AN ABSTRACT OF THE THESIS OF

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Title: PALEOZOIC GEOLOGY OF THE DOBBIN SUMMIT - CLEAR CREEK AREA, MONITOR RANGE, NYE COUNTY, NEVADA

Abstract approved: Redacted for Privacy

J. G. Johnson

Paleozoic limestones, dolomites, quartz arenites, and other clastic rocks were mapped in the vicinity of Dobbin Summit and Clear Creek in the central Monitor Range. Sedimentary rock units present in this area represent the shallow-shelf eastern assemblage and basin and also the basin-slope facies of the traditional limestone-clastic assemblage.

The four oldest, Ordovician, units were deposited in shallow shelf environments. The Lower Ordovician Goodwin Formation is composed of about 1200 feet of calcareous shales and thin-bedded limestones. The overlying Antelope Valley Limestone is about 500 feet thick and consists of wackestones, packstones, and rare algal grainstones. The Copenhagen Formation (135 feet thick) is the highest regressive deposit of sandstone, siltstone, and limestone below the transgressive Eureka Quartzite. The Eureka is a quartz

arenite 181 feet thick, with an intercalated shallow marine dolomite member.

The transition from shallow to deep water conditions can be seen in the change from algal boundstones to laminated lime mudstones in the Hanson Creek Formation (190 feet thick). The superjacent Roberts Mountains Formation (285 feet thick) is composed of lime mudstones and allodapic beds deposited in basinal, deep water conditions. During earliest Devonian time, the facies boundary between eastern dolomites and limestone-clastic transitional facies was situated within the map area. The Lone Mountain Dolomite (510 feet thick) is representative of the eastern facies. The limestone-clastic facies are represented by basinal lime mudstones and allodapic skeletal beds of the Windmill Limestone (170 feet thick), the Rabbit Hill Limestone (315 feet thick) and the Denay Limestone (150 feet thick). The upper plate of the Roberts Mountains thrust interrupts the stratigraphic sequence of the area, and an allochthonous unit of western assemblage cherts and fine grained clastics (Ordovician Vinini Formation) overlies Middle Devonian rocks.

The Mississippian rocks of the area are part of the "overlap assemblage" and overlie older facies boundaries in central Nevada. The Webb Equivalent is a siliceous argillite 400 feet thick and the Camp Creek Equivalent (350 feet thick) is a sequence of distal and proximal turbidites. Both were deposited in the elongate basin which paralleled the rising Antler orogenic highland to the west of the map area during early Mississippian time. The filling of the basin is indicated by the change, within the Diamond Peak-Chainman Equivalent rocks (750 feet thick), from fine-grained limestones and thin sandstones to thick chert-pebble and limestone conglomerates. Source for the detrital chert was western assemblage rocks, then eroding from the Antler Highland, and eastern shelf carbonates. The final episode of the Paleozoic evident in the area was uplift, erosion, and tectonism followed by deposition of shallow-water fossiliferous Pennsylvanian rocks (150 feet thick in incomplete section), to form an angular unconformity.

The extreme thinness of uppermost Ordovician through Middle Devonian strata may be due to a shift from the eastern shelf depositional regime to a slope and basinal regime. The stratigraphic sequence of these rocks in the map area closely resembles that of Antelope Valley, 10 miles to the north. Mississippian overlap assemblage rocks more closely match those of the Carlin-Pinyon Range area 100 miles to the north.

Paleozoic Geology of the Dobbin Summit - Clear Creek Area, Monitor Range, Nye County, Nevada

by

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Claudia Dubois handled preparations of conodont samples. Kurt Klaffke acted as field assistant for a week and helped with fossil collecting. Barbara Priest drafted the stratigraphic columns and part of the geologic map.

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Last, but not least, I dedicate this thesis to Michael Wise - husband, field assistant, paleontologist, photographer, biostratigrapher, typist, and provider of moral (and physical) support - without whose efforts this project would never have gotten on the ground.

Figure 1. Mississippian and Pennsylvanian rocks of Clear Creek Canyon.

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INTRODUCTION

Purpose

The thesis project was chosen in order to provide more detailed information about the Paleozoic lithofacies of the Dobbin Summit-Clear Creek area in conjunction with a study of its biofacies by Michael T. Wise. It was hoped that a parallel project such as this would contribute to both the regional lithostratigraphy and biostratigraphy of the central Monitor Range, for which little published information is available. Such information is important for reconstructing depositional environments of the Paleozoic outer shelf and slope between eastern shallow water environments and western deep water, basinal environments. The detailed map of the area provides a necessary reference point for discussion of these environments.

Location and Accessibility

The map area is situated in roughly the western quarter of the Stargo Creek 7-1/2-minute quadrangle, the eastern third of the Dobbin Summit 7-1/2-minute quadrangle, and the northeastern quarter of the Danville 7-1/2-minute quadrangle, in northern Nye County, Nevada. The area occupies 30 square miles in the north central Monitor Range, and is approximately 76 miles southwest of Eureka and 90 miles northeast of Tonopah (Figures 2 and 3). The area is entirely within the Toiyabe National Forest. Dirt and gravel roads, maintained by the Bureau of Land Management, provide access to the area. A few jeep trails within the area are used seasonally by hunters and ranchers with 4-wheel drive vehicles.

Previous Work

Previous work in the map area has been concentrated on the Ordovician strata at Clear Creek Canyon. Maps of the east half of the canyon were made by J. M. Greene (unpublished A. M. thesis, 1953) and R. M. Christensen (unpublished M. S. thesis, 1957). Lowell (1966) studied the Lower and Middle Ordovician stratigraphy and depositional environments below the Eureka Quartzite. Webb (1958) measured the Middle Ordovician section at Clear Creek as part of a regional correlation of eastern Nevada and western Utah Ordovician strata.

The greater part of the map area is less well known than Clear Creek Canyon. Reconnaissance mapping on a 1 to 250,000 scale was done by Kleinhampl and Ziony (1967). Fossil collections were made from the Roberts Mountains, Windmill, and Rabbit Hill formations

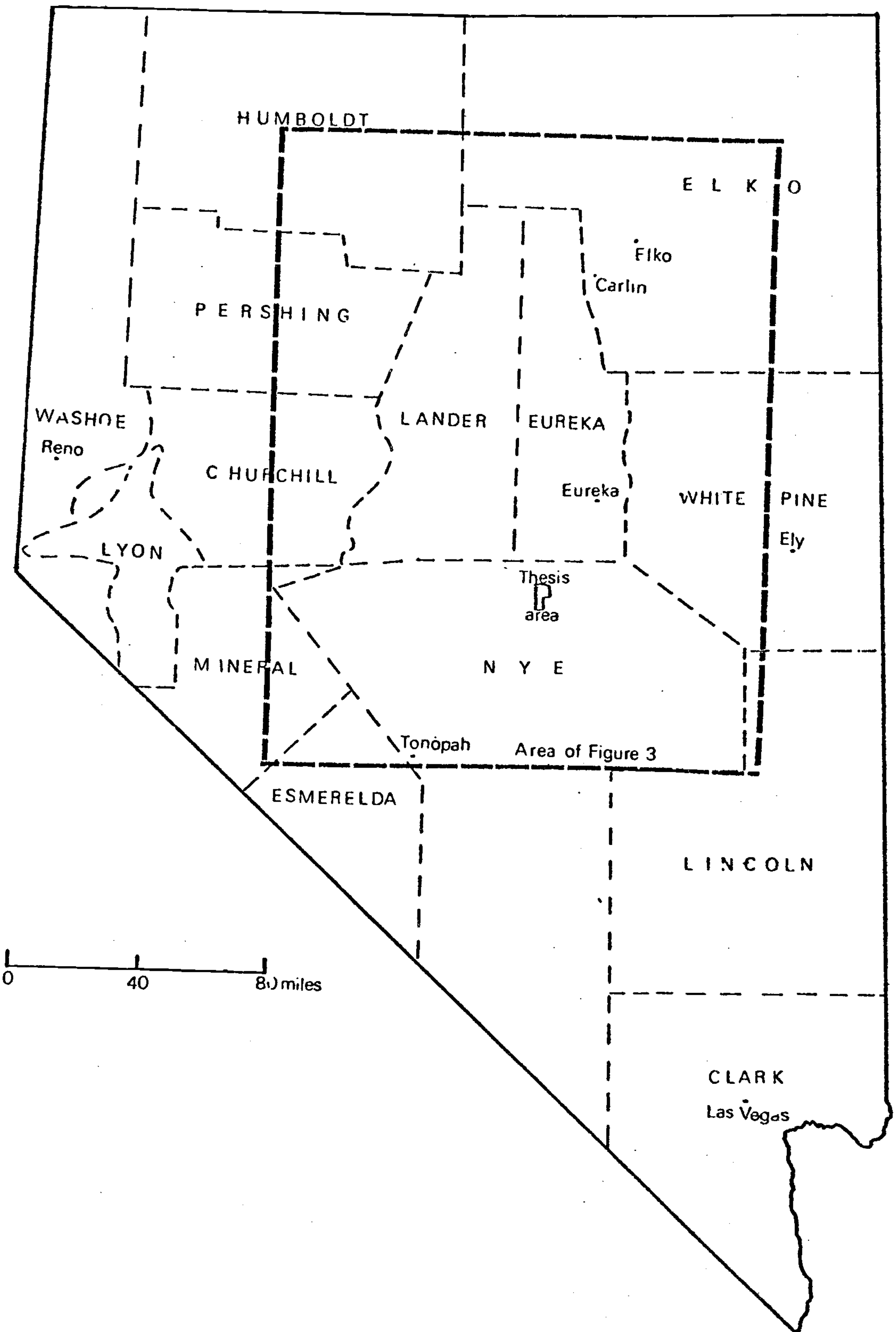


Figure 2. Index map of Nevada, showing counties and area of Figure 3.

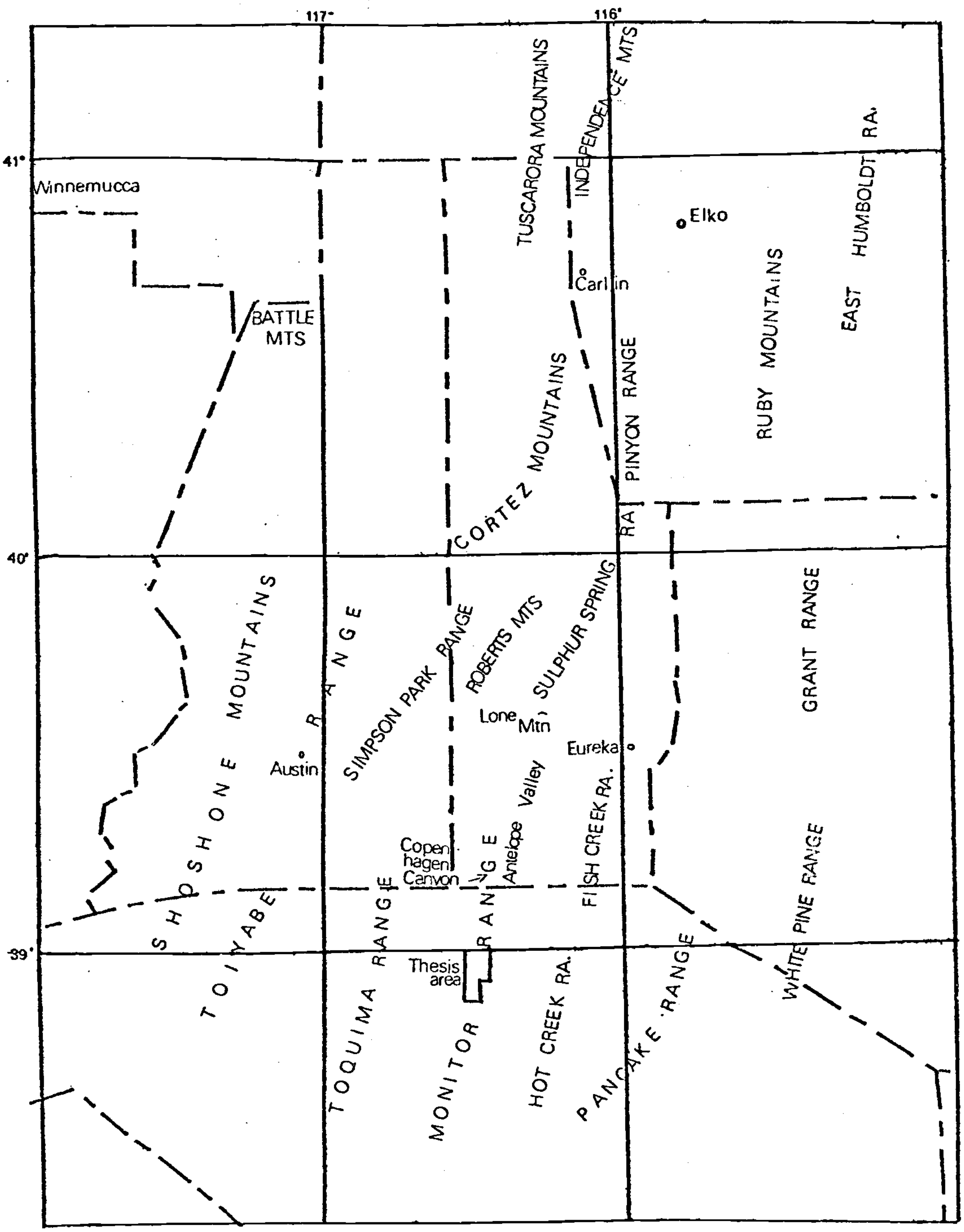


Figure 3. Index map of central Nevada, showing thesis area.

AGE		ROCK UNIT		THICKNESS (feet)
Tertiary		Volcanic Rocks		Several thousand feet
Pennsylvanian		Pennsylvanian Rocks		150 - incomplete
Mississippian		Diamond Peak - Chainman Equivalent		750
		Camp Creek Equivalent		350
		Webb Equivalent		400
Devonian			Vinini Fm.	
	150 ft	Denay Ls.		
	315 ft	Rabbit Hill Ls	Lone Mountain Dolomite	510
	170 ft	Windmill Ls		
Silurian		Roberts Mountains Fm		285
Ordovician		Hanson Creek Fm		190
		Eureka Quartzite		181
		Copenhagen Fm		135
		Antelope Valley Ls		500 - incomplete
		Goodwin Ls		1200 - incomplete

Figure 4. Summary stratigraphic section for the Dobbin Summit - Clear Creek area.

by F. G. Poole and A. J. Boucot (unpublished fossil lists by Johnson and Boucot). No other work has been done on the Devonian and younger rocks in the area.

Geologic Setting

During the early and middle Paleozoic, the present Great Basin was part of the Cordilleran Geosyncline, which extended from the Canadian Arctic south to California. In terms of plate tectonics, the region is believed to have been at the continental margin and separated from an offshore island arc system (with underlying, east-dipping subduction zone) by a series of marginal basins (Burchfiel and Davis, 1972; Churkin, 1974). Three subparallel facies belts paralleling the continental margin were present in central Nevada from middle Cambrian through Devonian time (Roberts and others, 1958). These are an eastern shelf carbonate assemblage, a western deep-water siliceous and volcanic assemblage, and a transitional limestone-clastic belt which separated eastern and western belts. The transitional zone, which was about 50 miles wide, contains many characteristics of slope deposition (Winterer and Murphy, 1960; Smith and Ketner, 1975). It was located roughly near the longitude of the Roberts Mountains in Silurian-Devonian time, but was 25 to 75 miles farther west during Cambrian and Ordovician time (Johnson and Potter, 1975).

During late Late Devonian or earliest Mississippian time, deposition of these facies was brought to an end by the emergence of a north-northeast-trending orogenic highland in west-central Nevada. This highland and its associated deformation and large scale eastward thrusting of western assemblage rocks over eastern carbonates, were part of the Antler orogeny. Maximum displacement occurred along the Roberts Mountains thrust, where allochthonous rocks were moved relatively as far east as the Sulphur Spring and Pinyon Ranges. Sedimentary rocks deposited after the Roberts Mountains thrust and during Antler deformation are termed the overlap assemblage, as those rocks depositionally overlap the earlier boundaries between the eastern, transitional, and western assemblages (Roberts and others, 1958; Poole, 1974). The overlap rocks range from early Mississippian through middle Pennsylvanian, and generally grade upward from fine-grained clastic rocks to coarse conglomerates and limestones (Smith and Ketner, 1974). The increase in grain size upward reflects the derivation of detritus from the rising Antler Highland to the west.

The thesis area is located in the eastern assemblage facies belt during the early Ordovician, and at the eastern edge of the transitional belt during the late Ordovician through Middle Devonian. The Goodwin Limestone, Antelope Valley Limestone, Copenhagen Formation, Eureka Quartzite, and lower Hanson Creek Formation represent eastern assemblage facies, shallow water deposits. A deepening trend is seen in the upper Hansen Creek rocks. The boundary between the transitional belt and the eastern assemblage is present within the thesis area during the Silurian and earliest Devonian time. The Lone Mountain Dolomite represents the eastern facies, and the transitional basin and basin-slope facies are present as the Roberts Mountains Formation, the Windmill Limestone, the Rabbit Hill Limestone, and the Denay Limestone. The Webb, Camp Creek, and Diamond Peak-Chainman Equivalents, and the Pennsylvanian rocks represent post-thrust overlap assemblage rocks. The uppermost of the Mississippian rocks contain chert conglomerates and breccias which probably were derived from the Antler Highland. Figure 4 is a summary stratigraphic section of the thesis area.

Methods

Twelve weeks were spent in the field during the summers of 1974 and 1975 by the writer and Michael Wise, University of Oregon, who aided with mapping and biostratigraphy. Field work involved measuring and describing sections, and mapping Paleozoic units. Samples were collected for lithologic and paleontologic study. Lithologic studies included preparation and analysis of thin sections; etched, stained, and oiled slabs; and acetate peels of stained slabs. Aerial photographs were used as an aid in determining the structure of the area.

Fossil collections were made for brachiopods, corals, and conodonts in measured sections. Thirty pound samples were taken for silicified brachiopods, which were etched free of enclosing carbonate by immersion in concentrated hydrochloric acid. The brachiopods were sorted and identified by Michael Wise and by J. G. Johnson of O.S.U. A Pennsylvanian brachiopod collection was identified by John L. Carter of the Carnegie Museum, Pittsburgh. Conodont samples of at least 10 pounds were processed by the writer and Claudia DuBois. The carbonate matrix of each sample was dissolved in dilute formic acid, the insoluble residue separated in heavy liquid, and the conodonts handpicked from the heavy fraction. Age determinations were made by Gilbert Klapper, University of Iowa. Tabulate coral samples were identified by Richard A. Flory, California State University at Chico. Gastropods were identified by Dave Rohr and tentaculites by S. Eldridge, both of O.S.U.

Terminology

The carbonate classification of Dunham (1962) was used for hand sample and thin section description. The term "micrite" is retained from Folk's (1959) earlier carbonate classification and is used as part of some sample descriptions. Bed thicknesses are the following: thin-bedded, 1 to 4 inches; medium bedded, 4 to 18 inches; thick bedded, over 18 inches.

Rock colors were determined by comparison with the Rock Color Chart of the Geological Society of America (1963).

The term 'allodapic' is from Meischner's (1964) definition of allochthonous calcareous sand carrying shoal-water faunas that is interbedded with pelitic basinal sediment.

TOPOGRAPHY, GEOMORPHOLOGY, AND VEGETATION

The map area is centered on the east flank of the Monitor Range, midway along the length of the range. The northern two-thirds of the area is on the crest of the range, and the southern third is a single hill to the east of the crest. The area of lowest relief is part of the Quaternary bajada in Little Fish Lake Valley in the east part of the map area. Most of the area is typified by west to north-west-trending valleys separated by steep-sided hills. The largest of the valleys are associated with four springs; Clear Creek Canyon, Tulle Canyon, East Dobbin Creek Valley, and Stargo Spring Valley. Smaller valleys are either perpendicular with or parallel to the general trend of the range, roughly NNE. Maximum relief in the area is 3025 feet, from a maximum of 10385 feet (south part of area) to a minimum of 7360 (east Clear Creek Canyon).

Normal faults and rock type are the dominant geologic controls of landforms. Major valleys have been eroded along the WNW-trending faults and minor valleys and saddles between hills are seen along many NNE-trending faults. Rock types affect the topography in general by their relative ages and resistance to weathering. Younger volcanic flows form the highest resistant ridges along the range crest, and silicified chert regolith, dolomite, and quartzite are dominant ridge and cliff-formers. Generally less resistant are the limestones, argillite, and shales, and basal Tertiary volcanics. An exception to the rule is the south side of Clear Creek Canyon, where Mississippian and Pennsylvanian limestones compose a steep 1100-foot cliff.

Vegetation is the type commonly found in the ranges throughout the Great Basin. The area is part of the Toiyabe National Forest, and is well-covered with pinyon pine, limber pine, juniper, mountain mahogany, and locally, willow, aspen, or bristlecone pine. Sage and rabbit brush predominate on the valley floors and in treeless areas. There is little or no relationship between rock type and vegetation type, except that cacti are often associated with otherwise bare rock outcrops. Elevation and availability of water are the chief factors affecting vegetation type in a particular area. For example, bristlecone pine is found only on the upper 50 feet of hill 10385, and aspen groves are associated with springs and seeps.

GOODWIN FORMATION

General Statement

The oldest exposed unit is the Lower Ordovician Goodwin Limestone, lowest member of the Pogonip Group. The formation crops out in the eastern portion of Clear Creek Canyon and forms the lower southeast slopes of hill 10385 in the south part of the map area.

Though the name "Goodwin" had been proposed for the lowermost 1500 feet of the Pogonip Group by Walcott in 1923, the type section of the formation was designated by Nolan and others (1956) at Goodwin Canyon, 1-1/2 miles southwest of Eureka. There it is composed of 900 to 1100 feet of well-bedded, fairly massive, fine-grained limestone, with occasional platy limestones and chert occurring low in the section. Merriam (1963) subdivided 1800 feet of the Goodwin Formation at Ninemile Canyon, Antelope Valley, into three units. Member A is a lower dark gray carbonaceous shale with *Caryocaris* sp., 150 feet thick; Member B is a thinly-bedded, platy weathering limestone with little chert, 700 feet thick; Member C is 900 feet of thicker bedded limestone with abundant light-colored chert. Lowell (1965) did not recognize member A at Clear Creek, but did describe a lower and an upper unit that correspond to

Merriam's members B and C, respectively.

Lower Member

Thin lime mudstones and well-bedded platy calcareous shales compose the lower member of the Goodwin Formation in the map area. The unit forms low, discontinuous cliffs on either side of Clear Creek. Outcrops have a massive, highly laminated appearance and a distinctive overall brown to orange-brown weathering color. The calcareous shales are medium dark gray on fresh surfaces, well-bedded, with even partings at 3-5 mm intervals that often contain 2-3 mm pyrite cubes. Medium gray lime mudstones occur as 1 to 2 cm thick interbeds and gradually increase in thickness and number upward. In thin section these beds are micrite recrystallized to microspar, with about 5% pellets. The shales contain alternating bands of clay and micrite with coarser sparry calcite up to 1 mm, and rare quartz silt grains. Primary structures evident mainly in talus are ripple marks, sole markings such as load casts, groove casts, and small asymmetrical pits occurring on otherwise smooth bedding surfaces.

Burrowings 1/4 inch wide were found in the same horizon as a trilobite, *Pseudokainella* sp.. Lowell (1965) collected a Lower Ordovician trilobite fauna from the lower member at Clear Creek which included *P. lata* Kobayashi, *Hypermecapsis* sp., and *Parabolinella* sp.

Upper Member

The upper unit of the Goodwin Formation is a medium gray lime mudstone with yellow weathering argillaceous laminations. Bedding is wavy to irregular, with partings at 2-18 inch intervals. Light gray chert is abundant as lenses and discontinuous stringers 1/2-1 inch thick that weather yellow-brown. In thin section the unit is a finely crystalline carbonate recrystallized from micrite, with 15% limonite stained clay and 5% pellets. No fossils were found in the upper member in the map area. The age of the upper unit is probably Early Ordovician, as the preceding rocks are Early Ordovician in age and the superjacent Antelope Valley Limestone has been dated at early Middle Ordovician.

Thickness and Contacts

The lower member of the Goodwin Formation is approximately 600 feet thick and the upper member is about 650 feet thick, as measured from aerial photographs. The contact between lower and upper members is gradational over 50 feet, from brown, well-bedded shale with little gray lime mudstone to entirely gray mudstone with minor clay. The upper contact of the Goodwin Formation is obscured by faulting and talus, but appears conformable and in abrupt contrast with the overlying Antelope Valley formation.

Depositional Environment

The fine-grained, argillaceous limestones lacking any significant quartz sand in both units of the Goodwin Formation suggest a quiet water, normal marine setting some distance from a major terrigenous source. The lower unit, contains current indicators such as ripple marks, flute marks, and load casts, and was probably part of a local flow regime with general downslope movement. No direct evidence exists of turbidite activity, which may be obscured by the fine-grained character of the sediment. Lowell (1965) found sedimentary boundinage, intraformational conglomerates, contorted laminae, and sole markings, all of which he considered evidence of slope deposition. Since the map area was in a transitional zone between the eastern carbonate facies and deeper-water siliceous rocks to the west, slope depositional features would be likely to occur there. No indicators of flowage have been found in the upper unit, which has much less clay and no fossils. Conditions were still quiet, as the limestone is still micritic and has the same appearance in thin section as the thin lime mudstones of the lower unit.

Regional Significance

The Goodwin Limestone is part of the eastern assemblage even though it does exhibit slope characteristics in the map area. Johnson and Potter (1975) believe that the Ordovician transitional belt may have existed as far west as the Toquima Range. The Stoneberger Shale of the Toquima Range (Kay and Crawford, 1964) is of the same age and stratigraphic position as the Goodwin. Locally the Goodwin Limestone is of comparable thickness in the map area, the type area, and in Antelope Valley to the north.

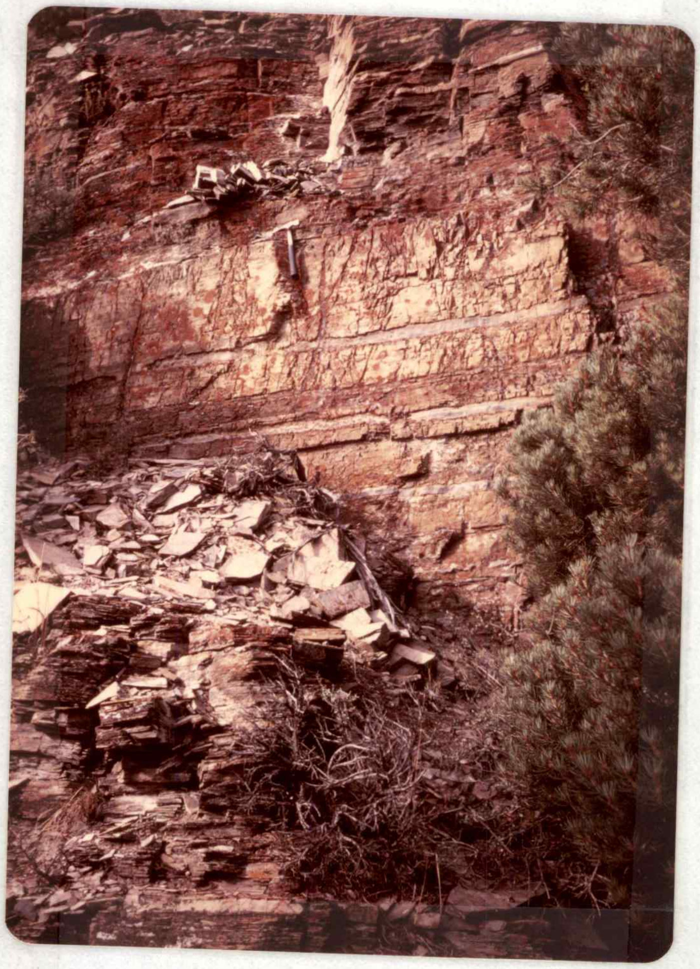


Figure 5. Lower member, Goodwin Formation. Thicker beds are lime wackestone.

ANTELOPE VALLEY FORMATION

General Statement

Overlying the Goodwin Formation is the youngest formation of the Pogonip Group, the Antelope Valley Limestone. It is generally a medium bluish gray, fine-grained limestone with medium to thick bedding. The Ninemile Formation, a dark gray shaly impure limestone with a distinctive lower Ordovician fauna, is missing in the map area, although it exists between the Goodwin Formation and the Antelope Valley Formation ten miles to the north at Antelope Valley. Merriam (1963) designated the type section at Antelope Valley a mile south of Ninemile Canyon, where the limestone reaches at least 1200 feet in thickness. At nearby Martin Ridge, Merriam measured 1000 feet of the formation and subdivided it into three faunal units, which correspond fairly well to lithologic divisions. The lower 75 feet, the *Orthidiella* zone, is a thin-bedded argillaceous limestone, weathering tan to yellow, and contains the earliest ostracodes and bryozoans found in the Pogonip Group. Next highest is the *Palliseria* zone, 650 feet of thick-bedded, nonargillaceous cliff-forming limestone, with abundant silicified gastropods, notably *Palliseria longwelli* and *Maclurites* sp. Other significant common fossils include nautiloids, *Receptaculites* spp. and *Girvanella*-type algal nodules.

The highest unit is the *Anomalorthis* zone, 350 feet thick, a thin-bedded flaggy, brown-weathering limestone with small high-spired gastropods, orthoid brachiopods, stony bryozoans, and algal nodules.

Location and Thickness

Best exposures of the Antelope Valley Limestone are on hill 9666, hill 9423, and east of hill 8218 in the north part of the map area. Irregular cliffs of the formation also crop out on either side of Clear Creek and on the southeastern slope of hill 10385 in the south. Thickness of the formation was estimated at 475 feet at Clear Creek ("Crocker Ranch") by Webb (1956). This agrees with the writer's estimate of 470 feet for the total thickness of exposures in the north part of the area.

Middle Unit

The thin, argillaceous limestones of the *Orthidiella* zone are not seen in the map area, nor is the fauna associated with the zone found above the contact with the Goodwin Formation. The lower beds of the Antelope Valley Formation correspond lithologically and faunally to the *Palliseria* zone. These are medium bluish-gray lime wackestone and minor grainstone which weather medium light gray and brownish gray. Limonite-stained clay occurs in a very few thin interbeds, and appears in thin section concentrated along stylolites.

Bedding averages 1/2 to 1 foot thick, but some 3- to 6-foot rectangular benches occur just below the contact with the upper unit on hill 9666. Talus is coarse and blocky, and weathered surfaces are pitted, with fine sand grains forming resistant points. In thin section the rock is a wackestone with 5% pellets and 2 to 3% fine quartz sand and silt grains. Fossils include gastropod, ostracod, and crinoid debris. Diagenetic effects are neomorphic recrystallization of micrite to microspar, pore-filling spar in some shell material, and crustal overgrowth on most allochems. Partially silicified gastropods were identified by D. M. Rohr as Palliseria longwelli and Maclurites sp. These fossils belong to the Palliseria zone fauna. Beds containing ovoid algal nodules 3 to 10 mm across the long axis are common throughout the unit (Figure 6). Petrographically, the nodules are composed of cores of silty micrite, pellets, or fossil fragments that are semi-coated with a fine intertwining tubular mass typical of the Girvanella form of blue-green alga (J. H. Johnson, 1961). Little of the algal coating is entirely concentric except on the largest and smallest nodules; most cores are 1/2 to 3/4 coated with a single layer. The largest nodules appear abraded and broken, and rounded fragments of algae 0.2 to 1.0 mm in diameter form 10% of one thin section. A few nodules have been burrowed and the burrows filled in with lime mud and silt.

Upper Unit

Platy silty lime grainstones with argillaceous partings at 3 to 12-inch intervals and blocky medium-gray dolomites compose the upper *Anomalorthis* zone lithology. The limestone is medium gray and weathers brown and gray; fossils and siltier layers weather orange-brown and yellowish-gray. Small round brachiopods, high-spired gastropods, horn corals, stony bryozoans and crinoid debris form as much as 40% of the allochems in the rock. Burrowings 5 mm in diameter along argillaceous partings in the upper 50 feet of the unit, have tentatively been identified as the Ichnogenus *Chondrites*. Algal nodules are present in the upper unit, but are less common than in the middle unit (Figure 7). They are more concentrically laminated and less broken than in the lower rocks. The dolomite, in thin section, is a totally recrystallized equivalent of the lime grainstone, containing ghosts of fossil fragments and algal nodules. At Clear Creek, planar cross-stratification was seen in a single 3 inch thick silty limestone bed.

Depositional Environment

The highly fossiliferous lime wackestones of the *Palliseria* zone were developed in a fairly shallow, normal marine environment. The presence of an abundant shelly fauna, and especially algal nodules, which are restricted to the photic zone, points to shallow water conditions. The area was adjacent to, but not directly within, a zone of agitation near wave base. Relatively quiet water is indicated by a lack of sparry calcite, the presence of pellets, and many unbroken fossils. This evidence is not conclusive, as the gastropods which dominate the fauna are thick shelled and would have survived some battering by waves. The water depth may have been at the lower limit of the photic zone, as seen in the incomplete development of concentricity in the algal nodules. Light-dependent algal growth occurs on the top side only of a core particle in place, and the particle must be overturned repeatedly by wave action in order for all surfaces to acquire algal lamination. In the lower unit few nodules show complete concentricity, and algal coatings are thin and poorly developed with one or two layers on only the upper side of the core. Rounded fragments of algae are much smaller in size than the nodules and would have been easily broken off and transported from an area nearer to wave base. Less micrite, winnowed fragmental fossils, no pellets, and a complete development of concentric laminations on algal nodules indicate shallower, more agitated conditions during deposition of the upper Anomalorthis unit. Dolomitization of part of the unit is secondary post-deposition replacement, as the original textures visible in the dolomites are nearly identical to those of the interbedded lime grainstones.

Regional Significance

The transitional belt remained west of the map area during Antelope Valley time. The Antelope Valley Formation is present in the Toquimas, Antelope Valley, and in the Hot Creek area. The Toquima Range rocks are dated to be younger than those of Antelope Valley, and are partially equivalent to the overlying Copenhagen Formation (Ethington and Schumacher, 1969).

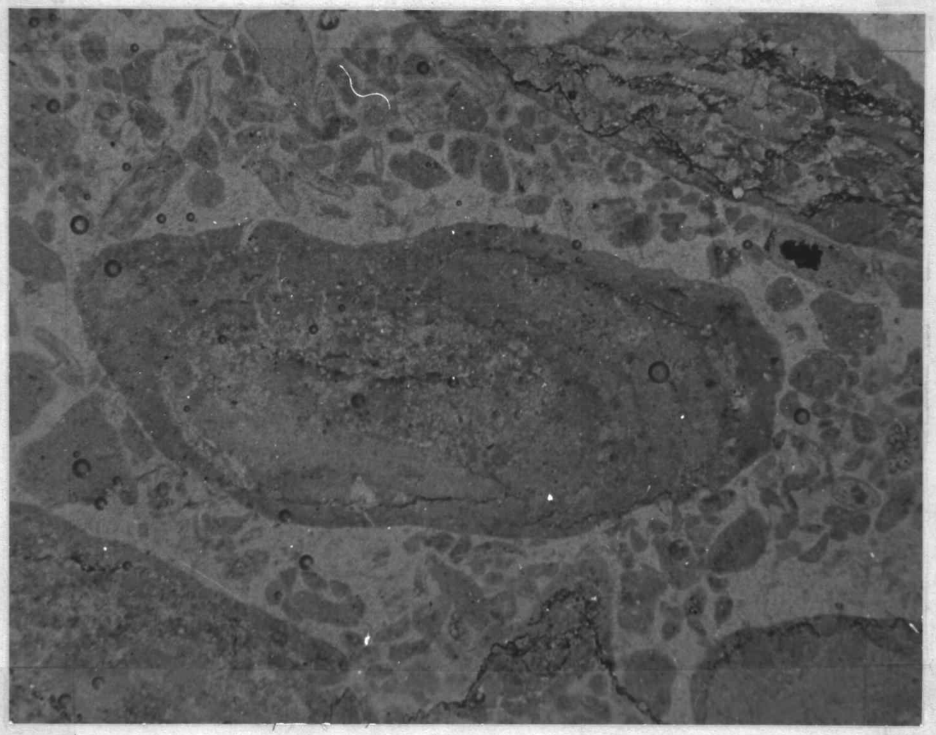


Figure 6. Micrite core and non-concentric lamination of algal nodule from lower part of the Antelope Valley Formation.

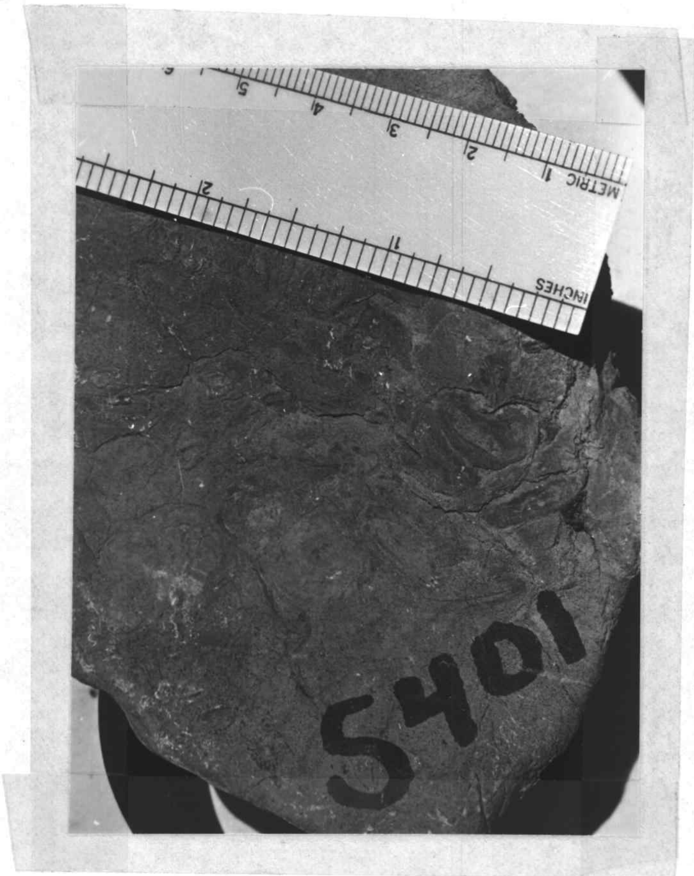


Figure 7. Concentrically laminated algal nodules from upper part of the Antelope Valley Formation.

COPENHAGEN FORMATION

General Statement

The Copenhagen Formation occupies an interval between the Antelope Valley Limestone and the Eureka Quartzite that is areally restricted to a narrow region extending from Lone Mountain south to the Hot Creek Range. The formation is thickest at the type section in Antelope Valley on Martin Ridge, a mile south of Copenhagen Canyon (Nolan and others, 1956) where it has been variously estimated at 350 feet (Merriam, 1963) to 600 feet thick (Webb, 1956). Both Merriam and Webb recognized three lithologic divisions of the Copenhagen Formation at Antelope Valley, as follows: a basal, fine-grained calcite cemented sandstone with Endoceras sp., a middle intercalated member of brown-weathering calcareous siltstones, argillites, and well-bedded lime wackestones and packstones; and an upper, dark gray argillite member with interbedded silty limestones. The two upper divisions contain a large and varied fauna including brachiopods, gastropods, graptoliters, and crinoids.

Greene (1953) measured about 135 feet of the Copenhagen Formation at Clear Creek, of which the lower 30 feet are a sandstone member containing Endoceras sp. Lowell (1965) collected a brachiopod fauna from the upper 105 feet of the formation at Clear Creek, corresponding to that of the upper two members at the type section.

Location and Contacts

The Copenhagen Formation is poorly exposed on the north side of Clear Creek, where it forms recessive slopes below cliffs of the overlying Eureka Quartzite. Best outcrops of the Copenhagen Formation are on the uppermost 120 feet of hill 9423 and on the small ridge on the south side of hill 9666, in the northern part of the map area.

The lower contact of the Copenhagen Formation at hill 9423 is conformable with the underlying Antelope Valley Limestone and is marked by an abrupt change from medium gray, platy limestone to fine-grained, brown-weathering sandstone. The upper contact is not exposed, due to faulting and cover by large float blocks of Eureka Quartzite.

Lower Member

The lowest 30 feet of the Copenhagen Formation are a very fine-grained, calcite cemented quartz arenite, which is light gray on fresh surfaces and weathers light brown to medium brownish gray. Bedding is poorly defined, with smooth partings every 4 to 6 feet and breaking off as smooth rectangular blocky talus. Fine parallel laminations are common at irregular intervals, some of which are disturbed by vertical burrowings (Figure 8). In thin section this unit is composed of 95% angular to sub-rounded, well sorted quartz grains 0.1 mm in diameter. Some silica overgrowth occurs at grain contacts. The cement is composed of microspar calcite and limonite, and thin concentrations of cement between layers of quartz grains give the laminated appearance to the sandstone. Minor constituents include a few grains of zircon, apatite, and brown phelochroic tourmaline, probably schorl. Vertical burrowings have been filled in with slightly more cement (up to 15%) than most of the rock, and contain about 5% chert.

Intercalated Member

The basal sandstone grades upward into intercalated sandstones similar to the lowest unit, silty lime wackestones and grainstones, and calcareous siltstones (Figure 9). The limestone is medium gray, weathering medium light gray and forms irregular flaggy 1/2 to 2-inch interbeds. The brown-weathering calcareous siltstones and very fine-grained sandstones have smooth partings at 4-inch to 2-foot intervals. The entire interval has been extensively burrowed both vertically and horizontally, so that little lamination is preserved. Most burrowings appear to be of the *Chondrites* variety of branching network, although single vertical burrows are common. Some siltstone layers show small-scale cross laminations 1 cm across. The limestones are medium gray, highly fossiliferous grainstones and minor wackestones. Fossils include small brachiopods, high-spired gastropods, bryozoans, small horn corals, and crinoid debris. In thin section the grainstones are composed of 0.5 to 2 mm fossil fragments, mostly crinoid plates and columnals, with micrite cement. The rock shows neomorphic recrystallization of micrite to microspar, and pore filling spar replacement of original shell material. The siltstones and fine sandstones are petrographically quartz arenites similar to the basal sandstone, but with an increase of up to 35% calcite cement. Occasional molds of shell fragments have been filled in by micrite and silt, and other fossils have been replaced by pore- filling spar.

Depositional Environment

The fine-grained terrigenous character of the sediments, large fauna of normal marine shelly fossils, and extensive vertical as well as horizontal burrowing of the detrital layers are all indicative of a shallow water, shelf environment.

Regional Significance

Deposition of the Copenhagen Formation is restricted to the edge of the continental shelf during the last phase of regression (Webb, 1958) of the Sauk sequence of Sloss (1963). Eastern equivalents are missing except for a shaly lower Eureka unit seen in the Grant Range (Webb, 1958). Ethington and Schumacher (1969) correlated the Copenhagen Formation with the Caesar Canyon Limestone in the Toquima Range.

Figure 8. Basal laminated sandstone, Copenhagen Formation, Vertical burrowings in upper third of hand specimen.

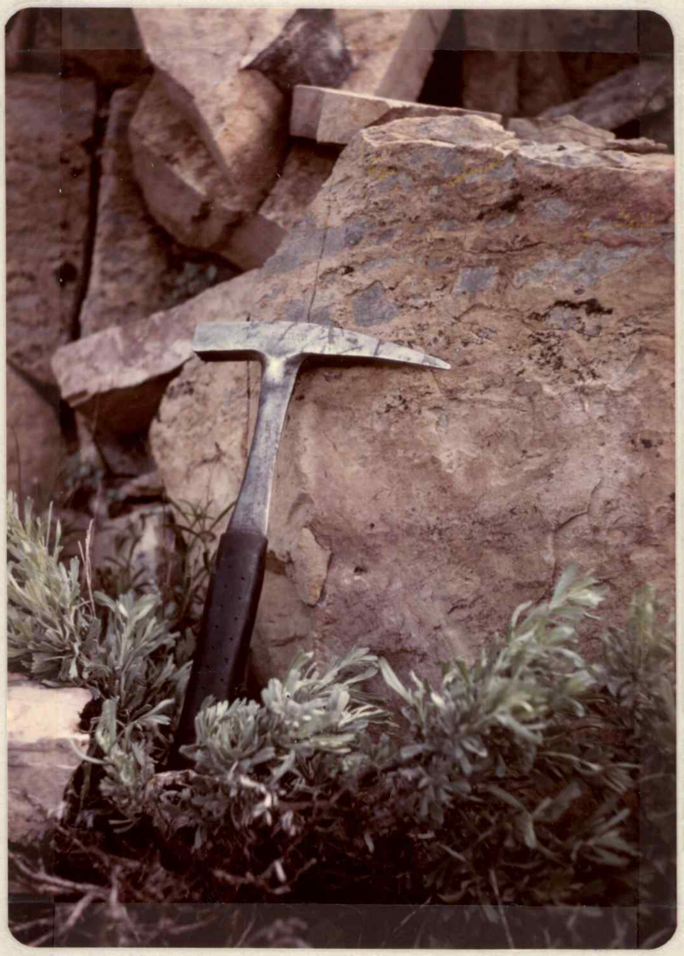


Figure 9. Brown-weathering siltstone with gray limestone lenses, Copenhagen Formation intercalated member.

EUREKA QUARTZITE

General Statement

The Eureka Quartzite is one of the most widespread and recognizable Paleozoic formations in the Great Basin. Hague (1883) named the formation for Eureka, Nevada, but did not establish a section due to the discontinuous and highly faulted nature of the nearby exposures. Kirk (1933) designated the type section on the west side of Lone Mountain, twenty miles west of Eureka. Three major divisions of the Eureka Quartzite were defined there by Webb (1958): a lower discolored quartzite member; a middle thinly bedded to massive white quartzite member with a cross-laminated central interval; and an upper gray quartzite member. The formation averages from 200 to 300 feet in thickness, and is 181 feet thick at Lone Mountain.

Location and Thickness

The Eureka Quartzite is prominently exposed in cliffs on the eastern margin of the map area, and a complete exposure crops out just north of Clear Creek. Webb (1958, p. 2345-2346) measured 181 feet of the quartzite at Clear Creek (locality referred to as "Crocker Ranch") and described the sequence as follows: 45 feet of the lower discolored member, banded red and gray; middle white quartzite member 55 feet thick, mottled gray at the base and cross-laminated; 20 feet of intercalated dark quartzite and dark dolomites, not present at the type section at Antelope Valley; and 63 feet of the upper gray quartzite member. Only the upper dark dolomite member and the upper gray quartzite are exposed at Miniature Grand Canyon.

Lithology

The quartz arenites of the Eureka Quartzite are massive, silica-cemented medium to fine grained sandstones with no significant change in grain size throughout the unit. They are white to medium gray on fresh surfaces. Limonite or hematite are the principal impurities that discolor the lower and upper members. Composition is 98% well-rounded and well-sorted quartz grains and silica over-growths, about 10% of which show wavy extinction. None of the grains appear frosted in thin section. No porosity was observed below the upper 2 feet of the formation, where the arenite becomes dark grey, less well cemented, and individual grains are easily discerned in hand specimen. The dolomite member is a medium dark-gray, fine grained rock with 3 to 4 foot bedding. The upper 2 to 3 feet is slightly sandy, but otherwise the rock is similar to the basal Hanson Creek Formation.

Contacts

The lower contact of the Eureka is obscured by talus, but appears to be abrupt with the silty argillites of the Copenhagen Formation. The upper contact is well exposed at Miniature Grand Canyon. As mentioned previously, the upper gray quartzite member is more loosely cemented in the upper 2 feet of the formation, but does not contain dolomite. Vertical and horizontal tubular burrowings 3 mm in diameter were observed in the upper surface of the unit (Figure 10). The burrowings are darker gray than the quartz arenite and are infilled with slightly smaller quartz grains than the surrounding rock. Between the burrowed zone of the upper quartzite and the calcite-veined dolomite of the overlying Hanson Creek Formation is a 2 to 3 inch thick transitional zone of very dark gray quartz-sandy dolomite (Figure 11). Grain size remains the same, but the rock contains about 15 to 20% dolomite cement, in very small (0.02 mm) rhombs.

Depositional Environment

The well-sorted, supermature quartz sands of the Eureka Quartzite, together with the cross-stratification of the middle member, suggest deposition in a beach-bar-lagoon environment (Webb, 1958). The dolomite member represents an eastward incursion of marine conditions as seen in few other localities. It is probably primary in origin as shown by its finely crystalline structure. The upper gray quartzite of the Eureka is more loosely cemented than the lower members, and contains horizontal as well as vertical burrowings. Horizontal burrowings do not appear at very shallow depths, and it is likely that the uppermost beds were deposited in a deeper environment than the rest of the formation, except for the dolomitic beds.

The source for the sand was postulated by Webb (1958, p. 32) to be basal Cambrian and latest Pre-Cambrian quartz sandstones from the Rocky Mountain area, and the lower Ordovician Swan Peak Quartzite of western Utah. This would account for the supermaturity of the sandstone.

Regional Significance

The Eureka Quartzite does not appear in the Toquima Range, indicating that the boundary between eastern and transitional facies had moved eastward during the Middle Ordovician. The Eureka Quartzite is 220 feet thick at Antelope Valley and 181 feet thick at Lone Mountain, both of which were near the facies boundary at the same longitude as the map area.

Figure 10. Darker burrowings in uppermost Eureka Quartzite.

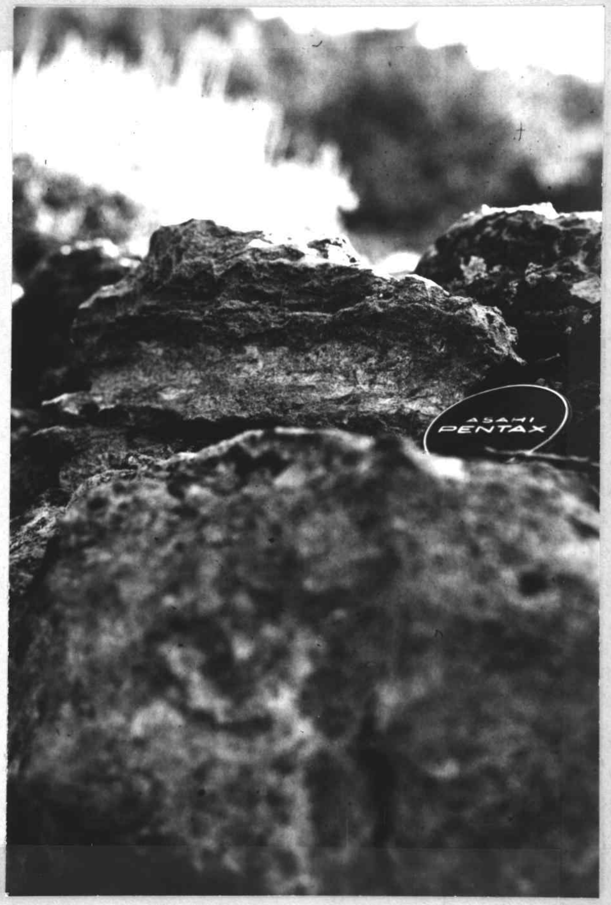


Figure 11. Dolomitic quartz arenite, transitional between the Eureka Quartzite and the Hanson Creek Formation.

HANSON CREEK FORMATION

General Description

The Hanson Creek Formation was defined by Merriam (1940, p. 10) to include upper Ordovician rocks between the Eureka Quartzite and the Silurian Roberts Mountains Formation in Eureka County. The type locality is at Pete Hanson Creek in the Roberts Mountains, where it comprises 60 feet of dark gray to light gray limestone. Lithology of the formation varies considerably, changing from a wholly dolomitic eastern facies to dolomitic limestone and limestone westward, and ranging in thickness from 300 to 800 feet (Roberts and others, 1967). The upper part has an inconspicuous but persistent quartz sand-bearing zone a few inches to 20 feet thick, the base of which is 15 to 68 feet below the top of the formation. This zone has yielded conodonts dating that part of the formation as early Silurian (Mullins and Poole, 1972).

In the map area the Hanson Creek crops out above the Eureka Quartzite north of Clear Creek and at Miniature Grand Canyon. It is much thinner here than at localities to the north, measured at 190 feet, and is composed entirely of dolomite and calcareous dolomite.

Lithology

The lower 30 feet of the Hanson Creek Formation at the Dobbin Summit section are medium light gray fine grained dolomite, weathered light gray with a brown network of partially silicified calcite veinlets. Bedding is poor, with partings at 1- to 2-foot intervals that form low blocky benches above the Eureka. No fossils are evident in hand specimen, but a few sparry areas seen in thin section might be remnants of crinoid debris. In thin section the rock is a dolomitized pelletal lime wackestone. Cement is a fine crystalline carbonate with few zoned dolomite rhombs. Pellets are visible as micritic 0.1 mm ghosts having some organic content and form 30% of the rock. Minor constituents totaling 3% include clay and chert concentrated along numerous tiny fractures and silt-sized quartz grains.

From 30 to 75 feet above the base of the formation the same color and bedding characteristics continue from the lower beds. Interbedded with the fine grained dolomite are 2-foot beds of limy dolomite boundstone which contain intraclasts, oolites, and irregular laminations not parallel to bedding planes, characteristic of algal binding of sediment (Figure 12). Intraclasts are 1/2 to 4 inches in diameter, elongate, angular to subrounded and are ripups of dolomite mudstone, oolite grainstone, and dolomitized carbonate breccia.

Oolites in discontinuous beds up to 1 cm thick and sparry calcite-cemented grainstone are a uniform 0.5 mm in diameter and show well-preserved concentric structure. Crystalline carbonate breccia clasts contain about 30% oolites, but these are badly recrystallized and vary from 0.5 to 2 mm in diameter. Also present in the breccia are about 10% medium to fine quartz sand grains and larger clasts of oolite grainstone and dolomite mudstone in a sparry cement stained yellow by limonite. The intraclasts are bound into irregular, wavy layers of dolomitized micrite, oolite fragments, and hematite-stained clay that are subparallel and wrapped around the top and sides of other laminated buildups. The laminations are typical of sediments trapped by algal mats on an irregular substrate, and are commonly found in the lower beds of the Hanson Creek Formation (John Dunham, oral communication). A few small horn corals and crinoid debris are found in the interval, but no diagnostic megafossils are present.

At 75 feet above the base of the formation, the lithology changes to a dark gray, fine grained dolomite with discontinuous silty laminae at 1/4 to 1/2 inch intervals. The unit weathers medium gray and brownish gray with orange brown to red laminations. Petrographically, the dolomite is a recrystallized pelletal wackestone similar to the basal unit. Pellets form 15% of the rock and average 0.5 mm in diameter. A few silicified horn corals were found in the upper beds. Laminations are parallel to the bedding plane and are concentrations of silt-sized quartz grains with hematite and limonite. The dark laminated beds are poorly exposed, low blocky outcrops forming the upper 115 feet of the formation. The 25 feet at the top of the unit is silty dolomite talus, but no definite quartz sand-bearing interval was found to correspond with that recognized by Mullins and Poole (1972) in Eureka County. According to their data, the sand-bearing zone thins southward from 17 feet at Lone Mountain to a few inches at Copenhagen Canyon; the zone may be too thin to recognize in the map area.

Contacts and Thickness

The lower contact of the Hanson Creek Formation is conformable with the Eureka Quartzite and is considered to be at the abrupt change from the transitional dark sandy dolomite to lighter colored micritic dolomite. The upper contact of the Hanson Creek is difficult to recognize in the map area. At the type locality, and in many places in Eureka County, the base of the overlying Roberts Mountains Formation is marked by the appearance of dark bedded cherts or cherty dolomites and limestones. No such boundary appears in the map area. Instead, thick beds of lime-cemented dolomite breccia containing silicified corals are interbedded with dolomites similar to the upper lithology of the Hanson Creek

Formation. The base of the first 10 foot breccia bed, which contains fossils of early Silurian age, is here assigned as the contact between the Hanson Creek and the Roberts Mountains Formation. At Dobbin Summit, this contact was measured at 190 feet above the top of the Eureka quartzite, and at the section on hill 10385, measured at 205 feet above the Eureka contact. The lower number is probably the actual thickness of the Hanson Creek Formation, as the section at hill 10385 has numerous faults of minor displacement affecting accurate measurement.

Depositional Environment

Fine-grained pelletal wackestones of the basal 30 feet point to a quiet water environment shortly after the trangressive Eureka quartz arenite was deposited. The depth of the area is not certain until the appearance of the interbedded algal boundstones. The lack of sparry calcite with algal-bound intraclasts and oolites indicates a shallow lagoonal, subtidal environment that occasionally received fragmental material from nearby high-energy sources. Oolites formed in a zone of warm water and high agitation, were later transported by high tides or storms into the lagoonal basin and were cemented along with ripups of grainstone and packstone. The clasts formed a solid irregular substrate on which algal stromatolites could establish themselves. A recent example of this type of algal stromatolite formation was studied by Logan (1961) at Shark Bay, western Australia. Deeper quiet water conditions prevailed during deposition of the rest of the formation, as evidenced by laminated, slightly pelletal lime muds. Dolomitization was secondary rather than primary; dolomite rhombs are zoned, and oolites and small fossil fragments are identifiable although often badly recrystallized. Graptolites were the only whole fossils found in the laminated muds, suggesting a deeper, possibly basinal, environment.

Regional Significance

The western equivalent of the Hanson Creek Formation in the Toquima Range is the Upper Ordovician, deeper water, Gatecliff Formation (Mullins and Poole, 1972). The eastern equivalents of the Hanson Creek Formation are the Fish Haven and Ely Springs Dolomites, which are widespread throughout eastern Nevada and western Utah. The Hanson Creek Formation in the map area is exceptionally thin (190 feet) when compared to nearby Antelope Valley (350 feet) and the Hot Creek Range (300 feet). This reflects its relatively close proximity to the transitional facies boundary, although Johnson and Potter (1975) postulate that the boundary must have been about 35 miles farther west in the Toiyabe Range.

Figure 12. Algal boundstone with oolitic grainstone intraclasts, lower Hanson Creek Formation.

ROBERTS MOUNTAINS FORMATION

General Statement

The Silurian and lowest Devonian rocks of the Dobbin Summit section comprise interbedded dark platy dolomites with fossiliferous thick limestone-dolomite breccias and thin graded lime wackestones that total 260 feet in thickness. A similar sequence of well-bedded lighter-colored carbonates 280 feet thick occurs at the same stratigraphic horizon at the summit 10385 section, but has been entirely dolomitized. Both lithologies are characteristic of the Roberts Mountains Formation at Antelope Valley (Merriam, 1963) and elsewhere in Eureka County.

The Roberts Mountains Formation was named by Merriam (1940) who established the type section at Pete Hanson Creek in the Roberts Mountains. The formation was shown to be a deeper-water facies of the lower part of the Lone Mountain Dolomite by Winterer and Murphy (1960), who mapped the facies boundary near the type section and grouped the Roberts Mountains lithologies there into three main types: 1) fine-grained rocks, ranging from almost pure limestone to silt and clay shale, often graptolitic; 2) medium-grained calcareous rocks, highly fossiliferous in shelly fauna, and 3) limestone breccias (mudstones and packstones containing large angular limestone clasts).

Dobbin Summit Section

The Roberts Mountains Formation of the Dobbin Summit measured sections D and E is an intercalated sequence of the three lithologic types mentioned above. The lower to middle two-thirds of the section are dominated by the fine-grained laminated rocks, and the basal 20 feet and upper third of the formation are composed of thick lime breccias and the medium-grained rocks, which are packstones and wackestones.

The fine grained rocks are thinly laminated argillaceous silty dolomites, dark to medium brownish gray on fresh surfaces which weather pinkish-gray, brown, yellowish gray, and have red to orange-brown laminations (Figure 14). The laminations are prominent nearly parallel at 5 to 2. 5 mm intervals, and are 0. 1 to 0. 5 mm-thick concentrations of clay, silt, organic material, and limonite that compose 15% of the rock. The dolomite is composed of 10 to 50 micron crystals of microspar, with rare zoned rhombs seen in the large sized crystals. Bedding is 1/2 to 4 inches with smooth partings, but is rarely seen. The dolomite is a slope former with platy and blocky talus in 4 to 5 inch pieces. The laminations gradually become less and less prominent, and the rock more calcareous, higher in the section. The only fossils found are graptolites, which are rare and found only in talus. The fine-grained rocks compose about 60% of the entire formation.

The medium-grained rocks include 6 inch graded lime wackestones and packstones in the basal 50 feet and dark gray pelletal and crinoidal packstones in the upper third of the formation. The lower lime packstones consist of a non-laminated, silty lime mud matrix, similar in composition to the fine-grained lithology, with 10% fossil fragments and up to 25% irregular clasts of pelletal bioclastic packstone, lime mudstone, and fine-grained dolomite. The beds are coarsely graded, with clastic material and fossils decreasing in size from 2 cm at the base to 1 mm at the top of the bed (Figure 15). Fossils include crinoid debris, bryozoans, trilobite fragments, brachiopods, gastropods, horn corals and favositids; most are whole near the base of the graded beds and become more broken as grain size decreases upward. The upper packstones are more thickly bedded at 2 to 3 foot intervals, are dark gray, and weather medium gray. The beds begin as pelletal wackestones, slightly dolomitic, with minor fossil debris. A point count of two thin sections yielded the following composition: 54% micrite, 32.2% pellets, 7% fossil fragments, 3% fine quartz sand grains, 2.5% clay, and the remaining 1.5%, clay, opaques and fracture-filling sparry calcite. A few flakes of mica were evident in each thin section examined.

The pelletal packstones are succeeded by crinoidal packstones and grainstones higher in the section. Composition here averages about 46% micrite recrystallized to microspar, 2% pellets, and 52% fossil fragments of which almost 90% are coarse sand-sized crinoid debris. The only grading observed in the upper packstones was in the amount of fine quartz sand, which decreased from 2% to 0 in some pelletal packstones. The rock has a slightly fetid odor when broken. One to 4 inch lenses of black chert become apparent at 30 to 50 feet below the top of the formation as do large, silicified tabulate corals.

The lime breccias occur in the basal third and at the upper contact of the formation. According to Dunham's 1965 classification, these are clastic fossiliferous lime wackestones. Outcrops of the rock are massive, 10 to 18 feet thick, medium gray weathering to medium light gray. Individual clasts average 1/2 to 3 inches in diameter, with a few elongate clasts as large as 7 inches long (Figure 13). In the basal beds, clasts are laminated micritic dolomite, unlaminated gray dolomite, and dark gray crinoidal lime packstone. Broken silicified tabulate corals, horn corals, and large crinoid columnals are scattered throughout, weathering dark brown and averaging 1 to 1-1/2 inches in diameter. The higher breccia beds contain none of the largest clasts, and have no dolomite or dolomite clasts. Micrite recrystallized to microspar cements the fossils and intraclasts, which are spread homogeneously throughout the rock with no visible grading.

Hill 10385 Section

All three lithologic types are present at the southern section in dolomitized form. The rocks are medium gray to medium light gray, and the fine-grained laminated rocks which form the lower to middle part of the section weather medium brown to yellow brown. The other two lithologies weather light gray and appear in thin section with much the same texture and composition as at Dobbin Summit, but with most of the fine detail and fossils obliterated by dolomitization. Zoned dolomite rhombs are common and slightly larger than the original microspar at 0.1 mm. Small stylolites occur in the central part of the formation, and are visible in thin section throughout the formation. Crinoidal packstone interbeds of the upper part are much more coarsely grained in the dolomite, with individual columnals up to 1 inch in diameter. Bedding is thick in the upper part, forming 2 to 4 foot exposures that become low, steep cliffs above the recessive mudstones of the lower part.

Contacts

The lower contact of the Roberts Mountains Formation, as discussed previously, lacks the chert interval usually described as the lower boundary of the formation. The contact has been arbitrarily set at the base of the first outcrop of calcareous breccia containing silicified corals. The upper contact at both Dobbin Summit and hill 10385 is placed at the last occurance of thick-bedded dolomite or dolomitic breccia that also contains silicified corals and laminated ripups. At hill 10385, this is the highest occurrance of silicified fossils and well-developed bedding, both of which are absent in the overlying Lone Mountain Dolomite.

Age

Fossil collections from measured section D through the Roberts Mountains Formation were identified by M. T. Wise and J. G. Johnson to be Silurian through earliest Devonian in age. Oldest brachiopod faunas (DO3) belong to C fauna, lower Ludlow stage, and the youngest (D221)are from brachiopod Interval 1, lower Lochkov stage. Llandovery and Wenlock-age brachiopods were not found in the lower beds of the Roberts Mountains Formation, but these are mainly lime mudstones that lack any fossils except poorly preserved graptolites.

Depositional Environment

Mud supported, laminated textures predominate in the Roberts Mountains Formation, which are essentially gradational from the upper Hanson Creek lime mudstones. They denote the continuation of quiet, deep water conditions from the uppermost Ordovician. Deep water conditions are also indicated by the lack of shelly indigenous fauna and the presence of graptolites.

The thick mud-supported breccias and medium grained rocks contain broken shelly fauna, show grading in thin sequences, and have dolomite intraclasts in a calcareous matrix. These beds form less than one-third of the total formation, and are probably allodapic. Winterer and Murphy (1960) noted that the thicker lithologies can occur at varying distances from the Lone Mountain--Roberts Mountains facies boundary, but are the dominant rock type only close to the boundary. Matti and others (1975) regarded the Roberts Mountains Formation at Copenhagen Canyon as representing a distal, basinal environment west of the facies boundary with the Lone Mountain Dolomite. The map area contains more and thicker allodapic beds than at Copenhagen Canyon, but fewer than at the facies boundary in the Roberts Mountains area. It is probably somewhere between the truly distal and proximal environments. Dolomitization was secondary and preferentially developed in the coarser grained skeletal beds of the south part of the area.

Regional Significance

Johnson and Potter (1975) postulate the downdropping of the continental margin during Silurian time, which resulted in the eastward shift of the facies boundary between transitional and eastern assemblages. With the initial downdropping, the boundary was changed from west of the map area to a position between the Monitor Range and the Hot Creek Range, during deposition of the lower lime mudstones of the Roberts Mountains Formation. The Hot Creek Range has Silurian dolomites, but these are not certainly identified with the Lone Mountain Dolomite (Potter, 1975). Dolomitization of the upper breccias and packstones at Clear Creek foreshadows the later migration of the facies boundary to a position between Clear Creek and Dobbin Summit. A western equivalent to the Roberts Mountains Formation is the Masket Shale in the Toquima Range (Matti and others, 1975).

Figure 13. Thick clastic lime breccia bed, top of Roberts Mountains Formation at Dobbin Summit.

Figure 14. Platy laminated dolomite, Roberts Mountains Formation.

Figure 15. Graded interval near base of Roberts Mountains Formation.

LONE MOUNTAIN DOLOMITE

General Statement

Massive, light gray dolomites of the Lone Mountain Dolomite are exposed in a 515 foot-thick rugged outcrop halfway up the east flank of hill 10385, north of Clear Creek (Figure 16). The dolomite does not exist in the Dobbin Summit section, where the interval above the Roberts Mountains Formation is occupied by lime mudstone and wackestone facies of the Windmill and Rabbit Hill Limestones. Both the limestone and dolomite facies lie conformably on an equivalent thickness of the Roberts Mountains Formation.

Hague (1883) originally defined the "Lone Mountain limestone" to include all rocks between the Middle Ordovician Eureka Quartzite and the Devonian Nevada Formation. Merriam (1940) restricted the Lone Mountain Dolomite to the upper nearly unfossiliferous dolomites of the interval, and assigned the Ordovician rocks to the Hanson Creek Formation and the Silurian fossiliferous limestones to the Roberts Mountains Formation.

Lithology

The Lone Mountain Dolomite at hill 10385 can be divided into two general lithologies; an apparently bedded lower dolomite, transitional from the underlying Roberts Mountains Formation, which grades into an upper massive dolomite more typical of the Lone Mountain Dolomite in its lack of fossils and internal structure. The lower division is grouped with the Lone Mountain rocks because it lacks the silicified fossils, intraclasts, and thinner bedding associated with the Roberts Mountains Formation. It is 215 feet thick, and consists of medium light gray dolomite with partings at 2 to 10 foot intervals that become spaced farther apart higher in the section. Bands of darker gray dolomite are visible at a distance, but not directly on the outcrop surface. The dolomite contains clastic crinoid fragments ranging from 1 to 10 mm in diameter, which gradually decrease in amount from 25 to 5% of the rock up section. In thin section, the matrix is composed of 10 to 50 micron dolomite rhombohedra. Slightly larger dolomite crystals form barely discernable fossil fragments, and smaller crystals clumped in 0. 25 to 0. 5 mm ovoids may be pellets, oolites, or fossil fragments. The upper division is completely massive, light gray dolomite which is banded with medium gray dolomite at 18 to 20-foot intervals. No fossils are found in the dolomite except for 1 to 2 mm ghosts of crinoid debris that are evenly distributed throughout the rock. Thickness of the unit is estimated at 300 feet. A normal fault of minor displacement cuts through the section 50 feet below the upper contact.

Environment of Deposition

Little inference can be made from an entirely dolomitized, almost structureless unit such as the Lone Mountain Dolomite. Dolomitization was probably secondary, as the lower part of the section was a crinoidal wackestone. Structures become more blurred, gradually upsection, until the upper 300 feet contain no features except for darker color variations visible at a distance. Deposition was in a quiet water environment, probably a carbonate bank or buildup at the edge of the shelf. The lower, somewhat bedded part of the dolomite is very similar to a transitional facies between the Lone Mountain Dolomite and Roberts Mountains Formation described by Winterer and Murphy (1960) at Pete Hanson Creek in the Roberts Mountains.

Regional Significance

The boundary between eastern and transitional facies is located between the Lone Mountain Dolomite at Clear Creek and the Windmill Limestone at Dobbin Summit. It is not known whether the two formations are time equivalents because diagnostic fossils have not been found in the Lone Mountain Dolomite in the map area. The dolomite is thinner (510 feet) than at other eastern assemblage locations, where it can be as thick as 3,000 feet. This is not due to its proximity to the facies boundary, but is part of a general thinning trend seen in all formations above the Eureka Quartzite in the map area.

The Lone Mountain Dolomite prograded over the Roberts Mountains Formation in the south part of the map area. This is a reflection of a marine regression or regional off-lap during Lochkovian time (Matti and others, 1975).

Figure 16. Ordovician through lower Mississippian section at hill 10385. View is southeast.

WINDMILL LIMESTONE

General Statement

The Windmill Limestone is a sequence of low ledges of allodapic lime packstones alternating with thin, recessive lime mudstone beds that crop out immediately above the Roberts Mountains Formation at Dobbin Summit. The formation is 165 feet thick, which is thin as compared with 515 feet of the Lone Mountain Dolomite that occupy the same stratigraphic interval at hill 10385.

The Windmill Limestone was included with the Rabbit Hill Limestone as defined by Merriam (1963) at Copenhagen Canyon. Johnson (1965) separated the Windmill from the Rabbit Hill rocks after study of a section of the formation at Coal Canyon in the Simpson Park Range. Both formations contain interbedded lime mudstones and allodapic lime packstones and grainstones, but the Rabbit Hill beds contain chert lenses not found in the Windmill Limestone and more lime mudstone, as well as a different fauna. Matti and others (1975) measured the Windmill Limestone at Copenhagen Canyon to be 455 feet thick and the formation at Coal Canyon to be 350 feet thick. Both localities are considered to be reference sections for the formation.

Lithology

The allodapic lime packstone beds, which make up the bulk of the Windmill Limestone, are similar in composition to the upper packstone and grainstone strata of the Roberts Mountains Formation. Bedding is 12 to 30 inches thick, with both graded and nongraded sequences of medium dark gray limestone that weather medium gray and pinkish gray. The coarsely graded beds contain well-rounded mudstone and wackestone intraclasts and silicified fossils, mostly favositids and crinoids (Figure 17). Grain size decreases upward from 1/2 to 2 inches in diameter to very fine sand-size. The borders of some clasts appear embayed by the surrounding mudstone matrix, as if they were still soft during transport and easily deformed. The average composition of the nongraded packstone is 40% micrite and 60% allochems, which include varying amounts of fossil fragments, 0.2 mm pellets, organic material, and 5% fine quartz sand and silt. The lime mudstones are thin-bedded, silty, and weather to yellowish gray to pinkish gray platy and flaggy chips. The rock contains up to 15% quartz silt, pellets, and crinoid fragments in mud support. Few fossils are found in the mudstones. Both lithologies have a slightly fetid odor when broken. The lower contacts of the allodapic beds are sharp and well defined over both the mudstones and other packstones. The upper contacts may be either sharp or gradational with the overlying mudstones.

Fossils and Age

The Windmill Limestone contains abundant fossils in the lime packstones, and many are silicified. A notable exception to this mode of preservation is trilobite debris, which is ubiquitous in the formation and composed of disassociated carbonized remains of phacopsids. Silicified fossils include horn corals and tabulates, brachiopods, tentaculites, gastropods, sponges, bryozoans and crinoid debris. Several collections taken from three measured sections through the Windmill Limestone also yielded conodonts (see Appendix). Brachiopods, conodonts, and corals from the formation are from brachiopod Intervals 2 through 4 (Johnson, pers. commun.) of Lochkov age, Early Devonian. A brachiopod fauna collected 30 feet above the base of the Windmill contains *Antirhynchonella* sp., *Ogilviella* cf. *rotunda*, *Werneckeella* sp., and *Thliborhynchia* sp. They are part of the upper Lochkovian Royal Creek fauna from the Yukon (Lenz, 1967) and are previously unknown in the Great Basin (M. T. Wise, pers. commun.).

Lower Contact

The lower contact of the Windmill Limestone with the Roberts Mountains Formation has been arbitrarily set at the top of the last massive slightly dolomitic wackestone that contains large intraclasts. The lower Windmill lime packstones are difficult to distinguish lithologically from the Roberts Mountains packstones, and the division between the two formations was made on the following criteria: 1) No thick outcrops of massive clastic wackestone occur in the Windmill Limestone, but many occur in the Roberts Mountains Formation near the facies boundary with the Lone Mountain Dolomite. Close proximity to the facies boundary is certain in the map area, as the dolomite replaces the Windmill limestones four miles away, at hill 10385. 2) Graded allodapic lime packstones are common in both formations, but the Roberts Mountains beds are 6 inches thick, well-graded, with some dolomite clasts, and interbedded with laminated dolomites in the lower part of the formation, and those of the Windmill Limestone average 2 feet thick, are poorly graded, and are interbedded with calcareous non-graded packstones. 3) Silicified brachiopods collected thirty feet below the proposed contact (D-221) were identified by M. T. Wise as part of the F fauna, of early Lochkov age. These are found in the highest Roberts Mountains beds elsewhere (Johnson and others, 1973). Corals taken from approximately 10 feet above the proposed boundary, were identified by R. A. Flory as belonging to the Squameofavosites murphii Zone. This zone coincides with brachiopod Interval 2 (Johnson, pers. communication) of the lowest Windmill rocks at Coal Canyon in the Simpson Park Range (Johnson, 1973).

Depositional Environment

The presence of mud-supported sediments with no shelly fossils indicates a low energy, fairly deep water environment for the lime mudstones of the Windmill Limestone. The mudstones are associated with graded beds of lime packstone containing broken shelly fossils, such as brachiopods and corals, which normally occur in shallow benthic marine assemblages. The grading and sharp basal contacts of the packstone beds, and shallow water fauna indicate transport from adjacent shallow-water environment, possibly by turbidity currents or grain flow mechanisms. This type of packstone has been termed an allodapic sediment, or allochthonous carbonate sand, by Meischner (1964). The thickness of the graded beds (2 to 3 feet) and resemblance to the A and E intervals of the Bouma sequence (Figure 17) is very similar to Facies C turbidites found in upper submarine fan and other proximal basin environments (Walker and Mutti, 1973).

Matti and others (1975) interpreted the Windmill Limestone at Copenhagen Canyon as a distal, basinal deposit. The Windmill Limestones of the map area are a more proximal version of these basinal deposits.

Regional Significance

The location of the facies boundary between eastern and transitional assemblages was between the Lone Mountain Dolomite and the Windmill Limestone, as discussed previously. Progradation of the dolomite could have continued for as long as the deposition of the Windmill Limestone, since a single light-colored dolomitic bed is found in the uppermost Windmill beds at Dobbin Summit.

The "Unnamed Dolomite" in the Hot Creek Range (Potter, 1976) is another eastern assemblage equivalent of the Windmill Limestone. Matti and others (1975) pointed out the lithologic similarity of the Windmill Limestone to the McMonnigal Limestone of the Toquima Range. The McMonnigal Limestone is a Lower Devonian series of skeletal lime packstone and grainstone that overlies the Masket Shale (Roberts Mountains Formation equivalent) described by Kay and Crawford (1964).

Figure 17. Coarsely graded limestone bed, lower part of Windmill Limestone at Dobbin Summit.

RABBIT HILL LIMESTONE

General Statement

The Rabbit Hill Limestone was named by Merriam (1963) for Rabbit Hill, which is located at the junction of Whiterock and Copenhagen Canyons. Merriam measured an incomplete section at that localityto be 250 feet thick. Matti and others (1975) estimated the entire formation near Rabbit Hill to be 420 feet thick, and recognized two informal members. The lower member, 200 feet thick, consists mainly of fine-grained, thin bedded lime mudstone, wackestone, and calcareous shale with laminated black chert layers and minor, medium-bedded allodapic limestones. The upper member, 220 feet thick, contains thin and medium bedded lime mudstones and wackestones, with subordinate thick-bedded allodapic limestone that becomes more abundant toward the top of the member. A middle Early Devonian (Pragian) age has been assigned to the Rabbit Hill Limestone on the basis of detailed brachiopod (Johnson, 1974) and conodont(Matti, 1971) biostratigraphy.

Both members are recognized in measured sections at Dobbin Summit, where they have a total thickness of 320 feet. Ten feet of lime mudstone containing lower Rabbit Hill-age fossils was found on top of the Lone Mountain Dolomite at hill 10385. The lime mudstone appears to conformably overly the dolomite, which is slightly calcareous in the top 2 feet below the contact.

Lithology

The lower contact of the Rabbit Hill Limestone is at the abrupt change from ledge-forming medium-bedded allodapic Windmill beds to recessive slopes of lime mudstone talus. The very fine grained mudstone weathers as yellowish gray, tan, and pinkish gray chips 2 to 3 inches in length. Few fossils are seen in the talus interval except for trilobite hash and silicified tentaculites. Above the talus, the lime mudstone is interbedded with 6 to 12 inch ledges of lime wackestone. These ledges are dark gray weathering to medium gray, have a fetid odor when broken and an abundant shelly fauna. The packstones are similar to the ungraded allodapic beds of the Windmill Limestone except that they are thinner and allochems are in mud-support rather than grain support. Thin lenses and beds of black chert 1 inch thick occur in the lower 200 feet of the formation. The cherts are laminated with 0.5 mm layers of micrite. The chert-bearing interval resembles the lower Rabbit Hill Limestone at the type locality. However, the beds in the map area are much less argillaceous and silty, and lack the brown-weathering calcareous shales seen at Rabbit Hill.

The remaining 120 feet show a gradual decrease in lime mudstone beds and an increase in medium-bedded, ledge-forming wackestones and packstones. Fossil content increases in the thicker beds, and includes silicified brachiopods, large tabulate corals, gastropods, crinoid and trilobite fragments, fenestrate bryozoans, sponges, small horn corals, and straight-shelled nautiloids (Figure 18). The highest 30 feet are entirely lime packstones and wackestones, with only a little lime mudstone seen along partings. One or two lime grainstone beds occur in this interval; these contain up to 60% silicified fossils. The typical wackestone contains up to 15% ovoid pellets, 0.2 mm in diameter; less than 1% very fine quartz sand and silt, and about 10 to 15% fossil fragments in mud support. Packstones have up to 40% fossil fragments, but are otherwise similar to the wackestones. Bedding plane contacts are fairly even though not exactly planar at the top and bottom of individual beds.

Brachiopods from the Rabbit Hill Limestone were identified by M. T. Wise, conodonts by Gilbert Klapper, and tabulate corals by R. A. Flory. Fossils found in Section B are from, in ascending order; the lowest *Spinoplasia* Zone, a mixed fauna from the upper *Spinoplasia* Zone and the *Trematospira* Subzone, and the *Acrospirifer kobehana* Zone. These range in age from lower Pragian to lower Zlichovian. The *A. kobehana* Zone (collections B 562 through B 600), present in the upper 40 feet of the formation, has not previously been found elsewhere in the Rabbit Hill Limestone but is known in the Kobeh Member of the McColley Canyon Formation.

Depositional Environment

The lower Rabbit Hill Limestone was deposited in a quieter basinal environment than the Windmill Limestone. Lime mudstones, with few fossils and thin chert beds, are indicative of a deeper water, below wave base, basinal environment. Although the upper coarse-grained beds contain no grading, there is some evidence that they are allodapic. Upper and lower contacts of individual wackestone and packstone beds are well defined though massive, much like those of grain-flow beds described as Facies B by Walker and Mutti (1973). They are interbedded with thin very fine grained mudstones, the same kind of deep-water sediments interbedded with allodapic packstones in the Windmill Limestone. Higher in the formation, single pedicle valves of *A. kobehana* outnumber brachial valves by 10 to 1 (M. T. Wise, oral communication). The brachial valves found are much smaller than most of the pedicle valves; the former may have been selectively removed during transport with the enclosing sediment. Other brachiopods have been damaged and show regeneration of shell material over the broken parts of the valves. All of the above indicate that the wackestone and packstone were transported from shallower waters into a deeper environment, and hemipelagic lime muds were deposited between the allodapic layers.

The large- and small-scale intraformational deformation seen in the upper Rabbit Hill beds at Rabbit Hill are not present in the map area. Wavy bedding, sedimentary boudinage, and soft sediment slumping seen at Rabbit Hill were interpreted by Matti and others (1975) as proximal slope deposits. The medium-grained allodapic beds at Dobbin Summit, with no intraformational deformation belong to a basinal environment which may or may not be closer to the shelf break than the Rabbit Hill beds. The Dobbin Summit beds have no indigenous brachiopod fauna, which may be due either to depth or lack of proper substrate.

Regional Significance

The lower Rabbit Hill Limestone has no proven eastern equivalent in the Roberts Mountains, but one has been identified at McColley Canyon in the Sulphur Spring Range (Matti and others, 1975, Figure 21; beds with *E. sulcatus* early form). The marine off-lap that occurred during deposition of the Windmill Limestone (Lochkovian time) ended and marine on-lap began with Rabbit Hill deposition during Pragian time (Merriam, 1963; Johnson, 1965, 1970, 1971; Matti and others, 1975). The presence of Pragian-age lime mudstones on top of the Lone Mountain Dolomite in the map area suggest that the lower Rabbit Hill Limestone is younger than the dolomite.

This model agrees with that of Johnson (1970, Figure 3) and one of two alternatives suggested by Matti and others (1974, Figure 22, upper).

The upper Rabbit Hill *Acrospirifer kobehana* Zone is definitely correlative with the Kobeh Member of the eastern assemblage McColley Canyon Formation.

Figure 18. Above: Blocky allodapic beds of upper Rabbit Hill Limestone, Dobbin Summit Section B (B590). Below: Highly fossiliferous lime packstone from near location above (B577).

DENAY LIMESTONE

General Statement

Dark blocky laminated limestones belonging to the Denay Limestone crop out above the Rabbit Hill Limestone only at the Dobbin Summit section. Excellent cliffy exposures of the Denay form a ridge south of hill 8878 on the south side of East Dobbin Creek.

The name "Denay Limestone" was proposed by Johnson (1966) for middle Devonian limestones between the McColley Canyon Formation and the Devils Gate Limestone. An unpublished manuscript by Murphy (1973) describes the lithology and contacts of the Denay Limestone in the northern Simpson Park Range and the northern Roberts Mountains. Murphy subdivided the formation into two mappable units. The lower member consists of lower laminated and thin bedded micrites containing a *Leptathyris circula* assemblage Zone fauna, and a middle part dominated by coarse-grained allodapic beds. The upper member is a cherty, laminated and very thin bedded limestone. Only the lowest laminated beds were recognized in the map area, which were measured at 160 feet in thickness. The total thickness of the Denay Limestone in the Roberts Mountains was much thicker (750 feet in the faulted WC II Section; J. G. Johnson, written communication).

Lithology

The lower contact of the Denay Limestone is obscured by talus. The highest blocky allodapic beds of the upper Rabbit Hill Limestone are overlain by lime mudstone in 1 to 3 inch chips. These contain silicified tentaculites, and have the same weathered appearance as the lime mudstones in the lower Rabbit Hill Limestone. The lithology abruptly changes 60 feet above the last Rabbit Hill allodapics to black and very dark gray, fetid, fine-grained blocky lime mudstone and wackestone. The basal outcrops weather dark gray and are outwardly massive, but internally well-bedded. Brown-weathering argillaceous laminations are slightly irregular, 1/8 to 1/4 inch apart, and partings occur every 4 to 6 inches. Petrographically, the Denay Limestone is a pelletal lime mudstone and wackestone with 2 to 3% quartz silt and up to 30% ovoid micrite pellets. A single nonlaminated 4 foot bed is seen in the lower 50 feet of the unit. This bed is probably allodapic as it contains barely discernable intraclasts and large broken tabulate corals. In the upper half of the interval, bedding becomes better defined, thinner, and very wavy (Figure 19). Channels 4 inches wide by 1 inch deep have been cut across the upper surfaces of some mudstone beds (Figure 20). These are filled with silicified brachiopod valves that are aligned and cemented together convex sides up. Other features indicating current activity occur only in float blocks. They include single 2-inch beds containing grain-supported brachiopod valves in the alignment described above, flute casts, and sole markings. The upper contact of the Denay Limestone is a thrust fault, with deep water cherts and shales of Ordovician age composing the overlying strata.

Age

Conodonts from the lower part of the Denay Limestone (collection B 714) are of middle Eifelian age (Klapper, pers. communication). A brachiopod sample collected higher in the section (D 885) was composed almost entirely of *Leptathyris circula* valves. Conodonts from the sample also are of upper Eifelian age. These are equivalent to the lower part of the Denay Limestone at Hot Creek, 15 miles southeast of the map area (Potter, 1975), and in the Roberts Mountains (Murphy, 1973). Fossils found in the channel fillings were too badly abraded and cemented together to be identified.

Depositional Environment

The dark, fine-grained, laminated lime muds of the Denay Limestone were deposited in a deeper, quieter basin than the Rabbit Hill Limestone. Few allodapic beds are seen in the formation, bedding is much thinner and wavier, and the limestone has no indigenous shelly fauna. In the Hot Creek Range, Potter (1976) noted a resemblance of the lower Denay limestones to contourites, which commonly occur on continental slopes. Since the map area is basinward of the Hot Creek Range, it is suggested that the Denay Limestone in the map area is a more distal facies. The shallow channeling of the uppermost lime mudstone beds in the map area is similar to surface channeling in submarine fans (Walker and Mutti, 1973).

Regional Significance

The easternmost occurrence of the Denay Limestone is along a north-south line immediately east of the Hot Creek Range and the Roberts Mountains (Murphy, 1973; Potter, 1976). The map area has one of the westernmost occurrences of the Denay Limestone. The Denay Limestone, therefore, occupies a 25 to 35 mile-wide belt in Eureka and Nye Counties. The formation probably has volcanic-clastic equivalents in west-central Lander County (Murphy, 1973).

Figure 19. Contorted bedding from upper beds of the Denay Limestone, Dobbin Summit.

Figure 20. Brachiopod filled channel in the upper beds of the Denay Limestone.

LOWER MISSISSIPPIAN (KINDERHOOK-OSAGE) ROCKS

General Statement

The earliest Mississipian rocks of the Great Basin are the upper Pilot Shale and Joana Limestone on the eastern platform and the Webb Formation and Chainman? Shale in the elongate trough which formed parallel to the rising Antler Highland in the west (Poole, 1974). According to a diagram by Poole (1974, p. 75) the map area was located somewhere within the trough, which Poole termed the Antler Foreland Basin. The Mississippian strata of the map area closely resemble that of the Carlin-Pinyon Range area and localities in western Elko County, where the rocks are known to be deep water, basinal in origin.

The siliceous argillites, claystones, and minor limestones of the Webb Formation overlap the Roberts Mountains thrust and have basal contacts with both the allochthonous rocks and the autochthonous rocks of the area (Smith and Ketner, 1968). This stratigraphic relationship was used by Smith and Ketner (1968) to date the minimum age of the Roberts Mountains thrust in the Carlin-Pinyon Range area. Conodonts from the Webb Formation are of Kinderhook (early lower Mississippian) age. A correlative unit of different lithology, termed the "Camp Creek" sequence, was found in the southern Independence Mountains, north of the Pinyon Range (Ketner, 1970). This is a 650-foot series of graded limestone beds believed by Ketner (1970) to have been deposited by turbidity currents.

The oldest Mississippian rocks of the map area have lithologic characteristics of both units. 450 feet of lime-cemented siliceous argillite, similar to the Webb Formation, were deposited on the thrust rocks in both the Dobbin Summit and the hill 10385 areas. The argillite is followed by 350 feet of graded sandy limestones with primary structures and burrowed layers similar to the turbidites of the Camp Creek sequence. Siphonodella spp. conodonts were found in the upper limestones in the map area, indicating that these are of Kinderhook-Osage age. The lower argillites are here designated as the Webb Equivalent and the limestones, as the Camp Creek Equivalent. The term "equivalent" is used because, although the lithologies are very similar, the map area is over 100 miles from the nearest outcrop of either formation and exact correlation is uncertain under these circumstances.

Webb Equivalent

The lower contact of the Webb Equivalent is not exposed, but is seen as the sudden change from black chert and light gray shales to yellowish gray-weathering, well-bedded lime-cemented rocks.

The lowest exposed beds of the unit at hill 10385 are wavy, thin to very thin-bedded sandy argillites and shales that react to dilute HCl. The major part of the rock unit forms recessive tree-covered slopes and weathers in 1 to 2 inch chips. Thin impure sandstone layers were seen in talus, but not in outcrop. The upper 75 feet of the unit exposed at Dobbin Summit are blocky, thin to medium bedded, laminated at 1 cm intervals, and are less sandy than the lower beds. Although the rock is superficially a limestone to calcareous shale, petrographically it has only 20 to 30% micrite. The groundmass is very fine grained spicular material and opaques. Grains are 10 to 50 microns in diameter, and compose at least 60% of the rock. The spicular material is siliceous and the long diameters of individual particles are aligned parallel and sub-parallel to the bedding plane. Hematite pseudomorphs of pyrite cubes account for 3% of the rock, and fine-grained, well-rounded quartz sand is 5 to 10%. The sandstone layers contain up to 60% quartz sand grains in a spicular matrix. Spheres of calcite 0.1 mm in diameter appear in thin section (Figure 21). These are probably calcite-replaced radiolarians, as a few spheres retain part of the original structure.

Camp Creek Equivalent

The black, medium-bedded argillites are overlain by thick-bedded, brownish gray sandy lime wackestones and mudstones, and intercalated thin black mudstones (Figure 24). The limestones are regularly repeated cycles of graded, laminated, and non-graded beds 2 to 4 feet thick, separated by 2 to 6 inch layers of black calcareous mudstone (Figure 22). The basal part of the graded sequences is nearly always a laminated interval containing well-rounded 0.2 mm quartz sand grains and fossil fragments. The amount of allochems decreases upward from 50% to 20% of the rock within a bed. The middle part of a sequence often has convolute lamination or barely discernable sedimentary boudinage (Figure 23). The upper part of all beds is a finely laminated to micritic zone with little or no quartz sand. Indications of current activity are found mostly in float blocks. Small-scale ripple marks are common, as well as sole marks (Figure 25) and load casts. Only a single bed was found with flute markings on the underside, and these indicate a southwest direction of flow. Soft-sediment slumping has also occurred, cutting across previously deposited cycles (Figure 24).

In thin section, compositional changes within a bed are gradational from quartz sandy lime wackestone and packstone at the base to spicular lime mudstone near the top. Allochems in the wackestones include pellets, rounded crinoid and shell fragments, and angular clasts of spicular argillite, lime mudstone, and black mudstone. Elongate clasts and fossil fragments are oriented with long axes parallel to the bedding plane. The upper lime mudstones contain fine siliceous spicular material and calcite spheres similar to those of the underlying Webb Equivalent, but in lesser amounts. Quartz grains and clays are concentrated along microscopic stylolites in nearly every thin section. The intercalated black mud layers are filled with horizontal burrowings identified as the Ichnofossil Nereites, usually found in a deep-water environment (Figure 23). These are nearly identical to the burrowings reported by Ketner (1970) in the interturbidites of the Camp Creek Sequence.

The upper third of the formation becomes more thinly bedded, and has calcareous sandstone layers. The sedimentary cycles here consist of coarsely graded and laminated lime wackestones and packstones 2 to 12 inches thick. Bedding is very wavy, and wave crests are 1-1/2 to 3 feet apart. Allochems form up to 60% of the rock and include fine quartz sand, fossil fragments, intraclasts, and pellets. Quartz sand grains average 0.2 to 0.25 mm, are subangular to rounded, and most have calcite overgrowths. Fossil fragments are reworked tentaculites, silicified brachiopod and crinoid fragments, bryozoans, and sponge spicules. Sandy beds and laminations weather orange to orange brown, and the wackestones are medium to brownish gray. Thin (1/2 to 4 inch) interbeds of red-weathering intraformational conglomerate (clastic lime packstone) crop out at the top of the formation. Clasts are elongate and discoid, well-rounded 1 to 10 mm fragments of lime mudstone, wackestone, opaque argillite, and fine crystalline carbonate in a quartz sandy pelletal matrix. These are graded even in the highest beds of the formation (Figure 25).

Age

Conodont collections were taken at several intervals in both the Webb Equivalent and the Camp Creek Equivalent, as neither formation has any visible megafauna. Several collections from the Camp Creek Equivalent (see Appendix) contained Siphonodella spp., notably S. obsoleta and higher Gnathodus sp. (G. Klapper, written communication). These are restricted to the lower Mississippian, below the Meramec series (Faunal unit 2 of Lane, 1974, p. 271).

Depositional Environment

The siliceous nature of the sediment, lack of significant terrigenous material and shallow water fauna, and the presence of radiolarians suggest a deep water, basinal environment for the Webb Equivalent.

Overall composition, as well as appearance in thin section is strikingly similar to that of deep water, hemipelagic flysch sediments described by Garrison and Fischer (1969, p. 31) in their discussion of geosynclinal sedimentation of Alpine Jurassic rocks. Wavy laminated bedding and ripple-marked talus in the lower part may also be some kind of distal turbidite deposition (Facies G, as described by Walker and Mutti, 1974), but conclusive evidence is lacking.

The deep-water, basinal regime continues through the deposition of the Camp Creek Equivalent rocks. The graded, cyclic nature of the limestones, sole markings and ripple marks, and deep water Nereites burrowings in the thin mud layers between cycles is highly suggestive of turbidite deposition. Beds with laminated lower, convolutely laminated middle, and finely graded upper divisions match Bouma (1962) sequences with divisions BCD (Figure 22). The burrowed mud layer resembles the hemipelagic, interturbidite division E. Basal contacts of all graded and laminated beds are sharp and upper contacts are gradational into the burrowed mud layer. Sole markings, when seen in outcrop, occur on the undersides of graded limestone beds, protruding into the mud layers below. The upper, thinner layers of sandstone and conglomerate have the AE or ABE divisions of coarsely graded sand, laminated fine sand, and hemipelagic mud.

Walker and Mutti (1974) in their discussion of turbidite depositional facies note that turbidite sequences beginning with division A usually lack, or show poor development of, divisions B, C, and/or D. Classic proximal turbidites have divisions A and E, are thin to medium bedded and are medium to fine grained (Walker, 1967). The upper beds of the Camp Creek Equivalent with AE and ABE development closely match the proximal variety of turbidite. The lower beds, beginning with division B, which are fine grained and somewhat thicker than the upper beds, are closer to the distal turbidite of Walker (1967), and would belong to facies E of Walker and Mutti's (1973) classification.

Regional Significance

The lower Mississippian overlap assemblage in central Nevada is composed of both eastern shallow water shelf and platform facies, and the deep water rocks of the Antler Foreland basin (Brew, 1971; Poole, 1974; Smith and Ketner, 1975). As mentioned previously, the Webb Formation and Camp Creek sequence occur in the Carlin-Pinyon Range area and the Independence Range respectively, and represent basinal facies. Eastern platform and shelf facies include the upper Pilot Shale and the Joana Limestone. Both are of Kinderhook-Osage age (Brew, 1971). To the west, the emergent Antler Highland was shedding detritus rather than receiving it during that time.

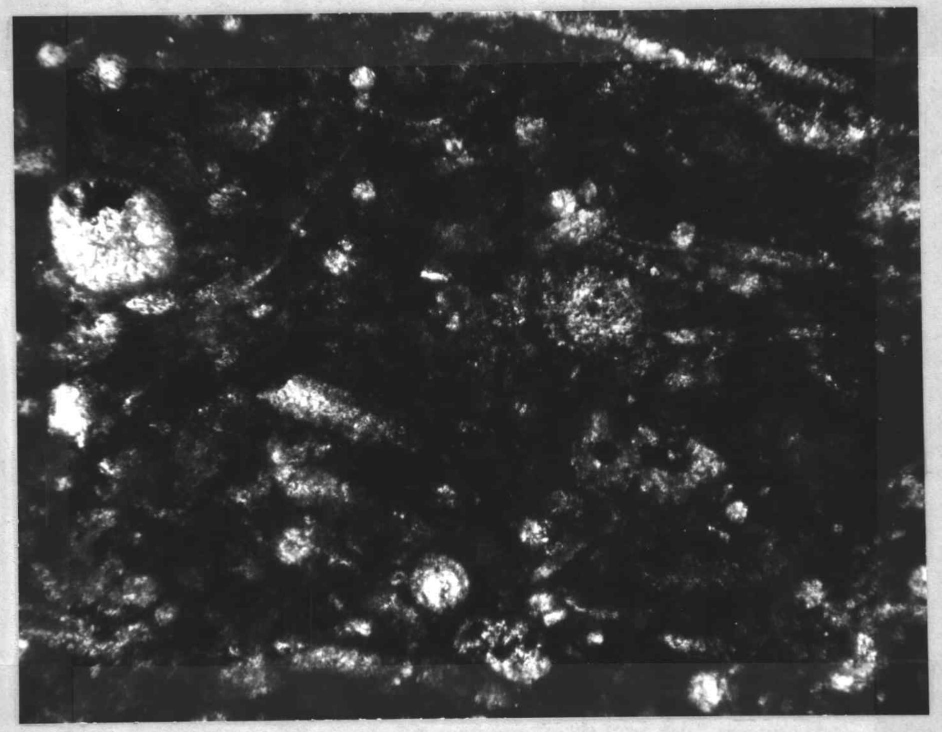


Figure 21. Radiolarian argillite from the Webb Equivalent, Kinderhook-Osage (?) age. Radiolarian is right center.

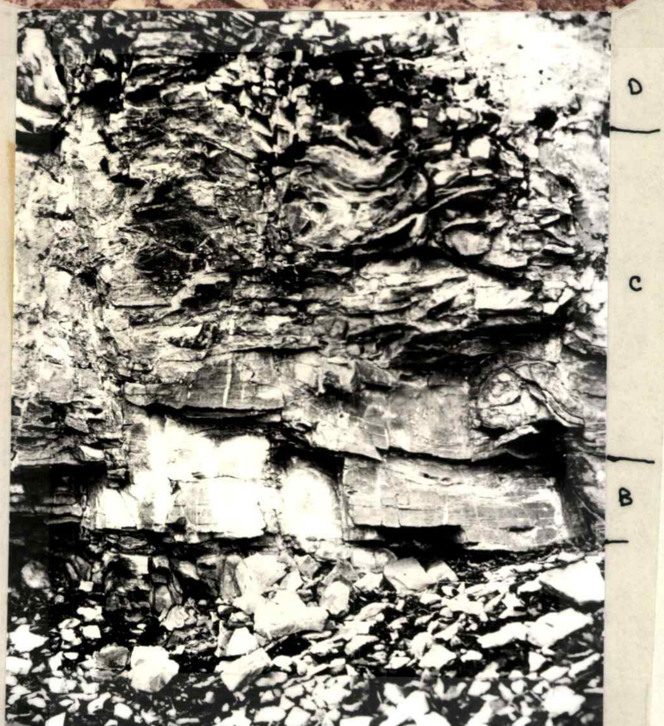


Figure 22. Typical BCD and BCDE Bouma sequences in the Camp Creek Equivalent at Dobbin Summit.

Figure 23. Above: Single block of the Camp Creek Equivalent, showing convolute and parallel laminations.
Below: Nereites burrowings in mudstone layer E, Camp Creek Equivalent.

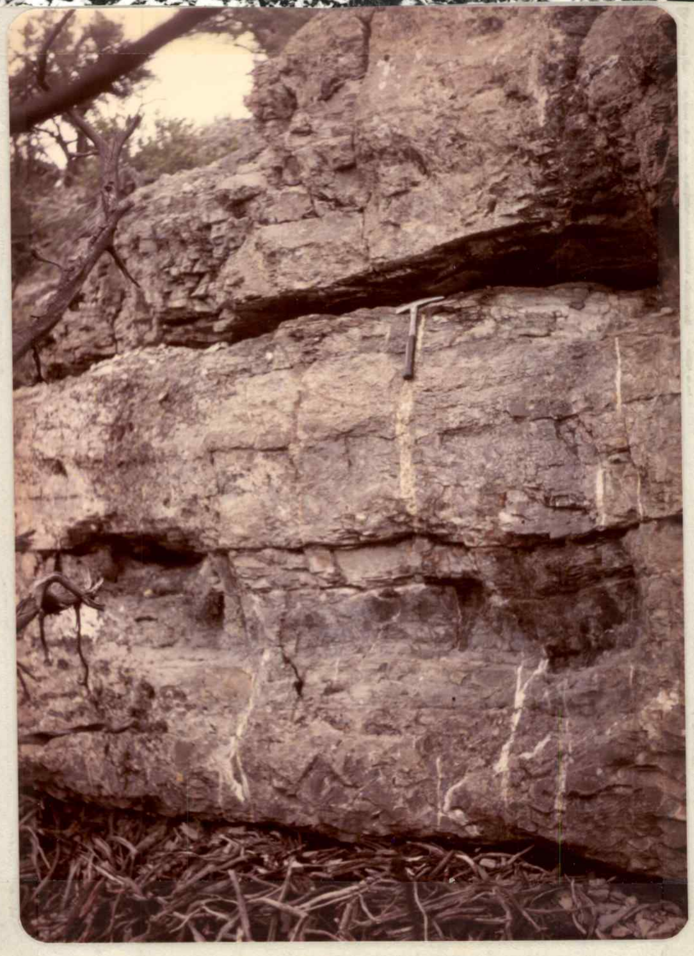


Figure 24. Above: At rock hammer, slump in Camp Creek Equivalent at Dobbin Summit.
Below: Three foot graded sequences separated by recessive mudstones, Camp Creek Equivalent, Dobbin Summit.

Figure 25. Above: Coarsely graded clastic bed, upper part of Camp Creek Equivalent at hill 10385.
Below: Sole marks to right of lens cap (2" diam.), from Camp Creek Equivalent at Dobbin Summit.

DIAMOND PEAK - CHAINMAN EQUIVALENT

General Statement

Approximately 750 feet of Mississippian strata superjacent to the Webb and Camp Creek equivalents crop out on the southwest quarter of hill 10385 (Figure 26) and on the north-facing cliff of Clear Creek Canyon (Figure 1). The rocks consist of lower limestones with intercalated thin sandstones, middle sandy limestone and chert conglomerates, and upper massive breccias and conglomerates. This sequence, which is unconformably overlain by middle Pennsylvanian or younger limestones, is stratigraphically equivalent to the Chainman and Diamond Peak Formations in central Nevada.

The Chainman Shale is a Mississippian series of soft gray shales, pebbly mudstones, quartz sandstones, and thin-bedded limestones. The Diamond Peak Formation is mostly sandstone and conglomerate with occasional highly fossiliferous limestones. Both are generally dated from Osage through Chester in age (Brew, 1971). The two formations are often interbedded and mapped as a single unit where equal percentages of conglomerate and fine-grained rocks are present in the same area. In the Carlin-Pinyon Range area, the Diamond Peak and Chainman combined thickness is 4700 feet (Smith and Ketner, 1968). The units are overlain either by conformable lower Pennsylvanian strata or unconformable upper Pennsylvanian-Permian rocks.

The Devonian-Mississippian Eleana Formation of southern Nye County (Ekren and others, 1971) is in closer proximity to the map area than the Carlin-Pinyon Range rocks, but has little lithologic similarity to the Mississippian sequence of the map area.

Lithology

The lower contact of the Chainman-Diamond Peak equivalent is not exposed, but appears to be gradational with the underlying thin graded conglomerates and limestones of the highest Camp Creek Equivalent beds. The lowest beds consist of 8 to 12 inch benches of blocky brownish-gray lime wackestone, regularly interbedded with 1/4 to 1 inch silty gray-brown lime mudstones and occasional coarse-grained sandstones. Bedding is undulatory in the basal 50 feet, with wave crests 10 to 20 feet apart. Silty and sandy layers weather brown to orange or pinkish gray. The lime wackestones are laminated at 3 inch intervals or finely graded, and contain mud supported 0.1 mm pellets and quartz sand grains. The sandstones are lime cemented, 1 to 3 inch beds of subrounded 1 to 2 mm quartz grains. With the exception of the large grain size, the sandstones resemble those of the upper Camp Creek Equivalent beds. One or two beds of what appeared in hand specimen to be fine-grained medium gray lime mudstone were different in thin section. The composition is 60% silica, as very fine (10 micron) spicular material; 30% opaque material, probably magnetite or hematite, and 1% phenocrysts of calcite and an unidentified green clay mineral.

Bedding becomes thicker above the first 50 feet of strata. The pelletal lime mudstones form even blocky 2 to 3 foot beds, with rare laminae. Siltier mudstones remain the same thickness, but are fewer in number. The coarse sandstone beds are 1/4 to 2 inches thick and are spaced at irregular 3 to 10 foot intervals. Quartz sand grains are angular to subrounded, and are accompanied by a few angular chert and limestone clasts (Figure 26). Some of the sandstones grade upward into limestones. Two or three stringers of black chert are seen in the lime mudstone beds.

At about 500 feet above the base of the lower unit, a few beds of edgewise conglomerate appear intercalated with the lime mudstone. The clasts are elongate, sub-parallel to the bedding plane and are composed of micrite, the silty lime mudstone and wackestone of the enclosing limestone beds, dark argillite with radiolarians, and angular chert. Six inch beds of graded conglomerate containing angular coarse sand-size light gray chert and 2 to 10 mm elongate limestone clasts are also common (Figure 27). Bed thickness is 2 to 3 feet, with smooth partings between beds.

The well-bedded limestones and fine conglomerates change abruptly to massive or indistinctly bedded lime-cemented conglomerates and breccias (Figure 27). Where bedding is seen, thin laminated coarse-grained sandstone layers separate jumbled intervals of poorly sorted conglomerate (Figure 28). Clasts range in size from coarse sand to pebbles and large cobbles. The largest clast seen was a boulder 1 foot in diameter. Composition of the clasts includes dark radiolarian argillite, crinoidal lime packstone, lime wackestone and mudstone, and varicolored chert pebbles. All lithologies, except for the chert pebbles, are representative of the lithologies of the preceding formations. Clasts are angular to subrounded, and chert clasts are more angular than limestone clasts on the average. Cement is quartz-silty micrite and minor sparry calcite. Crudely graded intervals crop out at a small hill west of hill 10385, in the south part of the area. The best estimate of thickness of the conglomerate interval is 250 feet.

Fossils

A few radiolarian spheres and silicified spincules were seen in thin section in the lower lime mudstone, but no other fossils were found. The edgewise conglomerate and coarsely graded sandstones contain fragments of brachiopods, crinoids, bryozoa, and sponge spicules. A few small whole brachiopods were found just below the massive conglomerate beds, but were too badly abraded to identify.

Conodont collections from the interval (see Appendix) have been identified as Kinderhook-Osage in age, equivalent to faunal unit 2 of Lane (1974) (G. Klapper, written communication).

Depositional Environment

The fine-grained pelletal lime mudstones were deposited in a quiet water, below wave base environment. The lack of shelly fauna even as allochthonous fragments, and presence of radiolarians indicate relatively deep water, probably a continuation of the basinal environment of the Kinderhood-Osage age sediments. The coarsening of the grain size and great abundance of clastic chert, not seen previously in the map area, indicates a western source for the conglomeratic sediments. Carbonate muds and skeletal detrital sediments must have come from the eastern carbonate shelf source, although direct evidence (current indicators) is lacking in the map area. Throughout the Mississippian, the rising Antler Highland to the west began shedding its accumulated deep-water siliceous detritus eastward into an elongate basin (Poole, 1974). The presence of clastic deep-water chert fragments, which are first seen in the middle of the Chainman-Diamond Peak Equivalent, is the first indication of erosion from this western source. Both eastern and western areas continue to affect the map area during deposition of the upper breccias, which contain a mixture of siliceous and carbonate clasts. The basin was rapidly infilled with coarse, angular material.

Regional Significance

The north-south trending basin east of the Antler Highland was at its greatest development during later Mississippian time (Poole, 1974). Deposition changed upward from fine grained, detrital and limestone sediments to westerly-derived clastic sediments as the basin became filled in. The clastics of the Diamond Peak Formation spread across the limestone shelf as far eastward as the White Pine Range (Brew, 1971) during latest Mississippian time. In southern Nevada the broadly conceived Eleana Formation includes all Mississippian age basinal deposits (Poole, Houser and Orkild, 1961; Ekren and others, 1971).

Graded carbonates with a shallow water shelly fauna occupy this stratigraphic interval in the Hot Creek Range (Potter, 1976). Both conodout and brachiopod collections from the Hot Creek area are Osagean in age.

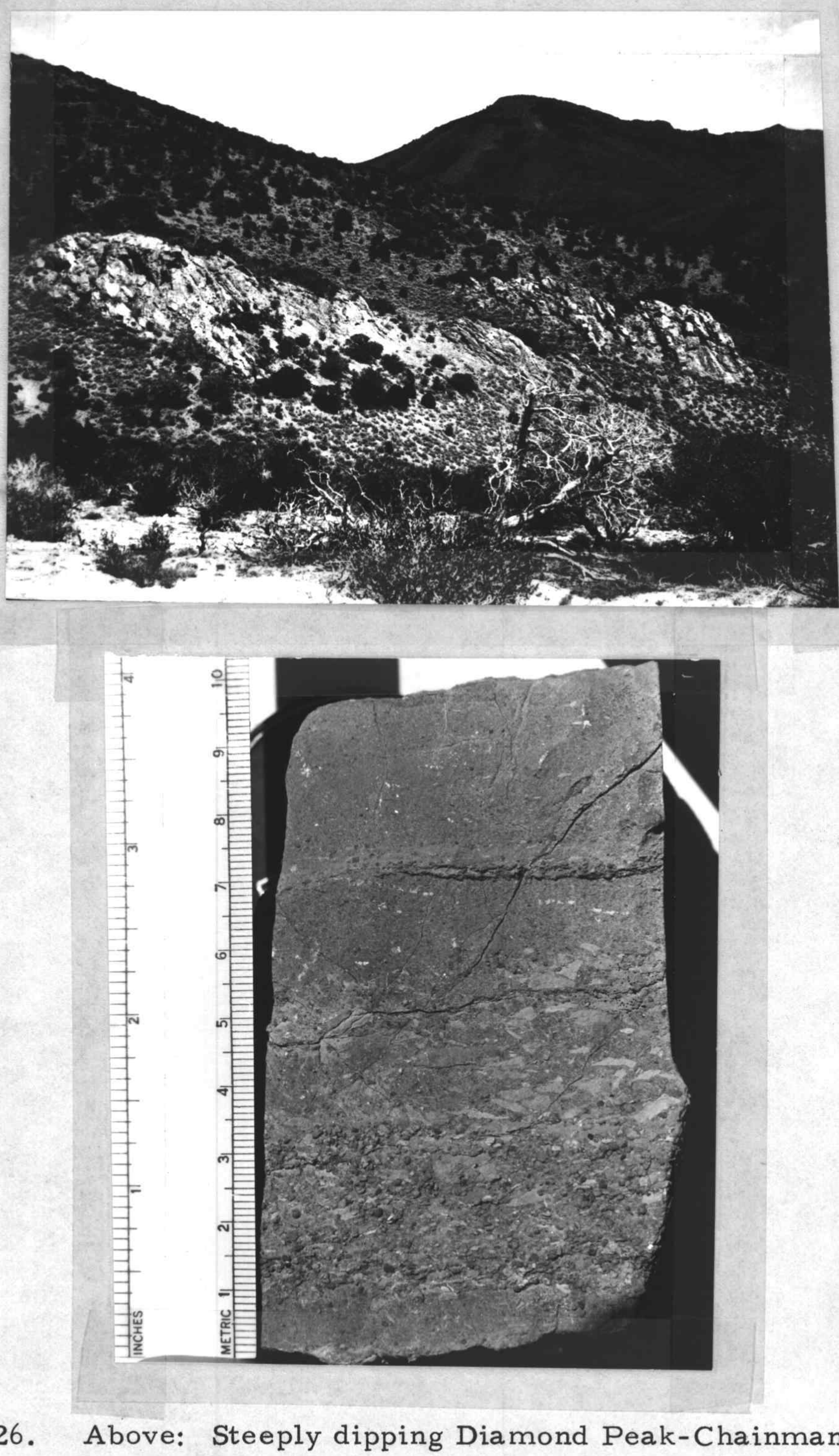


Figure 26. Above: Steeply dipping Diamond Peak-Chainman Equivalent beds at Clear Creek Canyon.
Below: Chert and carbonate clasts in graded bed, middle Diamond Peak-Chainman Equivalent.

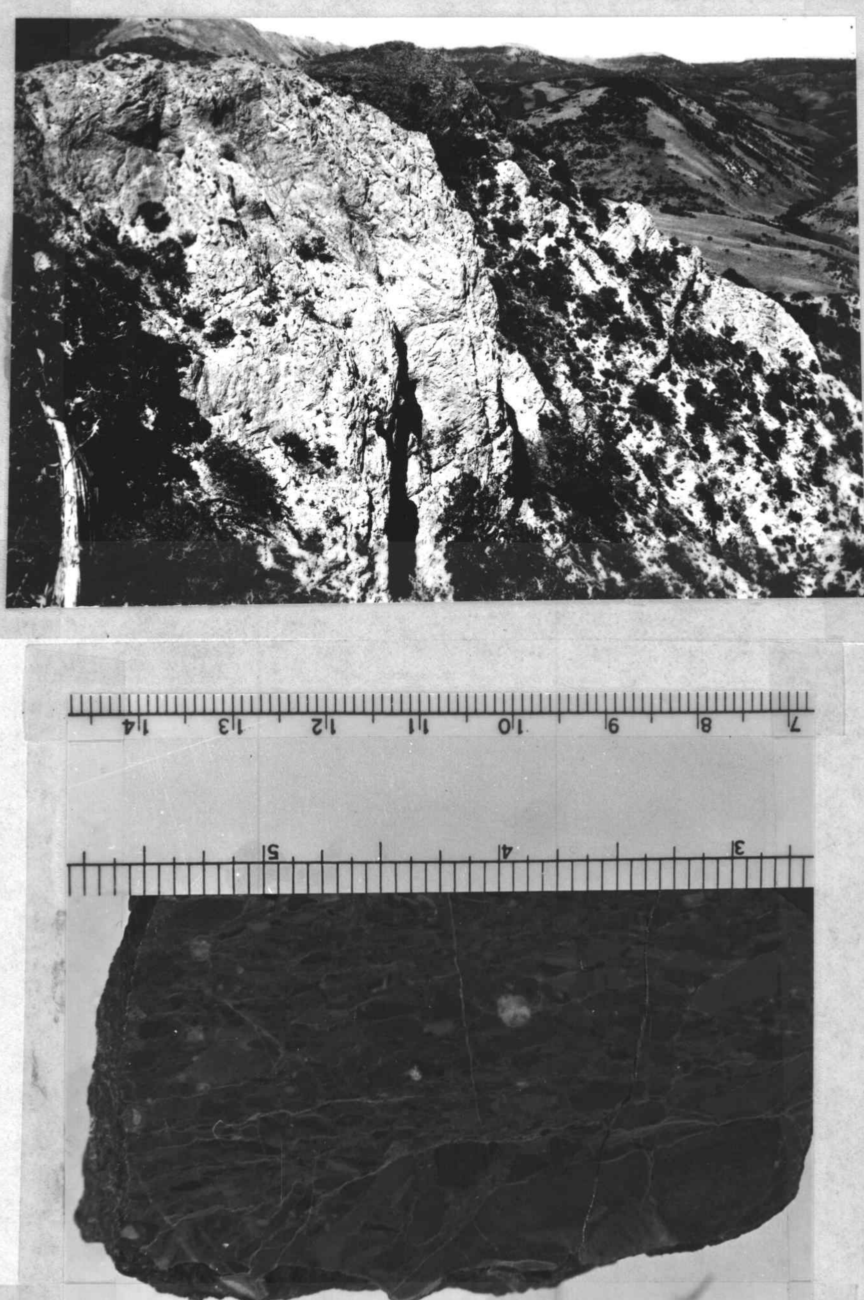


Figure 27. Above: Massive chert and limestone breccia above bedded conglomerates, Diamond Peak-Chainman Equivalent.
Below: Edgewise conglomerate from middle beds, Diamond Peak-Chainman Equivalent.

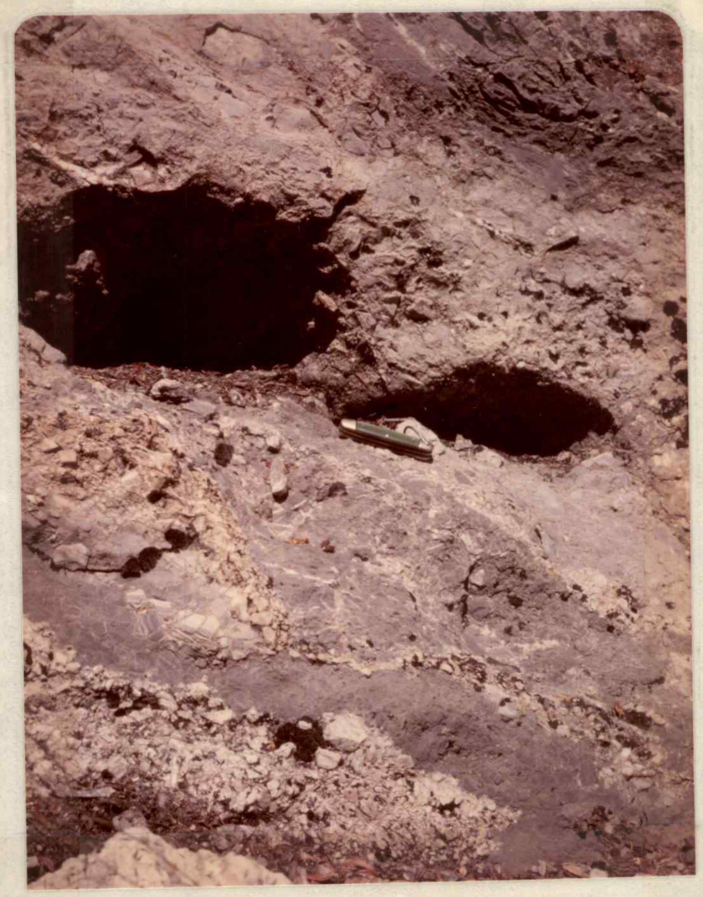


Figure 28. Flow structure in lime and chert-pebble conglomerate, upper part of Diamond Peak-Chainman Equivalent.

PENNSYLVANIAN ROCKS

General Statement

An angular unconformity cuts across the top of the Diamond Peak-Chainman Equivalent, as can be seen on the upper cliffs of Clear Creek Canyon (Figure 29). The fine crystalline limestones and silty lime wackestones above the unconformity have brachiopods of middle Pennsylvanian or younger age. A similar angular unconformity, which beveled strata of middle Devonian through middle Pennsylvanian age, is present in the Carlin-Pinyon Range area (Smith and Ketner, 1968), and is overlain by late Pennsylvanian through Permian-age rocks. These are the youngest Paleozoic rocks of the map area.

Lithology and Age

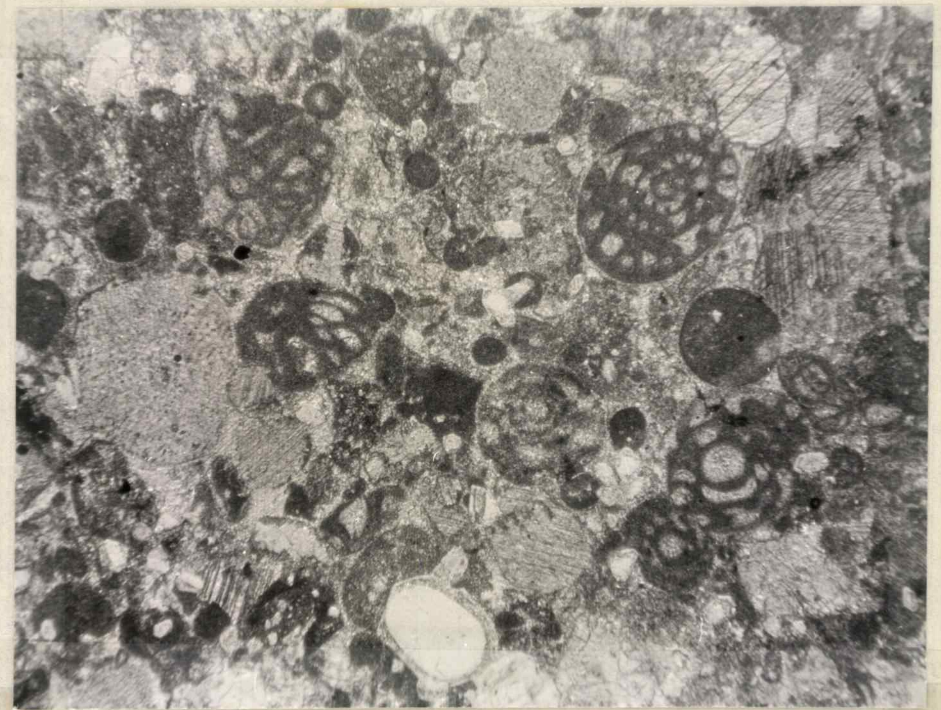
About 150 feet of Pennsylvanian strata crop out above the unconformity. The rocks are smooth, blocky, light to medium gray limestones with silty, yellow-weathering fossiliferous interbeds. The limestones are medium-grained crystalline carbonate to pelletal lime packstones in 2 to 3 foot beds. In thin section the lime packstones contain about 10% 1 mm quartz sand grains that have optically continuous hexagonal silica overgrowths. Rounded pellets and abraded fusulinids are also common as allochems in the packstones (Figure 29). Megafossils are numerous in the silty interbeds, and include large productid brachiopods, crinoid debris, and fenestellate bryozoans.

Brachiopods sent to John L. Carter were identified as Hustedia mormoni, Buxtonia sp., and Kutorginella sp. These have a maximum age of middle Pennsylvanian and may be younger.

Moldic porosity accounts for 2 to 3% of the rock where shelly fossil fragments have been dissolved. The limestone has undergone neomorphic recrystallization of the micrite matrix to microspar. Most fossils, especially fusulinids could not be identified due to diagenetic effects. Sparry calcite cement is present, although it composes a much smaller percentage of the cement than does micrite.

Depositional Environment

The Pennsylvanian rocks are relatively pure carbonates as compared to the earlier, Mississippian, basinal sediments. The reappearance of shelly fossils, and especially the presence of fusulinids, which were benthic organisms, indicate a shallow water environment. Sparry calcite in the cement and the rounded and broken condition of the fusulinids, indicates at least slightly agitated conditions, and the area may have been just below wave base, shortly after erosion at the unconformity at the base of the formation.



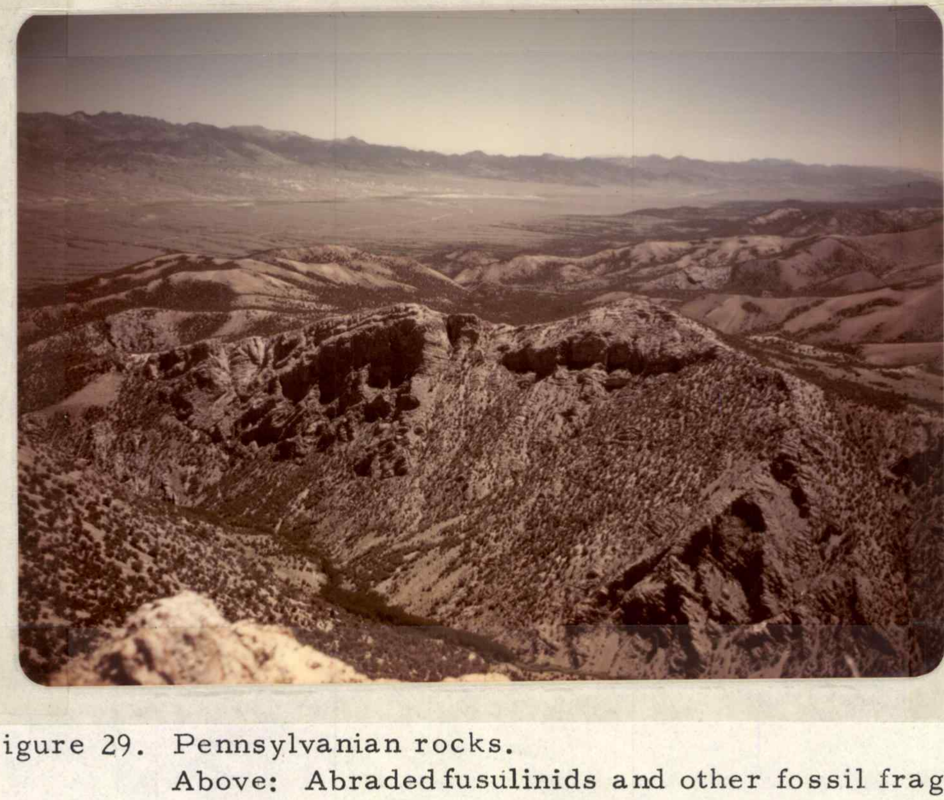


Figure 29. Pennsylvanian rocks.
Above: Abraded fusulinids and other fossil fragments. Note hexagonal overgrowth on quartz grain, lower middle part of photograph.
Below: Unconformity between Mississippian and Pennsylvanian strata at Clear Creek Canyon. Photograph area about three miles wide.

ALLOCHTHONOUS ROCKS

Allochthonous western basinal assemblage rocks were brought into the map area as part of the Roberts Mountains thrust plate sometime between the early Middle Devonian and early Mississippian time. Two types of allochthonous rocks are present in the map area: the older unit interrupts the regular stratigraphic sequence, and the younger forms an isolated block with basal contacts of bedded chert which are the same as those of the older type.

The older rocks, dated by conodonts (S509) as Late Ordovician, belong to the Vinini Formation. The formation was named by Merriam and Anderson (1942) for exposures at Vinini Creek on the east side of the Roberts Mountains. The Vinini rocks crop out above the Denay Limestone at Dobbin Summit, and above the early Pragian age mudstones that top the Lone Mountain Dolomite at hill 10385. They are a maximum of 130 feet thick at Dobbin Summit, in measured section D (Figure 30). There they are composed of 20 feet of black, well-bedded chert followed by 110 feet of varicolored shales, thin sandstones, and light-colored cherts. The chert layer is present at hill 10385, but the upper rocks are missing at the locality. The Vinini beds are overlain by the lower Mississippian (?) Webb Equivalent which is part of the overlap assemblages, at both localities.

The other type of allochthonous beds crop out in the north part of the area. A single thick block with a basal black chert, in normal fault contact with Tertiary volcanics and Ordovician rocks, underlies two hills, 9034 and 8793, north of Stargo Creek. They are bluish-gray dolomites, white porcellanites, brown fine-grained quartz arenites, and brown-weathering light gray cherts. The sandstones are often dolomitic and show sedimentary boudinage (Figure 31) or are very wavy bedded. The cherts are interbedded with the dolomites, which are thick bedded. The dolomites are very finely crystalline, and individual dolomite rhombohedra are very clear and interlock with no visible porosity. No fossils were found in these beds except for badly weathered remnants of crinoids and what appeared to be ghosts of tentaculites. No age was found for these allochthonous beds, but they are lithologically similar to the Devonian Woodruff Formation in the Carlin-Pinyon Range area as described by Smith and Ketner (1975).

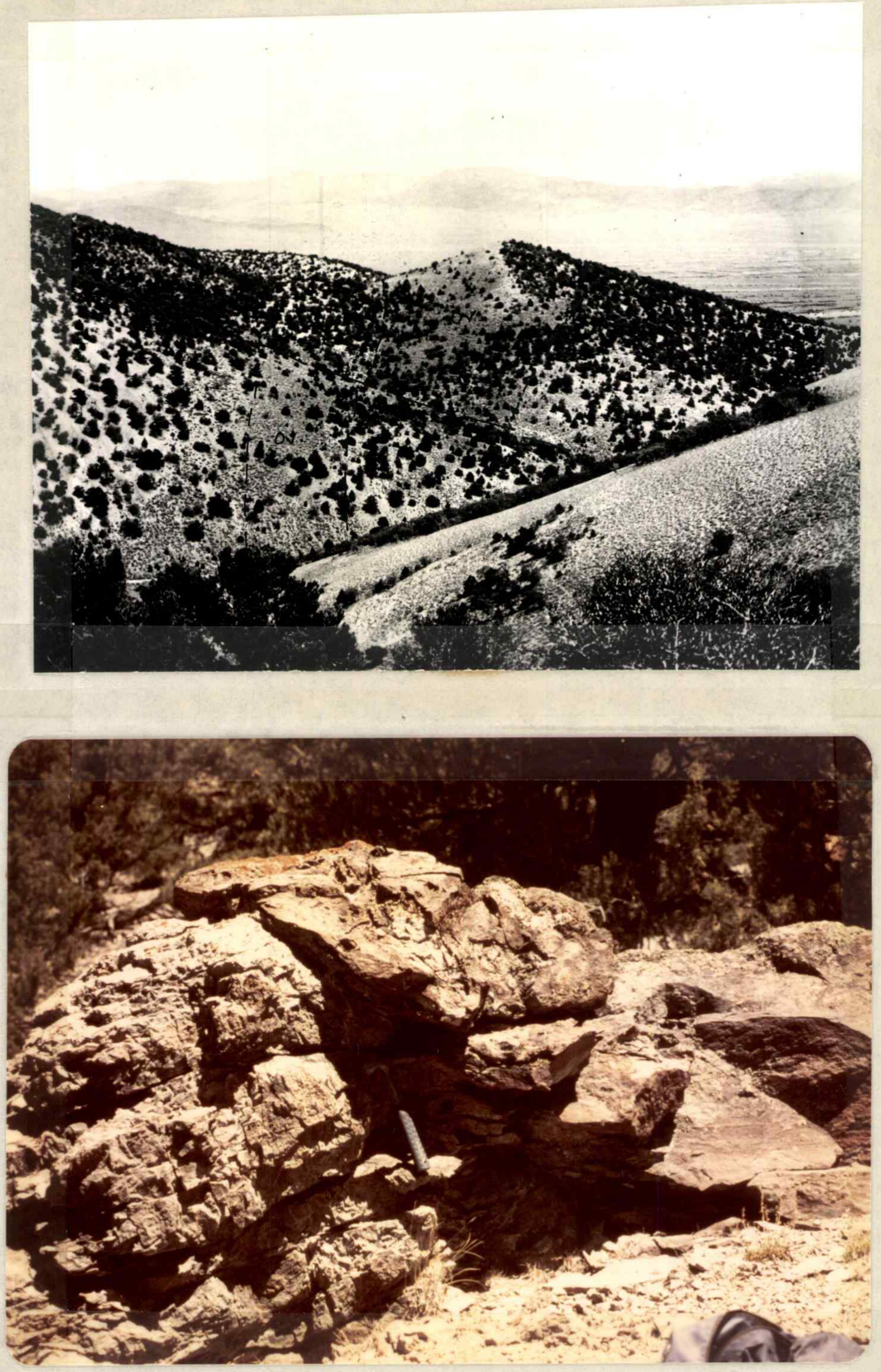


Figure 30. Above: Thrust rocks (Vinini Formation) in Dobbin Summit area.
Below: Silicified regolith, alteration of dolomite to chert at right of hammer.

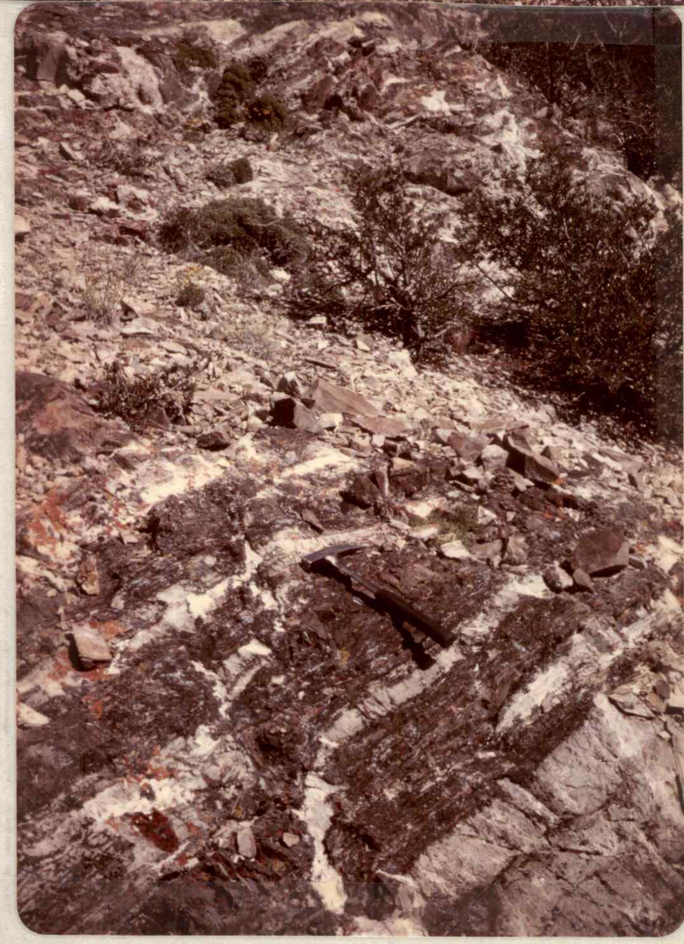


Figure 31. Devonian (?) age allochthonous rocks.
Above: Sedimentary boudinage in silty dolomite.
Below: Dark bands of chert in dolomite.

STRUCTURE

General Statement

Structure in the map area is controlled by two major episodes of fault activity that are typically found at this longitude in central Nevada. Thrust faulting obducts deep water cherts and fine grained detrital rocks from the western assemblage over autochthonous transitional and eastern assemblage rocks. This event occurred between Middle Devonian and early Mississippian time. The fault block Basin and Range topography was caused by large-scale Tertiary normal faulting. The ranges trend north and north-northeast in south-central Nevada. Both trends can be seen in the map area.

Thrust Faulting

The Vinini Formation can be seen on the map as an allochthonous unit overlying the Denay Limestone and the Lone Mountain Dolomite. The questionably Devonian allochthonous rocks are present in a single block in the north part of the area. Evidence that these rocks are allochthonous is as follows:

1. The Denay Limestone is seen in contact with the Vinini at three locations--the Dobbin Summit measured sections, the valley immediately northeast of East Dobbin Creek, and the northernmost

part of the map area. In all three locations, both the black chert and the underlying limestone are fractured. A similar bedded chert is seen Clear Creek between the Lone Mountain Dolomite and the Webb Equivalent, but is badly weathered and fractured.

2. The chert is folded or otherwise deformed in many places, especially at the base of the Devonian (?) block, which shows little other sign of thrust relationship in the area.

3. The Vinini Formation is lithologically anomalous to the carbonate rocks below them (however, they are very similar to the siliceous argillites of the Mississippian overlap assemblage).

4. A conodont sample dates the Vinini thrust detrital rocks as late Ordovician, which is much older than the autochthonous Devonian and Mississippian rocks that flank them.

5. The Woodruff (?) rocks contain light-colored deep water cherts, and the lowest exposures are the same deformed black cherts that are basal to the Vinini Formation within the map area.

Widespread eastward thrusting of western assemblage rocks occurred in latest Devonian--earliest Mississippian time in central Nevada during the Antler orogeny (Roberts and others, 1958). The Roberts Mountains thrust is the best known of these, and is dated in the Carlin-Pinyon Range area as earliest Kinderhook in age, before the deposition of the Webb Formation. The earliest conodont age date of the overlap assemblage in the map area is early but not earliest Kinderhook in age.

Normal Faulting

The entire stratigraphic sequence in the map area is cut by numerous normal faults. Displacements vary from a few inches to several thousand feet. The oldest major faults in the map area are longer, and trend north to north-northeast. These caused the vertical displacement of the range several hundred feet relative to the basin valleys on either side. A secondary fault system, roughly perpendicular to the main fault trend, was caused by later adjustment of the large, faulted blocks. Most of the north-trending faults have been interrupted by this later movement along west-trending faults.

At least one major reverse fault is present in the map area at Clear Creek Canyon. This north-striking fault juxtaposes the Diamond Peak-Chainman Equivalent with the Antelope Valley Limestone. The estimated throw of this fault is 2, 000 feet.

Secondary faults in the map area have smaller vertical displacements, ranging from a few inches to tens of feet. These are best documented where obtained from both aerial photographs and field observation, in the south part of the map area. Measured sections, where the stratigraphy could be more precisely determined, also have better documentation of faults.

Some of the youngest Teritary volcanic flows are cut by the major faults. The best examples are the hexagonally-jointed andesite flows on the ridge crests on either side of East Dobbin Summit Spring, which are visibly tilted and offset. It is probable that most of the faulting in the area is post-volcanic.

CONCLUSIONS

Shallow shelf deposition with a few variations existed in the map area during most of the Ordovician Period. Primary structures in the lower Goodwin Formation reflect local slope conditions that disappear higher in the formation. A shallowing trend is seen in the Antelope Valley Limestone. The overlying Copenhagen Formation represents the last phase of regression of the Sauk sequence. The dolomite member of the Eureka Quartzite indicates an eastward incursion of marine conditions into a possibly supratidal environment. Intertidal lagoonal conditions indicated by the lower Hanson Creek Formation were followed by much deeper, basinal deposition in the upper part of the formation. The boundary between eastern shelf and transitional slope facies shifts from the west to east of the map area during the Silurian. The Roberts Mountains Formation is the deepest basinal facies yet seen in the map area, and is probably some distance from the facies boundary. Dolomitization of the Roberts Mountains Formation at Clear Creek foreshadows the progradation of the overlying Lone Mountain Dolomite.

The boundary between the eastern dolomite suite and the limestone clastic suite is established between Clear Creek and Dobbin Summit during earliest Devonian time. The Windmill Limestone is entirely equivalent to part of the Lone Mountain Dolomite. The lower part of the Rabbit Hill Limestone is possibly equivalent to the uppermost Lone Mountain Dolomite. The Windmill and Rabbit Hill Limestones have proximal basin lithologies, with somewhat thicker allodapic beds than exist at Copenhagen Canyon. The Denay Limestone is composed of distal, basin sediments which indicate a deeper environment than either of the preceeding formations.

The most striking feature of the formations between the Eureka Quartzite and the Roberts Mountains thrust plate is their thickness, or lack of same. Even the Lone Mountain Dolomite is only 510 feet thick which is less than half the thickness the formation achieves elsewhere. Such condensation of a normal section could occur in a slope area which is often eroded by contourites or turbidites, or in a starved basin beyond the edge of the platform or the base of the continental shelf.

The oldest date for the Roberts Mountains thrust in the map area is early Kinderhook. The earliest Mississippian overlap assemblage rocks in the map area are deep water facies of the Antler Foreland basin. They bear a striking resemblance to the Mississippian rocks of the Carlin-Pinyon Range area. The Webb Equivalent is a deep water radiolarian argillite. The Camp Creek Equivalent begins as an intermediate, thick-bedded distal turbidite facies and grades upward to a classic proximal turbidite facies.

Sources for the chert and carbonate conglomerates of the Diamond Peak-Chainman Equivalent are the Antler Highland to the west and the carbonate platform rocks to the east.

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APPENDIX

FAUNAL LISTS AND LOCALITIES

All localities in Stargo Creek, Dobbin Summit, and Danville 7-1/2 minute quadrangles, northern Nye County, Nevada.

Identifications and age assignments as follows (except where noted):
Brachiopods: M. T. Wise and J. G. Johnson
Conodonts: G. Klapper
Tabulate corals: R. A. Flory

Section: A - Dobbin Summit
Location: Approximately 0.8 mi. S 67° W of the NE corner of section 5, T. 12 N., R. 49 E., Stargo Creek 7-1/2 minute quadrangle.

Collection: AO (float) Tabulate Corals
Footage: Base of section A

Favosites birchensis

Collection: A1 (float) Tabulate Corals
Footage: 1 foot

Favosites birchensis
Squameofavosites murphyi
Favosites sp. A
Aulopora sp. (possibly *A. watkinsi*)

Collection: A2 (float) Tabulate Corals
Footage: 2 feet

Squameofavosites murphyi
Favosites sp. A

Collection: A5 (float) Tabulate Corals
Footage: 5 feet

Favosites birchensis
Favosites sp. A
Aulopora sp.

Collection: A30 (float) Tabulate Corals
Footage: 30 feet

Favosites birchensis
Favosites sp. A
Emmonsia sp. A

Age and correlation: Tabulate corals of A0 to A30 ". . . belong to the *Squameofavosites murphyi* Zone" (= *Gypidula pelagica lux* fauna). (Flory, written comm. Aug. 5, 1976). 1617 brachiopod fauna (Johnson, 1973) of Brachiopod Interval 2 is associated with this tabulate coral zone (Flory, oral comm. July 1, 1976). Early Lochkovian.

Collection: A35 Conodonts
Footage: 35 feet

Ozarkodina excavata excavata
O. n. sp. aff. O. carlsi

Age and correlation: Conodont Fauna 4?

Collection: A35 (float) Tabulate Corals
Footage: 35 feet

Favosites sp. A
Favosites sp. B

Collection: A40 Silicified Brachiopods
Footage: 40 feet

Spirigerina supramarginalis 2
indet. brachiopod 1

Age and correlation: Brachiopod Interval 3 or 4 (Quadrithyris Zone)

Collection: A40 (float) Tabulate Corals
Footage: 40 feet

Favosites sp. B

Collection: A99 Tabulate Corals
Footage: 99 feet

Favosites sp. A

Age and correlation: Tabulate corals of ". . . A35 to A99 contain species that are new to me and therefore I am unable to assign them to specific zones. . . . " (Flory, written comm. Aug. 5, 1976). Corals directly above this interval belong to the Favosites windmillensis Zone (equivalent to the upper part of Brachiopod Interval 2 and Brachiopod Interval 3 (Johnson, oral comm. Aug. 12, 1976)). Conodonts within this interval (at A35) are questionably assigned to Conodont Fauna 4 (= Brachiopod Interval 4) and brachiopods within this interval (at A40) belong to either Brachiopod Interval 3 or 4. Since conodonts are questionably assigned, then brachiopod and tabulate coral faunas are used to give a probable age assignment to Brachiopod Interval 3 (Johnson, Aug. 12, 1976). Late Lochkovian.

Collection: A106 (float) Tabulate Corals
Footage: 106 feet

Favosites windmillensis
Favosites sp. C

Collection: A107 (float) Tabulate Corals
Footage: 107 feet

Favosites windmillensis
Favosites sp. D

Age and correlation: ". . . A106 to A107 is characteristic of the Favosites windmillensis fauna. . ." (Flory, written comm. Aug. 5, 1976). These tabulate corals are equivalent to upper Brachiopod Interval 2 and Brachiopod Interval 3. Late Lochkovian.

Collection: A113 (float) Tabulate Corals
Footage: 113 feet

Squameofavosites cf. S. coalcanyonensis

Collection: A114 (float) Tabulate Corals
Footage: 114 feet

Syringopora sp. A
Thamnopora sp. A

Collection: A115 (float) Tabulate Corals
Footage: 115 feet

Squameofavosites coalcanyonensis

Age and correlation: ". . . A113 to A115 is characteristic of the Squameofavosites coalcanyonensis Zone. . ." (Flory, written comm. Aug. 5, 1976). These tabulate corals are equivalent to Brachiopod Interval 4. Late Lochkovian.

Collection: A119 Tentaculites (identified by S. Eldridge)
Footage: 119 feet

Nowakia acuaria
Age and correlation: Late Lochkovian to Pragian.

Section: B - Dobbin Summit
Location: Approximately 0.9 mi. S 66° W of the NE corner of section 5, T. 12 N., R. 49 E., Stargo Creek 7-1/2 minute quadrangle.

Collection: B10 Silicified Brachiopods, and Conodonts
Footage: 10 feet

Skenidioides aff. S. robertsensis 90
Salopina submurifer 217
Schizophoria sp. 10
Protocortezorthis sp. 2
Resserella elegantuloides 8
Leptaena sp. A 1
Eoschuchertella sp. 7
Aesopomum sp. 7
indet. strophomenid 1
Antirhynchonella sp. 63
Gypidula sp. (small and smooth) 75
Werneckeella hartensis 7
Thliborhynchia? sp. (fine ribbed) 2
Atrypa sp. 37
Reticulatrypa sp. 169

Spirigerina supramarginalis 19
Ogilviella cf. rotunda 16
Protathyris sp. 29
Metaplasia lenzi 62
Cyrtina sp. A 23
Cyrtinaella sp. 5

Ozarkodina sp. nov. C
O. sp. nov. D
Pedavis pesavis subsp. nov. A

indet. pelecypod
indet. platycerid

Age and correlation: Brachiopods and conodonts assign the collection to Brachiopod Interval 3 (Lower Quadrithyris Subzone). No previous brachiopod assemblage from Interval 3 is known from central Nevada. The closest correlative assemblage is from Royal Creek, Yukon, in section II 603-630 feet above the base. (Lenz and Pedder, 1972). Late Lochkovian.

Collection: B64 Silicified Brachiopods, and Conodonts
Footage: 64 feet

indet. dalmanellid 5
indet. gypidulid 3
Meristina sp. A 4

Ozarkodina excavata excavata
O. n. sp. aff. O. carlsi
Icriodus n. sp. (characteristic species of Fauna 4)

Age and correlation: Meristina sp. A and Fauna 4 conodonts assign the collection to Brachiopod Interval 4. Late Lochkovian.

Collection: B145 Silicified Brachiopods (in float), and Conodonts (in outcrop)
Footage: 145 feet

Levenea sp. 1
Spinoplasia sp. A 42

Pedavis sp. nov. A
Icriodus "latericrescens" n. subsp. B
I. huddlei curvicauda

Age and correlation: This is probably basal Spinoplasia Zone (Brachiopod Interval 5) based on a precurser species to Spinoplasia roeni of the Spinoplasia Zone and the occurrence of Icriodus "latericrescens" n. subsp. B in an intermediate position between shelly faunas of the Quadrithyris and Spinoplasia zones. Early Pragian.

Collection: B186 Silicified Brachiopods, and Conodonts
Footage: 186 feet

Orthostrophella monitorensis 14
Dalejina sp. 4
Levenea navicula 16

Leptaena fremonti 5
Eoschuchertella sp. 1
indet. stropheodontid sp. 2
Anoplia sp. 2
Pleiopleurina anticlastica 5
Coelospira concava 302
Leptocoelia murphyi 67
Meristella martini (without ventral sulcus) 30
Pseudoparazyga sp. 1
Howellella cycloptera 35
Spinoplasia roeni 66
Cyrtina sp. 10
Rensselaerina? sp. 1

Icriodus huddlei curvicauda
I. "latericrescens" subsp. B

Indet. porifera

Collection: B255 Silicified Brachiopods, and Conodonts
Footage: 255 feet

Levenea navicula 20
Eoschuchertella sp. 1
Pleiopleurina anticlastica 2
Atrypa? sp. 2
Coelospira concava 19
Leptocoelia murphyi 34
Meristella martini 6
Howellella cycloptera 19
Megakozlowskiella magnapleura 7
Rensselaerina? sp. 2

Icriodus huddlei curvicauda

Age and correlation: The conodonts (found in Faunas 5 and 6) and brachiopods of the Lower Spinoplasia Subzone assign these collections to Brachiopod Interval 5. Early Pragian.

Collection: B430 Silicified Brachiopods, and Conodonts
Footage: 430 feet

Dalejina sp. 1
Meristella martini 5
Howellella cycloptera 13

Eognathodus sulcatus (late form)
Icriodus huddlei curvicauda?

indet. gastropod

Collection: B448 Silicified Brachiopods
Footage: 448 feet

Levenea navicula 4
Coelospira concava 1
Leptocoelia sp. 3
Meristella martini 10
Howellella cycloptera 2
Rensselaeria? sp. 1

Age and correlation: Conodonts from this interval (at B430) belong to Fauna 6. The majority of the brachiopods are assignable to the Spinoplasia Zone (= Brachiopod Intervals 5 and 6). The existence of a Trematospira Subzone brachiopod (Rensselaeria? sp.) in collection B448 indicates a possible mixing of biofacies. Rensselaeria? sp. and Fauna 6 conodonts assign these collections to Brachiopod Interval 6. Mid Pragian.

Collection: B535 Silicified Brachiopods, and Conodonts
Footage: 535 feet

Leptocoelia murphyi 15
Howellella sp. 5

Icriodus huddlei curvicauda

Age and correlation: Brachiopods from this collection occur in Brachiopod Intervals 5 and 6; conodonts occur in Conodont Faunas 5 - 7 (= Brachiopod Intervals 5 - 9). Brachiopod and conodont faunas are too limited in collection to assign a definite age other than Pragian. Stratigraphically, this is probably assignable to Brachiopod Interval 6. Pragian.

Collection: B562 Silicified Brachiopods
Footage: 562 feet

Dalejina sp. 64
Levenea cf. navicula 19
Leptaena sp. 1
Eoschuchertella sp. 15
Coelospira sp. 5
Leptocoelia murphyi 117
Meristella martini 449
Nucleospira sp. B 11
Acrospirifer kobehana 139
Megakozlowskiella cf. raricosta 33
Spinoplasia sp. C 5
Cyrtina sp. 2
Centronella? sp. (biconvex) 2
indet. brachiopods 4

indet. gastropods
indet. porifera

Age and correlation: Brachiopods from this collection belong to the Acrospirifer kobehana Zone (= Brachiopod Interval 8 and 9). None of the listed species are indicative of either the upper or lower subzones, but are representative throughout the zone. The two exceptions are Centronella? sp. (biconvex) and Spinoplasia sp. C which have not been previously reported. Late Pragian.

Collection: B577 Silicified Brachiopods, and Conodonts
Footage: 577 feet

Dalejina sp. 9
Levenea cf. navicula 16
Leptaena sp. 2
Stropheodonta filicosta? 3
Coelospira sp. 8
Leptocoelia murphyi 33
Meristella martini 97
Nucleospira sp. 2
Acrospirifer kobehana 99
Megakozlowskiella sp. 5
Spinoplasia sp. C 44
Centronella? sp. (biconvex) 11

Polygnathus dehiscens
Icriodus huddlei group

indet. gastropod
indet. orthocone nautiloid cephalopod
crinoid calices - ". . . firmly identified as flexible crinoids (Subclass Flexicrinidae). They stand somewhere between the genus Lecanocrinus, which ranges from the base of the Niagran to the top of the Middle Devonian, and the genus Mespilocrinus, which is confined to the lower half of the Mississippian. . . . They are not close to any of the other genera in this group of crinoids and may be new. . . . " (N. G. Lane, written comm. May 18, 1976).

Age and correlation: Conodonts belong to Fauna 7 and brachiopods belong to the A. kobehana Zone. Based on the overlapping of P. dehiscens and the A. kobehana Zone (= Brachiopod Intervals 8 and 9), this collection can be assigned to the upper subzone of the A. kobehana Zone (Brachiopod Interval 9). Late Pragian.

Collection: B590 Conodonts
Footage: 590 feet

Polygnathus dehiscens
Icriodus huddlei group

Age and correlation: Conodonts belong to either Fauna 7 or 8 and may be equivalent to the upper part of the A. kobehana brachiopod zone or the lower part of the Eurekaspirifer pinyonensis brachiopod zone (= Brachiopod Intervals 9 or 10). Late Pragian or Early Zlichovian.

Collection: B714 Conodonts
Footage: 714 feet

Polygnathus pseudofoliatus
P. kockelianus australis
P. parawebbi

Age and correlation: "approx. middle Eifelian". P. k. australis is found with brachiopods of the Leptathyris circula Zone (= Brachiopod Intervals 15 and 16). Mid Couvinian.

Collection: B749
Footage: 749 feet

indet. brachiopods
indet. styliolinids (tentaculites)

Age and correlation: Tentaculites assign this collection to the Devonian.

Section: D - Dobbin Summit
Location: Approximately 0.5 mi. S 46° W of the NE corner of section 5, T. 12 N., R. 49 E., Stargo Creek 7-1/2 minute quadrangle.

Collection: D03 Silicified Brachiopods, and Conodonts
Footage: 3 feet

indet. orthid 1
Skenidioides sp. 3
Salopina? sp. 1
Chonetoidea andersoni 2
Conchidium synclastica? 2
Cymbidium? sp. 3
Brooksina? sp. 4
Pentamerifera? sp. 1
indet. ribbed pentamerid 1
indet. smooth pentamerid 29
"Atrypa" sp. 5
Reticulatrypa savagei 6
Cryptatrypa? sp. 2
indet. brachiopods 27

Ozarkodina excavata excavata

Age and correlation: Brachiopods assign this collection to C fauna (Johnson, and others, 1976). Early Ludlovian.

Collection: D45 Silicified Brachiopods, and Conodonts
Footage: 45 feet

indet. orthid 2
Kirkidium cf. vogulicum 1
Atrypa sp. 2
Gracianella? cf. plicumbra 3

Ozarkodina confluens beta morphotype
O. excavata excavata

Age and correlation: Brachiopods occur somewhere between C and D faunas (Johnson, and others, 1976). Early to mid Ludlovian.

Collection: D160 Silicified Brachiopods, and Conodonts
Footage: 160 feet

Ptychopleurella sp. 1
"Dolerorthis" sp. 8
Dicaelosia cf. nitida 4
Pentamerifera? sp. (w/cardinal process) 60
Reticulatrypa neutra 59
Atrypella sp. 76
Cryptatrypa triangularis 11
Gracianella sp. 36
Delthyris sp. 7
indet. brachiopod 2

Ozarkodina excavata excavata

indet. halysitid
indet. auloporid
indet. favositids
indet. rugosans
indet. crinoid calicus

Age and correlation: The brachiopod fauna is "like at PHC IIc 998 - 1156 . . . " feet (Pete Hanson Creek, Roberts Mountains, Nevada) ". . . late Ludlow or early Pridoli". This is based on brachiopod faunal similarity - especially the occurrence of Pentamerifera? sp. (w/cardinal process). (Johnson, written comm., July 2, 1976) Late Ludlovian or early Pridolian.

Collection: D187 Conodonts
Footage: 187 feet

Pelekysgnathus index
Ozarkodina excavata excavata
Delotaxis elegans

Age and correlation: "P. index fauna in Roberts Mountains, approx. = Pridolian" (Klapper, written comm., Apr. 27, 1976). Pridolian.

Collection: D221 Silicified Brachiopods
Footage: 221 feet

Skenidioides sp. 1
Salopina submurifer 17
Schizophoria sp. 15
Anastrophia sp. 1
Gypidula cf. pelagica 18
Machaeraria sp. 13
Atrypa nieczlawiensis 289
Spirigerina marginaliformis 94
Cryptatrypa sp. 6
indet. ribbed atrypid 4

indet. smooth atrypid 1
Meristella cf. wisniowskii 6
Undispirifer? sp. 1
Cyrtina sp. 2

indet. platycerid
indet. rugosan
indet. echinoid?
indet. crinoid calices and large (2 cm diam.) columnals
indet. porifera

Age and correlation: This brachiopod assemblage can be assigned to F fauna (Johnson, and others, 1973), Brachiopod Intervals 1 and 2. Lower Lochkovian.

Collection: D280 Silicified Brachiopods, and Conodonts
Footage: 280 feet

Skenidioides aff. S. robertsensis 342
Salopina submurifer 521
Schizophoria sp. 102
Protocortezorthis sp. 11
Resserella sp. 30
Leptaena sp. 4
Leptaenisca sp. 8
Eoschuchertella sp. A 5
Aesopomum sp. 7
Antirhynchonella sp. 91
Gypidula cf. sp. F 1
Gypidula sp. (small and smooth) 38
Thliborhynchia kerri 9
Werneckeella hartensis 4
Atrypa sp. 107
Reticulatrypa sp. 472
Spirigerina supramarginalis 101
Ogilviella cf. rotunda 32
Protathyris sp. 59
Metaplasia sp. 58
Cyrtina sp. A 64
Cyrtinaella sp. 37

Ozarkodina sp. nov. C
O. sp. nov. D

Orthonychia sp. (gastropod identified by D. Rohr)
indet. platycerid
indet. ostracods
indet. crinoid calices and large (1.5 cm diam.) columnals
indet. auloporid
Rhyziophyllum sp.
indet. rugosan

Age and correlation: Brachiopods are assignable to the Lower Quadrithyris Subzone (= Brachiopod Interval 3). Conodonts belong to Fauna 3. This collection is virtually identical to collection B10. Late Lochkovian.

Collection: D735 Tentaculites (identified by S. Eldridge)
Footage: 735 feet

Nowakia sp.
Viriatella procera

Age and correlation: V. procera is equivalent in age to the Leptathyris circula Zone (= Brachiopod Interval 15 to 16). Lower Couvinian.

Collection: D880 Conodonts
Footage: 880 feet

Polygnathus parawebbi
P. aff. P. eiflius
Belodella sp.
Ozarkodina n. sp. (precursor of O. brevis)

Age and correlation: "approx. upper Eifelian. P. aff. P. eiflius known in the Cherry Valley in New York (Klapper, 1971)" (Klapper, written comm., Aug. 12, 1976). Late Couvinian.

Collection: D885 Silicified Brachiopods, and Conodonts
Footage: 885 feet

Cassidirostrum? sp. 3
Leiorhynchus sp. 40
Anatrypa (Variatrypa) licta 1
Dubaria cf. thetis 6
Leptathyris cf. circula 598
Warrenella kirki praekirki 83
Echinocoelia denayensis 26
indet. brachiopods 5

Polygnathus kockelianus kockelianus
P. pseudofoliatus
P. parawebbi
P. intermedius

Age and correlation: Conodonts are dated as "upper Eifelian" (Klapper, written comm., Apr. 27, 1976). Brachiopods in this collection are assigned to the L. circula Zone (= Brachiopod Intervals 15 and 16). L. circula Zone brachiopods have previously been found associated with Polygnathus kockelianus australis. This is the first reported collection in which L. circula Zone brachiopods have been associate with the stratigraphically younger P. k. kockelianus (Johnson, oral comm. Aug. 12, 1976). This would indicate that the collection is assignable to Brachiopod Interval 16. Late Couvinian.

Section: F - Dobbin Summit
Location: Approximately 0.75 mi. N 75° W of the SE corner of section 32, T. 13 N., R. 49 E., Stargo Creek 7-1/2 minute quadrangle.

Collection: F170 Conodonts
Footage: 170 feet

Gnathodus punctatus
Siphonodella isosticha
S. quadruplicata
Pseudopolygnathus multistriatus
reworked Palmatolepis spp.

Collection: F293 Conodonts
Footage: 293 feet

Siphonodella sp. indet.

Collection: F346 Conodonts
Footage: 346 feet

Siphonodella sp. indet.
Polygnathus communis communis

Collection: F464 Conodonts
Footage: 464 feet

Siphonodella sp. indet.
S. isosticha
Polygnathus communis communis
reworked Palmatolepis spp.

Collection: F500 Conodonts
Footage: 500 feet

Siphonodella isosticha
Gnathodus punctatus
Pseudopolygnathus sp.
reworked Palmatolepis spp.

Age and correlation: "The youngest species from these collections (G. punctatus, S. isosticha, and Pseudopolygnathus multistriatus) suggest a correlation with faunal unit 2 of Lane (1974, AAPG Bull.). This faunal unit occurs near the Kinderhookian-Osagean boundary. . . . " Kinderhookian-Osagean

Collection: SC710-4 Silicified Brachiopods
Location: Approximately 0.7 mi. N 87^{o} W of the NE corner of section 5, T. 12 N., R. 49 E., Stargo Creek 7-1/2 minute quadrangle.

Dalejina sp. 4
Levenea navicula 36
Leptaena sp. 1
Eoschuchertella sp. 1
indet. rhynchonellid? 1
Coelospira pseudocamilla 16
Leptocoelia murphyi 4
Meristella martini 5
Costispirifer arenosus 5
Cyrtina cf. varia 6

indet. spiriferoid 2
Rensselaeria? sp. 1
indet. brachiopods 7

Age and correlation: The brachiopods of the collection are assignable to Brachiopod Interval 7 (Costispirifer Subzone). Middle Pragian.

Collection: S509 Conodonts
Location: Approximately 0.94 mi. S 75° W of the NE corner of section 17, T. 13 N., R. 49 E., on the very western edge of the Stargo Creek 7-1/2 minute quadrangle.

Plectodina furcata
(all six elements) - dominant species of fauna

Oulodus oregonia ulrichi

Phragmodus sp.
Plegagnathus nelsoni
Belodina sp.
Protopanderodus insculptus
Dapsilodus mutatus
Coelocerodontus trigonius
Panderodus sp.
Drepanoistodus suberectus

Age and correlation: Late Ordovician.

Collection: T102 Tabulate Corals
Location: Approximately 200 feet N 17° W of the NW corner of section 31, T. 12 N., R. 49 E., Danville 7-1/2 minute quadrangle.

Favosites copenhagenae

Age and correlation: F. copenhagenae ". . . is found in both the Striatopora Zone and the Grabaulites distincta fauna at Rabbit Hill." (Flory, written comm., Aug. 5, 1976). The Striatopora issa Zone and Grabaulites distincta fauna are associated with Spinoplasia Zone Brachiopods (5 Brachiopod Interval 6). Lower Pragian.

Collection: K206 Conodonts
Location: Approximately 0.6 mi. S 68° W of the summit of Hill 10385 in the unsectioned portion of the Danville 7-1/2 minute quadrangle.

Gnathodus punctatus
Siphonodella isosticha
Polygnathus communis communis
reworked Palmatolepis spp.

Collection: K304 Condonts
Location: Approximately 0.7 mi. N 71° W of the summit of Hill 10385 in the unsectioned portion of the Danville 7-1/2 minute quadrangle.

Gnathodus punctatus
Siphonodella obsoleta

The following are interpreted as reworked into this association:

Siphonodella quadruplicata
S. cooperi
S. lobata
S. sandbergi
S. duplicata
Pseudopolygnathus marburgensis
P. trigonicus
P. dentilineatus
Polygnathus longiposticus
P. inornatus
P. distortus
reworked Palmatolepis spp.

Age and correlation: These collections are equivalent in age to those in section F at Dobbin Summit, Kinderhookian-Osagean. "With these Mississippian collections. . . . we are assuming that the youngest species (G. punctatus, etc.) are indigenous, whereas in fact they could also be reworked." (Klapper, written comm. Aug. 12, 1976). Kinderhookian-Osagean.

Collections: 731-5 and 84-4 Brachiopods identified by J. L. Carter.
Location: Approximately 1.05 mi. N 56° W of the SW corner of section 6, T. 11 N., R. 49 E., Danville 7-1/2 minute quadrangle.

Buxtonia n. sp.
Hustedia "mormoni"
chonetid -- indeterminate genus
Kutorginella sp. (little likelihood for this to be any other genus)
?Antiquatonia sp. (ID uncertain because ears not preserved)

Age and correlation: ". . . 84-4 and 731-5 appear to be Mid-Pennsylvanian or younger in age due to the presence of Hustedia "mormoni" and Kutorginella sp. At least I am not aware of any older occurrences for the forms than Middle Penn." (Carter, written comm. Nov. 6, 1974). Mid Pennsylvanian or younger.