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Stratigraphic comparison of the Precambrian Wyman and Johnnie Formations in the Western Great Basin, California

Johnnie Nathan Moore
University of California - Los Angeles

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UNIVERSITY OF CALIFORNIA

Los Angeles

Stratigraphic Comparison of the Precambrian Wyman and Johnnie Formations in the Western Great Basin, California

PART I: Text
Appendix I
Appendix II

A thesis submitted in partial satisfaction of the requirements for the degree Master of Science in Geology

by

Johnnie Nathan Moore

1973
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ABSTRACT OF THE THESIS
Stratigraphic Comparison of the
Precambrian Wyman and Johnnie Formations in
the Western Great Basin, California

by

Johnnie Nathan Moore

Master of Science in Geology
University of California, Los Angeles, 1973

Professor Clemens A. Nelson, Chairman

The Precambrian Johnnie Formation in the Death Valley area and to
the south is separable into two facies. The southern facies contains
six distinct members: the transitional, quartzite, lower carbonate-
bearing, siltstone, upper carbonate-bearing, and Rainstorm members.
Dolomite, quartzite, and mudstone characterize the southern facies,
as does the presence of the Johnnie oolite. To the north the Johnnie
oolite pinches out and the amount of mudstone in the formation increases.
The dominantly mudstone northern facies contains local gray limestone
lenses closely similar to limestone in the Wyman Formation in the
White-Inyo Mountains. Generally outcrops of the northern facies of the
Johnnie are indistinguishable from those of the correlative Wyman
Formation.

A significant unconformity separates the Wyman Formation from the
overlying Reed Dolomite and locally the Stirling Quartzite unconformably
rests on the Johnnie. This supports a correlation model that omits
strata in the White-Inyo Mountains equivalent to the lower Stirling and includes the Johnnie and underlying formations as equivalent to the Wyman.

A shallow sea with local reef-like areas and low-lying temporary islands in the northwestern or western areas was the site of deposition for the Johnnie and Wyman Formations. The sea covered a westward subsiding open basin or a northwestward subsiding trough.
INTRODUCTION

LOCATION AND ACCESSIBILITY

The Wyman Formation is extensively exposed in the White-Inyo Mountains of east-central California. The Johnnie Formation is exposed in the Death Valley area and to the southeast. Several localities for each of these formations were examined (Fig. I) and some were measured. All areas studied are accessible by paved or dirt roads and a walk of not more than four miles. During this study all dirt roads were passable to a small passenger car, but conditions change yearly because many roads are maintained only sporadically. Areas visited are more precisely located on the portions of U.S. Geological Survey Quadrangle Maps included in Appendix I; the appropriate quadrangle may be consulted for determination of best access to each area.

PURPOSE

The purpose of this study was to determine whether the Johnnie Formation is a correlative of the Wyman Formation and to determine the contact relationships between the Wyman Formation and Reed Dolomite. Fieldwork and petrographic analysis of samples were undertaken to establish facies changes within the Johnnie, and allow detailed comparison and correlation of the Wyman and the northern facies of the Johnnie.

FIELDWORK AND ACKNOWLEDGEMENTS

Fieldwork was undertaken on weekends and holidays from late
FIGURE I

INDEX MAPS

EXPLANATION

--- Paved road
--- Dirt road
--- County boundary
--- State boundary


Dry lake


3 □ Location of examined area or section

1- Southern Nopah Range
2- Southern Salt Spring Hills
3- Southern Black Mountains
4- Johnson-Six Springs Canyons
5- Hanaupah Canyon
6- Rogers Peak-Mahogany Flats
7- Trail Canyon
8- Aguereberry Road
9- Blackwater Wash

10- Andrews Flats
11- Jackass Flats
12- Cowhorn Valley
13- Hines Road
14- Waucoba Road
15- Soldier Canyon
16- Roberts Ridge
17- Wyman Canyon
November, 1971, through June, 1972. Previously measured sections of Johnnie Formation were examined, sampled, some remeasured and some new sections measured. Detailed study of Wyman Formation sequences emphasized the lithology. Large scale geologic maps were constructed to determine contact relationships of the Wyman and overlying Reed Dolomite. Mapping was done on the enlarged portions of U.S. Geological Survey 15 minute quadrangles which are included in Appendix II.

I am indebted to Dr. C.A. Nelson for suggesting this project and instilling in me an enthusiasm for Precambrian rocks. His guidance in fieldwork and in the preparation of this report is also appreciated. Dr. H. Loeblich and Dr. J. Sackett critically reviewed the thesis and made many valuable comments. The Geology department, University of California, Los Angeles defrayed most of the field expenses.

I also want to thank Wes Hildrith of the University of California, Berkeley for his advice regarding the Johnnie Formation in the central Panamint Range and for the use of his rented cabin in Wildrose Canyon on several occasions. The help of K. Hale in measuring two stratigraphic sections in the Johnnie is also appreciated.

I am indebted to the faculty and staff of California State University, Northridge, who made available equipment and space for petrographic studies. The National Park Service at Death Valley facilitated the study by allowing rock samples to be taken from the National Monument. Brian C. Miller of the United States Forest Service, Bishop, California deserves thanks for allowing collection of samples in the Ancient Bristlecone Pine Forest.

Lastly I wish to thank my parents who gave me financial and
logistic support during fieldwork and preparation of the report.

CLIMATE, VEGETATION AND TOPOGRAPHY

The regional climate ranges from arid to semi-arid. Death Valley and the area to the southeast is the most arid region in California, Death Valley receiving an average annual rainfall of 4.2 centimeters and has an evaporation rate of 385 centimeters per year (Hunt and Mabey, 1966, p. A3). The highest temperature ever recorded in the United States (134°F) was attained at Furnace Creek during summer of 1913. Summer temperatures generally are above 100°F but winters are relatively mild with temperatures above freezing.

Because of the low precipitation, vegetation is sparse in this region and locally is completely absent. Creosote bush and sage brush are the most common vegetation but too sparse to be of consideration in fieldwork.

The arid environment also results in a very rugged topography. Slopes are generally very steep and talus-covered. These unstable surfaces commonly obscure the outcrops and make walking frustrating.

Panamint Range

At the lower elevations of the canyons on the east flank of the Panamints the climate, vegetation and topography is like that previously discussed, but higher elevations, near the crest of the range, have considerably more precipitation; and snow normally covers Telescope Peak during the winter. Winters are colder than in Death Valley but summers are more moderate with highest temperatures below 100°F.
On the crest above 7,500 feet elevation, vegetation consists of sparse to moderate stands of pinon pine and juniper. Small stands of limber and bristlecone pine occur at the summit of the highest peaks. On gentler slopes soil and plant debris cover the bedrock.

Topography along the crest of the Panamints is rugged, although the increased precipitation has rounded the peaks and ridges. Slopes are generally very steep and covered by large talus fields.

White-Inyo Mountains

The White-Inyo Mountains lie in the rain shadow of the Sierra Nevada. Higher elevations in the area receive more precipitation than do lower elevations. Below 7,000 feet elevation sage brush cover is sparse to moderate, from 7,000 feet to 8,000 feet elevation pinon pine and juniper grow in moderate stands; limber pine and bristlecone pine are dominant above 9,000 feet to about 12,000 feet elevation, being concentrated on carbonate outcrops.

Rounded ridges and peaks dominate the topography in the area. Slopes are gentle to moderate and talus and soil minimize good exposures. The best outcrops are found along steep-sided stream canyons where soil and talus can not accumulate.

GENERAL STRUCTURAL CONSIDERATION

The southern Great Basin is an area of complex faulting and folding. Thrust faults with large displacements, mapped in the area studied (Stewart and others, 1966), may be a continuation of the Sevier Fold and Thrust Belt of Nevada and Utah (Stewart, 1970, p. 5).
Armstrong (1963, p. 10) reported 40 miles of displacement within this belt and Stewart (1970, p. 5) suggested this amount could be equaled in the southern Great Basin. Such displacement would exaggerate facies changes in the Precambrian strata in the area because sedimentary transport direction for the sediments is in the opposite direction of postulated thrusting. Two extensive strike-slip faults in the area, the Death Valley Fault and Furnace Creek Fault, are right strike-slip, but the amount of separation on these faults is controversial. Noble and Wright (1954, p. 157) have suggested 12 miles of separation, whereas 15 to 30 miles of displacement is suggested by Drewes (1963, p. 56). Stewart (1967, p. 133) regards facies and thickness changes in the Precambrian and Lower Cambrian strata as indicating a separation of 50 miles across the two fault zones. The displacement along these zones is suggested by Burchfiel (1965, p. 186) and Stewart (1967, p. 133) to be taken up by giant folds (oroflexures) to the north and south, but evidence is lacking for a southern oroflucture.

Wright and Troxel (1966 and 1967), by mapping "geologic lines" which include intersection of unconformities and lines of pinch-out of certain facies, determined a separation of less than 7 miles across the two faults, and suggest that no separation is needed to explain their patterns.

These two basic hypotheses of large separation or little or no separation on the Death Valley and Furnace Creek Fault Zones affects the interpretation of the paleogeography of the Late Precambrian strata, and will be discussed in that section.
JOHNNIE FORMATION

NOMENCLATURE AND PREVIOUS WORK

The Johnnie Formation was first described and named by Nolan (1929) for exposures along Johnnie Wash, north of Johnnie Mine, Spring Mountains, Nevada. Murphy (1932) named and briefly described the Hanaupah and Death Valley Formations in the southern Panamint Range. The Hanaupah is lithologically similar to the Johnnie Formation in the Panamint Range and is considered equivalent to it. Murphy's description of the Death Valley Formation is sketchy, but that formation is probably also equivalent, at least in part, to the Johnnie Formation. Hazzard (1937) considered rocks in the southern Nopah Range to be "...stratigraphically and lithologically comparable to the Johnnie formation of Nolan..." but identified them as "Johnnie (?)," because the large amount of quartzite, sandy shale, slate and schist that characterizes the lower three-quarters of the formation at Johnnie Wash were not present in the Nopah Range.

However, Nolan's type section is incomplete (the bottom is not exposed), and it is bounded by faults; Hazzard's section, therefore, is used as a working type section for the Johnnie Formation.

Noble (1941) used the name "Johnnie Formation" without the query because "both series of strata occupy a similar stratigraphic position beneath the Stirling Quartzite, and the beds in Hazzard's area and southern Death Valley are lithologically similar to the upper quarter of Nolan's Johnnie Formation."

Hopper (1947) measured a 1500 foot section of Johnnie Formation in the Panamint Range. He described the Johnnie Formation in the
Harrisburg-Aguereberry area as shale, slate and phyllite with subordinate limestone and dolomite.

Wheeler (1948) included the Johnnie Formation in the Nopah Range in his cross section through southern Nevada.

In the Wildrose area, Panamint Range, Lanphere (1962) described two members in the Johnnie Formation, distinguished by color and weathering characteristics. The lower member was described as a "porphyroblastic andalusite-biotite-muscovite-quartz rock" which weathered dark brown and produced massive, rubbly float. The upper member weathered greenish gray and formed slabby and slaty float of argillite.


Hunt and Mabey (1966) mapped Death Valley but added little to the internal stratigraphy of the Johnnie Formation in the area.

Stewart (1966) correlated the Johnnie from the Nopah Range and Spring Mountains to the Resting Spring Range and Echo Canyon, and suggested that the Wyman Formation in the White-Inyo Mountains in part, may be correlative to the Johnnie.

McDowell (1967) mapped three members in the Johnnie Formation in the central Panamint Range. In a measured section in Hanaupah Canyon, he described a gradational member, middle argillite member and upper limy argillite member.

In the most extensive and detailed work done on the Johnnie,
Stewart (1970) subdivided the formation into six members and correlated the Johnnie Formation across the entire southern Great Basin. He noted the difficulty of correlating the Wyman Formation to the Death Valley area but suggested that it possibly included his A, B and C members of the Stirling Quartzite and all or part of the Johnnie Formation.

The Emigrant Canyon Quadrangle is currently being mapped by Wes Hildrith of the University of California, Berkeley.

AGE

The Johnnie Formation was originally considered to be Cambrian by Nolan (1929, p. 463) and Hazzard (1937, p. 279). Noble (1941, p. 952) regarded the Johnnie Formation as lithologically more similar to Precambrian strata but nevertheless included it in the Lower Cambrian. The Johnnie currently is regarded as Precambrian (Lanphere, 1962; Barnes and others, 1965; Hunt and Mabey, 1966; Stewart, 1966; McDowell, 1967). Because the Johnnie Formation is "8,000 feet below the lowest known occurrence of olenellid trilobites or archeocyathids and 5,000 feet below the lowest known occurrence of trace fossils," Stewart (1970, p. 17) considered it Precambrian, and the present writer concurs.

DISTRIBUTION AND EXPOSURES

The present study of the Johnnie Formation is restricted to exposures in the Panamint Range, Southern Black Mountains, Nopah Range and Salt Spring Hills (Fig. I), although the formation occurs over an area of approximately 10,000 square miles in southern Great Basin (Stewart 1970). Generally, the Johnnie Formation is well exposed;
the carbonates and quartzites form resistant ledges and mudstones and shale produce slopes. Locally, talus from the more resistant strata covers large areas. The top of the formation is poorly exposed where large angular blocks of overlying Stirling Quartzite obscure the contact and the upper few meters of Johnnie Formation; similarly, where the Johnnie consists largely of slope-forming mudstone and shale, exposures are poor.

The Johnnie oolite, a prominent oolitic dolomite bed in the upper part of the formation, occurs throughout the Salt Spring Hills, Nopah Range, Southern Black Mountains and north into the Panamint Range to Johnson Canyon, providing an important tool for correlation.

LITHOLOGY AND INTERNAL STRATIGRAPHY

General Statement

A description of each Johnnie section examined, from the Southern Salt Spring Hills to Blackwater Wash, is detailed in Appendix III. All samples collected are listed, together with thin section descriptions for many of them.

In his work in the southern Great Basin, Stewart (1970) divided the Johnnie Formation in the Death Valley-Kingston Range area into six members, from bottom to top: transitional member, quartzite member, lower carbonate-bearing member, siltstone member, upper carbonate member and Rainstorm Member (Table A).

The transitional member is composed generally of rocks transitional from the underlying Noonday Dolomite to the overlying quartzite member. Where the Johnnie Formation is coarser-grained,
# TABLE A

**THICKNESS OF JOHNNIE FORMATION AND MEMBERS**

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>THICKNESS IN METERS OF MEMBERS</th>
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<tbody>
<tr>
<td>Salt Spring Hills</td>
<td>337</td>
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<td>Nopah Range</td>
<td>677</td>
</tr>
<tr>
<td>Southern Black Mountains</td>
<td>568</td>
</tr>
<tr>
<td>Johnson-Six Springs Canyon</td>
<td>547½</td>
</tr>
<tr>
<td>Hanaupah Canyon</td>
<td>699</td>
</tr>
<tr>
<td>Trail Canyon</td>
<td>*1018?</td>
</tr>
<tr>
<td>Aguereberry Road</td>
<td>*585</td>
</tr>
<tr>
<td>Blackwater Wash</td>
<td>1018</td>
</tr>
</tbody>
</table>

? - thickness questionable due to faulting

* - incomplete

( ) - thickness of strata which are possibly correlative to that member

± - thickness approximately this value
the contact between the Noonday Dolomite and the transitional member is placed at the first quartzite bed, but in the central Panamint Range the placement of the contact is less straightforward, as discussed later.

The quartzite member is composed dominantly of quartzite in the south but the amount of carbonate and mudstone increases towards the north and in the central Panamint Range the member is difficult to recognize.

The lower carbonate member is the most difficult to correlate from place to place, as it is relatively thin and in the southern area carbonate beds occur throughout the Johnnie Formation. It can usually be identified by its stratigraphic position.

The siltstone member and upper carbonate-bearing member are easily separated in the Salt Spring Hills, Nopah Range, Southern Black Mountains and Johnson-Six Springs Canyons but cannot be recognized farther north. The upper carbonate-bearing member commonly contains more quartzite and mudstone than carbonate adding to the difficulty of recognizing it in the central Panamint Range where mudstone and quartzite are dominant.

In the south the Rainstorm Member is easily distinguishable because of the presence of the Johnnie oolite. Unfortunately, the northernmost occurrence of the oolite is the Johnson-Six Springs locality; farther north separation of the Rainstorm Member is difficult as the formation is lithologically similar throughout.

Where possible Stewart's members are used and when these are unidentifiable, numbered units are used for convenience in describing
the formation. The members and numbered units serve as a means of describing the formation to determine its variation northward through the Panamint Range, but correlation of numbered units with Stewart's members are suggested (Fig. 2). A much better understanding of the relation of these units will be gained when detailed mapping of the Johnnie Formation is completed from Johnson-Six Springs Canyons northward to the limit of exposure in the central Panamint Range.

**Lower Contact with Noonday Dolomite**

In the southern Nopah Range, southern Black Mountains, Johnson-Six Springs Canyons and Hanaupah Canyon the Johnnie Formation is underlain by the Noonday Dolomite, which consists largely of medium-light-gray to very light-gray dolomite which weathers pale yellowish brown to very light gray. The Noonday contains structureless to indistinctly laminated beds 30 to 100 centimeters thick, with sandy layers \( \frac{1}{2} \) to 10 millimeters thick, in aphanocrystalline to coarsely crystalline dolomite. Sandy dolomite in the Nopah Range contains silt- to fine-grained quartz, in the southern Black Mountains and Six Springs Canyons medium- to very coarse-grained quartz and in Hanaupah Canyon very fine- to fine-grained quartz. Also in Hanaupah Canyon rounded sandy dolomite and dolomite clasts, 2 by 5 millimeters to 1 by 20 centimeters, and angular 2 by 5 millimeter argillite clasts are present locally. Sandy and conglomeratic layers are seen near the top of the formation whereas the lower part is nearly pure carbonate (dolomite in the southern areas and limestone in the northern areas). Irregular tube-shaped structures in the Noonday Formation of the Nopah Range (Plate 2) are said to resemble *Skolithus* tubes, but are of problematical origin;
TUBE-SHAPED STRUCTURES IN NOONDAY DOLOMITE, NOPAH RANGE
(Southern Nopah Range, Section 4, T. 20 N., R. 8 E., Tecopa, California 15' Quadrangle (USGS), 1950 Edition)
possibly they represent some type of burrow or may be algal in origin (Stewart, 1970, p. 15).

Farther north in the Panamint Range the Noonday Dolomite is a medium-light-gray limestone which weathers very light gray and light olive gray. In Trail Canyon limestone beds 1 to 2 meters thick are interbedded with mudstone beds \( \frac{1}{2} \) to 20 centimeters thick but the upper sandy unit is missing. In Blackwater Wash, the thinly stratified limestone with beds \( \frac{1}{2} \) to 2 centimeters, contains \( \frac{1}{2} \) to 10 millimeter thick interbeds of dolomitic sandstone.

The Noonday Dolomite conformably underlies the Johnnie Formation and is gradational with it through the upper sandy unit in all locations examined except in Trail Canyon where the two are in fault contact. Ledgy cliffs characterize exposures of the Noonday Dolomite, and in the central Panamint Range the unit is less massive and forms a more ledgy exposure.

**Southern Facies**

All of Stewart's six members of the Johnnie Formation are recognizable from Hanaupah Canyon southward. However, in Hanaupah Canyon the members are difficult to distinguish and farther north they cannot be recognized. What is here termed the southern facies includes the Johnnie Formation in these southern areas: Hanaupah Canyon, Johnson-Six Springs Canyons, southern Black Mountains, Nopah Range and southern Salt Spring Hills.
Transitional Member

In the Nopah Range and the southern Black Mountains the transitional member contains 50 percent medium-gray to yellowish-gray quartzite which weathers brown, and 50 percent medium-dark-gray to olive-gray dolomite and sandy dolomite which weather light olive gray to yellowish brown (Appendix III). Quartzite is laminated to thinly stratified and commonly cross-stratified in beds 15 to 120 centimeters thick; it is composed of subrounded to rounded, fine to very coarse grains and locally is pebbly. Dolomite in the member is structureless to irregularly laminated with algal structures in beds 15 to 150 centimeters thick. Sandy dolomite occurs in beds 10 to 100 centimeters thick and contains fine to coarse, subrounded to well rounded, quartz grains which locally form up to 80 percent of the rock. In the Black Mountains (Appendix III) the member is locally conglomeratic and contains subrounded dolomite, sandy dolomite and quartzite clasts up to 20 by 5 centimeters which are possibly transposition structures.

In Johnson-Six Springs Canyons the transitional member contains more dolomite and sandy dolomite (80 percent) and less quartzite (15 percent) and the first notable amount of mudstone (5 percent) (Appendix III). Quartzite, dolomite and sandy dolomite are as in the Nopah Range and southern Black Mountains but dolomite is locally indistinctly pisolitic. Mudstone is greenish-gray and yellowish-brown, medium silt-grained; locally mudcracks (?) and worm burrows (?) are present along bedding planes.

The amount of dolomite and sandy dolomite in Hanaupah Canyon (85 percent) (Appendix III) is similar to that in Johnson-Six Springs
Canyons but the transitional member contains only 2 percent quartzite and 13 percent argillite. Dolomite is structureless to indistinctly thinly stratified and sandy dolomite is laminated to very thinly stratified. Quartzite in the member is dominantly fine- to medium grained and laminated to thinly stratified, and locally cross-stratified. Argillite is yellowish-brown to dark-gray, locally phyllitic and clay- to silt-grained. McDowell (1967) described a gradational member in Hanaupah Canyon but the transitional member here recognized forms only the lower part of McDowell’s member.

In the southern Panamints and to the southeast, the lower contact of the transitional member with the Noonday Dolomite is placed at the first occurrence of quartzite in the section. This generally corresponds to the end of cliff-forming dolomite and the start of ledgy slopes of the transitional member. Farther north in the central Panamints these criteria are not used and the contact is placed above the last occurrence of ledgy cliff-forming limestone and interbedded mudstone of the Noonday Dolomite. (Lanphere, 1962, and Hildrith, personal communication).

The transitional member in the southern Salt Spring Hills, Nopah Range, Johnson-Six Spring Canyons and Hanaupah Canyon forms a definite ledgy slope.

**Quartzite Member**

The quartzite member in the Salt Spring Hills, Nopah Range and southern Black Mountains consists largely of quartzite with subordinate sandy dolomite and dolomite that is generally concentrated near the center of the member, and mudstone (Appendix III). Quartzite is variously
colored but is dominantly gray or yellowish-gray and weathers yellowish-brown to moderate brown. Quartzite is laminated, in beds 10 to 120 centimeters thick, thinly stratified and commonly cross-stratified and very fine-grained to pebbly. In the Salt Spring Hills the member contains 35 percent quartzite breccia, but is only locally pebbly and bouldery elsewhere. Sandy dolomite and dolomite are in beds 10 to 150 centimeters thick as in the transitional member. Cross-stratification also occurs in the laminated to thinly stratified sandy dolomite.

The amount of mudstone in the member increases to the north from none in the Salt Spring Hills, minor amount in the Nopah Range, 5 percent in the Black Mountains and 10 percent in Johnson-Six Springs Canyons. Mudstone grades from mudstone to sandy mudstone, generally occurring in beds 2 to 100 centimeters thick and in lenses within the quartzite. Contacts between mudstone and quartzite are very sharp.

The percentage of mudstone continues to increase northward and the quartzite member in Hanaupah Canyon contains 15 percent argillite, 45 percent fine- to medium-grained quartzite, which grades into quartzitic mudstone, and 20 percent dolomite (Appendix III). Quartzite is finer-grained and occurs in thinner beds (1 to 40 centimeters thick) than in the southern localities. Beds of argillite are 1 to 25 centimeters thick; dolomite beds are 25 to 100 centimeters thick. A complete gradation occurs from quartzite to argillite with sharp contacts only bounding dolomite beds. Generally the percentage and form of dolomite in the member changes little from the Salt Spring Hills to Hanaupah Canyon but the clastic rocks are finer-grained and thinner-bedded. A rather abrupt change occurs between Johnson-Six
Springs Canyons and Hanaupah Canyon.

In the Salt Spring Hills to Johnson-Six Springs Canyons the contact of the transitional and quartzite members is marked by the first occurrence of a large amount of quartzite in the section, which generally produces a ledgy cliff. In the southern locations the quartzite member forms a ledgy, clffy slope.

**Lower Carbonate-bearing Member**

Lithology and thickness of the lower carbonate-bearing member is varied in the area south of Trail Canyon (Appendix III). In the southern Salt Spring Hills, the most southern exposures examined, the member is 25 meters thick and consists of dolomite and sandy dolomite with a minor amount of mudstone, shale, and quartzite. Dolomite and sandy dolomite occurs in structureless beds 20 to 150 centimeters thick and sandy dolomite containing very fine sand grains occurs in laminated beds 20 to 60 centimeters thick. Thinly stratified to structureless light gray mudstone and shale is in sharp contact with the carbonates. Yellow-ish-gray, very fine- to fine-grained quartzite in laminated beds 10 to 40 centimeters thick also is present in the member.

In the Nopah Range the member is about one-third as thick as in the Salt Spring Hills and contains less carbonate. Forty percent of the member is medium-gray dolomite in structureless beds 15 to 30 centimeters thick. The remainder is composed of yellow-brown to gray-ish-orange sandstone, mudstone and shale in beds 5 to 20 centimeters thick. As these are identical to units in the overlying siltstone member, recognition of the member is difficult.
Farther north in the southern Black Mountains the lower carbonate-bearing member is 17 meters thick and lithologically different from that at either of the previously discussed areas. It consists of 50 percent medium-gray dolomite and sandy dolomite which is laminated in beds 25 to 300 centimeters thick. Sandy dolomite contains medium to very coarse sand grains and is locally cross-stratified. The remainder of the member is yellowish-gray to pinkish-gray, medium- to coarse-grained quartzite in beds 10 to 30 centimeters thick, locally cross-stratified and ripple-marked.

In Johnson-Six Springs Canyons the member is represented by a 2½ meter thick medium-gray dolomite bed which forms a distinctive ledge above the quartzite member.

The lower carbonate-bearing member in Hanaupah Canyon is 5½ meters thick and consists of 70 percent medium-dark gray dolomite, 23 percent greenish-gray phyllite and 7 percent medium-gray limestone. All lithologies occur in laminated to thinly stratified beds 2 to 35 centimeters thick.

Throughout the southern region the member is generally poorly to moderately exposed as a ledgy slope with carbonate forming the ledges. The bottom of the member is usually marked by dolomite forming a distinct steep ledgy slope. The top contact is marked by the slope-forming mudstone of the siltstone member.

**Siltstone Member**

The Siltstone Member in the southern Salt Spring Hills is from 38 to 86 meters thick (Appendix III), and composed of thinly stratified
gray mudstone grading into very fine- to fine-grained light gray laminated quartzite with beds 2 to 100 centimeters thick. A minor amount of grayish-orange dolomite forms structureless beds 10 to 25 centimeters thick; locally it is limy and sandy.

In the Nopah Range and to the north the member thickens (Table A) and is composed of 90 percent yellowish-brown to grayish-orange mudstone, shale and sandstone, 5 percent yellowish-brown sandy dolomite and 5 percent yellowish-brown quartzite. Mudstone and shale in beds 5 to 20 centimeters thick are gradational with very fine-grained sandstone. Quartzite is very fine- to medium-grained in beds 5 to 20 centimeters thick; sandy dolomite in platy beds 5 to 20 centimeters thick contains very fine to medium sand grains in a dolomite matrix.

The siltstone member where examined in the southern Black Mountains contains 30 percent pale-red sandy limestone, but otherwise is like equivalent rocks exposed in the Nopah Range. Sixty percent of the member is a greenish-gray to grayish-red mudstone and very fine-grained sandstone interbedded with sandy limestone, 5 percent consists of gray dolomite and sandy dolomite in laminated to structureless beds 15 to 20 centimeters thick and the remaining 5 percent is a yellowish-brown to grayish-red, very fine-grained, platy quartzite.

In Johnson-Six Springs Canyons the member is mudstone and very fine- to fine-grained sandstone as in the Nopah Range. The two lithologies are generally gradational through sandy mudstone. Mudstone occurs in beds 2 to 100 centimeters thick interlayered with laminated and minor cross-stratified sandstone.

The siltstone member and upper carbonate-bearing member are not
separable in Hanaupah Canyon, and together contain dominantly greenish-gray, indistinctly laminated phyllite and hornfels with about 10 percent greenish-gray, very fine-grained, silty quartzite.

Throughout the areas examined the siltstone member is exposed as a platy slope with thicker ledge-forming beds of quartzite and dolomite. The member is gradational with the lower and upper carbonate-bearing members through mudstone within those members. The bottom contact is placed above the last occurrence of abundant carbonate. The top contact is similarly placed below the first occurrence of carbonate.

Upper Carbonate-bearing Member

The upper carbonate-bearing member in the southern Salt Spring Hills is distinguished from the underlying siltstone member mostly by the change to a dominantly quartzite unit with dolomite concentrated in the lower and upper part. The member is composed of 15 percent gray dolomite in laminated to structureless beds about 30 centimeters thick, 15 percent yellowish-gray mudstone in thinly stratified beds 10 to 60 centimeters thick and 70 percent pale-red to yellowish-gray quartzite in laminated and cross-stratified beds 10 to 80 centimeters thick.

In the southern Nopah Range the member is much thicker than in the Salt Spring Hills (Table A) and contains less quartzite. It consists of 45 percent light-gray, fine- to medium-grained quartzite, 45 percent orangish-pink sandy dolomite and 10 percent grayish-orange dolomite. All lithologies occur in beds generally 10 to 100 centimeters thick. A minor amount of gray sandstone and mudstone is present.

Percentage of mudstone (20 percent) in the member is much higher
in the southern Black Mountains than in the Nopah Range, the amount of quartzite (48 percent) remaining about the same. Quartzite is commonly dolomitic and platy, is thinly interlayered with mudstone throughout the unit, and only occurs as distinct individual beds in the upper half of the member.

In Johnson-Six Springs Canyons the member contains 50 percent dolomite and sandy dolomite, 35 percent quartzite, 10 percent mudstone to sandstone and 5 percent dolomitic and limy sandstone, thus being very similar to its composition in the Black Mountains. One apparent difference is in the bedding. In Johnson-Six Springs Canyons beds are generally irregularly and thinly laminated (\(\frac{1}{2}\) to 1 millimeter) and from 1 to 50 centimeters thick, but in the southern Black Mountains they are 15 to 100 centimeters thick and evenly laminated to thinly stratified.

The upper carbonate-bearing member is exposed as a ledgy slope wherever examined. Its lower contact is placed at the first occurrence of carbonate and quartzite above the siltstone member. The upper contact is placed above the last carbonate bed before the sandstone of the lower Rainstorm Member. This contact is fairly easy to recognize because of its relation to the Johnnie oolite.

**Rainstorm Member**

The Rainstorm Member in the southern Salt Spring Hills, Nopah Range, southern Black Mountains and Johnson-Six Springs Canyons is characterized by a very pale-orange oolitic dolomite bed (Johnnie oolite) in its lower part. The member is composed dominantly of
mudstone gradational with sandstone and quartzite (Appendix III). Mudstone to sandstone is generally grayish-red to greenish-gray or yellow-brown and is laminated to thinly stratified. From south to north the amount as well as thickness of individual beds of quartzite and sandstone decreases, and the grain size of sandstone also decreases northward.

In the southern Salt Spring Hills the member is 95 percent quartzite to dolomitic quartzite, mudstone and shale. Quartzite and dolomitic quartzite are laminated less than 1 millimeter, very fine-grained and interbedded with mudstone. The two are gradational through silty quartzite. One bed of dolomite 2 meters thick is exposed 5 meters from the base of the member. The bed is structureless to oolitic and is in sharp contact with mudstone above and below.

The section in the Nopah Range is very similar to that in the southern Salt Spring Hills but above the oolite bed a unit of pale-red-purple silty to very fine-grained sandy limestone is exposed. The limestone is laminated with 1 to 5 millimeter thick silty and sandy layers, and is gradational with mudstone. The very well formed ooliths comprise about 75 percent of the Johnnie oolite in the Nopah Range. The basal 30 centimeters of the bed contains subangular to subrounded clasts of dolomite.

As in the two localities to the south the oolite in the southern Black Mountains is about 2 meters thick, but the bed does not contain a basal breccia. The Rainstorm Member also contains more silty limestone (10 percent) interlayered with mudstone in beds 2 to 10 centimeters thick. In addition to the oolite and sandy dolomite,
thin dolomite beds occur within the member in the southern Black Mountains.

In Johnson-Six Springs Canyons the member contains about the same amount of pale-red limestone interbedded with mudstone but there is more pale-red limy mudstone. Limy mudstone is irregularly ripple-laminated and dragmarks (?), trails (?) and ripple-marks are common on bedding planes. The dominant mudstone grades into very fine-grained sandstone. The Johnnie oolite is about 1 meter thick and forms a re-entrant in steep cliffs of very resistant mudstone. Dolomite breccia present at the base of the oolite is laminated and interlayered with structureless dolomite layers 5 to 10 centimeters thick.

Absence of the oolitic dolomite bed in Hanaupah Canyon hampers identification of the Rainstorm Member. The member is composed dominantly of gray phyllitic argillite with thin irregular interlayers of very fine- to medium-grained quartzite, very fine-grained sandstone and mudstone. Six percent of the member is pale-red limestone, and sandy dolomite in beds 2 to 4 centimeters thick interlayered with phyllitic argillite (Appendix III). All lithologies are gradational and occur in beds 1 to 25 centimeters thick. In approximately the stratigraphic position of the oolite bed a unit of conglomerate is exposed with beds 2 to 200 centimeters thick interbedded with phyllite. The conglomerate contains clasts of limestone and phyllite.

In Hanaupah Canyon the member forms a ledgy slope, whereas cliffy slopes dominate in Johnson-Six Springs Canyons, and at all locations to the south it is poorly exposed as a slope with the oolite bed forming a prominent ledge near the base. The overlying Stirling
Quartzite is in sharp contact with the Rainstorm Member and is marked by ledgy cliff-forming quartzite.

**Northern Facies**

In Trail Canyon and to the north Stewart's members are not recognizable in the Johnnie Formation. In these northern sections (Trail Canyon, Aguereberry Road and Blackwater Wash), mudstone is dominant, with a silty limestone forming the only traceable unit. Numbered units are used in the columns (Appendix III) to describe the sections at each location (Fig. II).

Units T1, A1, B1-B2-B3

The lowest unit in Trail Canyon (T1) is quite different from the lowest part of the formation to the south. The section is incomplete but probably nearly all of it is present. Mudstone and shale form 85 percent of the unit with the remaining 15 percent composed of limestone and sandy limestone (Appendix III).

Mudstone is light-colored to dark-gray and occurs in beds 4 to 15 centimeters thick. Irregular laminae of coarse silt are present in the gray mudstone which occurs in the lower and upper part of unit T1. Light-colored mudstone generally is structureless and dominates the central part of the member. In its lower 18 meters the unit contains gray limestone in beds 1 to 10 centimeters thick interbedded with gray mudstone. Laminae of sandy limestone 3 to 5 millimeters thick are present in the limestone. Limestone near the top of the member forms structureless beds 2 to 3 meters thick interbedded with gray shale beds.
FIGURE II

POSSIBLE CORRELATION OF STEWART'S (1970) MEMBERS OF THE SOUTHERN FACIES WITH NUMBERED UNITS OF THE NORTHERN FACIES USED IN THIS REPORT.
1 to 2 meters thick.

In exposures along Aguereberry Road unit Al is probably equivalent to units T1 and T2 in Trail Canyon (Fig. II). Limestone beds like those at the top of unit T1 are exposed in the middle of unit Al and probably are equivalent.

Above and below the limestone at Aguereberry Road are identical greenish-gray to medium-dark-gray mudstones, that are structureless to laminated, composed of coarse silt grains and commonly phyllitic to slaty. The unit is exposed in slopes covered with angular, elongate and platy to slabby talus. Limestone occurs as 1 to 1½ meter thick beds which are thinly interstratified with 0.1 to 10 centimeter thick silty and "pure" limestone layers. Stretched limestone clasts (?) and indistinct ooliths (?) occur in the limestone. Limestone beds grade into mudstone through 30 to 50 centimeter thick beds of thinly stratified silty limestone, that weather yellowish brown. Limonite pseudomorphs after pyrite occur throughout the entire unit and locally in the mudstone form euhedral cubes up to 1 centimeter on a side.

In the section on Blackwater Wash, correlation is largely based on stratigraphic position of the units as compared to the Trail Canyon section. Units B1, B2 and B3 in Blackwater Wash are considered to be equivalent to unit T1 in Trail Canyon and the lower part of Al at Aguereberry Road, even though these units are considerably thicker (510 meters) here than at the other localities.

Unit B1 is composed of 50 percent phyllite and schist (in a zone near the bottom of the section), 40 percent dominantly medium-dark-gray
mudstone with minor light-colored mudstone and 10 percent sandy
dolomite, dolomite, quartzite and limestone breccia (Appendix III).
Limestone breccia is concentrated in the basal 13 meters of the unit
and the carbonates decrease towards the top of the unit. Unit B2 is
mostly a light-colored to gray mudstone with minor sandstone and
dolomitic sandstone. Gray mudstone is laminated and locally phyllitic;
the light-colored structureless to platy mudstone is present mainly in
the lower half of the unit. Unit B3 is gray silty and sandy limestone
in beds about 1 meter thick interbedded with platy, silty limestone
and limy mudstone. Unit B3 is analogous to the interbedded limestone
and shale unit at the top of unit T1.

Even though the contacts are placed differently in various
locations (see transitional member) the boundaries of the Noonday
Dolomite are probably fairly consistent from Johnson-Six Springs
Canyons northward to Blackwater Wash. The change in criteria for
locating the upper contact corresponds to a change in the lithology of
the overlying Johnnie Formation. Possibly the lowest part of Stewart's
transitional member in Hanaupah Canyon is equivalent to Noonday
Dolomite. This would then correspond to what Lanphere (1962) and
Hildrith (personal communication) map as Noonday and what is considered
in this report as Noonday farther north in the Panamint Range.

Also, the section measured by Stewart (1970, p. 103 to 105) at
Rogers Peak and correlated to the Johnnie Formation is regarded here
as mostly Noonday Dolomite, conformably overlying the Kingston Peak
Formation. Lanphere (1962) mapped this section as Noonday and
Hildrith (personal communication) considers it Noonday. The outcrop
pattern of this unit is easily distinguishable in the Wildrose-Rogers Peak area and generally conforms to overlying and underlying strata. It is traceable to the north where it thins considerably near Aguereberry Road probably due to structural deformation (Hildrith, personal communication).

To the north in Trail Canyon, Aguereberry Road and Blackwater Wash the lower units of the Johnnie Formation form a platy slope with only minor ledge-forming rocks; they are difficult to distinguish from other units higher in the Johnnie Formation.

Units T2, Top of Al and B4

These units, correlatives of the Quartzite Member, show the northward trend to dominant mudstone in the Johnnie as in the transitional member. In Trail Canyon unit T2 is composed of dark-gray mudstone to argillite containing irregular and discontinuous interlayers of quartzite and sandstone. Sandstone and quartzite are very fine-grained and silty, and rocks in the entire unit are laminated to thinly stratified. This unit is much different from the upper part of Al at Aguereberry Road but is here correlated with it because of its relation to the limestone beds in T1. Unit T2 probably also is correlative to the quartzite member in the southern facies and T1 to the transitional member.

As strata above and below the limestone beds at Aguereberry Road are identical, they combined in unit Al. This previously discussed unit contains no quartzite. In Blackwater Wash, unit B4 is probably a correlative of the upper part of Al and T2. B4 contains about 30
percent quartzite and 70 percent mudstone. Mudstone is dark gray and weathers moderate brown and is laminated to thinly stratified. Very fine-grained quartzite occurs as laminated interbeds 1 to 5 centimeters thick within the mudstone, and one bed of laminated to thinly stratified sandy limestone 1 meter thick occurs near the base of the member. Contacts between mudstone and quartzite are gradational as in Trail Canyon.

All the rocks below the silty limestone unit of the Johnnie Formation in the central Panamint Range form poorly exposed slopes. The best exposures occur along steeply cut stream canyons, as in Blackwater Wash and along Aguereberry Road.

**Silty Limestone-Limy Mudstone Unit**

A distinct addition to the Johnnie Formation occurs in the northern facies that is not present in Hanaupah Canyon. Unit T3, here called the silty limestone-limy mudstone unit is 27 meters thick and composed of 40 percent grayish-orange-pink, limy mudstone which weathers light brown, and 60 percent greenish-gray mudstone. Limy mudstone locally grades into silty limestone, is thinly stratified and interlayered with very fine sandy layers 2 to 5 millimeters thick in beds about 50 centimeters thick which are locally cross-stratified. Mudstone is dominant in subunits 4 to 6 meters thick that are interlayered with laminated and thinly stratified to structureless greenish-gray mudstone. This unit forms a distinctive orangish and greenish ledgey slope that can be traced several hundred meters north from Trail Canyon. Possibly Stewart's lower carbonate-bearing member is
equivalent to the silty limestone-limy mudstone unit but they are lithologically dissimilar, and may not represent the same stratigraphic position, especially at Aguereberry Road and Blackwater Wash where the present unit is very high in the section.

Along Aguereberry Road unit A2 forms the same distinctive ledge slope but contains 80 percent grayish-orange-pink silty limestone to limy mudstone and 20 percent greenish-gray mudstone. Lithologically the unit is almost identical to unit T3 as described in Trail Canyon but contains much more silty limestone. The member is about 75 meters thick although many small folds and faults make this very uncertain.

Unit B5 of the Johnnie Formation in the Blackwater Wash section is composed of grayish-orange-pink silty and sandy limestone interlayered in beds 1 to 10 centimeters thick and rarely up to 10 to 20 centimeters thick. Sandy limestone contains very fine to fine sand grains with a minor amount of medium sized sand grains. The unit contains no green mudstone but is clearly lithologically similar to the silty limestone-limy mudstone unit as described in Trail Canyon and along Aguereberry Road.

The silty limestone-limy mudstone unit is characterized by sharp contacts. It invariably forms a ledge slope on the exposure that cannot be mistaken for any other unit in the northern facies of the Johnnie.

Even though incomplete (Appendix III), the Johnnie Formation is much thicker in Trail Canyon than along Aguereberry Road (a complete thickness of about 760 meters is calculated from a cross section construction along the section at Aguereberry Road [Hunt and Mabey, 1966,
Plate 1). To the north, the thickness of the silty limestone-limy mudstone unit (Fig. II) decreases. However, it is probable that unit T4 (above the silty limestone-limy mudstone unit in Trail Canyon) is too thick due to repetition of strata, and the decrease to the north is exaggerated.

Units T4, A3 and B6

Unit T4 in Trail Canyon is composed of light-olive gray to greenish-gray mudstone to argillite in beds 1 to 10 centimeters thick, interlayered with laminae 1 to 4 millimeters thick and beds 2 to 30 centimeters thick of fine-grained quartzite and sandstone. The unit forms a platy to blocky slope and is generally poorly to moderately exposed. All lithologies are gradational with very few distinct beds. The measured thickness is probably exaggerated by faulting.

Along Aguereberry Road unit A3 is in the same stratigraphic position as T4, above the silty limestone-limy mudstone unit, but is dominantly greenish-gray laminated mudstone and shale that locally are phyllitic. About 50 meters from the base of the member occurs a one meter thick bed of silty limestone, as in unit A2. Unit A3 is poorly exposed as rounded hills and slopes.

In Blackwater Wash unit B6 is probably, in part or wholly, equivalent to units A3 and T4. It lithologically resembles unit T4 in Trail Canyon where it is dominantly greenish-gray mudstone and shale with laminae of very fine-grained quartzite. In the upper 15 meters of the unit are several 50 centimeter-thick beds of grayish-red-purple dolomite interbedded with shale. The dolomite is exposed as a distinctive ledgy
slope just below the contact with the Stirling Quartzite. The contact is sharp but is mostly covered by blocky talus from the overlying Stirling.

Units T5 and A4

The last unit in the section at Trail Canyon, unit T5, is composed of about equal amounts of gray mudstone to argillite and interlayered quartzite to sandstone. Mudstone is laminated, in beds 5 to 30 centimeters thick, and sandstone and quartzite layers are 1 to 2 centimeters thick. At the base of T5 a lens of light-gray structureless to laminated limestone with very fine-grained sandy layers is exposed (Plate 3). Yellowish-brown weathering, laminated sandy limestone separates the gray limestone from overlying and underlying mudstone. Both lithologies are exposed in a lens approximately 3 by 5 meters which locally contains subrounded to rounded clasts of limestone and sandy limestone up to 30 by 40 centimeters (Plate 4). Wherever the lenses are exposed they are gradational with surrounding mudstone through sandy limestone. Possibly this conglomeratic lens is equivalent to the conglomerate in the basal Rainstorm Member in Hanaupah Canyon which would support the suggested correlation of Figure II.

The 7 meters above the limestone lens contain grayish-orange-pink limy sandy mudstone in beds about 50 centimeters thick. The beds are thinly stratified, locally cross-stratified and grade into silty limestone. Unit T5 is poorly exposed as a platy slope, becoming cliffy near the top of the formation, with the lower carbonate-rich portion forming a ledgy slope.
PLATE 3

LIMESTONE LENS EXPOSED ALONG SOUTH FORK
OF TRAIL CANYON

(Section 1, T. 19 S., R. 45 E., Emigrant
Canyon, California 15' Quadrangle (USGS)
1952 edition)
PLATE 4
LIMESTONE CLASTS WITHIN JOHNNIE LIMESTONE LENS,
TRAIL CANYON
(Section 1, T. 19 S., R. 45 E., Emigrant Canyon,
California 15' Quadrangle (USGS), 1952 edition)
At the base of the last unit in the formation at Aguereberry Road, unit A4, a limestone lens similar to that in Trail Canyon, is exposed. The lens is about 3 by 20 meters and is composed of gray laminated limestone surrounded by grayish-orange laminated silty limestone. This unit may be equivalent to the limestone lens in Trail Canyon but because of their local extents the correlation is uncertain.

The Aguereberry Road section mudstone is locally phyllitic and slaty and the upper 100 meters is very platy. The top 3 meters of the unit is composed of variegated (red and white) shale and mudstone. Poorly exposed as a thinly platy saddle below the Stirling Quartzite, the shale forms a subtle pinkish band, but is commonly covered by blocky talus from above.

Unit A4 is indistinguishable from the underlying unit A3 and can be recognized only by the lower limestone lens or the upper variegated shale. The unit forms a poorly exposed, platy slope and is in sharp contact with the overlying Stirling Quartzite.

Upper Contact of the Johnnie Formation with the Stirling Quartzite

The Stirling Quartzite that overlies the Johnnie Formation was named by Nolan (1929, p. 463) and in the southern Great Basin contains five members, A through E from bottom to top (Stewart 1966, p. C 70). The Stirling is largely a light-colored quartzite, locally conglomeratic. To the northwest the formation is much thicker and contains more carbonate and silty strata. Stewart has correlated the upper part of the Stirling to the Reed Dolomite in the White-Inyo Mountains and the lower part is possibly correlated to the Wyman Formation. In all localities
examined the Stirling is composed dominantly of quartzite with pebbly conglomerate common near the base, and is in sharp contact with the Johnnie Formation.
The Johnnie Formation generally thickens to the north (Table A) in the area examined. However, thickness trends are difficult to determine because of the incompleteness of some sections (Trail Canyon, Aguereberry Road), the uncertainty of the thickness (Trail Canyon) and the uncertainty as to the contacts of the Johnnie Formation (Hanaupah Canyon). Members in the southern facies do not show any thickness trends, other than the northward increase of the Rainstorm Member.

The most obvious change in the formation to the north is the increase in percentage of mudrocks, and decrease in quartzite, dolomite and sandy dolomite (Table B). In the southern facies the increase in percentage of mudrocks is very slight to Johnson-Six Springs Canyons, but the amount of mudstone to sandstone also increases to the north. In Hanaupah Canyon the change is quite apparent and the formation is dominated by mudrocks. Mudrocks in the southern facies are generally concentrated in the siltstone member and Rainstorm Member, but in Hanaupah Canyon they occur throughout the section.

The decrease in quartzite is substantial to the north, and its mode of occurrence is different in the northern and southern facies. In the southern facies quartzite forms distinct, sharp-bounded beds and gradational interbeds; in the northern facies distinct beds do not occur and nearly all the quartzite is in thin gradational interbeds within the mudrocks.

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<td>Dolomite</td>
<td>12%</td>
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<td>18%</td>
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<td>Sandy dolomite</td>
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<td>Limestone-</td>
<td>1%</td>
<td>7%</td>
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<td>Silty &amp; Sandy</td>
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*(inc.)*-incomplete section
the southern facies, but would decrease in Hanaupah Canyon if the lowest portion of the Johnnie Formation there is considered Noonday. Sandy dolomite and dolomite are replaced in the northern facies by sandy limestone and limestone beds.

Hanaupah Canyon contains strata transitional between the typical southern facies, characterized by ledgy exposures of quartzitic dolomite and sandy dolomite with some mudrocks, and the northern facies, composed dominantly of slope-forming mudstone and argillite. The Hanaupah Canyon section is considered as part of the southern facies because Stewart's six members can be recognized.

Thickness of beds in the formation also decreases northward and Hanaupah Canyon is again a transitional area. To the south of Hanaupah Canyon beds generally are from 20 to 150 centimeters thick except in the dominantly mudstone and argillite members. In Hanaupah Canyon all lithologies occur in much thinner beds, 1 to 40 centimeters thick and generally about 5 centimeters thick with only a small number of thicker beds.

The northern facies contains beds generally from 1 to 20 centimeters thick and dominantly about 1 to 10 centimeters thick. Most of the mudrocks contain laminae of quartzite and sandstone less than 1 millimeter to 5 millimeters thick and generally about 1 to 2 centimeters apart, with gray limestone forming the only beds thicker than 20 centimeters.

The Johnnie Formation is also very thinly bedded in the Rogers Peak-Mahogany Flat area. The formation has been metamorphosed and the dominant lithology is banded interlayered very fine yellow-gray
quartzite and hornfels. The rock is very well indurated and is poorly exposed as platy and blocky slopes. Quartzite occurs as discontinuous layers $\frac{1}{2}$ to 3 centimeters thick separated by hornfels of about the same thickness.

Gray limestone lenses are found only in the northern facies and their first occurrence is in Trail Canyon. They are exposed in the measured section (Appendix I) and also along the south fork of Trail Canyon (Plate 3).

Another characteristic northward change in the Johnnie Formation is the decrease in grain size of the coarser clastic rocks. In the southern localities quartzite is generally fine- to coarse-grained and commonly pebbly. In the northern localities quartzite is very fine- to fine-grained and dominantly very fine-grained. There are no conglomeratic quartzites or sandstones and only limestone lenses contain conglomerate.

The limy mudstone-silty limestone unit of the northern facies is also first exposed in Trail Canyon. This unit increases in thickness to the north and the amount of interlayered greenish-gray mudstone decreases. Grain size of the rock increases to the north as does the amount of limestone. In Trail Canyon the unit is dominantly limy mudstone and in Blackwater Wash dominantly silty and sandy limestone.

The lower contact of the Johnnie Formation with the Noonday Dolomite is gradational through sandy dolomite in the southern facies and silty and sandy limestone in the northern facies. The contact is conformable throughout the southern Great Basin (Stewart, 1970, p. 17).

Stewart considered that the Johnnie generally conformably underlay
the Stirling Quartzite. In the Salt Spring Hills, Silurian Hills and Silver Lake he regarded the contact as unconformable because of the absence of the upper unit of the Rainstorm Member (Stewart, 1970, p. 17, and 31). In the Aguereberry Road section and in exposures of Johnnie at Mahogany Flat a variegated mudstone and shale unit occurs just below the Stirling Quartzite. This unit is not present at the Stirling-Johnnie contact in Trail Canyon and Blackwater Wash; possibly an unconformity separates the two formations. A local unconformity would also help explain the decrease in thickness of strata above the limy mudstone-silty limestone unit from Aguereberry Road to Blackwater Wash. But the actual relation of this unit to the Stirling can only be known when detailed mapping of the Johnnie Formation in the area north of Blackwater Wash is completed.

In summary, there are seven major regional changes from south to north in the Johnnie Formation:

1) Increase in total thickness.
2) Increase in the percentage of mudrock (mudstone, shale, argillite and phyllite).
3) Decrease in the amount of quartzite, sandy dolomite and dolomite.
4) Decrease in thickness of beds.
5) Decrease in grain size of quartzite and sandstone.
6) Appearance of gray limestone lenses in Trail Canyon and Aguereberry Road.
7) Possible local unconformable contacts between the Johnnie and overlying Stirling in southern and northern localities.
In their reconnaissance of the Inyo Range, Knopf and Kirk (1918, p. 23) described strata which were later named the Wyman and Roberts Formations by Maxon (1934, p. 314). The Wyman Formation, as described by Maxon in Wyman Canyon, unconformably overlies the Roberts Formation which contains less carbonate-bearing rocks. The McAffe series described by Fiedler (1937) is equivalent to the Wyman as now recognized. Nelson (1962, p. 140) by detailed mapping in the White-Inyo Mountains showed that no unconformity exists between the Roberts and Wyman Formations and that a formational division can not be distinguished throughout the area. He redefined the Wyman to include both Maxon's formations. Dorsey (1960) described the Squaw Peak Formation in the Marble Canyon area, which also is considered Wyman by Nelson (1971). The Wyman was included in Albers' and Stewart's (1962) and McKee and Moiola's (1962) work in Esmeralda County, Nevada. The Wyman is included in U.S. Geological Survey Geological Quadrangle Maps of Blanco Mountain (Nelson, 1966a), Waucoba Mountain (Nelson, 1966b) and Waucoba Spring (Nelson, 1971).

Nelson (1962) considered the Wyman Formation to be Precambrian because it is more than 4,000 feet below the oldest trilobite faunas in the area and underlies an unconformity. The overlying Reed Formation, Deep Spring Formation and lower part of the Campito
Formation were regarded as Cambrian. Cloud and Nelson (1966) moved the Cambrian boundary below the Reed Dolomite but still considered the Wyman as Precambrian. The Wyman is here considered to be Precambrian because it lies well below all substantiated lower Cambrian Faunal zones and below questionable Cambrian rocks.

**DISTRIBUTION AND EXPOSURE**

Study of the Wyman Formation in this report is restricted to exposures in the White-Inyo Mountains, California. About sixty-two square miles of the formation are exposed in this area; the formation is also exposed in Esmeralda County, Nevada (Stewart, 1970, p. 52). In most areas the Wyman is poorly exposed in rounded hills and slopes, but it is generally well exposed in steep-walled stream canyons. Gray limestone units within the formation are generally better exposed as rounded ledgy steep slopes. The upper contact of the formation is commonly obscured by large talus blocks from the overlying Reed Dolomite, and its lower contact is nowhere exposed.

**LITHOLOGY**

**General Statement**

Although the base of the Wyman Formation is not exposed, the formation has a reported minimum thickness of about 2750 meters (Nelson, 1962, p. 140). The formation is dominantly dark-gray argillite, mudstone, quartzite and sandstone, commonly phyllitic and slaty in thin beds with interbedded gray limestone lenses and beds throughout. All lithologies are intergradational. Three partial sections of the Wyman
were measured and described in detail (see Appendix III). The contact between the Wyman and the Reed also was examined in several localities to determine relationships between the two formation.

The Wyman contains no units traceable throughout the White-Inyo Mountains but many of the gray limestone units are locally mappable and can be traced for one or two miles. In detail the Wyman is very heterogeneous but has an overall homogeneous appearance because of the absence of persistent distinctive units.

Primary structures are rare within the Wyman Formation but poor ripple marks, cross-bedding and transposition structures are present locally. South of Hines Road worm (?) trails have been reported on bedding planes within the Wyman by G. Langille of the State University of New York, Binghamton, New York, (S. Alpert, personal communication) but none were seen in any of the areas examined for this report. Pittman (1958, p. 21) reported mudcracks and ripple marks in the Wyman in the Blanco Mountain Quadrangle.

Andrews Flat

The flat area east of Andrews Mountain is here referred to as Andrews Flat. An 1854 meter thick incomplete section of the Wyman Formation was measured along the canyon draining east from Andrews Flats to Marble Canyon (Plate 19). The strata form the west limb of a large northwest trending anticline (Nelson, 1966b), and are generally well exposed along the canyon. The section is divided into nine units for descriptive purposes only, as the rocks are identical from unit to unit and only the percentage of each type changes. The lithology is
dominated by medium-dark-gray argillite and mudstone, which weathers medium light gray to moderate brown. Argillite and mudstone are laminated to structureless in beds usually \( \frac{1}{2} \) to 8 centimeters thick and very rarely up to 70 centimeters thick (Units 3 and 6). Interbedded with argillite and mudstone are irregular beds of \( \frac{1}{2} \) to 5 centimeters of silty, very fine-grained light-gray sandstone and quartzite. A 3 meter thick unit of sandstone and quartzite in beds 5 to 20 centimeters thick is interlayered with mudstone about 140 meters above the base of unit 5. These are the coarsest-grained and thickest sandstone and quartzite beds seen in the section and occur only at this location. Sandstone, quartzite, mudstone and argillite are commonly limy and grade into sandy limestone. Sandy limestone is light-gray and weathers olive gray to yellowish brown, in irregular beds \( \frac{1}{2} \) to 10 centimeters thick, interlayered with mudstone, argillite and limestone. Sandy limestone contains fine sand grains and commonly is silty. All these lithologies are intergradational and commonly are difficult to differentiate. Medium-dark-gray limestone is also interbedded with the other lithologies but forms beds \( \frac{1}{2} \) to 12 meters thick. Limestone is laminated to structureless and commonly is fissile and platy. Locally the limestone contains limestone clasts and ellipsoidal medium-gray oncoliths up to 3 by 5 centimeters. Limestone is generally interlayered and gradational with sandy limestone, mudstone and argillite, and forms rounded knobby slopes. Limestone beds and units are not persistent laterally and the thinner beds generally pinch out within a few meters.

The unit above unit 9 in this section consists entirely of light-gray, massive, very coarsely crystalline dolomite, and is considered
herein to be Reed Dolomite as it is identical to the Reed elsewhere. Nelson (1966b) mapped this unit as dolomitized Wyman limestone because the limestone units are dolomitized elsewhere (Dorsey, 1960, p. 21-27), and the unit at Andrews Flat possibly is equivalent to a limestone unit to the north (Nelson, personal communication).

**Hines Road**

Northwest of Hines Road (Plate 11) a small incomplete section of Wyman (Appendix III) is dominantly argillite and mudstone, with lithologies almost identical with those in Andrews Flats. However, in the upper part of the section the bedding planes show discontinuous ripple marks (?) with about \( \frac{1}{2} \) centimeter relief and 12 to 15 centimeter wavelength. The unit becomes sandier upward and at the contact with the Reed several cross-stratified beds of sandstone and quartzite 10 to 40 centimeters thick are exposed. Sandstone and quartzite are laminated and grade laterally into thin beds of sandy mudstone.

One massive gray limestone unit 24 meters thick is exposed near the bottom of the section. The unit contains many secondary calcite veins and is irregularly laminated with white limestone, but does not contain oncoliths as described from the Andrews Flat section.

Above and below the limestone, the unit is composed of interbedded argillite, mudstone, quartzite, sandstone, limestone and sandy limestone in beds dominantly 5 to 10 centimeters thick, and generally laminated, thinly stratified and intergradational. The unit contains erosional channels, small internal folds, ripple laminae (?) and transposition structures in several locations. The lower part of the section is well
exposed in an arroyo but the upper part is poorly to moderately exposed on a rounded ridge.

Cowhorn Valley

On the east side of Cowhorn Valley a small imcomplete section of Wyman Formation is well exposed (Plate 19, Appendix I, Plate 5). The section contains thickly interbedded argillite, limy sandstone, quartzite limestone and sandy limestone all of which are gradational in beds generally 1 to 50 centimeters thick. Sandy limestone, limy sandstone and quartzite are pale-yellowish brown to very light-gray and contain fine to medium-dark-gray to black laminated argillite and very fine-grained quartzite; locally they are cross-stratified and form channels in underlying argillite and quartzite. A unit of fine- to medium-grained quartzite in structureless to laminated beds 20 to 100 centimeters thick, and exposed just below the Reed Dolomite, was seen only in the Cowhorn Valley section and is not known to be present elsewhere in the Wyman. The upper part of the measured section contains light-gray limestone similar to that exposed in the Andrews Flats and Hines Road sections. The laminated to structureless limestone commonly interlayered with argillite and quartzite, and sheared and locally nearly foliated. Locally the limestone contains very fine to fine sand grains. In outcrop the limestone is identical to those previously described, as are the other lithologies in the Cowhorn Valley section.
PLATE 5

WYMAN AND REED EXPOSED ON EAST SIDE OF COWHORN VALLEY

Reed Dolomite forms the white band capping the
ridge above the slope of Wyman.

(Section 26, T. 9 S., R. 36 E., Waucoba Mountain,
California 15' Quadrangle (USGS), 1951 edition)