5-1973

# Petrography and Geochemistry of the Fish Haven Formation and Lower Part of the Laketown Formation, Bear River Range, Utah

Brent H. Mecham
*Utah State University*

# PETROGRAPHY AND GEOCHEMISTRY OF THE FISH HAVEN FORMATION AND LOWER PART OF THE LAKETOWN FORMATION, BEAR RIVER RANGE, UTAH

by

Brent H. Mecham

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

of

MASTER OF SCIENCE

in

Geology

Approved:

UTAH STATE UNIVERSITY
Logan, Utah

1973

## ACKNOWLEDGMENTS

Sincerest thanks are extended to Dr. Raymond L. Kerns, Jr., for his help and advice in outlining and directing the thesis. His criticisms and encouragement were most helpful in completion of the thesis.

Other faculty members who offered advice and criticism throughout the project were Dr. Richard R. Alexander, Dr. Clyde T. Hardy, Dr. Robert Q. Oaks, Jr., Dr. Donald R. Olsen, and Dr. Joseph C. Street. Their help and advice was appreciated.

Thanks are extended to Mrs. Gloria Kerns and Mrs. Dora Mecham for their help in typing the manuscript.

Thanks are also extended to Gulf Oil Corporation for their financial assistance during the summer of 1972.

Brent H. Mecham

# TABLE OF CONTENTS

# LIST OF TABLES

# LIST OF FIGURES

## ABSTRACT

Petrography and Geochemistry of the Fish Haven Formation
and Lower Part of the Laketown Formation,
Bear River Range, Utah

by

Brent H. Mecham, Master of Science

Utah State University, 1973

Major Professor: Dr. Raymond L. Kerns, Jr.
Department: Geology

Near Logan, Utah, the Fish Haven Formation is a thick-bedded, dark-gray dolostone. The Laketown Formation, which rests on the Fish Haven, is a less resistant, medium-gray dolostone. The Ordovician-Silurian boundary has been placed locally at the top of the Fish Haven by stratigraphers, and in the lower Laketown Formation by paleontologists.

Four sections of the Fish Haven and Laketown dolostones were measured near Logan, Utah. The samples from these four sections were examined using petrography, insoluble residue analyses, x-ray diffraction, quantitative and qualitative x-ray fluorescence spectroscopy, and statistical analysis.

Petrography appears to be the best lab technique for distinguishing the two dolostones. This technique shows the grain size decreases in going from the Fish Haven Formation to the Laketown Formation. This decrease in grain size is also seen in the field.

All other laboratory techniques show that the two dolostones are very similar and cannot, in general, be distinguished. To summarize, the percent insoluble residue and the percent of quartz and illite found in each formation are independent of formational boundaries. X-ray diffraction, X-ray fluorescence spectroscopy, and statistical analysis all show that the two formations are geochemically similar.

A comparison of dolostones shows that they may, in general, be divided into two categories of pure and impure. The $Fe_2O_3$ content of pure dolostones may be less than the $Fe_2O_3$ content of impure dolostones. Other than the change in $Fe_2O_3$ content dolostones tend to be the same geochemically. This suggests that the process of dolomitization tends to obliterate any differences which may have originally existed and make all dolostones essentially uniform in composition.

(73 pages)

# INTRODUCTION

## Purpose

This study deals with the geochemistry and petrography of the Fish Haven Formation and lower part of the Laketown Formation near Logan, Utah. The rocks studied include the Fish Haven and Budge's (1966, p. 18-27) lower members (A and B) of the Laketown. Locally the Ordovician-Silurian boundary has been placed at the Fish Haven-Laketown contact; but several authors (Beus, 1963; Budge, 1966; Budge and Sheehan, 1969) have found fauna in the lower Laketown which are upper Ordovician in age, implying that the Ordovician-Silurian boundary probably should be placed at the top of Budge's Member A in the Laketown, rather than at the Fish Haven-Laketown contact. The purpose of this study was to investigate these two dolostones to see if they can be distinguished geochemically, or if they can be defined only on lithologic characteristics. Analytical techniques include petrography, x-ray diffractometry, x-ray fluorescence spectroscopy, insoluble residue analyses, and a statistical treatment of the x-ray fluorescence data to test for variance.

## Previous Work

The Fish Haven Formation is time-correlative with several other formations in the western United States. In central Nevada the correlative formation is the Hanson Creek Formation. This formation grades from cherty beds of limestone and dark-gray siltstone in the Toquima Range, (McKee and Ross, 1969, p. 423), to a dark-gray dolostone, thick-bedded at the base and grading to thinner beds at the top near Carlin, Nevada (Roberts, 1958, p. 2830). The Fish Haven is correlative with the Ely Springs Formation in eastern Nevada (Ross, 1964, p. 1531). To the north, in central Idaho, the Fish Haven is correlative with the Saturday Mountain Formation, a shaly dolostone containing pebbles of quartzite and black carbonaceous material (Ross, 1937, p. 19). The correlative formation to the northeast is the Bighorn Dolomite. This formation is found in northwestern Wyoming and southern Montana. As first described by Darton (1904, p. 395), the Bighorn consists of three units: a basal sandstone, a cliff-forming dolostone, and a thin-bedded dolostone grading into a dolomitic limestone at the top.

The Laketown Formation and its correlative formations have a smaller regional extent than do the Fish Haven and its correlative formations due to an erosional surface between the Silurian and the Middle Devonian (Gibbs, 1972, p. 86). The Laketown Formation is found in central Idaho (Ross, 1934, p. 957), northern Utah (Budge, 1966, p. 14), and east-central Nevada (Osmond, 1954, p. 1919). In the Tintic District, central Utah, the formation is correlated with the lower part of the Bluebell Formation (Morris and Lovering, 1961). This is a blue-gray, well-bedded dolostone containing sparse fossils and chert. To the west, in central Nevada, the correlative unit is the Lone Mountain Limestone. This formation is a well-bedded, dark-gray limestone. The upper 220 feet has been dolomitized (Merriam, 1940, p. 12).

Richardson (1913, p. 410) first named the Fish Haven Formation from exposures in Fish Haven Canyon in southeastern Idaho. The Fish Haven was reported as "about 500 feet" thick (1913, p. 407-410). Later reports indicated, however, that the type locality of the Fish Haven is faulted

(Beus, 1963, p. 20; Allan Keller, personal communication), thus the true thickness at this location is unknown.

Williams (1948, p. 1137-1138) reported that the Fish Haven Formation is "about 140 feet thick" in Green Canyon, near Logan, Utah, and rests unconformably on the Swan Peak Formation. Although Williams found no angular unconformity, the changing lithology and thickness of the Swan Peak, when compared to the uniform lithology and thickness of the Fish Haven, were taken as an indication of a hiatus.

The Laketown Formation was named by Richardson (1913, p. 407, 410) from exposures in Laketown Canyon in the Randolph quadrangle. Williams (1948, p. 1138) found the Laketown Formation to be 1150 feet thick in Green Canyon near Logan, Utah. Dolomitization is complete. Corals are the only fossils reported by Williams which have not been completely obliterated by diagenesis. Beus (1963, p. 21), while studying the Laketown Formation in the Blue Springs Hills, identified an Ordovician form of *Streptelasma* near the base of this dolostone. The entire formation had previously been considered Silurian in age.

Budge (1966), in studying the Laketown Formation between Bear Lake and Logan, Utah, divided the formation into four members. The present study is concerned with the Fish Haven Formation and Budge's two lower members of the Laketown. The lowest member, Member A, consists of an interbedded light and dark-gray, fine-crystalline dolostone with "an average thickness of 300 feet". From the fauna found in this member, Budge believed it to be Late Ordovician in age. The second member, Member B, is a medium light-gray to grayish-black, fine-crystalline dolostone. Faunal evidence indicates that this is Silurian in age.

Budge and Sheehan (1969, p. 490) later identified *Bighornia, Paleophyllum, Streptelasma, Lichenaria,* and *Foerstephyllum* faunal assemblages in Budge's Member A as Late Ordovician. A *Virgiana* faunal assemblage was identified in Member B as middle Llandoverian in age, giving further evidence that the Ordovician-Silurian boundary, locally, should probably be placed between Budge's Member A and Member B.

Gibbs (1960), working in central Idaho found the Fish Haven Formation to have a maximum thickness of 1150 feet at Bear Canyon. The fauna from the Fish Haven identified in this area are apparently Upper Ordovician in age, whereas the fauna collected in the Laketown are probably Middle Silurian (Gibbs, 1960, p. 33; E. C. Stumm, personal communication), thus the Ordovician-Silurian boundary in central Idaho is at the top of the Fish Haven.

To summarize, northward from Logan, Utah, into Idaho, the Fish Haven Formation thickens from 140 feet to 1150 feet; whereas the Ordovician-Silurian boundary, 300 feet up in the Laketown at Logan, seems to move downward to the Fish-Haven-Laketown contact in central Idaho.

# METHODS AND MATERIALS

## Sample Collection

### Location

Four sections of the Fish Haven and lower Laketown Formations were measured near Logan, Utah. The four sections measured are in Smithfield Canyon, Green Canyon, Logan Canyon, and Blacksmith Fork Canyon. The location of each section is shown in Figure 1. All four sections are very similar in lithologic characteristics and contain units which can be easily correlated. A diagrammatic representation of the lithology of the two dolostones is shown in Figure 2. This diagram is derived from data from the Logan Canyon Section. All other sections are essentially the same with thicknesses and marker beds in each section occurring within 20 feet of their equivalent counterparts in other sections.

### Procedure

Each section was measured using a Brunton compass and a Jacob's Staff. Where possible, samples were collected at approximately 20 foot intervals. Dip slopes or covered units were collected where outcrops exist. Large enough samples were collected for thin sectioning, insoluble residue and x-ray analyses. In most instances 250 grams was sufficient.

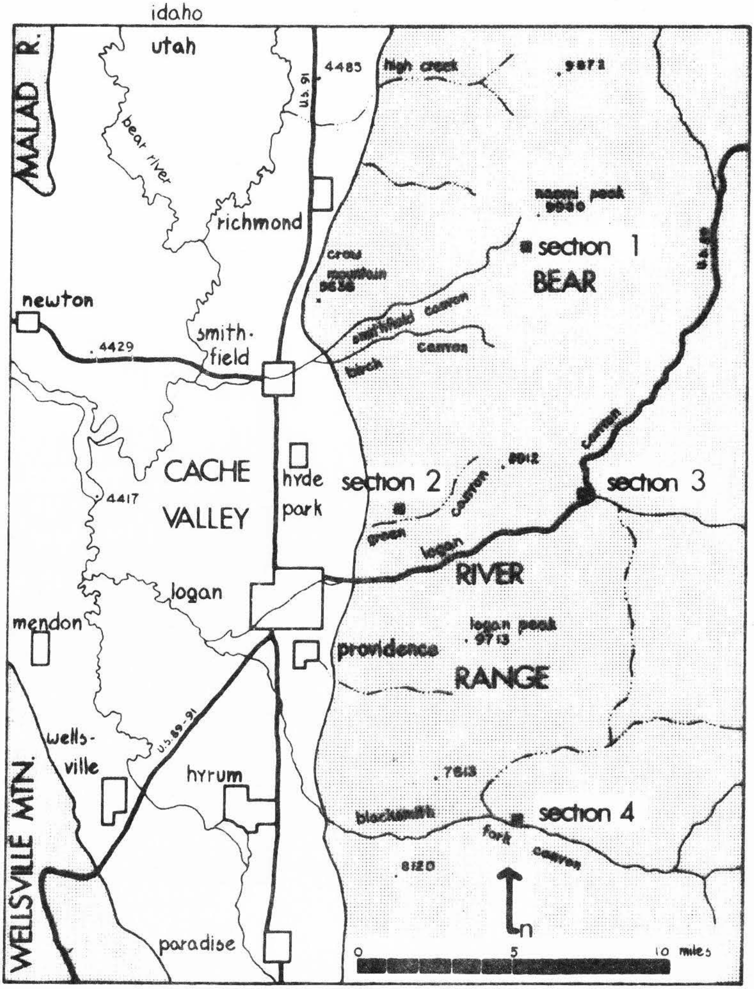


Figure 1. Index map of central part of northern Utah showing location of the four sections measured.

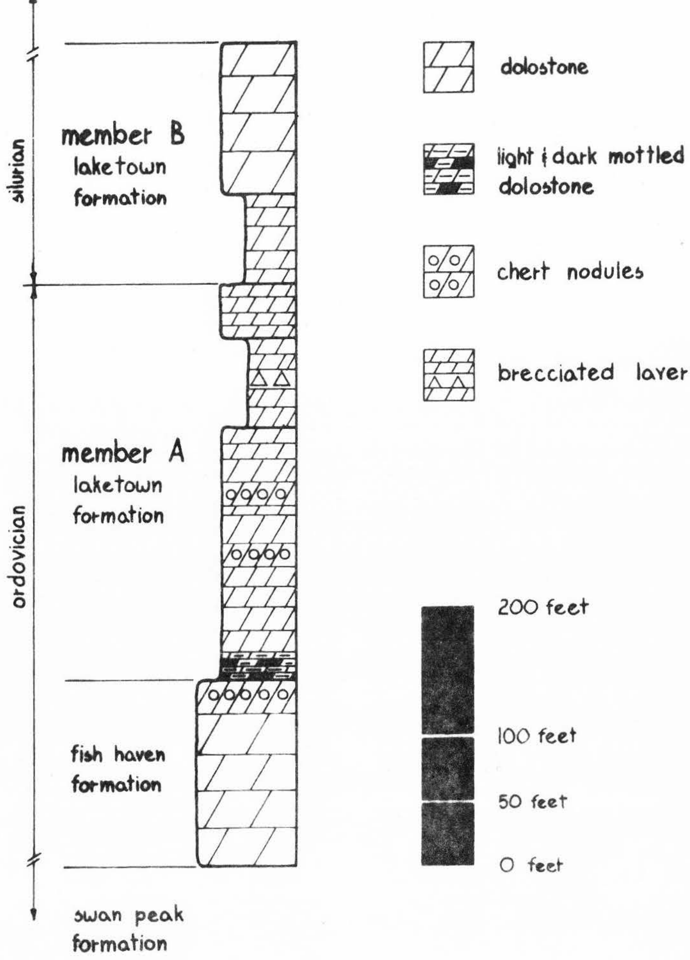


Figure 2. Diagrammatic representation showing the relationship between the Fish Haven and Laketown Formations.

## Petrography

### Sample preparation

Thin sections were prepared from the collected samples. Samples of rock were cut and polished, placed on a frosted microscope slide with epoxy, and left overnight for the epoxy resin to set. After setting, the thin sections were ground to a thickness of 0.03 millimeter.

Because dolomite and calcite are often hard to distinguish in thin sections, each thin section was stained according to a procedure described by Warne (1962, p. 34-35). Each slide was etched in a dilute solution of 9 percent HCl for approximately two minutes. The slide was then placed in a solution of Alizarin Red-S for a period of three minutes. The dolomite remains essentially unstained, and the calcite is stained a deep red.

The final step in thin-section preparation was to cement a cover glass on each thin section.

### Equipment

A Zeiss petrographic microscope (model R-POL), fitted with a 8X ocular and 2.5, 10, and 40X objectives, was used for the petrographic examination of thin sections. The microscope was fitted with a light source adjustable to five intensities.

### Procedure

Thirty-three thin sections were examined. Samples were taken from both the Fish Haven and the Laketown Formations and examined for detrital material, ghost structures, clues to diagenesis, and opaque materials.

## X-ray Diffractometry

### Sample preparation

In the laboratory 50 grams of each sample were ground according to the following procedure: Each 50 gram sample was initially crushed with a cast-iron mortar and pestle to pass through a 60-mesh sieve. Iron filings derived from the cast-iron mortar and pestle were removed with a magnet. Any sample that could now pass through a 115-mesh sieve was placed in a sample container and labeled, while the remaining sample was placed in a mechanically operated mortar and pestle. As the sample was ground fine enough to pass through a 115-mesh sieve, it was also placed in the sample container. This process was repeated until all the sample could be passed through the 115-mesh sieve. Each container was then shaken for five minutes to homogenize the sample.

### Equipment

X-ray diffraction analyses were obtained with a Siemens Crystalloflex IV generator, diffractometer, and recording panel. The diffractometer was equipped with a 750-watt, copper-target, x-ray generating tube. The goniometer, which holds a flat slide, was rotated at a standard rate of 2 degrees 2θ per minute. A collimating slit of 1 millimeter and a receiving slit of 0.2 millimeter were used. A nickel filter was used to selectively eliminate the copper $K_\beta$ radiation, thereby enhancing the monochromatic copper $K_\alpha$ radiation. Diffraction peaks were recorded on a motor-driven chart.

Procedure

Each sample was examined by x-ray diffractometry. A thin film of vaseline was placed on a glass slide. The powdered sample was then passed through a sieve to the vaseline-covered slide, thus helping to obtain a random orientation of the powder on the slide. A beam of monochromatic x-rays was next passed across the sample with the resulting diffraction peaks being detected and recorded. Each sample was rotated in the beam into a position so that the x-rays diffracted from various parallel crystal planes reinforced each other. The distance between crystal planes could then be determined by using Bragg's equation:

$$\lambda = 2d \sin \theta. \quad (1)$$

where $\lambda$ is the wavelength of the monochromatic radiation, $\theta$ is the Bragg angle of diffraction, and d is the distance between crystal planes (Nuffield, 1966, p. 58). By knowing the relative intensities of each peak and the corresponding distance between crystal planes, in angstrom units, the x-ray patterns of each sample can then be identified through the use of A. S. T. M. data cards.

Because dolostones may contain minerals other than dolomite, x-ray patterns often contain peaks due to more than one mineral. To determine the minerals present, a comparison between x-ray patterns of different minerals was made. Figure 3 shows patterns of pure calcite, quartz, and dolomite. When two or more of these minerals are found in the same sample, peak intensities due to each mineral are recorded. The peak intensities depend upon: (1) degree of crystallization, (2) random grain orientation, and (3) the percentage of the sample that particular mineral represents. Assuming that conditions (1) and (2) have little or no


Figure 3. X-ray diffractograms of (A) dolomite, (B) calcite, and (C) quartz.

effect, the relative intensities of the major peaks of the various minerals may be used to determine their relative abundances.

### Insoluble residue

A comparison was made between the insoluble residues of the Fish Haven and Laketown dolostones. Approximately 100 grams of dolostone from various samples in the Fish Haven and Laketown Formations were dissolved in a solution containing 38 percent HCl. After the HCl had time to react with the dolostone, the solution was decanted and the insoluble residue washed with distilled water. The residue was then dried and weighed. From this the percent of insoluble residue was calculated. An x-ray diffractogram of each sample was run to determine the mineral composition of the clay-size particles and silicates that exist in the dolostones. Each pattern was run from 3 to 50 degrees 2θ.

## X-ray Fluorescence Spectroscopy

### Sample preparation

Briquettes of each powdered sample were prepared for x-ray fluorescence spectroscopy according to the following procedures: One gram of polyvinyl alcohol was used as a cementing agent in each briquette. To this, nine grams of the previously powdered sample were added. Each sample was then homogenized by shaking for five minutes. Each homogenized sample was then placed in a die and pressed with 20 tons pressure. Under pressure, the polyvinyl alcohol becomes fluid. As the pressure is removed, the polyvinyl alcohol solidifies and cements the powdered dolomite into a briquette.

Before samples could be analyzed quantitatively for iron and strontium, standards had to be made containing known percentages of each element. They were prepared according to the following procedure: The bulk of each standard had to be prepared so as to have approximately the same chemical composition as dolomite. This was done by thoroughly mixing 80 percent $CaCO_3$ with 20 percent MgO. Iron standards of 0.25, 0.50, 1, and 2.5 percent were prepared by mixing 0.025, 0.05, and 0.1 and 0.25 grams of $Fe_2O_3$ with 9.975, 9.95, 9.9, and 9.75 grams of bulk sample, respectively. Each standard was homogenized for half an hour to make sure each was uniform throughout. Nine grams from each standard were then added to one gram of polyvinyl alcohol, homogenized, and formed into a briquette according to the procedure previously described. Strontium standards containing 0.1, 0.5, and 1 percent $Sr(NO_3)_2$ were prepared by mixing 0.01, 0.05, and 0.1 grams of $Sr(NO_2)_3$ with 9.99, 9.95, and 9.9 grams of bulk sample, respectively. Thus, the 0.1, 0.5, and 1 percent standards contain 0.0486, 0.243, and 0.486 percent SrO, respectively.

## Equipment

X-ray fluorescence spectroscopy was completed using the same Siemens Crystalloflex IV generator and recording panel used for x-ray diffraction. A different diffractometer, however, was used. The diffractometer was equipped with a 2,600-watt chromium-target, x-ray generating tube. The goniometer, which holds a briquette, was rotated at a standard rate of 1 degree $2\theta$ per minute. An analyzing crystal of lithium fluoride was used.

## Procedure

Each briquette was examined in two ways on the x-ray fluorescence unit: (1) scans were run to identify what elements are present in each sample, and (2) each sample was examined quantitatively for iron and strontium.

In x-ray fluorescence scans the sample is placed in the beam of x-rays. Elements, when excited by this x-ray beam, give off energy characteristic of that particular element. Therefore, as the spectrometer is rotated, energy derived from different elements is detected by a scintillation counter at angles corresponding to wavelengths of the characteristic spectra.

In order to examine the spectrum for all elements which could possibly be detected, the scintillation counter was rotated from 15 to 80 degrees $2\theta$.

For quantitative analysis the iron peak was first located at 57.645 degrees. Two minute readings in counts per minute were taken to obtain the peak intensities. A one minute background count was taken on each side of each peak and added together to give a two minute background count. This background count was subtracted from the peak to obtain the counts per minute due to iron. At the beginning of each day of analysis, the blank and all four iron standards were run, measuring the peak and background intensities. Next, four samples were run followed by a standard and four more samples. This procedure was followed throughout the day. At the end of each day the blank and all four standards were run again to make sure the power supplied to the x-ray machine had not varied throughout the day. Once the known standards had been run they could be plotted on a graph of counts per minute *versus* percent iron. From this graph, the percent iron in each sample was interpolated. This same procedure was repeated for strontium.

Statistical analysis

An analysis of variance was applied to quantitative data by using a standard F-test (Freund, 1965, p. 289-293). By using an F-test it is possible to measure variance among three or more groups. The general theory of an F-test is as follows: Each section is divided into three or more groups. The mean of each group is then calculated to test whether the discrepancies among these means are significant or whether they may be attributed to chance. By letting $\mu_1$, $\mu_2$, and $\mu_3$ represent the averages of each group, the hypothesis

$$\text{Null hypothesis: } \mu_1 = \mu_2 = \mu_3. \qquad (2)$$

is tested by applying the following formula:

$$F = \frac{kn(n-1) \cdot \sum_{j=1} (\bar{x}_j - \bar{x})^2}{(k-1) \cdot \sum_{i=1}^{k} \sum_{j=1}^{k} (x_{ij} - \bar{x}_j)^2} \qquad (3)$$

where k equals the number of groups, n equals the number of observations of each group, $\bar{x}$ equals the overall mean, $\bar{x}_j$ equals the mean of groups j, and $x_{ij}$ stands for the $i^{th}$ observation of the $j^{th}$ group. The calculated F is next compared with an F which is dependent upon degrees of freedom of the sampling. The latter F is found in tables at proficiency levels of 95 and 99 percent. If F calculated $>$ F found in the table, the null hypothesis is rejected, and if F calculated $\leq$ F found in the table, then the null hypothesis is accepted that there is no significant variance among the groups selected.

An F-test was applied to quantitative data by dividing each section into four groups. Each section was divided at a point where a change in SrO or $Fe_2O_3$ may exist. The first group included from the base to the top of the Fish Haven Formation. The top of the second group was placed about half-way up Budge's Member A at a location where the SrO percent seemed to change. The third group goes to the top of Budge's Member A, and the fourth group includes the dolostone of Budge's Member B. Each group was then compared with each of the other three groups in that section to see if there is a variance.

# DATA

## Field Description

The Fish Haven Formation rests unconformably on the Swan Peak Formation. The contact is sharp and distinctive with no apparent gradational boundary. The Fish Haven, within an inch or two of the Swan Peak contact, contains up to forty percent rounded quartz grains. The dolostone five feet above this contact contains no quartz. The lower 100 to 115 feet of Fish Haven can be characterized in all four sections as a thick-bedded, dark-gray, medium- to fine-crystalline dolostone containing solution cavities (5 x 5 cm) and, in places, algal structures. These algal structures are parallel wavy bands which often arch over solution cavities. On one dip slope in the Fish Haven good examples of laterally-linked hemispheroids (5 x 3 x 3 cm) were seen. Logan (1964), while working with recent algal stromatolites, identified similar algal structures and interpreted them as forming in intertidal mudflat environments in protected bays and behind barrier bars. Other fossils found in this unit include *Halysites* and *Favosites*. Examples were also found of tabulate and rugose corals.

The upper 30-40 feet of the Fish Haven contains chert nodules. The nodules are irregularly shaped with a maximum diameter of 7 centimeters and range in color from light gray to medium-dark gray. Some chert nodules have a pale brown tinge. The dolostone in this unit is dark gray, medium- to fine-crystalline. The uppermost chert-bearing bed marks the top of the Fish Haven.

Algal structures in the Laketown Formation are parallel and wavy, but are no longer associated with solution cavities as they were in the Fish Haven Formation. Algal structures found in the Laketown are essentially flat and form mats, rather than mounds or hemispheroids. The writer could not distinguish Budge's Members A and B. Since a distinction needed to be made for later analyses, the top of Member A was placed 300 feet above the Fish Haven Formation in all four sections.

## Petrographic Data

Petrographic analyses show that the Fish Haven and Laketown Formations are very similar. There are two sizes of pseudospar in both formations (Appendix A). The large pseudospar, with an average grain size of 0.20 mm is the dominant pseudospar in the Fish Haven, and generally comprises better than 50 percent of the grains in this formation. The smaller pseudospar is the dominant pseudospar in the Laketown, with an average grain size of 0.1 mm, and comprises better than 50 percent of the grains in this formation. Thin sections show that both sizes of pseudospar are generally in pockets and associated with pseudospar of the same general size range. In the Fish Haven the small pseudospar is generally associated with a dark, fine-grained material, which masks the grains and grain boundaries (Figure 4). In the Laketown this dark material is again present and associated with the small pseudospar, but this dark material is not so abundant as in the Fish Haven (Figure 5).

Figure 6 shows a photomicrograph of a thin section from the Fish Haven Formation at its contact with the Swan Peak Formation in Green Canyon. This thin section contains about 40 percent rounded quartz in micrite. Micrite is found in pockets with the quartz surrounding it.

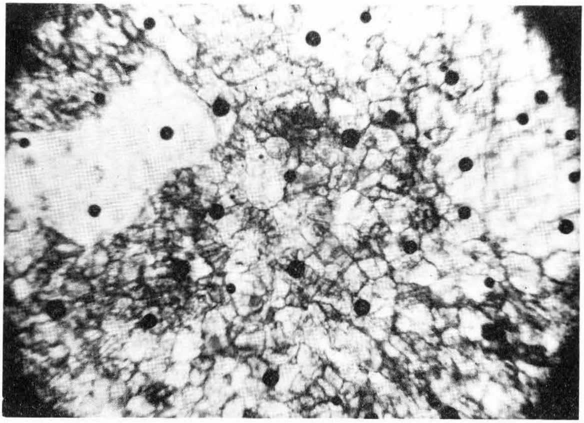

Figure 4. Photomicrograph of pseudospar from the Fish Haven Formation.

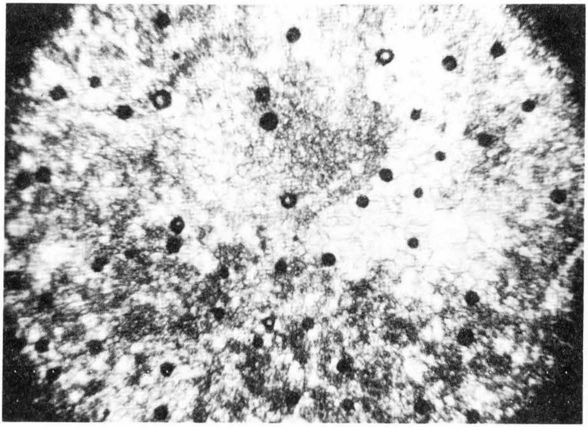

Figure 5. Photomicrograph of pseudospar from the Laketown Formation.

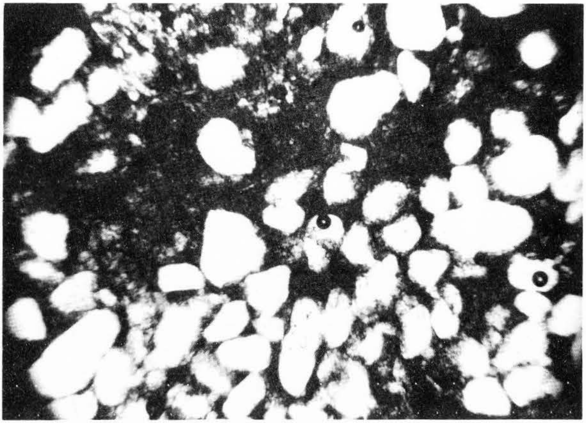

Figure 6. Photomicrograph of detrital quartz in the Fish Haven at its contact with the Swan Peak.

Figure 7 shows a photomicrograph of a thin section taken from the Laketown Formation in Green Canyon. This thin section shows an example of the only type of microfossil that has not been destroyed completely by diagenesis. This microfossil is elliptical. It is 0.40 x 0.20 mm, elongate, and a dark-brown color. Although large, this is probably a pellet. No other type of microfossil was recognized.

## X-ray Diffraction Data

In general, all samples were essentially pure dolomite with the exception of minor amounts of quartz and calcite found in a few samples. Tables found in Appendix B summarize the x-ray diffraction patterns of these samples. These tables show that usually only a trace of quartz or calcite exists in the dolostone. This is inferred because the most intense peak for calcite and quartz is the only peak found on the x-ray diffractograms for these two minerals; and these peaks are generally very small when compared to the most intense peak for dolomite on the same x-ray pattern. Figure 8 shows x-ray diffractogram patterns of pure dolomite, dolomite with calcite, and dolomite with quartz taken from samples in the Logan Canyon Section. The units containing quartz were compared with field notes. It was found that each diffractogram containing a quartz peak could be directly correlated with those beds in the Fish Haven and Laketown Formations which contain chert, whereas the calcite peaks were often related to fracture filling, which could be seen in the hand specimens.

A summary of the insoluble residue analyses is shown in Appendix C. In examining this data, the writer could find no correlation between the percentages of insoluble residues in the Fish Haven and in the Laketown.

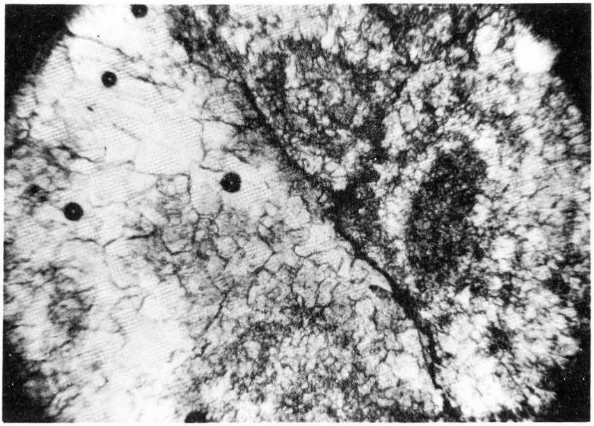

Figure 7. Photomicrograph of pellets from the Laketown Formation 8 feet above its contact with the Fish Haven Formation.

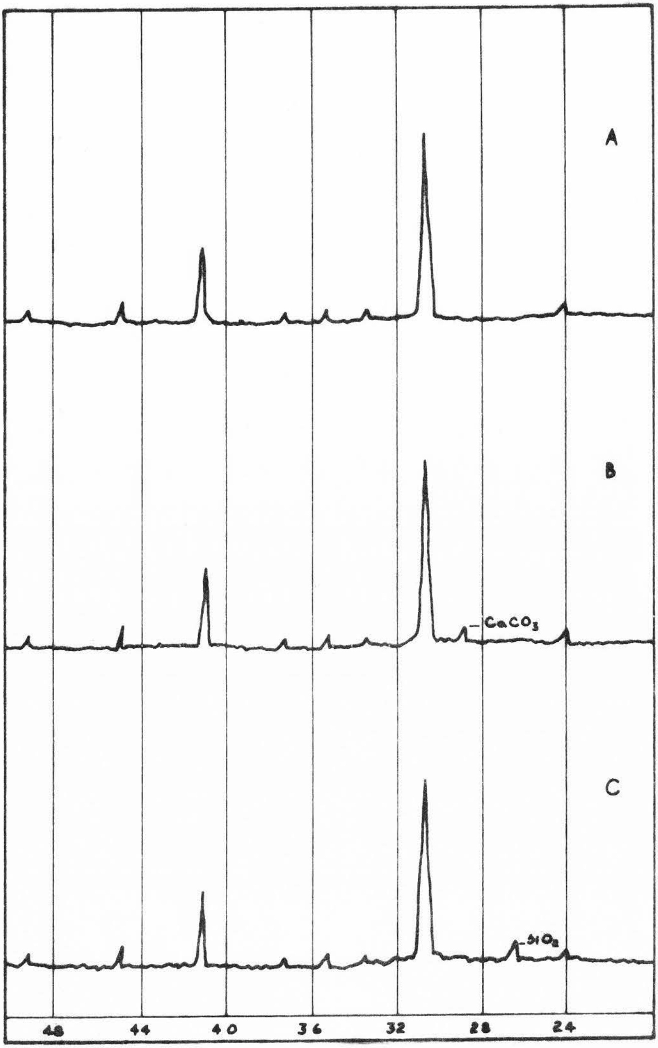


Figure 8. X-ray diffractograms from Logan Canyon Section. (A) Sample number 36, pure dolomite, (B) Sample number 106, dolomite with a minor amount of calcite, and (C) Sample number 60, dolomite with a minor amount of quartz.

The residue varied from a low of 0.09 to a high of 2.14 percent. Both high and low percentages exist in both formations.

X-ray diffractometry of the residue showed that all samples contained varying amounts of quartz and illite. Here also, no direct correlation between either dolostone and its insoluble minerals could be found. Figure 9 shows an x-ray diffractogram of the insoluble residue from a Green Canyon sample.

## X-ray Fluorescence Spectroscopy Data

### Results of chemical analyses

X-ray fluorescence scans show peaks for strontium, iron, gallium, manganese, copper, nickel, zinc, and chromium. Figure 10 shows an x-ray fluorescence scan of a sample from the Logan Canyon Section. Strontium, iron, gallium, and manganese all occur in the dolomite. The peaks due to copper, nickel, zinc, and chromium are a function of the x-ray system. The chromium $K_\alpha$ and $K_\beta$ peaks are due to energy released from the chromium target in the x-ray generating tube. Radiation striking the brass chamber where samples are held emits energy characteristic of copper and zinc, which are the two elements found in brass. Although the chamber walls are not in direct line with the x-ray beam, radiation scattered from the briquette may reach these walls and be recorded on the fluorescence scan.

Quantitative analysis of the two dolostones shows that the iron content stated as $Fe_2O_3$ is generally about 0.33 percent of the composition of the rocks (Appendix D). The strontium content in the samples is less than that of iron. The strontium content, stated as SrO, varies from about 0.002 to 0.01 percent, and seems to increase slightly in going from the base to the top of each section.

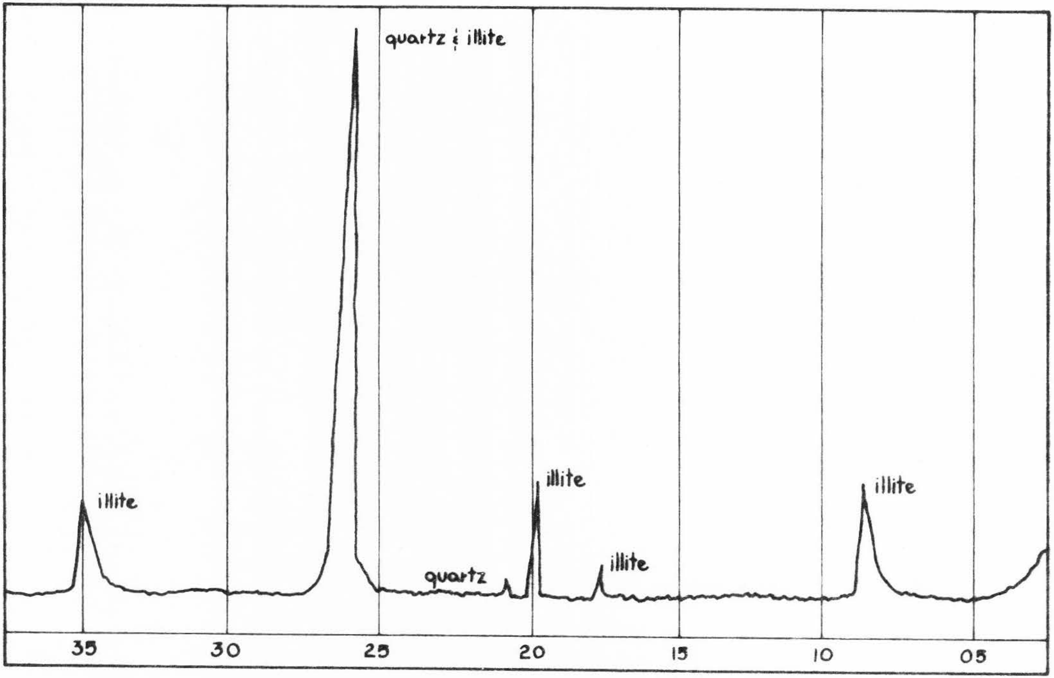


Figure 9. X-ray diffractogram of insoluble residue number 141 from Green Canyon showing the peaks due to illite and quartz.

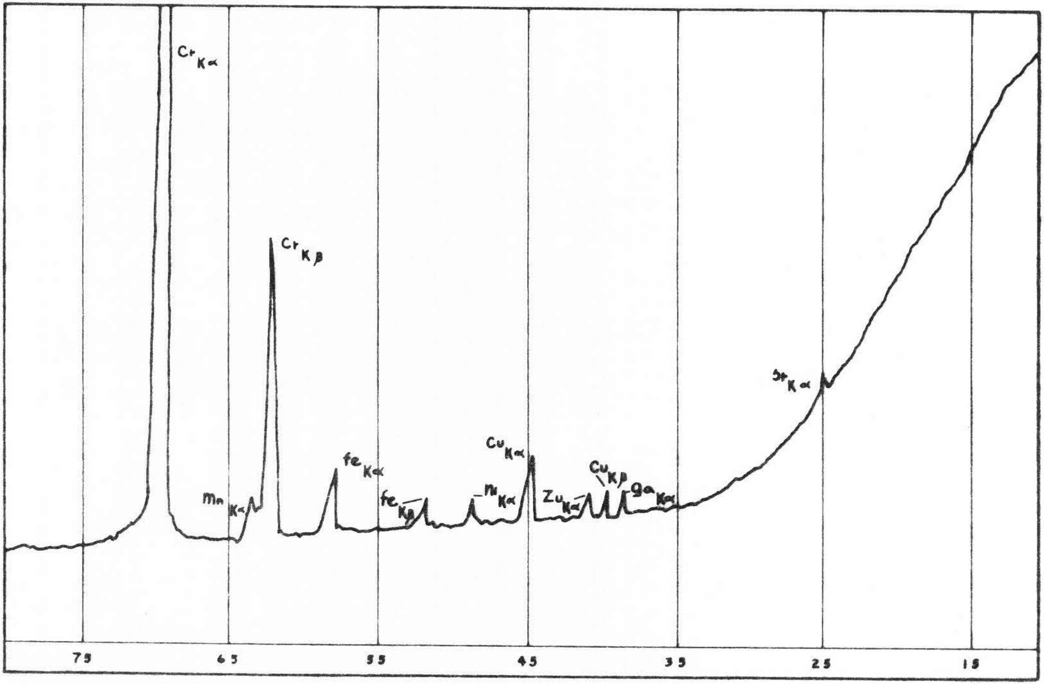


Figure 10. Fluorescence scan of Sample number 60 from Logan Canyon Section, with peaks indicating those elements present.

Results of statistical analysis

Statistical analysis of all four sections shows that, in general, there is no variance in the first three sections, Smithfield, Green, or Logan canyons. The only exception is the 5 percent level in the Smithfield Canyon Section were a slight variance in SrO is seen. The Blacksmith Fork Canyon Section, however, shows a variance in SrO and $Fe_2O_3$ at both the 1 and 5 percent levels. A summary of this analysis is shown in Table 1.

Table 1. Analysis of Variance

| Section (Canyon) | Oxide | df $V_1$ | df $V_2$ | F | Critical F 5% | Critical F 1% | Conclusion |
|---|---|---|---|---|---|---|---|
| Smithfield | SrO | 3 | 20 | 4.4906 | 3.8587 | 5.8177 | Accept* |
| Green | SrO | 3 | 20 | 1.9648 | 3.8587 | 5.8177 | Accept |
| Logan | SrO | 3 | 32 | 2.6647 | 3.5894 | 5.2388 | Accept |
| Blacksmith Fork | SrO | 3 | 22 | 14.9590 | 3.7829 | 5.6524 | Reject |
| Smithfield | Fe 0 | 3 | 20 | 1.6230 | 3.8587 | 5.8177 | Accept |
| Green | Fe 0 | 3 | 20 | 1.1855 | 3.8587 | 5.8177 | Accept |
| Logan | Fe 0 | 3 | 32 | 3.4738 | 3.5894 | 5.2388 | Accept |
| Blacksmith Fork | Fe 0 | 3 | 22 | 8.1014 | 3.7829 | 5.6524 | Reject |

*Reject at 5 percent level

Null Hypothesis: $\mu_1 = \mu_2 = \mu_3 = \mu_4$.

Comparative Analyses

An effort was made to compare the analyses of the Fish Haven and Laketown Formations with analyses of other dolostones. The purpose of this comparison was to see if dolostones, in general, can be distinguished geochemically.

Nine samples from five local dolostones were collected. These dolostones were examined using the same procedures followed for geochemical analyses of the Fish Haven and lower Laketown Formations. These samples came from the middle and upper Laketown Formation, one from the St. Charles, and two each from the Nounan, Blacksmith, and Langston Formations. Appendix B also shows a summary of data from x-ray diffractograms from these nine dolostones. They are all similar to the Fish Haven and lower Laketown in that they may contain minor amounts of calcite or quartz. They cannot, however, be distinguished from the dolostone in the Fish Haven and lower Laketown Formations by x-ray diffraction methods alone.

All fluorescence scans for the Fish Haven Formation, the lower Laketown Formation, and the nine other dolostones were essentially the same, with the exception of the Langston Formation. Samples from the Langston show a much higher peak for iron, indicating a greater iron content in the Langston Formation than in other local dolostones. Williams and Maxey (1941) subdivided the Langston into two tan-weathering dolostone members separated by a limestone. This tan dolostone probably derives its color from its high iron content.

Quantitative analyses of the nine dolostones show that the content of the samples is generally about 0.33 percent iron-oxide (Appendix D). The only exceptions are the two samples from the Langston Formation, which have 2.201 and 1.876 percent $Fe_2O_3$. The strontium oxide analyses from the nine local dolostones is similar to the strontium analyses for the Fish Haven and lower Laketown Formations.

Chemical analyses of dolostones from Illinois compiled by Lamar (1957) were also studied (Appendix E). In comparing the relatively pure dolomites (50 to 56 percent $CaCO_3$ and 42 to 47 percent $MgCO_3$) with those containing a greater percentage of clays and silicates (40 to 49 percent $CaCO_3$ and 29 to 43 percent $MgCO_3$), it becomes apparent that pure dolostones contain a smaller percent of iron than do dolostones containing high percentages of clays and other silicates.

Dolostones of the Fish Haven and lower Laketown Formations are similar in $Fe_2O_3$ content to the pure dolostones from Illinois. The nine other local dolostones are also similar to the pure dolostones of Illinois in $Fe_2O_3$ content, with the exception of the Langston Formation. The iron in that formation compares with the iron percentages found in the impure dolostones of Lamar's study (1957).

# DISCUSSION

Generally, the Fish Haven and Laketown Formations are very similar, with only very subtle differences. The two dolostones can be distinguished most easily by lithologic characteristics. The Fish Haven Formation is characterized as a thick-bedded, dark-gray dolostone which weathers to form cliffs; whereas the Laketown Formation is a medium- to thin-bedded, medium-gray dolostone which weathers back to form pinnacles and spires.

X-ray diffractometry aids very little in distinguishing the two dolostones. All samples were essentially pure dolomite, with only minor amounts of quartz and calcite. The quartz in both formations is related to chert beds. The calcite is related to minor fractures.

Petrography shows the grain size decreases in going from the Fish Haven to the Laketown Formation. Microfossils in both formations have been destroyed by dolomitization, and only possible ghosts of pellet-like structures remain.

The amount of insoluble residue in the two formations is low, and the grain size is very fine. Two alternative explanations are proposed. Algal banding seen in the field implies this was a shallow sea, therefore, these formations were deposited either: (1) far enough from shore that the detrital material deposited was windblown or suspended in the water; or (2) the craton, at the time of deposition, was near base level and very little detrital material was derived from it.

X-ray fluorescence spectroscopy data are summarized in the analysis of variance. Three sections, Smithfield, Green, and Logan canyons, show show virtually no variance for either SrO or $Fe_2O_3$. The Blacksmith Fork Canyon Section, however, shows a variance in both SrO and $Fe_2O_3$. From these analyses it is apparent that local variance in SrO and $Fe_2O_3$ may be a function of lateral location, rather than vertical extent in any one section. Thus, the composition of the rocks in each section is possibly a function of the dolomitizing process and the associated fluids in that area.

## SUMMARY

Petrographic and geochemical analyses of the Fish Haven Formation and lower part of the Laketown Formation near Logan, Utah, indicate the two formations are essentially the same, chemically. Presently the two formations can be separated best by field observations. The two formations may also be separated petrographically by a decrease in average grain size in going from the Fish Haven to the Laketown Formation.

## SELECTED REFERENCES

Beus, S. S. 1963. Geology of the central Blue Springs Hills, Utah-Idaho. P.D. Dissertation. Univ. Calif. Los Angeles, Calif.

Budge, D. R. 1966. Stratigraphy of the Laketown dolostone faunas, north central Utah. M. S. Thesis. Utah State University, Logan, Utah.

Budge, D. R. and P. M. Sheehan. 1969. Evaluation of Laketown dolomite faunas north central Utah. (abs). Geol. Soc. America Spec. Paper 121:490-491.

Darton, N. H. 1904. Comparison of the stratigraphy of the Black Hills Bighorn Mountains and Rocky Mountain Front Range. Geol. Soc. America Bull. 15:379-448.

Freund, J. E. 1965. Modern elementary statistics. Prentice-Hall, Inc. New Jersey.

Garrels, R. M., M. E. Thompson, and R. Siever. 1960. Stability of some carbonates at 25C and one atmosphere total pressure. Am. Jour. Sci. 258:402-418.

Gibbs, F. K. 1972. Silurian system. in Geologic atlas of the Rocky Mountain region. Rocky Mtn. Assoc. Geol. Denver, Colo.

Gibbs, R. J. 1960. The stratigraphy and paleontology of the Fish Haven dolomite of south central Idaho. M. S. Thesis. Northwestern University, Evanston, Illinois.

Graf, D. L. and J. R. Goldsmith. 1956. Some hydrothermal synthesis of dolomite and protodolomite. Jour. Geol. 64:173-186.

Hsü, K. J. 1967. Chemistry of dolomite formation. in Chilingar, G. V., Bissel, H. J. and Fairbridge, R. W. (eds). Developments in sedimentology. V9B. Carbonate rocks: physical and chemical aspects. Elsevier. New York.

Kinsman, D. J. J. 1969. Interpretation of $Sr^{+2}$ concentrations of carbonate minerals and rocks. Jour. Sed. Petrology. 39:486-508.

Krauskopf, K. B. 1967. Introduction to geochemistry. McGraw-Hill. New York.

Lamar, J. E. 1925. Chemical analysis of Illinois limestones and dolomites. Ill. State Geol. Survey Bull. 46:317-333.

Logan, J. E., R. Rezak, and R. N. Ginsburg. 1964. Classification and environmental significance of algal stromatolites. Jour. Geol. 72:68-83.

Lovering, T. S. 1969. The origin of hydrothermal and low temperature dolomite. Econ. Geol. 64:743-754.

McKee, E. H. and R. J. Ross, Jr. 1969. Stratigraphy of eastern assemblage rocks in a window in Roberts Mountain Thrust, northern Toquima Range, central Nevada. Am. Assoc. Petroleum Geol. Bull. 53:421-429.

Merrian, C. W. 1940. Devonian stratigraphy and paleontology of the Roberts Mountain region, Nevada. Geol. Soc. America Spec. Paper 25.

Morris, H. T. and T. S. Lovering. 1961. Stratigraphy of the east Tintic Mountains, Utah. U. S. Geol. Survey Prof. Paper 516D.

Nuffield, E. W. 1966. X-ray diffraction methods. John Wiley and Sons, Inc. New York.

Osmond, J. C. 1954. Dolomites in Silurian and Devonian of east-central Nevada. Am. Assoc. Petroleum Geol. Bull. 38:1911-1956.

Pettijohn, F. J. 1957. Sedimentary rocks. Harper and Row. New York.

Richardson, G. B. 1913. The Paleozoic section in northern Utah. Am. Jour. Sci. 36:406-416.

Roberts. R. J., P. E. Hotz, J. Gilluly, and H. G. Ferguson. 1958. Paleozoic rocks of north central Nevada. Am. Assoc. Petroleum Geol. Bull. 42:2813-2857.

Ross, C. P. 1934a. Correlation and interpretation of Paleozoic stratigraphy in south central Idaho. Geol. Soc. America Bull. 45:937-1000.

Ross, C. P. 1937. Geology and ore deposits of the Bighorse region, Custer County, Idaho. U. S. Geol. Survey Bull. 877.

Ross, R. J., Jr. 1964. Relation of middle Ordovician time and rock units in basin ranges, western United States. Am. Assoc. Petroleum Geol. Bull. 48:1526-1554.

Warne, S. St. J. 1962. A quick field or laboratory staining scheme for the differentiation of the major carbonate minerals. Jour. Sed. Petrology. 32:29-38.

Wainerdi, E. W. and E. A. Uken. 1971. Modern methods of geochemical Analyses. Plenum Press. New York.

Williams, J. Stewart. 1948. Geology of the Paleozoic rocks, Logan quadrangle, Utah. Geol. Soc. America Bull. 59:1121-1164.

Williams, J. Stewart and G. B. Maxey. 1941. Cambrian section of the Logan quadrangle, Utah and vicinity. Am. Jour. Sci. 239:276-285.

# APPENDICES

## Appendix A

## Petrographic Analyses

Table 2. Petrographic analysis of Smithfield Canyon Section

| Unit | Distance (feet) | Small Spar (mm) | % | Large Spar (mm) | % | Other |
|---|---|---|---|---|---|---|
| Laketown Member B | 500 | 0.1 | 80 | 0.20 | 20 | |
| Laketown Member A | 250 | 0.15 | 95 | --- | --- | Vugs |
| | 200 | 0.1 | 60 | 0.20 | 40 | |
| | 140 | 0.2 | 50 | 0.90 | 50 | |
| Fish Haven | 125 | 0.1 | 20 | 0.20 | 75 | Vugs |
| | 75 | --- | -- | 0.20 | 100 | |
| | 0 | 0.1 | 20 | 0.20 | 80 | |

Table 3. Petrographic analysis of Green Canyon Section

| Unit | Distance (feet) | Small Spar (mm) | % | Large Spar (mm) | % | Other |
|---|---|---|---|---|---|---|
| Laketown Member B | 583 | 0.1 | 70 | 0.15 | 25 | Fracture |
| Laketown Member A | 428 | 0.2 | 95 | 0.70 | 3 | Fracture |
| | 348 | 0.1 | 95 | 0.25 | 5 | |
| | 298 | 0.1 | 75 | 0.15 | 25 | |
| | 230 | 0.1 | 90 | 0.25 | 10 | |
| | 205 | 0.1 | 85 | 0.30 | 10 | Fracture |
| | 139 | 0.1 | 64 | 0.25 | 35 | Fracture |
| Fish Haven | 117 | 0.1 | 10 | 0.20 | 90 | |
| | 86 | 0.1 | 45 | 0.25 | 55 | |
| | 39 | 0.1 | 35 | 0.25 | 65 | |
| | 20 | 0.1 | 84 | 0.20 | 15 | |
| | 0 | micrite | 60 | --- | -- | Quartz |

Table 4. Petrographic analysis of Logan Canyon Section

| Unit | Distance (feet) | Small Spar (mm) | % | Large Spar (mm) | % | Other |
|---|---|---|---|---|---|---|
| Laketown Member B | 566 | 0.1 | 90 | 0.30 | 5 | Vugs |
| Laketown Member A | 320 | 0.1 | 70 | 0.20 | 25 | Fracture |
| | 165 | 0.1 | 90 | --- | -- | Calcite |
| Fish Haven | 145 | 0.1 | 90 | 0.30 | 10 | Fracture |
| | 130 | 0.1 | 5 | 0.18 | 90 | Vugs |
| | 85 | --- | -- | 0.20 | 95 | Vugs |
| | 60 | 0.1 | 20 | 0.20 | 80 | |
| | 0 | 0.1 | 90 | 0.25 | 5 | Quartz |

Table 5. Petrographic analysis of Blacksmith Fork Canyon Section

| Unit | Distance (feet) | Small Spar (mm) | % | Large Spar (mm) | % | Other |
|---|---|---|---|---|---|---|
| Laketown Member A | 200 | 0.1 | 75 | 0.20 | 20 | Fracture |
| | 170 | 0.1 | 90 | 0.15 | 5 | Fracture |
| | 145 | 0.1 | 95 | 0.35 | 2 | Fracture |
| Fish Haven | 105 | 0.2 | 65 | 0.80 | 35 | |
| | 85 | --- | -- | 0.20 | 90 | Vugs |
| | 0 | 0.1 | 30 | 0.20 | 70 | |

# Appendix B

## X-ray Diffraction Data

Table 6. X-ray diffraction data from Smithfield Canyon Section

| Unit | Station Number | Distance (feet) | Dolomite | Calcite | Quartz |
|---|---|---|---|---|---|
| Laketown Member B | 115 | 575 | X | | |
| | 110 | 550 | X | | |
| | 105 | 525 | X | | |
| | 100 | 500 | X | | |
| | 90 | 450 | X | | |
| Laketown Member A | 85 | 425 | X | | tr |
| | 75 | 375 | X | X | |
| | 70 | 350 | X | | |
| | 65 | 325 | X | | |
| | 60 | 300 | X | | |
| | 55 | 275 | X | | |
| | 50 | 250 | X | | |
| | 45 | 225 | X | | |
| | 40 | 200 | X | | |
| | 28 | 140 | X | | |
| Fish Haven | 25 | 125 | X | | |
| | 20 | 100 | X | | |
| | 15 | 75 | X | | |
| | 10 | 50 | X | | |
| | 5 | 25 | X | | |
| | 0 | 0 | X | | |

tr = trace

Table 7. X-ray diffraction data from Green Canyon Section

| Unit | Station Number | Distance (feet) | Dolomite | Calcite | Quartz |
|---|---|---|---|---|---|
| Laketown Member B | 141 | 583 | X | | |
| | 139 | 573 | X | | |
| | 138 | 568 | X | | |
| | 137 | 562 | X | | |
| | 130 | 535 | X | | |
| | 128 | 528 | X | | |
| | 109 | 457 | X | | |
| Laketown Member A | 101 | 428 | X | | |
| | 98 | 428 | X | | |
| | 94 | 420 | X | | |
| | 90 | 385 | X | | |
| | 82 | 340 | X | | |
| | 74 | 308 | X | | |
| | 66 | 264 | X | | |
| | 51 | 209 | X | | |
| | 32 | 139 | X | | |
| Fish Haven | 26 | 117 | X | | |
| | 24 | 109 | X | | |
| | 12 | 59 | X | | |
| | 10 | 49 | X | | |
| | 4 | 20 | X | | |

Table 8. X-ray diffraction data from Logan Canyon Section

| Unit | Station Number | Distance (feet) | Dolomite | Calcite | Quartz |
|---|---|---|---|---|---|
| Laketown Member B | 130 | 626 | X | | |
| | 126 | 606 | X | | |
| | 122 | 586 | X | | |
| | 118 | 566 | X | | |
| | 114 | 546 | X | | |
| | 110 | 526 | X | | |
| | 106 | 506 | X | tr | |
| | 100 | 480 | X | | |
| | 92 | 447 | X | | |
| Laketown Member A | 86 | 420 | X | tr | |
| | 81 | 395 | X | | tr |
| | 74 | 365 | x | | tr |
| | 68 | 430 | X | | |
| | 64 | 320 | X | | |
| | 60 | 300 | X | | tr |
| | 56 | 280 | x | tr | |
| | 62 | 260 | X | | |
| | 56 | 260 | X | | |
| | 48 | 240 | X | | |
| | 44 | 220 | X | | |
| | 40 | 200 | X | | |
| | 36 | 180 | X | | |
| | 33 | 165 | X | | |
| | 31 | 155 | X | | |
| Fish Haven | 29 | 145 | X | | |
| | 26 | 130 | X | | tr |
| | 21 | 105 | X | | tr |
| | 17 | 85 | X | | |
| | 14 | 70 | X | | |
| | 11 | 55 | X | | |
| | 8 | 40 | X | | |
| | 5 | 25 | X | | |
| | 2 | 10 | X | | |
| | 0 | 0 | X | | tr |

tr = trace

Table 9. X-ray diffraction data from Blacksmith Fork Canyon Section

| Unit | Station Number | Distance (feet) | Dolomite | Calcite | Quartz |
|---|---|---|---|---|---|
| Laketown Member B | 120 | 600 | X | | |
| | 115 | 575 | X | | |
| | 110 | 550 | X | | |
| | 105 | 525 | X | | |
| | 100 | 500 | X | | |
| | 95 | 475 | X | | |
| | 90 | 450 | X | | |
| Laketown Member A | 84 | 420 | X | | |
| | 81 | 405 | X | | |
| | 76 | 380 | X | | |
| | 71 | 355 | X | | tr |
| | 65 | 325 | X | | |
| | 60 | 300 | X | | |
| | 55 | 275 | X | | |
| | 50 | 250 | X | tr | |
| | 45 | 225 | X | | |
| | 34 | 170 | X | | |
| | 29 | 145 | X | | |
| Fish Haven | 21 | 105 | X | | X |
| | 17 | 85 | X | | |
| | 10 | 50 | X | | |
| | 0 | 0 | X | | |

tr = trace

Table 10. X-ray diffraction data from nine local dolostones

| Formation | Dolomite | Calcite | Quartz |
|---|---|---|---|
| Laketown top | X | X | |
| Laketown middle | X | | |
| St. Charles | X | | |
| Nounan top | X | | |
| Nounan base | X | | |
| Blacksmith top | X | | |
| Blacksmith base | X | | |
| Langston #2 | X | | |
| Langston #1 | X | | tr |

tr = trace

# Appendix C

## Insoluble Residue Analyses

Table 11. Insoluble residue analyses from Smithfield Canyon Section

| Unit | Station Number | Distance (feet) | % Insolu-ble Residue | Percent Illite |
|---|---|---|---|---|
| Laketown Member B | 115 | 575 | 0.78 | 15 |
| Laketown Member A | 74 | 375 | 0.18 | 69 |
| | 28 | 140 | 0.54 | 25 |
| Fish Haven | 25 | 125 | 1.43 | 21 |
| | 15 | 75 | 0.81 | 16 |
| | 5 | 25 | 0.40 | 16 |

Table 12. Insoluble residue analyses from Green Canyon Section

| Unit | Station Number | Distance (feet) | % Insolu-ble Residue | Percent Illite |
|---|---|---|---|---|
| Laketown Member B | 141 | 583 | 0.47 | 69 |
| | 139 | 573 | 0.20 | 67 |
| | 138 | 568 | 0.17 | 50 |
| | 137 | 562 | 2.13 | 67 |
| | 130 | 535 | 0.13 | 82 |
| | 128 | 528 | 0.14 | 33 |
| | 109 | 457 | 1.02 | 42 |
| Laketown Member A | 101 | 428 | 0.73 | 60 |
| | 98 | 417 | 1.43 | 50 |
| | 94 | 402 | 2.14 | 91 |
| | 90 | 385 | 0.40 | 100 |
| | 82 | 348 | 0.12 | 100 |
| | 74 | 308 | 0.33 | 81 |
| | 66 | 164 | 0.17 | 90 |
| | 51 | 209 | 0.63 | 65 |
| Fish Haven | 24 | 109 | 0.63 | 25 |
| | 12 | 59 | 0.12 | 25 |
| | 10 | 49 | 0.24 | 53 |
| | 4 | 20 | 0.57 | 35 |

Table 13. Insoluble residue analyses from Logan Canyon Section

| Unit | Station Number | Distance (feet) | % Insolu- ble Resiude | Percent Illite |
|---|---|---|---|---|
| Laketown Member B | 130 | 626 | 0.15 | 50 |
| | 106 | 506 | 0.15 | 100 |
| Laketown Member A | 64 | 320 | 0.38 | 67 |
| | 36 | 180 | 0.11 | 82 |
| | 31 | 155 | 0.35 | 100 |
| Fish Haven | 29 | 145 | 0.27 | 95 |
| | 26 | 130 | 0.83 | 10 |
| | 21 | 105 | 0.27 | 50 |
| | 17 | 85 | 1.31 | 0 |
| | 8 | 40 | 0.19 | 33 |

Table 14. Insoluble residue analyses from Blacksmith Fork Canyon Section

| Unit | Station Number | Distance (feet) | % Insolu- ble Residue | Percent Illite |
|---|---|---|---|---|
| Laketown Member B | 120 | 600 | 0.10 | 54 |
| Laketown Member A | 65 | 325 | 1.25 | 81 |
| | 55 | 275 | 0.09 | 100 |
| Fish Haven | 21 | 105 | 1.25 | 10 |
| | 17 | 85 | 1.25 | 9 |
| | 10 | 50 | 0.39 | 10 |

# Appendix D

## X-ray Fluorescence Data

Table 15. X-ray fluorescence data from Smithfield Canyon Section

| Unit | Station Number | Distance (feet) | $\%Fe_2O_3$ | $\%SrO \times 10^{-2}$ |
|---|---|---|---|---|
| Laketown Member B | 115 | 575 | 0.359 | 1.011 |
| | 110 | 550 | 0.333 | 0.593 |
| | 105 | 525 | 0.309 | 1.095 |
| | 100 | 500 | 0.373 | 0.610 |
| | 90 | 450 | 0.343 | 0.626 |
| Laketown Member A | 85 | 425 | 0.324 | 0.567 |
| | 75 | 375 | 0.311 | 0.375 |
| | 70 | 350 | 0.390 | 1.068 |
| | 65 | 325 | 0.412 | 1.304 |
| | 60 | 300 | 0.308 | 0.369 |
| | 55 | 275 | 0.320 | 0.470 |
| | 50 | 250 | 0.309 | 0.340 |
| | 45 | 225 | 0.362 | 0.577 |
| Fish Haven | 40 | 200 | 0.327 | 0.402 |
| | 28 | 140 | 0.281 | 0.460 |
| | 25 | 125 | 0.355 | 0.437 |
| | 20 | 100 | 0.307 | 0.461 |
| | 15 | 75 | 0.331 | 0.552 |
| | 10 | 50 | 0.331 | 0.407 |
| | 5 | 25 | 0.325 | 0.455 |
| | 0 | 0 | 0.363 | 0.414 |

Table 16. X-ray fluorescence data from Green Canyon Section

| Unit | Station Number | Distance (feet) | $\%Fe_2O_3$ | $\%SrO$ x $10^{-2}$ |
|---|---|---|---|---|
| Laketown Member B | 141 | 583 | 0.300 | 0.781 |
| | 139 | 573 | 0.301 | 0.993 |
| | 138 | 568 | 0.288 | 0.971 |
| | 137 | 562 | 0.474 | 1.339 |
| | 130 | 535 | 0.270 | 0.498 |
| | 128 | 528 | 0.266 | 0.388 |
| | 109 | 457 | 0.412 | 1.029 |
| Laketown Member A | 101 | 428 | 0.357 | 0.965 |
| | 98 | 424 | 0.412 | 1.393 |
| | 94 | 420 | 0.339 | 1.033 |
| | 90 | 385 | 0.342 | 0.929 |
| | 82 | 348 | 0.270 | 0.468 |
| | 74 | 308 | 0.301 | 0.454 |
| | 66 | 264 | 0.294 | 0.365 |
| | 51 | 209 | 0.305 | 0.392 |
| | 32 | 139 | 0.328 | 0.612 |
| Fish Haven | 26 | 117 | 0.361 | 0.454 |
| | 24 | 109 | 0.331 | 0.368 |
| | 12 | 59 | 0.298 | 0.225 |
| | 10 | 49 | 0.370 | 0.248 |
| | 4 | 20 | 0.372 | 0.420 |

Table 17. X-ray fluorescence data from Logan Canyon Section

| Unit | Station Number | Distance (feet) | $\%Fe_2O_3$ | $\%SrO_2$ x $10^{-2}$ |
|---|---|---|---|---|
| Laketown Member B | 130 | 626 | 0.341 | 0.336 |
| | 126 | 606 | 0.280 | 0.426 |
| | 122 | 586 | 0.327 | 0.505 |
| | 118 | 566 | 0.341 | 0.552 |
| | 114 | 546 | 0.301 | 0.394 |
| | 110 | 526 | 0.344 | 1.025 |
| | 106 | 506 | 0.393 | 0.708 |
| | 100 | 480 | 0.329 | 0.369 |
| Laketown Member A | 92 | 447 | 0.347 | 0.396 |
| | 86 | 420 | 0.386 | 0.800 |
| | 81 | 395 | 0.390 | 0.553 |
| | 74 | 365 | 0.421 | 0.660 |
| | 68 | 340 | 0.379 | 0.302 |
| | 64 | 320 | 0.351 | 0.443 |
| | 60 | 300 | 0.445 | 0.547 |
| | 56 | 280 | 0.347 | 0.553 |
| | 52 | 260 | 0.322 | 0.432 |
| | 48 | 240 | 0.385 | 0.481 |
| | 44 | 220 | 0.356 | 0.368 |
| | 40 | 200 | 0.355 | 0.219 |
| | 36 | 180 | 0.337 | 0.343 |
| | 33 | 165 | 0.330 | 0.319 |
| | 31 | 155 | 0.375 | 0.275 |
| Fish Haven | 29 | 145 | 0.356 | 0.205 |
| | 26 | 130 | 0.504 | 0.591 |
| | 21 | 105 | 0.367 | 0.440 |
| | 17 | 85 | 0.421 | 0.612 |
| | 14 | 70 | 0.380 | 0.421 |
| | 11 | 55 | 0.412 | 0.516 |
| | 8 | 40 | 0.355 | 0.378 |
| | 5 | 25 | 0.363 | 0.394 |
| | 2 | 10 | 0.479 | 0.274 |
| | 0 | 0 | 0.761 | 0.494 |

Table 18. X-ray fluorescence data from Blacksmith Fork Canyon Section

| Unit | Station Number | Distance (feet) | $\%Fe_2O_3$ | $\%SrO \times 10^{-2}$ |
|---|---|---|---|---|
| Laketown Member B | 120 | 600 | 0.424 | 0.781 |
| | 115 | 575 | 0.379 | 0.537 |
| | 110 | 550 | 0.362 | 0.478 |
| | 105 | 525 | 0.392 | 0.522 |
| | 100 | 500 | 0.342 | 0.710 |
| | 95 | 475 | 0.337 | 0.542 |
| | 90 | 450 | 0.340 | 0.642 |
| Laketown Member A | 84 | 420 | 0.355 | 0.918 |
| | 81 | 405 | 0.330 | 0.787 |
| | 76 | 380 | 0.319 | 1.108 |
| | 71 | 355 | 0.353 | 0.728 |
| | 65 | 325 | 0.463 | 0.942 |
| | 60 | 300 | 0.371 | 0.508 |
| | 55 | 275 | 0.597 | 0.430 |
| | 50 | 250 | 0.538 | 0.464 |
| | 45 | 225 | 0.322 | 0.252 |
| | 40 | 200 | 0.258 | 0.183 |
| | 34 | 170 | 0.300 | 0.411 |
| | 29 | 145 | 0.281 | 0.230 |
| Fish Haven | 21 | 105 | 0.287 | 0.466 |
| | 17 | 85 | 0.288 | 0.243 |
| | 10 | 50 | 0.313 | 0.411 |
| | 0 | 0 | 0.273 | 0.372 |

Table 19. X-ray fluorescence data from nine local dolostones

| Formation | $\%Fe_2O_3$ | $\%SrO_2 \times 10^{-2}$ |
|---|---|---|
| Laketown top | 0.325 | 0.457 |
| Laketown middle | 0.261 | 0.681 |
| St. Charles | 0.310 | 0.358 |
| Nounan top | 0.387 | 0.231 |
| Nounan base | 0.470 | 0.117 |
| Blacksmith top | 0.411 | 0.229 |
| Blacksmith base | 0.463 | 0.265 |
| Langston #2 | 2.201 | 0.118 |
| Langston #1 | 1.876 | 0.276 |

# Appendix E

## Standard Dolostones from Illinois

Table 20. Standard dolostones from Illinois

| Formation | %$CaCO_3$ | %$MgCO_3$ | %$Fe_2O_3$ |
|---|---|---|---|
| Pure Dolomite* | | | |
| Stewartville | 54.55 | 41.46 | 1.15 |
| Prosser | 54.84 | 43.61 | 0.37 |
| Racine | 54.60 | 44.57 | 0.21 |
| Racine | 54.57 | 43.03 | 0.25 |
| Racine | 54.71 | 44.43 | 0.11 |
| Stewartville | 54.71 | 42.13 | 0.41 |
| Stewartville | 55.17 | 43.13 | 0.85 |
| Niagaran | 53.50 | 42.70 | 0.43 |
| Racine | 54.14 | 43.26 | 0.20 |
| Joliet | 54.85 | 42.86 | 0.29 |
| Niagaran | 54.68 | 42.84 | 0.86 |
| Niagaran | 54.00 | 44.54 | 0.26 |
| Niagaran | 54.73 | 42.79 | 0.83 |
| Niagaran | 54.86 | 47.28 | 0.35 |
| Niagaran | 55.12 | 44.03 | 0.27 |
| Niagaran | 55.10 | 43.34 | 0.35 |
| Niagaran | 55.01 | 44.24 | 0.27 |
| Niagaran | 54.84 | 43.47 | 0.34 |
| Impure Dolomite* | | | |
| Shakopee | 45.37 | 39.50 | 1.18 |
| Shakopee | 42.36 | 33.94 | 1.64 |
| Shakopee | 42.93 | 29.23 | 1.60 |
| Shakopee | 43.94 | 35.61 | 0.84 |
| Shakopee | 44.45 | 36.20 | 1.10 |
| Shakopee | 49.72 | 39.96 | 1.05 |
| Niagaran | 47.73 | 35.86 | 1.12 |
| Niagaran | 46.18 | 35.05 | 1.19 |
| Niagaran | 40.14 | 32.52 | 1.70 |
| Niagaran | 40.86 | 43.54 | 1.40 |
| Niagaran | 44.02 | 36.68 | 0.76 |
| Niagaran | 49.80 | 43.74 | 0.21 |
| Niagaran | 42.01 | 31.20 | 0.55 |
| Edgewood | 40.51 | 32.35 | 1.41 |
| Niagaran | 48.02 | 40.55 | 0.51 |
| Niagaran | 45.88 | 38.12 | 0.51 |
| Niagaran | 45.42 | 37.83 | 0.47 |
| Niagaran | 47.61 | 39.38 | 1.07 |
| Waukesha | 46.15 | 37.41 | 0.17 |

*Data taken from Lamar (1957).

# Appendix F

## Measured Sections

## Section 1

Section measured near the head of Smithfield Canyon, Utah; beginning in the NE¼NW¼ sec. 11, T. 13N., R. 2E.; ending in the SE¼NE¼ sec. 11, T. 13N., R. 2E., Salt Lake base and meridian.

| | Thickness (feet) |
|---|---|
| Laketown Dolostone: | |
| 7. Dolostone, medium light gray, weathers light gray, fine crystalline, medium bedded. . . . . . . . . | 65 |
| 6. Dolostone, medium light gray, weathers light gray, fine crystalline, medium to thin bedded, breccia zone 25 feet above base of this unit . . . . . | 160 |
| 5. Dolostone, medium gray, weathers medium gray, fine crystalline, resistant cliff former, contains chert in places, thin bedded . . . . . . . . . . | 150 |
| 4. Dolostone, fine crystalline, medium gray, weathers medium gray, thin bedded, base contains irregular light and dark mottled dolostone.. . . . . . | 65 |
| Total. . . | 440 |
| Fish Haven Dolostone: | |
| 3. Dolostone, dark gray, weathers medium gray, medium to fine crystalline, chert nodules in beds, massive cliff former, thick bedded. . . . . . | 35 |
| 2. Dolostone, dark gray, weathers medium gray, medium to fine crystalline, contains algal bands and solution cavities, thick bedded. . . . . . . | 80 |
| 1. Dolostone, medium light gray, weathers light gray, fine crystalline, slope former, medium bedded . . . . . . . . . . . . . . . . . . . . . . . . | 20 |
| Total. . . | 135 |

Swan Peak Formation

## Section 2

Section measured near the Swan Peak rock quarry, Green Canyon, Utah, beginning in the NE¼SW¼ sec. 17, T. 12N., R. 2E.; ending in the NW¼SE¼ sec. 17, T. 12N., R. 2E., Salt Lake base and meridian.

| | | Thickness (feet) |
|---|---|---|
| Laketown Dolostone: | | |
| 8. | Dolostone, resistant, thin algal bands, medium bedded. . . . . . . . . . . . . . . . . . . . . . | 20 |
| 7. | Covered; light gray dolostone float, fine crystalline, light gray, thin bedded, dip-slope breccia locally in float . . . . . . . . . . . . | 162 |
| 6. | Dolostone, mixed light and dark mottled dolostone, fine crystalline, thin bedded . . . . . . . | 21 |
| 5. | Dolostone, medium gray, weathers light gray fine crystalline, thin to medium bedded, resistant cliff former . . . . . . . . . . . . . . . . . | 173 |
| 4. | Covered; unit forms a dip slope, medium gray dolostone float, weathers medium light gray fine crystalline . . . . . . . . . . . . . . . . . . . | 80 |
| | Total. . . | 456 |
| Fish Haven Dolostone: | | |
| 3. | Covered; unit forms dip slope, medium dark gray dolostone float, weathers medium dark gray, breccia, thick bedded, medium to fine crystalline. . . . . . . . . . . . . . . . . . . . . . | 40 |
| 2. | Dolostone, medium gray, weathers medium gray, medium bedded, resistant cliff former, contains local areas of breccia, solution cavities, and algal bands, medium to fine crystalline, thick bedded. . . . . . . . . . . . . . | 83 |
| 1. | Dolostone, medium gray, weathers medium gray, weathers back, fine to medium crystalline, thick bedded, parallel wavy bands at base . . . . . . . . . . . . . . . . . . . . . . . | 8 |
| | Total. . . | 131 |

Swan Peak Formation

## Section 3

Section measured near the right hand fork of Logan Canyon, Utah; beginning in the SE¼NE¼ sec. 18, T. 12N., R. 3E.; ending in the SW¼SE¼ sec. 7, T. 12N., R. 2E., Salt Lake base and meridian.

| | Thickness (feet) |
|---|---|
| Laketown Dolostone: | |
| 7. Dolostone, medium gray, weathers light gray, fine crystalline, resistant cliff former, medium bedded, base of unit is oolitic and pale orange. . . . . . . . . . . . . . . . . . . . . | 125 |
| 6. Dolostone, medium gray, weathers medium light gray, fine crystalline, weathers to a slope, medium to thin bedded . . . . . . . . . . . | 61 |
| 5. Dolostone, medium gray, weathers medium light gray, fine crystalline, resistant, thin bedded. . . . . . . . . . . . . . . . . . . . . | 45 |
| 4. Covered; light gray dolostone float, weathers medium light gray, breccia zone 50 feet above base of this unit, fine crystalline, medium to thin bedded. . . . . . . . . . . . | 55 |
| 3. Dolostone, medium gray, weathers light gray, fine crystalline, medium to thin bedded, local chert nodules in beds with irregular light and dark mottled dolostone at base . . . . . . | 195 |
| Total. . . | 481 |
| Fish Haven Dolostone: | |
| 2. Dolostone, medium dark gray, weathers medium gray, medium to fine crystalline, thick bedded, contains yellowish-gray chert in beds. . . . | 30 |
| 1. Dolostone, medium dark gray, weathers medium gray, medium to fine crystalline, thick bedded, solution cavities. . . . . . . . . . . . . . | 115 |
| Total. . . | 145 |

Swan Peak Formation

## Section 4

Section measured near the left fork of Blacksmith Fork Canyon, Utah, beginning in the NE¼SW¼ sec. 2, T. 10N., R. 2E.; ending in the SE¼SW¼ sec. 35, T. 11N., R. 2E., Salt Lake base and meridian.

| | Thickness (feet) |
|---|---|
| **Laketown Dolostone:** | |
| 5. Dolostone, medium light gray, weathers light gray, medium bedded, resistant, fine crystalline, local algal laminations. . . . . . . | 201 |
| 4. Dolostone, medium light gray, weathers light gray, fine crystalline, slope former, local irregular light and dark mottled dolostone, breccia zone 100 feet above base, medium to thin bedded . . . . . . . . | 129 |
| 3. Dolostone, medium light gray, weathers light gray, fine crystalline, thin to medium bedded, chert nodules in some beds, irregular light and dark mottled dolostone at base. . . . . . . . . . . . . . . . . . . | 130 |
| Total. . . | 460 |
| **Fish Haven Dolostone:** | |
| 2. Dolostone, dark gray, weathers medium dark gray, medium to fine crystalline, cherty, thick bedded, iron staining along fractures. . . . . . . . . . . . . . . . . . . . | 40 |
| 1. Dolostone, dark gray, weathers medium dark gray, fine to medium crystalline, fractured, contains solution cavities, thick bedded . . . . . . . . . . . . . . . . . . . . . | 100 |
| Total. . . | 140 |

Swan Peak Formation

# VITA

Brent H. Mecham

Candidate for the Degree of Master of Science

Thesis: Petrography and Geochemistry of the Fish Haven Formation and Lower Part of the Laketown Formation, Bear River Range, Utah.

Major Field: Geology

Biographical Information:

Personal data: Born at Grand Junction, Colorado, June 8, 1947, son of Howard A. and Dora T. Mecham.

Education: Attended elementary school in St. Charles, Idaho; graduated from Fielding High School in 1965; received the Bachelor of Science degree from Utah State University with major in geology in 1971; did graduate work in petrography and geochemistry 1971-1973; completed requirements for Master of Science degree at Utah State University in 1973.

Professional Experience:

Teaching assistantship at Utah State University 1972-73.