AN ABSTRACT OF THE THESIS OF

Storr L. Nelson for the degree of Master of Science in Stratigraphy presented on May 21, 1996. Title: Lower and Middle Devonian Carbonate-Platform and Outer-Shelf-Basin Deposits Flanking Railroad Valley, Nevada.

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Lower and Middle Devonian strata crop out on the former stable carbonate platform that existed in the Quinn Canyon Range, through the carbonate shelf edge in the Pancake Range, to the carbonate slope and outer-shelf basin in the Reveille Range.

The strata of the Reveille Range record a transition from deposition on the carbonate platform in the Lower Devonian, to deposition at the carbonate platform margin, to deposition in the outer-shelf basin in the Middle Devonian. Conodonts collected from the base of the Sevy Dolomite yield a *kindlei*-Zone age, an indication that the Sevy Dolomite is younger than previously recognized.

Throughout the Lower and Middle Devonian, carbonate strata of the Pancake Range and Quinn Canyon Range were deposited on the shallow carbonate platform. Conodonts collected from the base of the Lower Alternating Member of the Simonson Dolomite in the Quinn Canyon Range have a slightly older age (*serotinus*- to *costatus* Zone) than other eastern Nevada locations.

The Lower Devonian Sevy Dolomite was deposited in a shallow carbonate subtidal through supratidal environment and is similar in outcrop throughout the ranges. Petrographic studies show that the samples are lithologically and diagenetically similar, indicating a similar intensity of dolomitization from the precursor calcareous mudstone. The Formation classifies as bioturbated mudstone and wackestone.

The Middle Devonian Simonson Dolomite was deposited in shallow carbonate subtidal through supratidal environments. The Simonson Dolomite was affected by Milankovitch Cycles, glacio-eustatic oscillations of sea level, producing a characteristic rhythmic bedding

The Middle Devonian Sadler Ranch Formation and Denay Limestone are lithologically and diagenetically different from the shallow water deposits of the Lone Mountain Dolomite, Sevy Dolomite, and Simonson Dolomite. The Sadler Ranch Formation and Denay Limestone were deposited at the carbonate platform edge and on the carbonate slope and outer-shelf basin, respectively. The Sadler Ranch Formation is dolomitized and may be classified as fossiliferous wackestone and mudstone. The Denay Limestone is not dolomitized and is classified as mudstone and fossiliferous grainstone and packstone.

Dolomitization in the Paleozoic strata of Nevada is a secondary feature, an early diagenetic replacement of strata which were originally limestone. This replacement process was controlled by transgressions and regressions of the shoreline. Shallow carbonate platform deposits (shelfal and tidal-flat) are dolomitized, whereas deep water outer-shelf basin and slope deposits are not.

Lower and Middle Devonian carbonate-platform and outer-shelf-basin deposits flanking Railroad Valley, Nevada

by

Storr L. Nelson

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APPROVED:

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I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

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INTRODUCTION

Literature review of the current local and regional stratigraphy, visits to type localities, and field studies in east-central Nevada in 1989 through 1993 (Figure 1), indicated that a revision in the local and regional Lower and Middle Devonian stratigraphic nomenclature was needed for east-central Nevada. Osmond (1954, 1962) was the first worker to conduct regional studies of the Sevy and Simonson Dolomite, a Devonian depositional couplet found throughout eastern Nevada and western Utah. More recent Devonian stratigraphic studies near Eureka, Nevada, by authors such as Klapper (1977), Trojan (1978), Johnson and Murphy (1984), and others define several new Devonian units, that can be correlated to these established regional stratigraphic units.

Devonian strata cropping out near Eureka were deposited near the carbonate shelf edge. The carbonate shelf edge is defined by an abrupt transition from broad expanses of carbonate mud on the platform to unstable shelf-edge and carbonate-slope deposits. The carbonate shelf edge was eustatically sensitive to several transgressions and regressions during the Devonian. Carbonate sediments created from a "carbonate factory" on the platform prograded toward the slope and outer-shelf basin.

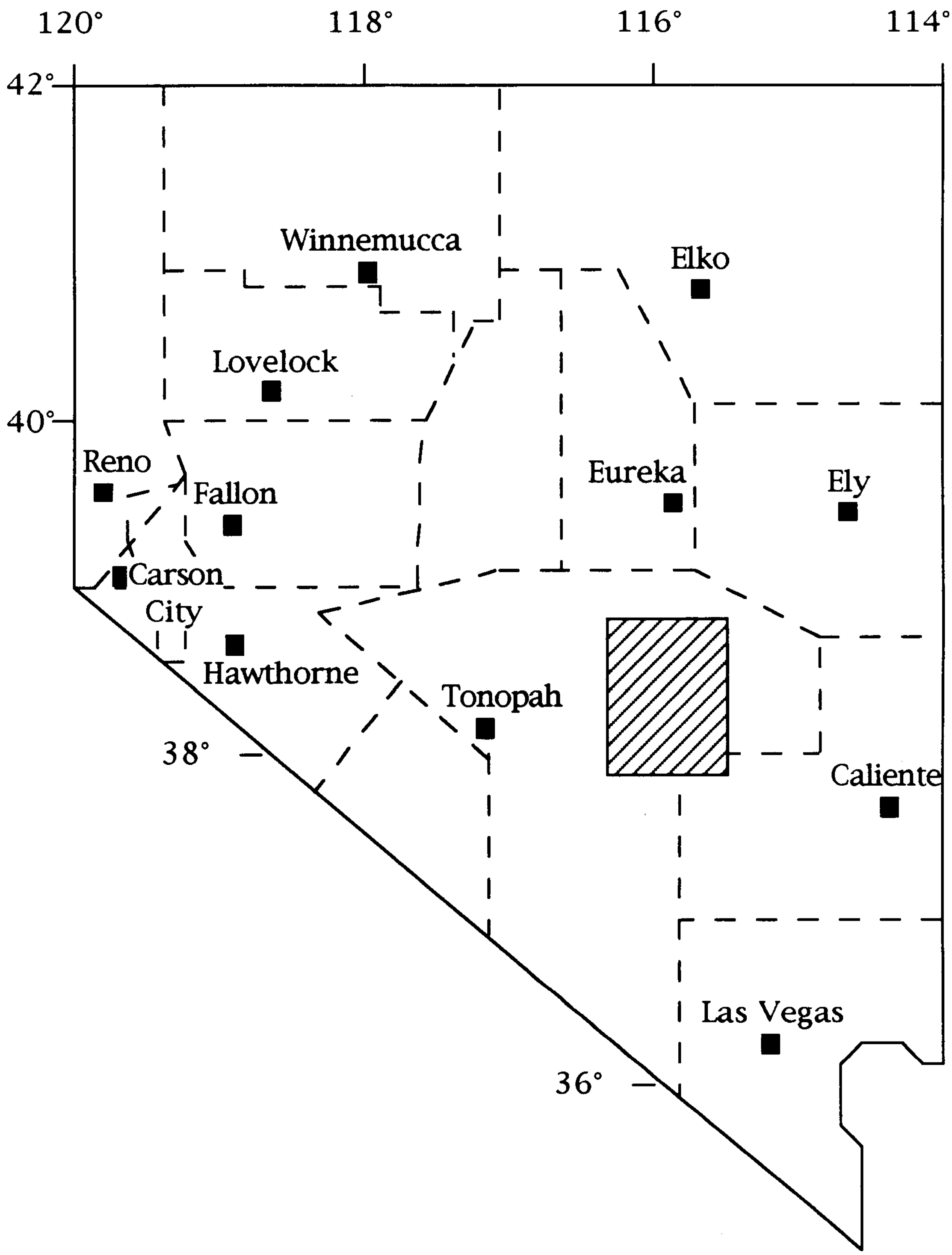


Figure 1. Map of Nevada with county outlines, cities, and location of study area (cross hatched rectangle).

This project is a new study of Lower and Middle Devonian strata that crop out on the former stable carbonate platform that existed in the Quinn Canyon Range, through the carbonate shelf edge in the Pancake Range, to the carbonate slope and outer-shelf basin in the Reveille Range (Figure 2). The stratigraphic nomenclature in the three ranges is simplified and extended to the more understood "eastern assemblage" Devonian strata exposed in eastern Nevada and western Utah and the "transitional" strata near Eureka.

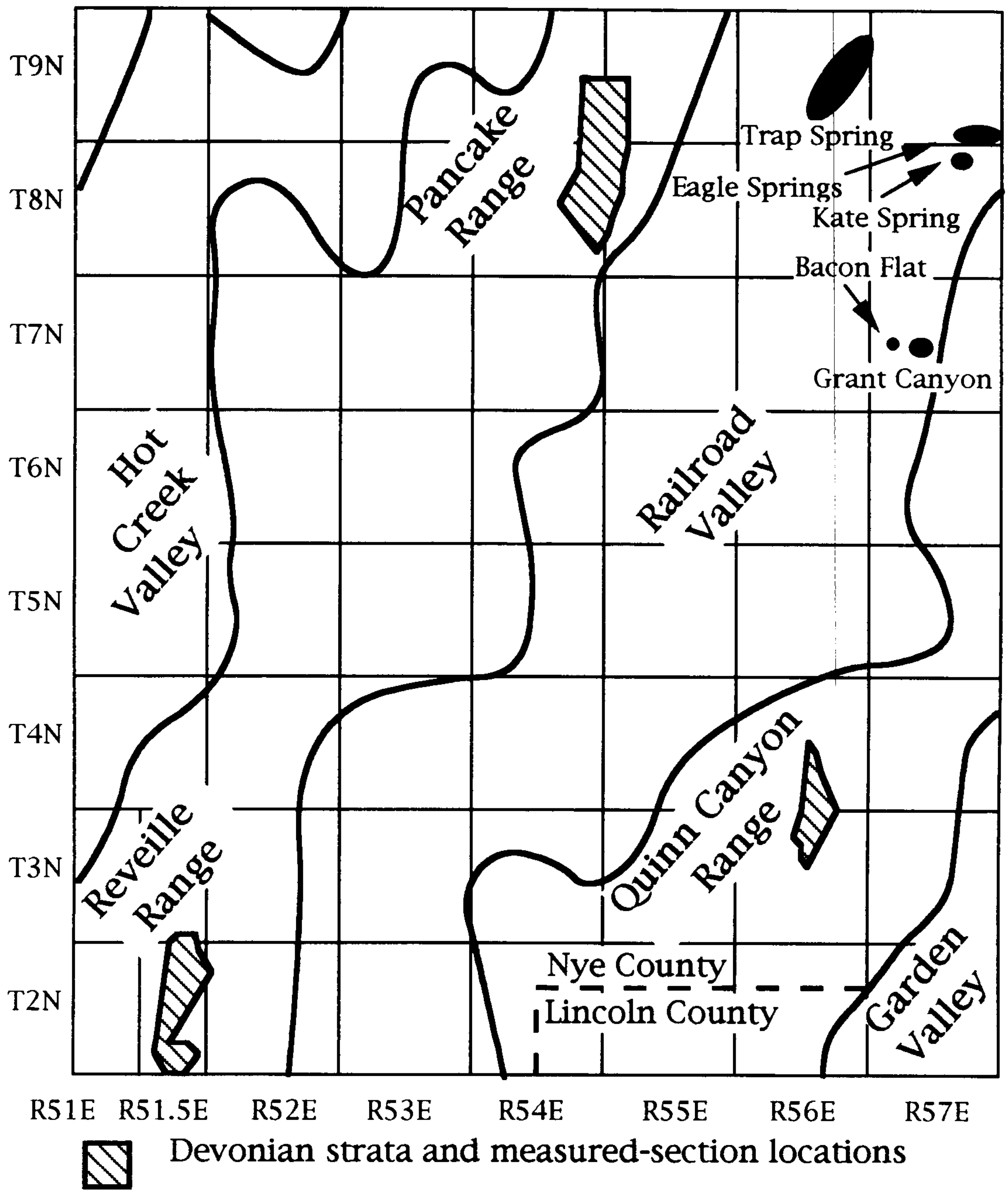


Figure 2. Location of measured sections, geographic features, mining districts, and producing oil fields.

East-central Nevada is part of the Basin and Range Province and is characterized by two principal commodities, oil and minerals. Substantial petroleum has been produced from five fields in Railroad Valley (Figure 2 and 3). Oil was first discovered in Nevada in 1954 at the Shell Oil #1-35 Eagle Springs well. The most recent field was developed by Marathon Oil Company at the #1 Kate Springs well in 1986. In the forty years since petroleum was first discovered, approximately 30 million barrels have been produced, primarily from Devonian reservoir rocks.

Figure 3. Pumping oil well in Railroad Valley. View is northeast toward the Grant Range, Nye County, Nevada.

OIL PRODUCTION

Eagle Springs Field. The Shell Oil #1-35 Eagle Springs well produces in a down thrown block of Tertiary volcanic and freshwater-carbonate rocks and Paleozoic limestone reservoir rocks. The reservoir of this field consists of pinchouts and lenses of Oligocene ignimbrites (Garrett Ranch Group) and Paleocene-Eocene freshwater carbonate rocks (Sheep Pass Formation). The field has produced over 3.9 million barrels of oil to date (Flanigan, 1989).

Trap Springs Oil Field. This field was discovered in 1976 by Northwest Exploration Company's #1 Trap Spring well. The field produces from ash-flow tuff of the Pritchard Station Formation. These Oligocene-age ignimbrites are important in forming the hydrothermal alteration of rocks adjacent to the Tertiary-Paleozoic unconformity. The Trap Springs Field has produced over 7.6 million barrels of oil (French, 1989).

Bacon Flat Field. The field was also discovered by Northwest Exploration Company in 1981 at the Bacon Flat well. Wells produce from Devonian dolomite, presumably the Guilmette Formation. The Devonian dolomite contains moldic porosity from dissolution of *Amphipora* thickets and stromatoporoid colonies, in addition to fracture porosity (Duey, 1983). The Bacon Flat Field has produced over 65,000 barrels of oil (Duey, 1983).

Grant Canyon Field. In 1983, Northwest Exploration Company's #1 Grant Canyon well discovered oil. The field that developed around that hole took the name of the discovery well. The wells in the field produce from the Simonson Dolomite and Guilmette Formation. Moldic porosity in the reservoir rocks was developed within stromatoporoid colonies and *Amphipora* thickets. Production from the Grant Canyon Field exceeds 10.7 million barrels of oil (Read and Zogg, 1989).

Kate Springs Field. In 1986, Marathon Oil Company discovered this field after drilling the #1 Kate Springs well. The wells produce from the Pennsylvanian Ely Limestone and the Devonian Guilmette Formation. The Kate Springs Field has produced over 100,000 barrels of oil (Flanigan, 1989).

MINERAL PRODUCTION

Nye County and east-central Nevada contain many commodities ranging from metallic and industrial mineral deposits to water, fuels, and geothermal resources. Metallic mineral production in east-central Nevada includes precious metals such as silver and gold, base metals (lead and zinc), and ferrous metals (magnesium and iron). Mineral production has been especially important in the Arrowhead (also called Needles), Reveille, Pancake, and Willow districts.

Arrowhead and Reveille Districts. The Reveille Range had two producing districts in the recent past, the Arrowhead (or Needles) and Reveille Districts. The Arrowhead District is north of the study area and produced over 335 tons of silver, gold, and stibnite ore from altered welded tuff and intrusive rhyodacitic rock. The mines in the Arrowhead District operated from approximately 1920 to 1939 (Kleinhampl and Ziony, 1984).

The mines of the Reveille District are located within the study area and produced 10,000 to 15,000 tons of silver, lead, zinc, copper, and antimony ore from veins along fractures and faults near the Paleozoic-Tertiary contact (Kleinhampl and Ziony, 1984). Mining activity in the Reveille District occurred from 1866 to the early 1980s.

Pancake District. The Pancake District produced only small amounts of silver, stibnite, and antimony ore from 1921 to 1953. The host rocks for the silver ore consisted of Devonian Simonson Dolomite and Guilmette Formation located near the Paleozoic-Tertiary unconformity (Kleinhampl and Ziony, 1984).

Willow Creek District. The Quinn Canyon Range is the locale of the Willow Creek Mining District. Gold and silver deposits were mined north of the study area, fluorspar and base metals to the south and east. Approximately 700 tons of fluorspar, gold, silver, and lead ore were mined from the Willow District from 1911 to 1961 from various host rocks (Kleinhampl and Ziony, 1984). The gold and silver ore deposits are within deformed Cambrian limy shale and limestone. The base metal deposits (bornite, chalcocite, chalcopyrite, galena, pyrite, and sphalerite) are within fault zones and fractures in Ordovician and Silurian limestone and dolomite. The fluorspar mines in the district are within fluorspar-mineralized zones in Tertiary volcanic rock and Paleozoic limestone.

BASIN AND RANGE PROVINCE

The Basin and Range Province is a geographic region extending from western Utah to eastern California and from southeastern Oregon and Idaho to Arizona. It is characterized by linear mountain ranges, generally trending northerly, separated by wide, relatively flat valleys. It is an area that receives little rainfall (Houghton *et al.*, 1975). The Basin and Range Province is a geologically young area that was uplifted only a few million years ago. The combination of recently uplifted mountain ranges and the arid climate provide excellent rock exposures (Figure 4).

Figure 4. Basin and Range topography. View is east from the Reveille Range to the Quinn Canyon Range, Nevada.

REGIONAL STRATIGRAPHY

The units discussed in the regional stratigraphy include those commonly cropping out in east-central Nevada as shown on Figure 5, and include the following:

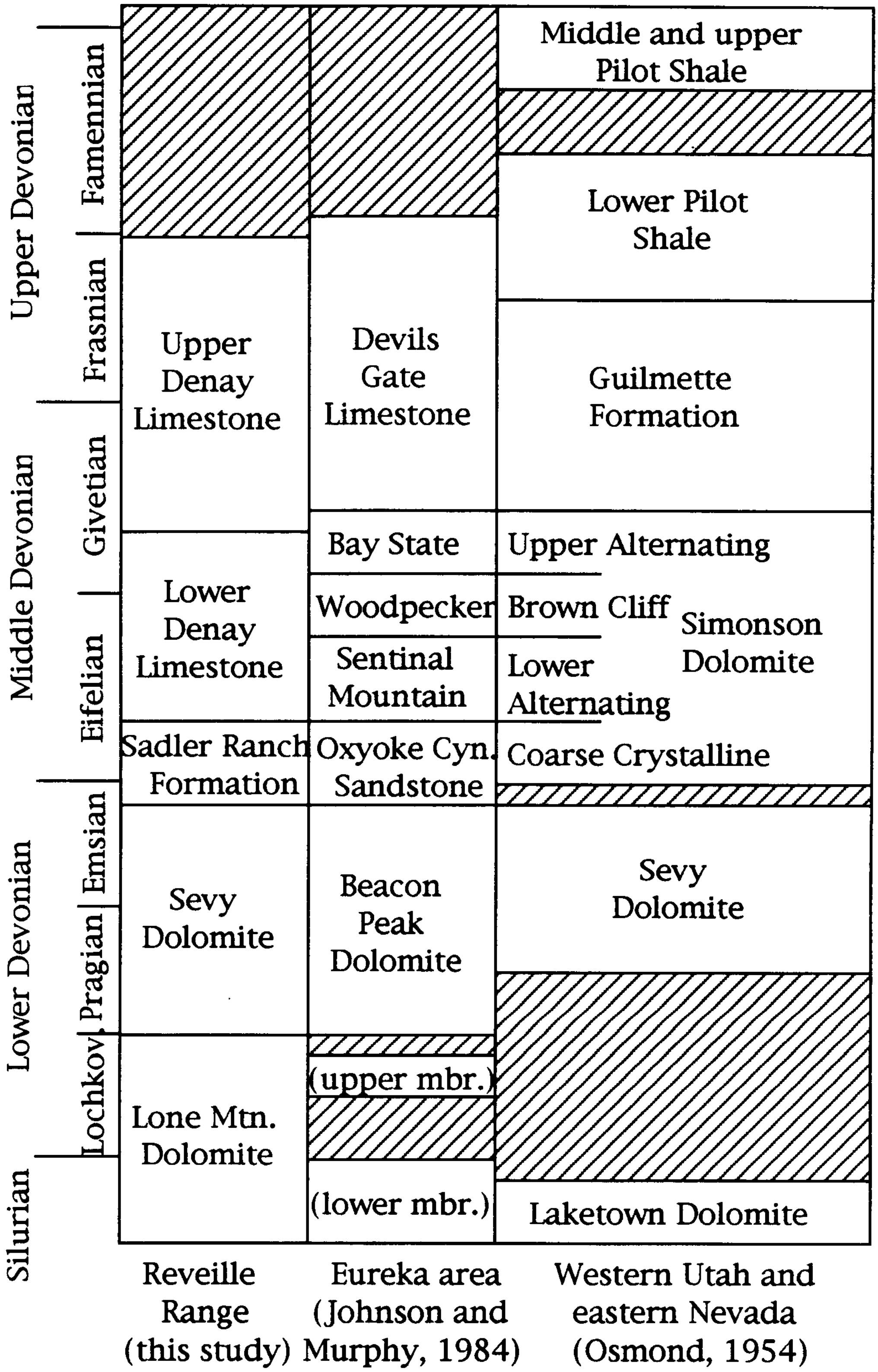
- Upper Silurian Laketown Dolomite,
- Upper Silurian to Lower Devonian Lone Mountain Dolomite,
- Lower Devonian Sevy Dolomite,
- Lower to Middle Devonian Simonson Dolomite,
- Middle Devonian Sadler Ranch Formation,
- Middle Devonian Lower Denay Limestone,
- Lower to Middle Devonian Eureka-area strata.

Regionally, the Upper Devonian is represented by the Denay Limestone, the Devils Gate Formation, and the Pilot Shale, but these units were not considered during this Lower to Middle Devonian study.

LAKETOWN DOLOMITE

General Description, Age, and Depositional Environment. The Laketown Dolomite, named by Richardson (1913) from exposures in Laketown Canyon in the Bear River Range, consists of three distinct parts: a dark gray lower, a light gray middle, and a dark gray upper dolomite sequence. The Laketown Dolomite is medium to coarsely crystalline and in many localities is difficult to distinguish from rock units above and below. Extensively replaced and recrystallized from a presumed limestone precursor, the Laketown is largely

Figure 5 (following page). Correlation chart of Eureka-area stratigraphy with the Reveille Range and western Utah and eastern Nevada.



Upper Devonian
Middle Devonian
Lower Devonian
Silurian
Famennian
Frasnian
Givetian
Eifelian
Emsian
Pragian
Lochkov
Upper Denay Limestone
Lower Denay Limestone
Sadler Ranch Formation
Sevy Dolomite
Lone Mtn. Dolomite
Devils Gate Limestone
Bay State
Woodpecker
Sentinal Mountain
Oxyoke Cyn. Sandstone
Beacon Peak Dolomite
(upper mbr.)
(lower mbr.)
Middle and upper Pilot Shale
Lower Pilot Shale
Guilmette Formation
Upper Alternating
Brown Cliff
Lower Alternating
Simonson Dolomite
Coarse Crystalline
Sevy Dolomite
Laketown Dolomite
Reveille Range (this study)
Eureka area (Johnson and Murphy, 1984)
Western Utah and eastern Nevada (Osmond, 1954)

structureless and unfossiliferous (Sheehan, 1980). The unit was deposited on a shallow-water carbonate platform in a low- to high-energy setting. Some early authors identified Silurian corals and brachiopods (Waite, 1956; Nolan, 1935; Merriam, 1940). The age of the Laketown Dolomite is now considered to be Lower? to lower Upper Silurian (Sheehan, 1980).

LONE MOUNTAIN DOLOMITE

General Description, Depositional Environment, and Age. The Lone Mountain Dolomite was first described by Hague (1892) for exposures near Eureka, Nevada. The Formation, as first described, included all strata between the Ordovician Eureka Quartzite and Devonian limestone. This proved to be too cumbersome and was later redefined by Merriam (1940). At the type section on Lone Mountain, Merriam described a light-gray weathering, massive to obscurely bedded, finely to coarsely crystalline dolomite.

The Lone Mountain Dolomite represents carbonate deposition on a generally shallow-marine carbonate platform in a low- to high-energy setting (Colman, 1979). Conditions were most likely similar to the depositional environment of the dolomite member of the Sevy Dolomite (see following section).

The Formation is largely unfossiliferous, making accurate dating difficult. However, sparse fossils collected from the base of the formation by various workers indicate a Late Silurian age for the Lone Mountain Dolomite (Hose *et al.*, 1982). Johnson and Murphy (1984) identified an unconformity within the Lone Mountain Dolomite and demonstrated an Early Devonian age (*pesavis* Zone) from conodonts collected from the uppermost part of the Lone Mountain Dolomite. A disconformity defines the top of the Formation, and the Lone Mountain Dolomite is overlain by the Sevy Dolomite and by Sevy-equivalent carbonate strata.

SEVY DOLOMITE

General Description. Osmond (1954) identified the Sevy Dolomite in east-central Nevada and other parts of west-central Utah and in 1962 subdivided the formation into three distinct formal members: the Dolomite Member, the Cherty Argillaceous Member, and the Sandy Member. The type section for the Sevy Dolomite is in Sevy Canyon, Deep Creek Mountains, near Gold Hill, Utah, where it was first described by Nolan (1935, p. 18) as follows:

> The Sevy Dolomite is remarkably homogeneous throughout the area of outcrop. The typical rock is a well-bedded mouse-gray dolomite in layers 6 to 12 inches [15 to 30 centimeters] thick and weathers to a light gray. It is of exceedingly dense texture and has a conchoidal fracture. In most of the beds a faint lamination parallel to the bedding is visible, in part at least, because of differences in color in adjoining laminae. A few beds of darker dolomite occur near the top of the formation, and locally there are present beds containing tiny nodules of light-colored chert.

The Dolomite Member of the Sevy Dolomite in east-central Nevada is a cliff former; differential weathering of the 1- to 1.5-meter thick beds creates ledges and slopes on the cliffs (Figure 6). The dolomite weathers into distinctive splinter-shaped fragments.

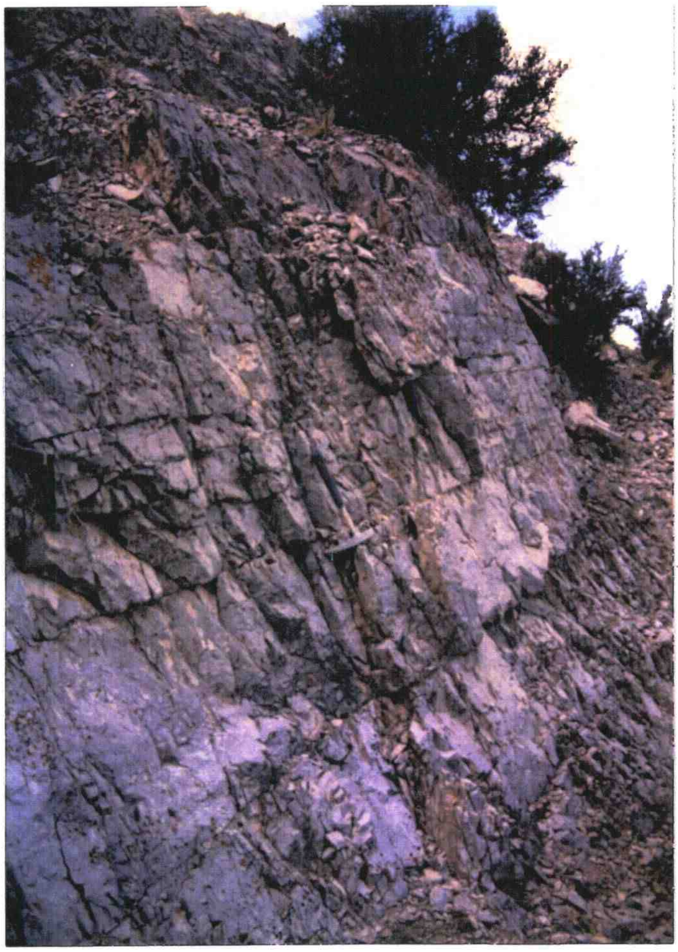


Figure 6. Bedded Sevy Dolomite (geologic hammer for scale). T8N, R56E, Sec. 1, Pancake Range, Nevada.

The Cherty Argillaceous Member was first described by Osmond (1954) from exposures in the Worthington Range and at Pahranagat Pass, Lincoln County, Nevada, as follows:

> The argillaceous dolomite is aphanitic, olive-drab on a fresh surface, and weathers to yellow-gray. It forms

> rounded blocks in contrast to the splinters and angular rhombs more characteristic of the Sevy.
>
> The chert nodules are irregularly shaped, individual or coalescing, and 1 to 3 inches [2 to 8 centimeters] high on the average with maximum height of 6 inches [15 centimeters]. All the chert has yellow-brown to reddish-tan rinds 1/5 to 1/2 inch [1/2 to 1 centimeter] thick. The silica for the chert was probably derived from the argillaceous matrix.

The cherty argillaceous unit is more erodible than the adjacent dolomite units and forms a yellowish-weathering saddle between the more resistant dolomite member and the sandy member.

The Sandy Member of the Sevy Dolomite was redesignated and described by Osmond (1962) as follows.

> Quartz and dolomite sand is commonly present in the upper part of the Sevy. The sand occurs in varying degrees of abundance ranging from a few scattered "floating" grains in a matrix of dolomite to brown-weathering dolomitic quartzite up to several hundred feet thick. This part of the Sevy was designated the sandy member because of its distinctive lithologic character and widespread occurrence.

The sand grains are predominantly well-rounded, well-sorted, and fine-grained, but coarse grains and clay-sized fractions are found. Quartz grains are typically frosted with only moderate sphericity and are cemented with dolomite.

Depositional Environment. The Dolomite Member constitutes most of the formation. Conditions of deposition for the Dolomite Member remained constant in order to produce hundreds of meters of well-bedded, finely crystalline dolomite. Osmond (1962) described a carbonate tidal mud flat, 800 kilometers long and 400 kilometers wide, covering western Utah and east-central Nevada (Figure 7).

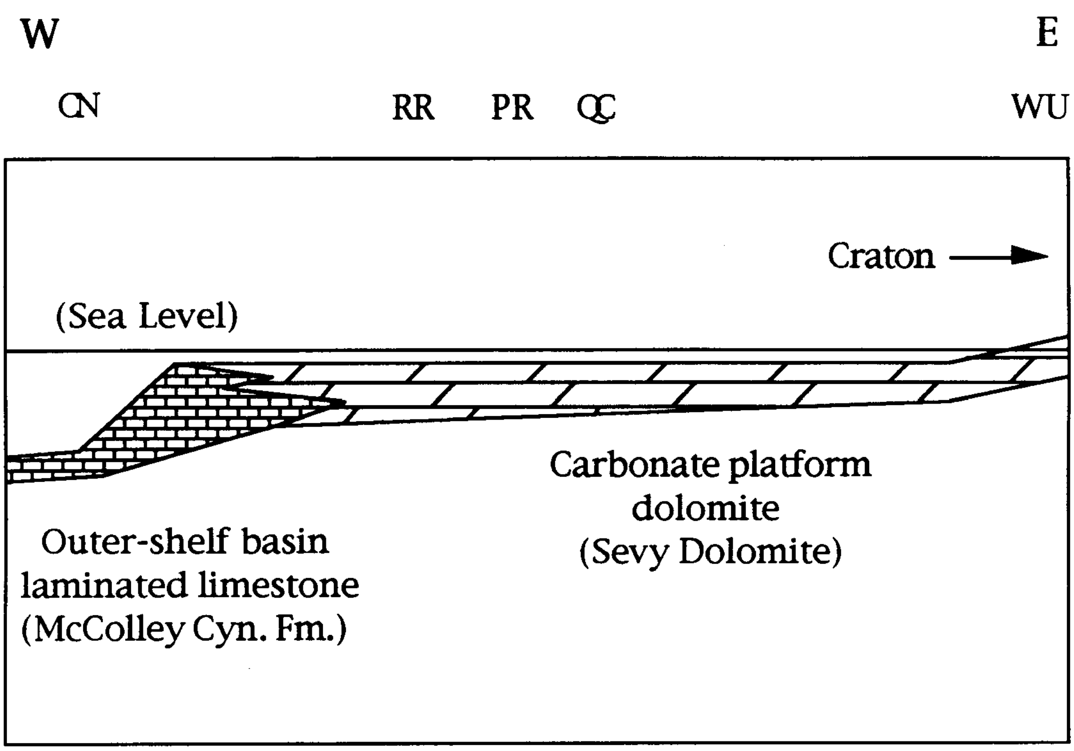


Figure 7. Depositional environment of the Sevy Dolomite. Key: CN - Central Nevada, RR - Reveille Range, PR - Pancake Range, QC - Quinn Canyon Range, WU - Western Utah.

Characteristic sedimentary structures that are formed in such a carbonate tidal mud flat environment include laminations, intraclast breccia (tidal channels), teepee structures, mud desiccation cracks, birds-eye fenestrae, mottling, and thin shallow channel fills (Figure 8 and 9). These structures are described by Hurtubise (1989) and Matti (1979) from exposures in, an near, the thesis area. Matti, like Osmond, identified the Sevy Dolomite throughout a large part of east-central Nevada. He described several facies of the Sevy Dolomite, including supratidal, intertidal, and shallow subtidal environments.

Figure 8. Laminations in Sevy Dolomite. T8N, R56E, Sec. 1, Pancake Range, Nevada.

The dominant facies of the Sevy Dolomite was deposited on the carbonate tidal mud flat (Figure 7). Secondary dolomitization of the original limy mudstone, wackestone, packstone, and grainstone on

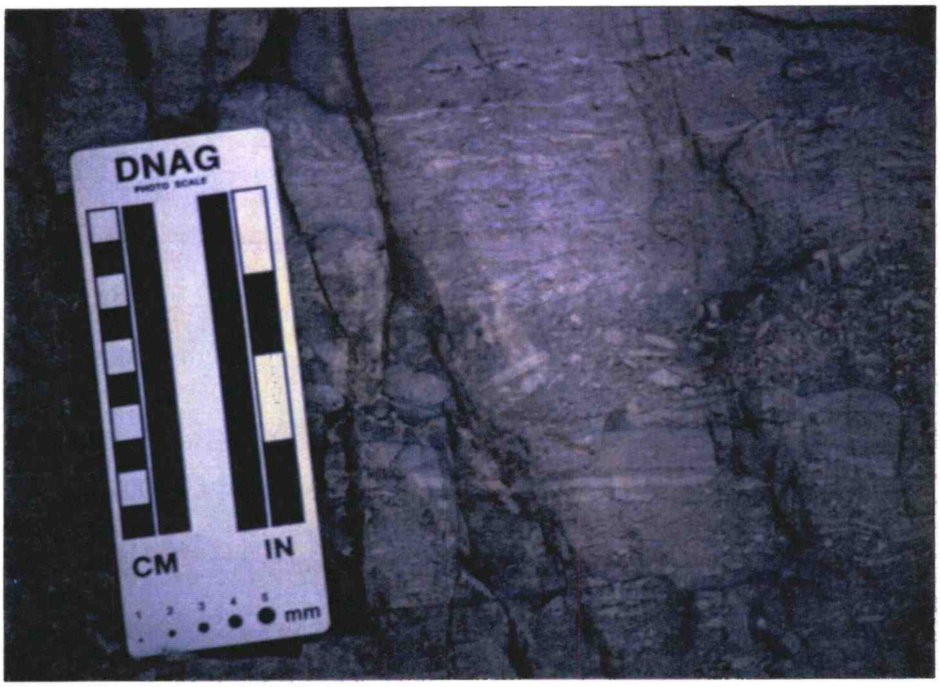


Figure 9. Intraclast breccia in Sevy Dolomite. T8N, R56E, Sec 1, Pancake Range, Nevada.

the shallow carbonate platform occurred during the Devonian when these limy sediments were subaerially exposed to freshwater recharge during regressions of the shoreline (Dunham and Olsen, 1978).

The Cherty Argillaceous Member represents a transgressive period of sedimentation. A shift from largely hypersaline tidal-flat to more nearly normal shallow marine conditions is represented by a transition from well-bedded, finely crystalline dolomite into clay-rich, siliceous carbonate. This correlates with published Devonian sea-level curves of Johnson *et al.*, (1985) that show a conodont _inversus_ Zone transgression and deposition of the Cherty Argillaceous Member on the former carbonate platform. This member is not as well-bedded, perhaps an indication that extensive bioturbation has occurred on the normal marine shelf. Secondary dolomitization and chert replacement altered the Cherty Argillaceous Member from, presumably, an original argillaceous limestone deposited in a shallow marine environment.

The depositional environment of the Sandy Member of the Sevy Dolomite was incorrectly characterized by Osmond (1962) as eolian with

> . . . the loose sand grains [being] blown westward across the mud flat. Where the surface was emergent and hard, they were not trapped, but in the water-filled depressions, they were caught and incorporated in the sediments.

These well-rounded and well-sorted sand grains were thought to have been derived from the east by erosion of cratonic sandstone and quartzite of the Precambrian, Cambrian, and Middle Ordovician (Osmond, 1962). This proves not to be the case, however (J.G. Johnson, 1991, personal communication; Hurtubise, 1989). The Sandy Member of the Sevy Dolomite was deposited by regressive seas as craton-derived sand draped over the carbonate platform (Figure 10).

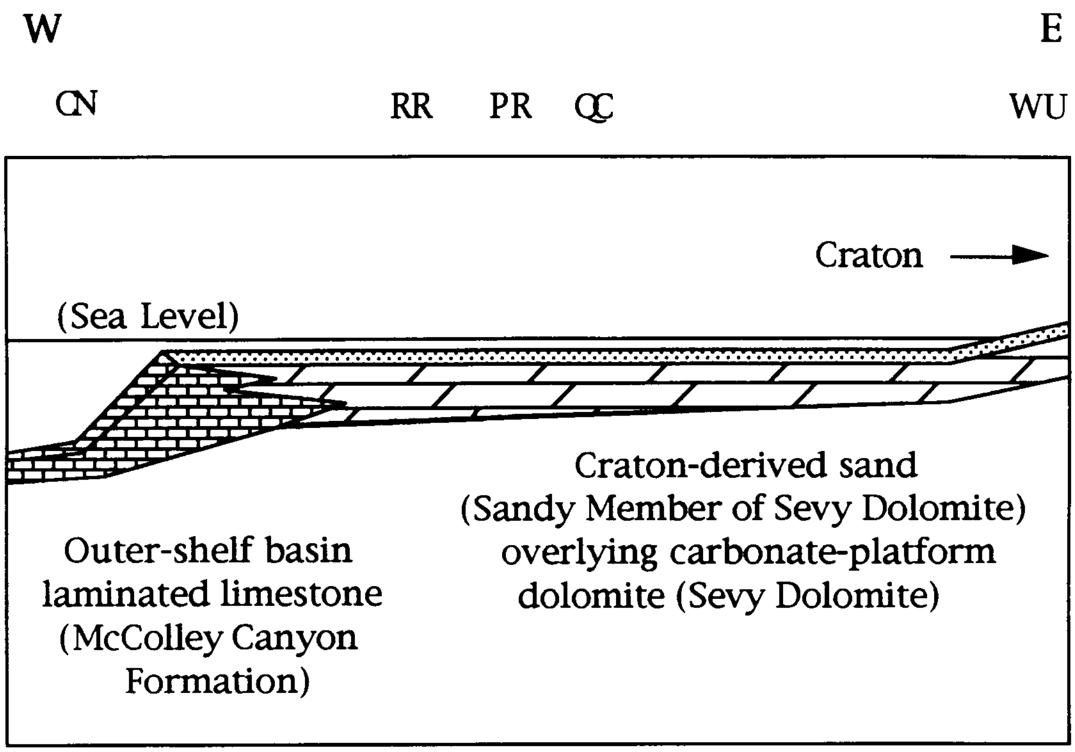


Figure 10. Depositional environment of the Sandy Member of Sevy Dolomite (See Fig. 7 for locations).

Beach and barrier-bar deposits are characterized by sedimentary structures such as parallel laminated beds, trough cross-stratification, ripple marks, hummocky bedding, and shallow erosional scour channels (Pettijohn, *et al.*, 1987). These sedimentary structures have also been identified by other workers in the Sandy Member of the Sevy Dolomite (Reso, 1963; Kendall, 1975; Kellogg, 1963; Hurtubise, 1989; and Matti, 1979). Osmond (1962) described "floating" sand grains in a dolomite matrix and concluded that eolian-transported sand grains were trapped in a soft carbonate sediment.

However, bioturbation in the shallow-marine and carbonate tidal-flat environment of originally laminated deposits can homogenize sediments and create the same texture.

Biostratigraphy. Because of the scarcity of fossils, accurate dating of the Sevy Dolomite is difficult. Johnson and Sandberg (1977) identified and dated an erosional unconformity and depositional hiatus beneath Sevy-age equivalent strata, the Beacon Peak Dolomite, in the ranges near Eureka, Nevada. This Lochkhovian-Pragian hiatus increases toward the east but is difficult to identify. "The phenomenon of light-colored dolomite overlying light-colored dolomite conceals a major unconformity below the Lower Devonian in eastern Nevada and western Utah" (Johnson and Sandberg, 1977). This is important to consider when attempting to date the Sevy Dolomite. Two errors are involved in dating the Sevy Dolomite by Osmond (1954), Johnson and Reso (1964), Poole *et al.* (1977), and Hurtubise (1989). Factors contributing to the erroneous dates are the inclusion of pre-Sevy dolomite in the formation and under estimating the magnitude of the Lochkhovian-Pragian hiatus. Johnson and Bird (1991) summarized the history of Sevy-age equivalent strata, including dating and nomenclature.

Nolan (1935) correctly identified and dated an unconformity at the top of the Laketown Dolomite in western Utah. He narrowed the age to Middle Devonian, because the Sevy Dolomite grades into the Simonson Dolomite that contains Middle Devonian fossils near Gold Hill, Utah, truncates the Laketown Dolomite in the Gold Hill Mining District of western Utah, and contains approximately 9 meters of conglomerate and dolomitic sandstone at the base. Sevy-age equivalent strata near Eureka, Nevada have also been dated by Murphy and Gronberg (1970). The Kobeh Member of the McColley Canyon Formation is Sevy-age equivalent strata deposited in the outer-shelf basin. The base of these Sevy-equivalent strata has been dated by conodonts as the *sulcatus* Zone (Murphy and Gronberg, 1970).

The Cherty Argillaceous Member and equivalent units have been dated by brachiopods as the *Eurekaspirifer pinyonensis* Zone by Johnson and Sandberg (1977). This was later identified by conodonts as an *inversus* Zone transgression (between F.I. 12 and 13 of Johnson *et al.*, 1989).

If the Sandy Member of the Sevy Dolomite was deposited during the regression following the *inversus* Zone transgression, the date is narrowed to the *serotinus* Zone (top of F.I. 13 of Johnson *et al.*, 1989). The regressive Sandy Member, therefore, would become younger to the west, making the date of the upper contact of the Sevy Dolomite slightly older in western Utah. The upper contact in eastern Nevada and western Utah lies somewhere in the Emsian Stage of the Lower Devonian.

The lower contact is more difficult to date. The Sevy Dolomite unconformably overlies the Upper Silurian Laketown Dolomite near the Gold Hill Mining District, western Utah (Nolan, 1935). However, Sevy-age equivalent strata conformably overlie the Lone Mountain Dolomite near Eureka, Nevada, where they have been dated by conodonts to be in the *sulcatus* Zone (Colman, 1979). This corresponds to the boundary between the Lochkhovian and Pragian

Stages. Thus, in the Sulphur Spring Range, Sevy-equivalent strata are at least Pragian in age. The published Devonian eustatic curve/stratigraphic unit figure of Johnson *et al.* (1991, Fig. 1) seems to mark the beginning of a transgression. If this is true, and if the lower contact of the Sevy Dolomite is also transgressive, the Sevy Dolomite would be younger to the east. The base would still be in the lower Pragian Stage, however.

Johnson and Murphy (1984) reidentified conodonts collected by Matti (1979) from the upper part of the Sevy Dolomite of the Pancake Range as *Pandorinellina exigua philipi*, placing the date in the *dehiscens* or *gronbergi* Zones. By correlating Sevy and Sevy-age equivalent formations with relative positions to units of known ages, the Sevy Dolomite is lower Pragian to middle Emsian (Lower Devonian).

SIMONSON DOLOMITE

General Description. Nolan (1935) first described the Simonson Dolomite from exposures near Gold Hill, Utah. A regional study by Osmond (1954) identified the formation in east-central Nevada and divided the Simonson into four distinct formal members: Coarse Crystalline, Lower Alternating, Brown Cliff, and Upper Alternating members. Hurtubise (1989) added another formal unit that he called the Fox Mountain Member from exposures in the Seaman Range.

The Coarse Crystalline Member derives the name from the coarse crystallinity of the tan dolomite. While this cliff-forming unit is easily identifiable in the field, the texture conceals most of the primary sedimentary structures, making satisfactory interpretation of the depositional environment difficult. Strata at some localities exhibit an alternating character of interbedded tan, coarsely crystalline dolomite and light-gray, finely crystalline dolomite similar to the Sevy Dolomite (Osmond, 1954). The thickness of the Coarse Crystalline Member ranges considerably throughout east-central Nevada (Osmond, 1954).

The Lower Alternating Member is well-bedded, consisting of alternating beds of light gray and brown dolomite. Upon closer inspection, however, brown beds grade into the light gray beds, with a sharp contact marking the beginning of the next brown to light gray sediment cycle. This sharp contact is in places marked by an intraformational pebble breccia or conglomerate in the lower layer of the brown and light gray couplet (Figure 11).

The Brown Cliff Member was first identified by Osmond (1954) in east-central Nevada from exposures in the Egan Range, Worthington Range, and Lime Mountains. Reso (1963) described the Brown Cliff Member in the Pahranagat Range as a

> cliff of phaneritic dolomite with distinct mottling. This unit is essentially a stromatoporoid biostrome within which are small bioherms. The member is replete with a variety of poorly preserved dolomitized and silicified organisms. A strong hydrocarbon fetid odor is emitted from the freshly broken rock.

Osmond (1954) easily identified this unit of the Simonson as a cliff-former between the stepped weathering of the Lower and Upper Alternating Members.

Figure 11. Conglomerate in Lower Alternating Member of the Simonson Dolomite. T3N, R56E, Quinn Canyon Range, Nevada.

The Upper Alternating Member is similar to the Lower Alternating Member described by Osmond (1954). Whereas the characteristics of the brown and light gray dolomite are comparable, the laminations are not. The Upper Alternating Member is thick-bedded with less contrast between the brown and light gray beds, producing a less prominent "striped-nature."

The Fox Mountain Member (Hurtubise, 1989) lies stratigraphically between the Upper Alternating Member of the Simonson Dolomite and the yellow slope-forming interval at the base of the overlying Guilmette Formation. At the type section in the Seaman Range, the member is "dominantly limestone, fossiliferous, readily recognized in relation to the Upper Alternating Member and yellow, slope-forming interval, and accessible" (Hurtubise, 1989). Three distinct units are recognized from base to top on the basis of texture and fossil content. Unit A is a laminated limestone, unit B is composed of crinoid and brachiopod wackestone and packstone, and unit C consists of framestone of stromatoporoid and brachiopods and wackestone with abundant gastropods (Hurtubise, 1989).

Depositional Environment. Some controversy exists on the depositional environment of the Coarse Crystalline Member of the Simonson Dolomite. Osmond (1954) believed that the unit was deposited in a transitional carbonate environment between the Sevy Dolomite, deposited on tidal mud flats, and the more rapidly deposited Lower Alternating Member in a deeper-water shelfal environment. Kendall (1975), from his work near Eureka, especially in the Sulphur Spring Range, envisioned the Coarse Crystalline Member being deposited in "a shallow, highly restricted environment." He regarded the Coarse Crystalline Member as the upper member of the Oxyoke Canyon Sandstone, because of the interbedded quartz sandstone and dolomite, especially in the western part of his study area (Sulphur Spring Range). Kendall (1975) postulated a higher energy and less restricted environment for the Coarse Crystalline Member of the Simonson Dolomite. Jarvis (1981), working on the same units north of Las Vegas, described a depositional setting of a barrier bar system (Sandy Member of the

Sevy Dolomite or the Oxyoke Canyon Sandstone near Eureka) with the Coarse Crystalline Member located behind the barrier in a restricted, lagoonal environment. I favor the model of Jarvis (1981), that best explains the probably restricted nature of the Coarse Crystalline Member of the Simonson Dolomite. The Coarse Crystalline Member and the Oxyoke Canyon Sandstone, where present, represent a shallowing-upward sequence (Figure 12).

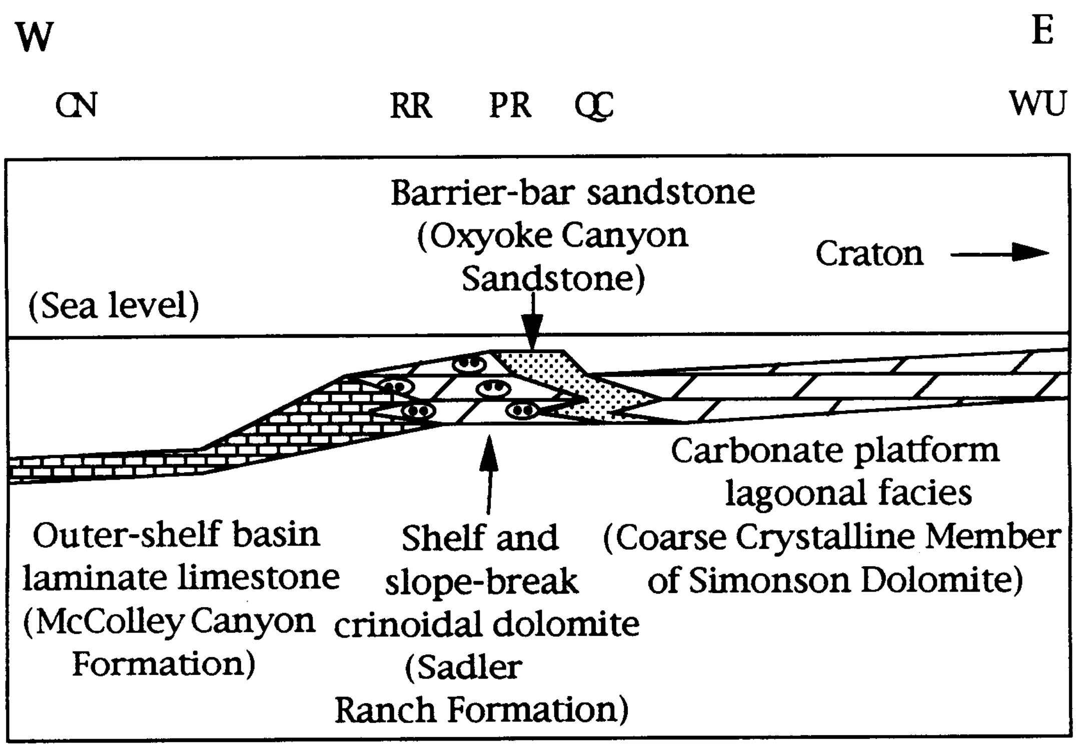


Figure 12. Depositional environments of Sadler Ranch Formation Oxyoke Canyon Sandstone, and Coarse Crystalline Member of Simonson Dolomite.

The depositional environment of the Lower Alternating Member of the Simonson Dolomite is similar to that of the Coarse Crystalline Member in that it represents a lagoonal setting behind a shoal or barrier bar (Figure 13). The Lower Alternating Member is composed of many shallowing upward cycles that are also partially restricted, and represent slightly deeper water conditions behind the shoal or barrier bar.

Restricted, anoxic bottom water are required in deep basins in order to preserve organic detritus, altered in place to bitumen, as it settles through the water column (Demaison and Moore, 1980). However, relatively shallow water conditions, similar to those described for the depositional environment of the Lower Alternating Member, can preserve organic detritus if living conditions become extreme with respect to salinity and/or temperature (Meissner, 1978).

The Lower Alternating Member is composed of many shallowing-upward cycles that are restricted but represent slightly deeper water conditions than those described for the depositional environment of the Coarse Crystalline Member. The Lower Alternating Member was deposited at a bay and tidal mud flat with similar dimensions to the Sevy Dolomite. The dark gray grading to light gray dolomite couplets described above are regressive-prone carbonate cycles of shallow subtidal facies overlain by tidal-flat facies: a result of cyclic, eustatic pulses or Milankovitch cycles (Schwarzacher, 1993). During the initial rise in sea level, normal marine water is introduced into a shallow lagoonal or broad peritidal-flat environment. This pulse of normal marine water

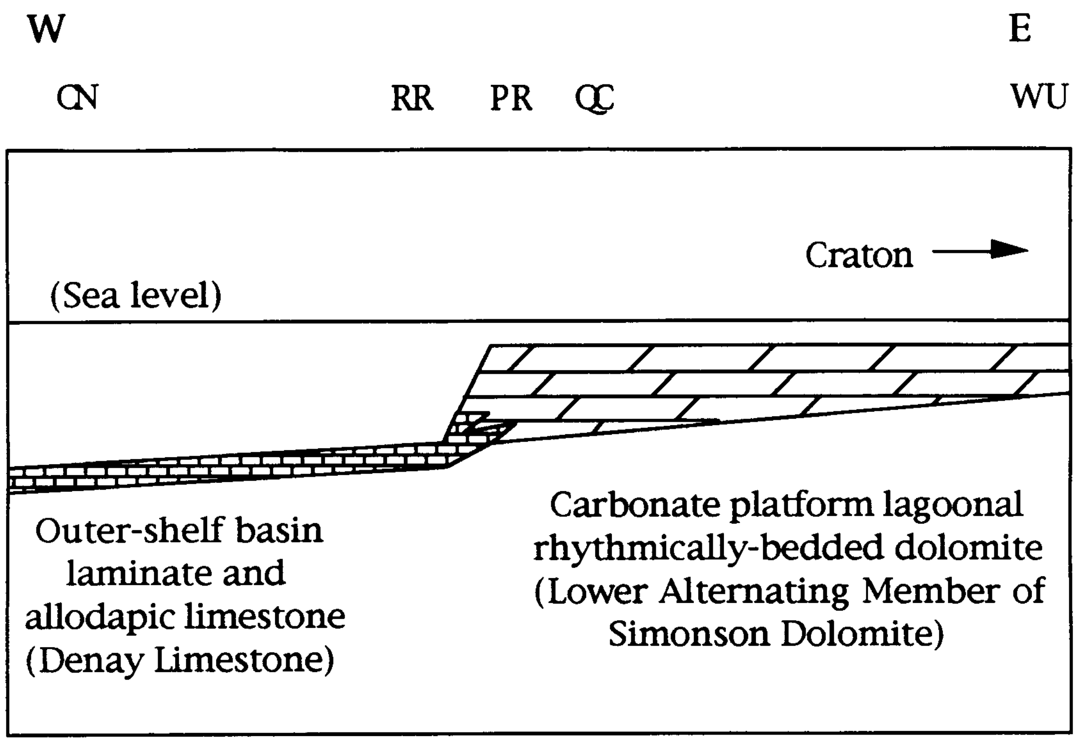


Figure 13. Depositional environment of Lower Alternating Member of Simonson Dolomite.

manifests itself by initial deposition of shell-bearing organic-rich carbonate mud (Elrick, 1995). As the carbonate depositional environment migrates from shallow subtidal to tidal-flat, conditions for the production and preservation of organic detritus became restricted. The result is a couplet of dark gray dolomite grading to laminated, light gray dolomite. The cycle repeated many times in deposition of the Lower Alternating Member of the Simonson Dolomite.

Similar eustatic, rhythmic cycles have been studied in the Simonson Dolomite of southern and eastern Nevada by Elrick (1995, 1996) and in the Devonian Lost Burro Formation of southeast California by Yang *et al.* (1995). Elrick (1996), in a sequence stratigraphy study, placed the rhythmic cycles of the Simonson Dolomite and transgressive and regressive cycles into 4 sequences, corresponding to T-R cycles Ic through If of Johnson *et al.* (1985). She characterized transgressive system tracts along the basin and slope by upward-deepening successions of proximal through distal allodapic flows overlain by hemipelagic deposits (Elrick, 1996). Transgressive system tracts on the shallow platform are composed stacks of peritidal cycles overlain by deeper subtidal cyclic or noncyclic deposits (Elrick, 1996). Maximum flooding zones on the shallow platform are deposited as stacked peritidal cycles. Elrick (1996) described highstand system tracts along the basin and slope as hemipelagic deposits overlain by distal through proximal allodapic flows. On the shallow platform, highstand system tracts are characterized by upward-shallowing successions of peritidal through subtidal cyclic facies (Elrick, 1996). Sequence boundary zones are seen on the shallow platforms as exposure-capped cycles and along the basin and slope as proximal allodapic flows or shoaling deposits. In addition, she was able to describe the platform and basin morphology changes between and within each sequence. The upper part of the Lower and Middle Devonian strata from my study are included in sequence 1 and 2 of Elrick (1996). Sequence 1 of Elrick (1996) includes those strata described in Figure 12. In this sequence, the ramp morphology changed from a homoclinal ramp, initially, to a distally steepening ramp. Sequence 2 of Elrick (1996) includes those strata described in Figure 13 and 15. In this sequence, the ramp morphology changed from the distally steepening ramp of sequence 1 to a flat topped ramp similar to Figure 13.

Osmond (1954) described the Brown Cliff Member as a biostromal deposit from many exposures in east-central Nevada, in that bioherms composed of stromatoporoid, tabular corals, and bryozoan buildups are common throughout. Jarvis (1981) attributed the Brown Cliff Member to "an incursion of a deeper water lithotope with better circulation upon the Alternating Member lithotope." This transgression agrees with the sea-level curve and associated sediments of Johnson *et al.* (1991).

Conditions similar to deposition of the Lower Alternating Member returned to deposit the Upper Alternating Member of the Simonson Dolomite. Eustatic pulses flooded the lagoon, and restricted conditions again allowed carbonate mud to be deposited in a shallowing-upward sequence (Figure 13). Conditions were not identical, however, because the brown to light gray dolomite cycles are thicker, and laminations are less prominent (Osmond, 1954).

The depositional environment of the Fox Mountain Member represents a transgression and more normal shallow marine shelf conditions, evidenced by the abundance of crinoid and brachiopod wackestone and packstone and stromatoporoid boundstone described by Hurtubise (1989). This transgression may be related to T-R cycle IIa of Johnson *et al.* (1985).

Biostratigraphy. The Coarse Crystalline Member is difficult to date because of the scarcity of fossils. Kendall (1975), from his work in the Sulphur Spring Range, located the Coarse Crystalline Member between the Sadler Ranch Formation below and the Lower Alternating Member above. This narrowed the relative age to late Emsian-early Eifelian (Middle Devonian). He described the Coarse Crystalline Member as a regressive unit, becoming younger to the west (Kendall *et al.*, 1983).

The Lower Alternating Member of the Simonson Dolomite contains abundant fossils that are poorly preserved, owing to dolomitization and partial silicification. Osmond (1954) described four distinct groups: *Cladopora* (coral), *Thamnopora* (coral), an unidentifiable intertangled tabular colonial organism (*Amphipora*?), and a stromatoporoid. Osmond (1954) could narrow the age only to Middle Devonian, but Jarvis (1981), from conodont collections in exposures to the south in Clark County, Nevada, confined the age of the Lower Alternating Member to between middle Eifelian and early Givetian (australis to lower varcus Subzone).

The Brown Cliff Member is dominated by stromatoporoids, but other faunal elements include bryozoans, corals, and brachiopods. Hurtubise (1989) identified similar faunal elements from the Seaman Range, but dolomitization obscured the fossils, preventing accurate dating. Johnson *et al.* (1989) correlated the Brown Cliff Member with the Woodpecker Limestone in the ranges surrounding Eureka, Nevada, that contain brachiopod assemblages dated by Johnson (1974) as correlative with the lower conodont ensensis Zone (Eifelian).

The Upper Alternating Member contains the first occurrence of *Stringocephalus.* Hurtubise (1989) identified this brachiopod from exposures in the Seaman Range, and Kleinhampl and Ziony (1985) report that the brachiopod is more common to the east. Although dolomitization has destroyed or obscured much of the member, other fossils include stromatoporoids and colonies of *Amphipora.*

The Fox Mountain Member is relatively fossiliferous compared to the rest of the Simonson Dolomite. Fossils include crinoids, brachiopods, gastropods, corals, and stromatoporoids. Hurtubise (1989) placed the member in the *Stringocephalus* Zone (Givetian).

SADLER RANCH FORMATION

General Description. The Sadler Ranch Formation was named from exposures in the Sulphur Spring Range, northwest of Eureka, Nevada, by Kendall *et al.* (1983). The formation has three formal units: Lower Dolomite Member, Middle Crinoidal Member, and Upper Dolomite Member.

The Lower Dolomite Member of the Sadler Ranch Formation lies conformably on the Bartine Member of the McColley Canyon Formation. The Lower Dolomite Member is moderately well bedded, medium to thick bedded, finely crystalline, light olive-gray to brownish-black, dolomitic mudstone and crinoidal wackestone and packstone that weathers yellowish gray to olive gray (Kendall *et al.*, 1983). Crinoid debris consists of one- and two-hole ossicles that are diagnostic of the Sadler Ranch Formation. Quartz-rich sandstone beds are common in the Lower Dolomite Member.

The Middle Crinoid Member of the Sadler Ranch Formation is a light gray to medium dark-gray, massive to moderately well-bedded, crinoidal packstone that weathers light olive gray to yellowish gray (Kendall *et al.*, 1983).

The Upper Dolomite Member is similar to the Lower Dolomite Member except in the number of quartz-rich sandstone interbeds. Quartz-rich dolomite beds near the top of the formation resemble beds in the overlying Coarse Crystalline Member of the Simonson Dolomite (Kendall *et al.*, 1983). The contact with the overlying unit is gradational, with beds of coarsely crystalline, light gray dolomite interbedded with crinoid-rich olive-gray dolomite.

Depositional Environment. Kendall *et al.* (1983) suggest a shallow, carbonate shelf and upper slope environment with a range of energy conditions (Figure 12). The Sadler Ranch Formation was deposited along a northerly trend, basinward from the clastic shoreline, longshore bar, or barrier bar of the Oxyoke Canyon Sandstone and Sandy Member of the Sevy Dolomite, and shoreward of the outer-shelf-basin and lower-slope deposits of the upper McColley Canyon Formation and lower Denay Limestone (Johnson *et al.*, 1989).

Biostratigraphy. The base of the Sadler Ranch Formation lies within the conodont *inversus* Zone (Kendall *et al.*, 1983). The formation was deposited after the *inversus* Zone transgression that was responsible for deposition of the Bartine Tongue and the Cherty Argillaceous Member of the Sevy Dolomite (Kendall *et al.*, 1983). They identified two upward-shallowing cycles within the formation.

The first transgression is within the *inversus* Zone. The basal Sadler Ranch Formation grades upward into regressive sandstone associated with the Quartzose Member of the Oxyoke Canyon Sandstone. Farther east, in Utah, this regression occurs as a depositional hiatus between the Sevy Dolomite and Simonson Dolomite (Johnson and Murphy, 1984). The second transgression and beginning of the upward-shallowing sequence is in the upper conodont *serotinus* Zone (Kendall *et al.*, 1983). This transgression perhaps involved a rapid deepening event and is manifested to the east by deposition of the Upper Member of the Oxyoke Canyon Sandstone and Coarse Crystalline Member of the Simonson Dolomite. An upward-shallowing sequence of carbonate deposition persisted until the transgression near the base of the conodont *australis* Zone (T-R cycle Id, Johnson *et al.*, 1991). The upper contact of the Sadler Ranch lies within the conodont *costatus* Zone.

DENAY LIMESTONE

General Description. Johnson (1966) first described the Denay Limestone from exposures in the northern Roberts Mountains and the northern Simpson Park Range. More recently Murphy (1977), and Trojan (1978) described lower, middle, and upper members. However, the Denay has two mappable members (Trojan, 1978; Hoffman, 1990).

The lower member of the Denay Limestone is an upward-shallowing carbonate cycle. The lower part of the member is characterized by Trojan (1978) as

> dark gray, thin-bedded to laminated, locally cherty or argillaceous, basinal lime mudstones. Interbedded allodapic packstones are rare throughout most of the unit, but are common in the lowermost 150 feet [45 meters] and are abundant in the gradationally overlying [upper part of the member].

The upper part of the member consists of light and medium gray to brownish gray, medium- to thick-bedded, cliff-forming, bioclastic packstone, grainstone, intraformational conglomerate and breccia. These deeper marine strata contain displaced shallow-water benthic fauna and conodonts. Dolomitization did not occur in the basinal, lower part of the formation. However, in the shallower water, shelf-slope-break deposits of the upper part of the unit, replacement dolomitization has obscured primary depositional features (Trojan, 1978).

The upper member of the Denay Limestone shows a return to deeper water lithotopes, that formed in response to the T-R IIa transgression of Johnson *et al.* (1991). Trojan (1978) described the upper member as

> fine-grained, thin-bedded or laminated, argillaceous lime mudstones and calcareous shales with subordinate beds of thin to thick-bedded allodapic limestone. Beds of allodapic limestone are dominant in the middle portion of the unit, and crop out in ledges and small cliffs between recessive-weathering lower and upper portions of the unit.

The upper member of the Denay Limestone is capped in the northern Antelope Range by a quartzose limestone (Waldman, 1990).

Depositional Environment. The Denay Limestone is interpreted by Trojan (1978) as a proximal-to-distal wedge of slope and basin turbidites. The lower Denay Limestone consists of thin-bedded, laminated lime mudstone overlying allodapic packstone. The lower packstone and grainstone beds of the Denay Limestone (of Trojan, 1978) belong in a deeper marine depositional setting with the underlying Coils Creek Member of the McColley Canyon Formation. The Coils Creek Member is a finely laminated, deep-water deposit that seems to shallow upward as quartzose-limestone beds become more and more common.

The thin-bedded mudstone that overlies the packstone beds of the lower Denay Limestone represents a deepening event in eastern Nevada. Johnson and Murphy (1984) identified such a transgression that corresponds to T-R cycle Id, near the base of the conodont *australis* Zone. On the carbonate shelf, this transgression is marked by deposition of the Lower Alternating Member on the Coarse Crystalline Member of the Simonson Dolomite (Johnson *et al.*, 1991). Near Eureka, this transgression is marked by deposition of the Sentinel Mountain Dolomite over the Oxyoke Canyon Sandstone.

The mudstone was deposited as a combination of distal allodapic fine-grained carbonate and hemipelagic carbonate mud (Figure 12). These "muddy" beds may represent the D and E divisions of the Bouma sequence of distal turbidites. The remainder of the lower member of the Denay Limestone records a progradation of the upper slope, shelf edge, and carbonate platform facies into the outer-shelf basin. Allodapic packstone beds deposited by turbidity currents indicate that the carbonate slope prograded over the outer-shelf basin. These crinoid and brachiopod-rich packstone beds are described by Trojan (1978) and Elrick (1996). The upper part of the lower member contains many sedimentary structures that are typical of deposition by turbidity currents (inverse-graded bedding; load, flame, and slump structures; and matrix-supported conglomerate and debris-flow breccia). The upper part of the lower unit represents a shallowing upward sequence and is capped by dolomitized packstone beds deposited on the carbonate platform near the shelf-slope break.

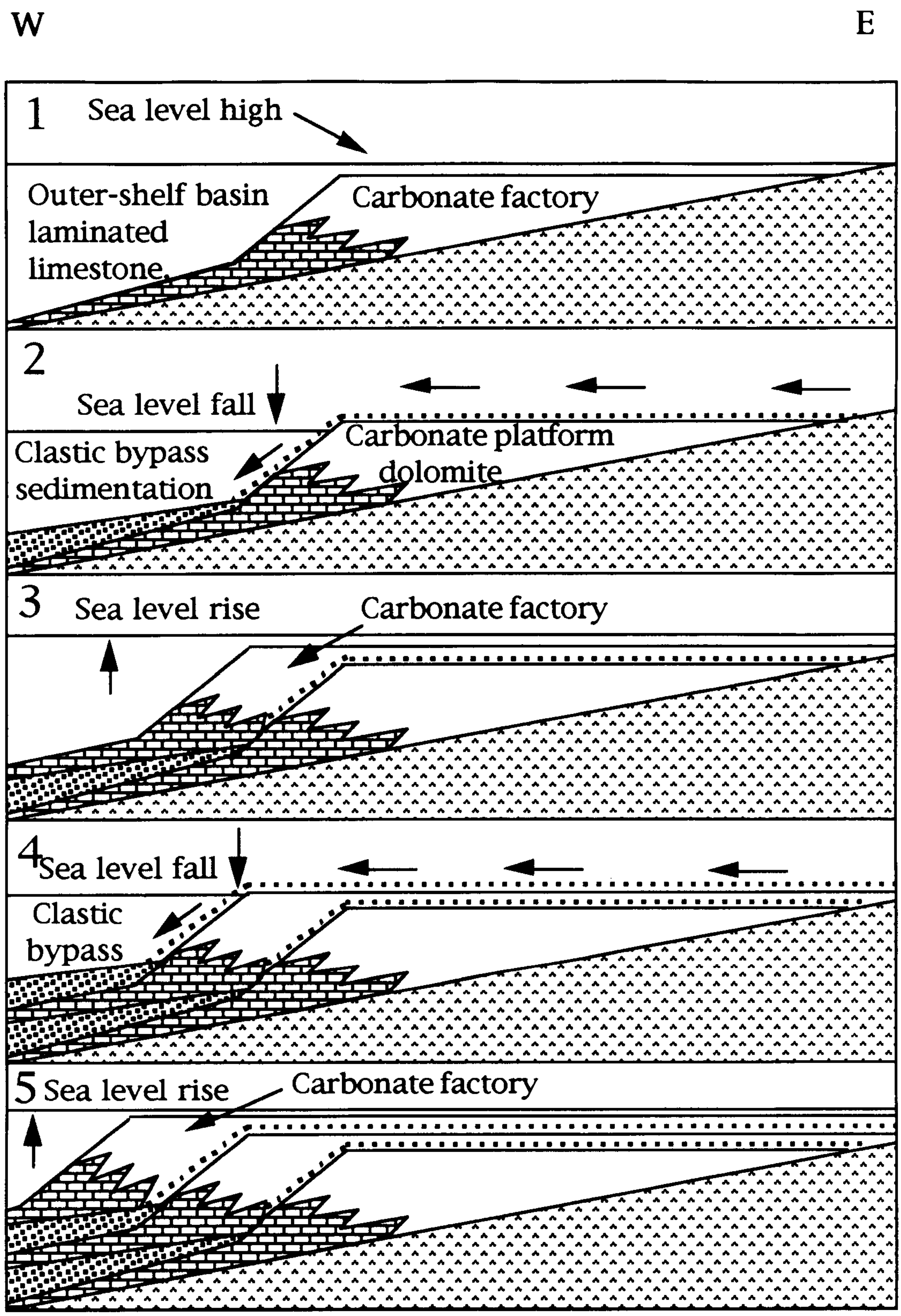
The base of the upper Denay Limestone represents the onset of deeper marine conditions (Hoffman, 1990). Thin-bedded or laminated, fine-grained, argillaceous lime mudstone and calcareous shale described by Trojan (1978) are characteristic of outer-shelf-basin deposits. These deeper marine deposits of the upper member are overlying the shallow marine deposits at the top of the lower member of the Denay Limestone. Coarser-grained allodapic packstone occurs near the middle of the upper Denay Limestone, but slope-deposited limestone conglomerate and breccia typical of the lower member are not found in the middle part of the upper member.

The Fenstermaker Limestone (Waldman, 1990) is a regressive sand-rich limestone that bypassed the carbonate platform and was deposited in the outer-shelf basin (Figure 14). This process of reciprocal sedimentation was described in the Mississippian of the western North America by Rose (1976). Reciprocal sedimentation involves the initial carbonate platform and outer-shelf basin configuration common in the early and middle Paleozoic of Nevada (Figure 14, scene 1). During sea level fall (regression), clastic sediment derived from the exposed craton to the east bypasses the shallow parts of the carbonate platform (Figure 14, scene 2) and is deposited directly on the outer platform, carbonate slope, and outer-shelf basin (Rose, 1976). During sea level rise (transgression), the original geomorphologic configuration returns with carbonate mud production and deposition on the carbonate platform and relative quiescence in the outer-shelf basin (Figure 14, scene 3). This process is common in the Paleozoic with similar examples found in the Ordovician Eureka Quartzite, the Lower Devonian Sandy Member of the Sevy Dolomite, the Lower to Middle Devonian Oxyoke Canyon Sandstone, and Upper Devonian sandy parts of the Guilmette Formation.

Biostratigraphy. Much of the Middle Devonian and lower part of the Upper Devonian conodont biostratigraphy was improved from the work of Trojan (1978), Johnson *et al.* (1980), and Hoffman (1990) in the northern Antelope Range (west of Eureka, Nevada).

The contact of the Lower Denay Limestone with the underlying McColley Canyon Formation or Sadler Ranch Formation lies within the conodont *costatus* Zone (Johnson *et al.*, 1986, fig. 3). Transgression IId (Johnson *et al.*, 1991) in the *australis* Zone is represented by the deeper water carbonate mudstone that overlies the packstone beds within the lower Denay Limestone.

Figure 14 (following page). Reciprocal sedimentation (Rose, 1976) of Denay Limestone and Fenstermaker Limestone in Nevada.


W
E
1 Sea level high
Outer-shelf basin laminated limestone
Carbonate factory
2
Sea level fall
Clastic bypass sedimentation
Carbonate platform dolomite
3 Sea level rise
Carbonate factory
4 Sea level fall
Clastic bypass
5 Sea level rise
Carbonate factory

For the rest of lower Denay deposition, the rate of buildup of the carbonate platform was able to keep pace and surpass the rate of rise in sea level. A regression, dated by conodonts to be within the lower and middle varcus Subzone, was responsible for an influx of fresh groundwater that dolomitized the upper slope and shallow marine platform deposits of the lower Denay Limestone (Dunham and Olsen, 1978).

The beginning of the Taghanic onlap (T-R cycle IIa) is marked by a rapid transgression within the middle varcus Subzone. The outer-shelf-basin deposits of the upper Denay Limestone that overlie the dolomite cap of the lower member represent the beginning of the Taghanic onlap in east-central Nevada (Johnson and Murphy, 1984). For the most part, the remainder of the Denay Limestone deposition consisted of deepening events associated with the Taghanic onlap. The quartzose beds of the upper Fenstermaker Limestone, however, were deposited during the T-R cycle IId regression in the former gigas Zone (Waldman, 1990).

UNITS IN THE EUREKA AREA, NEVADA

Beacon Peak Dolomite. The Beacon Peak Dolomite was first identified by Nolan *et al.* (1956) and is described as

> . . . beds of dolomite that on a fresh fracture are a rather uniform light olive-gray to slightly brownish creamy-gray color, but which weather to a pale gray to white that has a faint blue tinge. The dolomite of the member is dense, or even porcellaneous in texture. It is brittle and commonly breaks with a conchoidal fracture.

The Beacon Peak Dolomite rests disconformably on the Lone Mountain Dolomite. The lowermost Beacon Peak Dolomite correlates with the *sulcatus* Zone (Klapper, 1977; Matti *et al.*, 1975). The contact with the Oxyoke Canyon Sandstone that overlies the Beacon Peak is sharply gradational (Nolan *et al.*, 1956). The Beacon Peak Dolomite is equivalent to the Sevy Dolomite (Figure 5).

Oxyoke Canyon Sandstone. The Oxyoke Canyon Sandstone was first described as a member of the Nevada Formation by Nolan *et al.* (1956) in Oxyoke Canyon near Eureka, Nevada. The Oxyoke Canyon Sandstone was elevated to formation status by Hose *et al.* (1982). Osmond (1954) identified the unit in east-central Nevada, but wrongfully included it as part of the Sandy Member of the Sevy Dolomite. Kendall (1975) described the unit from the type exposures in Oxyoke Canyon, south of Eureka, Nevada.

The Oxyoke Canyon Sandstone is a fine to medium sand-sized, medium- to thick-bedded, cross-bedded, dolomitic quartz arenite (sedimentary quartzite) and quartzose dolomite that is white on a fresh surface and weathers to a characteristic rust-brown (hematite). The sand grains are well-sorted and rounded, exhibiting textural and compositional supermaturity (Jarvis, 1981). The unit is resistant and forms prominent cliffs. The Oxyoke Canyon Sandstone has two members: a lower predominantly sandstone unit, and an upper cyclicly bedded unit (Kendall, 1975). The lower contact with the Beacon Peak Dolomite is gradational. The upper contact is gradational; beds of coarse dolomite (similar to the overlying Sentinel Mountain Dolomite) are cyclicly intercalated with beds of sandstone of the Oxyoke Canyon (Kendall, 1975). The Lower Member near Eureka, Nevada, is in part correlative with the hiatus between the upper Sevy Dolomite and lower Simonson Dolomite of western Utah. However, this hiatus is time-transgressive and, in eastern Nevada, is short-lived, if present. The Upper Member of the Oxyoke Canyon Sandstone correlates with the Coarse Crystalline Member of the Simonson Dolomite (Figure 5).

Sentinel Mountain Dolomite. The Sentinel Mountain Dolomite was named and described by Nolan *et al.* (1956) and was elevated to formation status by Hose *et al.* (1982). The Sentinel Mountain Dolomite is characterized by thick-bedded dolomite that cyclicly alternates from dark brown to light gray beds (see discussion of Lower Alternating Member of the Simonson Dolomite). The light gray part of each cycle is more coarsely crystalline than the darker gray dolomite of each cycle. This is probably a post-depositional dolomitization phenomenon rather than a primary lithologic difference. This formation correlates with the Lower Alternating Member of the Simonson Dolomite in eastern Nevada and western Utah (Figure 5).

Bay State Dolomite and Woodpecker Limestone. The Bay State Dolomite and Woodpecker Limestone were both named by Nolan *et al.* (1982). The Bay State Dolomite is a fairly uniform, massive bedded, dark colored, cliff-forming dolomite. The base of the unit consists of a light-gray dolomitic sandstone. Most of the formation is a massive biohermal dolomite, containing abundant *Cladopora*-type coral, *Amphipora*?, and *Stringocephalus*, a large diagnostic Givetian brachiopod. The top of the formation consists of light and dark dolomite. The alternating cycles are thicker than those in the Sentinel Mountain Dolomite. The Bay State Dolomite is overlain by the massive bedded Devils Gate Limestone. The contact is gradational (Nolan *et al.*, 1956).

The Woodpecker Limestone was first described from outcrops near Eureka, Nevada, by Nolan *et al.* (1956). The formation consists of thin- to medium-bedded, sandy or argillaceous, recessive-weathering limestone. The formation ranges from light-olive to dark gray, but the limestone composition of the unit separates it from the dolomite above and below (Nolan *et al.*, 1956).

The Bay State Dolomite and Woodpecker Limestone are part of the same depositional sequence (Figure 15). Johnson and Sandberg (1977) first described this depositional sequence of a western belt of shelfal biohermal limestone buildups (Bay State Dolomite) adjacent to an eastern belt of protected lagoonal facies (Woodpecker Limestone). This lagoon must have been deep enough to inhibit the secondary replacement dolomitization of Dunham and Olsen's model (1978). The base of the Woodpecker Limestone correlates with the base of the Brown Cliff Member, where present, or the base of the Upper Alternating Member of the Simonson Dolomite (Figure 15).

The beginning of T-R cycle II lies within the Bay State Dolomite and Woodpecker Limestone depositional complex (Johnson *et al.*, 1991). Although this transgression cannot be located within the Bay State Dolomite, carbonate strata to the west of the shelf-slope break and to the east in the back-barrier lagoon define this transgression.

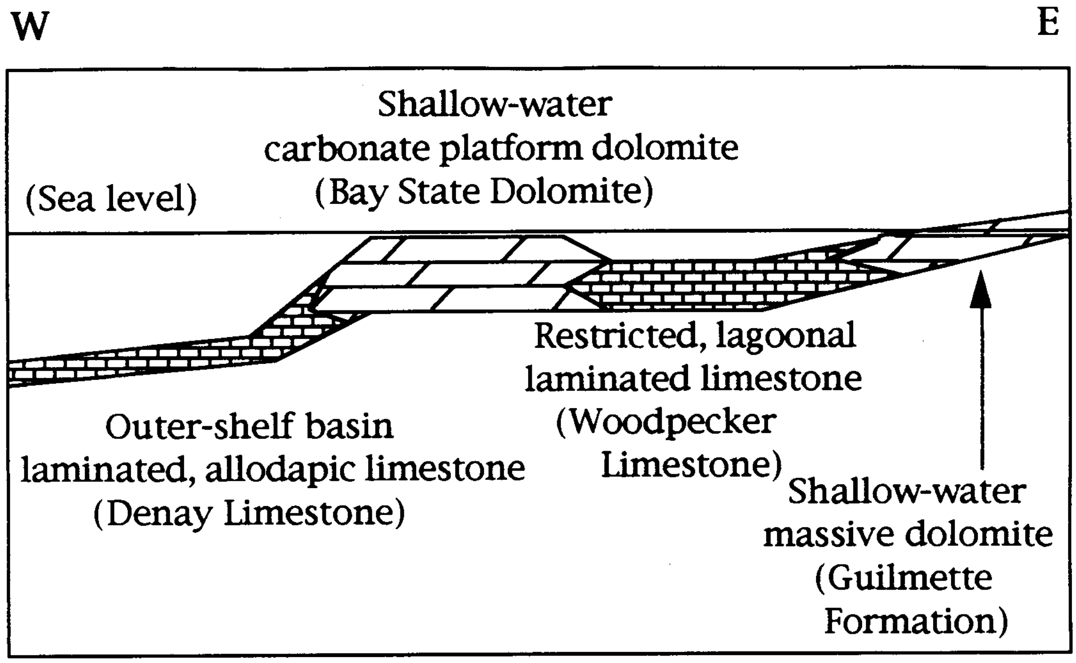


Figure 15. Bay State Dolomite and Woodpecker Limestone depositional model.

This can be attributed to the ability of the Bay State biohermal buildup to keep pace with the rising sea level. In the outer-shelf basin, the Denay Limestone marks this transgression at the lower member to upper member boundary. This is a change from shallow marine deposition, defined by the upward-shallowing dolomite cap on the lower member that is overlain by deeper water limestone of the upper member. Back lagoonal carbonate facies also reflect this transgression. The Fox Mountain Member of the Simonson Dolomite is a deeper water deposit associated with the IIa transgression (Johnson *et al.*, 1991).

The upper contact of the Bay State Dolomite with the Devils Gate Limestone is succeeded by T-R cycle IIb (Johnson *et al.*, 1991). This contact correlates with the basal contact of the yellow slope-forming member of the Guilmette Formation.

Devils Gate Limestone. The Devils Gate Limestone was first described by Merriam (1940) at Devils Gate, west of Eureka, Nevada. The Devils Gate Limestone is subdivided into a lower and upper member. Both are upward-deepening deposits (Sandberg *et al.*, 1989). The lower member is characterized by a transition from medium- to thick-bedded shallow marine biohermal and biostromal limestone, with abundant stromatoporoids to thinner, wavey-bedded, deeper water limestone near the top of the unit (Sandberg *et al.*, 1989). The upper member consists of deeper water carbonate deposits, including allodapic limestone and carbonate debris-flow deposits (Haskins, 1979).

The Lower Member of the Devils Gate Limestone correlates with the lower part of the Guilmette Formation in eastern Nevada and western Utah (Niebuhr, 1980). The biohermal and biostromal facies of the lower Devils Gate Limestone cannot be distinguished from biohermal and biostromal limestone of the Guilmette Formation. The carbonate shelf-slope break was located farther to the west of the Devils Gate depositional environment (Johnson and Murphy, 1984).

STRATIGRAPHY OF STUDY AREA

REVEILLE RANGE

Ekren *et al.* (1973) divided the stratigraphy of the Reveille Range into several units that include Lower to Middle Devonian strata. A Silurian to Lower Devonian Dolomite and Lower to Middle Devonian Nevada Formation are discussed below.

Silurian to Lower Devonian Dolomite. Ekren *et al.* (1973) define a lower and upper unit of the Silurian to Lower Devonian Dolomite, with the upper unit probably correlated to the Devonian and Silurian Lone Mountain Dolomite (Figure 5). The Silurian to Lower Devonian unit is divided into two similar, yet distinguishable subunits, approximately 285 meters thick. The lower part of the sequence is described as light gray, massive dolomite, approximately 75 meters thick. The dolomite is generally finely to medium crystalline, with abundant medium to coarsely crystalline secondary dolomite in veinlets that are irregularly distributed. There is also some inconspicuous color banding in shades of light gray (Ekren *et al.*, 1973). The upper part of the sequence is described as a color-banded dolomite, approximately 215 meters thick. It consists of light- to dark-gray, finely to medium crystalline, thin- to thick-bedded dolomite. The uppermost 80 meters is generally more finely crystalline and less conspicuously banded in shades of light to medium gray. The top of this sequence is marked by an approximately 1 meter thick bed of quartzose sandy dark gray dolomite that weathers to a distinctive brownish gray. Crinoid ossicles occur 10 to 30 meters above the base of the upper sequence.

Lower to Middle Devonian Nevada Formation. Ekren *et al.* (1973) divided the 195-meter thick Nevada Formation into lower and upper members. The lower unit is dark-gray, finely to medium crystalline, laminated to thick-bedded dolomite, approximately 42 meters thick. The laminated dolomite is finely color-banded in shades of light and dark gray. Some beds contain angular dolomite clasts as much as 20 centimeters or more in diameter (Figure 16). The formation contains two-hole crinoid ossicles and a conodont fauna suggesting Emsian age (Ekren *et al.*, 1973).

Figure 16. Clasts in Sadler Ranch Formation. T2N, R51.5E, Reveille Range, Nevada.

The upper unit of the Nevada Formation is medium- to dark-gray, aphanitic to finely crystalline, laminated to thin-bedded. It consists of platy splitting, locally fossiliferous limestone and silty limestone and contains lenticular layers of medium-gray, medium- to thick-bedded limestone. These layers are composed of abundant subangular limestone clasts about 20 centimeters or more in diameter (Ekren *et al.*, 1973). The upper unit is at least 153 meters thick with the top of the unit not being exposed in the Reveille Range due to Tertiary volcanism and Quaternary deposition.

PROPOSED REVEILLE RANGE STRATIGRAPHIC NOMENCLATURE

The Devonian section studied in the Reveille Range crops out in a lower to middle Paleozoic block surrounded by Tertiary volcanics. The Devonian section is most likely a hinterland to thrusting of the Garden Valley Thrust System (Bartley and Gleason, 1990) near Railroad Valley and the Eureka Fold and Thrust Belt (Carpenter *et al.*, 1993), that are exposed to the north and south of the thesis area (Figure 17). Approximately 307 meters of Devonian strata was measured and sampled for conodonts and brachiopods (Figure 18-20).

After studying type localities for the Upper Silurian, Devonian, and Lower Mississippian units in eastern Nevada, reviewing the geologic literature, and correlating local lithologies to regional stratigraphic units, a revised stratigraphic nomenclature is proposed for the Reveille Range that also has regional implications. Regional Devonian nomenclature first described in western Utah and eastern Nevada and more recent stratigraphic nomenclature developed for

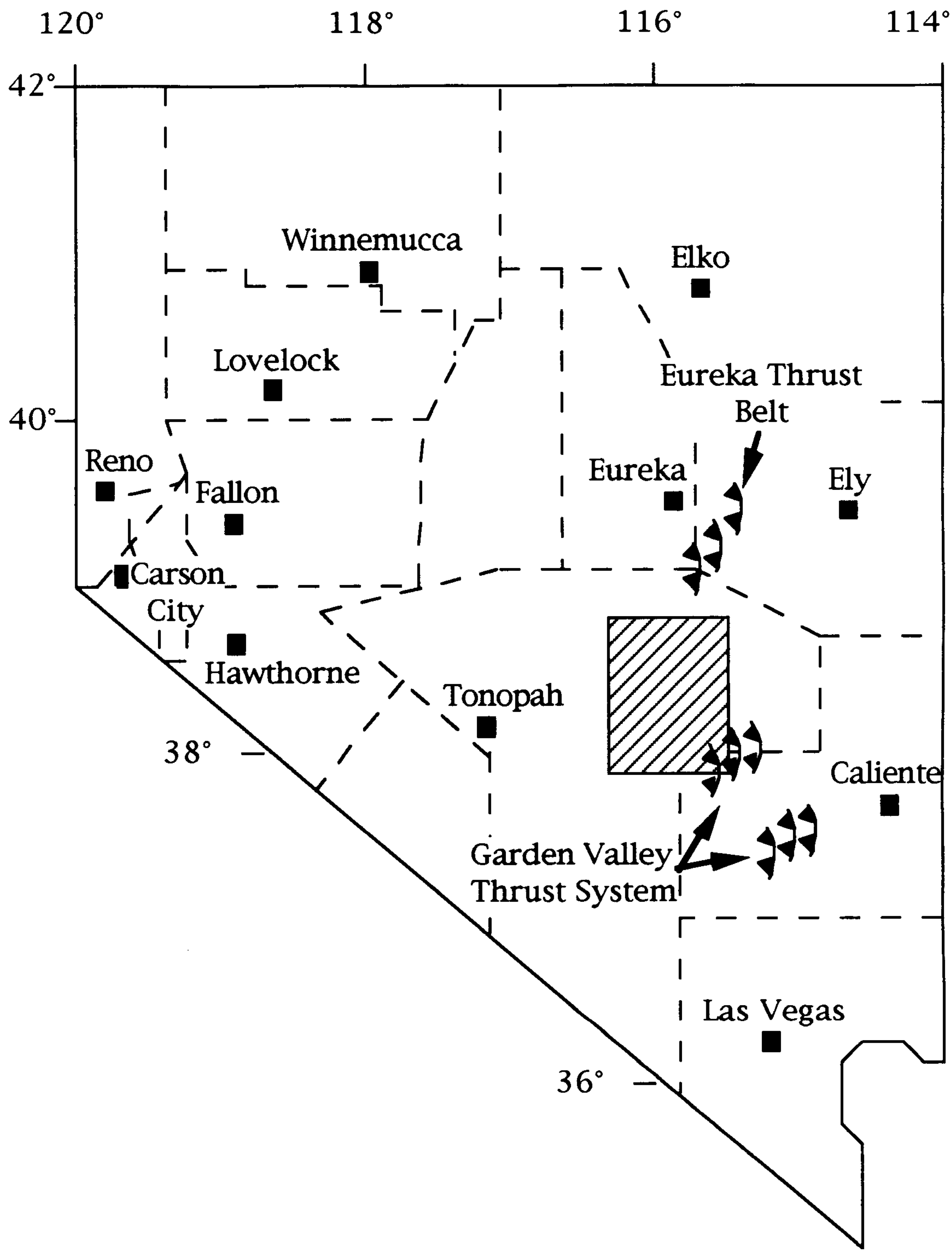


Figure 17. Thesis area relative to the Eureka Thrust Belt and Garden Valley Thrust System.

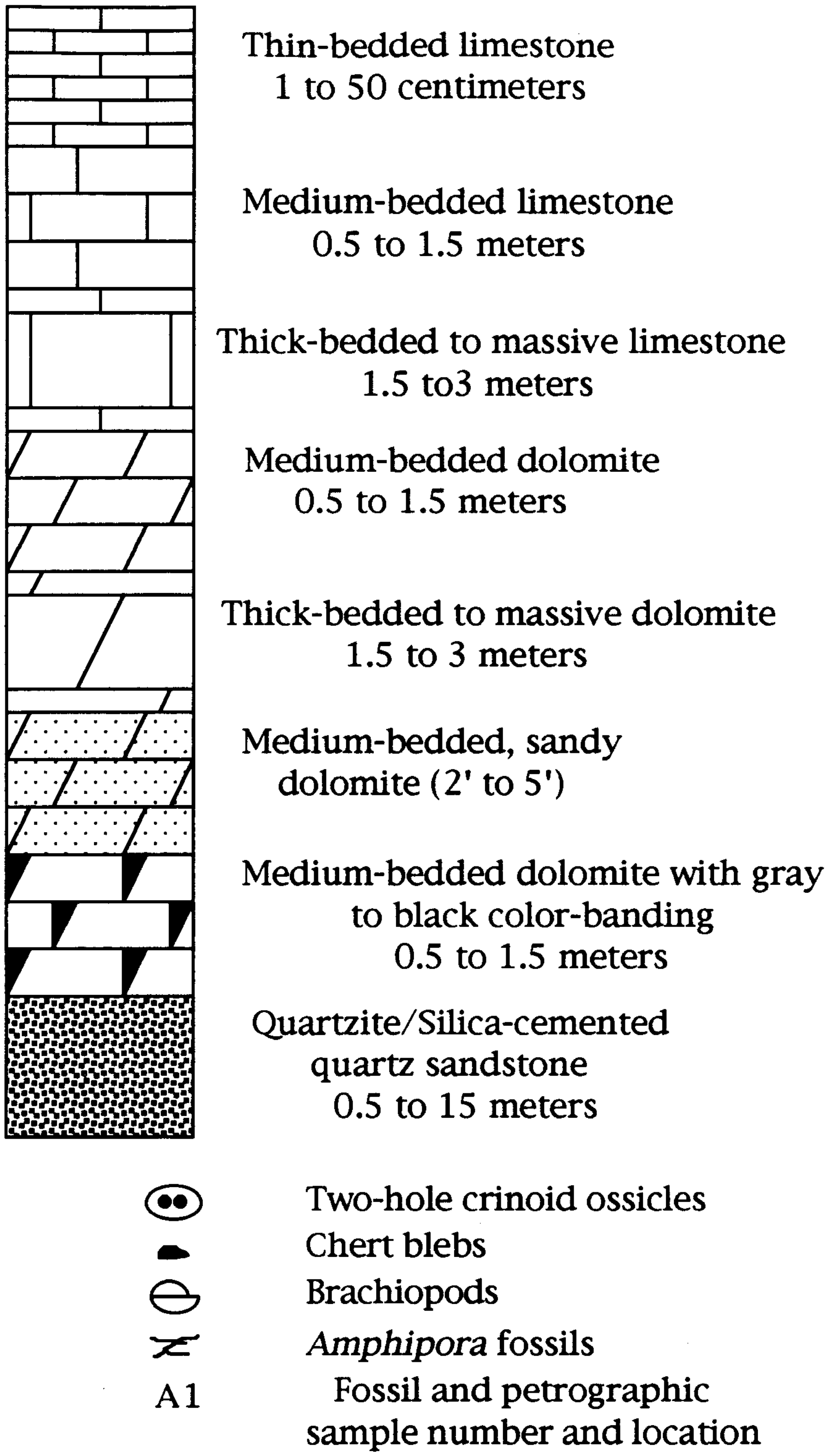


Figure 18. Key for measured sections in Reveille, Pancake, and Quinn Canyon Ranges, Nevada.

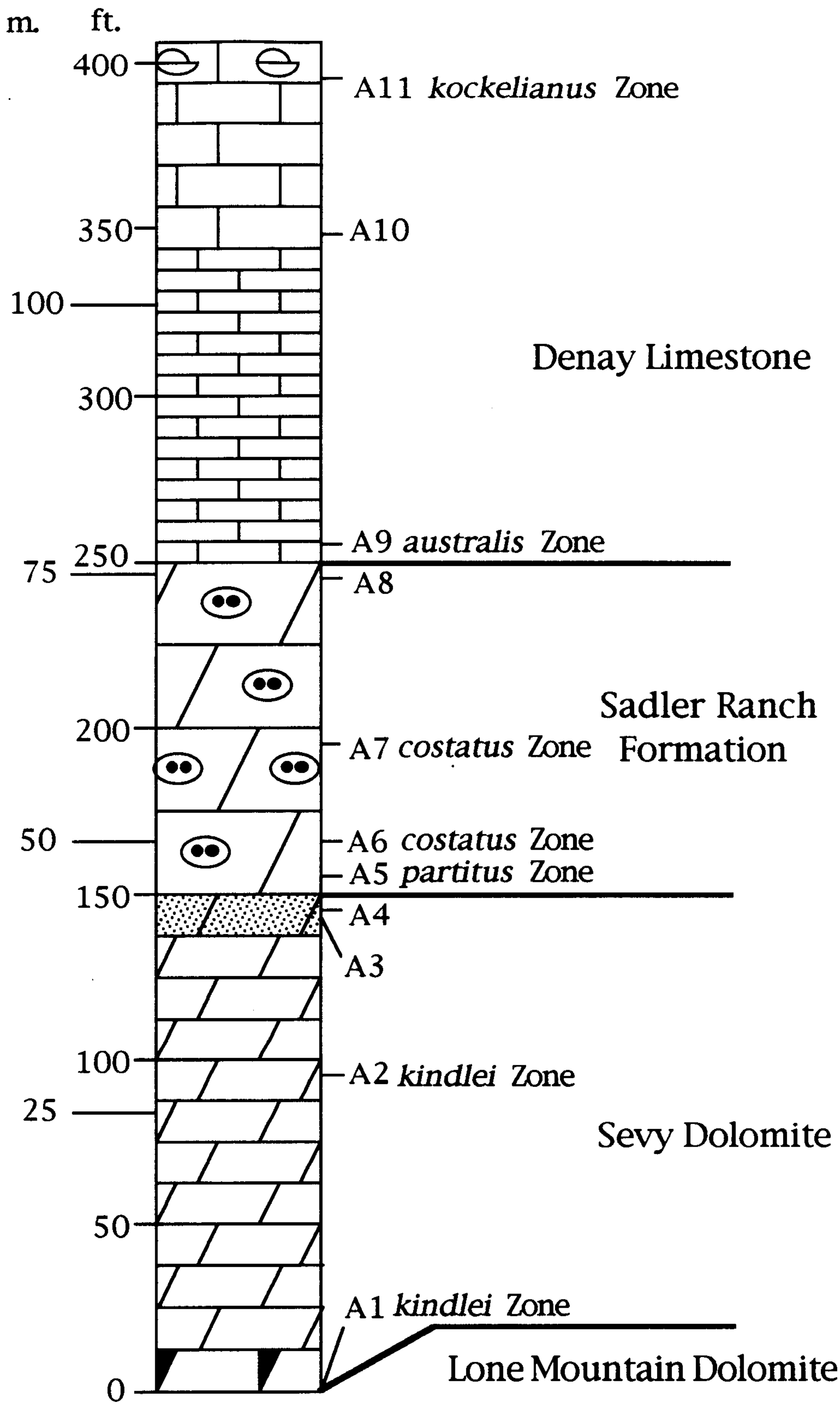


Figure 19A. Reveille Range measured section RRA-1, see Figure 18 for symbol key.

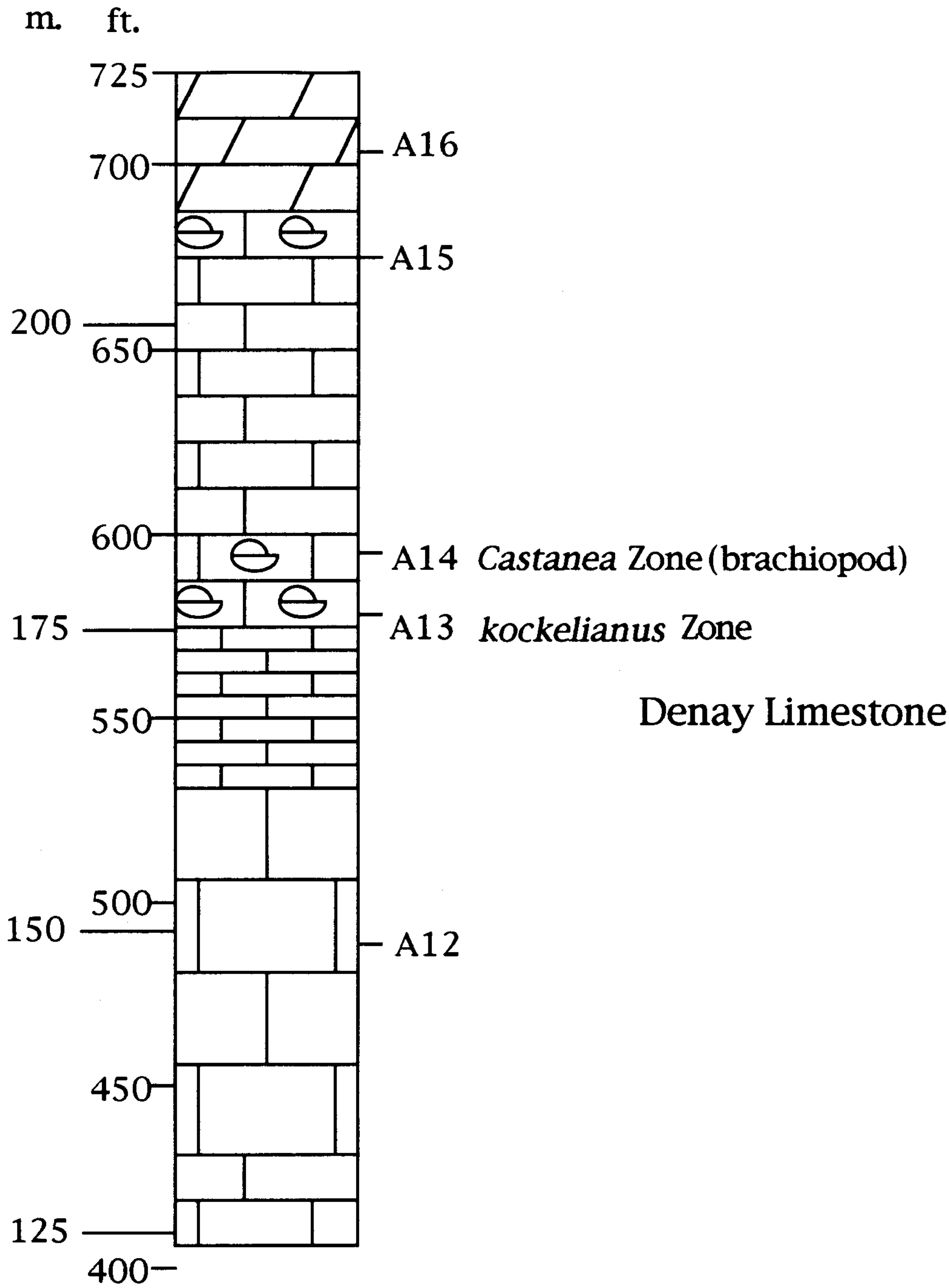


Figure 19B. Reveille Range measured section RRA-2, see Figure 18 for symbol key.

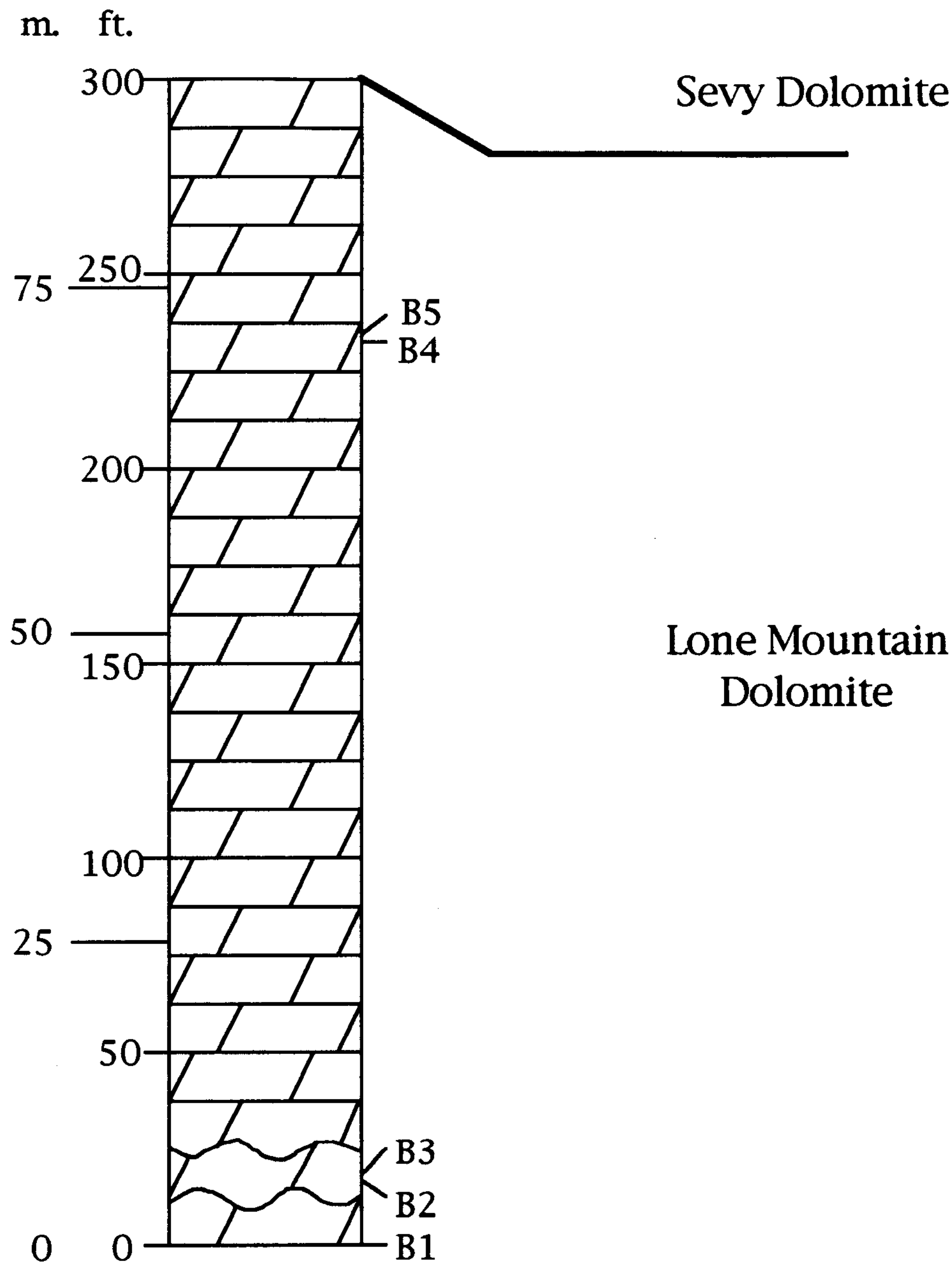


Figure 20. Reveille Range measured section RRB, see Figure 18 for symbol key.

the "transitional" dolomite to limestone facies near Eureka, Nevada, are incorporated into this newly revised stratigraphic nomenclature for the Reveille Range (Figure 21).

In this proposed revised stratigraphic scheme, the Lone Mountain Dolomite is equivalent to the upper unit of the undifferentiated Silurian to Devonian dolomite of Ekren *et al.* (1973). A lower contact was not identified in this study. The Sevy Dolomite is equivalent to the uppermost unit of the undifferentiated Silurian to Devonian dolomite. The Sadler Ranch Formation is equivalent to the lower unit, and the Denay Limestone is interpreted to represent the upper unit of the Nevada Formation of Ekren *et al.* (1973).

<u>Lone Mountain Dolomite.</u> The lowermost unit in the Devonian-age stratigraphy of the Reveille Range is the Lone Mountain Dolomite (Figure 5). In the Reveille Range, the Lone Mountain Dolomite consists of medium-bedded, light to medium gray, finely to medium crystalline dolomite that weathers to low ledges and benches (for further descriptions of the Lone Mountain Dolomite, see Regional Stratigraphy). The unit is generally unfossiliferous, but fossiliferous zones were identified approximately 20 meters below the top of the formation. These zones consist of recrystallized brachiopod and crinoid fragments. Lower parts of the dolomite contain juvenile stromatoporoid bioherms (Figure 22) and local discontinuities or erosion channels (Figure 23), characterized by dark gray dolomite containing light gray dolomite clasts that abruptly overlie light gray dolomite layers. Two small scale unconformable surfaces are 5 and 8 meters above the beginning of measured section RRB.

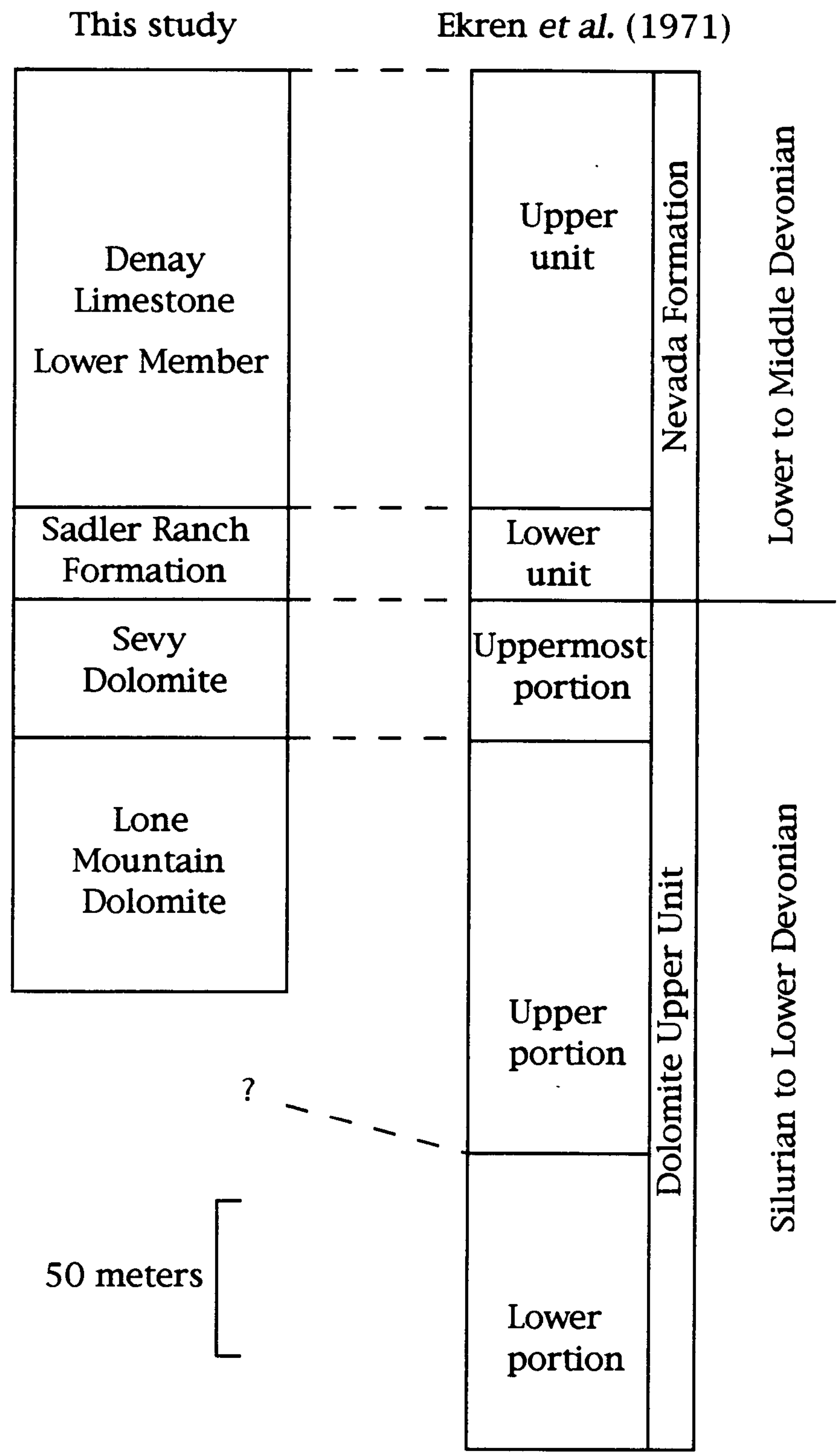


Figure 21. Reveille Range stratigraphy.

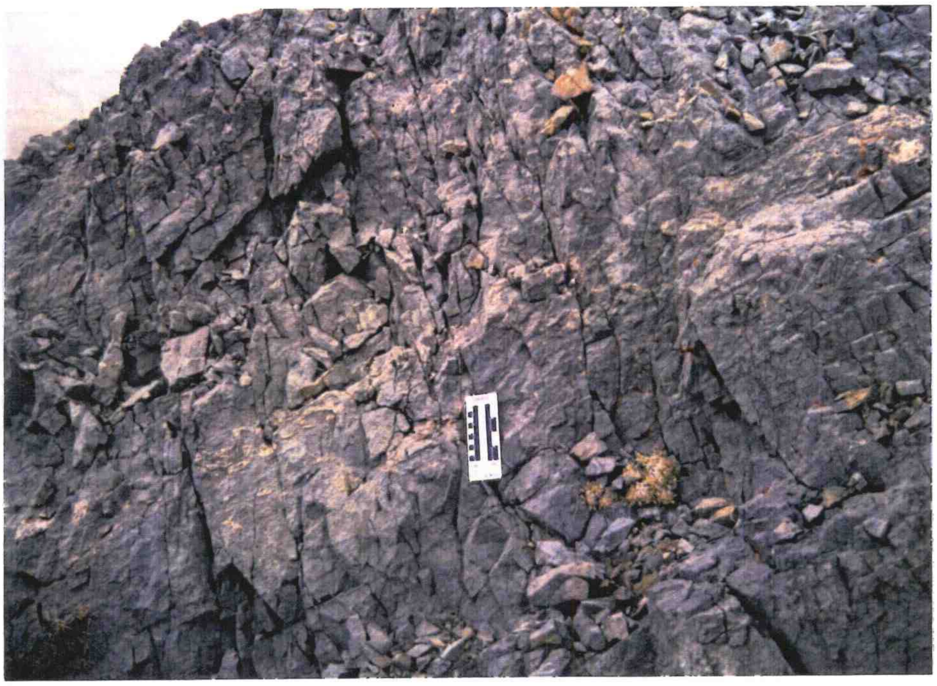


Figure 22. Juvenile stromatoporoid bioherm. T2N, R51.5E, Reveille Range, Nevada.

The contact of Lower Devonian with Silurian strata was not identified because all samples from the Lone Mountain Dolomite yielded conodonts of a probable Lower Devonian age. Lying below the Lone Mountain Dolomite are undifferentiated Silurian and Ordovician dolomite, quartzite, and limestone. Relative ages, based on stratigraphic position, place the age of the uppermost part of the Lone Mountain Dolomite as Early Devonian from other locations in eastern Nevada (Colman, 1979). The Lone Mountain Dolomite corresponds to the upper part of the Silurian and Lower Devonian Dolomite Upper Unit of Ekren *et al.* (1973). The Lone Mountain

Figure 23. Discontinuities in Lone Mountain Dolomite (geologic hammer for scale). T2N, R51.5E, Reveille Range, Nevada.

Dolomite in the Reveille Range is at least 90 meters thick. This total thickness is uncertain because the base of the formation was likely not measured for the section and the thickness may be substantially more than 90 meters. Stratigraphically above the light gray Lone Mountain Dolomite is the darker gray Sevy Dolomite, a lithologically similar unit with the contact easier to identify from a distance rather than in hand specimen.

Sevy Dolomite. The Sevy Dolomite unconformably overlies the Lone Mountain Dolomite in the Reveille Range (Figure 21). Typically, the Sevy Dolomite in other areas of east-central Nevada is composed of three members, the Dolomite Member, the Cherty Argillaceous Member, and the Sandy Member. In the Reveille Range, the Sevy Dolomite consists of one dominant lithology; a medium gray, finely crystalline, medium-bedded dolomite that most resembles the Dolomite Member (for further description of the Sevy Dolomite, see Regional Stratigraphy). The Sevy Dolomite is capped by a 2 meter thick, brown-weathering, sandy dolomite to dolomitic sandstone (Figure 24). The sandy zone contains some parallel laminations and low angle cross-stratification (Figure 25).

Conodonts collected from the base of the Sevy Dolomite were dated by G. Klapper (written communication, 1990) in the *kindlei* Zone (middle Pragian). This date is significant because definitive dates from the carbonate-platform-deposited lower Sevy Dolomite have not been previously identified in east-central Nevada (Figure 26). Outer-shelf basin deposited strata of the Kobeh Member of the McColley Canyon Formation (presumably Sevy-age equivalent strata) have been dated as the *sulcatus* Zone age of the early Pragian (Murphy and Gronberg, 1970). Therefore, the dates obtained from this study and from Murphy and Gronberg (1970) lie within different biozones, indicating that the Sevy Dolomite and the McColley Canyon Formation are not equivalent, or more likely, that deposition of the Sevy Dolomite (and equivalent strata) is time transgressive and becomes younger to the east.

Figure 24. Sandy upper part of the Sevy Dolomite (geologic hammer for scale). T2N, R51.5E, Reveille Range, Nevada.

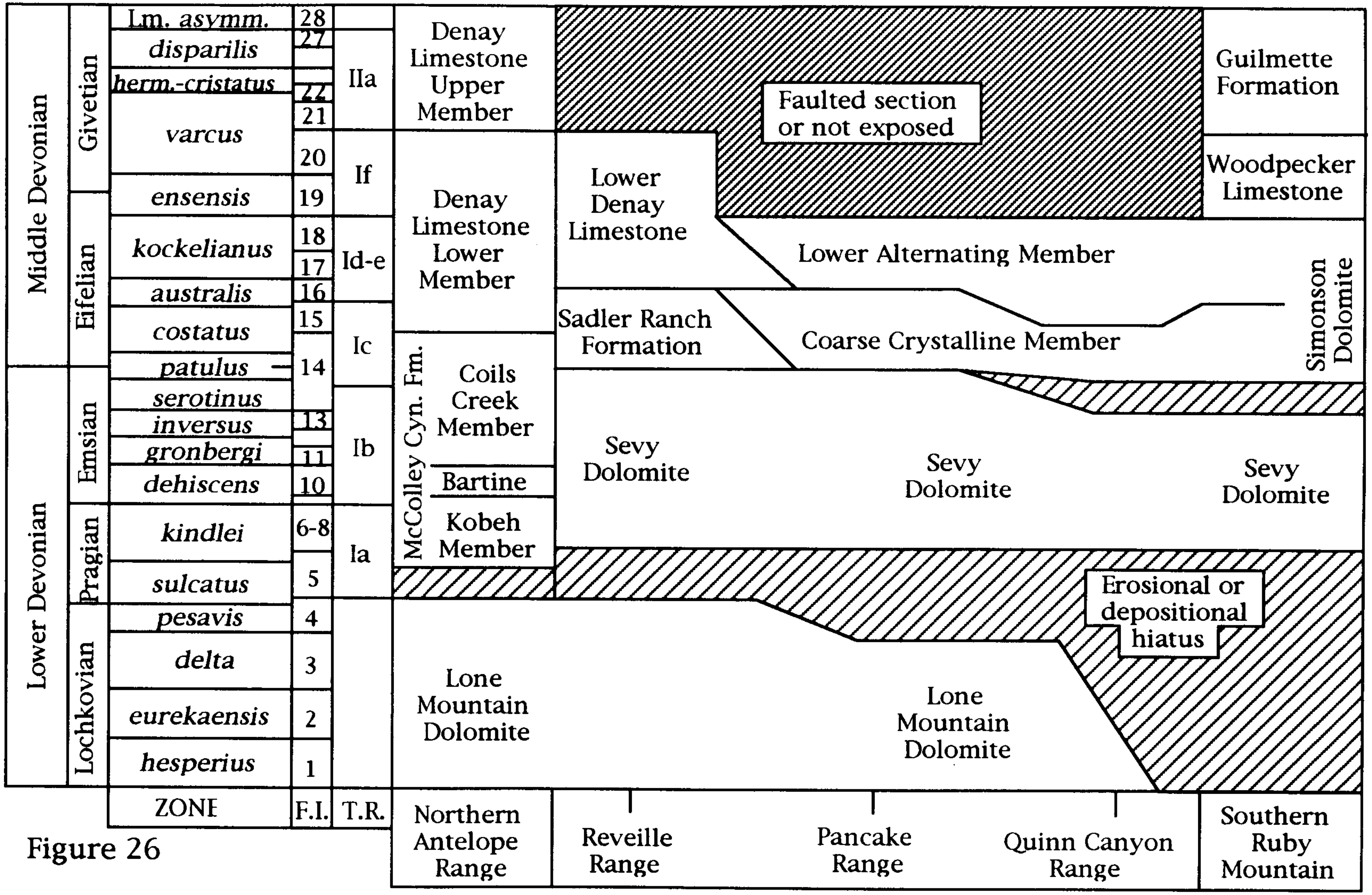
The upper contact of the Sevy Dolomite (Sandy Member) is conformable with the overlying Sadler Ranch Formation in the Reveille Range. Samples collected at the top of the formation yielded no identifiable conodonts. However, conodonts from the base of the Sadler Ranch lie in the *partitus* Zone (early Eifelian). The Sevy Dolomite corresponds (Figure 21) to the uppermost part of the Silurian and Lower Devonian Dolomite Upper Unit of Ekren *et al.*

(1973). The Sevy Dolomite is approximately 45 meters thick in the Reveille Range.

Figure 25. Laminations and low-angle cross-stratification in the sandy upper part of the Sevy Dolomite. T2N, R51.5E, Reveille Range, Nevada.

<u>Sadler Ranch Formation.</u> Stratigraphically above the Sevy Dolomite is the Sadler Ranch Formation (Figure 21 and 26). This unit is easily identifiable in east-central Nevada due to the presence of two-hole crinoid ossicles in a nearly black, finely crystalline dolomite matrix. The Sadler Ranch Formation was first described near Eureka, Nevada, in the "transitional" lithotopes of Kendall *et al.* (1983). This nomenclature is used in the Reveille Range not because of the

Figure 26 (following page). Time-rock transect from the Northern Antelope (Johnson and Murphy, 1984), Reveille, Pancake, and Quinn Canyon Ranges (this study), and the Southern Ruby Mountains (Johnson and Murphy, 1984). Faunal intervals (F.I.) are from Johnson (1977) and Johnson *et al.* (1980); transgressive-regressive cycles (T.R.) are those designated by Johnson *et al.* (1985) and Johnson and Sandberg (1988).



Middle Devonian
Lower Devonian
Givetian
Eifelian
Emsian
Pragian
Lochkovian
Lm. asymm.
disparilis
herm.-cristatus
varcus
ensensis
kockelianus
australis
costatus
patulus
serotinus
inversus
gronbergi
dehiscens
kindlei
sulcatus
pesavis
delta
eurekaensis
hesperius
28
27
22
21
20
19
18
17
16
15
14
13
11
10
6-8
5
4
3
2
1
IIa
If
Id-e
Ic
Ib
Ia
ZONE
F.I.
T.R.
Denay Limestone Upper Member
Denay Limestone Lower Member
McColley Cyn. Fm.
Coils Creek Member
Bartine
Kobeh Member
Lone Mountain Dolomite
Faulted section or not exposed
Lower Denay Limestone
Sadler Ranch Formation
Lower Alternating Member
Coarse Crystalline Member
Sevy Dolomite
Sevy Dolomite
Sevy Dolomite
Erosional or depositional hiatus
Lone Mountain Dolomite
Guilmette Formation
Woodpecker Limestone
Simonson Dolomite
Northern Antelope Range
Reveille Range
Pancake Range
Quinn Canyon Range
Southern Ruby Mountain

Figure 26

proximity to the Eureka area, but due to the similar lithologic and stratigraphic relationships between the two areas.

In the Reveille Range, the Sadler Ranch Formation is a medium dark to dark gray, finely to medium crystalline, medium-bedded to massive dolomite. The lower part is locally conglomeratic, containing clasts of light gray dolomite "floating" in a dark gray dolomite matrix (Figure 27). This unit erodes into low cliffs and ledges, whereas the upper part erodes into steep slopes, perhaps due to the less resistant thinner bedded nature of the upper part. The upper part of the Sadler Ranch Formation contains fewer two-hole crinoid ossicles. The Sadler Ranch Formation contains finely disseminated organic matter, and it emits a strong fetid odor from freshly broken surfaces.

Figure 27. Clasts within the Sadler Ranch Formation. T2N, R51.5E, Reveille Range, Nevada.

The upper contact of the Sadler Ranch Formation with the overlying Denay Limestone is sharply gradational. A definitive age was not obtained from samples collected from either unit, but an australis Zone age was obtained from conodonts collected at the base of the overlying Denay Limestone. The Sadler Ranch Formation corresponds (Figure 21) to the lower unit of the Lower and Middle Devonian Nevada Formation of Ekren *et al.* (1973). The Sadler Ranch Formation is approximately 30 meters thick in the Reveille Range.

Denay Limestone. The Denay Limestone overlies the Sadler Ranch Formation in the Reveille Range (Figure 21). The unit is characterized by light to medium gray, thin- to thick-bedded, fossiliferous limestone. The lower member of the formation crops out in the Reveille Range and is capped by a light gray, thick bedded dolomite.

The Denay Limestone is an outer-shelf basin deposit that remained undolomitized due to a relatively deeper water depositional environment compared with that of the platform and near-shelf-edge Lone Mountain, Sevy, and Sadler Ranch Formations, that were probably dolomitized during sea-level regressions (Dunham and Olsen, 1978). The Denay Limestone in the Reveille Range consists of light to medium gray, thin- to thick-bedded, finely crystalline limestone that is commonly fossiliferous, locally silty, and chert-bearing. Fossiliferous parts of the Denay Limestone contain silicified brachiopods in several zones throughout the formation. These brachiopods usually occur in thinner bedded intervals. The thinly bedded parts of the Denay Limestone rarely crop out, generally forming low slopes and saddles (Figure 28). The thicker bedded parts of the formation weather to low benches and small ledges.

Figure 28. Highly erodible, platey Denay Limestone. T2N, R51.5E, Reveille Range, Nevada.

In other areas of east-central Nevada, the Denay Limestone is composed of two lithologically similar limestone members, separated by a dolomite zone (Trojan, 1978). This dolomite zone defines the top of the lower member, a shallowing upward sequence that is capped by a light gray unfossiliferous dolomite. The dolomite zone is present in the Reveille Range. It is unclear, due to ambiguous stratigraphic positions and large area of secondary silicification, whether the upper member of the unit crops out in the Reveille Range.

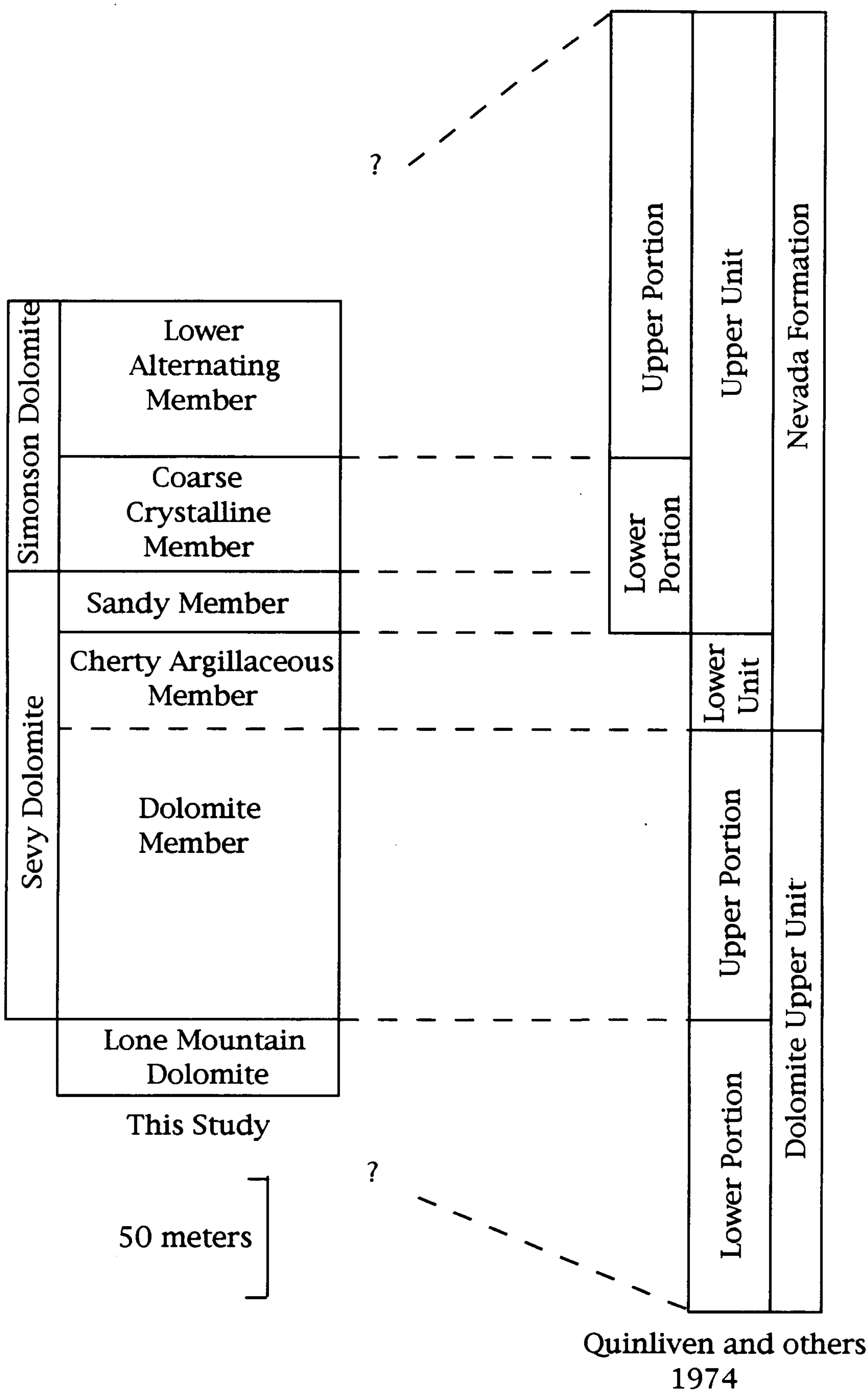
The base of the formation was dated as _australis_ Zone (middle Eifelian) from conodonts, but the age of the unfossiliferous dolomite cap is unknown (Figure 26). Brachiopods collected approximately 15 meters below the dolomite cap indicate a _Castanea_ Zone age (F.I. 19-20 of Johnson and Murphy, 1984). The lower member of the Denay Limestone corresponds (Figure 21) to the Lower and Middle Devonian Nevada Formation Upper Unit of Ekren *et al.* (1973). The Lower Member of the Denay Limestone is approximately 140 meters thick in the Reveille Range.

PANCAKE RANGE

Quinlivan *et al.* (1974) divided the section containing Lower to Middle Devonian strata in the Pancake Range into three distinct units: The upper part of the Silurian and Devonian Dolomite, the lower unit of the Lower and Middle Devonian Nevada Formation, and the upper unit if the Nevada Formation (Figure 29).

Silurian and Devonian Dolomite Upper Unit Quinlivan *et al.* (1974) divided the upper unit of the Silurian and Devonian Dolomite into two distinct sequences. The lower part of the unit is approximately 100 meters thick and is composed of faintly color-banded dolomite. This dolomite is light to medium gray, medium to coarsely crystalline, and locally vuggy. It is laminated to thick-bedded, blocky to massive splitting, and weathers to slightly darker shades of gray or yellow-gray. The upper part of the unit is approximately

Figure 29 (following page). Pancake Range Devonian Stratigraphy



Simonson Dolomite
Lower Alternating Member
Coarse Crystalline Member
Sandy Member
Sevy Dolomite
Cherty Argillaceous Member
Dolomite Member
Lone Mountain Dolomite
This Study
50 meters
?
?
Upper Portion
Lower Portion
Upper Unit
Lower Unit
Nevada Formation
Upper Portion
Lower Portion
Dolomite Upper Unit
Quinliven and others 1974

120 meters thick and is characterized by light to medium gray, finely crystalline dolomite. It is also partly vuggy, mostly laminated to thin-bedded, and weathers to light gray (Quinlivan *et al.*, 1974). The uppermost 8 meters is dominantly medium to dark gray silty to sandy dolomite that weathers yellowish to brownish-gray. The silty to sandy dolomite becomes increasingly sandy upward and is locally a sedimentary quartzite. Quinlivan *et al.* (1974) noted an important marker bed in the upper part of the unit. Approximately 20 to 30 meters below the top of the unit is a prominent zone of mottled to faintly color-banded dark-gray dolomite that is 5 to 10 meters thick (Figure 30 and 31).

Figure 30. Color banded dolomite within the Sevy Dolomite (looking south). T8N, R56E, Sec. 1, Pancake Range, Nevada.

Figure 31. Close-up of color banded dolomite within the Sevy Dolomite. T8N, R56E, Sec. 1, Pancake Range, Nevada.

The base of the upper unit is a conglomerate or breccia composed of randomly oriented clasts of light gray, finely crystalline dolomite. The matrix is described by Quinlivan *et al.* (1974) as silty to argillaceous, coarsely crystalline, yellow-weathering dolomite that contains quartz grains and inconspicuous light gray oolites. These oolites are most likely peloids, that commonly occur in the shallow carbonate deposits of east-central Nevada.

Lower and Middle Devonian Nevada Formation Lower Unit.
Quinlivan *et al.* (1974) described the lower unit of the Lower and

Middle Devonian Nevada Formation as slope-forming, light to dark gray, finely crystalline, thin- to thick-bedded dolomite that weathers to dark yellowish-orange and light red. This lower unit is approximately 40 meters thick in the Pancake Range. The lower unit is locally fossiliferous, and contains small nodules and lenses of red-weathering chert.

Lower and Middle Devonian Nevada Formation Upper Unit.

Quinlivan *et al.* (1974) divided the upper part of the Lower and Middle Devonian Nevada Formation into two distinct sequences, an interbedded dolomitic and quartzitic lower part and a color-banded dolomitic upper part.

The quartzite in the lower unit is light gray, brown weathering, finely crystalline, faintly laminated to thick-bedded. It is generally massive, lenticular, and forms low cliffs. Interbedded with the quartzite is less resistant dolomitic sandstone and sandy dolomite that becomes more abundant upward. The basal 6 to 20 meters is predominantly quartzite (Quinlivan *et al.*, 1974). The total thickness of the lower part of the Nevada Formation in the Pancake Range is approximately 53 meters.

The upper dolomitic unit, according to Quinlivan *et al.* (1974), is light to dark gray, finely to medium crystalline dolomite that is laminated to thick-bedded and weathers to various shades of gray, grayish red, and dark-reddish brown. The upper unit is approximately 344 meters thick in the Pancake Range. Color bands are several centimeters to tens of meters thick. The upper half of the color-banded dolomite contains sparse to moderately abundant fossils, including algal heads, stromatoporoids, gastropods, and brachiopods. The top of the color-banded unit in the Pancake Range is placed by Quinlivan *et al.* (1974) at the contact with the basal yellowish-gray silty limestone and dolomite of the overlying Devils Gate Limestone. This distinctive unit is recognized throughout east-central Nevada (Johnson *et al.*, 1990).

PROPOSED PANCAKE RANGE STRATIGRAPHIC NOMENCLATURE

The oldest dated unit of Devonian age in the southern Pancake Range is the Sevy Dolomite (Figure 29). There is no known age for the uppermost part of the underlying Lone Mountain Dolomite. The Devonian section studied in the Pancake Range is in an uplifted Paleozoic fault block that involves strata ranging from the Ordovician Eureka Quartzite through the Mississippian Chainman Shale (Kleinhampl and Ziony, 1985). The Devonian section is presumably a hinterland to the Garden Valley Thrust System, but the relationship to the Eureka Fold and Thrust Belt to the north is unknown (Figure 17). Approximately 300 meters of Devonian strata were measured and sampled for brachiopod and conodont biostratigraphy (Figure 32A-34).

<u>Lone Mountain Dolomite.</u> The Lone Mountain Dolomite is stratigraphically the oldest formation measured in the Pancake Range (Figure 29). This unit consists of light to medium gray, medium crystalline, medium-bedded dolomite. The upper contact with the overlying Sevy Dolomite is sharp in the Pancake Range but was not dated from the conodonts collected for this study. The Lone

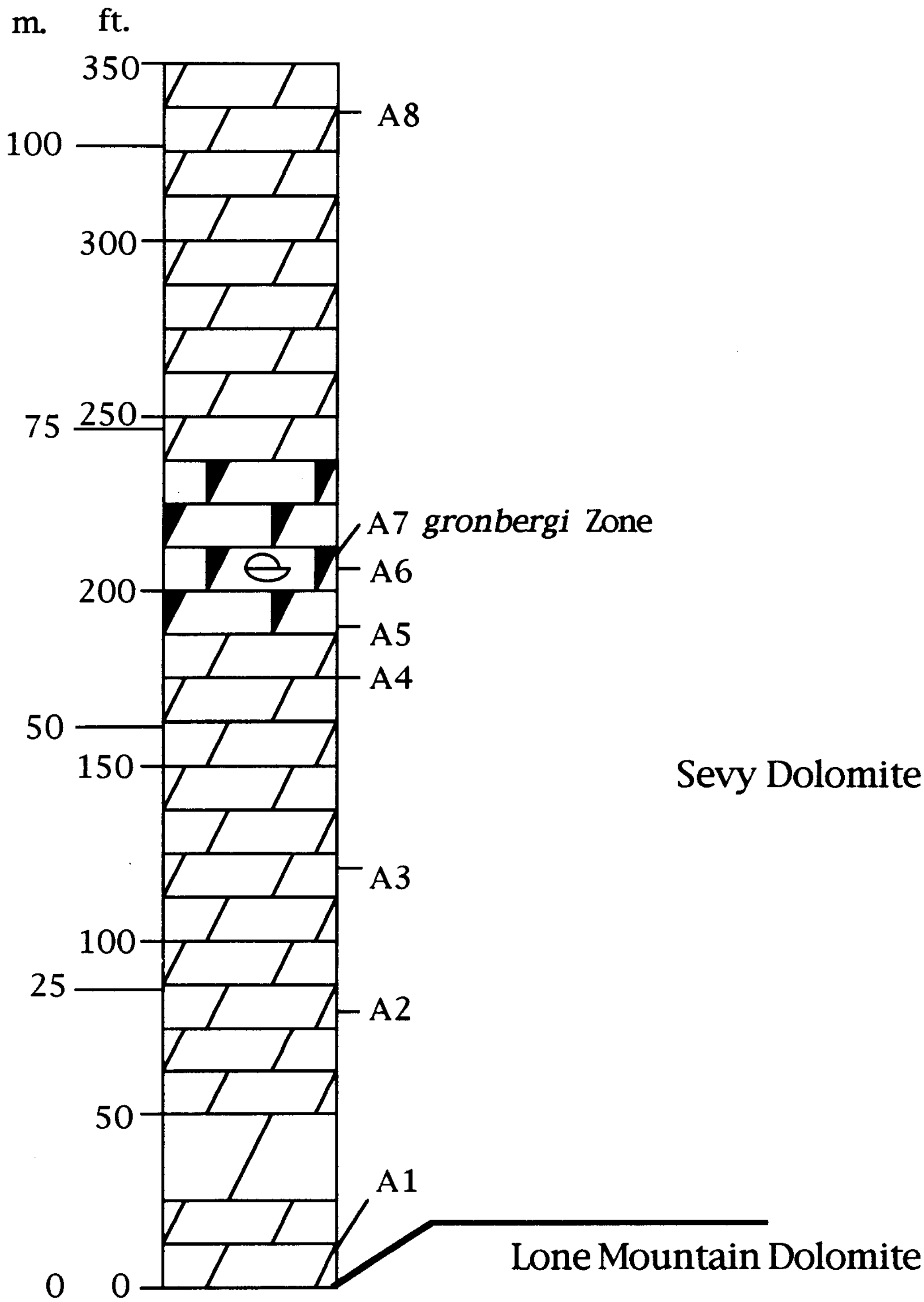


Figure 32A. Pancake Range measured section PRA-1, see Figure 18 for symbol key.

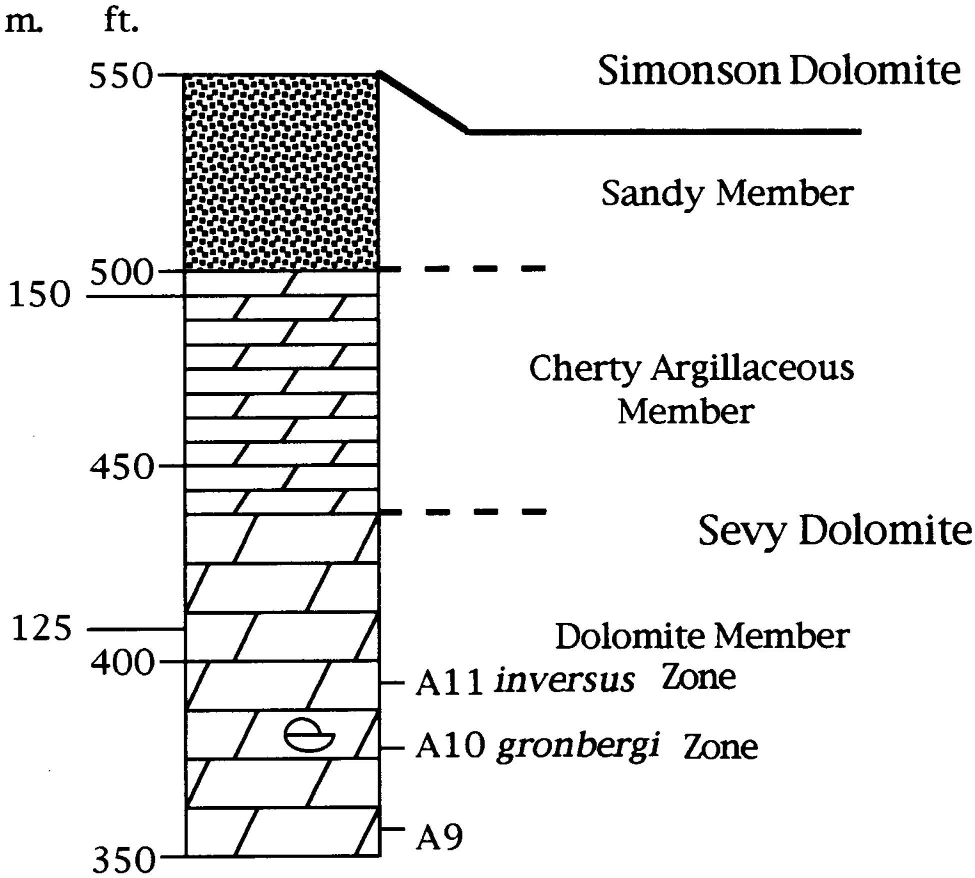


Figure 32B. Pancake Range measured section PRA-2, see Figure 18 for symbol key.

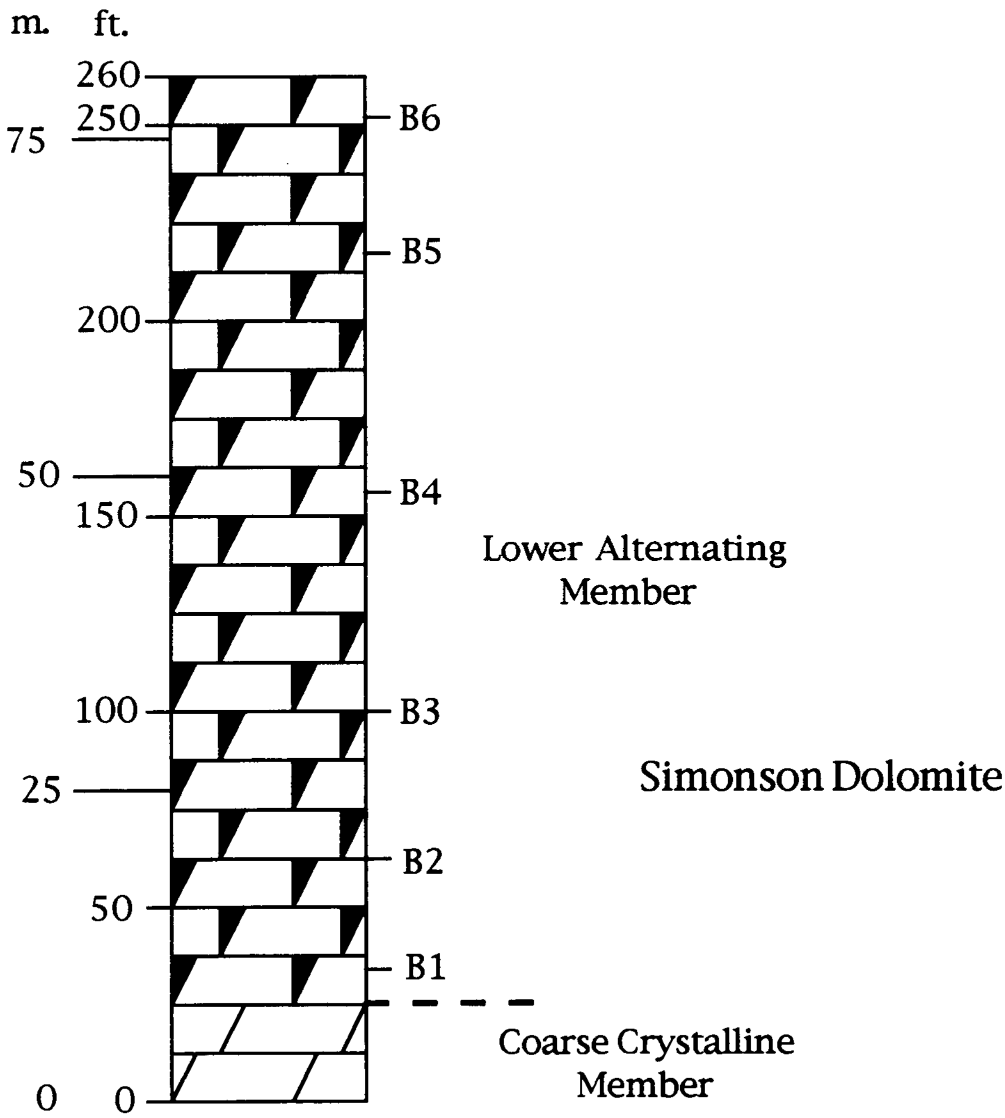


Figure 33. Pancake Range measued section PRB, see Figure 18 for symbol key.

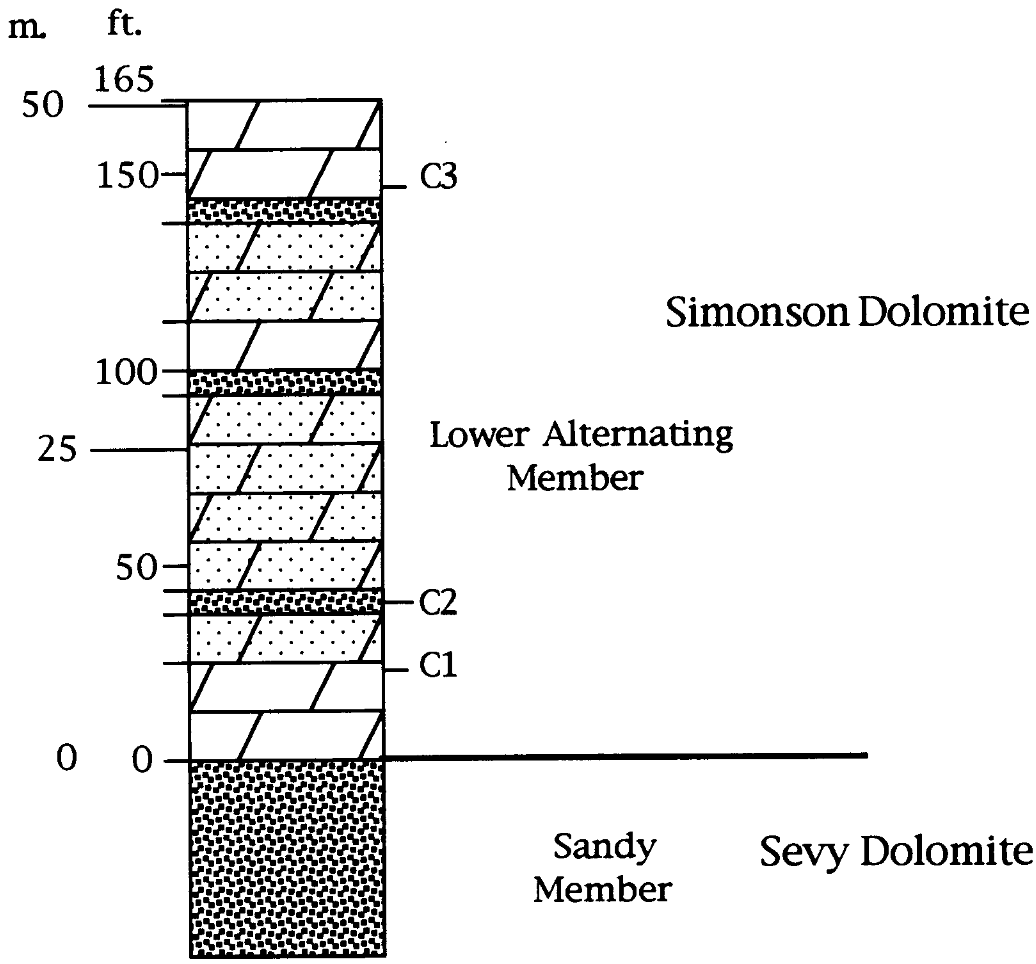


Figure 34. Pancake Range measured section PRC, see Figure 18 for symbol key.

Mountain Dolomite corresponds (Figure 29) to the lower part of the upper unit of the Silurian and Lower Devonian Dolomite of Quinlivan *et al.*, 1974. The thickness of the Lone Mountain Dolomite is estimated to be approximately 100 meters thick (Quinlivan *et al.*, 1974).

Sevy Dolomite. The Sevy Dolomite in the Pancake Range consists of three members: the Dolomite Member, the Cherty Argillaceous Member, and the Sandy Member. The Dolomite Member is conglomeratic at the base but generally consists of unfossiliferous, light gray, medium-bedded, finely to medium crystalline dolomite (Figure 35).

Figure 35. Evenly bedded Dolomite Member of the Sevy Dolomite. T8N, R56E, Sec 1., Pancake Range, Nevada.

The unit becomes sandy between 107 meters and 115 meters in section PRA. Dark sandy dolomitic beds in this part of the formation (Figure 27) yield a *gronbergi* Zone age (G. Klapper, 1990, written communication). The Dolomite Member of the Sevy Dolomite corresponds (Figure 30) to the upper unit of the Silurian and Devonian Dolomite of Quinlivan *et al.* (1974). The unit is approximately 115 meters thick in the Pancake Range.

The middle part of the Sevy Dolomite is characterized by yellowish weathering, bioturbated, sandy, argillaceous dolomite (Cherty Argillaceous Member). Conodonts and brachiopods from 34 meters below the top of Cherty Argillaceous Member in section PRA indicate the *inversus* Zone age of the middle Emsian (Figure 27; G. Klapper, 1990, written communication; J.G. Johnson, 1990, verbal communication).

The Sandy Member of the Sevy Dolomite is a prominent cliff former in the Pancake Range. The unit is massive brown-weathering quartzite and is approximately 15 meters thick. The Sevy Dolomite is 167 meters thick in the Pancake Range.

Simonson Dolomite. The Simonson Dolomite unconformably overlies the Sevy Dolomite in the Pancake Range (Figure 29). The lower two members of the formation were measured for this study and include the Coarse Crystalline Member and the Lower Alternating Member.

The Coarse Crystalline Member consists of interbedded light gray, medium to coarsely crystalline dolomite and brown-weathering quartzite. The age of the member is uncertain from samples collected for this study. The Coarse Crystalline Member corresponds

(Figure 29) to the lower part of the Lower and Middle Devonian Nevada Formation of Quinlivan *et al.*, 1974. The Coarse Crystalline Member is 50 meters thick in the Pancake Range.

The Lower Alternating Member conformably overlies the Coarse Crystalline Member in the Pancake Range. It is rhythmically medium-bedded, medium crystalline, black to light gray dolomite. Conodonts collected from several samples yielded no identifiable species. The Lower Alternating Member of the Simonson Dolomite corresponds (Figure 29) to the upper part of the Lower and Middle Devonian Nevada Formation of Quinlivan *et al.* (1974). The Lower Alternating Member is at least 65 meters thick in the Pancake Range.

QUINN CANYON RANGE

Few previous stratigraphic studies have been conducted in the Quinn Canyon Range. Much work has been done in the Grant Range to the north by Hyde and Huttrer (1970), Lund *et al.*, (1987), and Fryxell, (1988). However, due to Mesozoic and Cenozoic thrust faulting, Devonian strata exposed in the Grant Range are not in the same structural window as the Quinn Canyon Range strata (Bartley and Gleason, 1990). In addition, regional investigations by Osmond (1954, 1962) do not provide sufficient resolution to accurately correlate strata from the different locales. In the Quinn Canyon Range, Murray (1985), however, did provide stratigraphic control from a structural study. She divided the Lower and Middle Devonian strata into two units, the Sevy and Simonson Dolomites.

Sevy Dolomite. According to Murray (1985), the Sevy Dolomite overlies the Silurian Laketown Dolomite in the Quinn Canyon Range. The Sevy Dolomite is a light gray to light bluish gray, finely to coarsely crystalline, porcellaneous, thin- to medium-bedded dolomite. The dolomite weathers light gray with abundant rill marks and solution pitting. Stylolites with red-brown hematitic staining are also common. At the top of the Sevy Dolomite is 15 to 23 meters of light gray, fine- to medium-grained, poorly sorted, quartz arenite. This unit is cross-bedded and dolomite-cemented. Murray (1985) estimated that the Sevy Dolomite is 180 meters thick in the Quinn Canyon Range.

Simonson Dolomite. The Simonson Dolomite unconformably overlies the Sevy Dolomite in the Quinn Canyon Range. Murray (1985) described the Simonson Dolomite as medium gray to dark gray, finely to coarsely crystalline, fossiliferous dolomite. This thin- to thick-bedded dolomite weathers light gray to light olive-gray. In the lower part, beds of dark gray coarsely crystalline dolomite with a "sugary" texture are overlain by finely to medium crystalline, alternating light and dark dolomite (Figure 36). The top of the Simonson Dolomite is not exposed in the Quinn Canyon Range, but the formation is at least 300 meters thick (Murray, 1985).

PROPOSED QUINN CANYON RANGE STRATIGRAPHIC NOMENCLATURE

The Devonian section studied in the Quinn Canyon Range crops out within the Garden Valley Thrust System (Figure 17; Bartley and Gleason, 1990) and is surrounded by Tertiary volcanic rocks.

Approximately 450 meters of Devonian strata was measured and sampled for conodont and brachiopod biostratigraphy (Figure 37).

Figure 36. Light and dark gray Simonson Dolomite beds (geologic hammer for scale). T3N, R56E, Quinn Canyon Range, Nevada.

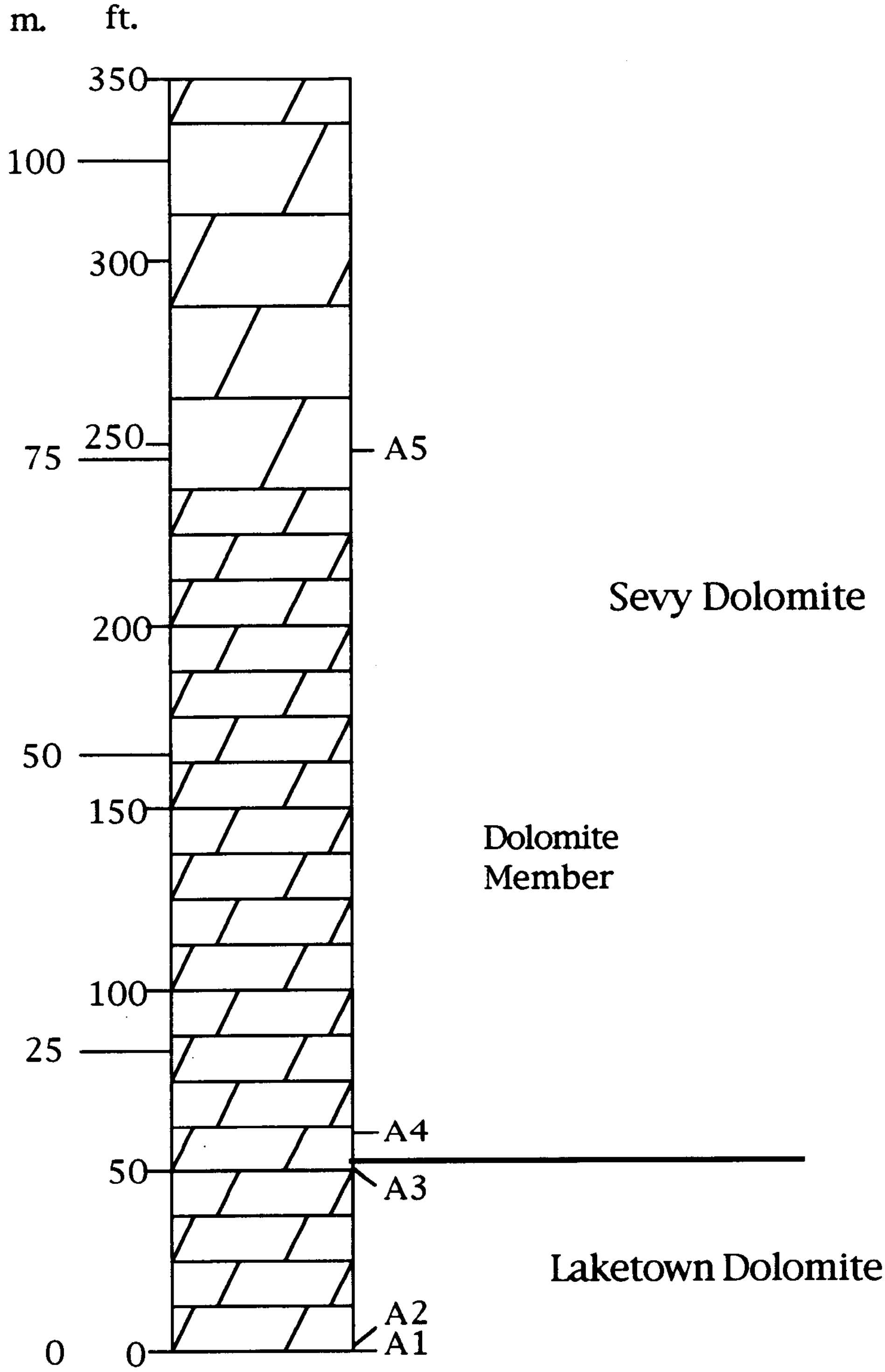


Figure 37A. Quinn Canyon Range measured section QCA-1
see Figure 18 for symbol key.

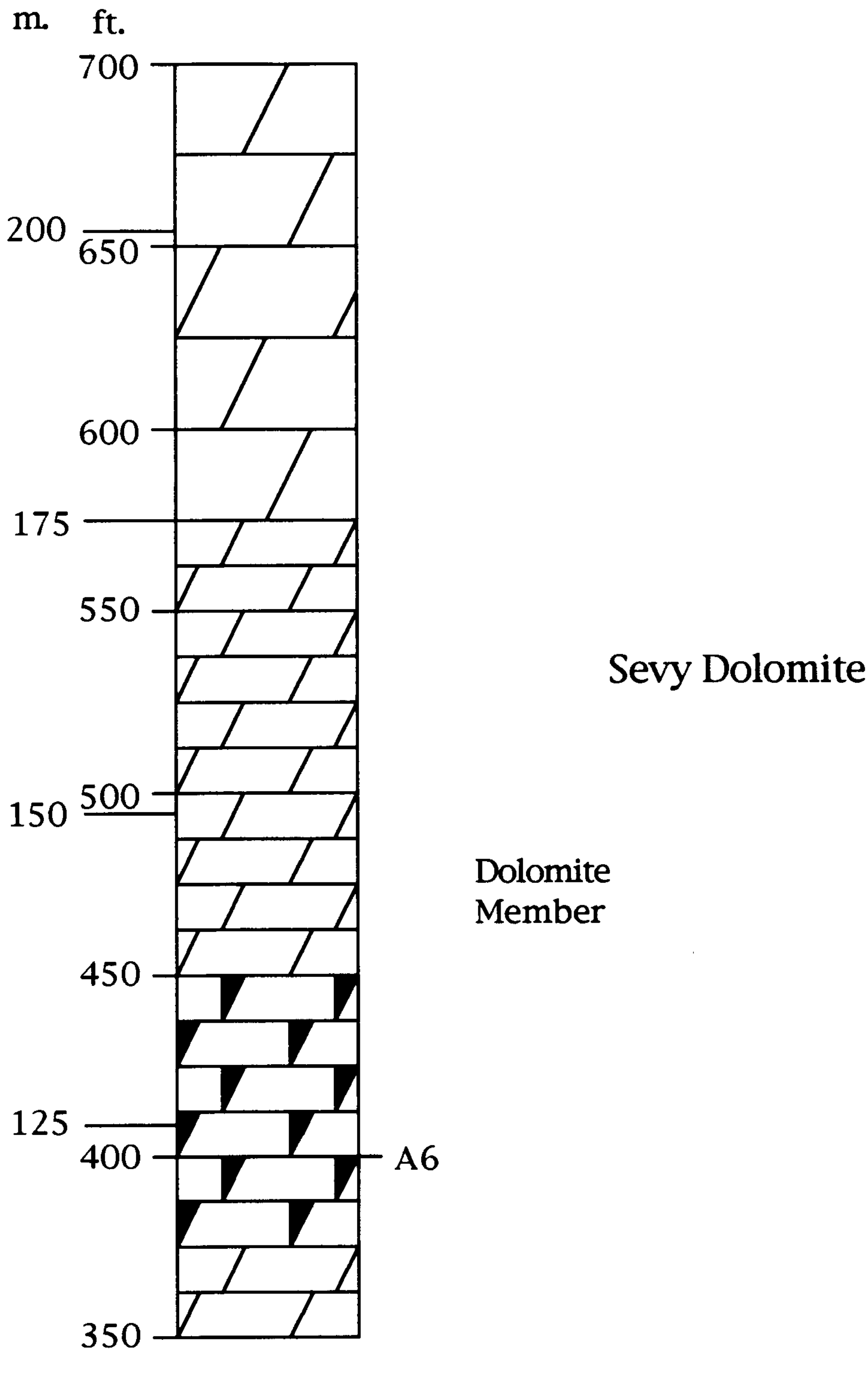


Figure 37B. Quinn Canyon Range measured section QCA-2
see Figure 18 for symbol key.

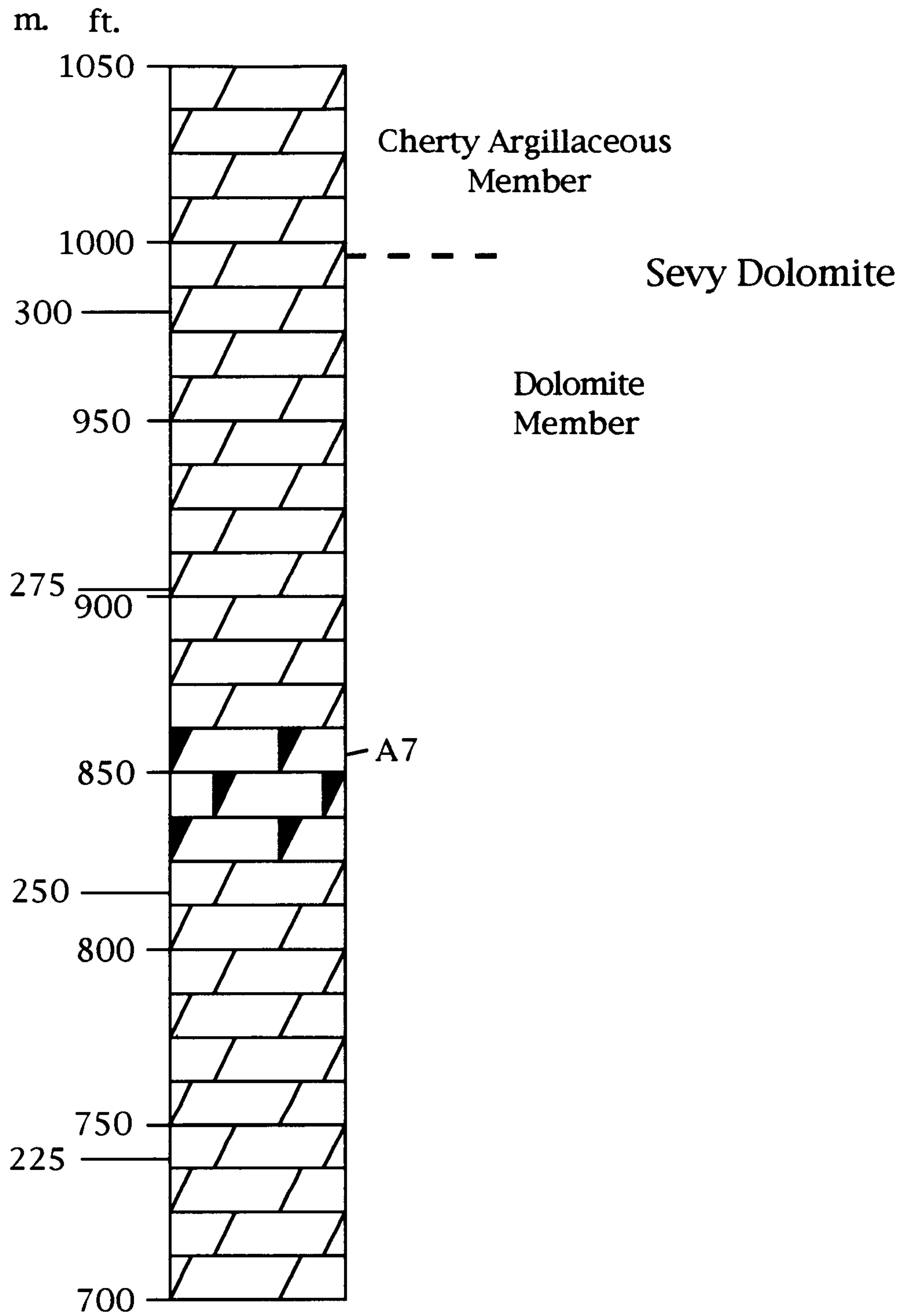
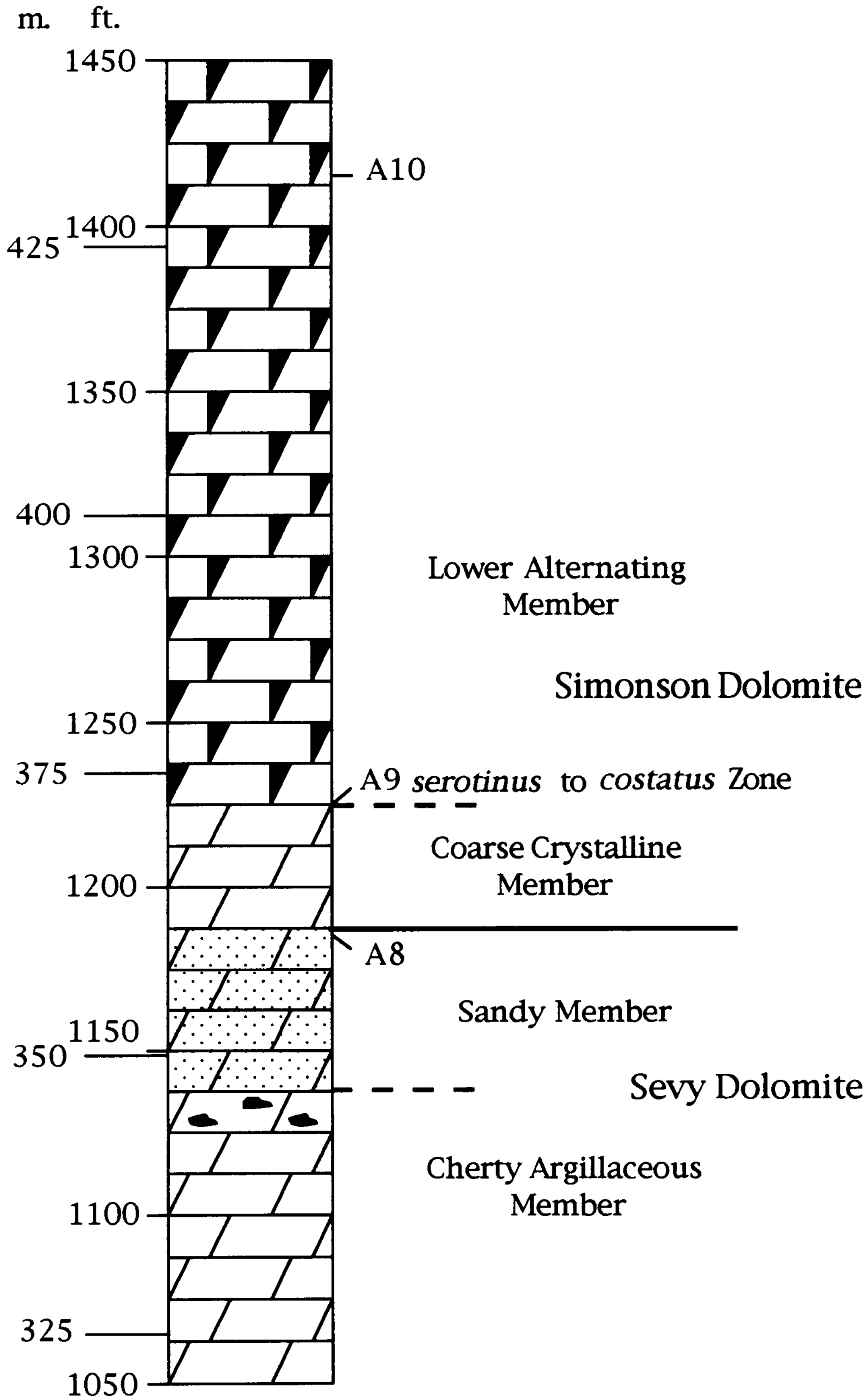


Figure 37C. Quinn Canyon Range measured section QCA-3 see Figure 18 for symbol key.

Figure 37D (following page). Quinn Canyon Range measured section QCA-4, see figure 18 for symbols.


m.
ft.
1450
A10
425
1400
1350
400
1300
Lower Alternating Member
Simonson Dolomite
1250
375
A9 *serotinus* to *costatus* Zone
Coarse Crystalline Member
1200
A8
Sandy Member
350
1150
Sevy Dolomite
Cherty Argillaceous Member
1100
325
1050

Laketown Dolomite. The Silurian Laketown Dolomite underlies the Sevy Dolomite in the Quinn Canyon Range (Figure 26). The Laketown Dolomite is dark gray, thick-bedded to massive, medium to coarsely crystalline dolomite.

Sevy Dolomite. The Sevy Dolomite in the Quinn Canyon Range is divided in this study into three distinct members: The Dolomite Member, the Cherty Argillaceous Member, and the Sandy Member.

The Dolomite Member is predominantly light gray, finely to medium crystalline, medium-bedded dolomite. In the lower part of the formation (from 114 meters to 133 meters in section QCA), a layer of fossiliferous alternating dark and light gray fetid dolomite is present. The fossils seem to be brachiopods, but they are unidentifiable because of silicification and recrystallization. This lithology is repeated from 249 meters to 277 meters in section QCA (Figure 37C and 38).

Dolomite beds are couplets in color, consisting of dark gray in the lower part, grading upward to light gray dolomite in the upper part. These layers may mark the incursion of more normal marine water into a restricted basin (see Simonson Dolomite section in Regional Stratigraphy). No definitive ages were obtained from any brachiopod or conodont samples in the dolomite member of the Sevy Dolomite.

Near the top of the Sevy Dolomite is a 42 meter section of tan-weathering, gray, sandy, silty, finely to medium crystalline, medium-bedded to massive dolomite. Cherty layers were also identified. This unit is the Cherty Argillaceous Member of the Sevy Dolomite.

Figure 38. Dark dolomite beds within the Sevy Dolomite (Juniper trees are approximately 2 meters tall for scale). T3N, R56E, Quinn Canyon Range, Nevada.

The uppermost part of the Sevy Dolomite is characterized by massive, tan-weathering, light gray to white, fine- to medium-sand-sized, moderately to well sorted, subrounded to rounded, dolomite-cemented quartz sandstone. This unit is assigned to the Sandy Member of the Sevy Dolomite. In the Quinn Canyon Range, the Sandy Member is approximately 15 meters thick.

The age of the Sevy Dolomite is uncertain because fossil collections yielded unidentifiable conodonts and brachiopods due to recrystallization, dolomitization, and poor or incomplete silicification.

The Sevy Dolomite is approximately 341 meters thick in the Quinn Canyon Range.

Simonson Dolomite. Regionally, the Simonson Dolomite typically consists of as many as 5 members. In the Quinn Canyon Range, the Simonson Dolomite unconformably overlies the Sevy Dolomite (Figure 26). The formation consists of two members, the Coarse Crystalline and Lower Alternating Members. Only 69 meters of the Simonson Dolomite were measured in the Quinn Canyon Range. Presumably, the formation is much thicker.

The Coarse Crystalline Member is coarsely crystalline, massive, tan-gray weathering dolomite. The member is unfossiliferous and is approximately 12 meters thick. The Lower Alternating Member consists of rhythmically medium-bedded, medium crystalline, black to light gray dolomite (Figure 39).

The base of the Lower Alternating Member lies within the *serotinus*- to *costatus* Zone (Figure 26). This date is important because it shows that the base of this unit is older in the Quinn Canyon Range than ages for the Lower Alternating Member equivalent strata previously determined by Murphy and Gronberg (1970) in the ranges near Eureka, Nevada. A thickness of approximately 57 meters was measured for the Lower Alternating Member of the Simonson Dolomite in the Quinn Canyon Range. The top of the formation is not exposed due to a regional thrust fault that emplaces Ordovician carbonate strata on the Lower Alternating Member of the Simonson Dolomite.

Figure 39. Beds of light and dark gray dolomite within the Lower Alternating Member of the Simonson Dolomite (geologic hammer for scale). Quinn Canyon Range, Nevada.

DISCUSSION

Dolomitization in the Paleozoic strata of Nevada is a secondary feature, an early diagenetic replacement of strata that were originally limestone (Dunham and Olsen, 1978). This replacement process is paleogeographically controlled, as small eustatic changes produced transgressions and regressions of the shoreline. In this way, the exposed land and adjacent submerged shelfal area were exposed to freshwater recharge and replacement dolomitization (for further discussion, see Dolomite).

The Devonian in Nevada is marked by deposition on a carbonate platform (relatively shallow water) and in an outer-shelf basin (relatively deep water). As a rule, shallow carbonate platform deposits (shelfal and tidal-flat), especially those befor the Antler Orogeny, are dolomitized, whereas deep water, outer-shelf basin and slope deposits are not. Thus, advances in knowledge of Devonian stratigraphy and paleogeography may lead to a better understanding of Devonian-age strata that are commonly the target of petroleum exploration in eastern Nevada.

The strata of the Reveille Range record the transition from carbonate platform deposition (Lone Mountain and Sevy Dolomite) in the Lower Devonian to deposition at the carbonate platform margin (Sadler Ranch Formation) to the outer-shelf basin (Denay Limestone) in the Middle Devonian. In addition, conodonts collected from the base of the Sevy Dolomite yield a _kindlei_-Zone age, an indication that, at least in the Reveille Range, the Sevy Dolomite is younger than previously recognized (Figure 26 and 40).

Throughout the Lower and Middle Devonian, carbonate strata (Sevy and Simonson Dolomite) of the Pancake Range and Quinn Canyon Range were deposited on the shallow carbonate platform. Conodonts collected from the base of the Lower Alternating Member of the Simonson Dolomite in the Quinn Canyon Range indicate a slightly older age (_serotinus_- to _costatus_ Zone) than other eastern Nevada locations (Figure 26 and 40). This is due to an early incursion of normal marine water within a depositional basin or tongue extending to the Quinn Canyon Range.

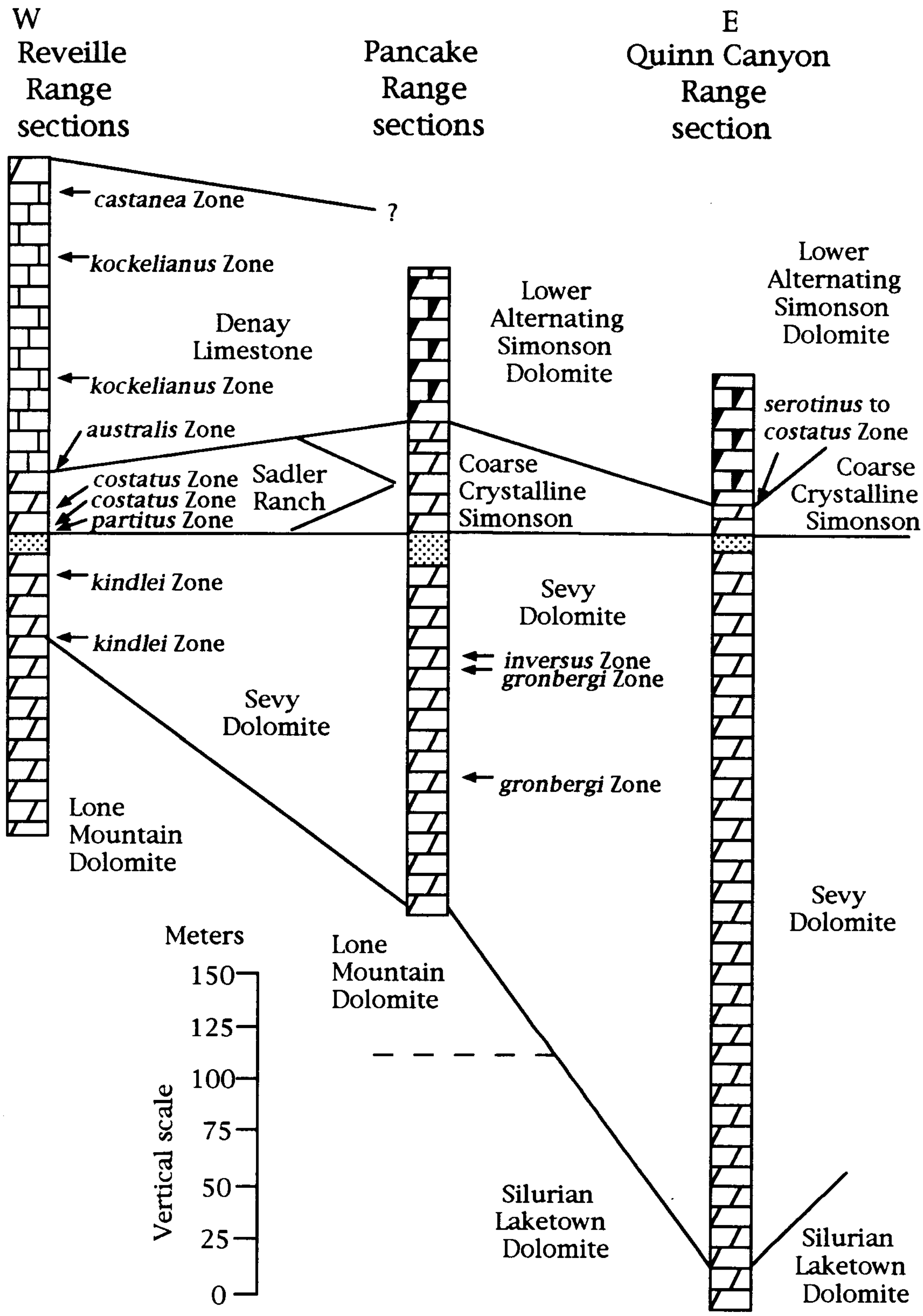


Figure 40. Correlation chart of Lower and Middle Devonian strata from the Reveille, Pancake, and Quinn Canyon Ranges, Nye County, Nevada.

PETROLOGY

A total of fifty-one (51) samples of limestone, dolomite, and quartz sandstone from the Reveille, Pancake, and Quinn Canyon Ranges were collected from measured sections in the summer of 1989. These samples are described in detail in Appendix I through VI. Many carbonate samples show evidence of stylolites. The stylolites under magnification are microscopic concentrations of opaque iron oxides and clays in wavey crenulations (Figure 41).

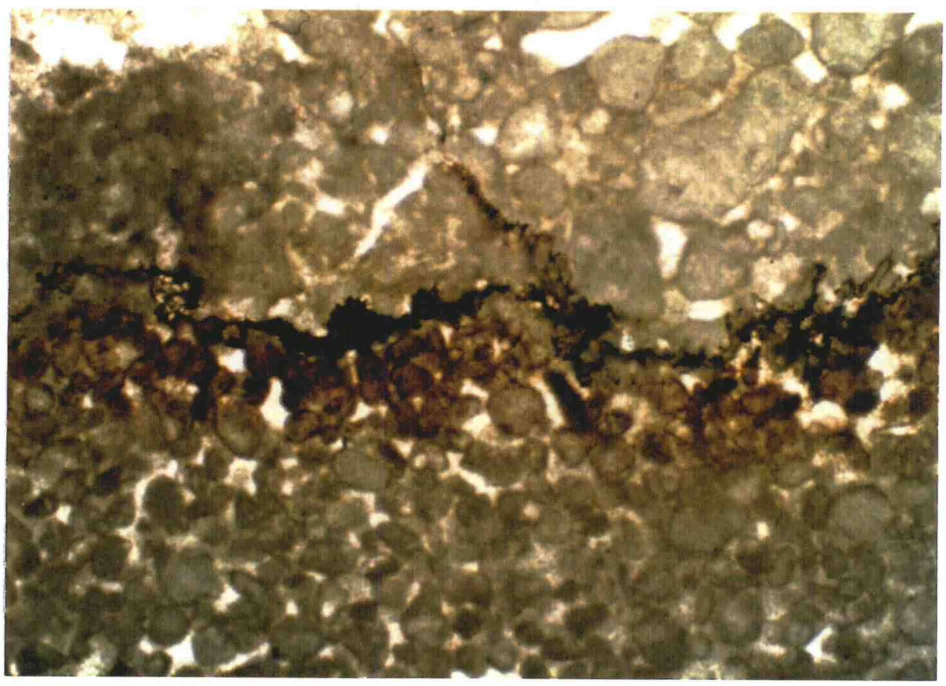


Figure 41. Photomicrograph of a microstylolite in the Sevy Dolomite (40X magnification, plane light, bottom of photograph is 3 mm for scale).

They represent pressure-solution fronts due to compaction after burial. The following section is a petrographic discussion of the samples and the formations they represent. This study uses Dunham's (1962) classification of carbonate strata (Figure 42).

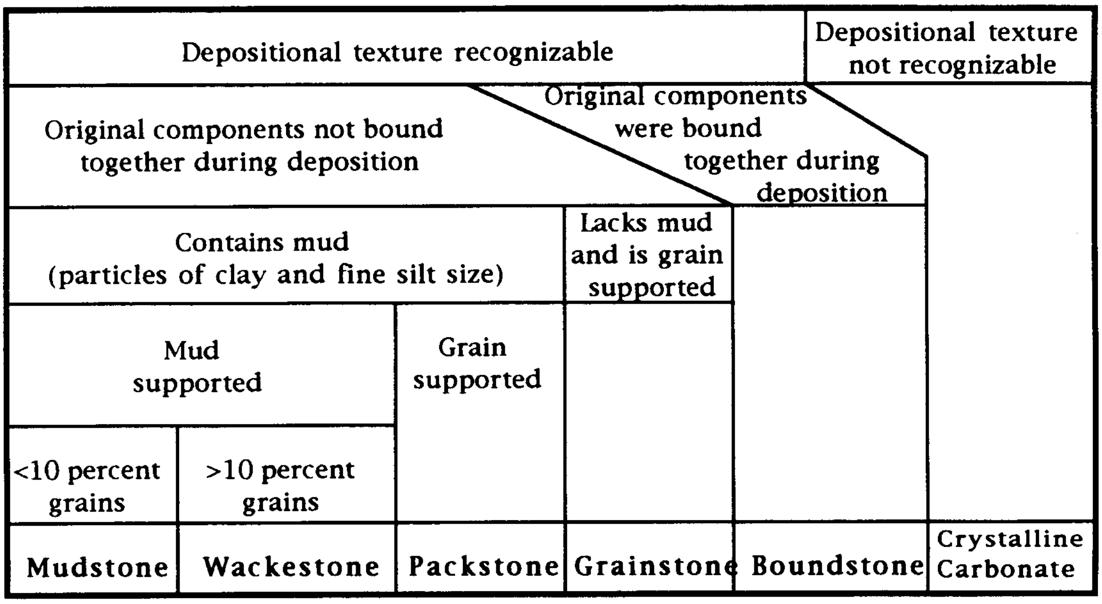


Figure 42. Limestone classification used in this study from Dunham (1962).

LAKETOWN DOLOMITE

The Silurian Laketown Dolomite does not crop out in the Pancake or the Reveille Range. However, farther east in the Quinn Canyon Range, the Laketown Dolomite lies stratigraphically below the Lower Devonian Sevy Dolomite (Figure 26). Three samples of the formation were collected from the lower 15 meters of section QCA (Figure 38A). Samples QCA-1, QCA-2, and QCA-3 are classified as dolomitized mudstone in thin section. For further petrographic information on the Laketown Dolomite, see Appendix IV.

Quinn Canyon Range. All three samples appear remarkably similar in thin section. Due to extensive postdepositional recrystallization to dolomite, any primary structures, if present, were obliterated. Samples QCA-1, QCA-2, and QCA-3 consist of an interlocking mosaic of subhedral to euhedral crystals of medium to coarsely crystalline dolomite (Figure 43). The three samples are cloudy.

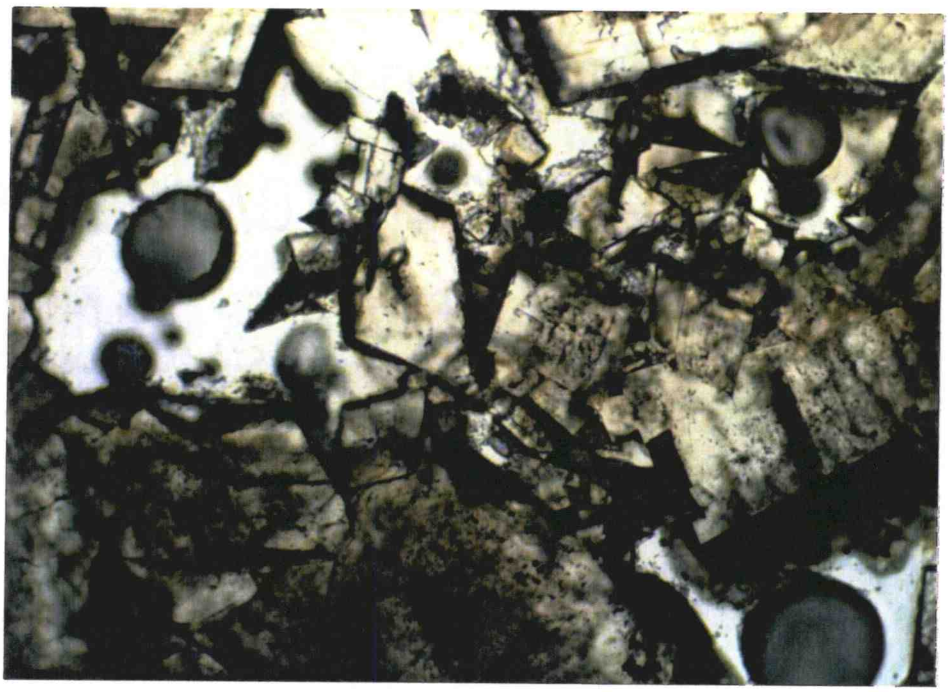


Figure 43. Photomicrograph of euhedral rhombs of dolomite crystals of the Laketown Dolomite, Quinn Canyon Range, Nevada (40X magnification, polarized light, bottom of photograph is 3 mm for scale).

Depositional and Diagenetic Environment. These observations suggest that the Laketown Dolomite was deposited as a rather structureless carbonate mudstone from suspension deposited micrite in a low energy limy shelfal or tidal-flat lagoonal environment in which bioturbation predominated. The calcite has been subsequently replaced after burial by nearly homogenous dolomite. Due to extensive replacement by dolomite, most primary sedimentary structures or textures of the original limestone are obscured.

LONE MOUNTAIN DOLOMITE

The Lone Mountain Dolomite crops out in the Pancake and Reveille Ranges, but due to a regional unconformity does not crop out in the Quinn Canyon Range (Figure 26). No samples of the Lone Mountain Dolomite were collected from the Pancake Range sections. Five samples were collected for petrographic analysis from the Reveille Range section RRB (Figure 20), from 0 to 90 meters. The samples are classified as dolomitized mudstone and peloidal mudstone in thin section.

Reveille Range. Samples RRB-1, RRB-2, and RRB-3 consist of cloudy, finely to medium crystalline, anhedral to subhedral dolomite. Secondary fractures and pore spaces are filled with clear, more coarsely crystalline, subhedral to euhedral dolomite cement. All three samples are remarkably similar in thin section. Due to extensive replacement by dolomite, most primary sedimentary structures or textures of the original limestone are obscured.

Samples RRB-4 and RRB-5 retain some primary depositional textures and fossils. RRB-4 contains approximately 5% fine sand-sized, moderately well-sorted, subrounded grains of monocrystalline quartz and approximately 50% peloids. The peloids in sample RRB-4 consist of elliptical, fine- to medium-sand-sized, finely crystalline to microcrystalline fragments that most likely formed by the rounding of intraclasts but some may have been fecal pellets. The remainder of the sample consists of cloudy, medium crystalline, subhedral dolomite. Sample RRB-5, like RRB-4, contains approximately 35% peloids and 5% recrystallized brachiopod fragments. The remainder of the sample consists of cloudy, medium crystalline, anhedral dolomite.

Depositional and Diagenetic Environment. These observations suggest that the Lone Mountain Dolomite was deposited as a bioturbated limy mud in a low-energy-shelf lagoonal or tidal-flat environment (similar to that of the Sevy Dolomite) and has been subsequently replaced after burial by relatively magnesium-rich pore water solutions to a nearly homogenous dolomite (Figure 7). Quartz grains, fossil fragments, and possibly fecal pellets were concentrated in the quiet lagoonal, carbonate tidal-flat, and subtidal areas by storm surges and wind from nearby quartz-rich barrier bars, longshore bars, spits, and rivers. The fossil fragments and peloids may be *in situ* constituents, such as fecal and carbonate mudstone rip-ups formed in a normal marine lagoonal or shelfal carbonate environment subject to minor current and wave reworking and bioturbation.

SEVY DOLOMITE

Matti (1979), in a regional study of the Upper Silurian to Lower Devonian dolomite of east-central Nevada, delineated 8 microfacies in the Sevy Dolomite from thin-section study (see following Microfacies description). Six of those microfacies were deposited in carbonate intertidal to supratidal environments (Figure 7). The Sevy Dolomite is exposed throughout east-central Nevada and was measured and sampled in the Reveille, Pancake, and Quinn Canyon Ranges. Four samples of the Sevy Dolomite were collected in the Reveille Range from 0 to 43 meters in section RRA (Figure 19A). Eleven samples were studied of the Dolomite and Cherty Argillaceous Members of the Sevy Dolomite from the Pancake Range from 3 to 119 meters in section PRA (Figure 19A). In the Quinn Canyon Range, five samples of the Dolomite and Sandy Members of the Sevy Dolomite were collected from 18 to 355 meters in section QCA (Figure 37). The majority of the samples studied in thin section from the Sevy Dolomite are classified as dolomitized mudstone, but dolomitized wackestone and grainstone lithologies are also present, especially in the Pancake Range.

The microfacies descriptions of the Sevy Dolomite are from Matti (1979) and aid in the petrologic descriptions in the following section.

MICROFACIES 1

- Depositional fabric - Texturally massive pelletoidal dolomitized mudstone and wackestone.
- Allochems - Pelletoids, uncommon bioclasts, and quartz grains.
- Grain size - Carbonate mud and floating sand-sized clasts.
- Sorting, rounding - Poor to excellent.
- Modifications of fabric - Massive fabrics modified by bioturbation.

- Depositional environment - Suspension-deposited carbonate mud: platform lagoon and ephemeral sea-margin ponds.
- Examples from this study - RRA-1, -2, -3, and -4
  PRA-2, -5, -6, -7, and -10
  QCA-4, -5, -6, and -7

MICROFACIES 2

- Depositional fabric - Fenestrae-bearing texturally massive pelletoidal dolomitized mudstone and wackestone.
- Allochems - Pelletoids, uncommon bioclasts, and quartz grains.
- Grain size - Carbonate mud and floating sand-sized clasts.
- Sorting, rounding - Poor to excellent.
- Modifications of fabric - Disruption of fabric creates fenestral pores.
- Depositional environment - Same as Microfacies 1; subaerial exposure and dessication disrupts fabric; dolomite fills voids.
- Examples from this study - (None)

MICROFACIES 3

- Depositional fabric - Mottled dolomitized mudstone and pelletoidal bioclastic wackestone.
- Allochems - Pelletoids and bioclasts.
- Grain size - Carbonate mud and floating silt- and sand-sized clasts.
- Sorting, rounding - Poor to excellent.
- Modifications of fabric - Bioturbated and burrow-churned.
- Depositional environment - Suspension-deposited carbonate mud;

low energy; subtidal platform lagoon.

- Examples from this study - PRA-9 and -11

MICROFACIES 4

- Depositional fabric - Smoothly flat-laminated dolomitized peloidal and intraclastic packstone and grainstone.
- Allochems - Peloids and intraclasts.
- Grain size - Silt- through sand-sized clasts.
- Sorting, rounding - Moderate to good.
- Modifications of fabric - (Not applicable)
- Depositional environment - Traction-current deposited; storm-surge sheet wash on supratidal-flats, levee backslopes, etc.
- Examples from this study - PRA-8

MICROFACIES 5

- Depositional fabric - Disrupted flat-laminated dolomitized peloidal and intraclastic packstone.
- Allochems - Peloids and intraclasts.
- Grain size - Silt- through sand-sized clasts.
- Sorting, rounding - Moderate to good.
- Modifications of fabric - Disruption of fabric (fenestrae) due to dessication.
- Depositional environment - Same as Microfacies 4; subaerial exposure and dessication disrupts fabric.
- Examples from this study - (None)

MICROFACIES 6

- Depositional fabric - Fenestrae-bearing crinkly laminated dolomitized mudstone an wackestone.
- Allochems - Peloids, intraclasts, and quartz grains.
- Grain size - Carbonate mud, organic filaments, and floating silt- and sand-sized grains.
- Sorting, rounding - (Not applicable)
- Modifications of fabric - Disruption of fabric (fenestrae).
- Depositional environment - Cryptalgal laminite (crinkled algal mats); supratidal and ephemeral ponds.
- Examples from this study - PRA-3

MICROFACIES 7

- Depositional fabric - Wavy-bedded, laminated, or massive dolomitized mudstone.
- Allochems - (Not applicable)
- Grain size - Carbonate mud.
- Sorting, rounding - (Not applicable)
- Modifications of fabric - (Not applicable)
- Depositional environment - Algal marsh.
- Examples from this study - (None)

MICROFACIES 8

- Depositional fabric - Dolomitized peloidal and intraclastic packstone and grainstone.
- Allochems - Peloids and intraclasts.
- Grain size - Carbonate mud through pebble-sized grains.

- Sorting, rounding - Moderate to excellent.
- Modifications of fabric - (Not applicable)
- Depositional environment - Storm-surge sheet wash on supratidal tracts.
- Examples from this study - PRA-4

Reveille Range. Sevy Dolomite samples from the Reveille Range (RRA-1, RRA-2, RRA-3, and RRA-4) are classified as dolomitized mudstone. The samples are composed of predominantly cloudy, finely to medium crystalline, anhedral to subhedral dolomite. Secondary fractures and pore spaces are filled with clear, medium to coarsely crystalline, subhedral to euhedral dolomite cement. Peloids are present in samples RRA-1, RRA-2, and RRA-3 and range in abundance from 15 to 20 percent. Peloids are elliptical masses of cloudy, microcrystalline to finely crystalline, anhedral dolomite. Fossil fragments are rare and found only in sample RRA-1. Crinoid and unidentifiable fossil fragments constitute 5 percent of that sample and have been replaced by clear, medium crystalline, subhedral dolomite. These lithologies would likely belong to Microfacies 1 (Matti, 1979).

Pancake Range. Eleven samples of the Sevy Dolomite were collected in the Pancake Range. They are classified as dolomitized mudstone (Samples PRA-2, -3, and -5), wackestone (Samples PRA-1, -6, -7, -9, and -10), packstone (Sample PRA-8), and grainstone (PRA-4). Dolomitized mudstone consists of at least 85 percent cloudy, medium crystalline, anhedral dolomite. Quartz grains (~5 percent) and peloids

(~15 percent) are present in sample PRA-2. Monocrystalline quartz grains are silt- and fine-sand sized and elliptical peloids are composed of cloudy, microcrystalline to finely crystalline, anhedral dolomite. Sample PRA-2 and PRA-5 would be classified in Microfacies 1 (Matti, 1979).

Sample PRA-3 is a laminated dolomitized mudstone, a cryptalgal laminite composed of alternating laminae of cloudy, finely crystalline, anhedral dolomite and clear, medium crystalline, subhedral dolomite. Cryptalgal laminites consist of alternating layers of carbonate mud and algal mat layers. During shallow burial, algal mats decay and locally produce gas bubbles (Bathurst, 1975). After early diagenesis, the algal mat organics and carbonate mud layers become cloudy, anhedral, finely crystalline dolomite. Pore water fills the gas bubble voids with coarse sparry calcite that is later dolomitized forming a fenestral fabric parallel to the laminations (Figure 44). The primary depositional porosity is now filled with clear, coarsely crystalline, euhedral dolomite rhombs. Current-transported peloids in the darker algal layers are cloudy, microcrystalline to finely crystalline, anhedral dolomite. Sample PRA-3 is typical of Matti's (1979) Microfacies 6.

Samples PRA-1, PRA-6, PRA-7, PRA-9, and PRA-10 are dolomitized wackestone. Sample PRA-1, collected near the bottom of section PRA (Figure 32A), contains matrix-supported intraclasts of clear, finely crystalline, anhedral dolomite in cloudy, medium crystalline, subhedral dolomite. This sample does not fall into the microfacies of Matti (1979), because this lithology was not encountered in the sections that he studied.

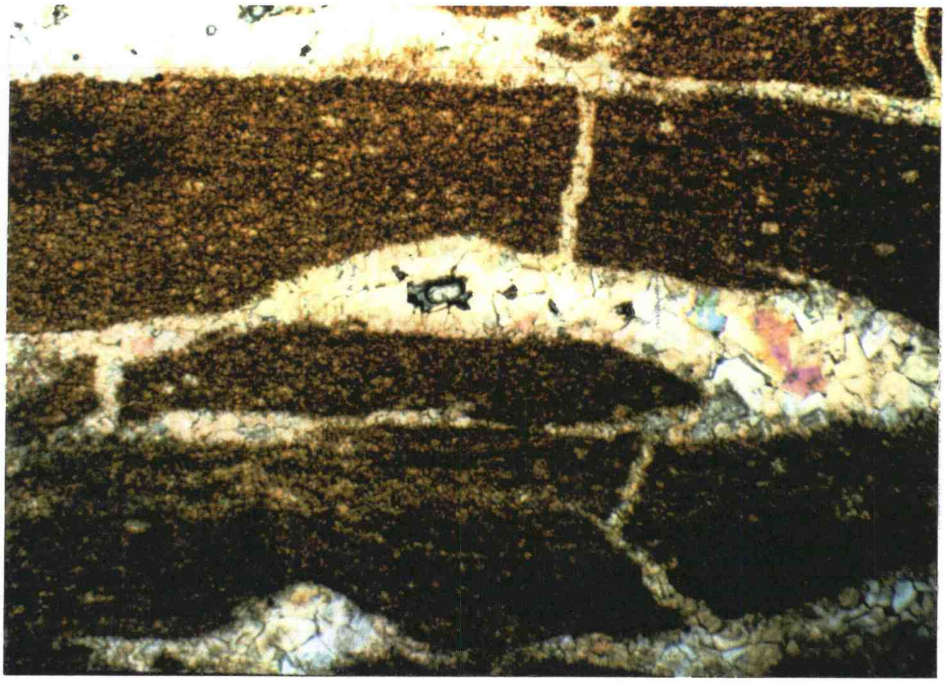


Figure 44. Fenestral fabric in cryptalgal laminite in the Sevy Dolomite, Pancake Range, Nevada (20X magnification, plane light, bottom of photograph is 6 mm for scale).

Samples PRA-6 and PRA-7 are dolomitized wackestone with abundant ghosts of *Amphipora*, a filamentous coral-like fossil that is now filled with clear, medium to coarsely crystalline, subhedral to euhedral dolomite (Figure 45). The matrix of these is cloudy, finely to medium crystalline, anhedral dolomite. Submerged thickets or meadows of *Amphipora* may have acted as a baffle, settling micrite grains out of suspension, but severe postdepositional dolomitization has obscured the true identity and growth patterns of the fossils. Sample PRA-6 and A-7 classify as Microfacies 1 (Matti, 1979).

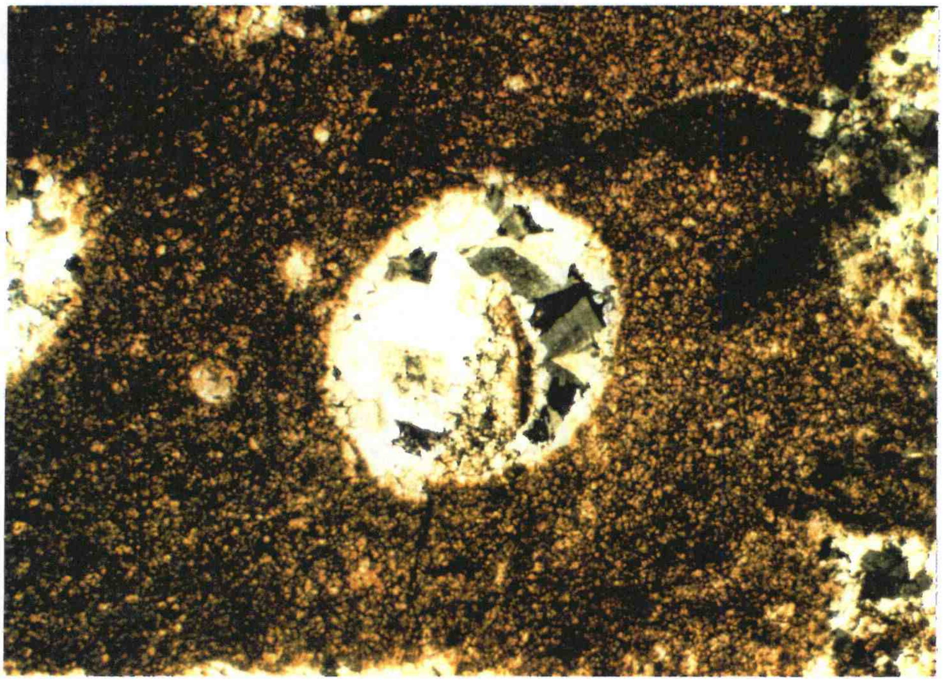


Figure 45. *Amphipora* "ghosts" in the Sevy Dolomite, Pancake Range, Nevada (20X magnification, polarized light, bottom of photograph is 6 mm for scale).

Sample PRA-8 classifies as a dolomitized peloidal packstone. The peloids are elliptical masses of cloudy, microcrystalline to finely crystalline, anhedral dolomite. Fossil fragments include brachiopods and calcispheres. Some brachiopod fragments may shelter a geopetal fabric (Figure 46). Calcisphere voids have been replaced and filled by clear, finely crystalline, anhedral dolomite. Quartz in the sample is fine-sand-sized, subangular to subrounded, and moderately to well-sorted, and forms distinct laminations. Sample PRA-8 classifies within Microfacies 4 (Matti, 1979).

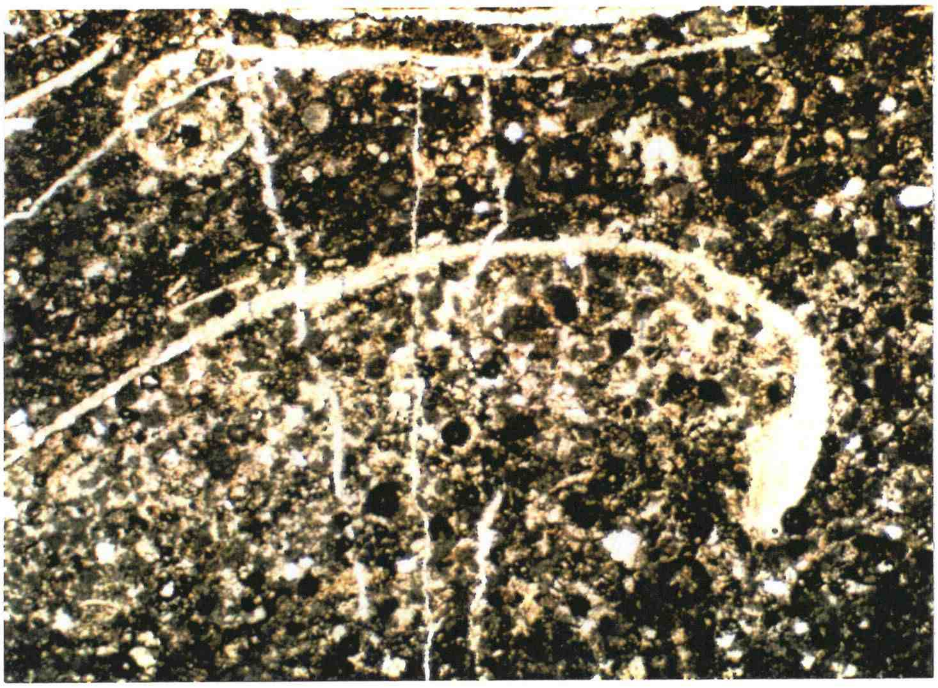


Figure 46. Brachiopod valve with possible geopetal fabric in pelletal dolomite mudstone of the Sevy Dolomite, Pancake Range, Nevada (40X magnification, plane light, bottom of photograph is 3 mm for scale).

Sample PRA-9 is a dolomitized peloidal wackestone, containing approximately 50 percent peloids. The peloids are cloudy, microcrystalline to finely crystalline, anhedral dolomite. Many are spherical to elliptical in shape. Monocrystalline quartz grains are medium-sand-sized, subangular to subrounded, and moderately to well-sorted. The matrix of the sample is cloudy, clay- or organic-rich, finely to medium crystalline, anhedral to subhedral dolomite. Lamination is not present in this sample suggesting homogenization by bioturbation. Sample PRA-9 classifies within the Sevy Dolomite Microfacies 3 of Matti (1979).

Sample PRA-10 is also a dolomitized wackestone that contains approximately 20 percent fossil fragments and approximately 15 percent sand grains. Fossil fragments are small to large crinoid ossicles and rarer brachiopod valve fragments that have been replaced by pore water to clear, finely to medium crystalline, subhedral dolomite during subsequent diagenesis. Quartz sand grains are fine to coarse sand-sized, subrounded to subangular, and moderately sorted. A lack of preserved laminations suggests extensive bioturbation. Sample PRA-10 classifies as Microfacies 1 (Matti, 1979).

Sample PRA-4 is a dolomitized peloidal grainstone containing approximately 70 percent elliptical peloids of cloudy, microcrystalline to finely crystalline, anhedral dolomite and 15 percent intraclasts of subrounded to rounded, cloudy, microcrystalline to finely crystalline, anhedral dolomite with micrite rims (Figure 47). Postdepositional clear, coarsely crystalline, euhedral dolomite rhombs fill fractures and pore space as a sparry carbonate cement. Sample PRA-4 classifies within Microfacies 8 of Matti (1979).

One sample of the Cherty Argillaceous Member of the Sevy Dolomite in the Pancake Range (PRA-11) was examined petrographically. This sample is classified as a bioturbated dolomitized wackestone and can be described as two regions of burrowed and unburrowed carbonate mud. The unburrowed part contains approximately 15 percent fossil fragments and 10 percent

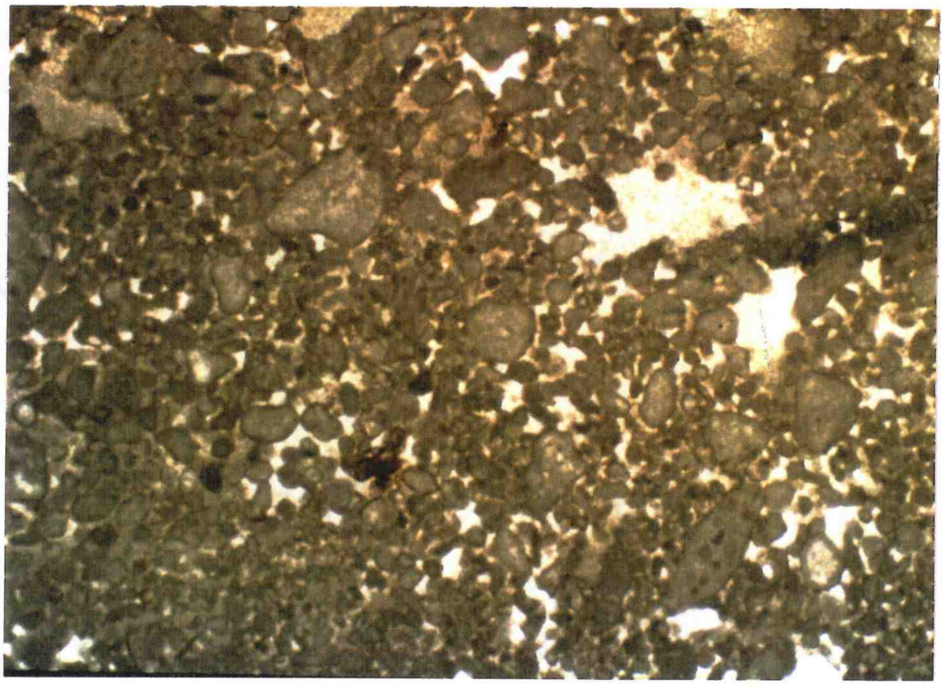


Figure 47. Micrite rims on peloids in the Sevy Dolomite, Pancake Range, Nevada (20X magnification, plane light, bottom of photograph is 6 mm for scale).

quartz sand grains. Some brachiopod fragments are recognizable, but most fossil fragments are not identifiable in thin section. The originally calcite biotic fragments have been replaced by clear, medium to coarsely crystalline, subhedral to euhedral dolomite. Monocrystalline quartz grains are fine to coarse sand-sized, subrounded to rounded, and moderately sorted. The burrowed part is cloudy, clay- or organic-rich, finely crystalline, anhedral dolomite. This sample classifies as Microfacies 3 of Matti (1979).

Quinn Canyon Range. Five samples of Sevy Dolomite in the Quinn Canyon Range were thin sectioned. Three are dolomitized mudstone (samples QCA-4, -5, and -6), one is dolomitized wackestone (sample QCA-7), and one is a quartz arenite from the Sandy Member (sample QCA-8).

The dolomitized mudstone samples are composed of cloudy, finely to medium crystalline, anhedral to subhedral dolomite (98 to 100 percent). The few brachiopod fragments have been replaced by clear, medium crystalline, anhedral to subhedral dolomite. Secondary postdepositional fractures, where present, are filled with clear, finely to coarsely crystalline, subhedral to euhedral dolomite. These samples (QCA-4, -5, and -6) would classify as Microfacies 1 (Matti, 1979).

A dolomitized wackestone (sample QCA-7) was collected at 257 meters in measured section QCA from a dark gray to black, organic-rich bed. Approximately 15 percent of the sample consists of brachiopod fragments that have been replaced by clear, medium to coarsely crystalline, subhedral to euhedral dolomite. The bioclasts are suspended in a matrix of cloudy, organic- or clay-rich, finely crystalline, anhedral dolomite. Secondary fractures are present in the dolomitized wackestone and are filled with clear, medium to coarsely crystalline, subhedral to euhedral dolomite cement. This sample would also classify as Microfacies 1 of Matti (1979).

The Sandy Member of the Sevy Dolomite constitutes the upper 13 meters of measured section QCA. Sample QCA-8, collected within this interval, classifies in thin section as a dolomite-cemented quartz arenite. Monocrystalline quartz grains constitute about 85 percent of the sample and are fine to medium sand-sized, subrounded to well-rounded, and moderately to well-sorted (Figure 48). The sample is compositionally supermature owing to the abundance of quartz. It is texturally mature (well-rounded and moderately sorted). These maturity ratings suggest a low-lying quartz source area (recycled) and extensive winnowing and reworking by currents (Pettijohn *et al.*, 1987). The interstices are filled with approximately 15 percent cloudy, finely crystalline, anhedral to subhedral dolomite cement. No sedimentary structures are visible in thin section, but microcross-stratification (possibly prograding ripple marks) were identified in the field.

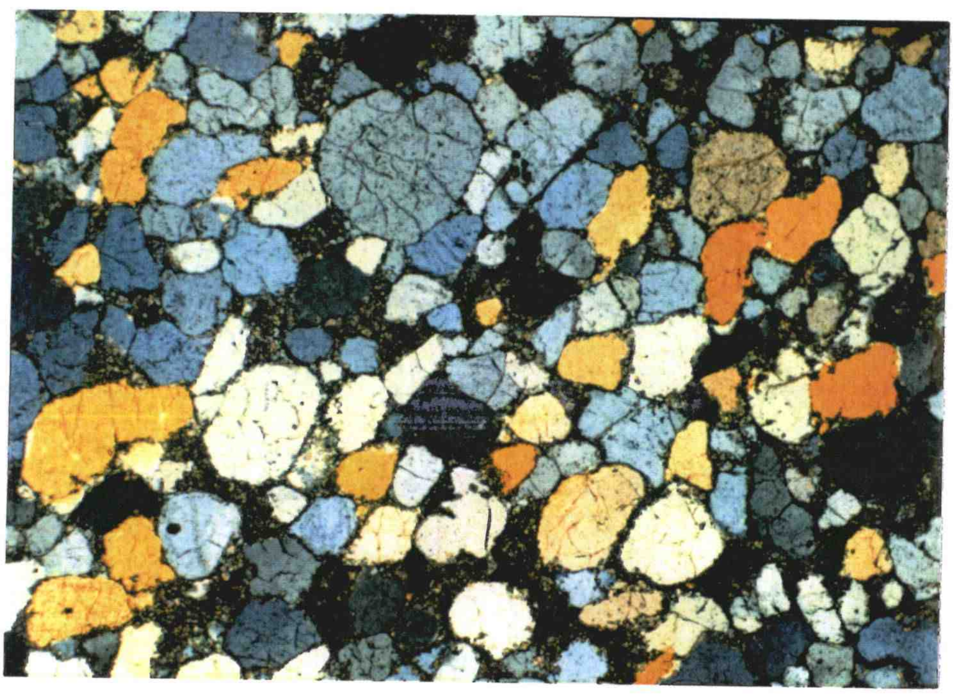


Figure 48. Photomicrograph of sandstone from the Sandy Member of the Sevy Dolomite, Quinn Canyon Range, Nevada (40X magnification, polarized light, bottom of photograph is 3 mm for scale).

Depositional and Diagenetic Environment. The petrographic evidence suggests that the Sevy Dolomite was deposited as structureless to laminated calcite mud in a low energy lagoonal or algal tidal-flat environment and has been subsequently replaced after burial by nearly homogenous dolomite (Figure 7). Quartz grains and shallow marine fossil fragments (brachiopods and crinoids ossicles) were transported from adjacent quartz-rich barrier bars and carbonate subtidal shelfal environments into the depositional environment by storm wave surges and, in the case of silt-sized quartz clasts, by wind. However, some fragments (*Amphipora*) may be *in situ* constituents in a partly-restricted, lagoonal environment. Carbonate muds were pelletized by mud-ingesting organisms, such as shrimp and worms. Parts of the formation show evidence of storm-surge deposition in the carbonate intertidal to supratidal environment (crinkled algal mats with fenestral structures). Similar dolomitized carbonate pelletized muds form in shallow subtidal to intertidal platforms of the Bahamas (Bathurst, 1975). Algal mats on tidal channel levees and intertidal to supratidal-flats occur with protodolomite on the Bahamas platform adjacent to Andros Island (Bathurst, 1975). In addition, parts of the formation were deposited in a well-oxygenated, subtidal lagoonal and shelfal carbonate platform environment and show evidence of bioturbation. The moderately sorted, well-rounded quartz grains of the upper Sevy Dolomite may have been deposited in or adjacent to a high-energy beach, barrier bar, longshore bar, and tidal-channel environment. In the field, microcross-stratification is present (prograding ripple marks).

SIMONSON DOLOMITE

The Simonson Dolomite is a shallow-marine deposit and in the thesis area is exposed only in the Pancake and Quinn Canyon Ranges (Figure 32 and 37). The Simonson Dolomite typically consists of five members, but only two are exposed in the Quinn Canyon Range and two were measured in the Pancake Range (Figure 26). Those two members are the Coarse Crystalline Member and the Lower Alternating Member. Five samples of the Coarse Crystalline Member were collected from the Pancake Range; none from the Quinn Canyon Range. The Coarse Crystalline Member lies stratigraphically between the Sandy Member of the Sevy Dolomite and the Lower Alternating Member of the Simonson Dolomite.

In the Pancake Range, the Coarse Crystalline Member consists of alternating beds of sandy dolomite and quartz arenite (Figure 32). Quartz arenite layers are characterized by medium-sand-sized, sub- to well-rounded, well-sorted, supermature, monocrystalline quartz grains. Samples PRC-2 and PRB-1 exhibit extensive quartz overgrowths that create an interlocking mosaic of quartz grains which most likely were originally well-rounded before the postdepositional quartz overgrowths visually obliterated the primary rounded shape of the grains. No porosity was observed in thin section.

Pancake Range. Sandy and sand-free dolomitized mudstone of the Coarse Crystalline Member was observed in thin section (samples PRC-1, -3, and PRB-2). Sand-rich mudstone contains up to 40 percent monocrystalline quartz grains. The quartz grains range from fine to coarse sand. Fine sand is angular, whereas medium to coarse sand is well rounded. The sand is moderately sorted and compositionally supermature. The bimodal distribution, due to high-energy wave and current conditions, was probably derived from physical breakage of the medium to coarse sand-sized quartz grains into fine sand-sized, angular fragments. The other constituent of the sandy samples and the principal constituent of the sand-free sample is cloudy, finely to coarsely crystalline, anhedral to euhedral dolomite. In addition, dolomite crystals are commonly zoned (Figure 49).

Figure 49. Photomicrograph of "cloudy" and zoned dolomite crystals from the Coarse Crystalline Member of the Simonson Dolomite, Pancake Range, Nevada (40X magnification, polarized light, bottom of photograph is 3 mm for scale).

A sample of the sand-free dolomitized mudstone contains approximately 5 percent radiating fibrous pore-filling or replacement chalcedony and about 10 percent porosity.

Six samples of the Lower Alternating Member of the Simonson Dolomite were collected from the Pancake and Quinn Canyon Ranges (samples PRB-3, -4, -5, -6 from the former and samples QCA-9, -10 from the latter). The samples are classified as dolomitized mudstone, but several interesting features occur on each sample. Sample PRB-3 was collected from the lower brown region of a Simonson couplet. Abundant finely disseminated "petrofilleous" organic matter (fetid odor when broken) discolors the dolomite and gives it a dark cloudy appearance. The sample is composed of cloudy, finely crystalline, subhedral to euhedral dolomite with a homogeneous (massive) texture. Although no bioclasts or burrows are obvious, intense bioturbation is a possible explanation for the massive or structureless texture of the sample. The preservation of abundant organic matter in the sample may rule out bioturbation, however, and suggests a more restricted depositional environment.

Sample PRB-4, however, shows evidence of bioturbation. Mottling of this dolomitized mudstone in hand specimen is caused by a textural difference in the dolomite revealed in thin section. Areas that may have been burrowed are less cloudy and appear to contain more anhedral crystals of dolomite as compared to the unburrowed regions that contain cloudy, finely crystalline, anhedral to euhedral dolomite.

A flat-pebble conglomerate (sample PRB-5) from the Lower Alternating Member of the Simonson Dolomite consists of eroded clasts of the underlying light-gray bed of a brown to light-gray couplet. In thin section, the sample is classified as a dolomitized intraclast mudstone. Approximately 20 percent of the sample is cloudy, finely crystalline, anhedral dolomite in angular clasts that show some evidence of rounding in hand specimen. The intraclasts are supported by a matrix of clear to cloudy, finely to medium crystalline, anhedral to euhedral dolomite rhombs. This sample may represent a storm-surge deposit of tidal-flat mud ripup clasts or erosion of a carbonate tidal-flat or sloughing of a channel wall followed by deposition in a meandering tidal channel.

A cryptalgal laminated dolomite (sample PRB-6) classifies as a dolomitized mudstone. In thin section, two distinct microtextures are evident (Figure 50). Approximately 40 percent of the sample is laminae of cloudy, finely crystalline, anhedral dolomite. These laminae alternate with laminae of clear, finely to medium crystalline, subhedral to euhedral dolomite (approximately 60 percent of the sample). The cloudy dolomite laminae were originally crinkled algal mats. In thin section, the crinkled form can be mistaken for filled fractures. Clear dolomite laminae are layers of carbonate mud that were washed over the intertidal to supratidal algal mats by storm waves or tractive currents.

Quinn Canyon Range. Two samples of the Lower Alternating Member of the Simonson Dolomite were collected from the Quinn Canyon Range (Figure 37). A black to dark gray, medium crystalline, laminated dolomite (sample QCA-9) from the dark-gray bed of a dark-gray to light-gray couplet classifies as dolomitized mudstone.

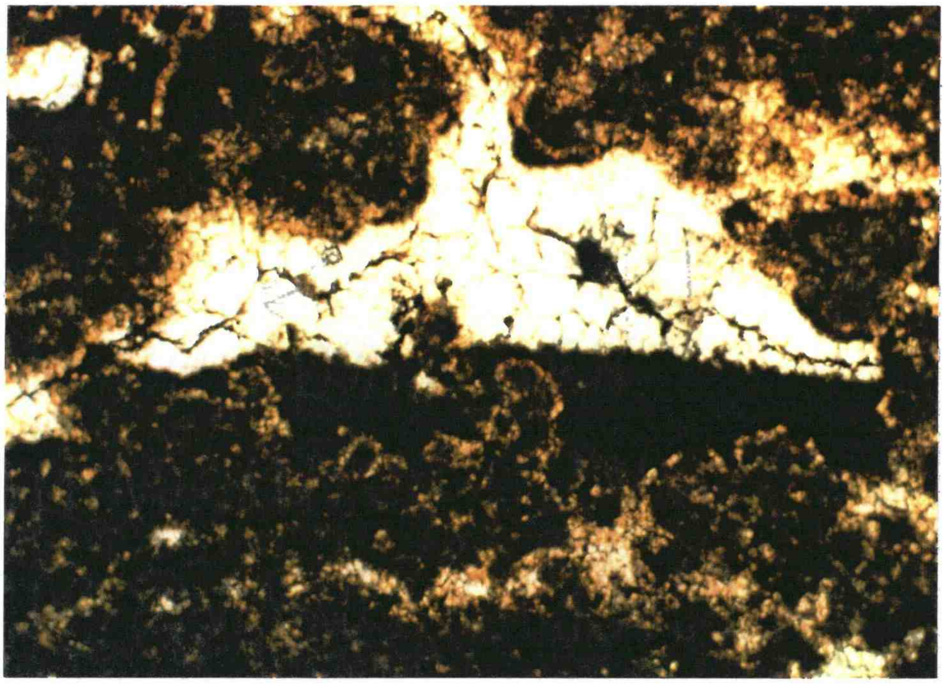


Figure 50. Cryptalgal laminite from the Lower Alternating Member of the Simonson Dolomite, Pancake Range, Nevada (20X magnification, polarized light, bottom of photograph is 6 mm for scale).

It is composed of cloudy or opaque, finely to medium crystalline, anhedral dolomite rhombs. Approximately 5 percent of the sample consists of replaced outlines ("ghosts") of fossil fragments. Original calcite or aragonite biotics were dissolved by pore water and clear, medium-crystalline, subhedral dolomite filled in the enlarged megapores. In addition, approximately 3 percent of the sample is fine to medium sand-sized, rounded, grains of quartz. The sample contains *in situ* breccia, but there is little evidence for displacement of the breccia clasts. Fractures between the breccia fragments are filled with clear, medium crystalline, subhedral dolomite cement.

A second sample of dolomitized mudstone (QCA-10) contains no bioclasts or quartz sand grains, however. The matrix of this sample is cloudy, finely to medium crystalline, anhedral to subhedral dolomite. Secondary fractures are filled with clear, finely to coarsely crystalline, subhedral to euhedral dolomite cement. The laminated texture of the sample is an indication that bioturbation was not prevalent during deposition of this upper part of a Simonson couplet.

Depositional and Diagenetic Environment. The petrographic evidence suggests that the Simonson Dolomite was formed as structureless to laminated calcite mud in a low-energy lagoonal or peritidal-flat environment and has been subsequently replaced by nearly homogenous dolomite (Figure 13). Detrital sand-sized quartz grains and fossil fragments were probably introduced into the depositional environment by storm waves and tidal currents and by wind for the silt and fine-sand quartz grains. However, the fossil fragments may be *in situ* constituents in a semirestricted lagoonal environment. Parts of the formation show evidence of deposition in the carbonate peri-intertidal to supratidal environment (crinkled algal mats and storm-surge deposits).

The dark-gray grading to light-gray dolomite couplets are regressive-prone carbonate cycles of shallow subtidal facies overlain by tidal-flat facies; a result of eustatic Milankovitch cycles (Schwarzacher, 1993). During the initial rise in sea level, normal marine water is introduced into a shallow lagoonal or broad peritidal-flat environment. This pulse of normal marine water manifests itself by initial deposition of shell-bearing organic-rich carbonate mud (Elrick, 1995). As the carbonate depositional environment tranforms from shallow subtidal to tidal-flat, the result is a couplet of dark-gray dolomite grading to laminated light-gray dolomite. The cycle repeats many times in the deposition of the Lower Alternating Member of the Simonson Dolomite (for further discussion, see Simonson Dolomite).

SADLER RANCH FORMATION

The Sadler Ranch Formation is a deeper normal-marine carbonate-platform deposit than the Sevy and Simonson tidal-flat and lagoonal dolomites. It is exposed only in the westernmost range of the studied area, the Reveille Range. Four samples of the Sadler Ranch Formation (samples RRA-5, -6, -7, and -8) were collected from section RRA (Figure 19A), at 48 to 73 meters. The samples are classified in thin section as dolomitized crinoidal wackestone and dolomitized mudstone.

Reveille Range. In the dolomitized crinoidal wackestone, biotic fragments constitute 17 to 60 percent of the rock. Most are 2-hole crinoid ossicles, but there also are brachiopod and unidentifiable fragments (Figure 51). Calcite and aragonite biotic fragments have been dissolved by pore water, and the resulting voids have filled with clear, medium crystalline, subhedral to euhedral dolomite rhombs. Subrounded to subangular, silt to fine sand-sized, monocrystalline quartz grains are also present in these samples from

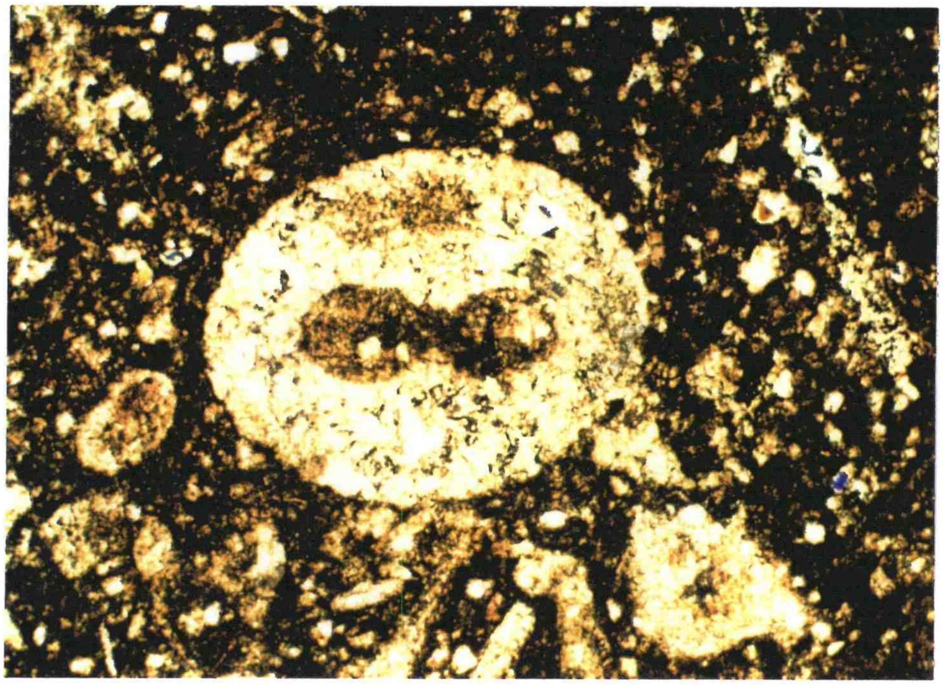


Figure 51. Two-hole crinoid ossicles in dolomitized dark micrite from the Devonian Sadler Ranch Formation, Reveille Range, Nevada (40X magnification, polarized light, bottom of photograph is 3 mm for scale).

the lower part of the formation (48 to 59 meters). Matrix and cement composes 40 to 83 percent of the rock. The cement is generally cloudy, microcrystalline to medium crystalline, anhedral dolomite. Finely disseminated opaque clay minerals and organic matter gives the finely crystalline dolomite a cloudy appearance. Secondary fractures, where present, are filled with clear, finely to coarsely crystalline, subhedral dolomite.

A sample of the dolomitized mudstone is markedly different from the dolomitized crinoidal wackestone samples. No fossil fragments or quartz clasts are present. The rock is almost entirely cloudy, microcrystalline to finely crystalline, anhedral dolomite. Fractures constitute approximately 10 percent of the sample and are filled with clear, finely crystalline, sparry anhedral to subhedral dolomite cement.

Depositional and Diagenetic Environment. Petrology suggests two possible origins for the Sadler Ranch Formation. Biotic fragments in matrix support and quartz grains (samples RRA-5, -6, and -7) indicate rapid deposition of outer shelf crinoidal mud by mass-gravity flow, allodapic deposit of periplatform mud, and homogenization of fossiliferous outer platform muds by bioturbation.

Stratigraphic evidence in the Reveille Range suggests that the Sadler Ranch Formation was deposited at the carbonate shelf edge and was susceptible to downslope movements. Conglomeratic beds one to two meters thick (debris-flow deposits) in the Sadler Ranch Formation contain subrounded to subangular matrix-supported clasts of dolomite, an indication that mass-wasting processes in addition to bioturbation on the shelf influenced deposition. The Sadler Ranch Formation presumably was deposited near the carbonate shelf edge at depths shallow enough to be affected by eustatic events. Eustatic changes of sea level created conditions conducive for early-replacement dolomitization, common in early Paleozoic strata in east-central Nevada (for further discussion, see section titled Dolomite).

DENAY LIMESTONE

The Denay Limestone is a deep-marine, outer-shelf-basin deposit. It is exposed only in the westernmost range of the study area the Reveille Range (Figure 26). Eight samples of Denay Limestone were collected from section RRA (Figure 19) from 77 to 211 meters. The Denay Limestone generally consists of mudstone, but beds of packstone and grainstone are also present.

Reveille Range. The lower Denay Limestone (samples RRA-9 and -10) consists of silty micrite. Laminations preserved in the cloudy, microcrystalline, anhedral calcite contains 3 to 7 percent angular silt-sized quartz grains (Figure 52). Biotic fragments, consisting of calcispheres and possibly conodonts or tentaculites, and evidence of bioturbation are rare.

Fossil clasts are abundant (samples RRA-12, -13, -14, and -15) in the upper part of the formation (for a description of formation members, see section titled Denay Limestone) and laminations are common to these four samples. RRA-12 classifies as a peloidal mudstone. Round, elliptical, silt-sized peloids of cloudy or nearly opaque microcrystalline, anhedral calcite are preserved in distinct layers. Detrital silt-sized, angular monocrystalline quartz grains and recrystallized calcispheres are present in minor amounts. The principal constituent is cloudy, microcrystalline, anhedral calcite crystals (80 percent).

A packstone (sample RRA-13) was collected from 173 meters in section RRA. The sample classifies as a brachiopod-bearing peloid-rich packstone, because of the grain-supported texture of the sample.

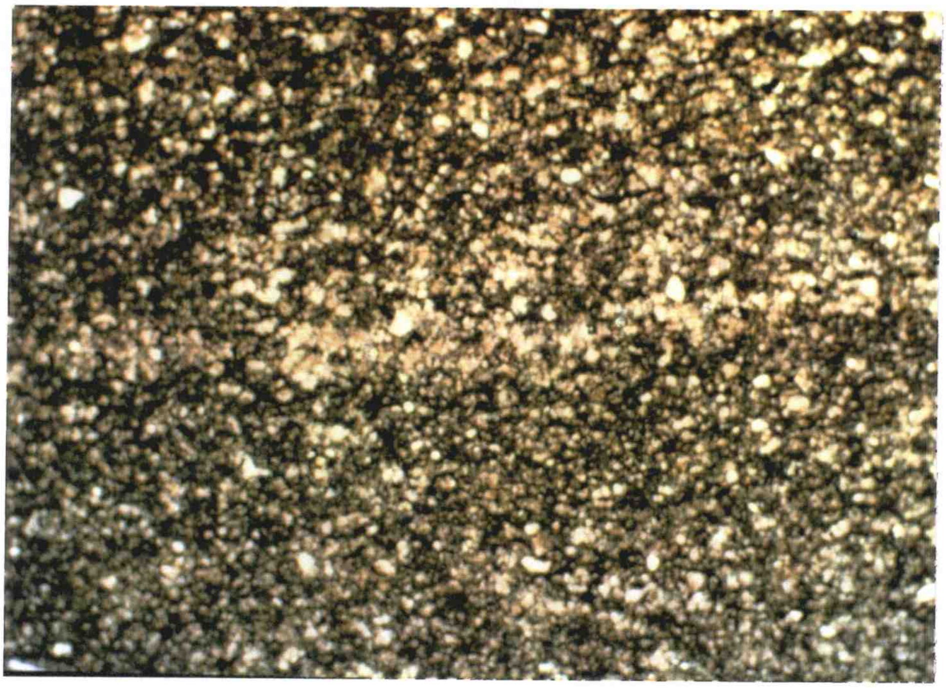


Figure 52. Photomicrograph of laminated Denay Limestone, Reveille Range, Nevada (40X magnification, polarized light, bottom of photograph is 3 mm for scale).

Biotic fragments (brachiopods, ostracods, calcispheres, conodonts, and possibly gastropods) constitute 25 percent of the sample. Some original shell microstructure is preserved, but most biotic shell fragments have been dissolved by pore water and the remaining voids filled in by clear, microcrystalline to finely crystalline, anhedral to subhedral calcite cement (Figure 53). Sixty percent of the sample is peloids, cloudy, microcrystalline to finely crystalline, anhedral calcite in an elliptical form. Some squashed, deformed peloids show evidence of compaction.

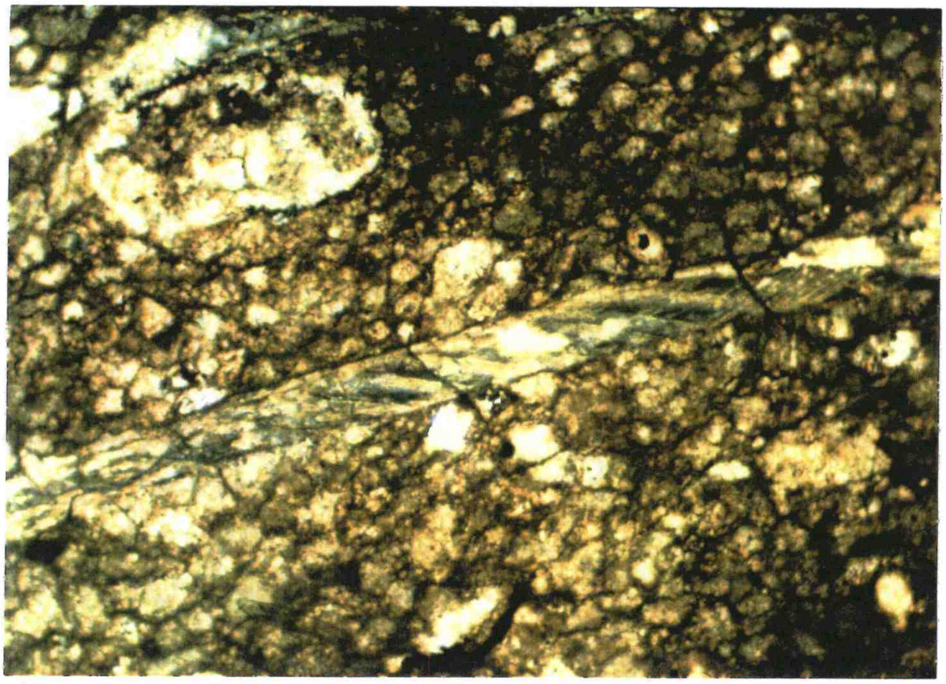


Figure 53. Photomicrograph of peloids and brachiopod shell fragments in the Denay Limestone, Reveille Range, Nevada (100X magnification, polarized light, bottom of photograph is 1.2 mm for scale).

A carbonate mudstone (sample RRA-14) was collected from 179 meters. The principal constituent is cloudy, microcrystalline, laminated micrite. Secondary fractures in the sample are filled with clear, finely to medium crystalline, anhedral to euhedral calcite crystals. This sample was probably not an allodapic flow owing to a lack of silt-sized quartz grains and bioclastic fragments. The only fossil evidence is sparry calcite pore-filled calcispheres. Deposition and preservation of the calcispheres is an indication of basinal quiet-water deposition (Bathurst, 1975).

A bioclastic grainstone (sample RRA-15) was collected from 203 meters in section RRA in the Reveille Range. Approximately 50 percent of the sample is bioclastic fragments of solitary coral, bryozoans, crinoid ossicles, and brachiopod shells. Most fragments have been replaced by chalcedony. Approximately 30 percent of the sample is peloids, consisting of cloudy, microcrystalline, anhedral micrite. Intraclasts and grapestone comprise approximately 15 percent of the sample (Figure 54).

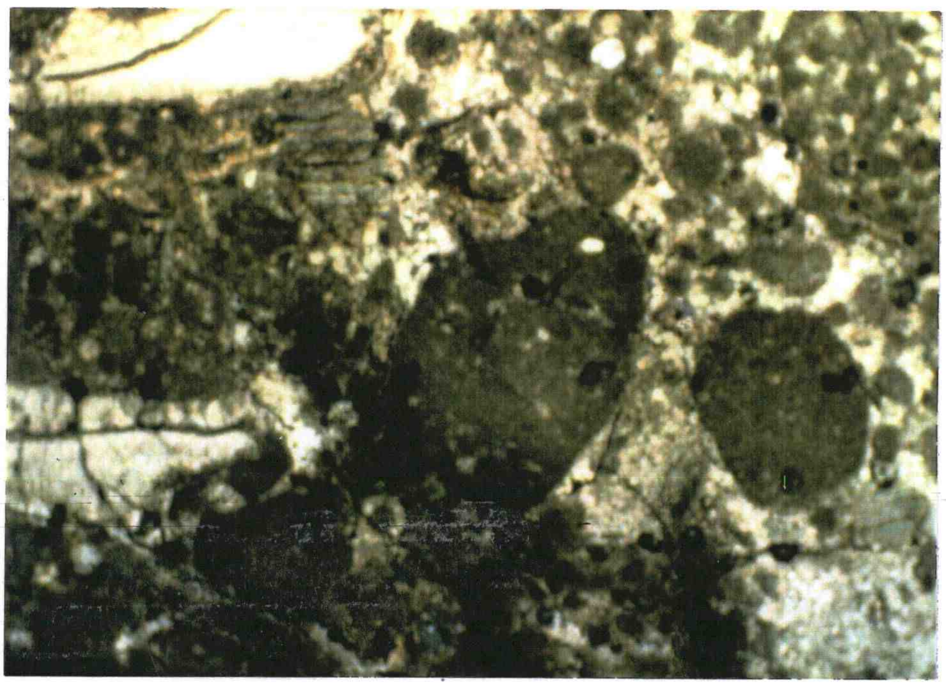


Figure 54. Photomicrograph of intraclasts and grapestone in the Devonian Denay Limestone, Reveille Range, Nevada (40X magnification, plane light, bottom of photograph is 3 mm for scale).

Grapestone fragments show the presence of calcite-cemented peloids within the clast. Only approximately 5 percent of the sample is orthochem material as cement and fracture fill. Cement and fracture fill consist of cloudy to clear, microcrystalline to finely crystalline, anhedral sparry calcite. This sample was most likely deposited in a shallower, higher-energy carbonate-platform environment than the previous sample.

Typical Denay Limestone deposits exhibit a shallowing upward sequence at the top of the lower member. A dolomitized mudstone (sample RRA-16) was collected from 211 meters in the Reveille Range section. The sample consists of cloudy, finely crystalline, anhedral to subhedral dolomite. Approximately 5 percent of the sample is silt and fine-sand sized, angular to rounded, quartz grains dispersed in the dolomite matrix. The homogenized texture of the sample may have been derived from bioturbation. Dolomite composition indicates shallow-water deposition to allow subsequent seawater and freshwater mixing reflux dolomitization associated with the subaerial landmass.

Depositional Environment. The Denay Limestone was regionally deposited on the carbonate slope and in an outer-shelf basin (Figure 12) as allodapic flows and periplatform oozes (Trojan, 1978; Hoffman, 1990). Most samples indicate that the low energy carbonate slope and anoxic outer-shelf basin may have been frequently oxygen-starved and lacking in carbonate and clastic detritus, as evidenced by the common occurrence of dark-gray, organic-rich, hemipelagic carbonate mudstone, such as in samples RRA-9, RRA-10, RRA-12, and

RRA-14. Some of the Denay Limestone was deposited by allodapic flows, and if allodapic flows behave similarly to turbidite flows, the above mentioned samples may correspond to Bouma "E" deposits. Bouma "E" deposits consist of distal turbidite mud and hemipelagic mud. Upper parts of the lower member, however, indicate higher energy storm wave shelfal environments. Grainstone and packstone deposits are identified in the Denay Limestone. Samples RRA-13 and RRA-15 characterize these outer platform deposits. Fragments of normal marine animals (brachiopods, bryozoans, corals, ostracods, and gastropods) are common. In addition, peloids, intraclasts, and grapestone fragments are abundant. These fragments show episodes of storm-wave rounding and fragmentation prior to or during redeposition. Finally, the Lower Member of the Denay Limestone contains a dolomite cap that characterizes the formation. Sample RRA-16 is a dolomitized mudstone that seems similar to the Sevy Dolomite and Lone Mountain Dolomite in thin section, an indication that similar shallow water platform depositional environments probably existed for each formation (and for the dolomite cap to the Lower Member of the Denay Limestone).

PRECAMBRIAN AND PALEOZOIC EVOLUTION

Early Paleozoic. After a successful rift from Antarctica and Australia at approximately 750 Ma (Sears and Price, 1978; Bell and Jefferson, 1987; Moores, 1991), western North America consisted of a passive margin characterized by deposition of a miogeoclinal wedge of clastic and carbonate strata (Palmer, 1960) throughout the early Paleozoic (Figure 55). However, deposition of this miogeoclinal wedge on the slowly subsiding carbonate platform ceased in the Silurian with the onset of deposition of and influence by the Shoo Fly Complex.

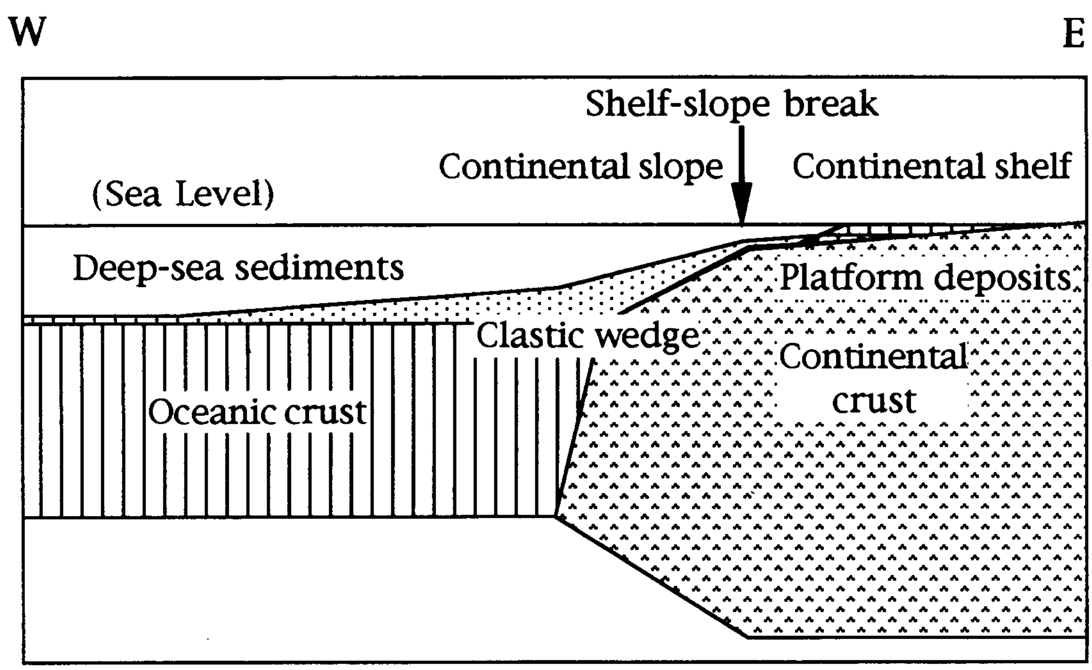


Figure 55. Generalized cross section across the miogeoclinal wedge (passive margin deposition) of western North America in the early Paleozoic.

The Shoo Fly Complex of northern California is characterized by phyllite, quartzose sandstone, and chert with minor amounts of volcaniclastic deposits. It also contains tectonic blocks of shallow-water limestone, that contain fossil brachiopods, conodonts, and stromatolites with North American affinities (Hannah and Moores, 1986). The quartz sandstone, probably of turbidite origin, contains 2 billion year old zircons from a plutonic-metamorphic source, presumably from the North American craton (Bond and DeVay, 1980). The volcanic and volcaniclastic rocks in the Shoo Fly Complex originated in the Klamath-Sierran island arc, the remnants of that now lie in northern and eastern California. The importance of the Shoo Fly Complex is that it records the transition from deposition in a passive margin to deposition at an active convergent margin. This transition is marked in the Shoo Fly Complex by an eastern melange consisting of greenstone, gabbro, limestone, and sandstone, characteristic of subduction zones (Hannah and Moores, 1986). Subduction continued, and in Late Devonian time, the Antler Orogeny began to deform the western North American margin.

Middle Paleozoic Antler Orogeny. Many plate-tectonic models have been presented to explain the Antler Orogeny. The key element of this orogeny is the Roberts Mountain Allochthon, that consists of a western assemblage of obducted rocks, including bedded chert, argillite, quartzose turbidites, and pillowed greenstone of either tholeiitic, oceanic, or calc-alkalic island-arc origin (Speed and Sleep, 1982).

Johnson and Pendergast (1981) provided a hypothesis for the Antler Orogeny, a modification of Poole's model (1974), that involved several constraints on the emplacement of the Roberts Mountains Allochthon (Figure 56). These constraints include an autochthonous shelf sequence, allochthonous outer-shelf and oceanic sequence, a lack of volcanics and volcaniclastics within the autochthon, and intricate thrusting within the allochthon. Johnson and Pendergast (1981) stated that "none of the primary constraints listed above necessitates either crustal collision or back-arc thrusting, and there is no evidence of flake tectonics."

The active Klamath-Sierran volcanic arc was too distant to supply volcanics or volcaniclastics to the Roberts Mountains Allochthon of Late Devonian through Mississippian age (Ketner, 1977). The model of Johnson and Pendergast (1981) favored the incipient subduction model of Dickinson (1977). This model hypothesized a decollement at or near the sediment-oceanic crust interface to explain the lack of ophiolites in the Roberts Mountains Allochthon.

The Antler Orogeny profoundly changed the depotectonics of east-central Nevada from the middle to late Paleozoic. Initially, east-central Nevada experienced an epeirogenic prelude, referred to by Johnson (1971) as the "Hogue effect." The Pilot Basin formed directly behind the foreland bulge in east-central Nevada and shifted the shelf edge (and limestone-dolomite transition front) eastward into easternmost Nevada and western Utah (Figure 57). The Pilot Basin received deep-marine clastic sediment from the Antler highlands to the west and allodapic limestone from the carbonate platform and

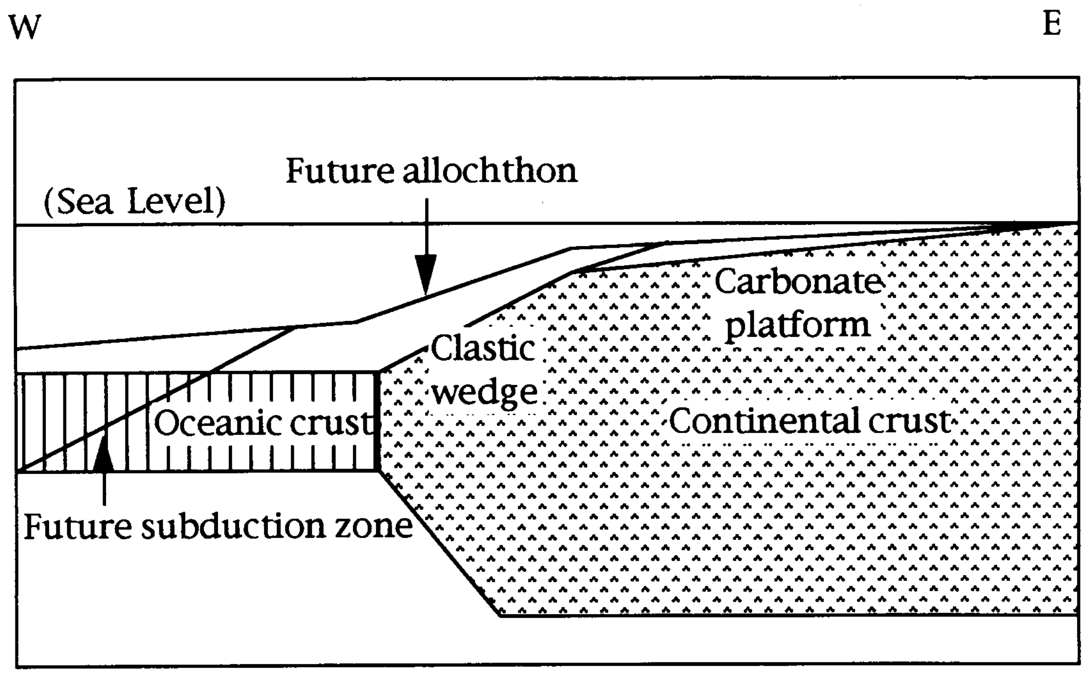


Figure 56A. Generalized cross section of passive western North American margin.

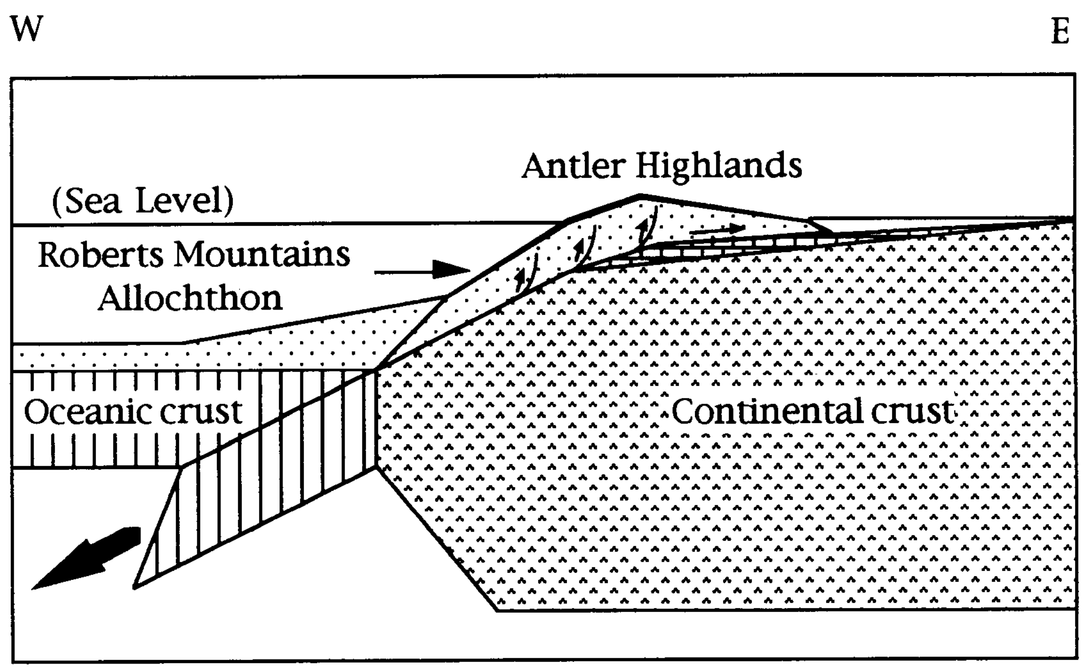


Figure 56B. Generalized cross section through Antler Orogenic Belt with Roberts Mountains Allochthon and Antler Highlands (after Johnson and Pendergast, 1981).

shelf edge to the east (Goebel, 1991). During the remainder of the Paleozoic, a mixture of carbonate and clastic strata accumulated in east-central Nevada. However, few or no deposits or post-Antler structures of late Paleozoic age lie within the present study area (Kleinhampl and Ziony, 1985).

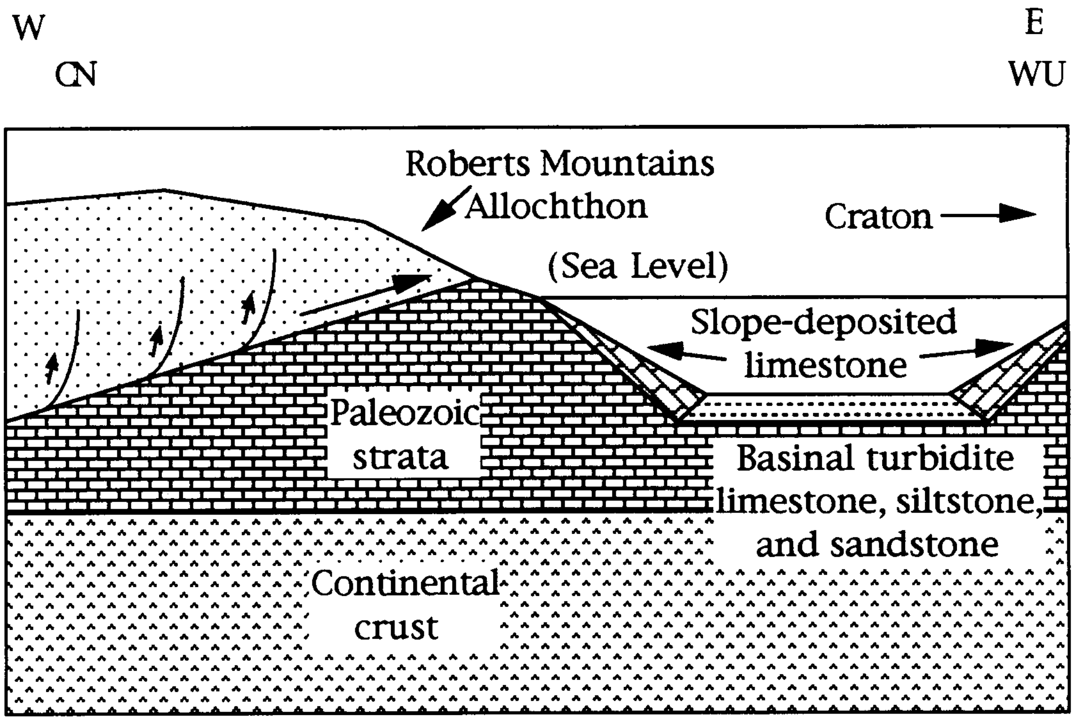


Figure 57. Late Devonian and early Mississippian Pilot Basin in the Foreland of the Roberts Mountains Allochthon.

MESOZOIC EVOLUTION OF EAST-CENTRAL NEVADA

The Mesozoic evolution of east-central Nevada, in many cases, has been obscured by extensional tectonics in the middle Tertiary (Fouch *et al.*, 1991). The Mesozoic is dominated by east-verging thrust faults and folds. Until recently (Bartley and Gleason, 1990; Carpenter *et al.*, 1993), east-central Nevada was considered the hinterland to the Sevier deformation belt of western Utah and southeastern Nevada (Figure 58).

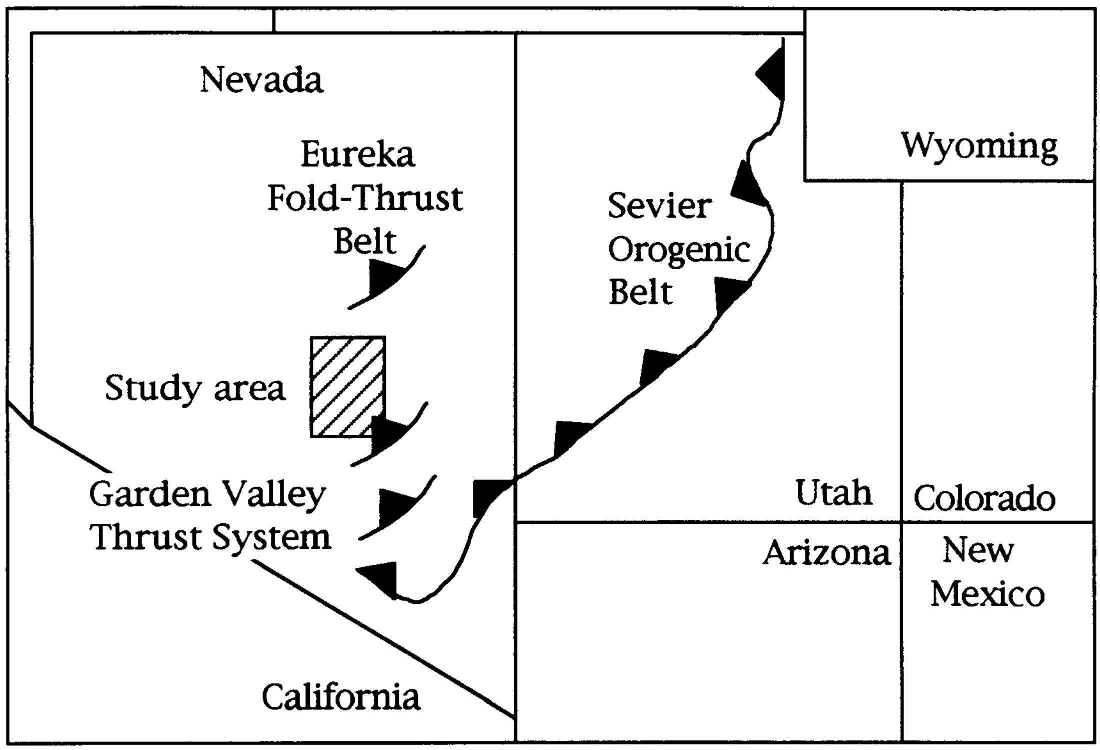


Figure 58. Outline map of western states showing position of Sevier Orogenic Belt.

Recent work in eastern Nye County, Lincoln County, and White Pine County, however, has identified and characterized a Mesozoic-age deformation, the Eureka fold and thrust belt and thrusts in the Garden Valley area (Speed *et al.*, 1988; Gleason, 1988; Camilleri, 1989; Martin, 1987; Armstrong and Bartley, 1993; Murray, 1985; Carpenter *et al.*, 1993). After Tertiary extension is restored, Bartley and Gleason (1990) and Carpenter *et al.* (1993) consider the Eureka fold and thrust belt and thrusts in the Garden Valley area to be part of the Sevier foreland thrust system (Heller *et al.*, 1988), not a deformational event in the Sevier hinterland, because of the proximity and similar structural styles and ages.

Thrusting in east-central Nevada is characterized by west-dipping thrust faulting and east-vergent folds (Roeder, 1989). Thrusts are generally assumed to sole in the Lower Cambrian section (Pioche Shale?) and are thought to ramp through most of the Paleozoic section and to flatten in the Mississippian section (Chainman Shale?). Carpenter *et al.* (1993) provided a detailed description of hanging-wall and footwall geometries of thrusting in the Eureka Fold and Thrust Belt. Thrust faults of the Eureka belt may project southward into Railroad Valley (Carpenter *et al.*, 1993), telescoping correlative Devonian strata from the Pancake Range to the Quinn Canyon Range.

Thrust faults in the Garden Valley system crop out in the Quinn Canyon Range, complicating Devonian correlations within the range. The westernmost thrust in the Garden Valley system is the Sawmill Thrust. It is exposed in the Quinn Canyon Range and places Upper Cambrian and Ordovician dolomite and limestone on Devonian carbonate strata, an offset of approximately 3000 meters. Bartley and Gleason (1990) conservatively estimated at least 8 kilometers of displacement. The Rimrock Thrust is structurally lower than the Sawmill Thrust and emplaces Ordovician middle Pogonip strata over Devonian Sevy Dolomite, a stratigraphic offset of approximately 1500 meters. The Rimrock Thrust, and the correlative Freiburg Thrust (Martin, 1987) to the south in the Worthington Mountains, are estimated to have displacements of 2 to 4 kilometers.

Two thrust faults lie structurally below the Rimrock-Freiburg Thrust: Thrust III (located in the southern Grant Range) of Cebull (1970), and the Golden Gate Thrust (located in the Golden Gate Range) of Armstrong and Bartley (1993). These thrusts are not continuous and are apparently unrelated, because the Golden Gate Thrust dies out into an anticline-syncline pair in the northern part of the range. Cebull (1970) estimated 2.4 kilometers of displacement on Thrust III. Farther south in the Timpahute Mountains and near Mt. Irish, Tschanz and Pampeyan (1970) described possible thrust faults of a similar age, style, and offset; but not enough information exists to correlate the "Pahranagat Fold and Thrust Belt" with thrusts in the Garden Valley area.

CENOZOIC EVOLUTION OF EAST-CENTRAL NEVADA

As with the Paleozoic and Mesozoic structures in the region, middle Tertiary extension has obscured the early Cenozoic tectonic evolution of east-central Nevada. Early Cenozoic depositional and tectonic history is based upon studies of the Late Cretaceous-Oligocene Sheep Pass Formation (Fouch *et al.*, 1991). Field relations and interpretation of the Sheep Pass Formation depositional environment and provenance indicate that topographic and structural relief were factors controlling the depocenters (Schmitt and Vandervoort, 1987). These depocenters were grabens with lacustrine deposits bounded by normal faults (Fouch *et al.*, 1991).

Early Cenozoic subduction is postulated to have occurred at a shallow angle and fast convergence rate (Eaton, 1979). By approximately 40 Ma, the angle had steepened, and extension began in the eastern Basin and Range. According to Kleinhampl and Ziony (1985), extension in central Nevada began approximately 21 to 16 Ma (early to middle Miocene), but regional extension in the Basin and Range province to the north is older. North of the study area, near Ely, Nevada, Gans *et al.* (1985) documented greater than 100 percent extension. Extension locally may be as high as 200 percent (Fryxell, 1988) in the Grant Range, a northern extension of the Quinn Canyon Range. This large amount of extension is accommodated by high-angle normal faults that have been rotated to low angles (Gans and Miller, 1983) and low-angle attenuation faults (Lund *et al.*, 1991). The amount of this early extension ranges greatly from locale to locale in the Basin and Range Province. Younger high-angle normal faults truncate the Eocene to Miocene listric faults (Gans *et al.* 1985; Fryxell, 1988). This extension produced faulting with a north to northeast strike, producing the current Basin and Range geomorphology.

Thus, the Devonian sections of the study area have been shortened and tectonically thickened due to low-angle thrust faulting in the late Paleozoic and Mesozoic, extended and thinned due to high- and low-angle normal faulting, and tilted due to rotation of the fault blocks in the Cenozoic.

STRUCTURE OF STUDY AREA

REVEILLE RANGE STRUCTURE

Most of the rocks exposed in the Reveille Range are Tertiary and Quaternary volcanic rocks that surround an uplifted window of Paleozoic strata in the central part of the mountain range (Figure 59).

Figure 59. Devonian section location within the Reveille Range (T2N, R51.5E), Nye County, Nevada.

This Paleozoic inlier is approximately 18 square kilometers. The strata studied in this investigation crop out near the former mining camps of New Reveille and Old Reveille (see Geologic map of a part of the Reveille Range, Plate 2). The Paleozoic block consists primarily of

Ordovician through Devonian strata in a west-dipping homocline (Geologic cross section of the Reveille Range, Plate 3) that is presumably bounded on the west by a north-trending normal fault (Kleinhampl and Ziony, 1985). Paleozoic strata exposed in the Reveille Range are autochthonous with respect to the Roberts Mountains Allochthon. Parts of the allochthon are exposed to the west in the Hot Creek Range. The Reveille Range is the hinterland (Figure 17) to thrusting of the Eureka Fold and Thrust Belt and Garden Valley Thrust System (Carpenter *et al.*, 1993; Bartley and Gleason, 1990).

Several smaller west-trending Tertiary normal faults with displacements on the order of tens of meters or less occur throughout the Paleozoic block. It is unclear if a "range-bounding" fault is present along the west boundary of the Reveille Range. Tertiary volcanic rocks crop out for several kilometers to the east and west of the margin of the Paleozoic window.

PANCAKE RANGE STRUCTURE

The study area in the Pancake Range is a block of Paleozoic limestone and dolomite that crops out just north of U.S. Highway 6 in east-central Nye County, Nevada (Geologic map of a part of the Pancake Range, Plate 4). This Paleozoic inlier is approximately 45 square kilometers. The Paleozoic "window" is surrounded to the north, west, and south by Oligocene and Miocene tuff and rhyolite, and to the east by late Tertiary and Quaternary alluvial deposits in Railroad Valley (Quinlivan *et al.*, 1974). The Paleozoic block is a homocline, dipping to the east at 15 to 30 degrees (Geologic cross section of the Pancake Range, Plate 5). This moderate dip continues beneath the valley, with the deepest parts of Railroad Valley lying adjacent to the Grant and Quinn Canyon Ranges. Several smaller Tertiary normal faults with displacements on the order of tens of meters or less generally trend east-west through the Paleozoic block. The "range-bounding" fault for the Pancake Range, if present, lies at the western margin of the Paleozoic block. The structure of the Pancake Range is complicated by the presence to the southwest of the Williams Ridge and Lunar Lake caldera complexes (U.S. Geological Society, 1968).

QUINN CANYON RANGE STRUCTURE

The study area in the Quinn Canyon Range is a Paleozoic "window" of Ordovician through Devonian limestone, dolomite, and quartz sandstone. This Paleozoic inlier is approximately 38 square kilometers. The inlier is surrounded on the east and south by Oligocene ash-flow tuff and rhyolite and to the north and west by Cambrian through Ordovician clastic and carbonate strata that have been thrust east and now lie above the Devonian strata (Geologic map of a part of the Quinn Canyon Range, Plate 6). The Paleozoic block is a homocline that dips west to northwest at 25 to 55 degrees (Geologic cross section of the Quinn Canyon Range, Plate 7). Several small late Tertiary normal faults with displacements on the order of a few tens of meters or less strike generally westward through the Paleozoic block.

DOLOMITE

DOLOMITIZATION

Many models exist for the formation of both primary, or depositional (protodolomite), and secondary, or replacement (diagenetic), dolomite. Dolomite can be precipitated directly from evaporation of marine water, but this process has been recognized in only a few select hypersaline areas, including carbonate supratidal and evaporite lagoons and lakes in Southern Australia, the Bahamas, Florida Bay, and the Persian Gulf. In these settings magnesium-calcium ratios are high (10:1) to overcome the interference effect of competing sodium, chlorine, and other ions in marine water and brines in forming poorly crystallized protodolomite (Purser *et al.*, 1994).

The most common formation of dolomite, however, is through replacement, albeit in many different depositional environments. Dolomitization is the process by which limestone is wholly or partly converted to dolomite (dolostone) or dolomitic limestone by replacement of the original high- and low-Mg calcite and aragonite, $CaCO_3$, by the mineral dolomite, $CaMg(CO_3)_2$. The balanced reaction for the replacement of calcite by dolomite is

$$2CaCO_3 + Mg^{2+} = CaMg(CO_3)_2 + Ca^{2+}$$

Replacement dolomite can occur only in situations where the Mg to Ca ion ratio has been reduced in the surrounding pore water and the effect of interfering cations and anions are reduced (Na and Cl in sea water). This can be achieved by dilution of sea water with freshwater (Figure 60). Normal marine water has a Mg to Ca ratio of nearly 3:1, conditions more favorable to the formation of calcite. Dolomite is a difficult mineral to precipitate because of the highly ordered nature of its crystals (Folk and Land, 1975). For this reason, exchanging magnesium for calcium in the crystal lattice is a slow process.

DOLOMITIZATION MODELS

Hypersaline dolomitization. Finely crystalline hypersaline dolomite is formed in both arid and humid climates. Hypersaline dolomitization occurs in sabkhas, low intertidal and supratidal areas of carbonate tidal-flats (Bathurst, 1975) and is a replacement of aragonite or calcite carbonate mud and biotics on supratidal-flats during short periods of exposure to evaporation by the Sun. Evaporation-formed minerals are first precipitated from marine water by capillary evaporation. Such crystals are rarely preserved, even though large amounts of calcite and gypsum are initially precipitated. They are dissolved by the next period of influx of sea water (a storm surge on a supratidal-flat). Even though there is a high salinity, the Mg to Ca ratio is high enough (approximately10:1) for finely crystalline replacement protodolomite to form (Folk and Land, 1975).

Deeper reflux dolomitization occurs in more deeply buried limestone when magnesium-rich brines, because of bulk density differences driving the system, displace connate water (Scoffin,

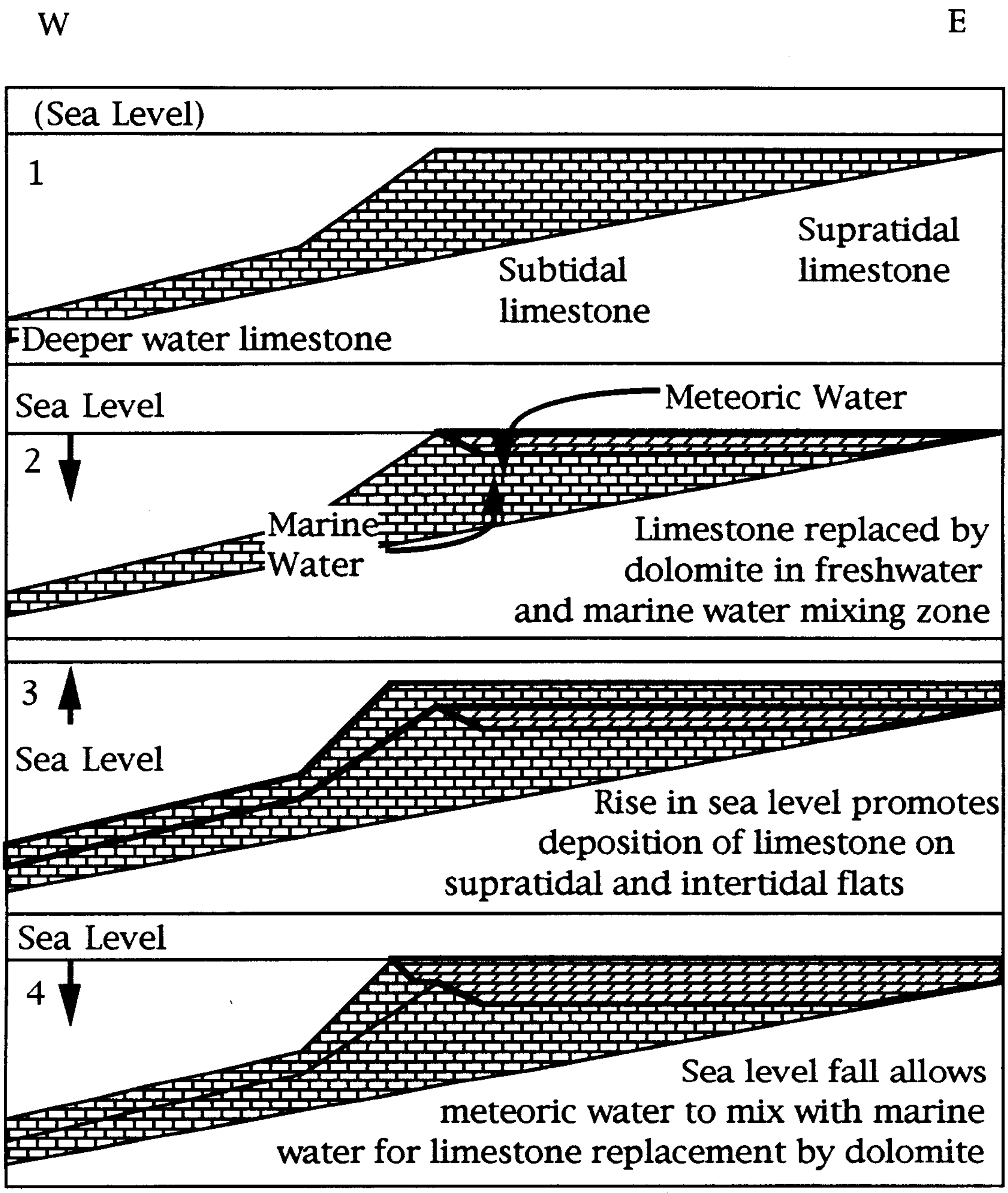


Figure 60. Model of paleodolomitization for the Paleozoic of Nevada.

1987). Evaporitic pumping as a cause of dolomitization is similar to the reflux theory: instead of a density driven system, marine water is pulled up through shallow-buried carbonate mud through capillary pores as water is evaporated on the saline, restricted supratidal-flat. Gypsum is precipitated, increasing the Mg to Ca ratio to the point where protodolomite is precipitated or replaces adjacent calcite and aragonite mineral grains and biotics.

Salt and Freshwater mixing. Replacement dolomitization can also occur at much lower Mg to Ca ratios (approximately1:1) with an influx of terrestrial or meteoric water into saline water in subsurface limestone (Folk and Land, 1975). This usually occurs when large tracts of carbonate sediment are exposed to brackish water conditions as freshwater from recharge meets saline water in the buried limestone beneath the shallow sea and on land masses. Transgression and regression of sea level shifts the zone of mixing landward and seaward, respectively (Figure 60). The addition of freshwater substantially lowers the Mg to Ca ratio and reduces the interference effect of other cations and anions in sea water, making the substitution of Mg for Ca in the dolomite crystal lattice thermodynamically and kinetically easier (Folk and Land, 1975). This process is slow but can dolomitize large areas of carbonate strata. This replacement dolomite is usually in medium to coarsely crystalline rhombs (i.e. the limpid dolomite of Folk and Land, 1975).

Cordilleran Miogeocline. Much of the dolomite in east-central Nevada is formed by secondary replacement during freshwater mixing in a shallow burial environment. This is suggested by three distinct lines of evidence including: 1) fossil fragments that were once calcite are now clear, medium to coarsely crystalline limpid dolomite rhombs, 2) a distinct lack of evaporitic minerals deposited along with primary protodolomite, and 3) dolomitization is not facies controlled (not exclusively in tidal and supratidal-flat facies; Dunham and Olson, 1978). In many instances, however, the origin of dolomite is uncertain. Blatt (1982) stated

> There are, however, many dolomites that lack clear evidence of replacement origin. Perhaps dolomitization completely destroyed the outlines and internal structures of pre-existing allochems; perhaps the original sediment was a homogeneous calcitic or aragonitic micrite that did not contain diagnostic features; or possibly the dolomite formed as an original chemical precipitate from modified seawater. For many dolomites, none of these three possibilities can be eliminated on the basis of either field or thin-section observations.

Early and middle Paleozoic carbonate strata in the Cordilleran Miogeocline show an increasing amount of dolomitization toward the craton, indicating that paleogeography was the controlling factor in formation of dolomite in the early and middle Paleozoic strata (Dunham and Olson, 1978). This is true for the study area, because shallow platform deposits in the Quinn Canyon Range and the Pancake Range are dolomitized, and deeper basinal deposits in the Reveille Range are not (Sevy and Simonson Dolomite to the east, and Denay Limestone to the west). The limestone-to-dolomite boundary is the break between the carbonate strata exposed to the freshwater and seawater mixing zone. The position of freshwater lenses and tracts of exposed carbonate strata (Figure 60) was controlled by paleogeography (Dunham and Olson, 1978).

Lower Devonian strata (Sevy Dolomite), exposed in the Quinn Canyon, Pancake, and Reveille ranges, were deposited in a shallow-carbonate subtidal environment. These units are lithologically and diagenetically similar in outcrop and when viewed with the petrographic microscope (similar intensity of replacement dolomitization of a presumably similar precursor mudstone).

Middle Devonian strata (Simonson Dolomite) in the Quinn Canyon and Pancake ranges were deposited in the shallow-carbonate subtidal environment. The Sadler Ranch Formation and Denay Limestone in the Reveille Range accumulated at the carbonate-platform edge, on the carbonate slope, and in the outer-shelf basin. Although these strata are lithologically and diagenetically similar in the eastern ranges (Quinn Canyon and Pancake ranges), they differ from age-equivalent strata in the western range (Reveille Range). The Sadler Ranch Formation is lithologically distinct from the Simonson Dolomite. Deposition of Devonian strata of the Reveille Range changed from shallow-platform dolomitized mudstone (Sevy Dolomite) to platform-edge dolomitized wackestone (Sadler Ranch Formation) ultimately to carbonate-slope and outer-shelf-basin packstone and mudstone (Denay Limestone). The slope and basin deposits have not been replaced by dolomite.

Because dolomitization is a result of freshwater mixing with sea water, the process must take place at shallow depth, soon after burial. The four principles that dolomitization (Dunham and Olson, 1978) followed in Nevada are as follows:

- The dolomite to limestone transition does not coincide with minor sea level changes in the depositional environment (diurnal tidal changes).

- The Devonian dolomite to limestone transition is controlled by the position of subaerial exposed tracts of carbonate strata during periods of onlap (transgression) and offlap (regression).

- Changes in regional paleogeography (the position of islands, land, tidal-flats, and carbonate-platform and basin areas) should produce changes in the position of the dolomite to limestone boundary.

- Dolomite formation occurred in the shallow subsurface (less than 100 meters), soon after the burial of carbonate units.

CONCLUSIONS

- The Lower Devonian strata exposed in the Quinn Canyon, Pancake, and Reveille Ranges were deposited in shallow carbonate subtidal through supratidal environments.

- The Sevy Dolomite from all these locations is similar in outcrop and when examined petrographically in thin section. The Formation is dolomitized and classifies as bioturbated mudstone and wackestone.

- The Middle Devonian strata of the Quinn Canyon and Pancake Ranges were deposited in shallow carbonate intertidal and supratidal environments, whereas the strata of the Reveille Range were deposited at the carbonate platform edge and on the carbonate slope and outer-shelf basin.

- The Simonson Dolomite from these locations is similar in outcrop and when examined petrographically in thin section. The Coarse Crystalline Member is dolomitized and contains quartz arenite layers with medium sand-sized, well rounded, well sorted, monocrystalline quartz grains and carbonate layers of structureless mudstone. The Lower Alternating Member is dolomitized and classifies as bioturbated mudstone.

- The Simonson Dolomite was affected by Milankovitch Cycles, glacio-eustatic oscillations of sea level, producing a characteristic rhythmic bedding.

- The Middle Devonian Sadler Ranch Formation and Denay Limestone of the Reveille Range are lithologically and diagenetically different from the shallow water deposits of the Lone Mountain Dolomite, Sevy Dolomite, and Simonson Dolomite. The Sadler Ranch Formation and Denay Limestone were deposited at the carbonate platform edge and on the carbonate slope and outer-shelf basin, respectively. The Sadler Ranch Formation is dolomitized and classifies as fossiliferous wackestone and mudstone. The Denay Limestone is not dolomitized and classifies as mudstone and fossiliferous grainstone and packstone.

- The Reveille Range strata record a transition from deposition on the carbonate platform (Lone Mountain and Sevy Dolomites) in the Lower Devonian, through the carbonate platform margin (Sadler Ranch Formation), to deposition in the outer-shelf basin (Denay Limestone) in the Middle Devonian.

- The base of the Sevy Dolomite in the Reveille Range is of *kindlei*-Zone age, an indication that, at least in the Reveille Range, the Sevy Dolomite is younger than previously recognized.

- The base of the Lower Alternating Member of the Simonson Dolomite in the Quinn Canyon Range has a slightly older age (*serotinus*-to *costatus* Zone) than at other eastern Nevada locations.

- The Early and Middle Devonian in Nevada is marked by deposition on a carbonate platform (relatively shallow water) and in an outer-shelf basin (relatively deep water). Shallow carbonate platform deposits (shelfal and tidal-flat) are dolomitized, whereas deep-water, outer-shelf basin and slope deposits are not.

- Dolomitization in the Paleozoic strata of Nevada is a secondary feature, an early diagenetic replacement of strata that were originally limestone. This replacement process is paleogeographically controlled, and small eustatic changes produced transgressions and regressions of the shoreline. In this way, the exposed land and adjacent submerged shelfal areas were exposed to freshwater recharge and replacement dolomitization.

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APPENDICES

APPENDICES

The following appendices are a summary of laboratory summary sheets for carbonate and clastic strata examined with a petrographic microscope and identified conodonts and brachiopods. Included in the summary sheet is sample number, formation name, relative (conodont or brachiopod zone if known) age, location (Township, Range, and Section), and stratigraphic position. Carbonate classification schemes are from Folk (1962) and Dunham (1962). Also included in the summary are macroscopic and microscopic descriptions and depositional and diagenetic interpretations.

APPENDIX I

CARBONATE REPORT SHEET

SAMPLE NUMBER: PRA-1
NAME OF FORMATION: Sevy Dolomite
AGE: Lower Devonian
LOCATION: T8N, R56E, Sec. 1, Southern Pancake Range
STRATIGRAPHIC POSITION: Section PRA, 3 meters (11 feet)
CLASSIFICATION (FOLK): Intradolosparite
(DUNHAM): Dolomitized wackestone
MACROSCOPIC DESCRIPTION: Light gray, finely crystalline angular dolomite clasts in a yellowish-gray, sandy matrix.

MICROSCOPIC DESCRIPTION:

TEXTURE: Brecciated, anhedral to euhedral dolomite rhombs, with coarsely crystalline dolomite as fracture fill.

ALLOCHEMS: 40%

BIOTICS: 0%

INTRACLASTS: Matrix-supported angular to subrounded intraclasts of finely crystalline, anhedral, dolomite.

OOLITES: 0%

PELOIDS: 0%

ORTHOCHEMS: 60%

CEMENT: Clear, coarsely crystalline, subhedral to euhedral dolomite rhombs as fracture fill. Matrix is anhedral to subhedral, cloudy, medium crystalline dolomite rhombs with occasional quartz clasts (1%) and microstylolites with clay residue.

DEPOSITIONAL AND DIAGENETIC ENVIRONMENT: Matrix-supported breccia suggests rapid deposition. Early fracturing and dolomitization imply shallow to subaerially exposed environment. Storm-wave or tidal channel clast rip-ups? Replacement dolomitization by freshwater mixing with marine water in the shallow subsurface.

Dolomitized flat-pebble breccia.

CARBONATE REPORT SHEET

SAMPLE NUMBER: PRA-2
NAME OF FORMATION: Sevy Dolomite
AGE: Lower Devonian
LOCATION: T8N, R56E, Sec. 1, Southern Pancake Range
STRATIGRAPHIC POSITION: Section PRA, 24 meters (80 feet)
CLASSIFICATION (FOLK): Peldolomicrite
(DUNHAM): Dolomitized peloidal mudstone
MACROSCOPIC DESCRIPTION: Lower part of gray grading to light gray, medium-bedded, medium crystalline dolomite.

MICROSCOPIC DESCRIPTION: Cloudy, anhedral, medium crystalline dolomite with occasional silt to fine sand-sized quartz grains and microstylolites with quartz enrichment and clay residue.

TEXTURE: Microcrystalline to medium crystalline dolomite.
ALLOCHEMS: 20% (5% silt to fine sand-sized quartz grains)
BIOTICS: 0%
INTRACLASTS: 0%
OOLITES: 0%
PELOIDS: 15% Micritized, microcrystalline to finely crystalline dolomite.

ORTHOCHEMS: 80%
CEMENT: Cloudy, anhedral, medium crystalline dolomite.

DEPOSITIONAL AND DIAGENETIC ENVIRONMENT: Originally deposited as micrite (carbonate tidal-flat?) that was later dolomitized in the shallow subsurface. Dolomite is not euhedral. Replacement dolomitization by freshwater mixing with marine water in the shallow subsurface.

Semi-restricted carbonate tidal-flat mudstone.

CARBONATE REPORT SHEET

SAMPLE NUMBER: PRA-3
NAME OF FORMATION: Sevy Dolomite
AGE: Lower Devonian
LOCATION: T8N, R56E, Sec. 1, Southern Pancake Range
STRATIGRAPHIC POSITION: Section PRA, 36 meters (120 feet)
CLASSIFICATION (FOLK): Cryptalgal dolomicrite
(DUNHAM): Dolomitized cryptalgal mudstone
MACROSCOPIC DESCRIPTION: Laminated, porous, light gray, medium crystalline dolomite.

MICROSCOPIC DESCRIPTION: Cryptalgal laminite with birds-eye void structures filled with clear, medium to coarsely crystalline, euhedral dolomite rhombs.

TEXTURE: Laminated with fenestrae.

ALLOCHEMS: 5%

BIOTICS: 0%

INTRACLASTS: 0%

OOLITES: 0%

PELOIDS: 5% Peloids are cloudy, finely crystalline, anhedral dolomite.

ORTHOCHEMS: 95%

CEMENT: Alternating layers of anhedral, finely crystalline dolomite with clear, euhedral, coarsely crystalline dolomite filling birds-eye fenestrae.

DEPOSITIONAL AND DIAGENETIC ENVIRONMENT: Cryptalgal laminites are composed of alternating layers of sediment and algal layers. Decaying algal layers produce gas bubbles. After shallow diagenesis, the calcareous muddy sediment layers become replaced by cloudy, anhedral, finely crystalline dolomite. The algal layers become subhedral, clear, medium crystalline dolomite. The gas bubbles are filled with coarsely crystalline, sparry-calcite that is later dolomitized. Replacement dolomitization by freshwater mixing with marine water in the shallow subsurface.

<u>Restricted carbonate tidal-flat cryptalgal laminite.</u>

CARBONATE REPORT SHEET

SAMPLE NUMBER: PRA-4
NAME OF FORMATION: Sevy Dolomite
AGE: Lower Devonian
LOCATION: T8N, R56E, Sec. 1, Southern Pancake Range
STRATIGRAPHIC POSITION: Section PRA, 53 meters (175 feet)
CLASSIFICATION (FOLK): Dolopelsparite
(DUNHAM): Dolomitized peloidal grainstone
MACROSCOPIC DESCRIPTION: Medium-bedded, light-gray, finely crystalline dolomite.

MICROSCOPIC DESCRIPTION: Cloudy, finely crystalline dolomitized peloids with stylolites and coarsely crystalline, clear dolomite filling original pore-space and fractures.

TEXTURE: Fractured, stylolites.
ALLOCHEMS: 85%
BIOTICS: 0%
INTRACLASTS: 15%
OOLITES: 0%
PELOIDS: 70% Structureless peloids that appear to be of pelletal origin. Cloudy, microcrystalline to finely crystalline dolomite in a well-rounded, spherical to elliptical grain.
ORTHOCHEMS: 15%
CEMENT: Clear, coarsely crystalline, euhedral dolomite filling fractures and primary pores. Hematite staining near, and insoluble residue filling the stylolite.
DEPOSITIONAL AND DIAGENETIC ENVIRONMENT: Peloids suggest a marine environment. Could be either shallow low energy, partially restricted carbonate subtidal or well-circulated intertidal lagoonal environment (like the Bahama platform). Replacement dolomitization by freshwater mixing with marine water in the shallow subsurface.

Dolomitized lagoonal mudstone.

CARBONATE REPORT SHEET

SAMPLE NUMBER: PRA-5

NAME OF FORMATION: Sevy Dolomite

AGE: Lower Devonian

LOCATION: T8N, R56E, Sec. 1, Southern Pancake Range.

STRATIGRAPHIC POSITION: Section PRA, 57 meters (190 feet)

CLASSIFICATION (FOLK): Dolosparite

(DUNHAM): Dolomitized fractured mudstone

MACROSCOPIC DESCRIPTION: Chocolate-brown, medium bedded, medium crystalline dolomite.

MICROSCOPIC DESCRIPTION: Highly fractured, brecciated dolomite.

TEXTURE:

ALLOCHEMS: 60%

BIOTICS: 0%

INTRACLASTS: 60% Anhedral, medium crystalline, cloudy dolomite intraclasts.

OOLITES: 0%

PELOIDS: 0%

ORTHOCHEMS: 40%

CEMENT: Clear, coarsely crystalline dolomite rhombs filling fractures.

DEPOSITIONAL AND DIAGENETIC ENVIRONMENT: Possibly micrite mud, carbonate tidal-flat deposit that was subsequently fractured and dolomitized. Replacement dolomitization by freshwater mixing with marine water in the shallow subsurface.

<u>Possibly restricted carbonate tidal-flat micrite.</u>

CARBONATE REPORT SHEET

SAMPLE NUMBER: PRA-6

NAME OF FORMATION: Sevy Dolomite

AGE: Lower Devonian

LOCATION: T8N, R56E, Sec. 1, Southern Pancake Range.

STRATIGRAPHIC POSITION: Section PRA, 62 meters (206 feet)

CLASSIFICATION (FOLK): *Amphipora* dolosparite

(DUNHAM): Dolomitized *Amphipora* wackestone

MACROSCOPIC DESCRIPTION: *Amphipora* fossils replaced with clear, coarsely crystalline dolomite in a medium gray, medium-bedded, medium crystalline dolomite matrix.

MICROSCOPIC DESCRIPTION: Elliptical to round *Amphipora* ghosts.

ALLOCHEMS: 40%

BIOTICS: 40% *Amphipora* ghosts that are now filled with clear, coarsely crystalline, euhedral dolomite rhombs.

INTRACLASTS: 0%

OOLITES: 0%

PELOIDS: 0%

ORTHOCHEMS: 60%

CEMENT: Anhedral, cloudy, medium crystalline dolomite.

DEPOSITIONAL AND DIAGENETIC ENVIRONMENT: *Amphipora* may have baffled water, depositing micrite, however, dolomitization obscures identity of original carbonate sediment. *Amphipora* thrived in well-circulated water. Replacement dolomitization by freshwater mixing with marine water in the shallow subsurface.

<u>Shelf or well-circulated lagoonal skeletal micrite.</u>

CARBONATE REPORT SHEET

SAMPLE NUMBER: PRA-7
NAME OF FORMATION: Sevy Dolomite
AGE: *gronbergi* Zone, Emsian Stage, Lower Devonian (conodont)
LOCATION: T8N, R56E, Sec. 1, Southern Pancake Range.
STRATIGRAPHIC POSITION: Section PRA, 63 meters (210 feet)
CLASSIFICATION (FOLK): *Amphipora* dolosparite
(DUNHAM): Dolomitized *Amphipora* wackestone
MACROSCOPIC DESCRIPTION: *Amphipora* and possibly other biotic fragments (brachiopod and coral?) replaced with clear, coarsely crystalline dolomite in a finely crystalline, light-gray, medium-bedded dolomite.

MICROSCOPIC DESCRIPTION: Dolomitized *Amphipora* ghosts in a mudstone matrix.

TEXTURE:

ALLOCHEMS: 30%

BIOTICS: 30% *Amphipora* skeletons now filled with clear, medium to coarsely crystalline, subhedral dolomite.

INTRACLASTS: 0%

OOLITES: 0%

PELOIDS: 0%

ORTHOCHEMS: 70%

CEMENT: Cloudy, finely crystalline, anhedral dolomite.

DEPOSITIONAL AND DIAGENETIC ENVIRONMENT: Similar to PRA-6. *Amphipora* most likely lived in well-circulated, low energy, carbonate subtidal to intertidal water, and acted as a baffle for the micrite mud in suspension. Dolomitization, however, has obscured the original sediment. Replacement dolomitization by freshwater mixing with marine water in the shallow subsurface.

<u>Lagoonal or carbonate subtidal mudstone.</u>

CARBONATE REPORT SHEET

SAMPLE NUMBER: PRA-8 (marked as PRA-11, but gray)

NAME OF FORMATION: Sevy Dolomite.

AGE: Lower Devonian

LOCATION: T8N, R56E, Sec. 1, Southern Pancake Range.

STRATIGRAPHIC POSITION: Section PRA, 101 meters (337 feet)

CLASSIFICATION (FOLK): Brachiopod pel-dolosparite

(DUNHAM): Dolomitized peloidal wackestone

MACROSCOPIC DESCRIPTION: Brownish-gray, slightly sandy from color-banded, medium-bedded, medium crystalline dolomite.

MICROSCOPIC DESCRIPTION: Laminated with occasional sand and many brachiopod fragments.

TEXTURE: Laminated

ALLOCHEMS: 85% (5% subangular to subrounded, fine sand-sized, moderately to well-sorted quartz grains).

BIOTICS: 15% thin-shelled brachiopod shells and fragments showing geopetal fabric and some original shell microstructure. Also, calcispheres that have been recrystallized to finely crystalline, clear, anhedral dolomite.

INTRACLASTS: 0%

OOLITES: 0%

PELOIDS: 65% Peloids are cloudy, microcrystalline to finely crystalline, anhedral dolomite.

ORTHOCHEMS: 15%

CEMENT: Cloudy, finely crystalline anhedral dolomite.

DEPOSITIONAL AND DIAGENETIC ENVIRONMENT: Laminations rule out the possibilities of bioturbation and dark gray, finely disseminated organic-rich sediment suggests restricted environment (anoxic bottom conditions). Restricted environment with normal marine brachiopods and quartz grains mixed by tractive bottom and storm waves. Perhaps storm wave deposits entering over barrier and into a restricted lagoonal environment. Replacement dolomitization by freshwater mixing with marine water in the shallow subsurface.

<u>Restricted lagoonal environment.</u>

CARBONATE REPORT SHEET

SAMPLE NUMBER: PRA-9
NAME OF FORMATION: Sevy Dolomite.
AGE: Lower Devonian
LOCATION: T8N, R56E, Sec. 1, Southern Pancake Range.
STRATIGRAPHIC POSITION: Section PRA, 107 meters (357 feet)
CLASSIFICATION (FOLK): Peloidal dolosparite
(DUNHAM): Dolomitized peloidal wackestone
MACROSCOPIC DESCRIPTION: Gray, medium-bedded, sandy, finely to medium crystalline dolomite.

MICROSCOPIC DESCRIPTION: Cloudy peloid-rich and quartz-rich dolomite.

TEXTURE:

ALLOCHEMS: 80% (30% subrounded to subangular, moderate to well-sorted, medium sand-sized, monocrystalline quartz grains).

BIOTICS: 0%

INTRACLASTS: 0%

OOLITES: 0%

PELOIDS: 50% Peloids are well sorted and medium sand-sized elliptical masses of cloudy, finely crystalline to microcrystalline, anhedral dolomite.

ORTHOCHEMS: 20%

CEMENT: Cloudy, finely to medium crystalline, anhedral to subhedral dolomite rhombs.

DEPOSITIONAL AND DIAGENETIC ENVIRONMENT: Floating quartz grains in a peloid-rich and cloudy dolomite matrix. Peloids suggest lagoonal or quiet water carbonate subtidal with floating quartz grains representing extensive bioturbation (homogenization). No apparent biotics suggest a restricted environment (like the Bahamas platform). Replacement dolomitization by freshwater mixing with marine water in the shallow subsurface.

<u>Possibly homogenized lagoonal deposit.</u>

CARBONATE REPORT SHEET

SAMPLE NUMBER: PRA-10

NAME OF FORMATION: Sevy Dolomite

AGE: *gronbergi* Zone, Emsian Stage, Lower Devonian (conodont and brachiopod)

LOCATION: T8N, R56E, Sec. 1, Southern Pancake Range.

STRATIGRAPHIC POSITION: Section PRA, 112 meters (372 feet)

CLASSIFICATION (FOLK): Crinoidal dolosparite

(DUNHAM): Dolomitized crinoidal wackestone

MACROSCOPIC DESCRIPTION: Gray, fossiliferous, partly silicified, medium-bedded, finely to medium crystalline dolomite.

MICROSCOPIC DESCRIPTION: Crinoid-rich, sand-rich dolomite

TEXTURE:

ALLOCHEMS: 35% (15% subrounded to subangular, moderately sorted, fine to coarse sand-sized, monocrystalline quartz grains).

BIOTICS: 20% Large to small, crinoid ossicles (one hole) and fragments and possibly brachiopod fragments. Burrows?

INTRACLASTS: 0%

OOLITES: 0%

PELOIDS: 0%

ORTHOCHEMS: 65%

CEMENT: Matrix cement composed of finely to medium crystalline, anhedral to subhedral, slightly cloudy dolomite.

DEPOSITIONAL AND DIAGENETIC ENVIRONMENT: Floating biotics and sand grains suggest bioturbation. Presence of quartz sand grains is puzzling. Lagoonal environment or open, shallow carbonate subtidal or intertidal marine suggested by biotics. However, environment could be restricted with presence of sand and biotics a result of storms. Bioturbation is important with some burrows? present. Replacement dolomitization by freshwater mixing with marine water in the shallow subsurface.

Possibly homogenized lagoonal deposit.

CARBONATE REPORT SHEET

SAMPLE NUMBER: PRA-11

NAME OF FORMATION: Cherty Argillaceous Member (Sevy Dolomite)

AGE: *inversus* Zone, Emsian Stage, Lower Devonian (conodont)

LOCATION: T8N, R56E, Sec. 1, Southern Pancake Range.

STRATIGRAPHIC POSITION: Section PRA, 119 meters (395 feet)

CLASSIFICATION (FOLK): Bioturbated dolosparite

(DUNHAM): Bioturbated dolomitized wackestone

MACROSCOPIC DESCRIPTION: Tan weathering, gray on fresh surface, finely crystalline, bioturbated dolomite.

MICROSCOPIC DESCRIPTION: Matrix composed of two different areas.

TEXTURE:

ALLOCHEMS: 25% (10% Rounded to subrounded, fine to coarse sand-sized, moderately sorted, monocrystalline quartz grains).

BIOTICS: 15% Mostly unidentifiable fossil fragments that have been recrystallized to medium to coarsely crystalline, clear, subhedral to euhedral dolomite. Some recognizable brachiopod fragments.

INTRACLASTS: 0%

OOLITES: 0%

PELOIDS: 0%

ORTHOCHEMS: 75% Burrows? are finely crystalline, cloudy, with occasional quartz fragments and no biotics. Unburrowed are sand and biotic-rich.

CEMENT: Finely to medium crystalline, cloudy, anhedral to subhedral dolomite.

DEPOSITIONAL AND DIAGENETIC ENVIRONMENT: Deeper water carbonate slope deposits modified by bioturbation. Perhaps lagoonal or deeper carbonate subtidal deposit that has storm-introduced quartz sand and biotics. Matrix supported unburrowed area suggests occasional storm surge deposits on the carbonate slope. Replacement dolomitization by freshwater mixing with marine water in the shallow subsurface.

Probably deeper carbonate subtidal environment.

APPENDIX II

SANDSTONE REPORT SHEET

SAMPLE NUMBER: PRB-1
FORMATION: Coarse Crystalline Member of Simonson Dolomite
AGE: Lower to Middle Devonian
LOCATION: T8N, R56E, Sec. 1, Southern Pancake Range.
STRATIGRAPHIC POSITION: Section PRB, 11 meters (35 feet)
NAME: Quartz arenite
MACROSCOPIC DESCRIPTION: Orange-brown weathering quartz sandstone (sedimentary quartzite), thin- to medium-bedded that is white on fresh surface with rounded quartz grains.
MICROSCOPIC DESCRIPTION: Quartz overgrowths with dolomite rhombs in a quartz arenite.

FRAMEWORK: 97%

GRAIN SIZE: Fine to medium sand-sized quartz.
ROUNDING: Quartz overgrowths have obscured original well-rounded shape of grains.

SORTING: Moderately to well-sorted
TEXTURAL MATURITY: Moderately mature
MINERALOGY: 97% monocrystalline quartz
COMPOSITIONAL MATURITY: Supermature

MATRIX: 3% Medium to coarsely crystalline, clear, subhedral dolomite.
CEMENT: Quartz cemented but overgrowths obscure clast-cement boundary.
POROSITY: <1% in fractures

PROVENANCE: Craton-derived recycled sandstone
DEPOSITIONAL AND DIAGENETIC ENVIRONMENT: Beach, barrier-bar, or tidal channel environment, high energy waves and currents to remove all finer grained clay and silt-sized detritus and physically abrade all softer clasts.

DIAGENESIS: Freshwater mixing, replacement dolomitization of coarsely to medium crystalline sparry calcite. Could also be primary dolomite as pore filling cement.

CARBONATE REPORT SHEET

SAMPLE NUMBER: PRB-2

NAME OF FORMATION: Coarse Crystalline Member of Simonson Dolomite

AGE: Lower to Middle Devonian

LOCATION: T8N, R56E, Sec. 1, Southern Pancake Range.

STRATIGRAPHIC POSITION: Section PRB, 19 meters (62 feet)

CLASSIFICATION (FOLK): Dolosparite

(DUNHAM): Dolomitized mudstone

MACROSCOPIC DESCRIPTION: Medium gray, vuggy (pitted), coarsely crystalline, massive dolomite.

MICROSCOPIC DESCRIPTION: Coarsely crystalline dolomite with chalcedonic quartz

TEXTURE: Dolomitized

ALLOCHEMS: 0%

BIOTICS: 0%

INTRACLASTS: 0%

OOLITES: 0%

PELOIDS: 0%

ORTHOCHEMS: 100%

CEMENT: Cloudy, finely to coarsely crystalline, anhedral to euhedral, zoned dolomite rhombs with approximately 5% radiating fibrous, pore filling or replacement chalcedony and approximately 10% porosity.

DEPOSITIONAL AND DIAGENETIC ENVIRONMENT: Micrite in lagoonal environment that may have been severely bioturbated (homogenized). Replacement dolomitization by freshwater mixing with marine water in the shallow subsurface.

Probably carbonate subtidal or lagoonal environment.

CARBONATE REPORT SHEET

SAMPLE NUMBER: PRB-3

NAME OF FORMATION: Lower Alternating Member of Simonson Dolomite

AGE: Middle Devonian

LOCATION: T8N, R56E, Sec. 1, Southern Pancake Range.

STRATIGRAPHIC POSITION: Section PRB, 30 meters (100 feet)

CLASSIFICATION (FOLK): Dolosparite

(DUNHAM): Dolomitized mudstone

MACROSCOPIC DESCRIPTION: Chocolate-brown weathering, gray, medium-bedded, medium crystalline dolomite.

MICROSCOPIC DESCRIPTION: Interlocking mosaic of cloudy, subhedral, finely crystalline dolomite rhombs.

TEXTURE: Homogenized, dolomitized

ALLOCHEMS: 0%

BIOTICS: 0%

INTRACLASTS: 0%

OOLITES: 0%

PELOIDS: 0%

ORTHOCHEMS: 100%

CEMENT: Finely crystalline, cloudy, subhedral to euhedral dolomite rhombs.

DEPOSITIONAL AND DIAGENETIC ENVIRONMENT: Abundance of dark organic matter suggests micrite origin in restricted subtidal or lagoonal environment. No fossils were observed. Probably a freshwater mixing replacement dolomitization of a homogeneous carbonate mudstone.

Probably restricted lagoonal environment.

CARBONATE REPORT SHEET

SAMPLE NUMBER: PRB-4

NAME OF FORMATION: Lower Alternating Member of Simonson Dolomite

AGE: Middle Devonian

LOCATION: T8N, R56E, Sec. 1, Southern Pancake Range.

STRATIGRAPHIC POSITION: Section PRB, 47 meters (156 feet)

CLASSIFICATION (FOLK): Dolosparite

(DUNHAM): Dolomitized mudstone

MACROSCOPIC DESCRIPTION: Dark and light gray mottled, medium to coarsely crystalline, medium-bedded dolomite.

MICROSCOPIC DESCRIPTION: Cloudy, subhedral, finely crystalline dolomite.

TEXTURE: Homogeneous, dolomitized

ALLOCHEMS: 0%

BIOTICS: 0%

INTRACLASTS: 0%

OOLITES: 0%

PELOIDS: 0%

ORTHOCHEMS: 100%

CEMENT: Finely crystalline, cloudy, anhedral to euhedral dolomite.

DEPOSITIONAL AND DIAGENETIC ENVIRONMENT: Abundance of organic matter suggests lack of bioturbation and apparent micrite origin may be found in restricted lagoonal or subtidal to intertidal environment. Probably a freshwater mixing replacement dolomitization of a homogeneous carbonate mudstone.

Probably origin in restricted lagoonal or carbonate subtidal to intertidal environment.

CARBONATE REPORT SHEET

SAMPLE NUMBER: PRB-5

NAME OF FORMATION: Lower Alternating Member of Simonson Dolomite

AGE: Middle Devonian

LOCATION: T8N, R56E, Sec. 1, Southern Pancake Range.

STRATIGRAPHIC POSITION: Section PRB, 65 meters (217 feet)

CLASSIFICATION (FOLK): Dolosparite

(DUNHAM): Dolomitized mudstone

MACROSCOPIC DESCRIPTION: Light gray, finely crystalline dolomite clasts in a darker gray, medium crystalline dolomite.

MICROSCOPIC DESCRIPTION: Cloudy, brecciated, subhedral, medium crystalline dolomite.

- TEXTURE: Brecciated
- ALLOCHEMS: 20%
  - BIOTICS: 0%
  - INTRACLASTS: 20% Rip-ups of finely crystalline, anhedral, cloudy dolomite clasts.
  - OOLITES: 0%
  - PELOIDS: 0%
- ORTHOCHEMS: 80%
  - CEMENT: Finely to medium crystalline, cloudy to clear, anhedral to subhedral, dolomite rhombs.

DEPOSITIONAL AND DIAGENETIC ENVIRONMENT: High-energy environment such as tidal channel or storm-surge deposit soon after deposition of original sediment (autochthonous) and rip-ups of previously deposited material (allochthonous). Probably a freshwater mixing replacement dolomitization of a homogeneous carbonate mudstone.

<u>Probably tidal channel or storm deposit.</u>

CARBONATE REPORT SHEET

SAMPLE NUMBER: PRB-6

NAME OF FORMATION: Lower Alternating Member of Simonson Dolomite

AGE: Middle Devonian

LOCATION: T8N, R56E, Sec. 1, Southern Pancake Range.

STRATIGRAPHIC POSITION: Section PRB, 76 meters (252 feet)

CLASSIFICATION (FOLK): Dolosparite

(DUNHAM): Dolomitized mudstone

MACROSCOPIC DESCRIPTION: Chocolate-brown weathering, laminated, medium crystalline dolomite.

MICROSCOPIC DESCRIPTION: Cryptalgal Laminite? Cloudy dolomite.

TEXTURE: Laminated, fractured, dolomitized

ALLOCHEMS: 0%

BIOTICS: 0%

INTRACLASTS: 0%

OOLITES: 0%

PELOIDS: 0%

ORTHOCHEMS: 100%

CEMENT: 60% Finely crystalline, cloudy, anhedral dolomite. 40% Clear, finely to medium crystalline, subhedral to euhedral dolomite rhombs fracture fill.

DEPOSITIONAL AND DIAGENETIC ENVIRONMENT: Probably cryptalgal laminite deposited in the supratidal environment with alternating organic and inorganic layers. Probably a freshwater mixing replacement dolomitization in the shallow subsurface.

Probably cryptalgal laminite in restricted intertidal to supratidal environment.

APPENDIX III

SANDSTONE REPORT SHEET

SAMPLE NUMBER: PRC-1

FORMATION: Coarse Crystalline Member of Simonson Dolomite.

AGE: Lower to Middle Devonian

LOCATION: T8N, R56E, Sec. 1, Southern Pancake Range.

STRATIGRAPHIC POSITION: Section PRC, 7 meters (23 feet)

NAME: Quartz Arenite

MACROSCOPIC DESCRIPTION: Light gray-weathering, darker on fresh surface, sandy dolomite and orange-weathering, white, dolomitic sandstone.

MICROSCOPIC DESCRIPTION: Sandy Dolomicrite or sandy dolomudstone.

FRAMEWORK: 40%

GRAIN SIZE: Fine to coarse sand

ROUNDING: Fine sand is angular and coarse sand is well-rounded.

SORTING: Moderate.

TEXTURAL MATURITY: Submature.

MINERALOGY: Framework is 100% monocrystalline quartz.

COMPOSITIONAL MATURITY: Supermature.

MATRIX: 60%

CEMENT: Medium to coarsely crystalline, anhedral to subhedral dolomite.

POROSITY: <5% in fractures (secondary)

PROVENANCE: Craton-derived quartz sand (probably recycled).

DEPOSITIONAL AND DIAGENETIC ENVIRONMENT: Back lagoon deposit with storm washover of quartz sand from quartz barrier bar. Bioturbation of original lagoonal micrite to homogenize deposit.

DIAGENESIS: Primary pore filling calcite and micrite mud is replaced by dolomite in the freshwater mixing zone of a shallow burial environment. Could also be primary pore filling dolomite.

SANDSTONE REPORT SHEET

SAMPLE NUMBER: PRC-2

FORMATION: Coarse Crystalline Member of Simonson Dolomite

AGE: Lower to Middle Devonian

LOCATION: T8N, R56E, Sec. 1, Southern Pancake Range.

STRATIGRAPHIC POSITION: Section PRC, 13 meters (42 feet)

NAME: Quartz Arenite

MACROSCOPIC DESCRIPTION: Light gray to white on fresh surface, orange-weathering sandstone.

MICROSCOPIC DESCRIPTION: Quartz-cemented quartz arenite.

FRAMEWORK: 85%

GRAIN SIZE: Medium sand-sized.

ROUNDING: Quartz overgrowths have obscured original probably well-rounded shape.

SORTING: Well sorted.

TEXTURAL MATURITY: Supermature.

MINERALOGY: Monocrystalline quartz.

COMPOSITIONAL MATURITY: Supermature.

MATRIX: 0%

CEMENT: 15% Quartz overgrowths

POROSITY: 0%

PROVENANCE: Craton-derived recycled quartz sand.

DEPOSITIONAL AND DIAGENETIC ENVIRONMENT: Beach or barrier-bar environment.

DIAGENESIS: Early burial and precipitation of quartz cement from silica-rich solution created this sedimentary quartzite.

SANDSTONE REPORT SHEET

SAMPLE NUMBER: PRC-3

FORMATION: Coarse Crystalline Member of Simonson Dolomite.

AGE: Lower to Middle Devonian

LOCATION: T8N, R56E, Sec. 1, Southern Pancake Range.

STRATIGRAPHIC POSITION: Section PRC, 45 meters (150 feet)

NAME: Sandy Dolosparite or Sandy dolomudstone

MACROSCOPIC DESCRIPTION: Light gray weathering, darker on fresh surface, sandy dolomite.

MICROSCOPIC DESCRIPTION: Sandy Dolomite.

FRAMEWORK: 20%

GRAIN SIZE: Fine to medium sand-sized.

ROUNDING: Medium sand-sized fraction is well rounded and fine sand-sized is subangular.

SORTING: Moderate.

TEXTURAL MATURITY: Submature.

MINERALOGY: 100% Monocrystalline quartz.

COMPOSITIONAL MATURITY: Supermature.

MATRIX: 80%

CEMENT: Medium to coarsely crystalline anhedral to subhedral dolomite rhombs.

POROSITY: <5% secondary fracture porosity.

PROVENANCE: Craton-derived recycled sand.

DEPOSITIONAL AND DIAGENETIC ENVIRONMENT: Storm washover of quartz sand in lagoonal carbonate environment; quartz sand and carbonate allochems are then homogenized by bioturbation?.

DIAGENESIS: Early replacement dolomitization in shallow burial environment by mixing of fresh and meteoric water with saline marine water.

APPENDIX IV

CARBONATE REPORT SHEET

SAMPLE NUMBER: QCA-1
NAME OF FORMATION: Laketown Dolomite
AGE: Upper Silurian
LOCATION: T3N, R56E, Quinn Canyon Range.
STRATIGRAPHIC POSITION: Section QCA, 0 meters (0 feet)
CLASSIFICATION (FOLK): Dolosparite
(DUNHAM): Dolomitized mudstone
MACROSCOPIC DESCRIPTION: Dark gray on weathered surface, lighter gray on fresh, massive to thickly bedded, medium to coarsely crystalline dolomite.

MICROSCOPIC DESCRIPTION: Medium to coarsely crystalline dolomite.

TEXTURE: Dolomitized.
ALLOCHEMS: 0%
BIOTICS: 0%
INTRACLASTS: 0%
OOLITES: 0%
PELOIDS: 0%
ORTHOCHEMS: 100%
CEMENT: Coarsely crystalline, slightly cloudy, euhedral to subhedral dolomite rhombs.

DEPOSITIONAL AND DIAGENETIC ENVIRONMENT: Replacement dolomitization by freshwater mixing with saline marine water in the shallow subsurface. Possibly a micritic origin suggesting carbonate tidal-flat or restricted lagoonal environment.

Possibly carbonate tidal-flat or restricted lagoonal environment.

CARBONATE REPORT SHEET

SAMPLE NUMBER: QCA-2
NAME OF FORMATION: Laketown Dolomite
AGE: Upper Silurian
LOCATION: T3N, R56E, Quinn Canyon Range.
STRATIGRAPHIC POSITION: Section QCA, 1 meter (3 feet)
CLASSIFICATION (FOLK): Dolosparite
(DUNHAM): Dolomitized mudstone
MACROSCOPIC DESCRIPTION: Light gray weathering to a smooth (porcellaneous) texture, medium to dark gray, finely to medium crystalline dolomite.

MICROSCOPIC DESCRIPTION: Medium crystalline, cloudy, anhedral to subhedral recrystallized dolomite. Medium to coarsely crystalline, clear, subhedral to euhedral dolomite as fracture fill.

TEXTURE: Fractured and dolomitized.
ALLOCHEMS: 0%
BIOTICS: 0%
INTRACLASTS: 0%
OOLITES: 0%
PELOIDS: 0%
ORTHOCHEMS: 100%
CEMENT: Medium crystalline, cloudy, anhedral to subhedral recrystallized dolomite. Medium to coarsely crystalline, clear, subhedral to euhedral dolomite as fracture fill.

DEPOSITIONAL AND DIAGENETIC ENVIRONMENT: Not as dolomitized as QCA-1, but similar. Possibly micrite origin suggesting carbonate tidal-flat or restricted lagoonal environment. Replacement dolomitization by freshwater mixing with marine water in the shallow subsurface.

Possibly carbonate tidal-flat or restricted lagoonal environment.

CARBONATE REPORT SHEET

SAMPLE NUMBER: QCA-3
NAME OF FORMATION: Laketown Dolomite
AGE: Upper Silurian
LOCATION: T3N, R56E, Quinn Canyon Range.
STRATIGRAPHIC POSITION: Section QCA, 15 meters (51 feet)
CLASSIFICATION (FOLK): Dolosparite
(DUNHAM): Dolomitized mudstone
MACROSCOPIC DESCRIPTION: Dark gray, coarsely crystalline, massive to thickly bedded dolomite.

MICROSCOPIC DESCRIPTION: Dolomite rhombs predominate with no fracturing.

TEXTURE:
ALLOCHEMS: 0%
BIOTICS: 0%
INTRACLASTS: 0%
OOLITES: 0%
PELOIDS: 0%
ORTHOCHEMS: 100%
CEMENT: Coarsely crystalline, euhedral to subhedral, cloudy dolomite rhombs.

DEPOSITIONAL AND DIAGENETIC ENVIRONMENT: Possibly micrite origin that has been dolomitized, suggesting carbonate tidal-flat or restricted lagoonal environment. Replacement dolomitization by freshwater mixing with saline water in the shallow subsurface.

Possibly carbonate tidal-flat or restricted lagoonal environment.

CARBONATE REPORT SHEET

SAMPLE NUMBER: QCA-4
NAME OF FORMATION: Sevy Dolomite
AGE: Lower Devonian
LOCATION: T3N, R56E, Quinn Canyon Range.
STRATIGRAPHIC POSITION: Section QCA, 18 meters (60 feet)
CLASSIFICATION (FOLK): Dolosparite
(DUNHAM): Dolomitized mudstone
MACROSCOPIC DESCRIPTION: Light gray, finely crystalline, well-bedded dolomite.

MICROSCOPIC DESCRIPTION:
TEXTURE: Slightly fractured
ALLOCHEMS: 2%
BIOTICS: 2% Brachiopod shell fragments replaced by clear, medium crystalline, anhedral to subhedral dolomite.

INTRACLASTS: 0%
OOLITES: 0%
PELOIDS: 0%
ORTHOCHEMS: 98%
CEMENT: Finely to medium crystalline, cloudy, anhedral to subhedral dolomite matrix with finely to medium crystalline, clear, subhedral dolomite rhombs filling secondary tectonic fractures.

DEPOSITIONAL AND DIAGENETIC ENVIRONMENT: Fossil fragments (brachiopod?) represent more normal marine conditions but more likely were washed into the normally quiet water environment, possibly restricted lagoonal or carbonate tidal-flat. Replacement dolomitization by freshwater mixing with saline water in the shallow subsurface.

Possibly carbonate tidal-flat or restricted lagoonal environment.

CARBONATE REPORT SHEET

SAMPLE NUMBER: QCA-5
NAME OF FORMATION: Sevy Dolomite
AGE: Lower Devonian
LOCATION: T3N, R56E, Quinn Canyon Range.
STRATIGRAPHIC POSITION: Section QCA, 74 meters (248 feet)
CLASSIFICATION (FOLK): Dolosparite
(DUNHAM): Dolomitized mudstone
MACROSCOPIC DESCRIPTION: Light gray, finely crystalline, thickly bedded to massive dolomite.

MICROSCOPIC DESCRIPTION:
TEXTURE: Fractured porphyroid with stylolites
ALLOCHEMS: 1%
BIOTICS: 1% Finely to medium crystalline, anhedral to subhedral, clear dolomite replacing a brachiopod? shell fragment.

INTRACLASTS: 0%
OOLITES: 0%
PELOIDS: 0%
ORTHOCHEMS: 99%
CEMENT: Finely to medium crystalline, cloudy, anhedral dolomite. Medium to coarsely crystalline, clear, subhedral dolomite in other areas, patchy in distribution.

DEPOSITIONAL AND DIAGENETIC ENVIRONMENT: Possibly micrite origin from carbonate tidal-flat or restricted lagoonal environment that was later dolomitized. Replacement dolomitization by freshwater mixing with saline water in the shallow subsurface.

<u>Possibly carbonate tidal-flat or restricted lagoonal environment.</u>

CARBONATE REPORT SHEET

SAMPLE NUMBER: QCA-6
NAME OF FORMATION: Sevy Dolomite
AGE: Lower Devonian
LOCATION: T3N, R56E, Quinn Canyon Range.
STRATIGRAPHIC POSITION: Section QCA, 120 meters (400 feet)
CLASSIFICATION (FOLK): Dolosparite
(DUNHAM): Dolomitized mudstone
MACROSCOPIC DESCRIPTION: Black to dark gray, medium crystalline, laminated dolomite.

MICROSCOPIC DESCRIPTION:
TEXTURE: Two sets of fractures, dolomitized, porphyroid
ALLOCHEMS: 0%
BIOTICS: 0%
INTRACLASTS: 0%
OOLITES: 0%
PELOIDS: 0%
ORTHOCHEMS: 100%
CEMENT: Matrix of cloudy, finely to medium crystalline, anhedral to subhedral dolomite rhombs with two sets of secondary tectonic fractures filled by clear, medium to coarsely crystalline, euhedral to subhedral dolomite.

DEPOSITIONAL AND DIAGENETIC ENVIRONMENT: Possibly micrite origin from carbonate tidal-flat or restricted lagoonal environment. Replacement dolomitization by freshwater mixing with saline water in the shallow subsurface.

Possibly carbonate tidal-flat or restricted lagoonal environment.

CARBONATE REPORT SHEET

SAMPLE NUMBER: QCA-7
NAME OF FORMATION: Sevy Dolomite
AGE: Lower Devonian
LOCATION: T3N, R56E, Quinn Canyon Range.
STRATIGRAPHIC POSITION: Section QCA, 257 meters (855 feet)
CLASSIFICATION (FOLK): Brachiopod dolosparite
(DUNHAM): Dolomitized Brachiopod wackestone
MACROSCOPIC DESCRIPTION: Black to dark gray, medium crystalline, laminated dolomite.

MICROSCOPIC DESCRIPTION:

TEXTURE: Dolomitic, porphyroid, and fractured

ALLOCHEMS: 15%

BIOTICS: 15% Clear, medium to coarsely crystalline, euhedral to subhedral dolomite replacing brachiopod shell fragments.

INTRACLASTS: 0%
OOLITES: 0%
PELOIDS: 0%

ORTHOCHEMS: 85%

CEMENT: Cloudy, finely crystalline, anhedral dolomite; secondary tectonic fractures filled by clear, medium to coarsely crystalline euhedral to subhedral dolomite.

DEPOSITIONAL AND DIAGENETIC ENVIRONMENT: Relatively high biotic content suggests more normal marine subtidal marine environment than previously encountered in the section, perhaps lagoonal or open marine shelfal carbonate environment. Replacement dolomitization by freshwater mixing with marine water in the shallow subsurface.

Possibly open lagoonal or subtidal shelf environment.

SANDSTONE REPORT SHEET

SAMPLE NUMBER: QCA-8

FORMATION: Sandy Member of Sevy Dolomite

AGE: Lower to Middle Devonian

LOCATION: T3N, R56E, Quinn Canyon Range.

STRATIGRAPHIC POSITION: Section QCA, 355 meters (1185 feet)

NAME: Dolomite-cemented quartz arenite

MACROSCOPIC DESCRIPTION: Massive sandstone with some minor cross-bedding, tan sandstone.

MICROSCOPIC DESCRIPTION: Dolomite-cemented, moderately sorted, subrounded, fine to medium sand-sized, quartz sandstone.

FRAMEWORK: 85%

GRAIN SIZE: Fine to medium sand.

ROUNDING: Subrounded to well-rounded.

SORTING: Moderately to well-sorted.

TEXTURAL MATURITY: Submature because of rounding and sorting and lack of clay matrix.

MINERALOGY: 100% monocrystalline quartz sand. Some grains contain heavy mineral inclusions.

COMPOSITIONAL MATURITY: Supermature because framework mineralogy is of 100 percent quartz.

MATRIX: 15%

CEMENT: Finely crystalline, anhedral to subhedral, cloudy dolomite rhombs.

POROSITY: 0%

PROVENANCE: Low-relief, highly physically and chemically weathered, craton-derived sandstone.

DEPOSITIONAL AND DIAGENETIC ENVIRONMENT: Beach or Barrier-bar environment. Sedimentary structures include minor low-angle cross-stratification. Clasts are well-rounded but are most likely recycled from older cratonic quartz sandstone.

DIAGENESIS: Dolomite suggests shallow deposition of calcite-cemented sandstone. Replacement dolomitization in the freshwater and marine water mixing zone in the shallow subsurface to a dolomite-cemented sandstone. Original pore-filling cement could have been dolomite.

CARBONATE REPORT SHEET

SAMPLE NUMBER: QCA-9

NAME OF FORMATION: Lower Alternating Member of Simonson Dolomite

AGE: *serotinus* Zone to *costatus* Zone, Emsian to Eifelian Stage, Lower to Middle Devonian (conodont)

LOCATION: T3N, R56E, Quinn Canyon Range.

STRATIGRAPHIC POSITION: Section QCA, 367 meters (1225 feet)

CLASSIFICATION (FOLK): Dolosparite

(DUNHAM): Dolomitized mudstone

MACROSCOPIC DESCRIPTION: Black to dark gray, medium crystalline, laminated dolomite.

MICROSCOPIC DESCRIPTION: Cloudy mudstone with some quartz sand and fossils.

TEXTURE: Brecciated, fractured, dolomitized.

ALLOCHEMS: 8% (3% fine to medium sand-sized, rounded monocrystalline quartz grains).

BIOTICS: 5% molds of small brachiopods, ostracods, or gastropods filled with clear, medium to coarsely crystalline, subhedral to euhedral dolomite rhombs.

INTRACLASTS: 0% (Much brecciation but little offset of breccia clasts, therefore these were not characterized as intraclasts).

OOLITES: 0%

PELOIDS: 0%

ORTHOCHEMS: 92%

CEMENT: Micrite that is now cloudy, finely to medium crystalline, anhedral dolomite. Fossil molds are now filled with clear, medium crystalline dolomite.

(continued on next page)

DEPOSITIONAL AND DIAGENETIC ENVIRONMENT: Probably micrite originating in lagoonal or subtidal carbonate shelf or platform environment, followed by early dolomitization and brecciation. Alternately, possibly carbonate tidal-flat environment with storm-surge introduced fossil fragments and quartz sand. Replacement dolomitization by freshwater mixing with saline water in the shallow subsurface.

Probably lagoonal or carbonate subtidal shelf or platform environment.

CARBONATE REPORT SHEET

SAMPLE NUMBER: QCA-10

NAME OF FORMATION: Lower Alternating Member of Simonson Dolomite

AGE: Middle Devonian

LOCATION: T3N, R56E, Quinn Canyon Range.

STRATIGRAPHIC POSITION: Section QCA, 425 meters (1415 feet)

CLASSIFICATION (FOLK): Dolosparite

(DUNHAM): Laminated dolomitized mudstone

MACROSCOPIC DESCRIPTION: Black to dark gray, medium crystalline, laminated dolomite.

MICROSCOPIC DESCRIPTION: Finely to coarsely crystalline, cloudy to clear, anhedral to euhedral dolomite.

TEXTURE: Dolomitized, laminated

ALLOCHEMS: 0%

BIOTICS: 0%

INTRACLASTS: 0%

OOLITES: 0%

PELOIDS: 0%

ORTHOCHEMS: 100%

CEMENT: 85% Cloudy, finely to medium crystalline, anhedral to subhedral dolomite. 15% Clear, finely to coarsely crystalline, euhedral to subhedral dolomite filling secondary tectonic fractures.

DEPOSITIONAL AND DIAGENETIC ENVIRONMENT: Probably alternating layers of laminated organic-rich and organic-poor micrite in a restricted lagoonal or subtidal carbonate platform environment that was later dolomitized. Replacement dolomitization by freshwater mixing with saline water in the shallow subsurface.

Probably restricted lagoonal or subtidal carbonate shelfal or platform environment.

APPENDIX V

CARBONATE REPORT SHEET

SAMPLE NUMBER: RRB-1
NAME OF FORMATION: Lone Mountain Dolomite
AGE: Lower Devonian (conodont)
LOCATION: T2N, R51.5E, Reveille Range.
STRATIGRAPHIC POSITION: Section RRB, 0 meters (0 feet)
CLASSIFICATION (FOLK): Dolosparite
(DUNHAM): Dolomitized mudstone
MACROSCOPIC DESCRIPTION: Light gray, medium bedded, medium crystalline dolomite.

MICROSCOPIC DESCRIPTION: Cloudy, anhedral, finely to medium crystalline dolomite with clear, subhedral, medium to coarsely crystalline dolomite filling fractures.

TEXTURE: Porphyroid
ALLOCHEMS: 0%
BIOTICS: 0%
INTRACLASTS: 0%
OOLITES: 0%
PELOIDS: 0%
ORTHOCHEMS: 100%
CEMENT: Cloudy, finely to medium crystalline, anhedral to subhedral dolomite with cloudy, subhedral, medium to coarsely crystalline dolomite as secondary tectonic fracture fill.

DEPOSITIONAL AND DIAGENETIC ENVIRONMENT: Probably dolomitized micrite deposited in a carbonate tidal-flat or restricted lagoonal environment with early fracturing and dolomitization. Replacement dolomitization by freshwater mixing with saline water in the shallow subsurface.

Probably carbonate tidal-flat or lagoonal environment.

CARBONATE REPORT SHEET

SAMPLE NUMBER: RRB-2

NAME OF FORMATION: Lone Mountain Dolomite

AGE: Lower Devonian

LOCATION: T2N, R51.5E, Reveille Range.

STRATIGRAPHIC POSITION: Section RRB, 5 meters (16 feet)

CLASSIFICATION (FOLK): Dolosparite (dolopseudospar)

(DUNHAM): Dolomitized mudstone

MACROSCOPIC DESCRIPTION: Light gray, medium-bedded, medium crystalline dolomite.

MICROSCOPIC DESCRIPTION: Cloudy, finely crystalline, anhedral dolomite with clear, coarsely to medium crystalline, euhedral to subhedral dolomite filling fractures

TEXTURE: Fractured, porphyroid mosaic of interlocking dolomite rhombs.

ALLOCHEMS: 0%

BIOTICS: 0%

INTRACLASTS: 0%

OOLITES: 0%

PELOIDS: 0%

ORTHOCHEMS: 100%

CEMENT: Cloudy, finely crystalline, anhedral dolomite as matrix with clear, medium to coarsely crystalline, euhedral to subhedral dolomite rhombs filling secondary tectonic fractures.

DEPOSITIONAL AND DIAGENETIC ENVIRONMENT: Possibly micrite originated as a carbonate intertidal or restricted lagoonal environment with early fractures and dolomitization. Replacement dolomitization by freshwater mixing with saline water in the shallow subsurface.

Probably carbonate intertidal or restricted lagoonal environment.

CARBONATE REPORT SHEET

SAMPLE NUMBER: RRB-3
NAME OF FORMATION: Lone Mountain Dolomite
AGE: Lower Devonian (conodont)
LOCATION: T2N, R51.5E, Reveille Range.
STRATIGRAPHIC POSITION: Section RRB, 5 meters (17 feet)
CLASSIFICATION (FOLK): Dolosparite
(DUNHAM): Dolomitized mudstone
MACROSCOPIC DESCRIPTION: Medium gray, medium-bedded, medium crystalline dolomite.

MICROSCOPIC DESCRIPTION: Cloudy, medium crystalline, anhedral to subhedral dolomite with clear, coarsely to medium crystalline, subhedral to euhedral dolomite filling fractures and pores (ghosts?)

TEXTURE: Porphyroid, fractured

ALLOCHEMS: 10%

BIOTICS: 10% enlarged molds of unidentifiable origin or affinity. Clear, medium to coarsely crystalline, subhedral to euhedral dolomite filling molds.

INTRACLASTS: 0%

OOLITES: 0%

PELOIDS: 0%

ORTHOCHEMS: 90%

CEMENT: Matrix is cloudy, medium crystalline, anhedral to subhedral dolomite. Secondary tectonic fractures are filled with clear, medium to coarsely crystalline, subhedral to euhedral dolomite.

DEPOSITIONAL AND DIAGENETIC ENVIRONMENT: Possibly micrite origin suggests a carbonate tidal-flat or restricted lagoonal environment with early secondary dolomitization and tectonic fracturing. Replacement dolomitization by freshwater mixing with saline water in the shallow subsurface.

Possibly carbonate tidal-flat or restricted lagoonal environment.

CARBONATE REPORT SHEET

SAMPLE NUMBER: RRB-4
NAME OF FORMATION: Lone Mountain Dolomite
AGE: Lower Devonian (conodont)
LOCATION: T2N, R51.5E, Reveille Range.
STRATIGRAPHIC POSITION: Section RRB, 70 meters (233 feet)
CLASSIFICATION (FOLK): Dolopelsparite
(DUNHAM): Dolomitized peloidal mudstone
MACROSCOPIC DESCRIPTION: Fossiliferous, medium gray, medium bedded, medium crystalline dolomite.

MICROSCOPIC DESCRIPTION:
TEXTURE: Porphyroid
ALLOCHEMS: 55% (5% fine sand-sized, subrounded quartz grains).
BIOTICS:
INTRACLASTS:
OOLITES:
PELOIDS: 50% Finely crystalline to microcrystalline, anhedral, cloudy dolomite. Elliptical in shape and moderately well sorted

ORTHOCHEMS: 45%
CEMENT: Cloudy, medium crystalline, subhedral dolomite.

DEPOSITIONAL AND DIAGENETIC ENVIRONMENT: Possibly micrite origin with wind blown quartz sand or movement by tidal currents. Lagoonal restricted with peloids or possible carbonate tidal-flat environment that was micritized and dolomitized. Replacement dolomitization by freshwater mixing with saline water in the shallow subsurface.

Possibly carbonate tidal-flat or restricted lagoonal environment.

CARBONATE REPORT SHEET

SAMPLE NUMBER: RRB-5
NAME OF FORMATION: Lone Mountain Dolomite
AGE: Lower Devonian (conodont)
LOCATION: T2N, R51.5E, Reveille Range.
STRATIGRAPHIC POSITION: Section RRB, 71 meters (235 feet)
CLASSIFICATION (FOLK): Dolopelsparite
(DUNHAM): Dolomitized mudstone
MACROSCOPIC DESCRIPTION: Fossiliferous, medium gray, medium-bedded, medium crystalline dolomite.

MICROSCOPIC DESCRIPTION:

TEXTURE:

ALLOCHEMS: 40%

BIOTICS: 5% Brachiopod? shell fragments filled with clear, medium crystalline, subhedral dolomite.

INTRACLASTS: 0%
OOLITES: 0%
PELOIDS: 35% Finely crystalline to microcrystalline, anhedral, cloudy dolomite in peloidal shape (elliptical). Peloids are fine to medium sand-sized, well rounded, and moderately well sorted.

ORTHOCHEMS: 60%

CEMENT: Medium crystalline, anhedral, cloudy dolomite rhombs.

DEPOSITIONAL AND DIAGENETIC ENVIRONMENT: Possibly mudstone origin that has been dolomitized. Carbonate tidal-flat or restricted lagoonal with transported fossil fragments representing more normal subtidal marine conditions. Replacement dolomitization by freshwater mixing with saline water in the shallow subsurface.

Possibly carbonate tidal-flat or restricted low-energy lagoonal environment.

APPENDIX VI

CARBONATE REPORT SHEET

SAMPLE NUMBER: RRA-1
NAME OF FORMATION: Sevy Dolomite
AGE: *kindlei* Zone, Pragian Stage, Lower Devonian (conodont)
LOCATION: T2N, R51.5E, Reveille Range.
STRATIGRAPHIC POSITION: Section RRA, 0 meters (0 feet)
CLASSIFICATION (FOLK): Brecciated dolosparite
(DUNHAM): Dolomitized brecciated mudstone
MACROSCOPIC DESCRIPTION: Fossiliferous, gray, finely crystalline, medium bedded dolomite.

MICROSCOPIC DESCRIPTION:

TEXTURE: Brecciated and fractured

ALLOCHEMS: 20%

BIOTICS: 5% Molds of crinoid and unidentifiable fossil fragments filled with clear, medium crystalline, subhedral dolomite rhombs.

INTRACLASTS: 0%

OOLITES: 0%

PELOIDS: 15% Finely crystalline to microcrystalline, cloudy, anhedral dolomite in peloid-form. Peloids are fine to medium sand-sized, well rounded, and moderately well sorted.

ORTHOCHEMS: 80%

CEMENT: Matrix is medium crystalline, cloudy, anhedral to subhedral dolomite with clear, coarsely crystalline, euhedral to subhedral dolomite as fracture fill.

DEPOSITIONAL AND DIAGENETIC ENVIRONMENT: Possibly mudstone origin suggesting a low energy carbonate platform, subtidal normal marine (crinoids) environment. Replacement dolomitization by freshwater mixing with saline water in the shallow subsurface.

<u>Possibly carbonate subtidal or lagoonal environment.</u>

CARBONATE REPORT SHEET

SAMPLE NUMBER: RRA-2
NAME OF FORMATION: Sevy Dolomite
AGE: *kindlei* Zone, Pragian Stage, Lower Devonian (conodont)
LOCATION: T2N, R51.5E, Reveille Range.
STRATIGRAPHIC POSITION: Section RRA, 29 meters (95 feet)
CLASSIFICATION (FOLK): Dolosparite
(DUNHAM): Dolomitized mudstone
MACROSCOPIC DESCRIPTION: Medium gray, finely crystalline, medium bedded dolomite.

MICROSCOPIC DESCRIPTION:
TEXTURE: Porphyroid, brecciated?, and fractured
ALLOCHEMS: 15%
BIOTICS: 0%
INTRACLASTS: 0%
OOLITES: 0%
PELOIDS: 15% Finely crystalline to microcrystalline, cloudy, anhedral dolomite in elliptical masses. Peloids are fine to medium sand-sized, well rounded, and moderately well sorted.
ORTHOCHEMS: 85%
CEMENT: Cloudy, medium crystalline, anhedral dolomite with two sets of fractures. Large fractures are filled with clear, coarsely crystalline, euhedral to subhedral dolomite. These are crosscut by fractures filled with medium crystalline, clear, subhedral dolomite.

DEPOSITIONAL AND DIAGENETIC ENVIRONMENT: Possibly mudstone origin from restricted subtidal to intertidal or low-energy lagoonal environment. Replacement dolomitization by freshwater mixing with saline water in the shallow subsurface.

Possibly restricted subtidal to intertidal or low-energy lagoonal environment.

CARBONATE REPORT SHEET

SAMPLE NUMBER: RRA-3

NAME OF FORMATION: Sevy Dolomite

AGE: Lower Devonian

LOCATION: T2N, R51.5E, Reveille Range.

STRATIGRAPHIC POSITION: Section RRA, 43 meters (145 feet)

CLASSIFICATION (FOLK): Dolosparite

(DUNHAM): Dolomitized mudstone

MACROSCOPIC DESCRIPTION: Dark gray to black, medium to coarsely crystalline, medium-bedded dolomite.

MICROSCOPIC DESCRIPTION:

TEXTURE: Fractured

ALLOCHEMS: 20%

BIOTICS: 0%

INTRACLASTS: 0%

OOLITES: 0%

PELOIDS: 20% Cloudy, finely crystalline to microcrystalline, anhedral dolomite in elliptical masses. Peloids are fine to medium sand-sized, well rounded, and moderately well sorted.

ORTHOCHEMS: 80%

CEMENT: Medium crystalline, anhedral to subhedral, cloudy dolomite with two sets of fractures. Secondary tectonic fractures filled with clear, medium crystalline, euhedral to subhedral dolomite.

DEPOSITIONAL AND DIAGENETIC ENVIRONMENT: Possibly mudstone origin from restricted carbonate subtidal or low-energy lagoonal environment. Replacement dolomitization by freshwater mixing with saline water in the shallow subsurface.

Possibly restricted carbonate subtidal or low-energy lagoonal environment.

CARBONATE REPORT SHEET

SAMPLE NUMBER: RRA-4
NAME OF FORMATION: Sevy Dolomite
AGE: Lower Devonian
LOCATION: T2N, R51.5E, Reveille Range.
STRATIGRAPHIC POSITION: Section RRA, 43 meters (143 feet)
CLASSIFICATION (FOLK): Dolosparite
(DUNHAM): Dolomitized mudstone
MACROSCOPIC DESCRIPTION: Gray weathering, dark gray, finely crystalline, medium-bedded dolomite.

MICROSCOPIC DESCRIPTION:
TEXTURE:
ALLOCHEMS: 0%
BIOTICS: 0%
INTRACLASTS: 0%
OOLITES: 0%
PELOIDS: 0%
ORTHOCHEMS: 100%
CEMENT: Finely to medium crystalline, anhedral to subhedral, cloudy dolomite with at least 3 sets of secondary tectonic fractures. Fractures filled with clear, medium to coarsely crystalline, euhedral to subhedral, sucrosic dolomite.

DEPOSITIONAL AND DIAGENETIC ENVIRONMENT: Possibly mudstone origin from a carbonate tidal-flat or restricted lagoonal environment. Replacement dolomitization by freshwater mixing with saline water in the shallow subsurface.

Possibly carbonate tidal-flat or restricted lagoonal environment.

CARBONATE REPORT SHEET

SAMPLE NUMBER: RRA-5

NAME OF FORMATION: Sadler Ranch Formation

AGE: *partitus* Zone, Emsian to Eifelian Stage, Lower to Middle Devonian (conodont)

LOCATION: T2N, R51.5E, Reveille Range.

STRATIGRAPHIC POSITION: Section RRA, 48 meters (160 feet)

CLASSIFICATION (FOLK): Crinoidal biodolosparite

(DUNHAM): Dolomitized crinoidal wackestone

MACROSCOPIC DESCRIPTION: Finely to medium crystalline, black, medium-bedded, fossiliferous dolomite.

MICROSCOPIC DESCRIPTION:

TEXTURE: Fractured and dolomitized

ALLOCHEMS: 25% (5% fine sand-sized, subrounded monocrystalline quartz grains).

BIOTICS: 20% Mostly crinoid fragments, some brachiopod and unidentifiable fossil fragments. Crinoid ossicles are 2-hole and 1-hole, replaced by medium crystalline, subhedral to euhedral, clear dolomite.

INTRACLASTS: 0%

OOLITES: 0%

PELOIDS: 0%

ORTHOCHEMS: 75%

CEMENT: Cloudy, microcrystalline to medium crystalline, anhedral dolomite.

DEPOSITIONAL AND DIAGENETIC ENVIRONMENT: Biotic fragments are matrix supported suggesting bioturbation in the normal marine subtidal carbonate platform environment. Replacement dolomitization by freshwater mixing with saline water in the shallow subsurface. Environment was still quite shallow to be dolomitized.

<u>Possibly subtidal normal marine carbonate platform or upper slope environment.</u>

CARBONATE REPORT SHEET

SAMPLE NUMBER: RRA-6

NAME OF FORMATION: Sadler Ranch Formation

AGE: *costatus* Zone, Eifelian Stage, Middle Devonian (conodont)

LOCATION: T2N, R51.5E, Reveille Range.

STRATIGRAPHIC POSITION: Section RRA, 49 meters (165 feet)

CLASSIFICATION (FOLK): Crinoidal biodolosparite

(DUNHAM): Dolomitized crinoidal wackestone

MACROSCOPIC DESCRIPTION: Finely to medium crystalline, black, medium-bedded, fossiliferous dolomite.

MICROSCOPIC DESCRIPTION:

TEXTURE: Dolomitized and fractured.

ALLOCHEMS: 60% (3-5% fine sand-sized, subangular quartz grains).

BIOTICS: 55-57% Biotics are mostly 2-hole crinoid ossicles with some brachiopod and unidentifiable fossil fragments, perhaps sponge spicules or brachiopod spines. These enlarged fossil molds have been filled with clear, medium crystalline, subhedral dolomite rhombs.

INTRACLASTS: 0%

OOLITES: 0%

PELOIDS: 0%

ORTHOCHEMS: 40%

CEMENT: Finely to medium crystalline, cloudy, anhedral dolomite. Secondary tectonic fractures are filled with clear, finely to coarsely crystalline, subhedral dolomite.

DEPOSITIONAL AND DIAGENETIC ENVIRONMENT: Matrix support suggests bioturbation. Relatively shallow to allow replacement dolomitization. Replacement dolomitization by freshwater mixing with saline water in the shallow subsurface.

Possibly transitional deposit on carbonate platform to carbonate slope environment.

CARBONATE REPORT SHEET

SAMPLE NUMBER: RRA-7
NAME OF FORMATION: Sadler Ranch Formation
AGE: *costatus* Zone, Eifelian Stage, Middle Devonian (conodont)
LOCATION: T2N, R51.5E, Reveille Range.
STRATIGRAPHIC POSITION: Section RRA, 59 meters (195 feet)
CLASSIFICATION (FOLK): Crinoidal biodolosparite
(DUNHAM): Dolomitized crinoidal wackestone
MACROSCOPIC DESCRIPTION: Black, massive to thickly bedded, medium crystalline, fossiliferous dolomite.

MICROSCOPIC DESCRIPTION: Cloudy, anhedral, finely to medium crystalline dolomite.

TEXTURE: Fractured, dolomitized, homogenized
ALLOCHEMS: 17% (2% Silt to fine sand-sized, subangular to subrounded quartz grains).
BIOTICS: 15% Molds of crinoid ossicles and brachiopod fragments have been filled with clear, finely to medium crystalline, subhedral dolomite rhombs.

INTRACLASTS: 0%
OOLITES: 0%
PELOIDS: 0%
ORTHOCHEMS: 83%
CEMENT: 78% Cloudy, anhedral, finely to medium crystalline dolomite and 5% anhedral to subhedral quartz filling secondary tectonic fractures.
DEPOSITIONAL AND DIAGENETIC ENVIRONMENT: Homogenization of ossicles and quartz suggests bioturbation or less likely allodapic deposition. Replacement dolomitization by freshwater mixing with saline water in the shallow subsurface.

Possibly bioturbated, carbonate shelf-edge and slope deposit (allodapic?).

CARBONATE REPORT SHEET

SAMPLE NUMBER: RRA-8

NAME OF FORMATION: Sadler Ranch Formation

AGE: Middle Devonian

LOCATION: T2N, R51.5E, Reveille Range.

STRATIGRAPHIC POSITION: Section RRA, 73 meters (245 feet)

CLASSIFICATION (FOLK): Dolomicrite

(DUNHAM): Dolomitized mudstone

MACROSCOPIC DESCRIPTION: Black, medium crystalline, massive to thickly bedded dolomite.

MICROSCOPIC DESCRIPTION: Cloudy, anhedral, finely crystalline dolomite

TEXTURE: Fractured, dolomitized, stylolites

ALLOCHEMS: 0%

BIOTICS: 0%

INTRACLASTS: 0%

OOLITES: 0%

PELOIDS: 0%

ORTHOCHEMS: 100%

CEMENT: 10% Clear, finely crystalline, anhedral to subhedral dolomite filling secondary tectonic fractures and 90% cloudy, microcrystalline to finely crystalline, anhedral dolomite.

DEPOSITIONAL AND DIAGENETIC ENVIRONMENT: Possibly micrite origin carbonate slope or subtidal carbonate platform environment. Environment must have been deep (quiet) enough for micrite deposition, but shallow enough for secondary dolomitization. Replacement dolomitization by freshwater mixing with saline water in the shallow subsurface.

Near carbonate shelf-slope break in subtidal carbonate platform or carbonate slope environment.

CARBONATE REPORT SHEET

SAMPLE NUMBER: RRA-9
NAME OF FORMATION: Lower Member of Denay Limestone
AGE: *australis* Zone, Eifelian Stage, Middle Devonian (conodont)
LOCATION: T2N, R51.5E, Reveille Range.
STRATIGRAPHIC POSITION: Section RRA, 77 meters (255 feet)
CLASSIFICATION (FOLK): Silty micrite
(DUNHAM): Silty mudstone
MACROSCOPIC DESCRIPTION: Light gray, thin bedded, finely crystalline limestone.

MICROSCOPIC DESCRIPTION: Microcrystalline, silty, laminated limestone.

TEXTURE: Laminated, fractured, homogenized, stylolites.
ALLOCHEMS: 8% (7% Silt-sized, angular quartz grains).
BIOTICS: 1% Unidentifiable biotic fragments (conodonts? or tentaculites?).

INTRACLASTS: 0%
OOLITES: 0%
PELOIDS: 0%
ORTHOCHEMS: 92%
CEMENT: 3% Clear, finely crystalline, anhedral to subhedral calcite filling secondary tectonic fractures and 89% cloudy, microcrystalline to finely crystalline, anhedral calcite.

DEPOSITIONAL AND DIAGENETIC ENVIRONMENT: Rapid deposited in the non-bioturbated, restricted, outer-shelf basin (allodapic?). Deposits with floating quartz silt and laminations preserved. Deeper water to prevent shallow subsurface replacement dolomitization. Pressure solution in the subsurface to dissolve carbonate along the stylolite and concentrate clay minerals.

Probably outer-shelf deposited (allodapic?) basinal limestone.

CARBONATE REPORT SHEET

SAMPLE NUMBER: RRA-10
NAME OF FORMATION: Lower Member of Denay Limestone
AGE: Middle Devonian
LOCATION: T2N, R51.5E, Reveille Range.
STRATIGRAPHIC POSITION: Section RRA, 104 meters (348 feet)
CLASSIFICATION (FOLK): Silty micrite
(DUNHAM): Silty mudstone
MACROSCOPIC DESCRIPTION: Gray, medium bedded, finely crystalline limestone.

MICROSCOPIC DESCRIPTION: Silty, faintly laminated limestone
TEXTURE: Highly fractured, homogenized, slightly laminated
ALLOCHEMS: 5% (3% Silt-sized, angular, quartz grains)
BIOTICS: 2% Burrows? of cloudy, microcrystalline, anhedral calcite. Calcispheres? and crinoid ossicles replaced by finely crystalline, anhedral, clear calcite.

INTRACLASTS: 0%
OOLITES: 0%
PELOIDS: 0%
ORTHOCHEMS: 95%
CEMENT: 20% Fracture-fill, clear, microcrystalline to finely crystalline, anhedral to subhedral sparry calcite and 75% anhedral, cloudy, microcrystalline calcite.

DEPOSITIONAL AND DIAGENETIC ENVIRONMENT: Floating silt and slightly laminated with only occasional burrows suggest deeper water (to preserve undolomitized limestone), rapid deposition to preserve limestone and laminations (allodapic?). Recrystallization in the subsurface to microcrystalline calcite from original micrite.

Probably outer-shelf basinal limestone (allodapic flow?).

CARBONATE REPORT SHEET

SAMPLE NUMBER: RRA-11

NAME OF FORMATION: Lower Member of Denay Limestone

AGE: *kockelianus* Zone, Eifelian Stage, Middle Devonian (conodont and brachiopod)

LOCATION: T2N, R51.5E, Reveille Range.

STRATIGRAPHIC POSITION: Section RRA, 119 meters (395 feet)

CLASSIFICATION (FOLK):

(DUNHAM):

MACROSCOPIC DESCRIPTION: Gray, thinly bedded, finely crystalline, fossiliferous limestone.

MICROSCOPIC DESCRIPTION: No thin-section for this sample

TEXTURE:

ALLOCHEMS:

BIOTICS:

INTRACLASTS:

OOLITES:

PELOIDS:

ORTHOCHEMS:

CEMENT:

DEPOSITIONAL AND DIAGENETIC ENVIRONMENT:

CARBONATE REPORT SHEET

SAMPLE NUMBER: RRA-12

NAME OF FORMATION: Lower Member of Denay Limestone

AGE: Middle Devonian

LOCATION: T2N, R51.5E, Reveille Range.

STRATIGRAPHIC POSITION: Section RRA, 145 meters (485 feet)

CLASSIFICATION (FOLK): Pelmicrite

(DUNHAM): Peloidal mudstone

MACROSCOPIC DESCRIPTION: Gray, thickly bedded, finely crystalline, cherty limestone.

MICROSCOPIC DESCRIPTION: Cloudy, laminated, slightly silty, limestone.

TEXTURE: Laminated, stylolites, fractured

ALLOCHEMS: 10% (2% Silt-sized, angular, quartz grains).

BIOTICS: 1% Calcispheres have been replaced by clear, anhedral, microspar calcite.

INTRACLASTS: 0%

OOLITES: 0%

PELOIDS: 7% Peloids in distinct layers (grain flow or commonly by marine tractive currents or storm surge events), microcrystalline, anhedral, cloudy limestone.

ORTHOCHEMS: 90%

CEMENT: 10% Clear, anhedral, microcrystalline to finely crystalline, sparry calcite filling secondary tectonic fractures and 80% cloudy, microcrystalline, anhedral micrite.

DEPOSITIONAL AND DIAGENETIC ENVIRONMENT: Preserved laminations, floating quartz grains, and an apparent lack of bioturbation suggest rapid deposition in restricted deeper water. Perhaps this is carbonate mud washed off the platform by dilute density currents or interflows. Deeper marine deposit also inhibits replacement dolomitization in the subsurface environment. Recrystallization in the subsurface to microcrystalline calcite from original micrite. Pressure solution in the subsurface to dissolve carbonate along the stylolite and concentrate clay minerals. Probably outer-shelf basinal limestone deposit.

CARBONATE REPORT SHEET

SAMPLE NUMBER: RRA-13

NAME OF FORMATION: Lower Member of Denay Limestone

AGE: *kockelianus* Zone, Eifelian Stage, Middle Devonian (conodont and brachiopod)

LOCATION: T2N, R51.5E, Reveille Range.

STRATIGRAPHIC POSITION: Section RRA, 173 meters (578 feet)

CLASSIFICATION (FOLK): Brachiopod biomicrite

(DUNHAM): Brachiopod packstone

MACROSCOPIC DESCRIPTION: Gray, finely bedded to laminated, finely crystalline, fossiliferous limestone.

MICROSCOPIC DESCRIPTION: Fossiliferous, silty, laminated, cloudy micrite.

TEXTURE: Laminated, stylolites, and fractured

ALLOCHEMS: 90% (5% Silt and fine sand-sized, angular quartz grains).

BIOTICS: 25% Fragments of brachiopod, ostracod, calcisphere, conodont and possibly gastropod. Some original calcite shell material present otherwise recrystallized to microcrystalline and finely crystalline, clear, sparry calcite.

INTRACLASTS: 60% (see below)

OOLITES:

PELOIDS: 60% Peloids that have been deformed by compaction. Cloudy, microcrystalline and finely crystalline, anhedral micrite in elliptical masses. Peloids are well rounded, fine to medium sand-sized, and moderately well sorted.

ORTHOCHEMS: 10%

CEMENT: 2% Clear, microcrystalline to finely crystalline, anhedral, sparry calcite filling secondary tectonic fractures and 8% cloudy, microcrystalline, anhedral calcite.

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DEPOSITIONAL AND DIAGENETIC ENVIRONMENT: Rapid deposition by marine tractive currents because of preserved lamination and bedding-parallel fossil fragments. Deep water deposit in order to prevent replacement dolomitization in the subsurface. Recrystallization in the subsurface to microcrystalline calcite from original micrite. Pressure solution in the subsurface to dissolve carbonate along the stylolite and concentrate clay minerals.

Probably outer-shelf-basin deposited limestone.

CARBONATE REPORT SHEET

SAMPLE NUMBER: RRA-14

NAME OF FORMATION: Lower Member of Denay Limestone

AGE: *Castanea* Zone, Eifelian to Givetian Stage, Middle Devonian (brachiopod)

LOCATION: T2N, R51.5E, Reveille Range.

STRATIGRAPHIC POSITION: Section RRA, 179 meters (595 feet)

CLASSIFICATION (FOLK): Biomicrite

(DUNHAM): Calcisphere mudstone

MACROSCOPIC DESCRIPTION: Light gray, medium bedded, finely crystalline, fossiliferous limestone.

MICROSCOPIC DESCRIPTION:

TEXTURE: Stylolites, laminated, and fractured

ALLOCHEMS: 5% (note lack of silt and fine sand-sized quartz grains compared to Denay samples).

BIOTICS: 5% Recrystallized and unaltered, silt-sized, spherical calcispheres.

INTRACLASTS: 0%

OOLITES: 0%

PELOIDS: 0%

ORTHOCHEMS: 95%

CEMENT: 15% Finely to medium crystalline, clear, anhedral to euhedral, calcite spar filling secondary tectonic fractures and 80% cloudy, microcrystalline, laminated, anhedral micrite.

DEPOSITIONAL AND DIAGENETIC ENVIRONMENT: Probably not an density current deposit due to lack of silt or platform allochems common in other Denay samples. Micrite and calcispheres settled out of suspension in an outer-shelf basin. Recrystallization in the subsurface to microcrystalline calcite from original micrite. Pressure solution in the subsurface to dissolve carbonate along the stylolite and concentrate clay minerals (not observed in thin section but in outcrop).

<u>Probably quiet-water, outer-shelf-basin deposit.</u>

CARBONATE REPORT SHEET

SAMPLE NUMBER: RRA-15

NAME OF FORMATION: Lower Member of Denay Limestone

AGE: Middle Devonian

LOCATION: T2N, R51.5E, Reveille Range.

STRATIGRAPHIC POSITION: Section RRA, 203 meters (675 feet)

CLASSIFICATION (FOLK): Intrabiomicrite

(DUNHAM): Bioclastic grainstone

MACROSCOPIC DESCRIPTION: Fossiliferous, gray, medium bedded, finely crystalline limestone.

MICROSCOPIC DESCRIPTION: Partially replaced by chalcedony, fossiliferous, cloudy, intraclast limestone.

TEXTURE: Grain-supported, massive, and slightly fractured.

ALLOCHEMS: 95% (1% Fine sand-sized, rounded, quartz grains).

BIOTICS: 50% Crinoid, brachiopod, and coral or bryozoan fragments. Most fragments are partially replaced by chalcedony.

INTRACLASTS: 15% Well-rounded, cloudy, anhedral micrite fragments and grapestone. Structureless, cloudy, microcrystalline limestone.

OOLITES: 0%

PELOIDS: 30% Peloids (or small, structureless intraclasts) of cloudy, anhedral, microcrystalline micrite.

ORTHOCHEMS: 5%

CEMENT: Microcrystalline to finely crystalline, clear to cloudy, anhedral calcite in fractures and between grains.

(continued on next page)

DEPOSITIONAL AND DIAGENETIC ENVIRONMENT: Probably density flows eroding the underlying shelf and slope deposit. Fragments are rounded and deposited downslope with micrite transported (winnowed) from the carbonate platform by "currents of removal." Deep water in order to prevent replacement dolomitization in the subsurface. Recrystallization in the subsurface to microcrystalline calcite from original micrite. Pressure solution in the subsurface to dissolve carbonate along the stylolite and concentrate clay minerals (not observed in thin section but in outcrop).

Probably outer-shelf-basin deposited allodapic grainstone.

CARBONATE REPORT SHEET

SAMPLE NUMBER: RRA-16
NAME OF FORMATION: Lower Member of Denay Limestone
AGE: Middle Devonian
LOCATION: T2N, R51.5E, Reveille Range.
STRATIGRAPHIC POSITION: Section RRA, 211 meters (703 feet)
CLASSIFICATION (FOLK): Dolomicrite
(DUNHAM): Dolomitized mudstone
MACROSCOPIC DESCRIPTION: Light gray, finely crystalline, massive to thickly bedded dolomite.

MICROSCOPIC DESCRIPTION: Silty, dolomitized, cloudy dolomite with microquartz veins.

TEXTURE: Fractured, dolomitized, homogenized, stylolites.
ALLOCHEMS: 5% Silt and fine sand-sized, angular to round quartz grains.

BIOTICS: 0%
INTRACLASTS: 0%
OOLITES: 0%
PELOIDS: 0%

ORTHOCHEMS: 95%

CEMENT: Finely crystalline, anhedral to subhedral, cloudy dolomite.

DEPOSITIONAL AND DIAGENETIC ENVIRONMENT: Probably micrite origin with floating quartz grains suggesting bioturbation (more likely) or rapid deposition (less likely). Deposition on the low energy, carbonate_platform shallow enough to allow secondary replacement dolomitization by freshwater and marine mixing in the shallow subsurface. Secondary microquartz veins cross-cut stylolites. Pressure solution in the subsurface to dissolve carbonate along the stylolite and concentrate clay minerals.

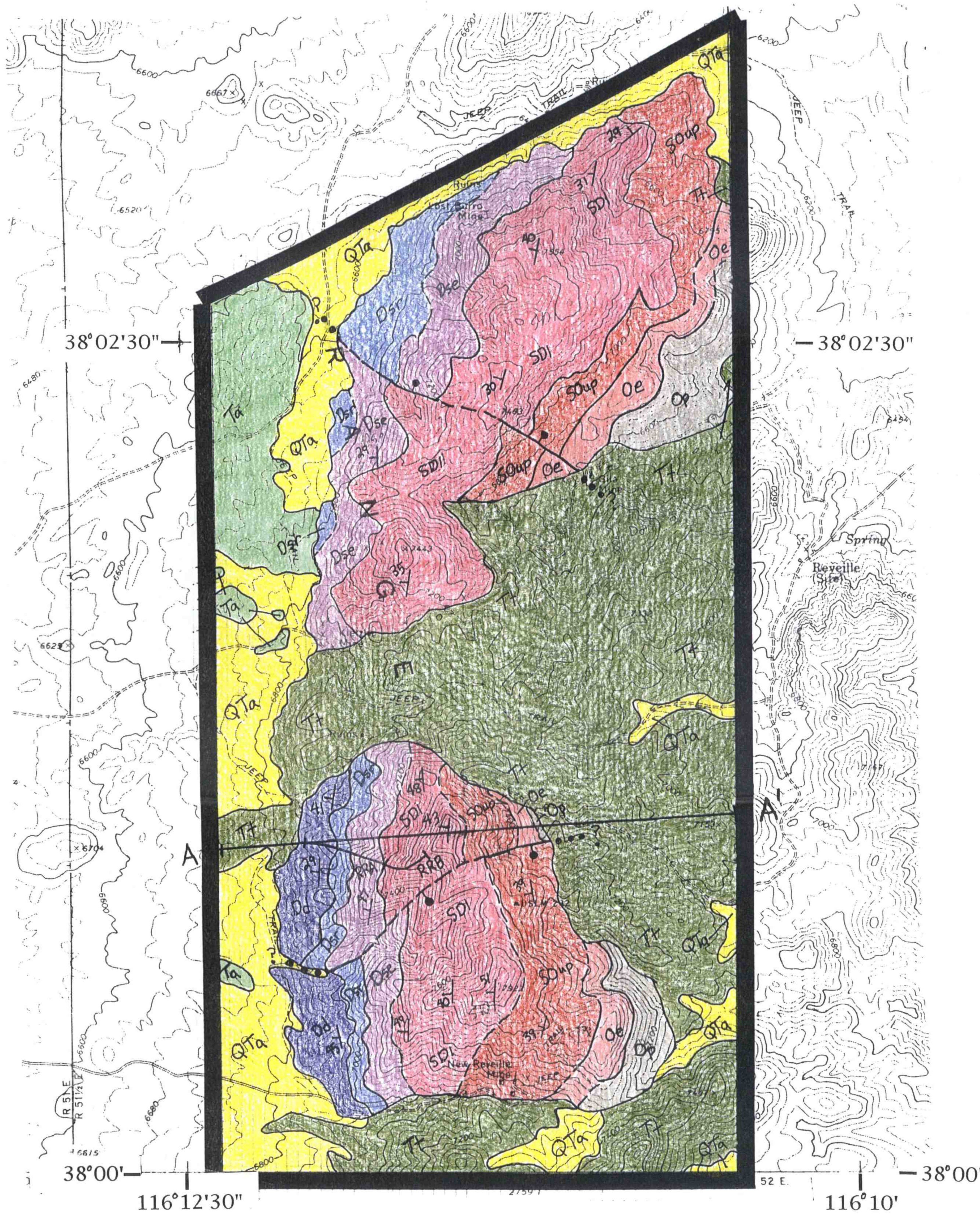
<u>Probably low energy, outer-platform limestone.</u>

Quaternary	Qa	Alluvium	*Tan gravel, sand, and silt*
Quaternary	Qc	Colluvium	*Tan gravel, sand, and silt*
Quaternary / Tertiary	QTa	Quaternary-Tertiary Undifferentiated Alluvium	*Tan gravel, sand, and silt (consolidated)*
		Unconformity	
Tertiary	Tt	Tuff and Ignimbrite	*Gray and pink tuff and ignimbrite*
Tertiary	Ta	Andesite	*Black to blue-gray andesite*
		Unconformity	
Lower to Middle Devonian	Dd	Denay Limestone	*Gray, fossiliferous limestone*
Lower to Middle Devonian	Dsr	Sadler Ranch Formation	*Dark gray to black dolomite*
Lower to Middle Devonian	Dsi	Simonson Dolomite	*Dark and light gray banded dolomite*
Lower to Middle Devonian	Dse	Sevy Dolomite	*Light gray, medium bedded dolomite*
Lower to Middle Devonian / Silurian	SDl	Silurian-Devonian Lone Mountain Dolomite	*Light gray, medium bedded dolomite*
Silurian	Sl	Silurian Laketown Dolomite	*Dark gray, medium bedded to massive dolomite*
Silurian / Ordovician	SOup	Silurian-Ordovician Upper Part Undifferentiated Dolomite	*Light gray, medium bedded dolomite*
Ordovician	Of	Fishaven Dolomite	*Light gray massive dolomite*
Ordovician	Oes	Ely Springs Dolomite	*Dark gray massive dolomite*
Ordovician	Oe	Eureka Quartzite	*Brown to yellow quartz arenite*
Ordovician	Op	Pogonip Group	*Gray limestone*

? · · · – – —	Contact, dashed where inferred, dotted where concealed, and querried where existence uncertain
? · · · – – —	Fault contact, dashed where inferred, dotted where concealed, and querried where existence uncertain
PRA	Measured section location
45	Strike and dip of bedding
	Normal fault (Ball on downthrown block)
	Thrust fault (Teeth on upper plate)

By Storr L. Nelson, June 1996

Plate 1- Explanation for Geologic Maps and Cross-sections of Lower and Middle Devonian strata and adjacent units, Reveille, Pancake, and Quinn Canyon ranges, Nye County, Nevada



Scale 1:24,000

1/2 1 mile

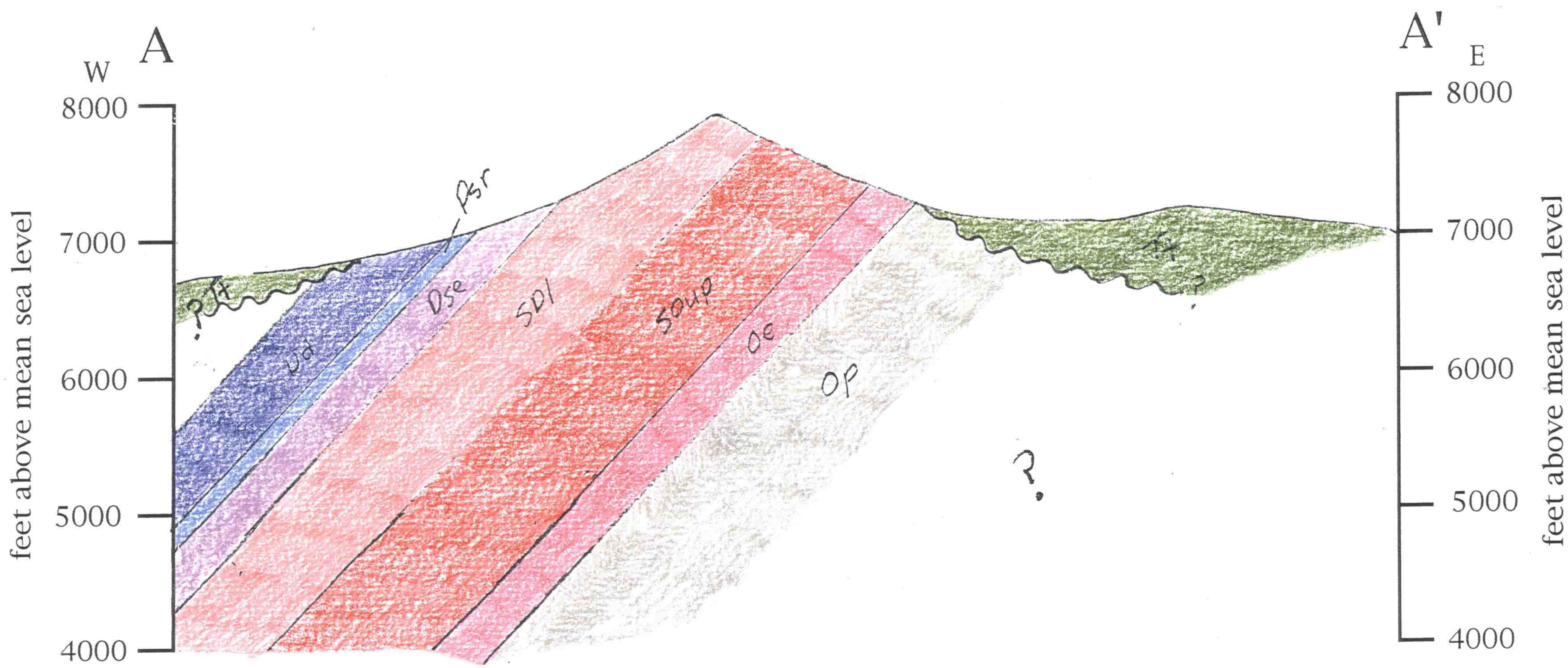
1/2 1 km

By Storr L. Nelson, June 1996

Base: Reveille Quadrangle, Nye County, Nevada
7.5 minute series (topographic)
contour interval 40 feet

N

Plate 2 - Geologic map of Lower to Middle Devonian strata and adjacent units, Reveille Range, Nye County, Nevada



Scale 1:12,000

No vertical exaggeration

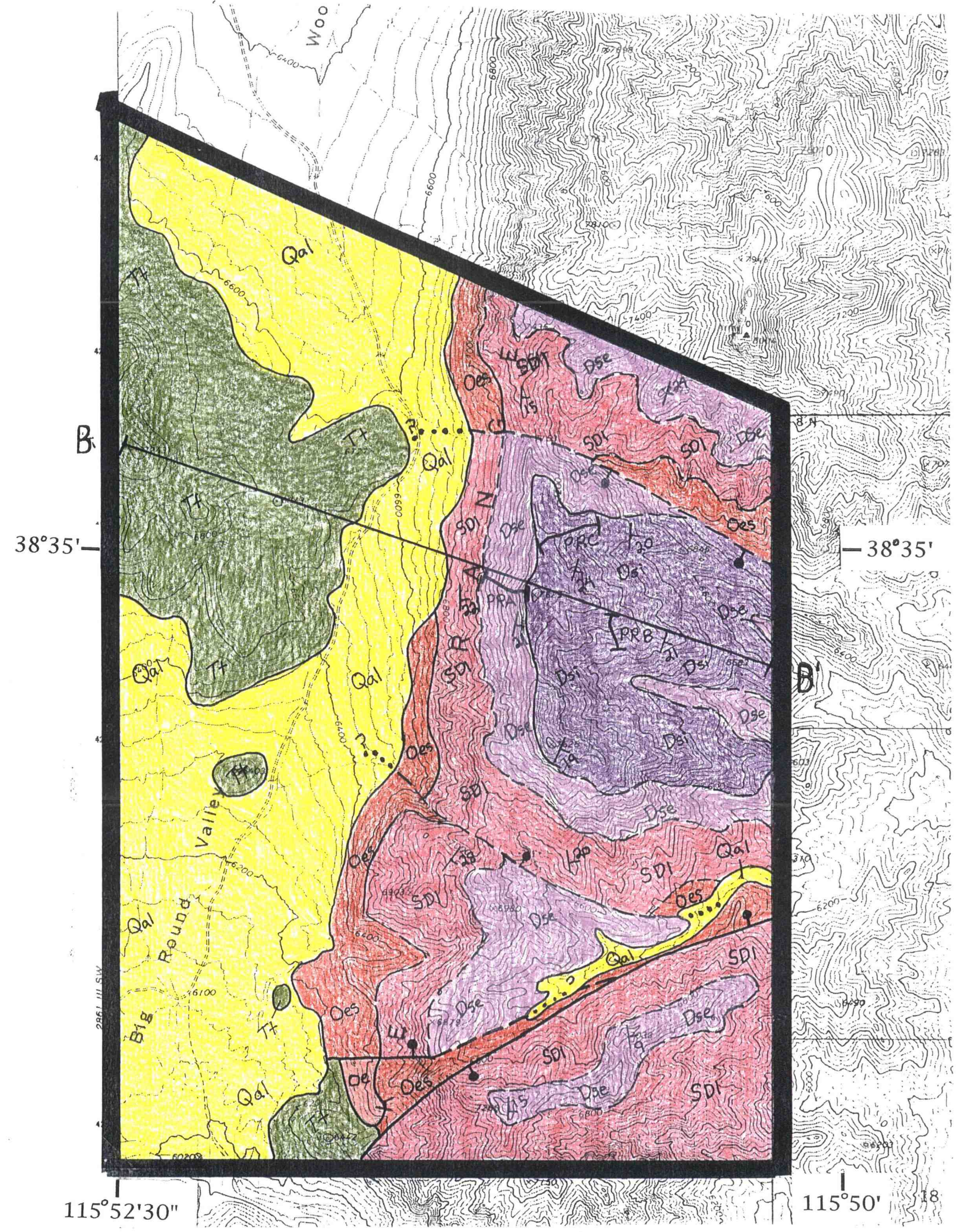
Drawn at 2X map scale

see: Plate 1 for explanation

Plate 2 for Geologic map

By Storr L. Nelson, June 1996

Plate 3 - Cross-section A-A' of Lower to Middle Devonian strata and adjacent units, Reveille Range, Nye County, Nevada



Scale 1:24,000

1/2 1 mile

1/2 1 km

By Storr L. Nelson, June 1996

Base: Lockes Quadrangle, Nye County, Nevada
7.5 minute series (topographic)
contour interval 40 feet

N

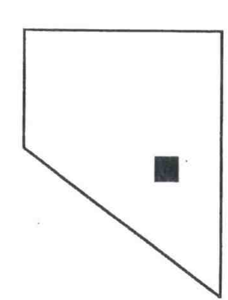
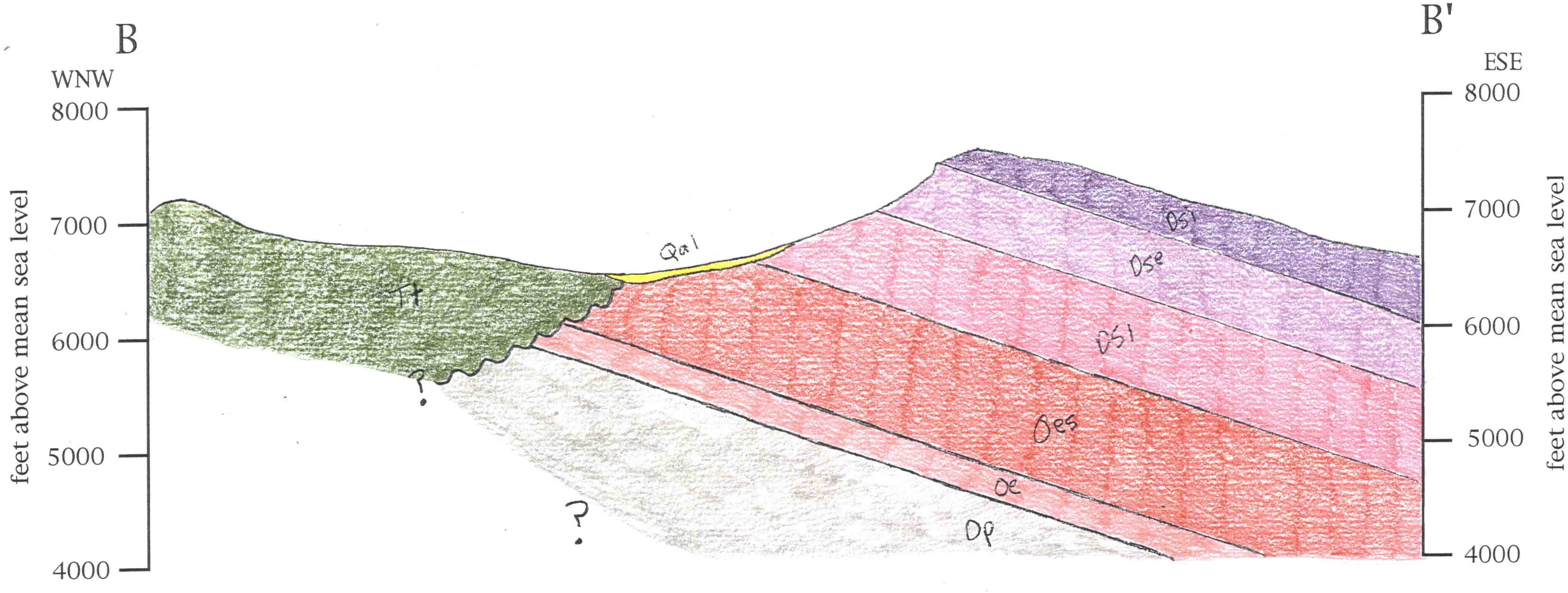


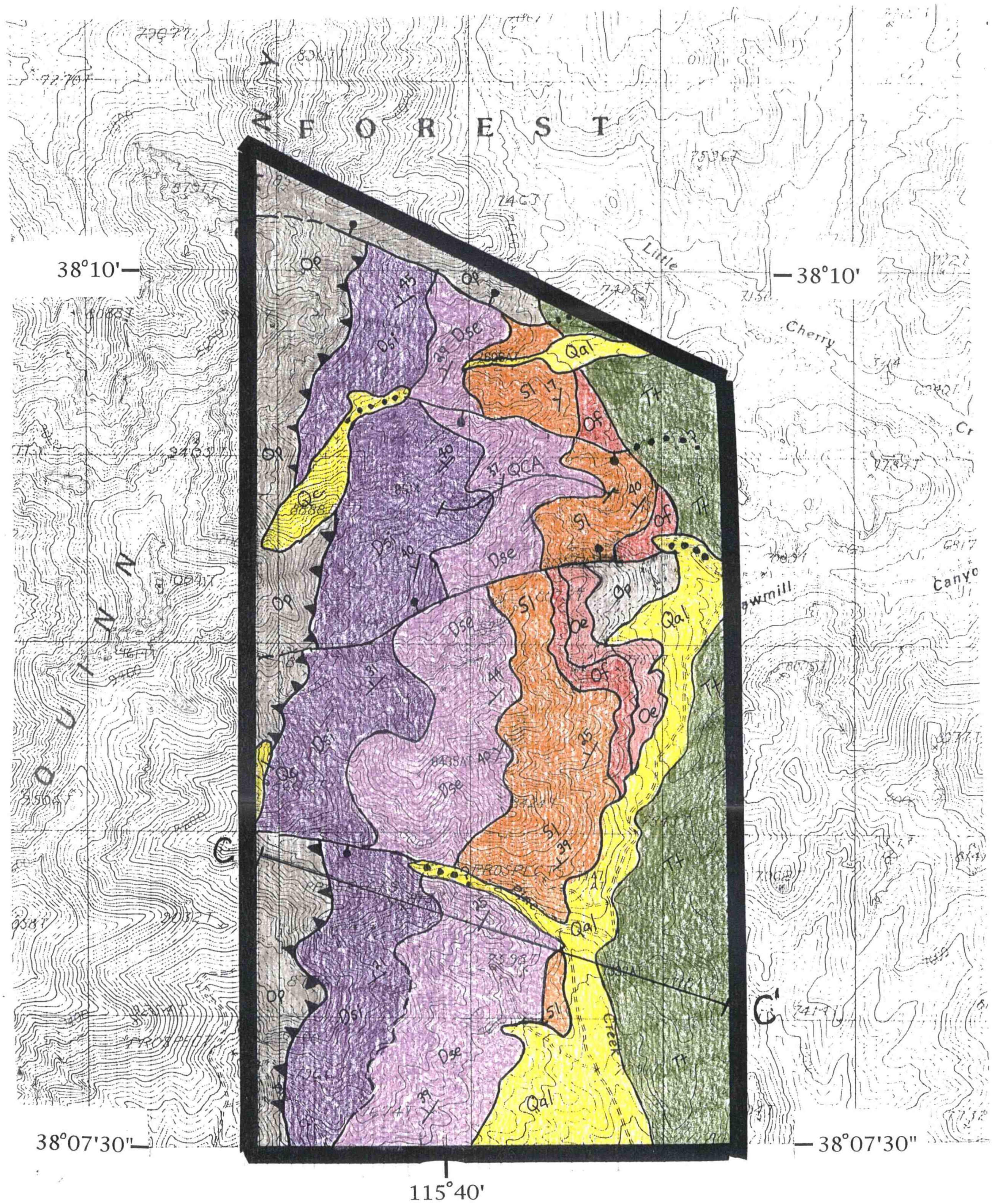
Plate 4 - Geologic map of Lower to Middle Devonian strata and adjacent units, Pancake Range, Nye County, Nevada



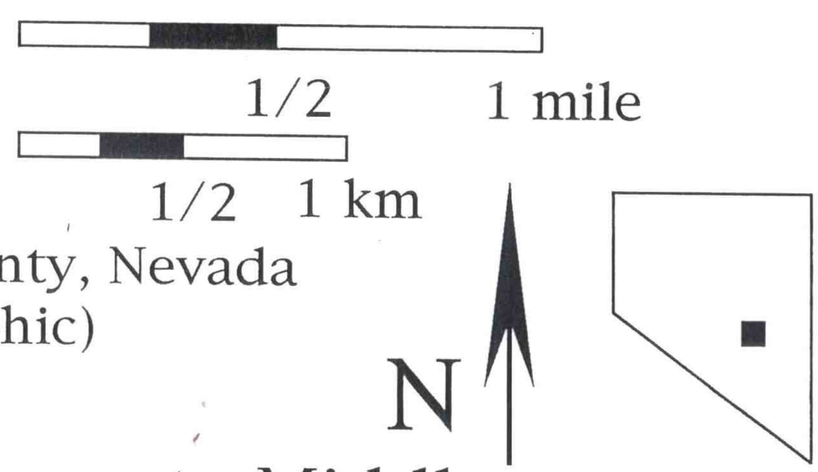
Scale 1:12,000
No vertical exaggeration
Drawn at 2X map scale
see: Plate 1 for explanation
Plate 4 for Geologic map

By Storr L. Nelson, June 1996

Plate 5 - Cross-section B-B' of Lower to Middle Devonian strata and adjacent units, Pancake Range, Nye County, Nevada



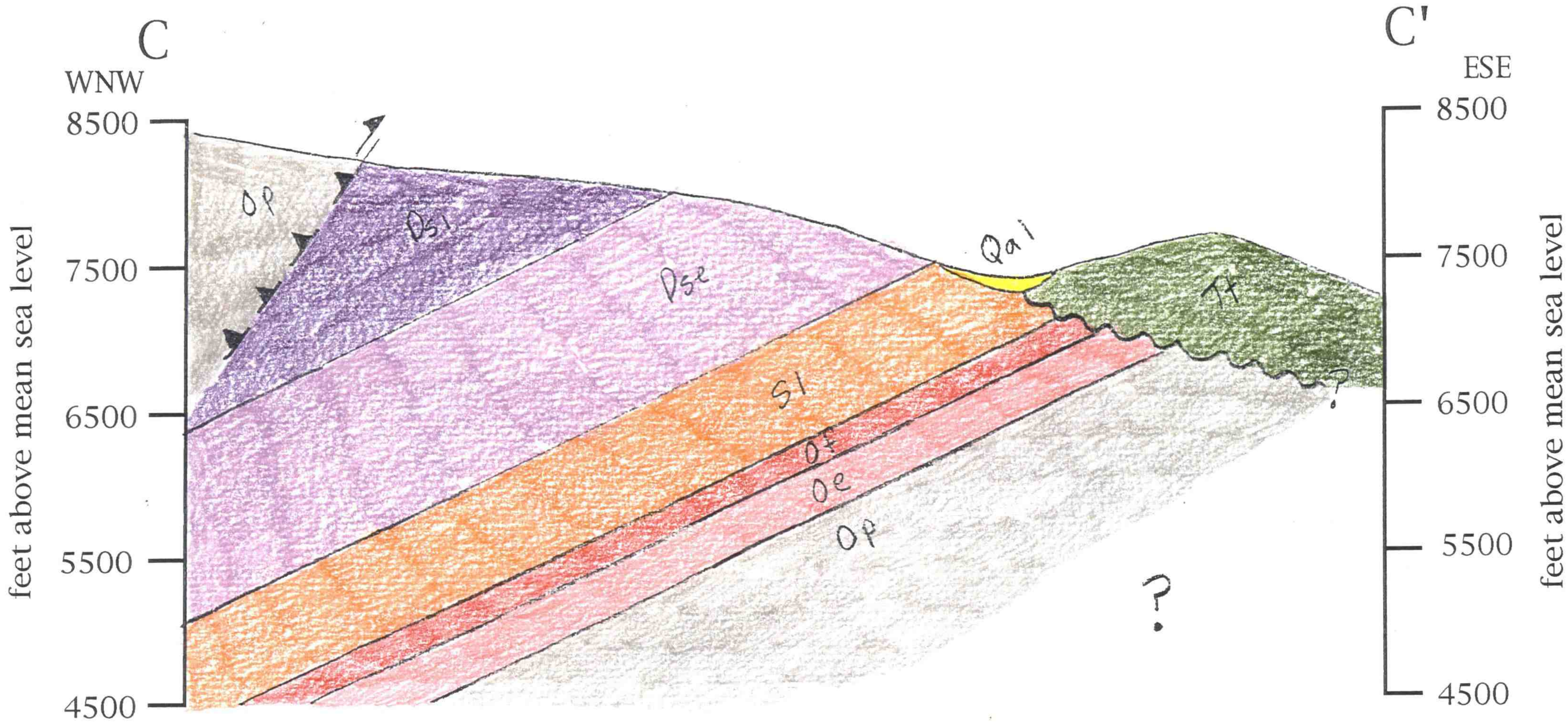
Scale 1:24,000



By Storr L. Nelson, June 1996

Base: Nyala Quadrangle, Nye County, Nevada
7.5 minute series (topographic)
contour interval 40 feet

Plate 6 -Geologic map of Lower to Middle Devonian strata and adjacent units, Quinn Canyon Range, Nye County, Nevada



Scale 1:12,000
No vertical exaggeration
Drawn at 2X map scale
see: Plate 1 for explanation
Plate 6 for Geologic Map

By Storr L. Nelson, June 1996

Plate 7 - Cross-section C-C' of Lower to Middle Devonian strata and adjacent units, Quinn Canyon Range Nye County, Nevada