Carlisle and others, 1957, p. 2178, 2184-2185). Individual beds of the Devils Gate commonly weather to smooth surfaces, but series of beds produce ledgy and in places cliffy slopes.

Thicknesses of the Devils Gate Limestone are minimal in the mapped area inasmuch as the top is at either an unconformity or a fault. Measured thicknesses are 940 feet at stratigraphic sections S5B and 850 feet at section S4B.

LITHOLOGY

The Devils Gate Limestone is composed mostly of medium- to thick-bedded light and dark-gray fine-grained limestone that weathers gray and bluish gray. Coral (*Amphipora*) "spaghetti" beds are scattered through the formation. At a very few places sparse rounded quartz grains occur in the limestone and a few lenses of chert-pebble conglomerate a few feet long and about 1 foot thick were seen.

In the Railroad mining district west of Bullion, sequences of dolomite, probably of secondary origin, are interbedded with limestone in the Devils Gate. Much of the limestone has been recrystallized to form distinctive alternating light and dark bands of "zebra" rock. Both the limestone and dolomite have been altered in places to white marble and to skarn. Where the rocks have been altered and recrystallized, the contact between the Devils Gate and underlying Nevada Formation is not easily recognized, but, as in less altered rocks, it is placed at the position separating mostly limestone above from mostly dolomite below. On the steep rubble-covered slopes in the mining district, this contact as drawn undoubtedly is not at one horizon but is at slightly different positions through a stratigraphic interval of perhaps several tens of feet.

At Pine Mountain also, much of this formation has been recrystallized to produce white limestone and white coarsely crystalline marble and layered "zebra" rock. Here, the "zebra" rock is not as well developed as that farther east in the mining district. Copper carbonate minerals stain some beds and fractures on Pine Mountain.

In several places, patches of Devils Gate are silicified. These patches are near faults or near the unconformity at the top of the formation. Locally, silicified carbonate rocks cap slopes on both the Devils Gate and Nevada Formations.

Stratigraphic sections S4B and S5B present descriptions of the Devils Gate Limestone.

SECTION S4B.—*Stratigraphic section of Devils Gate Limestone in E½ sec. 21, T. 30 N., R. 53 E.*

[Measured with Abney level on Jacob staff. Location of section shown on pl. 1]

	Feet
Mississippian System:	
Limestone, dark-gray to black, platy; weathers tan.	
Unconformity.	
Devonian System:	
Devils Gate Limestone:	
2. Limestone, silicified	50
1. Limestone, light-gray and some dark-gray; weathers gray; beds 1-3 ft thick in places but many massive units, some of which form ledges 15 ft high with no visible bedding; weathered surfaces are mainly smooth but a few are slightly rough. Small irregular patches of secondary silica weather brown and form a mottled surface; many white calcite veinlets trend in all directions, most less than ½ in. wide, but some veins as much as 5 ft wide. Limestone is brecciated locally. About 140 ft above the base, thin beds contain widely scattered rounded medium grains of quartz; similar grains may occur elsewhere in the formation but were seen only in this position along our line of section. Small stylolites occur in places but are not common. Dolomite occurs spottily in the lower 25 ft, near the transition from the underlying Nevada Formation. Fossils are common in places but generally are seen	

SECTION S4B.—*Stratigraphic section of Devils Gate Limestone in E½ sec. 21, T. 30 N., R. 53 E.*—Continued

	Feet
Devonian System—Continued	
Devils Gate Limestone—Continued	
1. Limestone—Continued only as sections in the rock. Along the line of the section, fossils were observed at the following positions above the base:	
650 ft to top—much "spaghetti" (*Amphipora*) rock and some brachiopods;	
290-320 ft—many gastropods in cross section, compressed coil types, maximum width 1 in.;	
235 ft—silicified bryozoans;	
225 ft—small brachiopods and gastropods;	
150 ft—corals and bryozoans;	
140 ft—small gastropods, ½ in. or less across;	
60 ft—lowest "spaghetti" corals seen; they, though, occur throughout the formation above this level;	
40 ft—gastropods in sections cut at all angles, largest are 2 in. long and ¾ in. across	800
Total thickness of Devils Gate Limestone	850
Contact between Devils Gate Limestone and underlying upper dolomite member of Nevada Formation is gradational with dolomite and limestone interbedded.	
Nevada Formation:	
Upper dolomite member.	

AGE AND CORRELATION

Fossil collections from the Devils Gate Limestone in the Carlin-Pinon Range area indicate an early Late and possibly late Middle Devonian age for the formation. This is in agreement with the generally assigned age, although we did not find most of the established faunal zones and none of the faunas as young as those reported elsewhere (Nolan and others, 1956, p. 50-52). Carlisle and others (1957, p. 2179, 2188-2189) recognized the *Spirifer argentarius* zone near the top of the Devils Gate in the Pinon Range; this is the lowest brachiopod zone recognized by Merriam in the Devils Gate and occurs in the lower part of the Upper Devonian (Nolan and others, 1956, p. 50-51). As mentioned previously, the upper contact of the Devils Gate is either an unconformity or a fault, and so the younger beds found elsewhere need not be represented in the Carlin-Pinon Range area.

Of our fossil collections, three identified by J. M. Berdan in 1957 contain only the stromatoporoid coral *Amphipora* sp.; two of these (USGS 4485-SD and 4486-SD; Nos. 54 and 55 on pl. 1) came from low in the formation and the third (USGS 4484-SD; No. 56 on pl. 1) from a small patch of limestone that is surrounded by much younger beds and is of unknown stratigraphic position within the formation. From a collection (SF-105; No. 57 on pl. 1) very near the base of the formation W. A. Oliver, Jr., in 1959 identified the corals *Tabulophyllum*(?) sp. and *Stictostroma* sp. and stated that they are probably early Late Devonian. Other coral collections from southwest and west-southwest of Emigrant Spring include stromataporoids *Amphipora* sp. and *Gerronostroma* sp., the tabulate *Thamnopora* sp., and rugose corals *Tabulophyllum*(?) sp. and *Thamnophyllum* sp. from collection 518 (No. 58 on pl. 1) and *Amphipora* sp. from collection 519 (No. 59 on pl. 1; (W. A. Oliver, Jr., written commun., 1958). As reported by Oliver, these forms occur in Middle or lower Upper Devonian rocks. Collection 518 also contained the brachiopod *Atrypa* sp., according to J. T. Dutro, Jr. A collection (SF-86; No. 60 on pl. 1) of brachiopods that occur in large numbers in a bed within about 20 feet of the base of the formation about 3 miles southeast of Spring

SECTION S5B.—*Partial stratigraphic section of Devils Gate Limestone in NW¼ sec. 5, T. 28 N., R. 53 E.*

[Measured with Brunton compass and steel tape and with Abney level on Jacob staff. Location of section shown by number on pl. 1]

	Feet
Quaternary System:	
Alluvium and colluvium.	
Unconformity.	
Devonian System:	
Devils Gate Limestone	
2. Limestone, mostly silicified	100
1. Limestone, light- and dark-gray; weathers same; dense to moderately granular crystalline; thin bedded to massive; units 5 ft thick may consist of series of beds ¼-1 in. thick, some distinct beds ½-2 ft thick. Irregular patches of chert as much as 2 ft across occur locally on weathered surfaces of limestone, and silicified limestone forms spots and patches on the surface locally. About 460 ft above the base, through a thickness of 50 ft, massive limestone has prominent layers and patches of brown nodular silicified limestone, silica occurs chiefly as a surface coating; some of the patches are made up mostly of silicified bryozoans. About 500 ft above the base, a pod of brownish-gray weathering dark-gray dense dolomite, about 10 ft long occurs in the limestone; also dolomitic limestone is interbedded with the limestone in a 30-ft zone; in the same area some coarse breccia consists of dolomite fragments with red chert stringers and white calcite. More than 575 ft above the base, brown silica coatings stand out as knobby surfaces from 1 in. to 1 ft across; blotchy patches of this material may cover areas 2-3 ft wide and 10 ft long. Much of the upper 300 ft is massive gray limestone in units 5 to almost 10 ft thick. Locally, calcite veins cut the limestone in random directions. *Amphipora* form "spaghetti" beds that are abundant throughout the formation. Some other fossils and their positions above the base noted along the line of section follow:	
In a few beds above 620 ft—cross sections of horn corals;	
460-500 ft—silicified bryozoans;	
430 ft—poor cross sections of brachiopods;	
Lower 350 ft—layers of brown silicified bryozoans and fragments of other fossils in places	840
Total thickness of incomplete exposed Devils Gate Limestone	940
Contact between upper dolomite member of Nevada Formation and overlying Devils Gate Limestone is gradational and intertonguing.	
Nevada Formation:	
Upper dolomite member.	

Canyon Mountain were identified as *Atrypa* cf. *A. missouriensis* Miller by C. W. Merriam, who reported that these forms are characteristic of the higher part of the Nevada Formation and are also to be expected in the lower part of the Devils Gate Limestone. This species is considered by him to be of probably late Middle Devonian age in Nevada.

From data obtained in the mapped area, nothing new can be added to earlier discussions of correlations between the Devils Gate Limestone and other formations. Eastward, the Devils Gate seems to be represented by part (Nolan and others, 1956, p. 52) or all (Carlisle and others, 1957, p. 2189; Langenheim and others, 1960, p. 67) of the Guilmette Formation at Gold Hill, Utah (Nolan, 1935, p. 20-21). Regional correlation of Upper Devonian rocks in the Great Basin are summarized by Poole and others (1967, p. 883-885).

UPPER CONTACT

The upper contact of the Devils Gate Limestone is a major unconformity along which the limestone is overlain by clastic rocks of Early Mississippian age. In many places the beds above and below the unconformity have essentially the same attitudes, but on a regional basis within the area of this report they are seen to be unconformable. Paleontologic dating of units above and below the contact indicate a major hiatus.

SILICEOUS (WESTERN) ASSEMBLAGE

WOODRUFF FORMATION

Devonian rocks of the siliceous assemblage in the mapped area crop out over much larger areas than any other units in the upper plate of the Roberts Mountains thrust. Strata making up this Devonian assemblage compose the Woodruff Formation named for exposures along and near Woodruff Creek (Smith and Ketner, 1968, p. 14-17). Rocks composing the Woodruff are principally siliceous mudstone and chert, lesser amounts of shale, siltstone, dolomitic siltstone, and dolomite, a few lenses of limestone, and very few beds of sandy limestone and calcareous sandstone. The siliceous mudstone, chert, and shale are chiefly dark gray to black and weather the same colors, so the slopes covered by weathered fragments commonly are dark. Other rock types are mostly tan and, locally, light gray and weather the same colors.

As well as in the vicinity of Woodruff Creek and west of there, the Woodruff Formation is exposed in several areas along the Pinon Range and in a strip more than 4 miles long near the south margin of the mapped area. No accurate thickness of the Woodruff could be determined because bedding attitudes are generally highly irregular, and we found no persistent marker beds that would enable us to compile a composite section. The thickness in the southern part of the area must be 3,000 feet. It probably is several thousand feet more than that in the entire area.

LITHOLOGY

Although the Woodruff Formation crops out in scattered and isolated blocks and lacks definitive marker beds that can be traced from one block to the next, a most general stratigraphic sequence can be constructed with the aid of fossils from scattered localities. Our thanks are extended to the paleontologists whose fossil identifications and age determinations make presentation of this general sequence possible.

Early Devonian.—The oldest strata exposed in the Woodruff are in the W½ sec. 34, T. 32 N., R. 52 E., and are of Early Devonian age on the basis of the occurrence of the diagnostic graptolite *Monograptus hercynicus nevadensis* Berry (Berry, 1967) in fossil collection D62SD (No. 35 on pl. 1) and on conodonts which are "almost exclusively *Icriodus latericrescens* with an occasional specimen of a new species of *Spathognathodus*" (R. L. Ethington, cited in Berry, 1967, p. B27). Berry (1970, p. 518) correlated the *Monograptus hercynicus nevadensis* zone in Nevada with the early part of the Siegen of Europe. Although the graptolites and conodonts are not from the same beds, they were collected within 10-20 feet stratigraphically of each other. *Tasmanites* identified by J. M. Schopf (written commun., 1957) were collected just above the conodont-bearing beds. They occur as flattened, wrinkled scalelike bodies in shale and as round unmashed forms in phosphatic nodules. Nodules (SF-31A; No. 36 on pl. 1) from this locality also contain, according to R. A. Scott (written commun., 1958), a diverse assemblage of chitinozoans, hystrichospheres, and at least five genera of plant spores which have well-defined trilete marks with some being very elaborate. These spores are characteristic of vascular land plants. Some of the nodules contain bone fragments, probably from primitive fish (R. J. Ross, Jr., oral commun., 1972).

The fossiliferous beds dated as Early Devonian consist of grayish-brown, tan, and gray siltstone. The rock is punky in places, massive to well bedded and locally shaly. Some beds are partly calcareous and others are very carbonaceous. Oval to round phosphatic nodules as much as 1½ inches in maximum dimension are abundant locally. Chemical analyses of nodules from two localities are given in table 4; the high P_2O_5 content of these nodules probably derives from the bone fragments. Dolomite occurs west of these strata. Similar dolomite is described under the discussion of the rocks of the type area of the formation (p. A30).

Middle to early Late Devonian.—conodont faunas in collections from two localities establish a Middle to early Late Devonian age for Woodruff strata in those areas. One conodont collection SF-75 (table 5; No. 37 on pl. 1) from just north of Cole Creek was studied by the late W. H. Hass, who concluded that the fauna was Middle

TABLE 4.—*Chemical analyses, in weight percent, of nodules from the Woodruff Formation*

[Analysts: Paul Elmore, Samuel Botts, and Gillison Chloe, 1962. Rapid rock analyses by methods similar to those described by Shapiro and Brannock (1962). Total carbon determined from induction furnace by I. C. Frost]

Lab. No.	159693	159694
Field No.	SR-109	SF-183
Locality	W½ sec. 34 T. 32 N., R. 52 E.	SW¼ sec. 34 T. 32 N., R. 52 E.
SiO_2	10	7.6
Al_2O_3	1.3	.62
Fe_2O_3	2.1	.34
FeO	.16	.10
MgO	.15	<.1
CaO	45.2	49.9
Na_2O	.15	.22
K_2O	.22	.05
TiO_2	.04	.02
P_2O_5	31.7	35.6
MnO	.00	.00
Loss on ignition (1,050°)	4.4	2.5
Total C	2.01	.53
CO_2	.82	.79
Acid insoluble	[1]2.3	....
Total	100.6	98.4

[1] Chiefly barite.

TABLE 5.—*Conodonts collected from the Woodruff Formation and from the transitional limestone and chert unit*

	Woodruff Formation					Transitional limestone and chert unit			
Locality No. on pl. 1	37	38	40	41	39	45	46	47	48
Field collection No.	[1]SF-75	[1]SF-88	[2]SF-89	[3]565	[3]568	[4]58RJ17	[4]58RJ19	[4]58RJ20	[4]SF-61
Bryantodus sp.				×		×		×	
Hibbardella sp.								×	
Hindeodella sp.	×	×							
Icriodus sp.		×				×	×	×	×
Ligonodina sp.						×			
Neoprioniodus cf. *N. alatus* (Hinde)								×	
sp.		×							×
Ozarkodina sp.	×	×							
Palmatolepis (*P. distorta* type)					×				
glabra Ulrich and Bassler			×						
(*P. subperlobata* type)				×	×				
sp.			×						
Polygnathus foliata Bryant						×			
linguiformis Hinde	×	×				×		×	×
pennata Hinde	×	×				×		×	
spp.	×					×		×	×
Spathognathodus sp.									×

[1]Middle to earliest Late Devonian; identifications by W. H. Hass.
[2]Late Devonian; identifications by W. H. Hass.
[3]Late Devonian; identifications by D. L. Clark.
[4]Middle and perhaps earliest Late Devonian; identifications by W. H. Hass.

Devonian to possibly early Late Devonian largely on the basis of *Polygnathus linguiformis* Hinde and *Polygnathus pennata* Hinde. Clark and Ethington (1966, p. 673) reported that *Polygnathus linguiformis* is the most persistent conodont in the Middle Devonian in the Great Basin and that it ranges into the lower part of the late Devonian.

The beds containing the conodonts are black to pale-brown siltstone about 1-6 inches thick. Some beds are very carbonaceous, enough so that powder from the rock will blacken the hands; other beds are calcareous. These exposures are less than a mile south of the Early Devonian fossil locality and are essentially along strike with it. Bedding attitudes allow the dated younger strata to be slightly higher stratigraphically. The beds on Cole Creek are similar lithologically to those to the north which contain the older fauna. We assume that the dated strata in the two locations form a continuous succession, as we did not recognize structural features that might disrupt the continuity of the beds.

The Woodruff Formation in the general area of Willow Creek is also of Middle to early Late Devonian age on the basis of the conodonts *Polygnathus linguiformis* and *P. pennata* in collection SF-88 (table 5; No. 38 on pl. 1) from a limestone lens in the SW¼ sec. 18, T. 29 N., R. 53 E.

Exposures of the Woodruff in the Willow Creek area are chiefly dolomitic siltstone, claystone, shale, and chert, and a few lenses of limestone. The characteristic siltstone and claystone are gray to tan, weather tan and buff, and break into platy pieces and irregularly shaped fragments mostly 1-2 inches across. All the strata are thin bedded in layers mostly one-half inch or less thick and, in many places, are thinly laminated in layers 0.1-0.2 mm thick. In thin sections these beds are seen to consist of rhombic dolomite grains that are mostly 0.005-0.05 mm across. Quartz grains form less than 5 percent of the rock and less than 1 percent in some sections. There are also traces of carbonaceous material and scattered specks of iron oxide. Very fine grained sandstone in laminae less than 4 mm thick are interbedded locally with the siltstone. The chert in the Willow Creek area is mostly shades of gray and some tan, weathers gray and tan, and occurs in beds 1-3 inches thick which contain argillaceous partings in places. Laminae are distinct on some weathered surfaces. The chert is interbedded with dolomitic siltstone or claystone and also occurs as irregular lenses and patches. Light-gray to white quartz veinlets chiefly less than one-eighth inch thick cut the chert, some of which is also brecciated on a small scale. Thin units of dark-gray to black dolomitic shale and mudstone form bands across the slopes but make up a minor part of the formation. This rock consists largely of dolomite grains 0.005-0.02 mm across which have some rhombic outlines; it also contains abundant carbonaceous material, trace quantities of quartz grains, and small round siliceous bodies believed to be radiolarian tests. Hard siliceous mudstone that is whitish gray to grayish tan crops out locally and weathers to form small irregular to platy fragments that come mainly from beds less than one-half inch thick. This siliceous mudstone contains scattered thin stringers of dark chert. Round black nodules, commonly about one-half inch in diameter, are abundant locally in the chert, siltstone, and shale.

Lenses of limestone in the Woodruff crop out in two places north and west of Willow Creek. Near the northwest corner of the Woodruff exposures here, one thin-bedded dense gray limestone forms a 2-foot-thick lens that is traceable for about 50 feet along the hillside. Another thin-bedded gray and dark-gray limestone and sandy limestone forms a 30-foot-thick lens that is exposed for about 300 feet along the strike. Laminations 1-4 mm thick are visible on weathered surfaces. The sandy beds contain *Tentaculites*. A third limestone lens near the north-central part of this area is about 30 feet thick and apparently of short lateral extent. This limestone is thin bedded, gray, and slightly sandy in places. It yielded conodont collection SF-88 (table 5; No. 38 on pl. 1), some fragments of crinoid columnals, and other unidentifiable fossils. Some beds or sequences of beds in this area were traced for about one-half mile in nearly straight lines along the strike, but in most places attitudes of beds are not distinct and ordered sequences of strata are not recognizable.

Late Devonian.—Exposures of the Woodruff extending from the south edge of the mapped area north to Pony Creek are dated as Late Devonian on conodonts from three collections. Collections 565 (No. 41 on pl. 1) from the N½ sec 6, T. 27 N., R. 53 E., and 568 (No. 39 on pl. 1) from just south of the area (table 5) are considered to be medial Late Devonian by David L. Clark (written commun., 1961) of the University of Wisconsin. Collection SF-89 (No. 40 on pl. 1) from the NW¼ sec. 5, T. 27 N., R. 53 E., was studied by W. H. Hass, who stated (written commun., 1959) that this material is from the Late Devonian and approximately equivalent to some lower part of the Famennian of Europe.

Rocks in this belt consist of gray to black carbonaceous shale and mudstone, dolomite, and black chert. Much of the shale is black pencil shale which in places contains many *Angustidontus* appendages. Some parts of this unit, particularly in the south near the structural windows of the upper dolomite member of the Nevada Formation, are light-colored calcareous shale and shaly dolomite with pink and lavender tints and are similar to some of the Pilot Shale near Eureka. The dolomite in thin section is seen to be composed mostly of rhombic grains of dolomite 0.007-0.05 mm across and to contain a trace to 10 percent of angular to rounded quartz grains 0.01-0.06 mm in diameter. Radiolarian tests are visible in most of the thin sections but are abundant in only one of the eight sections examined. A thin sandy bed in this shale contains conodont collection 565 (No. 41 on pl. 1). The chert is chiefly black, in beds commonly 1-4 inches thick, and contains contrasting spheres and elongate pods of white chert. Chert forms an almost continuous band along the east side of the formation in the southern part of the belt. There, the chert is underlain by shale, but northward the two lithologic types are interbedded and do not form discrete units. Attitudes of strata in the southern part of the belt of Woodruff are not clear in most places, but, from general relations, it is estimated that 500-600 feet of shale underlies 700-800 feet of chert. Farther north along Pony Creek the estimated thickness of interbedded chert and shale is at least 3,000 feet.

The youngest dated beds in the Woodruff are of late Late Devonian age as based on faunas in two fossil collections USGS 4981-SD (No. 42 on pl. 1) and USGS 4982-SD (No. 43 on pl. 1) from mudstone near the west edge of sec. 30, T. 32 N., R. 53 E., in the type area in the vicinity of Woodruff Creek. These collections contain, along with *Angustidontus* appendages, crushed goniatites of the genus *Platyclymenia* (*Pleuroclymenia*), an entomid ostracode referable to *Richterina* (*Richterina*), and indeterminant brachiopods and crustaceans according to Mackenzie Gordon, Jr., and Jean M. Berdan. They stated (written commun., 1958) that "In Europe, *Platyclymenia* (*Pleuroclymenia*) is characteristic of the *Platyclymenia* zone of the Upper Devonian, that is, about the middle of Famennian (Kayser's Abriss des Geologie, v. 2, 1954 [Brinkmann, 1954, facing p. 78]). In North America, *Platyclymenia (Pleuroclymenia)* is found in the Three Forks Shale***."

The Woodruff in the type area contains the youngest beds recognized in the formation. There, it may have a greater age span than is indicated in this report because fossils were not found throughout the exposed thickness. The formation in this area and nearby consists of siliceous mudstone, chert, and lesser amounts of shale and dolomite. The mudstone is carbonaceous and brown to gray on fresh surfaces, light gray on weathered ones, and breaks into tabular nonfissile chips about ½-4 inches across; in places a soft soil has developed on areas underlain by mudstone. Chert, which forms prominent exposures at places, is mainly black and weathers gray to brown. Bedding in the chert generally is 1-4 inches thick, and laminae a few millimeters thick are visible on some weathered surfaces; argillaceous partings are common. Crinkly bedding surfaces in places resemble stylolites. Spheres and elongate pods of white chert one-fourth inch across and as much as 4 inches long are common and contrast with the dark chert. The chert is very brittle and breaks with an uneven to conchoidal fracture. Examination of thin sections indicates that the chert contains clay, abundant organic material, and many spheres of radiolarian tests and molds. At places these spheres are hollow, and the specific gravity of the rock is noticeably low. Detrital grains of quartz form as much as 1 percent of the rock in some sections. Round nodules mostly ½-1 inch in diameter and commonly gray to black occur locally in the chert and in the mudstone. Shale, which makes up a minor part of the formation in the type area, is dark gray, siliceous, and poorly fissile.

Gray to brown dolomite that weathers yellow to brown forms a small but noticeable percentage of the formation in places. It occurs in beds ¼-6 inches thick which contain some prominent laminae about 1 mm thick. In thin section the dolomite is seen to consist of mostly dolomite rhombohedron crystals which are 0.005-0.03 mm across. Some of these rhombs are rounded, indicating that the grains include clastic and diagenetic, or primary, ones as defined by Sabins (1962), as well as secondary crystals. One section is made up of 95 percent dolomite grains, 0.01-0.03 mm in diameter, which appear to be mostly clastic fragments and 5 percent rounded quartz grains of the same size; all are set in a dolomite cement. Subangular to rounded quartz grains, 0.01-0.04 mm in diameter, make up as much as 50 percent of the rock in some sections. Some sulfide minerals are disseminated through the rock. Clastic grains of barite occur in a few places; these grains may have been carbonate minerals at the time of deposition and have since been replaced by barite. A trace of feldspar was noted in one thin section.

The carbonate rocks that form a prominent part of the Woodruff Formation are considered to be largely calcitic dolomite or dolomite on the basis of percentages of calcium and magnesium. These rocks, however, contain high proportions of noncarbonate clastic fragments; their range in the calcite-dolomite-clay series classification of Guerrero and Kenner (1955, p. 46) is greatly varied and is given in table 6.

The Woodruff Formation along South and Dixie Fork of Trout Creek—although it consists mostly of black shale and mudstone, gray to black shale of differing fissility, and less black chert—contains limestone that differs from other carbonate rocks in the formation. Thin limestone lenses about 1 foot thick, which form less than 1 percent of the total unit here, are black to dark gray, carbonaceous, and dense (grain size 0.005-0.02 mm). The limestone contains black vitreous hydrocarbon as vein fillings, as irregular patches one-half inch or less thick, and as scattered specks.

Rocks of Devonian age exposed on Marys Mountain in the mapped area, and more extensively just to the west, consist of mostly sandy limestone and calcareous sandstone, some siltstone and sandstone, and less conglomerate composed of angular clasts of chert as much as 2 inches across. Some units are crossbedded on a small scale. The sequence of beds cropping out in this small area is provisionally assigned to the Woodruff Formation even though the varieties and kinds of lithologic types suggest that it may be part of a transitional assemblage between the carbonate and siliceous rock assemblages. Gray and brown chert above the limestone, west of our area, may be part of the same sequence; however, we made no detailed study of the relations between the limestone and chert outside the mapped area. The sandy beds contain medium- to coarse-grained fragments of chert. An abundant and significant conodont fauna from coarse sandy beds just west of the map boundary was first collected by us (collection 639; No. 44 on pl. 1) and then re-collected and studied by Clark and Ethington (1967,

TABLE 6.—*Analyses, in weight percent, of carbonate, calcium, and magnesium and Ca/Mg molal ratios of 11 rock samples from the Woodruff Formation*

[Analyst: James A. Thomas, 1963. Samples are grouped by general areas. Ca and Mg are reported as the element. Methods of analysis are accurate within ±3 percent]

Sample No.	Field No.	Locality	Total calculated carbonate	Ca/Mg molal ratio	Ca	Mg	Classification in calcite-dolomite-clay series of Guerrero and Kenner (1955, p. 46)
			Woodruff Creek and exposures in T. 32 N., R. 52 E.				
1	822c	SW¼ sec. 24	53.0	1.07	11.9	6.7	Dolomitic marl.
2	541	NE¼ sec. 33	63.6	1.08	14.3	8.0	Do.
3	543	NE¼ sec. 15	30.2	1.86	8.3	2.7	Calcitic dolomitic marl.
4	SR-173	W. edge sec. 34	57.1	1.11	13.0	7.1	Dolomitic marl.
			Willow Creek and north of Willow Creek in T. 29 N., R. 53 E.				
5	SR-141	NW¼ sec. 19	24.0	1.23	5.7	2.8	Calcitic dolomitic clay.
6	142	NW¼ sec. 19	77.7	1.20	18.3	9.2	Line between marly dolomite and marly calcitic dolomite.
7	148	E. center sec. 13, T. 29 N., R. 52 E.	91.4	23.8	35.3	.9	Marly magnesian limestone (gray lens containing *Tentaculites*).
8	146	NE¼ sec. 36	16.6	1.27	4.0	1.9	Calcitic dolomitic clay.
			Dixie Fork of Trout Creek in T. 30 N., R. 53 N.				
9	SR-5	SW¼ sec. 29	80.7	15.47	30.6	1.2	Marly dolomitic limestone.
			Southern part of area				
10	538	SW¼ sec. 18, T. 28 N., R. 53 E.	55.8	1.09	12.6	7.0	Dolomitic marl.
11	536	Center N½ sec. 6, T. 27 N., R. 53 E.	70.8	1.25	16.9	8.2	Calcitic dolomitic marl.

p. 19-21). Their fauna represents the *Polygnathus asymmetricus* zone which occurs near the base of the Late Devonian. Clark and Ethington considered it the lowest of the Late Devonian conodont zones that they recognize in the Great Basin. Studies of the area to the west and northwest might reveal more strata of these lithologies and, if they are fossiliferous, perhaps establish their position and age range more firmly.

AGE AND CORRELATION

The Woodruff Formation spans essentially all of Devonian time—from near the earliest (early Siegenien) to near the latest (medial Famennian). Our sparse fossil collections from this thick section of rocks do not indicate that the complete sequence of the formation is present in this area, nor do they indicate which part, if any, is absent. As the formation there is allochthonous, chances are that some parts are not represented in the mapped area.

The fossils most abundant and widespread, areally and stratigraphically, in the Woodruff are clawlike or jawlike rami (fig. 7) of the probable arthropod *Angustidontus*. The rami are so widespread throughout the formation that with diligent search one can find them almost anywhere in gray shale or mudstone, tan-weathering dolomite siltstone, and black pencil shale. In places, particularly in some of the pencil shales, the rami are so abundant in a few square feet of exposure as to suggest unusual concentration after death of the animals. These rami or appendages first were referred to the eurypterid genus *Pterygotus* (*Pterygotus*) by Jean M. Berdan and K. E. Caster. After reevaluating our collections and others from east-central Nevada, Miss Berdan concluded that these rami are more likely *Angustidontus* than *Pterygotus*. She summarized her conclusions by stating (written commun., 1964) that "the clawlike or jawlike rami of *Angustidontus* are almost certainly part of an arthropod rather than a vertebrate but are not necessarily part of a eurypterid. The stratigraphic range as known at present is from the Silurian into the Lower Mississippian, and at present there is no way of distinguishing between Silurian and younger forms."

The known age span of the Woodruff makes it equivalent to several formations of both the siliceous (western) and the carbonate (eastern) assemblages. The Slaven Chert, which consists of gray to black chert, less dark shale and sandstone, and sparse limestone in the Shoshone Range (Gilluly and Gates, 1965, p. 37-42) west of the mapped area and in the Cortez quadrangle (Gilluly and Masursky, 1965, p. 59-61) to the southwest, is also in the upper plate of the Roberts Mountains thrust. The youngest fauna in the Slaven is Middle and perhaps in part Late Devonian (Gilluly and Gates, 1965, p. 41); hence, these beds are equivalent to part of the Woodruff.

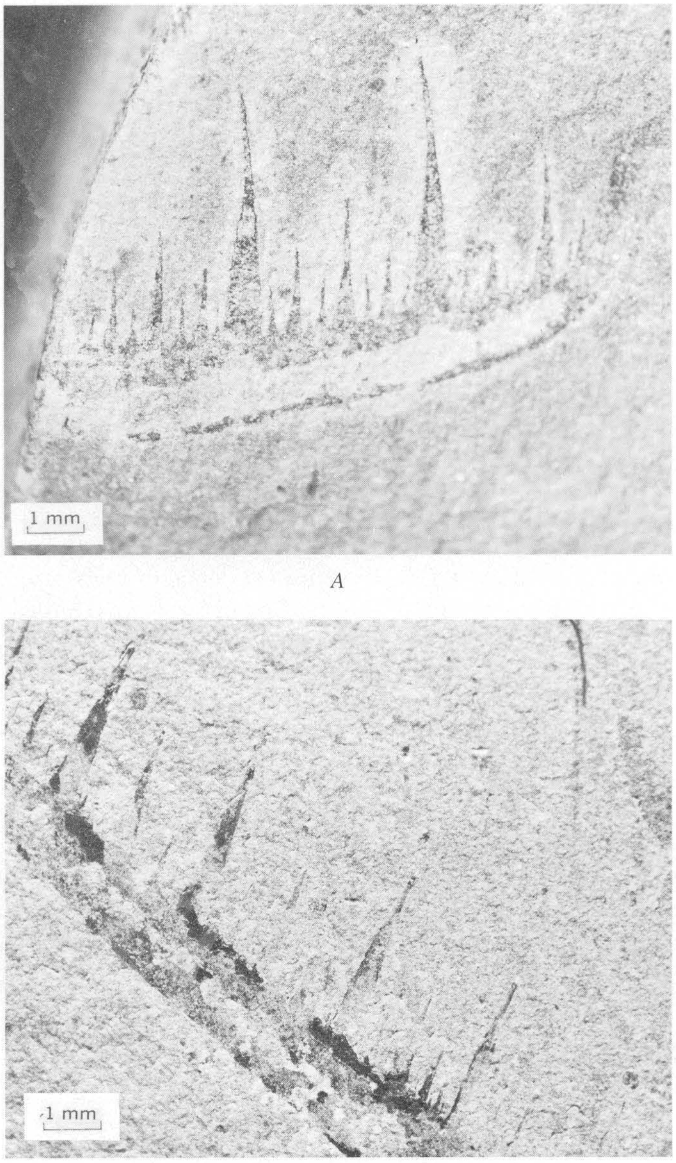


FIGURE 7.—Photomicrographs of part of the clawlike or jawlike rami of *Angustidontus*. This probable arthropod appendage is widespread both areally and stratigraphically in the Woodruff Formation. Photographs by Louise Hedricks.

The Woodruff differs from the Slaven in containing relatively much less chert and much more very fine grained clastic siliceous rock and fine-grained dolomite. Part of the Woodruff also is equivalent to the Lower Devonian Rabbit Hill Limestone (Merriam, 1963, p. 43-44), as the lower Woodruff contains the same conodont fauna as the Rabbit Hill in the northern Monitor Range (D. L. Clark, written commun., 1963). Other formations equivalent to the Woodruff include the Nevada Formation, the Devils Gate Limestone, the lower part of the Pilot Shale, and the upper part of the Roberts Mountains Formation, as recognized at Swales Mountain (Ketner, 1970, p. D19) about 14 miles north of Carlin.

UPPER CONTACT

The Woodruff Formation is overlain unconformably by the Lower Mississippian Webb Formation and Lower and Upper Mississippian Chainman Shale. Along one short strip where the upper contact of the Woodruff occurs on the southeast side of Cole Creek, Permian rocks appear to be unconformable on the Woodruff, but, there, it is difficult to determine whether the contact is depostional or is a fault.

TRANSITIONAL ASSEMBLAGE

ROBERTS MOUNTAINS FORMATION

The small part of the Roberts Mountains Formation exposed in the Carlin-Pinon Range area occurs in a thrust slice and has an outcrop area of less than one-quarter square mile. Although this formation is recognized as being of Silurian age in nearby areas (for example, Nolan and others, 1956, p. 37; Gilluly and Masursky, 1965, p. 28), the thin sequence of beds cropping out in the mapped area contains graptolites that establish its age as Early Devonian according to W. B. N. Berry (written commun., 1972).

The Roberts Mountains Formation was named by Merriam (1940, p. 11-13) for exposures on the west side of Roberts Creek Mountain and has been discussed further by Nolan, Merriam, and Williams (1956, p. 36-37) and by Winterer and Murphy (1960). Beds correlated with the Roberts Mountains Formation change from largely dolomitic on the east to calcitic on the west and reflect a continuation of the change in type of carbonate rock that first appeared with the Hanson Creek Formation. This change in the Roberts Mountains Formation and equivalent beds is along a belt which is very close to the Carlin-Pinon Range area and which trends generally north (fig. 8).

Strata in the Carlin-Pinon Range area that are included in the Roberts Mountains Formation are black silty dolomites or dolomitic marl. As carbonate rocks these beds are similar to the carbonate or eastern assemblage, but as platy or shaly black rocks containing abundant graptolites they are also similar to both transitional- and siliceous-assemblage units. The Roberts Mountains Formation, therefore, is placed in the transitional assemblage. For convenience of presentation on the geologic map explanation (pl. 1), the Roberts Mountains Formation is included with upper-plate rocks of the Roberts Mountains thrust, although it may not actually be part of the upper plate; the formation is allochthonous in the mapped area.

Beds in this formation crop out or cover slopes with platy fragments in sec. 36, T. 29 N., R. 52 E. Thickness of the formation is unknown here, because the Roberts Mountains Formation is in thrust contact with adjacent formations, all of which are in a larger thrust plate. In addition, attitudes are variable and the rocks contorted. The exposed thickness probably is at least 200 feet but can be no more than about 500 feet. Very dark brown to black shaly and platy carbonaceous laminated silty dolomite and dolomitic marl, which weather dark gray to black, make up the Roberts Mountains Formation on Willow Creek. Many beds are ¼-½ inch thick and so the rock breaks into plates; other beds have an imperfect shaly parting and produce thinner and smaller pieces. In thin section the rock is seen to consist of about 70 percent dolomite, 10 percent quartz, and organic material which appears to make up 20 percent. The organic material evidently smears on thin sections, because the actual percentage of organic carbon in the rock is 4.2 as analyzed by I. C. Frost of the U.S. Geological Survey. Both dolomite and quartz grains are angular and are 0.01-0.03 mm in diameter.

Two rock samples from this area that were analyzed by James A. Thomas of the U.S. Geological Survey (written commun., 1963) are calcitic dolomitic marl according to the classification of Guerrero and Kenner (1955, p. 46). The total calculated carbonate percent of the specimens is 59.8 and 70, and the Ca/Mg molal ratio, 1.57 and 1.51.

AGE AND CORRELATION

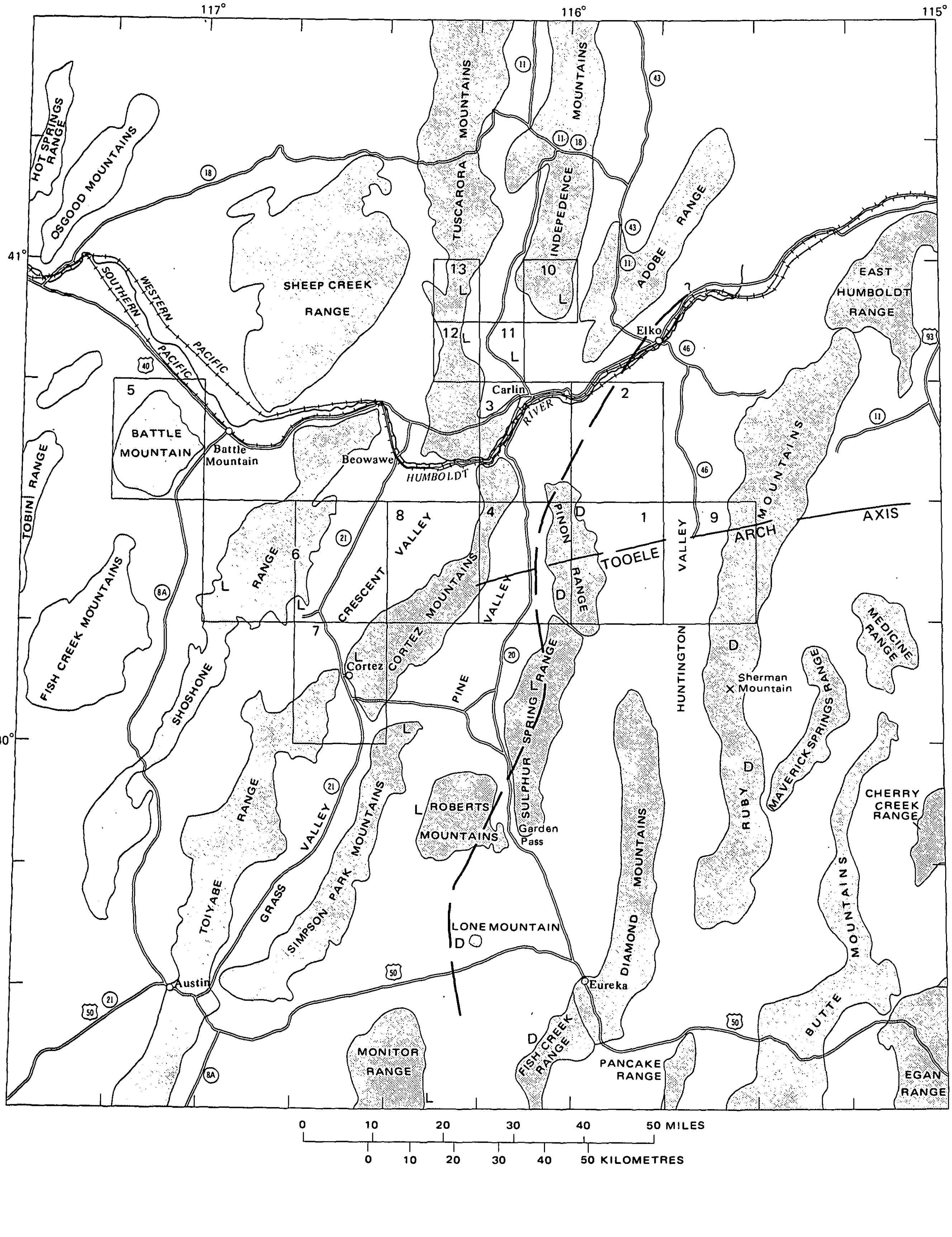
Graptolites are abundant in these beds although they are commonly poorly preserved. Five collections (D58-SD and D59-SD, Nos. 29, 30 on pl. 1; D58A-SD and D73-SD, Nos. 31, 32 on pl. 1; D176-SD, No. 33 on pl. 1), which were studied by R. J. Ross, Jr., and W. B. N. Berry, contain *Monograptus* aff. *M. praehercynicus* Jaeger and thus identify these beds as belonging to the *Monograptus uniformis* zone of earliest Devonian (Gedinnian) age (Berry, written commun., 1972).

As the Roberts Mountains Formation in the mapped area is allochthonous, its position at the time of deposition is not known. The Lone Mountain Dolomite in the mapped area must be equivalent to part, if not all, of the Roberts Mountains Formation in adjoining areas. A lateral change from Roberts Mountains lithology to

FIGURE 8.—Localities where transitional-assemblage Roberts Mountains Formation and probable equivalent carbonate-assemblage rocks are exposed in region, indicating whether the beds are dominantly calcitic (L) or dominantly dolomitic (D). In places the formation is mostly siltstone or sandstone, but only the dominance of calcite or dolomite is indicated. The broad dashed line marks the approximate east edge of the dominantly limestone lithology. In the Carlin-Pinon Range area at least part of the Lone Mountain Dolomite is taken to be the equivalent unit. Sources of data, other than from the present study, are Merriam (1963, p. 28, 37-39), Nolan, Merriam, and Williams (1956, p. 36-37), Rigby (1960, p. 174), Roberts, Hotz, Gilluly, and Ferguson (1958, p. 2834-2835), Sharp (1942, p. 660-661), Winterer and Murphy (1960, p. 123-127), Gilluly and Gates (1965, p. 18), Gilluly and Masursky (1965, p. 25-28), Ketner (1970, p. D19), Ketner, Evans, and Hessin (1968, p. 2), Donald Carlisle (written commun., 1958), Evans and Ketner (1971), Evans (1972a, b), and Evans and Cress (1972). ▶

Lone Mountain lithology may be interfingering in the manner depicted by Winterer and Murphy (1960, p. 134; Johnson, 1965, p. 372).

That part of the Roberts Mountains Formation in the Carlin-Pinon Range area is the oldest of the Devonian siliceous- or transitional-assemblage rocks. The oldest



recognized beds in the siliceous Woodruff Formation are in the *Monograptus hercynicus nevadensis* zone and, thus, are younger than the *Monograptus uniformis* zone (Berry, 1970, p. 516).

LIMESTONE AND CHERT UNIT

Other Devonian rocks assigned to the transitional assemblage in the Carlin-Pinon Range area consist of limestone, sandy limestone, and chert, and, therefore, have lithologic types common to both the carbonate and siliceous assemblages. This transitional unit has been studied by Carlisle and others (1957) in the Sulphur Spring Range south of the Pine Valley quadrangle. In the area of the present report, it is exposed only in the small northernmost tip of the Sulphur Spring Range, where the outcrops are on tree-covered ledgy slopes.

Strata making up the limestone and chert unit seem to occur in a rough stratigraphic sequence, but some beds are overturned, and attitudes differ so much in very small areas that any thickness measurements in the report area are impracticable. Assuming that we have interpreted the stratigraphic order correctly, the following general rock units make up the formation, in ascending order. About the lower 50 feet consists of gray quartz- and chert-sandy limestone and calcareous sandstone. This is overlain by chert that forms a prominent dark band about 50 feet thick which can be traced along the hillside. The chert is black to gray and brown, commonly conglomeratic and composed of slabs and pebbles of chert in a chert matrix and, in places, is a sedimentary breccia. A limestone section of indeterminate thickness overlies the chert conglomerate and breccia. Black chert occurs as large pods and fracture fillings in the limestone, and along fractures the chert forms irregular patterns at angles to the bedding. This chert and the fractures seem to be epigenetic, but the chert appears to be similar to the apparently syngenetic chert clasts in the unit below. The limestone is a gray clastic rock that is thin to thick bedded, crossbedded in places, and in lenticular units. Much of it contains grains of quartz and chert. A conglomerate unit interbedded with the limestone is about 10 feet thick and consists of angular clasts, 1-8 inches in diameter, composed of gray limestone set in a matrix of light-gray limestone.

Gray flaggy limestone crops out on the lower slopes on the west side of the Sulphur Spring Range and seems to be the highest unit in the sequence here. It is gray to black on fresh surfaces. Some beds are sandy and are brown on weathered surfaces; the purer limestone generally is gray on weathered surfaces. Beds most commonly are ½-1 inch thick, although they range in thickness from about 1/20 inch to slightly more than 1 foot. Sandy limestone beds which alternate in places with nearly pure limestone contain quartz and brown to black chert grains that range from fine to granule size. The quartz grains are well rounded, but the chert grains are angular. This unit of flaggy limestone also is of indeterminate thickness.

The Devonian age of the limestone and chert unit is established on conodonts in four collections (table 5) from sandy limestone that also contains *Tentaculites*. These collections were studied by W. H. Hass, who reported (written commun., 1958) that they probably are Middle Devonian and perhaps early Late Devonian.

The limestone and chert unit and the Woodruff Formation are in part age equivalents. The limestone and chert also is equivalent to parts of the Nevada Formation and the overlying Devils Gate Limestone.

Contacts between this unit and other Paleozoic formations are faults.

LATE LATE DEVONIAN-EARLY EARLY MISSISSIPPIAN UNCONFORMITY

Devonian strata in the Carlin-Pinon Range area are overlain unconformably by beds of early Early Mississippian age. The time interval between deposition of Devonian and Mississippian units in this area was the time of deformation and of movement of siliceous- and transitional-assemblage rocks into the mapped area on the Roberts Mountains thrust during the Antler orogeny. Regionally, this orogeny has been dated as latest Devonian to Early Pennsylvanian in age (Roberts and others, 1958, p. 2850). Previously, the principal deformation in the area of the present report was considered to be pre-Pennsylvanian from limited evidence in Carlin Canyon (Kay, 1952), but close control on the time of principal deformation and thrusting here is afforded from evidence farther south. The general unconformable relations are well demonstrated in the northern part of the mapped area, where basal Mississippian rocks of the Webb Formation rest on several different formations, including the Ordovician Vinini Formation, the Devonian Woodruff Formation, and the Devonian Devils Gate Limestone (Smith and Ketner, 1968, p. I16). Lower Mississippian rocks that are unconformable on Devonian strata of both carbonate and siliceous assemblages in the southern part of the mapped area are part of the Chainman Shale which is partly equivalent to the Webb. The Mississippian and younger rocks that are unconformable on the units brought together by the Roberts Mountains thrust are called the overlap assemblage (Roberts and Lehner, 1955).

The relations across this unconformity effectively date the Roberts Mountains thrust and deformation in the report area as being post-middle Late Devonian and pre-early Early Mississippian (equivalent to Kinderhook beds of the midcontinent region; the oldest beds may be early but not earliest Kinderhook).

Depositional environments changed drastically during and following the orogeny in this area, and the sedimentary rocks that were deposited in the Carlin-Pinon Range area from Early Mississippian to Middle Pennsylvanian time reflect this change and contrast lithologically with the Ordovician to Devonian strata deposited before the orogeny.

MISSISSIPPIAN SYSTEM

WEBB FORMATION

The oldest Mississippian rocks in the area are chiefly siliceous mudstone and claystone and some sandstone and limestone in lenticular beds that are different enough from equivalent units in the region to be considered a separate formation. Consequently, this sequence of strata was named the Webb Formation for exposures near Webb Creek in the southeast quarter of the Carlin quadrangle (Smith and Ketner, 1968, p. I8-I12). The type section is near the north edge of sec. 19, T. 31 N., R. 53 E., and in the SE¼ sec. 13, T. 31 N., R. 52 E. There, the formation is 735 feet thick, and the mudstone is well exposed in many places, but no limestone or sandstone is exposed along the line of the measured section.

The Webb has a maximum thickness of at least 800 feet in its northern exposures. Exact thicknesses, however, cannot be measured in the field or from the map because of the difficulty of finding good bedding. In the northern half of the mapped area, the Webb forms a wedgeshaped mass that is thickest at the north and pinches out between the type section and the head of Webb Creek. Farther south, the formation is discontinuous and crops out as lenticular bodies. The lenticular bodies east and north of the upper part of Trout Creek may be 300 feet thick in places and consist mostly of limestone, some shale and fine-grained sandstone, and a very small amount of chert. The southernmost outcrop of the Webb consists of a limestone lens that rests depositionally on the Devils Gate Limestone southeast of Willow Creek. Farther south in the report area the Webb is absent, and the Chainman Shale rests depositionally on Devonian rocks. Approximate thicknesses of the Webb and the formations on which it lies are shown in figure 9.

LITHOLOGY

The mudstone and claystone that make up most of the Webb Formation are chiefly gray and weather gray to brown; a few beds have a pink cast. Some strata, particularly near the top, are black and weather black and are more argillitic and finer grained than most beds in the formation. All these rocks are thin bedded, and a few are faintly laminated; some are shaly. Slopes formed on these beds are covered with chips and chunky fragments, mostly about 2 inches across. Spicules are abundant locally in the mudstone. In thin section the mudstone is seen to consist of angular grains of quartz and chert, each forming about 10 percent of the rock. Grains have diameters of 0.05 mm and are set in a submicroscopic matrix. Some of the chert appears to occur as tiny chalcedonic nodules that probably are recrystallized radiolarians. Hematite is abundant. Chemical analyses of three samples of the siliceous mudstone reveal that they contain 84-86 percent SiO_2 (Smith and Ketner, 1968, p. I9).

In some places, thin layers of sandstone interbedded with the mudstone contain many grains as large as medium sand and sparse grains of very coarse sand. A thin section of the sandstone shows well-rounded chert grains 0.1-0.5 mm in diameter and well-rounded quartz grains 0.5-1.5 mm in diameter. The chert grains make up 85 percent of the section, and chert forms the cement. Hematite and limonite stains are prominent.

Limestone in the Webb Formation occurs in lenses from about 1 foot to mostly about 30 feet thick and from a few feet to about 1½ miles long. One lens, however, in sec. 16, T. 30 N., R. 53 E., is almost 200 feet thick. In some places these lenses form the top of the formation. Limestone is well exposed southeast of Rye Patch Spring and along the west side of the Pinon Range northeast of Trout Creek. The limestone is black to gray, weathers mainly tan, is dense and thin bedded, and breaks down into platy fragments in many places. Study of thin sections of the limestone from separated localities revealed that calcite grains, 0.003-0.03 mm across, form the principal constituents of the rock. Quartz occurs as silt-size clastic grains and is less abundant; some of the quartz is partly replaced by a carbonate material, probably calcite. Chemical analyses of five samples of this rock by James A. Thomas show that it contains more very fine grained noncarbonate material than is recognized in most of the thin sections. This noncarbonate material is evidently obscured by the carbonate in the very fine grained part of the sections. The total calculated carbonate percentages range from only 47 to 65. Four of the samples have Ca/Mg molal ratios of 100 and are classed as marl according to the classification of Guerrero and Kenner (1955, p. 46). The fifth sample has a Ca/Mg molal ratio of 6.40 and is a dolomitic limy marl. All the thin sections contain sparse to abundant vague spherical microfossils mostly 0.03-0.1 mm in diameter that are largely recrystallized. These are probably radiolarians. Vague irregularly shaped microfossils occur much less commonly than the spherical ones.

Claystone nodules, many of which contain barite, occur at the top of the formation in many places and also in the lower beds of the overlying Chainman Shale. Beds of gray to black chert generally 1 inch or less thick crop out at a very few places in the Webb Formation.

AGE AND CORRELATION

The Early Mississippian age of the Webb Formation is based on conodont faunas (table 7) identified by the late W. H. Hass and by J. W. Huddle, both of the U.S.

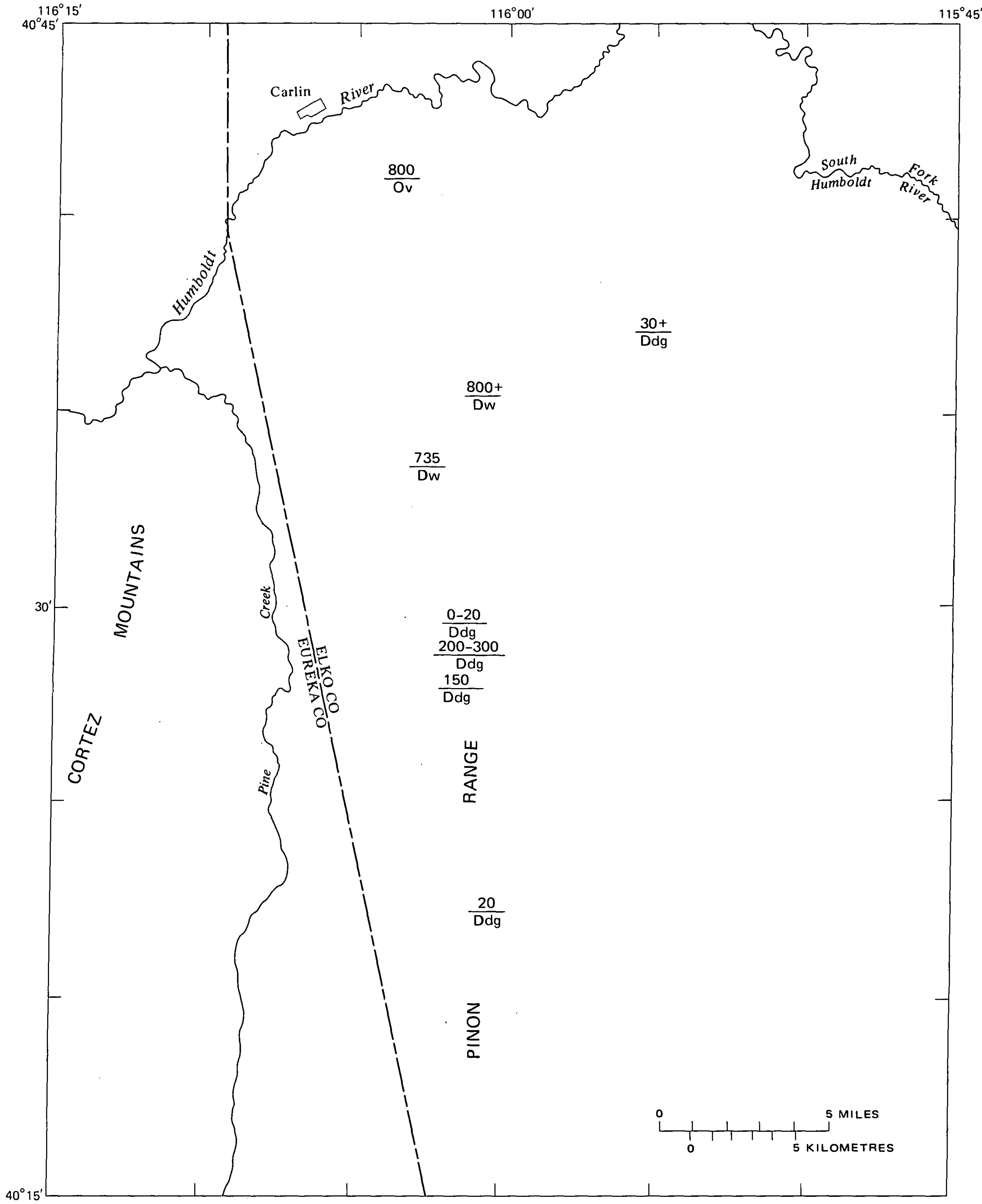


FIGURE 9.—Approximate thicknesses (indicated by number), in feet, of the Webb Formation and the formations on which it lies: Ov, Vinini Formation; Dw, Woodruff Formation; Ddg, Devils Gate Limestone.

TABLE 7.—*Conodonts from the Webb Formation*

[Fossil-collection localities shown on pl. 1]

Locality No. on pl. 1 USGS fossil colln. No. Field colln. No.	61 17304-PC [1]525	62 17306-PC [1]540	63 17303-PC [2]544	64 22839-PC [3]800	65 .... SF-251 [4]SF-252	66 .... SF-250 [4]SF-253
Bryantodus sp.	×	×				
Dinodus fragosus (E. R. Branson)	×			×		
Elictognathus lacerata (Branson and Mehl)	×					
Elictognathus sp.				×		
Gnathodus punctatus (Cooper)		×		×		
Hibbardella sp.				×		
Hindeodella sp.				×		
spp.	×					
Icriodus sp. (regarded as reworked)				×		
Ligonodina sp.				×		
Lonchodina sp.				×		
Neoprioniodus sp.				×		
Ozarkodina sp.	×			×		
Pinacognathus? sp.				×		
Polygnathus communis Branson and Mehl			×			
Polygnathus inornata E. R. Branson		×		×		
Polygnathus sp.	×	×				
spp.		×				
Siphonodella cooperi Hass		×				
obsoleta Hass		×		×		
cf. *S. obsoleta* Hass			×			
duplica (Branson and Mehl)						×
quadruplicata (Branson and Mehl)	×				×	
sp.		×				×
spp.	×					
Spathognathodus sp.	×					
2 species				×		
Synprioniodina sp.	×					

[1]Collections from mudstone, argillitic in places, from near top of formation. Identifications by the late W. H. Hass.
[2]Collection from limestone near top of formation. Identifications by W. H. Hass.
[3]Collection from limestone at top of formation. Identifications by John W. Huddle, U.S. Geological Survey.
[4]Collections from sandstone in a mostly mudstone sequence near base of formation. Identifications by David L. Clark, University of Wisconsin.

Geological Survey, and by D. L. Clark of the University of Wisconsin.

Collections studied by Hass are all of Early Mississippian age (equivalent to Kinderhook of the midcontinent region). Regarding collection 540 (No. 62 on pl. 1) Hass stated (written commun., 1959): "This collection comes from rocks of Early Mississippian age. In the Llano region of Texas, the specifically identified conodonts in the above list [table 7] are present in a faunal zone of the Chappel limestone, which zone is considered to be of late Kinderhook (Chouteau) age on the basis of megafossils. These same conodont species are present in other upper Kinderhook rocks, including the Welden limestone of Oklahoma."

Regarding collection 800 (No. 64 on pl. 1) Huddle stated (written commun., 1962) that of the specimens recovered *Siphonodella obsoleta* Hass makes up about 80 percent and *Gnathodus punctatus* (Cooper) about 10 percent. He concluded that the presence of these species "suggests a correlation of the rock containing them with the Chappel Limestone of Texas and the Chouteau Limestone of the Mississippi Valley. *Gnathodus punctatus* has been found in the Lower Carbonfierous in Germany. *Pinacognathus, Falcodus*, and *Elictognathus* all indicate an Early Mississippian age. *Icriodus*, a Devonian genus, is represented by a single broken specimen and is regarded as reworked. The rock containing this conodont fauna is probably Early Mississippian."

The four collections studied by David L. Clark are also of Early Mississippian age. Of these collections from siliceous sandstone, two, SF-251 and SF-252 (No. 65 on pl. 1) just northwest of the center of sec. 16, T. 30 N., R. 53 E., contained *Siphonodella quadruplicata* (Branson and Mehl), and the other two, SF-250 and SF-253 (No. 66 on pl. 1) just southwest of the center of sec. 16, T. 30 N., R. 53 E., contained *Siphonodella* sp. and *Siphonodella duplicata* (Branson and Mehl). Clark stated (written commun., 1963) that these are Early

Mississippian in age, and probably early but not earliest Kinderhookian.

The Webb Formation, then, as dated on conodonts is of Early Mississippian age, equivalent to Kinderhookian rocks in the midcontinent region. This age makes the Webb probably equivalent to at least part of the Joana Limestone (Nolan and others, 1956, p. 54-56; Langenheim, 1960, p. 75) of eastern Nevada and to the upper part of the Pilot Shale (Gordon, in Brew, 1971, p. 34-35). Lithologically, the Webb mudstone is similar to the Pilot Shale in the type locality of the Pilot in the Ely district (Spencer, 1917, p. 26). East of Eureka (Nolan and others, 1956, p. 52-53; Brew, 1971, p. 10), the Pilot Shale and Joana Limestone form a sequence which rests conformably on the Devils Gate Limestone. The Pilot and Joana together have an age span of Late Devonian to Early Mississippian. Fossils reported by Nolan, Merriam, and Williams (1956, p. 53) from the Pilot near Eureka are from the lower part of the formation and are of Late Devonian age, but those from the upper part south of Eureka are of Early Mississippian age (Gordon, in Brew, 1971, p. 34). The only fossils we found in the Webb are of Early Mississippian age. The Pilot and Webb differ markedly in their lower contacts; the Pilot near Eureka seems conformable on carbonate-assemblage Devils Gate Limestone, whereas the Webb is unconformable on both carbonate- and siliceous-assemblage formations.

The Webb also may be equivalent to the lowest part of the Chainman Shale and Diamond Peak Formation undivided in the south half of the Carlin-Pinon Range area. The lowest part of the Chainman and Diamond Peak sequence there is also of Early Mississippian age on the basis of megafossils. The southward wedge-out of the Webb may be partly by gradation into the Chainman and Diamond Peak, although no actual gradation between the two units was observed.

LOWER CONTACT

The basal contact of the Webb Formation is an erosional unconformity; across the mapped area the Webb rests on the Devils Gate Limestone of the carbonate assemblage and the Vinini and Woodruff Formations of the siliceous assemblage. Where the Webb rests on the Devils Gate, bedding attitudes are so nearly the same that the units appear to be conformable, but relations across the area demonstrate an unconformity, and fossil dates indicate a hiatus. The regional angularity that must exist at the contact between the Webb and the Vinini and Woodruff Formations is difficult to demonstrate because bedding attitudes can be obtained in so few places in these formations. Unconformable relations between the Webb and Vinini are strongly suggested northeast of Rye Patch Spring, however, where the few obtainable attitudes in the Vinini are discordant to the contact. An angular discordance between the Webb and Woodruff Formations is indicated in the Woodruff Creek area and also where the patch of Webb rests on the Woodruff in secs. 25 and 36, T. 32 N., R. 53 E. In many places, the Vinini and Woodruff Formations are deformed into tight folds, whereas the Webb has steep dips but no visible tight folds.

Some very fine grained clastic units in the Webb and Woodruff Formations are similar enough that identification of the formation is difficult where exposures are small. Fundamental differences in lithology, however, can be used to distinguish the formations. The Woodruff contains much chert, the Webb almost none; the Woodruff contains dolomitic siltstone that weathers to form tan platy fragments, the Webb contains no similar rock; the Woodruff contains black shales and black pencil shales not found in the Webb; the Woodruff contains lenses of gray limestone in a few places, but they are not similar to the lenses of distinctive gray and black limestone in the Webb and are not as widespread; no units in the Woodruff are as coarse grained as some of the sandy beds in the Webb; and *Angustidontus* rami are widespread in the tan dolomitic siltstone and in some of the gray shale and black pencil shale in the Woodruff.

UPPER CONTACT

The conformable contact between the Webb Formation and the overlying Chainman Shale is both gradational and abrupt. Hard siliceous mudstone or shale generally characterize the upper beds of the Webb, whereas soft shale generally characterizes the basal beds of the Chainman. In some places, coarse-grained sandstone forms the basal Chainman, and in other places, baritic nodules occur in both the Webb and Chainman at or near the contact.

ARGILLITE UNIT OF LEE CANYON

Black siliceous argillite and minor black chert crop out in a north-trending belt that centers about Lee Canyon. This argillite weathers to form steep slopes with imposing outcrops (fig. 10) and intervening rubble-covered surfaces which are mostly bare of vegetation. The bare black slopes and ridges formed on this unit are prominent features that contrast with other slopes and ridges in the area. Assuming that there is no structural repitition of beds in the unit, the thickness is about 5,000 feet. No important repetition or omission of beds was seen although the unit is cut by some small faults. Strata are so uniform through most of the unit that it was not possible to identify single beds or groups of beds in order to determine whether they are repeated or omitted. Beds are mostly an inch to several inches thick.

LITHOLOGY

The dense black argillite of Lee Canyon is too fine grained for components to be identified megascopically. Study of 10 thin sections reveals that the rock consists

FIGURE 10.—View west down Mill Creek from very head of creek. Slopes in foreground and part way downvalley are on Chainman Shale; bold dark outcrop is argillite of Lee Canyon. Hill in middleground with few trees along crest is Pine Mountain. Cloud shadows are on Cortez Mountains.

mostly of fine silt-size quartz grains forming a mosaic texture. These grains are mainly 0.01 mm in diameter, but larger angular silt-size quartz grains are scattered throughout the sections. All thin sections are very carbonaceous; therefore, some sections are opaque or nearly so. In places, blebs of carbonaceous material have been weathered from the rock to leave holes or pockets. This carbonaceous material is not soluble in ether or acetone and is probably amorphous carbon; an X-ray of one specimen showed no graphite. The X-ray analysis indicates that in addition to quartz this specimen contains less than 10 percent clay and less than 10 percent potash feldspar. The potash feldspar occurs as small euhedral grains, which are probably authigenic crystals. Pyrite, much of which has been oxidized, is common in most of the rock and is concentrated along fractures. Diopside, occurring as rosettes and sheaves, also is common and makes up about 30 percent of the rock in two thin sections. In some sections, poorly preserved Radiolaria are visible.

The upper part of the unit contains a few beds of coarser grained rocks. Conglomerate lenses as much as 700 feet long and a few feet thick consist mostly of black and gray chert pebbles and granules. Quartzite beds consist of quartz grains or of quartz and some chert grains, both of fine to medium sizes. These coarser grained beds are best exposed on the southeast side of Pine Mountain.

Metamorphism of the siltstone to form an argillite probably is related to the same processes that formed marble from Devonian carbonate rocks in places on Pine Mountain and in the Railroad mining district. An aeromagnetic survey of this region by the U.S. Geological Survey (Philbin and others, 1963; U.S. Geological Survey, 1967) revealed a pronounced large magnetic high that underlies outcrop of argillite and the surrounding area. This high is interpreted by D. R. Mabey of the U.S. Geological Survey to indicate a large buried intrusive body. Metamorphism of the rocks exposed in this vicinity probably took place during intrusion of this body.

AGE

The argillite of Lee Canyon is provisionally considered to be of Early Mississippian age and probably equivalent in part to the Webb Formation and to the lower part of the Chainman Shale in the mapped area. In spite of much careful search for fossils, we found only one poorly preserved plant fragment in the argillite; hence, no direct paleontologic date for the unit is possible. Much of the argillite is very similar to some black argillitic mudstone near the top of the Webb Formation, which has yielded early Early Mississippian conodonts. The coarser grained beds in the upper part of the argillite of Lee Canyon are similar to beds in the Chainman Shale.

CONTACTS

The argillite of Lee Canyon seems to rest with fault contact on the Chainman Shale and the Woodruff and Webb Formations. Its contact with the Chainman appears to be essentially conformable, but as the rocks are sheared along the contact and in places attitudes near the contact are discordant with it, the contact evidently is a zone of movement. Where the argillite rests on the Woodruff and Webb Formations, map relations show that the contact must be a fault. We interpret this basal contact as a thrust fault and the argillite of Lee Canyon as an allochthonous unit thrust generally westward into the area. Evidence of westward movement is found in the lower plate of the thrust wherein an anticline is sharply overturned to the west.

The upper contact of the argillite of Lee Canyon is considered conformable beneath Chainman Shale on the south side of the lower part of Webb Creek. Here, black argillite underlies soft gray shale typical of the Chainman. Barite nodules like those at the base of the Chainman elsewhere occur along this contact. Most of the exposed top of the argillite on the east side of Pine Mountain is against Devonian carbonate rocks along a normal fault.

MISSISSIPPIAN AND PENNSYLVANIAN SYSTEMS

CHAINMAN SHALE AND DIAMOND PEAK FORMATION

The Chainman Shale and Diamond Peak Formation compose a flyschlike and molasselike sequence of clastic rocks in which is recorded the depositional history of material derived from the region of continuing uplift in the Antler orogenic belt. Although these rocks become, in general, coarser upward, coarse clastic materials also occur low in the sequence. Coarse- and fine-grained units interfinger and grade abruptly into one another. The two formations are essentially one major sequence, as noted by previous workers (Nolan and others, 1956, p. 56-59; Sadlick, 1960, p. 82-83; Stewart, 1962). History of nomenclature for beds of Mississippian age in central Nevada has been reviewed by Nolan, Merriam, and Williams (1956, p. 56-59).

On the geologic map (pl. 1) we have separated these Mississippian to Lower Pennsylvanian rocks into three units: (1) Chainman Shale, where the rocks are mainly shale and sandstone; (2) Diamond Peak Formation, where the rocks are mostly conglomerate and sandstone; and (3) Chainman Shale and Diamond Peak Formation undivided, where conglomerate, sandstone, and shale seem to be about equally prominent. The Tonka Formation of Dott (1955) is included in the Diamond Peak. Where the Chainman and Diamond Peak are mapped separately, the contact between the two formations is gradational and interfingering and does not represent a single traceable stratigraphic horizon. A divergence between a time-stratigraphic unit and the contact between the two formations is well demonstrated south of Spring Canyon Mountain. Here the northwest-trending Ferdelford fossil beds, which mark essentially a time-stratigraphic unit, make a 20°-40° angle with the formational contact.

CHAINMAN SHALE

The name Chainman Shale has been extended from its type locality in the Ely district (Spencer, 1917, p. 26-27) to the vicinity of Eureka (Nolan and others, 1956, p. 59-61; Brew, 1971, p. 13-17). In both areas the Chainman rests on the Joana Limestone. In the Carlin-Pinon Range area, however, the Joana is not recognized and the Chainman and Diamond Peak sequence rests on the Webb Formation which is partly a time equivalent to the Joana. As pointed out previously, we have mapped the dominantly finer grained clastic rocks in the lower part of the sequence as Chainman, although in places much conglomerate is included. The Chainman in this area is generally coarser than it is farther east, and some sections consist almost entirely of sandstone. Our Chainman includes beds mapped by Dott (1955, p. 2233, fig. 5) as "White Pine-type shales."

LITHOLOGY

Shale in the Chainman is mostly soft and is very carbonaceous locally; it is light gray to gray and weathers gray. Small pieces of mica fleck the shale locally. Commonly, the shale is not well exposed, but the ground surface is covered with small pieces less than one-fourth inch across. In places these very fine grained rocks are not fissile and, thus, are classified as siltstone, which is gray and weathers gray to almost white in a few localities. Some shale units are lenticular and may be fairly well exposed along creek banks; shale outcrops commonly seem to end away from the creeks, owing to the abundance of sandstone fragments which form a more complete cover and obscure the shale fragments on the slopes.

Most of the sandstone in the Chainman, which locally is quartzite or quartzitc, is a distinctive rock type unique to the formation and to the lower part of the Chainman and Diamond Peak undivided. It is mostly gray or tan and brown and weathers tan and brown with much limonite surface stain in places; some beds have a green cast. The sandstone beds are lenticular and thin, chiefly one-half inch to about 6 inches thick. Some beds grade laterally into pebbly layers and into conglomerate, in which the clasts are composed of the same rock types as the grains making up the sandstone. The sandstone consists of quartz and chert grains set in a matrix of largely chert, clay, and some micaceous material; some sandstone can be classed as subgraywacke. Relative percentages of quartz and chert differ widely, and in only a very few places are the grains all quartz or all chert. Some units are composed of shiny grains of what appears to be almost black quartz, but much of the dark color seems to be imparted by the dark matrix. The chert grains are mostly gray, green, tan, and black and range in size from very fine to granule. Quartz grains are subangular to well rounded and commonly better rounded than chert grains. Sorting ranges from poor to good; in some beds, quartz grains particularly are very well sorted. Locally, comminuted fragments of plants are abundant as carbonaceous coatings along bedding surfaces of the sandstone; although some fragments retain the shapes of foliage, none we collected was well enough preserved for definite identification, according to S. Mamay.

In five thin sections of representative sandstone examined, quartz and chert grains make up most of the rock. Quartz grains are dominant, are subangular to well rounded, and are 0.05-0.5 mm in diameter. Chert grains are subordinate, are subangular to subrounded, and of silt size to 1 mm in diameter. Overgrowths occur on some quartz grains. Highly sutured fragments of quartzite are sparse and grains of plagioclase feldspar are even more sparse. The matrix consists of a mixture of chert, clay, and some micaceous fragments. In a single thin section the grains, particularly quartz, may vary from tightly packed with grain contact in one part of the section to loosely packed with fine-grained siliceous matrix or cement filling the spaces in another part.

From about 1 mile north of Trout Creek northward to Lee Canyon the sandstone and shale are progressively metamorphosed, and in the vicinity of Lee Canyon the formation consists of interbedded siliceous argillite, siltstone, and lesser amounts of quartzite. The rocks are gray or black on fresh surfaces and mostly brown on weathered surfaces; the brown outcrops contrast with the black outcrops of the argillite of Lee Canyon to the west. Beds range in thickness from a few inches to 2 feet. The siliceous argillite of the Chainman is composed chiefly of fine intergrown quartz grains, carbon, authigenic potash feldspar, and clay, and, near the base of the formation, contains secondary diopside and garnet. The siltstone and quartzite consist mainly of quartz grains and lesser amounts of chert grains. Metamorphism of this part of the Chainman coincided with metamorphism of the black argillite of Lee Canyon. The argillite and quartzite are cut off abruptly on the north by the east-west fault extending eastward from the head of Webb Creek. Much of the Chainman on the high ridge just north of this fault consists of quartzite composed almost entirely of quartz grains and forms the purest quartz sand observed in Mississippian rocks in the area. To the north it grades upward into typical Chainman quartz- and chert-grain sandstone.

Limestone, sandy limestone, and calcareous sandstone crop out locally throughout the formation and particularly in the lower part, but as a group these calcareous rocks form only a fraction of 1 percent of the total thickness of the formation. The limy beds are mostly gray or tan and 1 foot or less thick. Commonly, they are fossiliferous, and many of our best fossil collections are from these limy beds or from their associated strata. Some slightly sandy gray limestone exposed along the creeks south of Papoose Canyon contain patches and coatings of black vitreous bituminous material, particularly on surfaces of small fractures.

A rock type characteristic of the Chainman in a number of places is pebbly mudstone (Crowell, 1957) probably formed by submarine mudflows. The pebbly mudstone seems to be most common and best developed near the base of the formation, but occurs through most of it. Good exposures of pebbly mudstone are on Dry Creek near the south edge of the map area, on Willow Creek near the mutual corners of secs. 30 and 31, T. 29 N., R. 53 E., and secs. 25 and 36, T. 29 N., R. 52 E., and in the E½ sec. 12, T. 31 N., R. 52 E. (See measured section S7.) It also occurs at other localities (fig. 11) and is suspected wherever poorly sorted loose pebbles, cobbles, and boulders are scattered on slopes of mostly shale or siltstone and claystone (fig. 12). Many of the clasts are very well rounded. Rock types composing the clasts in the pebbly mudstones may differ somewhat from one locality to another; the lithologic differences reflect different source areas, some of which probably were near the sites of deposition.

Pebbly mudstone at the Willow Creek locality contains scattered clasts in a matrix of black siltstone and mudstone which appears cherty in places. Rounded clasts are chiefly quartzite and less abundant ones are black chert. They occur as smooth and commonly well rounded pebbles and cobbles, mostly from ¼ inch to 3 inches in diameter. Also set in the matrix are pieces of

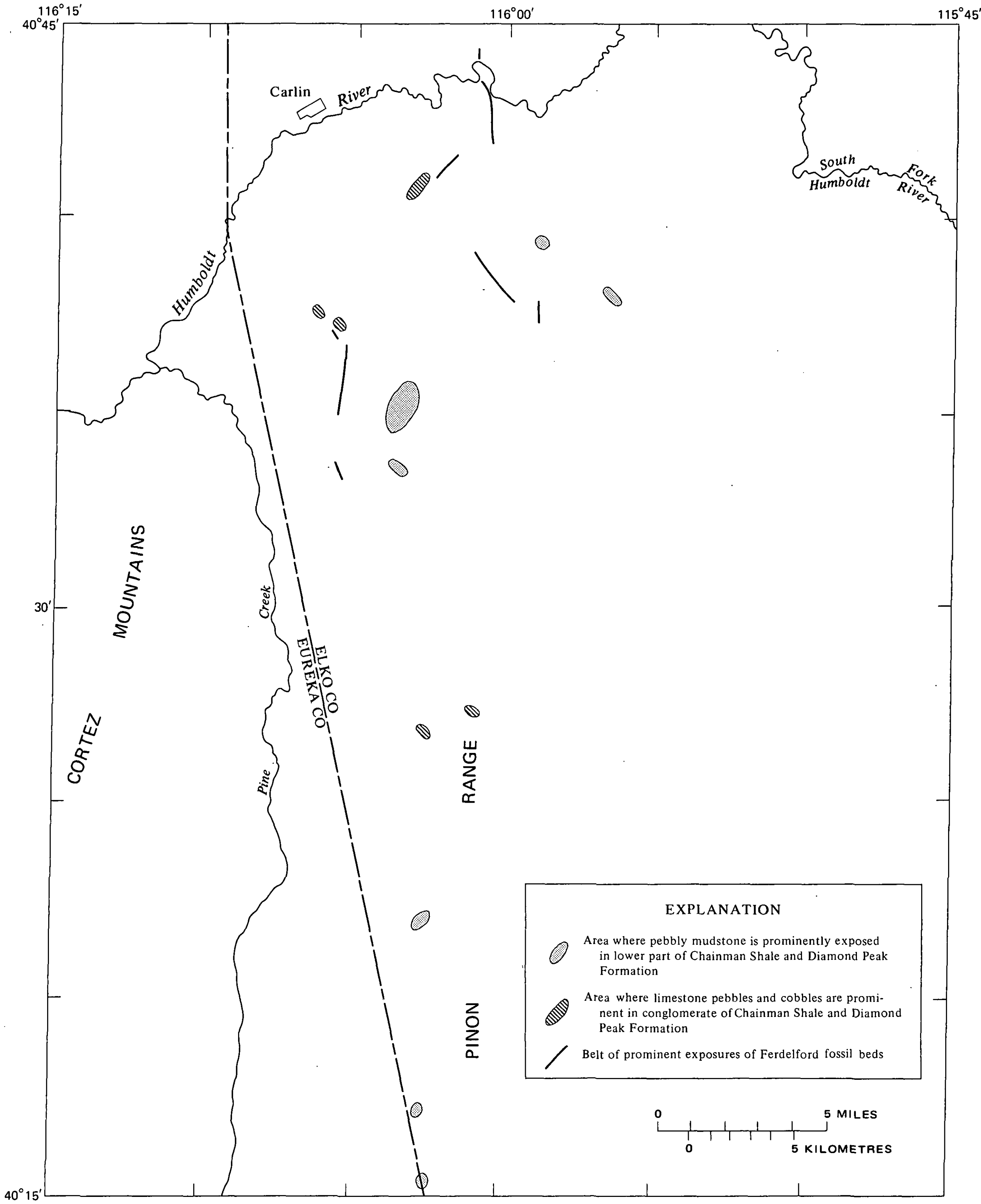


FIGURE 11.—Areas of prominent exposures of pebbly mudstone and of limestone pebbles and cobbles in the Chainman Shale and Diamond Peak Formation and belts of prominent exposures of Ferdelford fossil beds.

A

B

FIGURE 12.—Pebbly mudstone in Chainman Shale, T. 31 N., R. 52 E. *A*, Pebbly mudstone overlain by sandstone near base of formation in NE¼ sec. 12. *B*, Weathered exposure; northeast side of creek near section line between secs. 13 and 24.

typical Chainman sandstone in the form of slabs, several feet across, partly rounded boulders, and angular blocks. One slab has flute markings and prod casts similar to those formed by turbidity currents (Dzulynski and others, 1959, p. 1116). In places, short lens-shaped bodies of sandstone or shale occur in the mudstone. Some of these bodies were folded on a small scale and one was bent into a small sharp fold that was formed by penecontemporaneous sliding or slumping or by later structural movement. At one exposure a bed of sandstone rests on pebbly mudstone along a scoured surface with about 6 inches of relief.

Pebbly mudstone north of Ferdelford Creek has pebbles, cobbles, and boulders scattered through a siltstone matrix. The clasts commonly are well rounded and consist principally of sandstone, quartzite, chert, and brown and gray limestone and less commonly of very micaceous sandstone. Sources for all the clasts can be identified except for the brown limestone and the micaceous sandstone. The chert and quartzite probably were derived from lower Paleozoic units of the upper plate of the Roberts Mountains thrust, the gray limestone from the Devils Gate Limestone of the lower plate, and much of the sandstone from the Chainman Shale of the overlap assemblage. The brown limestone may have been derived from the Woodruff Formation, but the micaceous sandstone has no recognizable local source. Thus, most of the clasts could have been derived from sources fairly close to their depositional sites.

Turbidite deposits, like the pebbly mudstones, also provide interesting data on the depositional history of the Chainman. These were identified definitely only along Willow Creek in the SW¼ sec. 30, T. 29 N., R. 53 E., where sandstone units have been undercut enough to permit observation of their bottom sides. Here sandstone and shale units about 3 feet thick are interlayered. In at least four localities in this small area, flute casts (Crowell, 1955, p. 1359-1360; Kuenen, 1957, p. 235-242) were found on the undersides of sandstone layers overlying shale. All the casts measured trend southeast and suggest that the transporting currents moved toward the southeast. In a few places, scour fillings with southeast trends also are exposed. Some of the sandstone layers have graded bedding, but in most the grading is relatively indistinct. Elsewhere in the Chainman, similar interlayers of sandstone and shale occur but they are not well enough exposed to permit observation of the undersides of sandstone beds.

Conglomerate in the Chainman occurs in lenticular beds and consists of angular to well-rounded pebbles, cobbles, and boulders of chiefly quartzite, chert, and sandstone in a sandstone matrix. Chert clasts are mostly gray, green, tan, and black and generally are less rounded than the quartzite clasts. Fragments of siliceous rocks in the conglomerates apparently were derived from lowe Paleozoic formations of the western or siliceous assemblage. A few conglomerate lenses contain gray limestone pebbles and cobbles which occur with the siliceous clasts or make up most of the clasts in the unit (fig. 11). The limestone clast-conglomerates are commonly well bedded but also contain thin units with no apparent bedding, wherein the clasts are poorly sorted and scattered as they are in pebbly mudstone.

On the north side of Smith Creek in the NE¼ sec. 1, T. 29 N., R. 52 E., solid bituminous material occurs mostly in shale that is like typical Chainman shale; the rocks here, however, are mapped as Chainman and Diamond Peak undivided. This bituminous material occurs as a narrow veinlike body and as fracture fillings and cement in the shale and sandstone (Anderson, 1909; Vanderburg, 1938, p. 56-57). Details of the occurrence are difficult to determine because exposures are very poor and prospect pits dug on the material are now nearly filled.

A sample of the bituminous material was studied by Vernon E. Swanson and Tom G. Ging, Jr. (written commun., 1970) of the U.S. Geological Survey, who suggested that the material should be called a solid bitumen rather than given a specific mineral name. An elemental analysis, in percent, indicates that the bitumen is in the general composition range of most solid bitumens:

Constituent	*Percent*
Carbon	83.75
Hydrogen	7.74
Nitrogen	2.07
Ash	.85
Oxygen plus sulphur (by difference)	5.59
	100.00

A semiquantitative spectrographic analysis (table 8) shows that the minor element content is not unusual for this type of material. In thin section, the bitumen is seen to be a glassy dark-brownish-black translucent material. It has slightly wavy banding, characteristic of flow structure, and contains irregular fractures.

Such bituminous material certainly is not widespread in the Chainman and Diamond Peak rocks in the area, but this occurrence does indicate that fluid bitumens were once present in these beds.

TABLE 8.—*Semiquantitative spectrographic analyses, in parts per million, of solid bitumen by the laser-fired method*

[Analyses, James M. Nishi (Feb. 1970)]

	On ash	On fraction remaining after benzene extraction		On ash	On fraction remaining after benzene extraction
Ti	300	<10	Ag	<0.5	<0.5
Zn	3,000	<50	Au	<5	<5
Mn	30	<10	Be	<.5	<.5
V	>10,000	1,500	Bi	<20	<20
Zr	<20	<20	As	<100	<100
La	<100	<100	Sb	<50	<50
Ni	>5,000	70	W	<50	<50
Cu	70	<2	Nb	<10	<10
Cd	<100	<100	Sc	<20	<20
Pb	<20	<20	Cr	200	<5
B	<5	<5	Ba	5	<5
Y	<50	<50	Sr	15	<5
Mo	10	<2	Fe	700	<500
Sn	<10	<10	Mg	500	<200
Co	300	<20	Ca	<500	<500

DIAMOND PEAK FORMATION

The Diamond Peak Formation as originally defined in the Eureka district (Hague, 1883, p. 252-253; 1892, p. 85, 158) consisted chiefly of quartzite and some conglomerate, shale, and limestone. Although this formation is generally considered to be a coarse clastic unit, it contains much shale and siltstone, particularly in the lower part at the type locality in the Diamond Mountains (Brew, 1961, 1971) and in the general vicinity of Eureka (Nolan and others, 1956, p. 56-61). In the Carlin-Pinon Range area, the Diamond Peak Formation as we have mapped it is much coarser than it is farther east and south.

Dott (1955, p. 2222-2233) named this sequence of mostly coarse clastic rocks near Carlin Canyon the Tonka Formation. He chose the name Tonka over Diamond Peak chiefly because at that time the status of the Diamond Peak was debatable, because the Diamond Peak in the type locality contained more fine-grained rocks and a unique upper siltstone member that was not recognized in the Carlin Canyon area, and because there was no proof of physical connection between the two units whose type localities are about 90 miles apart. Dott tentatively correlated the Tonka and the Diamond Peak, however, and pointed out that the Diamond Peak at the north end of the Diamond Mountains bears more similarity to the Tonka than it does to the Diamond Peak at the type locality at Diamond Peak toward the south end of that range. Although there is no apparent physical tie between the Diamond Peak in the Diamond Mountains and similar rocks in the Carlin-Pinon Range area, we believe that the intimate relation between the fine- and coarse-grained clastic rocks in the two areas and the similar stratigraphic position beneath the Ely Limestone or equivalent rocks justifies use of the name Diamond Peak in the area of the present report. Also, our mapping has extended this sequence of clastic rocks farther south so that the separation between the Diamond Peak strata in the north end of the Diamond Mountains and in the southern part of the Pinon Range is only about 20 miles.

The Diamond Peak Formation makes many prominent outcrops, such as those at the west end and on the southwest side of Carlin Canyon and along part of Ferdelford Creek. Many of the conglomerate and quartzite units crop out as cliffs or ledges that are commonly brown or reddish brown. Many slopes on the Diamond Peak are also brown and are covered with loose gravels between scattered outcrops.

LITHOLOGY

Conglomerate forms the most prominent beds in the Diamond Peak but not everywhere the dominant ones. Conglomerate units generally are lenticular, and bedding commonly is indistinct within units although it may be fairly sharp between them. Where bedding is visible it seems to range in thickness from 1 to 5 feet. Bedding is most distinct where layers of sandstone 1 inch to several inches thick occur in the conglomerate. In a few places, sandstone units are crossbedded. Locally, conglomerate lenses have filled shallow channels cut into underlying beds.

Most of the conglomerate clasts are of siliceous rocks—chert, quartzite, and sandstone—and range from pebbles to boulders. Relative amounts of chert to quartzite and sandstone differ widely. Clasts of chert are mostly gray, tan, green, and black and are angular to subrounded. Clasts of quartzite are tan, gray, and almost white and are subangular to rounded; they are better rounded than the chert clasts at most places. Some beds are well sorted, whereas others are so poorly sorted that the mixture of pebbles and cobbles appears to have been quickly dumped into place. The coarsest conglomerates seen are in the lower part of the section. In a few places pebbles and cobbles of gray limestone are abundant (fig. 11), and most of them were probably locally derived from the Devils Gate Limestone.

In general, the percentage of fine-grained rocks (shale and sandstone) relative to coarse-grained ones (sandstone and conglomerate) increases southward across the report area in the Diamond Peak and in the undivided Diamond Peak and Chainman. A similar change also may be seen within short distances, such as along the upper part of Papoose Canyon, where lenses of conglomerate end in shale toward the south. In the area from South Fork Trout Creek to Willow Creek, shale and siltstone occur prominently throughout the exposed sequence of Mississippian rocks; part of this sequence is equivalent to a section of almost all conglmerate and sandstone north of Ferdelford Creek. The percentage of conglomerate in the total sequence also seems to decrease southward across the region. Conglomerate makes up 40-60 percent of the nearly 4,700 feet of Diamond Peak beds exposed in the northern part of the mapped area, whereas this formation about 75 miles to the south at the type section at Diamond Peak in the Diamond Mountains contains only about 13½ percent conglomerate (Brew, 1971, p. 18). In Packer basin about 12 miles south of the type section the top of the sequence is eroded but conglomerate makes up less than 2 percent of the total section of 4,700 feet and only 7 percent of the highest 860 feet (Stewart, 1962, p. C58-C59).

A most distinctive, unique series of beds in the Diamond Peak Formation consists mainly of tan and yellow shale and siltstone that weather tan and yellow and are very fossiliferous. Many of the beds are calcareous. These strata are referred to informally as the Ferdelford fossil beds. Gray limestone and calcareous siltstone units ½-5 feet thick are interlayered with the shale in places; beds in these units commonly are 1/16-½ inch thick. Lenses of conglomerate and sandstone tongue into the fossil-bearing rocks or even replace them laterally. The Ferdelford fossil beds are recognizable over much of the north half of the mapped area (fig. 11), but not the south half. These beds have a maximum measured thickness of 650 feet, but the most fossiliferous part generally has a thickness of no more than 500 feet. North of Ferdelford Creek this unique unit is 1,475 feet above the base of the Diamond Peak Formation and 3,600 feet above the base of the Chainman Shale.

In the upper part of the Diamond Peak, above the Ferdelford fossil beds, limestone and calcareous sandstone are more common than they are lower in the formation. At some places, thin red calcareous sandstone beds containing many crinoid columnals weather to produce abundant platy fragments on the slopes.

UPPER CONTACT

The Diamond Peak Formation is conformable beneath the Moleen Formation or the undivided Moleen and Tomera Formations of Pennsylvanian age. The contact is abrupt in places, as on Grindstone Mountain where reddish-brown conglomerate and sandstone are overlain by gray limestone. Commonly, the top of the Diamond Peak is on a slope underlain by poorly exposed red silty and sandy material, and the base of the Moleen is a prominent ledge-forming limestone 8-15 feet thick. In the southern half of the mapped area the contact is less distinct. About 1¼ miles south of station Elliott in sec. 10, T. 29 N., R. 53 E., the Diamond Peak and younger formations appear to interfinger and to be gradational. Northwestward from a ridge crest in sec. 16, T. 29 N., R. 53 E., the overlying Lower Pennsylvanian strata grade laterally by interfingering from mostly limestone and some conglomerate into all conglomerate and sandstone similar to that in the underlying Diamond Peak. Where these Diamond Peak and overlying Pennsylvanian strata are so similar lithologically, the contact between these strata on the geologic map (pl. 1) is an extension along strike from the more easily recognizable contact.

Further evidence of a gradational contact between the Diamond Peak and the Moleen Formations is suggested by comparing fossil collection 17298-PC (No. 90 on pl. 1) from the Moleen in the NE¼ sec. 34, T. 29 N., R. 53 E., with the Early Pennsylvanian collections from the Diamond Peak shown in table 11. Collection 17298-PC contains trepostomatous bryozoans, stenoporoid bryozoans, *Rugoclostus* n. sp., *Flexaria* n. sp., *Antiquatonia* n. sp., *Wellerella* sp. indet., *Hustedia* sp. indet., *Cleiothyridina* sp., *Composita* sp. indet. according to Mackenzie Gordon, Jr., who stated (written commun., 1964): "Three species of productoid brachiopods in this collection are new, but are typical forms of the *Rugoclostus* assemblage, the earliest Pennsylvanian assemblage in the Great Basin." Here, then, lowermost Pennsylvanian beds are included in the Moleen Formation whereas near Carlin Canyon they are placed in the Diamond Peak Formation.

Most of the rocks on the ridge south of the Elliott High Ranch in sec. 13, T. 30 N., R. 53 E., are silicified, and it is difficult to distinguish the contact between the Diamond Peak and the undivided Moleen and Tomera. As mapped (pl. 1), the contact is drawn along a zone above which silicified limestone is prominent and along which a lens of unsilicified gray limestone crops out for a short distance. The contact along this ridge seems gradational, but the occurence of the coral *Chaetetes* (p.A57) not far above the contact as drawn suggests that we have placed it higher stratigraphically here than we did farther north. Possibly the contact is a fault, although the trace of the contact and the parallel attitudes of the beds on either side of it suggest a normal depositional relation.

COMPOSITE MEASURED SECTION OF THE DIAMOND PEAK FORMATION AND THE CHAINMAN SHALE

The thickness of the Chainman and Diamond Peak sequence ranges from 6,000 to 7,000 feet. A good complete section is not exposed in any one part of the mapped area, and our best composite section of these formations comes from measured sections S7, S8, S9, and S10 (pl. 1) and from Dott's (1955, p. 2292-2293) section of his Tonka Formation; from Dott we have included the 1,200 feet above the base of a 13-foot fossiliferous limestone unit that is 710 feet above the base of his measured section. Sections S7, S8, and S9 were connected by tracing beds from one locality to the next, and section S10 was joined to S9 on the basis of a recognized fossil zone. Section S10 was tied directly to Dott's section. This composite stratigraphic section has a thickness of 6,245 feet and is presented as being representative of the Chainman Shale and Diamond Peak Formation.

AGE AND CORRELATION OF DIAMOND PEAK FORMATION AND CHAINMAN SHALE

Beds comprising the Chainman Shale and Diamond Peak Formation in the area of this survey range in age from Early Mississippian to Early Pennsylvanian. Dating is based on many fossil collections that have been

SECTION S10.—*Partial section of Diamond Peak Formation in SW¼ sec. 27, T. 33 N., R. 53 E.*

[Measured with Brunton compass and steel tape. Location of section shown by number on pl. 1]

	Feet
Mississippian System:	
Diamond Peak Formation:	
Limestone, fossiliferous; 13-ft-thick unit that is 710 ft above base of section measured by Dott (1955, p. 2292-2293); thickness from base of this unit to top of Tonka Formation according to his measurement is 1,199 ft.	
6. Conglomerate, sandstone, siltstone, and limestone. Conglomerate consists of clasts of gray, black, and green chert and less quartzite that are angular to well rounded and as much as 4 in. in diameter; well bedded and thin bedded in units 1-5 ft thick; in upper 90 ft of unit conglomerate also contains some red chert and reddish-brown-weathering chert pebbles. Limestone, limited to upper 90 ft of unit, is gray with a pink cast in places, pebbly in places. Silty and sandy beds are poorly exposed, but some fragments were seen which form float on slope. All rock types grade into one another laterally and vertically; amount of limestone in upper part increases to the north along the slope. Conglomerate directly underlies 13-ft-thick fossiliferous unit of Dott's measured section (p. 2293)	360
5. Limestone and chert: limestone is light gray; weathers gray; chert is light gray to light brown; weathers light brown; chert is in irregular stringers along bedding and in nodules; chert bands mostly 1-4 in. thick, but in places they are thicker and coalesce so that most of rock is chert with limestone stringers. Measured section offset about ¼ mile to north on this prominent unit	20
4. Covered along line of section. A few hundred feet north and south of section prominent outcrops of conglomerate contain mostly chert and some quartzite clasts with maximum diameters of 5 in.; well bedded locally. Sandstone and siltstone occur as poorly exposed interbeds, which are red in places	240
3. Conglomerate, containing clasts of chert and quartz with maximum diameter of 5 in.; and interbedded sandstone; forms a prominent brown outcrop that varies in lithology along strike. Interval to north contains a lens of gray limestone about 300 ft long with a maximum thickness of 40 ft	95
2. Sandstone, tan; weathers tan; made up of fine to coarse grains of quartz and chert; well bedded in layers ½ in. to 1 ft thick; prominent units 5-15 ft thick. Interbedded are pebble conglomerate layers, with pebbles as much as ½ in. in diameter, and poorly exposed siltstone; some siltstone is red and purple, and some contains scattered pebbles. Northward the upper part of the unit grades into conglomerate	275
Total thickness of incomplete Diamond Peak Formation	990
1. Sandstone, tan, calcareous, containing the colony coral *Siphonodendron*. Below base of section these beds are sandier than in most other exposures and contain pebble conglomerate beds 6 in. to 3 ft thick; contain variety of fossils. The unit extends north and south along the west side of the ridge below the base of the measured section. (Same as unit 6 of section S9.)	

SECTION S9.—*Partial section of Diamond Peak Formation in SW¼ sec. 11 and E. central part of sec. 10, T. 31 N., R. 52 E.*

[Measured with Brunton compass and steel tape. Location of section shown by number on pl. 1]

	Feet
Mississippian System:	
Diamond Peak Formation:	
6. Siltstone and shale, yellow and tan; weather yellow and form a soft slope. Contain corals, brachiopods, bryozoans; colonial coral *Siphonodendron* occurs in upper part and solitary coral *Canadiphyllum*(?) occurs in lower few feet. Top unit of Ferdelford fossil beds (same as unit 1 of section S10)	85
5. Conglomerate and sandstone, yellow; weather yellow; conglomerate is calcareous and contains quartzite and chert pebbles and cobbles with maximum diameters of 4 in.; conglomerate forms lower 4 ft of unit and grades upward into fine- to coarse-grained sandstone. To the south across a covered area along the creek this stratigraphic position is occupied by gray pebbly limestone	10
4. Sandstone, yellow and tan; weathers yellow and brown; fine to coarse grained with angular to rounded quartz and chert grains; well bedded in layers ½-1 in. thick	30
3. Siltstone and shale and some thin calcareous beds, all yellow and tan, weather same; unit is very fossiliferous, containing mostly corals, brachiopods, and bryozoans. Basal unit of Ferdelford fossil beds	325
2. Conglomerate; poorly exposed but produces pebble- and cobble-strewn slope; pebbles and cobbles of quartzite and chert; largest clast noted was a quartzite boulder 1 ft in diameter	140
1. Sandstone and quartzite mostly, fine- to coarse-grained, light-gray to almost white; weather brown; chiefly subangular to rounded quartz grains; some angular fragments of light-gray chert are larger than the quartz grains; contain scattered pebbles of quartzite and chert; beds probably ½-1 ft thick but not well exposed. Conglomerate occurs in beds 1-3 ft thick made up of quartzite and chert pebbles and cobbles mostly less than 2 in. in diameter but as much as 5 in.; conglomerate forms the more prominent outcrops in this unit but the ratio of sandstone and quartzite to conglomerate is probably about 4 to 1 (same as unit 7 of section S8)	415
Total thickness of incomplete Diamond Peak Formation	1,005

studied chiefly by Mackenzie Gordon, Jr., and Helen Duncan. No part of the undivided Diamond Peak and Chainman shown on plate 1 is as young as Pennsylvanian.

Particularly good collections are from rocks of Early Mississippian age (equivalent to upper Kinderhookian Series) and of late Early and possible early Late Mississippian (equivalent to Osagean Series and possibly lower Meramecian Series). A preliminary report was published on these Early Mississippian faunas by Gordon and Duncan (1961). Gordon and his associates are continuing their studies of extensive collections from

SECTION S8.—*Partial section of lower part of Diamond Peak Formation in sec. 14, T. 31 N., R. 52 E.*

[Measured with Abney level on Jacob staff. Location of section shown by number on pl. 1]

	Feet
Mississippian System:	
Diamond Peak Formation:	
7. Sandstone, brown (same as unit 1 of section S9)	
6. Conglomerate, mostly brown; weathers brown; cobbles and boulders of chert and quartzite. Forms top and west slope of hill	410
5. Conglomerate and sandstone interbedded, mostly brown; weather brown; conglomerate clasts mostly pebble size	400
4. Conglomerate and sandstone and grit interbedded, brown; weather brown; beds commonly 1-5 ft thick; many cobbles in conglomerate; crossbedding dips at top of unit suggest current direction toward southeast	300
3. Sandstone and conglomerate interbedded; more sandstone than in units below	115
2. Conglomerate and sandstone interbedded; conglomerate clasts mostly pebble size with 2 in. maximum diameter; some sandstone beds 1 in. thick	200
1. Conglomerate and sandstone, mostly brown; weather brown; conglomerate clasts range from pebbles to boulders; well-rounded clasts of quartzite and sandstone, more angular and smaller clasts of chert; some limestone cobbles	50
Total thickness of incomplete Diamond Peak Formation	1,475
Total thickness of composite section of Diamond Peak Formation (includes 1,200 ft of Dott's section of Tonka Formation)	4,670
Contact between Chainman Shale and Diamond Peak Formation is sharp along line of measured section but is mostly gradational and intertonguing elsewhere in mapped area.	
Chainman Shale:	
Shale (appears to be same stratigraphic unit as unit 15 of section S7).	

this area. Other good collections are from beds of late Late Mississippian and early Early Pennsylvanian ages. Relatively few well-preserved fossils were found in the sequence between strata containing late Early Mississippian fossils and strata containing late Late Mississippian ones, but the lack locally of diagnostic fossils does not necessarily indicate a depositional break in this continuous rock sequence.

The most diagnostic of the oldest fossils in this sequence is the goniatite *Protocanites lyoni* (Meek and Worthen) (Gordon and Duncan, 1961, p. C233) in collections 16526-PC and 16527-PC (Nos. 67, 68, pl. 1; table 9). These two collections are from localities south of Papoose Canyon where we were not able to establish their exact stratigraphic distance above the base of the sequence, but it is estimated to be several hundreds of feet. Collection SF-168 (No. 71 on pl. 1), containing three crushed and very poorly preserved goniatites that are likely of Early Mississippian age (Gordon, written

SECTION S7.—*Section of Chainman Shale in the NW¼ sec. 18, T. 31 N., R. 53 E., and S½ sec. 12, T. 31 N., R. 52 E.*

[Measured with Abney level on Jacob staff and with Brunton compass and steel tape. Location of section shown by number on pl. 1]

	Feet
Mississippian System:	
Diamond Peak Formation:	
Conglomerate	
Contact between Diamond Peak Formation and Chainman Shale is covered along line of section.	
Chainman Shale:	
15. Covered; probably gray shale; cover includes some gravel on ridge crest (same stratigraphic position as Chainman Shale at base of section S8)	45
14. Shale, gray; weathers gray; very small amount of sandstone. A thin calcareous and sandy bed containing fossil fragments occurs 150 ft above base	220
13. Shale, gray; weathers gray; some beds are hard and black; very small amounts of sandstone and quartzite; uncommon layers of ferruginous siltstone ¼ in. or less thick. Fossils occur in top 5 ft of unit; this fossiliferous zone contains scattered pebbles as much as 2 in. in diameter and is probably a pebbly mudstone; the shale is contorted as a result of penecontemporaneous sliding or slumping	255
12. Sandstone and quartzite and subordinate gray shale	110
11. Sandstone, tan; fine grained with rounded quartz and angular gray chert grains; well cemented; slightly ferruginous	35
10. Shale, similar to that unit 9, contains some sandstone but less than in unit 9	165
9. Shale, soft, gray; weathers to form soft gray slope; thin interbeds of fine-grained sandstone in beds generally ¼-½ in. thick, some 2 in.; sandstone consists largely of quartz in sand and some silt-size grains, some angular chert grains and small flakes of mica; sandstone weathers tan and gray and reddish brown in places and forms platy fragments. Shale makes up most of unit, some thin beds are of ferruginous siltstone. Plant fragments were seen on bedding surfaces of some sandstone pieces; a poorly preserved goniatite was found in a loose piece of sandstone 65 ft above base of unit	200
8. Shale, soft, gray; weathers gray	85
7. Shale, soft, gray; weathers gray; some coarse sandstone and some "mudflow" conglomerate or pebbly mudstone; upper 10 ft of unit lacks "mudflow" conglomerate but contains ferruginous sandstone	75
6. Sandstone, similar to that in unit 4, and conglomerate; some of conglomerate is mudflow type containing pebbles, cobbles, and boulders of brown limestone, of quartz- and chert-grain sandstone similar to that elsewhere in the section, and of chert, quartzite, and gray limestone; gray limestone clasts probably derived from Devils Gate Limestone	40
5. Shale, soft, gray; weathers gray; some "mudflow" conglomerate (pebbly mudstone) with well-rounded pebbles, cobbles, and boulders of sandstone, brown limestone, and chert. A lens of conglomerate about 12 ft thick and 30 ft long contains pebbles and cobbles of black and green chert and pebbles to boulders of gray limestone that probably were derived from the Devils Gate Limestone; largest limestone boulder is 1 ft in diameter	115

SECTION S7.—*Section of Chainman Shale in the NW¼ sec. 18, T. 31 N., R. 53 E., and S½ sec. 12, T. 31 N., R. 52 E.*—Con.

	Feet
Mississippian System—Continued	
Chainman Shale—Continued	
4. Sandstone (possibly subgraywacke), medium- and coarse-grained; composed chiefly of angular to subrounded black, tan, and green chert grains and fewer rounded quartz grains; also contains angular, mostly elongate, pebbles of gray chert and some fragments of black mudstone (similar to some mudstone in Webb Formation) and gray siltstone. Beds are 1½-6 ft thick. Unit is a lens that extends about 900 ft along the strike	45
3. Shale, soft, light-gray to gray; weathers gray; shale breaks into small pieces, mostly less than ¼ in. across; contains scattered pebbles in places. Basal 80 ft of unit contains subspherical to elliptical gray claystone nodules ½-2 in. across, some of which contain barite. Scattered grains of quartz in some shale layers. 35 ft above base is a lens of sandstone made up of coarse-grained chert fragments	185
Total thickness of Chainman Shale	1,575
Contact between Chainman Shale and Webb Formation is gradational.	
Webb Formation:	
2. Shale, siliceous, dark-gray to almost black; weathers gray, brown, and bluish gray and breaks into plates 1/16-¼ in. thick and 2 in. across. Unit is transitional into Chainman Shale	25
1. Mudstone, hard, siliceous, gray and tan and some black; weathers gray and tan; makes scree slope	12

commun., 1961), is about 250 feet above the base of the Chainman and Diamond Peak sequence in Lee Canyon. Collection 17297-PC (No. 72 on pl. 1), from about 200 feet above the base, contains the same *Protocanites lyoni* and a fragment of the goniatite *Tribolocerus*. Collection 17289-PC (No. 73 on pl. 1) from the SW¼ sec. 5, T. 28 N., R. 54 E., also contains the Early Mississippian fauna but is from a small klippe resting on other Mississippian rocks; hence, its stratigraphic position is unknown. A somewhat younger fauna than that with the *Protocanites lyoni* is represented by collection 17140-PC (No. 74 on pl.1) from 75 feet of gray shale in the NE¼ sec. 11, T. 29 N., R. 52 E. The fauna includes the following fossils identified by Gordon and Duncan (1961, p. C233):

> *Menophyllum*? cf. sp. A., *Trochophyllum* sp., *Permia* sp., *Amplexizaphrentis* cf. *A. welleri* (Grove), "*Amplexus*" sp., *Cyathaxonia* sp., *Leptagonia* cf. *L. analoga* (Phillips), *Setigerites* sp., *Schizophoria* sp. A., *Spirifer* aff. *S. imbrex* Hall, *S.* aff. *S. floydensis* Weller, *Cleiothyridina* cf. *C. incrassata* (Hall), *Straparollus* (*Euomphalus*) sp., and *Loxonema* sp.

The greatest variety of well-preserved megafossils in the Mississippian sequence occurs in the informally designated Ferdelford fossil beds about 3,600 feet above the base of this Chainman and Diamond Peak sequence

TABLE 9.—*Fossils of Early Mississippian age (Kinderhookian Series) from the Chainman Shale and the undivided Chainman Shale and Diamond Peak Formation in the Carlin-Pinon Range area, Nevada*

[Identifications by Mackenzie Gordon, Jr., and Helen Duncan]

Locality No. on pl. 1	67	68	69	70	71	72	73
USGS fossil colln. No.	16526-PC	16527-PC	16283-PC	17138-PC	[1]SF-168	17297-PC	17289-PC
Corals:							
Horn corals	×	×		×			
Bryozoans:							
Fenestella sp.				×			
Echinoderms:							
Crinoid columnals				×			
Echinoid spines				×			×
Brachiopods:							
Lingula sp.							×
Chonetes aff. *C. illinoisensis* Worthen							×
Leptaena analoga Hall			×				
Marginicinctus cf. *M. wortheni* (Hall)							×
Schizophoria sp.	×						
Schuchertella sp.				×			
Schuchertella? sp.	×						
Setigerites? sp.				×			×
Pustula sp.							×
Rhipidomella aff. *R. theimi* (White)							×
sp.			×				
Productid indet.	×		×				
Labriproductus cf. *L. wortheni* (Hall)			×				
aff. *L. keokuk* (Hall)			×				
Labriproductus? sp.				×			
Tetracamera cf. *T. subtrigona* (Meek and Worthen)	×						
Dialasmid indet.	×						
Beecheria sp.				×			
Strophopleura? sp.	×						
Spirifer cf. *S. brazerianus* Girty			×				
aff. *S. grimesi* Hall			×				
aff. *S. logani* Hall	×			×			
aff. *S. marionensis* Shumard			×				
aff. *S. missouriensis* Swallow				×			×
aff. *S. shepardi* Weller							×
aff. *S. subaequalis* Hall			×				
sp. A (with moderately long dental plates)			×				
sp.	×						
Tylothyris sp.							×
Torynifer aff. *T. cooperensis* Swallow							×
Dimegalasma aff. *D. plenum* (Hall)			×				
sp.	×						
Cleiothyridina aff. *C. tenuilineata* (Rowley)			×	×			
Eumetria sp.							×
Composita sp.							×
Pelecypods:							
Nuculana? sp.	×						
Yoldia sp.							×
Parallelodon sp.							×
Aviculopinna sp.				×			
Aviculopecten? sp.	×						×
Leptodesma? sp.	×						
Lithophaga sp.							×
Lithodoma sp.	×						
Sphenotus sp.	×						
Edmondia? sp.	×						
Allorisma sp.	×	×		×			×
Sulcatopinna sp.				×			
Schizodus sp.	×						
Small pelecypods indet.	×						
Pelecypod indet.		×					
Gastropods:							
Bellerophontid indet.	×						
Naticopsis sp.	×						
Straparollus sp.	×						
Aclisinid indet.	×						
Loxonema sp.	×						
Small gastropods indet.	×						
Gastropod indet.				×			
Cephalopods:							
Nautiloid? indet.	×						
Triboloceras sp. (fragment)							×
Pseudorthoceras sp.	×						
Dolorthoceras? sp.	×						
Bactrites sp.		×					
Protocanites lyoni (Meek and Worthen)	×	×			×?	×	
Trilobites:							
Trilobite pygidium indet.							×

[1]Field number.

in the northern half of the area. These fossil beds have a maximum measured thickness of 650 feet, but the most fossiliferous part generally has a thickness of 500 feet or less. Our best collections from these beds were made on the northwest side of Ferdelford Creek in the E½ sec. 22, T. 31 N., R. 52 E. The fossil lists given in table 10 are representative but incomplete for this zone. More complete collections tied carefully to more detailed stratigraphic sections were made by Duncan, Gordon, and us; these collections are being studied by Gordon and his colleagues. According to Mr. Gordon and Miss Duncan, most of the Ferdelford fossil beds are late Early Mississippian (Osagean Series of the midcontinent region) in age and the highest beds may be as young as early Late Mississippian (lower Meramecian Series). Collections from near the west end of Carlin Canyon and just north of the Humboldt River in sec. 21, T. 33 N., R. 53 E., contain the same faunal assemblage (table 10). Here the fossils occur in tan and yellow beds of lithology similar to those at Ferdelford Creek. Collection USGS 17267-PC (No. 77 on pl. 1) in the SW¼ sec. 36, T. 30 N., R. 52 E., contains about the same fauna as the unique Ferdelford beds, but the distinctive lithology of the Ferdelford Creek area is lacking.

Fossils are scarce and poorly preserved in the Upper Mississippian strata between the Ferdelford beds and younger beds that contain the *Diaphragmus phillipsi* (Norwood and Pratten) fauna of late Chesterian age. One collection (USGS 21602-PC; No. 78 on pl. 1) from the NE¼ of sec. 11, T. 32 N., R. 53 E., obtained from this part of the sequence contains a fragmental valve of *Orbiculoidea* sp., *Striatifera*? sp., and a valve of *Echinocoelia*? sp., according to Mackenzie Gordon, Jr. (written commun., 1964). He stated that the *Striatifera* "probably represents a species related to *Striatifera brazeriana* (Girty) [that] in the Great Basin is particularly characteristic of the upper part of the Meramec Series, as it is recognized in this region."

Beds of very Late Mississippian age are dated by fossils at the localities of collections USGS 17134-PC (No. 79 on pl. 1), 17135-PC (No. 80 on pl. 1), 17136-PC (No. 81 on pl. 1), 20503-PC (No. 82 on pl. 1), 20504 (No. 83 on pl. 1), and 20505-PC (No. 84 on pl. 1), which are all grouped on the south side of the Humboldt River in secs. 27 and 34, T. 33 N., R. 53 E.; these collections are from beds equivalent to Dott's 80-foot-thick coquinoid limestone unit described in his measured section of the Tonka Formation (Dott, 1955, p. 2293). Another collection 21599-PC (No. 85 on pl. 1) containing this same faunal assemblage is from the W½ sec. 24, T. 32 N., R. 54 E. The fossils in these collections (table 11) represent the *Diaphragmus phillipsi* faunal assemblage of late Chesterian age (Gordon, written commun., 1964).

As stated by Gordon (written commun., 1958): "In terms of the section in the Confusion Range, Utah, and

TABLE 10.—*Fossils of late Early (Osagean Series) and possibly early Late (lower Meramecian Series) Mississippian age, which are representative of the Ferdelford fossil beds, from Ferdelford Creek and from near the west end of Carlin Canyon, Nev.*

[Identifications by Mackenzie Gordon, Jr., and Helen Duncan]

Collection area	Ferdelford Creek[1]	Carlin Canyon[2]
Corals:		
Michelinia sp.	X	.....
"*Monophyllum*" sp.	X	.....
Siphonodendron n. sp.	X	.....
Diphyphyllum sp.	X	.....
Horn coral	X	X
Amplexoid coral	X	.....
Phaceloid colonial coral	X	.....
Lithostrotionelloid coral	X	.....
Bryozoans:		
Fenestella sp.	X	.....
Cystodictya sp.	X	X
Polypora sp.	X	.....
Fistuliporoid bryozoan	X	.....
Rhomboporoid bryozoan	X	X
Stenoporoid bryozoan	X	X
Bryozoan indet.	X	.....
Echinoderms:		
Crinoid columnals	X	X
Brachiopods:		
Strophomenid indet.	X	.....
Leptaena analoga Phillips	X	X
Schuchertella sp.	X	.....
Schuchertella? sp.	.....	X
Chonetes loganensis Hall and Whitfield	X	.....
cf. *C. loganensis* Hall and Whitfield	X	.....
cf. *C. logani* Norwood and Pratten	X	.....
aff. *C. logani* Norwood and Pratten	X	.....
Plicochonetes sp.	X	.....
Avonia sp.	.....	X
Productid indet.	.....	X
"*Dictyoclostus*" sp.	X	.....
Setigerites n. sp. A	X	X
n. sp. B	.....	X
sp.	X	.....
n. sp.	X	.....
Echinoconchus cf. *E. alternatus* (Norwood and Pratten)	X	X
sp. indet. (fragment)	X	.....
Rhipidomella cf. *R. oweni* Hall and Clarke	X	X
sp.	.....	X
Schizophoria n. sp.	X	.....
sp. A	X	X
Camarotoechia sp.	X	.....
Torynifer sp.	X	X
Spirifer aff. *S. floydensis* Weller	X	X
n. sp. aff. *S. imbrex* Hall	X	.....
aff. *S. incertus* Hall	X	.....
aff. *S. pellaensis* Weller	X	.....
aff. *S. subaequalis* Hall	X	.....
sp.	X	.....
sp. indet.	.....	X
Spiriferinid sp. indet.	X	X
Crurithyris sp.	X	.....
Punctospirifer sp.	.....	X
Dimegalasma cf. *D. neglectum* (Hall)	X	.....
sp.	X	X
Cleiothyridina cf. *C. glenparkensis* Weller	X	.....
sp.	X	X
Brachiopods—Continued		
Composita cf. *C. pentagona* Weller	X	.....
sp.	X	X
Composita? sp. indet.	X	.....
Beecheria sp.	X	.....
Pseudosyrinx sp.	X	.....
Pelecypods:		
Cypricardinia sp.	X	.....
Myalina sp.	X	.....
Allorisma sp.	X	X
Pelecypod indet.	X	.....
Gastropods:		
Orthonychia sp.	.....	X
Loxonema sp.	X	.....
Straparollus (*Euomphalus*) sp.	X	.....

[1]Collections from Ferdelford Creek, NE¼ sec. 22, T. 31 N., R. 52 E. (No. 75 on pl. 1). 16144-PC and 16145-PC by Smith and Ketner; 17115-PC, 17116-PC, 17117-PC, 17123-PC, 17124-PC, 17125-PC, 17126-PC, 17127-PC, and 17128-PC by Mackenzie Gordon, Jr., and assistants.

[2]Collections from west end of Carlin Canyon, N½ sec. 21, T. 33 N., R. 53 E. (No. 76 on pl. 1). 17118-PC, 17119-PC, 17120-PC, 17121-PC, and 17122-PC by Mackenzie Gordon, Jr., and assistants.

particularly in the presence of *Kozlowskia* n. sp., this fauna is very late Mississippian in age and generally is found about 100 to 300 feet below the earliest appearance of the typical Pennsylvanian *Dictyoclostus coloradoensis* fauna as represented by collection 17132." Collection USGS 17132-PC (No. 88 on pl. 1), which contains the Lower Pennsylvanian *Dictyoclostus coloradoensis* fauna, is very near the top of the Chainman and Diamond Peak sequence and indicates that the Mississippian-Pennsylvanian systemic boundary occurs within this sequence. This conclusion is in agreement with Dott (1955, p. 2232-2233) who placed the systemic boundary within his Tonka Formation. Fossil collections of Early Pennsylvanian age from the upper Diamond Peak in Carlin Canyon are listed in table 12.

In summary, the Chainman Shale is mostly of Early Mississippian age but does include some beds of Late Mississippian age, the Diamond Peak Formation is of Early and Late Mississippian and very Early Pennsylvanian age, and the two formations where mapped as one unit are of Early and Late Mississippian age.

In the northern part of the mapped area the Chainman and Diamond Peak sequence rests conformably on the Webb Formation, but in the southern part this sequence rests unconformably on both eastern- and western-assemblage rocks of Devonian age. The lowest part of the Mississippian section in the south may be equivalent to the Webb. (See p.A38.) The early Early Mississippian age of this sequence makes it possibly equivalent in part to the Pilot Shale to the south and east of the mapped area (Nolan and others, 1956, p. 52-53; Langenheim, 1960, p. 74-75). Correlations of the Chainman and Diamond Peak Formations discussed for the Eureka area (Nolan and

TABLE 11.—Diaphragmus phillipsi *assemblage of late Late Mississippian age in the Carlin-Pinon Range area, Nevada*

[Prepared by Mackenzie Gordon, Jr.]

Locality No. on pl. 1	79	80	81	82	83	84	85
USGS fossil collection No.	17134-PC	17135-PC	17136-PC	20503-PC	20504-PC	20505-PC	21599-PC
Corals:							
Horn corals incl. *Amplexizaphrentis*	×	×	×	×	×	×	×
Bryozoans:							
Stenoporoid, encrusting form				×			
Echinoderms:							
Crinoid columnals	×		×	×	×	×	×
Echinoid plates		×	×				
Echinoid spine					×		
Brachiopods:							
Schizophoria cf. *S. resupinoides* (Cox)	×	?	×	?	×		
cf. *S. texana* Girty							×
Schuchertella sp.	×				×		
Neochonetes sp.	×		×	×		×	
Heteralosia sp.	×						×
Kozlowskia n. sp.	×	×	×	×	×	×	
Inflatia sp. A	×	×	×	×	×	×	
sp. B	×	×	×	×	×	×	×
Flexaria sp. indet.	×						×
Echinoconchus sp. indet. (fragment)	×						
Diaphragmus phillipsi (Norwood and Pratten)					×		×
n. sp. aff. *D. phillipsi* (N & P)	×	×		×	×	×	×
Ovatia sp. A	×						×
sp. B	×	×	?	×	×	×	
Camarotoechia sp.		×	?	×	×		×
Anthracospirifer sp.	×	×	×	×	×	×	×
Punctospirifer transversus (McChesney)	×	×	×	×	×	×	×
Reticulariina spinosa (Norwood and Pratten), var.	×	×	×	×	×		×
Torynifer cf. *T. setiger* (Hall)	×						×
Hustedia sp.							×
Cleiothyridina aff. *C. suborbicularia* (Hall)	×	×	×	×	×	×	×
Composita sp.	×			×	×	×	×
Nucleospira sp.					×		
Beecheria? sp.	×	×		×	×		
Pelecypods:							
Solenomorpha? sp.				×			
Wilkingia sp. indet.	×						
Astartella? sp. indet.			×				
Gastropods:							
Bellerophontid, gen. and sp. indet.			×	×			
Knightites (*Retispira*)? sp. indet.					×		
Glabrocingulum sp. indet.				×			
Naticopsis sp. indet.			×		?		
Straparollus sp.			×				
(*Amphiscapha*) sp.				×			
Platyceras sp. indet.				×			
Trilobites:							
Palladin? sp. indet. (pygidium)			×				
Fish:							
Fragment				×			

TABLE 12.—*Fossils of Early Pennsylvanian age from the upper part of the Diamond Peak Formation near Carlin Canyon*

[Identifications by Mackenzie Gordon, Jr., and Helen Duncan]

Locality No. on pl. 1	86	87	88	89
USGS fossil colln. No.	17130-PC	17131-PC	17132-PC	17133-PC
Corals:				
Horn corals	×	×		
Bryozoans:				
Trepostomatous, ramose form			×	
ramose form	×			
Stenoporoid, encrusting form	×			
Fistuliporoid, encrusting form			×	
Rhomboporoid			×	
Bryozoan indet., bifoliate			×	
Echinoderms:				
Crinoid columnals	×		×	
Worms:				
Spirorbis? sp.	×			
Brachiopods:				
Rhipidomella aff. *R. carbonaria* (McChesney)			×	×
Schizophoria cf. *S. texana* Girty	×	×		×
sp. (large form)			×	
Spinose productoid aff. *Krotovia*			×	
Small spinose productoid aff. *Krotovia*	×			×
Rugoclostus sp. *R. semistriatus* (Meek)	×		×	
sp. (one fragmental pedicle valve)				×
Flexaria? sp. indet.	×			
Echinoconchus sp. A. (large species)			×	
sp. B. (small species)			×	
sp.				×
Antiquatonia sp.	×		×	×
Linoproductus sp.	×		×	
Linoproductid indet.				×
Camarotoechia sp. indet.	×			
Rhynchopora sp.			×	
Anthracospirifer occiduus (Sadlick)				×
sp.	×		×	
Condrathyris cf. *C. perplexa* (McChesney)	×		×	
Crurithyris sp. indet.	×			
Hustedia sp.			×	
Composita sp.	×		×	×
Terebratuloid indet.			×	
Pelecypods:				
Astartella sp. indet.	×			

others, 1956, p. 56-61) also apply to the Carlin-Pinon Range area. In the latter area, however, this sequence includes a broader age range. Nolan, Merriam, and Williams (1956, p. 56-61) referred their sequence to the Upper Mississippian and recognized that the uppermost beds of the Diamond Peak may be Lower Pennsylvanian. This range in the Eureka area is not as broad as the Lower Mississippian to Lower Pennsylvanian range in the Carlin-Pinon Range area.

Rocks equivalent to the Lower Mississippian part of the Chainman and Diamond Peak sequence in the area of the present report crop out in the Windermere Hills northeast of Wells (Oversby, 1972, p. 2678-2679) and in the Pequop Mountains 75 miles to the northeast. Furnish, Miller, and Youngquist (1955) referred a goniatite from black shale east of the summit of the Pequop Mountains to *Proctocanites lyoni* (Meek and Worthen) which indicates an Early Mississippian (late Kinderhookian) age for these beds. We have examined these strata along U.S. Highway 40 where it crosses the Pequop Mountains and consider them to be similar litholgoically to the Chainman Shale in the Carlin-Pinon Range area. Some of the undifferentiated Carboniferous strata of Sharp (1942, p. 669-670) in the southern Ruby Mountains are probably correlative with the Diamond Peak Formation.

PENNSYLVANIAN SYSTEM

Rocks of early Early Pennsylvanian age rest conformably on the Chainman and Diamond Peak sequence. They crop out prominently along Carlin Canyon and on Grindstone Mountain in the northern part of the mapped area and along parts of the crest and east side of the Pinon Range in the southern half of the area. These rocks consist of limestone, which contains widely different amounts of clastic fragments, and of conglomerate and sandstone. The high percentage of coarse siliceous rock fragments in these beds indicates that uplift continued in the source area to the west and northwest during Pennsylvanian time. The Carlin-Pinon Range area was in a region of abrupt lateral change in texture of the deposits; units of mostly conglomerate pass laterally into units of mostly limestone in short distances.

Stratigraphy of the Pennsylvanian rocks in that part of the area which embraces Carlin Canyon and the country from the lower canyon of the South Fork Humboldt River southwest to Spring Canyon Mountain was mapped and studied by Dott, (1955, p. 2234-2248, figs. 3, 5). In our opinion, his work was so well done that we did no additional detailed work in that part of the area. We remapped the units on topographic base maps but have used Dott's measured stratigraphic sections and other data. Although our map differs somewhat in detail from that of Dott, no essential concepts are changed.

These Pennsylvanian strata are age equivalent to at least part of the Ely Limestone as defined in the Ely district (Spencer, 1917, p. 27-28) and later extended westward to the vicinity of Eureka (Nolan and others, 1956, p. 61-63), but they differ from the Ely in having a much higher percentage of coarse clastic beds. Dott (1955, p. 2234) proposed that the name Ely be elevated to a group and that it be divided into two formations, the Moleen and Tomera. We adopt these formation names but not Ely Group. In parts of the area where the complete sequence is too similar to be divided into two formations, we have mapped it as undivided Moleen and Tomera Formations.

The exposed thicknesses of this Pennsylvanian sequence differ widely over the mapped area mainly because the upper contact is a pronounced unconformity below which the Moleen and Tomera Formations are lacking in places. The lower contact with the Diamond Peak Formation is conformable and is gradational and probably interfingering locally; therefore, it is not possible to map the same horizon in all parts of the area. The combined maximum thickness of the two formations is about 3,300 feet (Dott, 1955, p. 2239, 2245) in the northeastern part of the mapped area.

The combined Moleen and Tomera Formations range in age from early Early to late Middle Pennsylvanian. Dott (1955, p. 2243) considered the Moleen to be Early and early Middle Pennsylvanian in age and to extend through the Morrowan Series and into the lower Atokan Series and to be equivalent to the lower part of the Ely Limestone. He (Dott, 1955, p. 2248) considered the Tomera as being of Middle Pennsylvanian age and extending from lower Atokan through lower Des Moinesian and as being equivalent to the upper part of the Ely Limestone. We made no extensive collections of fossils but did collect both megafossils and microfossils in scattered localities (table 13). These collections were made largely to aid in confirming our identification of rock units, especially where Pennsylvanian and overlying Permian rocks are very similar. All microfossil collections, except one studied by Lloyd G. Henbest, were studied by Raymond C. Douglass, who also visited us in the field and made some of the collections. Megafossils were studied by Mackenzie Gordon, Jr. Formation ages based on these collections are in accord with those determined by Dott who made more extensive collections of both megafossils and microfossils.

Separation of the Moleen and Tomera Formations is based chiefly on three features: (1) the Moleen contains prominent bands of limestone with nodules, pods, and layers of chert; (2) the Tomera contains more clastic fragments of quartz and chert that form thick beds of conglomerate in places; and (3) the Tomera contains better developed coquinites and more whole fossils. The following discussions of the formations are brief, and the reader is referred to Dott (1955, p. 2234-2248) for more detailed descriptions.

MOLEEN FORMATION

The name Moleen was taken from Moleen siding on the Southern Pacific railroad and the type section was designated as being on the west side of Grindstone Mountain in the NW¼ sec. 33, T. 33 N., R. 54 E., and east of the north end of the mountain in the NE¼ sec. 34, T. 33 N., R. 54 E. (Dott, 1955, p. 2234). The type section is 1,270 feet thick (Dott, 1955, p. 2239), but elsewhere the formation ranges from about 1,200 to about 1,600 feet. Much of the Moleen is well exposed on the west slope of Grindstone Mountain, where it forms a series of ledges of limestone and gentler intervening slopes underlain by less well exposed thin-bedded silty and sandy limy units.

The limestone forming the ledges is various shades of gray and weathers the same colors. Beds are generally 1-4 feet thick, but some are only 3-4 inches thick. The limestone is detrital, ranging from fine to coarse grained and containing many fossils and fossil fragments. Some beds are sandy or silty and some contain conglomerate lenses made of green, brown, and gray chert pebbles set in a calcareous or calcareous sandstone matrix. Characteristically, the limestone contains chert as pods a few inches long and irregular layers as much as 10 feet long. The layers generally are 1-4 inches thick but may be as much as 8 inches thick. Most of the chert is gray to very dark gray and weathers brown or tan. The chert-bearing limestone is very similar to much of the Ely Limestone farther east and south in Nevada.

Mostly thin-bedded quartz sandy or silty limestone

TABLE 13.—*Fossils of Pennsylvanian age from the Moleen and Tomera Formations from selected localities in the Carlin-Pinon Range area, Nevada*

[Identifications by Mackenzie Gordon, Jr.]

	Moleen Formation							Tomera Formation			Moleen and Tomera Formations			
Locality No. on pl. 1	90	91	92	93	94	95	96	97	98	99	100	101	102	103
USGS fossil colln. No.	17298-PC	17275-PC	17139-PC	16529-PC	17287-PC	17290-PC	17291-PC	17300-PC	21600-PC	17299-PC	16147-PC	16148-PC	17285-PC	17284-PC
Foraminifera:														
Fusulinella sp.									×					
Climacammina sp.									×					
Corals:														
Horn corals		×	×		×	×		×			×	×	×	×
Caninoid corals									×					
Zaphrentid corals									×					
Chaetetes													×	
Echinoderms:														
Echinoid plate			×											
Crinoid columnals			×				×				×	×		×
Bryozoans:														
Trepostomatous bryozoan, ramose form	×													
Stenoporoid bryozoan, ramose form					×	×	×		×	×				
Stenoporoid bryozoan, encrusting form	×				×									
Rhomboporoid bryozoan				×	×		×							
Fenestella sp.											×			
Polypora sp.						×								
Brachiopods:														
Orbiculoidea sp.					×				×					
Derbyia sp.								×						
Chonetes cf. *C. geinitzianus* Waagen				×										
cf. *C. tumescens* Easton						×					×			
sp.			×									×		
Rugoclostus n. sp.	×													
Flexaria n. sp.	×													
Kozlowskia nuda (Lane)								×						
Kozlowskia? sp.			×						×					
Desmoinesia muricatina (Dunbar and Condra)									×					
Antiquatonia aff. *A. coloradoensis* (Girty)									×					
n. sp.	×													
Dictyoclostus (*Antiquatonia*) *coloradoensis* (Girty)		×	×				×							
(*Antiquatonia*) *coloradoensis* (Girty)?														×
cf. *D. hermosanus* Girty						×					×	×		
cf. *D. inflatus* (McChesney)			×				×				×	×		
n. sp.		×												
sp.							×							
sp. indet.					×									
Dictyoclostus? sp.													×	
"*Buxtonia*" sp.			×				×							
Juresnia cf. *J. nebrascensis* (Owen)												×		
Juresnia? sp.			×											
Echinoconchus sp.			×											
Marginifera cf. *M. wabashensis* (Norwood and Pratten)											×	×		
sp.							×							×
Marginifera? sp.			×											
Rhipidomella nevadensis (Meek)		×												
cf. *R. carbonaria* (Swallow)												×		
n. sp.					×	×								

TABLE 13.—*Fossils of Pennsylvanian age from the Moleen and Tomera Formations from selected localities in the Carlin-Pinon Range area, Nevada*—Continued

	Moleen Formation							Tomera Formation			Moleen and Tomera Formations			
Locality No. on pl. 1	90	91	92	93	94	95	96	97	98	99	100	101	102	103
USGS fossil colln. No.	17298-PC	17275-PC	17139-PC	16529-PC	17287-PC	17290-PC	17291-PC	17300-PC	21600-PC	17299-PC	16147-PC	16148-PC	17285-PC	17284-PC
Brachiopods—Continued														
Rhipidomella—Continued														
sp. indet.									X	X	X			
Reticularina campestris (White)			X	X	X									
campestris (White)?						X								
cf. *R. spinosa* (Norwood and Pratten)							X							
sp.								X	X	X				
Productus aff. *P. inflatus* McChesney				X										
Productid indet.			X			X								
Productus? sp.			X	X										
Linoproductus prattenianus (Norwood and Pratten)									X					
sp.			X			X	X					X	X	X
Camarotoechia sp.												X		
cf. *Beecheria bovidens* (Morton)					X									
Schizophoria cf. *S. texana* Girty						X								
sp.			X								X			
Spirifer occidentalis Girty				X			X				X			
cf. *S. occidentalis* Girty		X										X		
occidentalis Girty?				X										
rockymontanus Marcou			X							X				
aff. *S. opimus* Hall									X					
sp.					X	X								X

Neospirifer dunbari King										×				
cf. *N. dunbari* King									×					
sp. indet.								×						
Phricodothyris perplexa (McChesney)				×										
Wellerella sp. indet.	×								×					
Hustedia mormoni Marcou										×				
cf. *H. mormoni* (Marcou)		×				×								
sp. indet.	×			×							×			
Condrathyris perplexa (McChesney)									×					
Crurithyris planiconvexa (Swallow)?			×											
Cleiothyridina orbicularis (McChesney)									×					
pecosi (Marcou)?				×										
cf. *C. pecosi* (Marcou)												×		
sp.	×	×	×		×	×	×	×						×
Cleiothyridina? sp.													×	
Composita subquadrata (Hall)?				×										
subtilita (Hall)			×			×	×	×	×	×	×			
sp.	×	×			×									
Composita? sp.													×	
Pelecypods:														
Aviculopecten sp.							×							
Allorisma cf. *A. terminale* Hall							×							
Gastropods:														
Bellerophontid indet.							×							
Trilobites:														
Trilobite pygidium			×											

underlies the poorly exposed intervals between the limestone ledges. Many of these beds are tan and weather to form tan platy fragments, some of which are highly fossiliferous.

The coral *Chaetetes* occurs prominently in places in the upper part of the Moleen Formation, either laterally along a single horizon for several tens of feet or through a vertical interval of about 200 feet. (See Dott, 1954; 1955, p. 2238-2242.) In addition to abundant *Chaetetes* in beds in the northern part of the area, a few specimens were recognized in scattered localities in the undivided Moleen and Tomera Formations on the ridge south of Elliott High Ranch and in the southernmost exposure of the Moleen Formation.

Descriptions of units of the Moleen Formation in the northern part of the mapped area are given in published measured sections by Dott (1955, p. 2292-2296) and in the southern part of the area are given in the following section (S11A) that we measured along the crest of the Pinon Range in the N½ sec. 22, T. 29 N., R. 53 E. The rocks in section S11A grade and interfinger laterally into conglomerate and sandstone to the northwest.

The contact between the Moleen Formation and overlying Tomera Formation is gradational. It is placed at the base of a unit containing more abundant conglomerate and quartz sand than the beds below. Where the entire sequence of Pennsylvanian rocks contains much conglomerate and quartz sand, the two formations are not mapped separately.

TOMERA FORMATION

The Tomera Formation was named for the Tomera Ranch in sec. 25, T. 33 N., R. 53 E., by Dott (1955, p. 2243) who designated exposures in east-central part of sec. 34 and west-central part of sec. 35, T. 33 N., R. 54 E., and in the SW¼ sec. 19, T. 33 N., R. 55 E., as the type section (Dott, 1955, p. 2243, 2296-2299). The formation is best exposed in the area east and south of Grindstone Mountain. The total thickness of the Tomera ranges from 1,700 to 2,000 feet (Dott, 1955, p. 2245).

The Tomera consists of interbedded and interfingering limestone and conglomerate. Chert pebble-conglomerate, which comprises a prominent part of the formation, consists chiefly of clasts of gray and green chert and some quartzite set in a matrix of sandstone or siltstone. Sandstone and siltstone with siliceous or calcareous cement are also interbedded. Conglomerate and sandstone grade laterally into gray limestone. The limestone is fragmental, commonly composed largely of fossil debris, and contains grains of quartz and fewer grains of chert. Little or no nodular chert occurs in these limestone beds in contrast to abundant chert in the Moleen. Some beds abound with fossils, many of which are less broken than those in the Moleen. The conglomerate in the Tomera is very similar to that in the

SECTION S11A.—*Stratigraphic section of Moleen Formation in sec. 22, T. 29 N., R. 53 E.*

[Measured with Brunton compass and steel tape. Location of section shown by number on pl. 1]

	Feet
Undivided Permian and Pennsylvanian Systems:	
Sandstone, conglomerate, and conglomeratic sandstone.	
Unconformity	
Pennsylvanian System:	
Moleen Formation:	
12. Limestone, conglomerate with calcareous matrix, and calcareous sandstone interbedded; all types grade into one another and all are well bedded. Limestone contains chert nodules in places. Conglomerate formed mostly of chert pebbles. Sandstone and conglomerate units have maximum thicknesses of about 5 ft; limestone units are thicker	110
11. Limestone, gray; weathers gray; in beds 3 ft thick; and shaly and platy sandy limestone; contains dark chert nodules in more massive upper part	13
10. Limestone, gray; weathers gray and light gray with tan tints in places; prominent layers of tan chert nodules; nodule layers in basal 6 ft are evenly spaced 2-3 in. apart; nodules in next higher 6 ft are larger, being as much as 3 in. across and 1 ft long	17
9. Limestone, gray; weathers gray; massive and platy; sandy limestone interbeds 5-10 ft thick; fossiliferous with conspicuous spirifers. Three conglomerate beds are about evenly spaced through the unit and increase in thickness northwest of line of section. Conglomerate contains prominent green chert pebbles, also tan and gray chert pebbles, and some quartzite pebbles; all set in a calcareous sandstone matrix. Some well-bedded gray calcareous sandstone that weathers gray is prominent, particularly near the base	145
8. Limestone, gray; weathers gray; massive, locally fossiliferous, slightly sandy in places; brown chert bands as much as 6 in. thick prominent along bedding	70
7. Limestone and conglomerate interbedded. Limestone is gray; weathers gray; fine to coarse grained; fossiliferous in places; occurs in beds 1-12 in. thick; some thin shaly layers; some tan beds are sandy and weather to form platy pieces; limestone units are 20-30 ft thick. Conglomerate is calcareous and weathers light brown; well bedded partly in beds ½-1 ft thick; made up chiefly of angular to rounded pebbles of tan, gray, white, and some black and green chert and sparse quartzite; maximum pebble diameter is 2 in.; flat chert pebbles, ¼ in. long or less, are locally alined along bedding; some beds of small pebbles are well sorted; beds with larger pebbles are poorly sorted and larger pebbles are widely scattered among small pebbles in some beds; conglomerate units average about 12 ft thick	185
6. Limestone, interbedded gray limestone and light-gray to tan limestone; beds as much as 2 ft thick, and many platy 1 in.-thick layers	128
5. Conglomerate, calcareous, with angular to subrounded pebbles of mostly gray, tan, and green chert as much as 1 in. long; red tint in places; grades laterally into limestone. This is the first conglomerate lens above the base of the formation along the line of section	2

SECTION S11A.—*Stratigraphic section of Moleen Formation in sec 22, T. 29 N., R. 53 E.*—Con.

	Feet
Pennsylvanian System—Continued	
Moleen Formation—Continued	
4. Limestone, light- and dark-gray; weathers gray with pink cast on some beds; mostly thin bedded in beds 1-2 in. thick, some 4-12 in. thick; forms series of low ridges	100
3. Like unit 1. Also a few beds 2-3 in. thick of white slightly porcellaneous siltstone that occurs mostly as loose pieces on slope	175
2. Limestone, gray; weathers gray; in beds mostly 1-4 ft thick; some beds contain quartz and chert grains; many fossil cross sections in the rock in places; unit is more massive and crops out better than unit 1 below	55
1. Limestone, dark- and light-gray; weathers gray; dense to crystalline, in beds generally 1 in. to 2 ft thick; tan and gray chert in layers as thick as 2 in. and in round and oval nodules as much as 4 in. across; some sandy limestone contains medium-size rounded grains of quartz. Tan sandy limestone and calcareous sandstone weathers to form units 2-4 ft thick that are internally bedded in layers ¼-1½ in. thick; contains rounded medium and coarse grains of quartz and angular grains of green and light-gray chert; some calcareous grit and a few layers of pebbles as large as ½ in. in diameter. Unit is fossiliferous in places, containing brachiopods, corals and bryozoans	225
Total thickness of Moleen Formation	1,225

Contact between Moleen and Diamond Peak Formation is gradational and intertonguing.

Basal Pennsylvanian System and Mississippian System:
Diamond Peak Formation:
Conglomerate of quartzite and chert pebbles and cobbles; weathers brown.

Diamond Peak Formation, but the more abundant limestone in the Tomera distinguishes it from the Diamond Peak. The Tomera Formation lies unconformably below the Pennsylvanian and Permian Strathearn Formation, and in part of the area the Tomera was completely eroded prior to deposition of the Strathearn.

TOMERA AND MOLEEN FORMATIONS UNDIVIDED

The Tomera and Moleen Formations are shown as one major unit in three parts of the mapped area. In these parts, beds equivalent to the Moleen Formation contain abundant conglomerate, and the entire sequence has a relatively high percentage of conglomerate compared with other rock types. An increase in the amount of conglomerate to the west and northwest indicates derivation of coarse detritus from the same area that was uplifted during deposition of the Chainman Shale and Diamond Peak Formation.

On both sides of the Humboldt River along the eastern part of Carlin Canyon, this undivided sequence of Pennsylvanian rocks contains limestone in the lower part that is similar to that in the Moleen Formation farther east. This lower part, however, also contains much more conglomerate than the equivalent beds to the east. This difference is conspicuous in Dott's (1955, p. 2292-2296) published sections of the Moleen. The section just south of the Humboldt River and east of Tonka Creek contains about 25 percent conglomerate, whereas the section on Grindstone Mountain, 4½ miles farther east, contains only about 2 percent conglomerate.

The most striking change westward and northwestward from limestone to mostly conglomerate takes place in the Pinon Range north and west of measured stratigraphic section 11A in sec. 22, T. 29 N., R. 53 E., of the Moleen Formation. Here the change occurs by interfingering of limestone and conglomerate, and in less than 1 mile a sequence of mostly limestone of the Moleen changes laterally into conglomerate and sandstone of undivided Moleen and Tomera. The high ridge just southeast of Smith Creek basin is underlain by this conglomerate and sandstone which is very similar to the conglomerate and sandstone of the nearby undivided Chainman Shale and Diamond Peak Formation.

Rocks mapped as Tomera and Moleen Formations undivided crop out on the ridge south of Elliott High Ranch and west of the upper part of Dixie Creek. Nearly all the rocks are silicified, and the sequence consists of silicified limestone and conglomerate, and quartzite. The lower stratigraphic position of *Chaetetes* in this sequence, in comparison with its stratigraphic position farther north, suggests that these silicified beds are equivalent to the Moleen and part of the Tomera. This situation indicates that our map contact between the Diamond Peak Formation and the undivided Tomera and Moleen Formations was placed higher stratigraphically here than elsewhere in the area because the formations have such close lithic similarity.

MIDDLE PENNSYLVANIAN UNCONFORMITY

Beginning in late Middle Pennsylvanian time the rocks were deformed, uplifted, and eroded before sediments of Late Pennsylvanian age (equivalent to the Missourian Series) were deposited, and a pronounced angular unconformity separates Middle Pennsylvanian and older units from Late Pennsylvanian and younger strata (fig. 13). At some places the strata above the unconformity have sharply different attitudes from those below, whereas in other places bedding attitudes across the unconformity are so nearly parallel that an angular discordance is not obvious. An irregular erosion surface was developed during this major hiatus, and, when the post-Middle Pennsylvanian sea invaded the region, it spread slowly over this surface. Consequently, the time interval indicated by adjacent beds across the unconformity differs considerably over the mapped area. At some

FIGURE 13.—Angular unconformity between Diamond Peak Formation (IPMd) and overlying Strathearn Formation (PIPs), looking northwest from south of railroad tracks and west of Tonka station. Slope of hill and perspective make some Strathearn beds appear to dip into contact; they do not, however. Similar contact relations are also well exposed north of the Humboldt River near the west end of Carlin Canyon.

localities, beds equivalent in age to about the lower Des Moinesian Series are overlain by those equivalent to the Missourian Series, whereas at other localities, Mississippian beds are overlain by Lower Permian strata.

PENNSYLVANIAN AND PERMIAN SYSTEMS

Rocks of Late Pennsylvanian and Early and Late Permian ages crop out in scattered localities but are mostly in the northeastern part of the area. Their maximum exposed thickness is about 5,000 feet, but no record of their original thickness is available because these strata are unconformable beneath all younger beds. They also rest unconformably on strata as old as Devonian and as young as Middle Pennsylvanian.

These upper Paleozoic units are composed mainly of carbonate and siliceous clastic rock fragments that range in size from clay to boulders. The most characteristic rocks are thin-bedded, mainly calcareous fine-grained sandstone to siltstone and fine-grained sandy or silty limestone. These rocks weather to form yellow, tan, and reddish-tan platy fragments that cover tan or yellowish-tan slopes; such slopes are also characteristic of the Permian in many nearby areas. Conglomerate beds and lenses and conglomeratic limestone indicate that the source area for their detritus was uplifted periodically and shed coarse rock fragments. The thickest and most prominent conglomerate beds are in the south-central part of the mapped area.

This rock sequence ranges in age from Late Pennsylvanian (Missourian and Virgilian) to Late Permian (Guadalupian). The basal beds are younger in the western exposures than in the eastern ones; therefore, those in roughly the western third of the mapped area are Permian and do not include any Upper Pennsylvanian strata. In fact, the basal beds in Tps. 29 and 30 N., R. 52 E., are late Early Permian in age to indicate that part of the area remained emergent well into Permian time.

Upper Pennsylvanian and Permian strata are similar enough lithologically in the area of this survey to make them generally identifiable as a major unit which is distinguishable from older Paleozoic units. Abrupt changes in facies, however, are indicated by both lateral and vertical changes in lithology. We have not assigned formal names to most of these rocks because, in our opinion, most of the distinct lithologic units are not yet recognized over large enough areas to be given formational status.

Formation names that have been applied to Late Pennsylvanian and Permian rocks in the northern part of the area are shown in table 14. We follow Dott in map-

TABLE 14.—*Names applied to Upper Pennsylvanian and Permian rocks in the area of Carlin Canyon*

SYSTEM	SERIES	DOTT, (1955)	FAILS, (1960)	BISSELL, (1962a, table 1, p. 196)	THIS REPORT Northern part	THIS REPORT Southern part
PERMIAN	GUADALUPIAN		Carlin Canyon Formation	Gerster Formation; Plympton Formation		
	LEONARDIAN	Undivided	Beacon Flat Formation	Pequop Formation	Limestone, dolomite, conglomerate, and conglomeratic sandstone, undivided; prominent tan and brown chert in upper part	Limestone, dolomite, conglomerate, and conglomeratic sandstone undivided
	WOLFCAMPIAN		Buckskin Mountain Formation	Ferguson Mountain Formation		
				?		
PENNSYLVANIAN	VIRGILIAN	Strathearn Formation	Strathearn Formation	Strathearn Formation	Strathearn Formation	
	MISSOURIAN					

ping the Strathearn Formation and Permian undivided in this part of the area but do not recognize the Strathearn in the southern part of the area, although time-equivalent beds crop out there. The units named by Fails (1960) are recognizable in a small area north of the Humboldt Rivr but not in other parts of the mapped area; thus, it seems impractical to adopt the names assigned by him. However, if studies north and east of the area of the present report show that his units can be mapped, the names could be used and extended. We refer to these rocks as Upper Pennsylvanian and Permian undivided in the sense of a unit that has certain similarities but also has a variety of rock types and an extensive age range. A variety of lithologic types in this sequence is to be expected in this area that evidently was near the source of the sediments.

These Upper Pennsylvanian and Permian rocks are distinguished on a general lithologic basis in figure 14 and on a general age basis in figure 15. Unit 1, figure 14, consists of thick- to thin-bedded limestone, sandstone, siltstone, and some conglomerate and conglomeratic limestone that is the Strathearn Formation except for the two small outcrop areas in the south-central part of the mapped area. Unit 2 consists of fine-grained clastic rocks that include much of the thin-bedded rocks that weather to tan and yellow platy fragments so characteristic of the Permian strata in this area; this unit includes the Buckskin Mountain and Beacon Flat Formations of Fails (1960, p. 1693-1699) north of the Humboldt River. Unit 3 consists chiefly of conglomerate; the large area of conglomerate in the south may not be at its original depositional site, as it seems to have been displaced structurally. Unit 4 contains much siltstone and is distinguished from unit 2 in the northern exposures by its prominent layers of chert; it is the same as the Carlin Canyon Formation of Fails (1960, p. 1699-1702). Age assignments shown in figure 15 are based on studies of microfossils by R. C. Douglass and L. G. Henbest and megafossils by Mackenzie Gordon, Jr. Age divisions undoubtedly are not as sharp as they are shown. Positions of shorelines are only approximate but clearly indicate that the Late Pennsylvanian and Early Permian sea moved very slowly to cover the mapped area.

STRATHEARN FORMATION

The Upper Pennsylvanian and Lower Permian Strathearn Formation was named by Dott (1955, p. 2248) for the old ranch headquarters of the Strathearn Cattle Co. in the N½ sec. 8, T. 33 N., R. 54 E., about 1 mile north of the area of the present report. The type section was designated as "west of the head of the lower canyon of the South Fork of the Humboldt River—in SW¼ sec. 19, T. 33 N., R. 55 E., and along the south line of sec. 24, T. 33 N., R. 55 E.," with a supplementary section

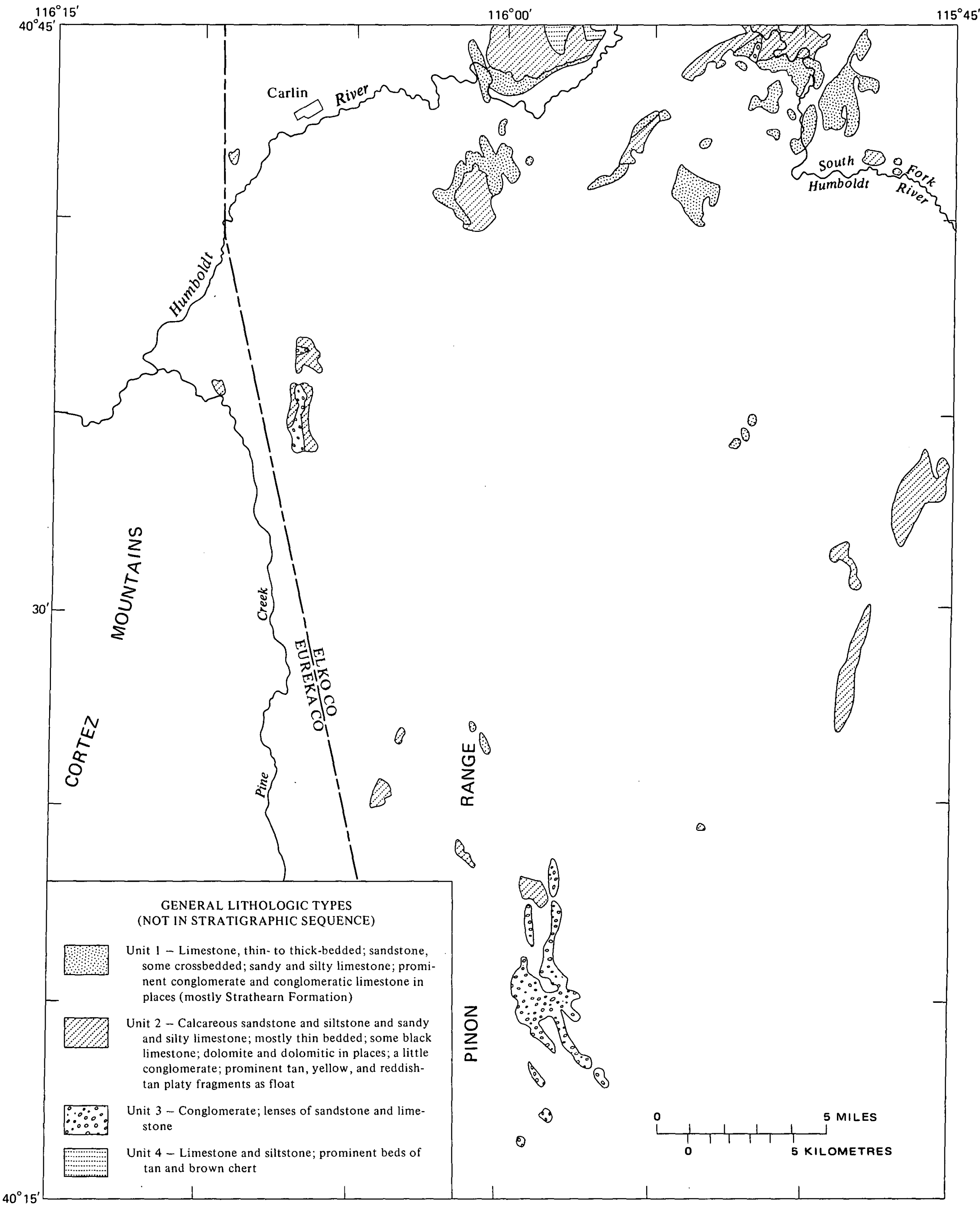


FIGURE 14.—Outcrops and general lithologic types of Upper Pennsylvanian and Permian rocks.

containing higher strata east of the river in the NW¼ sec. 31, T. 33 N., R. 55 E. (Dott, 1955, p. 2248). In this area near the lower canyon of the South Fork Humboldt River, the Strathearn is 1,200-1,500 feet thick, and north of Carlin Canyon it is more than 2,000 feet thick (measured section S12A). In the vicinity of Buckskin Mountain the Strathearn may be as thin as 300 feet. Differences in thickness of the Strathearn reflect in part the fact that the upper contact is not everywhere mapped at the same stratigraphic horizon, because it is gradational into and interfingers with the overlying Permian strata. Also, the Strathearn must differ some in thickness because it was deposited on an irregular surface.

A variety of calcareous rocks makes up the Strathearn Formation, and nearly all the rock units contain clastic fragments (Dott, 1955, p. 2249-2253). Gray limestone in thin- to thick-bedded units is characteristic of the Strathearn and is important in distinguishing it from the overlying undivided Permian rocks. Platy, silty, and sandy beds in the Strathearn, however, are similar to those in the overlying Permian strata. Abundant fusulinids occur in some of the gray limestone and commonly in some of the tan- and yellow-weathering calcareous siltstone. Quartz sand and silt are common constitutents of the limestone beds, and chert pebbles are abundant in some. Some sandy to pebbly units are crossbedded on a small scale and form a characteristic lithologic type of this formation. Chert and quartzite pebbles most commonly are ¼-2 inches in diameter, but in places well-rounded cobbles are as much as 8 inches across. The chert clasts are black, green, gray, and red similar to those in conglomerates of older formations. Conglomerates grade laterally into limestones and form prominent lenses at places.

Measured sections S12 and S12A present descriptions of the Strathearn Formation. Section S12 is incomplete inasmuch as the top is terminated by a fault, but it is presented largely because several collections of fusulinids are from this section.

SECTION S12.—*Partial section of Strathearn Formation in N½ sec. 21, T. 33 N., R. 53 E., Carlin quadrangle*

[Measured with steel tape and Abney level on Jacob staff. Location of section shown by number on pl. 1. Foraminifera identifications by R. C. Douglass (written commun. 1962); all fusulinids collected are Upper Pennsylvanian forms]

Tertiary System:
Tuffaceous deposits.
Fault contact.
Lower Permian and Upper Pennsylvanian Series:
Strathearn Formation:

	Feet
13. Limestone, gray; weathers gray; in beds generally 1-3 ft thick; limestone grades laterally and vertically into sandy and conglomeratic beds; local crossbedded limestone unit contains brown chert fragments generally less than ¼ in. across, and in places scattered quartzite and chert pebbles and cobbles 1½-5 in. across; some gray limestone contains 1/16-in. laminae of very fine grained quartz grains; many bryozoans in some beds	90

SECTION S12.—*Partial section of Strathearn Formation in N½ sec. 21, T. 33 N., R. 53 E., Carlin quadrangle*—Continued

Lower Permian and Upper Pennsylvanian Series—Con.
Strathearn Formation—Continued

	Feet
12. Limestone, gray; weathers gray; in beds 1-3 ft thick; intervening largely covered intervals of fine-grained sandy or silty limestone, weathers tan; near top is a 10-ft-thick unit containing many 4- to 8-in.-thick layers of conglomerate consisting of well-rounded quartzite and light-gray chert pebbles with maximum diameter of 2 in. set in a calcareous sandstone matrix; also gray limestone with scattered grains of chert and some crossbedded sandy limestone; unit grades laterally into gray limestone	100
11. Limestone, gray, and interbedded prominently crossbedded layers of chert grains; contains some chert pebbles as much as ½ in. in diameter; crossbedded layers like unit 9	28
10. Limestone, gray; weathers gray; massive; contains some sandy and some conspicuous brown beds of angular chert grains mostly 1/16 in. or less in diameter and a few as large as ¼ in.	75
9. Sandstone, calcareous, and sandy limestone, brown and gray; weathers brown and gray; contains brown chert grains 1/16 in. or less in diameter and consipicuous crossbeds 1/16-¼ in. thick	8
8. Limestone, gray; weathers gray; in beds ¼-½ in. thick; forms light- and dark-gray banded outcrop with brown chert along some bands; silty in places; contains chert grains toward top	25
7. Limestone, gray; weathers gray; in beds 1-3 ft thick; in massive outcrops; contains some thin chert bands and some chert pebbles 1/16-¼ in. in diameter; many crinoid columnals seen in some beds. Float pieces of yellow silty limestone contain small silicified brachiopods	38
6. Limestone, sandy and silty, gray and tan, platy; mostly covered. Foraminifera—Late Pennsylvanian—Millerellid and *Triticites* (immature specimens only) (colln. USGS f 20793) collected 116 ft above base of unit and Schubertellid? and *Triticites* (colln. USGS f 20792) collected about 4 ft above base of unit	142
5. Limestone, gray; weathers gray; in beds 1-4 ft thick that form massive outcrops and cap ridge. Partly covered slope with some platy fragments ½-1 in. thick of yellow silty and very fine-grained sandy limestone; yellow beds contain many fossil fragments. Foraminifera—Late Pennsylvanian—Textularid and *Triticites* (colln. USGS f20791) collected from top of unit	90
4. Limestone, gray; weathers gray; in beds 1-4 ft thick that make massive outcrops; contains brown chert pods 3-4 in.long and broken chert layers 1-2 in.thick; some layers ¼-½ in. thick and parallel to bedding are silicified on surface and form prominent brown bands; thin calcite seams in places. Float pieces of sandy limestone containing fine-grained quartz grains weather from unexposed interbeds. Foraminifera—Late Pennsylvanian—Endothyrid, Textularid, *Tetrataxis*, Schubertellid, and *Triticites*	

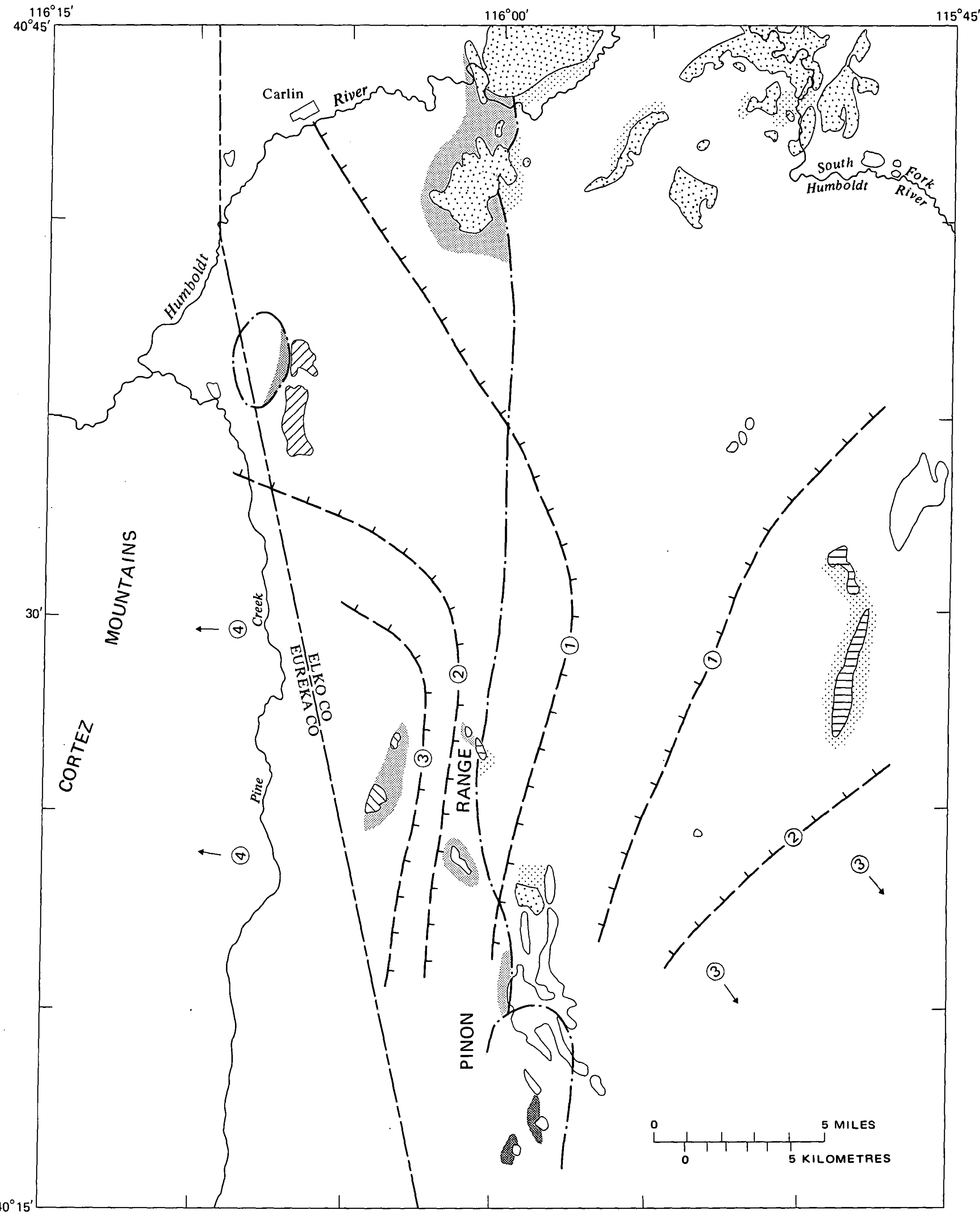


FIGURE 15. (above and facing page).—Outcrops and ages of basal beds of Upper Pennsylvanian and Permian rocks where their contacts with older formations are exposed, rock systems on which they were deposited, and possible positions of shorelines at four stages during their deposition.

EXPLANATION

Outcrop areas of upper Pennsylvanian and Permian rocks showing ages of basal beds where their contacts with older formations are exposed

Unit 4 – Upper Permian

Unit 3 – Lower Permian (post-Strathearn Formation)

Unit 2 – Lower Permian (upper Strathearn Formation and equivalent beds)

Unit 1 – Upper Pennsylvanian – Missourian and Virgilian series (lower Strathearn Formation and equivalent beds)

Permian: not well dated within system, or contacts with older formations not exposed

Possible positions of shorelines at stages 1 to 4 for units listed; hachures on seaward side. ④⟶ shoreline somewhere beyond direction of arrow

Rocks on which Upper Pennsylvanian and Permian sediments were deposited

Pennsylvanian rocks

Mississippian rocks

Devonian rocks in upper plate of Roberts Mountains thrust

Devonian rocks in lower plate of Roberts Mountains thrust

Approximate boundary of pre-Upper Pennsylvanian rocks at time of deposition of Upper Pennsylvanian and Permian sediments

Figure 15.—Continued.

UPPER PENNSYLVANIAN AND PERMIAN ROCKS UNDIVIDED

Units included in the undivided Upper Pennsylvanian and Permian rocks in the northern and northeastern parts of the mapped area are all Permian in age because they are younger than the Strathearn Formation, but in the southern part of the area, they span the entire Late Pennsylvanian and Early to early Late Permian time interval. The most characteristic lithologic types of this sequence are thin-bedded siltstone and sandstone that are calcareous in different amounts and that weather to

Section S12.—*Partial section of Strathearn Formation in N½ sec. 21, T. 33 N., R. 53 E., Carlin quadrangle*—Continued

	Feet
Lower Permean and Upper Pennsylvanian Series—Con.	
Strathearn Formation—Continued	
4. Limestone—Continued (colln. USGS f 20789) collected from bed 30 ft above base of unit, and *Globivalvulina*, Textularid, and *Triticites* (colln. USGS f 20790) collected 36 ft above base of unit	100
3. Sandstone, shaly, yellow	0.5
2. Limestone, conglomeratic with many scattered angular and rounded tan and black chert pebbles as much as 1 in. in diameter but mostly ¼ in. or less; pebbles decrease in number upward. Limestone is gray and tan, weathers mostly gray but outcrop appears rusty. Foraminifera—Late Pennsylvanian—*Globivalvulina*, *Bradyina*, Textularid, *Pseudofusulinella*, and *Triticites* (colln. USGS f 22522) collected from top of unit	2.5
1. Conglomerate of chert and quartzite pebbles similar to those in Diamond Peak Formation below; maximum pebble size is 2½ in.; matrix is sandy and limy; conglomerate fills channel cut into Diamond Peak beds below. Unit extends only about 20 ft along strike	3
Total thickness of incomplete Strathearn Formation section	702
Unconformity	
Mississippian System:	
Diamond Peak Formation	
Shale, yellow and purple; unit is about 10 ft thick, and underlain by interbedded conglomerate and shale.	

Section S12A.—*Section of the Strathearn Formation in sec. 27, T. 33 N., R. 53 E., on the north side of Carlin Canyon*

[Measured with tape and Brunton compass. Location of section shown by number on pl. 1. Foraminifera identifications by R. C. Douglass (written commun., 1970)]

	Feet
Permian System:	
Undivided rocks:	
Siltstone mostly, calcareous, platy; weathers tan and reddish tan; silty and sandy limestone.	
Contact between the Permian undivided rocks and Strathearn Formation below is gradational and is placed at the top of prominent outcrops of gray limestone.	
Permian and Pennsylvanian Systems:	
Strathearn Formation:	
9. Limestone, gray, sandy in part; interbeds of silty and sandy limestone and calcareous siltstone and sandstone; some thin limestone beds are mostly fossil hash of mainly bryozoans and crinoid columnals; some prominent brown beds up to 1 ft thick are composed mostly of granule-size chert grains; also some bands and nodules of brown chert. Good exposures along creek but generally poor on slopes between valleys	100
8. Sandstone and siltstone, some calcareous; beds break down into tan and reddish-tan pieces that cover slopes; also a few pieces of gray sandy limestone seen	165
7. Limestone, gray, sandy, and interbedded calcareous sandstone; similar to unit 5 below. Foraminifera—Early Permian (Wolfcampian)—elongate *Pseudofusulina* (colln. USGS f 23125) collected about 140 ft above base of unit and a slender elongate species of *Pseudofusulina* (colln. USGS f 23124) collected about 105 ft above base of unit	380

SECTION S12A.—*Section of the Strathearn Formation in sec. 27, T. 33 N., R. 53 E., on the north side of Carlin Canyon*—Con.

	Feet
Permean and Pennsylvanian Systems—Continued	
Strathearn Formation—Continued	
6. Limestone, gray, sandy, and interbedded calcareous sandstone; similar to unit 5 below except that gray limestone forms more massive outcrops along creek just east of line of section. A sedimentary breccia bed containing limestone blocks as much as 1 ft across is about 40 ft below top of unit	410
5. Limestone, gray, sandy, and interbedded calcareous sandstone, mostly tan and tannish gray, and weather tan; sand grains are mostly quartz of very fine size; beds appear to be 1 in. to 2 ft thick, although generally poor exposures preclude observation in most places; a few outcrops of massive gray limestone; sparse brown chert in bands and nodules; very locally, beds of granule-size chert grains are crossbedded. Noncalcareous sandstone and quartzite in beds 2-3 in. thick form less than 1 percent of unit. Local very fossiliferous beds contain brachiopods, bryozoans, crinoid columnals, and fewer gastropods	350
4. Limestone, gray, sandy, massive in part; conspicuous bands of brown chert 1 in. thick and 4-5 ft long; contains many silicified fossils including brachiopods, bryozoans, gastropods, and crinoid columnals. Forms prominent outcrop along line of section but is not continuous along slope	25
3. Limestone, gray and tan, sandy, and gray and tan calcareous sandstone; contains mostly well rounded fine grains of quartz; very fossiliferous in places with chiefly fragments of brachiopods and crinoid columnals. Slopes covered with rock fragments mostly 1 in. or less thick and several inches long, but some up to 3 in. thick; also many small reddish-brown platy fragments	380
2. Limestone, gray, chiefly massive, and pebble conglomerate forming dark-brown beds; pebbles are angular, composed of brown chert, mostly ¼-½ in. across, but as much as 1½ in.; conglomerate is well bedded in pockets up to 5 ft thick and 10 ft long	20
1. Limestone, light-gray; weathers light gray; sandy in part with medium and coarse grains of chert and rounded quartz; some grains are scattered through limestone, whereas others make up definite thin beds; some scattered angular chert pebbles up to ¼ in. in diameter are tan and brown and weather brown; chert occurs as a few nodules up to 2 in. across and as layers ½-1 in. thick and up to 4 ft long; some pods of brecciated chert are 2-3 ft across. Forms massive outcrops with beds 1/16 in. to 5 ft thick; definition of bedding is largely dependent on amount of quartz and chert grains in rock. Poorly exposed intervals between massive units are similar in lithology to the massive beds. Foraminifera—Late Pennsylvanian—*Triticites* sp. and scattered *Climacammina* sp. (colln. USGS f 23123) collected about 55 ft above base of unit	210
Total thickness of Strathearn Formation	2,040

Angular unconformity.

Note: The Strathearn Formation is unconformable on older formations throughout the area.

Mississippian System:

Diamond Peak Formation:

Conglomerate of quartzite and chert pebbles.

form yellow, tan, and reddish-tan platy fragments that litter the slopes in places. These carbonate rocks range from limestone to dolomite. Percentages of calcium and magnesium and the Ca/Mg molal ratios of represenative rock samples are given in table 15. The yellow calcareous siltstone, as seen in thin section, contains angular to subrounded quartz grains 0.01-0.02 mm in diameter and calcite grains 0.01-0.02 mm across, some carbonaceous material, and a small amount of iron-oxide stain. These undivided Upper Pennsylvanian and Permian rocks differ enough within the mapped area to warrant descriptions of major lithologic types for each general outcrop area.

NORTHERN PART OF AREA

In the north, gray limestone to dolomite occur in thin to thick beds and form prominent local outcrops; the limestone beds are very fossiliferous in places. Conglomerate and conglomeratic sandstone occur in scattered lenses and thin beds but are not as abundant as in the Strathearn Formation. Angular to moderately well rounded pebbles in the conglomerate are mostly less than 1½ inches in diameter and are composed of chert and quartzite and some silicified limestone. Some sandstone beds contain white, gray, green, tan, and red angular grains of chert, but many beds contain almost entirely fine to medium quartz grains. These quartz grain sandstones are distinctive and differ from the earlier Pennsylvanian and older sandstones which commonly contain a mixture of chert and quartz grains. Gray and tan chert in thin layers and nodular bodies are prominent locally but make up a very small fraction of the total section, except in the upper 950 feet in the northern part of the area, where much chert forms prominent outcropping bands as much as 15 feet thick. Much of this chert appears to be silicified limestone. These Permian rocks in the northern and northeastern parts of the area were described by Dott (1955, p. 2256-2261) and Fails (1960).

Two stratigraphic sections measured north of the eastern part of Carlin Canyon (sections S13 and S14, pl. 1) present descriptions of most of the undivided Permian rocks in the northern part of the report area. Allowing for slight overlap of the two sections, this sequence has a total measured thickness of about 3,065 feet. Still younger Permian rocks are exposed north and northeast of the mapped area.

SOUTHERN PART OF AREA

Upper Pennsylvanian and Permian rocks undivided in the southern half of the area are equivalent to both the Strathearn Formation and to the younger Permian rocks in the north. Most of the exposed Strathearn-equivalent beds crop out in sec. 22, T. 29 N., R. 53 E., where they make up about the lower 1,400 feet of a total exposed

TABLE 15.—*Analyses, in percent, of calcium and magnesium and Ca/Mg molal ratios of some Upper Pennsylvanian and Permian rocks*

[Analyst: James A. Thomas. Percentages indicated by weight. Ca and Mg are reported as the element. Methods of analysis are accurate within ±3 percent. All samples except SR-88, −196, and −238 are arranged in descending stratigraphic order]

Sample No. (SR−)	Locality		Total calcium carbonate	Ca/Mg molal ratio	Ca	Mg	Classification in calcite-dolomite-clay series of Guerrero and Kenner (1955, p. 46)[1]
Samples from measured stratigraphic sections							
Permian undivided							
	Measured						
	Section	Unit					
205......	14	21	24.3+	100	9.7	Tr.	Calcitic clay.
202......	14	16	21.5	3.17	6.8	1.3	Dolomitic limy clay.
201......	14	10	35.4	1.20	8.3	4.2	Calcitic dolomitic marl.
199......	14	3	73.8	100	29.5	Tr.	Marl.
194......	13	27	81.0	1.16	18.8	9.8	Marly dolomite.
193......	13	24	26.3	1.21	6.2	3.1	Calcitic dolomitic marl.
190......	13	16	45.2	1.11	10.3	5.6	Dolomitic marl.
189......	13	16	41.2	3.15	13.0	2.5	Dolomitic limy marl.
188......	13	14	91.9	1.09	20.8	11.5	Marly dolomite.
187......	13	12	45.9	2.63	13.9	3.2	Calcitic dolomitic marl.
186......	13	12	65.6	1.19	15.4	7.8	Dolomitic marl.
184......	13	8	35.2	3.43	11.3	2.0	Dolomitic limy marl.
Strathearn Formation							
198......	12	7	83.3+	100	33.3	Tr.	Marly limestone.
Time equivalent to Strathearn Formation; from southern part of area							
238......	11B	5	33.2	3.88	10.9	1.7	Dolomitic limy marl.
Samples from localities other than measured stratigraphic sections							
Permian undivided							
88.......	Center N½ sec. 16, T. 32 N., R. 53 E.		47.8	1.12	10.9	Tr.	Dolomitic marl.
196[2].....	SE¼ sec. 16, T. 33 N., R. 53 E.		16.8+	100	6.7	Tr.	Calcitic clay.

[1]This assumes that the insoluble fraction is clay size; some of it is silt size.
[2]Tan and yellow platy calcareous siltstone; a common rock type above the Strathearn Formation.

thickness of 2,210 feet in the following measured section (S11B).

Strata in the upper 800 feet of measured section S11B are equivalent to the undivided Permian strata farther north and similar in lithology except for being less calcareous. These beds in the area of section S11B consist mostly of thin-bedded gray, tan, and red siliceous siltstone that weathers to brown, tan, and reddish-tan platy fragments. No limestone was noted in the top 600 feet of this section, but gray limestone and sandy limestone units as much as 50 feet thick crop out southeast of the line of section in rocks equivalent to those in the upper part of the section or slightly above. These limestones are very fossiliferous, but many fossils are poorly preserved. A few beds in this general area are conglomeratic and contain pebbles of chert and quartzite. The east edge of these exposures in the SE¼ sec. 22, T. 29 N., R. 53 E., is composed of a band of brown-weathering rocks that form a prominent outcrop extending up the ridge to the north. The beds are largely quartzite, siltstone, and conglomerate, and are silicified in places. They have aberrant dips in relation to beds to the west, truncate these beds to the west, and must be near or along a fault. Clasts in the conglomerate are mostly angular pieces of quartzite and silicified siltstone.

Isolated outcrops of Permian rocks northwest of measured section S11B are mainly equivalent to post-Strathearn beds farther north and are successivly younger westward, as shown in figure 16. The Permian strata in the W½ sec. 17, T. 29 N., R. 53 E., are thin-bedded brown, tan, and yellow calcareous fine-grained sandstone and some sandy limestone that are similar to undivided Permian rocks north of Carlin Canyon, particularly to the yellow beds in the NE¼ sec. 21, T. 33 N., R. 53 E.

Farther north in secs. 28 and 33, T. 30 N., R. 53 E., Permian rocks in two small areas are mostly equivalent to post-Strathearn rocks in the northern part of the report area, although one fossil collection suggests that the oldest beds may be equivalent to the upper part of the Strathearn. Gray limestone, sandy limestone, sandstone, and conglomerate comprise the Permian strata in these two small areas. Some of the limestone is very fossiliferous. In places, these rocks are silicified. The Permian units seem to have both unconformable

SECTION S13.—*Partial section of Strathearn Formation and Permian undivided in NW¼ sec. 24 and S½ sec. 13, T. 33 N., R. 53 E.*

[Measured with Abney level on Jacob staff and Brunton compass and steel tape. Location of section shown by number on pl. 1. Foraminifera identifications and age determinations by R. C. Douglass (written commun., 1962); collections from base through unit 11 are of Early Permian age (possibly Wolfcampian) and those from unit 12 and above are slightly younger (possibly early Leonardian). Therefore, in this section, the Strathearn Formation and about the lower 850 ft of the overlying undivided Permian is Early Permian and equivalent to the Wolfcampian]

	Feet
Top of section covered.	
Permian rocks undivided:	
29. Chert, light-brown; weathers yellowish brown; in beds 1-3 ft thick; all probably silicified limestone. A gray limy bed at top is partly silicified	25
28. Covered on back slope of hill; 60 ft above base of unit is an outcrop of gray limestone, above which float pieces are chiefly plates of tan silty limestone	175
27. Dolomite, calcitic, to limestone, dolomitic, gray; weathers gray; thin bedded; many very thin beds and laminae 1/16-¼ in. thick form prominent banded outcrop; some beds are as much as 1 ft thick; contains small oval chert nodules about 3 in. long and a few thin beds of chert. At top of unit is a tan and brown limestone, weathering gray and containing gastropods and brachiopods that show in cross section on weathered surfaces. Unit forms massive outcrop at top of hill	30
26. Covered; float pieces of tan platy calcareous siltstone	28
25. Limestone, gray, silty; dolomitic in places; interbedded tan chert in layers 1-12 in. thick; in places chert is dominant. Forms prominent banded outcrop. This unit is probably correlative with unit 1 in stratigraphic section 14 to the west	20
24. Siltstone, tan and yellow, calcareous; weathers tan and yellow; thin bedded and platy; slightly nodular in places; specimen from one typical bed is seen in thin section to consist of carbonate and quartz grains mostly less than 0.008 mm across; some carbonate grains are recrystallized; carbonate grains are composed mostly of calcite and minor dolomite; trace of iron oxide minerals. Near base of unit is a 1-ft-thick bed of gray dense dolomitic limestone. Bands of chert 1 ft thick near top of unit. Sequence is poorly exposed	51
23. Limestone, gray, dense, massive; sugary texture in places; contains scattered chert grains mostly 1/16 in. or less in diameter in basal 2 ft of unit; some podlike lenses of yellow calcareous siltstone 4 ft thick and 10 ft long like siltstone in unit 22. Contains discontinuous chert layers as much as 1 ft thick	38
22. Siltstone, tan and yellow; weathers tan and yellow; very calcareous	8
21. Sandstone, calcareous, medium- to coarse-grained, poorly sorted; contains gray, green, tan, white, and red angular chert grains; beds seem to be about 1½ ft thick but not well exposed. One 4-in.-thick layer is red calcareous sandy siltstone	8
20. Covered; probably calcareous sandstone and conglomeratic sandstone	37
19. Conglomerate, pebbles are mostly ¼ in. in diameter with scattered pebbles as much as 1½ in.; beds are 2-12 in. thick; pebbles are gray, tan, and white chert and angular to moderately well rounded; some pebbles of white siliciifed limestone are similar to silicified limestone lower in section; matrix is medium- to coarse-grained calcareous sandstone	15

SECTION S13.—*Partial section of Strathearn Formation and Permian undivided in NW¼ sec. 24 and S½ sec. 13, T. 33 N., R. 53 E.*—Continued

	Feet
Permian rocks undivided—Continued	
18. Covered; probably conglomeratic beds similar to those in unit 19 above	25
17. Sandstone, light-gray and tan; weathers darker tan and brown; very calcareous to slightly calcareous, fine grained; occurs in beds 2 in.-2 ft thick; some calcareous siltstone beds; coarser grained beds seem to be more calcareous than finer grained ones; lenticular conglomeratic beds contain pebbles of gray and brown chert mostly about ¼ in. in diameter, but some are as much as 1 in. across. Forms prominent brown unit on slopes	20
16. Limestone, dolomitic, and dolomite and calcareous siltstone; similar to unit 15 below, but contains more limestone and siltstone; a few gray and tan chert layers 2 in. thick. Forms good local outcrops	15
15. Limestone, dolomitic, and dolomite; both are tan to light gray and weather tan and yellow; beds are chiefly ½-2 in. thick with a few up to 1 ft thick; some gray limestone weathers gray and forms ½-in.-thick plates; unit contains some silty beds and calcareous mudstone and siltstone. Sparse fragments of chert suggest less than 1 percent chert. Slope is mostly covered by platy fragments; there are some prominent outcrops. Foraminifera—Early Permian (late Wolfcampian to Leonardian)—Textularid, Schubertellid, and *Schwagerina* near *Parafusulina* (colln. USGS f 22520 and f 22521) collected near line of measured section from correlative beds about 130 ft above base of this unit	215
14. Dolomite and dolomitic limestone, gray and tan; weather chiefly gray; thin bedded in lower 8 ft; massive gray dolomite above; sandy in part; contains some chert pods and stringers as much as 3 ft long and 2 in. thick. Many silicified crinoid columnals and bryozoans in upper 3 ft. Unit forms prominent local outcrop	22
13. Limestone, dolomitic, dense, grayish-tan; weathers tan; well stratified in beds 2-4 in. thick; some sandy beds	12
Section offset: Section was measured across axis of syncline and projected across valley; because specific beds could not be traced or correlated, as much as 50 ft of section may be lost in transfer.	
12. Siltstone, chiefly, and very fine grained sandstone; both are calcareous; tan, yellow and some red, weathers to same colors; only a few outcrops seen, but float is mostly irregularly shaped plates and chips 4-6 in. across with some as small as ½ in. across; red pieces are generally less than 2 in. across. Upper part of unit contains some dolomite and dolomitic limestone, some of which is sandy or silty; some carbonate rock is coarsely crystalline or dense and thin bedded; makes rough rubbly surface on steep slopes. In upper half of unit beds are generally 2-4 in. thick and very fossiliferous, containing particularly crinoid hash and bryozoans; these beds are lenticular with maximum thickness of 1 ft. Foraminifera—Early Permian (late Wolfcampian to Leonardian)—Textularid and *Schwagerina* or early *Parafusulina* (colln. USGS f 22519) collected about 270 ft above base of unit	420

SECTION S13.—*Partial section of Strathearn Formation and Permian undivided in NW¼ sec. 24 and S½ sec. 13, T. 33 N., R. 53 E.*—Continued

	Feet
Permian rocks undivided—Continued	
11. Limestone, gray; weathers gray; some platy; chertlike bands are actually limestone silicified on weathered surface only; contains crinoid columnals and corals silicified on weathered surfac only. Foraminifera—Early Permain (late Wolfcampian to Leonardian)—Textularid, Schubertellid (or *Boultonia*), Staffelid, and *Schwagerina* (colln. USGS f 22518) collected at base of unit	20
10. Similar to unit 8	54
9. Limestone, gray; weathers gray; generally massive, in beds 2-3 ft thick and a few thin gray or brown beds 1/16 in. thick. Some limestone, particularly near base of unit, is crystalline and contains many fossil fragments, especially recrystallized crinoid columnals; upper 30 ft of unit is not as crystalline as lower part and contains fewer fossil fragments. Light-brown chert layers 1-2 in. thick and 2-8 ft long and chert pods 2-4 in. across and 6-8 in. long. Poorly exposed slopes between prominent outcrops probably are underlain by sandy limestone	62
8. Siltstone, chiefly, and very fine grained sandstone; thin bedded and platy; ranges from calcareous siltstone to silty limestone; tan, yellow, and red; weathers to same colors. Slopes are mostly float covered with plates and chips generally 4-6 in. across, but some only ½ in.; red pieces are generally less than 2 in. across	705
Total thickness of incomplete Permian undivided	2,005

Conformity:

Note: Contact between Strathearn Formation and overlying Permian undivided is gradational; top of Strathearn is at top of exposed massive gray limestone, above which float consists of plates and chips of tan, yellow, and red sandy and silty limestone.

	Feet
Lower Permian and Upper Pennsylvanian Series:	
Strathearn Formation:	
7. Limestone, gray, weathers gray, massive; cleaner limestone than most limestone below; fossil fragments in places. Fusulinids—Textularid and *Schwagerina* (colln. USGS f 22517) collected 8 ft above base of unit	30
6. Covered mostly; float of gray limestone and sandy limestone	96
5. Limestone, gray; weathers gray; sandy with fine-grained angular quartz grains, in places contains rounded medium quartz grains; beds 1 ft thick and massive units 10-15 ft thick with no distinct bedding; contains some 6- to 12- in.-thick beds of cream-colored gray-weathering crystalline limestone. Fusulinid—Early Permian (Wolfcampian)—Textularids, *Schubertella*, and *Pseudofusulina* (colln. USGS f22515) collected from a 1-ft-thick bed 25 ft above base of unit and *Tetrataxis*, *Pseudofusulina*, and *Schwagerina*? (colln. USGS f22516) collected from a 2-ft-thick bed 108 ft above base of unit. Most of slope between the two fusulinid-bearing beds is covered	110
4. Limestone, gray and tan; weathers gray and tan; sandy; in beds generally 1-12 in. thick that are crossbedded in places; fine- to coarse-grained, fine grains are mostly quartz and coarse grains are mostly chert; some beds contain fossil fragments. Limestone crops out in ledges 3-5 ft thick but about 70 percent of slope is float covered	110
3. Limestone, gray; weathers gray; sandy and pebbly; contains layers of chert pebbles and many silicified fragments of bryozoans, brachiopods, and crinoid columnals. Unit contains some relatively clean limestone	7
2. Limestone, tan and gray; weathers brown and gray; sandy, and some fine-grained sandstone; thin bedding and crossbedding in layers generally 1-2 ft thick. Angular pebbles of tan and gray chert form prominent layers 1 in. thick; granules scattered through some 1-ft-thick beds. Upper 30 ft is poorly exposed and covered chiefly with float of fine-grained quartz sandstone	74
1. Covered; float of gray limestone	11
Total thickness of incomplete Strathearn Formation	438

Contact is a fault that cuts out lower part of Strathearn Formation.

Pennsylvanian System:

Tomera and Moleen Formations undivided:

Conglomerate of chert and quartzite pebbles and cobbles; weathers brown.

and fault contacts with Mississippian and Pennsylvanian units, but true relations along all contacts are difficult to determine because of rubble-strewn slopes.

Figure 16 demonstrates the magnitude of the post-Middle Pennsylvanian unconformity whereby Upper Pennsylvanian beds rest on Middle Pennsylvanian ones in the eastern exposure and Lower Permian beds rest on Mississippian ones in the western exposure.

The westernmost outcrops of Permian rocks in the southern part of the report area are in sec. 25, T. 30 N., R. 52 E., and in sec. 2, T. 29 N., R. 52 E. These beds are equivalent to the youngest Permian rocks north of Carlin Canyon based on the occurrence of *Punctospirifer* sp. both here (colln. USGS 17268, No. 104 on pl. 1) and in unit 7 of measured stratigraphic section S14. The sequence in sec. 25 consists of gray limestone, tan and yellow sandy and silty limestone, limy siltstone, and conglomerate. The silty and sandy beds weather to form platy fragments and are similar to units in post-Strathearn-equivalent beds north of Carlin Canyon. This southern *Punctospirifer*-bearing sequence differs from the sequence north of Carlin Canyon in that it contains conglomerate and lacks tan and brown chert. The conglomerate is made of clasts of quartzite and chert and occurs in units as much as 30 feet thick. It is indistinguishable from conglomerate in underlying Lower

SECTION S14.—*Partial section of upper part of Permian undivided in SE¼ sec. 14 and SW¼ sec. 13, T. 33 N., R. 53 E.*

[Measured with Abney level on Jacob staff. Location of section shown by number on pl. 1]

Top of section ends on downthrown side of normal fault.

	Feet
Permian System:	
Youngest Permian rocks in north part of mapped area:	
21. Covered mostly; small float pieces of siltstone and chert; scattered float pieces of gray limestone in upper 50 ft. About 275 ft above base of unit is a thin-bedded calcareous siltstone and silty limestone bed with some small-scale crossbedding. About 150 ft above base is much float of yellowish-gray or light-brown gray-weathering dense limestone	380
20. Chert, tan and brown, in layers 2-12 in. thick; unit forms prominent outcrop band	15
19. Limestone, siltstone, and some chert	16
18. Chert	2
17. Float pieces of tan platy limestone, which weathers tan, and of siltstone, and some chert	25
16. Siltstone, calcareous and dolomitic, weathers yellow, and siliceous siltstone; seem to occur in alternating beds 1-3 ft thick but poorly exposed; mostly float cover	90
15. Chert, chiefly, and siliceous siltstone; few good outcrops, but most beds appear to be 2-12 in. thick	65
14. Chert and siltstone interbedded in layers 2-3 ft thick	65
13. Chert	3
12. Siltstone similar to unit 10 below	5
11. Chert, tan and some red	4
10. Siltstone, yellowish-gray; weathers tan and yellow; dolomitic; occurs in layers generally ½ in. thick; forms platy fragments 4-10 in. across. In thin section siltstone seen to consist of quartz grains mostly less than 0.02 mm in diameter but a few grains 0.05 mm; in addition, about 35 percent dolomite grains 0.005-0.02 mm across	25
9. Siltstone, tan and yellow, calcareous; weathers to form platy pieces; conspicuous bands of tan and brown chert 1-3 ft thick are spaced about every 5-10 ft through unit	60
8. Limestone, gray; weathers gray; contains small crinoid columnals, bryozoans, and small brachiopods that are silicified on weathered surfaces and weather brown	3
7. Limestone, yellow and tan; weathers yellow and tan; fossiliferous. Unit contains Late Permian brachiopods (*Punctospirifer* sp., identified by M. Gordon, Jr.), clams (myolinids), bryozoans, and gastropods (colln. 61G150)	2
6. Covered; float of 1 to 3-in.-thick platy fragments of tan and yellow siltstone and scattered pieces of chert	30
5. Covered; float of brown and tan angular pieces of chert and few platy fragments of silty limestone and calcareous siltstone; chert and silty rocks are probably interbedded	25
4. Covered; float of tan and yellow calcareous siltstone in pieces mostly 1 in. or less across	60
3. Limestone, yellowish-gray; weathers light gray; thin bedded, some beds are faintly crossbedded; forms plates mostly ¼-½ in. thick that litter surface	30
2. Covered; float of small plates of yellow to tan calcareous siltstone	30
1. Limestone, silty, gray; weathers light gray; pods and layers of chert 2 in.-1 ft thick; amount of chert in unit differs along strike; locally rock is well banded with alternating limestone and chert in layers 2-6 in. thick. This unit is probably correlative with unit 25 in stratigraphic section S13 to east	15
Total thickness of incomplete youngest Permian rocks	950

SECTION S11B.—*Partial section of undivided Upper Pennsylvanian and Permian rocks in sec. 22, T. 29 N., R. 53 E.*

[Measured with Brunton compass and steel tape. Location of section shown by No. S11B on pl. 1]

	Feet
Pennsylvanian System:	
Conglomerate.	
Fault.	
Permian and Pennsylvanian Systems undivided:	
9. Siltstone, very light gray, tan, and reddish-tan, siliceous; no outcrop; slope covered mostly with flat irregularly shaped pieces that are generally 1-2½ in. across with some larger pieces and a few chunky pieces	610
8. Limestone and siltstone, mostly gray; weather brown and tan, silicified. Basal 10 ft is prominent outcrop and remaining 190 ft is slopes mostly covered with small hard tan and red pieces of calcareous siltstone. Beds appear to be 2-6 in. thick although bedding is generally obscured. Silicified Permian fossils studied by R. C. Douglass include Textularid, *Schubertella* sp., *Schwagerina* sp., *Parafusulina* sp., and bryozoans (colln. USGS f 22533 collected from silicified limestone 5 ft above base of unit; according to Douglass the fusulinid fauna is equivalent to those above the Strathearn Formation and probably correlates with late Wolfcampian to Leonardian interval farther north. Silicified brachiopods, corals, and crinoid columnals occur along bedding surfaces on float pieces in upper part of unit	200
7. Siltstone, calcareous, tan and brown; weathers to same colors and breaks into small chunky and platy pieces. Small pieces of brown chert are scattered on slope. Unit is probably equialent to top of Strathearn Formation	155
6. LImestone, black; weathers tan; platy; silty in places and sandy in places; slope covered with platy fragments mostly ¼-½ in. thick and a few blocky pieces; bedding as thin as 1/16 in. seen on small fragments. Small fragments of brown chert are on slope but do not crop out. Poorly preserved brachiopods occur in float in places; a 1-in.-thick limestone layer 130 ft above base of the unit contains many crinoid columnals and bryozoans	145
5. Limestone, black, platy, and platy calcareous siltstone and shale; platy beds about ¼ in. thick; mostly limestone in lower 75 ft of unit; black siltstone that weathers tan increases in amounts above lower 75 ft; some pieces of black chert about 2 in. thick are scattered on slope. Small brachiopods occur locally in lower 150 ft	415
4. Sandstone, fine-grained, and siltstone, light gray and tan with pink cast in places; in laminae mostly about 1/32 in. thick; weather to form slope covered with	

SECTION S11B.—*Partial section of undivided Upper Pennsylvanian and Permian rocks in sec. 22, T. 29 N., R. 53 E.*—Con.

	Feet
Permian and Pennsylvanian Systems—Continued	
4. Sandstone—Continued pinkish-gray and tan platy and blocky fragments. Fossils collected from lower part of unit, but more than 85 ft above the base, include *Triticites* sp., cystodictid bryozoan, productid, *Wellerella* sp., and *Crurithyris* sp. (colln. USGS 17270), identified by M. Gordon, Jr., and R. C. Douglass. They consider this fauna to be Late Pennsylvanian to Early Permian in age, and most likely Late Pennsylvanian on the basis of fusulinids	480
3. Quartzite, sandstone, siltstone, and a few conglomeratic beds; all mostly silicified; weather red and brownish red; unit contains some silicified limestone	90
2. Dolomite and limestone in about 1:1 ratio; both are light gray and weather gray and are fine grained	30
1. Sandstone, conglomerate, and conglomeratic sandstone. Upper part covered mostly by float of brown sandstone and conglomeratic sandstone; a 2-ft-thick conglomerate bed is made up of tan, green, brown, black, and red chert and some quartzite pebbles and cobbles as much as 5 in. across; it is underlain by a 3-ft lens of gray dolomitic limestone which is underlain by about 6 ft of sandstone which grades downward into about a 3-ft-thick conglomerate. In this conglomerate, which is at the base of the section unit, clasts are tan, green, and gray chert of about 3 in. maximum diameter but mostly 1 in. or less; a few clasts are of quartzite and as large as 4 in.; some black chert and platy limestone clasts are similar to some limestone in the Pennsylvanian rocks below; one cobble of gray limestone containing a chert nodule also is similar to some limestone in the Pennsylvanian below; the clasts are angular to round; the conglomerate is well bedded and noncalcareous. Exposures of this unit are not good continuously, and its beds are probably mostly lenticular	85
Total thickness of incomlete section of undivided Permian and Upper Pennsylvanian rocks	2,210
Unconformity.	
Pennsylvanian System:	
Moleen Formation	

Mississippian strata. Silicified fossils are locally abundant in limestone in the lower part of the Permian sequence. Much white calcite occurs near the southwesternmost part of the Mississippian-Permian contact and near the range front fault. The contact here is not a fault, however, and presumably the calcite is related to the frontal fault.

The most extensive exposures of Permian rocks that are of essentially the same lithology in the southern part of the mapped area extend south from the NW¼ sec. 27, T. 29 N., R. 53 E., to within 1½ miles of the south edge of the area. Conglomerate is the dominant lithology cropping out, but sandstone and clastic limestone also form significant parts of the sequence, and gradations occur between all three lithologic types. Rocks equivalent in age to these strata range from post-Strathearn Formation rocks dated on fusulinids from collection USGS f12467 (No. 106 on pl. 1) to possibly as old as the Pennsylvanian and Permian systemic boundary or about medial Strathearn dated on fusulinids from collection USGS f12468 (No. 105 on pl. 1).

The conglomerate is much like conglomerate units in nearby Mississippian and Pennsylvanian beds, but the associated lenses of clastic limestone serve to distinguish the Permian strata as a whole from the older rocks. Most of the conglomerate clasts are quartzite and chert of various colors and range in size from pebbles to boulders as much as 1½ feet in diameter. The matrix is sandstone. Also, in some places, the conglomerate contains pebbles and cobbles of siltstone, sandstone, limestone, and silicified limestone that are similar to Upper Pennsylvanian and basal Lower Permian rocks found elsewhere in the mapped area, to suggest that some of the clasts were derived from these older beds.

Layers and lenses of sandstone occur with the conglomerate. Bedding in the sandstone ranges in thickness from about 1 inch to several feet. Most of the sandstone consists of quartz grains, but some consists of quartz and chert grains ranging in size from fine sand to grit. Most commonly the cement is calcareous. Sandstone that differs markedly in color from other Permian sandstones crops out in the S½ sec. 10 and the NE¼ sec. 15, T. 28 N., R. 53 E. It is maroon and very thin bedded with partly platy fragments up to 1½ inches thick littering the surface over these beds. This sandstone consists mostly of fine grains of quartz and scattered well-rounded coarse grains of quartz. Presumably, this sandstone grades into, and interfingers with, conglomerate northward.

The sequence of prominent conglomerate seems to have both unconformable and fault contacts with other units. Permian beds in secs. 27 and 28, T. 28 N., R. 53 E., appear to rest unconformably on Devonian rocks of the carbonate or eastern assemblage. Other contacts between this Permian sequence and older rocks either are faults or they are concealed by surficial materials. Two factors suggest that much of the conglomerate sequence has a fault relation with the mostly nonconglomeratic Upper Pennsylvanian and Permian sequence represented by measured section S11B in sec. 22, T. 29 N., R. 53 E., as follows: (1) The two sequences contrast more sharply in lithology than is normal for the mapped area but are very close spatially, and their contained fusulinid faunas overlap in age, and (2) the conglomerate sequence is structurally discordant with the other sequence and has more complex internal structure. The conglomerate exposed on the narrow ridge in sec. 27, T. 29 N., R. 53 E., would lie stratigraphically above the beds of measured section S11B in sec. 22 to the north if the succession were normal. The conglomerate, however,

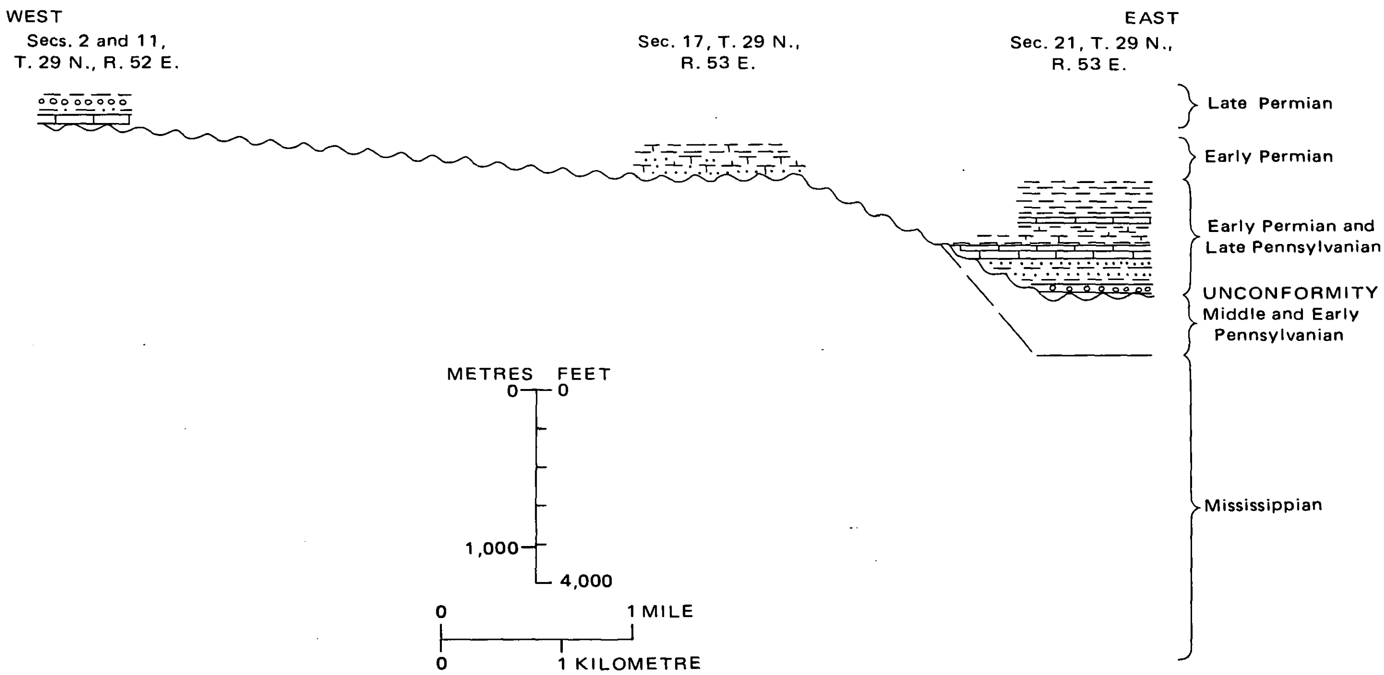


FIGURE 16.—Westward onlap of Upper Pennsylvanian and Permian rocks in southern part of Carlin-Pinon Range area.

has steep dips and small tight folds, and thus, is discordant structurally with the other rocks which dip homoclinally southwestward. The more complex structure in the presumed younger conglomerate beds suggests that they may have been moved into their present position on a thrust fault. If so, the magnitude and direction of the thrusting are not known, but inferred paleogeographic conditions suggest that this conglomerate sequence was deposited farther west.

COLE CREEK AREA

Permian strata crop out in the northwestern part of the mapped area on Cole Creek and in a belt extending south from there to the creek east of Red Springs. Fusulinids collected from near the base of the map unit along Cole Creek indicate that the oldest part of this sequence is Early Permian in age and is equivalent to the uppermost part of the Strathearn Formation. This sequence near Cole Creek demonstrates abrupt changes in lithology due to gradational and interfingering relations between conglomerate and finer grained rocks. Such abrupt changes are characteristic of Upper Pennsylvanian and Permian rocks in the Carlin-Pinon Range area. The beds along Cole Creek consist mostly of tan, tan- and yellow-weathering platy-splitting thin-bedded limestone and silty limestone. Lenses of sandstone and conglomerate containing quartzite, chert, and limestone pebbles to boulders are interbedded with the limestone; these more coarsely clastic units commonly weather purple and resemble beds in the Chainman Shale and Diamond Peak Formation sequence. Southward, the percentage of quartzite and chert clast conglomerate increases in the Permian section, and north of the valley east of Red Springs, several hundred feet of mostly conglomerate is between limestone and sandstone units. Conglomerate of a different kind occurs locally in the western exposures just south of Cole Creek. It is made of angular fragments of tan siltstone and dolomitic siltstone that were probably derived from the nearby Woodruff Formation.

Permian rocks lie unconformably on Mississippian rocks in the area near Cole Creek and Red Springs. They also appear to be unconformable on the Woodruff Formation for a short distance in the N ½ sec. 4, T. 31 N., R. 52 E.; here the Permian beds at the depositional contact are several hundred feet above the base of the Permian section farther east up Cole Creek. Hence, a hill of older rocks was present at this locality during deposition of the Permian. The conglomerate containing fragments of Woodruff siltstone also suggests proximity to a hilly area.

AGE AND CORRELATION

These Upper Pennsylvanian and Permian rocks range in age from possibly Missourian to Guadalupian, based on our fossil collections. This confirms the age assigned to this sequence by Dott (1955, p. 2254-2255, 2260-2261). Our collections were made along the lines of measured stratigraphic sections and from widely scattered localities in the mapped area. They include Foraminifera, chiefly fusulinids, ostracodes from one locality, and megafossils from several localities. Collections made from units within our measured sections are listed in sections S11B, S12, S12A, S13, and S14 in this report.

The Foraminifera were studied by R. C. Douglass

TABLE 16.—*Late Pennsylvanian Foraminifera from lower part of Strathearn Formation and equivalent beds*

[Identifications by R. C. Douglass, except for colln. f12357 identification, which was by L. G. Henbest]

Locality No. on pl. 1	([1])	([2])	117	118	([3])	([3])	([3])	([3])	([3])	([3])	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133
USGS fossil colln. No.	f17270	f23123	f20794	f12357	f20793	f20792	f20791	f20790	f20789	f22522	f22527	f22524	f22525	f22523	f21817	f21672	f21816	f21678	f20788	f22532	f21799	f21803	f21807	f20776	f21808
Endothyra or *Globivalvulina* sp.				×																					
Endothyrid									×																
Bradyina sp.										×	×	×	×			×									
Textularid							×	×	×	×	×	×	×	×											
Climacammina sp.		×																							
Globivalvulina sp.								×		×															
Tetrataxis sp.									×				×	×		×									
Millerella sp.														×											
Millerellid					×													×							
Schubertella											×	×		×											
Schubertellid						×			×																
Kansanella? sp.											×														
Triticites sp.	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×		
Triticites or *Pseudofusulina* sp.				×																					
Barthramella? sp.																						×			
Pseudofusulinella sp.										×		×				×									
Pseudofusulinella? sp.																							×	×	×
Pseudofusulinella or *Schubertella* sp.				×																					

[1]Measured section S11B. [2]Measured section S12. [3]Measured section S12A.

(written commun., 1963), who related the isolated collections to those from the measured sections. He separated the fusulinid assemblages into four major age groups: (1) Late Pennsylvanian, lower Strathearn Formation equivalent; (2) latest Pennsyvlanian(?) to Early Permian (Wolfcampian), middle Strathearn equivalent; (3) Early Permian (Wolfcampian), upper Strathearn equivalent; and (4) Early Permian (probably late Wolfcampian to Leonardian), post-Strathearn equivalent (tables 16-19). The Strathearn Formation thus ranges in age from Late Pennsylvanian (Virgilian and probably Missourian) to Early Permian (Wolfcampian). This breakdown, except for the youngest Permian rocks, is the basis for the age groupings shown in figure 15. *Triticites* is the most abundant and diagnostic fusulinid in the lower part of the Strathearn Formation and its equivalent rocks. The lithology and thickness of the Strathearn Formation and the undivided Upper Pennsylvanian and Permian rocks and the positions of fossils are shown graphically in three measured stratigraphic sections on plate 2.

We found no fusulinids in the upper 1,200 feet of the exposed Permian rocks but did collect brachiopods, clams, bryozoans, and gastropods from beds about 450 feet below the top of these strata. (See unit 7 in measured section S14.) Diagnostic brachiopods identified as *Punctospirifer* n. sp. by Mackenzie Gordon, Jr., also occur in the Permian rocks that crop out to the south in secs. 25 and 26, T. 30 N., R. 52 E., and in the NW¼ sec. 11, T. 29 N., R. 52 E., and is regarded by Gordon (written commun., 1958) as indicative of the Late Permian of this region. Fails (1960, p. 1700-1702) also reported pelecypods and gastropods from his Carlin Canyon Formation, the youngest Permian unit that he recognized in the general area north of Carlin Canyon.

Widely scattered fossil collections were made to confirm Late Pennsylvanian or Permian ages for some groups of beds or to establish the age of a series of beds in the sequence. Megafossils were identified by Mackenzie Gordon, Jr., and most of the microfossils, by R. C. Douglass.

Several collections from the area of sec. 22, T. 29 N., R. 53 E., are useful in establishing the age range of the beds there. Collection USGS 17273-PC (No. 107 on pl. 1) contains horn corals and the brachiopods *Linoproductus* (*Cancrinella*) sp., *Pugnoides* sp., and *Crurithyris* sp. of Late Pennsylvanian or Early Permian age (Gordon, written commun., 1958). This collection is about 1,500 feet stratigraphically above the base of the sequence. Two other collections from beds that occupy approximately that same stratigrahic position are considered by Gordon as Early Permian in age. These two collections are USGS 17271-PC (No. 108 on pl. 1) in the NW¼NE¼ sec. 27, T. 29 N., R. 53 E., which contains *Pseudofusulina*? sp., stenoporoid bryozoans, rhomboporoid bryozoans, crinoid columnals, Strophomenid indet., *Linoproductus* sp., *Pustula* sp., *Spirifer* sp., *Hustedia* sp., and *Cleiothyridina* sp., and USGS 17272-PC (No. 109 on pl. 1) in the SW¼ sec. 22, T. 29 N., R. 53 E., which contains *Pseudofusulina*? sp., stenoporoid bryozoans, rhomboporoid bryozoans, *Cystodictid*? bryozoans, *Dictyoclostus* sp., *Linoproductus* sp., *Rhipidomella* sp., *Crurithyris* sp. and brachiopod indet. According to Douglass (written commun., 1963), the fusulinids in collection 17272-PC date these beds as Early Permian and equivalent to post-Strathearn rocks.

Five collections from the westernmost exposures of Permian rocks between South Fork Trout Creek and

TABLE 17.—*Pennsylvanian(?)-Permian Foraminifera from middle part of Strathearn Formation and equivalent beds*

[Identifications by R. C. Douglass]

Locality No. on pl. 1	134	105	135	136	137	138	139	140	141	142	143	144	145
USGS fossil colln. No.	f12466	f12468	f21818	f21673	f21679	f21675	f21800	f21792	f21806	f21809	f21793	f21802	f21805
Bradyina sp.		×		×	×								
Climacammina sp.		×											
Climacamminid					×	×							
Tetrataxis sp.				×									
Schubertella sp.							×				×		
Schubertellid						×							
Triticites sp.	×	×								×			
sp. aff. *T. ventricosus*							×						
?*Triticites* sp.				×	×								
Triticites? sp.			×										
Triticites or *Pseudofusulina* sp. aff. *Schwagerina providens*								×					
Pseudofusulina sp.			×								×		
sp. aff. *Schwagerina providens*									×			×	
Pseudofusulina? sp. aff. *Schwagerina providens*											×		
Pseudofusulinella sp.										×			
Schwagerina sp.		×	×									×	×
Pseudoschwagerina sp.						×							

TABLE 18.—*Early Permian Foraminifera from the upper part of the Strathearn Formation and equivalent beds*

[Identifications by R. C. Douglass]

Locality No. on pl. 1	146	(1)	(1)	(1)	147	148	149	150	151	152	115	(2)	(2)
USGS fossil colln. No.	f12469	f22515	f22516	f22517	f21794	f22530	f21811	f21812	f21810	f21813	f21002	f23124	f23125
Textularid		×		×									
Tetrataxis sp.			×										
Schubertella sp.		×											
Kansanella sp.						×							
Triticites sp. aff. *T. primarius*						×							
Pseudofusulina sp.		×	×								×	×	×
sp. aff. *Schwagerina providens*								×					
Parafusulina sp. cf. *P. linearis* Dunbar	×												
Schwagerina sp.				×	×		×		×	×			
Schwagerina? sp.			×										

[1]Measured section S13. [2]Measured section S12A.

Papoose Canyon include forms that according to Gordon suggest that these beds are of Late Permian age. Collection localities and faunal lists follow: USGS 17268-PC (No. 104 on pl. 1), S½ sec. 25, T. 30 N., R. 52 E., *Rhynchopora* sp., *Punctospirifer* n. sp., *Composita* sp., and *Schizodus*? sp.; USGS 17283-PC (No. 110 on pl. 1), N½ sec. 36, T. 30 N., R. 52 E., sponge?, *Polypora* sp., *Punctospirifer* sp., *Septimyalina*? sp., and *Limipecten* sp.; USGS 16520-PC (No. 111 on pl. 1) slightly east of middle of west line of sec. 1, T. 29 N., R. 52 E., *Chonetinella* sp. A, "*Avonia*" sp. A, *Aulosteges* sp., and productid genus and sp. indet.; USGS 16521-PC (No. 112 on pl. 1), top of knoll about 600 feet west of SE. cor. sec. 2, T. 29 N., R. 52 E., "*Avonia*" sp. A, *Punctospirifer* sp. A, *Cleiothyridina* sp. (fragment), *Composita* sp., and *Septimyalina* aff. *S. sinuosa* Morningstar; USGS 17141-PC (No. 113 on pl. 1) from limestone overlying conglomerate in NE¼NW¼ sec. 11, T. 29 N., R. 52 E., *Aulosteges hispidus* Girty, *Avonia subhorrida* (Meek), *Punctospirifer* n. sp., myalinid (very large), *Limipecten* sp., and *Trigonia*-like pelecypod.

The largest assemblage of Permian megafossils was collected on the west-facing bluff of Cole Creek in the S½ sec. 34, T. 32 N., R. 52 E. Included in this collection USGS 16528-PC (No. 114 on pl. 1) are bryozoans, crinoid columnals, *Derbyia*? sp., *Chonetes* cf. *C. flemingi* Norwood and Pratten, *Marginifera* (*Kozlowskia*?) sp., *Dictyoclostus* (*Antiquatonia*?) aff. *D. hermasanus* (Girty), *Linoproductus* cf. *L. prattenianus* Norwood and Pratten, *Waagenoconcha* sp., productid indet. (large spine bases), *Rhipidomella* sp., *Schizophoria* sp., *Rhynchopora* sp., *Camarotoechia* sp., *Rhynchonellid* in-

TABLE 19.—*Early Permian Foraminifera from undivided beds above the Strathearn Formation*

[Identifications by R. C. Douglass, except for f12358 identification, which was by L. G. Henbest]

Locality No. on pl. 1	106	109	(1)	153	154	155	(2)	(2)	(2)	(2)	156	157	158
USGS fossil collection No.	f12467	f17272	f22533	f21006	f12358	f22536	f22518	f22519	f22520	f22521	f21676	f21815	f21677
Globivalvulina sp.						×							
Textularid			×			×	×	×	×	×			
Climacammina sp.					×								
Climacamminid											×		
Tetrataxis sp.	×												
Geinitzina? sp.					×								
Spandelina or *Spandelinoides* sp.					×								
Staffellid							×						
Schubertella sp.			×								×		
or *Boultonia* sp.					×								
Schubertellid						×			×	×			
(or *Boultonia* sp.)							×						
Pseudofusulina? sp.		×											
Pseudofusulinella sp.	×				×	×							
Parafusulina sp.			×		×								
sp. aff. *P. schucherti* Dunbar and Skinner					×								
Colaniella? sp.					×								
Schwagerina sp.	×		×	×			×						×
near *Parafusulina* sp.									×	×			
or early *Parafusulina* sp.								×					
sp., very close to *Parafusulina* in its development						×							
?*Schwagerina* sp.											×	×	

[1]Measured section S11B. [2]Measured section S13.

det., *Crurithyris* sp., *Cleiothyridina*? sp., *Composita* cf. *C. subtilita* Hall, and *Helicoprion* sp. This assemblage was dated as Permian by Mr. Gordon (written commun., 1957). It is several hundred feet stratigraphically above a fusulinid collection (USGS f21002; No. 115 on pl. 1) from the base of the Permian on the south fork of Cole Creek. According to Mr. Douglass (written commun., 1963), this fusulinid assemblage occurs in the upper part of the Strathearn Formation near Carlin Canyon. The beds containing the megafossils, then, are equivalent to the upper part of the Strathearn or to post-Strathearn Permian rocks. Lithologically, the Cole Creek rocks at fossil locality USGS 16528-PC are similar to post-Strathearn rocks north of Carlin Canyon.

Yellow-weathering siltstone and sandstone that crop out in sec. 17, T. 29 N., R. 53 E., contain abundant but poorly preserved ostracodes in places. These microfossils (colln. 207; No. 116 on pl. 1) were examined by I. G. Sohn who reported (written commun., 1956) that they may belong to *Miltonella*, although surfaces of the valves are not preserved. This genus ranges from Wolfcamp to Word age in Texas and occurs in the upper part of the Phosphoria Formation in Sublette County, Wyoming (Sohn, 1954, p. 17). In our opinion, these beds are probably correlative with the post-Strathearn rocks in the northern part of the mapped area. They are similar lithologically to some of the post-Strathearn rocks, and the yellow slopes developed on them are typical of the yellow slopes developed on Permian rocks in the region.

Upper Pennsylvanian and (or) Permian rocks equivalent in age to those in the Carlin-Pinon Range area are widespread in eastern Nevada (Nolan and others, 1956, p. 63-68; Steele, 1960; Bissell, 1960, 1962a, 1970; Brill, 1963). Strata equivalent to the Upper Pennsylvanian lower part of the Strathearn Formation are more restricted geographically (Steele, 1960, p. 98), but those equivalent to the Permian part of the Strathearn and to younger Permian rocks crop out in many mountain ranges in east-central Nevada.

Because of the abrupt lithic changes and variety of lithic types represented, we do not believe that distant correlations with named units outside the mapped area are justified until more studies are made in the intervening areas. The area of the present report was so close to the main source of Upper Pennsylvanian and Permian sediments that the sedimentary rocks formed have great lateral lithic variation. Rocks of the same age as the Strathearn Formation in the southern half of the mapped area are enough different from the Strathearn that they are not given the same name. The undivided Permian rocks are similar in some respects to the Garden Valley Formation of the Eureka area (Nolan and others, 1956, p. 67-68). In particular, the conglomerate units are very similar, but the stratigraphic sequence of the four members of the Garden Valley is not recognized in the Carlin-Pinon Range area.

In the Cortez Mountains west and southwest of the Carlin-Pinon Range area, the Brock Canyon Formation (Gilluly and Gates, 1965, p. 44-47; Gilluly and Masursky, 1965, p. 65-66; Muffler, 1964, p. 6-14) consists of dolomite, conglomerate, and calcareous sandstone and siltstone. Fossils collected from these rocks include poorly preserved mollusks that suggest a Pennsylvanian or Permian age according to E. L. Yochelson and Mackenzie Gordon, Jr., and poorly preserved plants dated by S. H. Mamay as possibly very late Pennsylvanian, if Pennsylvanian at all, and perhaps as Permian or even Mesozoic (Muffler, 1964, p. 7). Westward onlap of the Upper Pennsylvanian and Permian rocks in the Carlin-Pinon Range area suggests that the Brock Canyon may be no older than Permian, if it was deposited as a sequence continuous with that in the Carlin-Pinon Range area.

In the area of Battle Mountain, 50 miles to the west, the Antler Peak limestone of the Antler sequence is equivalent to the Strathearn Formation and the overlying undivided Permian rocks (Roberts and Arnold, 1965, p. B8-B9).

DEPOSITIONAL HISTORY

The depositional history of the exposed rock units in the Carlin-Pinon Range area began in Ordovician time—Middle Ordovician in the carbonate (eastern) assemblage and Early Orodvician in the siliceous (western) and transitional assemblages. The carbonate assemblage is autochthonous and forms a continuous rock succession in the original area of deposition, whereas the siliceous and transitional assemblages are allochthonous on the Roberts Mountains thrust fault. Units within the two allochthonous assemblages cannot be restored accurately to their original sites of deposition; hence, relative positions of equivalent units must also remain problematical and can be established only broadly on an interpretative basis. The overlap assemblage, whose oldest deposits are of Early Mississippian age, is largely autochthonous and most units are at or near their original depositional sites.

The rocks of Ordovician, Silurian, and Devonian ages were deposited in a miogeosyncline on the east, including the area of this report, and in an eugeosyncline on the west, perhaps some tens of miles west of the area of this report. The miogeosynclinal units are largely carbonate rocks and the eugeosynclinal units largely fine-grained siliceous clastic rocks, chert, and volcanic rocks (Roberts and others, 1958; Ross, 1961; Kay, 1947 [Fraser and Millard belts], 1960; Nolan and others, 1956 [mostly for carbonate rock sequence]). The only Paleozoic volcanic rocks recognized in the mapped area are greenstones in the Ordovician Valmy Formation in the Sulphur Spring Range. Units of the transitional assemblage have rock types characteristic of each of the other two major assemblages (Hotz and Willden, 1955; Roberts and others, 1958, p. 2817, 2826-2829, 2831-2832, 2835; Kay 1960, p. 99-100) and probably were deposited between the other two. These transitional units probably were deposited in a belt that fluctuated with time and that was irregular geographically.

ORDOVICIAN

The oldest miogeosynclinal shallow-water sediments make up the dolomite and shale of the upper part of the Pogonip Group. The carbonate part of the Pogonip was probably deposited as limestone and then altered to dolomite in association with the much later intrusion of the stock west of Bullion. During this deposition the sea floor afforded an environment favorable for the growth of benthonic shell fish, especially brachiopods. Succeeding the Pogonip is the Eureka Quartzite which was deposited as 70 feet of fine-grained sand that consists of about 99 percent quartz grains. No fossils were found in the Eureka sand body in the small area of exposure, so evidently the environment was not suitable for animal life or the conditions for preservation were poor. In spite of the abrupt change in lithology from the Pogonip to the Eureka, the contact seems conformable, although it is unconformable regionally (Nolan and others, 1956, p. 30-31). Environmental conditions changed again at the close of Eureka time with deposition of carbonate material to form the carbonate sequence of the Hanson Creek Formation. In one place, this change from quartzite to carbonate rock seems to be gradational through a thickness of 2 feet, although this contact, too, is unconformable regionally (Nolan and others, 1956, p. 30-31). Bottom conditions during deposition of the Hanson Creek were favorable for the growth of corals and brachiopods at least part of the time, as these forms are abundant in some beds. While this Ordovician sequence of chiefly lime mud and sand was being deposited in the miogeosyncline, a completely different sequence of mostly siliceous clastic sediments was being deposited in the eugeosyncline farther west.

These eugeosynclinal clastic rocks are represented by the Valmy and Vinini Formations, of which the Valmy contains the only greenstone and quartzite in the mapped area. Roberts, Hotz, Gilluly, and Ferguson (1958, p. 2833) suggested that quartzite beds in the Valmy grade eastward into finer grained rocks in the Vinini. On this basis, the sand, mud, opaline silica, and lava that make up most of the Valmy sequence in the mapped area were deposited farther west than any other Ordovician rocks now exposed here. At the same time and somewhat farther east, similar siliceous materials with less quartz sand were deposited to form the Vinini Formation. In the part of the Vinini exposed in the Carlin-Pinon Range area, no lavas or tuffs are included in the sequence. Apparently, farther east but still west of the report area, the transitional assemblage of Ordovician age was deposited. This assemblage is now exposed on the east side of Marys Mountain. The depositional sequence of these beds on Marys Mountain, based on graptolite and conodont chronology, began with introduction of mud and some sand during Early and Middle Ordovician time, was followed by coarse-grained chert, sandy lime, limy sand,

and some chert during Middle Ordovician time, then by more sand, which is locally crossbedded, and less mud during Middle and perhaps early Late Ordovician time, and finally by mud and clay again during the remainder of Late Ordovician time. Toward the close of Ordovician time and perhaps in Early Silurian time, lenses of lime mud were deposited with the mud and clay. These lenses contain both graptolites and trilobites and may have formed as small carbonate banks. The trilobites must have been shifted and winnowed some by currents after death, as no well-preserved cranidia were found with the numerous pygidia. Chert occurs with some of these beds but is not nearly so prominent as it is in units of the siliceous western assemblage. The chert grains in the Middle Ordovician chert sandy beds probably were derived from older eugeosynclinal or transitional-assemblage cherts, and record erosion of lithified chert and deposition of chert grains with limy muds. Conodonts were the only fossils found in these beds.

The source of all the silica required for the thick sequences of siliceous shales, mudstone, and chert in these and some of the younger Silurian and Devonian siliceous-assemblage rocks is a matter of conjecture. The lack of greenstone in most of the units in the mapped area and the lack of preserved remnants of shards or other evidence of tuffaceous deposits have led us to conclude that volcanic materials from local volcanism need not comprise a part of a local sequence of very siliceous rocks (Ketner and Smith, 1963b). The Vinini and Valmy Formations, however, contain more greenstone and tuff to the west and south of the area of this survey (Merriam and Anderson, 1942, p. 1694; Roberts, 1951; Roberts and others, 1958, p. 2832-2833; Gilluly and Gates, 1965, p. 22-42) and, thus, afford evidence that submarine volcanism could have been a source of silica in parts of the geosyncline. Ketner (1969, p. B33) has suggested that dissolved silica carried to the sea by rivers furnishes ample supplies for thick accumulations of highly siliceous deposits. He concluded, further, that the thick Ordovician eugeosynclinal siliceous rocks indicate the presence of abundant dissolved silica derived from the land and a general lack of detrital fragments.

Paleontologic evidence regarding the environments of deposition of the Ordovician eugeosynclinal rocks that contain mostly graptolites has been reviewed by Ross (1961, p. 335-341), who concluded that deposition of eugeosynclinal sediments in very deep water is not indicated by available evidence. No paleontologic data from the Carlin-Pinon Range area cast any additional information on the depositional environments of the siliceous western-assemblage beds. Several features in the transitional assemblage, however, suggest that these beds were deposited in relatively shallow water: (1) some of the quartzite units are crossbedded on a small scale and could have been deposited in shallow waters; (2) the coarse angular grains of chert in the sandy limestone and limy sandstone probably were not transported far before being deposited in limy mud; (3) the irregular, knobby, and podlike chert interbeds associated with these limestones are similar to those so common in limestone of shallow water origin elsewhere; and (4) the lenses of dense limestone may represent bank deposits where conditions were favorable for the growth of trilobites and may be shallow-water deposits.

SILURIAN

On evidence from the Carlin-Pinon Range area, the Silurian record of carbonate(eastern)-assemblage rocks began in Middle Silurian time, with deposition of the Lone Mountain Dolomite. This formation appears to be conformable on the Ordovician Hanson Creek Formation southwest of Bullion, but, there, a major hiatus is indicated by the possibility that the lower part of the Lone Mountain may be of Late Silurian age. The Roberts Mountains Formation of the transitional assemblage that at places occurs below the Lone Mountain outside the area of this report (Nolan and others, 1956; Carlisle and Nelson, 1955) is lacking near Bullion.

The Roberts Mountains Formation and the Lone Mountain Dolomite have been interpreted by Winterer and Murphy (1960) as forming a reef complex. They based their interpretation chiefly on the abnormally great thickness of Silurian rocks in the Roberts Mountains area, on the partial lateral equivalency of the Lone Mountain Dolomite and the Roberts Mountains Formation in the same area, and on lithologic features of the Roberts Mountains Formation which suggest to them that much of it was formed by material shed from the reef complex forming the Lone Mountain Dolomite. The Lone Mountain in the Carlin-Pinon Range area is at least partly a lateral equivalent of the Roberts Mountains Formation in nearby areas, but we have not observed any particular evidence in the mapped area to support or dispute the idea that these formations are part of a reef complex.

Regardless of their relation to a reef complex, the Silurian carbonate rocks were deposited as shallow-water sediments in the miogeosyncline and along its western margin. Along a zone that passes near the Carlin-Pinon Range area, the Roberts Mountains Formation and equivalent beds, the Lone Mountain in this area, change from dolomite on the east to limestone on the west (fig. 17). This zone remained remarkably the same from Middle Silurian into Middle Devonian time and probably marked the area of a shelf edge or continental margin leading to deeper water on the west.

Siliceous(western)-assemblage Silurian rocks on Marys Mountain include chert and siliceous siltstone of Middle or late Early Silurian age. These siliceous rocks are similar to the Ordovician eugeosynclinal deposits and evidently were deposited in a similar environment,

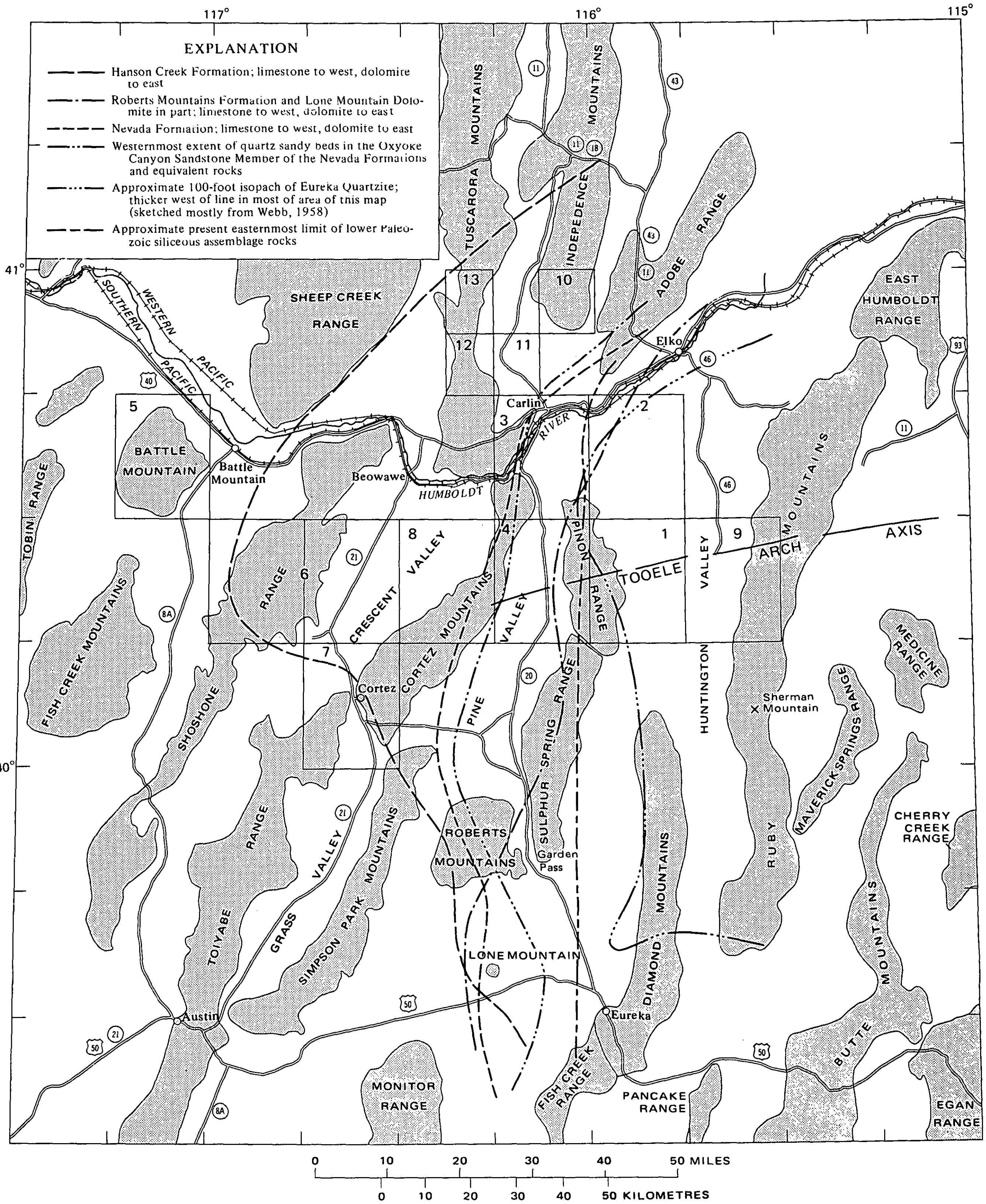


FIGURE 17.—Approximate position of east-to-west change from mostly dolomite to limestone for several Paleozoic formations, approximate present easternmost position of lower Paleozoic siliceous-assemblage rocks, and 100-foot ispoach of Eureka Quartzite.

except that no submarine lavas accompanied deposition of those Silurian beds now found in the mapped area.

DEVONIAN

Devonian rocks of the carbonate assemblage were deposited in a miogeosynclinal shallow-water environment similar to the one that existed during deposition of older Paleozoic formations of this assemblage. Bottom conditions were favorable for development of a shallow-water marine fauna, as these beds contain brachiopods, corals, gastropods, and bryozoans.

During Early and part of Middle Devonian time, the Carlin-Pinon Range area was along the belt where there is now a change in the Nevada Formation from dolomite on the east and northeast to limestone on the west and southwest (fig. 17), a feature pointed out previously (Nolan and others, 1956, p. 41; Johnson, 1962, p. 545). Limestone becomes more abundant southward in the Sulphur Spring Range (Carlisle and others, 1957) and westward in the mapped area between the northern part of the Pinon Range and Pine Mountain. The position of two limestone units in the lower part of the formation on Pine Mountain suggests that the westward change from dolomite to limestone takes place by interfingering of the two carbonate rock types. Here and in the following paragraphs we do not attempt to consider the origin of dolomite—that is, whether it is syngenetic, diagenetic, or epigenetic. The east-west change from limestone to dolomite is real, whatever the cause.

The area of the present report is also along the zone of westward decrease in quantity of quartz sand in the Nevada Formation, mostly in the Oxyoke Canyon Sandstone Member. This is indicated chiefly by the thin lenses of Oxyoke Canyon quartzite along Pine Mountain in comparison with the generally greater thickness of this member in the Pinon Range a few miles to the east. Quartz grains continued to be introduced into the area following deposition of the main body of the Oxyoke Canyon and were deposited as a minor part of the upper member of the Nevada Formation which consists mostly of dolomite.

In late Middle Devonian time a gradual change in conditions resulted in deposition of sediments that eventually became limestone rather than dolomite. The gradual change is indicated by the gradational and interfingering contact between the Nevada Formation and the overlying Devils Gate Limestone. Deposition of lime mud continued into Late Devonian time and was widespread over this part of the region.

In the region of transitional-assemblage deposits, presumably west of the report area, fine-grained sediments were deposited during earliest Devonian time. Graptolites flourished in the waters in which these beds were laid down. The resulting rocks probably form that part of the Roberts Mountains Formation exposed in a thrust slice in the mapped area.

While sedimentation of beds now forming the upper part of the Nevada Formation and the Devils Gate Limestone was taking place, beds that eventually became mostly limestone containing large chert pods, chert breccia, quartz- and chert-sandy limestone, and calcareous sandstone were deposited somewhere farther west to make up the limestone and chert unit of the Sulphur Spring Range. As these strata contain lithologic types common to both the carbonate and siliceous assemblages, presumably they were deposited in an intervening transitional zone. The original site of deposition of these beds cannot be determined at the present time. Lack of dolomite indicates that the formation was deposited west of the area of dolomite and the presence of large pods of chert suggests that the depositional site was toward the area of deposition of the siliceous assemblage, although this chert differs from the bedded cherts of that assemblage. The chert fragments and grains evidently were derived from older rocks of the siliceous assemblage, and, thus, are indicative of erosion of that sequence; the source of the quartz grains is unknown. As this limestone and chert unit can be dated only as Middle to early Late Devonian, no apparent record remains of Lower Devonian sediments deposited beneath this allochthonous transitional unit.

The siliceous(western)-assemblage rocks of the Woodruff Formation of Devonian age presumably were deposited in the eugeosyncline and farther west than the limestone and chert unit. Chert, mudstone, and shale compose much of the Woodruff and, thus, make it in part similar to the pre-Devonian eugeosynclinal deposits. It contains no greenstone, however.

The Woodruff also differs from the older eugeosynclinal deposits in containing appreciable amounts of dolomite and silty dolomite. Possibly, the material forming dolomite was deposited where the water was more shallow than it had been earlier. Dolomite grains appear to be of three types: detrital, primary or diagenetic, and secondary. These grains are about the same size as the quartz grains in the rock, and deposition of grains of similar size evidently required enough agitation of the water to cause some sorting, a condition easily obtained by slight currents in shallow water. Furthermore, the dolomite was possibly deposited or formed in warm water, which also suggests that the water was shallow. Chert grains and pebbles in the chert-sandy limestone and angular chert-pebble conglomerate on Marys Mountain indicate erosion of a chert terrain whether it was above or below sea level.

Fossils found in the Woodruff differ from those found in the older eugeosynclinal deposits, which contain graptolites almost exclusively, although graptolites do occur also in the lowest beds of the Woodruff. In the Woodruff, rami of the probable arthropod *Angustidontus* are widespread in the mudstone, shale, and some of the dolomitic siltstone and are very abundant at some localities; no fragments other than appendages of these animals were found. Little is known about the their life habit. Conodonts occur in the Woodruff, and the only definite conclusion that can be drawn regarding their habitat seems to be that they were marine. Other fossils, which occur sparsely in the formation, include the goniatite *Platyclymenia* in mudstone and shale containing *Angustidontus* rami, crinoid columnals in a limestone lens containing conodonts, and *Tentaculites* in another limestone lens. It would seem that all these fossils could have lived in relatively shallow water. Some of the chert beds contain abundant Radiolaria which may have been deposited in relatively deep water.

The fauna and some of the lithologic features of the Woodruff Formation suggest that these strata were deposited both in shallow water and in deep water. This formation contains probably the youngest rocks yet recognized in siliceous assemblage units in the nearby region. The sea in which the Woodruff Formation was deposited probably was becoming more shallow in places than it had been during earlier Paleozoic time. At least part of the eugeosynclinal belt was being uplifted. This uplift evidently was an early stage of the movements that became the Antler orogeny and associated Roberts Mountains thrust.

MISSISSIPPIAN AND EARLIEST PENNSYLVANIAN

The Antler orogeny and associated Roberts Mountains thrust brought about a profound change in the environment of deposition throughout this region. Mississippian sediments deposited from a rising source area to the west are the types to be expected under such conditions; in general they grade upward through several thousand feet from very fine-grained clastic materials to very coarse clastic material, from mudstone and shale to conglomerate. In detail, however, the oldest Mississippian sediments differ enough to be separated into two units, the Webb Formation and the lowest part of the undivided Chainman Shale and Diamond Peak Formation in the southern part of the area. The argillite of Lee Canyon, an allochthonous unit in the mapped area, may be equivalent to both of the other units.

The Carlin-Pinon Range area probably was very near the original eastern limit of upper-plate rocks of the Roberts Mountains thrust, and the Early Mississippian sea floor in this area must have been irregular. Irregularities on this sea floor and irregularities generally to the west in the source area of the sediments served in combination to control the lithologic differences in the early deposits. The very fine grained siliceous fragments that make up much of the Webb Formation evidently were derived from a low-lying terrain, and the oldest parts were received in a basin in the northern part of the mapped area before any material was deposited in the southern part. As the basin was filled, the sediments covered a larger area and spread southward. Also, lime mud was deposited to form scattered lenses. A general lack of fossils in the Webb suggests that for most of the time the environment was not suitable for prolific life. The bottom may have been poorly aerated or too muddy. Rapid deposition of the very fine grained siliceous material probably aided in creating conditions unsuitable for abundant marine life. Existence of some life forms is indicated by conodonts, many spicules, radiolarians, and by a few broken shells of brachiopods seen in one limestone lens.

During the latest stages of deposition of the Webb Formation, some of the oldest beds of the undivided Chainman Shale and Diamond Peak Formation were being deposited in the southern part of the mapped area. During this same time in the north, conditions changed gradually to lead to deposition of the Chainman Shale. This change is reflected mostly in the occurrence of coarser grained clastic rocks that are more indicative of uplift of the source area than of any pronounced changes in the area of deposition. Silt- and clay-size material continued to be introduced into the sea during Chainman time, but periodically more sand-size grains of quartz and chert were introduced. The chert sand obviously was derived from a terrain formed on lower Paleozoic siliceous-assemblage strata. Instability of accumulating sediments developed occasionally, and turbidity currents flowed down the submarine slopes, submarine mudflows formed pebbly mudstones, and contorted beds were formed locally by slumping. Thin beds of lime mud were deposited in a few places. Locally, siliceous gravels were deposited in channels even near the base of the Chainman beds. These gravels indicate vigorous stream action in the source area which was continuing to be uplifted; the gravels probably were not transported very far from shore. Fossils are not abundant in the Chainman and its equivalent beds, but some of the limestone or calcareous sandstone strata contain brachiopods, corals, bryozoans, and sparse goniatites. This faunal assemblage is more suggestive of deposition in shallow than in deep water. Shale and sandstone units are mostly unfossiliferous but, in places, contain comminuted land-plant fragments that must have been transported. The shales and sandstones contain no features that require their deposition in deep water, although some mud and sand were transported by turbidity currents which could have carried them considerable distances from shore and into deep water.

The argillite of Lee Canyon, as we interpret it, was deposited east of the report area and later was thrust westward into its present position. Time of its deposition possibly coincided with that of the Webb Formation and with part of the Chainman Shale. This approximately 5,000 feet of very fine grained rocks, made up mostly of silt-size or smaller grains of quartz, was deposited in a sag on the sea floor into which fine clastic particles were dumped very rapidly. A few lenses of siliceous-pebble conglomerate in the upper part of the unit make it similar to other Mississippian rock sequences and suggest more uplift and vigorous stream action in the source area. Our search yielded no fossils that might be used in interpreting the depositional environment. Radiolarians are scattered through the rocks but are not abundant, and the one poorly preserved fragment of a land-plant stem we found near the top of the unit must have been washed into its position. The abundant carbonaceous material, which makes thin sections of this rock opaque or nearly so, probably was derived from finely comminuted plant material transported with the siliceous grains. Lack of recognizable fossils may have resulted from an unfavorable environment for marine life, but fossils may have been more abundant and in part destroyed or made more difficult to find by the probable metamorphic change of the shale or mudstone to argillite. Black shale of Mississippian age occurs north of Elko and shale similar to this may have been altered to the argillite of Lee Canyon. This Lee Canyon unit is interpreted to have been deposited east of its present position, because it is finer grained than its possible equivalent Webb Formation and presumably was deposited farther from the western source area.

Following deposition of the Lower Mississippian fine-grained clastic sediments, much coarser grained material ranging from sand grains to boulders was transported into the mapped area. Obviously, the source region continued to rise, considerable relief must have been developed, and stream action at times must have been extremely vigorous to transport the boulders that are prominent parts of some conglomerate lenses. The lenticular units of mainly conglomerate and sandstone and a little shale in places were probably deposited as fanlike deltas composed of material derived from a terrain of mostly chert and quartzite of the lower Paleozoic siliceous-assemblage rocks which were part of the upper plate of the Roberts Mountains thrust; most of the chert and quartzite clasts could have come from the Valmy and Vinini Formations. At places, pebbles and cobbles of Devils Gate Limestone indicate that eminences of lower plate carbonate rocks stood as islands projecting above the upper plate or perhaps in the sea. In a very few places lateral decreases in clast sizes within single lenses suggest that the direction of transport was from northwest to southeast. A southeast direction of sediment transport is also suggested on a regional stratigraphic basis when the Diamond Peak Formation in Carlin-Pinon Range area is compared with the same formation in the Diamond Mountains to the south. Direction of sediment transport might change abruptly in a deposit of this type; however, it is apparent that the source direction was generally to the west. Rocks equivalent to the Chainman and Diamond Peak sequence are not known on the west edge of the mapped area in the Cortez Mountains, which may well have been an emergent source area for part of the sediments now in the Pinon Range.

About the middle of Mississippian time (late Osagean and early Meramecian) depositional conditions became more quiet, and the quantity of coarse clastic material being introduced was greatly diminished, probably indicating that the height and relief of the emergent source area had been greatly reduced by erosion. During this time interval, the clay, silt, and sand of the Ferdelford fossil beds were deposited in relatively quiet and shallow water on a sea floor that was populated by abundant marine life—mostly brachiopods, corals, pelecypods, gastropods, bryozoans, and crinoids. These deposits differ in thickness over the mapped area, probably, in part, because they covered an irregular surface formed by the preceding torrentially introduced deposits. Even during the relatively quiet deposition in a sea containing many shellfish, locally the earlier more turbulent conditions were obtained again, and streams carrying gravel were active in forming conglomerate lenses.

A nearly complete return to earlier Mississippian conditions followed the formation of the Ferdelford fossil beds as an upper sequence of lenticular beds of sand, gravel, mud, and lime mud was deposited. These sediments were more varied than those forming the earlier sequences and were deposited on a slightly irregular sea floor while there were slight changes in currents, and while uplift of the source area to the west probably was more sporadic and streams that brought sediments to the sea waxed and waned and shifted their channels. Marine life continued to dwell in the ocean and was abundant in favorable areas that apparently were more restricted areally and also in time than they had been during deposition of the Ferdelford beds. These slightly fluctuating conditions continued from middle Mississippian into earliest Pennsylvanian time.

PENNSYLVANIAN

Conditions changed during Early Pennsylvanian time and calcareous sediments became the dominant deposits. In large part, these sediments consisted of transported limestone fragments and contained much siliceous detrital material which was introduced periodically from the west. Interlayering of limestone and siliceous clastic deposits reflects a cyclic pattern of deposition in parts of the area, particularly in the Moleen Formation and near Grindstone Mountain (Dott, 1958).

A most striking feature of the Pennsylvanian sediments in this area is that they, too, contain abundant coarse clasts of chert and quartzite derived from lower Paleozoic siliceous-assemblage formations. In Early and early Middle Pennsylvanian time, siliceous fragments were poured into the area in large volumes locally, as is demonstrated along the ridge southeast of Smith Creek basin, where the entire Pennsylvanian section consists of siliceous conglomerate and sandstone. The mass of gravel and sand deposited there interfingers with limy sediments southeastward, and, in a distance of about 1 mile, the full sequence of conglomerate and sandstone changes to one of mostly limestone. The abrupt eastward decrease in the amount of conglomerate in the lower part of the Pennsylvanian sequence also is reflected by comparison of the lower 850 feet of the Moleen Formation from the east part of Carlin Canyon to Grindstone Mountain, a distance of about 4½ miles. Here, as computed from the measured stratigraphic sections of Dott (1955, p. 2292-2296), the western section contains 25-30 percent conglomerate, and the eastern section, no more than 2 percent. The eastern margin of deposition of thick deposits of gravel during Early and early Middle Pennsylvanian time was along a line that extends roughly north-south through the central part of the Carlin-Pinon Range area.

During Middle Pennsylvanian time (Atokan Series) wedges of gravel were spread farther east to form a prominent part of the Tomera Formation, although none of the gravel and sand was introduced in enough bulk locally to equal that in the older strata southeast of Smith Creek basin. Thick lenses of gravel were interbedded with limy sediment, much of which was fragmental, to form the Tomera. These gravel lenses were similar to those deposited during Diamond Peak time but were not as thick and did not compose as high a percentage of the total sediments.

Shellfish, particularly brachiopods, flourished in the Pennsylvanian seas. Many of the shells were broken and abraded by currents, and shell fragments formed most of the sediment in some layers. Some shells remained relatively undisturbed after death, and the coral *Chaetetes* was buried in growth position at many places in the upper part of the Moleen Formation.

These Pennsylvanian sediments were deposited on a continental shelf in relatively shallow water. The western shoreline was not far west of the area and may have been in essentially the same position as it was during much of Mississippian time. This shore marked the east edge of an uplifted terrain of mostly western-asemblage rocks which were probably part of the upper plate of the Roberts Mountains thrust. At times the land area evidently had considerable relief, and large streams transported large volumes of coarse siliceous detritus to the sea to form thick delta or fanlike deposits which extended no more than a few miles from shore. Deposition of these shelf deposits continued from Early Pennsylvanian to at least late Middle Pennsylvanian (Des Moinesian Series) time, when the mapped area again underwent deformation, was uplifted, and was deeply eroded in places before deposition of the younger sequence of Upper Pennsylvanian and Permian strata.

LATE PENNSYLVANIAN AND EARLY PERMIAN

The Late Pennsylvanian sea, which invaded the area after the Pennsylvanian orogeny, moved across an irregular surface and probably surrounded highlands to form islands. Beds exposed on this surface had steep dips in places and were virtually flat in others; across the unconformity between these and the younger deposits, therefore, bedding attitudes are sharply discordant in places and nearly parallel in others. On the basis of dated fusulinid collections in the sequence, the earliest sea covered a funnel-shaped area with the wide-flaring end at the north (fig. 15). The shoreline receded southeastward and westward as the sea transgressed until probably all of the mapped area was submerged by late Early Permian time. Exposures of Permian rocks are small and scattered in the western half of the area, but fossils from them indicate that to the west the basal beds are successively younger and that the sea moved westward very gradually. From Late Pennsylvanian (Missourian Series) to Early Permian (Leonardian Series) time, the shore may have shifted westward little more than 5 miles. In the southern half of the mapped area, the oldest basal rocks of this Upper Pennsylvanian and Lower Permian sequence rest on Lower Pennsylvanian beds, whereas youngest basal rocks, in the most western exposures, rest on Lower Mississippian beds. This relation evidently indicates that continued erosion in advance of the slowly moving shoreline exposed successively older rocks to the west.

Few data are available on the rates or times of southeastward recession of the southeastern shoreline. The highland area of nondeposition during latest Pennsylvanian time (pre-Wolfcampian Series) evidently extended far to the south, as beds of this age are not recognized in the northern part of the Diamond Mountains (Dott, 1955, p. 2271; Larson and Riva, 1963) or in the vicinity of Eureka (Nolan and others, 1956, p. 64-68). Following deposition of earliest Permian sediments equivalent to the upper part of the Strathearn Formation, however, the sea had transgressed southeastward across the area of the present report.

The environment during deposition of this Upper Pennsylvanian and Lower Permian sequence was similar to the one that prevailed during deposition of the older Pennsylvanian strata. Most of the deposits were calcareous and included silt, sand, and gravel and abundant fragmental limy material, all deposited under shallow-water conditions on a shelf. In a number of places changes in depositional facies, particularly as reflected by changes in sizes of clastic fragments, were abrupt.

In the northern part of the report area, very fine grained siliceous clastic material was deposited throughout this interval, and coarse-grained fragments and gravel were deposited only in the older part. Chert and quartzite clasts making up conglomerate, conglomeratic limestone, and sandy beds in the Strathearn Formation probably were derived from uplifted siliceous-assemblage rocks and presumably came from the west or northwest. Two factors, however, suggest that part of the Strathearn may have been deposited by westward-moving currents and that the debris was possibly derived from the east or northeast: (1) More coarse gravel was deposited in the Strathearn in the area near the lower canyon of the South Fork Humboldt River than was deposited farther west near Carlin Canyon, and (2) measurements of crossbedding by Dott (1955, p. 2250, 2251, 2256) in the vicinity of the type section of the Strathearn, near the lower canyon of the South Fork, suggest that the beds were deposited by currents moving from the east.

Very fine sand and silt grains of quartz compose an important and distinctive part of the Permian sediments above the Strathearn Formation in the northern part of the area. These grains occur in beds that are calcareous in different degrees and probably were deposited on broad submarine banks or flats. The fine-size quartz grains may have come from a low-lying land area across which clastic particles were initially sorted by the streams; final sorting, however, must have been accomplished by marine currents.

In the southern part of the mapped area, very fine grained clastic material was deposited throughout the entire sequence of these rocks. Gravel was deposited near the base in places as the sea transgressed westward.

The thick conglomerate and sandstone unit in the southern part of the area must have been deposited as a wedge of detritus that probably accumulated rapidly. This conglomerate may be in thrust contact with the beds below, and its site of deposition is not known.

Permian strata that probably were derived from a nearby source are exposed south of Cole Creek near the top of the hill in the southern part of sec. 34, T. 32 N., R. 52 E. These strata consist of small angular fragments of siltstone and chert in sandy calcareous cement. The fragments are similar to those that now cover slopes on the Woodruff Formation nearby and probably were derived from a local source, perhaps an island, where the Woodruff was exposed.

Life in the Late Pennsylvanian and Early Permian sea was abundant and varied. At places, shells are broken, which indicates that they were moved by current or wave action. Some fusulinid tests are slightly alined locally to indicate that they were moved by currents. In a few places, though, the shells are whole and unabraded to slightly abraded and seem to have been moved only slightly or not at all prior to burial.

The exposed record of the history of deposition of the Paleozoic rocks in the Carlin-Pinon Range area ended with the deposition of lower Upper Permian sediments.

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