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Contents

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GEOLOGY OF THE FISH SPRINGS MINING DISTRICT, FISH SPRINGS RANGE, UTAH*

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ABSTRACT.— The lead-silver mines of the Fish Springs mining district are currently inactive but produced over $2.5 million worth of ore in the early 1900s.

Exposed sedimentary rocks, more than 5,000 feet thick, range in age from Upper Cambrian to Middle Devonian and are predominantly dolomite with some limestone, shale, and quartzite. This sequence of rocks indicates a shallow marine environment. Small rhyolite and andesite dikes trend in an east-west direction through the mining district.

Three episodes of structural activity occurred in the area: (1) thrusting in the Cretaceous, (2) intrusion of dikes in the Oligocene (?), and (3) block-faulting from the Miocene until Holocene.

Geochemical studies indicate that lead is concentrated 20 to 30 feet to the side of the dikes, while copper and zinc are concentrated adjacent to the dikes. This observation may be useful in the exploration for ore in the area.

Mineralization of the mining district accompanied the emplacement of the dikes. Folds and faults produced by the Sevier Orogeny are the structural controls, but no stratigraphic controls are apparent.

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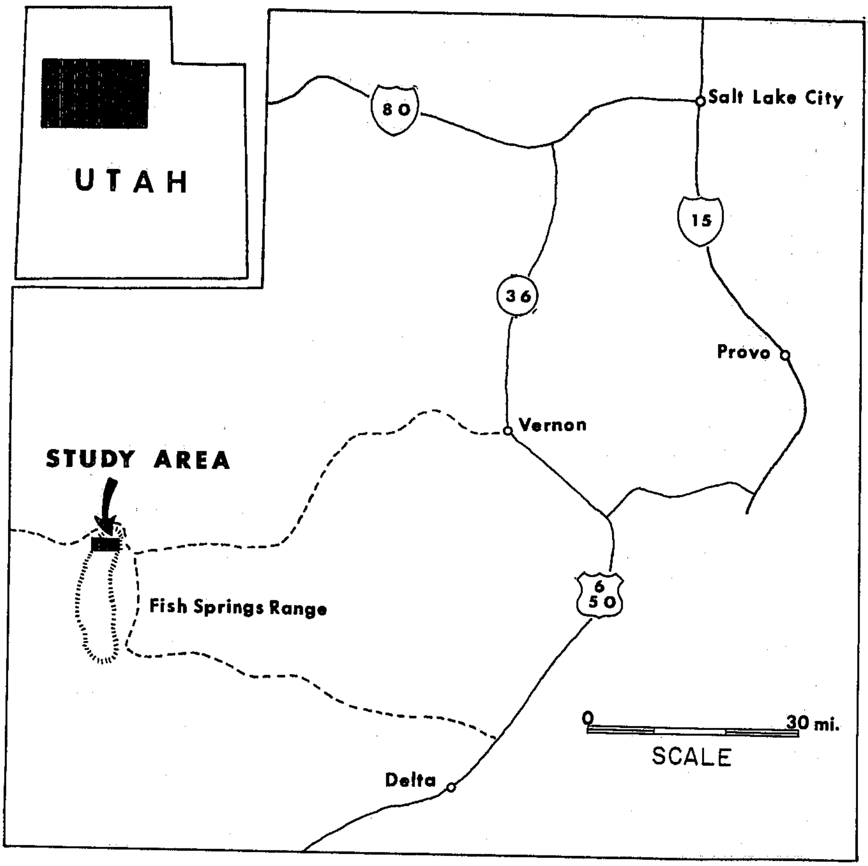
*A thesis submitted to the Department of Geology in partial fulfillment of the requirements for the degree Master of Science, April 18, 1975. Thesis chairman, Lehi F. Hintze.

INTRODUCTION

The Fish Springs mining district, since its organization in 1891, has yielded over $2.5 million worth of ore. The major pulse of mining activity in the area was between 1891 and 1917; the area is currently inactive. Previous geological work in the Fish Springs mining district has been reconnaissance in nature. The purpose of this paper is to present a detailed geological study of the Fish Springs mining district with particular emphasis given to probable ore controls.

Previous Work

The Fish Springs mining district is located in western Utah as shown in Text-figure 1. G. K. Gilbert did the first studies of the Fish Springs area



TEXT-FIGURE 1.— Index map showing location of the study area.

when he made a reconnaissance of the area in 1872 with the Wheeler Survey and again in 1879-80 while preparing his monograph on Lake Bonneville. In 1901 Gilbert and W. D. Johnson visited the area to make topographic and geologic surveys. Their map of the area was not completed because Johnson's field notes were destroyed, but Gilbert's notes were published in 1928, ten years after his death. He described the present range as an example of block faulting.

Butler (1920) studied the Utah mine and other mines in the Fish Springs district. He found that the ore deposits are caused by replacement of the limestone along the footwall of a granite porphyry dike.

Meinzer (1911) conducted a ground water survey in the Fish Springs area. He stated that the springs were fault controlled. Crawford (1941) reported the discovery of magnesite deposits in the Fish Springs mining district. It is believed that the main granite porphyry dike of the Fish Springs mining district generated these deposits.

Hintze (1951) measured the Ordovician stratigraphy of the Fish Springs Range. Kepper (1960) mapped the southern half of the Fish Springs Range, and S. B. Willes prepared a geological map of the northern end of the Fish Springs Range for the geological map of Utah (Stokes, 1963). In May 1973 Brigham Young University geology students (I was a member of this group) described the stratigraphy of the Fish Springs area and mapped the geology at a scale of 1:24,000.

Methods of Study

During May and June 1974 geologic mapping of the study area was completed on aerial photographs on 1:10,000 scale. Forty-one rock samples were collected and analyzed for zinc, copper, lead, and silver. Samples of intrusive material were collected for petrology work.

Acknowledgments

The author wishes to express his gratitude to Dr. L. F. Hintze for his assistance with the field work and preparation of the manuscript, and to Dr. Willis Brimhall for assistance with geochemistry. The author also wishes to thank Allan Morton, Lee Piekarski, Cathy Johnson, Richard Schafer, and Crea McMullin for their assistance with the geologic mapping. Special thanks to my wife, Mary Ann, for her moral support and continual encouragement.

STRATIGRAPHY

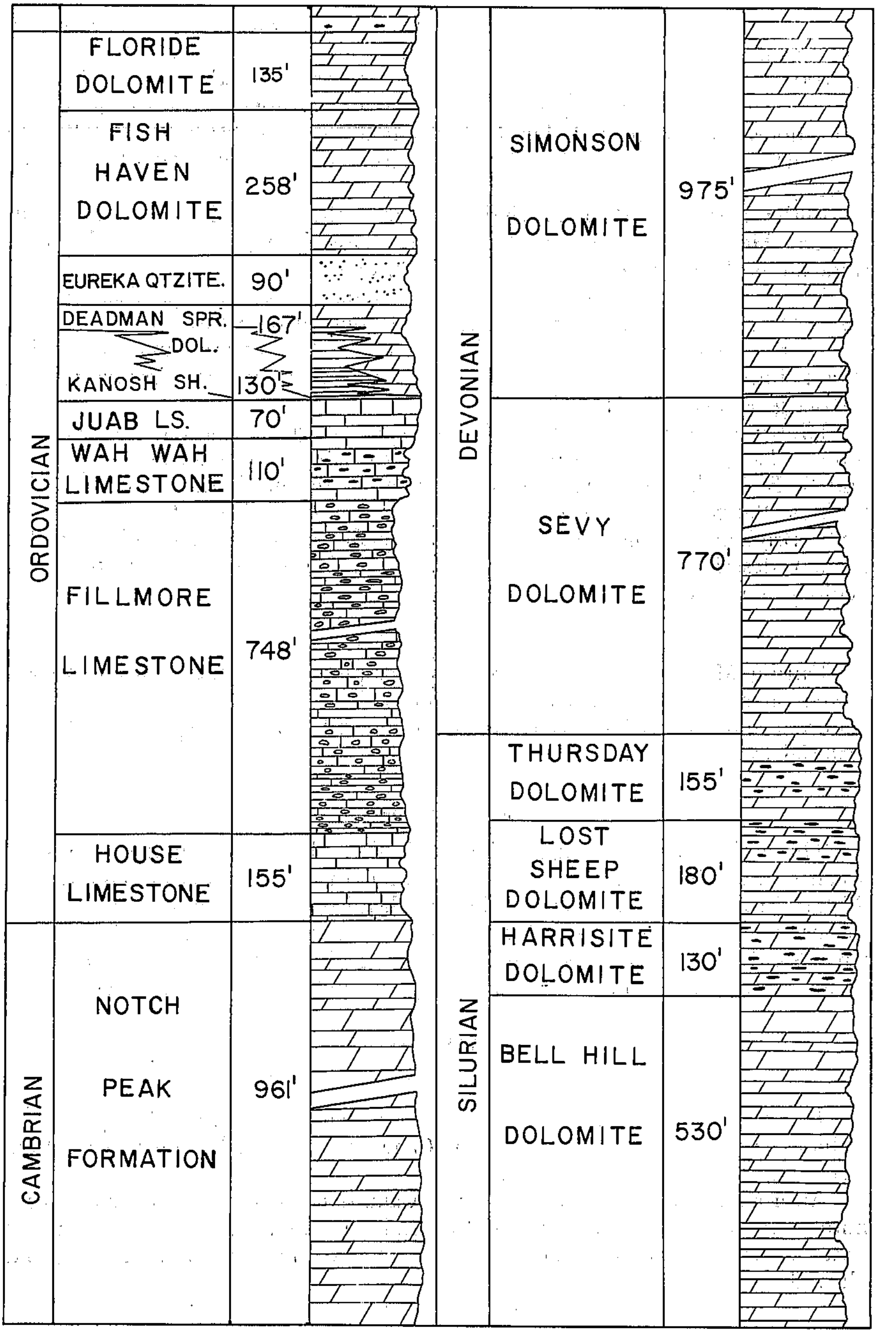
General Statement

The sedimentary sequence of the northern half of the Fish Springs Range includes a thick sequence of Upper Cambrian to Middle Devonian strata (Text-fig. 2) and Quaternary alluvium.

Approximately 5,500 feet of Upper Cambrian to Middle Devonian dolomite with some limestone, shale, and quartzite are well exposed in the mapped area. Quaternary deposits consist of Lake Bonneville terraces, valley fill, and alluvial fans.

Cambrian System

Notch Peak Formation.— The Notch Peak Formation forms prominent cliffs in the southeastern part of the mapped area. Although the lower contact of the



TEXT-FIGURE 2.— Stratigraphic sections exposed in the northern half of the Fish Springs Range.

formation is not exposed in the mapped area, the formation is about 1,000 feet thick in the central part of the Fish Springs Range (see Appendix). The Notch Peak Formation also crops out in the western side of the mapped area as small exposures.

The Notch Peak Formation is a thick-bedded, gray, ledge-forming dolomite. The upper 135 feet of the formation has light to medium gray mottling with meringue weathering. Chert stringers and nodules are found 80, 715, and 835 feet from the base of the formation. Calcite stringers and veins are present throughout the formation. Pisoliths are found in a 28-foot-thick unit 635 feet from the base of the formation. Cross-bedded laminations can be found about 100 feet from the base of the formation.

The only fossils found are *Matthevia* sp. in the lower part and algal heads in the top of the formation. The age of the Notch Peak Formation is Upper Cambrian to Lower Ordovician (Miller, 1969).

Ordovician System

House Limestone.— The House Limestone is a ledge-forming limestone lying directly over the massive cliffs of the Notch Peak Formation. Good exposures of the House Limestone are found south of the Pony Express Trail and on the eastern side of the Fish Springs Range. Low outcrops are found on the western side of the mapped area. A total of 155 feet of the House Limestone was measured in the northern part of the Fish Springs Range (see Appendix).

The House Limestone is a medium-bedded, fine to very finely crystalline, medium gray limestone forming thick ledges with intermitting small slopes. The upper 120 feet of the formation has a saccharoidal texture. Meringue weathering is evident on the rock surface with small vugs and thin stringers of calcite present throughout the limestone. Chert nodules and stringers are present in the upper part of the formation.

The only fossils found in this area in the House Limestone are fragments of crinoid stems, brachiopods, and gastropods. The age of the House Limestone is Lower Ordovician (Hintze, 1951).

Fillmore Limestone.— The Fillmore Limestone forms slightly rounded slopes over the thick ledges of the House Limestone. Good exposures of the Fillmore Limestone are found south of the Pony Express Trail and on the eastern side of the Fish Springs Range. Low outcrops are found on the western side of the Fish Springs Range. A measured section of the Fillmore Limestone (see Appendix) in the study area shows it to be 748 feet thick.

The Fillmore Limestone is a thin-bedded, coarse crystalline, ledge-slope-forming, light to medium gray intraformational conglomerate. The pebbles in the intraformational conglomerates are equant to elongated, round to sub-round, poorly sorted, and pebble in size. The pebbles appear to be micritic. Two to five percent chert nodules and stringers are present throughout the formation. Cross-ripple marks are found 183 and 291 feet from the base of the formation.

The fossils found in the Fillmore Limestone are *Calathium*, crinoid stems, gastropod fragments, brachiopod fragments, and echinoderm plates. The age of the Fillmore Limestone is Lower Ordovician (Hintze, 1951).

Wah Wah Limestone.— The Wah Wah Limestone forms the first prominent ledges above the slope-forming Fillmore Limestone. The Wah Wah Limestone crops out along the eastern flank of the Fish Springs Range with small, low exposures of it present on the western flanks of the same range. The Wah Wah Limestone was found to be 110 feet thick in the study area (see Appendix).

The Wah Wah Limestone can be described as a medium- to thick-bedded, chert, medium light gray, very finely crystalline limestone with some interbedded siltstones and intraformational conglomerates forming a ledge-slope topographic expression. The chert nodules and stringers range from 10 percent near the base to 20 percent near the top of the formation. Ripple marks were found on bedding surfaces near the base of the formation.

The following fossils were found in the Wah Wah Limestone: brachiopod and trilobite fragments, high spiraled gastropods, crinoid stems, sponges, and *Phyllagraptus* sp. (found by Cathy Johnson, June 1974). The age of the Wah Wah Limestone is Lower Ordovician (Hintze, 1951).

Juab Limestone.— The Juab Limestone forms a massive cliff above the thick-bedded ledge-slopes of the Wah Wah Limestone on the eastern side of the Fish Springs Range and also forms low outcrops on the western side of this range. A total of 70 feet of the Juab Limestone was measured in the study area (see Appendix).

The Juab Limestone is a thick to very thick bedded, very finely crystalline, fossiliferous, medium dark gray limestone forming prominent ledges. Very little chert can be found throughout the formation. The Juab Limestone weathers to blocky to massive size fragments with meringue weathering.

The fossils found in the Juab Limestone are the following: orthid brachiopods, trilobite fragments, crinoid stems, and high spiraled gastropods. The age of the Juab Limestone is Middle Ordovician (Hintze, 1951).

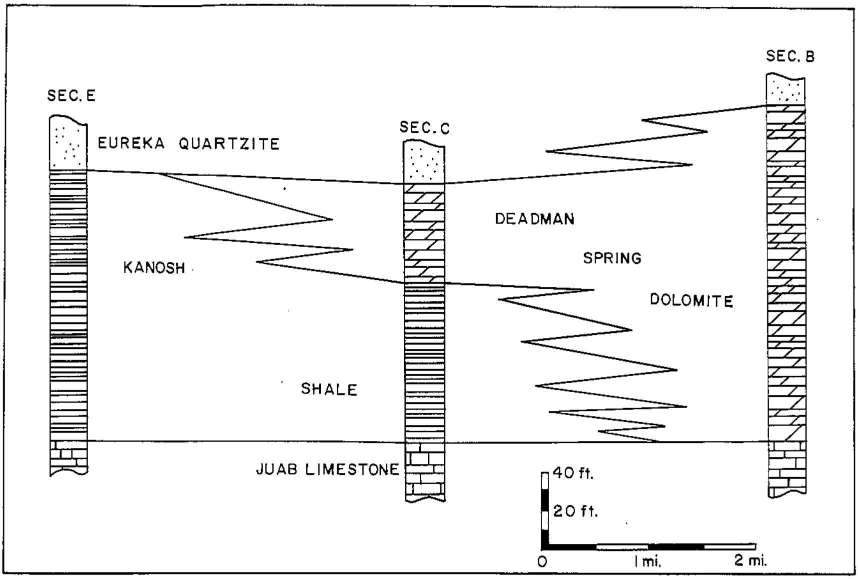
Kanosh Shale.— The Kanosh Shale forms a reddish orange slope above the massive ledges of the Juab Limestone. Excellent exposures of the Kanosh Shale are found south of the study area. The Kanosh Shale is intertongued with the Deadman Spring Dolomite, as shown in Text-figure 3. The Kanosh Shale ranges in thickness from zero north of the study area to 130 feet just south of the study area.

Kanosh Shale is a thin-bedded, slightly calcareous, very finely crystalline, moderate yellow brown, slope-forming, interbedded shale and intraformational conglomerate. Commonly a reddish brown iron stain is present along its bedding planes. A reddish brown soil develops from weathering of this formation.

Trilobite, gastropod, brachiopod, and crinoid fragments were found in the Kanosh Shale, placing its age Middle Ordovician (Hintze, 1951). Two measured sections of the Kanosh Shale are present in the Appendix.

Deadman Spring Dolomite (new).— This formation is named after Deadman Spring, located on the northeastern side of the Fish Springs Range. The type section is in NW¼, NE¼ Sec. 10 T 11 S R 14 W section B in Text-figure 9.

The Deadman Spring Dolomite forms a yellow brown unit above the dark gray Juab Limestone. The lower boundary of the Deadman Spring Dolomite is drawn where the massive, dark gray Juab Limestone changes into a yellow brown, slope-forming dolomite. The upper boundary of the Deadman Spring Dolomite is drawn where the Deadman Spring Dolomite changes from a ledge-forming, yellow brown dolomite to a slope-forming, light gray quartzite of



TEXT-FIGURE 3.— Intertonguing relationship between the Kanosh Shale and the Deadman Spring Dolomite. Locations of sections B, C, and E in Text-figure 9.

the Eureka Quartzite. The Deadman Spring Dolomite extends from about one to two miles south of the Pony Express Trail to the northern tip of the Fish Springs Range. In its type section the Deadman Spring Dolomite is 167 feet thick.

The Deadman Spring Dolomite can be described as a medium- to thin-bedded, moderate yellow brown to light gray, sandy dolomite. The lower 128 feet of the formation forms a slope; the upper 39 feet forms a ledge. The grains are equant, round to subround, well sorted, and silt to medium grain size. The cementing material appears to be dolomitic. Chert forms 1 percent of the formation as brown stringers along the fractures. No fossils were found. See Appendix (section B) for a more detailed description.

The age of the Deadman Spring Dolomite is Middle Ordovician. The basis for this conclusion is that the Deadman Spring Dolomite and the Kanosh Shale are in an intertonguing relationship and hold the same stratigraphic position.

Eureka Quartzite.— The Eureka Quartzite is a distinctive yellow formation among the gray dolomites of the Fish Springs Range. Exposures are found throughout the northern half of the Fish Springs Range. The Eureka Quartzite is 90 feet thick in the study area (see Appendix). In places the Eureka Quartzite has been highly brecciated and attenuated as a result of tectonic activity.

The Eureka Quartzite is thick- to medium-bedded, medium light gray, fine-grained, sandy quartzite. It forms ledges and includes interbedded lenses of sandstone. The grains of the sandstone lenses are equant, rounded, and fine grained, showing good sorting. A sandy dolomite, 19 feet thick, occurs 24 feet above the base. Generally the formation is fractured with bands of iron stain, a few inches wide, found along the fractures. Although the Eureka Quartzite is unfossiliferous, it is dated on the basis of fossil-bearing rocks above and below as Middle Ordovician.

Fish Haven Dolomite.— The Fish Haven Dolomite forms gray dolomite above the light-colored Eureka Quartzite along the ridge line south of the Pony Express Trail and on the western and eastern flanks of the Fish Springs Range. The Fish Haven Dolomite is 258 feet thick in the study area (see Appendix).

The Fish Haven Dolomite can be divided into two units. The lower unit is a predominant slope-former, while the upper unit is a predominant ledge-former. The lower unit forms about half of the formation and is medium- to thin-bedded, very finely crystalline, medium gray dolomite. Bedded chert nodules make up 1 percent of the lower unit. The upper unit is a thick-bedded, medium dark gray, very finely crystalline dolomite; 1 percent of the unit is brown chert. Vugs and stringers of calcite are found throughout both units.

The following silicified fossils were found in the upper unit: rugose corals, *Favosites* sp., *Halysites* sp., brachiopod fragments, crinoid stems, and an indeterminable nautiloid. The age of the Fish Haven Dolomite is Upper Ordovician (Staatz and Osterwald, 1959).

Floride Dolomite.— The Floride Dolomite forms a light gray band between the underlying dark gray Fish Haven Dolomite and the overlying medium gray Bell Hill Dolomite. Exposures of the Floride Dolomite are found along both flanks of the Fish Springs Range. A measured section (see Appendix) in the study area indicates the Floride Dolomite to be 135 feet thick.

The Floride Dolomite is a thin- to medium-bedded, finely crystalline, light gray dolomite. The lower 115 feet of the formation forms slopes, and the upper 20 feet forms a ledge. Pinkish gray to dark brown chert nodules, about 3 to 4 inches long and 1 to 2 inches wide, make up about 1 percent of this formation. Small cavities are generally found on the rock surface along with meringue weathering. No fossils were found, but the age of the Floride Dolomite is Upper Ordovician (Staatz and Osterwald, 1959).

Silurian System

Silurian strata in the Fish Springs Range were compared with similar strata of the nearby Thomas Range where Staatz and Osterwald (1959) had defined several formations. It was concluded that the Thomas Range Silurian nomenclature could be used in the Fish Springs Range as well.

Bell Hill Dolomite.— The Bell Hill Dolomite appears as an alternating light- and dark-banded dolomite above the light gray Floride Dolomite. The Bell Hill Dolomite crops out north of the Pony Express Trail on the western and eastern flanks of the Fish Springs Range. A total of 530 feet of the Bell Hill Dolomite was found in the study area (see Appendix).

The Bell Hill Dolomite of the Fish Springs Range can be divided into two units. The lower unit, which is about 490 feet thick, composes about nine-tenths of the formation. The lower unit is a thin- to medium-bedded, fine to coarse crystalline, saccharoidal, alternating light and dark bands of dolomite forming a ledge-slope topography. The light bands are medium to medium light gray and finely crystalline, while the dark bands are medium dark gray to a blackish gray and coarsely crystalline. The upper unit is a medium- to thick-bedded, fine to medium crystalline, light olive gray, saccharoidal dolomite forming ledges. This unit is 40 feet thick. The upper unit forms an excellent marker bed between the lower unit of the formation and the dark cherty Harrisite Dolomite.

Fossils found in the Bell Hill Dolomite are the following: stromatoporoids, *Virigiana* sp., and *Favosites sp.* (Keith Luke pers. comm., May 1973), pentameroid brachiopod fragments, *Halysites* sp. (?), rugose corals, and crinoid stems. The age of the Bell Hill Dolomite is Middle Silurian (Staatz and Osterwald, 1959).

Harrisite Dolomite.— The Harrisite Dolomite forms a prominent dark ledge above the light-colored upper unit of the Bell Hill Dolomite. The Harrisite Dolomite can be found north of the Pony Express Trail on the western and eastern flanks of the Fish Springs Range. The Harrisite Dolomite is 130 feet thick in the study area (see Appendix).

The Harrisite Dolomite is thick to very thick bedded, finely crystalline, medium dark gray with slight light gray mottling, cherty, ledge-forming dolomite. Chert content ranges from 10 to 15 percent with the dark brown nodules and stringers about 1 to 1½ inches wide. Vugs and stringers of calcite about ¼ to ½ inch wide are found throughout the formation. No fossils were found, but the age of the Harrisite Dolomite, based on fossiliferous rocks above and below, is Silurian (Staatz and Osterwald, 1959).

Lost Sheep Dolomite.— The Lost Sheep Dolomite forms both a light and a dark band above the dark cherty Harrisite Dolomite. Exposures of the Lost Sheep Dolomite are found north of the Pony Express Trail on the western and eastern flanks of the Fish Springs Range. A total of 180 feet of the Lost Sheep Dolomite was measured in the study area (see Appendix).

The Lost Sheep Dolomite can be divided into two units. The lower unit, about 80 feet thick, is a medium- to thick-bedded, fine to medium crystalline, light olive gray, saccharoidal, ledge-forming dolomite. The upper unit is a thick to very thick bedded, medium dark gray, cherty, ledge-forming dolomite about 100 feet thick. It has 10 to 12 percent chert nodules and stringers about 2 to 3 inches thick.

Echinoderm debris and tabulate corals were the fossils found in the Lost Sheep Dolomite. The age of the Lost Sheep Dolomite is Silurian (Staatz and Osterwald, 1959).

Thursday Dolomite.— The Thursday Dolomite appears as an alternating light- to dark-colored dolomite over the dark cherty unit of the Lost Sheep Dolomite. Exposures of the Thursday Dolomite are found on the ridge line and backslopes of the eastern side of the Fish Springs Range. A measured section of the Thursday Dolomite (see Appendix) shows it to be 155 feet thick.

The Thursday Dolomite is a thick to very thick bedded, light to medium dark gray, medium to coarse crystalline dolomite. The lower 115 feet of the formation is a ledge former, while the upper 40 feet is a ledge-slope former. The middle 65 feet of the formation contains 10 to 12 percent chert nodules and stringers.

Tabulate corals and brachiopod fragments were found in the Thursday

Dolomite. The age of the Thursday Dolomite is Upper Silurian (Staatz and Osterwald, 1959).

Devonian System

Sevy Dolomite.— The Sevy Dolomite forms rounded ledge-slopes above the ledge-forming Thursday Dolomite. Exposures of the Sevy Dolomite are found only north of the Pony Express Trail. A measured section of the Sevy Dolomite (see Appendix) indicates it to be 770 feet thick.

Sevy Dolomite is a laminated to thin-bedded, medium to light gray, very finely crystalline dolomite forming slopes with low protruding ledges. Generally the formation is homogeneous in character. Small nodules and stringers of brown chert less than 1 percent are found throughout the formation.

No fossils were found in the Sevy Dolomite, but Osmond (1962) considers it to be Devonian.

Simonson Dolomite.— The Simonson Dolomite appears as alternating light to dark bands of ledges above the light gray slopes of the Sevy Dolomite. Exposures of the Simonson Dolomite are found only north of the Pony Express Trail. The thickness of the Simonson Dolomite is 975 feet, but the top contact of it is not present in the area (see Appendix).

The Simonson Dolomite is a thick- to medium-bedded, medium dark gray and medium light gray, banded, finely crystalline dolomite forming a ledge-slope topography. Two major dolomitic breccia zones 30 and 50 feet thick are found 80 and 570 feet respectively from the base of the formation. Generally the entire formation contains less than 1 percent chert nodules and stringers.

Fossils found in the Simonson Dolomite include high spiraled gastropods, brachiopod fragments, and spaghetti stromatoporoids. The age of the Simonson Dolomite is Middle Devonian (Nolan, 1935).

INTRUSIONS

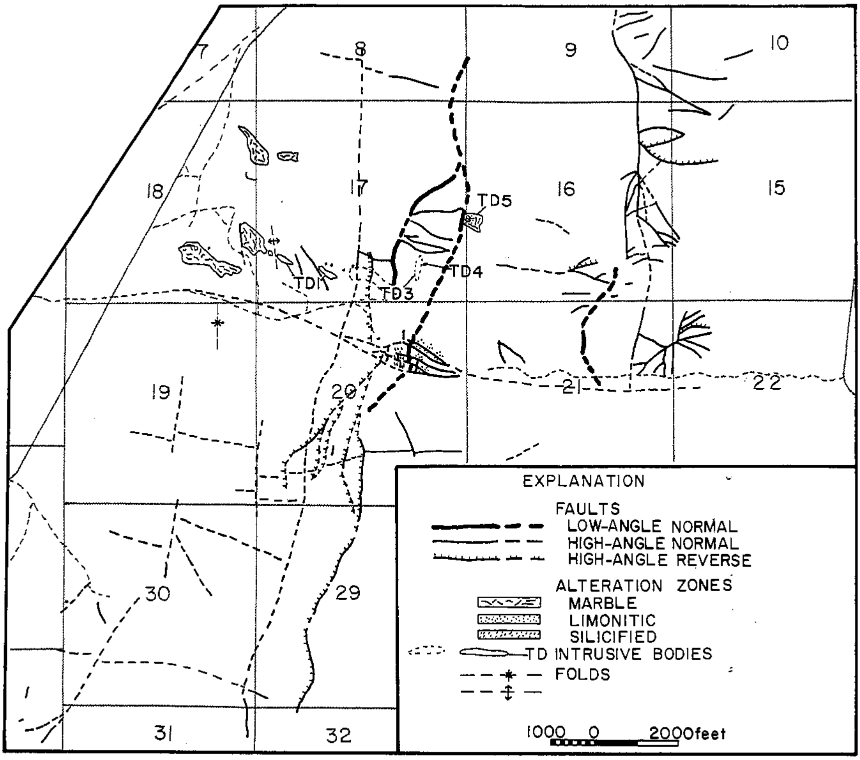
Six dikes were examined in and around the study area (Text-figs. 4, 6). The largest dike, TD1, was the main source of mineralization in the area (Butler, 1920). TD2 is not shown because it does not crop out at the surface but was discovered by underground mining. Only remnants of TD3 were found, with most of the dike being weathered away. The dikes were classified only on the basis of phenocryst content.

Dike TD1, is a rhyolite (Butler, 1920, called it a granite porphyry). In hand sample the dike is light gray to tan with phenocrysts of biotite and potassium feldspar. In thin section the dike is made up of 10 percent phenocrysts of quartz, biotite, and potassium feldspar in an aphanitic ground mass.

Dikes TD2 and TD3 are rhyodacites. In hand samples the dikes are light gray with phenocrysts of quartz. In thin section the dikes are made up of 10 percent phenocrysts of quartz, biotite, plagioclase, sanidine, and secondary muscovite set in an aphanitic ground mass.

Dikes TD4, TD5, and TD6 are andesites. In hand sample the dikes are dark gray with phenocrysts of plagioclase. In thin section the dikes are made up of less than 10 percent phenocrysts of plagioclase, pyroxene, and amphibole set in an aphanitic ground mass.

The age of emplacement of the dikes is discussed in the following structural section of this paper.



TEXT-FIGURE 4.— Tectonic map of the study area.

STRUCTURE

General Statement

The structural history of the area can be divided into three episodes of activity:

1. Sevier orogenic activity during late Mesozoic time
2. Intrusive activity during Oligocene (?) time
3. Basin and range block faulting from Miocene until Holocene

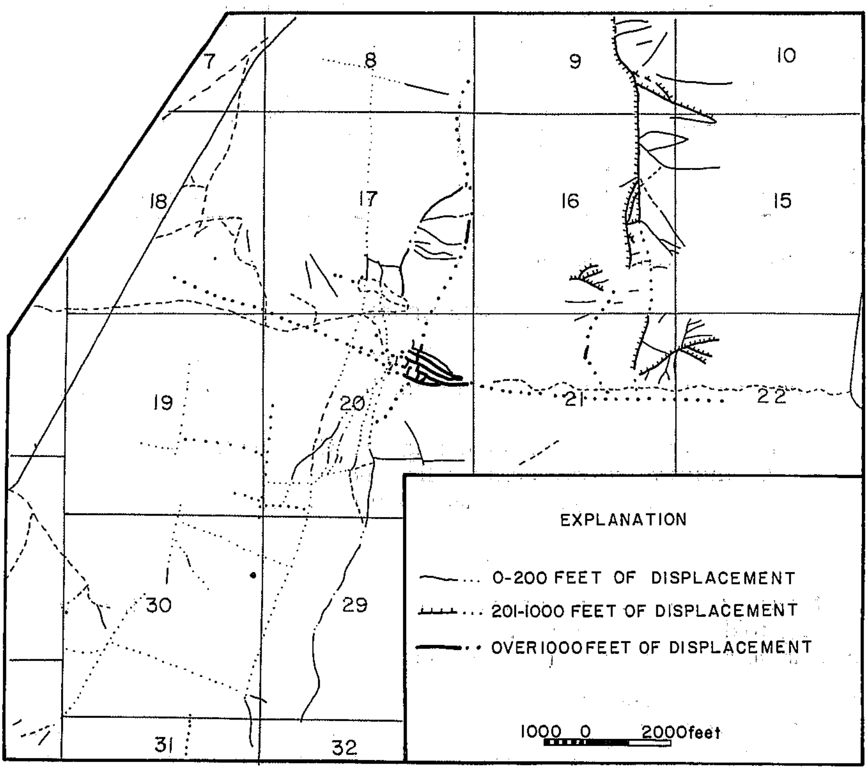
Sevier Orogenic Activity

Sevier orogenic activity produced compressional features in the area, including folding, low-angle normal faulting, east-west high-angle faulting, and high-angle reverse faulting (Text-fig. 4).

Folding.— An asymmetric anticline on the western side of the study area appears on Text-figure 4 and in the cross sections of Plate 1. The axis strikes north to northeast, and the eastern limb of the anticline is steeper, suggesting compression from the west. The folding may have a strong effect on the economics of the area as discussed in the economic section of this paper. The folds appear to be the oldest structural feature in the range. The folds are cut by both the high-angle reverse and normal faulting.

Low-Angle Normal Faults.— Three low-angle normal faults in Sec. 16, 17, 20, and 21 (Text-fig. 4) are major faults in the study area. These low-angle normal faults have a north-south trending strike with an average displacement on two of the faults of about 2,500 to 3,000 feet, while the other fault has a displacement of 1,000 to 1,500 feet (Text-fig. 5). These faults, as shown in the cross sections AA′ and BB′ in Plate 1, dip east, with the two faults on the west dipping 30° to 35° and the fault on the east dipping about 10°. These faults have down dropped the Devonian into contact with the Ordovician to form a grabenlike structure. This faulting appears to be postfolding but prenormal and reverse faulting (see NE¼ Sec. 20 in Text-fig. 4). These low-angle normal faults are probably gravity slides toward the east.

East-West High-Angle Faults.— The displacement on east-west high-angle faults ranges from more than 2,000 to less than 50 feet, with most of the faults having a displacement of 50 to 150 feet (Text-fig. 5). The east-west fault following the Pony Express Trail (Plate 1) has the greatest displacement, 2,500 to 3,000 feet. This fault has stratigraphically down dropped the



TEXT-FIGURE 5.— Amount of displacement along faults in study area.

northern end of the Fish Springs Range. A highly altered zone is found along this fault as it splits west of the pass (see NE¼ Sec. 20 in Text-fig. 4). The relation of this fault to mineralization in the area is discussed in the section on economic geology in this paper.

These east-west faults are probably tear faults related to compressional forces from the west. As shown in NE¼ Sec. 20 (Text-fig. 4), these faults cut the low-angle normal faults but are cut by both the reverse faults and north-south normal faults as in S½ Sec. 20 (Text-fig. 4).

High-Angle Reverse Faults.— High-angle reverse faults are predominantly found along the western side of the study area (Text-fig. 4), generally striking north-south with an average displacement of 100 to 150 feet (Text-fig. 5). These north-south reverse faults apparently represent the leading edges of minor thrusts from the west. Along with the north-south set of faults there is also a minor east-west set of faults that may be associated with the tear faults. This reverse faulting may represent the last phase of activity of the Sevier Orogeny.

I associate these structural elements with the Sevier Orogeny because they seem to have resulted from compressional forces from the west and are typical of the structural features of that orogeny.

Intrusive Activity

The dikes are found predominantly around the mining district (see Sec. 16, 17, and 20 in Text-fig. 4). If the strikes of the dikes are projected toward the northwest, they intersect northwest of the mining district (E½ Sec. 18). This intersection may imply a larger intrusion in that area with the dikes radiating from it. The dikes were probably emplaced during the Oligocene. Reasoning for this is that the dikes appear to be unaffected by the Sevier activities but are cut by the north-south block faulting. Although no radiometric dates are available for the Fish Springs Range, rhyolite in the Thomas Range is dated as Middle Tertiary (Staatz and Carr, 1964). Rhyolite in the Honeycomb Hill was dated as Late Tertiary (Erickson, 1963). Leedom (1964) and Pierce (1974) dated the volcanic activity in the Drum Mountains at 37 m.y.

Basin and Range Block Faulting

North-south trending high-angle normal faults (Text-fig. 4) comprise about 25 percent of the faults in the area. The amount of displacement of faults of this system is greater on the eastern side than on the western side of the range. The eastern faults have an average displacement of 1,000 to 1,500 feet, while the western faults have an average displacement of 50 to 150 feet (Text-fig. 5). These normal faults cut all preexisting structures in the range, and, due to the north-south trend and tensional nature of the faults, they fit into the geologic framework as part of the Basin and Range block faulting. The age of this faulting is Miocene to Recent. Recent movement was discovered along a fault on the eastern margin of the range about three miles south of the study area where Lake Bonneville sediments have been displaced (Gilbert, 1928).

SUMMARY OF THE GEOLOGIC HISTORY

The western Utah area had a thick accumulation of marine sediment during the Cambrian through the Devonian in the Cordilleran miogeosyncline. During the Lower Ordovician the area apparently had a tidal flat environment (Hintze, 1973), which is represented by the Fillmore Limestone. During Upper Ordovician to Middle Devonian, a warm, shallow-water lime mud bank and shelf environment existed (Hintze, 1973), indicated by the uniformity of the lithologies and the presence of corals and brachiopods as the predominant fauna. Younger Paleozoic and early Mesozoic sediments were probably deposited but have since been removed by extensive erosion.

During the Cretaceous the area was the site of diastrophism. Folding, faulting, and thrusting from the west occurred in this area. These compressional forces are related to the Sevier Orogeny which occurred in eastern Nevada and western Utah (Armstrong, 1968).

Intrusive activity occurred after the Sevier Orogeny and before the Basin and Range block-faulting. Buranek and Crawford (1942) suggested that these intrusions may be related to the intrusions in the Deep Creek Range and Gold Hill which are Late Eocene to Oligocene (Nolan, 1935). This age determination concurs with the geologic framework of this area (Leedom, 1974; and Pierce, 1974).

The present relief of the range was produced by Basin and Range block-faulting which began during Miocene and continued to Recent. Quaternary sediments have since been deposited as alluvial fans and valley fill. These sediments have subsequently been reworked or covered by the sediments of Pleistocene Lake Bonneville

GEOCHEMICAL SURVEY

Introduction

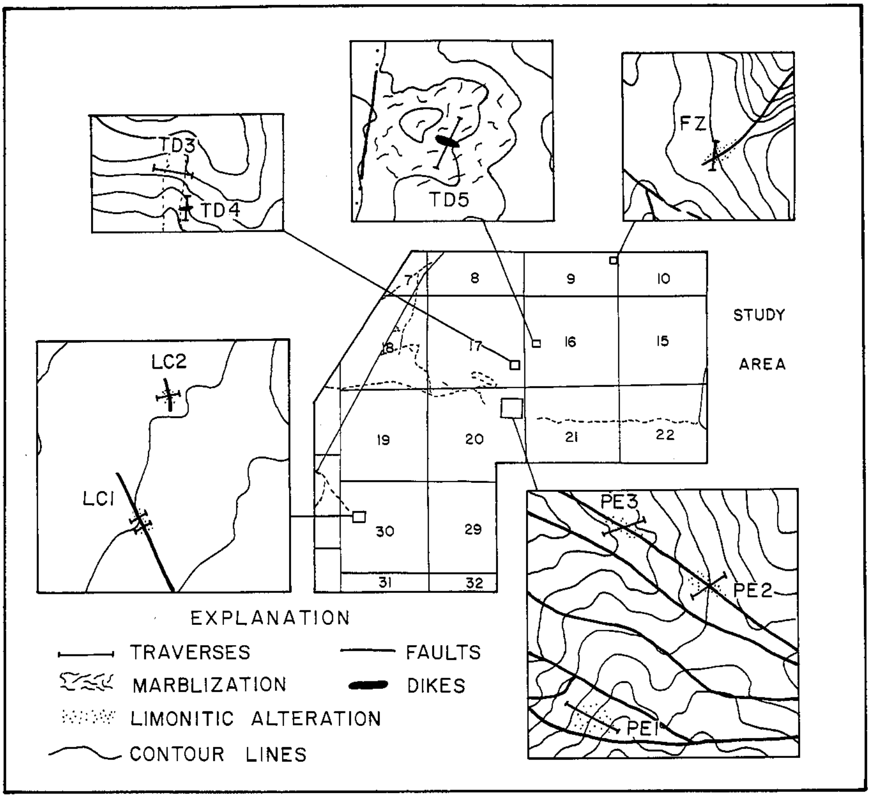
A total of 41 rock samples were collected across dikes and areas of surface alteration (Text-fig. 6). These were analyzed for zinc, copper, silver, and lead.

Preparation of the rock samples is outlined in Text-figure 8. Samples were analyzed using a Perkin-Elmer model 303 atomic absorption spectrophotometer. A sample of reagent blank of calcium carbonate was analyzed along with the samples to measure calcium interference in the rock samples, with the values of this sample subtracted from the values of the rock samples. Table 1 in the Appendix is a tabulation of the results with the corrected values for the rock samples.

Discussion and Interpretation of Results

The results for each traverse were plotted on a graph with the vertical scale logarithmic for each element (Text-fig. 7). The purpose of these graphs is to determine trends between ore deposition and the structures.

The graphs showed that zinc and copper generally followed the same trends. These two elements concentrate over either a dike or a fault. The lead concentrated sometimes over the faults but never over the dikes. Rather, it concentrated to the side of the dikes. Lead might be very useful in determining the possible presence of an intrusion along or beneath a fault. An example of this can be seen in the trend of PE3 (Text-fig. 7). This traverse shows that zinc and copper concentrate over the fault, while lead concentrates to one side of the fault. If the hypothesis is true, then an intrusion is associated with the fault. The silver results appear to have the same general trend as does the lead.



TEXT-FIGURE 6.— Location of geochemical traverses in study area.

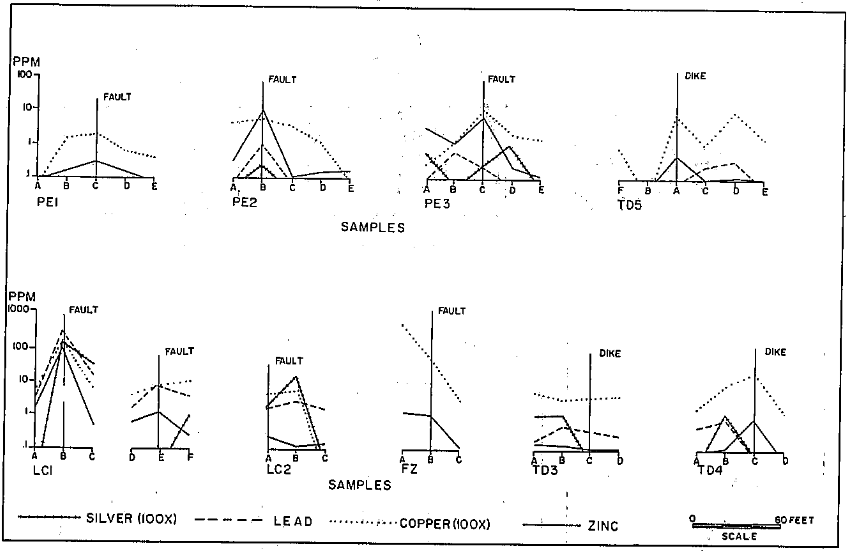
The relationship of this study to the economics of the area is discussed in the following section of this paper.

ECONOMIC GEOLOGY

Introduction

The Fish Springs mining district was organized on March 20, 1891 (Butler, 1920). Since the district was organized, it has yielded more than $2.5 million worth of silver-lead ore. Most of the mining took place between the time of its organization and 1917; the area is currently inactive. The two main mines in the area were the Utah and Galena. The Utah mine produced 12,997 tons of ore at a value of $1,580,186 (Butler, 1920). The Galena mine produced 3,000 tons of ore at a value of $330,000 (Butler, 1920). Butler (1920, p. 468) states "that all of the ore deposits are lead-silver ores, in which the silver content is uniformly high and gold content low."

The ore produced from the Utah and Galena mines has come from the footwall side of the dike with very little ore from the hanging-wall side. Butler (1920) states the usual method of mining is to follow an ore fissure,



TEXT-FIGURE 7.— Graphs of the trends for each element across the traverses. The vertical scale is logarithmic with the values for silver and copper exaggerated 100 times.

even though it appears to be barren. These barren fissures have been followed to valuable deposits.

I did not have an opportunity to go down into the mines, which were closed, to examine the mineralization. The following is an account of the mineralization from Butler (1920, p. 468). He states, "The primary mineralization in the Utah mine consists of galena and pyrite and a little sphalerite replacing the limestones. Secondary copper minerals in small amounts have probably resulted from the alteration of chalcopyrite. The final products of alteration are commonly cerusite and limonite. Before the oxidation is complete sulphates are locally present in considerable abundance."

Surface Alteration

Three types of surface alteration are recognized in the study area: limonitic, silicified, and marble zones. Text-figure 4 shows the relationships of these alteration zones to the structures and dikes of the area.

Limonitic and silicified zones are found associated with the faults and dikes. The areas where this type of alteration is most developed are associated with a highly faulted area (see NE$\frac{1}{4}$ Sec. 20 in Text-fig. 4). The Limonitic zones are recognized as bright reddish zones which stand out in contrast to the light gray dolomites. The silicified zones have replaced the rocks to such an extent that it is almost impossible to identify the original formations. These two zones have formed in association with faults or dikes which have channeled mineralized fluids.

The marble zones are bleached dolomitic areas. Crawford (1941) reported deposits of magnesite from the marble zones in SE$\frac{1}{2}$ Sec. 18. These marble zones are found in close association with intrusions, not with faulting. The main marble zone (see Sec. 18 and 19 in Text-fig. 4) is also found in association with an anticlinal axis running down the middle of this marble zone. It appears that the marble zones are associated with a large intrusive body in that area and that the fold has been an influence upon the concentration of the solutions. Buranek and Crawford (1942, p. 10) state that "solutions arising from the dike are presumed to have attacked the dolomite, causing the breakdown of the dolomite molecule into its two constituents—calcium carbonate and magnesium carbonate. Hence, the dolomite country rock was in part changed to a marble made up largely of calcite, while the magnesium carbonate thus extracted from the dolomite was concentrated as pure magnesite in the fractured zones along the axis of the anticline." Thus the marblized zones are associated with folds and/or intrusive bodies.

Ore Controls

Because all mineralization is associated with an intrusion, intrusions are the source of the ore solutions of the area. The controlling factors of ore emplacement and migration are structural. Stratigraphy appears not to be a controlling factor because all ore deposits and alteration are not restricted to any one formation.

Principal structural controls are the Sevier faulting and folding in the area. This folding and faulting took place in late Mesozoic time, well before the emplacement of the dikes in the middle Tertiary. Where the fold axis has not been broken by faults, some of the ore solutions have collected along the axis of the anticline, as in the case of the magnesite. Where the fold axis has been offset by faults, the ore solutions have followed the easier path of migration along the faults. It appears that some of the dikes have also followed some of the major fault systems (see NE¼ Sec. 20 in Text-fig 4). By comparing Text-figures 4 and 5, one can see that most of the alteration and mineralization is associated with faults that have a displacement of over 2,000 feet. It also appears that the strongest alteration occurs at the intersection of two fault systems, the north-south low-angle normal and east-west high-angle tear faults.

The geochemical survey shows zonation of the ore around the intrusions; the lead is found to the side of the intrusions, but the zinc and copper occur directly over them (Text-fig. 7). This is interpreted as a zone of lead and possibly silver further away. The migration of ore is not far because the lead is concentrated 20 to 30 feet from the intrusions.

CONCLUSIONS

Ore controls for the Fish Springs mining district are twofold: first, the ore solutions accompanied the intrusive activity in the area during the Oligocene; secondly, the migration and concentration of the ore solutions were controlled by the folding and faulting of the Sevier Orogeny which occurred in late Mesozoic. No stratigraphic controls exist.

Geochemical studies indicate zonation of ore around the intrusions; for example, a zone of zinc and copper directly around the intrusion with a zone of lead and silver 20 to 30 feet from the intrusion. Geochemical studies show that lead always concentrates to the sides of the intrusions, with copper and zinc concentrating directly over the intrusions. This observation would be very useful in the exploration of buried intrusions.

Exploration efforts using geochemical surveys on the structural elements of the Sevier Orogeny may result in the discovery of more ore deposits in the area. Possible target areas for exploration may be to the north and northeast of the mining district where surface alteration is present.

APPENDIX

A-Section

This section is located northeast of the Pony Express Pass as shown in Text-figure 9. A complete section of the Sevy Dolomite is exposed here. An incomplete section of the Simonson Dolomite is exposed, but it is the best Simonson section available in the range.

Unit	*Description*	*Feet/ Unit*	*Total Feet*
Simonson Dolomite			
7	Dolomite: similar to unit 1; mottling in upper 100 feet of unit; 10 feet from top a light brown unit 5 feet thick is found in unit 7; small fragments of chert, less than 1 percent present in unit 7; top of the formation not seen.	355′	975′
6	Dolomitic breccia: matrix-white calcite; clasts—dark gray weathers to medium dark gray dolomite; thin to medium bedded; flaggy to slabby; clasts—equant to elongated, angular, poorly sorted, saccharoidal, fine to medium grain size; no chert; gradational contact with underlying unit, partly covered, goes from a dark gray dolomite to a breccia; weathers into rubble; forms low ledge.	50′	620′
5	Dolomite: similar to unit 1; breccia zone, 2-3 feet thick 100 feet from base; high spiraled gastropods and brachiopod shells 123 feet from base with massive stromatoporoids 153 feet from base; less than 1 percent stringers of chert.	273′	570′
4	Dolomite: light olive gray, weathers pinkish gray; microcrystalline; medium to thick-bedded; flaggy to slabby parting; highly fractured; chert present as stringers and dark brown specks, less than 1 percent; small amount of brown stain; sharp contact with underlying unit (from a dark gray dolomite to pinkish gray dolomite); weathers into rubble with meringue weathering along bedding plane; forms low ledge.	27′	297′
3	Dolomite: similar to unit 1; mottling in	160′	270′

	upper 10 feet of unit 3; chert nodules in middle of unit 3, less than 1 percent; gradational contact with underlying unit; no breccia zones.		
2	Dolomitic breccia: matrix—medium gray, weathers to light olive gray; clasts—dark gray, weathers to olive gray; few clasts yellow gray weathering to light greenish gray; matrix finely crystalline, saccharoidal; clasts—elongated-platy, angular, poorly sorted, saccharoidal, pebble to cobble size; thin bedded; slabby with fracturing; less than 1 percent of dark brown chert in fractures; stringers and vugs of calcite; sharp contact with underlying unit (from a light gray dolomite to a breccia); weathers into rubble; low ledge former with slope.	30′	110′
1	Dolomite: alternating light and dark bands; dark bands, dark gray, weathers medium dark gray; light bands, medium dark gray, weathers medium light gray; finely crystalline; thick to medium bedded; slabby with fracturing and parting; veins and vugs of calcite in dark bands; breccia zones 5 and 30 feet from base about 2-3 feet thick; contact with underlying Sevy is sharp (changes from a thin-bedded, light gray dolomite to a thick-bedded, dark gray dolomite); meringue weathering with rubble; ledge-slope former with dark bands forming better ledges.	80′	80′
	Total thickness	975′	
Sevy Dolomite			
6	Dolomite: similar to unit 2; bands of chert $\frac{1}{4}$ inch thick 115 and 330 feet from base of unit 6; gradational contact with underlying units based on banding in upper unit.	350′	770′
5	Dolomite: similar to unit 2; mostly covered; fragments of dark brown chert, less than 1 percent in unit 5.	45′	420′
4	Dolomite: medium gray, weathers to a medium dark gray; fine grained; saccharoidal; thin bedded; banding; slabby with fracturing; sharp contact with underlying unit (from medium gray to medium dark gray dolomite); weathers into rubble	20′	375′

	with very weak meringue weathering; ledge-slope former, about 1:1 ratio.		
3	Dolomite: medium gray, weathers medium gray with light brown stain covering; very finely crystalline; laminated to thin bedded; slabby; nodules of chert same as unit 2; gradational contact with underlying unit (change based on brown stain); weathers into rubble; mostly covered; forms slope.	155′	355′
2	Dolomite: medium gray, weathers medium gray; similar to unit 1; nodules and stringers of dark brown chert, less than 1 percent in unit 2 with banding.	50′	200′
1	Dolomite: medium gray, weathers light gray; very finely crystalline; laminated to thin bedded; slabby, with fracturing and parting; no chert or fossils; upper 50 feet slightly darker; gradational contact with Thursday Dolomite (from a dark gray to a light gray dolomite); low outcrops, partly covered; weathers into rubble with weak meringue weathering; ledge-slope former.	150′	150′
	Total Thickness	770′	

B-Section

This section is located in the northeastern part of the Fish Springs Range just southwest of North Springs, as shown in Text-figure 9. Complete sections of the Thursday Dolomite, Lost Sheep Dolomite, Harrisite Dolomite, Bell Hill Dolomite, Floride Dolomite, Fish Haven Dolomite, Eureka Quartzite, and Deadman Spring Dolomite are exposed here.

Thursday Dolomite

3	Dolomite: light gray, weathers medium light gray; thick bedded; slabby with fracturing; coarsely crystalline; saccharoidal; gradational contact with underlying unit (from a dark cherty to a light gray dolomite); weathers into rubble; ledge-slope former.	40′	155′
2	Dolomite: medium gray, weathers medium dark gray; thick to very thick bedded; blocky to slabby with fracturing and parting; brachiopod fragments 55 feet from base; 10-12 percent chert nodules and stringers; stringers and vugs of calcite 2 to 3 inches thick; sharp contact with underlying unit (from a light to	65′	115′

	a dark cherty dolomite); weathers into rubble; ledge former.		
1	Dolomite: light brown gray, weathers light olive gray; thick to very thick bedded; blocky to slabby with fracturing and parting; tabulate corals at base; medium crystalline; sharp contact with Lost Sheep Dolomite (from a dark cherty to light dolomite); weathers into rubble; ledge former.	50′	50′
	Total thickness	155′	

Lost Sheep Dolomite

2	Dolomite: medium gray, weathers medium dark gray; thick to very thick bedded; slabby with fracturing and parting; tabulate corals in upper portion; medium crystalline; 10-12 percent light gray to tan chert nodules and stringers about 2 to 3 inches thick with 15 percent chert 25 to 30 feet from base; vugs and stringers of calcite; sharp contact with underlying unit (from a light to a dark cherty dolomite); weathers into rubble with meringue weathering; ledge former.	100′	180′

Note: The measured section offsets to the northeast one-half mile to a better exposure of the lower Lost Sheep Dolomite.

1	Dolomite: light brownish gray, weathers light olive gray; medium to thick bedded; blocky to slabby with fracturing and parting; fine to medium crystalline; saccharoidal; 3 percent light brown nodules of chert in lower 10 feet; 45 feet from base, a 2-foot-thick band of brown stain; small stringers of brown chert about .1 inch wide 75 feet from the base; few vugs and stringers of calcite; sharp contact with the Harrisite Dolomite (from a dark cherty to a light olive gray dolomite); weathers into rubble with the rock surface pitted with meringue weathering; ledge former.	80′	80′
	Total thickness	180′	

Harrisite Dolomite

1	Dolomite: dark gray, weathers medium dark gray with slight mottling; thick to very thick bedded; slabby to blocky; finely crystalline; 10-15 percent dark brown nodules and stringers of chert about 1 to $1\frac{1}{2}$ inches wide; vugs and stringers of	130′	130′

	calcite, $\frac{1}{4}$ and $\frac{1}{2}$ inch wide; sharp contact with Bell Hill Dolomite (from a light olive gray to a dark cherty dolomite); weathers into rubble with meringue weathering; ledge former.		
	Total thickness	130′	
Bell Hill Dolomite			
4	Dolomite: light brownish gray, weathers light olive gray; medium to thick bedded; slabby to blocky with fracturing and parting; fine to medium crystalline; saccharoidal; 1 percent dark brown stringers of chert at base; sharp contact with underlying unit (from a dark dolomite to a light olive gray dolomite); weathers into rubble with the rock surfaces pitted; ledge former.	40′	530′
3	Dolomite: dark gray, weathers dark gray to a blackish gray; thin to medium bedded; slabby with fracturing and parting; 65 to 75 feet from base brachiopoda fragments and Rugose corals with tabulate corals and stromatoporoids; medium crystalline; saccharoidal; 1 percent dark brown chert nodules and stringers about 1 to $1\frac{1}{2}$ inches in diameter, with 3 percent chert 225 feet from base; faint cross-bedding; vugs and stringers of calcite 155 and 225 feet from the base; slight mottling 260 feet from base; gradational contact with underlying unit (from a slope to a ledge, also change in color); weathers into rubble with slight meringue weathering; ledge former.	275′	490′
2	Dolomite: alternating light and dark bands; saccharoidal; light bands—light gray, weathers medium light gray; dark bands—medium dark gray, weathers medium gray; 28 feet from base a brownish bed 2 to 3 feet wide; medium to thin bedded with $\frac{1}{4}$- and $\frac{1}{2}$-inch-wide bands; slabby with fracturing and parting; light bands—fine crystalline; dark bands—medium to coarsely crystalline; 30 feet from base 1 percent dark brown chert stringers; stringers and vugs of calcite; gradational contact with underlying unit (from a dark to a light dolomite); weathers into rubble with meringue weathering; ledge-slope former.	95′	215′

1	Dolomite: medium dark gray, weathers medium gray with slight mottling and brown stains; medium bedding with .1- to .2-inch bands; slabby with fracturing; fine crystalline; 3 percent brown chert nodules and stringers about 5 feet from the base, also 2-foot chert band 25 feet from base; vugs and stringers of calcite with about 5 percent vugs 100 feet from the base; Rugose corals 50 feet from the base; gradational contact with the Floride Dolomite (change based on color and an increase in chert); weathers into rubble with angular fragments with meringue weathering; ledge-slope former.	120′	120′
	Total thickness	530′	
Floride Dolomite			
2	Dolomite: medium light gray, weathers light gray; thin to medium bedded; slabby with fracturing; fine crystalline; 1 percent pinkish gray chert nodules along bedding planes; sharp contact with underlying unit (from a slope to a ledge); weathers into rubble; ledge former.	20′	135′
1	Dolomite: medium light gray, weathers light gray; thin to medium bedded; slabby with fracturing and parting; fine crystalline; 1 percent dark brown chert nodules about 3 to 4 inches long and 1 to 2 inches wide; sharp contact with the Fish Haven Dolomite (from a ledge to a slope, also change in color); weathers into rubble with cavities on the rock surface meringue weathering; low outcrops; slope former.	115′	115′
	Total thickness	135′	
Fish Haven Dolomite			
4	Dolomite: medium gray, weathers medium dark gray; thick bedded; slabby with fracturing; Rugose corals, Favosites and Halysites corals, brachiopod fragments, crinoid stems and nautiloids in upper portion of the unit; very fine crystalline; 1 percent brown chert nodules; vugs and stringers of calcite; less than 1 percent calcite crystals about .05 inch wide on weathered surface; sharp contact with underlying unit (from a slope to a ledge former); weathers into rubble with meringue weathering; ledge former.	115′	258′

3	Dolomite: medium dark gray, weathers medium gray, with slight mottling 95 feet from base; medium to thin bedded with wavy bedding 40 feet from base; .1-inch-thick bands present; slabby with fracturing and parting; very fine crystalline; 1 percent chert nodules along bedding planes; calcite stringers along bedding planes .2 to .3 inch wide; slight breccia 30 feet from base; gradational contact with underlying unit (from a ledge to a slope former); weathers into rubble with meringue weathering; partly covered with low outcrops in slopes; slope-ledge former.	120′	143′
2	Dolomite: dark gray, weathers medium dark gray; medium to thick bedded; slabby with fracturing and parting; very fine crystalline; sharp contact with underlying unit (from a light to a dark dolomite); weathers into rubble with meringue weathering; ledge former.	10′	23′
1	Dolomite: light with 1-foot-wide dark bands at 3 and 11 feet from the base; light bands—medium gray, weathers medium light gray with mottling; dark bands—dark gray, weathers medium dark gray; medium to thick bedded; slabby with fracturing and parting; very fine crystalline; 4 feet from base stringers of iron stain .2 to .4 inch wide; 10 feet from base 1- to 2-inch clasts of dark dolomite in light dolomite; sharp contact with Eureka Quartzite (from a quartzite to a dolomite); weathers into rubble with meringue weathering; ledge former.	13′	13′
	Total thickness	258′	

Note: The measured section offsets to the south 500 feet to a better exposure of the Eureka Quartzite.

Eureka Quartzite

6	Quartzite: very light gray, weathers medium light gray; thick to medium bedded with faint banding $\frac{1}{4}$ inch wide; blocky to slabby with fracturing; iron stain present; fine grained; lenses of fragile sandstone, similar to unit 3, 15 and 17 feet from the base about 1 foot thick; gradational contact with underlying unit (from	22′	90′

	a ledge to a slope); weathers into rubble; ledge-slope former.		
5	Quartzite: very light gray, weathers medium light gray with grayish yellow to dusky yellow brown iron stain; thick bedded; slabby with fracturing; silt size; faint banding .2 to .4 inch wide; sharp contact with underlying unit (from a sandstone to a quartzite); weathers into rubble; ledge former.	10′	68′
4	Sandstone: saccharoidal; dark dusky brown; medium to thick bedded with banding .2 to .3 inch wide; slabby with fracturing; faint graded bedding; sharp contact with underlying unit (from a thin-bedded, fragile sandstone to a thick-bedded sandstone); weathers into rubble; ledge former.	12′	58′
3	Sandstone: fragile; light olive gray, weathers gray orange; thin bedded; slabby with fracturing; grains—equant, rounded, good sorting, fine grain size with dolomitic cement; iron stain present along fractures; sharp contact with underlying unit (from a dolomite to a fragile sandstone); weathers into small rubble with rock surfaces being pitted; slope former.	3′	46′
2	Dolomite: sandy; very light gray, weathers very light gray to medium light gray; thick to very thick bedded; blocky to slabby with fracturing and parting; grains—equant, rounded, good sorting, fine grain size with dolomitic cement; dusky brown bands of iron stain 6 inches and 2 feet wide, 1 and 13 feet from base respectively; sharp contact with underlying unit (from a quartzite to a dolomite); weathers into rubble; ledge former.	19′	43′
1	Quartzite: covered; sharp contact with Deadman Spring Dolomite (from a dolomite to a quartzite); weathers into rubble; slope former.	24′	24′
	Total thickness	90′	

Deadman Spring Dolomite

2	Dolomite: sandy; medium light gray, weathers moderate yellow brown to light gray with mottling in places toward top;	39′	167′

	medium bedding; slabby with fracturing and parting; grains—equant, round to subround, good sorting, silt to medium grain size with dolomitic cement; 1 percent dark brown stringers of chert along fractures; sharp contact with underlying unit (from a slope to ledge former); weathers into rubble with meringue weathering and rills; ledge former.		
1	Dolomite: mostly covered; medium light gray, weathers moderate yellow brown; thin bedded; slabby; gradational contact with Juab Limestone, partly covered; slope covered.	128′	128′
	Total thickness	167′	

C-Section

This section is located south of the Pony Express Pass, as shown in Text-figure 9. Complete sections of the Deadman Spring Dolomite, Kanosh Shale, Juab Limestone, Wah Wah Limestone, and the Fillmore Limestone are exposed here.

Deadman Spring Dolomite			
1	Dolomite: sandy; light reddish brown, weathers reddish brown; very fine to finely crystalline; medium to thick bedded; slabby with extensive fracturing; sharp contact with underlying Kanosh Shale (from a slope forming shale to a ledge forming dolomite); weathers into rubble; ledge former.	49′	49′
	Total thickness	49′	
Kanosh Shale			
1	Shale: dolomitic; light olive gray, weathers a moderate yellow brown; thin bedded; fine grained; dark brown coating in the lower 12 feet of the unit; sharp contact with underlying Juab Limestone (from a ledge-forming limestone to a slope-forming shale); weathers into rubble; slope former.	79′	79′
	Total thickness	79′	
Juab Limestone			
1	Limestone: dark gray, weathers medium dark gray; very finely crystalline; thick to to very thick bedded; block to massive with some slabs with fracturing; brachiopods, trilobite fragments, crinoid stems, and high spiraled gastropods; very little	70′	70′

	chert; sharp contact with underlying Wah Wah Limestone (from a thick to a very thick bedded limestone); weathers into rubble with rills and meringue weathering; ledge former.		
	Total thickness	70′	
Wah Wah Limestone			
8	Limestone: brachiopods 5 feet from base; similar to unit 2.	20′	110′
7	Limestone: 20-25 percent chert nodules and stringers 2 to 3 inches thick; similar to unit 3.	25′	90′
6	Limestone: similar to unit 2.	15′	65′
5	Limestone: 20 percent chert; similar to unit 3.	5′	50′
4	Limestone with interbedded interformational conglomerates: medium dark gray, weathers medium light gray; thin bedded; slabby with fracturing and parting; trilobite fragments and crinoid stems; 10 percent brown nodules and stringers of chert; few veins of calcite about .05 inch thick; ripple marks 8 feet from base; sharp contact with underlying unit (from a ledge to slope former); weathers into rubble with meringue weathering; slope former.	15′	45′
3	Limestone with interbedded siltstones 10 and 12 feet from the base: medium dark gray, weathers medium light gray; thick to very thick bedded; slabby with fracturing and parting; crinoid stems; very fine crystalline; 10 percent dark brown nodules and stringers of chert about 2 to 2½ inches thick; sharp contact with underlying unit (from a slope to a ledge former); weathers into rubble with small cavities; meringue weathering; ledge former.	15′	30′
2	Limestone: medium dark gray weathers medium light gray; thin bedded; slabby with parting; trilobite fragments and gastropods; very fine crystalline; less than 1 percent nodules of chert at base; sharp contact with underlying unit (from a ledge to a slope); weathers into rubble; slope former.	10′	15′
1	Limestone: medium dark gray, weathers medium light gray; medium to thick bed-	5′	5′

	ded; slabby with fracturing and parting; calathium; very fine crystalline: ripple marks at base; few vugs of calcite; gradational contact with underlying Fillmore Limestone (from a slope to a ledge former); weathers into rubble with meringue weathering; ledge former.		
	Total thickness	110′	
Fillmore Limestone			
6	Intraformational conglomerate: medium light gray, weathers medium gray; coarsely crystalline; thin to medium bedded; slabby with fracturing; crinoid stems found 20 feet from base; Calathium present; no chert; stringers and vugs of calcite; gradational contact with underlying unit; weathers into rubble; ledge-slope former.	130′	748′
5	Intraformational conglomerate: light medium gray, weathers light gray; medium to thin bedded; 3 percent dark brown chert nodules with 10 percent 75 feet from base and about 20 percent 115 feet from base about 8 inches thick; ledge-slope former, more ledgely; this unit similar to unit 1.	125′	618′
4	Intraformational conglomerate: medium light gray, weathers light gray; Calathium and gastropod fragments found 75 feet from base; upper 150 feet mostly slope; 1-2 percent dark brown chert nodules; cross ripple marks found 70 feet from base; this unit similar to unit 1.	272′	493′
3	Limestone: medium gray, weathers to medium light gray; coarsely crystalline; saccharoidal; very thin to thin bedded; slabby with parting; stringers and nodules of dark brown chert along bedding plane about 3-5 percent; sharp contact with underlying unit (based on lithologic change); weathers into rubble with meringue weathering; ledge former, low ledges.	23′	221′
2	Intraformational conglomerate with interbedded shale: cross ripple marks 109 feet from base; stringers of calcite; ledge-slope former; this unit is similar to unit 1.	124′	198′
1	Intraformational conglomerate: dark gray, weathers dark greenish gray with reddish	74′	74′

brown stain around pebbles; very thin to thin bedded; slabby with fracturing; pebbles—equant to elongated, round to subrounded, poorly sorted, composed of micrite, pebble in size; sharp contact with underlying House Limestone (based on lithologic change); weathers into rubble with meringue weathering on pebbles; mostly covered with low outcrops; slope former.

Total thickness 748′

D-Section

This section is located on the east side of the Fish Springs Range north of the Pony Express Trail, as shown in Text-figure 8. A complete section of the House Limestone is exposed here.

House Limestone

3	Limestone: light gray, weathers medium light gray; thick bedded; slabby with fracturing and parting; few crinoid stems;	75′	155′

FLOW CHART FOR PREPARATION OF ROCK AND SOIL SAMPLES

Crush sample to powder

↓

Place 5 gms of sample in 250 ml beaker

↓

Add 25 ml of aqua regia

↓

Heat to almost dryness

↓

Dissolve residue in 50-75 ml of 2m HCL

↓

Centrifuge liquid

↙ Discard residue

↘ Bring filtrate up to 250 ml with 2m HCL and place in properly marked bottles

TEXT-FIGURE 8.— Flow chart for the preparation of the rock samples.

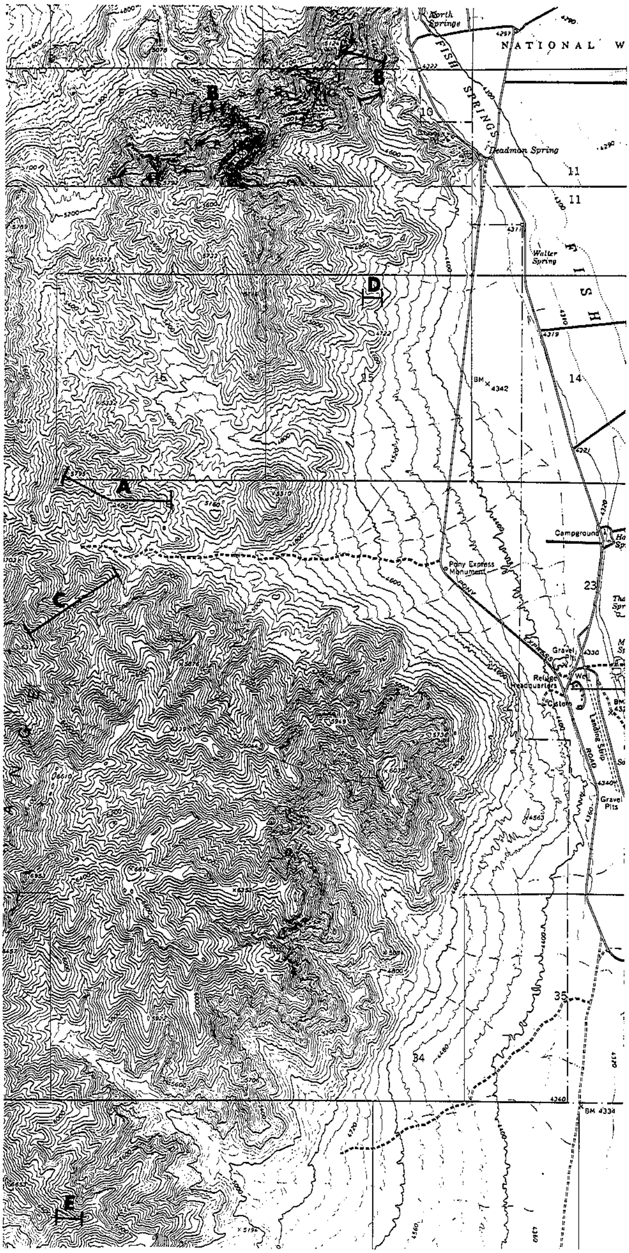
	less than 1 percent dark brown stringers of chert $\frac{1}{4}$ inch thick and 3 inches long; vugs and stringers of calcite about $\frac{1}{8}$ to $\frac{1}{4}$ inch thick; gradational contact with underlying unit (from a slope to a ledge former); weathers into rubble with the rock surface pitted with meringue weathering; ledge former.		
2	Limestone: medium light gray, weathers medium gray; medium bedded; slabby with fracturing and parting; very fine crystalline; saccharoidal; 40 feet from base a 1-foot-thick bed interformational conglomerate: stringers of calcite about $\frac{1}{8}$ to $\frac{1}{4}$ inch thick; gradational contact with underlying unit (from a slope to a ledge former); weathers into rubble with slight meringue weathering; ledge-slope former.	46′	80′
1	Limestone: mostly covered with low outcrops; medium light gray, weathers medium gray; medium bedded; slabby; contact with underlying Notch Peak Formation gradational (from a dolomite to a limestone); weathers into rubble; slope former.	34′	34′
	Total thickness	155′	

E-Section

This section is located about 3 miles southwest of the Fish Springs National Wildlife Refuge Headquarters, as shown in Text-figure 9. A complete section of the Kanosh Shale is exposed here.

Kanosh Shale

7	Shale: mostly covered; similar to unit 1.	15′	130′
6	Interformational conglomerate: mostly covered; similar to unit 2.	10′	115′
5	Shale: covered; similar to unit 1.	40′	105′
4	Interformational conglomerate: covered; similar to unit 2.	5′	65′
3	Shale: covered; similar to unit 1.	5′	60′
2	Interformational conglomerate: mostly covered; pale reddish brown, weathers a moderate yellow brown; thin bedded; coarsely crystalline; crinoid stems and brachiopod fragments; contact with underlying unit covered; slope former.	25′	55′
1	Shale: slightly calcareous; pale reddish brown, weathers moderate yellow brown;	30′	30′



TEXT-FIGURE 9.— A portion of the Fish Springs NW and SW 1:24,000 topographic maps showing locations of measured sections A, B, C, D, and E.

thin bedded; slabby to flaggy with fracturing and parting; gastropod and trilobite fragments 15 feet from the base; brachiopods fragments 25 feet from base; very fine crystalline; reddish brown iron present in bedding plane; contact with underlying Juab Limestone (from a limestone to a shale); weathers into rubble with the soil having a reddish color; rock surfaces pitted; low outcrops; slope former.

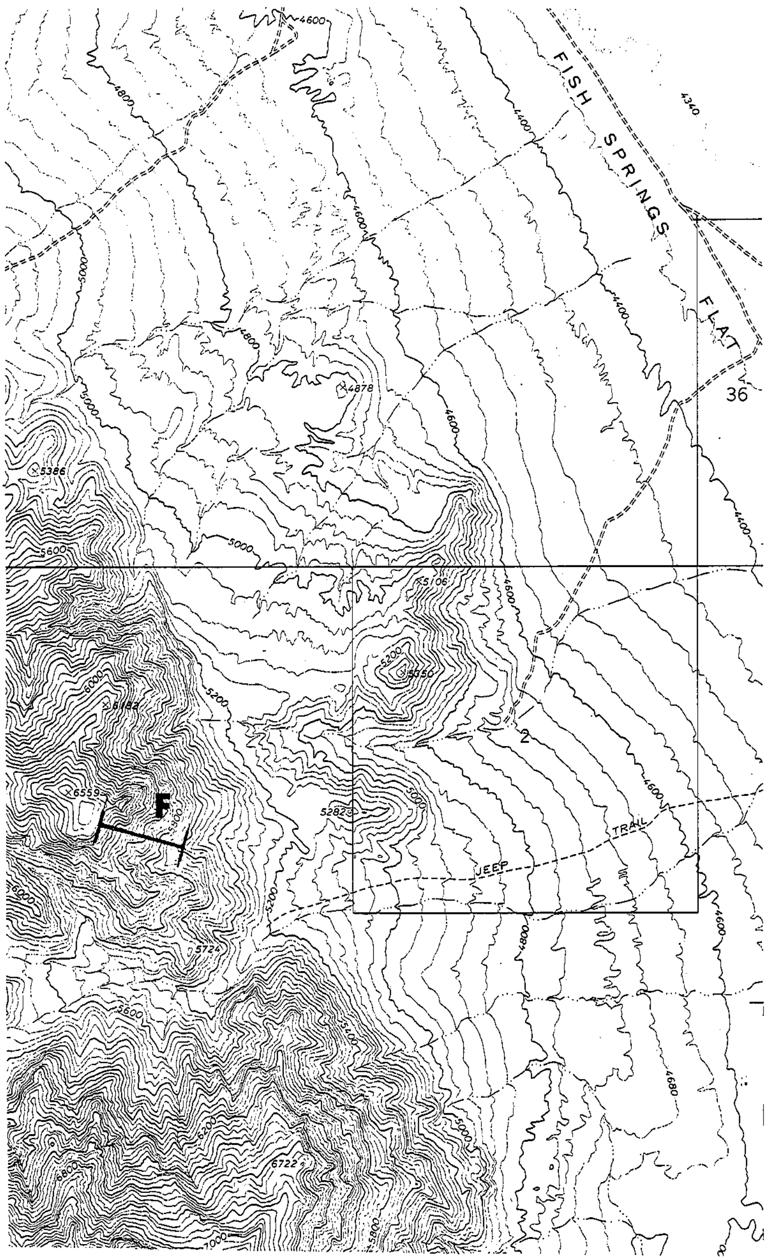
Total thickness 130′

F-Section

This section is located in the southern part of the Fish Springs Range, as shown in Text-figure 10. A complete section of the Notch Peak Formation is exposed here. The section was measured by Dr. L. F. Hintze, LaRell Nielson, and Richard Schafer during BYU Geology Summer Field Camp 1974.

Notch Peak Formation

10	Dolomite: light gray, weathers light olive gray; fine crystalline; thick to very thick bedded; intricate splitting; mottling and meringue weathering; weathers into rubble; sharp contact with underlying unit (from a dark to a light colored dolomite); ledge former.	41′	961′
9	Dolomite: light gray, weathers medium gray; fine crystalline; thick bedded; moderately fractured parallel and perpendicular to the bedding; mottling and little meringue weathering; dark brown chert at 845 feet; intricate fracturing near top; sharp contact with underlying unit; ledge former.	94′	920′
8	Limestone: very light gray, weathers light gray; very fine crystalline; thin bedded; slabby weathered features; sharp contact with underlying unit (from a limestone to a dolomite); ledge former.	3′	826′
7	Dolomite: medium to light gray, weathers olive brown; very fine crystalline; massive bedded; fractures along bedding; rock weathers to large angular blocks; abundant calcite stringers near top; gradational contact with underlying unit; ledge former.	53′	823′
6	Dolomite: medium gray, weathers light olive gray; fine crystalline; massive bed-	107′	770′



TEXT-FIGURE 10.— A portion of the Sand Pass NW 1:24,000 topographic map showing location of measured section F.

	ded; highly fractured; splitting; weathers into angular blocks; grainy texture; few calcite vugs; sharp contact with underlying unit (based on color); ledge former.		
5	Dolomite: medium dark gray, weathers a brownish gray; fine crystalline; medium bedded; moderately fractured with parting; pisoliths; sharp contact with underlying unit (based on presence of pisoliths); ledge former.	28′	663′
4	Dolomite: medium light gray, weathers olive gray; very fine crystalline; thick bedded; moderately fractured and minor splitting; weathers into angular blocks; 20 percent chert stringers and nodules 85 and 200 feet from the base; banding; calcite stringers and veins 55 feet from the base; sharp contact with underlying unit (based on coarseness of grains and presence of chert); ledge former.	250′	635′
3	Dolomite: light gray, weathers light olive gray; coarsely crystalline; thick bedded; moderately fractured; weathers into angular slabs; ledge former.	25′	385′
2	Dolomite: dark gray, weathers brownish gray; fine crystalline; thick bedded; fractured perpendicular to bedding plane; weathers into angular blocks; *Matthevia* sp.; gradational contact with underlying unit (based on change in color); ledge former.	20′	360′
1	Dolomite: silty; medium gray, weathers dark medium gray; fine crystalline; thick bedded; forms jagged knobs; weathers into small rubble; cross-bedding laminations 100 feet from base, with it seen in bands; 80 feet from base large chert nodules and stringers ranging from 2 to 4 mm in thickness; 140 feet from base calcite stringers and veins; ledge former.	340′	340′
	Total thickness	961′	

TABLE 1

CONCENTRATION (PPM) OF LEAD, SILVER, ZINC AND COPPER IN SAMPLES TAKEN AT STUDY SITE.

Sample Number	Pb	Ag	Zn	Cu
PE1-A	0	0	.02	0
PE1-B	0	0	.29	.040
PE1-C	0	0	.56	.050

PE1-D	0	0	.26	.010
PE1-E	0	0	0	.008
PE2-A	0	0	.59	.080
PE2-B	2.52	.005	24.28	.090
PE2-C	0	0	.16	.075
PE2-D	0	0	.28	.030
PE2-E	0	0	.33	.001
PE3-A	.11	.008	5.98	.050
PE3-B	1.10	0	1.26	.020
PE3-C	.47	.005	8.67	.180
PE3-D	0	.010	.30	.040
PE3-E	0	0	.18	.025
TD3-A	.30	.010	.29	.070
TD3-B	.70	.011	.27	.055
TD3-C	.60	0	.13	.06
TD3-D	.50	0	.13	.067
TD4-A	.70	0	.07	.030
TD4-B	.90	.020	.17	.090
TD4-C	0	0	1.06	.370
TD4-D	0	0	0	.020
TD5-A	0	0	.93	.160
TD5-B	0	0	.03	0
TD5-C	.51	0	.06	.030
TD5-D	.71	0	.15	.240
TD5-E	0	0	.13	.051
TD5-F	0	0	.08	.028
LC1-A	5.21	0	2.42	.070
LC1-B	419.00	2.77	123.00	1.280
LC1-C	25.10	.510	.72	.080
LC1-D	2.79	0	.79	.06
LC1-E	8.11	0	1.51	.080
LC1-F	6.56	.010	.45	.120
LC2-A	2.55	.023	.43	.059
LC2-B	4.20	2.84	.19	.07
LC2-C	2.00	0	.23	0
FZ-A	0	0	1.78	6.67
FZ-B	0	0	.97	.680
FZ-C	0	0	.15	.055

REFERENCES CITED

Armstrong, R. L., 1968, Sevier orogenic belt in Nevada and Utah: Geol. Soc. Amer. Bull., v. 79, p. 429-58.

Butler, B. S., 1920, Ore deposits of Utah: U.S. Geol. Surv., Prof. Paper 111, p. 465.

Buranek, A. M., and Crawford, A. L., 1942, Report of the magnesite deposits of the Silver Shield Mining and Milling Company, Juab County, Utah: Utah Dept. of Pub. Ind. Dev. Circ. 14.

Crawford, A. L., 1941, Magnesite: A new economic mineral for Utah: Utah Acad. Sci. Proc. 18, p. 18.

Erickson, M. P., 1963, Volcanic geology of western Juab County, Utah: Utah Geol. Soc. Guidebook, no. 17, p. 23-35.

Gilbert, G. K., 1928, Studies of basin and range structures: U.S. Geol. Surv. Prof. Paper 153, p. 70.

Hintze, L. F., 1951, Lower Ordovician detailed stratigraphic section for western Utah: Utah Geol. Min. Surv. Bull. 39, p. 98.

———, 1973, Geologic history of Utah: Brigham Young Univ. Geol. Studies, v. 20, pt. 3, p. 181.

Kepper, J. C., 1960, Stratigraphic and structure of the southern half of the Fish Springs Range, Juab County, Utah: Unpublished M.S. thesis, Univ. Wash., Seattle.

Leedom, S. H., 1974, Little Drum Mountains, an Early Tertiary shoshonitic volcanic center in Millard County, Utah: Brigham Young Univ. Geol. Studies, v. 21, pt. 1, p. 73-108.

Meinzer, O. E., 1911, Groundwater in Juab, Millard, and Iron counties, Utah: U.S. Geol. Surv. Water Supply Paper 277, p. 124.
Miller, J. F., 1969, Conodont fauna of the Notch Peak Limestone (Cambro-Ordovician), House Range, Utah: Jour. Paleont. v. 43, no. 2, p. 413-39.
Nolan, T. B., 1935, The Gold Hill mining district, Utah: U.S. Geol. Surv. Prof. Paper 177, 172 p.
Osmond, J. C., 1962, Stratigraphy of Devonian Sevy Dolomite in Utah and Nevada: Amer. Assoc. Petrol. Geol. Bull., v. 38, no. 9, p. 1911-56.
Pierce, C. R., 1974, Geology of the southern part of the Little Drum Mountains, Utah: Brigham Young Univ. Geol. Studies, v. 21, pt. 1, p. 109-30.
Staatz, M. H., and Carr, W. J., 1964, Geology and mineral deposits of the Thomas and Dugway ranges, Juab and Tooele counties, Utah: U.S. Geol. Surv. Prof. Paper 415, 188 p.
———, and Osterwald, F. W., 1959, Geology of the Thomas Range Fluorspar District, Juab County, Utah: U.S. Geol. Surv. Bull., v. 1069, p. 97.
Stokes, W. L., 1962, Geologic map of Utah, 1:250,000, northwest quarter: Utah State Geol. Min. Surv. separate maps.