Bezzorides - O'Neil Pass

Pennsylvanian

Oquirrh Fm. (?)

best exposures NE side of Cold Spg. Mt.
900 ft.
predominantly gy. lst., mass. to platy, rough surfaced outcrops highly silicified in places. Mudstone intbdd., Tn. to brn. (F), red+yell. chips (W).
Base not exposed. In Gardner's area, the Oquirrh conformably overlies intbdd. lst. + ss. (M - E.P.)
fossils: Derbyia sp. Carbonif. - P
Composita sp. L.D. - P
Roberts says these rocks resemble the Oquirrh Fm. at the Delno District.

Permian

Phosphoria Fm.

at type locality 200-480 ft. tk.
dk. chert, phosphorite, cherty mudst. & minor dk. carbonate rx.

at O'Neil Pass:
" ~~The~~ Dark siltstone, cht., and phosphorite bds. of t. Phosphoria are easily distinguished from underlying lst. of the Oquirrh Fm (?) and the basal cg. and brn. to Tn., platy sts. of the Dinwoody Fm. thkness ≅ 800-900'.
Permian fossils; Roberts agrees This is Phosphoria

Triassic

Dinwoody Fm.—

2,400' = Total.

lower member (660') - prominent cg. bds. 50' to < 1" tk.

upper member (1,740') — sts.
Only one ammonite - E.T. (Silberling)

Thaynes Fm.—

mainly lst. w/ minor calcareous sts. bds.

620 ft. tk. Lst. is lt. brn. to tn. (w), forms tk. ledges. Intbdd. w/ t/b, x-bdd sts. & zones of broken foss. frags.

Alternating w/ brn. lst. are dense, rexlized, bk.- blu. gy. lst. bds.

Ammonoids nr. base Psuedosageceras (cf. P. multilobatum) Silberling

Granodiorite Intrusive

dikelike Jurassic (??)

lt. colored, m. grn.
visible xls. of feldspar, qz. & highly weathered Bt.
hypidiomorphic-granular, xls. 1 mm - 3 mm., Pg (highly altered)
An_{30-40} = 30%. Kspar (rel. fresh) = 10%; qz = 17%;
Bt = 20%; chlorite. Mt. Zr, Ap

Tertiary

Ash underlies Rhyolite flows.

ash = wh. to gy., mass. to well-bdd., no non-volc. debris.
vitric tuff, mainly of glass shards in glass dust.
minor phenos. of Pg (An_{30-35}) & a mafic (prob. amphibole).
probabely air-laid.
about 50 ft tk. 260' in Gardner's area.

Rhyolite — flow(s)
rd.-gy., porphyritic, rd-brn (W) smooth surface.
many phenos. of Qz & fdsp.
Qz, sanidine, Pg. & Bt = phenos. (wxm.)
groundmass = felted mosaic of microxln. fd. + Qz. intergrown
Mt + Zc.
max. tk. = 500 ft.
~ to rx. in Contact mining dist. (Schrader, 1935)
15.4 m.y. old (Schilling, 1965, p. 58)

Contents continued

INTRODUCTION

Location

The O'Neil Pass area is located on the northeast side of the Snake Mountains[1] in Elko County, northeastern Nevada. Wells, Nevada, about 40 miles to the south, is the nearest incorporated town; the settlement of Contact, on U. S. Highway 93, is about 10 miles north of the O'Neil Pass area. Highway 93, the main route from Twin Falls, Idaho to Wells, is a short distance east of the area (Figure 1). The O'Neil Pass area covers about 25 square miles, including parts of T. 43 and 44 S., R. 62 E.; it lies between latitudes 41° 34' and 41° 45' N., and longitudes 114° 52' and 115° W. The Wells, Nevada 1:250,000 Army Map Service sheet is the only topographic map that includes the area.

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[1] The name Snake Mountains is not official and does not appear on many maps but is now being considered by the Board on Geographic Names, and it is therefore adopted here. Other names that have been applied to this range include Antelope Peak Mountains, Bishop Creek Mountains, Burnt Creek Mountains, Burnt Peak Mountains, Fountain Head Hills, Hot Creek Mountains, O'Neil Mountains, Stormy Mountains, and Tabor Mountains.

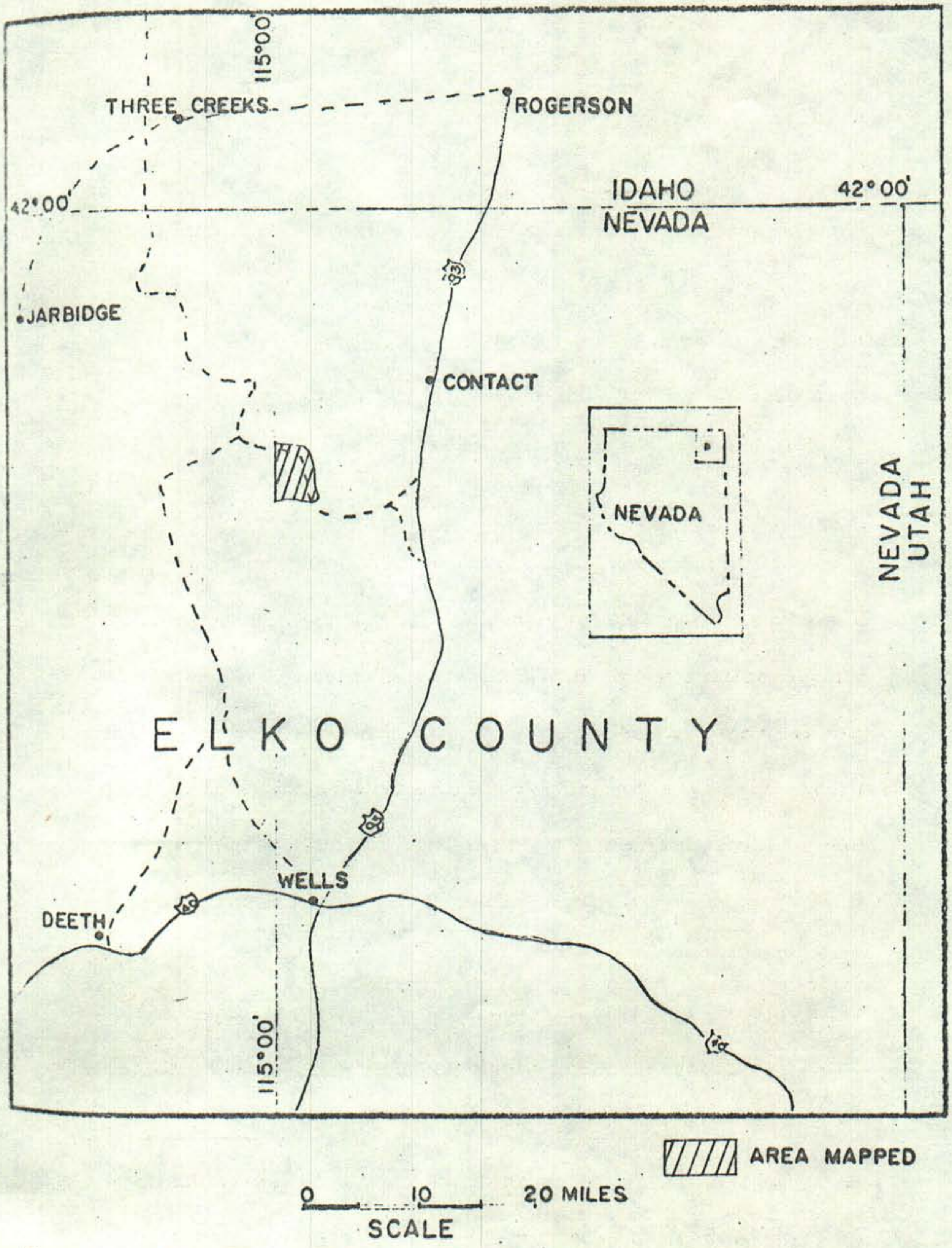

Figure I Index map showing location of thesis area

VITA

Theodore Lynn Bezzerides was born April 26, 1941 in Visalia, California. He graduated from Fresno High School, Fresno, California in June, 1959.

He entered Fresno State College in September, 1959 and received a Bachelor of Arts degree in geology in February, 1964. After graduation from Fresno State College, he worked as a geologist for the California Department of Water Resources until he began graduate work at the University of Oregon in September, 1964. At the University of Oregon he held the position of graduate assistant during the academic years of 1964-65, 1965-66, and 1966-1967.

During the summer of 1965, he worked for Mobil Oil Company and did library research on Basin and Range geology.

Approved

E. M. Baldwin
Advisor for the thesis

TRIASSIC STRATIGRAPHY AND GEOLOGY
OF THE O'NEIL PASS AREA
ELKO COUNTY, NEVADA

by

THEODORE LYNN BEZZERIDES

A THESIS

Presented to the Department of Geology and
the Graduate School of the University of Oregon
in partial fulfillment
of the requirements for the degree of
Master of Science

June 1967

ILLUSTRATIONS

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CONTENTS

ABSTRACT

The O'Neil Pass area lies in the northern part of the Basin and Range province.

Paleozoic rocks in the area total nearly 2, 000 feet in thickness and are divided into two formations. The Oquirrh Formation (?) of Pennsylvanian age consists of limestone and siltstone. The Permian Phosphoria Formation is composed mainly of siltstone with minor amounts of chert, limestone, and phosphorite.

Mesozoic sedimentary rocks exposed in the area are 3, 000 feet thick. The Dinwoody Formation of Early Triassic age consists of a lower conglomerate member and an upper siltstone member. The Thaynes Formation, also Early Triassic in age, consists of limestone with minor amounts of siltstone. The Meekoceras zone occurs near the base of the Thaynes Formation. Granodiorite of Jurassic (?) age intrudes siltstone of the Dinwoody Formation.

Tertiary rocks in the area are volcanic. An ash layer composed of vitric tuff is overlain by a flow or number of flows of rhyolite.

Numerous high-angle faults and related folds are exposed in the area. Structure is probably related to Cenozoic Basin and Range faulting.

Accessibility

The O'Neil Pass area is easily accessible from U.S. Highway 93. The O'Neil Pass road leaves Highway 93 about 36 miles north of Wells, Nevada. It is a heavy duty gravel road which is passable except during periods of exceptional snowfall. Ten miles west of its junction with Highway 93, the O'Neil Pass road enters the area and continues through the area for the next 7 miles. Within the O'Neil Pass area, access for two-wheeled drive vehicles is limited to the O'Neil Pass road.

Climate

Climate of the O'Neil Pass area is typical of the northern Great Basin, with rather severe winters and mild to hot summers. The average rainfall measured at Contact is 8.47 inches per year for the period 1952-57. Snowfall can be heavy during the winter. Average temperature for the months May through September is 62 degrees.

Vegetation

The region is sparsely covered by plant life. Except in the stream canyons the predominant plants are big sagebrush (Artemisia tridentata) and low sagebrush (Artemisia arbusula, A. nova). In the meadows and in stream canyons beautiful stands of aspens (Populus tremuloides) provide welcome areas of shade.

Land Use

Most of the land within the area is controlled by the U.S. Bureau of Land Management and is leased to ranchers in the area for cattle grazing. Some of the land along the creeks is privately owned. Several wells with windmills and natural springs in the region are used for watering stock. A small cabin at Ford Corral was used as base camp during the author's stay in the area. There is evidence that prospecting for gold and silver has taken place not long ago, as several claim markers were found. At the present time the only mining in the region is concentrated in the Contact area. The nearest services are at Contact where gasoline and a limited supply of groceries are available.

Methods of Study

The author spent two months during the summer of 1966 mapping and collecting rock and fossil samples. Mapping was carried out in the field on 1:22,000 aerial photographs. Data were transferred to the Wells, Nevada 1:250,000 AMS sheet enlarged to 1: 31,680. Stratigraphic sections were measured with a Jacob's Staff and plane table and alidade. In the laboratory thin sections were prepared to better deliniate rock types present. Fossils were sent to specialists for further study and classification.

Geomorphology

Thornbury (1965, p. 471), in his text on geomorphology of the United States, summarizes the geomorphic character of the Basin and Range province as follows:

> Taken as a whole this is the most arid geomorphic region in the United States. Although geologic structures are variable within the province, one particular type, commonly referred to as block faulting, is so prevalent that it has notably influenced topographic characteristics. The mountains . . . are typically isolated, subparallel ranges that rise abruptly above adjacent plains. The desert plains over much of the province are essentially debris-filled intermountain basins, but in some areas they are more erosional than depositional surfaces.

The thesis area lies in a region of fault block mountains; Cold Springs Mountain to the northeast and the Snake Mountains to the southwest. Although within an area of complex faulting, topographic evolution is primarily controlled by lithology. The resistant rock types form the highs; therefore conglomerate, limestone, and volcanic rocks make up the ridges and hills; shale and siltstone underlie the valleys. Lithologic control is well illustrated along the Windmill Mountain fault where shales on the upfaulted block stand at a much lower elevation than adjacent limestones in the downfaulted block (Plate 1, figures 1 and 2).

Plate 1

Figure 1. View north toward Cold Springs Mountain

Figure 2. View south from top of Cold Springs Mountain

O'NEIL PASS AREA

Previous Work and Geologic Setting

The O'Neil Pass area lies in the northeastern part of the Basin and Range province, an area characterized by Tertiary block faulting. Thirty miles north of the area volcanic rocks of the Columbia Plateau obscure the Basin and Range structure.

Studies of the geologic features of the Basin and Range province began with the surveys of the 40th parallel under the leadership of Clarence King in 1867 to 1873. These surveys did not indicate the presence of Triassic rocks in the eastern part of the Great Basin.

J. P. Smith (1932) describes in detail an ammonoid fauna collected from Lower Triassic rocks located about 70 miles south of Wells, Nevada.

Wheeler and others (1949) note a thick Triassic section in the Currie area about 100 miles south of the O'Neil Pass area. They apply the formational names Thaynes, Shinarump, and Chinle to this section. Snelson (1955), Nelson (1956), and Harlow (1956) also describe Triassic rocks in this general area. Snelson uses the name Dinwoody for the Lower Triassic, Meekoceras bearing strata in the southern Pequop Mountains.

Clark is the first to mention Triassic rocks in the O'Neil Pass area. He outlines the area of Early Triassic deposition in the eastern Great Basin. From the O'Neil Pass area he describes about

1,000 feet of strata which he states, because of structural complications, is probably less than the true thickness in the area. On the basis of two conodonts, Neoprioniodus bransoni Müller and Gondolella sp., Clark places the Meekoceras zone near the base of the section. Because of the limited knowledge of the Early Triassic in the eastern Great Basin and because of inconsistencies in the use of known formational names for the Lower Triassic rocks in the eastern Great Basin, Clark rejects the use of formational names Dinwoody, Thaynes, Shinarump, and Chinle for these rocks.

Ferguson and Muller (1939, 1949) recognize Mesozoic rocks in the Hawthorne and Tonopah quadrangles in western Nevada. According to them, great thicknesses of Triassic volcanic rocks, and Triassic and Jurassic clastic and carbonate sedimentary rocks accumulated in basins that probably were not connected with the Early Trassic seaway that existed to the east in southeastern Idaho, northwestern Utah, and eastern Nevada.

Geologists who have contributed to the knowledge of the Paleozoic history of the region are numerous, and only a few are mentioned here. Probably the best outline of events during the Paleozoic of north-central Nevada is given by Roberts and others (1958). Their work shows that the O'Neil Pass area was well within the region receiving carbonate type sediments during the Early Paleozoic. They also bring into clear focus the extent of thrusting during Paleozoic orogenies in the Cordilleran region.

Silberling and Roberts (1962) summarize the structural and stratigraphic history of northwestern Nevada. Lower and Middle Paleozoic rocks were deformed by the Antler orogeny in Late Devonian and Mississippian time, after which shallow-water limestones and clastic sediments were deposited during the Pennsylvanian and Permian periods. After an episode of Permian orogeny, Upper Permian and Triassic volcanic rocks and two different facies of Lower Mesozoic sedimentary rocks were deposited. Folding and thrusting commenced again in late Early Jurassic and continued into Cretaceous time. Silberling and Roberts suggest that because of geographic complications, the terms western and eastern facies used to designate the contrasting rock types deposited during the Paleozoic in Nevada should be dropped in favor of detrital-volcanic and carbonate respectively.

The tectonic framework of Late Paleozoic basins in northeastern Nevada, northwestern Utah, and south-central Idaho is described by Roberts and others (1965). They outline areas of Oquirrh and Phosphoria age deposition in the Pennsylvanian and Permian basins of the eastern Great Basin.

Until recently, geologic investigations of the region around the O'Neil Pass area have been, with the exception of the Contact Mining district, only on a broad regional scale.

The Contact Mining district is examined in detail by Schrader (1935). The Contact area is underlain by folded and tilted Carboniferous rocks, intruded by granitic bodies, and surrounded by Tertiary lavas. The sedimentary section consists of limestone with minor amounts of quartzite, slate or dark slaty to shaly quartzite, and a basal quartzite. The limestone has been metamorphosed along the contact with the granite for a distance up to several hundred feet from the contact. Igneous rocks of the district comprise several types of granitic intrusive rocks and Tertiary volcanic rocks. The oldest of the intrusive rocks is granodiorite which is exposed in an area 25 miles long in an east-west direction and 6 miles wide north-south. Later intrusive activity culminated with the intrusion of syenitic dikes. Schrader (1935) finds that the mineralization in the district is primarily associated with the later syenitic intrusions. Mineralization also occurs in the contact zone bordering the granodiorite. Copper is the main metal, but the deposits also contain some gold and silver.

Fifteen miles east of the O'Neil Pass area on Knoll Mountain, Riva (1962) maps a complex area of Lower and Upper Paleozoic sedimentary rocks. He groups these rocks into three main stratigraphic subdivisions: 1. Autochthonous Lower Carboniferous (?) quartzites and Permian limestones, quartzites and volcanic rocks; 2. Allochthonous Ordovician-Silurian argillites, bedded cherts, and intercalated volcanics; 3. Pennsylvanian-Permian limestones and sandstones overlying both the allochthonous Ordovician-Silurian detrital-volcanic facies and autochthonous Lower Carboniferous quartzite. Although Riva does not date the thrusting on Knoll Mountain, it appears from his map that one and possibly two periods of thrusting were involved. Post-Permian thrusting is necessary to explain the map pattern, and a post Early Mississippian (?) pre-Pennsylvanian episode of thrusting seems possible although not necessary. Riva makes no mention of Triassic sedimentary rocks on Knoll Mountain.

Immediately west and southwest of the O'Neil Pass area in the Snake Mountains, Douglas Gardner (personal communication, 1966) has mapped carbonate facies rocks of Middle to Late Ordovician age tectonically overlain by volcanic-detrital rocks that are possibly correlative to the Valmy Formation exposed farther west. Unconformably above the Lower Paleozoic units is a sequence of Pennsylvanian (?) and Permian (?) limestone, sandstone, and chert. Rocks resembling Lower Triassic sedimentary rocks of the O'Neil Pass area occur in probable fault contact with Upper Paleozoic (?) limestone and chert in the Snake Mountains.

Extrusive igneous rocks cover much of the surface to the north and northeast of the O'Neil Pass area. Lowlands to the south are underlain by Tertiary lake deposits (Granger and others, 1957).

The map area is included in the Reconnaissance Geologic Map of Elko County, Nevada (Granger and others, 1957). The O'Neil Pass area is mapped as Tertiary lake deposits and undifferentiated Paleozoic sedimentary rocks.

STRATIGRAPHY

Rocks exposed in the O'Neil Pass area range in age from Pennsylvanian to Tertiary. Paleozoic rocks have a thickness of approximately 2,000 feet and are divided into two formations. The Oquirrh Formation (?) of Pennsylvanian age consists of limestone, sandstone, and shale. The overlying Phosphoria Formation is Permian and is composed of siltstone, chert, limestone and phosphorite. Overlying the Paleozoic rocks is 3,000 feet of Lower Triassic conglomerate, siltstone, and limestone tentatively assigned to two formations. The Dinwoody Formation consists of a lower member of conglomerate and siltstone and an upper member of siltstone with minor limestone units. Overlying the Dinwoody is massive limestone tentatively assigned to the Thaynes Formation.

A Jurassic (?) granodiorite dike intrudes Lower Triassic sedimentary rocks. A thin contact metamorphic zone is associated with the intrusion.

Tertiary ash and rhyolite flows totaling 500 feet in thickness overlie much of the area. Recent alluvium occurs along Jakes Creek and in the canyon followed by the O'Neil Pass road.

PENNSYLVANIAN

Oquirrh Formation (?)

Strata tentatively assigned to the Oquirrh Formation make up the bulk of Cold Springs Mountain and also occur along the north side of Jakes Creek in the southeastern part of the thesis area.

The Oquirrh Formation was named by Gilluly (1932) for exposures in the Oquirrh Mountains west of Salt Lake City, Utah. In the type area Gilluly describes the Oquirrh Formation as ". . . the great mass of alternating limestone and sandstone . . ." (Gilluly, 1932, p. 34). He reports the total thickness of the formation in the type area as 16,000 to 18,000 feet.

Lithology

The best exposed and thickest section of Oquirrh Formation in the O'Neil Pass area is on the northeast side of Cold Springs Mountain. Here, about 900 feet of beds are exposed, with gray limestone predominant. The limestone is massive to platy and forms very rough surfaced resistant outcrops. In places it is highly silicified. Interbedded with the limestone beds are thinner beds of mudstone. The mudstone is tan to brown on fresh surfaces and weathers to red

Sounds like Pequop Fm. of Permian age.

and yellow chips. Thin section examination shows silt sized fragments of quartz and feldspar in calcite cement which is extensively replaced by silica.

Contact Relationships

The base of the Oquirrh Formation (?) is not exposed in the O'Neil Pass area. D. Gardner (personal communication, 1967) finds similar beds in the Snake Mountains to the southwest and reports that they conformably overlie a series of interbedded limestone and sandstone beds of Mississippian to Early Pennsylvanian age. Strata similar to limestone beds of Oquirrh Formation exposed on the top of Cold Springs Mountain occur along the lower portion of Jakes Creek. North-dipping limestone strata along Jakes Creek apparently are overlain by Permian cherts and mudstones that crop out along the road to Ford Corral. Although exposures between Jakes Creek and the road to Ford Corral are sparse, lithologic and structural relations suggest the contact between the Oquirrh Formation (?) and the overlying Permian Phosphoria Formation should be drawn in this area. The nature of the contact is not known.

Age and Correlation

The Oquirrh Formation was deposited over a relatively long period of time. Roberts and others (1965) place the base at the

Mississippian-Pennsylvanian boundary or possibly even in the uppermost Mississippian. They extend the formation to Early Permian.

In the O'Neil Pass area the Oquirrh Formation (?) is locally very fossiliferous. Distinctive index fossils, however, were not found. Brachiopods, Derbyia sp. with range Carboniferous to Permian, and Composita sp. ranging from Late Devonian to Permian provide the best age control. Stratigraphic position of the Oquirrh Formation (?), above Mississippian to Lower Pennsylvanian strata in the Snake Mountains and below the Phosphoria Formation along Jakes Creek, indicates Pennsylvanian to Early Permian age.

Roberts and others (1965, p. 1932) show that the O'Neil Pass area is between localities where exposures of Oquirrh Formation are known to the east and southeast, and areas where the correlative Strathern Formation is exposed, to the west and southwest.

R. J. Roberts examined the section on Cold Springs Mountain and suggested (personal communication, 1966) that rocks present resemble in many ways those of the Oquirrh Formation in the Delano mining district about 40 miles to the east.

PERMIAN

Phosphoria Formation

The Phosphoria Formation was named by Richards and Mansfield (1912, p. 684) for exposures at Phosphoria Gulch, Bear Lake County, Idaho. According to McKelvey (1959, p. 20), in the vicinity of the type locality:

> . . . the formation ranges from 200 to 480 feet in thickness and consists mainly of dark chert, phosphorite, cherty mudstone, and minor amounts of dark carbonate rock.

At its type locality the Phosphoria is underlain by the Grandeur Tongue of the Park City Formation and overlain by the Dinwoody Formation of Triassic age. McKelvey (1959, p. 20) marks the upper boundary of the Phosphoria ". . . by a nodular phosphorite which contains casts of sponge spicules (?) and is readily separable in good exposures from the tan calcareous siltstones of the basal part of the Dinwoody." In the O'Neil Pass area the Phosphoria Formation is recognized on the basis of distinctive lithologic characteristics. Dark siltstone, chert, and phosphorite beds of the Phosphoria are easily distinguished from underlying limestone of the Oquirrh Formation (?) and the basal conglomerate and brown to tan, platy siltstone of the

Dinwoody Formation. The Phosphoria Formation forms most of the low lying hills south of Cold Springs Mountain and the lower part of the bluff along the east side of the O'Neil Pass road in the southeastern part of the area. Thickness of the Phosphoria Formation exposed in the area is 800 to 900 feet. Incomplete section, in map shown as bounded by faults.

Lithology

Dark siltstone and bedded chert are predominant in the Phosphoria Formation in the O'Neil Pass area. The siltstone is generally poorly exposed, weathering to small tan to brown chips. Fresh surfaces are brown to gray and are commonly streaked with black, carbonaceous material. Cement is mostly calcareous but locally is siliceous. Examination of several siltstone thin sections show that they are composed of silt sized fragments of quartz and lesser amounts of feldspar. Minor muscovite, pyrite, and chert are also present. Cement is mostly calcareous, but in places calcite is replaced by silica. Carbonaceous material is so abundant that it commonly masks other constituents of the rock.

Interbedded with siltstone are units of limestone and chert. Limestone beds up to 25 feet thick are composed of organic rich micrite. The limestone is gray on fresh and weathered surfaces and forms rough, resistant outcrops. Chert beds are very common throughout the Phosphoria Formation and become the dominant lithologic type near the top of the formation. Bedded chert layers 1 to 2 inches thick, separated by shaly interbeds, form much of the prominent bluff above the O'Neil Pass road in the southeastern part of the area (Plate 2, figure 1). The chert is black, both on fresh and weathered surfaces. It is highly fractured and cut through with both calcite and quartz veins. In places the chert is nodular and forms knobby surfaces (Plate 2, figure 2), but it generally weathers to smooth surfaced blocks. Thin section examination reveals that there are actually several types of rocks that are classified in the field as cherts. Some of the siltstone in which the cement has been replaced by silica looks very much like pure chert in the field. However, the non-detrital cherts are thoroughly cut through with fractures filled with calcite and quartz; the silicified siltstones are less fractured. Carozzi (1960, p. 317) notes that fractures are common in cherts and are probably caused by shrinkage during diagenesis. He also notes that shrinkage cracks are rare in calcareous cherts where dehydration has been largely inhibited. The pure cherts are composed of microcrystalline silica that is weakly birefringent to isotropic (Plage 3, figures 1 and 2). Where individual quarts grains in the matrix can be observed, they have undulatory extinction, which according to Carozzi (1960, p. 316) ". . . could be attributed to strain

Plate 2

Figure 1. Bedded chert near top of Phosphoria Formation

Figure 2. Nodular chert near top of Phosphoria Formation

CHERT, PHOSPHORIA FORMATION

generated when silica passed from the colloidal state in which it was deposited to a crystalline state . . ." Iron oxide and carbonaceous pigments are irregularly distributed through the rock giving it a mottled appearance.

Dolomite rhombs are also scattered throughout the nonclastic cherts. Individual rhombs range from .03 mm to .01 mm in size; they are well developed crystals that have sharp boundaries with the surrounding microcrystalline quartz matrix (Plate 3, figure 2). Commonly the dolomite rhombs are zoned, being cloudy in the center and clear around the edges. According to Warner (1956, p. 34), this indicates that as the crystal grew it met with increasing resistance and therefore tended to reject impurities. Warner, on the basis of observations of dolomite in the Rex Chert member of the Phosphoria Formation, believes". . . that the dolomite and silica were deposited more or less concurrently prior to the lithification of the rock . . ." Dolomite is distinguished from calcite by its brown color and well developed crystal form.

Fractures, visible in hand specimen, thoroughly cut the rock. They are filled with coarsely crystalline calcite, finely to coarsely crystalline quartz, and chalcedony. Larger cracks are filled with quartz, and chalcedony. Vein quartz appears to grade into the microcrystalline quartz of the chert matrix. Where calcite is present

Plate 3

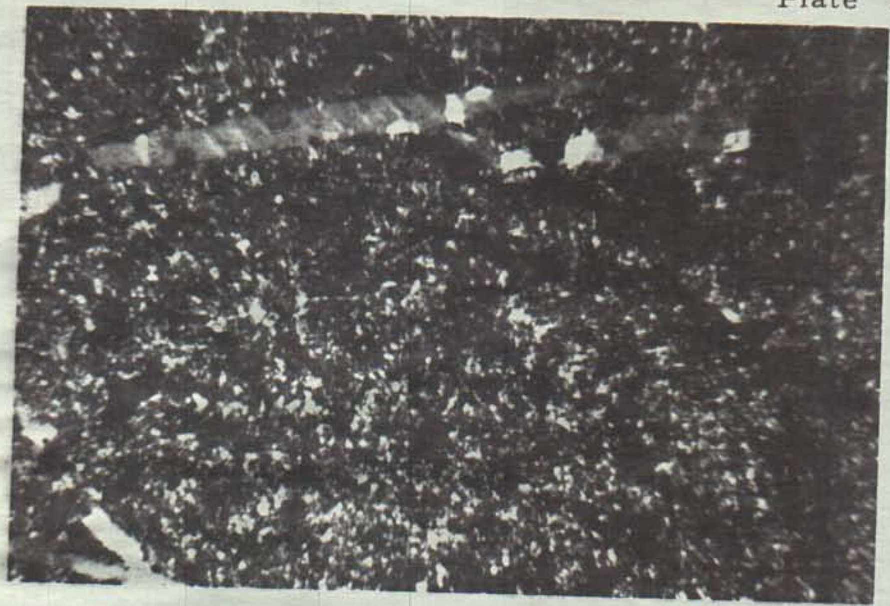


Figure 1. Chert. Microcrystalline quartz, calcite vein partially replaced by quartz. Crossed polars. 60X

Figure 2. Microcrystalline and isotropic silica. Dolomite rhombs. Calcite vein partially replaced by quartz and dolomite. Crossed polars. 250X

PHOTOMICROGRAPHS OF CHERT, PHOSPHORIA FORMATION as vein material it is commonly replaced by silica, especially along contacts with the adjacent chert (Plate 3, figure 1). Carozzi (1960, p. 517) suggests that this is evidence that ". . . the cracks and their infilling were contemporaneous and not due to disturbance subsequent to consolidation."

Interbedded with the chert in the upper part of the Phosphoria Formation are minor beds that are rich in phosphate. Phosphatic beds up to 2 feet thick are distinguished from the chert by rough, granular surface, compared with the smoother chert. The phosphate rock is black, both on fresh and weathered surfaces. It appears in hand specimen to be made of numerous small black grains in finer grained black to brown matrix. White specks of punky kaolinite are visible on fresh surfaces. Thin section study shows the rock to be composed primarily of phosphatic ovules. These are round to elliptical in shape, range in size from 0.2 mm to 1.2 mm and, for the most part, are massive. Some appear to be compound, that is, they have phosphatic cores with massive ovulitic texture surrounded by more phosphatic material (Plate 4, figure 1). Other ovules contain fossil fragments which have been replaced by phosphate. Quartz fragments occur in the cores of some ovules. A few of the phosphatic nodules have oölitic texture. Cement consists mostly of submicroscopic, isotropic phosphate. Both sharp and gradational contacts

Plate 4

Figure l. Phosphate ovules. Ovules both compound and massive. Ovule on right shows partial replacement by calcite. Calcite cement. Crossed polars. 64X

PHOTOMICROGRAPH OF PHOSPHORITE
PHOSPHORIA FORMATION

Babylonites and *Cancrinella phosphatica* (Girty) both occur in the Meade Peak Member of the Phosphoria Formation. The particular species of *Babylonites* has not been found in the Meade Peak Member but is present high in the slightly younger Cherry Creek and Word Formations of West Texas (Yochelson, written communication, 1967). *Notospirifer* sp. is characteristic of the Permian and is abundant and widespread in the southern hemisphere but ". . . is poorly known in the western United States" (Yochelson, written communication, 1967).

In the Sublett Range of south-central Idaho, Youngquist and Haegele (1955) and Cheney and McKelvey (1956) describe Permian strata correlated with the Phosphoria Formation which, from their descriptions, appear very similar to beds assigned to the Phosphoria Formation in the O'Neil Pass area. Cheney and McKelvey (1956, p. 1716) state:

> In the Sublett Range the Phosphoria formation consists of about 85 feet dark mudstone and phosphorite, overlain successively by about 450 feet of dark chert and about 260 of cherty mudstone and subordinate phosphorite.

These units are overlain by the Dinwoody Formation (?) of Triassic age (McKelvey and others, 1959).

Roberts and others (1965) show on a generalized facies map for rocks of Park City age (Phosphoria) the mudstone facies of the Phosphoria Formation extending into northeastern Nevada.

R. J. Roberts examined the O'Neil Pass area in the company of the writer and stated that the lithologic types present in the Permain aged rocks are very similar to those of the Phosphoria Formation in northeastern Nevada.

Permian - Triassic Boundary

In the O'Neil Pass area, the contact between the Permian and Triassic is best exposed along the bluff on the east side of the O'Neil Pass road in the southeastern part of the area. Here, coarse-grained conglomerate assigned to the base of the Dinwoody Formation overlies black, bedded chert at the top of the Phosphoria Formation. Structurally, the contact is concordant, or nearly so. Fossils were not found near the top of the Phosphoria. The only fossil found near the base of the Dinwoody is a poorly preserved ammonoid whose age can only be assigned to the Early Triassic (N. J. Silberling, written communication, 1967). The zone containing Babylonites carinatus Yochelson and Notospirifer sp. is 300 to 400 feet below the top of the Phosphoria chert. Thus, there is an apparent gap in the fossil record that spans possibly part of Guadalupian and all of the Ochoan stages. Elsewhere in the eastern Great Basin a similar gap is present. The upper part of the Phosphoria and the lower Dinwoody are nonfossiliferous. In the O'Neil Pass area the conglomerate at the base of the

Dinwoody Formation contains reworked Phosphoria clasts which suggests that the transition from Permian to Triassic was not a time of continuous sedimentation but one of nondeposition and submarine reworking.

TRIASSIC

Introduction

Two formations of Triassic age are recognized in the O'Neil Pass area. Triassic age strata occupy much of the valley followed by the O'Neil Pass road. Slightly more than 3,000 feet of Triassic age beds are divided on lithologic characteristics into two mappable units here tentatively assigned to the Dinwoody and Thaynes Formations.

Dinwoody Formation

Introduction

The Dinwoody Formation was named and defined by Blackwelder (1918, p. 425) from outcrops in Dinwoody canyon on the northeastern slope of the Wind River Mountains, near Dubois, Wyoming. Because the upper boundary, as defined by Blackwelder, was found not to be mappable, Newell and Kummel (1942, p. 941) redefined the Dinwoody at the type locality to include only dominant silty strata between the Phosphoria and the top of the resistant siltstone about halfway to the top of the original Dinwoody. As redefined at its type locality, the Dinwoody is 90 feet thick. The Dinwoody and overlying Thaynes

Formation are thickest in the Fort Hall region of southern Idaho, where Kummel (1955) notes 6,500 feet.

In the O'Neil Pass area, strata tentatively assigned to the Dinwoody Formation total 2,400 feet in thickness, and are divided into two lithologic members. The lower member, 660 feet thick, contains prominent conglomerate beds. Above the lower member are 1,740 feet of siltstone assigned to the upper member of the Dinwoody Formation.

Lower Member

Along the east side of the O'Neil Pass road, between the road to Ford Corral and Windmill Mountain, the lower member of the Dinwoody Formation is fairly well exposed. The most extensive of the conglomerate beds, at the base of the member, is well exposed, and caps the bluff on the east side of the O'Neil Pass road in the southeastern part of the area.

Lithology

Conglomerate beds from 50 feet thick to less than one inch thick make up perhaps 15 percent of the lower member of the Dinwoody Formation (Plate 6, figures 1 and 2). Thinner conglomerate beds, one inch to 5 feet thick, are lenticular and extend along strike for

Plate 6

Figure 1. Conglomerate at base of Dinwoody Formation

Figure 2. Conglomerate beds in siltstone, Dinwoody Formation

CONGLOMERATE BEDS, DINWOODY FORMATION

distances from a few inches to 30 feet (Plate 7, figure 1). Thicker conglomerate beds probably also are lenticular but cannot be traced along strike because of cover and structural complications. Clast size within conglomerate beds varies with the thickness of the bed, the thicker beds containing cobbles and boulders. Boulders up to 7 feet long and 4 feet wide are found in the thick conglomerate bed at the base of the formation. All conglomerate beds studied are unsorted. In a few places individual clasts within the conglomerate beds are thicker than the surrounding material (Plate 7, figure 2). Except in one locality at the top of the lower member, no grading was observed in any of the conglomerate beds. As the gravel was deposited, fragments of the underlying siltstone were incorporated within the conglomerate and occur as clasts. Some scouring of underlying beds is visible. Overlying beds show compaction features over large clasts in the conglomerate, and in places matrix of the conglomerate was removed before overlying muds were deposited (Plate 8, figure 1). Clasts in the conglomerate are well rounded to angular. They are mostly chert and limestone with minor amounts of siltstone and phosphorite. No quartzite clasts were found. The matrix is composed of silt-sized fragments of quartz and feldspar, carbonaceous material, and minor amounts of clay. Calcium carbonate is the cementing material. Siltstone beds in the lower member are

Plate 7.

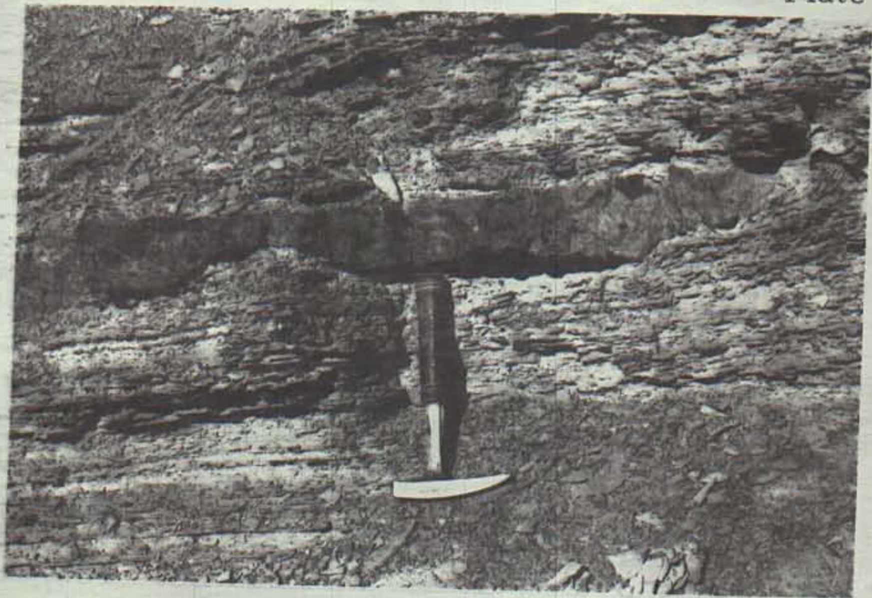


Figure 1. Conglomerate lens, Dinwoody Formation

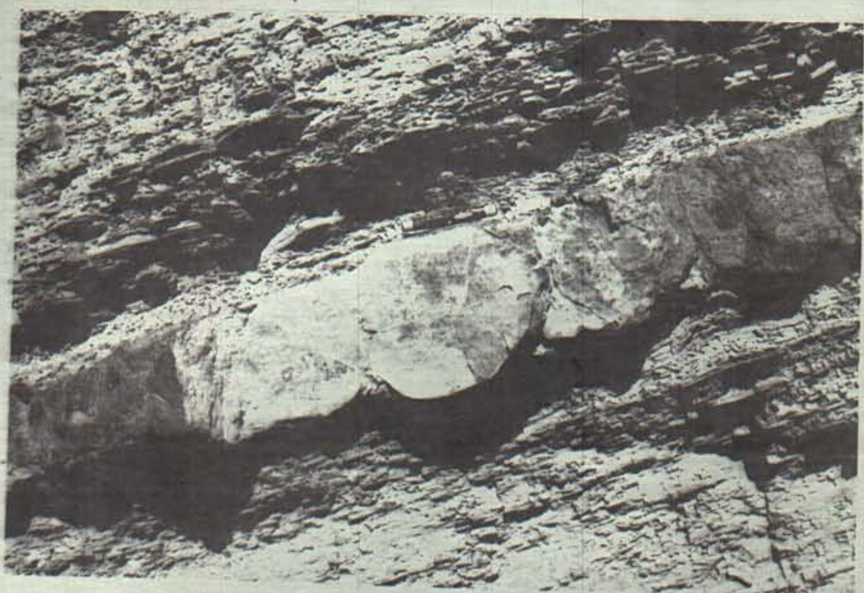


Figure 2. Conglomerate with large limestone clast

CONGLOMERATE BEDS, DINWOODY FORMATION

Plate 8

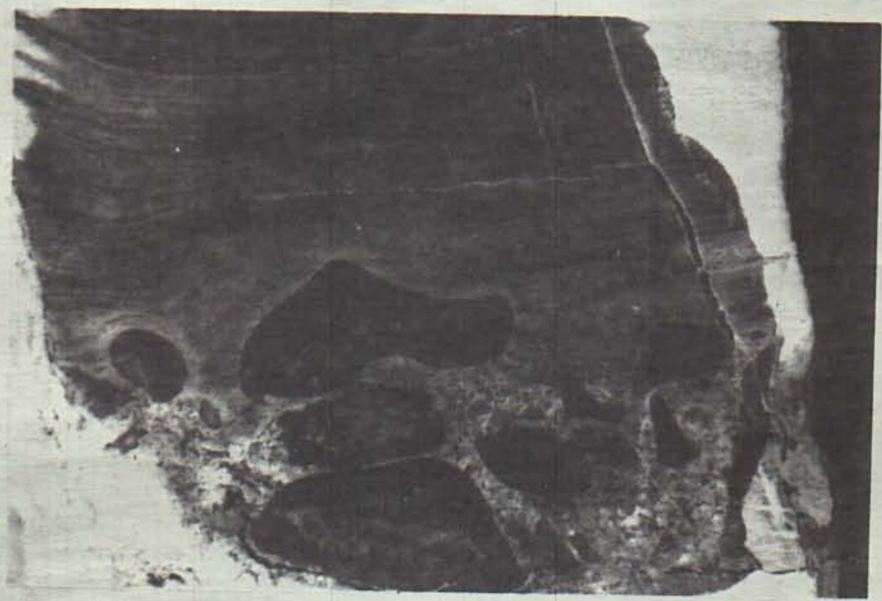


Figure 1. Contact between conglomerate and siltstone. Note partial removal of conglomerate matrix. 1X

CONGLOMERATE AND SILTSTONE, DINWOODY FORMATION very similar to the matrix of the conglomerate and to the siltstone in the upper member of the Dinwoody Formation. These beds tend to be massive, although one siltstone bed near the base of the member weathers out in large plates a half an inch to 2 inches thick. Ripple marks and cross-bedding are visible but not very common. Some slump structures within siltstone beds occur, but fold axis measurements can be made at only four outcrops, which is not a large enough sample to be meaningful

Fucoidal markings occur in one of the siltstone beds not far above the base of the Dinwoody Formation (Plate 9, figure 1). Also, in the first massive siltstone above the thick conglomerate at the base of the formation, pyrite concretions (?) weather out. They are completely replaced by limonite (Plate 9, figure 2).

The uppermost conglomerate bed of the lower member of the Dinwoody Formation is 16 feet thick and includes abundant chert and limestone clasts up to 2 feet in diameter. The top of this bed is graded--beginning with coarse-grained sand, the graded zone passes in 3 to 4 inches to the fine-grained mud of the overlying siltstone. Above this contact the conglomerate intervals in the upper member of the Dinwoody Formation are minor and contain only pebble sized clasts.

Plate 9

Figure l. Fucoidal markings

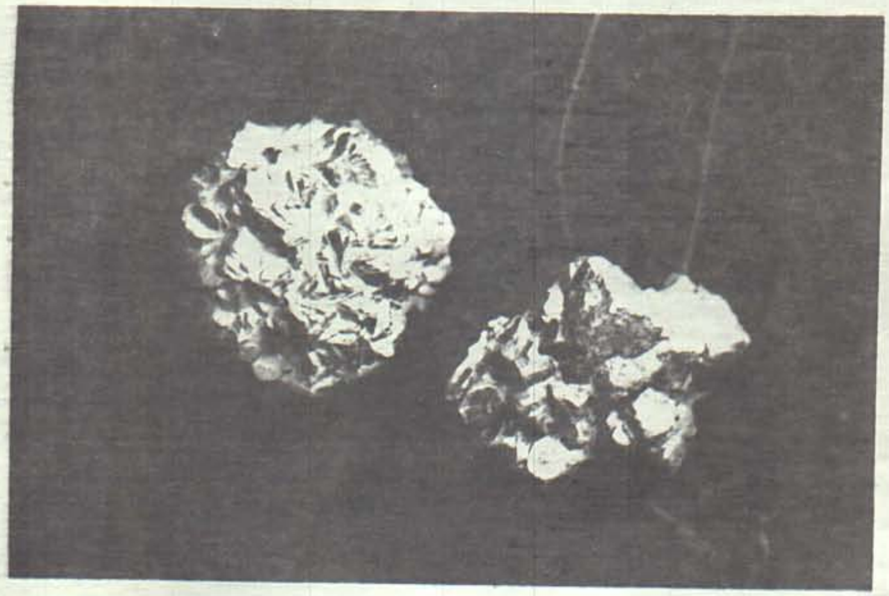


Figure 2. Pyrite concretions, replaced by limonite.

DINWOODY FORMATION

Lithology

Siltstone tends to offer little resistance to erosion; therefore this member is a valley former. Siltstone units range from massive with little or no suggestion of bedding, to very well bedded units that weather to large plates a half an inch to 3 inches thick (Plate 10, figure 1). Bedding is best developed where carbonaceous laminae are present (Plate 10, figure 2). Some units are cross-bedded on a very small scale and, again, this is best developed where carbonaceous material is present. Nearly all the siltstone beds are some shade of gray on fresh surfaces and weather to brown, tan and gray. Thin section examination of siltstones shows that they are composed of silt-sized fragments of quartz and feldspar in a matrix of carbonaceous material, finely disseminated pyrite, and clay minerals. Cementing material is calcite.

Large allochthonous blocks of chert and phosphorite, probably derived from the Phosphoria Formation, occur in the first unit of the upper member of the Dinwoody Formation (Plate 11, figure 1). These blocks, up to 12 feet in diameter, are not in conglomerate, but rather are isolated in siltstone. Compaction of underlying and overlying layers around the blocks is evident.

Thin limestone beds are common in the upper member of the Dinwoody. These beds range in thickness from one inch to 10 feet.

Plate 10

Figure 1. Siltstone

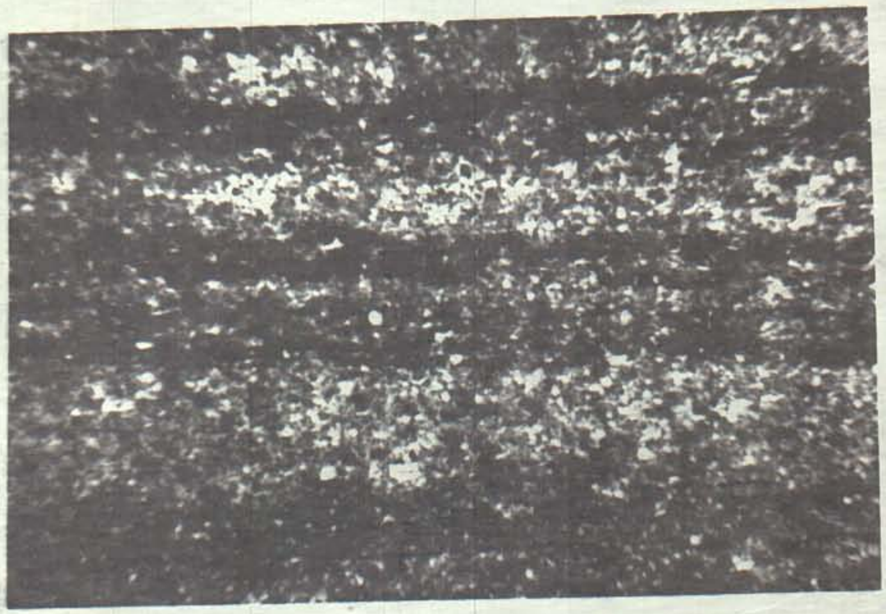


Figure 2. Siltstone. Quartz and feldspar clasts. Dark bands of carbonaceous material. Calcite cement . Plane light. 60X

OUTCROP AND PHOTOMICROGRAPH, DINWOODY FORMATION

Plate 11

Figure 1. Allochthonous blocks of Phosphoria Formation in siltstone.

ALLOCHTHONOUS BLOCKS, DINWOODY FORMATION

The limestone is black to bluish gray on fresh surfaces. They weather brown, forming resistant outcrops that commonly stand out above the less resistant siltstone. Thin section examination reveals that the limestone is composed of micrite.

The upper member of the Dinwoody Formation becomes more calcareous towards the top and grades into the thick limestone of the Thaynes Formation.

Thaynes Formation

The Thaynes Formation was originally defined by Boutwell (1907) from outcrops in Thaynes Canyon in the Park City mining district, Utah. In the type area the Thaynes Formation consists of 1,190 feet of limestone and calcareous clastic rocks. At its type locality it is underlain by the Woodside Formation and overlain by the Ankareh Formation (Kummel, 1954).

In the O'Neil Pass area, strata tentatively assigned to the Thaynes Formation are mainly limestone with minor calcareous siltstone beds. Limestone of the Thaynes Formation forms Windmill Mountain, the low hills beneath volcanic caprock west of the O'Neil Pass road in the center of the area (Plate 12, figure 1), and the hills in the northwest part of the area. A total of 620 feet of strata assigned to the Thaynes was measured in the O'Neil Pass area.

Plate 12

Figure 1. Tertiary rhyolite capping Thaynes and Dinwoody Formations.

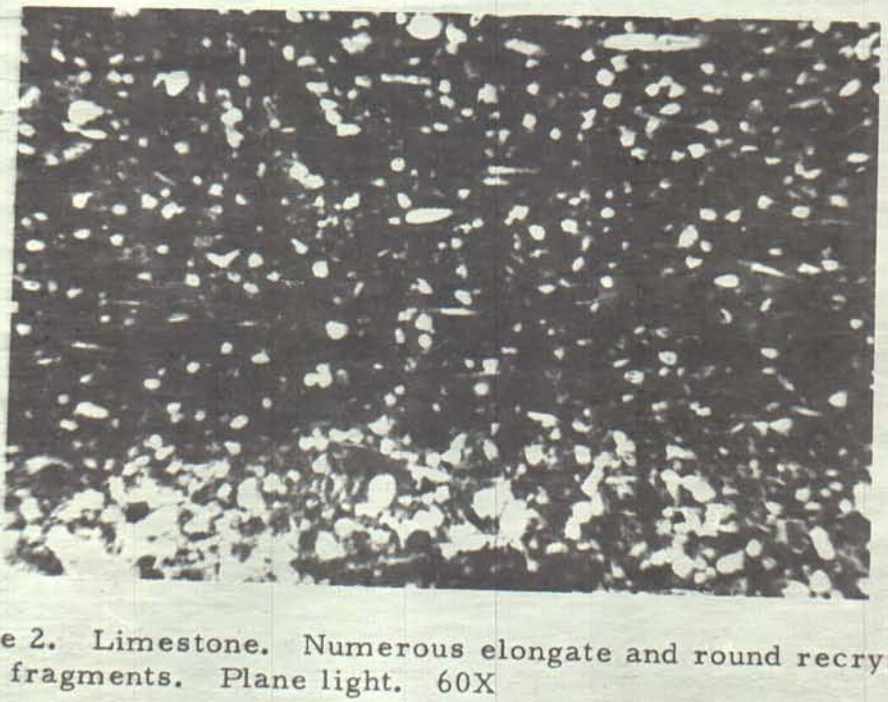


Figure 2. Limestone. Numerous elongate and round recrystallized fossil fragments. Plane light. 60X

OUTCROP AND PHOTOMICROGRAPH, THAYNES FORMATION

Lithology

Thick limestone beds of the Thaynes Formation form prominent outcrops on Windmill Mountain and in the northwestern part of the area. In these localities light brown-to tan-weathering limestone forms thick ledges. Interbedded with the limestones are thin beds of cross-bedded siltstone and zones of broken fossil fragments.

Alternating with brown limestone are beds of dense, recrystallized, black to bluish gray limestone. These dark limestones form more subdued and rounded outcrops. Thin section examination of the limestone shows that the lighter colored rocks contain higher percentages of clastic material and lesser amounts of fine carbonaceous material than the darker ones (Plate 12, figure 2). Clastic beds are mostly quartz and feldspar siltstone similar to that of the Dinwoody Formation.

Age and correlation

Triassic Formations

Lower Triassic marine sedimentary rocks in the eastern Great Basin are identified by the Meekoceras zone fauna as well as stratigraphic position and lithologic characteristics.

Strata in the O'Neil Pass area tentatively assigned to the Dinwoody and Thaynes Formations are, for the most part, relatively nonfossiliferous. The Dinwoody Formation is well known for its lack of distinctive fossils, and in the mapped area the only fossil the writer found in the Dinwoody Formation is a nondescript ammonite of Early Triassic age (N. J. Silberling, written communication, 1967).

Thaynes Formation limestone is in places fossiliferous, but the fossils are mostly recrystallized fragments. A collection of ammonoid fragments from near the base of the Thaynes Formation was examined by N. J. Silberling who identified (written communication, 1967) two specimens that belong to the genera Pseudosageceras, probably P. multilobatum. Smith (1932) studied Lower Triassic ammonoids in North America and found Pseudosageceras multilobatum to be an important index fossil for the Early Triassic. He reports (1932, p. 88):

Pseudosageceras multilobatum is one of the most widely distributed and characteristic of Lower Triassic ammonites in the middle part of the Lower Triassic of the Salt Range, the Himalayas, on Timor, on Madagascar, in Idaho, California, and Nevada. It is essentially of what is called *Flemingites* beds in the Salt Range, *Hedenstroemia* beds in the Himalayas, and *Pseudosageceras multilobatum* subzone of the *Meekoceras* zone in Idaho, all of the same age and virtually the same fauna. This is one of the most definite interregional zones in the Triassic or in any part of the geologic column and is of great importance in the correlation of faunas in Asia and America.

In southeastern Idaho and northwestern Utah, the Dinwoody and Thaynes Formations are well known. The Dinwoody consists of shale, siltstone, and limestone. The Thaynes Formation is predominantly limestone. The *Meekoceras* zone is in the basal, dark gray crystalline limestone (Kummel, 1955, p. 71).

In the Currie, Nevada area, 100 miles south of the O'Neil Pass area, the *Meekoceras* zone occurs within 100 feet above the base of the Triassic section. These beds are assigned to the Thaynes Formation (Wheeler and others, 1949). Snelson (1955) describes *Meekoceras* bearing strata in the southern Pequop Mountains, north of Currie, that, because of lithologic characteristics, he assigns to the Dinwoody Formation. Other writers (Harlow, 1956, and Nelson, 1956) follow Snelson and use the name Dinwoody for *Meekoceras* bearing strata in the Currie and Spruce Mountain areas of Nevada. Wheeler (1952) describes, from several undesignated localities in northeastern Nevada, a section consisting of several thousand feet of post-Late (?)

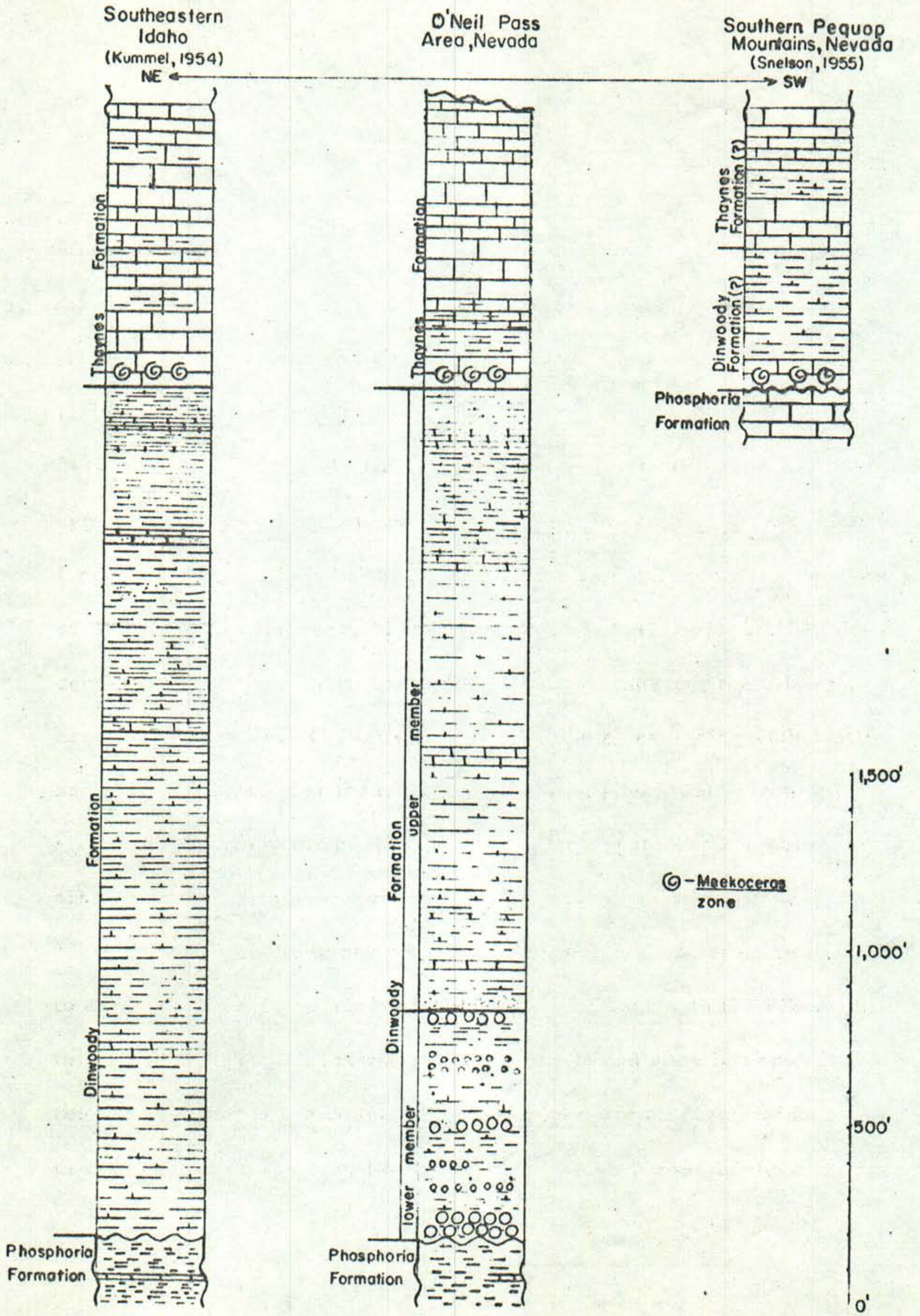
Permian to post-Meekoceras Triassic shales that he assigns to the Dinwoody Formation.

Clark (1957, p. 2,207) rejects the use of the name Dinwoody in the Currie area partly because of ". . . the irregular age assignment which would be necessary because of Meekoceras beds . . ."

Triassic beds in the O'Neil Pass area appear lithologically and faunally similar to those described in southeastern Idaho and northwestern Utah and are correlated with them (Figure 2).

In western Nevada several formations of Early Triassic age are known. The Tobin Formation, exposed in the Augusta Mountains in the southern part of the Sonoma Range quadrangle in north-central Nevada, is lithologically similar to Lower Triassic sedimentary rocks in the eastern Great Basin (Silberling and Roberts, 1962). Elsewhere in western Nevada Lower Triassic rocks are dominantly volcanic or volcaniclastic and are not comparable to similar age rocks in the O'Neil Pass area.

Figure 2 - Correlation of Triassic Formations



JURASSIC (?)

Jurassic (?) intrusive igneous rock forms the core of a small hill located just southeast of Windmill Mountain. The intrusion is a dike that forms smooth, rounded, and highly weathered outcrops (Plate 13, figure 1). The rock is light colored, medium grained with visible crystals of feldspar, quartz, and highly weathered biotite. In thin section (Plate 14, figure 1), the rock is seen to have a hypidiomorphic-granular texture with crystals ranging in size from 1 mm to 3 mm. Highly altered plagioclase feldspar (An_{30-40}) makes up 30 percent of the rock. Relatively fresh potash feldspar (10 percent), quartz (17 percent), and biotite (20 percent) are the other essential minerals. Chlorite is very abundant, replacing both biotite and an amphibole. Secondary calcite replaces feldspar. Iron oxide stains surround many of the altered biotite crystals. Magnetite, zircon, and apatite are accessory minerals.

Siltstone of the upper part of the Dinwoody Formation is baked to a very low grade hornfels where it is in contact with the dike. In the field dark reddish brown float from the baked zone is very distinctive. Close to the contact white specks up to an eighth of an inch in size appear in the baked siltstone. In places pieces of the country

Plate 13

Figure 1. Granodiorite dike. Note highly weathered, rounded outcrop.

JURASSIC DIKE

Plate 14

Figure 1. Granodiorite. Composed of plagioclase (An_{30-40}), potash feldspar, quartz, and biotite. Crossed polars. 60X

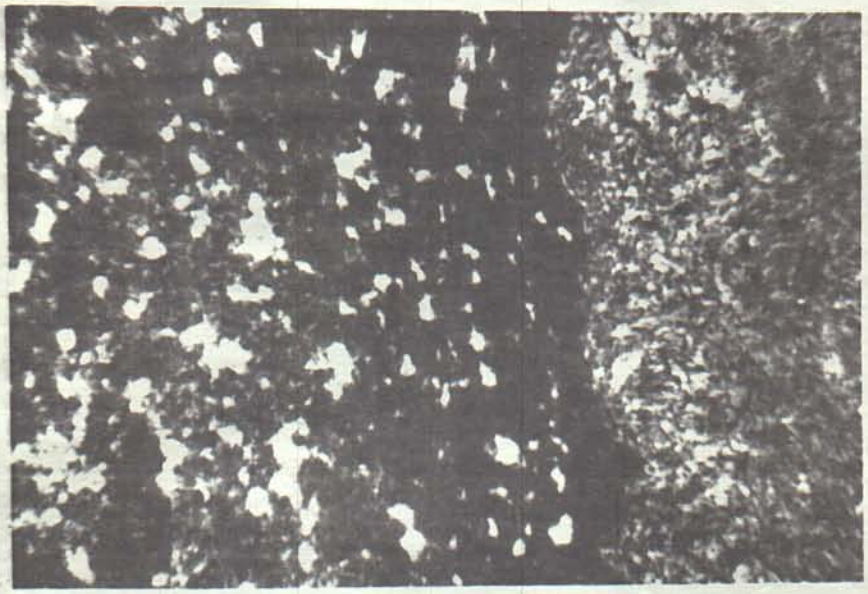


Figure 2. Contact zone. Low-grade hornfels on left, chilled border of dike on right. Large white areas are recrystallized calcite matrix. Plane light. 60X

PHOTOMICROGRAPHS, JURASSIC DIKE AND CONTACT ZONE rock are included within the dike rock. Thin section examination shows the white specks are composed of recrystallized calcite (Plate 14, figure 2).

Age and Correlation

The Contact intrusion, located 10 miles to the north, is the nearest large intrusive body. Schrader (1935, p. 8) describes the granodiorite of the Contact area as follows:

> It is a gray speckled rock of hypidiomorphic texture. Most of the grains have maximum dimensions of 1 mm to 2 mm. The rock contains about 55% of zoned plagioclase, 20% granular interstitial quartz, 10% perthitic potash feldspar which tends to lie between and wrap around the plagioclase crystals, 10% of pale brown biotite, and 5% of green biotite . . .

The Contact intrusion has been dated (Coats, Marvin, and Stern, 1965) by the potassium-argon method as 143-160 million years old and by lead-alpha determination or zircon as 140-180 million years old.

Intrusive activity in the O'Neil Pass area is probably related to the Contact intrusion.

Significance of Conglomerate Beds

Conglomerate similar to that at the base of the Triassic section in the O'Neil Pass area has been reported from only two other localities in the eastern Great Basin. Clark (1957) reports thin conglomerate beds in Lower Triassic shales exposed at Beaver Creek and Coal Canyon which are located north of Elko, Nevada, 30 and 60 miles respectively from the O'Neil Pass area.

The writer believes that the conglomerate was derived from a local high, possibly a fault that became active during the Early Triassic. At times, slopes along the high would become unstable and debris would be sent off into the deeper parts of the basin flanking the high. The presence of large unstable shale clasts within the conglomerate, and the almost complete lack of sorting or grading in the conglomerate beds suggests that transport was only of short duration. Absence of quartzite clasts within the conglomerate indicates that only Permian and possibly Pennsylvanian sources were involved, as older Paleozoic rocks of the region contain numerous quartzite units.

Upper Member

Strata assigned to the upper member of the Dinwoody Formation underlie most of the low hills beneath volcanic cap rock west of the O'Neil Pass road.

TERTIARY

Introduction

Volcanism is the only event of Tertiary age recognized in the O'Neil Pass area. Detailed correlation of volcanic rocks has not been attempted in this study. In general, there appear to be at least two episodes of volcanism within the mapped area. An ash layer overlies truncated Mesozoic and Paleozoic strata. After minor erosion of the ash, rhyolite flows covered the area.

Sedimentary rocks of Tertiary age do not occur in the mapped area but are known to occur in the valley to the east (Granger and others, 1957) and are reported on Knoll Mountain 15 miles east of the O'Neil Pass area Riva, 1962).

Ash

White to gray ash was the first product of Tertiary volcanism in the O'Neil Pass area. It occurs beneath rhyolitic cap rock west of the O'Neil Pass road (Plate 15, figure 1), and in the canyons of the north and middle forks of Jakes Creek. Patches of ash also occur near the southeast corner of the area.

Ash was deposited over an eroded surface of Triassic and Upper Paleozoic rocks. In places erosion removed the ash before younger flows covered the area. Ash deposits, where studied, are massive to well bedded and for the most part do not contain nonvolcanic detrital material. Thin section study reveals the ash is a vitric tuff composed mainly of long, arcuate glass shards in a matrix of glass dust (Plate 15, figure 2). Minor phenocrysts of plagioclase (An_{30-35}) and a mafic mineral, probably an amphibole, along with a few fragments of glassy volcanic rock make up the rest of the rock. Chlorite has almost completely replaced the mafic mineral, and iron oxide surrounds many of the altered and resorbed phenocrysts.

Absence of nonvolcanic material and lack of slumping and cross bedding in the ash deposits leads the writer to believe the ash was air lain rather than deposited in water.

Thickness is estimated to be up to 50 feet in the area. D. Gardner (personal communication, 1966) measured 260 feet of the same ash in Jakes Creek west of the O'Neil Pass area.

Rhyolite

Overlying the ash is a flow or a number of flows of rhyolite. Rhyolite forms the cap rock west of O'Neil Pass road (Plate 15, figure 1). Many isolated hills within the mapped area are also capped

Plate 15

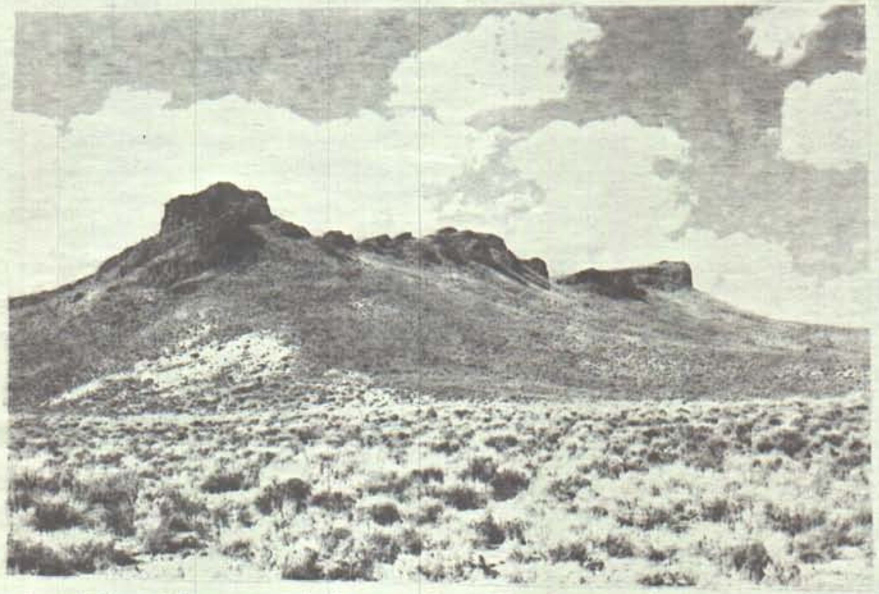


Figure 1. Rhyolite overlying ash. West of O'Neil Pass road.

Figure 2. Vitric tuff. Arcuate glass shards, crystals of sodiac plagioclase, and magnetite in matrix of glass dust. Plane light 98X

OUTCROP AND PHOTOMICROGRAPH, TERTIARY ASH by flow rock. The predominant rock making up the flows is a reddish gray, porphyritic rhyolite which weathers to red-brown, smooth surfaced blocks. Many phenocrysts of quartz and feldspar are visible. Microscopic examination shows phenocrysts of quartz, sanidine, plagioclase, and biotite. Feldspar phenocrysts are commonly partially resorbed to glass. Iron-rich biotite is altered to hematite. The groundmass is a felted mosaic of microcrystalline feldspar and quartz, commonly intergrown. Accessory minerals are magnetite and zircon. Chemical analysis of one sample from rhyolite collected west of the O'Neil Pass road is given in Table 1. Maximum thickness estimated in the area is 500 feet.

Age and Correlation

The nearest area where similar volcanic rocks have been described is in the Contact mining district about 10 miles north of the O'Neil Pass area. Schrader (1935) describes rhyolite flows and ash deposits that are similar to those in the thesis area. He correlates the rhyolites in the Contact area with young rhyolite flows of the Jarbidge district. Young rhyolites in the Jarbidge district have been dated by radiometric methods as 15.4 million years old (Schilling, 1965, p. 58).

TABLE 1

Chemical analysis of rhyolite from cap rock west of O'Neil Pass road. Analysis, G. W. Bode, Department of Geology, University of Oregon.

Oxide	Percent
SiO_2	70.4
TiO_2	0.36
Al_2O_3	12.12
FeO	0.36
Fe_2O_3	3.97
P_2O_5	0.15
MgO	0.26
CaO	1.88
Na_2O	4.20
K_2O	4.10
MnO	0.12
H_2O+	1.41
H_2O-	0.24
Total	99.61

STRUCTURAL GEOLOGY

Introduction

Structure of the O'Neil Pass area is complicated by numerous faults, including several with displacements measured in thousands of feet, and small folds that are probably related to faulting. Predominant dip direction is west, but occurrences of formation outcrops are controlled more by faulting than by stratigraphic order. The area can be best characterized as a mosaic of fault blocks.

Structure is probably related to regional tectonics. Evidence of large-scale thrust faulting is found to be southwest in the Snake Mountains (D. Gardner, personal communication, 1967), and to the east on Knoll Mountain where Riva (1962) maps thrust contacts of post-Permian and possibly Carboniferous. The O'Neil Pass area probably was affected by thrusting, but direct evidence was not found in the area.

Presumably there is some control on the pattern of Cenozoic Basin and Range faults; most of the O'Neil Pass area normal faults trend northwest or northeast, but the area is too small to serve as an adequate basis for structural interpretation, and the structure of the surrounding region is relatively little known. Therefore, the following discussion of structure is essentially descriptive.

Faults

Three major faults and seven minor faults are mapped in the O'Neil Pass area. Attitudes of the fault planes are not determined, but the faults are all high-angle, probably normal, as shown by their straight or nearly straight traces.

The majority of fault movement in the area is older than the Miocene (?) volcanic rocks that cover much of the region. Some minor post-volcanism movement is indicated by displaced volcanic contacts.

Trending N. 45° W. along the southwest side of Cold Springs Mountain, a high-angle fault brings limestone of the Oquirrh Formation (?) up on the north against Permian and Triassic rocks in the downfaulted block. To the northwest the fault is buried beneath volcanic rocks.

The trace of another high-angle fault is easily followed northeastward from where it emerges from beneath volcanic cover southwest of Windmill Mountain. The fault bounds the topographically high Thaynes limestone on Windmill Mountain and dies out in siltstone to the north of Windmill Mountain. Relative movement along the fault is up to the north, but because siltstone exposed in the upthrown block is less resistant than the limestone across the fault, the downfaulted block is higher. Maximum throw along the fault is 3,500 feet. Some post-volcanism movement has taken place (Plate 16, figure 1).

A complex network of high-angle faults is mapped in the southeastern part of the area. The main fault parallels the O'Neil Pass road for 2 miles from the southeast corner of the area, and then, where the road turns west, the fault continues north and apparently dies out in bedding beneath a cover of volcanic rock. Relative displacement on the fault is up to the east. Chert and phosphatic beds of the Phosphoria Formation and the lower conglomerate beds of the Dinwoody Formation on the east are in fault contact with higher siltstone beds of the Dinwoody to the west. Associated with the main fault are several minor high-angle faults that join the main fault from the east and on which relative displacement is up to the north. A high-angle fault joins the main fault just north of the junction of the O'Neil Pass road with the road to Ford Corral. Relative displacement is up to the south with Phosphoria strata brought against Dinwoody siltstone beds.

Folds

Folding in the O'Neil Pass area is generally related to faulting; drag folds are associated with most of the faults. A large drag fold associated with the Windmill Mountain fault is located on the southeast

Plate 16

Figure 1. Windmill Mountain fault. View southwest from Cold Springs Mountain. Windmill Mountain shown by W. Hills in middle-distance capped by Tertiary lavas.

WINDMILL MOUNTAIN FAULT

side of the fault. The axial trace passes near the summit of Windmill Mountain but cannot be traced across the O'Neil Pass road. A poorly defined anticlinal axis parallels the Windmill Mountain fault near its west end, and from there it swings northward.

In the southern part of the area, east of the O'Neil Pass road, rocks of the Dinwoody Formation are gently folded into two synclines and an anticline whose axes trend north. The folds are symmetrical and plunge north at a low angle.

GEOLOGIC HISTORY

Precambrian and Paleozoic

Precambrian, and Lower and Middle Paleozoic rocks are not exposed in the O'Neil Pass area; therefore, events during these times can only be considered on a regional scale.

Precambrian events in the Great Basin are not well documented. Lower Precambrian is represented by strongly folded, medium- to high-grade metamorphic rocks exposed in a few of the structurally high ranges in the region. In late Precambrian deposition began in a trough located in western Nevada, and by Early Cambrian dominantly clastic sediments were deposited as far east as central Utah (Stewart, 1964, p. 21).

Probably the best synthesis of the regional geology of Paleozoic rocks in northern Nevada is by Roberts and others (1958). In eastern Nevada, east of longitudes 116° to 117°, Paleozoic rocks from Middle Cambrian to Mississippian are primarily limestone and dolomite. In central and western Nevada correlative strata are dominantly clastic sedimentary rocks and cherts, with intercalated volcanic rocks. Starting in Late Devonian and continuing into Mississippian, orogenic activity in central Nevada shed coarse detritus into eastern Nevada.

Thrust sheets moved eastward from central Nevada during the Antler orogeny. Rocks of the detrital-volcanic facies were placed in juxtaposition with those of the carbonate facies. In the Snake Mountains immediately west of the O'Neil Pass area, Gardner mapped thrusts of Paleozoic age (personal communication, 1966). R. J. Roberts agrees with Gardner's interpretation and stated that the thrusts are probably part of the Roberts Mountain thrust sheet of the Antler orogeny (personal communication, 1966). By Pennsylvanian time sedimentation resumed. In the Snake Mountains Mississippian to Lower Pennsylvanian conglomerate overlies allochthonous detrital-volcanic facies rocks. Above the conglomerate is a series of limestone and sandstone beds of probable Pennsylvanian age (D. Gardner, personal communication, 1966). These are probably in part correlative with strata that in the O'Neil Pass area are assigned to the Oquirrh Formation (?). The Oquirrh Formation was deposited near the western margin of the northern lobe of the Oquirrh basin that extended west from the vicinity of the Great Salt Lake in Utah (Roberts and others, 1965, p. 1937). West of the O'Neil Pass area the Moleen, Tomera, and Strathern Formations were deposited in a trough in approximately the same position as the earlier Mississippian Chainman-Diamond Peak trough adjacent to the Antler orogenic belt (Roberts and others, 1965, p. 1932).

The nature of the transition from the Oquirrh Formation (?) to the Phosphoria Formation in the O'Neil Pass area is unknown because of lack of exposure of the contact. Fifteen miles east of the area, Riva (1962) mapped Leonardian age limestone and siltstone beds unconformably overlying Atokan and Missourian strata. Elsewhere in the basin Roberts and others (1965) report Wolfcampian and Leonardian beds in the upper part of the Oquirrh Formation.

The Phosphoria Formation was deposited during a period of great stability that persisted over most of northwestern Utah, northeastern Nevada, and southern Idaho (Roberts and others, 1965, p. 1944). Several facies are recognized in the Phosphoria, the deposition of which is controlled mainly by the depth of water and type of ocean currents in the Phosphoria Sea (Cheney and Sheldon, 1959). The area of greatest subsidence of the Phosphoria basin was located near the common corner of Nevada, Utah, and Idaho. In this area the phosphorite-chert facies of the Phosphoria Formation is best developed and thickest. These beds pass laterally to the mudstone facies to the south and east (Roberts and others, 1965, p. 1941). Deposition in the O'Neil Pass area during Phosphoria time was mainly mudstone with minor amounts of chert, limestone, and phosphorite.

Over much of the West, rocks of Ochoan age are apparently missing. Uncertainities in correlation of rocks in southeastern Idaho and Wyoming with those assigned to Guadalupian and Ochoan of West Texas may in part explain the hiatus. Oriel (1959, p. 21) deals directly with this problem:

> Rocks of the Ochoa series may represent deposition at a time when no other part of the continent was receiving sediments, as currently believed. On the other hand, rocks now assigned to this series may be contemporaneous with rocks considered of Guadalupe age elsewhere on the continent, or possibly, in part, with Lower Triassic rocks.

Mesozoic

Depositional conditions prevailing during deposition in early Dinwoody time were not greatly different than those existing in the Phosphoria Sea. Siltstones characterize the bulk of the Phosphoria and Dinwoody Formations over large areas of southern Idaho and northwestern Utah (Oriel, 1959). In the O'Neil Pass area, except for the conglomerate shed from a local source, deposition of the lower part of the Dinwoody took place during a time of great stability which is characteristic and probably a continuation of conditions existing during Phosphoria time. The quiet-water conditions that existed at times during deposition of the Dinwoody is evidenced by the finely laminated, dark gray to black siltstone beds. Limestone deposition began during Dinwoody and continued into Thaynes time where limestone is the dominant lithology.

Lower Triassic rocks of the eastern Great Basin represent the last record of marine deposition in the area.

During the Nevadian orogeny in Late Jurassic, intrusions were emplaced in the O'Neil Pass area. Dikes that are probably related to the Contact intrusion are exposed intruding siltstone beds of the upper member of the Dinwoody Formation.

Tertiary

Beginning in Eocene normal faults began to outline the modern mountain ranges of the Basin and Range province (Youngquist, personal communication, 1965). Large scale normal faulting has continued to the present (Gilluly, 1963).

Tertiary volcanism in the area began in Miocene (?) time. Ash and rhyolite flows covered much of the O'Neil Pass area and are now preserved as cap rock. Minor post-Miocene (?) movement has taken place along some of the faults.

APPENDIX

Measured Section

Section complied from three localities in the area.

Thaynes Formation

Unit No.	Description	Thickness Feet
1.	Limestone. Black; weathers brown to tan. Dense, recrystallized, massive.	197
2.	Limestone. Like 1. Zones of fossil fragments.	190
3.	Limestone. Light gray; weathers gray.	200
4.	Limestone. Like 1. *Pseudosageceras multilobatum*.	31
	TOTAL THAYNES	618

Dinwoody Formation

Unit No.	Description	Thickness Feet
5.	Calcareous shale. Gray; weathers tan to green-gray. Paper thin.	160
6.	Calcareous shale, limestone. Like 5. Thin limestone beds. Gray; weathers brown to gray. Finely crystalline, thin carbonaceous laminations.	234
7.	Calcareous shale. Gray to black; weathers tan. Forms plates 1/8-1/4 inch thick with wavy surfaces. Thin carbonaceous laminations.	197
8.	Limestone. Like 6.	5
9.	Calcareous shale. Green to tan with gray streaks; weathers tan. Forms large plates 1/8-1/4 inch thick. Interference ripple marks. Grades upward to 8.	348

Dinwoody-continued

Unit No.	Description	Thickness Feet
10.	Calcareous siltstone. Gray to black; weathers tan. Forms chips 2 to 3 inches wide. Minor ripple marks.	408
11.	Calcareous siltstone. Gray to black; weathers tan to brown. Forms plates 1/4 to 1/2 inch thick that stand out above ground. Thin carbonaceous layers, commonly cross-bedded.	244
12.	Calcareous mudstone. Brown-gray to black. Forms massive, earthy outcrops.	46
13.	Silty limestone. Gray; weathers tan to gray. Forms irregular chips 1/8 inch thick. Minor cross-bedding.	36
14.	Limestone. Brown to blue-gray; weathers brown. Forms rough surfaced plates 1/2 to one inch thick; coarsely crystalline.	18
15.	Calcareous siltstone. Black, tan, and gray; weathers brown to black. Forms blocks 1 to 5 inches thick. Minor cross-bedding, load casts, and shale partings. Contains exotic blocks of Phosphoria Formation up to 12 feet in diameter.	45
	TOTAL THICKNESS Upper Member	1,740
16.	Conglomerate and sandstone. Gray to black; weathers brown. Clasts up to 2 feet in diameter, angular to well rounded, poorly sorted. Calcareous mudstone matrix. Grades upward to unit 15.	16
17.	Calcareous shale. Green to gray; weathers green to tan. Forms small chips. Contains many thin chert and limestone pebble conglomerate lenses.	109

Dinwoody-continued

Unit No.	Description	Thickness Feet
18.	Conglomerate. Like 16. Massive, clasts up to 1 foot, composed of chert, limestone, and minor phosphorite.	27
19.	Calcareous siltstone. Gray with black laminae; weathers tan to gray. Forms blocks 1 to 4 inches thick, minor cross-bedding. Contains minor conglomerate lenses.	223
20.	Conglomerate. Like 16. Massive.	95
21.	Calcareous siltstone, conglomerate. Siltstone like 19. Conglomerate lenses up to 3 feet thick. Clasts are angular to rounded, fair sorting, composed of chert and limestone. Unit forms slopes with conglomerate lenses weathering out.	71
22.	Calcareous siltstone. Gray; weathers brown to tan. Like 21. Minor ripple marks and slumped zones. Contains fucoidal markings and ammonoid impressions.	41
23.	Calcareous shale. Green to gray; weathers tan. Forms plates 1/4 to 1/2 inch thick, well laminated. Contains pyrite concretions up to 2 inches in diameter.	23
24.	Conglomerate. Like 16. Clasts up to 7 feet in diameter, very poorly sorted. Massive, forms cliffs.	56
	TOTAL THICKNESS Lower Member	660
	TOTAL THICKNESS DINWOODY	2,400

Phosphoria Formation

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TYPED BY: Arlene Paxton

MULTILITHED BY: Margaret Pluid

Bezzerides

Figure - Correlation of Triassic Formations

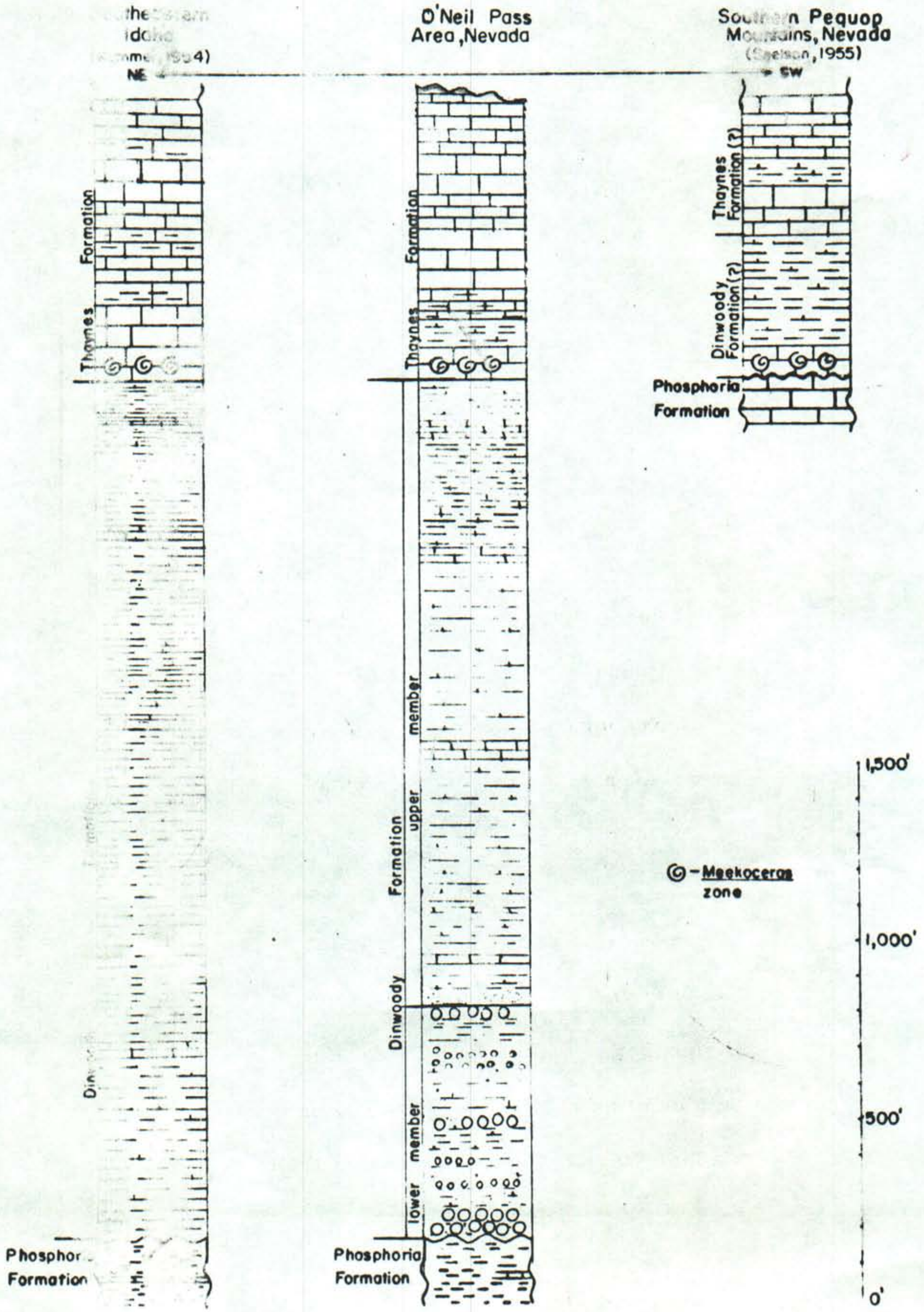

TABLE 1

Chemical analysis of rhyolite from cap rock west of O'Neil Pass road. Analysis, G. W. Bode, Department of Geology, University of Oregon.

Oxide	Percent
SiO_2	70.4
TiO_2	0.36
Al_2O_3	12.12
FeO	0.36
Fe_2O_3	3.97
P_2O_5	0.15
MgO	0.26
CaO	1.88
Na_2O	4.20
K_2O	4.10
MnO	0.12
H_2O+	1.41
H_2O-	0.24
Total	99.61

APPENDIX

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Section complied from three localities in the area.

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4.	Limestone. Like 1. *Pseudosageceras multilobatum.*	31
	TOTAL THAYNES	618

Dinwoody Formation

Unit No.	Description	Thickness Feet
5.	Calcareous shale. Gray; weathers tan to green-gray. Paper thin.	160
6.	Calcareous shale, limestone. Like 5. Thin limestone beds. Gray; weathers brown to gray. Finely crystalline, thin carbonaceous laminations.	234
7.	Calcareous shale. Gray to black; weathers tan. Forms plates 1/8-1/4 inch thick with wavy surfaces. Thin carbonaceous laminations.	197
8.	Limestone. Like 6.	5
9.	Calcareous shale. Green to tan with gray streaks; weathers tan. Forms large plates 1/8-1/4 inch thick. Interference ripple marks. Grades upward to 8.	348

Dinwoody-continued

Unit No.	Description	Thickness Feet
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11.	Calcareous siltstone. Gray to black; weathers tan to brown. Forms plates 1/4 to 1/2 inch thick that stand out above ground. Thin carbonaceous layers, commonly cross-bedded.	244
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14.	Limestone. Brown to blue-gray; weathers brown. Forms rough surfaced plates 1/2 to one inch thick; coarsely crystalline.	18
15.	Calcareous siltstone. Black, tan, and gray; weathers brown to black. Forms blocks 1 to 5 inches thick. Minor cross-bedding, load casts, and shale partings. Contains exotic blocks of Phosphoria Formation up to 12 feet in diameter.	45
	TOTAL THICKNESS	1,740
	Upper Member	
16.	Conglomerate and sandstone. Gray to black; weathers brown. Clasts up to 2 feet in diameter, angular to well rounded, poorly sorted. Calcareous mudstone matrix. Grades upward to unit 15.	16
17.	Calcareous shale. Green to gray; weathers green to tan. Forms small chips. Contains many thin chert and limestone pebble conglomerate lenses.	109

Dinwoody-continued

Unit No.	Description	Thickness Feet
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19.	Calcareous siltstone. Gray with black laminae; weathers tan to gray. Forms blocks 1 to 4 inches thick, minor cross-bedding. Contains minor conglomerate lenses.	223
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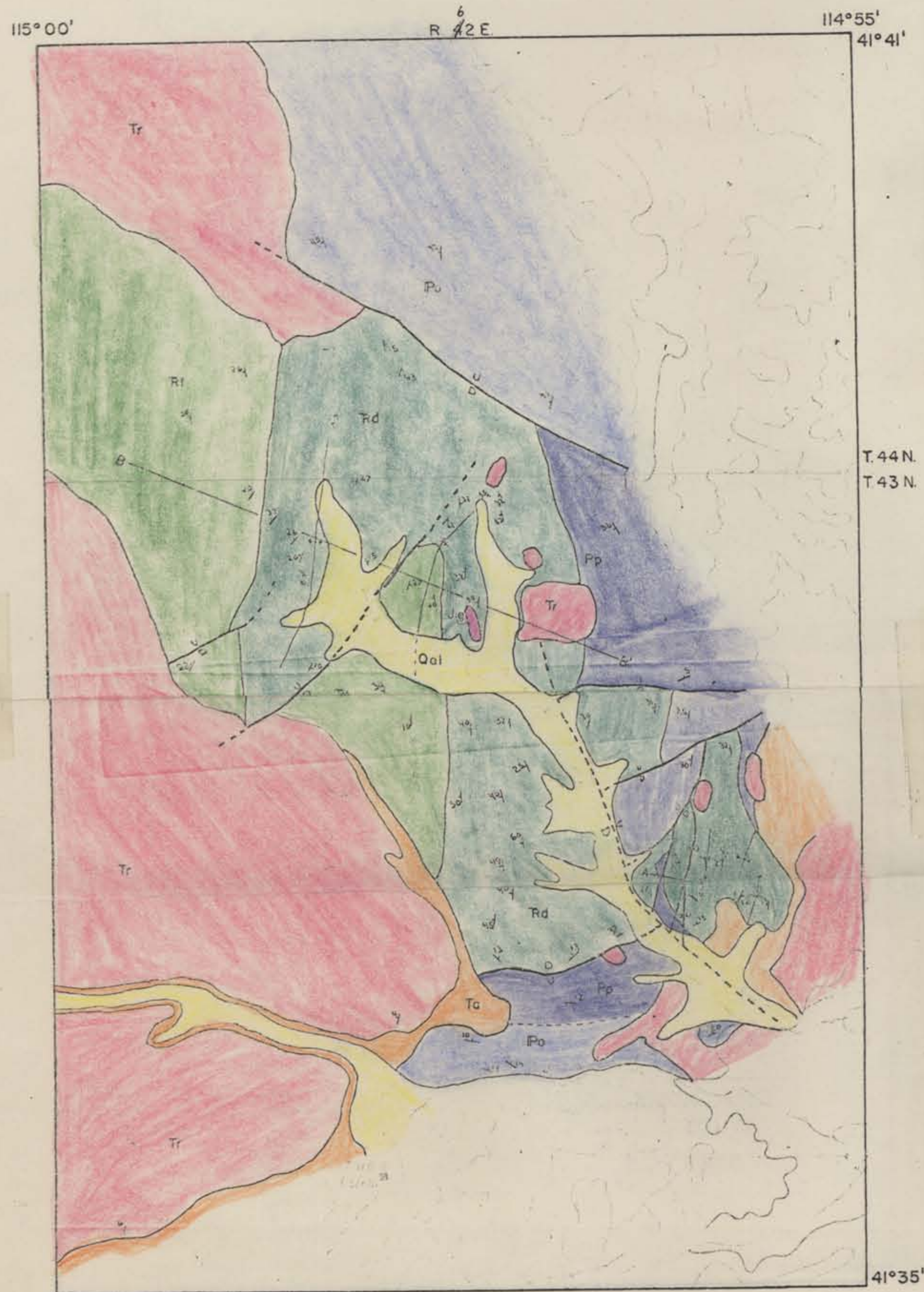
24.	Conglomerate. Like 16. Clasts up to 7 feet in diameter, very poorly sorted. Massive, forms cliffs.	56
	TOTAL THICKNESS Lower Member	660
	TOTAL THICKNESS DINWOODY	2,400

Phosphoria Formation

GEOLOGY of the O'NEIL PASS AREA ELKO COUNTY, NEVADA



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Geology by T.L. Bezzerides, 1967

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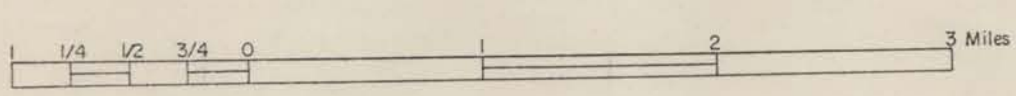
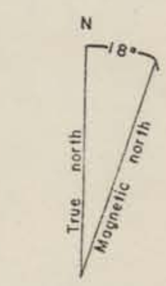


EXPLANATION

Qal	Alluvium	QUATERNARY
	Unconformity	
Tr	Rhyolite	MIOCENE (?)
Ta	Ash	MIOCENE (?)
	Unconformity	
Jig	Granodiorite	JURASSIC (?)
	Unconformity	
Rt	Thaynes Formation	TRIASSIC
Rd	Dinwoody Formation	TRIASSIC
	Unconformity	
Pp	Phosphoria Formation	PERMIAN
Po	Oquirrh Formation (?)	PENNSYLVANIAN

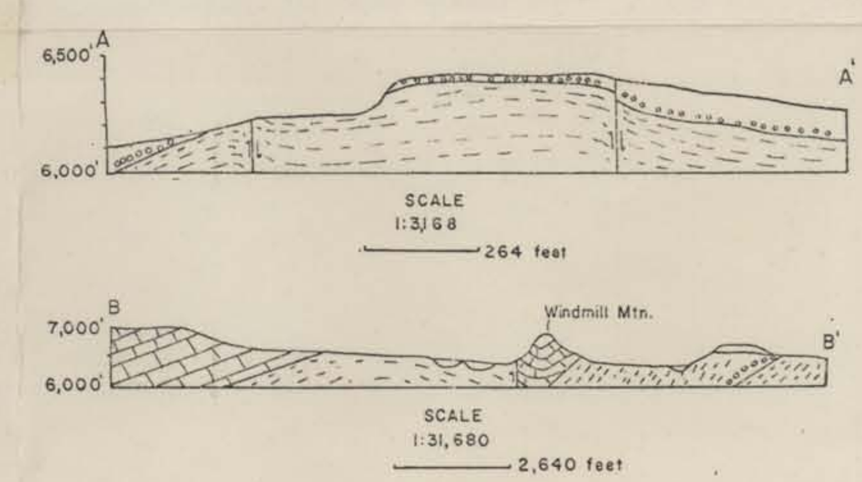
May be Pequop Fm. of Leonardian age (?)

- Contact, dashed where inferred
- Fault, dashed where inferred
- 45 Attitude of bedding
- Anticlinal axis
- Synclinal axis
- A — A' Location of cross section



Approximate mean declination, 1966

Geologic Cross Sections



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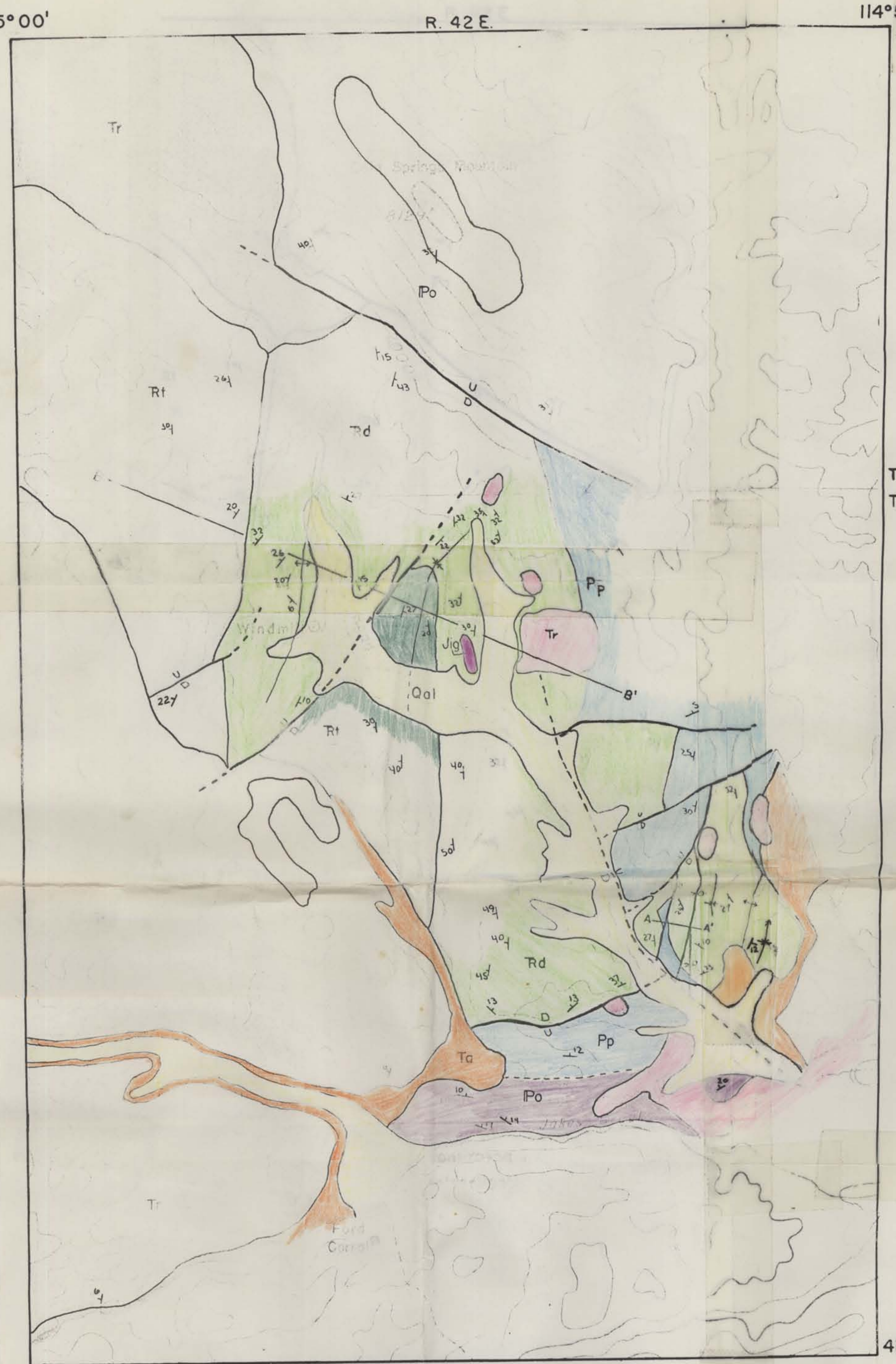

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Contour interval 200 feet

Geology by T. L. Bezzerides, 1967

GEOLOGY of the O'NEIL PASS AREA ELKO COUNTY, NEVADA

SCALE 1:31,680

1 1/4 1/2 3/4 0 1 2 3 Miles

EXPLANATION

Alluvium		QUATERNARY
Unconformity		
Rhyolite		MIOCENE (?)
Ash		
Unconformity		
Granodiorite		JURASSIC (?)
Unconformity		
Thaynes Formation		TRIASSIC
Dinwoody Formation		
Unconformity		
Phosphoria Formation		PERMIAN
Oquirrh Formation		PENNSYLVANIAN

Contact, dashed where inferred

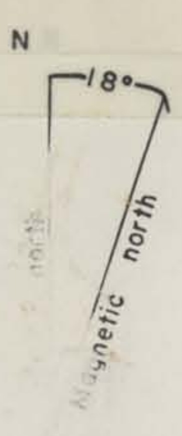
Fault, dashed where inferred

45 Attitude of bedding

Anticlinal axis

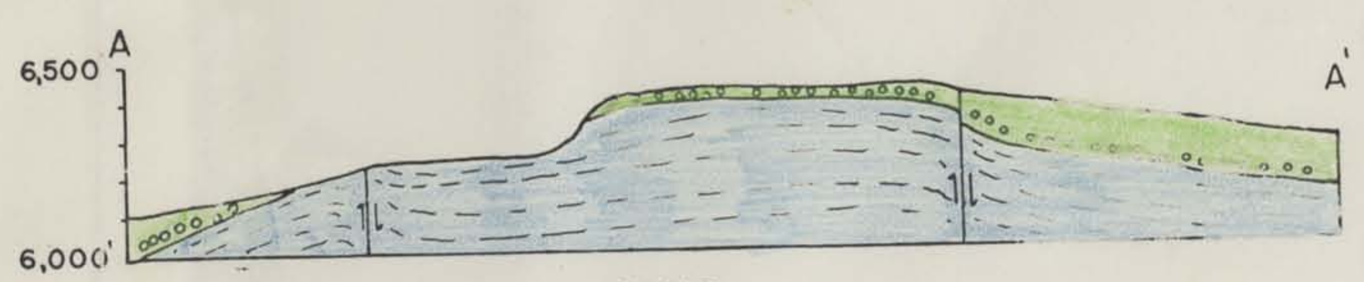
Synclinal axis

A—A' Location of cross section



Approximate mean declination, 1966

Geologic Cross Sections



SCALE
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264 feet

SCALE
1:31,680
2,640 feet

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