THE GEOLOGY OF THE SOUTHERN PEQUOP MOUNTAINS
ELKO COUNTY, NORTHEASTERN NEVADA

by

SIGMUND SNELSON

A thesis submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

UNIVERSITY OF WASHINGTON

1955

Approved by____________________

Department Geology

Date May 25, 1955

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

Figure		Page
25b	Unconformity hypothesis	40
26	Diagramatic cross-section - Cottontail Fault.	41
27	Cottontail Fault.	42
28	Diagramatic cross-section - Dolly Varden anticline.	43
29	Southern Pequops.	43
30	Overturned fold axis.	44
31	Normal and overturned Thaynes(?) "A" limestones	44
32	Diagramatic cross-section - Dolly Varden. . . . . anticline south of Cottontail fault	45
33	Sheep Ridge thrust brecciation zone	46
34	Termination of Isolation Ridge.	47
35	Buckled middle limestone of Phosphoria(?) formation	47
36	Indian Ridge Fault.	48
37	Reconstruction diagram of Indian Ridge fault.	49
38	Isolation Ridge	49
39	Isolation Ridge area brecciation zone	50
40	Diagramatic cross-section of Isolation Ridge syncline	50
41	Diagramatic cross-section of Isolation Ridge syncline	50
42	Jackrabbit fault.	51
43	Geologic Map of the Southern Pequop Mountains, Nevada	53
44	Caprock Ridge	54
45	Old Valley Floor.	55
46	Pediment Fans	55
47	Dissected pediment Fan.	56

INTRODUCTION

The Basin and Range province, consisting of roughly parallel, northerly-trending ranges separated by wide desert basins, has been reported to comprise over one-tenth the area of the United States (Fenneman, 1931). The region is one of complex and controversial geology involving folding, faulting (including thrusting), igneous activity and metamorphism. This report is concerned with the geology of the southern Pequop Mountains, one of the typical basin ranges in northeastern Nevada.

Location, Description, and Accessibility of Area

The map area is in southeast Elko County, northeastern Nevada. The southern margin of the area lies 15 miles north of the town of Currie, and the boundaries lie within the limits of latitudes 114° 28' and 114° 35' north and longitudes 114° 30' and 114° 45' west. The area covers approximately 85 square miles.

The area of greatest relief is the southern part of the northerly-trending Pequop Range. At its southernmost extent, this range swings westerly and joins the northerly-trending Spruce-Chase Spring Mountains, thus forming a hook or U-shaped aerial pattern. The relief of the mountains is contrasted against the wide, relatively flat expanses of the surrounding valleys.

Independence Valley forms a broad lowland separating the northern Chase Springs Mountains and the Pequop Mountains. East of the Pequops lies Steptoe Valley, which merges to the east in name only, into Antelope Valley, and passes into Goshute Valley to the north. Steptoe Valley also bounds the area on the south. Clover Valley forms the lowland to the west of the Spruce-Chase Spring Range.

The area is reasonably accessible by gravel and dirt roads, which are not accurately or completely shown on available maps. A convenient way to reach the area is via a graded gravel road which leaves the east side of

Highway 93 approximately seven miles north of the town of Currie. The gravel road trends easterly for about one-half mile, where it then forks to the northeast and continues for approximately four miles. The road forks again to the east, trending another four miles, and then heads northerly. A short distance beyond the turn, an abandoned oil well-site is encountered. The road continues without gravel cover and reaches a T-intersection in less than a mile to the north. The east fork of the "T" meets a northeast-trending road which continues toward Shafter along the east flank of the Pequop Mountains. Several unimproved dirt road cut-offs heading westerly into the range itself are encountered to the north. These are shown on the U.S.G.S. Pequop Mountains South, Nevada quadrangle (1953).

The Nevada-Northern Railroad crosses the southeast corner of the area and passes through the nearby towns of Currie, Shafter, and Cobre.

Geography

Topography and Drainage

Steptoe Valley, which covers much of the eastern part of the area, has an average elevation of about 5600 feet. Elevation increases westward toward the Pequop Mountains, where the relief becomes more varied. Within the Pequops are three distinctive northeasterly ridge trends, the highest of which reaches an elevation of 8300 feet. Drainage from these ridges and other parts of the area is intermittant. There are two active springs, Boone and Lower Boone Springs. The former is the more productive, although both flow during most of the summer season.

Climate

According to Eakin *et al* (1951):

> The climate of (Steptoe) valley is arid to semiarid and characterized by low precipitation, low humidity, and high evaporation, and a large temperature range both daily and seasonally. Precipitation is least on the valley floor and greatest in the higher parts of the mountains.....

A (precipitation) record is available at Toana, just west of Cobre (see index map for location on p. 2). There the period of record was from 1870 to 1905. The annual precipitation ranged from 1.80 inches in 1881 to 20.38 inches in 1891. The altitude of Toano (5,975 feet above sea level) is about 300 to 400 feet greater than the floor of Goshute-Antelope Valley, and the precipitation may be slightly greater also. The following table summarizes the precipitation at Toano:

Average monthly and annual precipitation at
Toano, Elko County
(Record broken)

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
0.92	0.85	0.87	0.81	0.92	0.66	0.28	0.22	0.25	0.44	0.64	1.30	8.16

No temperature records are available for the valley. However, Clover Valley station, about 25 miles west of Shafter, is believed to be representative. The temperature data are summarized below:

*Temperature at Clover Valley, Elko County (5800')

	Jan.	Feb.	Mar.	Apr.	May	June	
Average	24.6	29.3	35.7	44.3	51.0	59.4	
Average minimum	12.3	17.9	23.1	29.2	35.3	42.3	
Average maximum	36.8	40.8	48.3	59.4	66.6	76.4	
	July	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**	**Year**
Average	67.2	65.8	57.5	47.0	36.7	26.3	45.4
Average minimum	49.3	47.6	39.3	30.1	21.9	13.6	30.2
Average maximum	85.2	83.9	75.7	63.8	51.6	39.0	60.6

*Temp. in degrees Fahrenheit; 27 yr. period ending 1930.

Vegetation

The vegetation of the Steptoe Valley includes big greasewood (*Sarcobatus vermiculatus*), shadscale (*Atriplex confertifolia*), big sage brush (*Artemisia tridentata*), white sage (*Eurotia lanata*), big rabbitbrush (*Chrysothamnus sp.*), and mixed grasses and other members typical of the Northern Desert Shrub plant association. (Eakin, *et al*, 1951).

Within the Pequop range, varieties of juniper, mountain mahogany, pinon, and white pine are found, together with some of the aforementioned brush and grass vegetation.

Previous Work

Although no published geologic work appears to exist for the southern Pequop Range specifically, there have been some reports and maps covering the general area on a small scale. The Geologic Map of the United States (1932), the Fortieth Parallel reports by King (1878) and Hague (1877), and the preliminary Geologic Map of Elko County (1" = 10 miles) compiled by the U.S.G.S. (1953) are apparently the only geologic maps available which cover the area. The earlier maps (1878 and 1932) showed the area as Carboniferous. The 1953 map notes Permian and Triassic-Jurassic formations.

Stratigraphic information is available from several sources. A detailed section of Triassic strata was measured across the east flank of the Southern Pequops by W. Frank Scott (1954). Reference to the occurence of Permian and Triassic strata near U. S. Highway 93 in the valley area south of Spruce Mountain and north of Currie was briefly mentioned by Wheeler, et al (1949). J. P. Smith (1932) listed the fauna of the lower Triassic *Meekoceras* zone which he discovered near Phelan Ranch, Elko County, Nevada.

Field Work

The area was mapped during the summer of 1954. The geology was annotated on U.S.G.S. aerial photographs (1:47,000) and was later transferred to the U.S.G.S. preliminary topographic map, Pequop Mountains, South, Nevada (1:62,500). An additional 14 square miles were mapped on aerial photographs in an area south of the published quadrangle. These data were sketched on the final geologic map, but without accurate survey control.

Acknowledgements

The writer wishes to thank the members of the geology faculty of the University of Washington who generously gave assistance whenever it was needed. Dr. Harry E. Wheeler supervised this thesis and was of constant aid during its preparation. For his suggestions, comments, and critical readings of the of the manuscript, and also for his summer visit to the field, the author is most indebted. Appreciation is also extended to Dr. Peter Misch who kindly arranged for the author to accompany him on a field trip in eastern Nevada during the early summer, 1954. Generous assistance in the field was given by William Hoffman, student at the University of Redlands, California. The company of George Harlow, who was mapping the Spruce Mountain quadrangle to the west, and the welcome visits of Howard Ritzma, Dan Flynn, Leo Waenek, Bob and Paula Steinbach, and Charles Price were greatly appreciated.

The author is deeply indebted to the General Petroleum Corporation for generous financial assistance, maps, transportation, and other facilities which were of immeasureable help in the field.

STRATIGRAPHY

General Statement

The southern Pequop Range consists essentially of Permian and lower Triassic strata, with a minor amount of Tertiary? volcanics and sediments. The Permian sequence is essentially calcareous. The lower 9000 ± feet of limestone and interbedded sandstone and mudstone are of probable Wolfcamp and Leonard age. The uppermost 1700 ± feet of limestone, chert, mudstone, and phosphate rock, appears in part similar to descriptions of the Phosphoria, Park City, Kaibab, and Gerster formations, is of probable Guadalupian age.

Pre-Kaibab(?) Succession

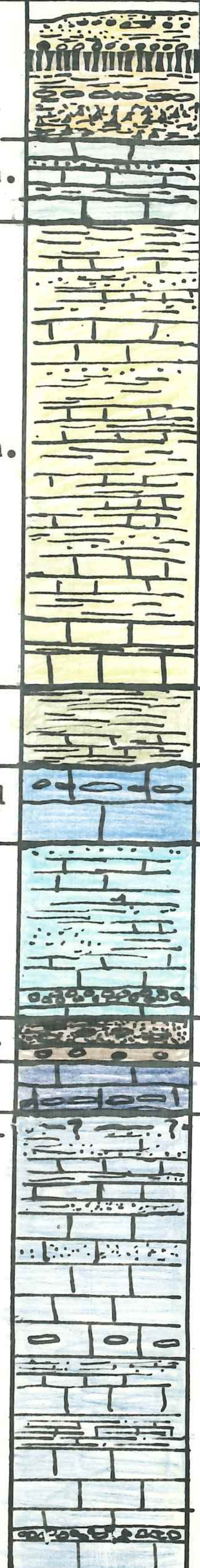
Lithology and Thickness

The pre-Kaibab(?) succession lies to the west of Permian Ridge in the southern Pequop Mountain area. The section was not measured in detail nor subdivided into formations or map units. It is estimated to be 9000 ± feet thick. Lithologically the sequence is primarily calcareous. Limestones vary from light grey to black, and are course to finely crystalline. Many form prominent ridges and scarps. Some limestones are silty and sandy and weather rusty orange to brown. Others contain black and brown chert layers, stringers, and nodules. The sandstones and mudstones in the succession are generally covered. Low in the sequence, and interbedded between grey limestone, is a ten-foot bed of chert-pebble conglomerate containing green, brown, grey, and black, sub-angular to rounded fragments up to ½ inch.

Age

At various intervals in the pre-Kaibab(?) limestones, fusilines, brachiopods, gastropods, corals, and crinoid stems were found. Previous indentification of fusilines in the general area by R. V. Hollingsworth, Midland, Texas, revealed _parafusilina_, _schwagerina_, _tricites_, _schubertella_,

GENERALIZED STRATIGRAPHY OF THE SOUTHERN PEQUOPS

AGE	NAME	COLUMNAR SECTION	THICKNESS IN FEET	CHARACTER AND DESCRIPTION
TERT.-QUAT.	Undifferentiated		850+	Stream, pediment, and playa dep. Minor basalt remnants Conglomerates, siltstones, s.s. Silver to whitish-grey tuffs
	Unconformity			
LOWER TRIASSIC	Thaynes(?) "B" fm.		450±	Arg. limestones, siltstone, shale
LOWER TRIASSIC	Thaynes(?) "A" fm.		2450±	Interbedded olive-drab to greenish-grey shales and fine to medium crystalline, grey limestones Basal ridge-forming grey lms.
LOWER TRIASSIC	Dinwoody(?) fm.		400±	Olive-drab to greenish-grey sh. with <u>Meekoceras</u> lms. near base
	Unconformity ?			
PERMIAN	Phosphoria(?) fm. — Upper Productid Limestone		400±	Grey chert-layered lms. with productids, spiriferoids, etc.
PERMIAN	Phosphoria(?) fm. — Middle Member		900±	Buff to grey limestones, Chert pebble sharpstone congl. near base
PERMIAN	Phosphoria(?) fm. — Lw. Chert-Phos.		175	Chert, mud stone, oolitic phosph.
PERMIAN	Kaibab(?) fm.		150-200	Grey lms., thin chert layers
	? Unconformity ?			
PERMIAN	Pre-Kaibab(?)		9000+	Primarily grey limestones, some argillaceous and arenaceous, and weather rusty-orange; some limestone with black and brown chert layers, stringers, and nodules. Sandstones, and mudstones generally covered. Some chert pebble conglomerate. Fusilines present.

paraschwagerina, pseudoschwagerina, and waeringella. These fossils were assigned to ages from lower Wolfcamp to upper Leonard. The upper Leonard species were apparently found at least 2800 feet stratigraphically below the Kaibab(?) formation.

Fig. 2. — Typical massive limestone ledge of Pre-Kaibab(?) showing minor faulting.

Unconformity?

In the field, the attitudes of the beds stratigraphically below the Kaibab(?) formation invariably were discordant with the Kaibab(?) as much as 90°. At these localities (see page 40) sharp anticlines, structural terraces, faulting, and other structural phenomena were postulated for the relationships observed.

With later integration, it became apparent that a pattern was being established, for on both flanks of the Thanynes Lowland syncline similar discordances occured. That these anomalies may in part be due to a stratigraphic break below but near the base of the Kaibab(?) formation would appear to warrant further investigation. For additional discussion on this topic, see p. 39-40.

Fig. 3. - Pre-Kaibab fusiline limestone talus.

Kaibab(?) Formation

Name

The Kaibab limestone was named by N. H. Darton (1910) for the top formation of the Aubrey group, overlying the Coconino sandstone and underlying the "Moencopi" formation, and capping the Kaibab Plateau on the north side of the Grand Canyon.

Lithology

The Kaibab(?) formation consists almost entirely of a light to medium grey, moderately to thickly bedded, fine to medium crystalline limestone. In parts of the formation are thin layers, stringers, and nodules of chert.

Under the hand lens some of the weathered limestone reveals a dense assortment of poorly preserved minute fossil fragments such as crinoid stems. The fresh surface of the same specimen, however, may appear crystalline and unfossiliferous.

The formation is 150-200 feet thick and forms a prominant outcrop band along the west flank of Phosphate Ridge.

Fig. 4. -- The Kaibab(?) formation on west blank of Phosphate Ridge as seen looking northeasterly.

Age

No identifiable fossils were found in the Kaibab(?) formation. The apparent occurance of upper Leonard parafusilina at least 2800 feet below the unit, would suggest that the Kaibab(?) may be Guadalupian. This would be in agreement with Newell (1948) who on paleontologic evidence regards both the Kaibab and Phosphoria as Guadalupian.

Phosphoria(?) formation

Name

The Phosphoria formation was named by Richards and Mansfield (1912), in southeastern Idaho for about 450 feet of limestone, massive cherts, and phosphate rock that comprise the upper two members of the Park City formation - - the 'upper Productus limestone' and the phosphatic shales.

Lithology and Thickness

Lower chert and phosphate member. - The basal 175 feet of the Phosphoria(?) formation consists primarily of black and brown chert, black mudstone, and some bluish-black oolitic phosphate rock.

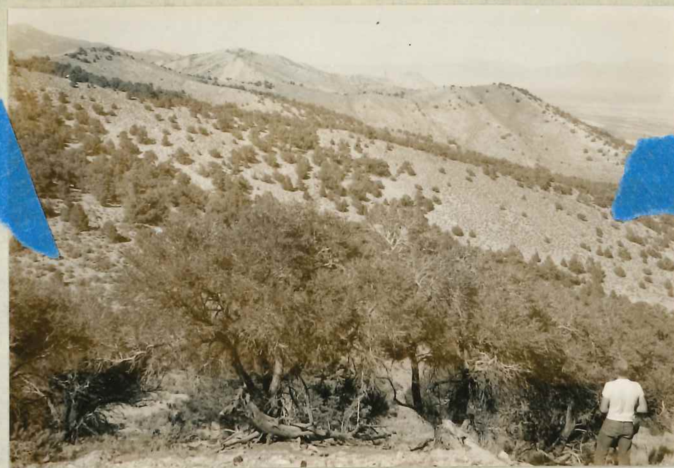


Fig. 5. -- Lower chert and phosphate member outcrops as dark band at far right. View was taken on Indian Ridge looking northeasterly. Beds are overturned with Kaibab(?) forming light schrub-covered exposure east (right) of the dark chert band.

Middle member. - Overlying the lower chert and phosphate member is 950 feet of lithogically varied and often poorly exposed strata. The basal 50 feet is a grey, finely to medium crystalline, grey limestone. It is overlain by about 90 feet of a orange-brown to buff chert pebble sharpstone conglomerate in a calcareous matrix. Above the chert are grey, buff, and brown, finely to medium grained limestones, many of which are argillaceous. Some have chert lagers and nodules. One distinctive limestone is buffish-white, porous, and contains 15-20 percent of poorly sorted, angular to rounded clastic chert fragments. Under the microscope, the limestone is seen to be organic.

Fig. 6. -- Poorly exposed middle member of Phosphoria(?) formation as seen looking northerly on Phosphate Ridge.

Upper Productid limestone member. - The uppermost 400 feet of the Phosphoria(?) formation is a very fossiliferous, grey to buff-grey, fine to medium crystalline limestone. It contains bands, stringers, and nodules of both chert and siliceous limestone. Its characterisitc fossil constituents are productids, spiriferoids, and compositas.

The unit forms a distinctive light-colored band along the east flank of Phosphate Ridge and along the west flank of Caprock Ridge and the southern extent of Indian Ridge.

Fig. 7. - Upper Productid limestone with characteristic siliceous layers and nodules viewed on east flank of Phosphate Ridge.

Fig. 8. - Close-up of upper Productid limestone showing typical weathered surface yielding silicified productids, spiriferoids, and compositas.

Age

In the lower chert and phosphate member of the Phosphoria(?) formation Orbiculoidea? and numerous unidentified fossils were found at locality #1 on the west flank on Phosphate Ridge. Dictyoclostus multistriatus?, Spiriferina pulchra, Spiriferina pseudocameratus?, Composita subtilita, and other species of these genera were found along with unidentified bryozoa and crinoid stems.

Most of the above forms were cited by Branson (1930) in his report on the Phosphoria formation. Regarding the age of the fauna, Branson (p.22) states:

> The Guadalupian rocks of Texas and New Mexico have a fauna which is typical to that of the Phosphoria in its general aspect. Only two species are common to both faunas, however, and it is probable that the two formations are of about the same age, but that the Guadalupian had a southern connection with the sea and the Phosphoria a northern one.

Newell (1948) also favors the Guadalupian age for the Phosphoria fauna.

Correlation of the Kaibab(?) and Phosphoria(?) formations

General Background

The upper Permian deposits known in Idaho, northern Utah, and west-central Wyoming generally have been placed in the Phosphoria formation. In northwestern Wyoming they are included in the Embar, and in the Wasatch Range in central Utah they are often placed in the Park City formation. In western most Utah at Gold Hill the highest exposed Permian is the Gerter formation, and in the southern Utah and northern Arizona area the uppermost Permian is the Kaibab limestone.

In eastern and northeastern Nevada various oil companies have recognized thick Permian successions, however, as yet little information has been published about them. The Arcturus formation, assigned originally to the

Pennsylvannian in the Ely district, eastern Nevada (Spencer, 1917), is now commonly regarded as Permian. In the area north of Currie, Nevada, Wheeler et al (1949) have called attention to a Permian succession.

That the Phosphoria formation, specifically, has a correlative in eastern Nevada was mentioned by Branson (1930). He listed the following fossils that had been collected by geologists of the United States Geological Exploration of the Fortieth Parallel in White Pine County, Nevada; and all of which occur in the Phosphoria formation:

Pustula nevadensis	Pustula subhorrida
Productus multistriatus	Composita mira
Spiriferina pulchra	Spiriferina kentuckiensis

Descriptions and Locations of the Phosphoria Kaibab and Park City Formations

Phosphoria of southeast Idaho. - The Phosphoria formation at its type locality in Phosphoria Gulch, southeastern Idaho (Richards and Mansfield, 1912), consists of a lower Phosphatic shale member about 180 feet thick, and a poorly developed upper member known as the Rex Chert, which is 240 feet thick. The latter consists of limestone, shale, and only 60 feet of chert. In most of southeastern Idaho and western Wyoming, however, a third member of the Phosphoria formation consisting of 15 to 75 feet of thin-bedded cherty mudstone overlies the Rex Chert. This unit is not well defined at the type locality of the Phosphoria. (Smart, 1954).

Kaibab of northwest Arizona and southern Utah. - In the Zion Park region, the Kaibab is 580 ± feet thick. It is a white to yellowish, massive, more or less dolomitic limestone, in part cherty, fossiliferous, and gypsiferous. It is reported to be unconformably overlain by the Triassic Moenkopi red beds (Gregory, 1950).

Kaibab and Phosphoria of west-central Utah. - In the Confusion Range, Newell (1948) found a Permian succession in which he recognized 2000 ± feet of Kaibab limestone overlain by a 4555-foot Phosphoria formation of abundantly fossiliferous limestones and limy shales. The strata have been truncated by a pre-Triassic erosion surface, over which have been deposited Triassic Woodside red beds. Newell stated that the upper fossiliferous limestone succession contains several species of productids, spiriferoids, a variety of bryozoans, and Composita mira, all typical of the Phosphoria fauna. At the base of the formation, Newell found a thin sequence of black shale, chert, and limestone.

Park City of north-central Utah. - According to Baker and Williams (1940), the Kaibab and Phosphoria formations of the aforementioned Confusion Range section appear to be closely related to the upper part of the 400- foot Permian sequence described at Hobble Creek near Provo, Utah. Baker and Williams designate the upper two limestone units and the intervening shale in this Permian locality as the Park City formation. The upper limestone consists of a cherty, thin-bedded to massive, grey to pink limestone, with some interbedded grey sandstone, red shale and siltstone. The middle shale unit of the Park City is mostly black shale, but contains thin beds of black cherty limestone and some thin beds of oolitic phosphate.

The upper limestone and the middle shale unit of the Park City contain the Phosphoria fauna, including Spiriferina pulchra (Meek), Spirifer pseudocameratus Girty, and other characteristic species (Baker and Williams, 1940).

Baker and Williams found the lower limestone of their Park City formation to consist of a thin bedded to massive, grey to pinkish grey limestone containing some grey to white chert and some interbedded grey sandy limestone and limy sandstone. It contained Kaibab and some elements of Phosphoria fauna.

At its type locality to the north (Boutwell, 1907), the Park City formation is only 590 feet thick and overlies the Weber quartzite. The three Park City units of the Hobble Creek section are less distinct here. However, according to Baker and Williams, the locally variable upper limestone member with cherts and sandstones, is equivalent to the upper or Rex Chert member of the Phosphoria formation, and the middle shale member is probably correlatable with the Phosphatic shale member of the Phosphoria formation.

Conclusions

On the basis of the foregoing information, it would appear that the Park City formation of the southern Wasatch region actually consists of three lithologic elements, a lower limestone, a middle black chert and shale unit with some oolitic phosphate, and an upper limestone with some interbedded clastic sediments and chert. The lower limestone appears correlatable lithologically and faunally with the Kaibab formation. The upper two units similarly appear to be equivalent to the Phosphatic shale and the Rex Chert members of the Phosphoria formation. It would seem that the Park City formation includes several lithologic units which are elsewhere distinct and mappable, and which also can be traced regionally.

The correlation is borne out faunally by Branson (1930, p. 21) who lists the following fossils which the Phosphoria and upper two members of the Park City have in common:

Orbiculoidea utahensis	Productus phosphaticus
Pustula montpelierensis	Rhynchopora taylori
Spiriferina pulchra	Composita subtilita
Nucula montpelierensis	Leda obesa
Plagioglypta canna	Euphemus carbonarius
Euphemus subpapillosus	Conularia crustula?

Branson (1930, p. 21) has stated:

> The base of the Phosphoria formation is a more logical division line than that which was defined as the base of the Park City, and the recent tendency is to substitute the name "Phosphoria" for the upper two members of the Park City in all localities.

Because the Gerster formation (Nolan, 1935) outcrops only in a narrow area in the structurally complex Gold Hill quadrangle, and contains the _Spiriferina pulchra_ fauna characteristic of the previously named Phosphoria formation (1912), it would not seem practical to expand this term.

For the sake of regional integration it would seem advantageous to either, (1) discard the name Park City and subdivide that succession into two formations, the Kaibab and Phosphoria, (2) retain the Park City formation and term the lower limestone unit the Kaibab member, and regard the middle shale and upper limestone and chert elements as subunits of the Phosphoria member.

Newell (1948) has followed the first alternative in the Confusion Range, Utah, where he recognized the Kaibab and Phosphoria formations in the upper part of his Permian section.

This author prefers to delineate the uppermost Permian sequence in the southern Pequop Range into two formations, the Kaibab(?) and the Phosphoria(?).

In the southern Pequops, the Kaibab(?) limestone is much thinner than the Kaibab of the Colorado Plateau area and is possibly a tongue of the latter. The Phosphoria(?) of the Pequops can be sub-divided into three members: a lower black chert and mudstone unit with some oolitic phosphate; a middle succession consisting in part of grey, buff, and brown limestone, and black and brown chert; and an upper grey limestone unit characterized by an abundant content of productids, spiriferoids, and compositas.

Permo-Triassic Boundary

Outcrops in the Southern Pequop Mountains

Within the southern Pequops the contact between the Permian and the Triassic lithologies is invariably covered inasmuch as the basal Triassic strata is an easily concealed greenish grey shale and reddish to chocolate brown limestone. Only in one area, at fossil locality #3 in section 20, T. 31 N., R 65 E, were fairly good exposures found. A minor stream valley follows the approximate lithologic boundary. The strata strikes northeasterly and dips moderately to the northwest. On the east side of the canyon is the grey fossiliferous Upper Productid limestone Member of the Phosphoria(?)

formation. The composite section as measured from the Permian is as follows:

Specimen	Description	Thickness
	Upper Productid limestone	
	Covered	3 feet
1	Grey, pink, and buff weathered, unevenly bedded light olive-brown limestone. Contains poorly preserved fossils.	1 ?
	Covered	2
2	Buffish-grey weathered, finely grained, unevenly bedded grey limestone. Contains poorly preserved fossils.	1
3	Buff to buffish-grey weathered, finely grained, unevenly bedded yellowish-brown limestone. Contains poorly preserved fossils. Has very irregular uppermost boundary which is in intimate contact with a dark reddish-grey, finely crystalline limestone. Thin section across contact shows both to be almost entirely organic. (see figs. 9 and 10)	2
4	Reddish-grey, finely crystalline, moderately bedded limestone.	2
	Covered (shale)	2
5	Reddish to chocolate-brown, iron-impregnated, finely to medium crystalline fossiliferous limestone. Contains ammonites and microfossils. Is lithologically similar to the <u>Meekoceras</u> zone as described by J. P. Smith (1932) near Phelan Ranch, Elko County, Nevada, and also the <u>Meekoceras</u> zone found by Scott (1954) in the valley area north of Currie, Nevada. (see fig. 11)	

Fig. 9. - Irregular contact between yellowish-brown and reddish-grey limestone of specimens 3 and 4.

Fig. 10. - Unevenly-bedded, buffish-grey weathered, yellowish-brown limestone. Specimen 3.

It will be noted that within approximately 16 feet, the succession passes from Permian to Triassic. Although no channeling, basal conglomerate, or truncation was observed in this interval, it is a possibility that such may occur in the covered areas.

In another locality south of the Jackrabbitt fault in Section 11,

T. 30 N., R. 64 E., an exposure of a siliceous grey limestone containing chert and fossil fragments was noted at or near the uppermost Permian which also was observed on the east flank of Phelan Butte, west of the area.

The Phosphoria(?) and the overlying Dinwoody(?) and Thaynes(?) formations in general correspond quite closely in attitude throughout the area, however, in section 16, T. 31 N., R. 65 E., distinctive discordances were noted between strikes and dips of the Thaynes(?) and those of the Phosphoria(?). These may or may not be post-Triassic features.

Summary of Regional Relationships

According to Baker and Williams (1940), in the southern Wasatch Mountains of Utah the Woodside formation bevels approximately 2000 feet of Permain strata in a horizontal distance of about 10 miles. In southwestern and central Wyoming, Newell and Kummel (1942) found an unconformity between the Phosphoria and the Dinwoody. In western Utah, Newell (1948) reports the Woodside with a marked angular unconformity truncating the Permian. In southwestern Utah, northeastern Arizona, and southeastern Nevada, Gregory (1950) and others have found the Moenkopi unconformably overlying the Kaibab.

In dealing with the Phosphoria-Woodside (Dinwoody equivalent) in southeastern Idaho, Mansfield (1927) found the two formations "marked by great regularity wherever ... shown," and that "field relations suggest conformity between the two systems." He adds, however, that the "striking faunal and lithogic differences ... point to very different conditions of deposition for the two formations and indicate a stratigraphic break of some magnitude."

In the vicinity of the thesis area, near Highway 93 between Currie and Spruce Mountain, Wheeler _et al_ (1949) reported the Triassic to disconformably overlie the Permian. At nearby Phelan Butte, a slight angular unconformity exists between the Permian and the Triassic (Wheeler, personal communication).

Conclusion

Assuming that the lowermost Triassic faunal unit in the southern Pequop Mountains is the Meekoceras zone, and that the Permian fauna is Guadalupian, a time interval must be accounted for. Whether this hiatus was caused by a period of sub-aerial erosion, submarine reworking, or non-deposition, cannot be firmly established. General conformity of attitudes, local presence of a limestone containing chert and fossil fragments, and possible local truncation -- these suggest that the Permo-Triassic boundary in the southern Pequop Range may be an unconformity possibly caused by any one or all of the above agencies.

Dinwoody(?) Formation

Name

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. The limits of this essentially greenish-grey shale sequence was defined by the Park City formation below, and the bright red shales and siltstones of the Chugwater formation above.

Lithology

A weak valley-forming succession which occurs in the southern Pequops and adjacent areas, consists primarily of an olive-drab to greenish-grey shale with interbedded Meekoceras-bearing reddish and chocolate-brown, iron-impregnated limestones near the base. The strata, which is about 400-feet thick, overlies the very fossiliferous upper Phosphoria(?) limestone and underlies a ridge-making sequence of grey basal limestones of the Thaynes(?) formation.

The succession is typically covered by a thin clayey soil mantle with interspersed reddish-brown limestone debris. The shales outcrop best in the SE$\frac{1}{4}$ of SW$\frac{1}{2}$ of Section 1, T. 30 N., R 64 E. The limestone is fairly well exposed at fossil localities 1, 2, 3, and 4.

Fig. 11. -- Meekoceras zone of Dinwoody(?) formation viewed at fossil locality #3.

Age

The section in the southern Pequops was previously measured and identified as essentially lower Triassic by Scott (1954), who discovered the Meekoceras zone 81 feet above the Permian. This author discovered ammonoids in Triassic sediments beginning 16 feet above distinctly Phosphoria fauna. The Meekoceras fauna and other ammonoids and microfossils were recovered in limestone interbeds.

The lowermost 16-foot interval, which may be Permian, Triassic, or both, contains pelecypods and other obscure fossils. It is possible that a critical analysis of this usually-covered sequence may reveal a pre-Meekoceras Triassic age.

Correlation of the Dinwoody(?) Formation

General Background

The shale and interbedded limestone valley-forming sequence constitutes a distinctive mappable lithologic unit, and the question of applying a formational name therefore arises. Units having the same stratigraphic position have been given formational names in adjacent regions. An essentially red shale and siltstone sequence overlying the Phosphoria formation in northern Utah, the Kaibab in west-central Utah, and the Gerster in northwest Utah, has been named the Woodside formation (Boutwell, 1907; Newell, 1948; Nolan, 1935). Green to olive-drab shales occupying the same stratigraphic position in southeastern Idaho and southern Wyoming have generally been called the Dinwoody formation. In the Hawthorne-Tonopah region of west-central Nevada, lithologies somewhat similar to the Dinwoody have been designated as the Candalaria formation (Ferguson and Muller, 1936). This formation overlies Permian volcanics.

Statigraphic Position and Age of the Dinwoody, Thaynes and Woodside Formations

Generally, the Dinwoody and the Woodside underlie the Thaynes formation whose base has in practice been determined by the position of the *Meekoceras* zone. It has been demonstrated that these two underlying formations are lateral and time equivalents of one another (Kummel, 1954), with the green Dinwoody lithologies regarded as the marine equivalent of the essentially continental Woodside red beds (Scott, 1954).

Although the Dinwoody was once regarded as of possible Permian age (Blackwelder, 1918), it has since clearly been demonstrated to be lower Triassic (Kummel, 1954), and to contain the same lowermost Triassic *Otoceras* and *Genodiscus* zones as also occur at Candalaria, Nevada.

As mentioned, the presence of Smith's third lower Triassic faunal unit, the *Meekoceras* zone, has generally been used to denote the base of the Thaynes formation. The lower Thaynes lithologies, however, have been reported as quite similar to the underlying units. For example, Mansfield (1927) states in his discussion of the Woodside:

> The upper limit is not so easily distinguished for the lithology of the Woodside and the overlying Thaynes is in many respects similar and

> the boundary has been somewhat arbitrarily placed at the layer immediately below the Meekoceras zone.

Elsewhere, beds above and below the Meekoceras zone are described as similar in lithology, and thus faunal, rather than lithologic boundaries, often have been used to distinguish the formations. If such a faunal basis were everywhere used to denote the base of the Thaynes formation, any lithologic-biostratigraphic transgressive relationships, if such occurred, would be obscurred. Further, the Stratigraphic Commission in 1948 decided that formations should be distinguished as much as possible on lithologic unity.

On the basis of a thick, newly-discovered green shale succession containing the Meekoceras zone and located in northern Elko County, northeastern Nevada (Wheeler, personal communication), it appears that the Thaynes limestones tongue out to the west as well as the east. Without significant lithologic change between the strata above and the strata below the Meekoceras zone in this Nevada area, the separation of the section into two formations would not be regarded as valid. Inasmuch as the name Dinwoody has been applied in southeastern Idaho to a sequence overlying the Permian, it is logical that it should be carried into northeastern Nevada to apply to the entire shale succession above and below the Meekoceras zone. The age of the Dinwoody(?) designated here, would be older, as well as partially equivalent in age to the Thaynes limestones as described in southeastern Idaho.

Scott (1954) measured several sections of the lower Triassic sequence in the general southern Pequop Mountains area. He tentatively referred to all the beds above the highest Permian strata and below the Shinarump(?) conglomerate as the Thaynes(?) formation. (His Currie-Dolly-Varden succession is incidently more complete than that in the Pequop Range to the north, where the Shinarump(?) has been faulted out.) Despite Scott's reference to the entire succession as Thaynes(?), he does acknowledge that (p. 85), "some of the greenish-grey shales at the base suggest Dinwoody." It appears to this author that Scott correlated his sections with the Thaynes formation as faunally defined (the base of the *Meekoceras* zone). In doing so, he was forced to overlook a distinctive 400-foot thick green shale and intercalated reddish-brown limestone succession which lies stratigraphically below grey ridge-forming limestones.

Conclusions

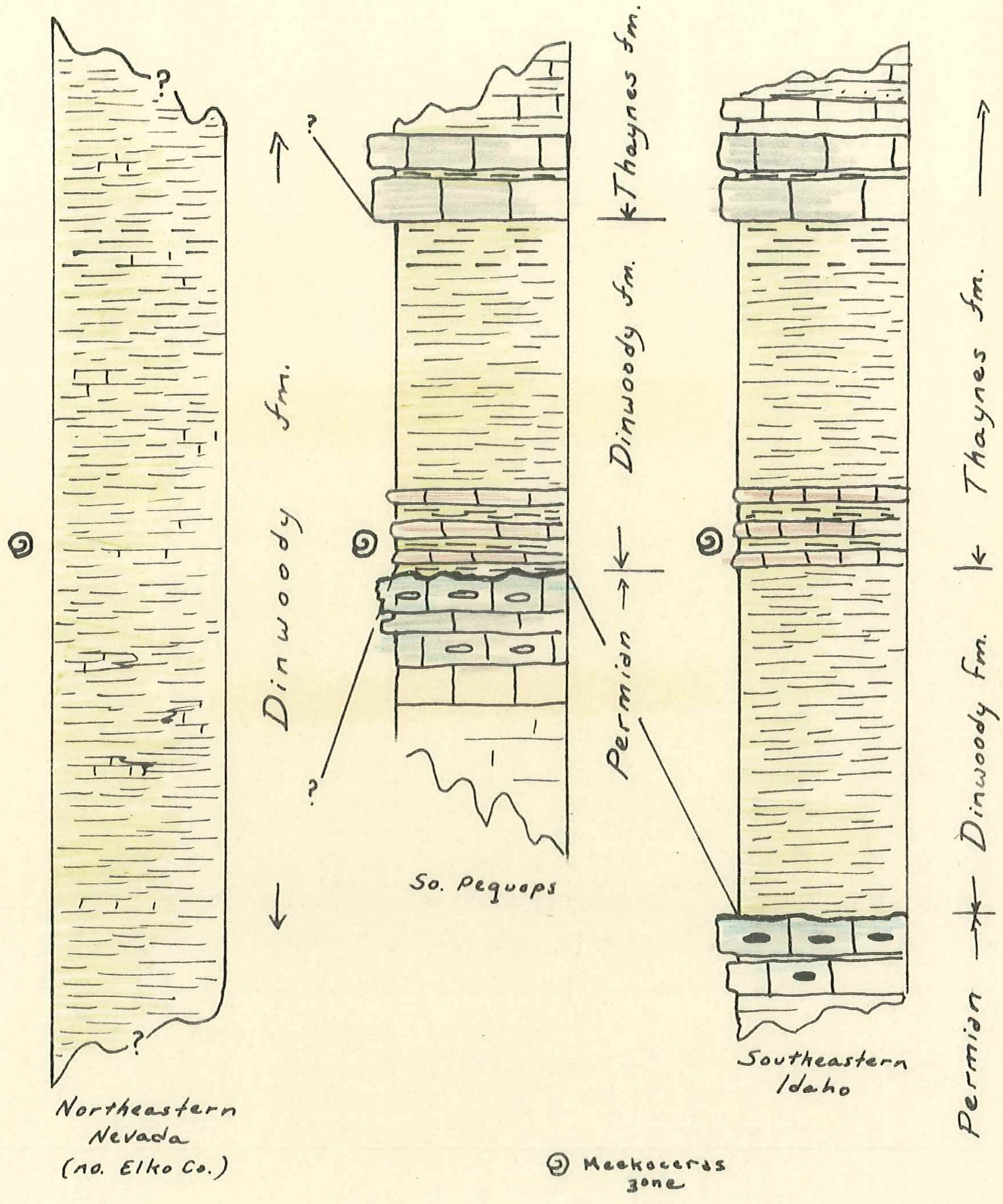
Because the Thaynes formation of southeastern Idaho apparently has been distinguished on a faunal basis which can no longer be regarded as valid, and because of the regional stratigraphic implications of the recently-discovered thick Dinwoody(?) succession in northeastern Nevada, a lithologic definition for the Dinwoody and Thaynes formations now appears necessary. Such a definition would logically regard the essentially shale sequence between the Permian limestones below and the Thaynes limestones above as the Dinwoody and/or Woodside formation: the latter alternatives depending upon whether the shales were green or red, respectively.

Thus, the 400-foot thick, weak valley-forming sequence of greenish-grey shales and interbedded reddish to chocolate-brown limestone in the southern Pequop Mountains, tentatively is designated as the Dinwoody(?) formation. The overlying succession, whose base is represented by the ridge-forming grey limestones, accordingly is tentatively regarded as the Thaynes(?) formation.

Thaynes(?) Formation

Name

The Thaynes formation was originally defined by Boutwell (1907) from outcrops in Thaynes Canyon, Park City Mining District, Utah. An essentially calcareous formation, its 1290 feet were divided into two limestone, sandstone, shale, and siltstone units separated by a red shale member.



COMPARATIVE NOMENCLATURE OF THE LOWER TRIASSIC STRATA OF NORTHEASTERN NEVADA AND SOUTHEASTERN IDAHO

The Thaynes has subsequently been carried into southeastern Idaho and western Wyoming, and has generally included that strata from the base of the *Meekoceras* zone up to the Ankarah, Timothy, or other equivalent red shale formation.

Lithology

In the southern Pequops, the Thaynes(?) has been separated into two members, "A" and "B". The base of each of these is marked by prominant ridge-forming limestones.

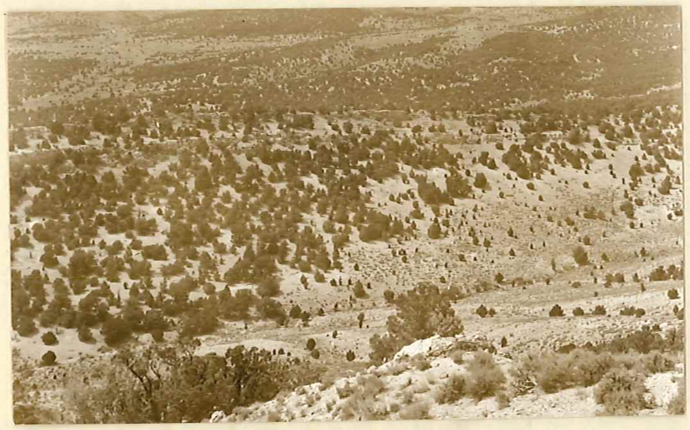


Fig. 13. -- Basal Thaynes(?) "A" ridge-forming limestones as viewed across intervening valley in foreground that is formed in weak Dinwoody(?) shales.

Member "A". - The resistant grey limestone beds at the base of the Thaynes(?) "A" member are represented by prominant ridges throughout the area. Some of these limestones are fossiliferous, but with the exception of *Terebratula thaynesiana*?, the fossils rarely weather out.

In contrast to the basal ridge-forming limestones, the immediately overlying succession of shale, siltstone, and limestone is generally covered. Some of the shales in the sequence appear very similar to those within the Dinwoody(?) formation. They are fissile and olive-drab to green. In addition to these shales, are calcareous shales with nodules of finely crystalline grey limestone; and orange-brown weathered, finely to medium crystalline, platy, grey limestone. The thickness of the Thaynes "A" member is estimated to be

2450 ± feet.

Fig. 14. -- Fissile shales of the Thaynes "A" member as exposed on the north side of Spring Creek at the NW¼ of NE¼, and the NE¼ of NW¼, of Section 6, T. 30 N., R. 65 E., where the units are nearly vertically inclined.

Fig. 15. -- Typical limestone within the Thaynes "A" formation.

Fig. 16. -- Fissile shales of the Thaynes "A" member with finely crystalline, grey limestone nodules.

Member "B". - The Thaynes "B" member is topographically represented by Sheep Ridge. The unit has been delineated because of its ridge-forming character and for its usefulness in illustrating structural relationships. The base of the member is an alternately orange and grey weathered, finely crystalline, argillaceous, and locally current-bedded, buffish-grey limestone, containing unidentified pelecypods. The overlying units consist of interbedded shales, siltstones, argillaceous limestones, and minor chert. The limestones weather buff, brown, grey, and red; are finely to medium crystalline; thin to thickly-bedded; and buff to dark grey. The siltstones and shales are essentially covered, forming minor sags between more resistant limestone units across the crest of Sheep Ridge.

The succession is approximately 450 ± feet thick from its base to a fault zone where Thaynes(?) "A" units have been thrust against it.

Age

The brachiopod Terebratula thaynesiana? Girty, and other poorly preserved fossils were found within the Thaynes(?) formation. The T. Thaynesiana? was originally discovered in the lower Triassic Thaynes group of southeastern

Idaho (Mansfield, 1927), and would suggest a similar age for the southern Pequop Thaynes(?).

Fig. 17. -- The basal argillaceous limestone of the "B" member of the Thaynes(?) formation located on the west flank of Sheep Ridge.

Thickness of the Triassic Sequence

The total thickness of the Triassic within the southern Pequop Range is estimated to be a minimum of 3300 ± feet from the upper member of the Permian Phosphoria(?) formation to the fault contact. This figure represents an additional 1100 ± feet than was previously reported in the area by Scott (1954) who reported 2375 feet of strata.

In the Currie-Dolly Varden area to the immediate south, Scott reported a total Triassic thickness of 2823 feet for the Thaynes, Shinarump, and Chinlee formations. If the combined 623-foot thickness of the Shinarump and Chinlee formations, as found in this southern area, were added to the 3300 ± feet of Dinwoody(?) and Thaynes(?) in the Pequops, the total thickness of the Triassic in this northeastern Nevada area would be close to 4000 feet.

Permian and Triassic History

Because of the limited area covered by this report, any treatment of the geologic history must be limited to those systems where the stratigraphic records are well-preserved, those being the Permian and Triassic. On the basis of data from the map area alone, diastrophism which followed and deformed these records, and which is doubtless responsible for the Pequop Range itself, cannot be more accurately dated than post-Triassic.

During Wolfcamp and Leonard time, over 9000 feet of predominantly calcareous material was being deposited in this general miogeosynclinal area. Preceding the deposition of the Guadalupian(?) Kaibab(?) limestone, there was possibly a deformational episode. It should be mentioned that this event is only a possibility and is in need of additional study. For further discussion see pages 9, 39 and 40.

In Guadalupian? time, the Phosphoria Sea which covered areas in Idaho, Utah, Montana, Wyoming, Colorado, and Nevada, deposited a varied sequence of phosphates, cherts, mudstones, and limestones, (see fig. 18).

Following Guadalupian? time was essentially a period of non-deposition, possibly accompanied by sub-aerial erosion and/or submarine reworking. When subsidence and deposition was resumed in lower Triassic time, a distinct change in lithology and faunal assemblange had occurred. The productids, spiriferoids, and compositas of the grey Permian limestones were replaced by the ammonoids of the Triassic green shales and reddish-brown limestones.

The green shales of the Dinwoody(?) and Thaynes(?) formations indicate that lower Triassic deposition was probably marine. Current-bedding found in the Thaynes "B" argillaceous limestones suggests periods of shallow water conditions, and a clastic origin for some of the limestones.

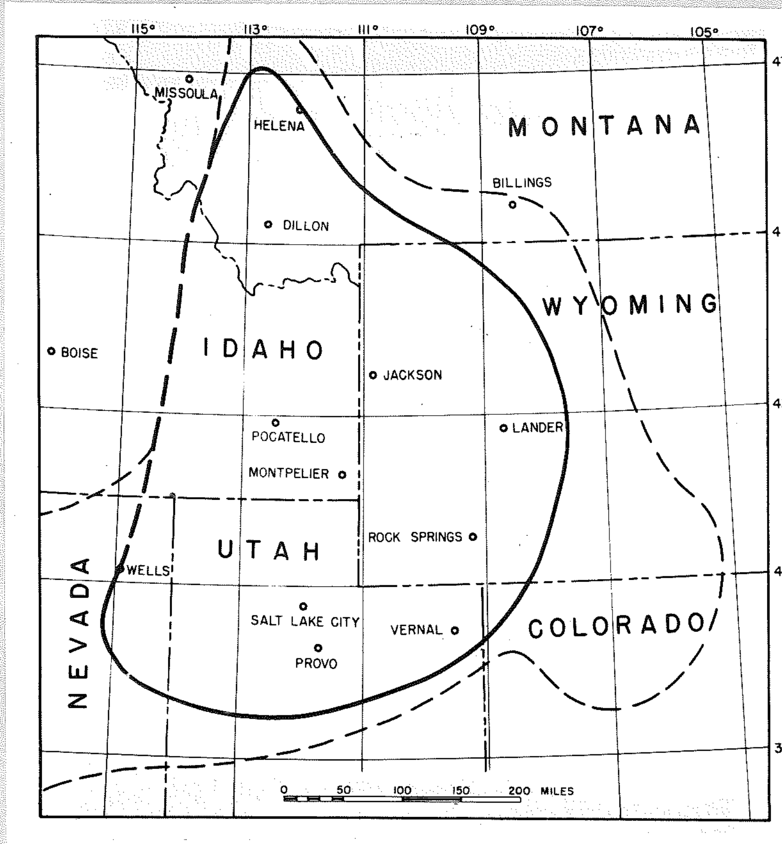


Fig. 18. -- Limits of the Phosphoria formation and its stratigraphic correlatives (dashed line) and their phosphate deposits (solid line). (From Swanson, _et al_, 1953).

Tertiary and Quaternary Strata

Introduction

The deposits of Tertiary to Quaternary age, with the exception of recent alluvium and playa lake clays and gravels, outcrop in a very small portion of the thesis area. Absence of fossils in the exposed strata prevented any exact age determination.

Exposures were found in two areas, one in sections 10, 15, and 16, T. 31 N., R. 64 E., at the southernmost boundary of Independence Valley, and the other in sections 3, 4, and 10, T. 30 N., R. 64 E., in the southwest portion of the thesis area.

Lithology

Northern Area. - Exposures in the northern area are quite sparce. Rock types include: indurated whitish-grey vitric tuff consisting of an intimate association of curved and spicule-like glass shards; a poorly indurated light tan tuffaceous? siltstone; remnants of an orange to dark grey weathered, augite and lamprobolite-bearing hypersthene basalt.

The relationship between these deposits and the Paleozoic limestones is obscure in this area. Attitudes of the Cenozoic beds range from apparently horizontal to 20° northeasterly, and the older limestones of the range dip an average of 25° southeasterly. These attitudes and the topographic position of the respective units suggest a possible fault relationship, the type or magnitude of which is unknown.

Southern Area. - Tertiary and Quaternary sediments are exposed along the Coyote Pass road, which heads northward along a dissected stream channel into the range. The outcrops were exposed for 1.8 miles south of the 40° 30' latitude and their dips approximated 5 to 8 degrees southerly. The thickness of these deposits is conservatively estimated to be at least 825 feet.

The basal unit in the southern area is about 15 feet of light silver-grey, fine grained, thinly-bedded, friable vitric tuff. It has a distinctly different texture from the whitish-grey vitric tuff of the northern area, lacking the cohesiveness and the curved and spicule-like shard development. But for its purity , the thin-bedding, the lack of induration and shard development suggests it represents a reworking of an earlier vitric tuff, possibly similar to the whitish-grey tuff deposit of the northern area. On the other hand, it may represent a bedded ash fall.

Fig. 19. -- View of the silver-grey vitric tuff and buff-weathered Paleozoic limestone in background. Seen looking northerly on east side of Coyote Pass in Section 3, T. 31 N., R. 64 E.

Although relationships of the silver-grey tuff to the Paleozoic limestone was generally obscure, at one locality (the base of a narrow east-west trending gulley following the common boundary between sections 3 and 10, T. 31 N., R. 64 E. at the 6680-foot contour), the tuff clearly lies unconformably upon the limestone and with a 10° to 12° southerly dip.

Fig. 20. -- Silver-grey, bedded vitric tuff (note pick) unconformably overlying grey Paleozoic limestone.

Overlying the basal tuff is a light tan conglomerate consisting of angular to sub-angular rock fragments of limestone and some chert. Above these units are alternating beds of tuffaceous? and calcareous siltstones, sandstones, and conglomerates.

Recent Deposits

Material in the present stream channels and on the pediment surfaces flanking the southern Pequops consists of poorly sorted and unconsolidated clay, silt, sand, pebbles, and cobbles. The cobble-size material is limestone and generally limited to stream channels. The finer debris of limestone and chert particles is found in the stream channels as well as on the interstream surfaces of the flanking pediment, where they form a thin veneer.

Fig. 21. -- Consolidated Quaternary alluvium.

Fig. 22. -- Unconsolidated Recent alluvium.

STRUCTURE

Regional Structure

The Basin and Range province, consisting of roughly parallel, northerly-trending ranges separated by wide desert basins, has been reported to comprise over one-tenth the area of the United States (Fenneman, 1931). The region is one of complex and controversial geology involving folding, faulting (including thrusting), igneous activity and metamorphism. Nolan (1943) and Eardley (1951) have discussed the broad regional structure and related problems. This writer's work has been local and detailed; and his experience outside the area of immediate study is limited. He therefore does not feel justified to draw conclusions as to the validity of the regional interpretations of these authors.

The Pequop Range and Spruce Mountain were first described geologically by King (1878), and Hague (1877). In discussing Spruce Mountain, Hague (p. 509) stated:

> But for its intimate topographical and geological connection with the extreme end of the Pequop uplift, Spruce Mountain, with its long ridge stretching to the northward, might be regarded as a separate range . . . . In its geological features, Spruce Mountain shows a very complicated structure, but in general would appear to be an anticlinal fold, the eastern side forming a syncline with the main ridge.

King (1878, p. 737) stated:

> The adjoining Pequop Range shows throughout its long north and south member a monoclinal (homoclinal) structure being composed of beds dipping entirely to the west, but in the southern portion these beds are seen to pass under a distinct synclinal and then west of the depression to rise and pass over a distinct anticlinal.

These were reconnaissance reports and, for this area at least, are considerably inaccurate.

Local Structure

The deformation in the southern Pequops consisted initially of large-scale folding with a north-northeasterly trend, and related faulting. The folding produced a southwesterly-plunging syncline over eight miles in length and an adjacent anticline of similar proportions to the east. The anticline became overturned in part, and was thrusted westward over a portion of the syncline. A homocline lies west of the syncline.

In addition to the above thrust, a series of transverse faults developed during the period of folding, some diagonal and some perpendicular to the fold and thrust trend. A group of northwesterly-trending transverse strike-slip faults occur along the southernmost boundary of the range and appear to be in part responsible for the southern termination of the Pequop Mountains.

Thaynes Lowland Syncline

This syncline forms the Thaynes Lowland which lies between two northeasterly-trending ridges, Phosphate Ridge on the east and Indian Ridge on the west. The lowland is about 1½ miles wide and approximately

Fig. 23. — View of outcrop patterns along west flank of Thaynes Lowland as seen looking southwest towards Phosphate Ridge. The tree-covered outcrops near the base of the ridge are the basal grey limestones of the "A" member of the Thaynes(?) formation. The lighter band near the ridge crest is the upper Productid limestone.

8 miles long. It has been formed in the weaker units of the "A" member of the Thaynes(?) formation. The more resistant units of the "B" member of the Thaynes(?) formation has formed Sheep Ridge which occupies the central part of the lowland along an approximate 3½ mile trend.

Fig. 24. -- Thaynes Lowland as viewed from the north. Sheep Ridge is located in center of panorama, with Indian Ridge on the east and Phosphate Ridge to the west.

Near the northernmost limits of the area in Section 9, T. 31 N., R. 65 E., the 20° southwesterly-plunging Triassic units are eliminated as they rise above the present topographic surface. Further south the plunge progressively decreases.

Unconformity or Structural Terrace?

A thick easterly to southeasterly-dipping sequence lies to the west of the Thaynes Lowland. Phosphate Ridge consists in part of the Phosphoria(?) and Kaibab(?) formations. The strata near the ridge crest are mostly steeply dipping with attitudes varying from 70° southeasterly to vertical, and locally overturned at the ridge's southern extent. Where exposed, pre-Kaibab(?) outcrops immediately west of the steep units of Phosphate Ridge generally reveal a gentle 4° to 16° southeasterly dip. Farther westward pre-Kaibab(?) attitudes approach 30° southeasterly. Hence, the locally overturned and thrusted Thaynes Lowland syncline would appear at first glance to pass westward into a structural terrace. The most notable discordance between the Kaibab(?) and pre-Kaibab(?) strata occurs in Section 2, T. 30 N., R. 64 E. Here, within a few hundred feet is pre-Kaibab(?) strata dipping 16° easterly toward overturned

Kaibab(?) dipping 70° northwesterly -- an almost perpendicular relationship. The pre-Kaibab(?) strikes almost due north, while the Kaibab(?) strikes N. 20° - 30° E. It is possible that shearing and faulting may have here accompanied the overturning of the eastern axis of a structural terrace, (see fig. 25a) however, no direct evidence for such a fault was observed.

In place of this faulted terrace interpretation, these relationships might be explained by the postulation of an angular unconformity at or immediately below the base of the Kaibab(?) formation, (fig. 25b). Because of similar discordances between the Kaibab(?) and pre-Kaibab(?) exist in other locations on both flanks of the Thaynes Lowland Syncline (section 7 and 8, T. 31 N., R. 65 E.; Section 13, T. 31 N., R. 64 E.; and sections 5, 21, and 29, T. 30 N., R. 65 E.), the possibility of a stratigraphic break would certainly warrant further investigation. (See pages 9 and 33 for additional discussion.

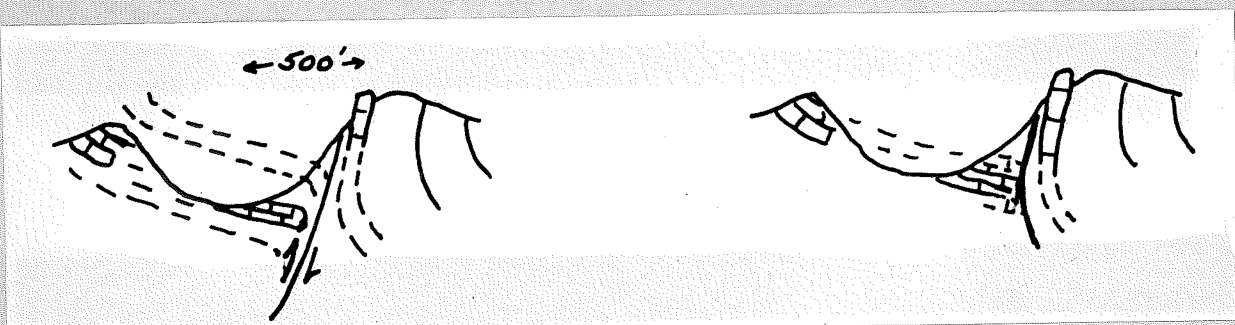


Fig. 25a. Fig. 25b.

Cottontail Fault

The limbs of the Thaynes Lowland syncline have been offset noticeably at several localities by transverse faulting. The most pronounced displacements occur at the south end of the range where several strike-slip faults progressively offset the Kaibab(?)-Thaynes(?) sequence right-laterally. This group of faults will be discussed later.

The east-southeasterly-trending transverse Cottontail fault occurs north of the above-mentioned area and immediately south of the southern terminus of Sheep Ridge. Its displacement increases eastward from an apparent zero immediately west of Phosphate Ridge to approximately 2000 feet in the Thaynes Lowland, thence decreases to zero at its eastern limit on the west slope of Caprock Ridge.

The fault apparently developed when the southern and northern blocks responded differently to the compressive agencies which formed Thaynes Lowland syncline. This differential yielding was manifested by the relative shifting of the synclinal axis left-laterally, with displacement along the fault gradually dying out on the eastern and western limbs.

The movement along the fault, although essentially a lateral shifting of the trough segment of the syncline during folding, has caused the beds to appear to be offset vertically as well as laterally; and a diagramatic section illustrating both elements, gives the impression that an eastern segment of the northern block was upthrown relative to the southern block an that a western segment was downthrown relative to the southern block in the manner shown (Fig. 26).

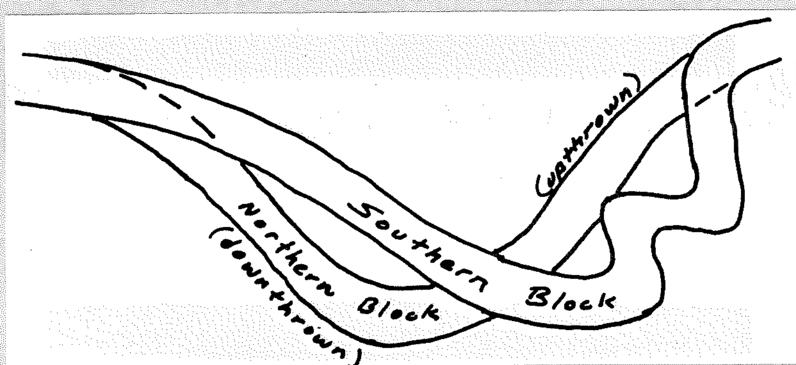


Fig. 27. -- Eastern termination of Cottontail fault on west flank of Caprock Ridge.

Dolly Varden Anticline

Southern Area

The Dolly Varden anticline was discovered by Wheeler and Thompson in 1949 in an area immediately south of this report (Section 36, T. 30 N., R. 64 E.). The part of the structure with which they were primarily concerned, however, is only the southern manifestation of a long anticline whose axis continues northward into the southern Pequop Range.

Within the southern part of the thesis area, the Dolly Varden anticline is a fold developed on the overriding easterly limb of another anticline which is overturned to the west (fig. 28). This multi-axial structure can be traced northward from the southern boundary of the area for approximately 3 miles, where it terminates against the Cottontail fault.

The east limb of the overturned fold, lying to the west of the Dolly Varden anticline, forms a prominant mesa capped by westerly-dipping basal Thaynes(?) "A" limestone. The mesa trends northward for approximately 1½ miles, in sections 24 and 25, T. 30 N., R. 64 E.

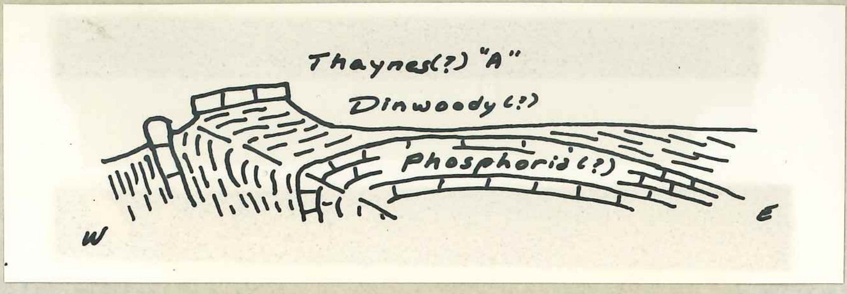


Fig. 28. -- Diagramatic east-west cross-section showing the Dolly Varden anticline as a fold developed on the overriding easterly limb of another anticline which is overturned to the west.

The steeply-dipping and overturned basal Thaynes(?) "A" limestones of the western limb of the overturned structure form a narrow ridge of lower relief to the west and north of the mesa. The ridge follows the strike of the Thaynes(?) "A" limestone northward, and bends progressively from northerly to easterly as the Jackrabbit fault zone is approached.

Fig. 29. -- View looking northward into the southern Pequops from the crest of the northerly-plunging Dolly Varden anticline. The upper Productid member of the Phosphoria(?) formation is in the foreground. Thaynes "A" basal limestones cap the mesa on the far left. Near Jackrabbit fault to the north, the strike of these limestones becomes easterly, thence resumes a northerly trend along the west flank of Caprock Ridge seen on the far right.

The axis of the overturned fold approximates the ridge trend. The normal westerly-dipping limestones and the overturned limestones are exposed within a few yards of each other at approximately the NW¼ of NE¼ of Section 24, T. 30 N., R. 64 E. (See figures 30 and 31).

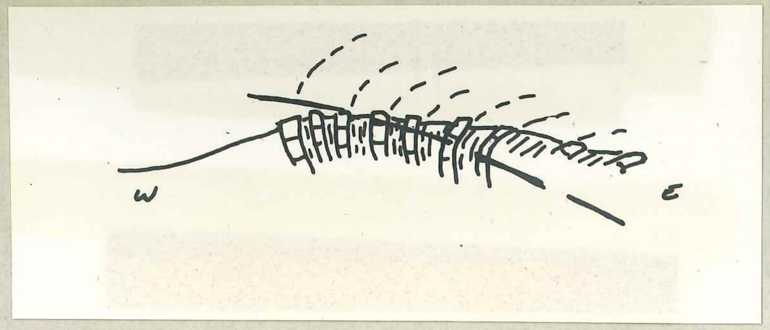


Fig. 30. — Diagramatic cross-section of locality (see text) where overturned basal Thaynes(?) "A" limestones are exposed within a few yards of normal westerly-dipping strata.

Fig. 31. -- Foreground shows the basal Thaynes(?) "A" limestones dipping normally westward and comprising the eastern limb of the overturned anticline diagramatically illustrated in figure 30. Note overturned Thaynes "A" beds in the background with more easterly strike.

The Dolly Varden anticline is largely covered in the southernmost part of the thesis area, and in Section 19, T. 30 N., R. 65 E., it doubly plunges to form a saddle under the alluvial veneer of the intervening pediment (fig. 29).

Northern Area

The Dolly Varden anticline is represented topographically to the north by Caprock Ridge, whose crest elevations correspond closely to its southerly plunge. In terms of relief, the anticline here becomes increasingly prominant, almost overshadowing the very minor and shallow syncline and overturned anticline lying immediately to its west (fig. 32). These subordinate folds to the west of the Dolly Varden structure occur only south of the previously discussed Cottontail fault. Immediately north of the fault, the west flank of the Dolly Varden anticline varies from a moderately steep westerly dip to vertical.

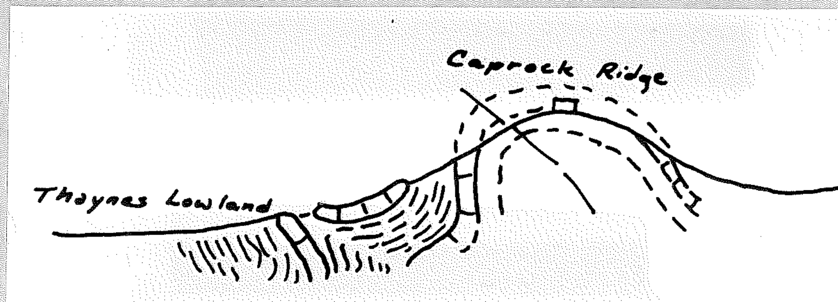


Fig. 32. — Diagramatic cross-section of the Dolly Varden anticline south of the Cottontail fault showing minor folds on west flank.

North of Spring Creek the anticline is in part topographically represented by Indian Ridge. The west flank of the structure is vertical to overturned to the east, reaching southeasterly dips as low as 35° about $1\frac{1}{2}$ miles northward.

Accompanying the overturning was the development of a thrust fault along the east flank of Sheep Ridge. East of this Sheep Ridge thrust, the Indian Ridge and Spring Creek tear faults developed transversely to the overturned structure. These two faults will be discussed later. About 2000 feet south of Indian Creek, the west limb of the Dolly Varden anticline reverts from overturned to normal. North of this area, in Section 20, T. 31 N., R. 65 E., the upper Productid limestone and the Dinwoody(?) formation have been partially repeated by high angle (normal?) faulting.

From Indian Ridge fault northward, the stratigraphic and structural relationships along this eastern ridge trend are considerably obscurred by slope wash.

Sheep Ridge Thrust

The Sheep Ridge thrust is a high angle thrust movement which is believed to have accompanied the overturning of the Dolly Varden anticline.

This thrust developed on or near the axis of the Thaynes Lowland syncline and is exposed along Sheep Ridge. Vertical to overturned Thaynes "A" beds are thrusted over easterly-dipping Thaynes(?) "B" strata. A part of the fault zone is clearly exposed on the north side of Spring Creek in the southwest corner of Section 36, T. 31 N., R. 65 E. Here, some of the Thaynes "B" units are considerably brecciated and calcite-veined, as seen in figure 33.

Fig. 33. -- Brecciated and calcite-veined Thaynes "B" limestone as exposed near thrust zone on north side of Spring Creek. Vertically inclined Thaynes "A" units lie to the east beyond a narrow covered area.

Northward, along the crest of Sheep Ridge in Section 30, T. 31 N., R. 65 E., several northerly trends of erratically dipping, angular limestone blocks are regarded as the northerly continuation of this fault zone.

The thrust appears to have an approximate dip in the uppermost reaches of 60° southeasterly, and apparently has a minimum displacement of about 800 feet. The fault is believed to die out near the northern terminus of Sheep Ridge, as the Dolly Varden anticline to the east reverts from overturned to normal.

Indian Ridge and Spring Creek Tear Faults

The Indian Ridge and Spring Creek faults transect portions of the southern end of Indian Ridge and lie within 1½ miles of each other. Both faults are transverse-rotational and increase in displacement eastward. They appear to die out to the west within or near the Dinwoody(?) formation.

The Spring Creek fault has caused the pronounced linear east-west trend of Spring Creek in sections 4, 5, and 6, T. 30 N., R. 65 E., and has effected the sudden termination of Isolation Ridge on the north. (See figure 34.)

Fig. 34. -- View of Isolation Ridge (left) and Caprock Ridge (right) as seen looking southwesterly across brush and gravel covered pediment. Note abrupt termination of Isolation Ridge.

On the east limb of the Dolly Varden anticline north of the Spring Creek fault, the strata are buckled (fig. 35); whereas, south of this fault the beds dip uniformly.

Fig. 35. -- Buckled middle limestone member of the Phosphoria(?) formation as exposed north of the Spring Creek fault.

The Indian Ridge fault trends essentially east-west and lies north of the Sheep Creek fault in sections 31 and 32, T. 31 N., R. 65 E. The northeasterly-striking Permian rocks which form prominant ridges and elongate knobs north of the fault are absent to the south, where only flexured Phosphoria(?) strata comprise the east limb of the asymetric Dolly Varden anticline. Truncation by the fault of the overturned Kaibab(?) and the lower chert and phosphate member of the Phosphoria(?) formation is particularly conspicuous (fig. 36). The trace of the fault zone follows in part an east-trending stream channel, the south flank of which shows well-exposed brecciated chert whose fractures have been filled with calcite.

As previously mentioned, the upper Productid limestone of the west limb of the asymmetric anticline south of the Indian Ridge fault dips steeply westerly to vertical, in contrast to the beds on the gentler and undulatory east limb. As the Indian Ridge fault is approached from the south, this west

Fig. 36. — East flank of the southern Pequops looking northeasterly toward Steptoe Valley and the Toana Range in the distance. The Indian Ridge fault is indicated in green. Note truncation of Kaibab(?) and lower Phosphoria(?) formation (dark brown band at far left).

limb productid limestone twists and overturns with an easterly dip. Evidence of rupturing without appreciable offset occurs at the fault itself, and the overturning immediately north of the fault is more pronounced.

During the period of compression and folding, the above-described tear faults evidently were developed as a result of horizontal shearing stresses which developed when the mass between the Spring Creek and Indian

Ridge faults responded at a different rate than the neighboring blocks to the north and south; thus resulting in three distinct segments of the differentially asymetric Dolly Varden anticline.

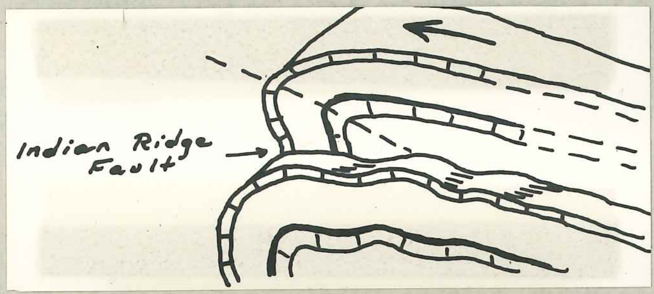


Fig. 37. — Hypothetical diagram illustrated the differential advance and overturning of the Dolly Varden anticline north of the Indian Ridge fault, contrasted against the flexuring of the structure in the southern block.

In the block south of the Spring Creek fault, the anticline is asymmetric and is topographically represented by Caprock Ridge. A diagramatic cross-section through this segment of the Dolly Varden structure appears in figure 32 on page 45. To the east of Caprock Ridge lies Isolation Ridge.

Isolation Ridge Syncline

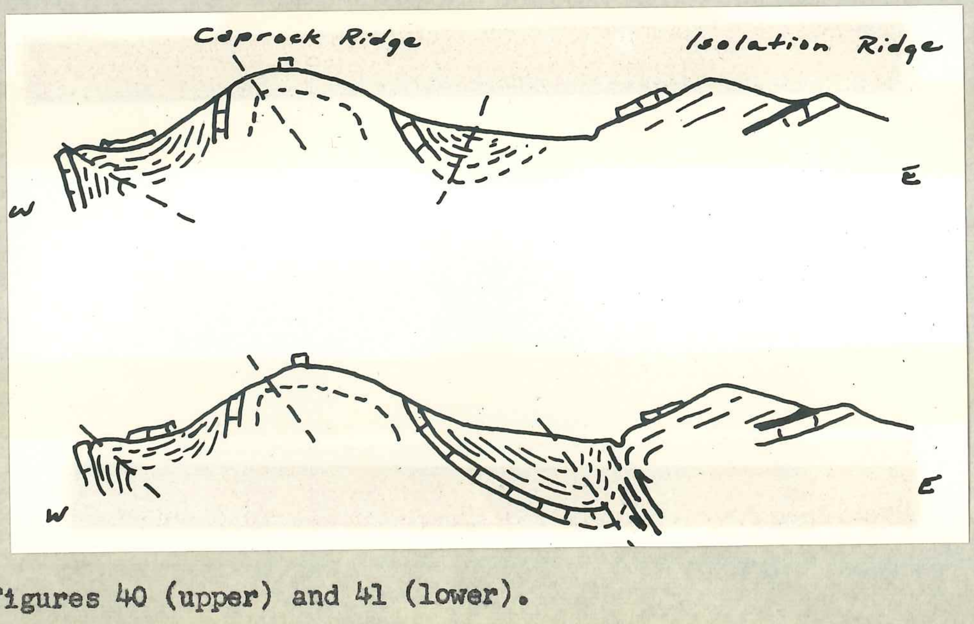
Isolation Ridge is a west-southwesterly-dipping homocline of Phosphoria(?) limestone; Caprock Ridge, on the other hand, is the topographic expression of the Dolly Varden anticline. Thus, a plunging syncline is indicated between these two ridges.

Fig. 38. — Isolation Ridge homocline as viewed looking southeasterly from Caprock Ridge. Note gentle dip slope ledges of upper Productid limestone on the ridge flanks.

Although most of the intervening valley is covered, some scattered outcrops along the drainage divide connecting the northern ends of the two ridges show brecciation and calcite veining, indicating the probable presence of a fault zone. (fig. 39).

If the syncline is unfaulted, it would be structurally asymmetric with its axial plain inclined westerly as in figure 40. This would be in marked contrast to the easterly inclination of other axial plains in the general vicinity. On the other hand, if the syncline is faulted, the axial plain logically may be easterly dipping as shown in figure 41.

Fig. 39. -- Exposure of brecciated and calcite-veined limestone as observed on drainage divide between Caprock and Isolation ridges.



Figures 40 (upper) and 41 (lower).

Jackrabbit and Related Strike-Slip Faults

Three parallel right-lateral strike-slip faults, trending N. 40° W. diagonal to the regional strike, and which have offset portions of the Thaynes Lowland syncline, occur along the southern termination of the Pequop Range in sections 11, 12, 13, and 14, T. 30 N., R. 64 E.

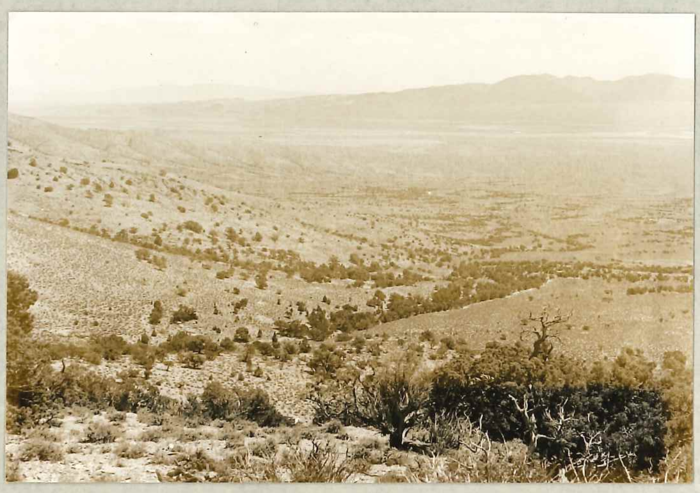


Fig. 42. -- Jackrabbit strike-slip fault zone as viewed looking easterly along the southern boundary of the Pequop Range.

The reported presence of a transversely strike-slip faulted section of Kaibab(?) through Dinwoody(?) formations at the southern end of Spruce Mountain, due west of Jackrabbit fault zone (Harlow, personal communication), indicates that both the southern limit of the Spruce and Pequop Ranges are marked by transverse fault zones that may or may not be continuous with one another.

In approaching the faulted area from the north, the Jackrabbit fault is the first encountered. It is four or more miles in length. Its displacement increases westward, in contrast to the Indian Ridge and Sheep Creek faults. Its maximum known displacement is about one mile. The fault zone is closely followed by a southeast-trending stream channel. Along this zone are a number of southwesterly-dipping isolated drag blocks of the resistant basal Thaynes "A" limestone which were torn loose and rotated during the horizontal shifting.

On the east limb of the Thaynes Lowland syncline, the upper Productid limestone of the Phosphoria(?) formation is abruptly offset about 1000 feet. In contrast, the basal Thaynes "A" limestone near the fault zone is bent from a N. 20° E. strike to almost due east, thence resuming its northeasterly trend. Some offsetting by small faults occurs, but it is subordinate to the bending. Apparently and logically, the basal Thaynes "A" limestone with its intercalated shales was considerably more plastic during deformation than the massive upper Productid limestone.

Two other transverse faults lie parallel to and southwest of the Jackrabbit fault at distances of one-half and three-fourths miles. Their displacement appears to involve only the units on the west limb of the Thaynes Lowland syncline. The northern fault offsets Thaynes "A" limestones about 1000 feet; and the approximate displacement along the southern fault is 2000 feet. Drag blocks occur along both fault zones.

PHYSIOGRAPHY

Both rock type and structure have influenced the development of the present topography in the southern Pequop Mountain area. The Thaynes Lowland and Isolation Valley are structurally synclines whose weak strata have been beveled, forming inter-ridge pediment surfaces. The Dolly Varden anticline is in part represented by Caprock Ridge, which has rather faithfully maintained in topographic outline, the original form of the structure.

Fig. 44. — Caprock Ridge as viewed from the north. Note close relationship between structure and topographic expression.

Most of the faults in the southern Pequop area have had a noticeable effect upon the relief. Jackrabbit fault, by the relative shifting of weak Triassic strata westerly, caused the partial termination of Phosphate Ridge on the south. The Spring Creek fault was responsible for the abrupt ending of Isolation Ridge on the north; and the Cottontail fault probably had some effect on the southern termination of Sheep Ridge in the Thaynes Lowland snycline.

Present-day drainage channels are essentially arroyos which have in some cases dissected earlier and often wider valley floors.

Fig. 45. -- Looking southeasterly along old valley floor presently being dissected by an arroyo whose channel is concealed from view by higher brush trend.

The transition from range to valley floor of the east side of the southern Pequops is essentially gradational. The transition of the west side is somewhat more abrupt, yet this abruptness appears primarily to be an erosional feature. North of the thesis area, along the base of the western range front, is, what appears to be a group of coallescing alluvial fans.

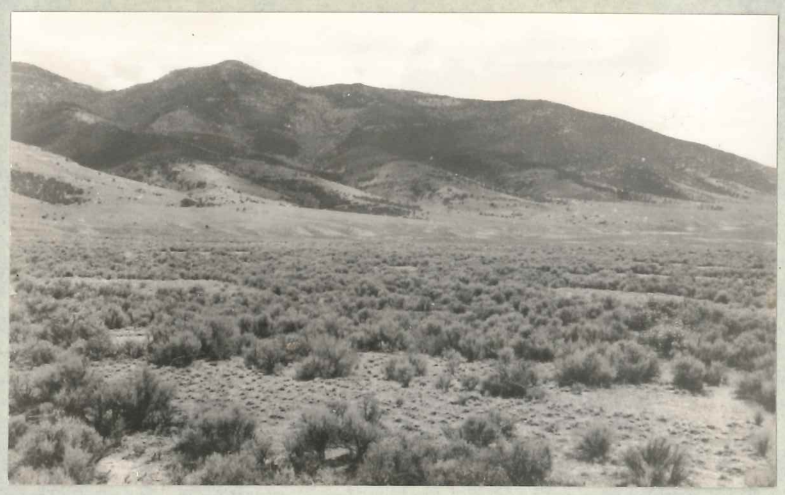


Fig. 46. -- Fans along the western base of the Pequop Range (Also see fig. 47).

However, these fans are not alluvial. They are pediments, and are capped by only a thin alluvial veneer.

Fig. 47. -- Truncated westerly-dipping limestone beds comprising thinly-veneered pediment fans on west flank of the southern Pequops, 9 miles north of the thesis area in Section 22, T. 33 N., R. 65 E.

A scarp of 10-20 feet terminates the pediment apron, generally at a distance less than one mile from the range front. This scarp is sinuous and can be traced for about 8 miles south of Hogan (see index map for location). The height of the scarp diminishes to the south, where it also transects contours instead of following them. A narrow graben is suggested by aerial photographs immediately west of the main scarp in Section 32, T. 33 N., R. 65 E.

The extent to which the main scarp was caused by faulting, wave action from the Independence Valley Quaternary lake, or both, is not known. It is possible that the scarps are due to Quaternary faulting and were modified in part by shore-line action.

Whether the scarp represents a renewal of activity along a major boundary fault or whether it is a late small scale feature having little significant influence on the present range topography is also unknown. Assuming the feature to be a modified fault scarp, a maximum displacement of approximately 20 feet is all that can presently be demonstrated.

Shoreline features of a Quaternary lake which occupied a part of Steptoe and Independence valleys, west and east of the southern Pequop Range, were observed both on aerial photographs and in the field. The highest distinct shoreline observed occupies the 5780-foot contour in both the above-mentioned valleys. In Steptoe Valley, it is marked by sweeping arc-shaped gravel bars and cuspate spits. Successive bars and cusps occur at narrow elevation intervals down to the present playa floor approximately at the 5600-foot contour.

Fig. 47. -- Cuspate spit terraces formed at successively lower levels of the now-evaporated Quaternary lake, which occupied the valley areas adjacent to the southern Pequops. View is from Steptoe Valley looking northwesterly.

LIST OF REFERENCES

Baker, A. A., and Williams, J. S., 1940, Permian in Parts of Rocky Mountain and Colorado Regions: Bull. Amer. Assoc. Petrol. Geol., V. 24, pp. 617-635.

Blackwelder, E., 1918, New Geological Formations in Western Wyoming: Jour. Wash. Academy Science, V. 8, p. 425-6.

Boutwell, J. M., 1907, Stratigraphy and Structure of the Park City Mining District, Utah: Jour. Geology, V. 15, p. 439-458.

Branson, Carl C., 1930, Paleontology and Stratigraphy of the Phosphoria Formation: Univ. of Missouri Studies, V. 5, p. 99.

Darton, N. H., 1910, A Reconnaissance of Parts of Northwestern New Mexico and Northern Arizona: U. S. Geol. Survey Bull. 435, p. 28-30.

Eakin, T. E., et al., 1951, Contributions to the Hydrology of Eastern Nevada, Water Resources Bull. No. 12: State of Nevada, office of the State Engineer.

Eardley, A. J., 1951, Structural Geology of North America: New York, Harper and Brothers.

Fenneman, N. M., 1931, Physiography of Western United States, p. 326: New York, McGraw-Hill Book Company.

Ferguson, H. G., and Muller, S. W., 1936, Triassic and Lower Jurassic Formations of West Central Nevada: Geol. Soc. America Bull.,V. 47, pp. 241-252.

Gregory, Herbert E., 1950, Geology and Geography of the Zion Park Region, Utah and Arizona: U. S. Geol. Survey Prof. Paper 220, pp. 55-56.

Hague, Arnold, 1877, U. S. Geological Exploration of the 40th Parallel, Vol. II, Descriptive Geology: Chief of Engineers, U. S. Dept. of War, 890p.

King, Clarence, 1878, U. S. Geological Exploration of the 40th Parallel, Vol. I, Systematic Geology: Chief of Engineers, U. S. Dept. of War, 803p.

Kummel, Bernard, 1954, Triassic Stratigraphy of Southeastern Idaho and Adjacent Areas: U. S. Geol. Survey Prof. Paper 254-4, 194 p.

Newell, N. D., 1948, Key Permian Section, Confusion Range, Western Utah: Geol. Soc. America Bull., V. 59, pp. 1053-1058.

Newell, N. D. and Kummel, B., 1942, Lower Eo-Triassic Stratigraphy in Western Wyoming.

Nolan, T. B., 1935, The Gold Hill Mining District - Utah: U. S. Geol. Survey Prof. Paper 177.

Nolan, T. B., 1943, The Basin and Range Province in Utah, Nevada, and California: U. S. Geol. Survey Prof. Paper 197D.

Richards, R. W., and Mansfield, G. R., 1912, The Bannock Overthrust: A Major Fault in Southeastern Idaho and Northeastern Utah: Jour. Geology, V. 20, p. 684.

Scott, W. F., 1954, Regional Physical Stratigraphy of the Triassic in Part of the Eastern Cordillera: Unpublished Ph.D. dissertation, Univ. of Washington Library, Seattle.

Smart, R. A., et al., 1954, Stratigraphic Sections of the Phosphoria Formation in Idaho, 1950-51: U. S. Geol. Survey Circ. 327, p. 4.

Spencer, A. C., 1917, Geology and Ore Deposits of Ely, Nevada: U. S. Geol. Survey Prof. Paper 96, p. 26.

Smith, J. P., 1932, Lower Triassic Ammonoids of North America: U. S. Geol. Survey Prof. Paper 167.

Swanson, R. W., 1953, Progress Report on Investigations of Western Phosphate Deposits: U. S. Geol. Survey Circ. 297.

Wheeler, H. E., et al., 1949, Permian-Mesozoic Stratigraphy in Northeastern Nevada (abs.): Geol. Soc. America Bull., V. 60, p. 1928.

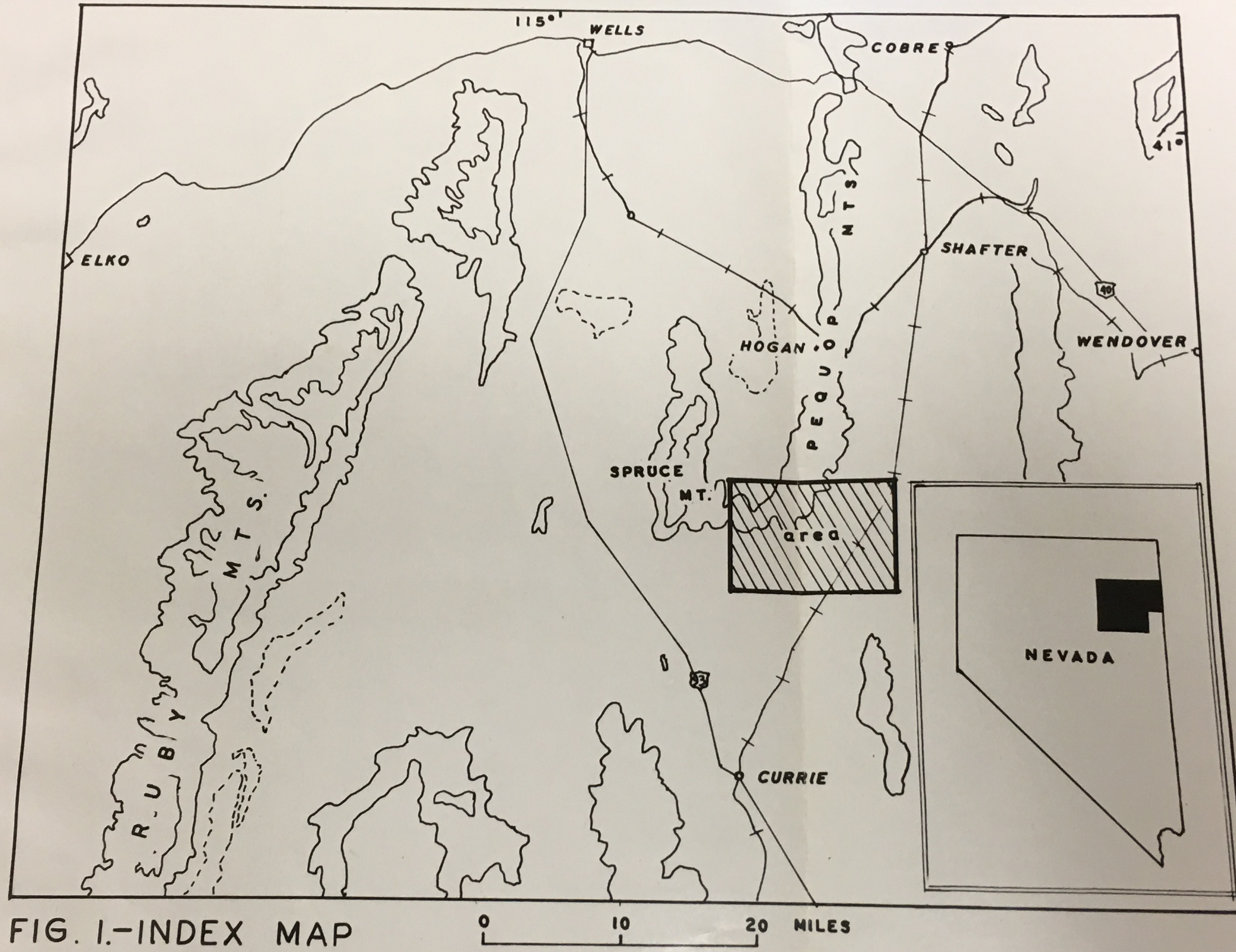
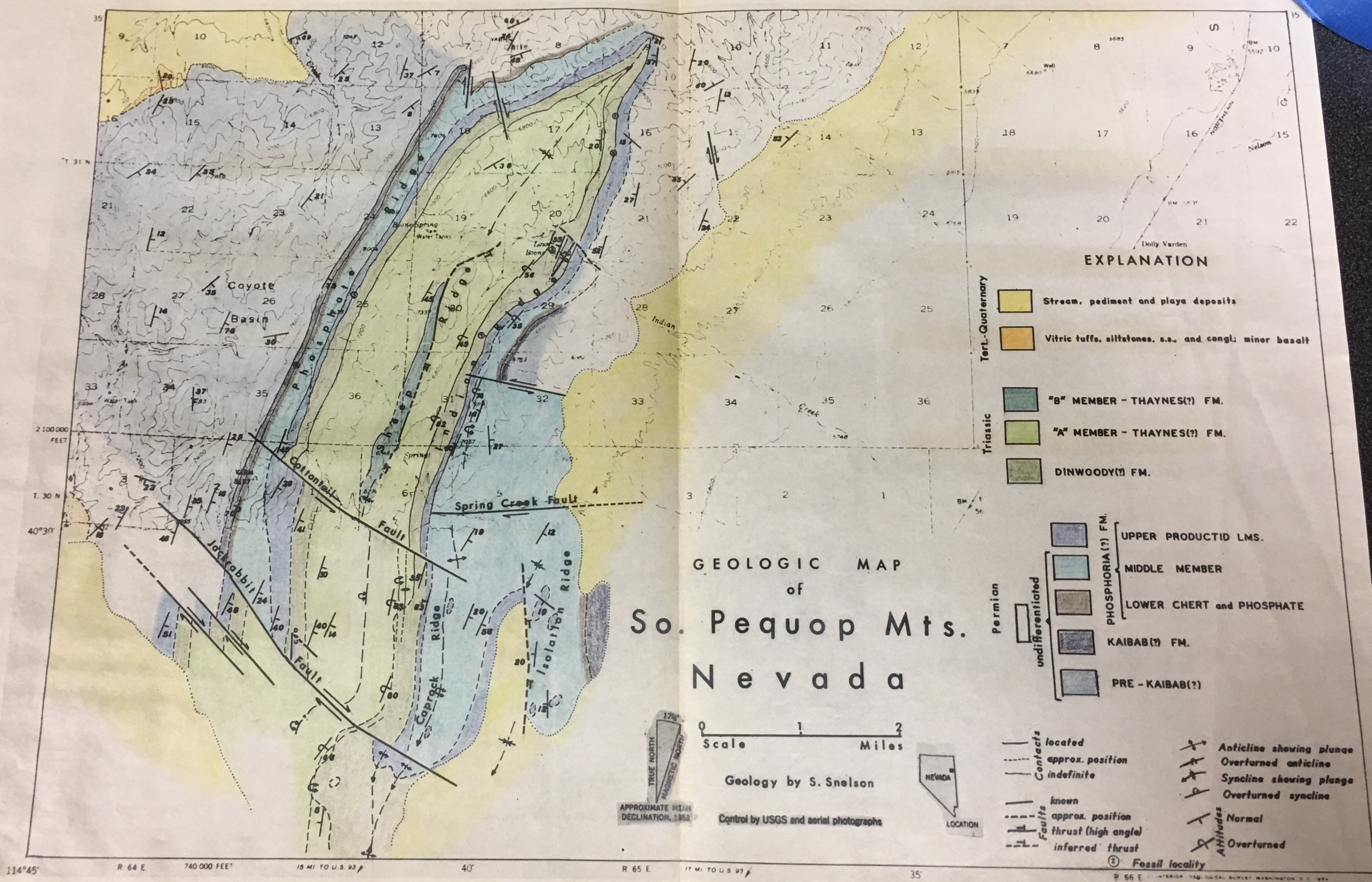


FIG. 1.-INDEX MAP


GEOLOGIC MAP
of
So. Pequop Mts.
Nevada
EXPLANATION
Tert.-Quaternary
Stream, pediment and playa deposits
Vitric tuffs, siltstones, s.s., and congl.; minor basalt
Triassic
"B" MEMBER - THAYNES(?) FM.
"A" MEMBER - THAYNES(?) FM.
DINWOODY(?) FM.
Permian
undifferentiated
PHOSPHORIA(?) FM.
UPPER PRODUCTID LMS.
MIDDLE MEMBER
LOWER CHERT and PHOSPHATE
KAIBAB(?) FM.
PRE-KAIBAB(?)
Contacts
located
approx. position
indefinite
Faults
known
approx. position
thrust (high angle)
inferred thrust
Fossil locality
Anticline showing plunge
Overturned anticline
Syncline showing plunge
Overturned syncline
Attitudes
Normal
Overturned
Scale
Miles
Geology by S. Snelson
Control by USGS and aerial photographs
TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION, 1958
NEVADA
LOCATION
Coyote
Basin
Phosphate Ridge
Sheep Ridge
Indian Ridge
Caprock Ridge
Isolation Ridge
Cottontail Fault
Jackrabbit Fault
Spring Creek Fault
Indian Creek
Boone Spring
Dolly Varden
T. 31 N.
T. 30 N.
R. 64 E.
R. 65 E.
R. 66 E.
114°45'
114°30'
40°30'
40'
35'
740 000 FEET
2 100 000 FEET
15 MI. TO U.S. 93
17 MI. TO U.S. 93