AN ABSTRACT OF THE THESIS OF

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Title: LOWER AND MIDDLE DEVONIAN STRATIGRAPHY AND DEPOSITIONAL ENVIRONMENTS OF THE SHEEP, DESERT, PINTWATER, AND SPOTTED RANGES, NORTHERN CLARK COUNTY, NEVADA

Abstract approved: Redacted for Privacy

J. G. Johnson

During much of the Early and Middle Devonian, shallow normal marine and peritidal sediments were deposited in northwestern Clark County, Nevada. Lack of a standard stratigraphic nomenclature for the area necessitates utilizing terminology from central Nevada and western Utah.

The Sevy Dolomite represents Early Devonian deposition in a tidal flat environment. A Zlichovian transgression initiated deposition of the normal marine McColley Canyon Formation in the area. Continuation of that transgression was responsible for the deposition of the lower part of the Pintwater Formation, a new formation which consists of silty, argillaceous dolomite with abundant secondary chert. A Dalejan regression occurred during deposition of the upper part of the Pintwater Formation; it was during the later phases of this regression that the Oxyoke Canyon Sandstone was deposited in a complex barrier bar system which paralleled the coastline.

Three Middle Devonian transgressions of varying magnitude have been recognized in southern Nevada. The first transgression, during the

early Eifelian, was responsible for the widespread deposition of the Coarse Crystalline Member of the Simonson Dolomite. The Coarse Crystalline Member represents an entire transgressive-regressive cycle. The second Middle Devonian transgression, which occurred later in the Eifelian, initiated deposition of the restricted, shallow subtidal to supratidal Alternating Member of the Simonson Dolomite. Deposition of this unit was marked by periodic minor rises in sea level. Each dark-light dolomite couplet represents a single transgressive pulse followed by upward-shallowing sedimentation. Peritidal sedimentation was brought to an end by the third Middle Devonian transgression. This transgression, which occurred during the middle to late Givetian, brought the deeper water lithotope of the Guilmette Formation into the area.

The tectonic setting in southern Nevada during the Early Devonian was significantly different than that in central Nevada; southern Nevada facies are different than central Nevada facies, and a relatively condensed conodont sequence indicates a slower rate of subsidence. During the Middle Devonian, however, facies throughout southern and east-central Nevada are markedly similar, as is the timing of depositional events. This indicates that the tectonic setting along the southern Cordilleran margin was more uniform by Middle Devonian time.

Lower and Middle Devonian Stratigraphy and Depositional Environments of the Sheep, Desert, Pintwater, and Spotted Ranges, Northern Clark County, Nevada

by

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TABLE OF CONTENTS

INTRODUCTION....................1

Purpose....................1
Previous Work....................1
Geologic Setting....................2
Location and Access....................3
Methods of Investigation....................6

FORMATIONAL NOMENCLATURE....................7

SEVY DOLOMITE....................10

General Statement....................10
Lithology....................10
Environment of Deposition....................11
Age and Correlation....................13

McCOLLEY CANYON FORMATION....................15

General Statement....................15
Lithology....................15
Environment of Deposition....................18
Age and Correlation....................21

PINTWATER FORMATION....................24

General Statement....................24
Lithology....................24
Environment of Deposition....................29
Age and Correlation....................32

OXYOKE CANYON SANDSTONE....................34

General Statement....................34
Lithology....................34
Environment of Deposition....................35
Age and Correlation....................39

SIMONSON DOLOMITE....................40

General Statement....................40
Coarse Crystalline Member....................40
Alternating Member....................43
Environment of Deposition....................54
Age and Correlation....................63

GEOLOGIC HISTORY....................65

REFERENCES CITED....................69

TABLE OF CONTENTS, continued

APPENDIX I..73

APPENDIX II...74

APPENDIX III..76

APPENDIX IV...78

LIST OF ILLUSTRATIONS

Figure		Page
1	Index map of Nevada counties	4
2	Devonian outcrops in northwestern Clark County	5
3	Summary of Lower and Middle Devonian nomenclature	8
4	Sandy Sevy Dolomite	12
5	Fossiliferous McColley Canyon Formation	17
6	Mudstone rip-ups in McColley Canyon Formation	19
7	Silicified brachiopods in McColley Canyon Formation	19
8	Exposure of lower Pintwater Formation	25
9	Cherty cliff in upper Pintwater Formation	27
10	Upper contact of Pintwater Formation	28
11	Photomicrograph of burrow in Pintwater Formation	30
12	Photomicrograph of inarticulate brachiopod fragment in Pintwater Formation	30
13	Typical exposure of Oxyoke Canyon Sandstone	36
14	Photomicrograph of quartz cement in Oxyoke Canyon Sandstone	36
15	Brecciated Oxyoke Canyon Sandstone	37
16	Laminations in Coarse Crystalline Member	42
17	Photomicrograph of quartz silt grain in dolomite	44
18	Outcrop of Alternating Member	44
19	Hand sample of Alternating Member	46
20	Outcrop of Alternating Member	47
21	Intraformational breccia, Alternating Member	47
22	Mottled dolomite, Alternating Member	49

LIST OF ILLUSTRATIONS, continued

Figure		Page
23	*Amphipora* marker bed	50
24	Problematic intraformational breccia	50
25	Possible bioherm in Alternating Member	52
26	Laminated bedding in biohermal unit	53
27	Contact between Simonson Dolomite and Guilmette Formation	55
28	Fine-crystalline clasts in coarse crystalline matrix	57
29	Photomicrograph of fine-crystalline clast in coarse crystalline matrix	58
30	Time-rock model for Lower and Middle Devonian deposition	66

LIST OF PLATES

Plate		
1	Geology of the southern Desert Range	in pocket
2	Sheep Range Section	in pocket
3	Desert Range Section	in pocket
4	Pintwater Range Section	in pocket
5	Spotted Range Section	in pocket
6	Transect of columnar sections	in pocket

LOWER AND MIDDLE DEVONIAN STRATIGRAPHY AND DEPOSITIONAL ENVIRONMENTS OF THE SHEEP, DESERT, PINTWATER, AND SPOTTED RANGES, NORTHERN CLARK COUNTY, NEVADA

INTRODUCTION

Purpose

The purpose of this project has been to determine what Lower and Middle Devonian lithofacies are present in the Sheep, Desert, Pintwater, and Spotted Ranges, and, with fossil control, to construct a depositional model for the Lower and Middle Devonian in southern Nevada. Facies relationships of Lower and Middle Devonian rocks in central Nevada have been studied for a number of years, and are fairly well understood (Matti and others, 1975; Johnson & Sandberg, 1977). This thesis makes a significant contribution to understanding the Devonian of Nevada by establishing a facies model in the southern part of the state, where published models do not apply.

Previous Work

Longwell and others (1965) did reconnaissance mapping of lower Paleozoic rocks in northern Clark County, but they did not differentiate formations within the Devonian. In the Ranger Mountains to the west of the thesis area, Johnson and Hibbard (1957) mapped 874 m of Devonian section, which they assigned to the Nevada Formation and the Devils Gate and Narrow Canyon Limestones. However, they gave no interpretation of depositional environments. To the east, in the Arrow Canyon Range, Langenheim and others (1962) mapped 599 m of

Devonian rocks as the Piute, Moapa, Arrow Canyon, and Crystal Pass Formations. They proposed that these rocks were deposited in a broad transitional zone between the platform to the south and the geosyncline to the northwest.

Guth (1980) conducted a detailed structural study of the Sheep Range. This study resulted in a geologic map at a scale of 1:50,000. This map was used to locate a suitable site for measuring a stratigraphic section in the Sheep Range, and no other geologic map was prepared for this area.

Geologic Setting

Lower and middle Paleozoic rocks of the Great Basin were deposited in the north-south-trending Cordilleran geosyncline. Stewart and Poole (1974) recognized four facies in the Devonian of the Great Basin. These are represented in the rock record by 1) carbonate and sedimentary quartzite; 2) limestone and shale; 3) shale and chert; and 4) chert. These rock types represent environments ranging from shallow shelf on the east through progressively deeper water to the west. In studying the Devonian rocks in southern Nevada, Langenheim and others (1962) found no recognizable boundary between the craton and the geosyncline. Instead, they suggested that the Devonian rocks represent a broad transitional zone between the two.

The thesis area is located near the southern end of the Cordilleran geosyncline, within the carbonate facies belt. With the exception of the clean quartz sandstones of the Oxyoke Canyon Sandstone, the Lower and Middle Devonian section is composed entirely of primary and secondary shallow marine and peritidal dolomites. Because the thesis area is situated where the axis of the geosyncline changes from predominantly north-south to east-west, the transect taken is not truly perpendicular to depositional strike, and therefore does not completely show facies relationships within the platform-geosyncline transition.

The regional structure must be taken into account when trying to reconstruct the transition of Devonian environments from the craton to the continental shelf. The Mesozoic Gass Peak thrust surfaces in the Las Vegas Range, with a probable horizontal displacement exceeding 30 km (Guth, 1980). The rocks within the thesis area are all in the upper plate of this thrust sheet and their present depositional relationships are affected only by Miocene and younger extension. However, care must be taken in correlating with rocks to the east, in the Arrow Canyon Range, because structural telescoping may have obliterated the original facies record between the thesis area and ranges to the east.

Location and Access

The study area is located in northwestern Clark County, Nevada, approximately 40 km northwest of Las Vegas (Figures 1 & 2). The eastermost part of the thesis area is part of the Desert National Wildlife Refuge. The remainder of the area is within the confines of the Nellis Bombing and Gunnery Range. Mapping was done in the Desert, Pintwater, and Spotted Ranges, at a scale of 1:24,000.

U.S. Highway 95 bounds the southern edge of the thesis area. From the highway, map areas are accessible within 1.5 to 5 km by dirt

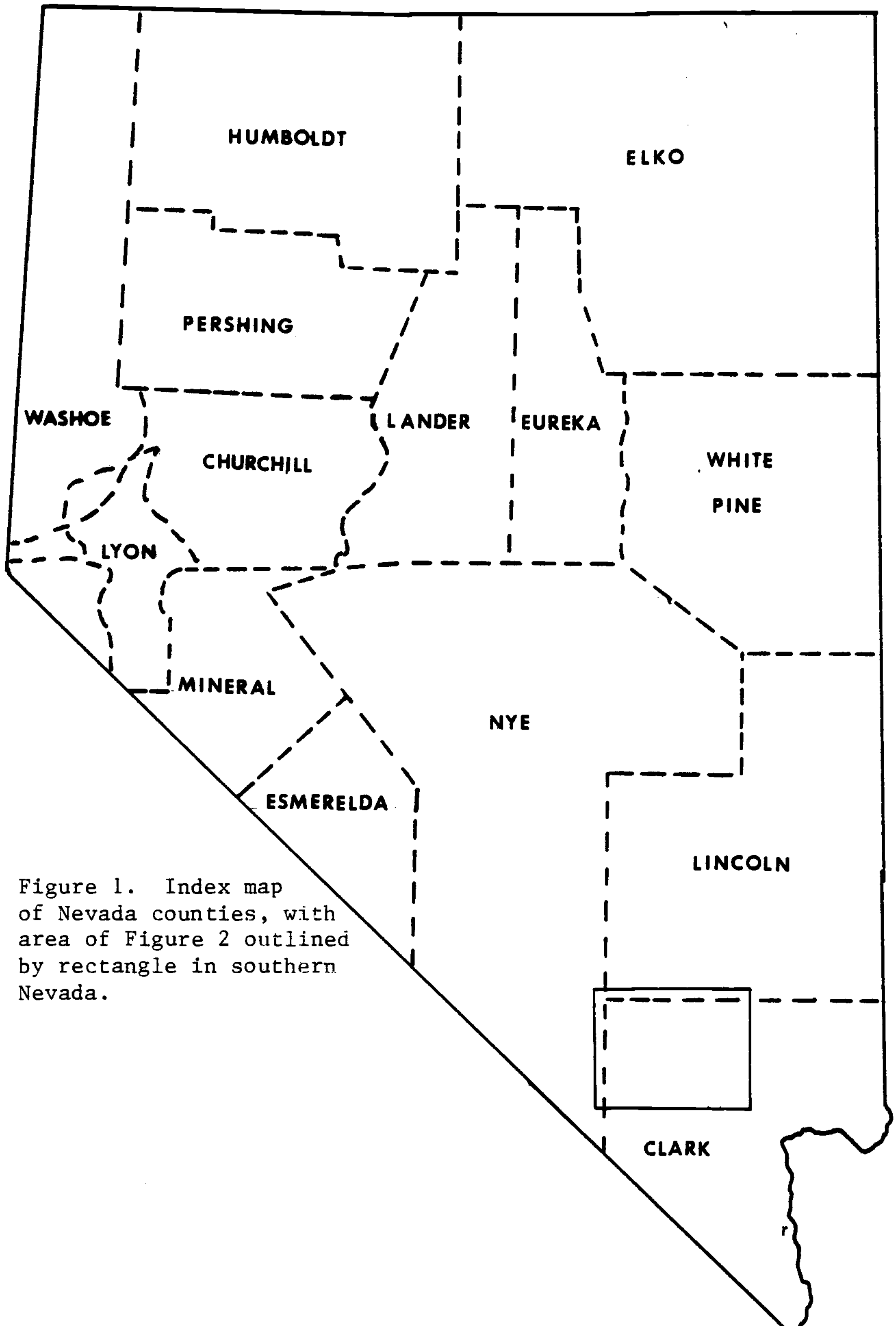

Figure 1. Index map of Nevada counties, with area of Figure 2 outlined by rectangle in southern Nevada.

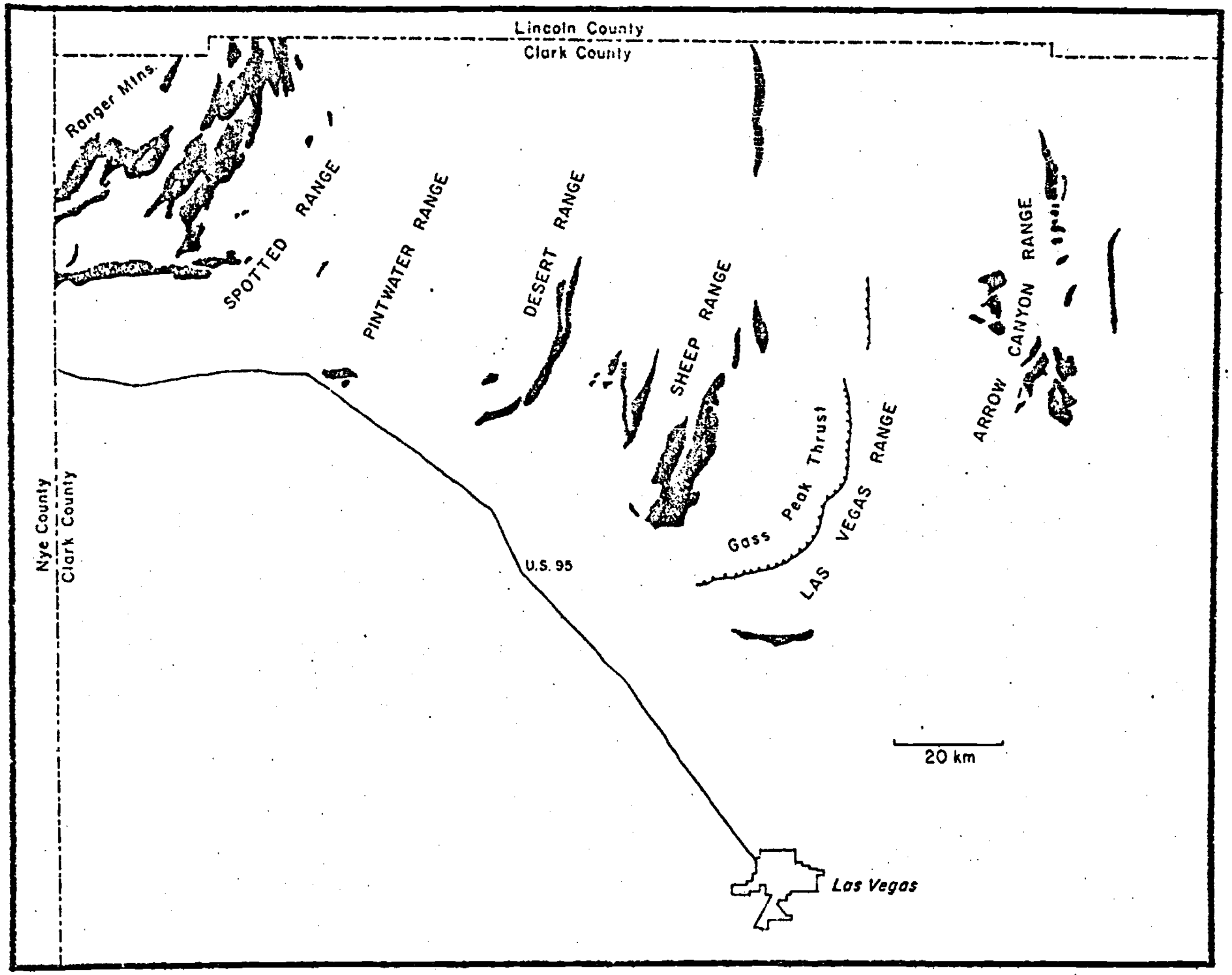

Figure 2. Devonian outcrop map of northwestern Clark County, Nevada.

and gravel roads.

Methods of Investigation

Field work for this thesis was undertaken during October 1979, and March 1980. Mapping utilized U.S. Geological Survey 7½-minute topographic quadrangles as base maps (Plate 1, and Appendices I-III). One stratigraphic section was measured in each of the four ranges in the thesis area (Plates 2-5).

Lithologic samples were collected to represent significant or unusual lithologies or sedimentary structures. Samples were also obtained for macrofossils and conodonts. Silicified macrofossils were separated from the dolomite matrix using concentrated hydrochloric acid. Non-silicified fossils were separated using a hydraulic rock-splitter. Brachiopods were submitted to Dr. J. G. Johnson, Oregon State University, for identification and age determination. Rugose corals were sent to Dr. W. A. Oliver, U.S. National Museum.

Conodont samples averaged 5-10 kg. To obtain the conodonts, samples were split and then dissolved in dilute formic acid. Claudia Regier separated the heavy mineral fraction and picked the conodonts. The conodonts were sent to Dr. Gilbert Klapper, University of Iowa, for identification and age determination.

FORMATIONAL NOMENCLATURE

Because of a lack of detailed study of the Devonian of the southern Great Basin, there has been no standard usage of formational names within the thesis area. It is believed that utilizing formation names from central Nevada and western Utah will permit a better representation of the regional stratigraphy. In addition, it will be easier to relate timing of depositional events in southern Nevada to those in the rest of the Great Basin. The regional nomenclature, both past and present, is summarized in Figure 3.

Johnson and Hibbard (1957) mapped and described rocks that they assigned to the Nevada Formation in the Ranger Mountains, to the northwest of the thesis area. Longwell and others (1965) mapped all the Devonian rocks in Clark County as Sultan Limestone. This usage is abandoned as there are several rock units present which are recognized elsewhere as formations. The Sevy Dolomite is present within the area, although it could not be distinguished in the field from underlying rocks of similar lithology. The McColley Canyon Formation is herein recognized in the southern Great Basin for the first time. These rocks were previously regarded as representing an atypical Bartine Member lithology (Johnson & Niebuhr, 1976). Pintwater Formation is a new name for a rock unit which is recognizable throughout the thesis area. The Oxyoke Canyon Sandstone, described by Nolan and others (1956) in central Nevada, is recognized in a restricted sense. The Simonson Dolomite of Nolan (1935) is present throughout the area. Although all four members of the Simonson described by Osmond (1954) are

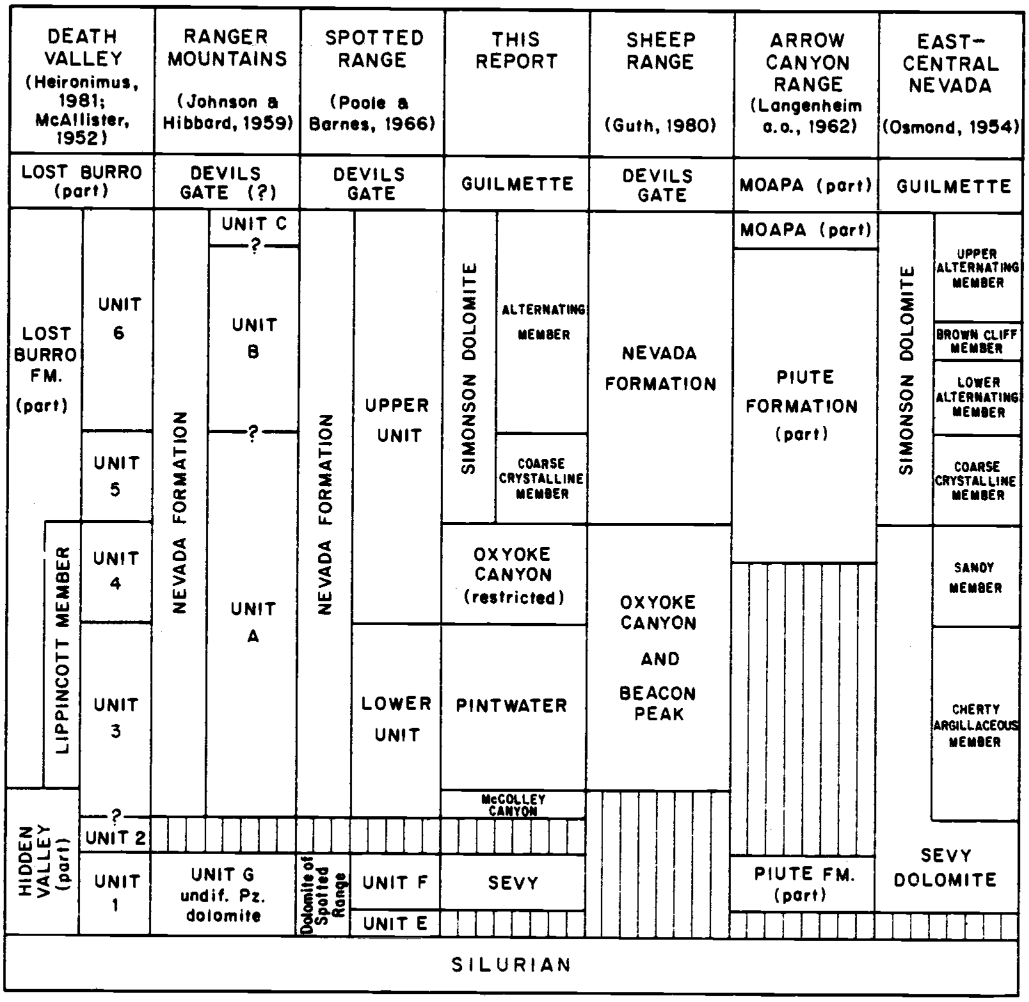

Figure 3. Summary of Lower and Middle Devonian formational nomenclature in the southern Great Basin.

not distinguishable, the formation can be divided into a Coarse Crystalline Member and an Alternating Member.

SEVY DOLOMITE

General Statement

The Sevy Dolomite was named and first described by Nolan (1935) in the Deep Creek Mountains of western Utah. Since then, the formation has been widely recognized and extensively studied in western Utah and throughout much of Nevada (Osmond, 1954; 1962; Reso, 1960; Matti, 1978).

The Sevy is characteristically a light grey, very fine crystalline dolomite, and can be recognized by its lithologic uniformity throughout its wide areal extent (Osmond, 1954; 1962). However, within the thesis area, the Sevy is difficult to distinguish from the underlying Silurian rocks. Because of this lack of field criteria for separating the Sevy from the subjacent dolomites it has not been mapped for this report. It is assumed that, with the exception of rocks in the Sheep Range, the light grey, finely crystalline dolomites beneath the McColley Canyon Formation belong to the Sevy Dolomite.

Lithology

The rocks which underlie the McColley Canyon Formation in the Desert, Pintwater, and Spotted Ranges are light grey to light medium grey, very finely crystalline dolomites which occur in beds 0.35-0.65 m thick. They are generally more resistant to weathering than the McColley Canyon Formation, and form a steep slope with step-like ledges.

In the Sheep Range, no rocks of Sevy lithology were observed. Instead, rocks of the Pintwater Formation were found to lie disconformably on the medium grey, medium-crystalline Laketown Dolomite. Guth (1980) supports the lack of a distinct Sevy lithology in the Sheep Range. However, Osmond (1962) reports 42.4 m of Sevy (excluding his sandy member) from the southern Sheep Range.

The Sevy Dolomite in the Spotted Range is equivalent to Unit F of the Dolomite of the Spotted Range (Poole, written commun.; Poole and others, 1977) and is 108 m thick in the southern Spotted Range in Nye County (Poole & Barnes, 1966). The Sevy in the Spotted Range differs from that in the Pintwater and Desert Ranges in that it contains a high percentage (10-20%) of well-rounded quartz sand in its upper 16.8 m. The sand occurs as floating grains, in laminae, and concentrated along stylolites (Figure 4). The base of this sandy interval is marked by the presence of an intraformational conglomerate (Figure 4).

Environment of Deposition

It is generally believed that the Sevy Dolomite was deposited on a broad tidal flat that covered much of Utah and Nevada (Osmond, 1962; Kendall, 1975; Matti, 1978). It lies disconformably on the Silurian Laketown Dolomite (Nolan, 1935; Osmond, 1962) and therefore must be transgressive at its base. An extensive study by Matti (1978) subdivided the formation into eight microfacies which indicate intertidal to supratidal deposition, with intermittent traction currents and storm surges. Schalla (1978) observed dark grey dolomite beds within the Sevy (=Beacon Peak Dolomite) which may indicate deepening along the

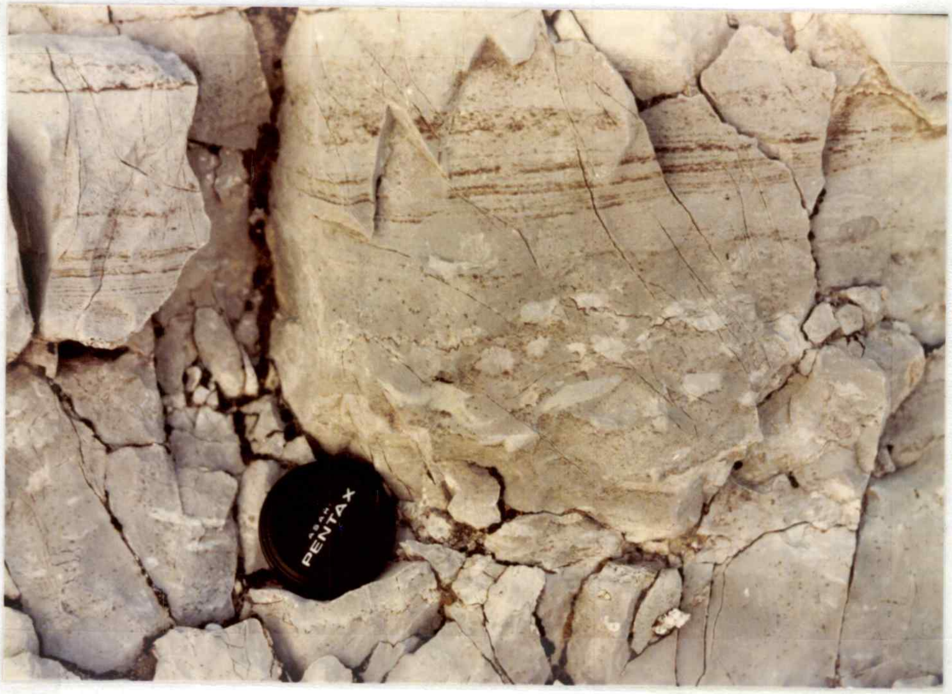

Figure 4. Sand laminae and intraformational conglomerate, Sevy Dolomite, Spotted Range.

western edge of the Sevy tidal flat.

Within the thesis area, Sevy deposition was terminated by a regression. This left the broad tidal flat exposed to subaerial erosion, which is evident throughout the area and in the Arrow Canyon Range to the east. Complex interfingering of the Sevy Dolomite with the Bartine Tongue of the McColley Canyon Formation, and with the Oxyoke Canyon Formation in central Nevada (Kendall, 1975) indicates that the unconformity produced by the regression was restricted to the southern Great Basin.

Age and Correlation

The Sevy Dolomite, throughout its areal extent, is sparsely fossiliferous (Osmond, 1962; Matti, 1978) and therefore is difficult to date. However, data on the age of the overlying McColley Canyon Formation, and macrofossils from Sevy remnants in the Arrow Canyon Range help to date the Sevy in the area.

Langenheim and others (1962) reported a thin interval of Sevy-like dolomite containing Acrospirifer kobehana in the Arrow Canyon Range, east of the thesis area. Johnson (1970, p. 192) later determined that these fossils were actually A. aff. murchisoni. These rocks lie unconformably on Laketown Dolomite. The presence of A. aff. murchisoni indicates that the Sevy in the Arrow Canyon Range is no older than the Lower Devonian Trematospira Zone. This indicates a probable middle Pragian age for part of the Sevy. However, it would be uncertain at best to try and extend this age into the thesis area. Greater thicknesses of the Sevy to the west indicate the probability of a longer period of Sevy deposition west of the Arrow Canyon Range. Since the base of the Pragian transgressive unit represented by the Sevy Dolomite is younger to the east (Johnson & Sandberg, 1977), it is likely that the base of the Sevy within the thesis area is somewhat older than that in the Arrow Canyon Range. In addition, structural telescoping between the Arrow Canyon Range and the Sheep Range of at least 30 km (Guth, 1980) increases the likelihood of an age slightly older than mid-Pragian for the base of the Sevy Dolomite.

The youngest age of the Sevy in the thesis area is constrained by the age of the overlying McColley Canyon Formation. The McColley Canyon in the thesis area is probably no older than the dehiscens Zone. Because of the presence of an unconformity between the Sevy and the McColley Canyon, Sevy deposition must have ceased in southern Nevada before mid-Zlichovian time.

McCOLLEY CANYON FORMATION

General Statement

The McColley Canyon Formation was originally defined by Carlisle and others (1957) as the lowest member of the Nevada Formation in the Sulphur Spring Range. Johnson (1962) elevated the McColley Canyon to formational rank. Gronberg (1967; Murphy & Gronberg, 1970) subdivided the formation into three members, the Kobeh, Bartine, and Coils Creek, in ascending order.

Strata regarded as atypical Bartine Member, or a facies of it, were reported by Johnson and Niebuhr (1976) in the Spotted and Pintwater Ranges, and in the Ranger Mountains. On closer examination in the thesis area, these rocks were determined to differ significantly from Bartine Member lithology, and that name is therefore rendered inappropriate. However, the general lithologic character recommends that the rocks be included as part of the McColley Canyon Formation. Because of the thinness of the formation in the area, the McColley Canyon has been mapped together with the overlying Pintwater Formation, except in the Sheep Range.

Lithology

The McColley Canyon Formation is present in the Desert, Pintwater, and Spotted Ranges, and is absent from the Sheep Range. Where present, the formation is remarkably uniform in both lithology and thickness. The formation itself is a dark finely crystalline dolomite which typically weathers to a yellowish grey, and forms a slope or saddle. At all localities, it is devoid of fossils at the bottom of the unit, and becomes abundantly fossiliferous at the top (Figure 5).

The McColley Canyon Formation, wherever present in the thesis area, lies disconformably on the Lower Devonian Sevy Dolomite. The contact between the two formations is marked by a sharp change from the light grey, well-bedded aphanitic dolomite of the Sevy to the dark greenish black, finely crystalline dolomite of the McColley Canyon. Poole (written commun.) observed as much as 36 cm of relief on the undulating iron-stained surface at the base of the McColley Canyon Formation in the Spotted Range in Nye County.

Although the McColley Canyon Formation shows an overall lithologic uniformity within the thesis area, there are significant minor alterations in lithology between the three ranges where the unit is present.

The easternmost exposures of the McColley Canyon Formation are found in the Desert Range, where it is 9.7 m thick. The formation there is a medium grey, finely crystalline dolomite which weathers to a yellowish grey. It occurs in beds 0.35-0.65 m thick, and forms a gentle slope. Fossil debris is abundant in the upper 3 m of the formation and consists mainly of brachiopod and pelmatozoan debris, and some tabulate corals. Few whole fossils were observed in the area. Also, there is little evidence in the Desert Range of the extensive bioturbation that is present at other localities.

In the Pintwater Range, the McColley Canyon Formation is 8.8 m thick. Here, it is a finely crystalline dolomite to limy dolomite, and the color on fresh surfaces ranges from medium light grey to

Figure 5. Fossiliferous dolomite, upper McColley Canyon Formation, Desert Range.

greenish black. Weathered outcrops vary in color from light grey to yellowish grey. The formation crops out in saddles or ravines between the more resistant subjacent Sevy Dolomite and the slope-forming superjacent Pintwater Formation. It occurs in beds 0.35-0.65 m thick. The rocks are extensively bioturbated. This is apparent on outcrop, but is seen more clearly on acid-etched specimens. In addition, the presence of mud rip-ups indicates intermittent currents through the area (Figure 6).

The fossils found in the McColley Canyon Formation in the Pintwater Range more often occur as whole specimens than they do in the Desert Range. Brachiopods are commonly articulated. Corals are especially abundant. Many fossils exhibit almost complete silicification (Figure 7).

Farther west, in the Spotted Range, the McColley Canyon Formation is 8.2 m thick. Here, it occurs in beds 15-35 cm thick, and forms step-like ledges on a gentle slope. Fresh surfaces are greenish black, and weather yellowish grey to light grey. As in the Pintwater Range, the upper part of the unit is abundantly fossiliferous, with the fauna being dominated by brachiopods and both rugose and tabulate corals. Here, too, there is evidence of extensive bioturbation.

Environment of Deposition

McColley Canyon deposition was initiated in the thesis area by transgression of a shallow marine environment over the exposed Sevy tidal flat. The fine-grained nature of the rocks indicates a low energy environment for McColley Canyon deposition, with intermittent

Figure 6. Fine-grained mudstone rip-ups (light grey) in McColley Canyon Formation, Pintwater Range.

Figure 7. Silicified brachiopods, upper McColley Canyon Formation, Pintwater Range.

storms and waves. Although the rock has been dolomitized, the predominance of microspar in the fabric indicates recrystallization from micrite mud. The presence of up to 10% quartz silt, and an abundance of argillaceous material, also indicate a low energy environment, and an influx of terrigenous material.

There seems to have been an increase in energy in the McColley Canyon environment from west to east. In the Spotted and Pintwater Ranges, articulated brachiopods are quite common. However, in the Desert Range, few articulated specimens are found. Disarticulated and abraded fragments are common. This suggests that the energy level in the Desert Range was sufficiently higher to break and abrade the abundant biotic material present. Because the McColley Canyon Formation pinches out between the Desert and Sheep Ranges, the Desert Range must have been close to the eastern McColley Canyon facies boundary, as was probably above wave base. Deeper water to the west would account for the lower energy level indicated in the Pintwater and Spotted Ranges.

Although the overall environment for the McColley Canyon Formation is low energy, there is evidence for intermittent currents through the area. Even though articulated brachiopods are common, disarticulated and broken specimens are also abundant. In addition, mudstone rip-ups occur locally. The currents could have been due either to storm or tide action.

Two collections of brachiopods from the McColley Canyon Formation indicate that the fauna belonged to an Atrypa-dominated community. Although work done by Niebuhr (1974; 1977) indicates that Atrypa-dominated communities belong to shallow pinyonensis biofacies, the collections in the thesis area do not fit the communities established by Johnson (1977) and Niebuhr (1977).

Slight changes in the faunal content in collections PRM II-3 and PRM II-7 indicate a fluctuation of water depth in the upper few meters of the formation. PRM II-3 contains the conodont genus Polygnathus, but not Pandorinellina, which dominates collection PRM II-7. In general, Pandorinellina occurs in a shallower water biofacies than does Polygnathus (Johnson, oral commun.). PRM II-7 brachiopods also belong to a shallower fauna than the PRM II-3 brachiopods (Johnson, oral commun.). Whether this is part of a shallowing trend or represents only a fluctuation of water depth cannot be determined.

Age and Correlation

The McColley Canyon Formation can be dated on the basis of conodonts, brachiopods, and rugose corals. Conodonts provide the most accurate data for age determination. Collections SP IV-2 and PRM II-3, from the upper few meters of the formation, have Polygnathus gronbergi, indicating the gronbergi Zone (Klapper, written commun.). The additional presence of P. dehiscens in PRM II-3 requires a lower gronbergi Zone assignment. Collections DRM I-3 and PRM II-7, with Pandorinellina exigua philipi, suggest dehiscens Zone or lower gronbergi Zone (Klapper, written commun.). Probably, the dehiscens-gronbergi zonal boundary is in the upper part of the formation.

Brachiopods in PRM II-3 and PRM II-7 are assignable to the pinyonensis assemblage zone (Johnson, written commun.). Brachiopods and conodonts, in combination, indicate Interval 11 (Johnson and others, 1980, Fig. 5).

The two collections of rugose corals from the McColley Canyon Formation support the pinyonensis Zone position of the formation. PRM II-3 contains Breviphrentis invaginatus, Sinospongophyllum? sp., and ?Papiliophyllum elegantulum, which is a typical pinyonensis Zone coral assemblage (Oliver, written commun.). These species occur in subzones D_1 and D_2 of Merriam (1974). Collection PRM II-7 however, contains an atypical pinyonensis fauna. Oliver (written commun.) identified only one possible Papiliophyllum, and found other specimens to more closely resemble species common to the eastern United States.

The pinyonensis Zone age of the upper part of the McColley Canyon Formation in the thesis area, and the assignment to I 11 and possibly I 10 indicate that it is the time equivalent of at least part of the Bartine Member of the McColley Canyon Formation in central Nevada (Johnson & Sandberg, 1977, Fig. 2). There, McColley Canyon deposition began with the Kobeh Member (Interval 5) lying disconformably on Lone Mountain Dolomite (Gronberg, 1967; Johnson & Sandberg, 1977; Schalla, 1978). As the transgressive pulse responsible for the inception of McColley Canyon deposition did not occur until at least Interval 10, it is suggested that the base of the McColley Canyon Formation is younger to the south.

The time of cessation of McColley Canyon deposition within the thesis area is significantly different than in central Nevada. While McColley Canyon deposition in the thesis area had probably ceased before the end of Interval 11, deposition of the partial time-equivalent Bartine Member continued through Interval 12, with the upper Bartine Tongue extending into Interval 13 (Johnson & Sadnberg, 1977, Fig. 2). Within the thesis area, Intervals 12 and 13 are included in the Pintwater Formation.

PINTWATER FORMATION

General Statement

The Pintwater Formation was previously considered to be the Cherty Argillaceous Member of the Sevy Dolomite (Osmond, 1954; 1962), but is herein recognized as a separate formation. Matti (1978) separated the unit from the Sevy Dolomite, and referred to it as the unnamed cherty argillaceous carbonate unit. The reasons for its recognition as a formation are its distinctive lithology and distribution compared to superjacent and subjacent rock units.

The type locality is the Pintwater Range, in the NE ¼, NW ¼, sec. 12, T. 17 S., R. 56 E. of the Indian Springs SE quadrangle (7½-minute series). It is present in all sections in the thesis area. In addition, rocks of similar lithology have been reported in the Worthington Range (Osmond, 1954); the Pahranagat Range (Osmond, 1954; Reso, 1960); the Ranger Mountains (Johnson & Hibbard, 1957); and the Reveille, Hot Creek, and Pancake Ranges (Osmond, 1962).

Lithology

The Pintwater Formation is composed of finely crystalline, argillaceous, olive grey dolomite which weathers to a light yellowish grey and forms a gentle slope in the lower part of the formation (Figure 8). Thicknesses range from 13.7 m in the Sheep Range to 50.7 m in the Pintwater Range. The lower part of the formation is unbedded and structureless. Chert appears within 6 to 12 m of the base of the

Figure 8. Slope of lower Pintwater Formation, Spotted Range. Cliff at top is cherty part of formation.

the formation at most outcrops, and increases in abundance towards the top of the unit. The chert occurs in blebs and coalescing stringers a few centimeters thick, and parallels bedding. The cherty upper part of the formation weathers to a distinct cliff (Figure 9). In addition, both burrows and fine laminations increase toward the top of the unit. No macrofossils were observed.

In the Desert, Pintwater, and Spotted Ranges, the Pintwater Formation appears to lie conformably above the McColley Canyon Formation. The sharp contact is marked by a distinct color change from the greenish black dolomite of the McColley Canyon to the light olive grey dolomite of the Pintwater Formation. There is also a change from the 0.35-0.65 m thick ledges of the McColley Canyon to the smooth slope of the Pintwater.

In the Sheep Range, the Pintwater Formation lies disconformably on the Silurian Laketown Dolomite. This contact is marked by an abrupt change from the medium-crystalline, medium grey, fossiliferous Laketown to the light olive grey, finely crystalline Pintwater.

The Pintwater Formation is everywhere conformable with the superjacent Oxyoke Canyon Sandstone. The boundary between the two units is gradational over an interval of approximately 3 m. It is characterized by alternating beds of Pintwater dolomite and quartz sandstone similar to the overlying Oxyoke Canyon. The contact between the two formations is defined at the base of the first thick (0.3 to 1 m) bed of quartz sandstone (Figure 10).

In hand sample, most rocks of the Pintwater Formation are very similar to those of the Sevy Dolomite. They are very dense, and

Figure 9. Chert stringers in dolomite, forming cliff at top of Pintwater Formation, Spotted Range.

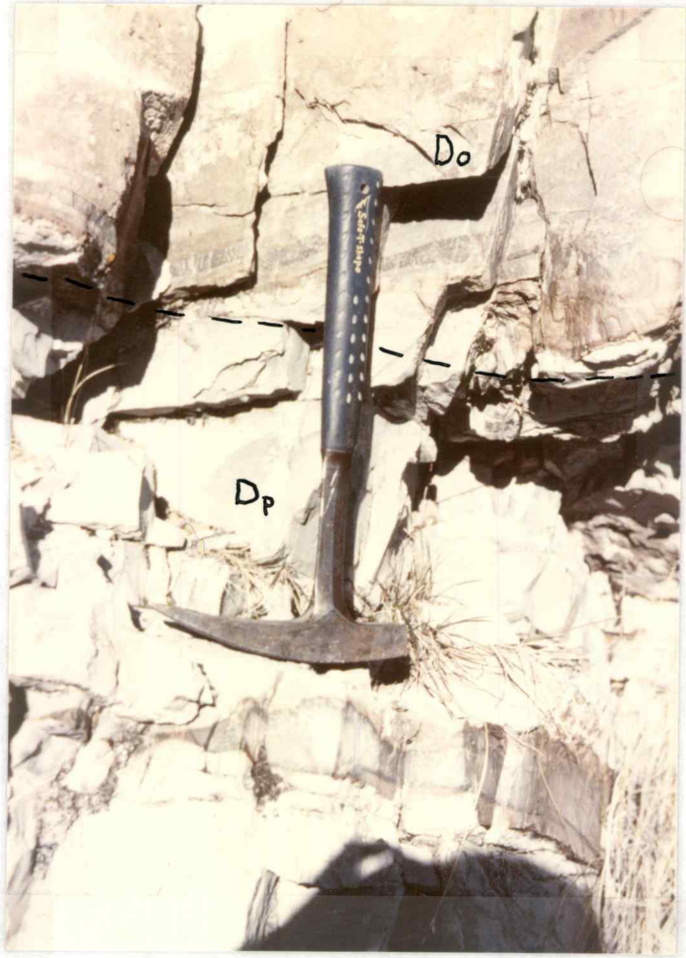

Figure 10. Contact between Pintwater Formation (Dp) and Oxyoke Canyon Sandstone (Do), Sheep Range.

display a subconchoidal fracture. However, petrographic examination reveals significant lithologic difference, and supports the designation of the Pintwater as a formation distinct from the Sevy.

In thin section, the Pintwater Formation is predominantly dolomite microspar; most dolomite crystals are euhedral. Angular quartz silt composes 20 to 30% of the rock, and is concentrated in burrows in quantities up to 70% (Figure 11). Inarticulate brachiopod fragments are common (Figure 12). Isolated grains of glauconite were observed.

Environment of Deposition

Pintwater Formation deposition in the thesis area was initiated by the shifting of the Pintwater lithotope over the McColley Canyon Formation. The fine-grained fabric and abundant quartz silt indicate a low energy environment. The presence of glauconite and conodonts suggests a normal marine setting. The formation is transgressive at the base, and regressive at the top.

The presence of *Polygnathus inversus* and *P. laticostatus* in the lower part of the Pintwater Formation indicates an offshore biofacies (Klapper & Johnson, 1980). This, together with the fact that the Pintwater Formation oversteps the McColley Canyon Formation between the Desert and Sheep Ranges (Plate 6), indicates that the lower part of the Pintwater Formation represents a continuation of the McColley Canyon transgression. The Pintwater lithotope then, must have originated seaward of the McColley Canyon lithotope.

The general absence of sedimentary structures within the Pintwater Formation is the result of intense bioturbation. This suggests slow,

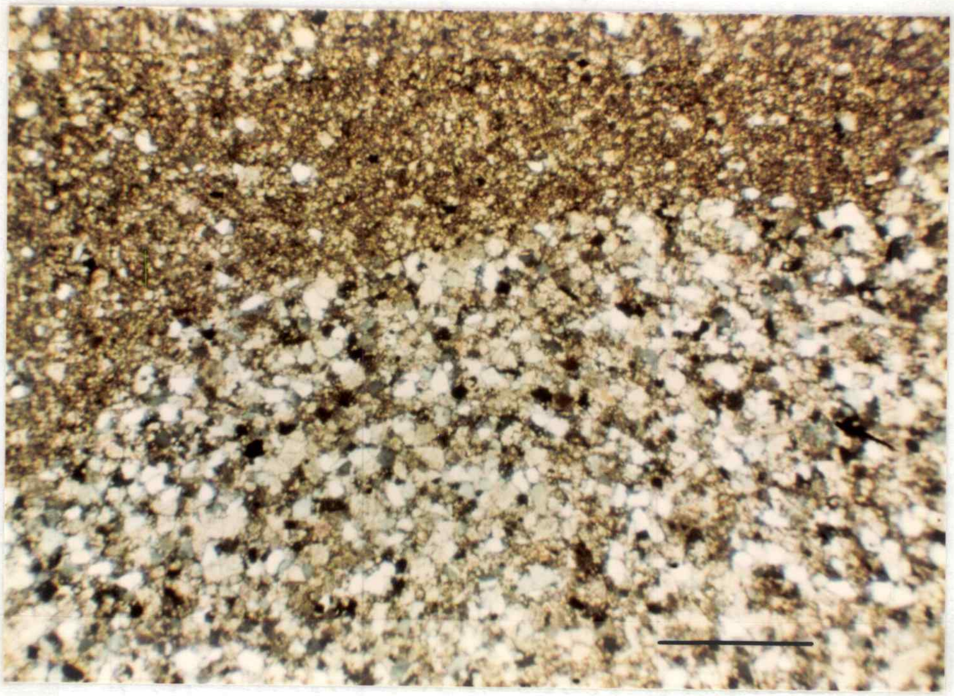

Figure 11. Burrow (light) with abundant quartz silt, Pintwater Formation. (crossed nicols; bar scale is 0.5 mm)

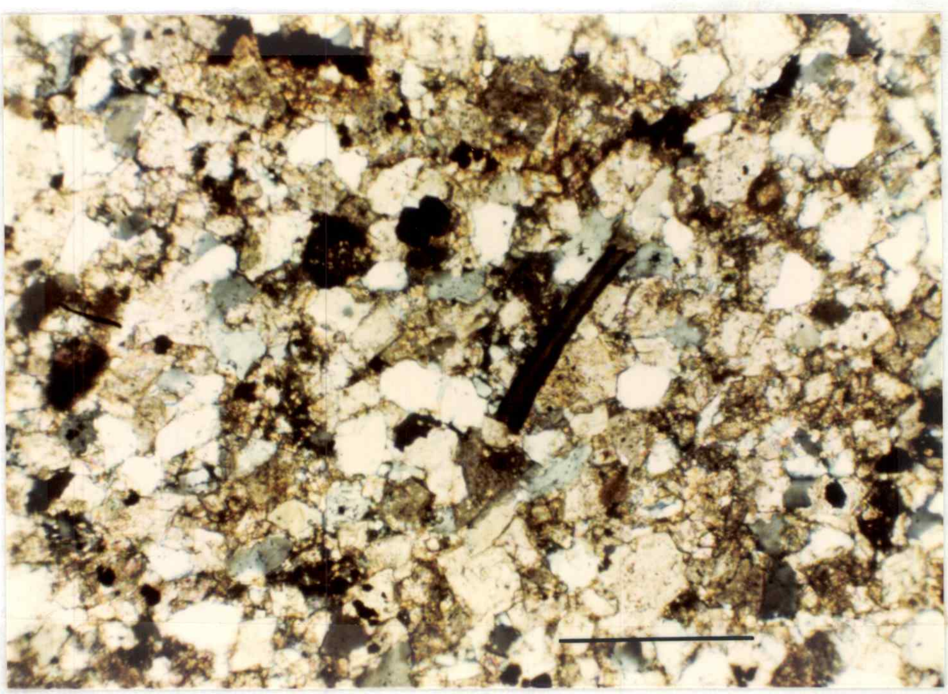

Figure 12. Inarticulate brachiopod fragment (right of center), Pintwater Formation. (crossed nicols; bar scale is 0.2 mm)

continuous deposition (Howard, 1978). The preservation of subhorizontal burrows within the upper part of the formation assists in defining a general depositional setting. Although individual ichnogenera could not be identified, the nature of burrow morphology indicates that they belong to the ichnofacies Cruziana (Seilacher, 1967). Horizontal burrows are feeding structures, and prevail in water of intermediate depths (Seilacher, 1967). The Cruziana ichnofacies occurs in shelf environments with normal salinity and high oxygen content (Howard, 1978). The absence of macrofossils is probably caused by the turbid nature of the water. The fine-grained rock, abundance of detrital quartz silt, overall lack of sedimentary structures, and relationship to the overlying Oxyoke Canyon Sandstone are indicative of a middle shoreface environment for the upper part of the formation, such as occurs as a seaward facies of barrier systems. The middle shoreface, as studied at Galveston Island, Texas, is characterized by very fine-grained sand and silt which are so extensively bioturbated that sedimentary structures are rarely preserved (Davies and others, 1971).

The abundant chert within the upper Pintwater Formation is of a replacement nature. Such cherts are commonly found in the thick Paleozoic carbonate section of southern Nevada (Niem, oral commun.). The most convincing evidence for the secondary origin of these cherts is the presence of fine laminations in the chert nodules. These laminations, where found, are continuous with laminations in the surrounding dolomite.

The source of the silica for chert in the Pintwater Formation is problematic. Osmond (1954) suggested that the silica was dissolved from the quartz silt within the formation. This is unlikely, because even very fine-grained quartz silt will not dissolve beyond equilibrium at low temperatures (Siever, 1962). The silica needed for the formation of secondary chert is generally believed to be of biogenic origin (Blatt and others, 1972), derived from the dissolution of opaline radiolaria tests and sponge spicules. However, radiolarians and siliceous sponges are usually associated with deeper water environments. If the silica source for the Pintwater chert is biogenic, one would have to appeal to long-distance migration of formation fluids from deeper water deposits in west-central Nevada.

Age and Correlation

The Pintwater Formation can be assigned a tentative age on the basis of two poorly preserved conodont collections. No other fossils were found within the formation.

The presence of Polygnathus laticostatus in collection SP IV-4, taken 5.2 m above the base of the formation, indicates an inversus Zone age for at least part of the Pintwater Formation (Klapper, written commun.). This age assignment was made with some reservation because of the very poor preservation of the specimens of P. laticostatus.

Collection PRM II-8 (collected 18 m above the base of the Pintwater Formation) yielded specimens of Polygnathus laticostatus? and P. inversus (Klapper, written commun.). Based on the range of P. inversus (Klapper, 1977, Fig. 3), this collection can be assigned an age ranging from the inversus Zone to the lower part of the serotinus Zone.

The Pintwater Formation is probably as old as gronbergi Zone, based on the age of the subjacent McColley Canyon Formation. Since the top of the McColley Canyon is within the gronbergi Zone, Pintwater deposition must have begun during gronbergi time. The fact that such a relatively small thickness of rock spans the better part of at least two conodont zones indicates that the Lower Devonian zonal sequence in the thesis area is condensed relative to that in central Nevada (Johnson, oral commun.). This indicates that the rate of subsidence in southern Nevada was much slower than in central Nevada.

The probable gronbergi to inversus age of the lower part of the Pintwater Formation makes it time-correlative with the upper Bartine Member of the McColley Canyon Formation in central Nevada (Johnson & Sandberg, 1977, Fig. 2). A probable serotinus age of the upper Pintwater Formation, based on stratigraphic position, indicates a time correlation with the lower Sadler Ranch Formation in the Sulphur Spring Range (Johnson & Sandberg, 1977).

OXYOKE CANYON SANDSTONE

General Statement

Nolan and others (1956) first named the Oxyoke Canyon Sandstone Member of the Nevada Formation in the Sulphur Springs Range in central Nevada. With the elevation of the Nevada Formation to group status (Johnson, 1962), the Oxyoke Canyon was necessarily elevated to formational rank. Kendall (1975) divided the formation into a lower Quartzose Member and an upper Coarse Crystalline Member.

In southern Nevada, Osmond (1954; 1962) considered the extensive Devonian quartzose sandstone to be a member of the Sevy Dolomite. Kendall (1975) also suggested that the sheet sands equivalent to his lower Quartzose Member be included in the Sevy. However, because of striking lithologic similarity and stratigraphic position, it seems prudent to extend the Oxyoke Canyon name to include Devonian quartz arenites in southern Nevada. The Oxyoke Sandstone of this report is used in a restricted sense in that it included only the equivalent of the lower Quartzose Member of Kendall (1975).

Lithology

The Oxyoke Canyon Sandstone is present throughout the thesis area. It is 18.3 m thick at the easternmost exposures in the Sheep Range, and thickens progressively to the west, reaching a maximum thickness of 41.2 m in the Spotted Range. The rocks are composed of fine- to medium-grained dolomitic sandstone to sandy dolomite. The sand is well sorted and the grains are well rounded. It exhibits both textural and compositional supermaturity, indicating that it is reworked from an older sandstone source. Fresh surfaces are light grey to white, and the formation weathers to a distinctive orange black cliff. Beds range in thickness from 15 to 35 cm near the lower and upper contacts, are are up to 1.5 m thick in the middle part of the unit. Low-angle (less than 20°) tabular-planar cross-beds, and plane laminated beds are common within the formation (Figure 13). The Oxyoke Canyon Sandstone is an easily recognizable marker throughout the area.

Some of the sandstone contains siliceous cement. The cement occurs as overgrowths of quartz in optical continuity with the sand grains (Figure 14). In other places, the sand is cemented by finely crystalline dolomite. There is little evidence of pressure solution of the sand grains.

At some localities, the Oxyoke Canyon Sandstone is brecciated. In hand sample, the well-indurated quartzite has distinct clasts of sandstone with siliceous cement (Figure 15a). In thin section, clasts of quartzite occur in a finely pulverized quartz matrix (Figure 15b). It appears as though induration occurred before brecciation took place. The quartz grains do not exhibit well developed strained extinction, but the overall fabric appears to be cataclastic. It is conceivable that brecciation occurred during Mesozoic thrusting.

Environment of Deposition

The Oxyoke Canyon Sandstone represents a continuation of the

Figure 13. Plane lamination and cross-bedding, Oxyoke Canyon Sandstone, Desert Range.

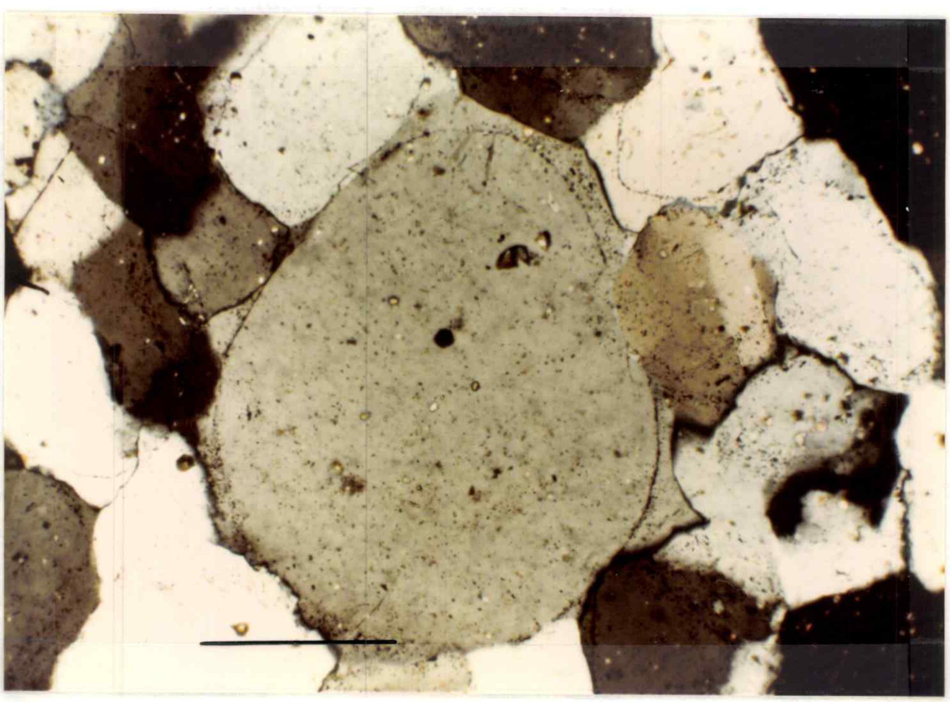

Figure 14. Quartz overgrowth on well-rounded sand grain, Oxyoke Canyon Sandstone. (crossed nicols; bar scale is 0.2 mm)

Figure 15a. Hand sample of brecciated Oxyoke Canyon Sandstone, Pintwater Range.

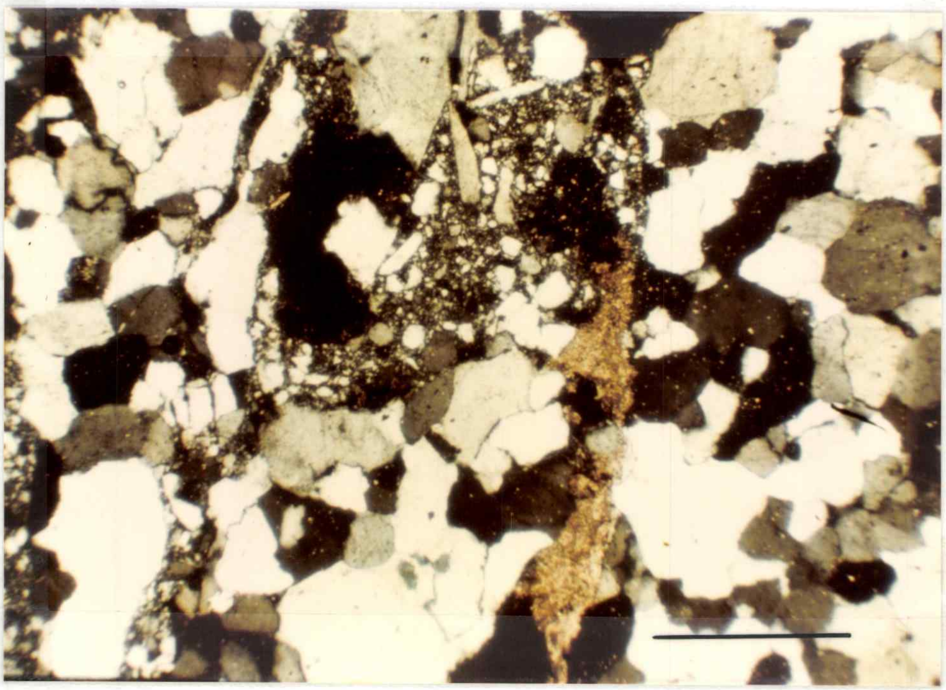

Figure 15b. Photomicrograph of 15a showing cataclastic fabric of brecciated Oxyoke Canyon Sandstone. (crossed nicols; bar scale is 0.2 mm)

regression which began during deposition of the subjacent upper Pintwater Formation. Kendall (1975) observed the regressive nature of the Quartzose Member of the Oxyoke Canyon Formation in central Nevada. There, the lower Quartzose Member interfingers with the Sadler Ranch Formation on the west and the Sevy Dolomite (=Beacon Peak Dolomite) on the east.

The well-rounded, well sorted quartz sands, as well as the parallel laminations and low-angle cross-beds of the Oxyoke Canyon Sandstone indicate a high energy depositional environment. Kendall (1975) concluded that the Quartzose Member of the Oxyoke Canyon Formation was deposited in a high energy beach-bar environment. This author agrees with the high energy barrier environment for the Oxyoke Canyon, and envisions a complex barrier system extending from central to southern Nevada, parallel to the Devonian shoreline.

The Oxyoke Canyon within the thesis area has the appearance of being a sheet sand which thins toward the craton. However, this does not reflect the true geometry of the unit, since the transect through the area is somewhat oblique to depositional strike. Even without the well-defined geometry, a barrier environment can be surmised with the available evidence. The abundant low-angle cross-beds and parallel laminations are typical of the upper shoreface of a barrier environment (Davies and others, 1971) and the relationship to the subjacent Pintwater Formation suggests a sand barrier prograding over the middle foreshore.

Age and Correlation

Because of the absence of fossils, precise dating of the Oxyoke Canyon Sandstone in the thesis area is not possible. In central Nevada, the formation has been dated by age determinations of enclosing formations.

The lower Oxyoke Canyon Sandstone is best dated at Union Mountain in the Sulphur Spring Range where it lies above conodonts of the inversus Zone and below conodonts no younger than the lower part of the costatus costatus Zone (Johnson & Kendall, 1976, p. 1117). Although this age cannot be confirmed in the thesis area, it is reasonable based on the inversus to possible serotinus Zone conodonts obtained from the subjacent Pintwater Formation. Oxyoke Canyon Sandstone deposition ended in the thesis area during the early Eifelian with the westward progradation of the Coarse Crystalline Member of the Simonson Dolomite.

The Oxyoke Canyon Sandstone in the thesis area is the same as the Sandy Member of the Sevy Dolomite (Osmond, 1954; 1962). It is correlative with the lower Quartzose Member of the Oxyoke Canyon Formation (Kendall, 1975) in central Nevada, and with the upper sandy beds of Member A of the Piute Formation in the Arrow Canyon Range (Frost, 1963). In central Nevada, the lower Quartzose Member of the Oxyoke Canyon Formation interfingers with the middle part of the Sadler Ranch Formation (Kendall, 1975).

SIMONSON DOLOMITE

General Statement

The Simonson Dolomite was named by Nolan (1935) in the Gold Hill Mining District of western Utah. An extensive investigation of the formation was conducted by Osmond (1954), and further work has been carried out on similar rocks in central Nevada (Gronberg, 1967; Schalla, 1978; Drake, 1978).

Osmond (1954) recognized four members of the Simonson Dolomite in east-central Nevada: the Coarse Crystalline, Lower Alternating, Brown Cliff-forming, and Upper Alternating Members. Only two distinct members were recognized within the thesis area: a Coarse Crystalline Member and an Alternating Member.

Only one complete, unfaulted section of the Simonson was found, which is in the Desert Range. The entire unit is present in the Sheep Range, but faulting and poor exposures prohibited measuring a complete section. In the Spotted Range, the formation is present through part of the Alternating Member, and only the Coarse Crystalline Member is present in the Pintwater Range.

Coarse Crystalline Member

The Coarse Crystalline Member of the Simonson Dolomite is present throughout the thesis area. It has a minimum thickness of 27.4 m in the Sheep Range, and reaches a maximum thickness of 69.9 m (minimum) in the Pintwater Range. The member comprises thick-bedded, coarse-grained cliff-forming dolomites which are medium grey on fresh surfaces and weather to a light grey to tan cliff. On close examination, weathered surfaces are covered with medium sand-sized dolomite rhombs.

The Coarse Crystalline Member is everywhere conformable with the underlying Oxyoke Canyon Sandstone. The contact is characterized by alternating beds of dolomitic sandstone and coarse-grained, sucrosic dolomite. The contact was arbitrarily placed at the top of the last thick (1-2 m) sand bed, which marks a change in lithology from predominantly sandstone to predominantly dolomite.

Pervasive dolomitization accounts for the coarse crystallinity of the unit, and has largely destroyed any primary sedimentary structures which may have been present. However, in the Spotted and Desert Ranges, faint parallel laminations were observed on outcrop (Figure 16). Petrographic analysis did not reveal the nature of these same laminations in thin section.

Petrographic analyses of samples from the Coarse Crystalline Member yield little information as to the character of the predolomitized sediment. Thin section study shows the rock to consist of an interlocking mosaic of subhedral to euhedral dolomite crystals. Many crystal contacts are sharp and planar, which is supposedly indicative of pore-filling sparry cement (Bathurst, 1971). Other crystal boundaries are less distinct, which would suggest neomorphic recrystallization (Bathurst, 1971). The dolomite crystals themselves have a "dirty" appearance, which may be from minute inclusions of calcite. In both hand sample and thin section, the Coarse Crystalline Member can be classified as a type 2 - mosaic dolomite (Mattes & Mountjoy,

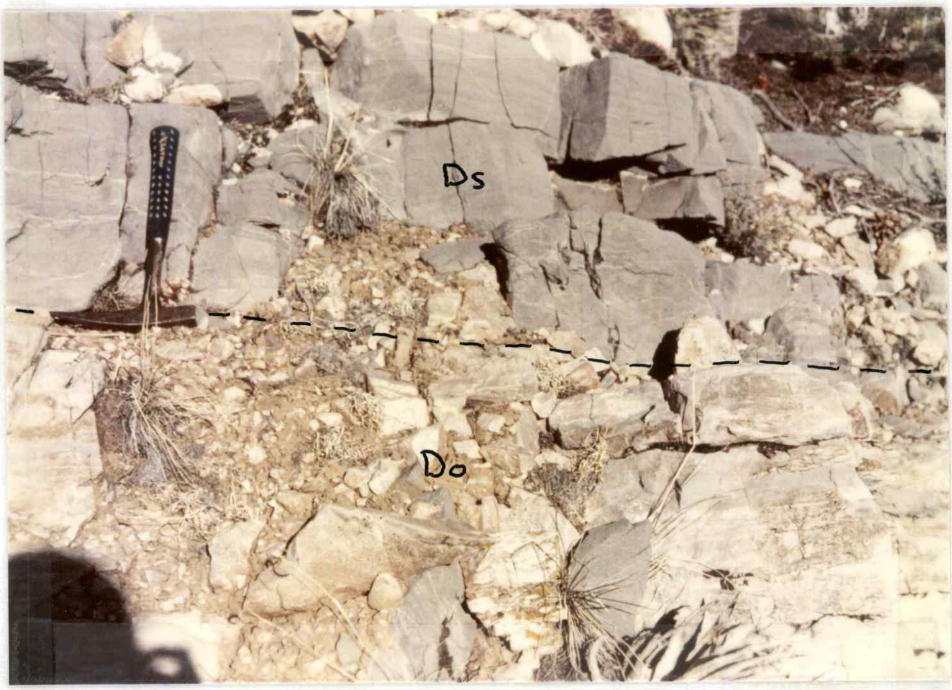

Figure 16. Laminations in base of Coarse Crystalline Member (Ds) above Oxyoke Canyon Sandstone (Do), Sheep Range.

1980).

The rock contains less than 1% angular quartz silt. Silt grains, where present, are embedded in dolomite crystals (Figure 17). Some relict biotic fragments can be recognized in thin section. A few of these fragments are tentatively identified as crinoid ossicles.

In the Spotted Range, the Coarse Crystalline Member exhibits more lithologic variety than elsewhere in the thesis area. There, two sub-units can be recognized on the basis of color and bedding character. The lower sub-unit is a medium dark grey dolomite which weathers light grey to greyish black. It is thickly bedded, and exhibits some parallel lamination. The upper sub-unit has indistinctly defined beds up to 1 m thick. This sub-unit weathers medium light grey to tan. Also, within this unit are isolated wavy laminations which appear to be of algal origin. In addition, dolomite intraclasts are common.

The contact between the Coarse Crystalline and Alternating Members, where exposed, was placed at a major lithologic break between the coarse-crystalline massive dolomite, and the first distinct bed of dark grey to black, medium-crystalline, laminated dolomite.

Alternating Member

The Alternating Member of the Simonson Dolomite is found throughout the thesis area, with the exception of the Pintwater Range. Here, faulting and/or erosion have removed this member. The Alternating Member is a very distinctive unit, and is recognized by a characteristic alternation of light and dark grey dolomites which occur in

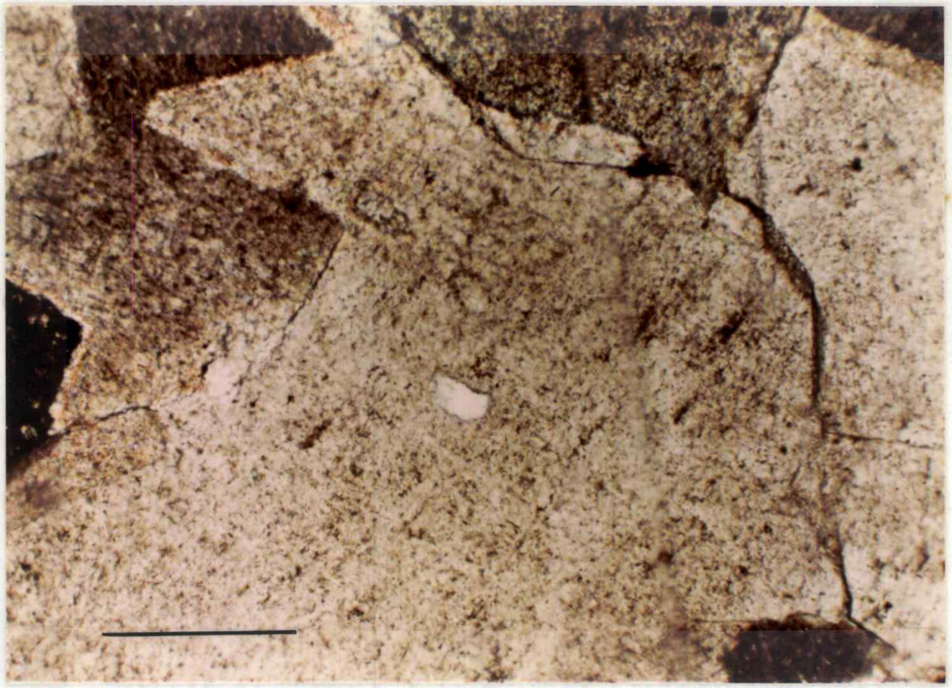

Figure 17. Quartz silt grain (center) embedded in dolomite crystal, Coarse Crystalline Member, Simonson Dolomite. (crossed nicols; bar scale is 0.2 mm)

Figure 18. Outcrop of Alternating Member, Simonson Dolomite, Desert Range, showing characteristic alternation of light and dark grey beds.

beds 0.35 to 1.5 m thick (Figure 18).

The dark beds of the Simonson are composed of fine- to medium-crystalline, dark grey dolomites which weather to a greyish black. The dark color of these beds is due to the presence of finely disseminated organic material. The lower contacts of the dark beds are generally sharp and planar (Figure 19), whereas upper contacts with the light beds are gradational in color, and undulose (Figure 20). These beds commonly are laminated; the laminations appear to be of stromatolitic origin. In addition, all the fossil debris found within the Simonson Formation is concentrated in the dark beds. Most fossil debris consists of small brachiopods and solitary corals. Freshly broken rocks emit a distinct fetid odor.

The light beds are more finely crystalline than the dark beds. They are medium light grey to light grey on fresh surfaces, and weather medium light grey to tan. Most beds are finely laminated and exhibit evidence of plastimorphic deformation. It is common to find angular clasts of dark beds within the light beds (Figure 21). The light beds are gradation in color from underlying dark beds, and are erosional at their tops.

Osmond (1954) summarized a comparison of light and dark beds within the Simonson Dolomite. The brown beds he described are equivalent to the dark grey to black beds of this report. Most of his descriptions can be applied to the alternating Simonson beds in the thesis area. The most obvious difference between Osmond's observations and those of this author is the nature of the contacts between light and dark beds. In the thesis area, the contact relationships

Figure 19. Hand sample showing sharp, planar contact at base of dark bed, Alternating Member, Simonson Dolomite. Note small burrow into light bed at left center. Bar scale at bottom right is 5 cm.

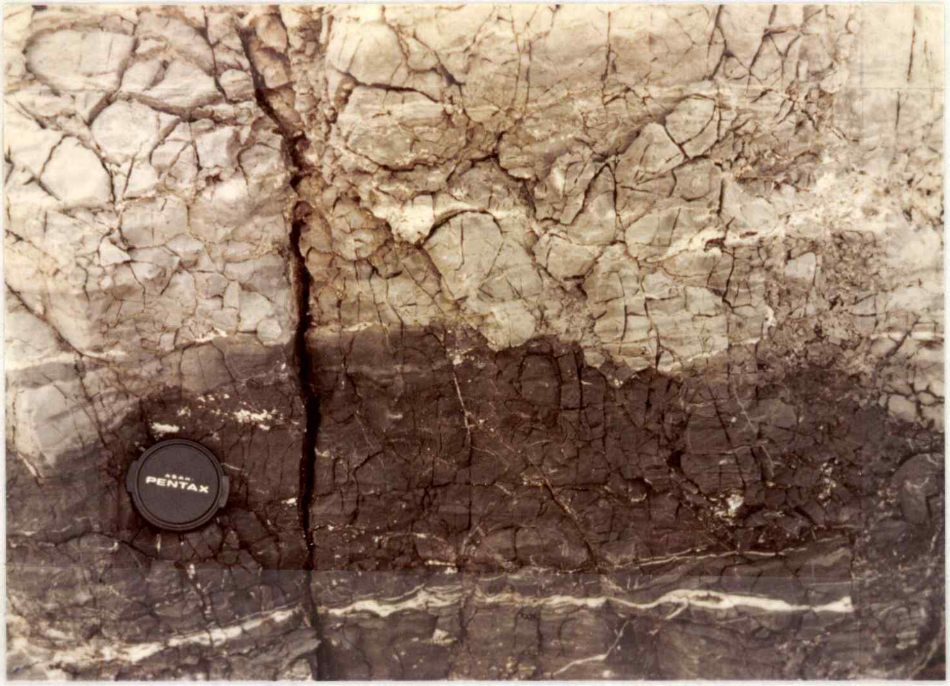

Figure 20. Undulose and gradational contact at top of dark bed. Alternating Member, Simonson Dolomite, Spotted Range.

Figure 21. Intraformational breccia of dark grey dolomite in light grey dolomite bed. Alternating Member, Simonson Dolomite, Spotted Range.

are reversed from Osmond's observation.

Near the base of the Alternating Member, beds of mottled light and dark grey dolomite are common (Figure 22a & b). Osmond (1956) studied these beds extensively and attributed the mottling to three controlling factors: lamination, intrastratal deformation, and random centers of dolomitization. The mottled beds in the thesis area appear to be the result of bioturbation. Boundaries between the light and dark patches are indistinct. Close examination of outcrops does not show evidence of obvious intrastratal deformation. Calcite-dolomite staining did not reveal any difference in composition between the light and dark patches.

Within the Alternating Member is a distinctive dark grey marker bed which contains abundant Amphipora (Figure 23). This bed ranges in thickness from 3.7 m in the Sheep Range to 8 m in the Desert Range. In the Spotted Range it is 4.6 m thick. This unit is medium-crystalline and sucrosic, and contains dolomite-filled vugs formed by the selective dissolution of biotic material. The rocks emit a strong fetid odor when broken.

There is an extensive intraformational breccia present within the Alternating Member of the Simonson. The base of this breccia in both the Desert and Spotted Ranges is about 30.5 m above the top of the Amphipora marker. The breccia consists of sub-rounded to angular clasts of dolomite in a very fine-grained dolomite matrix (Figure 24). The basal contact of the breccia is sharp, but the upper contact is indistinct.

Clasts range in size from a few millimeters to greater than

Figure 22a. Outcrop character of mottled dolomite, Alternating Member, Simonson Dolomite, Desert Range.

Figure 22b. Polished slab of mottled dolomite, Alternating Member, Simonson Dolomite.

Figure 23. Typical outcrop of Amphipora marker bed, Alternating Member, Simonson Dolomite, Desert Range.

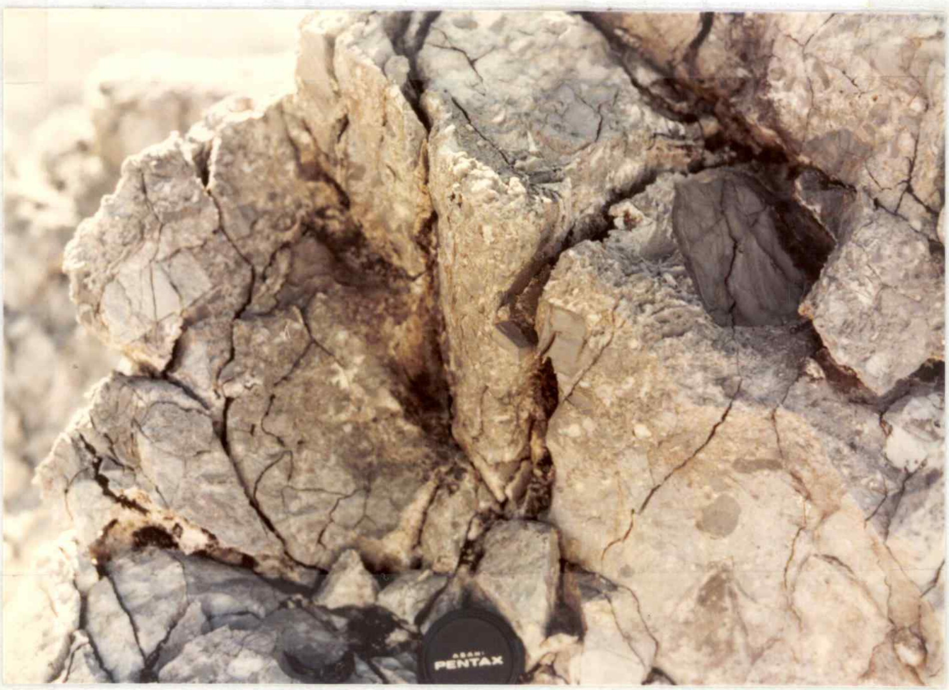

Figure 24. Outcrop of problematic intraformational breccia, Alternating Member, Simonson Dolomite, Desert Range. Note especially large, angular clast at upper right.

38 cm, and are in matrix support. The sub-rounded clasts are light grey, similar to the lithology of the surrounding light grey dolomite beds. Most of the more angular clasts are light or dark grey, and are laminated. Laminations are terminated abruptly at the edges of clasts, which suggests that the original rock was indurated before brecciation occurred. In thin section the matrix of the breccia is very fine-grained and does not exhibit the extensive recrystallization observed in the surrounding dolomite beds.

In the Spotted Range, there occurs a rock type within the Alternating Member of the Simonson Formation which is found nowhere else in the thesis area. Directly overlying the above-mentioned breccia, and in gradational contact with it is a massive, brown-weathering, coarse-crystalline dolomite. This unit is internally chaotic, with brecciation common (Figure 25). It is markedly vuggy, with the vugs probably being formed by early selective dissolution of biotic material. Common within this massive unit are irregular grey masses with faint internal laminations which are probably of algal origin.

Near the top of this unit are isolated beds 0.61 to 1.2 m thick that more closely resemble the underlying banded dolomite (Figure 26). These normally stratified beds are similar on color and internal structure to the dark grey beds of the Alternating Member. However, they are more coarsely crystalline and are discontinuous along strike.

Near the top of the Alternating Member is a 6.1 to 12.2 m thick brachiopod biostrome. The brachiopods probably belong to the stringcephaloid genus Geranocephalus (Johnson, oral commun.) based on their size, the thinness of their shells, and the lack of a median septum.

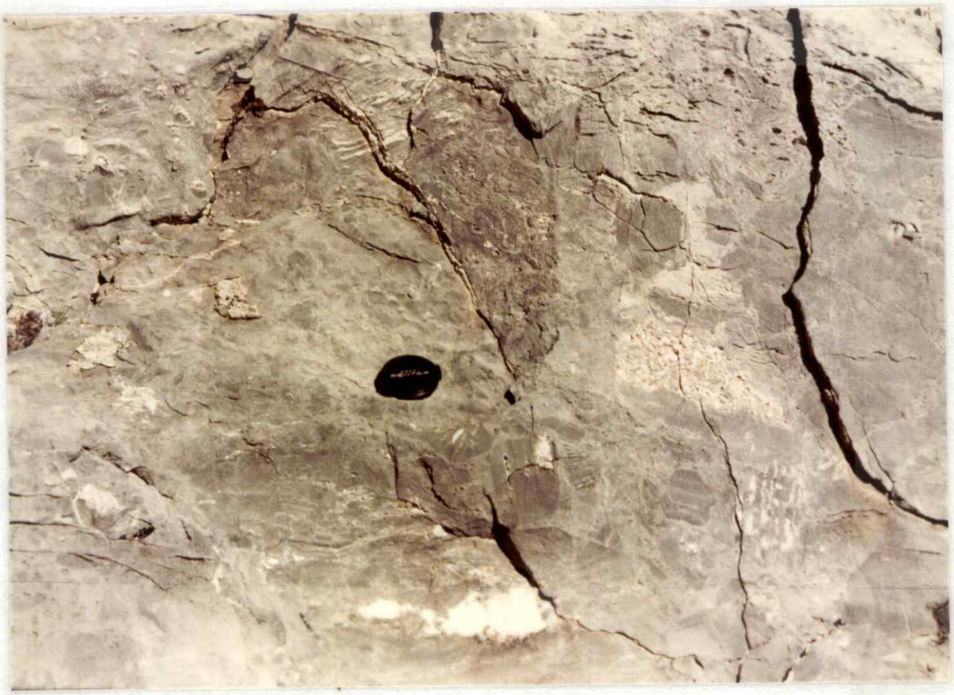

Figure 25. Typical outcrop of possible bioherm within Alternating Member, Simonson Dolomite, Spotted Range. Note unbedded outcrop character, chaotic fabric, and brecciation within unit.

Figure 26. Outcrop of bioherm, Alternating Member, Simonson Dolomite, with laminated bedding (near backpack) between structureless dolomite.

These brachiopods occur in a dark grey, finely sucrosic dolomite, as in the Mahogany Hills (Gronberg, 1967).

Overlying the Simonson Dolomite is the Middle to Upper Devonian Guilmette Formation. The contact between the two can be observed in both the Sheep and Desert Ranges. The contact, which is conformable, is marked by an abrupt lithologic change from the well-bedded light and dark dolomites of the Simonson to a yellow orange-weathering limy siltstone which seems to characterize the base of the Guilmette in the area (Figure 27).

Environment of Deposition

The origin of the Coarse Crystalline Member of the Simonson Dolomite in the thesis area is problematic. Complete dolomitization and recrystallization of the original sediment has virtually obliterated the primary fabric. However, possible environments can be surmised from the few pieces of evidence that remain.

The initial problem in establishing the environment of the Coarse Crystalline Member lies in determining the original grain size. Kendall (1975, p. 138) suggested that the Coarse Crystalline Member of the Oxyoke Canyon Formation may initially have been similar to the Sevy Dolomite mudstones. This author disagrees with Kendall's interpretation.

Murray and Lucia (1967) observed that fine-grained carbonate sediments are more likely to enter into transformation reactions during early diagenesis, and become less likely to enter into such reactions with increasing depth of burial, as a result of progressive dewatering and lithification. Because the mosaic fabric of the Coarse Crystalline

Figure 27. Conformable contact between Simonson Dolomite (Ds) and Guilmette Formation (Dg), Desert Range.

Member implies late burial diagenesis (Mattes & Mountjoy, 1980), it seems unlikely that the unit was deposited as a fine, Sevy-like mud. In addition, the coarse crystallinity of the rock is distinctly different from that of the sub- and superjacent dolomites. If all of the dolomites within the stratigraphic section began as fine-grained carbonates, given the same diagenetic history, it seems unlikely that only one unit would preferentially become so coarsely crystalline.

The presence of thin, elongate, finely crystalline carbonate mudstone clasts within the coarse mosaic dolomite matrix also supports a relatively coarse initial grain size for the Coarse Crystalline Member. Sample SP IV-7 exhibits this phenomenon (Figures 28 & 29). Many of the clasts are discontinuous, but there are some continuous fine-grained layers which are separated by coarse-grained layers. This suggests a definite bimodal size distribution of the original sediment.

Kendall (1975) suggested a highly variable, restricted depositional environment for the Coarse Crystalline Member of the Oxyoke Canyon Formation and concluded that it was deposited under higher energy and better circulation conditions than the equivalent Coarse Crystalline Member of the Simonson Dolomite. This interpretation was based on the presence of cross-beds in the Coarse Crystalline Member of the Oxyoke Canyon which are not found in correlative beds in the Simonson Formation. However, the lack of cross-bedding in the Simonson does not preclude the possibility of an environment very similar, if not identical to that of the Coarse Crystalline Member of the Oxyoke Canyon Formation.

The landward position of the coarse crystalline Simonson relative

Figure 28. Hand sample showing thin, fine-grained dolomite clasts in coarse-grained matrix, Coarse Crystalline Member, Simonson Dolomite, Spotted Range. Note nearly continuous fine-grained layers near bottom of sample.

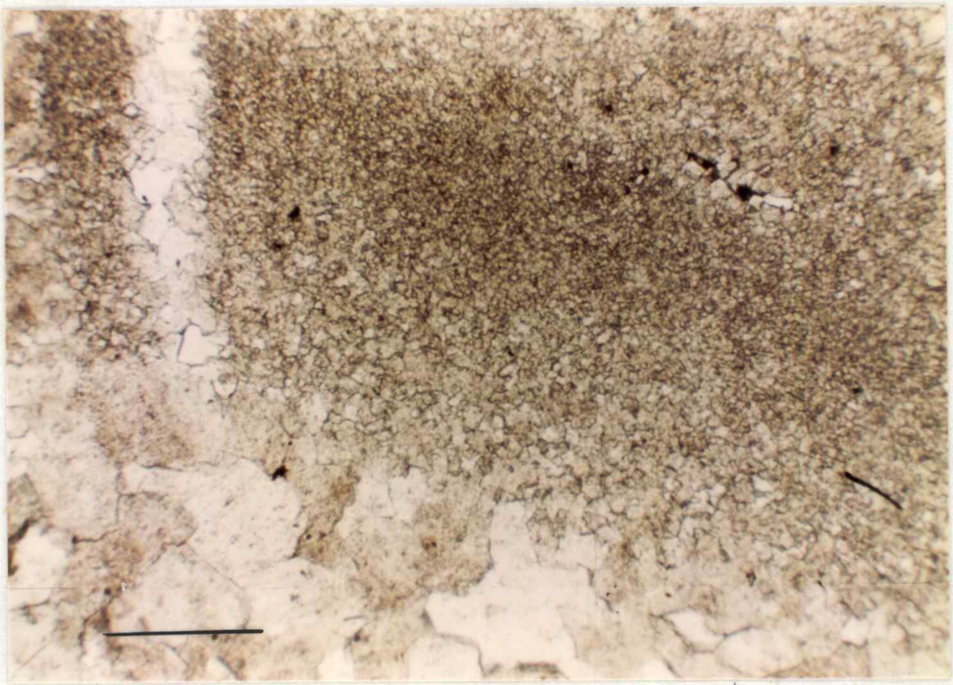

Figure 29. Photomicrograph showing interface between fine- and coarse-grained dolomite of Figure 28. Note probable lamination within fine-grained clast. (plane light; bar scale is 0.5 mm)

to the Oxyoke Canyon Sandstone barrier system would be favorable to the deposition of calcarenites derived from biotic materials. A similar situation of calcareous sands found on the landward side of a barrier system (albeit a reefal barrier) is found on the South Florida Shelf (Sellwood, 1978).

Since the biogenic carbonate sands on the South Florida Shelf are somewhat limited in extent compared to the widespread coarse crystalline Simonson, another depositional model may explain the broad areal extent of the Coarse Crystalline Member of the Simonson Dolomite. Thick widespread carbonate sands which might be analogous to the Coarse Crystalline Member can be found in Shark Bay, western Australia. The carbonate bank there covers approximately 400 square miles, and consists mainly of sands derived from mollusks and forams (Davies, 1970).

The Coarse Crystalline Member of the Simonson Dolomite is correlative with the Coarse Crystalline Member of the Oxyoke Canyon Formation in central Nevada (Kendall, 1975). Kendall (1975) concluded that the Coarse Crystalline Member is a slightly diachronous, regressive unit. This author agrees is part with this interpretation, but thinks that only the upper part of the unit is regressive, as explained below.

The Coarse Crystalline Member of the Simons Dolomite is the subtidal equivalent of Member B of the Piute Formation in the Arrow Canyon Range (Frost, 1963). Member B appears to have been deposited in a shallow subtidal to supratidal environment. Based on the carbonate bank model and Shark Bay, Australia (Davies, 1970), one would expect an interfingering relationship between the Coarse Crystalline Member of the Simonson Dolomite and Member B of the Piute Formation. If the entire Coarse Crystalline Member were regressive, application of Walther's Law would necessitate superposition of the Member B lithology on the Coarse Crystalline Member. This is not seen.

The author believes that a transgression occurred during early Coarse Crystalline time. This transgression was responsible for the widespread extent of the Coarse Crystalline Member throughout east-central and southern Nevada. Johnson (oral commun.) supports the initiation of a transgression during Coarse Crystalline time.

The Coarse Crystalline Member of the Simonson Dolomite is an upward-shallowing deposit. Johnson (oral commun.) envisions shoaling in the carbonate sand unit behind a buildup at the shelf edge. This author concurs with Johnson's model.

Deposition of the Alternating Member began when a transgression brought a slightly deeper, more restricted lithotope into the area. The initial transgressive pulse was strong, based on the presence of Alternating Member-type beds in the Arrow Canyon Range. There, alternating light and dark beds occur in Member C of the Piute Formation (Frost, 1963). The position of these beds above the intertidal to supratidal deposits of Member B of the Piute Formation indicates an abrupt deepening of water in the area.

The Alternating Member of the Simonson Dolomite represents a shallow, restricted lagoonal environment. The dark grey beds, with their sparse biota and abundant Amphipora are analogous to the dark Amphipora facies of Krebs (1974). This facies is characteristic of both back reef lagoons and broad shelf lagoons. In the case of the

Simonson Dolomite, the dark beds in the Alternating Member would be indicative of a broad, widespread shelf lagoon behind a carbonate buildup at the shelf margin, as hypothesized by Johnson (oral commun.).

The fine crystallinity, fine laminations and plastimorphic deformation within the light beds of the Alternating Member suggest a shallow, low energy intertidal to supratidal environment. The gradational contacts between the dark and light beds indicate an upward-shallowing environment. This could be caused either by evaporation or infilling of the lagoon by carbonate mud, or both. In any case, each dark-light couplet represents a single upward-shallowing event during a stillstand of sea level. The sharp contact at the base of the dark beds indicates an abrupt return of the shallow restricted environment, probably caused by slight rises of sea level.

The formation of the sedimentary breccia within the Simonson Dolomite is problematic. Osmond (1954) attributed an intraformational breccia between the Coarse Crystalline Member and the Lower Alternating Member to large-scale slumping of sediments into the Confusion Basin. It seems unlikely that the breccia in the thesis area is depositional. The environment of the Alternating Simonson appears to be low energy, and the depositional slope was probably very low. The totally chaotic nature of the rock fabric and large size of many of the clasts would not be expected in such a low energy environment. The dolomite matrix, which does not exhibit the well-developed crystallinity of the surrounding dolomites, indicates that the brecciation may have been both post-depositional and post-diagenetic.

The gross lithologic character of these breccias is remarkably similar to Mississippian solution-collapse breccias in southwestern Montana (Middleton, 1961). However, no regional studies have reported evidence of extensive evaporite deposits at this stratigraphic level, and no petrographic evidence for evaporites was found associated with the breccia. Further study is needed to determine the exact nature of the formation of the Simonson breccias.

The massive brown dolomite at the top of the stratigraphic section in the Spotted Range is probably of biohermal origin, as suggested by its massive nature, chaotic fabric, and limited geographic extent. Osmond (1954) attributed a biostromal origin to the Brown Cliff Member, which is in a stratigraphic position similar to that of the massive dolomite in question. Unfortunately, a lack of overlying strata from faulting and erosion makes it impossible to define the geometry of the unit and therefore to confirm a biohermal origin. In addition, Basin and Range structure limits the possibility of finding any flank beds that may have been associated with a bioherm.

Presence of a bioherm within the Alternating Member of the Simonson Dolomite indicates an incursion of a deeper water lithotope with better circulation upon the Alternating Member lithotope. This is supported by the presence of the Brown Cliff Member of Osmond (1954) elsewhere in Nevada and Utah. The discontinuous occurrence of normal stratification near the top of the bioherm in the Spotted Range indicates the beginning of the return to shallower, more restricted deposition as is found in the rest of the Alternating Member. Termination of Simonson deposition occurred when a major transgression caused the deeper water environment of the Guilmette Formation to invade the area.

Age and Correlation

Precise dating of the Simonson Dolomite within the thesis area is difficult. Even though some horizons within the Alternating Member are fossiliferous, there are no readily identifiable macrofossils. Although one conodont collection was obtained from the Alternating Member in the Sheep Range, dating of the Simonson Dolomite is dependent largely on data from central Nevada.

The Coarse Crystalline Member of the Simonson Dolomite, as previously mentioned, is correlative with the Coarse Crystalline Member of the Oxyoke Canyon Formation as defined by Kendall (1975) in central Nevada. No fossils were found in the Coarse Crystalline Member within the thesis area. However, and early Eifelian age for the Coarse Crystalline Member of the Oxyoke Canyon Formation is probable, based on the presence of a costatus costatus Zone conodont fauna in the upper Sadler Ranch Formation at Modoc Peak (Kendall, 1975).

In southern Nevada, the Coarse Crystalline Member of the Simonson Dolomite is correlative with Member B of the Piute Formation as defined by Frost (1963). This correlation is based on the relative stratigraphic position of the two units. Each of the two units is underlain by cross-bedded to plane-laminated quartz arenites, and is overlain by alternating beds of light and dark dolomites.

The Alternating Member of the Simonson Dolomite can be correlated with the Sentinel Mountain and Bay State Dolomites and the Woodpecker Limestone (Johnson & Sandberg, 1977). In addition, it is also equivalent to the lower Guilmette Formation at Blackrock Canyon (Johnson & Sandberg, 1977, Fig. 2). The age of the Alternating Member in the thesis area ranges from middle Eifelian to at least early Givetian.

One collection of conodonts from the Alternating Member above the Amphipora biostrome in the Sheep Range yielded specimens of Polygnathus parawebbi (Klapper, written commun.). This species ranges from the australis Zone through the Lower varcus Subzone (Klapper, 1977). This supports the Eifelian to Givetian age of the Alternating Member.

The presence of the Geranocephalus biostrome near the top of the Simonson Dolomite helps to place an upper limit on the age of the formation. This brachiopod occurs in Interval 19 and possibly Interval 20 (Johnson and others, 1980, Table 12). This interval assignment shows that the Geranocephalus biostrome was deposited during the ensensis conodont Zone and possibly into the Lower varcus Subzone (Johnson and others, 1980, Fig. 5).

By combining conodont and brachiopod date from the Alternating Member, it can be concluded that Simonson deposition did not continue past middle Givetian time. This information, plus the Eifelian age of the Coarse Crystalline Member shows that Simonson deposition was confined to the Middle Devonian.

GEOLOGIC HISTORY

During the Early and Middle Devonian, five major sedimentary units were deposited in the shallow marine and peritidal environments which covered northwestern Clark County. A summary of these lithofacies and the timing of their deposition is presented in Figure 30.

Devonian deposition began during Pragian time with a transgression which brought the Sevy Dolomite lithotope into the area. The Pragian sea transgressed over a carbonate terrain of exposed Silurian Laketown Dolomite. Sevy deposition continued into the lower Zlichovian. A late Pragian regression left the Sevy tidal flat exposed to erosion. Although Sevy Dolomite is found only in the Spotted, Pintwater, and Desert Ranges, the presence of Sevy remnants in the Arrow Canyon Range indicates the possibility of Sevy deposition in the Sheep Range as well. Sevy rocks, if deposited in the Sheep Range, must have been eroded away prior to Zlichovian time.

In the Zlichovian, another transgression occurred, which initiated deposition of the McColley Canyon Formation. The Zlichovian sea transgressed over the exposed and eroded Sevy tidal flats. The abundant normal marine fauna of the pinyonensis Zone indicates that water depths in the area, although shallow, were probably greater during late McColley Canyon and early Pintwater time than at any other time through the Middle Givetian.

The Pintwater Formation, at its base, was probably an offshore facies of the McColley Canyon lithotope during the gronbergi Zone. Westward progradation within the Pintwater lithotope probably began

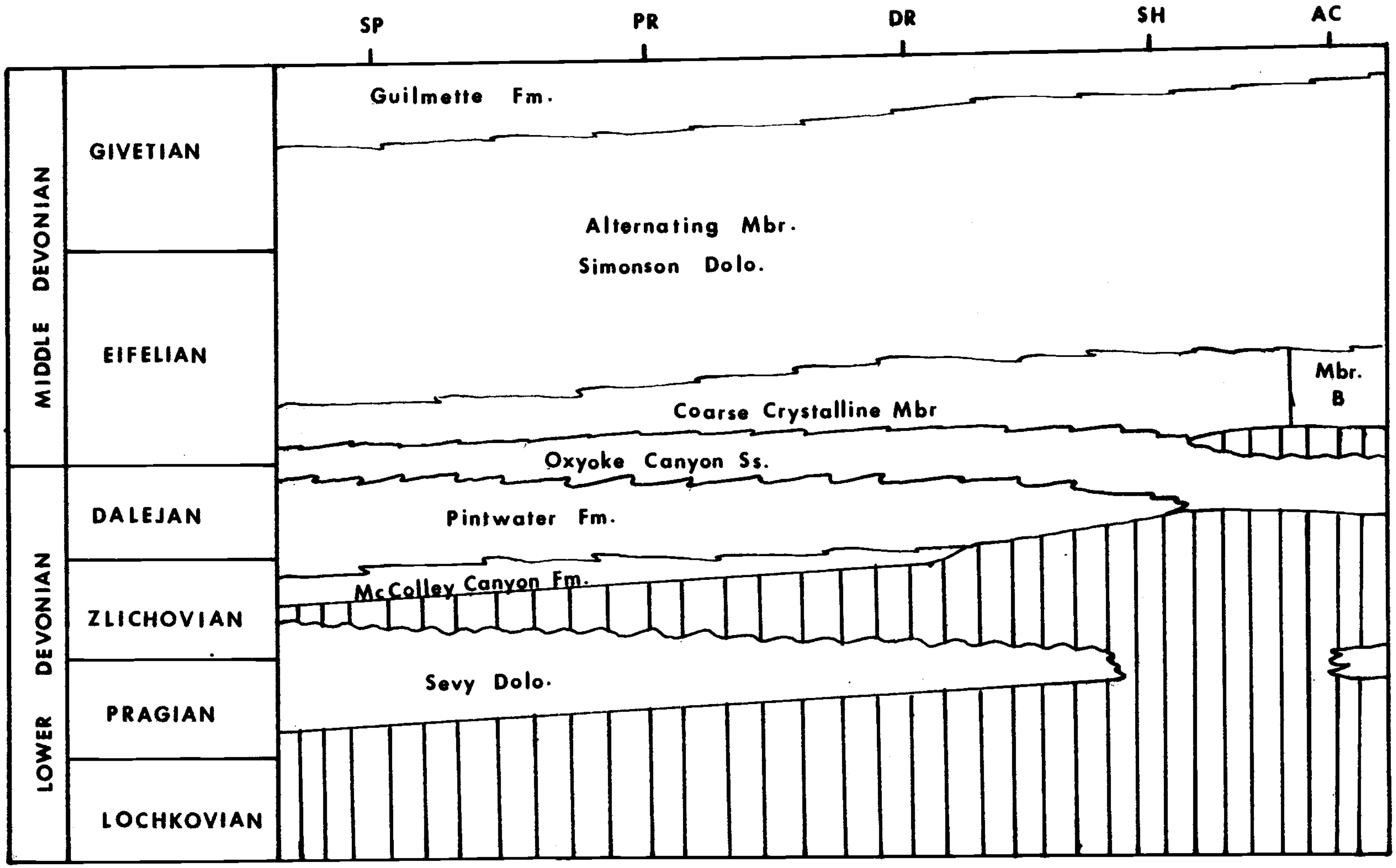

Figure 30. Time-rock model of Lower and Middle Devonian deposition in northwestern Clark County, Nevada. SP=Spotted Range; PR=Pintwater Range; DR=Desert Range; SH=Sheep Range; AC=Arrow Canyon Range.

in Dalejan time. A similar but earlier westward progradation of a shallow environment is seen in central Nevada, where a tongue of Beacon Peak Dolomite progrades over the lower Bartine Member of the McColley Canyon Formation (Johnson & Sandberg, 1977, Fig. 3). The transgressive pulse in southern Nevada similar to the one during inversus time which accounted for widespread deposition of the Bartine Tongue of the McColley Canyon Formation (Kendall, 1975) in central Nevada is represented by the lower part of the Pintwater Formation.

The Oxyoke Canyon Sandstone in the thesis area represents a continuation of the upper Pintwater Dalejan regression into Eifelian time. The Oxyoke Canyon lithotope consisted of a complex system of quartzose barrier bars and inner shelf sands parallel to the early Middle Devonian shoreline.

The Coarse Crystalline Member of the Simonson Dolomite is the product of a transgressive-regressive cycle. An early Middle Devonian transgression superimposed the calcareous sands of the Coarse Crystalline Member on the quartz sands of the Oxyoke Canyon Sandstone. This transgression, which is also seen in central Nevada, was responsible for extending the Coarse Crystalline lithotope over a wide area of Nevada and Utah. There was a shallowing during late Coarse Crystalline time, and finally a new transgression associated with the deposition of the peritidal Alternating Member of the Simonson Dolomite.

The Alternating Member of the Simonson Dolomite represents a widespread shallow, restricted lithotope that covered much of Nevada and Utah during Eifelian and Givetian time. The dark-light couplets represent shallowing-upward sequences which were probably initiated by minor rises in sea level. Following each minor pulse, a stillstand of sea level allowed for enough carbonate sediment accumulation to replace the shallow subtidal lagoonal environment of the dark beds with supratidal deposition.

Peritidal deposition was ended in southern Nevada sometime during the middle to late Givetian by a major transgressive pulse which marked the beginning of deeper water sedimentation associated with deposition of the Guilmette Formation.

In comparing timing of events in southern Nevada as discussed above with those in central Nevada, a few significant differences can be observed. These differences appear to be concentrated in the Lower Devonian, with their effects being minimized in the Middle Devonian.

In central Nevada, the thick Lower Devonian section indicates that the amount of subsidence during that time must have been substantial. However, in southern Nevada, the conodont sequence is condensed, and the Lower Devonian sequence is relatively thin. The thin sequence, when compared to that in central Nevada, indicates that the rate of subsidence in southern Nevada was much slower during the Early Devonian.

In the Middle Devonian, differences between southern and central Nevada are minimal. Starting with the Oxyoke Canyon Sandstone and continuing through the top of the Simonson Dolomite, depositional facies are the same throughout southern and east-central Nevada. In addition, the timing of depositional events in the two regions seems to coincide. This indicates that during the Middle Devonian, in contrast to the Early Devonian, there probably existed a more uniform tectonic setting along the Cordilleran margin in the Great Basin.

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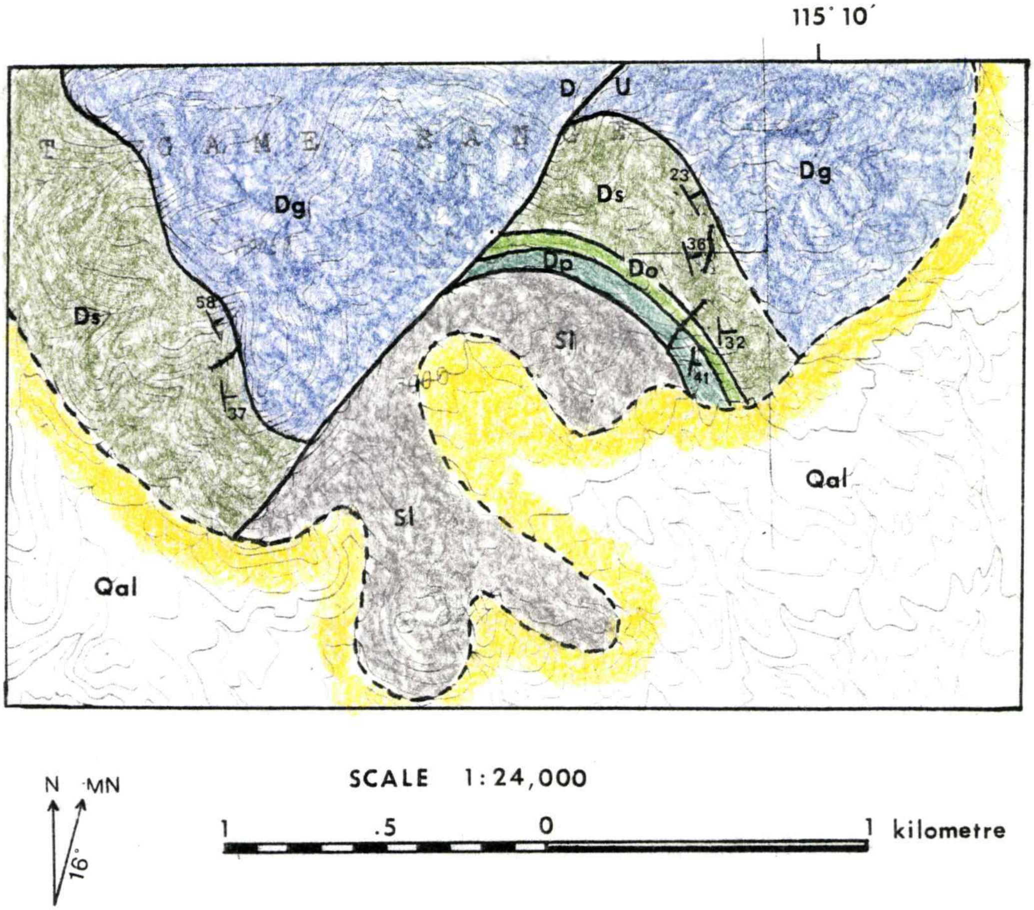
APPENDICES

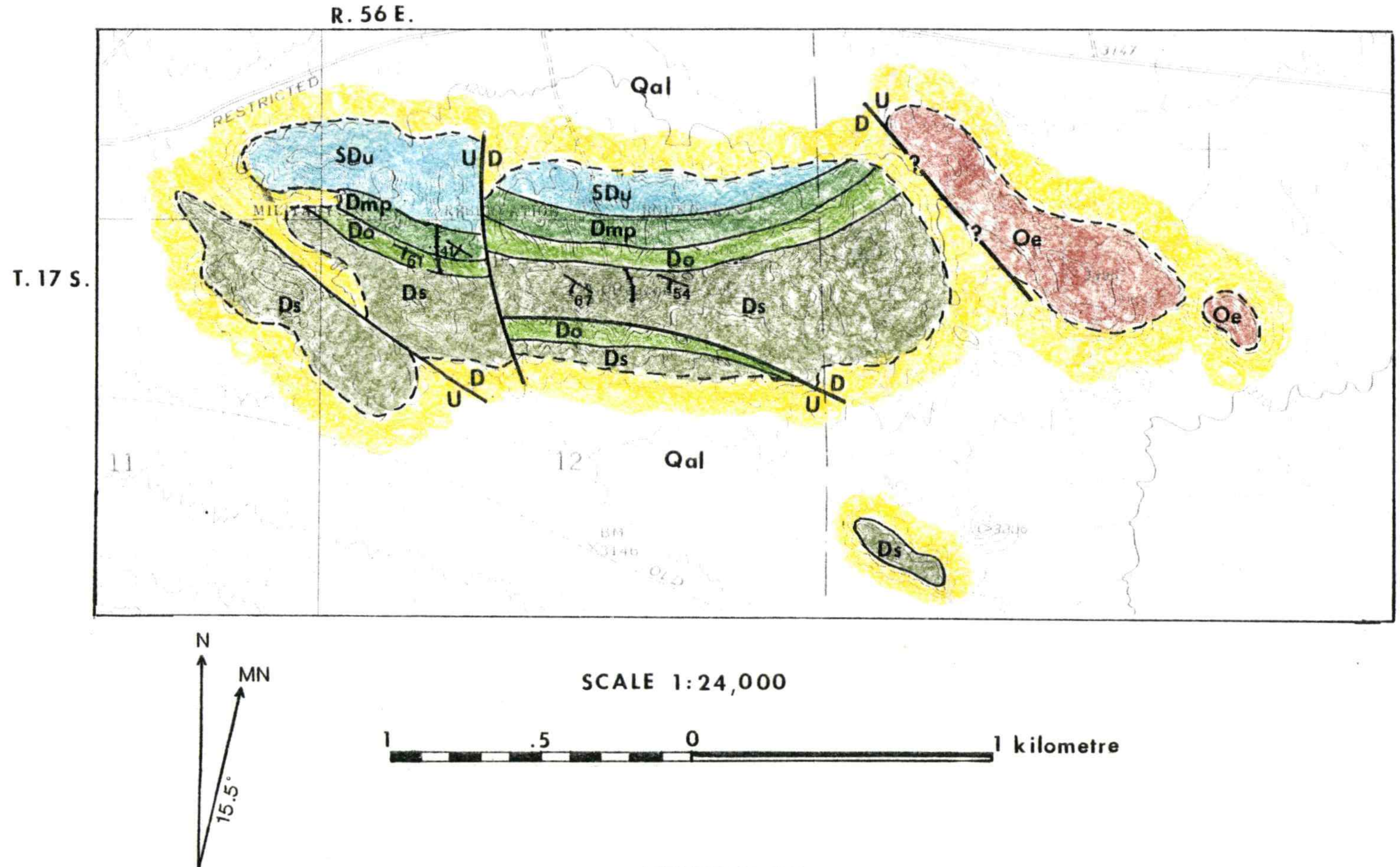


APPENDIX I

Locality map for measured section in the central Sheep Range, Clark County, Nevada. Base map: U.S.G.S. Sheep Range 4 SW 7.5-minute quadrangle (unpublished advance sheet). Geology modified from Guth (1980). See Plate 1 for key.

APPENDIX II

Geology of the southernmost Pintwater Range, Clark County, Nevada. Base map: U.S.G.S. Indian Springs SE 7.5-minute quadrangle. Geology by L.J. Jarvis, 1980. See Plate 1 for key.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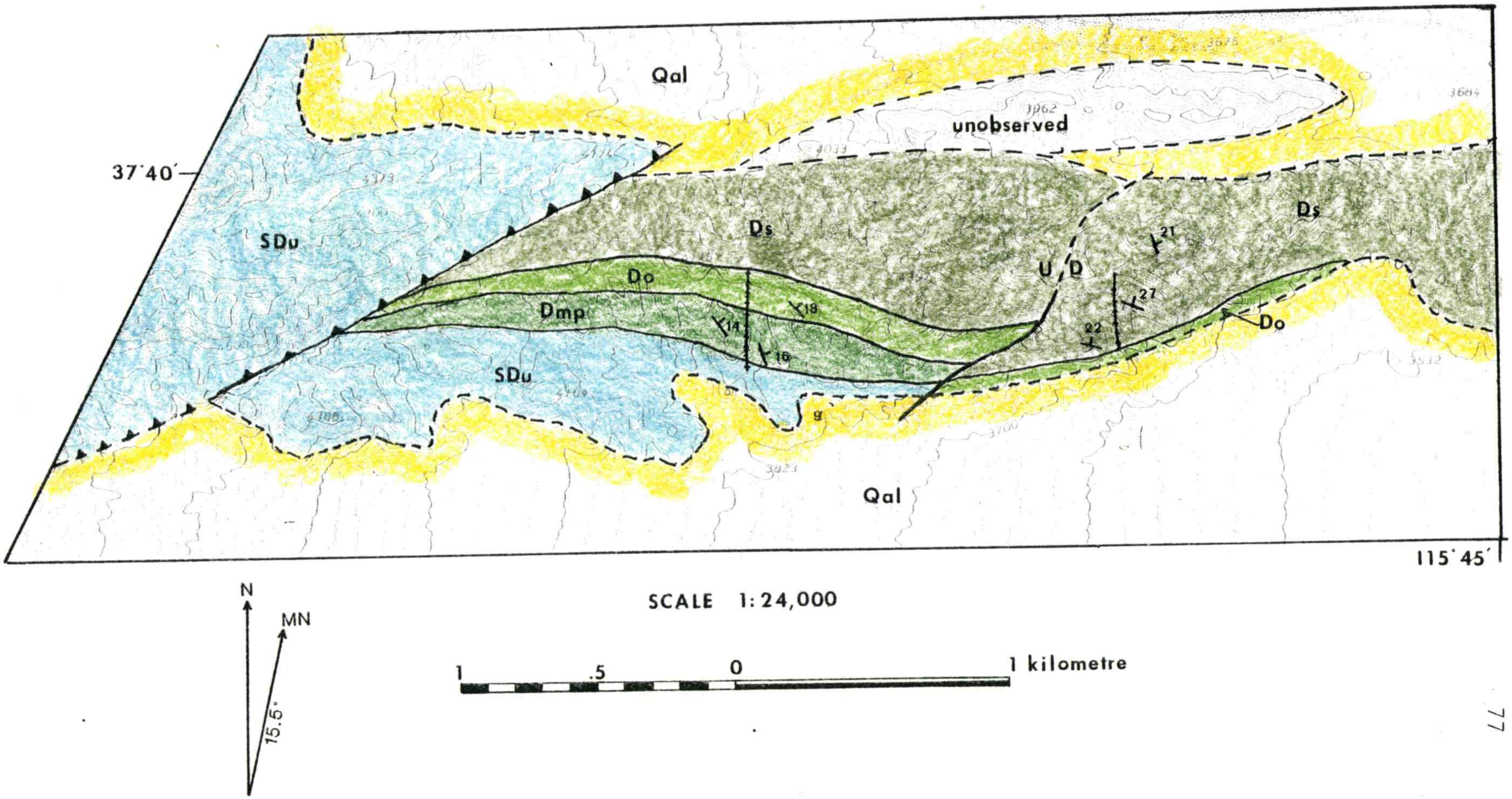
APPENDIX II

APPENDIX III

Geology of part of the southern Spotted Range, Clark County, Nevada. Base map: U.S.G.S. Mercury NE 7.5-minute quadrangle. Geology by L.J. Jarvis, 1980. See Plate 1 for key.



APPENDIX III

APPENDIX IV

FOSSIL COLLECTIONS

Sample: SHM III-4

Location: Sheep Range Section, 427 m south, 244 m west of peak 7705

Footage: 4.5 m above _Amphipora_ marker, Alternating Member, Simonson Dolomite

Conodonts

Polygnathus parawebbi Chatterton

indet. simple cone

Age: _australis_ Zone to Lower _varcus_ Subzone

Sample: DRM I-3

Location: Desert Range Section, 122 m south, 122 m east of peak 3708

Footage: upper 1 m, McColley Canyon Formation

Conodonts

Pandorinellina exigua philipi (Klapper)

Icriodus nevadensis Johnson & Klapper

_I._ sp. indet.

Panderodus sp.

Belodella sp.

Age: _dehiscens_ Zone to lower part of _gronbergi_ Zone

Sample: PRM II-3

Location: Pintwater Range Section, 30.5 m FNL, 366 m FWL, Sec. 12, T. 17 S., R. 56 E.

Footage: upper 0.8 m, McColley Canyon Formation

APPENDIX IV, continued

Conodonts

Polygnathus gronbergi Klapper & Johnson

P. dehiscens Philip & Jackson

Icriodus nevadensis Johnson & Klapper

Panderodus sp.

Belodella sp.

Brachiopods

Dalejina sp. (large)	2
Strophonella sp.	1
Parachonetes macrostriatus	3
Atrypa nevadana	21
Howellella? sp.	2

Corals

Breviphrentis invaginatus	2 + 4?
Sinospongophyllum? sp.	4 + 3?
?*Papiliophyllum elegantulum*	6
indet. rugosan	

Trilobites

Phacops sp.	3

Age: *pinyonensis* brachiopod Zone; lower part of *gronbergi* conodont Zone; Interval 11

Sample: PRM II-7

Location: Pintwater Range Section, 61 m FNL, 488 m FWL, Sec. 12, T. 17 S., R. 56 E.

APPENDIX IV, continued

Footage: upper 0.6 m of McColley Canyon Formation

Conodonts

Polygnathus dehiscens Philip & Jackson ?
(1 incomplete specimen)

Pandorinellina exigua philipi (Klapper)

Icriodus sp. indet.

Panderodus sp.

Brachiopods

Rhipidomella sp.	48
Leptaena sp.	1
Parachonetes macrostriatus	4
Atrypa nevadana	191
Coelospira sp.	3
Howellella? sp.	1
Cyrtina? sp.	1

Corals

Cystiphylloides? sp. (or Zonophyllum? sp.)	2
Heterophrentid coral	1
Neaxon sp.	2 + 2?
Papiliophyllum? sp.	1
Zaphrentid? corals	2
undetermined rugosans	2
indeterminate fragments	numerous
indet. favositid sp.	3
Syringopora sp.	6 clusters

APPENDIX IV, continued

Sample: PRM II-7 (continued)

Mollusks

Platycerus sp.	3 (2 with spires)
herniconical gastropods	4

Age: pinyonensis brachiopod Zone; dehiscens to lower part of gronbergi conodont Zones

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Sample: PRM II-8

Location: Pintwater Range Section, 61 m FNL, 366 m FWL, Sec. 12, T. 17 S., R. 56 E.

Footage: 18 m above base of Pintwater Formation

Conodonts

Polygnathus inversus Klapper & Johnson

P. laticostatus? Klapper & Johnson (1 specimen)

Pandorinellina exigua exigua (Philip)

Icriodus trojani Johnson & Klapper

I. sp. indet.

Belodella sp.

Age: inversus Zone to lower part of serotinus Zone

Sample: PRM II-9

Location: Pintwater Range Section, 18 m FNL, 366 m FWL, Sec. 12, T. 17 S., R. 56 E.

Footage: basal 1 m, McColley Canyon Formation

APPENDIX IV, (continued)

Sample: PRM II-9 (continued)

Conodonts

Icriodus sp. indet.

Age: no zonal determination

Sample: SP IV-1

Location: Spotted Range Section, 854 m east, 244 m south of peak 4397

Footage: 5.5 m above base of Lower Alternating Member, Simonson Dolomite

Conodonts

Icriodus sp. indet.

Age: no zonal determination

Sample: SP IV-2

Location: Spotted Range Section, 549 m west, 244 m south of peak 4397

Footage: 6.5 m above base, McColley Canyon Formation

Conodonts

Polygnathus gronbergi Klapper & Johnson

Icriodus nevadensis Johnson & Klapper

I. sp. indet.

Pandorinellina steinhornensis subsp. indet.

Panderodus sp.

Age: *gronbergi* Zone

APPENDIX IV, continued

Sample: SP IV-3

Location: Spotted Range Section, 549 m west, 274 m south of peak 4397

Footage: basal bed, McColley Canyon Formation

Conodonts

Icriodus sp. indet.

Age: no zonal determination

Sample: SP IV-4

Location: Spotted Range Section, 549 m west, 183 m south of peak 4397

Footage: 5 m above base of Pintwater Formation

Conodonts

Polygnathus laticostatus Klapper & Johnson

P. sp. indet.

Icriodus sp. indet.

Panderodus sp.

Age: *inversus* Zone, with some qualification due to poor preservation

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Sample: SP IV-11

Location: Spotted Range Section, 854 m east, 122 m south of peak 4397

Footage: 5.6 m above *Amphipora* marker, Alternating Member, Simonson Dolomite

Conodonts

Polygnathus sp. indet.

"*Coelocerodontus*" sp.

Age: no zonal determination