GEOLOGY OF THE EASTERN PART OF THE RAFT RIVER RANGE, BOX ELDER COUNTY, UTAH*

By Clarence E. Felix

INTRODUCTION

Geologically, the northwestern part of Utah, including the Raft River Range, Grouse Creek Range, and Goose Creek Range, is little known. Geologic reports of this area are practically nil. Small-scale mining activities in the area during the late 1800's and early 1900's prompted brief reports of the mining operations (MacFarren, 1909; Higgins, 1909), which were later summarized by Butler (1920). Since then, several reports on adjacent areas have been published—Goose Creek Basin, Cassia County, Idaho (Piper, 1923); eastern Cassia County, Idaho (Anderson, 1931); and a report on the small Ashbrook silver mining district, Utah, was written by Peterson (1942).

More recently, several oil companies' geologists have reconnoitered the area, an abstract on the Raft River has been published (Stokes, 1952), and a groundwater reconnaisance report of the Park Valley-Kelton areas has been prepared (Thorp, 1953). At present several students are writing theses on individual ranges and mining localities in the area.

The Raft River Range lies in the northwestern part of Box Elder County, Utah; is about 30 miles long and from 5 to 10 miles wide. (See index map, Fig. 12) The base of the north flank of this east-west trending range nearly parallels the Utah-Idaho state line. Physiographically, the range lies in the Great Basin section of the Basin and Range province (Fenneman, 1946). The highest peaks are approximately 10,000 feet above sea level and are over 5,000 feet above the plains at the base of the range.

The eastern terminus of the range is separated from the south tip of the Black Pine Range by the low, wide Kelton Pass near Strevell, Idaho. The west end merges with the south end of the Albion Range, the northeast end of the Goose Creek Range and the north end of the Grouse Creek Range. Via highway, the east part of the Raft River Range is 140 miles from Salt Lake City, Utah, and about 70 miles from Tremonton, Utah.

*Resume of Ph.D thesis, University of Utah.

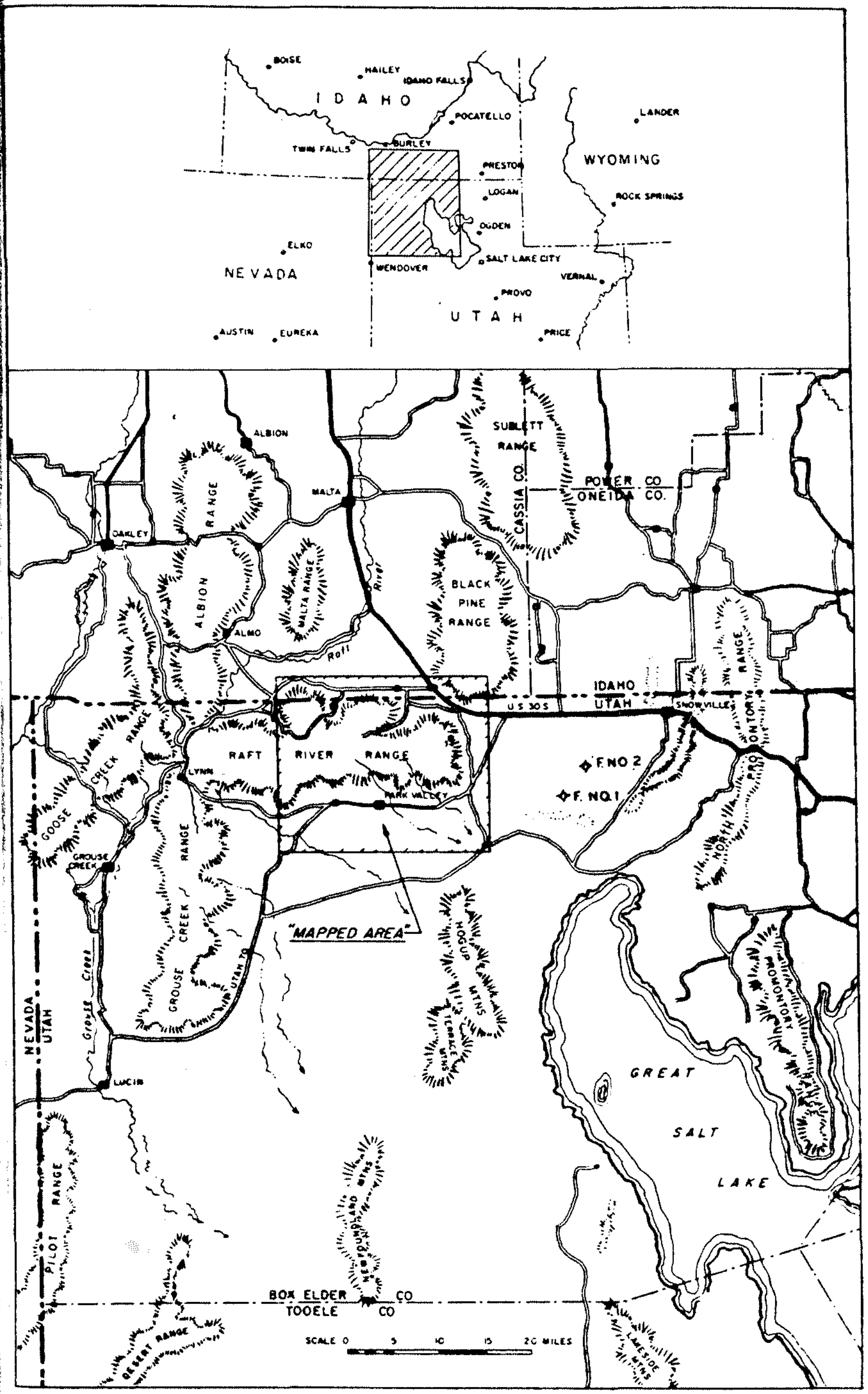

Fig. 12 — *Index Map of the Raft River Range Region.*

Broad alluvial valley plains flank the range—Raft River Valley on the north, Curley Valley on the east, and Park Valley on the south. Small farming and ranching communities are sparsely spaced around the mountains. Chief occupations of the inhabitants include farming, cattle and sheep raising and some lumbering. Average annual precipitation is about 10 inches. Scattered springs and wells provide livestock water and limited irrigation water. Only the larger canyons contain small perennial streams which are diverted for irrigation or flow short distances into the alluvial valleys and disappear.

SEDIMENTARY ROCKS

Precambrian Harrison (?) Series

Albion Range rocks. Anderson (1931) named the Harrison series after Mount Harrison of the Albion Range, Idaho, where approximately 8,500 feet of metaquartzites, schists, and marbles are exposed. He divided the series into three "divisions," a summary of which follows:

	Lithology	*Approx. Thickness* (feet)
Upper division	Metaquartzite	500
Middle division	Schist	150
	Ls. marble, & schist	700
	Metaquartzite	1,500
	Ls., marble, & metaquartzite	500
Lower division	Micaceous quartzite	2,000
	Metaquartzite	3,000
Raft River Range Units		
Unit B	Metaquartzites & schists	600
Unit A	Schist	1,300

Although there appears to be no close lithologic or thickness correlation between the exposed sections in the two ranges, the Raft River exposures are herein temporily called "Harrison series" pending further investigation and study at the intersection of the two ranges where the true relationship of the lithologic units may be revealed. The lenticular nature of Unit B in the Raft River Range suggests the possibility that lithologic facies changes occur between the two ranges.

It should also be noted that the metamorphic facies between e Precambrian rocks in the two ranges are different. According to urner (1954, p. 232), the sillimanite-kyanite-garnet schists that nderson (1931(pp. 24-273) describes represent high-grade metaorphic schists in the granulite facies. The biotite-muscovite-quartz d muscovite-chlorite-quartz-albite schists and the zoisite amphiolites in the Raft River Range represent low-grade schists in the eenschist and lower albite-epidote-amphibolite facies.

Unit A—Unit A consists almost entirely of dark, drab, pelitic ica schist. Thin lenses of quartz schist are sparsely scattered through e unit. The lower contact is the irregular, discordant surface of e granite stock that occupies the core of the range. The upper conct is at the base of the lowest metaquartzite or quartz schist member Unit B.

The highly schistose rock of Unit A is soft and easily split and aked parallel to the foliation. Fresh surfaces are medium to medium ark gray according to the Goddard rock-color chart (1951). Staing on weathered surfaces is moderate brown.

Thin sections show that the rock contains 40-55% platy minalts of which red-brown biotite is dominant, dull green chlorite and olorless muscovite are minor. Segregation layering is well develped. The parallel to sub-parallel platy minerals enclose trains of ongated, interlocking quartz grains. All the quartz shows strong ndulatory extinction. Strain-slip cleavage, due to microflding, is ommon.

Most of the canyons on the south side of the range have cut into his unit; only several on the north side have eroded deep enough. The exposed thickness of this unit depends upon the extent of canon development and the elevation to which the granite has been ntruded. In one of the deepest cut canyons, Indian Creek canyon, ver 1300 feet of Unit A are exposed.

Unit B—This unit appears to be conformable with the underying Unit A. Unit B consists of a series of metaquartzites and quartz chists alternating with mica schists, chlorite-mica schists and minor hyllites. A thin limestone bed was observed in the unit in Johnson Creek canyon. The upper contact is a thrust-fault surface that apparntly is present over the area maped. Exposed in and adjacent to the mouth of Indian Creek canyon is 620 feet of Unit B. Here, slightly ver half of the unit is composed of resistant, ledge and cliff forming metaquartzites and quartz schists. These two rock types are gradational and differ mainly in the amount of sericite and muscovite which impart schistosity to the rock. These quartzose rocks are mostly white to light gray on the south side of the range with more grayish orange and light brown hues on the north side. In localized areas at the base of the south flank of the range the quartz schists are light blue green, light green, moderate green, and grayish green. The green coloration is due to the presence of the chromium-bearing mica, fushite. This rock is now being quarried for decorative building stone. Thin sections of the metaquartzite show that the quartz has recrystallized. The quartz crystals are sutured and are 5 or more times as long as wide. The rock is dense and vitreous in hand specimen.

The resistant metaquartzite beds clearly reveal the anticlinal structure of the main mountain mass. From long distances away these strata can be seen to be dipping moderately steep along the flanks of the range and gently eastward in the canyons at the east end of the range where the anticlinal structure plunges beneath the concealing younger rocks and alluvium of Curlew Valley.

The lowest metaquartzite and quartz schist unit is a continuous bed throughout the area mapped. The upper metaquartzites in Unit B, however, interfinger with wedges of gray and brown schists. Two metaquartzite bodies occur as isolated disc- or lens-shaped forms with areas of from 1 to 3 square miles (See geologic map).

The thicker schists of Unit B closely resemble those of Unit A. The thin schist members, from 1 to 10 feet thick, are generally slippery-feeling, dusky green to dark gray chlorite-muscovite-quartz-albite schists. The schists are weakly resistant to weathering and are generally covered with a brownish, micaceous soil.

Degree of Metamorphism — The degree of metamorphism throughout the area mapped seems to be constant for the same stratigraphic horizon with minor irregularities along the contact of an underlying granite which will be described later. The metamorphic effects of the granite emplacement are small. In some places the schist within 5 to 10 feet of the contact is gneissic and contorted. In most places the exact contact is covered, but the schist is more quartzose and feldspathic in a halo of from 20 to 50 feet away from definite granitic rock. The metamorphism of units A and B is definitely regional metamorphism. The mineral suit of the pelitic schists establishes that they are low-grade schists of the greenschist facies (Turner, 1954, p. 210). The lower biotite schists and occurrences of

phibolite indicate that the facies in the deeper rocks is at or near albite-epidote-amphibolite line.

Environment of Deposition—The metaquartzites beds are thin d even. Ripple marks and cross-bedding have been noted but are ry uncommon. No conglomerate was observed except in a small ce of float. The original quartz sand was fine grained and well ted. No fossils or evidences of life have been found. The schists resent muds and silts. No primary structures are known to exist the schists other than bedding planes which are generally parallel the foliation. A thin light gray limestone is interbedded in the ists and metaquartzites in the northwest part of the area.

The above evidence indicates that the Precambrian sediments the Raft River Range were below wave base. The sands were obably carried in from a nearby fluctuating shoreline. The direcon to the shoreline is indefinite at present.

Age—Precambrian rocks of Utah and vicinity have been clasified into a younger unmetamorphosed system, an intermediate etamorphosed system, and an older highly metamorphosed system Blackwelder, 1935, 1949).

The oldest system consists of highly metamorphosed rocks inuding gneisses, schists and metaquartzites. This division has been presented by the Farmington complex in the Weber-Farmington ction of the Wasatch Range (Bell, 1951). It is largely a migmate but seven metamorphic facies are recognized from low grade reen-schist to high grade hornblende-biotite granite. It may be oughly correlative with the Vishnu schist of the Grand Canyon egion and other gneissic formations that are widely distributed hrough the Rocky Mountains.

The intermediate system consists of metaquartzite and silvery mica schists that correlate with the Encampment, Atlantic Pass and Medicine Bow districts of Wyoming. The Harrison series of the Raft River Range would fall into this division.. However, according to the high-grade metamorphic mineral suite of the Albion Range schists, they would more closely fit into the "oldest" system.

The established youngest system is a series of quartzites and slates best exemplified in the central part of the Wasatch Mountains and the Uinta Mountains. A series of alternating quartzites and slaty shales up to about 12,000 feet thick are exposed in the lower half of Big Cottonwood Canyon, southeast of Salt Lake City. These rocks are generally believed to be equivalent in age to the Belt system of western Montana and the Grand Canyon system of northern Arizona.

The above classification is based almost wholly upon degree of regional metamorphism and therefore has inherent weaknesses. For example, the Raft River rocks would be classified as intermediate, but the possibility exists that they may be the youngest system more highly metamorphosed or the oldest system less highly metamorphose. The problem of correlating the Precambrian in the intermountain area is difficult because of the distances between outcrops and the occurrence of numerous localized deformational structures.

Applying other lines of evidence, the Raft River rocks are distinguished by the light gray and light green metaquartzites, the well-assorted materials, and the evenness and regularity of bedding. Making a comparison, the Big Cottonwood series consists of alternating beds of dusty and red sandstone or quartzite and conglomerate and deep red argillites. The Raft River rocks have a marine or lacustrine origin whereas the Big Cottonwood series is distinguished by much cross-bedding, ripple marks and mud cracks, and is supposed to have been deposited on a floodplain or in a shallow embayment. However, the light green, fushite-bearing metaquartzites of the Raft River Range are duplicated in a series of Precambrian rocks east of Willard and Brigham City in the Wasatch Range, and these are regarded by Eardley and Hatch (1940) as equivalent to the Big Cottonwood series. A comparison with all the Precambrian exposures in the area should throw some light upon the problem. As this has not been undertaken, the Precambrian in the Raft River Range is very tentatively assigned to "intermediate pre-Cambrian", because of the lithologic and metamorphic differences between the series that have been classified "youngest" and "oldest" Precambrian.

Lower (?) Paleozoic Rocks

Divisions and general characteristics—The units that have been mapped as "Lower (?) Paleozoics" are subject to further and more extensive study. Three easily recognized units, A, B, and C, were mapped so that the over-all relationships would be revealed. The section is somewhat metamorphosed and many of the carbonates and quartzites have been recrystallized. Fossils in this division are very rare, the only ones that have been found so far are several small crinoid columnals and a small symmetrically segmented impression that reminds one of a trilobite pygidium. The main occurrences of

this group are at east end of the range and in the hills of a mountainous block that obtrudes from the range northward between Yost and Stanrod. This block is herein called the Yost-Stanrod salient. Smaller exposures of these rocks are found in small klippen on the crest of the range and in low remnant hills along the base of the flanks of the range.

Unit A—A measured section of the lowest Unit A was made from the mouth of One Mile Creek canyon southeastward to the contact with Unit B. Due to a large amount of soil cover and poor exposures, it is likely that several undetected faults were crossed and that the measured thicknesses are not exact. The total thickness is 3500 feet. Of the exposed portions, 40% is limestone, 34% is dolomite, 12% is quartzite, and 1% is schist. The unit is essentially a series of alternating limestones and dolomites with lesser amounts of quartzite. The carbonates have crystallinities from fine to coarse and most could be called marbles. Some of the quartzites are dolomitic or slightly limy. Approximately two-thirds of the exposed section is light colored—from white to light gray and grayish orange. Weathered surfaces are commonly shades of light brownish yellow. Part of the limestones provide the darker gray tones.

The lower contact is nowhere exposed. The upper contact is at the base of Unit B, a white metaquartzite. The lowest member exposed in One-Mile Creek canyon is a very light gray metaquartzite, somewhat schistose, which underlies a thin gray, brownish weathering muscovite-chlorite-quartz schist. The base of the carbonate-quartzite section is conformable with the schist.

Metamorphic processes have erased practically all fossil evidence. Found near the top of the section on the east end of the range were several possible crinoid columnals and a small segmented symmetric impression that appears to be of organic origin—possibly the outline of a trilobite pygidium or a graptolite. Lithologic comparison shows no relationship to Paleozoic units to the east or south. Some of the platy, schistose limestones, however, resemble parts of metamorphosed Pogonip formation in Nevada.

Unit B—This unit is a dense, white, vitreous metaquartzite. It makes an ideal horizon marker, being hard, white, resistant and persistant throughout most of the mapped area. The thickest exposure, 197 feet, is in the north part of the Yost-Stanrod salient. In some places it is entirely missing due to original lens-type deposition or because it lies beneath an unconformity. The average thickness is about 40 feet. On the southeast side of the range its thickness is less than five feet (west of Indian Creek). On the east end of the range the unit is from 20 to over 100 feet thick. In the Yost-Stanrod salient, the thickness increases northward from about 20 feet to 197 feet.

The color of this metaquartzite is generally white or very pale orange, but may be locally streaked with light and medium gray. No fossils have been found in it. The original fine grained sands were well sorted. A study of thin sections shows that the rock is very pure, that the quartz has recrystallized and that the crystals are now well sutured. Although there is a slight orientation of the grains, the definite elongation that exists in the Precambrian metaquartzites is not present.

Unit B is associated with the major thrusting in the area by being present in most of the small klippen that remain on the crest of the range and by being near the fault surface on the east end of the range. At these places and at a location near a normal fault in the Yost-Stanrod salient, this brittle metaquartzite has been highly fractured and rotated, then recemented with quartz. The resulting rock is a light yellowsh orange metaquartzite breccia. At several places on the east end of the range the breccia exhibits intrusive characteristics. During fault movements, the fractured quartzitic mass was forced into fractures under pressure, and metaquartzite breccia dikes resulted.

Unit C—This unit is a light gray and very light gray finely crystalline dolomite. It is from 0-100 feet thick. The dolomite exhibits a characteristic weathered surface due to solution along very closely spaced irregular fracture lines. The bottom contact is an erosion surface upon Unit B. At several spots the white Unit B is absent and Unit C rests upon Unit A. The upper contact is an erosional unconformity above which are the limestones and sandstones of the Pennsylvanian Oquirrh formation. Unit C is found at most places where Unit B is present. At one locality at the east end of the range, small crinoid columnals were found. No other fossils have been observed.

The recrystallized nature of these Lower (?) Paleozoics suggests that they are much older than the Pennsylvanian limestones above. However, porphyro-blasts have been found in a recrystallized schistose crinoidal limestone at the base of the unit mapped as Oquirrh formation. The Lower (?) Paleozoics were closer to the regional source of heat and had a greater overburden than the younger rocks. They

may also have a greater metamorphic susceptibility than the younger rocks. Grant Steele (personal communication) has observed a series of several dense white quartzites like Unit B, stratigraphically between definite Desmoinesian and Virgilian strata in the south end of the Grouse Creek Range. There is the possibility that the Lower (?) Paleozoics of the Raft River Range are metamorphosed Carboniferous strata.

Pennsylvanian Oquirrh Formation

The larger exposures of the Oquirrh formation in the Raft River Range are in the Yost-Stanrod salient and the east end of the range. Several small hills along the foot of the range on the north and south flanks also contain these Pennsylvanian rocks. In the north part of the Yost-Stanrod salient up to 1,600 feet of alternating unfossiliferous and crinoidal limestones are exposed. This unit exhibits apparent onlap relations southward toward the main mountain mass. The lower 1,400 feet were not deposited 6,000 feet southward. The beds have a peculiar coloration. Some are very light gray to white, some light to medium gray, and some exhibit large-scale mottling of white and gray patches. Minor discontinuous dolomites are present. The limestone unit is overlain by nearly 1,200 feet of medium to dark gray and olive gray weathering sandy and silty fossilferous limestones. The exposures on the east end of the range consist of about 2,000 feet of sandy and silty limestones and brownish weathering quartz sandstones and quartzites. The south tip of the Black Pine Range is composed of gray, drab-weathering quartz sandy limestones.

Most of the fossils, including the fusilinids, are slicified and the destruction of the significant fine parts has made identification difficult. Fusulinids are more common in the sands and quartzite beds. Bryozoan remains are numerous in the silty, limy portions. Brachiopods are rare and poorly preserved. Crinoid columnals are numerous in the purer limestones. A few small gastropods have been found. In one zone numerous markings occur.

Most of the fusilinids identified are large specimens of *Triticites* from the upper sandstone and quartzite beds. Of several that were not completely silicified, R. V. Hollingsworth reports "*Triticites*—Virgil, Shawnee, about Deer Creek, in age." Grant Steele, paleontologist for Gulf Oil Company, identified "*Triticites*, aff. *cullomensis*—high Virgil; *Triticites*, aff. *hobblensis*—highest Virgil." Mr. Steele also identified "*Fusilenella*—middle Atokan" from the rocks at the south tip of the Black Pine Range. Stokes (1952) reports the presence of *Waeringella*—Virgil in the Raft River Range rocks.

Numerous bryoboans are present in nearly all the exposures of the silty and arenaceous limestones. Identification has been hindered by silicification. However, Dr. Maxim K. Elias, University of Nebraska, has been able to identify the following:

Stenopora (?) n. sp., aff. *ramosa* Ulrich
Penniretepora
Fenestella c. *stocktonensis* Condra and Elias
Fenestella cf. *stocktonensis* Condra and Elias
Fenestelal cf. *elongata* Cumings
Fenestella cf. *tenax* Ulrich
Fenestella tetratheca Condra and Elias
Rhombopora cf. *lepidodendroides* Meek
Rhombocladia cf. *delicata* Rogers
Hemitrypa sp.
Streblotrypa cf. *nicklesi* Ulrich
Polypora cf. *cestriensis* Ulrich
Polypora n. sp., aff. *distincta* Ulrich
Goniocladia ? sp.
Fistulipora ? sp.

Concerning the identified specimens, Dr. Elias states, "The silicified bryozoans are not well preserved, hence nearly all identifications are approximations, not exact. However, some identifications of the species described by Condra and Elias (1944) from the type-section of the Oquirrh formation of Utah indicate this equivalency of your bryozoan faunas, even if no *Archimedes* is present. . . ."

The lower limestones of the formation as represented in the Yost-Stanrod salient form slopes of alternating ledges and covered strips. The upper silty and arenaceous limestones and quartzites typically form rounded, smooth-sloped hills strewn with drab gray and grayish brown pebbles. The sequence of an increasing percentage of clastics upward fits the description of the Oquirrh formation in surrounding areas.

Tertiary Salt Lake Group or Payette Formation

Massive tuff, thin bedded tuffaceous shales and marls crop out in several places on the south side of the Raft River Range. These are referred to as the Salt Lake group and Salt Lake formation to conform to the terminology given to similar Tertiary strata exposed in other parts of the Great Salt Lake Basin and northeastern Utah areas. Similar beds are exposed on the north side of the range in

Utah and in Cassia County, Idaho, but have been referred to the Payette formation (Anderson, 1931) which is widely distributed throughout southcentral and southwestern Idaho. Anderson (1931, p. 43-44) has noted some evidences that indicate the equivalency of the two formations and are mapped as the same unit for this report. Refer also to first article of this guidebook.

Several thousands of feet of these beds are exposed in low hills and washes on the northwest side of the Yost-Stanrod salient. These beds are largely unfossilferous, gray, green and bluish green tuffaceous shales, mudstones and sandstones. There are masses of coarse conglomerates at the western base of the high ridge that interfinger with the tuffaceous shales westward.

On the south side of the range north of Utah State Highway 70 Lake Bonneville wave-cut cliffs expose beds of massive light gray pumiceous tuff. Other outcrops include tuffaceous shales, marls and mudstones similar to those on the north side of the range. The beds on the south side are grayish yellow and greenish yellow and are not so colorful as on the north side of the range. Outcrops are small and scattered.

The Tertiary beds around the Yost-Stanrod salient dip as high as 55° to the west, although 30-40° dips are more common. The strata on the south side of the range dip from 10° to 25° southward. An outcrop in the low hills on the east end of the range dips 55° to the east. Dissected pediment surfaces underlain by Tertiary beds are present around the north part of the Yost-Stanrod salient and south of the eastern part of the range above the highest Lake Bonneville shoreline. These pediments are post-tilting and pre-Bonneville.

Critical fossils in the Tertiary strata are rare. Sparse plant remains occur as thin carbonized films and leaf impressions. The only significant fossil known from the Raft River area is a fossil fish found by Mr. John M. Carter of Park Valley, Utah. Many years ago, as a young man, Mr. Carter found the fossil while helping his father quarry blocks of tuffaceous marl and mudstone approximately on the section line between sections 5 and 8, township 12 north, range 12 west, Salt Lake meridian, about one-eighth mile eastward from the west section corner. The author was unable to locate other fish specimens in this area, but obtained permission from Mr. Carter to send his fossil to Dr. Robert R. Miller, Associate Curator of Fishes, University of Michigan. Dr. Miller was unable to complete his identification of the fossil during the time he had it. At present the fossil is in possession of Mr. Carter. Dr. Miller reported that this specimen belongs—

> "to the family Centrarchidae, which includes the well-known large- and small-mouth basses and sunfishes.
>
> "According to available paleontological literature, this family probably arose in the Eocene. . . . By Miocene and, particularly, Pliocene times, the group apparently was widely established and probably included a large variety of kinds. The fossils discovered to date show that the family had a wide distribution in North America, and one genus from the Eocene of Europe has been tentatively assigned to the family. Today, however, the centrarchids are strictly North American, ranging from southern Canada to northern Mexico. Throughout this area they are all but confined to the region east of the crest of the Rocky Mountains and of the Sierra Madre Oriental. The single exception is *Archoplites interruptus*, the so-called Sacramento perch, which is confined to the Sacramento River system and certain drainages which were connected with that basin during the Pleistocene—all in California. All other centrarchids, such as the basses, bluegill, green sunfish, etc., which are common west of the Rockies, have been introduced by man. . . .
>
> "As the age of the formation in which the fossil occurs, I would hazard the guess that it cannot be more recent than Pliocene; it might be Miocene." (Personal communication.)

Lake Bonneville Sediments

Lake Bonneville sediments consist of bar and beach gravels along the ancient shore lines, and unconsolidated quartz sands and tuffaceous silts exposed in numerous washes and around the bases of several basalt buttes.

The uppermost shoreline, the Bonneville level (elevation not accurately determined), is readily traced on aerial photographs. The long ridges and gullies of the dissected Salt Lake group pediment end abruptly where wave action of the lake ceased its erosive action.

The broad, low pass known as Kelton Pass, that connects the Black Pine Range with the east end of the Raft River Range one mile southeast of Strevell, Idaho, is about 75 feet above the Bonneville level. If Lake Bonneville had risen another 75 feet without flowing over Red Rock Pass, the lake probably would have debouched at Kelton Pass into the Snake River.

Glaciation and Glacial Deposits

Evidences of glaciation are present in the Raft River Range. Cirques were developed in some of the high canyons near the crest

the range above an elevation of about 8,000 feet. Prominent ques occur at the heads of Sawmill Canyon, Rosevere Fork Canyon d Lake Fork Canyon. Another lake in the head of Fisher Creek nyon probably is of glacial origin also. Small morainal deposits of sorted boulders, gravel and sand occur in upper Clear Creek Canyon and probably in others as well.

Anderson (1931, pp. 46-47) has observed glacial deposits in e Albion Range. Blackwelder (1931), the foremost student of aciations in the Great Basin region, points out that all well-preserved glacial deposits and features such as moraines and cirques rive from the Wisconsin glaciations. Antevs (1952, p. 99), from e evidence at the foot of the Wasatch mountains south of Salt ake City, concludes that "the presence of moraines beneath deltas nd of delta material in the gap between the lateral moraines close or up to the Bonneville level shows that the glaciers culminated nd withdrew above the Bonneville shoreline before or during the ormation of this shore and before the lake reaches the overflow evel."

The well-preserved evidence of glaciation in the Raft River Range suggests a Wisconsin stage.

Quarternary Alluvial Deposits

The lower slopes of the hills are covered with poorly sorted rock fragments and soil which conceal the underlying formations. Where the dissected pediments in Tertiary rocks are not present, coalescing alluvial fans connect the mountain fronts to the broad alluvial plains of the valleys.

IGNEOUS ROCKS

Granite

The name "Raft River stock" is here applied to the granitic mass that forms the core of the Raft River Range. The stock crops out in the deeper eroded parts of all the larger canyons on the south side of the range. Of the northward drainages, Jim, Rice Creek and Italian canyons have small granite exposures. Large outcrops occur in the western part of Clear Creek Canyon and its tributaries.

Hand specimens of the rock range from very light gray to light medium gray granite and granite porphyry. In some areas the rock is medium grained hypautomorphic granular although it is generally porphyritic. Orthoclase and microcline phenocrysts longer than one inch have been observed. The dominant minerals are othoclase and microcline (55%), quartz (25%), oligoclase (13%), biotite and hornblende (5%); magnetite and chlorite are accesesry. Thin sections from within the shock show no shearing or effects of cataclasis. The signs of metamorphism are nil or were not recognized. The border phase, however, shows some tendency to have a gneissic structure. The evidence seems to indicate that the stock is younger than the period of metamorphism of the main mountain mass.

The granite does not extend above the schists of Harrison series Unit A, but in some areas is nearly tangential to the lowest metaquartzite. Boundary contacts of the granite with the invaded schist are not sharp but gradatinoal. In Indian Creek, for example, the schist is lighter in color and is enriched with quartz and feldspars in the boundary phase. As the true granite is approached the rock becomes coarser and the intermediate stage resembles a granite gneiss. In minor instances the relatively thin border phase is gneissic and highly contorted showing evidence of movement. A small schist xenolith with the bedding and schistosity in a vertical attitude was observed in Big Hollow. Barren white quartz veins up to several feet thick are common in some parts of the stock. The above evidences and those discussed in the structure section of this report indicate that the mode of granite emplacement was assimilation.

Scattered in east Clear Creek and other canyons at the east end of the range, are numerous thin to thick pegmatic pods or fingers containing crystals one-fourth to over one inch in length of feldspar, quartz and muscovite. The larger bodies are more granitic than the smaller ones and seem to be gradational between granite and the coarser pegmatites. These pegmatite fingers are lens-sharpd in cross-section and are generally concordant with the bedding and schistosity planes.

Amphibolite

A very dark granitic to schistose rock occurs in parsely scattered fashion in the east end of the range. Most of these dark rock masses, from 20 to over 100 feet in diameter, are discordant plug- or pipe-like bodies, whereas some seem to have lens-shaped sill-like form.

Thin sections of this rock show it to be a zoisite amphibolite containing green and yellow-green crystals of actinolite (40-60%) generally fractured and disrupted, fine to coarse quartz (20-30%)

segregated into trains or rough spherical masses, nests of fine colorless crystals of non-ferrian zoisite (15-20%) that exhibit a characteristic anomalous blue interference color, and sparsely scattered crystals of albite (2%). This rock was probably a diorite or gabbro before metamorphism. It also represents the low-grade albite-epidote-amphibolite metamorphic facies.

Quartz Latite

Several remnants of quartz latite flows occur along the base of the north flank of the range. Anderson (1931, pp. 61-64) describes the Malta range (5 miles north of the Lost-Stanrod salient) as being composed entirely of quartz latite flows with slightly different colors. The quartz latite in low hills at the base of the Raft River Range is dark yellowish brown and pale brown; it weathers to a moderate brown or dusky brown. The rock is generally dense but may be vesicular or glassy near the base or top of a flow. Phenocrysts are easily seen with the naked eye. The phenocrysts make up approximately 25% of the volume of the rock and are composed of about equal amounts of oligoclasse (43% and orthoclase (43%) and about 14% anhedral quartz crystals. Many of the feldspar crysts show resorbtion.

From a study of the latite flows in the area and the intercalated sedimentary strata, Anderson (1931, p. 65) feels that most of the latite "belongs well up in the upper Miocene."

Basalt

Several low buttes and hills composed of dark gray basalt occur in the southeastern part of the mapped area. These buttes form a band from the southeast corner of the range southward to and beyond Kelton, where they become covered by alluvium.

Weathered basalt boulders are dark gray, browish black and olive black; the fresh rock is dark gray, finely crystalline and slightly to highly vesicular depending upon its position in the flow. Several flows are exposed. Columnar jointing is common.

Petrographic examination shows that the basalt has an intergranular texture, and is composed of labradorite (58%) laths, augite (30%), olivine (10%) and magnetite (2%).

The basalt buttes are scarred by wave-cut cliffs and terraces of Lake Bonneville. The basalt flows originally covered a much larger area and probably extended far out into Curley Valley. Prior to Lake Bonneville time, most of the basalt was eroded except for the remnants now visible and under cover. Lake Bonneville came and left its marks and the hills remained until today. No age relation has been established for the basalt in this area. Lake Bonneville sediments mask the basal contact and the upper contact either has been eroded away or is covered by soil or lake sediments. It is likely that this basalt is related to basalt remnants on the north end of the Malta range and in the Sublett region. These remnants occur on top of the latitte flows and are associated with the Payette formation. Anderson (1931, p. 65-66) concludes that the basalt is late Tertiary (Pliocene). It is unlikely that this basalt is equivalent to the relatively fresh and uneroded Pleistocene Snake River basalt.

STRUCTURE

Folds and Joints

The general topographic form of the Raft River Range conforms so closely with the structure that the range can be regarded as truly anticlinal. (See Fig. 14 in pocket.) Folding in the range is simple, except in blocks of the younger strata that have been associated with thrusting and faulting. The main axis of the Raft River anticline trends north 80° east, although the axial trace is slightly arcuate. The axis very nearly corresponds to the crest of the range, plunging eastward at the east end and plunging southwestward at the west side of the mapped area. The anticline is asymmetrical. The south limb is a simple, regularly dipping structure, but the north limb has a triangular-shaped bulge (in the northcentral part of the map) and several smaller folds and undulations whose axes closely parallel the main axis.

The metaquartzites and quartz schists of the Harrison (?) series are highly jointed. A point diagram made from joint-attitude determinations scattered over the range shows that two dominant join sets exist. The average strikes of these two sets are north 8° east and north 28° west. The joint surfaces have steep dips . . . the mean attitude is nearly vertical with a slight preponderance of northeast and northwest dips. This conjugate joint system indicates that the least and greatest strain axes are horizontal. The strike of the fold axis bisects the obtuse angles of the joint system. Joints that have this relationship to folds are considered to be shear fractures (Billings, 1942 p. 126). Theoretically, shear fractures would form at

45° angles from the direction of a compressive force. Experimental work, however, indicates that these angles are always less than 45° (Billings, 1942 p. 108). And in the case of the Raft River Range anticline, the direction of the horizontal compressive force, therefore, would be the bisectrix of the acute angles (36°), or north 10° west (also normal to the strike of the anticlinal axis). (See Fig. 13.) The asymmetric shape of the anticline indicates that the active force existed to the north of the range.

The above evidences strongly suggest that the Raft River Range anticline was produced by horizontally acting forces rather than by vertical forces that may have existed during the intrusion of an igneous mass. The relatively unmetamorphosed state of the Raft River granite also supports the possibility that the igneous stock was emplaced after the anticline was formed and that its emplacement had

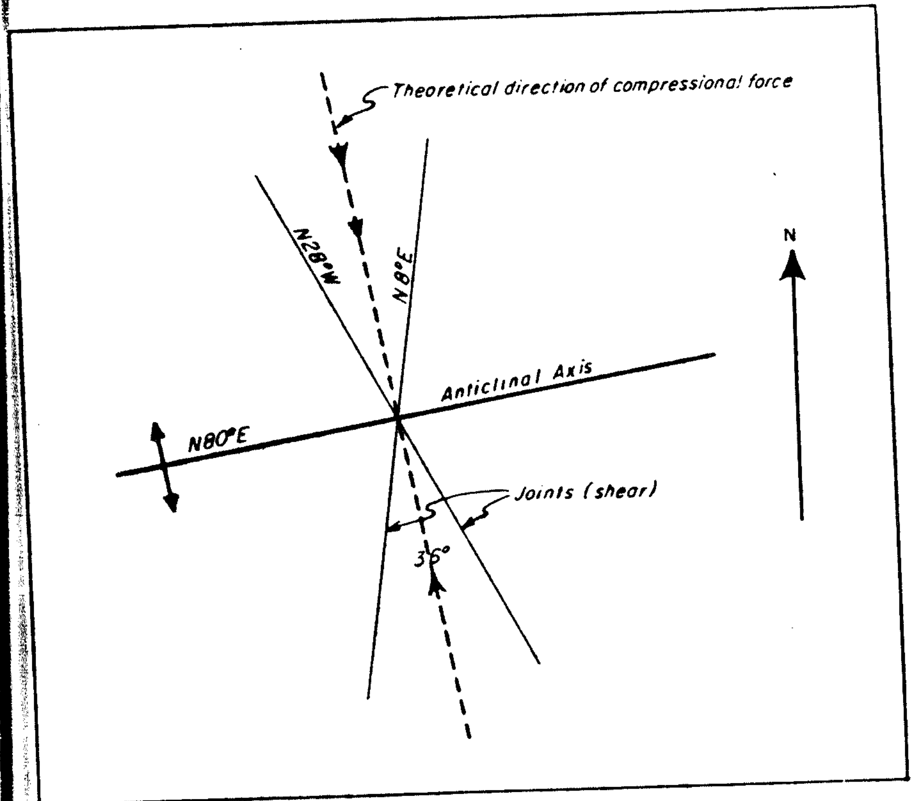

Fig. 13 — ***Diagram showing relationship of joints, anticlinal axis and direction of compression.***

little effect upon the alteration of the structure. The granite was probably emplaced by the process of assimilation.

Faults

A study of the geologic map of the Raft River Range shows that the Lower (?) Paleozoics and the Oquirrh formation truncate units of the Harrison series. From the outcrop patterns, two alternative relationships are possible. Either an angular unconformity exists or the elements involved are in fault contact with each other. If a thrust fault relationship is correct, the situation of younger beds being thrust over older strata is uncommon but not impossible or unknown (Billings, 1933). Following are evidences that support the thrust-relationship situation.

1. Thrust plate remnants or klippen on the crest of the range are highly fractured and contorted having dips up to vertical whereas the underlying autochthon has low dips or is horizontal.

2. On the east end of the range the thrust strata dip in an opposite direction to the plunging anticlinal nose of the Raft River Range anticline. If the younger strata were restored to the near horizontal attitude of deposition, the anticlinal structure would be standing on end.

3. On the east end of the range the numerous normal and reverse faults in the thrust plate are almost wholly of pre-thrust origin and do not cut the underlying Harrison series.

4. The outcrop pattern of the involved units shows discordant relationships.

5. Several large drag folds are present in the autochthonous metaquartzite and schist.

6. The thrust strata, near and away from the fault surface, are generally highly fractured, indicating major movement in the area.

7. The absence of basal conglomerates and coarse sediments at the truncation contacts supports the thrust relationship theory.

The structural circumstance requisite to thrusting younger rocks onto older rocks where the autochthon is not sharply folded would be that of a structural basin adjacent to a prominent structural high. By action of horizontal forces the basin strata could be thrust onto older rocks that may have been thousands of feet below them in the basin relationship.

During the major thrusting process, some older-over-younger rusting occurred in the rocks of the thrust plate as suggested by ntacts mapped at the eastern end of the range.

The numerous faults in the thrust plate at the east end suggest e-thrust or penecontemporaneous faulting. Both normal and rerse faults exist and appear to belong to two sets which strike north 0-30° west and north 30-50° east.

Faults, mainly normal, present in the Yost-Stanrod salient, are lso probable pre-thrust faults since they cannot be traced into the e-Cambrian strata.

SUMMARY OF GEOLOGIC HISTORY

The absence of strata representing many of the geologic periods, he metamorphic alteration, and the extensive thrusting make it dificult to interpret the geologic history and paleogeography of the rea. The order of a few events, however, can be deciphered with ome degree of certainty. The following is the author's interpretation f the geologic history of the area and is subject to revision as new nformation comes to light.

1. The Precambrian Harrison (?) series was deposited in a shallow seaway.
2. Diorite or gabbro necks or pipes were intruded.
3. Hiatus??
4. Miogeosynclinal lower Paleozoic beds deposited (See second article in this guidebook), and perhaps some strata of the lower Carboniferous.
5. Gentle uplift in the Raft River Range and areas to the west.
6. Removal of some of the sediments. Deposition in basins to the north, east and south.
7. Deposition of upper Pennsylvanian carbonates and clastics (and perhaps younger strata).
8. Hiatus??
9. Horizontal compression to form the Raft River Range anticline.

10. Trusting of Paleozoics and Pennsylvania strata over Raft River high. Faulting of the thrust plate into small blocks may have occurred during the thrusting cycle in periods of relaxation of compression.
11. Emplacement or granite stock by assimilation.
12. Erosion.
13. Deposition of Tertiary tuffs and marls and extrusion of latite and basal.
14. Added uplift of Raft River Range area and/or faulting around the flanks to tilt the Tertiary beds.
15. Erosion and pedimentation of Tertiary strata.
16. Dissection of pediments.
17. Glaciation and Lake Bonneville.
18. Reduction of Lake Bonneville to Great Salt Lake.

ECONOMIC GEOLOGY

Numerous prospect pits are scattered over the Raft River Range. The only mines of any consequence were operated at Golden, the principal mining camp, in the late 1800's and early 1900's. This camp was built in Century Hollow on the south flank of the range at the west edge of the mapped area.

The Century property was first operated between 1895 and 1905. The better grade of ore was exhausted in 1905 and the mine was closed after producing about $400,000 of gold, silver and lead (Butler, 1920). Then the extension of the Century vein was found to the west on the Susannah property where gold ore was mined continuously until 1909. Thereafter, mining was done very sporadically. The Century vein was a mineralized quartz vein and fissure that cut the granite and fragments of schist. The unoxidized ore contained galena, sphalerite, pyrite, chalcopyrite and arsenopyrite; however, most of the ore mined was largely oxidized.

At present a small mining company is prospecting in Corner Canyon, west of Century Hollow.

Some of the Tertiary tuffaceous mudstone and tuff has been quarried for building blocks. At present some small quarrying operations are extracting the colorful green quartz-fushite schist for decorative building stone. Recent road-building operations have utilized Lake Bonneville and alluvial fan gravels.

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