Stratigraphy of Post-Paleozoic Rocks and Summary of Resources in the Carlin-Pinon Range Area, Nevada

GEOLOGICAL SURVEY PROFESSIONAL PAPER 867-B

Prepared in cooperation with
Nevada Bureau of Mines and Geology

Stratigraphy of Post-Paleozoic Rocks and Summary of Resources in the Carlin-Pinon Range Area, Nevada

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

With a section on AEROMAGNETIC SURVEY

By DON R. MABEY

GEOLOGY OF THE CARLIN-PINON RANGE AREA, NEVADA

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A study of a thick sequence of Jurassic, Cretaceous, and Eocene through Pliocene Tertiary nonmarine sedimentary rocks and volcanic and intrusive rocks

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CONTENTS

ILLUSTRATIONS

TABLES

STRATIGRAPHY OF POST-PALEOZOIC ROCKS AND SUMMARY OF RESOURCES IN THE CARLIN-PINON RANGE AREA, NEVADA

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

ABSTRACT

Post-Paleozoic rocks in the Carlin-Pinon Range area, which consists of four 15-minute quadrangles in northeast Nevada, range in age from Jurassic to Holocene. These rocks have a composite maximum thickness of about 9,300 m (30,500 ft), of which about 2,745 m (9,000 ft) is Jurassic, about 915 m (3,000 ft) Cretaceous, and about 5,640 m (18,500 ft) Tertiary and a little Quaternary.

The types of rocks formed in this area were influenced by four principal events: (1) Regional uplift that brought an end to marine deposition (probably Triassic); (2) Development of basins from Cretaceous to early Tertiary time; (3) Tertiary volcanism; (4) Block faulting that outlined the basin and range topography of essentially the present configuration (Miocene).

1. *Regional uplift that brought an end to marine deposition.* — This event, which probably occurred during Triassic time, was followed during the Jurassic by emplacement of a thick series of nonmarine volcanic and volcaniclastic rocks now exposed almost entirely in the Cortez Mountains: They make up the Pony Trail Group, which consists, in ascending order, of volcaniclastic rocks of the Big Pole Formation, largely silicic ash-flow tuff of the Sod House Tuff, and andesite to rhyolite lavas and much less tuff and clastic sedimentary beds in the Frenchie Creek Rhyolite. This group of rocks was intruded by a rhyolite(?) plug assigned to the Frenchie Creek and by alaskite and granodiorite, all exposed more extensively west of the mapped area.

2. *Development of basins from Cretaceous to early Tertiary time.* — Beginning in late Early Cretaceous time and continuing into early Tertiary time, basins became the sites of deposition of lacustrine and fluviatile sediments. Cretaceous sedimentary beds compose the Newark Canyon Formation, which is thickest and most extensive on the east side of the Cortez Mountains. This formation consists of a heterogeneous mixture of beds ranging from conglomerate to limestone. These beds contain volcanic rock fragments in places but do not contain any volcanics or pyroclastic detritus of contemporary origin.

Basins also received sediments beginning in Eocene(?) time and extending to the end of Eocene. The rocks formed consist of a nonvolcanic sequence that in a broad way can be divided into two parts, a lower part containing some coarse clastic beds along with fine clastic strata and limestone, and an upper part composed of limestone. This sequence is mapped as four informal units in a stratigraphic order, but they may be in part facies equivalents. Overlying these units is the Oligocene or Eocene Elko Formation (a new name), most of which is also nonvolcanic. The Elko contains claystone, siltstone, shale and oil shale, and limestone, which were deposited in a relatively large basin that extended many kilometres north of the area of this report. This entire sequence of Eocene(?) and Eocene strata seems to reflect a general decrease in relief of source areas of the sediments and an enlarging of the basin or basins.

3. *Tertiary volcanism.* — A tuff that is about 610 m (2,000 ft) above the base of the Elko Formation where that formation is thickest in the Carlin-Pinon Range area and the older intermediate volcanics mark the first local evidence of volcanic activity. Cretaceous and Tertiary rock units were all nonvolcanic before deposition of both the tuff, which is K-Ar dated as 38.6±1.2 m.y., and the volcanics, which may be 41.4±1.4 m.y., based on a sample from outside the mapped area. After, they were volcanic or contained contemporaneous pyroclastic material, except for the most recent alluvial and colluvial deposits; however, even Holocene alluvium has some very small pockets of volcanic ash.

Volcanic rocks of intermediate composition and probably about the same age as the upper part of the Elko Formation cover a small area in the northwest quarter of the mapped area. East of the Pinon Range, mafic to silicic volcanics and some interlayered sandstone overlie the Elko; these volcanics have less than 2.5 km^2 (1 mi^2) of exposure.

Silicic intrusive rocks of Tertiary age form two stocks and a number of dikes. One stock and most of the dikes are near the center of the mapped area, where they are evidently offshoots of a large buried intrusion interpreted from aeromagnetic data. Paleozoic rocks above this intrusion are slightly metamorphosed. The Railroad mining district is near the stock.

Essentially nonwelded to intensely welded ash-flow tuffs and a series of sedimentary rocks that are interlayered with the tuffs in places make up the Indian Well Formation, a newly named formation of radiometrically dated Oligocene age. A basal unit of this formation consists of a variety of tuffs and tuffaceous sedimentary rocks that occur in isolated exposures. The principal sedimentary part of the formation is composed of fine to very coarse rocks, many of which are tuffaceous, and of limestone and tuff having a total thickness of about 1,015 m (3,330 ft); these beds grade upward from mostly fluviatile deposits into mixed fluviatile and lacustrine deposits. The ash-flow tuffs are silicic and are about 610 m (2,000 ft) in maximum thickness.

Intermediate to silicic volcanics, which are mostly lavas but include some tuff, overlie the Indian Well ash-flow tuff in the

southeast quarter of the report area. These volcanics are about 305 m (1,000 ft) thick and are presumably of Oligocene age.

A few mafic to intermediate small plugs and dikes of Oligocene age are exposed high on the east flank of the Cortez Mountains. In the same area, a small remnant of an Oligocene rhyolitic welded tuff truncates the Cretaceous Newark Canyon Formation and the tuff of the Indian Well Formation.

4. *Block faulting that outlined the basin-and-range topography of essentially the present configuration.* — Block faulting during Miocene time outlined the basins and ranges in essentially their present forms. Basin deposits younger than the beginning of this faulting reflect the sources of detritus as the mountains bounding the basins and also record continued relative uplift of the mountains by the types and textures of derived rock materials. The oldest of these deposits in the Carlin-Pinon Range area makes up the Humboldt Formation (restricted), as we restrict it to include an upper Miocene sequence of fluviatile and lacustrine deposits that contain much vitric ash as well as tuffaceous material in other beds. East of the Pinon Range these beds are about 537 m (1,765 ft) thick. West and northwest of the range, the Humboldt Formation (restricted) includes the upper part of the Raine Ranch and the Carlin Formations of Regnier (1960), which have a wedge of Palisade Canyon Rhyolite between them.

Andesite and basaltic andesite remaining in scattered patches in the east half of the mapped area and a few small basalt plugs at the north end of Pine Valley also are probably upper Miocene.

The Hay Ranch Formation of middle Pliocene to middle Pleistocene age covers much of Pine Valley and consists of typical basin-fill deposits, which grade basinward from coarse fanglomerate in places near the mountains through sandstone into siltstone, clay, and limestone beds that are lacustrine. Most of the clastic beds are tuffaceous, and vitric ash and tuff are interlayered in the sequence.

Youngest materials in the area are alluvial and colluvial and occur mostly along streams and as cappings of benches and terraces over broad flats.

Data from an aeromagnetic survey of the area were interpreted by D. R. Mabey. These data show that a northwest-trending magnetic field occurs in the northeast part of the area, that a distorted zone of magnetic highs and lows occurs from the southeast corner to the northwest corner, and that other highs occur near the west edge of the area. The distortions indicate the presence of igneous rocks either on the surface or at shallow depths. Three probable buried intrusive bodies are indicated: (1) near the center of the mapped area; (2) in the northwest corner, as part of a body that extends to the northwest beyond this area; and (3) near the center west edge of the area. A fourth possible intrusion or an iron concentration is indicated in the southwest quarter of the area and a problematical buried intrusion in the southeast quarter.

Metallic mineral resources that have been produced in the area are principally silver, copper, and lead from the Railroad mining district. Mineralization was associated with the intrusion of the Oligocene stock and dikes, which are above the large buried intrusion. Similarly mineralized rock may exist at reasonably shallow depths elsewhere above the buried intrusion, particularly under Pine Mountain and directly south of the Railroad district. Iron ore has been mined west of the Carlin-Pinon Range area. The aeromagnetic high in the southwest quarter of the mapped area may conceivably indicate a buried magnetic rock similar to that at one of the iron mines to the west. Prospecting for vanadium has been conducted in shale and siltstone of lower Paleozoic siliceous rock formations.

Recognized nonmetallic resources or potential resources include a variety of materials: sand and gravel, crushed volcanic rock for railroad ballast, diatomite, volcanic ash, zeolites, and perlite or perlitic rock identified only in small patches or pockets. Barite occurs sparingly and has been mined from a vein, but no large deposits have been recognized.

Possible source rocks for petroleum crop out in the area, but the existence of traps is difficult to assess because of the complex structure. Oil shale in the Elko Formation is high grade at least in some beds, but the quantity of such shale that remains covered in the basins is impossible to determine on the basis of existing exposures. Conceivably, oil could have been derived under natural conditions from this shale. Mudstone and shale containing carbonaceous material occur in several Paleozoic formations in the area and may possibly have been petroleum source rocks. The thickest and most widespread of these shales are in the Mississippian Chainman Shale.

Water resources in this area certainly appear to be ample to support ranching as the continuing chief economic activity. Perennial streams supply water for irrigation of hay crops. Many springs in the mountains and basins afford water for livestock, and some springs are large enough to maintain perennial streams, which add to the streamflow in the axial valleys. At least three springs qualify as thermal.

INTRODUCTION

Since Paleozoic time northeast Nevada has undergone a complicated history involving deformation, uplift and depression both locally and regionally, and very extensive erosion at a number of different times. As a result, rock remnants from which the history may be deciphered are widely scattered, and critical parts of the stratigraphic section are completely missing over wide areas. Some parts of the stratigraphic section may have been removed by erosion, whereas other parts are now covered by younger material in basins.

Many pieces of the stratigraphic section are exposed in the four 15-minute quadrangles that make up the Carlin-Pinon Range area. Some of these pieces are small, but even so they contribute to an understanding of the post-Paleozoic geologic picture. Many parts of the Cretaceous and Cenozoic deposits in Pine Valley and in the Dixie Flats-Huntington Creek areas are now exposed because they are being eroded rather than being filled, in contrast to many intermontane valleys in the Great Basin.

Post-Paleozoic rock units recognized in the area of this report are listed in table 1. As a number of the units are recognized only west or east of the Pinon Range that forms the north-trending backbone of the area, the units are listed for the west and east halves of the Carlin-Pinon Range area. The basin on the west is Pine Valley and the one on the east, Huntington Valley and Dixie Flats.

A composite section of post-Paleozoic rocks composed of the maximum measured thickness of each unit in the mapped area is about 9,300 m (32,000 ft). Of this amount, about 2,745 m (9,000 ft) is Jurassic, about 915 m (3,000 ft) Cretaceous, and almost 5,640 m (18,500 ft) Tertiary and a little Quaternary. An estimate of about 3,050 m (10,000 ft) of Cenozoic fill in Pine Valley at the southern edge of the mapped area and farther south has been made on the basis of gravity data (Mabey, 1964).

Gravity data indicate that the thickness of post-Paleozoic fill in the basins is much less than the

TABLE 1. — *Post-Paleozoic rocks of the Carlin-Pinon Range area, Nevada*

West half of area	East half of area	Intrusive rocks
Landslide deposits, alluvium and colluvium, gravel, sand, and silt	Alluvium and colluvium, gravel, sand, and silt	
	QUATERNARY and TERTIARY Pleistocene and Pliocene	
Hay Ranch Formation	Hay Ranch Formation	
	TERTIARY Miocene	
	Andesite and basaltic andesite	Basalt plugs
Humboldt Formation (restricted)	Humboldt Formation (restricted)	
Palisade Canyon Rhyolite		
Humboldt Formation (restricted)		
	Oligocene	
Rhyolitic welded tuff	Younger intermediate to silicic volcanics	Mafic to intermediate plugs and dikes
Indian Well Formation:	Indian Well Formation:	
Lapilli tuff	Ash-flow tuff and sedimentary rocks	Silicic intrusive rocks
Basal unit	Basal unit	
	Mafic to silicic volcanics	
	Oligocene or Eocene	
Older intermediate volcanics	Elko Formation	
	Eocene	
	Limestone	
	Cherty limestone	
	Eocene(?)	
	Conglomerate, sandstone, siltstone, and limestone	
	Limestone and limestone-clast conglomerate	
	CRETACEOUS	
Newark Canyon Formation — Basal unit	Newark Canyon Formation	
	JURASSIC	
		Alaskite
Frenchie Creek Rhyolite	Frenchie Creek(?) Rhyolite	Rhyolite(?) plug
Sod House Tuff		
Big Pole Formation		

composite thickness of the units. This factor and the widely different thicknesses of exposures of single units indicate a number of different times of deposition and erosion, which evidently indicate repeated relative uplift and depression of the area or of parts of the area.

On a broad basis these post-Paleozoic rocks may be separated into two lithologic groupings: (1) those sequences containing volcanic rocks or pyroclastic debris, and (2) those containing no volcanic rocks or pyroclastic debris. In this respect the Jurassic rocks are in the volcanic category, the Cretaceous and most of the Eocene rocks in the nonvolcanic category, the very highest Eocene through the lower Quaternary in the volcanic, and the upper Quaternary, including alluvium, colluvium, gravels, and other silt and sand, in generally nonvolcanic. All the sedimentary deposits are nonmarine and are both lacustrine and fluviatile.

THE CARLIN-PINON RANGE AREA

The country here designated the Carlin-Pinon Range area comprises four 15-minute quadrangles — the Carlin, Dixie Flats, Pine Valley, and Robinson Mountain quadrangles — in northeast Nevada (fig. 1). The north-trending Pinon Range that forms the central part of the area contains most of the Paleozoic rocks. Most of the post-Paleozoic rocks are in the lowlands and valleys east and west of this range and in the Cortez Mountains along the west edge of the mapped area.

Drainage is all to the Humboldt River, the principal river in this part of Nevada. It crosses the north part of the mapped area from east to west through the narrow Carlin Canyon, along a broad valley northeast and southwest of the town of Carlin, and then through the narrow Palisade Canyon. The South Fork of the Humboldt River also flows through a meandering canyon before it enters the flood plain of the main river about 13 km (8 m) southwest of Elko. The valleys on each side of the Pinon Range are occupied by permanent streams.

FIELDWORK AND ACKNOWLEDGMENTS

Fieldwork upon which this report is based extended mainly from August 1955 to August 1964. Most studies of the post-Paleozoic rocks were made from 1961 to 1964 and during a few days each year in 1965, 1969, and 1971. Results of the stratigraphic studies are reported in two parts: a previous report on the Paleozoic rocks, and this report on 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 generalizations of map units and contact lines in many places.

We were fortunate in having able assistance in the field from a number of people whose field sessions with us ranged from 1 month to 5 months. 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

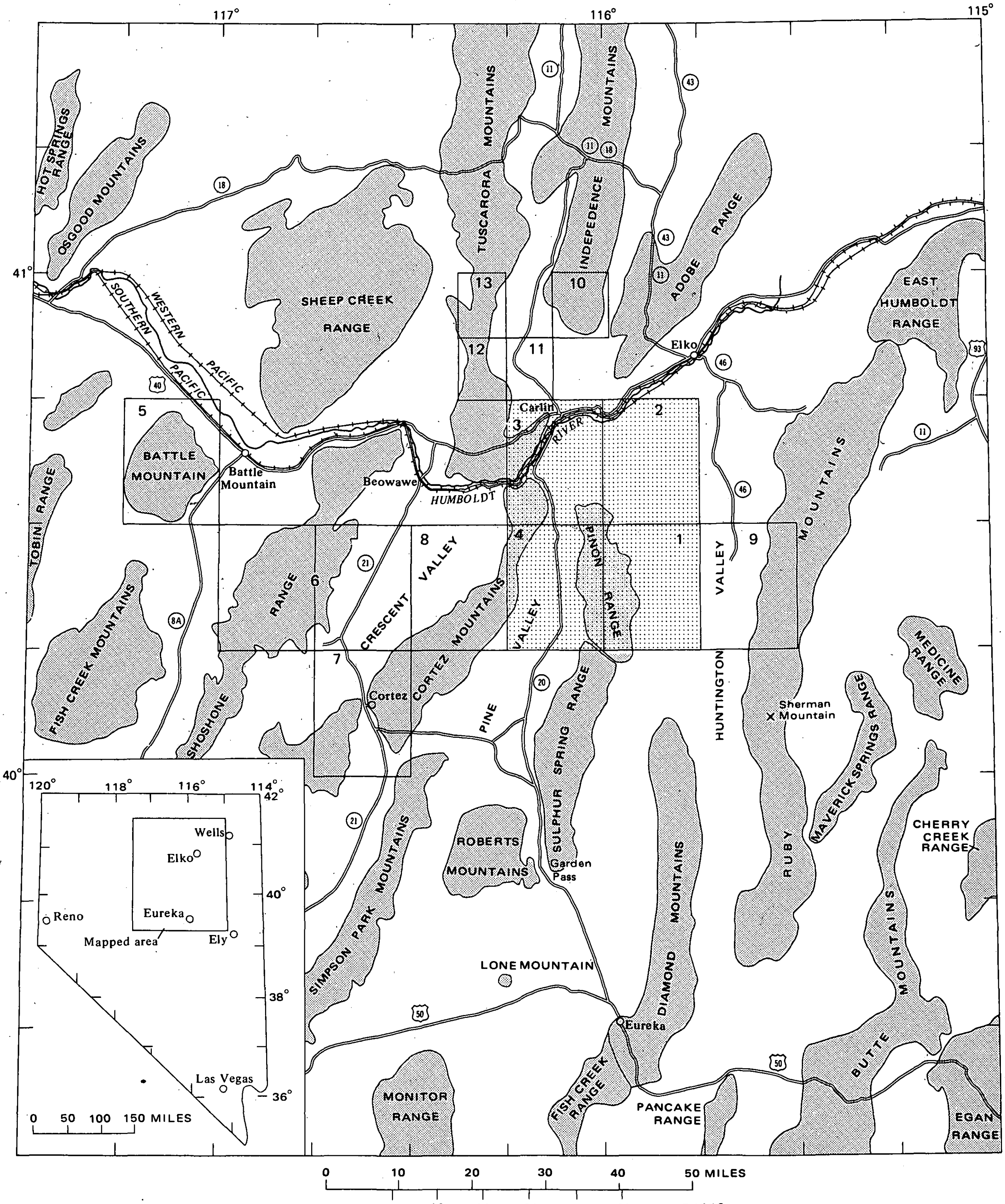

FIGURE 1.—Index map of part of northeast Nevada, showing the locations of the quadrangle maps — (1) Robinson Mountain, (2) Dixie Flats, (3) Carlin, and (4) Pine Valley — that make up the Carlin-Pinon Range area (dot-patterned area), and the locations of recently published maps of nearby quadrangles — (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 (Willden 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, 1974b), and (13) Rodeo Creek NE (Evans, 1974a).

in work on both post-Paleozoic and Paleozoic units include David D. Blackwell in 1961 and 1962, William L. Lembeck in 1963, and Robert K. Smith in 1964. Assistance in studies primarily of Paleozoic rocks came from Robert N. Diffenbach in 1956, Richard S. Kopp in 1956 and 1957, Lucian B. Platt in 1957, John B. Corliss and George Ditsworth in 1958, Pedro A. Gelabert and Jack A. Wolfe in 1959, William M. Briggs in 1960, and Jose B. Alarcon, from Chile, in 1961. To all these people we extend our sincere thanks.

Although we were not very successful in finding large numbers of fossils in these post-Paleozoic units, some of the collections were diagnostic in establishing the rock ages. For fossil identifications and age determinations we are grateful to Estella B. Leopold, G. Edward Lewis, Raymond E. Peck, I. G. Sohn, Dwight W. Taylor, and Jack A. Wolfe. Specific references to reports of each of these paleontologists are made at appropriate places in the text.

Radiometric ages were invaluable in establishing stratigraphic positions of several of the volcanic rock units. For determination of K-Ar ages we are most grateful to Richard F. Marvin and his colleagues H. H. Mehnert, Violet Merritt, and J. D. Mensik, and for a zircon fission-track age of the Humboldt Formation (restricted), we thank Charles W. Naeser.

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

PREVIOUS WORK

Post-Paleozoic rocks of this area were first examined by members of the 40th Parallel Survey (King, 1877, p. 462, 540; King, 1878, p. 434-443), who made reference to the "Humboldt group" of Tertiary age and to the "Elko shales" in Dixie Valley of Eocene age. Van Houten (1956), in his survey of the Cenozoic of Nevada, made many references to the area of the present report and suggested broad correlations. Studies of smaller areas more directly related to the Carlin-Pinon Range area include those of Sharp (1939), Regnier (1960), and Muffler (1964). Our map of Pine Valley and of the Tertiary beds farther north is essentially the same as that of Regnier. A few minor changes were made, and the ages of some units were changed in light of fossil collections and radiometric age data not available to him. We have used the units set up by Muffler in the Cortez Mountains. Sharp's work on the Humboldt Formation served as a most useful guide, though on the basis of more detailed mapping and additional information on ages of units we are restricting the Humboldt to include less of the rock section than was included in it by Sharp. Recent studies of ground water include those of Eakin (1961) for Pine Valley and of Rush and Everett (1966) for Huntington Valley.

ROCK FORMATIONS

JURASSIC SYSTEM

PONY TRAIL GROUP

In the Cortez Mountains west of the Pine Valley quadrangle, a sequence of volcaniclastic and volcanic rocks was named the Pony Trail Group by Muffler (1964, p. 20-39) and separated into three formations — from bottom to top, the Big Pole Formation, the Sod House Tuff, and the Frenchie Creek Rhyolite. Biotite from a flow in the Frenchie Creek Rhyolite has been dated as 151±3 m.y. by Richard L. Armstrong, L.J.P. Muffler (written commun., Mar. 1972). This date places the uppermost of the three formations in the Upper Jurassic according to the "Geological Society Phanerozoic time-scale 1964" (Harland and others, 1964); presumably the entire group is Jurassic, as was postulated by Muffler (1964, p. 21-22) before the rhyolite flow was dated radiometrically.

BIG POLE FORMATION

The Big Pole Formation is exposed over an area of less than 0.6 km^2 (0.25 mi^2) at the west edge of the area north of Big Pole Creek. This formation is composed chiefly of beds of poorly sorted clastic material, consisting of fragments of volcanic rocks, plagioclase, and quartz set in a matrix of argillaceous matter, and of very fine grained quartz and finely broken volcanic detritus. The thickness is probably at least 305 m (1,000 ft) in this small area of exposure and may be 1,830 m (6,000 ft) in the Frenchie Creek quadrangle (Muffler, 1964, p. 22). For further information on the Big Pole Formation the reader is referred to Muffler's description (1964, p. 22-26).

SOD HOUSE TUFF

The Sod House Tuff crops out mostly around one hill along the southwest edge of the mapped area and covers almost 10.4 km^2 (4 mi^2). This formation is also more extensively exposed in the Frenchie Creek quadrangle and is well described by Muffler (1964, p. 26-32), and so only a very brief description is offered in the present report. Exposures of the formation extend through a vertical distance of about 305 m (1,000 ft), and as no folds or faults were identified positively in this sequence the Sod House Tuff is probably at least 305 m (1,000 ft) thick.

Rock units making up the Sod House Tuff are largely silicic ash-flow tuffs, which are most commonly gray to almost white. Quartz and feldspar (commonly sanidine), and less biotite are the principal phenocrysts. The largest quartz phenocryst noted is about 2.6 mm across; many of the larger quartz pieces are embayed or rounded. The largest sanidine observed is about 2.25 mm across. Plagioclase phenocrysts are prominent in some samples, and in one thin section examined, plagioclase formed 35 percent of the phenocrysts that compose 25 percent of the rock.

The groundmass is aphanitic, and it, as well as the feldspar and biotite phenocrysts, is much altered, mostly to clay minerals. Much of the biotite has been altered to an opaque material.

Pumice fragments are prominent in some layers, but shards are very poorly defined if observable at all. Inclusions are common in the tuffs and autoliths abundant in some units. Fragments of foreign rocks are much less abundant than autoliths.

Sandstone occurs locally with the tuffs but is seen mainly as float. Thin lava flows make up a very small percentage of the whole formation.

Relations between the Sod House Tuff and the underlying Big Pole Formation are poorly discernible in the area of the present report. In the Frenchie Creek quadrangle to the west, the Sod House is unconformable on the Big Pole, at least locally (Muffler, 1964, p. 26). The Sod House appears to be overlain unconformably by the Frenchie Creek Rhyolite.

FRENCHIE CREEK RHYOLITE

The Frenchie Creek Rhyolite (Muffler, 1964, p. 32-37) which forms the backbone of the range, is exposed along most of the Cortez Mountains in the area of this report. Bold outcrops occur on cliffs and jagged ridges and peaks. According to Muffler (1964, p. 32) the formation is about 760 m (2,500 ft) thick at the type locality in the Frenchie Creek quadrangle. As determined from map relations in the Carlin-Pinon Range area, the thickness may be as much as 2,135 m (7,000 ft).

As the lower part of the formation in the mapped area contains tuffs, sedimentary beds, and flows, and the upper part contains nearly all flows, the formation is shown as two members on the geologic map (pl. 1). A gradational and most likely interfingering contact joins the two informal members; as a result, probably no two mappers would place the contact at exactly the same place. The interfingering contact shown in secs. 15, 16, and 21, T. 30 N., R. 51 E. is essentially diagrammatic.

Lava flows are prominent in both members, and, of course, dominant in the upper one. They range from rhyolite to andesite, are commonly fine grained porphyritic, and are light gray to black. Reddish-brown or maroon and black are the most common colors. Study of thin sections suggests that andesite predominates in the mapped area, but chemical analyses indicate that a number of samples are more silicic than andesite (table 2). Rhyolite is the dominant rock type in the Frenchie Creek quadrangle as based on chemical analyses (Muffler, 1964, p. 33-34). Phenocrysts compose only a few percent to about 30 percent of these rocks. Nearly all the flows are somewhat sericitized and chloritized, and some are so much altered that the original composition is most uncertain. Most of these rocks must have been vitrophyric, and many now have a devitrified glassy matrix.

Flow layering or banding is quite common in the Frenchie Creek Rhyolite. In many places the layers are much contorted and obviously cannot be used to determine the attitudes of the flows. Where the layers are fairly regular for distances of a few tens of metres, they may represent the attitude of the flow; a few such attitudes are plotted on the geologic map (pl. 1).

Tuffs are very light to dark gray and tan or yellow. Most are much altered but seem to range from silicic to intermediate composition. Some are glassy.

Sedimentary rocks in the lower member of the Frenchie Creek Rhyolite are dominantly fine- to medium-grained sandstones, which are mostly brown, green, and black. Bedding generally ranges from about 2.5 to 10 cm (1 to 4 in.) in thickness, and the thickest sedimentary unit noted was almost 15 m (50 ft) thick. Quartz and plagioclase compose most of the grains. Some fragments of volcanic rocks as much as 4 cm (1.5 in.) long also occur in these beds. Cement is mostly siliceous but in some layers is slightly calcareous.

Volcanic rocks in a small area in sec. 15, T. 28 N., R. 53 E., on the east side of the Pinon Range, consist of somewhat altered lavas of dacitic to andesitic composition. These are included questionably as part of the Frenchie Creek Rhyolite, because they are of similar composition and they are in the correct stratigraphic position. At least they appear to be older than a poor exposure of probable Newark Canyon Formation, and the youngest volcanic rocks older than the Newark Canyon in the mapped area are in the Frenchie Creek Rhyolite. As part of the Frenchie Creek Rhyolite these volcanics are of particular interest, because they mark the easternmost recognized volcanic rocks of Jurassic age in this general region and indicate that the Frenchie Creek was formerly much more widespread than it is now.

Rhyolite (?) plug. — In sec. 32, T. 30 N., R. 51 E., much altered rhyolite forms the extension of a plug into this area from the Frenchie Creek quadrangle. We merely observed the rock and mapped its rather indefinite boundaries along its small exposure in the area of the present report. We take the liberty of quoting Muffler (1964, p. 39) regarding this and similar plugs: "The rhyolite(?) of these plugs contains phenocrysts of plagioclase, biotite, and quartz, as well as chlorite pseudomorphs. The groundmass is trachytic, but contains no quartz stringers. The plagioclase is altered to a cryptocrystalline brown material, and is partly replaced by secondary albite."

UPPER JURASSIC INTRUSIVE ROCKS

A group of intrusive rocks having variable compositions and forming several types of bodies is discussed under the heading of Lower Cretaceous(?)

TABLE 2. — *Chemical analyses of rocks from the Frenchie Creek Rhyolite (in weight percent)*

[Leaders (.....) indicate not determined. Analyst for Nos. 8 and 9, George O. Riddle; analyst for all other samples, Christel L. Parker]

Sample	1	2	3	4	5	6	7	8	9
Serial No.	D100271	D100272	D100273	D100267	D100268	D100269	D100270	D103224	D103225
Field No.[1]	868	836	838	854	837	866	857	SR-364	SR-365
SiO_2	69.44	62.45	61.43	59.78	63.00	61.17	59.36	62.95	61.29
Al_2O_3	12.23	15.16	14.93	15.98	15.82	15.43	14.88	16.09	15.45
Fe_2O_3	2.38	4.10	2.16	2.35	3.42	1.00	1.20	4.34	1.14
FeO	.85	1.04	.92	3.94	.63	3.96	3.35	.53	3.33
MgO	2.55	2.14	2.28	3.46	2.42	4.31	3.69	1.51	3.71
CaO	2.22	4.29	5.17	6.13	4.83	5.31	4.78	4.48	5.18
Na_2O	1.57	3.07	2.20	3.26	3.08	3.42	2.96	3.23	3.43
K_2O	3.40	3.76	3.49	2.40	3.00	1.51	2.95	3.23	1.98
H_2O+	2.55	1.17	2.84	.97	1.02	2.08	.72	.95	2.33
H_2O-	1.61	.78	1.86	.25	1.33	.25	.24	1.04	.65
TiO_2	.65	.83	.80	.87	.91	.91	.79	.84	.82
P_2O_5	.19	.22	.27	.31	.24	.24	.21	.24	.22
MnO	.03	.08	.10	.14	.10	.09	.07	.12	.09
CO_2	.01	.63	1.24	.05	.03	.02	4.54	.02	.01
Cl	.01	.01	.01	.01	.04	.01	.02	.02	--	--
F	.09	.09	.06	.06	.07	.04	.05	--	--
Subtotal	99.78	99.82	99.76	99.99	99.91	99.76	99.81	99.57	99.63
Less O	.04	.04	.03	.04	.03	.02	.02	--	--
TOTAL	99.74	99.78	99.73	99.95	99.88	99.74	99.79	99.57	99.63

[1]Sample localities are on plate 1.

SAMPLE DESCRIPTIONS

1. Biotite andesite porphyry. Sparse, subhedral, zoned andesine; rare, small, euhedral to subhedral quartz; and both fresh and altered biotite in a devitrified and altered glass matrix. Vesicles filled with zeolites.
2. Pyroxene andesite porphyry. Euhedral to subhedral, zoned, somewhat altered andesine; small subhedral pyroxene (probably augite); biotite mostly altered to chlorite; and sparse corroded quartz in an altered matrix.
3. Lithic tuff of andesite composition. Coarse-grained rock composed of angular fragments of plagioclase, devitrified glass, fine-grained igneous rock fragments, and very sparse quartz.
4. Pyroxene andesite porphyry. Fresh, euhedral to subhedral, zoned andesine; small euhedral and broken pyroxene (probably augite); and sparse biotite in a trachitic matrix.
5. Biotite andesite porphyry. Sparse subhedral andesine extensively replaced by carbonate; rather common corroded quartz; and sparse altered biotite in a trachitic matrix partly replaced by carbonate. Vesicles filled with quartz.
6. Pyroxene andesite porphyry. Small, broken and corroded, slightly altered andesine; and small, corroded pyroxene (probably augite) in a trachitic matrix.
7. Biotite andesite porphyry. Euhedral to subhedral andesine, fresh to partly altered, zoned, as much as 5 mm long; and mostly altered biotite in intensively altered devitrified glass matrix.
8. Pyroxene andesite porphyry. Euhedral to subhedral andesine, some zoned, maximum length about 1.3 mm; subhedral pyroxene, some broken, stubby and elongate, maximum length about 1.5 mm; sparse altered biotite; very fine grained trachitic matrix; stringers of iron oxide alteration.
9. Pyroxene andesite porphyry. Euhedral to subhedral plagioclase, mostly andesine, some labradorite, some zoned, maximum length about 2.0 mm; small stubby and elongate pyroxene, maximum length 2.0 mm; trachitic and glassy matrix.

plutonic rocks by Muffler (1964, p. 39–64). These rocks are of Late Jurassic age on the basis of a radiometric age of ±140 m.y., determined by R. L. Armstrong as a reasonable estimate of the age of one of the alaskite bodies in this group (Muffler, 1964, footnote p. 39). This Jurassic age is according to the Phanerozoic time-scale of the Geological Society of London (Harland, and others, 1964).

In four places, parts of some of these bodies extend into the area of the present report. The two southern extensions cover very small areas and connect with Muffler's undivided intrusive rocks. From megascopic examination of these unites in the Carlin-Pinon Range area, they appear to be near granodiorite in composition. They are medium-grained, generally equigranular, mostly gray or speckled very light gray and gray, and much altered.

The only other rock type in this general grouping is alaskite, which occurs in two intrusive bodies in the Cortez Mountains; both bodies are much larger to the west in the Frenchie Creek quandrangle (Muffler, 1964, pl. 1). Pink to light gray are the common colors, though in places the rock is almost white. The alaskite is fine grained to medium grained and is mostly porphyritic in the mapped area, but some is granitic. Most common phenocrysts are quartz, albite, and orthoclase, and in most exposures the rock is much altered, in places so much so that many phenocrysts are not identifiable in hand speciman. Spheroidal weathering is well developed locally. Contacts between the alaskite and the country rock are obscure over much of their extent, largely because both the intrusive and country rocks are altered.

CRETACEOUS AND YOUNGER SYSTEMS

Dating of Cretaceous and younger rocks is based on rock and fossil collections from the Carlin-Pinon Range area, in contrast to the dating of Jurassic rocks, which is based mainly on Muffer's work (1964) in the Frenchie Creek quadrangle. Table 3 presents the radiometric ages and diagnostic fossils of post-Jurassic rocks.

CRETACEOUS SYSTEM

NEWARK CANYON FORMATION

The name Newark Canyon Formation was applied by Nolan, Merriam, and Williams (1956, p. 68–70) to a group of heterogeneous rocks of Cretaceous age in the Eureka area (fig. 1). The name includes Cretaceous rocks of a variety of nonmarine types in the Cortez Mountains and the Pinon Range. Included in the Newark Canyon are conglomerate, sandstone, siltstone, mudstone, shale, and limestone. As the lithologic types are somewhat different in each group of exposures, areas of outcrop are described separately.

The thickest and most extensively exposed rocks of the Newark Canyon form an almost continuous belt about 12 km (7.5 mi) long and slightly more than (1.5 km (1 mi) across in the widest part, along the east flank of the Cortez Mountains. The series of beds exposed here was called the Rand Ranch Formation by Regnier (1960, p. 1193), who dated them tentatively as Oligocene on inferential evidence.

A basal member consisting mostly of poorly consolidated dark-gray to black massive mudstone occurs locally at the base of the Newark Canyon in the Cortez Mountains. It also contains tan siltstone, poorly consolidated sandstone, and conglomerate and sandstone lenses (fig. 2).

A lens of poorly consolidated conglomerate forms the base of the member for a distance of about 1.6 km (1 mi). The conglomerate consists of rounded pebbles and cobbles of volcanic rocks, as much as 15 cm (6 in.) in diameter. Most clasts are aphanitic and are light colored to almost white; they weather tan and light gray and have pitted surfaces. Some of the smaller pebbles are generally darker but are also chiefly aphanitic volcanic rocks; a few are chert and very sparse ones are quartzite. This conglomerate is poorly consolidated but can be traced by the litter of pebbles and small cobbles along the slope. A lens of very fine grained sandstone and siltstone overlies the

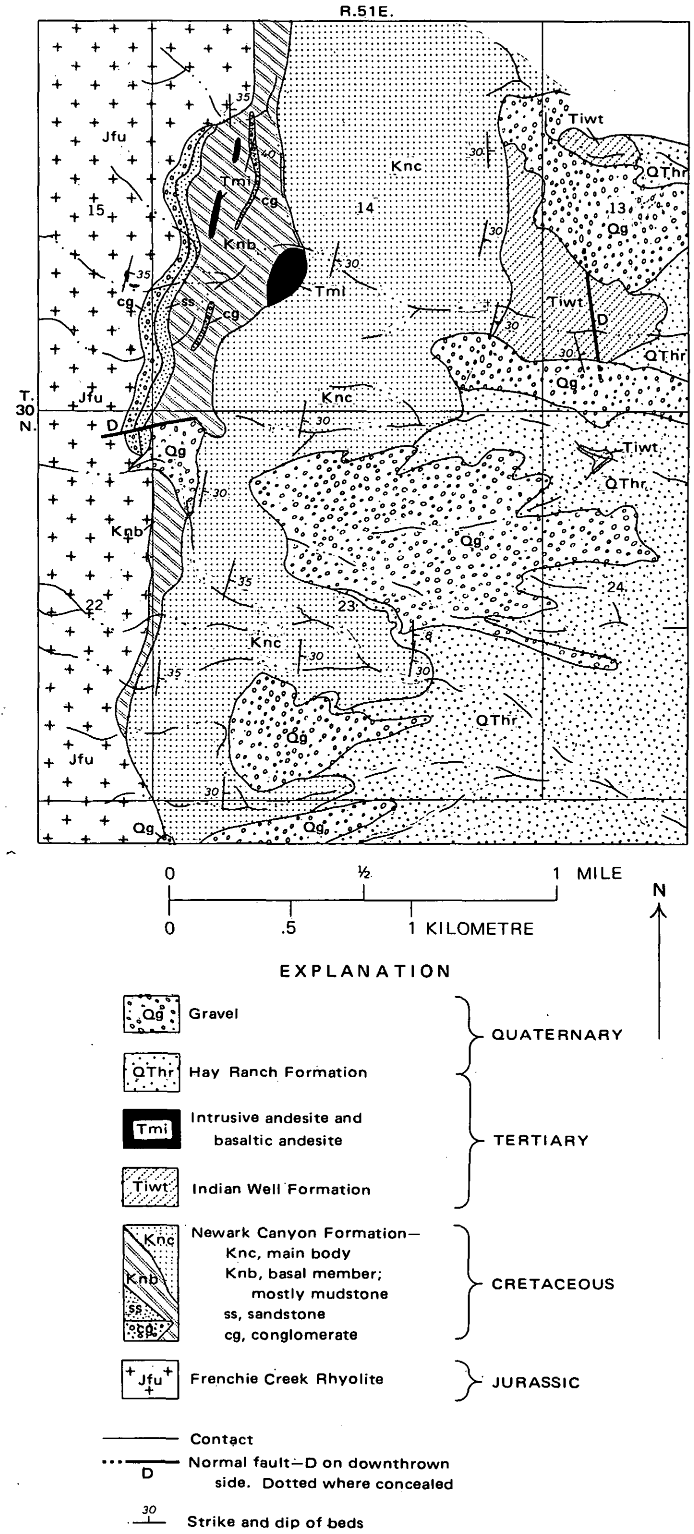

FIGURE 2.—Sketch map of lenticular units in the Newark Canyon Formation on the east side of the Cortez Mountains.

basal conglomerate lens. A few conglomerate stringers that occur in the fine-grained lens consist of nearly all chert clasts but contain some quartzite

TABLE 3. — *Radiometric ages and diagnostic fossils of the Cretaceous, Tertiary and Quaternary rocks in the Carlin-Pinon Range area, Nevada*

System	Series	Unit	Radiometric age in millions of years	Material analyzed	Analyst(s) and method	Diagnostic fossils and identifying paleontologist or source of data
Quaternary	Holocene Pleistocene	Alluvium and colluvium-landslide deposits--gravel, sand, and silt				Mammoth, Mammuthus (Parelephas) columbi (Falconer) (G. E. Lewis)
Tertiary	Pliocene	Hay Ranch Formation				Equus, sensu lato (G. E. Lewis) Vertebrates (Regnier, 1960, p. 1203)
	Miocene (upper)	Andesite and basaltic andesite; basalt plugs				
		Humboldt Formation (restricted)	9.5±1.9	Zircon	C. W. Naeser--fission track	Vertebrates (Regnier, 1960, p. 1199)
		Palisade Canyon Rhyolite	15.0±1.0	Whole rock	R. L. Armstrong (1970, p. 212-213, Sample 112)--K-Ar	
		Humboldt Formation (restricted)				Merychippus sp.; rhinocerotid (?Aphelops sp.); camelids (?Procamelus sp., ?Aepycamelus sp., and/or ?Hesperocamelus sp.) (G. E. Lewis) Vertebrates (Regnier, 1960, p. 1195 and 1197)
	Oligocene	Rhyolitic welded tuff	31.2±1.0	Sanidine	R. F. Marvin, H. H. Mehnert, and Violet Merritt--K-Ar	
		Mafic to intermediate plugs and dikes	31.9±1.1	Whole rock	R. F. Marvin, H. H. Mehnert, and Violet Merritt--K-Ar	
		Younger intermediate to silicic volcanics				
		Indian Well Formation	33.2±0.7 34.9±0.7 36.2±0.7 37.6±1.3	Sanidine Biotite do. do.	R. F. Marvin, H. H. Mehnert, and J. D. Mensik--K-Ar do. R. L. Armstrong (1970, p. 212-213, Sample 111)--K-Ar R. F. Marvin, H. H. Mehnert, and Violet Merritt--K-Ar	
		Silicic intrusive rocks	36.8±1.0 35.4±1.1 35.3±0.7 36.0±1.4	Biotite Sanidine Biotite Whole rock	R. F. Marvin, H. H. Mehnert, and J. D. Mensik--K-Ar do. R. L. Armstrong (1970, p. 214-215, Sample 109)--K-Ar R. L. Armstrong (1970, p. 214-215, Sample 110)--K-Ar	
		Mafic to silicic volcanics				
	Oligocene or Eocene	Elko Formation	38.6±1.2	Biotite	R. F. Marvin, H. H. Mehnert, and J. D. Mensik--K-Ar	Snails (D. W. Taylor)
		Older intermediate volcanics				
	Eocene	Limestone				
		Cherty limestone				Snails-early Oligocene or Eocene (D. W. Taylor)
Tertiary(?)	Eocene(?)	Conglomerate, sandstone, siltstone, and limestone				Snails and clams-early Tertiary or Cretaceous (D. W. Taylor)
		Limestone and limestone-clast conglomerate				
Cretaceous	Upper and Lower	Newark Canyon Formation				Plants: Asplenites tenellum (Knowlton) Dorf and Araucarites longifolia (Lesquereux) Dorf (J. A. Wolfe) Pollen: Gymnosperm and fern assemblage mainly, 11 genera (E. B. Leopold) Ostracodes (Sohn, 1969) Ankylosaurid dinosaur (G. E. Lewis)

clasts and very sparse volcanic ones. The maximum clast size is about 8.5 cm (3.5 in.). Small lenses of conglomerate similar to the basal conglomerate lens also occur higher in the mudstone unit.

Conglomerate of nonvolcanic pebbles occurs in very sparse thin layers above the base of the mudstone unit. These conglomerate layers consist of highly polished pebbles that are angular but have rounded and smoothed edges. The pebbles are almost entirely chert and silicified limestone; some contain sections of bryozoans, crinoid stems, and brachiopods. Most pebbles are 1.5 cm (1 in.) or less in maximum dimension, but a few noted are as much as 10 cm (4 in.) long and flattened. Definite layers are difficult to distinguish in these poorly consolidated beds, but some must be no more than a pebble thick and a few metres long. Most commonly, the pebbles weather from the mudstone to lie on the slopes. These pebble layers are of particular significance because the dinosaur bones and teeth on which these rocks are dated are associated with them. A few small pieces of silicified wood were found in the same area.

The mudstone unit is exposed in two strips between the Frenchie Creek lava flows and the main body of the Newark Canyon Formation. Probably the mudstone and associated conglomerate and sandstone were deposited in low areas on the flows. The thickness of the mudstone unit ranges from 0 to about 215 m (700 ft), as determined from the map. Thickness differences must be in part the result of deposition on an irregular surface and possibly in part the result of some erosion before deposition of the rest of the Newark Canyon Formation.

The principal part of the Newark Canyon in the Cortez Mountains consists dominantly of sandstone and conglomerate, and contains less siltstone and a few percent of limestone. The rocks are gray, tan, brown, and red. Some siltstone beds in particular are red; float from them, in places, and red sandstone give the formation a reddish color that may be seen from the center of Pine Valley. The sandstones are both evenly bedded and crossbedded, are fine grained to coarse grained, are poorly sorted to well sorted, and have calcareous or siliceous cements. The conglomerates occur in beds and lenses as much as 7 m (25 ft) thick; are commonly crossbedded, on a large scale in places; and commonly fill scour channels. Fragments of volcanic rocks constitute many grains in the sandstones and many clasts in the conglomerates in the lower 90–135 m (300–450 ft) of the principal part of the formation. Volcanic-rock clasts range in composition mostly from rhyolite to andesite and have a maximum diameter of about 20 cm (8 in.). Other clasts are of sandstone, quartzite, chert of a variety of colors, limestone, and silicified limestone; these clasts most commonly are pebbles 5 cm (2 in.) or less in diameter, but also occur as boulders up to 0.3 m (1 ft) in diameter. Nearly all the sedimentary rocks, from pebbles to boulders, can be identified as derived from Paleozoic strata in the region. Some of the limestone ones contain fossils.

Some sandstone beds are composed almost entirely of volcanic grains that generally are angular to subangular. Other grains that compose the sandstone include quartz and a trace to small percentages of chert and weathered feldspar. Above the lower few hundred metres, some of the sandstone beds consist of up to 99 percent quartz grains.

Limestone in the Newark Canyon on the east side of the Cortez Mountains occurs in the upper 228 m (750 ft) of the section. The limestone is light and dark gray, tan, and creamy tan, and weathers mostly gray. It is in beds generally 0.6–5 cm (0.25–2 in.) thick and weathers to form platy fragments most commonly 0.6–2 cm (0.25–0.75 in.) thick. The rock is dense and silty; grain size is observed in thin section to be commonly 0.0005 to 0.02 mm.

The following stratigraphic section of the Newark Canyon above the basal mudstone unit is 660 m (2,170 ft) thick and was measured near the south end of the exposures.

Measured stratigraphic section (S1 on pl. 1) of Cretaceous rocks on the east side of Cortez Mountains in secs. 9 and 10, T. 29 N., R. 51 E., Pine Valley quadrangle

[Start about 213 m (700 ft) southwest of center of sec. 9, then go east along north side of creek, cross creek at prominent bend in sec. 10 and continue on south side to about 305 m (1,000 feet) southeast of center of sec. 10. Measured with Abney level on Jacob Staff and with Brunton compass and steel tape]

	Thickness *m*	*ft*
Quaternary System:		
Gravel, sand, and silt.		
Unconformity.		
Cretaceous System:		
Newark Canyon Formation:		
20. Limestone, light gray and creamy tan; weathers tan and yellow in platy pieces; bedding mostly 0.6–1.3 cm (0.25–0.5 in.) thick	15	50
19. Covered, probably mostly sandstone	110	360
18. Conglomerate, brown-weathering; evenly bedded in beds 0.3–1.2 m (1–4 ft) thick, but whole unit is probably lenticular; contains lenses and thin beds of sandstone. Clasts are well rounded and consist of siliceous siltstone, quartzite, sandstone (fine grained and coarse grained) containing grains of gray to white chert and quartz, and gray silicified limestone; maximum pebble size about 5.1 cm (2 in.); fairly well graded. Unit is east edge of exposure of Cretaceous rocks on north side of creek	29	95
17. Covered; float pieces are sandstone and much less platy silty limestone	23	75
16. Limestone, silty, gray and tan; weathers same; in platy beds 0.6–2.5 cm (0.25–1 in.) thick	3	10

Measured section (S1) of Cretaceous rocks on the east side of Cortez Mountains — Continued

	Thickness m	Thickness ft
Cretaceous System — Continued		
Newark Canyon Formation — Continued		
15. Covered chiefly; a few outcrops of sandstone	22	70
14. Conglomerate, brown-weathering; similar to unit 5	6	20
13. Covered; probably sandstone and siltstone	46	150
12. Sandstone, conglomeratic beds, and siltstone, all calcareous; gray limestone, gray platy limestone, and dark-tan limestone, in beds 0.3–0.6 m (1–2 ft) thick; total thickness of limestone in unit probably about 3 m (10 ft); some sandstone is made up of coarse, rounded quartz grains and scattered angular chert grains, and is calcareous. Fossils from this unit date the formation; they include plants in the sandstone, pollen in sandstone, poorly preserved snails, poorly preserved ostracodes, algae, and silicified wood fragments	11	35
11. Sandstone, siltstone, and conglomerate similar to that below; contains some pebbles of volcanic rocks	18	60
10. Sandstone, chiefly; light-tan fine-grained sandstone is prominently crossbedded; siltstone and conglomerate near base. A 3-m (10-ft) conglomerate contains black chert, quartz, and limestone cobbles as much as 7.6 cm (3 in.) in diameter; the limestone clasts contain fragments of fossils, chiefly crinoid columnals. All rocks and the slope are mostly tan and brown. All rocks are calcareous except for a few thin beds of dark siltstone. Lower sandstone beds contain poor plant fragments	23	75
9. Sandstone, chiefly, fine- to coarse-grained; some siltstone and conglomerate beds containing many red chert pebbles in places. Most rocks are tan and weather to form a tan slope, in contrast to unit below. Most beds are calcareous. Some poorly exposed interbeds are probably siltstone	23	75
8. Sandstone, fine-grained, calcareous, pale-red to pink; in beds 2.5–10 cm (1–4 in.) thick and crossbedded. Overlain by sandstone, conglomerate layers and lenses containing quartzite and chert clasts generally less than 2.5 cm (1 in.) in diameter and maximum of 7.6 cm (3 in.), and siltstone; all calcareous. Also, evidently interbedded red shaly siltstone that tends to color entire slope. Within 4.5 m (15 ft) of top is red calcareous sandstone	40	130

Measured section (S1) of Cretaceous rocks on the east side of Cortez Mountains — Continued

	Thickness m	Thickness ft
Cretaceous System — Continued		
Newark Canyon Formation — Continued		
7. Sandstone, grit, and pebbly layers similar to those below but somewhat redder; scattered conglomerate layers and a prominent one in upper 9 m (30 ft); poorly exposed gray shaly siltstone in places	61	200
6. Sandstone, very fine grained to coarse-grained, chiefly light-whitish-gray and tan; also some siltstone, grit, and pebbly beds; similar to unit 4	21	70
5. Conglomerate, light-colored, weathers brown; contains mostly well rounded pebbles of siliceous rocks — siliceous siltstone, quartzite, sandstone (fine grained and coarse grained) with grains of gray to white chert and quartz, pebble conglomerate, and gray silicified limestone (some of which contains fossil fragments); matrix chiefly grit size fragments of gray, tan, and green chert; more grit and pebbly beds in upper part. Moderately well sorted in places and poorly sorted in others. Bedding generally indistinct; no crossbedding or channel fill observed. Forms prominent outcrop that extends across valley	11	35
4. Sandstone, chiefly, very fine grained to medium-grained mostly, but some grit-size; white to brown, reddish brown, and red, ferruginous; composed of quartz grains mainly and some chert grains, well rounded to angular; in some beds are scattered gray and tan chert pebbles, mostly less than 1.3 cm (0.5 in.) in diameter; crossbedded on small scale in one exposure — might be more but exposures are not good enough to show bedding. About 38 m (125 ft) above base of unit is a conglomerate layer, about 3 m (10 ft) thick, made up of well-rounded pebbles, as much as 5.1 cm (2 in.) in diameter, of hard siliceous siltstone and of scattered pebbles of poorly cemented coarse-grained sandstone consisting of angular to rounded chert and quartz grains. Some pebble-conglomerate beds, generally 0.3–1.2 cm (1–2 ft) thick, are below this 3-m (10-ft) layer, and more are above it; the pebbles in these beds are quartzite, chert, and some silicified limestone. Gray shaly siltstone crops out in one place near the top of the unit. Sandstone in the upper 15 m (50 ft)		

Measured section (S1) of Cretaceous rocks on the east side of Cortez Mountains — Continued

	Thickness m	ft
Cretaceous System — Continued		
Newark Canyon Formation — Continued		
contains a few poor impressions of plants. The sandstone units are of different colors, depending on the iron content, and are 1.5–4.5 m (5–15 ft) thick chiefly; where beds are exposed on the valley sides, the slopes are striped light gray to red, brown, and almost white	113	370
3. Sandstone, very fine grained to medium grained, nearly white to brown; weathers same; brown sandstone speckled with limonite; some consists largely of angular quartz grains and is friable. Some siltstone is interbedded with the sandstone. Lenticular beds of small pebble conglomerate contain angular to rounded pebbles of tan chert and hornfels. Unit is not well exposed; sandstone float shows bedding in even layers about 0.6 cm (0.25 in.) thick	41	135
2. Conglomerate, tan overall; weathers tan; contains clasts of tan and gray chert, tan fine-grained sandstone and siltstone, quartz, and fewer volcanic rocks; largest cobbles are sandstone and siltstone having maximum noted diameter of 12.7 cm (5 in.); most clasts are angular, but scattered quartz ones are rounded. Some volcanic rock clasts contain quarts phenocrysts, but most do not; some contain fresh biotite. Conglomerate is poorly sorted and matrix consists of fine- to coarse-grained fragments of the same rock types that form the clasts. Thin indistinct sandstone to the south	4.5	15
1. Sandstone, fine- to coarse-grained, and interbedded siltstone and shaly siltstone, mostly tan, weathers tan; some gray siltstone. Slope largely float covered with many scattered outcrops of beds 0.3–0.5 m (1–1.5 ft) thick. Grains are gray and tan chert, and fewer volcanic rocks are found in most beds, but some sandstone is made up almost entirely of fragments of volcanic rocks; most grains are angular to subangular. Pebble-size fragments are scattered through the sandstone	43	140
Exposed Newark Canyon Formation above the basal mudstone unit	660	2170

Contact with underlying mudstone unit is not exposed but appears to be depositional and disconformable. The poorly exposed mudstone unit is about 288 m (175 ft) thick.

In the vicinity of the base of this measured section the basal mudstone unit of the Newark Canyon Formation appears to be essentially concordant on the Frenchie Creek Rhyolite, although the relations along the full extent of the contact suggest that the Frenchie Creek was partially eroded before the Newark Canyon was deposited.

The Newark Canyon Formation crops out in secs. 16, 20, 21, T. 29 N., R. 53 E. in the central part of the Pinon Range. Here the rocks are dark-gray shale and mudstone, sandstone, and limestone. The shale is thin bedded, almost papery in places, and carbonaceous, and seems to form the thickest part of the sequence, although exposures are not good enough to permit accurate thickness measurements. The limestone is dark to light gray and most commonly is found in beds 1.3–1.9 cm (0.5–0.75 in.) thick. It has scattered thin carbonaceous fragments on some surfaces. In places a crinkly texture, which may be of algal origin, essentially parallels the bedding. A few grayish-tan calcareous beds as much as 1.3 cm (0.5 in.) thick are a fossil hash of ostracode fragments. The sandstone is gray and consists of angular to rounded, fine- to medium-size grains; one sample examined in thin section contains 30–40 percent quartz grains, and other grains about equally divided among rock fragments, chert, and feldspar. The Newark Canyon here is unconformable on Mississippian strata and in fault contact with Devonian and Mississippian beds.

Poorly exposed conglomeratic sandstone and some limestone in two small areas in Tps. 27 and 28 N., R. 53 E. are included in the Newark Canyon Formation. These rocks are similar to beds in the younger Eocene(?) conglomerate, sandstone, siltstone, and limestone unit, except that they contain pebbles of volcanic rocks. The volcanic-rock clasts were not derived from volcanics in the hills nearby. Some of the volcanic pebbles are very fine grained and have light-colored pitted weathered surfaces, much like pebbles in lenses of the mudstone unit at the base of the Newark Canyon Formation in the Cortez Mountains.

The Cretaceous age of the Newark Canyon Formation in the report area is based on the identifications of reptile bones and teeth, fossil plants, pollen, and ostracodes. Three collections of reptile bones and teeth were made from the basal mudstone unit in the Cortez Mountains. These collections were studied by Edward Lewis, who reported (written commun., 1961) that some of the forms might be ankylosaurian dinosaurs of Late Cretaceous age. Collection SF-246 from just west of center sec. 14, T. 30 N., R. 51 E. (loc. F-3 on pl. 1) was the most useful for determinations; it contained "crocodilian, gen. and sp., indet., two tooth fragments, and two tooth fragments and crown of tooth with broken root that might be ankylosaurian" (Lewis, written commun., 1961). This material was referred by Lewis to the late Dr. Barnum Brown, American Museum of Natural History in New York City, who replied (letter to Lewis, Oct. 21, 1961) that he considered "a tooth, rib fragment, and end of vertebra to be from an Ankylosaurid dinosaur of Cretaceous or Jurassic age." Collection SF-248 from NW¼, sec. 14, T. 30 N., R. 51 E. (loc. F-4 on pl. 1) contained one tooth fragment of a ?coelurid dinosaur; Lewis (written commun. 1961) reported that "typical coelurids are most abundant in formations of Late Cretaceous age. The foregoing evidence leads me to *guess* that the forms inconclusively identified may be of Late Cretaceous age."

The plants and pollen are from the west half of sec. 10, T. 29 N., R. 51 E., and from unit 12, about 396 m (1,300 ft) above the base of the stratigraphic section measured on the east side of the Cortez Mountains. Jack A. Wolfe (written commun., 1959) reported that collection SF-131-A (loc. F-1 on pl. 1) from this locality contains filicinae, *Asplenites tenellum* (Knowlton) Dorf, and coniferales, *Araucarites longifolia* (Lesquereux) Dorf. Regarding these forms, Wolfe stated:

"Both species are known only from rocks of Cretaceous age. All specimens are unfortunately poorly preserved. Of particular significance is the araucarian conifer, because this group is unknown in North America in the Tertiary, except at a few localities in the lower part of the Fort Union. Precise age determination using the present collection is impossible, because both species are known from the Mesaverde and the Lance. Thus, the rocks containing these specimens could be as old as early Late Cretaceous or as young as latest Cretaceous."

Sandstone collected from the same locality (USGS Palebot. loc. D1521) was examined by Estella B. Leopold, who reported (written commun., 1960) as follows:

"Assemblage mainly composed of Gymnosperms and ferns. Only one angiospermlike form was encountered and it is cf. Aquifoliaceae. However, this identification is only tentative, for it is badly preserved and may not even be a dicot. The other forms include the following:

Dacridiumites florinii Cookson & Pike 1953
**Alisporites opii* Daugherty 1941
Piceae-pollenites microalatus Pot. 1931
Laricoidites sp.
**Araucariacites australis* Cookson 1947
Monosulcites minimus Cookson 1947
Cibotiidites zonatus Ross 1949
Classopollis torosus (Reiss.) Couper 1958
**C. classoides* Pflug 1953
Lophozonotriletes lebedianensis Naumova 1953
Deltoidospora halli Miner 1935
(Starred, *, items are common in the assemblage)

Though the forms that are starred are known to occur occasionally in lower Paleocene sediments, I know of no New World strata younger than Turonian in which they are frequent. This sample could be either of Early Cretaceous or early Late Cretaceous age."

According to Richard A. Scott (written commun., 1960), fossil wood from the same locality "is assignable to the form genus *Cupressinoxylon*, a category for fossil conifer woods having the characteristics of the modern Cupressaceae. Woods of this type range from Cretaceous to Holocene."

Ostracodes, collected from sec. 21, T. 29 N., R. 53 E. (loc. F-2 on pl. 1) in the Pinon Range, reported on by I. G. Sohn (1969), identify these beds as of Early Cretaceous (late Aptian) age. Sohn established two new nonmarine forms, *Cypridea (Cypridea) pecki* n. sp. and *C. (Bisulcocypridea) bicostata* n. subgen., n. sp., from the collections.

The fossil evidence indicates that the Newark Canyon Formation in the Cortez Mountains is certainly of Cretaceous age and possibly near the boundary between Early and Late Cretaceous, and that in the Pinon Range it is of Early Cretaceous age.

The Newark Canyon Formation rests unconformably on older rocks. Angular differences in attitudes across the unconformity are not pronounced where the Newark Canyon is on the Frenchie Creek Rhyolite, but they are pronounced where the Newark Canyon is on Paleozoic rocks.

TERTIARY(?) AND TERTIARY SYSTEM

EOCENE(?) AND EOCENE SERIES

NONVOLCANIC ROCKS

East of the Pinon Range, a series of beds younger than the Cretaceous Newark Canyon Formation consists of conglomerate, sandstone, siltstone, claystone, and limestone that ranges from almost pure to sandy. This group of rocks contains no volcanic material of contemporaneous origin and thus marks a continuation of the volcanic inactivity that existed during the deposition of the Newark Canyon Formation.

Four lithologic units and their stratigraphic order are recognized, but all compose essentially one sequence of beds. Parts of the different units may be more or less contemporaneous facies. They were deposited on a rough terrain as is indicated by the coarse conglomerates and also suggested by variations in gravity values in the Dixie Flats and Huntington Creek area (Mabey, 1964). The outcrop area of each unit is relatively small, but the thickness of the units suggest that extensive basins and lakes existed in the region. Because the country was eroded at times, both during and following deposition of this nonvolcanic rock sequence, and much of the area has been covered by younger materials, the picture of the original extent of this sequence is obscure.

EOCENE(?) SERIES

LIMESTONE AND LIMESTONE-CLAST CONGLOMERATE

This unit, referred to informally as the limestone and limestone-clast conglomerate, consists principally of tan dense limestone and some gray limestone, and of conglomerate composed mostly of limestone pebbles to boulder that can be identified as derived from Paleozoic rocks in the immediate vicinity. Fine-grained sandstone and siltstone, which are poorly exposed and are red locally, make up a small part of the unit. In many places, red weathered surfaces suggest the possible presence of this unit.

The following stratigraphic section of the limestone and limestone-clast-conglomerate unit was measured where it appears to be thickest and best exposed.

Measured stratigraphic section (S2 on pl. 1) of limestone and limestone-clast conglomerate unit in N½ sec. 20, T. 33 N., R. 55 E., Dixie Flats quadrangle.

[Measured by use of Abney level on Jacob Staff]

	Thickness m	Thickness ft
Tertiary(?) System, Eocene(?) Series:		
Limestone and limestone-clast conglomerate:		
Top eroded.		
4. Limestone, dense, creamy, tan; weathers light tan and light gray; poorly exposed; slope covered with fragments. A very few platy pieces of light-gray claystone that weather white are evidently derived from scattered thin beds. Exposures in upper part are too poor to permit adequate determinations of attitudes and measurements of thickness	76+	250+
3. Limestone, dense, creamy, tan; weathers tan and light gray; contains veinlets and small irregular pieces of quartz and calcite locally, which give surface a wormy look; forms massive ledges of beds 1-3 m (2-10 ft) thick	23	75
2. Limestone, dense, creamy, tan; weathers light tan and light gray in places; contains veinlets and small irregular pieces of quartz and calcite locally, which give surface a wormy look; mostly has a smooth weathered surface with scattered spots and curving veinlets of quartz. Poorly exposed but probably in beds 0.3-1 m (1-3 ft) thick; some platy pieces on slope. One small patch of algal limestone crops out about 23 m (75 ft) below top of unit. In upper part of unit, north of line of section, is ostracod coll. SF-303 (loc. F-5 on pl. 2), containing fragments and poorly		

Measured section (S2) of limestone and limestone-clast conglomerate unit — Continued

	Thickness m	Thickness ft
Tertiary(?) System, Eocene(?) Series — Continued		
Limestone and limestone-clast conglomerate — Continued		
preserved steinkerns of Gen. undet. large, smooth, *Cypridea?* aff. *C. bisulcata* (Swain), and Gen. smooth, small according to I. G. Sohn (written commun., 1964), who stated that the fossils are suggestive of an Eocene age when compared with other ostracod collections from the area	75	245
1. Conglomerate, generally gray and gray-weathering; consists of angular clasts mostly 3.8 cm (1.5 in.) or less long of gray and tan chert and angular to rounded clasts of gray limestone; limestone clasts are mostly Permian limestone and range from pebbles to boulders; along line of section they are mostly pebbles and cobbles, but farther north they are boulders as much as 1.1 m (3.5 ft) across; conglomerate mostly massive and poorly bedded; sorting ranges from poor to good; matrix is gray limestone; 5.1-cm (2-in.)-wide piece of coral *Chaetetes* forms one clast. Thickness differs along strike	20	65
Thickness	194+	635+
The formation is unconformable on Permian rocks here. Scour and fill irregularities of 1-1.3 m (3-4 ft) occur locally at the contact.		
Permian System.		

In the northeast part of the mapped area, the basal beds of this unit are conglomerate in nearly all exposures (fig. 3). Clasts in the conglomerate are mostly limestone and less chert, although some beds contain many chert grains and pebbles. The matrix is limestone. Limestone clasts are rounded to angular, and the largest one observed is 1.2 m (3.5 ft) across. Most boulders obviously were derived from nearby Permian limestone before they were enclosed in the deposited limestone matrix, and many boulders in the basal beds certainly did not move many metres from their original positions as they weathered or broke loose from the bedrock. These conglomerates obviously were deposited on an irregular surface and, in places, a surface that probably was very similar to the present one. Locally these beds fill scours 1-1.3 m (3-4 ft) deep and a few metres across. Elsewhere they form a unit a few metres thick that conforms to an irregular surface on Permian limestone below, and in places they appear to have been deposited against and plastered against steep hillsides or valley sides.

The northeasternmost exposures of this unit in secs. 15 and 16, T. 33 N., R. 55 E. consist mostly of conglomerate derived from the Diamond Peak Formation and look much like the Diamond Peak.

Near the east end of Carlin Canyon, this limestone and conglomerate unit crops out on both sides of the Humboldt River. Here, it is in a northeast-plunging syncline and has a fault along the northwest side, north of the river. Conglomerate is the dominant lithology north of the river. It is tan and buff, weathers the same, and is in beds from 2.5 cm–1 m (1 in.–3 ft) thick, but most commonly is 0.3–0.5 m (0.5–2 ft). Locally, the conglomerate is crossbedded on a large scale. Pebbles are largely carbonate rocks, dominantly dolomite or silicified carbonate and less sandy limestone and limestone, and are angular. Clasts in the beds appear to have been derived mostly from Permian strata in the general area. The matrix is tan to buff calcareous siltstone, and in some beds the pebbles are closely packed with essentially no matrix. A very few conglomerate lenses consist of chert and conglomerate pebbles. Some light-red or pink siltstone layers containing widely scattered pebbles are interbedded with the conglomerate. Columnar and spirelike erosional forms have developed on these beds north of the Humboldt River.

FIGURE 3.—Limestone-clast conglomerate in limestone and limestone-clast conglomerate unit. An angular boulder is just below 33-cm- (13-in.-) long hammer. Pebbles to boulders of limestone are rounded to angular. S½ sec. 18, T. 33 N., R. 55 E.

South of the river, the conglomerate is like that to the north, except that boulders are as much as 0.75 m (2.5 ft) across and calcareous siltstone and sandstone beds are more common. These fine-grained beds are red, tan, and yellow and weather the same colors; as in the northeast part of the area, reddish slopes in places are a characteristic feature of the limestone and limestone-clast-conglomerate unit.

A suggested Eocene age of the limestone and conglomerate unit comes from ostracode collections studied by I. G. Sohn. Regarding collection SF-141 from SW¼ sec. 15, T. 33 N., R. 55 E. (loc. F-6 on pl. 1) Sohn stated (written commun., 1960):

"The ostracodes break out and etch as incomplete steikerns that suggest a species related to *Iliocypris arvadensis* Swain, 1949, described from Paleocene and Eocene sediments from Montana and Utah. The generic determination of the species has been debated. Peck (Jour. Paleontology, v. 25, p. 314, 1951) considers it to belong to the genus *Cypridea*, and refers to it as a synonym, the Green River species, *Cypridea bisulcata* Swain, 1949.

Because of the poor preservation of the material on hand, I cannot make a positive identification and would guess that the age is probably Green River equivalent, but reserve the right to change the age should better material become available. The possible range in age based on the material is older than Oligocene and younger than Jurassic."

Collection SF-303 from NW¼ sec. 20, T. 33 N., R. 55 E. (loc. F-5 on pl. 1) and between 76 and 92 m (250 and 300 ft) above the base of the unit contained "fragments similar to the bisulcate notched form in SF-141, suggesting an Eocene age for the collection" (Sohn, written commun., 1964). Included in SF-303 were a large smooth undeterminate genera, a small smooth undeterminate genus, and *Cypridea(?)* aff. *C. bisulcata* (Swain).

Charophyte gyrogonites (fruits) in collections SF-136-A and SF-136-B from NE¼ sec. 20, T. 33 N., R. 55 E. (loc. F-7 on pl. 1) were examined by Raymond E. Peck, who reported (written commun., 1965) that they were beautifully preserved but not previously identified specimens. Regarding these, Peck wrote: "This type of gyrogonite with a well developed neck and a small summit opening is not known above the Paleocene and really is most characteristic of the Cretaceous. My best estimate of the age of your sample is late Late Cretaceous but this estimate hangs on a pretty thin thread."

Thus, on the basis of rather sparse fossil evidence, this unit may be Late Cretaceous or early Tertiary in age. We assign these beds to the Eocene(?) because they are more similar to younger strata of probable

Tertiary age than they are to ones of known Cretaceous age. Also, they are found in the present basins whereas the Mesozoic rocks are found mostly in the mountains.

The limestone and limestone-clast conglomerate rests on Paleozoic rocks with angular unconformity, pronouncedly so in places.

CONGLOMERATE, SANDSTONE, SILTSTONE, AND LIMESTONE

A sequence of conglomerate, sandstone, siltstone, and limestone is exposed in widely scattered areas on the east side of and east of the Pinon Range. Like the Cretaceous Newark Canyon Formation and the Tertiary(?) limestone and limestone-clast conglomerate, this unit of varied lithology characteristically has a red weathered surface or red soil om it in many places. A stratigraphic section measured in sec. 34, T. 32 N., R. 55 E. is presented as a representative section of these rocks.

Measured stratigraphic section (S3 on pl. 1) of the conglomerate, sandstone, siltstone, and limestone unit in E½ sec. 34, T. 32 N., R. 55 E., Dixie Flats quadrangle

[Measured by use of Brunton compass and steel tape]

	Thickness m	Thickness ft
Tertiary(?) System, Eocene(?) Series:		
Conglomerate, sandstone, siltstone, and limestone:		
Top eroded at crest of ridge.		
5. Conglomerate, limestone, and some sandstone; mostly poorly exposed on float-covered slope. Conglomerate in a few scattered outcrops is similar to that in unit 1 but does not contain as many clasts of cobble size; a few clasts of Permian fossiliferous limestone in the upper part of the unit are 0.5 m (1.5 ft) across; limestone clasts are dominant, although chert and quartzite clasts are conspicuous in some beds. Float pieces of brown and maroon dense limestone appear to weather from thin interbeds of limestone in the conglomerate; some pebbly limestone present. Also found are brown and red calcareous interbeds of coarse-grained sandstone with well-rounded grains of quartz and scattered angular grains of chert. All slopes are light red and tan ..	36	120
4. Limestone like that in unit 2 below	2.6	8
3. Limestone, brown; weathers tan and brown; contains high- and low-spired snails..................	0.6	2
2. Limestone, brown, weathers tan and light brown, some weathers light gray; poorly exposed but appears to be in beds 2.5-15.3 cm (1-6 in.) thick. Some soft interbeds probably are silty or fine grained sandy. A few scattered lenses of limestone-pebble conglomerate...	22	70
1. Conglomerate, mostly gray; weathers gray; clasts largely of limestone, subangular to rounded, and as much as 20.4 cm (8 in.) across; many are fossiliferous Permian and Pennsylvanian limestones; a few angular pebbles of chert; sorting ranges from poor to good; matrix mostly pebbly, calcareous, fine-grained sandstone; beds irregular and 15.3 cm-1.7 m (6 in.-5 ft) thick. A few interbeds about 7.6 cm (3 in.) thick consist of red sandstone and siltstone containing pebbles............................	111	365
Thickness....................	172+	565+

Measured section (S3) of the conglomerate, sandstone, siltstone, and limestone unit — Continued (Tertiary(?) System, Eocene(?) Series — Continued; Conglomerate, sandstone, siltstone, and limestone — Continued) begins at "thick. Some soft interbeds..." in unit 2 above.

The base is not exposed along the line of the measured section, but the bottom of unit 1 probably is close to the base.

Conglomerate makes up a prominent part of this rock unit (fig. 4). Clasts in the conglomerate are mostly limestone, range from pebbles to boulders, and are angular to rounded; pebbles tend to be fairly well rounded, and cobbles and boulders tend to be subangular to angular. All clasts appear to have been derived from Paleozoic rocks in the mapped area, and many from beds exposed nearby. Sorting ranges from poor to good. The matrix is mainly quartz sand and is both calcareous and noncalcareous.

The sandstone is fine grained to coarse grained, poorly to well sorted, and evenly and well bedded to indistinctly bedded, and consists mostly of quartz and chert grains. These beds are tan, brown, and gray annd weather brown and reddish brown. Poorly exposed siltstone seems to be interbedded with the sandstone. Both the sandstone and siltstone contain scattered pebbles.

Limestone in the unit is brown and gray and weathers mostly tan, brown, and red. Some beds are dense and fairly pure limestone, and others are clayey, sandy, or pebbly. A few beds contain fossils of snails and clams.

The band of these rocks mainly along the west side of T. 27 N., R. 54 E. consists of a sequence of mostly conglomerate and sandstone in the lower part, limestone in the middle part, and conglomerate and sandstone in the upper part. Exposures are not adequate to permit measurement of a good section,

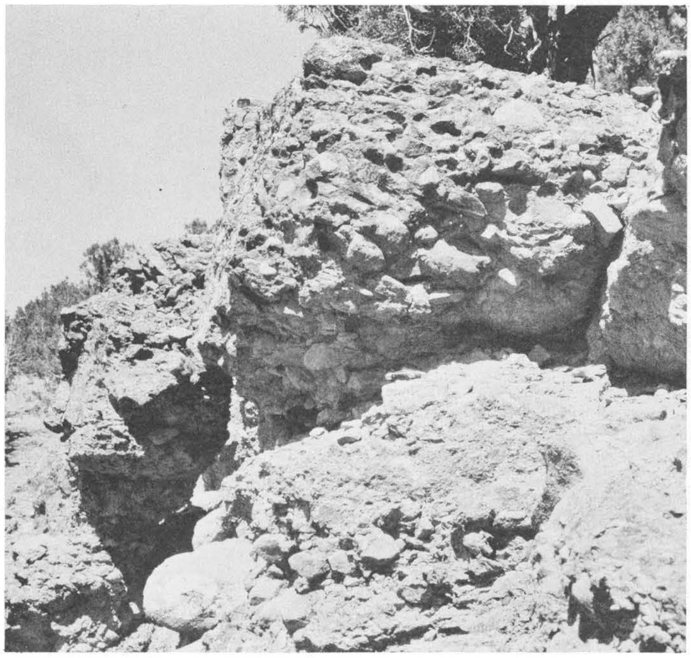

FIGURE 4. — Conglomerate containing boulder-size clasts in the Eocene(?) conglomerate, sandstone, siltstone, and limestone unit. Clasts are of Paleozoic rocks. N½ sec. 3, T. 31 N., R 55 E. Pocketknife (near center of photograph) is 7.6 cm (3 in.) long.

but as measured from the map the thickness in this part of the area must be at least 760 m (2,500 ft).

This unit of conglomerate, sandstone, siltstone, and limestone is similar to the limestone and limestone-clast conglomerate unit, and the two may be in part lateral equivalents. Near the east edge of the mapped area, in secs. 10 and 15, T. 31 N., R. 55 E., however, the more clastic unit overlies the limestone and limestone-clast conglomerate. Each unit is readily identifiable in the field, but some of the differences are subtle and difficult to describe. In the following listing of features that may be used as guides in distinguishing between the two units, the limestone and limestone-clast conglomerate is called unit A, and the conglomerate, sandstone, siltstone, and limestone, unit B, for simplicity in handling the descriptions.

1. Outcrop areas of unit A are generally of lighter color, although both units have reddish soil associated with them in places.
2. Much of the unit A limestone is dense and has a creamy or light-tan color. Less limestone in unit B is dense, and the limestone beds are somewhat darker, commonly tan or brown.
3. Much of the unit A limestone is fairly pure calcium carbonate. Much of the unit B limestone is sandy or silty.
4. Limestone in unit A forms massive beds, particularly in some exposures in the northeast part of the mapped area. Limestone in unit B mostly is not in such massive beds.
5. No snails or clams were found in unit A, but they were in unit B.
6. Unit A conglomerates tend to be nearly monolithologic in places and to contain clasts derived from Paleozoic rocks very close or immediately adjacent to the depositional sites of the conglomerates. Clasts in Unit B conglomerates were also derived from Paleozoic rocks in the area, but they are generally somewhat better rounded than those in unit A, they differ more in lithologic types, and they probably were transported farther and from less restricted source areas.
7. The conglomerate matrix of unit A in much of the eastern part of the mapped area is reasonably pure limestone and in the Carlin Canyon area is mostly calcareous siltstone. No essentially pure limestone forms the conglomerate matrix in unit B. The matrix in unit B is either calcareous or noncalcareous siltstone and sandstone.

Two collections (USGS M2929 and USGS M2930, loc. F-8 and F-9 on pl. 1) of snails and clams from sandy limestone in this unit of conglomerate, sandstone, siltstone, and limestone, in the NE¼ sec. 34, T. 32 N., R. 55 E. were examined by Dwight W. Taylor. They contain *Sphaerium, Valvata, Ferrissia(?), Physa* or *Bulinus,* and *Oreohelix* and are lower Tertiary or Cretaceous (Taylor, written commun., June 1968). Charophyte fruits also occur in the same beds in places.

EOCENE SERIES

CHERTY LIMESTONE

A unit of limestone containing abundant opaline chert crops out in the northeastern part of the mapped area (fig. 5). The limestone is mostly gray and dense and weathers about the same color. Bedding is generally indistinct, but most beds appear to be 1.3–2.5 cm (0.5–1 in.) thick and some are 0.3–0.6 m (1–2 ft) thick; locally layers are massive algal limestone. Black, brown, tan, and some almost white chert that is commonly opaline occur as nodular pods and lumps in the limestone and weather out to form many fragments on the surface. Most of the pods apparently are 25 cm (10 in.) or less in maximum dimension, but layers of brown chert 10 cm (4 in.) thick and 3 m (10 ft) long were noted. Most of the black chert has a greasy luster. Many snails and a few clams and ostracods are scattered through the limestone.

This cherty limestone unit must be several hundred metres thick and probably is more than 305 m (1,000 ft) thick. Bedding attitudes are difficult to determine, and thus a reliable thickness is difficult to measure. Local aberrant attitudes suggest that there may be more structural complexities in this unit than are apparent from the general appearance of the exposures.

This cherty limestone is the same as limestone exposed on a bluff face on the west side of Huntington Creek about 0.6 km (1 mi) east of the mapped area and 1 km (0.5 mi) south of Twin Bridges, at the junction of Huntington Creek and the South Fork of the Humboldt River. According to Van Houten (1956, p. 2812), D. W. Taylor reported that snails from this locality "are early Cenozoic (pre-Miocene) in age." Taylor also responded (written commun., June 1968) regarding two collections from the area of the present report. One collection (USGS M2932), from the center east edge of sec. 3, T. 21 N., R. 55 E. (loc. F-11 on p. 1) contained *Valvata* and *Physa* or *Bulinus* of early Tertiary or Cretaceous age, and the other (USGS M 2931), from east center of sec. 34, T. 32 N., R. 55 E. (loc. F-10 on pl. 1), contained *Sphaerium*, *Valvata*, *Ferrissia*(?) and *Bulinus* of Tertiary (Eocene or early Oligocene) age. These beds are older than the Elko Formation, which is dated radiometrically as near the Eocene-Oligocene boundary. Thus, on the basis of fossils and of the age of the overlying Elko Formation, the cherty limestone is considered to be Eocene.

The cherty limestone rests on the conglomerate, sandstone, siltstone, and limestone unit and on the limestone and limestone-clast conglomerate unit. The nature of the contact is difficult to determine, but it probably is slightly disconformable in most places

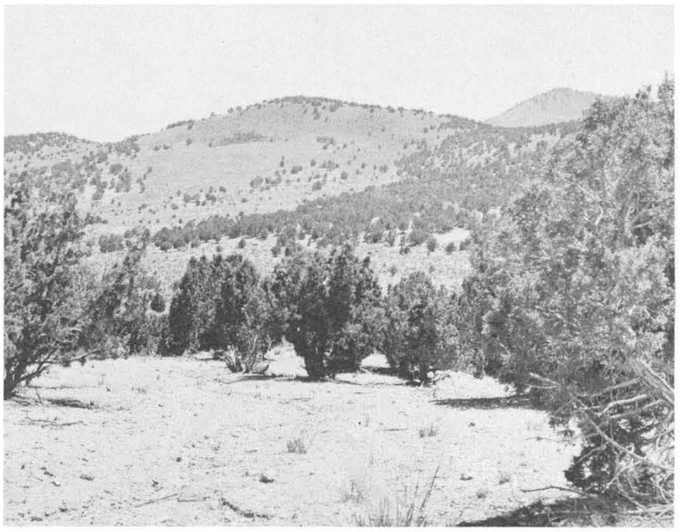

FIGURE 5. — Typical exposure of cherty limestone on slope in foreground. Dark hill on middle skyline is underlain by a younger andesite and basaltic andesite unit. Viewed toward the south near west edge of Lee quadrangle, just east of Dixie Flats quadrangle. Photograph taken from NE¼ sec. 35, T. 32 N., R. 55 E.

and may be an angular discordance in places on the limestone and limestone conglomerate.

This unit is the same as the limestone forming the lower member of the Humboldt Formation of Sharp (1939, p. 145, column A of figure 5).

LIMESTONE

A limestone unit that contains no chert covers an area of about 2.5 km^2 (1 mi^2) at the east edge of the map area. This limestone is dense and sugary, gray to light tan and white, and thick bedded. Some beds are algal and have irregularly vuggy surfaces. Fine- to coarse-grained calcareous sandstone and sandy limestone are interbedded with the limestone in places. Grains in the sandy layers are principally quartz and some chert; nearly all grains are angular. This unit is at least 305 m (1,000 ft) thick and may be as much as 610 m (2,000 ft) thick.

The limestone is similar in some respects to limestone in the cherty limestone unit, but it contains no chert nodules and no snails were found in it. Its position above the cherty limestone unit is inferred on the basis of spatial relations; the base of the limestone is covered by alluvium and colluvium. By interpretation this limestone overlies the Eocene cherty limestone and underlies the late Eocene or early Oligocene Elko Formation, and thus must be of Eocene age.

EOCENE OR OLIGOCENE SERIES

ELKO FORMATION

The name Elko Formation is given in this report to the group of beds in which the oil shale (Winchester, 1923, p. 91-102) south of Elko occurs. This formation is composed of claystone; siltstone; shale, including paper-thin carbonaceous shale and oil shale; some limestone; and tuff. The most extensive and thickest exposures of the Elko are in the general area of secs. 2, 3, and 10, T. 31 N., R. 53 E. A stratigraphic section measured near the boundary between secs. 10 and 15, T. 31 N., R. 53 E. is here designated the type section.

Type stratigraphic section (S4 on pl. 1) of Elko Formation near the line between secs. 10 and 15, T. 31 N., R. 53 E., Dixie Flats quadrangle

[Measured by use of tape and Brunton compass. Because of poor exposures in units 1 through 5, bedding attitudes representative of several tens of metres of beds cannot be determined accurately; the thickness measurements, then, are based on our best approximation of an average dip for each unit. Dips differ within units, but in general increase from west to east along the line of section, and, as used in the measurements, they range from an average of 40° in unit 1 to an average of 70° in unit 6. In this measured section, the brown to black, laminated or papery shales, which weather white in places, are the oil shales]

	Thickness *m*	*ft*
Tertiary System, Oligocene Series:		
Indian Well Formation:		
Ash-flow tuff; contains lumps of pumice and of welded tuff, and contains fragments of shale from Elko Formation below. Contact		

Type section (S4) of Elko Formation — Continued
Tertiary System, Oligocene Series — Continued
Indian Well Formation — Continued

	Thickness m	Thickness ft
between Indian Well and Elko Formation along creek is unconformable, although not very obviously so where exposed. Dip of contact is about same as dip of underlying beds.		
Tertiary System, Oligocene or Eocene Series:		
Elko Formation:		
12. Tuff, white, appears slightly chalky in part; much medium- to coarse-grained biotite, very little quartz; chiefly massive, but bedded in part; does not contain fragments like those in Indian Well Formation tuff above. A few 7.6-10-cm (3-4-in.)-thick beds of white calcareous siltstone; some paper shale at top is like that lower in formation	26	85
11. Claystone, white, calcareous to only slightly calcareous, dense, porcelaneous in part; in units as much as 0.3 m (1 ft) thick and beds 1.3-2.5 cm (0.5-1 in.) thick; layers of tuff as much as 0.3 (1 ft) thick	9	30
10. Shale and tuff, in beds 5.1 to 38.1 cm (2-15 in.) thick; some white calcareous siltstone in beds 2.5 cm (1 in.) thick; tuff layers increase in numbers upward	31	100
9. Tuff, light-gray to white	0.3	1
8. Shale, carbonaceous, chocolate-brown and brown; weathers very light gray to almost white, some with very light bluish white tint, laminated and papery; some single laminated beds are 0.6 cm (0.25 in.) thick; edges of some layers weather yellow or tan. At least 10 layers of tuff from 5.1 to 35.5 cm (2-12 in.) thick, gray, weather gray to yellow	15	50
7. Shale, papery, carbonaceous, chocolate-brown to brown; weathers very light gray to almost white, some with bluish-white tint; in layers 7.6 to 10 cm (3-4 in.) thick. Interbedded tan calcareous claystone in beds as much as 10 cm (4 in.) thick	24	80
6. Shale, platy and papery, carbonaceous, chocolate-brown; weathers very light gray to almost white; in layers 7.6 to 10 cm (3-4 in.) thick; some buff dense silty limestone or calcareous siltstone in beds as much as 0.3 m (1 ft) thick. Tuff in a layer 15.3 cm (6 in.) thick occurs 4.5 m (15 ft) above base of this unit; contains prominent biotite, quartz, and feldspar phenocrysts; this is the lowest tuff noted in the formation	9	29
5. Shale, papery, carbonaceous, brown and some almost black; weathers		

Type section (S4) of Elko Formation — Continued
Tertiary System, Oligocene or Eocene Series — Continued
Elko Formation — Continued

	Thickness m	Thickness ft
very light gray to almost white. Some interbedded limestone. Ostracods occur in the shale near the top and probably are scattered throughout unit. Upper part forms a prominent band on slope	43	140
4. Limestone, like unit 2 below	49	160
3. Shale and interbedded limestone; shale very light gray and white; laminated, forms paper-thin plates, mostly less than 0.2 cm (0.06 in.) thick, many juch less, on slope; some ostracods noted near base. Interbedded limestone like that in unit 2 below. Light-brown and black chert in a few bands as much as 10 cm (4 in.) thick, some with a very small-scale wavy texture; nodules of black chert, some 10 cm (4 in.) across. A few beds of dense tan limestone with wavy laminations. Exposures are poor, and slope is covered with fragments of shale and limestone	223	730
2. Limestone, dense, white to cream and light-tan; some calcareous claystone. Exposures poor on light-yellow or tan and white slopes covered with angular limestone pieces, generally 0.6-1.3 cm (0.25-0.5 in.) thick and 1.3-5.1 cm (0.5-2 in.) across. Some beds evidently are thicker and weather to form irregular chunky fragments several centimetres across; thicker beds as much as 10 cm (4 in.) seem to be more common in upper part of unit. Gray limestone in two lenticular beds as much as 0.3 m (1 ft) thick. 1.3-cm (0.5-in.)-thick tan ostracod-bearing limestone in upper part	137	450
1. Limestone, mostly tan and cream, dense; forms platy pieces on slope; some gray mottled limestone in beds 0.3-0.6 m (1-2 ft) thick that form prominent outcrops, algal at least in part. Some platy siltstone. A little dark chert in nodules	67	220
Measured thickness of Elko Formation, base not exposed and top at an unconformity	633	2075

An additional several hundred metres of the formation may underlie unit 1 of this measured section. Scattered pieces of yellow siltstone as well as some red soil similar to that observed elsewhere on the Elko Formation are in the valley just west of unit 1. Up the hillside farther southwest are outcrops of Elko Formation siltstone and limestone. As there are

FIGURE 6. — Steeply dipping Elko Formation forms prominent outcrop (lower right) overlain unconformably by sedimentary rock, here mostly ash, of the Humboldt Formation (restricted). Lower slope to left beneath the Elko is underlain by Permian rocks but is mostly covered by Tertiary float. Viewed north-northwestward across creek in SE¼ sec. 5, T. 31 N., R. 55 E.

no good exposures between the base of unit 1 and the Paleozoic rocks farther west, an accurate determination of the thickness of these lower beds cannot be made, but an estimated figure from measurement on the map is 150 m (500 ft). This would indicate a maximum thickness of more than 760 m (2,500 ft) for the Elko Formation. Other exposures of the formation are much smaller and no more than a few tens of metres or a few hundred metres of strata are exposed.

Strata that make up the Elko Formation are unconformable on Paleozoic rocks in most areas where the base of the Elko can be seen. It also must be unconformable on older Tertiary or Cretaceous strata. The upper contact of the Elko is an unconformity (fig. 6).

Rock types that serve best to identify the Elko Formation are thin-bedded limestone and laminated shale. This limestone is light gray and light tan, commonly has a yellow tint, and weathers about the same colors. Beds containing abundant ostracod coquinas are very characteristic of the formation; these beds commonly weather to platy fragments. Other limestones are dense and creamy looking and have associated chert bands and nodules in places. The laminated or papery shales (fig. 7) are brown, chocolate brown, and almost black in some strata; they are the oil-bearing shales. Exposed bedding surfaces of these strata have weathered in many places to almost white or light bluish gray. Ostracods and in a very few places plants are found in the shale. Noncarbonaceous shales, claystone, and marly beds are interlayered with the other strata. Reddish dirt or soil is suggestive that an area may be underlain by the Elko Formation, but thin red soils occur also on other lower Tertiary(?) units, and red soil does not occur on all the Elko.

FIGURE 7. — Vertical beds of oil shale in the Elko Formation; tops of beds are to the right. Hammer rests on tuff. SE¼ sec. 10, T. 31 N., R. 53 E.

Tuff in the Elko Formation is of particular significance to the Tertiary history, as the tuff records one of the two dates of earliest Tertiary volcanism in this area. This tuff occurs in beds generally 5.1-35 cm (2-14 in.) thick in the type section, although beds are thicker near the top of that section. The tuff is medium to coarse grained and commonly contains prominent biotite, quartz, and feldspar crystals. The oldest tuff noted forms a 15-cm (6-in.)-thick bed 523 m (1715 ft) above the base of the type section; a chemical analysis of this tuff is given in table 4. A K-Ar age determination made on biotite from this tuff by R.F. Marvin, H.H. Mehnert, and J.D. Mensik (written commun., 1965; McKee and others, 1971, p. 32, sample no. 73) dates it as 38.6±1.2 m.y. Evidence of Jurassic volcanism is prominently displayed by the Frenchie Creek Rhyolite in the Cortez Mountains. Evidently no volcanic activity occurred in the region from Late Jurassic time until 38.6 m.y. ago, an age near the Eocene-Oligocene boundary.

TABLE 4. — *Chemical analyses of tuff from the Elko Formation and andesite from the mafic to silicic volcanics (in weight percent)*

[Leaders (—) indicate not determined. Analyst, George O. Riddle.]

Sample	1	2
Serial No.	D103219	D103223
Field No.[1]	SR-414	SR-78
SiO_2	66.24	53.23
Al_2O_3	15.92	16.99
Fe_2O_3	.76	1.94
FeO	.45	3.55
MgO	1.25	2.38
CaO	4.32	8.38
Na_2O	2.57	3.32
K_2O	1.36	2.02
H_2O+	4.06	1.90
H_2O-	2.41	.52
TiO_2	.23	1.27
P_2O_5	.09	.37
MnO	.02	.15
CO_2	.02	3.56
Subtotal	99.70	99.58
Less O	--	--
TOTAL	99.70	99.58

[1]Sample localities are on plate 1.

SAMPLE DESCRIPTIONS

1. Tuff.
2. Andesite. Aphanatic rock in which plagioclase, oligoclase to andesine, and alkali feldspars are partly obscured by carbonate alteration product; hornblende largely replaced by carbonate; opaque minerals; trace of biotite partly altered; and sparse quartz.

The oil content of two oil-shale samples that were selected because they appeared to be high grade are given in table 5. Area and thickness of exposures of oil shale in the area of this report do not appear to be sufficient to indicate a tonnage of economic significance under present conditions.

The Elko Formation is of late Eocene or Oligocene age. The K-Ar age of 38.6±1.2 m.y. on the oldest tuff (loc. 1 on pl. 1) in the Elko Formation places the age of the formation as near the Eocene-Oligocene boundary, which is 37-38 m.y. according to Harland, Smith, and Wilcock (1964). Fossils collected from the Elko include ostracods, snails, and a few plants. The ostracods, although abundant in some limestone in the formation, are generally smooth and poorly preserved, and not identifiable or diagnostic as to age according to I. G. Sohn (written commun., 1963). One sample, collected from the NE¼ sec. 16, T. 31 N., R. 53 E. (loc. F-12 on pl. 1), contained a bisulcate notched form of the "Cypridea" group as reported by Sohn (written commun., 1962), who stated that "The recorded range of this group is from Upper Jurassic to Oligocene, but in the U.S. bisulcate forms are present in Eocene rocks." Ostracods embedded in tuff in the upper part of the formation were reported on by Sohn (written commun., 1971) as follows: "In addition to the several smooth "Cyprid" genera, this is one tiny species (between 0.4 and 0.5 mm in greatest length) of either of the freshwater genera *Limnocythere* or *Ilyocypris*, that may prove to be of future use. The presence of small and large (1 mm in greatest length) specimens as carapaces and as single valves, some of which are nested inside each other, suggest a low energy environment." A collection (U.S.G.S. Cenozoic locality 21695, loc. F-13 on pl. 1) of 5 snails from the NW¼ sec. 31, T. 29 N., R. 54 E. contained a freshwater form, Lymnaeidae, cf. *Stagnicola*, and a land snail, Helminthoglyptidae, indeterminate, which on slender evidence are suggestive of an Oligocene or perhaps late Eocene age according to Dwight W. Taylor (written commun., 1959).

TABLE 5. — *Modified Fischer assay analyses of oil-shale samples from Elko County, Nev.*

[I. C. Frost, analyst]

Serial No.	D115138	D115139
Field No.	[1]SR-420	[2]SR-421
Raw shale:		
Oil: percent	26.8	19.0
1/t	308.0	214.0
gal/ton	73.9	51.2
Water: percent	6.8	10.2
1/t	72.0	102.0
gal/ton	17.4	24.4
Gas and loss percent	10.4	11.3
Assay residue, percent	56.0	59.5
Oil from assay:		
Sp. gr. at $\frac{15.6°C}{15.6°C}$	.869	.889
Spent shale, from retort:		
Ash, 900°C, percent	80.5	64.0

[1]Catlin plant south of Elko; thickness 0.3 m (1 ft).

[2]SE 1/4 sec. 10, T. 31 N., R. 53 E; thickness 0.6 m (2 ft); same beds as in unit 5 of type section of Elko Formation.

Two collections of fossil plants from the Elko Formation were submitted to Jack A. Wolfe for study. One (SF-261-A) from the NE¼ sec. 36, T. 29 N., R. 53 E. (loc. F-14 on pl. 1) contained *Taxodium sp., Metasequoia* cf. *M. glyptostrobiodes* Hu and Cheng, *Salix* sp., and *Acer* sp., which is apparently a new species (Wolfe, written commun., 1962). The other collection (U.S.G.S. Paleobot, loc. 9938, loc. F-15 on pl. 1) from the NW¼ sec. 2, T. 31 N., R. 53 E. contains a new species of *Mahonia* and elm determined as *Ulmus* sp. cf. *U. newberryi* Knowlton (Wolfe, written commun., 1963).

The Elko Formation seems to be somewhat younger than the lower and middle Eocene Green River Formation (Bradley, 1964, p. A28) and thus marks a time of slightly later oil-shale deposition than that in Colorado, Utah, and Wyoming.

Nearly all the beds in the Elko were deposited in standing water that probably was not vigorously agitated most of the time. Whether one large lake received the sediments or whether several lakes received them cannot be determined from the generally small area included in the scattered outcrops. The minimum thickness of 760 m (2,500 ft) in the area of most extensive exposures suggests that the lake basin of deposition must have been reasonably large. Very likely the basal beds were deposited on an irregular surface.

We do not know the extent of the oil shale outside the mapped area, but beds belonging to the Elko are recognized at least 33 km (20 mi) north of Elko, and oil shale is reported about 56 km (35 mi) farther northwest in the Bull Run quadrangle (Decker, 1962, p. 27-28, 56). The southernmost exposure of the Elko Formation in the mapped area is almost 65 km (40 mi) south of Elko, and so the known north-south extent of the oil-shale formation is at least 100 km (60 mi) and may be almost 160 km (100 mi). Similar beds of the Elko are now recognized across an east-west width of about 33 km (20 mi). A thick lapilli tuff of the Indian

Well Formation on the west side of Pine Valley has a radiometric age of 37.6±1.3 m.y. and thus is near the same age as the oldest tuff in the Elko, suggesting that the Elko lakebeds were not deposited as far west as Pine Valley.

OLDER INTERMEDIATE VOLCANICS

Volcanic rocks of latitic to andesitic composition rest on the Frenchie Creek Rhyolite at the west edge of the mapped area. These volcanics are similar to those near the south end of the Independence Mountains (fig. 1), according to J. H. Stewart and J. G. Evans (J. H. Stewart, written commun., 1972). A radiometric age on biotite from a sample of latite from the Independence Mountains area is 41.4±1.4 m.y., and another on biotite(?) from another sample is 37.1±1.3 m.y. (Evans and Ketner, 1971). Presumably, then, these similar volcanic rocks in the Carlin-Pinon Range area are late Eocene or early Oligocene age and thus about the same age as the tuff in the Elko Formation. (See p. 21.) Deposits composing the Elko Formation, then, probably did not extend as far west as the western part of the Carlin-Pinon Range area where volcanics were being emplaced.

The contact between this latitic to andesitic lava unit and the underlying Frenchie Creek Rhyolite is not readily identified, but these younger volcanics dip at lower angles and are unconformable on the Frenchie Creek.

OLIGOCENE SERIES

MAFIC TO SILICIC VOLCANICS

Rocks making up this unit of intermediate to silicic volcanics crop out in three areas covering a total of less than 2.5 km^2 (1 mi^2) in sec. 11, T. 29 N., R. 53 E. and secs. 2, 3, and 10, T. 31 N., R. 53 E. Mafic volcanics compose the two northern exposures, and intermediate and silicic rocks and some sandstone, the southern exposure. Although the rock types differ in the three areas, they are included as one unit because they underlie the Indian Well Formation.

The southernmost outcrops in sec. 11 consist of a series of thin flows and two thin beds of volcaniclastic sandstone having a total thickness of about 90-120 m (300-400 ft). They are unconformable on Mississippian strata. The flows are dark gray and aphanitic. By thin-section examination, one flow is seen to be andesite (table 4) in which carbonate as a replacement product obscures much of the section. Hornblende replaced by carbonate, a trace of biotite, opaque minerals, and some quartz are set in an obscurely felty matrix of calcic and potash feldspars. Another flow is quartz latite, which also has much replacement carbonate. It is an aphanitic rock in which hornblende, which is replaced by carbonate, and a trace of biotite are set in a trachvtic matrix of alkali feldspar, plagioclase (andesine) in laths mostly less than 0.6 mm long and quartz. Also included are scattered opaque minerals. The sandstone is gray and weathers gray with a reddish tint in places. It is medium grained and contains angular to subangular grains of quartz, volcanic rock fragments, and minor amounts of gray chert.

The two small northern exposures consist of black basalt, which is probably not more than 30 m (100 ft) thick. These flows are unconformable on the Elko Formation and are overlain unconformably by ash-flow tuff of the Indian Well Formation. Euhedral to anhedral crystals of pyroxene as much as about 0.6 mm in maximum dimension are set in a trachytic matrix of labradorite microlites that flow around the larger crystals.

These lavas must have originally covered a much larger area than the areas in which they are now exposed. Their unconformable relations to the underlying Paleozoic rocks and the Elko Formation suggest that they were deposited on an irregular surface. A source for the lavas is not recognized. Extensive erosion certainly followed emplacement of these rocks.

The lava and sandstone are of Oligocene age, for they are underlain by the Elko Formation dated as near the Eocene-Oligocene boundary and overlain by the Indian Well Formation of Oligocene age.

INDIAN WELL FORMATION

The Indian Well Formation is named here for a water well by that name in the SE¼ sec. 30, T. 31 N., R. 55 E. This formation, as defined, is made up of a thick sequence of tuffaceous sedimentary rocks of lacustrine and fluviatile origin, of tuff, and of ash-flow tuff welded in different degrees. Four different units are mapped as part of the Indian Well Formation (pl. 1): (1) Tuffaceous sedimentary strata, tuff, and some ash-flow tuff in a basal unit that occurs in scattered areas of outcrop beneath the ash-flow tuff of unit 2; (2) ash-flow tuff; (3) tuffaceous sedimentary rocks; and (4) interlayered ash-flow tuff and tuffaceous sedimentary rocks. The ash-flow tuff of unit 2 and the sedimentary rocks of unit 3 compose the major part of the formation. These two rock sequences are interlayered near the center of the eastern half of the area to form unit 4 and demonstrate the equivalency of the two major units. Only the gross aspects of the ash-flow tuffs were studied.

A measured section mostly of the sedimentary part of the formation is designated the type section. This section is pieced together from two parts by tracing and fitting beds and like groups of beds. Exact stratigraphic positions may not be matched from one part to the next, but they are close enough that the total measured thickness of 1,015 m (3,330 ft) must be within a few tens of metres of the true thickness. The base of the section is in the S½ sec. 3, T. 30 N., R. 54 E., where the sedimentary rocks are on welded tuff of the same formation. The top is near the north-central edge of sec. 29, T. 31 N., R. 55 E., where it is covered by Quaternary alluvium. The measured thickness is probably a minimum one for the original thickness.

Type stratigraphic section (S5 on pl. 1) of Indian Well Formation in secs. 2 and 3, T. 30 N., R. 54 E., sec. 25, T. 31 N., R. 54 E., and secs. 29 and 30, T. 31 N., R. 55 E., Dixie Flats quadrangle.

[Measured by use of Abney level on Jacob Staff]

	Thickness m	Thickness ft
Quaternary System:		
Alluvium.		
Unconformity		
Tertiary System, Oligocene Series:		
Indian Well Formation:		
10. Sandstone, tan, mostly calcareous, very fine- grained to coarse-grained, tuffaceous; thin-bedded to massive, grains of quartz, tuff, and chert. Conglomerate, not more than 5 percent of unit, consists of angular to subrounded pebbles of dominantly welded tuff and less sandstone, quartzite, and gray, tan, brown, and black chert; largest clast observed was 20.3 cm (8 in.) in diameter; conglomerate matrix is calcareous sandstone. Platy, dense, earthy white limestone in beds 0.3-1.3 cm (0.12-0.5 in.) thick and in units 1-1.5 m (3-5 ft) thick is interlayered with sandstone; limestone fragments less than 1.3 cm (0.5 in.) across are common on slope .... approx.	490	1600
9. Sandstone, on soft tan slopes with few good outcrops, evidently like sandstone in unit below; some poorly exposed conglomerate containing clasts mostly of welded tuff and as much as 25.4 cm (10 in.) in diameter. Some thin platy white tuff in pieces 0.6 cm (0.25 in.) thick on slope. Almost white, clayey limestone occurs very locally as blocks on slopes. Small white chert nodules and black chert pebbles rest on slopes in places, but not seen in outcrop. Scattered pieces of calcareous tufa in a very few places	53	175
8. Sandstone and pebbly sandstone, light tan, calcareous, tuffaceous; sandstone fine grained to coarse grained; pebbles scattered through sandstone or commonly in layers 2.5-7.6 cm (1-3 in.) thick and 7.6 cm-0.3 m (3 in.-1 ft) long; some larger lenses; pebbles angular to rounded and flat and consist of gray, purple, and brown welded		

Type section (S5) of Indian Well Formation — Continued

	Thickness m	Thickness ft
Tertiary System, Oligocene Series — Continued		
Indian Well Formation — Continued		
tuff, white claystone, tan, brown, and gray chert, gray sandstone from both Paleozoic and Tertiary rocks; largest cobble noted was 20 cm (8 in.) in diameter. Bedding is generally indistinct but ledges or layers of harder units 0.3-0.6 m (1-2 ft) thick are spaced at 1.5-3 m (5-10 ft) intervals with soft slopes between	9	30
7. Tuff, light-gray; beds mostly 0.3-0.6 cm (0.12-0.25 in.) thick; platy calcareous tuff weathering to flakes 0.2 cm (0.06 in.) thick; some soft slopes with no exposures, probably underlain by ash. On basis of float there are beds at least 2.5-7.6 cm (1-3 in.) thick of gray tuffaceous limestone like those in unit 6; some pieces have mud cracks and curls on weathered surfaces. At 31 m (100 ft) above base and higher, white flat chert nodules mostly 0.6 cm (0.25 in.) thick and 5.1-7.6 cm (2-3 in.) long contain ostracods; collection SF-313 (loc. F-16 on pl. 1), 31 m (100 ft) above base of unit, contains *Candona* spp.; genus indeterminate, age indeterminate (I. G. Sohn, written commun., 1965)	63	205
6. Limestone, gray and silvery-gray, tuffaceous, and calcareous tuff; weather light gray, in beds mostly 2.5-3.8 cm (1-1.5 in.) thick; irregular ripple marks, 2.5-5.1 cm (1-2 in.) across, are on some large platy pieces on the slope; a few pieces of grayish-white silty limestone and limy siltstone 0.3-0.6 cm (0.12-0.25 in.) thick occur on slopes. Slopes are very light to whitish gray ...	41	135
5. Covered by alluvium; bedrock probably like units 6 and 4	41	135
4. Gravel forms covering along most of line of section; pieces of sandstone and tuffaceous sandstone like in unit 3 on slope. A few hundred metres south of the line of section is an about 18-m (60-ft)-thick white to buff exposure of sandstone, tuffaceous sandstone, and conglomerate; all are calcareous. Sandstone is dominant, massive to thin bedded, fine grained to very coarse grained, mostly of quartz grains, many of which appear to have been derived from ash-flow tuffs to west. Conglomerate occurs in sandstone as lenses as much as 0.5 m (1.5 ft) thick and 6 m (20 ft) long;		

Type section (S5) of Indian Well Formation — Continued

	Thickness m	Thickness ft
Tertiary System, Oligocene Series — Continued		
Indian Well Formation — Continued		
clasts nearly all welded tuff, white, tan, gray, and lavender, angular to subrounded, largest noted 0.3 m (1 ft) in diameter; pebbles and very coarse grains occur, in places, in layers one pebble or one grain thick; single cobbles sit in sandstone locally. Crossbedding and channeling are typical of fluviatile deposits..................	84	275
3. Sandstone, light-gray, calcareous, massive, fine- to coarse-grained; quartz and white and black chert grains, a few biotite grains; upper 3 m (10 ft) is similar but whiter and tuffaceous......................................	15	50
2. Very poorly exposed and largely gravel covered. Sandstone and conglomerate like in unit 1 below. Much float of tan and white siliceous mudstone 0.3-cm (0.12-in.) thick platy pieces	218	715
1. Sandstone and conglomerate, light-cream and buff, irregular bedding in layers generally 2.5–5.1 cm (1–2 in.) thick; sandstone, mostly coarse angular to rounded grains of tuff, chert, quartz, vitreous quartz like that in welded tuff to west, chalcedony, some black glass like that in welded tuff just below; conglomerate of mostly angular pebbles as much as 5.1 cm (2 in.) across of welded tuff, platy porcellaneous siltstone, light- and dark-gray chert probably from the Elko Formation, some green chert, and medium-grained quartz sandstone probably from Paleozoic rocks. This unit varies along the strike .	3	10
Measured thickness	1015	3330
Along the line of the measured section, this unit 1 appears to be unconformable on welded tuff, although the contact is not well exposed. The unconformity, though, probably does not represent much of a time break.		

The Indian Well Formation rests unconformably on older Tertiary, Jurassic, and Paleozoic rocks. The varied stratigraphic positions of the units underlying the Indian Well suggest that the ash flows and tuffaceous sediments of this formation covered a somewhat irregular surface. The basal unit probably was deposited in topographic lows on this surface and also was probably somewhat eroded before the main body of the formation was emplaced.

The basal unit of the Indian Well contains a mixture of rock types found in the rest of the formation, and, along the Pinon Range, layers of different lithologic types are indistinct in places and the unit appears to be more heterogeneous than the rest of the formation. Along the east side of the range, this unit consists of a variety of tuffs and coarse- to fine-grained tuffaceous sedimentary rocks exposed in six irregular patches. Many layers are fragmental and contain pieces of tuff and pumice as well as pieces of quartzite, chert, and silicified rocks from Paleozoic strata. Phenocrysts in the tuffs are quartz, feldspar, and biotite; they differ in proportions from one flow to another and from area to area. Both the ash flows and the sedimentary strata are generally thinly banded and lenticular on a relatively small scale. Colors are mostly white, gray, tan, and tints of green. Exposures of this unit are commonly poor and many of the rocks are weathered and altered. Because of the poor exposures and mostly indefinite layering or bedding, a true thickness cannot be measured; it may be as much as 90–120 m (300–400 ft).

The basal unit east of the Pinon Range rests on the Elko Formation, apparently unconformably, in two places. Elsewhere it is on Paleozoic rocks or has its base covered by alluvium or colluvium. It is overlain by ash-flow tuffs of the main part of the formation, on a contact that seems to be unconformable, although the actual contact is not exposed anywhere.

Tuffaceous sedimentary beds and tuffs in secs. 8 and 17, T. 28 N., R. 53 E., on the west side of the Pinon Range, are included with this basal unit. Here the rocks consist of conglomeratic and pebbly beds with tuffaceous matrices and of ash-flow tuffs, which are mostly white, gray, and purple. Conglomeratic beds contain angular to rounded clasts, as much as 10 cm (4 in.) long, of volcanic fragments and of sedimentary rocks fragments derived from the Devonian Oxyoke Canyon Sandstone Member of the Nevada Formation, of sandstone from the Mississippian Chainman Shale, and of silicified carbonate rocks from Paleozoic strata. Some very fine grained tuffs contain platy fragments of similar tuff 1.3–2.5 cm (0.5–1 in.) thick and several centimetres across.

A sequence of water-laid tuffs, tuffaceous volcanic conglomerate and sandstone, and minor limestone at the north end of Pine Valley form the basal unit west of the Pinon Range. These rocks make up the Safford Canyon formation of Regnier (1960). The vitric tuffs are mainly altered to chert and to heulandite (Regnier, 1960, p. 1193). Volcanic material comprising most of the conglomerate and sandstone fragments was derived from the Frenchie Creek Rhyolite. A few rock fragments were derived from Paleozoic formations. Even bedding of most of the tuffs and crossbedding and scour-and-fill channels attest to the water-laid origin of these strata. The limestone is oolitic and algal in places. This rock sequence is slightly more than 305 m (1,000 ft) thick.

Gray- and salmon-colored welded tuffs occur in several patches in this unit in secs. 11, 12, 13, and 14, T. 31 N., R. 51 E. These ash flows have generally the same attitudes as do the sedimentary beds, although in places they are obviously uncomformable on them. Presumably the unconformable relations have little time significance.

On the basis of the measured type section, the main sedimentary sequence of the Indian Well Formation may be separated roughly into two parts. About the lowest 305-360 m (1,000-1,200 ft) consist of fluviatile deposits which are dominantly sandstone and less conglomerate (fig. 8), siltstone, and mudstone. Many beds are tuffaceous. Conglomerate clasts are mostly pebble- and cobble-size pieces of ash-flow tuff derived from ash-flow tuff in the formation, although, in a few places, particularly near the base, some are quartz sandstone, probably derived from Paleozoic rocks, and some siltstone and chert, probably from the Elko Formation; one boulder-size tuff clast was noted. Crossbeds and channel cut and fill in these beds are typical of fluviatile deposits.

Above this lower unit, fluviatile deposits are still dominant and consist mainly of tuffaceous sandstone, but some prominent lacustrine tuff beds occur, particularly in the lower 90 m (300 ft), and lacustrine limestone is interbedded with the sandstone through the entire section. The limestone is gray to almost white, commonly silty, and in beds only a few centimetres thick. Irregular ripple marks and mud cracks occur on some of the limestone. Knobby and irregularly shaped chert nodules are abundant on the slopes in places. Conglomerates contain clasts of mostly ash-flow tuff but seem to have a few more Paleozoic and perhaps earlier Tertiary rocks than were noted in the lower part of the section.

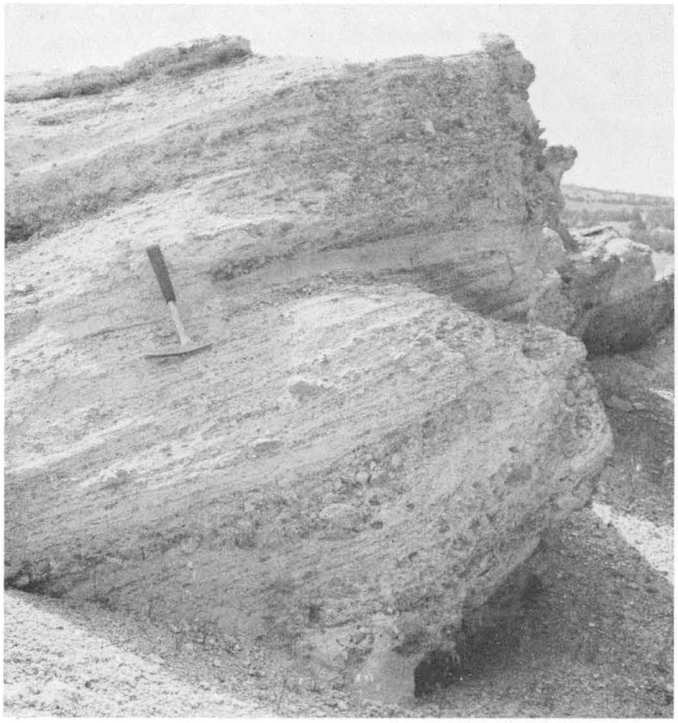

FIGURE 8. — Tuffaceous sandstone and conglomerate in the sedimentary rock part of the Indian Well Formation. Clasts are ash-flow tuff, also from Indian Well Formation. Note crossbedding and channeling. W½ sec. 2, T. 30 N., R. 54 E.

This sequence of beds indicates a progressive change over time from mostly stream deposits to stream and some pond or lake deposits. The older clastic beds may have been deposited nearer the basin margin with pond or lake deposits farther out in the basin, but the exposures are not sufficient for any interpretation to be made regarding this possibility.

Most of the part of the Indian Well Formation that is chiefly ash-flow tuff approximates quartz latite; the composition range is rhyolitic to dacitic. The tuffs range from nonwelded to densely welded. Our study of this rock unit involved only its gross features, as no attempt was made, for instance, to identify cooling units or to trace individual flow units. Any exact thickness of these rocks is difficult to determine, but as established from field and map relations the maximum thickness is probably close to 610 m (2,000 ft). The thickness differs over the area, of course, because the ash flows spread over an irregular surface and the top of the unit has been eroded. No source for these ash flows is recognized.

Prominent cliffs, hills, and ridges are formed on the ash-flow tuffs, and, as expected, the more conspicuous exposures commonly develop on the more thoroughly welded units. Less-welded to non-welded tuffs are softer and crop out in places on flats or in very poor exposures, although they make some cliffs and prominent outcrops also. Small alcoves, potholes, and irregularly shaped eroded features mark the less-welded tuff units in many localities.

Nonwelded and slightly welded tuffs east of the Pinon Range are most commonly almost white to light gray and are pink in a few localities. In many places these tuffs contain conspicuous lapilli of pumice or of the same material as the tuff matrix; in a few places they contain blocks, as much as a metre across, of the same composition.

The more thoroughly to densely welded tuffs east of the Pinon Range occur in a variety of colors — light and dark gray, pinkish gray, brown, purple, black, and green — and, like the less welded ones, commonly contain autoliths. One tuff autobreccia noted is about 5 m (15 ft) thick and is composed almost entirely of angular fragments, many of which are

0.25 m (10 in.) across, and some, 0.5 m (1.5 ft). In places this autobreccia seems to have essentially no matrix but to consist of packed fragments. In a very few places near the base of the ash-flow-tuff sequence, fragments of sandstone and quartzite derived from Paleozoic rocks and of shale and siltstone from older Tertiary rocks are included in the ash-flow tuff.

The tuffs range from ones composed almost entirely of glass shards to crystal tuffs composed of almost 60 percent phenocrysts, mostly of feldspar, quartz, and biotite. The phenocrysts are prominent, even though of widely different percentages in most of the ash-flow tuffs. Quartz phenocrysts have a maximum observed size of about 3.5 mm and range from almost perfect crystals to somewhat rounded ones; some quartz grains are fractured and some fragmented. Potassium-feldspar phenocrysts, which are largely sanidine, are commonly about the same size as the quartz phenocrysts, although one fragmented piece of sanidine noted is about 7.5 mm long. Plagioclase phenocrysts are commonly zoned and about 2 mm in longest dimension in the largest observed. Biotite flakes are prominent in hand specimens as well as in thin section and attain cross sections of as much as 3.5 mm. Altered iron oxide minerals occur in almost all thin sections examined and range from a trace to about 2 percent of the rock. In some areas where exposures are poor, anthills composed of quartz crystals indicate the presence of tuff beneath the surficial cover. Shards in the matrix are largely glassy in some sections and partly to completely devitrified in others.

Vitrophyres crop out prominently in a few places. They are most commonly black to very dark gray, and some are green to greenish gold. Phenocrysts make up 12–15 percent of the rock, with biotite and feldspar the most conspicuous ones and quartz less abundant.

Chemical compositions of representative specimens of the ash-flow tuffs are given in table 6.

Volcanic breccia consisting of cobbles and boulders of hard tuff occurs in the tuff part of the Indian Well Formation in the area of secs. 3, 4, 5, 9, 10, 15, and 16, T. 30 N., R. 54 E. Exposures are generally poor, and the surface is covered with the cobbles and boulders. At places the breccia seems to be at the base of the ash-flow sequence, but at least two breccia layers probably occur in this ares. This volcanic breccia east of the Pinon Range is in the general zone between mostly ash-flow tuffs on the south and west and mostly sedimentary rocks on the north and east.

Interlayered ash-flow tuffs and tuffaceous sedimentary rocks of the Indian Well Formation are recognized in T. 30 N., R. 54 E. Along the creek in the south ½ sec. 7 in this township and range, interlayered ash-flow tuffs and bedded tuff and tuffaceous coarse-grained sandstone are well exposed; one layer of sandstone contains ash-flow-tuff pebbles and cobbles as much as 15 cm (6 in.) in diameter. In secs. 21 and 28, the scattered outcrops of ash-flow tuff in one place and bedded tuff containing waterworn grains and pebbles in another suggest that this is an area where the two lithologic types are interlayered. Bedding, though obvious in places, is not well developed in all the strata. Some of these beds look as if they may have been formed by a slight reworking of loose tuff, perhaps by the washing of small waves.

Rocks in the Cortez Mountains included in the ash-flow-tuff part of the Indian Well Formation consist of as much as 120 m (400 ft) of lapilli tuff (fig. 9), volcanic breccia, and some basalt. Regnier considered this group of rocks to be the basal member of

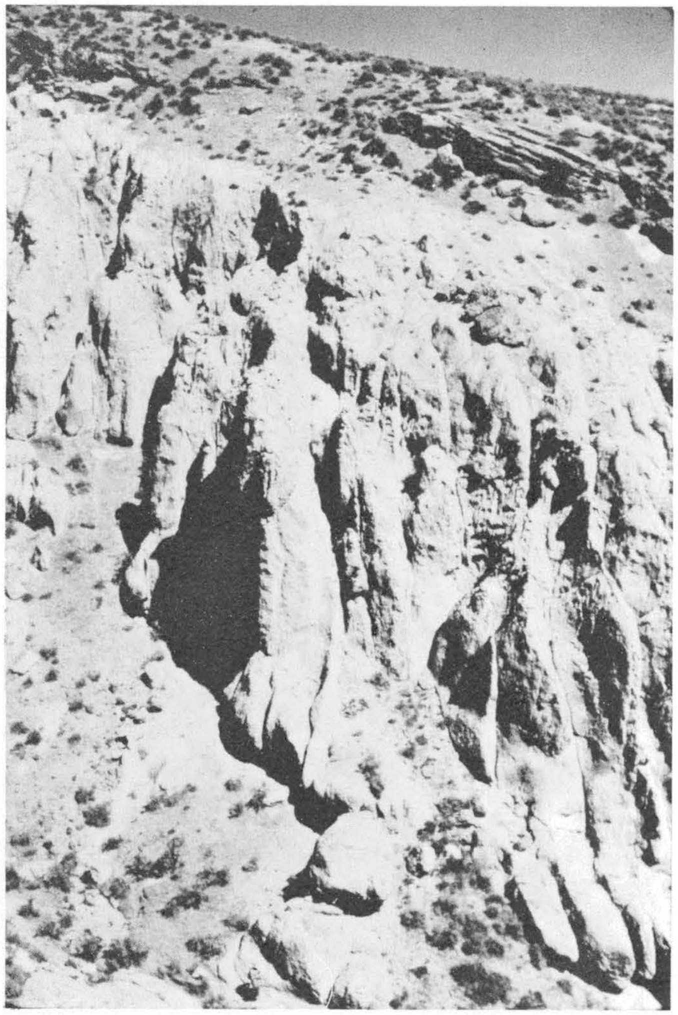

Figure 9. — Massive lapilli tuff in the Indian Well Formation overlain by east-dipping conglomerate and sandstone of the Humboldt Formation (restricted). Tuff is almost 60 m (200 ft) thick. Located on the east side on Cortez Mountains in the NW¼ sec. 12, T. 30 N., R. 51 E. Photograph by David D. Blackwell.

TABLE 6. — *Chemical analyses of ash-flow tuffs from the Indian Well Formation (in weight percent)*

[Leaders (- -) indicate not determined. Analyst, George O. Riddle]

Sample	1	2	3	4	5
Serial No.	D103215	D103220	D103218	D103216	D103217
Field No.[1]	SR-344	SR-374A	SR-375	SR-376	SR-333
SiO_2	63.68	70.06	68.84	69.86	63.83
Al_2O_3	15.24	13.90	13.84	15.10	16.11
Fe_2O_3	3.35	1.23	1.17	2.27	3.84
FeO	.23	.62	.63	.32	.59
MgO	1.48	.44	.58	.49	1.53
CaO	4.32	1.72	1.85	2.82	3.42
Na_2O	3.05	2.89	1.89	3.30	2.98
K_2O	2.70	4.47	4.78	3.67	3.00
H_2O+	1.76	3.59	4.75	.54	1.31
H_2O-	2.27	.23	.98	.75	2.19
TiO_2	.51	.22	.22	.43	.64
P_2O_5	.14	.07	.08	.14	.21
MnO	.05	.06	.06	.03	.04
CO_2	.01	.01	.01	.02	.02
Cl	.76	--	--	--	--
F	.07	--	--	--	--
S	.14	--	--	--	--
Subtotal	99.76	99.51	99.68	99.74	99.71
Less O	.27	--	--	--	--
TOTAL	99.49	99.51	99.68	99.74	99.71

[1]Sample localities are on plate 1.

SAMPLE DESCRIPTIONS

1. Ash-flow tuff. Radiometrically dated sample; loc. 6 on plate 1.
2. Vitrophyre.
3. Ash-flow tuff. 9 m (30 ft) above No. 2.
4. Ash-flow tuff. 9 m (30 ft) above No. 3.
5. Ash-flow tuff. From isolated outcrop on west side of Pinon Range.

his Raine Ranch Formation (1960, p. 1195) and he adequately described (p. 1195) the lapilli tuff as "a soft, massive, white to cream-colored rock, composed of rounded pumice fragments up to 6 inches in diameter, embedded in a matrix of smaller pumice fragments, glass dust, and crystals of labradorite, sanidine, quartz, biotite, hornblende, and pyroxene. The tuff contains also some angular fragments of lava ranging from rhyolite to basalt." Volcanic breccia that overlies the tuff in places is as much as 30 m (100 ft) thick. Scoriaceous basalt locally forms a thin flow above the breccia.

An Oligocene age is established for the Indian Well Formation on the basis of radiometric age determinations of minerals from the ash-flow tuff. Sample SR-344 of massive tuff in SW¼ sec. 32, T. 30 N., R. 54 E. (loc. 6 on pl. 1), collected by us, was dated by R. F. Marvin (McKee and others, 1971, p. 33, sample 76) as 33.2±0.7 m.y. on sanidine and 34.9±0.7 m.y. on biotite. A sample from the SE¼ sec. 34, T. 31 N., R. 53 E. (loc. 5 on pl. 1) was collected and dated by R. L. Armstrong (McKee and others, 1971, p. 33, sample 75) as 36.2±0.7 m.y. on biotite. Biotite from near the base of the lapilli tuff in NE¼ sec. 12, T. 31 N., R. 51 E. (loc. 2 on pl. 1), near the north end of Pine Valley, is 37.6±1.3 million years (R. F. Marvin, H. H. Mehnert, and Violet Merritt, written commun., Nov. 6, 1972).

As recorded in the measured type stratigraphic section, an ostracod collection is of indeterminate age according to I. G. Sohn (written commun., 1965).

SILICIC INTRUSIVE ROCKS

Intrusive rocks that are mostly silicic and of Tertiary age occur as dikes and stocks in parts of the area. Because of similarities in composition, these rocks are presumed to be about the same Oligocene age as has been established radiometrically on samples of the stock in the Railroad mining district, west of Bullion, near the center of the mapped area. The ages of this stock are 35.4±1.1 m. y. on feldspar and 36.8±1.1 m.y. on biotite from the granitic out shell of the stock (loc. 3 on pl. 1) (Analysts: R. G. Marvin, H. H. Mehnert, and J. D. Mensik, Written Commun., 1965), and 35.3±0.7 m.y. on biotite adamellite and 36.0±1.4 m.y. on whole rock of rhyolite porphyry (Armstrong, 1970, p. 214-215, samples 109 and 110; loc. 4 on pl. 1)

A principal area of concentration of intrusive bodies near the center of the mapped area contains the stock west of Bullion and many dikes. A number of thin dikes along faults near and west of the crest of the Pinon Range in this central area are not included on the geologic map (pl. 1), because showing them would clutter the map at this scale. Most dikes, even though not along faults, have trends that are essentially parallel to the faults. This area of concentration of intrusive bodies overlies a large aeromagnetic high anomaly that D. R. Mabey (see "Aeromagnetic Survey") interprets as reflecting a large intrusive body.

The stock near Bullion is made of an outer shell of medium-grained granite, quartz monzonite, monzonite, and quartz diorite and a core essentially of rhyolite porphyry. As reported previously (Ketner and Smith, 1963b, p. B11-B13),

"Typically the granite, monzonite, and quartz diorite in the outer shell of the stock is hypautomorphic granular to porphyritic and fine to medium grained. Many of the larger plagioclase grains are zoned progressively outward but also show uncommon reversals. Biotite is the only mafic mineral.

The rhyolite composing the core, the northeast margin of the stock, and a faulted body on the east side of the district typically is porphyritic and consists of euhedral phenocrysts of quartz, sanidine, and, less commonly, plagioclase, 1 to 6 mm in diameter. The matrix consists mainly of potassium feldspar and quartz grains 0.01 to 0.1 mm in diamter. Iron- and magnesium-bearing minerals are scarce. The rhyolite is interpreted as intrusive because of its sharp contact with the granitic shell."

The dikes in this central part of the mapped area are generally similar petrographically to the rhyolite-porphyry core. Granite, however, forms some chubby dikes on the southwest side of Pine Mountain. Chemical analyses of samples from the stock and from a large dike are given in table 7.

Sedimentary rocks in the vicinity of the stock and west onto Pine Mountain have been slightly metamorphosed. The carbonate units are marbleized in places, and some limestone has been dolomitized. Skarn consisting of garnet and diopside, and of lesser amounts of penninite, phlogopite, magnetite, pyrite, pyrrhotite, and chalcopyrite has been formed adjacent to or very near the stock. Quartzite and argillite also occur in the area above the buried intrusion.

The other largest exposed intrusive body is mostly in secs. 27 and 34, T. 29 N., R. 53 E. and is also a stock. The rock is white to gray rhyolite, consisting of quartz and feldspar phenocrysts as much as 4 mm across in a dense groundmass. In contrast to the Bullion stock, this stock is essentially of one composition and does not appear to have been a two-fold intrusion. Also, the sedimentary beds near this stock were not altered. Some limestone beds near the stock are silicified, but silicified rocks in this area are much more widespread than the exposed contacts of intrusive bodies.

One small, poorly exposed mafic dike in Papoose Canyon is included with the silicic dike map unit.

Those intrusive bodies along the northwest margin of the mapped area are considered to be part of the same general group as the Tertiary silicic rocks, although they have not been dated radiometrically and could be older than Oligocene. They are generally about quartz monzonite in composition and of fine- to medium-grained granitic to porphyritic texture (table 7, sample 845). Adjacent to the body cropping out at the Humboldt River, the country rock is bleached and some skarn has developed.

YOUNGER INTERMEDIATE TO SILICIC VOLCANICS

A sequence of volcanic rocks that consists mainly of lavas occurs on prominent hills along the south edge of the southeast quarter of the mapped area. Ash-flow tuffs are interlayered with the lavas in places, and volcanic breccias containing angular pieces as much as 0.6 m (2 ft) across are prominent locally. This rock sequence is between 275 and 305 m (900 and 1,000 ft) thick.

The lavas range in composition largely from andesite (table 8) to quartz latite and some rhyolite. Plagioclase, generally close to andesine, is a most common phenocryst. Pyroxene and biotite are prominent in many flows and quartz is prominent in some.

A coarse-grained, speckled, dark-gray rock that crops out in the E½ sec. 28, T. 28 N., R. 54 E. contains well-informed sanidine crystals as much as 5.1 cm (2 in.) long. The coarse texture of this rock suggests that it might be intrusive, but no field relations observed on the rubble-covered slopes conclusively prove its intrusive or extrusive origin. A high magnetic anomaly (E, pl. 1) that extends east of the outcrop of this coarse-textured rock may indicate the existence of a buried intrusive body.

This unit of mostly lavas seems to be somewhat unconformable on the Indian Well Formation ash-flow tuff, but it is presumed to be of Oligocene age and

TABLE 7. — *Chemical analyses of Tertiary silicic intrusive rocks (in weight percent)*

[Leaders (.....) indicate not determined. Analyst Nos. 1 to 6, Ellen S. Daniels; analyst No. 7 Christel L. Parker]

Sample	1	2	3	4	5	6	7
Serial No.	I4167	I4168	L4169	L4170	L4171	L4172	D100265
Field No.[1]	654	672	662	665	657	659	845
SiO_2	70.52	69.23	69.72	72.26	66.14	77.33	65.94
Al_2O_3	15.05	15.27	15.18	14.87	13.75	12.29	14.91
Fe_2O_3	.86	1.04	.61	.24	4.26	.40	1.57
FeO	1.04	1.80	2.05	.50	.09	.12	2.34
MgO	.67	.95	.86	.30	.15	.02	1.73
CaO	2.78	2.95	2.95	1.59	.38	.44	2.62
Na_2O	3.25	3.47	3.41	2.85	.38	2.14	2.46
K_2O	4.26	3.65	3.69	5.78	6.98	5.93	4.64
H_2O+	.51	.43	.44	.50	.98	.64	1.64
H_2O-	.06	.11	.12	.18	.19	.17	.48
TiO_2	.37	.40	.39	.27	.44	.09	.55
P_2O_5	.13	.14	.14	.09	.18	.02	.16
MnO	.04	.07	.05	.02	.02	.01	.11
CO_2	.14	.18	.12	.13	.12	.03	.23
Cl	.02	.01	.03	.02	.01	.01	.07
F	.08	.06	.08	.04	.05	.01	.08
SO_3[2]	--	--	--	--	.05	--	--
BaO	--	--	--	--	5.46	--	--
Subtotal	99.78	99.76	99.84	99.64	99.63	99.65	99.53
Less O	.03	.03	.04	.02	.02	.00	.05
TOTAL	99.75	99.73	99.80	99.62	99.61	99.65	99.48

[1]Sample localities are on plate 1.
[2]Total sulfur calculated to SO_3.

SAMPLE DESCRIPTIONS

1, 2, and 3. Quartz monzonite. From granite to quartz diorite outer shell of stock west of Bullion. See text for general description.
4. Rhyolite porphyry. From core of stock west of Bullion. See text for general description.
5. Rhyolite porphyry. Bunker Hill dike (Ketner and Smith, 1963b, p. B11-B13).
6. Rhyolite porphyry. From core of stock west of Bullion. See text for general description.
7. Porphyritic quartz monzonite. Broken, corroded, and altered zoned andesine; euhedral altered pyroxene; and wispy altered biotite in a matrix of equigranular quartz and potassium feldspar.

to have been formed as part of the same Oligocene volcanic episode.

MAFIC TO INTERMEDIATE PLUGS AND DIKES

Mafic to intermediate plugs and dikes of Oligocene age occur in a relatively narrow band along the east flank of the Cortez Mountains. The rocks are dark gray to black, dense, and aphanitic.

Outcrops of these intrusive bodies are reasonably prominent, but the ground on them is mostly covered by a rubble of large chunks of rock. The dikelike plug in the western part of sec. 11, T. 30 N., R. 51 E. has crude curving columnar jointing. Contacts with adjoining rocks are generally obscure. The intrusive nature of the small plug cutting the mudstone unit of the Newark Canyon Formation near the north end of

TABLE 8. — *Chemical analyses of andesites from the younger intermediate to silicic volcanics (in weight percent)*

[Leaders (- -) indicate not determined. Analyst, George O. Riddle]

Sample----------	1	2	3
Serial No.-------	D103226	D103227	D103228
Field No.[1]-------	SR-358	SR-359	SR-368
SiO_2 -----------	62.51	62.36	65.55
Al_2O_3 -----------	16.46	16.57	11.41
Fe_2O_3 -----------	2.36	3.13	6.22
FeO ------------	2.21	1.91	.09
MgO ------------	1.95	1.87	1.00
CaO ------------	4.81	5.15	3.19
Na_2O -----------	2.69	3.18	1.86
K_2O ------------	3.64	3.19	3.69
H_2O+ -----------	1.78	.49	3.44
H_2O- -----------	.17	.61	2.07
TiO_2 -----------	.74	.81	.75
P_2O_5 -----------	.24	.26	.19
MnO ------------	.08	.07	.04
CO_2 ------------	.01	.02	.05
Subtotal---------	99.65	99.62	99.55
Less O-----------	--	--	--
TOTAL------------	99.65	99.62	99.55

[1]Sample localities are on plate 1.

SAMPLE DESCRIPTIONS

1. Pyroxene andesite porphyry. Euhedral to subhedral plagioclase, mostly andesine, as much as 4 mm long, many zoned, some broken and some partly altered; sparse alkali feldspar as much as 2.5 mm long; small euhedral to subhedral pyroxene having maximum length of 0.6 mm; sparse biotite; devitrified glassy matrix with well-developed flow lines around crystals.
2. Pyroxene andesite porphyry. Euhedral to subhedral plagioclase, mostly andesine, as much as 4 mm long, many zoned, some broken; small euhedral to subhedral pyroxene having maximum length of 0.6 mm; sparse biotite; fine-grained trachitic matrix with some glass.
3. Biotite andesite porphyry. Euhedral to subhedral plagioclase, mostly andesine, as much as 4 mm long, many zoned, some broken and some altered; sparse alkali feldspar as much as 0.8 mm long; biotite much altered; sparse quartz as much as 4 mm across, embayed; glassy matrix; many quartz veinlets probably account for higher silica percentage.

the mudstone exposures is indicated, however, by hornfels that caps the plug. This hornfels is evidently baked Newark Canyon mudstone.

The nature of the largest exposure of dense black andesite (table 9) in sec. 35, T. 31 N., R. 51 E. and secs.

TABLE 9. — *Chemical analyses of volcanic rocks from the mafic to intermediate plugs and dikes, the rhyolitic welded tuff, and the andesite and basaltic andesite units (in weight percent)*

[Leaders (- -) indicate not determined. Analyst, George O. Riddle]

Sample ----------	1	2	3
Serial No.-------	D103221	D103222	D103229
Field No.[1]-------	SR-530	SR-531	SR-330
SiO_2 -----------	58.12	73.41	60.19
Al_2O_3 -----------	15.90	13.48	16.83
Fe_2O_3 -----------	1.62	1.71	1.98
FeO ------------	4.35	.14	3.89
MgO ------------	4.98	.17	2.33
CaO ------------	6.85	.95	5.44
Na_2O -----------	2.99	3.64	2.82
K_2O ------------	2.53	5.15	4.10
H_2O+ -----------	.66	.40	.69
H_2O- -----------	.27	.33	.32
TiO_2 -----------	.86	.16	.74
P_2O_3 -----------	.28	.05	.38
MnO ------------	.11	.04	.11
CO_2 ------------	.24	.02	0
Subtotal---------	99.76	99.65	99.82
Less O-----------	--	--	--
TOTAL------------	99.76	99.65	99.82

[1]Sample localities are on plate 1.

SAMPLE DESCRIPTIONS

1. Pyroxene andesite (mafic to intermediate plugs and dikes unit). Small subhedral stubby and elongate pyroxene crystals make up 15-20 percent of the rock, mostly less than 0.2 mm long, maximum length of 1.5 mm; altered olivine as much as 1.3 mm across forms 1-2 percent; trachitic matrix of andesine to labradorite microlites; some glass.
2. Rhyolitic welded tuff (rhyolitic-welded-tuff unit). Phenocrysts make up 10-15 percent of section and are set in a matrix of devitrified glass shards; most phenocrysts are sanidine, as much as 4 mm across, somewhat frayed and embayed; oligoclase as much as 1.5 mm long; sparse small biotite and hornblende; fine-grained quartz in matrix.
3. Andesite (andesite and basaltic andesite unit). Phenocrysts are less than 5 percent in a cryptocrystalline and glassy matrix; mostly small pyroxene less than 0.8 mm long; sparse altered andesine as much as 1.0 mm long and sparse hornblende; very sparse irregular quartz as much as 2.5 mm across.

2 and 11, T. 30 N., R. 51 E. is uncertain, because the contacts are obscure there also. The topographic relation to the slightly younger rhyolitic welded tuff

to the east almost certainly requires that the contact between these two units be a fault. The contact with the older Newark Canyon Formation is mostly rubble covered, and the relation between the two rock units is too indefinite to determine certainly whether the andesite is a flow remnant on the sedimentary rocks, or more probably, a near-surface intrusive through them. It is mapped as an intrusive plug because of its general relation to and alinement with small intrusives farther south.

An Oligocene age for these rocks is established on a whole-rock radiometric age determination made by R. F. Marvin, H. H. Mehnert, and Violet Merritt. The sample analyzed is from near the south edge of the E½ sec. 2, T. 30 N., R. 51 E. (loc. 7 on pl. 1) and is dated as 31.9±1.1 m.y.

RHYOLITIC WELDED TUFF

Rhyolitic welded tuff (table 9) caps a north-trending flat-topped ridge about 1.2 km (0.75 mi) long and slightly less than 0.4 km (0.25 mi) wide, near the north-south center of the mapped area and about 2.4 km (1.5 mi) east of the crest of the Cortez Mountains. The ash flow is about 60 m (200 ft) thick.

The Oligocene age of this ash flow (loc. 8 on pl. 1) is 31.2±1 m.y., as determined radiometrically on sanidine by R. F. Marvin, H. H. Mehnert, and Violet Merritt (written commun., Nov. 1972). Although this rock unit is slightly younger than the dated ash-flow tuff in the Indian Well Formation east of the Pinon Range, it probably was formed as part of the same general episode of mostly silicic volcanism.

The rhyolitic welded tuff occupies a somewhat unique position in relation to other Tertiary volcanic rocks near Pine Valley. It is an isolated remnant about 335 m (1,100 ft) above the floor of Pine Valley. Its base appears to be essentially horizontal, and it rests with angular unconformity on the Newark Canyon Formation and the lapilli tuff of the Indian Well Formation. Beds of the Miocene Humboldt Formation (restricted), just east of the flow remnant, dip about 20° to the east. Because these younger rocks were tilted, evidently the ash-flow tuff was tilted also; therefore, its base must not have been strictly horizontal at the time of emplacement.

Evidence from the unconformable position of the rhyolitic welded tuff and from some welded tuffs near Dixie Creek, particularly in secs. 8 and 17, T. 30 N., R. 54 E., tuffs that also truncate older sedimentary beds and ash-flow tuffs, points to tilting and also erosion at times during the Tertiary volcanic episode. The eastern tuffs are included as part of the Indian Well Formation.

MIOCENE SERIES

HUMBOLDT FORMATION (RESTRICTED)

The name "Humboldt group" was applied to upper Tertiary rocks covering a wide area in western Utah and eastern Nevada by members of the Fortieth Parallel Survey (King, 1878, p. 434–443). Tertiary rocks in the Huntington Creek-Pinon Range area were included in the Humboldt (King, 1878, p. 438–439 and 1877, p. 540). Sharp (1939) designated the Tertiary basin deposits in northeast Nevada, and particularly those in the Elko to Ruby Mountains region, as the Miocene Humboldt Formation and suggested that the beds exposed along Huntington Creek, about 3.2 km (2 mi) east of the Dixie Flats quadrangle, be taken as the type section. On many maps of parts of northeast Nevada since then, all Tertiary sedimentary rocks have been shown as the Humboldt Formation, although Van Houten (1956, p. 2813) pointed out that the oil shale at Elko and some of the rocks in the Dixie Flats-Huntington Valley area are older than the Miocene rocks and not part of the same formation. Regnier (1960, p. 1199) correlated his Carlin Formation, with the middle member of Sharp's Humboldt Formation.

In the present study and in mapping the Lee quadrangle east of the Dixie Flats quadrangle, we found that what has been called the Humboldt can actually be mapped as a number of separate units. We are restricting the name Humboldt Formation to an upper Miocene sequence of beds that contains much vitric ash and tuffaceous rocks and designating a section along the east side of Huntington Creek (fig. 10) in the Lee quadrangle as the reference section; by this designation, the Humboldt Formation includes the middle member and at least part of the upper member of the Miocene Humboldt Formation as used by Sharp (1939, p. 143–145). In accord with this definition of the restricted Humboldt Formation, the upper part of the Raine Ranch Formation and the Carlin Formation of Regnier (1960) are included in the Humboldt, although these two units are separated by a slight unconformity (Regnier, 1960, p. 1199).

Beds constituting the Humboldt Formation (restricted) are of both fluviatile and lacustrine origin and consist of ash and tuff, conglomerate, sandstone, siltstone and claystone, and thin beds of limestone. The most common rock colors are light gray to almost white, and so most exposures are very light; locally siltstone and sandstone beds have a pinkish-orange cast and form pinkish bands along the slopes.

FIGURE 10. — Lower part of the Humboldt Formation (restricted) at the reference section on the east side of Huntington Creek, in Lee quadrangle, east of Dixie Flats quadrangle. Arrow points to unit 1 of the measured reference stratigraphic section (p. 35). Ruby Mountains in far background. Eastward view. Photograph taken from sec. 1, T. 31 N., R. 55 E.

For convenience of discussion, the strata east and west of the Pinon Range are considered separately in part. These upper Miocene beds are the earliest ones deposited on basin-and-range terrain of essentially the present configuration, and thus the basins east and west of the Pinon Range had partly different sources for nonpyroclastic material deposited in them. Those beds on the east side and including the designated reference section are described first.

Reference section of the Humboldt Formation (restricted) along the east side of Huntington Creek, secs. 1 and 12, T. 31 N., R. 55 E., and secs. 6, 7, and 18, T. 31 N., R. 56 E., about 3 km (2 mi) east of the Dixie Flats quadrangle

[Measured using Abney level on Jacob Staff]

	Thickness m	Thickness ft
Tertiary System, Miocene Series:		
Humboldt Formation (restricted):		
Top gravel-covered.		
19. Sandstone and siltstone mostly; some tuffaceous sandstone, pebbly and gritty beds, and ash and tuff. A 3-m (10-ft)-thick bed of very light gray vitric ash is at base of unit and a prominent tuff bed is about 31 m (100 ft) above base. An ostracod collection (SR)281) from the lower part of this unit about 1.6 km (1 mi) south of the line of the measured section includes *Candona* spp., *Darwinula* sp., one valve, *Eucypris(?)* sp., that should be either Miocene or Pliocene, as reported by I. G. Sohn (written commun., June 16, 1964)	60+	200+

Reference section of the Humboldt Formation (restricted) along the east side of Huntington Creek — Continued

	Thickness m	Thickness ft
Tertiary System, Miocene Series — Continued		
Humboldt Formation (restricted) — Continued		
18. Siltstone and sandstone and less claystone, conglomerate, and limestone; very light gray to almost white; a few beds of siltstone, claystone, and sandstone have a pinkish-orange cast and form bands along the slope. Sandstone consists of grains ranging from very fine to granule size, mostly rounded to angular quartz, a few chert, and biotite and muscovite in some beds; crossbedded on a small scale. Conglomerate beds are lenticular and consist of pebbles derived from crystalline rocks (quartzite, gneiss, granitic rocks, and marble) in the Ruby Mountains to the east; pebbles of gray carbonate rocks make up less than 5 percent of the total; a very few pebbles are white dense limestone and white crystalline limestone; pebbles are mostly well rounded and less than 5.1 cm (2 in.) in diameter; a few cobbles are 10 cm (4 in.). Some claystone beds are bentonitic. A number of beds of white and creamy limestone seem to be in lenses a few metres long, but exposures are poor and actual lens sizes are indeterminate; some limestone is slightly sandy. Units of any one lithologic type are about 1-4.5 m (3-15 ft) thick	165	540

Reference section of the Humboldt Formation (restricted) along the east side of Huntington Creek — Continued

Tertiary System, Miocene Series — Continued Humboldt Formation (restricted) — Continued	Thickness *m*	*ft*
17. Sandstone, tuffaceous and calcareous; sandy limestone; some tuff; a few beds contain granules and scattered pebbles as much as 2.5 cm (1 in.) in diameter; rocks chiefly gray and weather gray, slight-pink tint to some pebbly beds; some tan and cream limestone. Units of single lithologic types appear to be 0.3-0.6 m (1-2 ft) thick	35	115
16. Sandstone, calcareous, tuffaceous, sandy limestone, and calcareous tuff interlayered in beds mostly 2.5 cm-0.3 m (1 in.-1 ft) thick; light gray to white; sandstone mostly medium grained, tuff very fine grained. Scattered thin lenses of pebble conglomerate. A ledgy slope in part is formed on these beds ..	17	55
Southward this unit grades into and interfingers with beds of gray conglomerate made up of pebbles chiefly less than 5.1 cm (2 in.) in diameter; the pebbles are of crystalline rocks (quartzite, gneiss, granitic rocks, and marble) from the Ruby Mountains and gray-banded limestone and gray dense medium-crystalline limestone, also probably from the Ruby Mountains (no pebbles that could be identified definitely as having come from limestone in the Pinon Range to the west were recognized); ratio of crystalline rock to gray-limestone pebbles about 50:50 to 60:40. Some sandstone lenses are crossbedded on a small scale. This conglomerate unit probably was deposited as a large channel fill or as a fan; exposures do not permit recognition of a three-dimensional picture of the unit.		
15. Ash and tuff, gray; weathers light gray to almost white; very fine- to fine-grained; beds thinly laminated to 0.6 m (2 ft) thick; thin lenses of pebble conglomerate in upper part. About 50 percent of the unit is calcareous, and calcareous parts form ledges	49	160
14. Conglomerate, gray, moderately well consolidated; pebbles are of crystalline rocks and gray limestone, all probably from Ruby Mountains, as much as 5.1 cm (2 in.) in diameter, rounded and commonly somewhat flattened; ratio of crystalline rock to gray limestone pebbles about 50:50 to 60:40; sparse chert pebbles. Matrix is coarse grained, mostly quartz and a few chert grains. Evenly bedded in layers 2.5 cm-1 m (1 in.-3 ft) thick. A lenticular unit traceable to several hundred metres along the slope	3	10
13. Tuff, gray; weathers gray and slightly darker than unit below; mostly calcareous; beds as much as 0.6 m (2 ft) thick. Contains scattered low-spired gastropods in upper part. Forms a ledgy slope	27	90
12. Turf and ash, gray and almost-white, vitric; beds 0.1 cm-0.6 m (0.03 in.-2 ft) thick, some evenly bedded, some crossbedded, some massive; hard calcareous beds 2.5-10 cm (1-4 in.) thick make up less than 1 percent of unit. Fraction of a percent of the unit consists of lenses of pebble conglomerate containing pebbles of well-rounded crystalline rocks from the Ruby Mountains and a few gray limestone. Forms a soft slope	70	230
11. Ash, gray, fine-grained, vitric, thin bedded; many beds about 0.2 cm (0.06 in.) thick; some small-scale crossbedding. Top 7.6 cm (3 in.) is hard, gray, brownish-gray-weathering calcareous tuff containing scattered clastic grains of quartz. A few low spired gastropods	26	85
10. Siltstone and claystone, calcareous, gray; weathers very light gray and white. Contains plants, tubers of *Equisetum* identified by Jack A. Wolfe (written commun., Nov. 8, 1963). Top about 2.5 cm (1 in.) is tuffaceous	0.3	1
9. Tuff, gray	2.7	9
8. Conglomerate, lenticular; contains pebbles as much as 2.5 cm (1 in.) in diameter of mostly crystalline rocks (quartzite, gneiss, and coarsely crystalline white marble) from Ruby Mountains, sparse oval pebbles as much as 7.6 cm (3 in.) long of gray limestone; thickens to as much as 1.5 m (5 ft) along strike.	0.3	1
7. Tuff and ash, gray	6	20
6. Ash, gray; weathers gray; mostly vitric; contains some fine-grained crystals of feldspar and less quartz; crossbedded in part in layers 0.2 cm-10 cm (0.06-4 in.) thick. Poorly exposed, in general, but top 1.2 m (4 ft) forms prominent outcrop	31	100

Reference section of the Humboldt Formation (restricted) along the east side of Huntington Creek — Continued

	Thickness m	ft
Tertiary System, Miocene Series — Continued		
Humboldt Formation (restricted) — Continued		
5. Limestone, white and cream-colored; weathers white; dense; beds 5.1 cm-1 m (2 in.-0.3 m) thick. Blocky pieces on slope	8	25
4. Ash, gray, vitric, consolidated but friable, weathers gray; glass shards clear, gray, some black; beds 20 cm-0.6 m (8 in.-2 ft) thick. Pieces of dense limestone must come from a bed about 20 cm (8 in.) thick in the upper part	21	70
3. Covered, dirt looks as if it may have been derived from gray tuff	21	70
2. Limestone, dense, buff; weathers white	0.3	1
1. Conglomerate, partly covered; pebbles and cobbles as much as 20 cm (8 in.) in diameter of chiefly gray limestone, well rounded; some fossiliferous pebbles and cobbles could be derived from Permian or Pennsylvanian beds to the west; others, particularly some banded ones, seem to be from source other than to the west, are probably from Ruby Mountains; very few pebbles of tan and reddish-tinted siltstone and quartzite; very sparse red and black chert pebbles. Most of the limestone clasts are gray, dense to fine grained; some are white, coarsely crystalline	18	60
Base not exposed; gravel covered		
Thickness	560+	1850+

The measured thickness of 560 m (1,840 ft), though obviously not the total thickness of the formation because both the bottom and top are covered, is probably not much less than the actual thickness. Map measurements on the Lee quadrangle indicate that 610 m (2,000 ft) is probably about the maximum thickness in this general region. In the area of the present report, a thickness of 537 m (1,765 ft) was measured in the following stratigraphic section.

Measured stratigraphic (S6 on fig. 2) section of the Humboldt Formation (restricted) in secs. 32 and 33, T. 31 N., R. 55 E., and secs. 3 and 4, T. 30 N., R. 55 E., Dixie Flats quadrangle

[Measured by use of Abney level on Jacob staff]

	Thickness m	ft
Quaternary System:		
Silt, sand, and some gravel.		
Tertiary System, Miocene Series:		
Humboldt Formation (restricted):		
12. Limestone, mostly, tan and white, tuffaceous, grainy-textured; in beds apparently 2.5-15.3 cm (1-6 in.) thick; sandy in places and contains small chert pebbles locally. Top is eroded on crest of ridge	36	120

Measured section (S6) of the Humboldt Formation (restricted) — Continued

	Thickness m	ft
Tertiary System, Miocene Series — Continued		
Humboldt Formation (restricted) — Continued		
11. Ash, vitric and silicified; gray vitric ash weathers gray, silvery; gray silicified ash weathers light gray, tan, and brown. Away from line of section, some good exposures are on bluffs as much as 9 m (30 ft) high; these are mainly vitric ash laminated in layers 0.1-10 cm (0.03-4 in.) thick and irregularly spaced layers of silicified ash that range in thickness from 2.5 cm to 1.2 m (1 in. to 4 ft) and in length from 0.6 m (2 ft) to the width of the exposure. Exposures mostly are poor, and pieces and slabs of silicified ash cover the slopes. Light-tan and light-gray grainy-textured limestone is interlayered with the ash	55	180
10. Limestone, similar to that below; some has grainy texture, blebs 0.1-0.2 cm (0.03-0.06 in.) in diameter, and may be algal. Pieces as much as 20.3 cm (8 in.) thick of white silicified limestone on the slope are brecciated on a small scale and have grainy texture in places. Very sparse beds of conglomerate contain angular to rounded pebbles as much as 5.1 cm (2 in.) in diameter of sandstone and gray sandy limestone, which probably were derived from Permian rocks; sandy matrix is calcareous and tuffaceous. Poorly exposed vitric ash and silicified ash make up part of the unit	146	480
9. Limestone, similar to that in unit below; tuffaceous and calcareous sandstone from fine grained to very coarse grained; many grains, particularly the coarse ones, are of tan, brown, and some black chert; a few small pebbles; some non calcareous, very slightly tuffaceous light-gray siltstone; probably some ash. All rocks on slope very light gray to almost white. Poorly exposed, in part covered by alluvium across small valley	119	390
8. Limestone, very light tan to white, slightly tuffaceous, in beds 0.6-15.3 cm (0.25-6 in.) thick, but bedding obscure; some dense, some porous; some gray calcareous ash in pieces on slope; farther north, bedded vitric ash is exposed in this unit; ledge-forming limestone 1-1.5 m (3-5 ft) thick at top of unit; exposures generally poor	36	120
7. Covered by alluvium	41	135

Measured section (S6) of the Humboldt Formation (restricted) — Continued

	Thickness *m*	*ft*
Tertiary System, Miocene Series — Continued		
Humboldt Formation (restricted) — Continued		
6. Ash, gray, vitric; in creek bed	1.5	5
5. Covered by alluvium	11	35
4. Limestone, light-gray, tuffaceous, in beds mostly 2.5–3.8 cm (1–1.5 in.) thick; float pieces have weathered irregular ripple marks on surfaces; some thin beds of almost white earthy limestone that is porous in places	14	45
3. Limestone, tuffaceous, and calcareous tuff; poorly exposed	29	95
2. Limestone, tuffaceous, very light gray to almost-white, some slightly sandy; bedding obscure but probably 5.1–0.3 m (2 in.–1 ft) thick; makes pieces on top of ridge. Platy, dense, tan to very light tan limestone in float; some surfaces covered with mud cracks. Very few pieces of soft gray vitric ash in float. Mollusk collection SF-315 (loc. F-18 on pl. 1), from dense limestone, contains a small species of Planorbidae, genus indeterminate (D. W. Taylor, written commun., 1966). Mollusk collection SF-314 (loc. F-17 on pl. 1), probably from same beds as those at top of unit, contains fresh water snails *Valvata, Lymnaea?, Radix,* and Planorbidae, genus indeterminate (D. W. Taylor, written commun., 1966)	36	120
1. Sandstone, conglomeratic, gray, calcareous; contains angular clasts mainly 5.1 cm (2 in.) or less across of platy limestone, sandy limestone, and calcareous sandstone; some clasts scattered through sandstone; others concentrated in pockets; obscure irregular bedding. Fragments were derived mostly from Permian rocks like those now exposed just to south on Cedar Ridge; unit probably is a tongue of sand and gravel in lake beds	12	40
Measured thickness	537	1765

The Humboldt Formation (restricted) here rests on the Indian Well Formation on what must be an unconformity, but exposures do not permit recognition of details of contact relations.

Ash and tuff are most prominent in about the lower 305 m (1,000 ft) of the reference section, and siltstone, sandstone, and conglomerate are most prominent above that. East of the Pinon Range, gray to silvery-gray vitric ash, which may weather gray, tan, or brown, makes striking outcrops in places (fig. 11). It commonly occurs in layers 1 mm–0.6 m (0.03 in.–2 ft) thick and is evenly bedded to crossbedded on a small scale. The vitric ash is silicified irregularly at places, with friable ash changing abruptly to hard resistant ash along or across the bedding. Chunks and slabs of this hard ash are prominent on some slopes. Hard ash layers cap some low parallel ridges in the southeast part of the Dixie Flats quadrangle, and so repetition by faulting is suggested, but examination of the rock successions indicates that such repetition is unlikely.

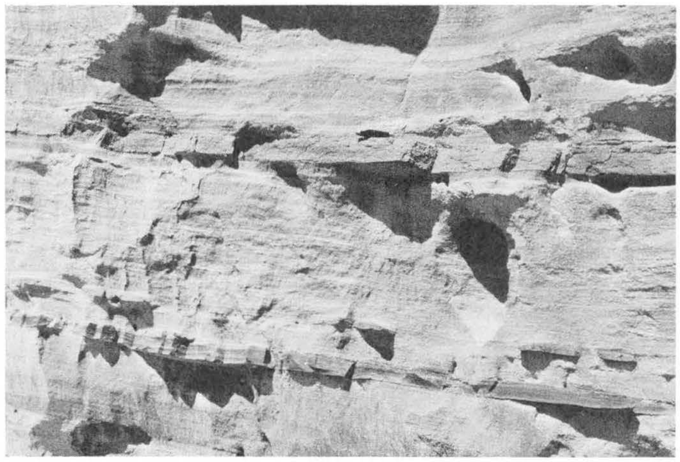

FIGURE 11. — Bedded vitric ash in the Humboldt Formation (restricted). Hard silicified layers project from surface; these layers are parallel to bedding in general but cross bedding at low angles as they pinch and swell or end. Knife (upper-center part of photograph) is 7.6 cm (3 in.) long. SW¼ sec. 21, T. 31 N., R. 55 E.

Four samples of ash from the Humboldt Formation (restricted) were examined in the laboratory by David Ramaley, then of the U.S. Geological Survey. He found that the glass shards are mostly platy to blocky and are commonly clear or gray and rarely are black. An intermediate and heavy fraction (2.42 sp gr) made up less than 1 percent of three samples and 3–4 percent of the fourth; minerals in these fractions are sanidine, plagioclase, quartz in traces, zircon, opaque minerals (mostly magnetite), and clinopyroxene in one sample, and biotite in a second sample. Detrital minerals in just as small quantities as the phenocrysts include chert, quartz, potassium feldspar, calcite, and opaque minerals (chiefly iron oxide).

Of the siltstone, sandstone, and conglomerate beds, the composition of the conglomerates presents a most interesting aspect, useful in interpreting some of the structural history of the region. The composition of the clasts in the reference section ranges from limestone in the lowest conglomerate beds to nearly all crystalline rocks in the upper ones, and reflects removal of the limestone to uncover the crystalline rocks in the Ruby Mountains, as was pointed out by

Sharp (1939, p. 140–141). Conglomerate in the basal unit of the section consists almost entirely of limestone clasts. Some could have been derived from Pennsylvanian or Permian rocks like those now exposed to the west at Cedar Ridge and the Pinon Range or to the northwest in the Grindstone Mountain area, but for many clasts there are no recognizable source rocks to the west. These, then, must have been derived from the Ruby Mountains, from limestone that overlay the crystalline rocks now forming the Ruby Mountains north of Harrison Pass. The crystalline-rock clasts are chiefly quartzite, gneiss, granitic rocks, and marble; for these the Ruby Mountains afford the only nearby source. At about 235 m (770 ft) above the base of the measured reference section, the ratio of crystalline-rock clasts to gray limestone clasts, all probably derived from the Ruby Mountains, is about 50:50 or 60:40. At around 285–300 m (930–980 ft) above the base, crystalline rocks make up more than 95 percent of the conglomerate clasts indicating that by this stage of erosion of the Ruby Mountains nearly all the gray unmetamorphosed limestone had been stripped from the north part of the mountains. This erosion of material from the mountains must have accompanied uplift of the range.

An interesting group of beds of conglomerates, much coarser than those in the reference section, is exposed in sec. 11, T. 31 N., R. 55 E. and for about 1.6 km (1 mi) farther east into the Lee quadrangle. The conglomerate here is considered to be at or near the base of the Humboldt Formation (restricted), because it contains no clasts of quartzite, gneiss, or granitic rocks identifiable as being derived from rocks exposed now in the Ruby Mountains, and thus was presumably deposited before these rocks were exposed. Some gray limestone boulders, commonly 0.5 m (1.5 ft) across and including one that measured 1.6x2 m (5x6 ft), could have been derived from Pennsylvanian or Permian limestone to the west, but many clasts of gray limestone and gray marble most likely had their sources in the Ruby Mountains. Some of these carbonate rocks are dark gray to almost black, are fine grained, and break into platy pieces. Angular blocks of gray limestone 0.5 m (1.5 ft) long and 0.3 m (1 ft) thick are fairly abundant on the surface in places. Some pebbles are of igneous rocks derived from an unidentified source, and one smooth and rounded boulder 1.6 m (5 ft) across is of a red granitic rock also of unknown source. These conglomerates probably are part of a fanglomerate deposited at or near the base of the Humboldt Formation, but some large boulders must be several kilometres from their sources and at least two rock types are of unknown source.

One conglomerate slightly northeast of the north end of Cedar Ridge consists of clasts of sandstone and limestone like the Paleozoic rocks on the ridge. The relations indicate that Cedar Ridge was a high area at the time of deposition of the Humboldt Formation and that a tongue of sand and gravel composed of eroded fragments of the ridge rocks was deposited near the base of a sequence of mostly lacustrine deposits.

Sandstone ranges from very fine grained sand to granule-size fragments and is both evenly bedded and crossbedded on a small scale. Grains are mostly rounded to angular quartz, less muscovite, and a few chert and biotite; muscovite flakes are abundant in some beds. Also, some sandstone beds are highly tuffaceous.

Siltstone and claystone are most abundant in the upper half of the formation and make prominent exposures in places in the Lee quadrangle. Beds are commonly light gray to almost white, but others are a pinkish orange or light red, and some are green. Some of these beds have been altered to montmorillonite and have been prospected in the SW¼ sec. 7 and W½ sec. 18, T. 31 N., R. 56 E., just east of Huntington Creek in the Lee quadrangle. These prospects are reported on by Papke (1970, p. 13, 19, 20) who suggested that the "montmorillonite was formed by diagenetic alteration of a stream-deposited volcanic ash." One prospect adit follows a slickensided surface that trends N. 20° E. and dips 60° E. According to Papke, there may have been some work done at this property as late as 1940; certainly there are no indications of recent work.

Limestone occurs most commonly in beds from about 5 cm to 0.3 m (2 in. to 1 ft) thick through much of the Humboldt Formation but does not form as great a percentage of the total section as do any other rock types. The limestone is both dense and porous earthy, is white, cream, or tan, and is slightly sandy in some beds.

The Humboldt Formation (restricted) west of the Piñon Range is made up of fluviatile and lacustrine deposits of vitric tuff and ash, limestone, diatomite, tuffaceous siltstone, sandstone, and conglomerate, which constitute the upper part of the Raine Ranch Formation of Regnier (1960, p. 1195–1198) and the Carlin Formation of Regnier (1960, p. 1198–1201). Although these formations of Regnier are separated by a slight unconformity, they are similar lithologically (Regnier, 1960, p. 1198). An uncommon rock type in all the Tertiary noted in the area is bluish-gray and yellow basaltic tuff that is exposed in sec. 18, T. 33 N., R. 53 E. Regnier's (1960) Carlin Formation is the same as the Humboldt Formation in Tps. 32 and 33 N., in the northwest part of the area of the present report, where exposures are poor except along some creeks and in some roadcuts. The present area of outcrop of this sequence of beds, including the area mapped by Regnier (1960) farther north, appears to be essentially the same as the original basin of deposition.

Differences between the beds in the Humboldt Formation (restricted) in the basins east and west of the Pinon Range are largely two. First, the clasts in the conglomerate differ, as would be expected because the source areas differed in part. The source of detrital material in beds on the west side of Pine Valley, for example, was the volcanic rocks in the Cortez Mountains, and the source of much of the material in the eastern part of and east of the mapped area was the carbonate and crystalline rock terrain of the Ruby Mountains. Second, the Pine Valley section and northwest-area section contain diatomite, whereas no diatomite was observed east of the Pinon Range. Crossbedding occurs on a small scale in both basins, but scour-and-fill channels and crossbedding on a spectacularly large scale may be seen in some of the valleys on the east side of the Cortez Mountains.

The uppermost beds recognized in the Humboldt Formation (restricted) in the vicinity of the mapped area crop out about 3.2 km (2 mi) east of the Dixie Flats quadrangle in the southwest part of the Lee quadrangle; they are in secs. 16, 17, 19, 20, 21, 29, 30, 31, and 32, T. 31 N., R. 56 E. This sequence of beds rests on older Humboldt strata on what is probably a slight angular unconformity, but as the sequence consists of upper Miocene ashy basin deposits it is included in the Humboldt. These beds consist of 75-90 (250-300 ft) of clay, silt, sand, and some small pebble conglomerate and are ashy or tuffaceous, but do not contain ash layers as prominent as those in the part of the Humboldt below. Most layers in the lower 18-20 (60-65 ft) of this upper unit consist of pink clay and silt, with some quartz sand grains and some pebbles to about 1.2 cm (0.5 in.) in diameter scattered throughout, and a few beds of fine- to medium-grained sand. Layers above the pink beds are buff and very light gray silt, sandstone, and pebble conglomerate. The sandstone and conglomerate exhibit good crossbeds in places. Grains are mostly quartz and less feldspar and gray, white, and black chert. Pebbles are generally angular pieces of feldspar, quartz, and crystalline rocks derived from the Ruby Mountains to the east and a few pieces of volcanic rocks probably derived from the Indian Well Formation.

The upper Miocene position of the Humboldt Formation (restricted) is based on several fossil collections and a fission-track date on zircon. A vertebrate fossil collection of several hundred fragments from a locality (805) on the boundary between secs. 14 and 15, T. 31 N., R. 55 E. (loc. F-19 on pl. 1) was studied by Edward Lewis, who reported (written commun., Sept. 29, 1961) that it

"includes *Merychippus* sp., 16 teeth and tooth fragments, 9 undetermined equid leg and foot bones; rhinocerotid *(?Aphelops* sp.), 9 tooth fragments, and 10 to 25 bone fragments that may represent this animal; camelids *(?Procamelus* sp., *?Aepycamelus* sp.), and 10 to 25 bone fragments of undetermined genera. The stratigraphic position is approximately the same as that of the Virgin Valley Formation (of Jones, Picard, and Wyeth, 1954, p. 2221) of Humboldt County, Nevada: upper Miocene."

According to Mr. Lewis this collection has the same general age range as the collections reported by Regnier (1960, p. 1195, 1197) from his Raine Ranch Formation.

A somewhat younger late Miocene age is indicated by vertebrate fossils collected at several localities about 5 km (3 mi) northeast of Carlin (Regnier, 1960, p. 1199). Edward Lewis stated (oral. commun., Aug. 10, 1972) that the genera listed by Regnier make up a characteristic upper Miocene fauna.

The probable late Miocene age of the beds to the east in the Lee quadrangle is based on several hundred small fragments of bone collected from nine localities and studied by Edward Lewis (written commun., Sept. 16, 1969 and Nov. 22, 1971). The collections are from 45-60 m (150-200 ft) above the base of the unit. Bone fragments include

"(loc. SF-317) distal fragment of metapodial of medium sized camelid, (loc. SF-318) proximal phalanx of moderately large camelid, (loc. SF-319) 2 rhinoceros phalanges, *?Teleoceras* sp., (loc. SF-320) distal fragment of ?rhinoceros tibia, (loc. SF-321) tooth fragments and medial phalanx of moderately large camelid, (loc. SF-322) proximal fragment of radius of medium-sized camel, (loc. SF-327) no diagnostic fragments, other than to say that they represent upper Tertiary ungulates, and (loc. SF-328) 26 fragmentary specimens only one of which, a metapodial of *?Teleoceras* sp., is identifiable to genus, with some doubt, but the others are indeterminate except for two that may represent small camelids. The age is probably latest Miocene, but might be early Pliocene."

A latest Miocene is accepted as the most probable age.

Other fossil collections include the one of ostracodes from the Lee quadrangle, listed in unit 19 of the reference section as either Miocene or Pliocene (I. G. Sohn, written commun., June 16, 1964), and tubers of *Equisetum* (Jack A. Wolfe, written commun., Nov. 8, 1963) from unit 10 of the reference section; similar fossil plants were noted at other localities east of Huntington Creek in the Lee quadrangle.

A late Miocene age for the Humboldt Formation (restricted) is further indicated on the basis of a fission track age of 9.5±1.9 m.y. determined on zircon by Charles W. Naeser (written commun., May 29, 1973). The zircon was separated from a vitric ash sample (66W148) from the SW¼ sec. 21, T. 31 N., R. 55 E. (loc. 10 on pl. 1). According to the Phanerozoic time-scale of the Geological Society of London (Harland and others, 1964) the end of Miocene time was at about 7 m.y., and so the age of the part of the Humboldt containing this dated ash is very late Miocene.

The Humboldt Formation (restricted) lies unconformably on Paleozoic rocks and on several older Tertiary units. It must have been deposited on a most irregular surface that formed as the modern basin and ranges were developing. As a result, the base of the formation in one area is not necessarily the time equivalent of the base in another locality. That part of the formation in the northwest part of the mapped area is unconformable on the Palisade Canyon Rhyolite, which is younger than the Humboldt Formation in Pine Valley to the south. Thus, the lavas of the Palisade Canyon form a wedge in the Humboldt Formation.

PALISADE CANYON RHYOLITE

Rhyolite flows of the Palisade Canyon Rhyolite cap a highland area and support prominent cliffs on both sides of the Humboldt River southwest of Carlin. This formation was named by Regnier (1960, p. 1198) for exposures along Palisade Canyon. The series of rhyolite flows is broadly folded, and so determination of exact thickness is difficult; the minimum thickness must be about 245 m (800 ft).

The rhyolite is mostly brown and reddish brown and weathers to darker shades. Flow banding is very prominent in many places, and attitudes of the banding delineate the broad folds. Regnier's good description (1960, p. 1198) of the rock follows: "It contains phenocrysts of sanidine, quartz, biotite, and pigeonite in a groundmass crystallized in small spherulites. The base of each flow is a glassy, black to dark-blue rock which is also flow-banded. It contains the same phenocrysts as the top of the flows in a glassy groundmass with abundant trichites and perlitic cracks." Chemical analyses of two samples of the Palisade Canyon Rhyolite are given in table 10. This lava is quarried in Palisade Canyon for railroad ballast.

The Palisade Canyon Rhyolite is upper Miocene, based on a whole rock radiometric age of 15.0±1.0 m.y. determined by Armstrong (1970, p. 212-213, sample 112, loc. 9 on pl. 1).

The Palisade Canyon Rhyolite forms a wedge of lava flows in the Humboldt Formation (restricted) in the northwest quarter of the mapped area. The lavas must overlie unconformably the sedimentary rocks of the Humboldt at the north end of Pine Valley, although the actual contact is not visible because the area is almost completely covered by landslide deposits developed where the lavas rest on the softer beds below. The Palisade Canyon is overlain on an irregular surface by the upper part of the Humboldt Formation.

TABLE 10. — *Chemical analyses of rhyolite from the Palisade Canyon Rhyolite (in weight percent).*
[Analyst, Christel L. Parker]

Sample	1	2
Serial No.	D100274	D100275
Field No.	855	856
SiO_2	67.68	71.42
Al_2O_3	13.70	12.94
Fe_2O_3	4.01	.92
FeO	.46	1.12
MgO	.37	.11
CaO	2.57	1.10
Na_2O	2.96	2.59
K_2O	4.52	5.74
H_2O+	.59	2.94
H_2O-	1.03	.30
TiO_2	1.05	.29
P_2O_5	.47	.06
MnO	.03	.03
CO_2	.02	.02
Cl	.01	.04
F	.14	.13
Subtotal	99.61	99.75
Less O	.06	.06
TOTAL	99.55	99.69

SAMPLE DESCRIPTIONS

1. Rhyolite porphyry. Sparse, small, euhedral oligoclase-andesine and quartz in a matrix of devitrified glass.
2. Rhyolite porphyry. Sparse corroded quartz phenocrysts and subordinate subhedral oligoclase-andesine in a glassy matrix.

ANDESITE AND BASALTIC ANDESITE

Andesite and basaltic andesite flows cover widely scattered areas east of the Pinon Range. These flows are the youngest volcanics east of this range in the mapped area and have a minimum thickness of about 305 m (1,000 ft); the top of the unit has been removed by erosion. The flows appear to be essentially horizontal and not to have been much deformed.

The andesite and basaltic andesite are dark gray to black and mostly dense and aphanitic. Some flows are porphyritic and contain small phenocrysts of plagioclase in an aphanitic groundmass. One andesite (table 9, no. 3) from this unit consists of less than 5 percent phenocrysts in a cryptocrystalline and glassy matrix. The phenocrysts are mostly small pyroxenes, sparse altered andesine and hornblende, and very sparse irregular quartz. A basaltic andesite has 12-15 percent small phenocrysts of almost entirely pyroxene set in a trachitic matrix of plagioclase (largely labradorite) microlites.

The andesite and basaltic andesite unit probably is of late Miocene age. In the area of the present report, the flows lie on the Indian Well ash-flow tuff so they must be younger than this Oligocene formation. By more indirect evidence the lavas are younger than the Humboldt Formation (restricted), because sedimentary rocks of that formation east of the Pinon Range do not contain grains or clasts derived from the andesitic unit, which surely would be present if these lavas had been in the area at the time of deposition of the Humboldt. Also, the Humboldt beds are tilted whereas the andesites are essentially horizontal. These lavas may be correlative with a thin basalt flow in the northeast part of the basin of deposition of the CarlinFormation of Regnier (1960, p. 1199).

This andesite and basaltic-andesite unit is unconformable on ash-flow tuff and sedimentary rocks of the Indian Well Formation and on Eocene nonvolcanic rocks. Quaternary silt, sand, and gravel lap up on the flanks of the andesitic lava hills in the northeast part of the area.

BASALT PLUGS

Small basalt plugs that intrude the Humboldt Formation (restricted) are clustered east of Pine Creek near the north end of Pine Valley. The dark plugs crop out prominently in the lighter colored Tertiary sedimentary rocks and are made of phenocrysts of labradorite, somewhat altered olivine, augite, and magnetite set in a glassy groundmass.

The plugs can be no older than late Miocene, and Regnier (1960, p. 1199) suggested that they may be the same age as basalt tuffs and a flow in his Carlin Formation, which in the present report is considered to be upper Miocene. They may be the same age as the younger andesite and basaltic-andesite lavas that crop out east of the Pinon Range.

TERTIARY AND QUATERNARY SYSTEMS

PLIOCENE AND PLEISTOCENE SERIES

HAY RANCH FORMATION

The Hay Ranch Formation, named by Regnier (1960, p. 1199-1203) for the ranch by that name in Pine Valley, covers much of Pine Valley and is a unit of typical basin-fill deposits. His measured section in secs. 16, 20, and 21, T. 28 N., R. 52 E. is designated the type section. Coarse fanglomerates containing boulders as much as 2 m (6 ft) in diameter in places near the mountain fronts interfinger with and grade basinward through sandstone into siltstone, clay, and limestone beds that are lacustrine. Among the best exposed coarse conglomerates are those on the north side of Mill Creek, west of Pine Mountain. Farther south on the east side of the valley, the conglomerates are not as coarse, and in places fine-grained rocks are at or near the mountain front. On the west side of the valley, pink or reddish-brown sandstone containing pebbles and cobbles is common.

Most of the clastic units are tuffaceous, and vitric ash and tuff, commonly altered to zeolites (Regnier, 1960, p. 1201) and to bentonite, are interlayered with the other beds. Data on the alteration to the zeolites heulandite and erionite are given by Regnier (1960, p. 1205-1208).

The most extensive zeolite deposits recognized are in secs. 17, 20, and 29, T. 28 N., R. 52 E. Here, three zeolite-rich beds have been prospected. This area of zeolites has been mapped and studied by Papke (1972, p. 21-23), who reported the most common zeolite associations to be erionite-phillipsite and erionite-clinoptilolite-phillipsite.

The Hay Ranch is the youngest rock unit containing much ashy or tuffaceous material. An ash that is tentatively identified as Pearlette-like ash by R. E. Wilcox and H. A. Powers (Wilcox, 1965, p. 811) occurs on the west side of Evans Flat near the 1,708 m (5,600 ft) altitude in sec. 15, T. 30 N., R. 52 E. At this altitude the ash is probably only slightly more than 61 m (200 ft) below the top of the Hay Ranch Formation. A somewhat similar ash is exposed north of Pony Creek at an altitude of 1,682 m (5,520 ft) just west of the center of sec. 23, T. 28 N., R. 52 E.

A minor amount of limestone occurs in the formation. It is generally massive, hard, and very light colored or white, and, together with very pale green to nearly white clay and siltstone, forms light-colored hills, particularly in the southern part of Pine Valley in the mapped area.

The Hay Ranch Formation must be at least 400 m (1,300 ft) thick as measured from the high and low altitudes of the essentially horizontal beds. It is faulted against Paleozoic rocks along the west side of the Pinon Range, and thus might be expected to have a relatively greater thickness there as material was filling a sinking basin. The Hay Ranch beds are essentially flat lying, however, and there is no evidence of tilted beds along basin margins.

For a more detailed description of the Hay Ranch Formation in Pine Valley, the reader is referred to Regnier (1960, p. 1199-1203).

West of Cedar Ridge in the eastern part of the mapped area, beds of mostly tan and in places light-gray siltstone, sandstone, and conglomerate are included in the Hay Ranch Formation. The conglomerate consists chiefly of angular pieces of limestone, sandstone, and sandy limestone derived from Paleozoic rocks on Cedar Ridge, and contains scattered boulders as much as 0.6 m (2 ft) across; in places the clasts are closely packed and there is little matrix. Some sandstones are crossbedded on a small scale. No vitric ashes like those in Pine Valley were found, but the siltstone and sandstone are tuffaceous in places. The material in these beds was evidently derived from Cedar Ridge and laps onto that ridge.

A middle Pliocene to middle Pleistocene age is established for the Hay Ranch Formation on the evidence of vertebrate fossils (Regnier, 1960, p. 1203). A collection (185) made by us from the NE¼ sec. 9, T. 30 N., R. 52 E. (loc. F-20 on pl. 1) was examined by Edward Lewis, who reported (written commun., 1956) that it contained scanty fragmental material that "might represent a very large *Pliohippus,* but I would hazard the *guess* that it is a horse of the genus *Equus,* no older than Pleistocene."

A fairly definite age may be placed on the Pearlette-like ash beds which occur in the area. Of three Pearlette family ash beds now recognized, the oldest (Type B) has a zircon fission-track age of 1.9±0.1 m.y. and the youngest (Type O) 0.6±0.1 m.y. (Naeser, Izett, and Wilcox, 1973). According to G. A. Izett (written commun., 1976) the pearlette ash bed of Evans Flat is probably a correlative of the Type B ash of Kansas based on its similar chemical composition, phenocryst assemblage, and paleomagnetic direction to other Type B ash beds, and the ash bed exposed near Pony Creek probably correlates with the much younger Type O Pearlette ash beds in its similar chemical composition, phenocryst assemblage, and paleomagnetic direction.

QUATERNARY SYSTEM

PLEISTOCENE AND HOLOCENE SERIES

GRAVEL, SAND, AND SILT

Material included in the gravel, sand, and silt map unit has a wide range in texture, from boulder to clay size, and occurs in various topographic positions, from high benches or pediment remnants to stream levels. A few thin beds of limestone were noted. Exposures are generally poor, and the unit is recognized mainly by loose material on the surface and by the topographic position. These deposits are almost all fluviatile, but some beds must be pond deposits; in places some slope wash or colluvium is included. The materials are unconsolidated to poorly consolidated; layers with calcareous cement tend to be the better consolidated ones. The unit is nontuffaceous, but in areas of poor exposures some tuffaceous beds and even some tuff may be included unintentionally; tuffaceous material or tuff, if observed, are placed in one of the older units.

As expected, most of the material is locally derived and the composition is that of the bedrock upstream. Broad gravel aprons must have spread over relatively wide areas and extended several kilometres from their source areas. For example, gravel remnants now on the west side of Cedar Ridge consist of material derived from Paleozoic rocks now at least 15 km (9 mi) to the west. In a very few places the gravel clasts have not been derived from present upstream terrain. On some of the surfaces, silt covers the coarser deposits over wide areas. This silt may be windblown in part, although no structures or features positively identifying it as windblown were recognized.

No accurate determination of the thickness of the gravel, sand, and silt is possible, because the exposures are poor and the material commonly tends to drip down a slope and obscure the base of the unit. The thickness undoubtedly varies considerably over the mapped area. It must be commonly 6-18 m (20-60 ft) on benches and perhaps 60-90 m (200-300 ft) in some places.

Topographic positions of this gravel, sand, and silt unit are different on the east and west sides of the Pinon Range. On the east side, these deposits mostly cover broad surfaces that slope gently to Dixie Creek and to Huntington Creek. Along many of the creeks in the southeast quarter of the mapped area, the gravel, sand, and silt on broad low benches grade imperceptibly into modern alluvium. Where this alluvium is too narrow to be mapped separately on the scale of the present map, it is included with the gravel, sand, and silt unit.

West of the crest of the Pinon Range, the gravel, sand, and silt mainly cover benches and, commonly, at their highest positions against the Pinon or Cortez Mountains, are 305-365 m (1,000-1,200 ft) above Pine Creek. The highest gravel is on the west side of Pine Mountain at about 488 m (1,600 ft) above Pine Creek.

The gravel, sand, and silt unit is probably entirely of Quaternary age and ranges from sometime in the Pleistocene to the Holocene. The different topographic positions and different amounts of erosion of these deposits indicate that they span some age range of unknown duration. Several bone fragments were found in these beds, but the only identifiable and meaningful one was found in a gravel pit near the boundary between secs. 11 and 14, T. 33 N., R. 56 E., about 10.5 km (6.5 mi) almost due east of the northeast corner of the mapped area. The top of the bench in which the pit is dug is 12-15 m (40-50 ft) above nearby Tenmile Creek, in the Elko East 7½ minute quadrangle. The fossil was collected by Mr.

Jon Scott of Elko, Nev., and studied by Edward Lewis, who reported (written commun., Nov. 19, 1971) that "it is an anterior fragment of a lower molar tooth, probably the third . . . of a mammoth, *Mammuthus (Parelephas) columbi* (Falconer). The age is late Pleistocene, probably Sangamon or Wisconsin." This confirms a Pleistocene age for some of the deposits, and a Holocene age certainly is indicated for the narrow bands of modern alluvium included in this unit.

An ostracod collection from a thin limestone in the SW¼ sec. 11, T. 32 N., R. 54 E. (loc. F-21 on pl. 1) contained the following genera, based on outlines, *Ilocypris?* sp., *Limnocythere* sp. or spp., *Laptocythere?* sp., and *"Candona"* sp. and "does not contradict a Pleistocene age" according to I. G. Sohn (written commun., June 16, 1964).

The gravel, sand, and silt unit is unconformable on all lithologic units on which it rests.

LANDSLIDE DEPOSITS

Landslide deposits cover a relatively small area north of the north end of Pine Valley. The slides occurred where the Palisade Canyon Rhyolite overlies the soft beds of the Humboldt Formation (restricted). The deposits consist of a mixture of very large to small blocks and pieces of the two formations.

At the west end of these deposits, movement has caused a change in the course of Pine Creek that included the formation of a broad curve. It is possible that the slide produced a dam along the present narrow canyon where the slide deposits and the basal unit of the Indian Well Formation are in contact, but no evidence of damming was found upstream. The relations to the alluvium at this narrow place in the valley indicate that at least part of the slide material is as young as the Quaternary alluvium.

ALLUVIUM AND COLLUVIUM

Alluvium and colluvium are lumped as a single unit, because at places in the mountains it is impractical to separate them as one grades imperceptibly into the other.

The strictly alluvial deposits occurring along the streams consist of material that ranges in size from clay to boulders. The texture of the alluvium naturally reflects in part the texture of the older deposits from which it was derived; much of the alluvium along Pine Creek, for example, is fine grained because it was derived from fine-grained beds in the Hay Ranch Formation. The texture also reflects the distance from the source area; alluvium along streams that flow across hard Paleozoic rocks is very coarse near the bedrock. Extremely coarse material is introduced into the alluvial valleys locally and suddenly as a result of very heavy rains in very restricted area. These rains have caused mudflows which transported large boulders into some of the creeks and which have blocked roads temporarily.

Volcanic ash was found in two places in alluvium in the mapped area, although no intense search for it was made. At both localities the alluvium is too narrow to show on the map. A sample from a pocket or lens of ash in the alluvium along the perennial stream at the SE edge of sec. 11, T. 31 N., R. 53 E. (fig. 12) was collected with R. E. Wilcox. Here, the ashy zone is about 1 m (3 ft.) below the top of the alluvium and is about 0.8 m (2.5 ft.) thick. Fairly clean ash in the lower part of the zone grades upward to silty and muddy ash. The ashy zone is white to light gray, in contrast to the dark gray to black of the enclosing alluvium. Thin lenses of ash are also exposed both upstream and downstream for a few tens of metres.

Ash of the collected sample was determined, using petrographic and chemical analysis by R. E. Wilcox, to be from the Mount Mazama eruption (Crater Lake, Oreg.), which occurred about 6,600 years ago (Powers and Wilcox, 1964, p. 1334; Wilcox, 1965, p. 810). Our sample is from the eastern of the two Mazama-ash localities in Nevada shown on the maps in the two reports (Powers and Wilcox, 1964, fig. 2; Wilcox, 1965, fig. 3).

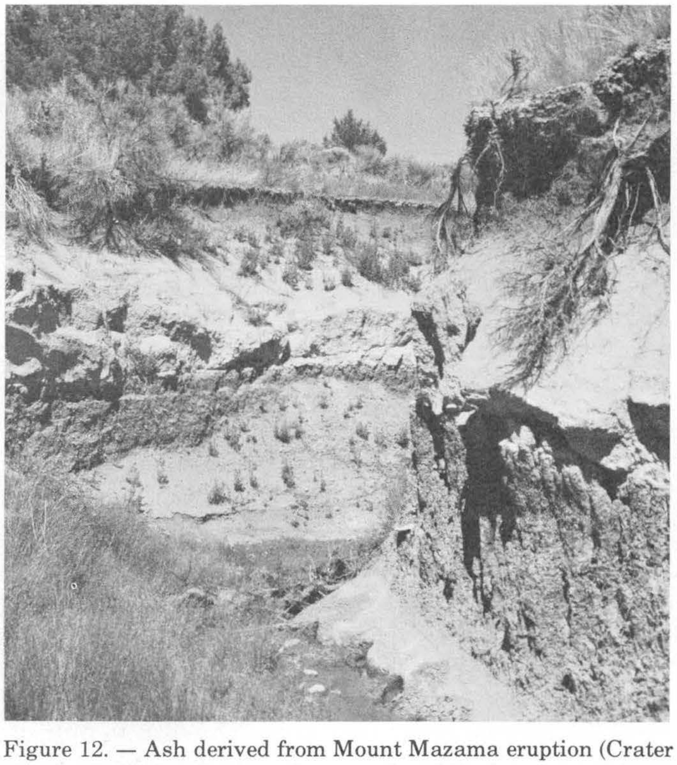

Figure 12. — Ash derived from Mount Mazama eruption (Crater Lake, Oreg.) in alluvium along creek at SE edge of sec. 11, T. 31 N., R. 53 E.

Ash was also noted forming a pocket in alluvium in SE¼ sec. 13, T. 31 N., R. 51 E., along the northeast slope of the Cortez Mountains. Ash from this locality has not been analyzed to determine its likeness to Quaternary ashes of the Western United States, but on the basis of its occurrence in a setting similar to that of the identified Mazama it too is presumed to be Mazama ash.

SUMMARY OF PRINCIPAL EVENTS THAT AFFECTED THE DEVELOPMENT OF POST-PALEOZOIC ROCKS

The types of post-Paleozoic rocks formed in the Carlin-Pinon Range area were influenced by four principal events: (1) Regional uplift that brought an end to marine deposition (probably Triassic); (2) Development of basins from Cretaceous to early Tertiary times; (3) Tertiary volcanism; (4) Block faulting that outlined the basin-and-range topography of essentially the present configuration (Miocene).

Following each event the lithology of the material changed somewhat, or the sizes, shapes, or areas of deposited rock units may have differed to some extent from those of earlier units.

1. *Regional uplift that brought an end to marine deposition.* — Deposition of Paleozoic marine strata was brought to a close by regional uplift, probably during Triassic time. Following this, a thick series of Jurassic sedimentary and volcanic rocks was formed and then folded during latest Jurassic or earliest Cretaceous time (Ketner and Smith, 1974). The west part of the mapped area was evidently prepared for receiving the Jurassic materials by downwarping and must have remained relatively low for a long time or have been downwarped again, because the rocks there were evidently not subjected to extensive erosion.

2. *Development of basins from Cretaceous to early Tertiary times.* — Beginning in late Early Cretaceous time and continuing into early Tertiary time, basins, which were formed in a region of considerable relief in places, became the sites of deposition of lacustrine and fluviatile sediments. No volcanic rocks were emplaced during this period, and no contemporaneously evolved pyroclastic debris was deposited with the sediments. Local uplifts, erosion, and changing of basin positions proceeded until a more subdued topography was developed and a large lake basin became the site of deposition of the sediments that made up the Elko Formation.

3. *Tertiary volcanism.* — The record of Tertiary volcanism in this immediate area began with the deposition of a tuff, dated as 38.6±1.2 m.y. in the sediments of the Elko Formation, and with emplacement of the older intermediate volcanics, which may be as old as 41.4±1.4 m.y. if they are truly correlative with rocks of that age north of the area of the present report. Volcanic activity, as represented by intrusion of dikes and stocks, by lavas, by ash-flow tuffs, and by pyroclastic debris in distinct layers or incorporated in lacustrine and fluviatile sediments, continued from that time into the Pleistocene. Upper Miocene andesite and basaltic andesite are the youngest volcanics in the mapped area and conform to the regional pattern in which intermediate and mafic volcanics are prominent in uppermost Tertiary units. (See, for example, McKee and others, 1970, p. 94.) Youngest Pleistocene and Holocene sediments are essentially ash free, although pockets of ash occur in them very locally.

4. *Block faulting that outlined the basin-and-range topography of essentially the present configuration.* — Block faulting during Miocene time outlined the basins and ranges in essentially their present forms. As a consequence of relative rising of the mountains and sinking of the basins, deposition continued in the basins until through-flowing streams began to drain them sometime during the Quaternary.

AEROMAGNETIC SURVEY

By Don R. Mabey

The normal magnetic field expressed by the evenly spaced northwest-trending magnetic contours in the northeastern part of the mapped area is strongly distorted in a zone that extends from the southeast to the northwest corners of the mapped area, and in two other places near its west edge (pl. 1). The distortions indicate the presence of igneous rocks, and, because the magnetic gradients are relatively steep, they indicate igneous rocks that are on the surface or at shallow depths rather than at great depths in a basement complex. Both high and low magnetic anomalies are present. The magnetic highs reflect rock that either has a normal remanent magnetization or has an induced magnetization greater than the remanent. The magnetic lows are polarizations lows paired with magnetic highs or reflect rocks with strong inverse magnetization.

Two major positive magnetic anomalies coincide with exposures of nonmagnetic Paleozoic sedimentary rocks and, therefore, are related to buried magnetic bodies, probably large intrusives. The most prominent anomaly in the mapped area coincides with exposures of Paleozoic rocks between the Railroad mining district and Pine Mountain (A, pl. 1). A small stock of granitic and quartz-porphyry composition is exposed in the northeast part of the anomaly, and siliceous dikes crop out throughout the area, indicating that the anomaly is caused by a largely buried siliceous intrusive. The large size of this anomaly suggests that the intrusive underlies an area of several square kilometres, and steep magnetic gradients indicate that the intrusive body lies at shallow depth. Another prominent anomaly is only partially shown in the extreme northwest corner of the mapped area (B, pl. 1). This anomaly is centered to the northwest over Paleozoic rocks of the southern Tuscarora Mountains and probably indicates a nearly completely buried intrusive of very large size.

A positive anomaly that probably indicates a completely buried magnetic body is in the southwest corner of the mapped area (C, pl. 1). The magnetic gradient indicates that the body is about 610 m (2,000 ft) below the surface. The axis of this anomaly is on strike with the Modarelli iron mine, which lies about 1.6 km (1 mi) west of the edge of the map. The Modarelli deposit consists in part of magnetite (Muffler, 1964, p. 78), which suggests that the anomaly at C could represent either an extension of the iron deposit or an intrusive perhaps genetically related to the deposit.

An elongate positive anomaly near the west edge of the mapped area (D, pl. 1) and a chain of small anomalies extending northward from it partially coincide with exposures of volcanic and volcaniclastic Jurassic rocks. Possibly these anomalies represent the more magnetic parts of exposed Jurassic rocks, but it is also possible that they represent completely buried intrusive bodies. Anomaly D is discordant with the strike of the exposed Jurassic rocks, and the gentle magnetic gradients suggest a buried source rather than a near-surface one.

The remaining positive anomalies coincide with volcanic and volcaniclastic rocks exposed at the surface or buried under what are probably thin veneers of Quaternary sediments. This association and the near-surface source indicated by the gradients combine to suggest that these volcanic rocks are producing the magnetic anomalies. However, it is possible that some of these anomalies could also reflect intrusives at shallow depths. One prominent anomaly (E, pl. 1) overlies volcanic rocks and a small area of igneous rocks of uncertain, possibly intrusive, origin. (See "Younger Intermediate to Silicic Volcanics.")

Some of the anomalies shown on plate 1 could have economic significance. The two that seem to have the most promise are anomalies A and C. Known mineral deposits in and around the exposed part of the intrusive of anomaly A indicate what might be encountered by drilling other parts. Anomaly C could represent an iron deposit similar to the Modarelli iron deposit in the adjoining Frenchie Creek quadrangle.

MINERAL AND WATER RESOURCES

Mineral and water resources of the Carlin-Pinon Range area are mostly in the post-Paleozoic rocks or are associated with post-Paleozoic geologic events. Some resources not necessarily related to geologic events that young, however, are also included in this brief summary of resources of the mapped area.

Metallic mineral resources, principally silver, copper, and lead, have been produced from the Railroad mining district (Emmons, 1910, p. 89-95; Ketner and Smith, 1963b) west of Bullion, near the central part of the mapped area. Mineralization was associated with intrusion of the Oligocene stock and associated dikes. The ores occur mainly along dikes and vertical chimneys at joint intersections in the Devonian carbonate rocks and are indicated at the surface by brown gossans. Skarn consisting mostly of garnet and diopside has formed near the stock. Spectrographic analyses of fine-grained material from mine dumps indicate anomalous concentrations of zinc, lead, silver, molybdenum, beryllium, yttrium, and lanthanum, particularly in the central part of the district (Ketner and Smith, 1963b, p. B17). The clay mineral halloysite is also abundant in many of the mine dumps in the district. Spectrographic analyses of some samples from the stock indicate more than average amounts of copper and molybdenum in two samples, of yttrium in one, and of silver in one (Ketner and Smith, 1963, p. B13).

Suggestions for prospecting in the Railroad mining district were made by us in 1963 (Ketner and Smith, 1963b). We hope prospecting will lead in time to discovery of additional ore bodies or extensions of old ones. Since publication of those suggestions, geologic and aeromagnetic mapping have indicated that the Railroad district occupies only a corner of a much larger area affected by igneous activity and possibly mineralized at depth. This larger area is a 4.8x4.8 km (3x3 mi) square extending slightly northwest and south from the Railroad district and overlying magnetic anomaly A on plate 1. Within the square, Mississippian rocks have been converted from sandstone and shale to quartzite and argillite, and the Silurian and Devonian rocks, especially the Devonian rocks at Pine Mountain, have been altered from limestone and dolomite to marble in places and have been somewhat mineralized with some barite and copper minerals. The concentration of igneous dikes within the square is much greater than in any other area in the Pinon Range and nearby area. Aeromagnetic data indicate that the square is underlain by a large igneous body at shallow depth.

In the Railroad district, carbonate rocks near the intrusive contact are strongly mineralized. Similar conditions quite possibly exist at shallow depth under Pine Mountain and directly south of the Railroad district under the high ridge of the Pinon Range, and therefore these areas are considered to be relatively favorable ones for prospect drilling. Other favorable areas, less favorable than those mentioned above, are the central part of the square, which is underlain by a thick sequence of siliceous rocks, and the area directly south of Pine Mountain, where rocks similar to those of Pine Mountain can be inferred to lie beneath part of the alluvial cover of Evans Flat. Although aeromagnetic data indicate the presence of intrusive rock below both of these areas, it is uncertain whether a contact zone between the intrusive and carbonate rocks is at a reasonably shallow depth.

The Safford mining district (Emmons, 1910, p. 110-112; Lincoln, 1923, p. 96), which is mainly just west of the mapped area near Safford Canyon and the Humboldt River, has been the site of production of mainly silver from veins in the Frenchie Creek Rhyolite and iron in the same formation. Mining of iron near Barth, about 1.6 km (1 mi.) west of the Carlin-Pinon Range area on the Southern Pacific, has continued in recent years, but other mines in the district have been inactive for many years.

Iron ore has been produced from the Modarelli mine (Shawe and others, 1962, p. 97-100) in sec. 30, T. 29 N., R. 51 E., about 1.6 km (1 mi.) west of the area of the present report. Here the ore of martite and less magnetite replaced lava of the Frenchie Creek Rhyolite (Muffler, 1964, p. 78). No similar deposit is recognized in the Frenchie Creek in the Carlin-Pinon Range area, but an aeromagnetic high near Little Pole Creek, (C, plate 1) has a northwest trend that strikes toward the Modarelli deposit and does indicate a buried magnetic deposit that may be similar to the Modarelli one. As interpreted by D. R. Mabey (p. 44), this anomaly indicates a body that is about 610 m (2,000 ft) below the surface.

Shales and siltstones have been examined for vanadium in much of this general region. The principal prospecting has been in the very fine grained clastic rocks of the lower Paleozoic siliceous or eugeosynclinal rock assemblages that were moved into the mapped area on the Roberts Mountains thrust. Bulldozing and drilling have been carried on in chiefly carbonaceous siltstone of the Devonian Woodruff Formation in sec. 34, T. 32 N., R. 52 E., and in a shale and chert sequence in the Ordovician Vinini Formation south of the Humboldt River, about 4.8 km (3 mi) east-southeast of Carlin. Semiquantitative spectrographic analyses of average unmineralized samples of Paleozoic siliceous mudstone from the mapped area gave the following percentages of vanadium (Ketner and Smith, 1963, p. B46): Ordovician, 0.01 to 0.02 percent in 6 samples; Silurian, 0.015 percent in one sample; Devonian, 0.005 to 0.07 percent in 4 samples; and Mississippian, 0.015 to 0.07 percent in 7 samples.

A few localities of anomalous radioactivity have been reported from the Carlin-Pinon Range area. The locations of these anomalous areas (Garside, 1973, p. 45-46) and our brief statements on the stratigraphic positions of the radioactive materials follow:

1. Deerhead group, sec. 24, T. 32 N., R. 52 E. — anomalous radioactivity in a silicified breccia zone. This group is in the Devonian Woodruff Formation. A small sample of brownish-gray chert with a few patches of yellow-green material on it was collected by us in that area; the sample contained 0.019 percent eU (C. Angelo, analyst, 1955).
2. Black Kettle group, W½ sec. 34, T. 32 N., R. 52 E. — anomalous radioactivity in siltstone. This group, too, is in the Devonian Woodruff Formation, at the same locality where bulldozing and drilling have been carried on in vanadium prospecting.
3. KEF No. 2 claim, sec. 24(?) or 19, T. 30 N., R. 52 E. — very weak radioactivity with clays, gypsum, and weak iron-staining in Tertiary lake beds. This claim must be in section 19 and in the upper Tertiary and lower Quaternary Hay Ranch Formation, although we did not see the actual locality.
4. Asphaltite prospect — U^3O^8 reported as 0.097 percent (Vanderburg, 1938, p. 57). The sample analyzed must have been from what is now a small exposure of solid bituminous material on the north side of Smith Creek in the NE¼ sec. 1, T. 29 N., R. 52 E. The bituminous material occurs in a narrow veinlike body and as fracture fillings and cement in shale and sandstone in the Mississippian undivided Diamond Peak Formation and Chainman Shale.

Although these areas of minor radioactive anomalies seem to be of no economic significance at present, they do indicate that radioactive solutions have moved through the rocks in this area.

Nonmetallic resources in the Carlin-Pinon Range area include a variety of materials. Gravel, which has been used mainly for highway construction, is available from the Holocene gravel, sand, and silt unit and the alluvium unit, and from gravel beds in the Humboldt Formation (restricted). Where the units are not well exposed, test pits are required to establish the presence of adequate gravel deposits. Rock to be crushed for use as railroad ballast on the Southern Pacific tracks has been quarried for many years from the Palisade Canyon Rhyolite on the northwest side of the Humboldt River in Palisade Canyon. Ample quantities of this rock are obviously still available.

Patches and pockets of perlite or perlitic rock also occur in the Palisade Canyon Rhyolite, but no specific tests have been made on the quality or quantity of the perlite.

Barite occurs sparingly in association with small areas of silicified Paleozoic rocks, along some faults, and in one recognized vein. The barite vein that is in the Devonian Devils Gate Limestone east of the center of sec. 7, T. 28 N., R. 53 E. was mined in the late 1950's. Barite along a fault was prospected in sec. 2, T. 29 N., R. 53 E. Barium occurs in above-normal quantities in some samples from the stock west of Bullion and in samples of fine-grained dump material from the Railroad mining district (Ketner and Smith, 1963b, p. B12, B13, and B18), although no commercial deposits of barite have been found there.

Several nonmetallic rock resources are found in the Tertiary sedimentary basin deposits. These include diatomite, which makes up part of the Humboldt Formation (restricted) in the north end of Pine Valley and north and northwest of the Humboldt River, where the thickest diatomite beds noted were 6-7 m (20-23 ft). Some diatomite was mined from the Humboldt Formation in secs. 18 and 19, T. 33 N., R. 53 E. Bedded volcanic ash, particularly in the Humboldt Formation (restricted), is available for any future use but has not been prospected in the area of this report. The zeolite mineral erionite occurs in the Hay Ranch Formation, principally in secs. 17, 20, and 29, T. 28 N., R. 52 E. Three zeolite-rich beds have been prospected in this locality, which also has been mapped and studied by Papke (1972, p. 21-23).

A number of geologic studies in northeast Nevada were made by oil companies following the discovery of petroleum in 1954 by the Shell Oil Co. in Railroad Valley (Smith, 1960), about 193 km (120 mi) southeast of the area of the present report. Production in the Shell discovery well was from Tertiary volcanic rocks, which overlie the Sheep Pass Formation of Winfrey (1960); oil was also found in the Sheep Pass in another well. This formation and the Eocene(?) and Eocene nonvolcanic sequence and Eocene part of the Elko Formation in the Carlin-Pinon Range area are similar lithologically in that neither contains volcanic rocks or volcanic detritus of contemporary origin and that they both consist largely of lacustrine deposits and grade upward from generally coarse clastic rocks near the base to mostly siltstone and shale near the top. Each sequence also contains limestone. Oligocene(?) ash-flow tuffs are above the Sheep Pass Formation and Oligocene ash-flow tuffs of the Indian Well Formation overlie the lower Tertiary nonvolcanic sequence in parts of the Carlin-Pinon Range area. Some oil residue occurs in the Sheep Pass Formation, but none was recognized in the nonvolcanic sequence in the area of the present report. However, no oil shale like that in the Elko Formation is reported from the Sheep Pass.

A difficulty in searching for petroleum in the lower Tertiary nonvolcanic rock sequence is in predicting where and how much of these beds may remain under the cover of younger materials. The Tertiary structural and erosional history indicates that at a number of different times the rocks were tilted, uplifted, and eroded in different amounts in different parts of the basins, with the result that no exact positions or thicknesses of buried units can be predicted. Also, no traps are obvious in the surface exposures of the Tertiary units, but stratigraphic traps could easily have been developed along both erosional and angular unconformities between units, and perhaps in lenticular clastic units.

The Elko Formation, which contains beds of oil shale, occurs in scattered exposures over the east half of the Carlin-Pinon Range area. Analyses of two samples of the shale indicate that thin parts of it, at least, have high oil content. (See table 5.) Predicting the quantity of oil shale in the area presents the same difficulty as predicting where and how much of the lower Tertiary non-volcanic rocks may be buried. On the basis of surface exposures, it is not possible to determine how much of the shale may remain under the cover of younger units.

The possibility that petroleum might have been derived from oil shale as a result of some natural conditions such as deep burial and accompanying increased temperature is hardly a matter for discussion in this report. If it is possible, however, conceivably the Elko oil shale could have been a petroleum source.

Possible petroleum source rocks of Paleozoic age are present in the Carlin-Pinon Range area, but the existence of suitable structural or stratigraphic traps in the Paleozoic units is most uncertain. Many units that contain organic material in varying degrees are possible source rocks. Siliceous mudstones from Ordovician to Mississippian age, for example, commonly contain small amounts of organic debris and amorphous carbon. Siltstone and shale in the Devonian Woodruff Formation are quite carbonaceous in some beds, and veinlets of black vitreous hydrocarbon occur in a few thin limestones in this formation. The Woodruff, however, is allochthonous in the area of this report, and the total rock volume is relatively small. The Roberts Mountains Formation of Devonian age in this area contains as much as 4.2

percent organic carbon (analyst, I. C. Frost, 1971), but this formation, too, is allochthonous and of low total volume in the mapped area, and so could not have been an important source rock locally. Probably the most likely source rock is the shale of the Mississippian Chainman Shale. The shale is dark and quite carbonaceous in some beds, but no specific measurements of organic carbon content were made for this report. A solid bitumen occurs in a narrow veinlike body, as fracture fillings, and as some cement in Mississippian shale on Smith Creek on the west side of the Pinon Range. Mississippian shales are widespread in the mapped area and are close to sandstone and conglomerate of the Diamond Peak Formation, which could conceivably serve as reservoir rocks.

Among the carbonate rocks, the upper member of the Devonian Nevada Formation contains much brown dolomite that has a highly petroliferous odor when freshly broken.

The presence of suitable traps for petroleum accumulation is made uncertain by the complex structure of the Paleozoic rocks. The combination of thrust and normal faults leaves only small parts of the exposed Paleozoic rocks that are not fractured in some form. Whether these extensive fractures served as conduits for movement of petroleum, or perhaps formed traps, or whether they destroyed any potential traps is not evident now. The structure of most of the Devonian and older chiefly carbonate rocks that probably underlie much of the area and form the lower plate beneath the Roberts Mountains thrust is not known with any certainty.

Water resources in this area certainly appear to be ample to support ranching as the continuing chief economic activity. Perennial streams, Humboldt River, Pine Creek, and Huntington Creek, afford water for irrigation of hay crops, although wells have been used to supplement the water supply during dry years. Water studies by Eakin (1961) indicated that substantial ground water is stored in the valley fill of Pine Valley and that conditions are favorable for obtaining irrigation water from wells. The Huntington Creek valley area, which includes Dixie Flats and White Flats east of the Pinon Range, also has ample ground water according to Rush and Everett (1966).

There are many springs in the Paleozoic and Mesozoic rocks in the mountains, and fewer ones are scattered in the younger rocks in the basins. Some are large enough to be the sources of perennial streams and thus to supply water to the axial valley streams. Others are little more than seeps that may dry completely during years of below-normal precipitation. A number of the springs, and particularly some of the larger ones, are along faults, but many have no obvious structural control. The widely scattered springs supply water for the cattle. The large springs in the valley west of Carlin are the water supply for Carlin and were the source of water for the railroad during the days of steam locomotives.

Identified thermal springs are widespread in Nevada (Waring, 1965, fig. 8, p. 18), and certain areas of these must be considered as potential sites for geothermal-energy development. According to Waring (1965, p. 4), a thermal spring in the United States is one "whose temperature is at least 15° F. above the mean annual temperature of the air" at its locality. On this basis three springs in the Carlin-Pinon Range area are known to qualify as thermal. Two of these are along the frontal fault on the west side of the Pinon Range, (1) the Hot Springs in sec. 12, T. 28 N., R. 52 E. have a reported temperature of 84° F., and (2) two springs in the SE¼ sec. 24, T. 28 N., R. 52 E. have reported temperatures of 95° F., and 102° F. (Both spring areas are recorded in Waring, 1965, p. 35.) The third spring or group of springs is in alluvium just east of the Humboldt River and west of the road in the south part of sec. 33, T. 33 N., R. 52 E., where it is close enough to the river to be diluted by water from it. In the summer of 1957 we measured a temperature of 150° F., in the bubbling pool that was farthest from the river. Much further testing would be required to determine whether any one of these spring areas might be suitable for geothermal energy development.

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