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## The Late Ordovician and Silurian of the Eastern Great Basin, Part 6: The Upper Ordovician Carbonate Ramp

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## Abstract

Two east-west transects examined in western Utah and eastern Nevada preserve Upper Ordovician-Lower Silurian lithofacies along a carbonate ramp transitional between a shelf and basin. Previous investigators have reconstructed this margin as a classic carbonate shelf with an abrupt, linear margin between shelf and slope. However, lithofacies change gradually between shelf and slope and are better explained by a carbonate ramp model. Intertidal and shallow subtidal dolomites are present to the east, with progressively deeper water limestones with increasing fine grained terrigenous content toward the west. Shelf edge reefs or shallow water carbonate margin buildups are absent.

Latest Ordovician glacio-eustatic decline in sea level produced a period of subaerial exposure in the shallow eastern region. However, deposition continued deeper on the ramp, where shallow-water, cross laminated, massive dolomites were deposited during the glacio-eustatic regression.

The carbonate ramp pattern was disrupted in the Middle or early part of the Late Llandovery, when an abrupt margin was established by listric growth faulting. The abrupt margin, characteristic of a carbonate shelf model, dominated the pattern of sedimentation during the Silurian and into the Devonian.

## Introduction

A classic carbonate shelf model has been implicitly employed by previous workers to expain Upper Ordovician and Silurian lithofacies patterns in the eastern Great Basin (Poole and others, 1977; Ross, 1976, 1977; Dunham, 1977; Dunham and Olson, 1980). The carbonate shelf model is centered about an abrupt margin separating the platform and the slope (Fig 1a; See Wilson, 1975). For many years the carbonate shelf model was the only one applied to ancient carbonates, because nearly all modern platform margins are of this type. Ahr (1973) provided an alternative carbonate ramp model which is applicable to many ancient carbonate margins. A carbonate ramp differs from a carbonate shelf in having a gradual rather than abrupt transition between shelf and slope (Fig. 1b). Marginal reefs and shelf-edge carbonate buildups are rare or absent on a ramp, as are turbidites and slumping.

Upper Ordovician (upper Caradocian-Ashgillian)-Lower Silurian (lower Llandovery) carbonates in northeastern Nevada and northwestern Utah preserve lithofacies along a carbonate ramp that was transitional between the carbonate platform and basin in central Nevada. The carbonates examined belong to the Fish Haven and Ely Springs dolomites, the Hanson Creek Formation and the unnamed limestone of McKee (1976). The formations are underlain by the Eureka or Swan Peak quartzites or the Antelope Valley Limestone and are overlain by the Laketown Dolomite or the Roberts Mountains Formation. This report analyzes the depositional environments and the depositional history along two transects of the ramp (Fig. 2).

Many features of a ramp model are exhibited in the Upper Ordovician carbonates of the eastern Great Basin, the most important being the absence of reef buildups and turbidites, the lack of an obvious shelf-slope break and slumping, and progressively increasing terrigenous content down-slope to the west with clean carbonates to the east. Shallow-water stromatolites and cryptalgal laminites are progressively less common down the ramp.

The interpretation of these sediments is complicated by a glacio-eustatic drop in sea level at the end of the Ordovician. The shallow seas in eastern Nevada and western

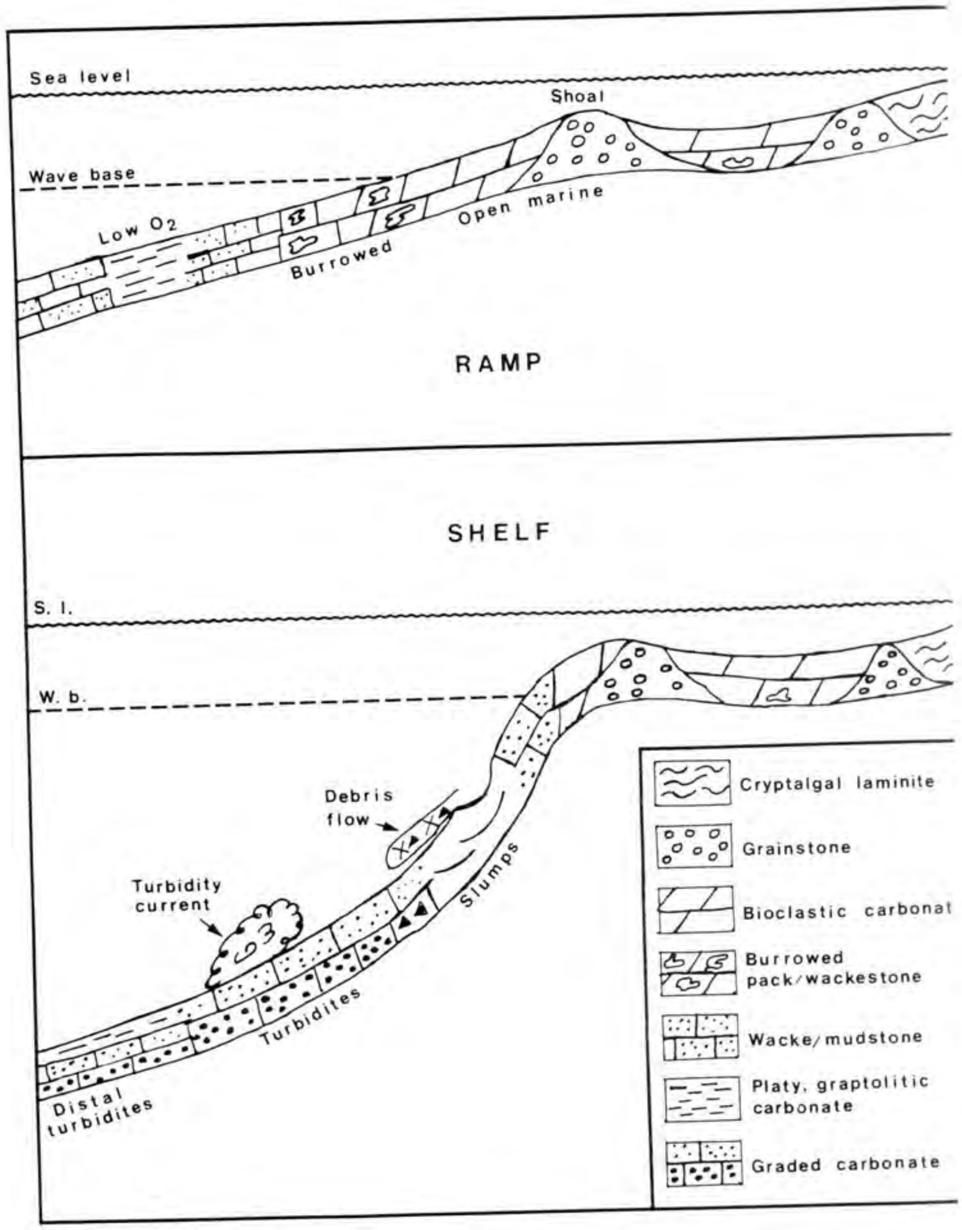


**Figure 1.** Models of Carbonate Platform margins. Figure la, Carbonate shelf model. Figur 1b, Carbonate ramp model.

Utah were drained at the close of the Ordovician. The drop in sea level brought shallow-water sedimentation onto the ramp as the upper part of the Hanson Creek Formation was deposited in central Nevada. Transgression caused by melting of the glaciers and eustatic rise in sea level brought renewed depostion on the platform (lower Laketown Dolomite) and correlative but once again deeper water-deposits of the uppermost Hanson Creek Formation on the ramp.

We suggest that down-faulting in the Middle or early Late Llandoverian (Johnson and Potter, 1975) disrupted the ramp and initiated an abrupt western margin which became the dominant trend in the Silurian (Sheehan, 1979, 1980b). The new pattern fits the carbonate shelf model (See Wilson, 1975) rather than the ramp model of Ahr (1973).

## Geologic Setting

Upper Precambrian to Upper Devonian rocks of the Cordilleran platform are shallow water, subtidal to supratidal deposits and include both terrigenous and carbonate strata. These strata increase in thickness from about 1000 m on the craton of central Utah to over 10,000 m in central Nevada (Stewart, 1980). They were deposited on a broad platform on the North American margin. Contemporaneous deposits of predominantely deeper water strata in western Nevada consist of shales, radiolarian chert, quartzites and pillow lavas (Stewart, 1980).

Stewart (1972) suggested that the western North American margin was formed by Late Precambrian rifting, which formed a north-trending continental margin in central Nevada. Platform carbonates were deposited east of the continental margin, while slope and basin sediments were deposited west of the margin (Stewart, 1972).

Deep-water continental rise, oceanic basin and/or back-arc settings have been proposed as the depositional environment of the basinal, or Western Assemblage deposits, because of the presence of radiolarian chert, graptolitic shale, deep water trace fossil assemblages and pillow lava with low vesicularity (Burchfiel and Davis, 1972; Poole, 1974; Stewart and Poole, 1974; Matti and others, 1975; Stanley and others, 1977; and Wrucke and others, 1978). Two models have been proposed for the early Paleozoic (see summary in Miller and others, 1984). One model employs a passive continental margin while the other employs a back-arc basin. Ross (1976, 1977) and Ketner (1977) disagree with these interpretations, proposing instead that the Western Assemblage was deposited in a mosaic of shallow, near shore to moderately deep off-shore environments. They suggest that radiolarian cherts and graptolitic shales do not necessarily indicate deep water, and point to the lack of graded beds and local occurrences of brachiopods as evidence for a variety of environments. Ketner (1977) suggested that granitic continental rocks with a sedimentary cover extended far west of the shelf margin, and shed clastics eastwards several times during the early Paleozoic.

Stewart (1980) recognized four Ordovician sedimentary provinces in the Great Basin. From east to west these provinces are: 1) an eastern carbonate and quartzite province, which includes the Upper Ordovician carbonates of this study; 2) a shale and limestone province with both graptolitic and shelly faunas; 3) a shale and chert province; and 4) a chert-shale-quartzite and greenstone province.

During the early Silurian the western part of the lower Paleozoic North American shelf margin subsided along listric growth faults (Johnson and Potter, 1975). A 60-70 km eastward displacement of the margin in northern Nevada has been suggested.

Paull (1976) proposed a similar eastward movement of the shelf margin in south-central Idaho during the Silurian. A continuous strip, 750 km in length, along the western North American continent edge may have been involved. The Klamath Mountains of California are possible remnants of an island arc, with growth of the back-arc basin providing tensional forces causing the marginal downdrop (Johnson and Potter, 1975).

There is an abrupt eastward indentation of lithofacies patterns of about 200 km from near Elko, Nevada, into northwestern Utah (Fig. 2). This indentation has been attributed to Mesozoic right lateral faulting (Thorman, 1970; Thorman and Ketner, 1979) or alternatively to an original depositional pattern (Sheehan, 1979; and Stevens, 1981). The latter view is accepted here.

The Silurian continental margin, delimited by the Silurian listric faults, may have acted as a barrier, inhibiting thrusting east of the margin during the Late Devonian-Mississippian Antler Orogeny (Sheehan, 1979). The east-west Silurian shelf margin in northern Nevada may have acted as a buttress to south- ward directed Mesozoic thrusting (see Ketner, 1984; Miller and others, 1984).

During the Antler Orogeny the Roberts Mountains allochthon was thrust eastward as much as 145 km. North-northeast trending Antler highlands were formed along the former continental margin and deep water siliceous and volcanic deposits of early Paleozoic age were thrust over contemporaneous shelf carbonates (Stewart, 1980; Nilsen and Stewart, 1980; Johnson and Pendergast, 1981; Speed and Sleep, 1982).

## Previous Investigations

Earlier investigations of Upper Ordovician stratigraphy have been summarized in Part 1 of this series (Budge and Sheehan, 1980a). Miller (1977) studied the paleoenvironments of the Middle Ordovician Eureka Quartzite and the basal part of the Upper Ordovician Ely Springs Dolomite in the Arrow Canyon Range of southern Nevada. Miller and Walch (1977) interpreted the depositional environments of Upper Ordovician to Lower Devonian strata in the southern Great Basin. Depositiona environments of Upper Ordovician strata in central Nevada were discussed by Dunham (1977), Dunham and Olson (1980), Nichols and Silberling (1977). Ros (1976, 1977) summarized Ordovician sedimentation and paleogeography of the western United States. Hintze (1959) investigated regional thickness variations of Ordovician sediments across the Tooele Arch.

An Ordovician-Silurian extinction caused by a glacio-eustatic lowering of sea leve which drained the epicontinental seas, has been discussed by Sheehan (1973, 1975 Berry and Boucot (1973) and Lenz (1976). Ordovician and Silurian faunal studie in the study area include Ross and Berry (1963), Sheehan (1969, 1976, 1980a, 1982), Berry and Boucot (1970), Ross (1970), Murphy and others (1977), Pandol (1985) and Budge (1972). Chamberlain (1977) and Sheehan and Schiefelbein (198 studied Ordovician trace fossils in Nevada. The first regional summary of Gre Basin Middle and Upper Ordovician conodont biostratigraphy was by Harris an others (1979).

Ten sections selected for this study (Fig. 1) are from regions that have bee examined in some detail previously. The geology of the Lakeside Mountains wa described by Young (1955) and Budge and Sheehan (1980b). The geology of the Silv Island Range was described by Budge and Sheehan (1980b) and Schaeffer (196 O'Neill (1968) discussed the geology of the southern Pilot Range. The geology

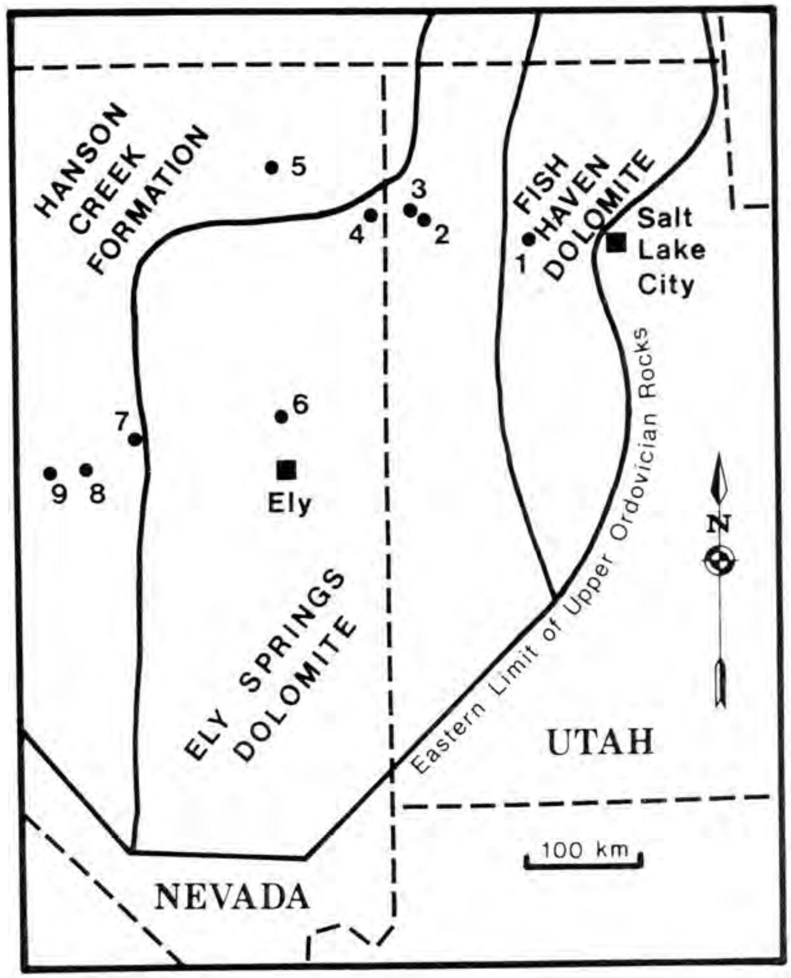


**Figure 2.** Index map showing location of stratigraphic sections, and the geographic distribution of Upper Ordovician formations. Northern transect: 1) Lakeside Mountains, 2) Northeastern Silver Island Range, 3) Northwestern Silver Island Range, 4) Pilot Range, 5) Antelope Peak. Southern transect: 6) Northern Egan Range, 7) Lone Mountain, 8) Copenhagen Canyon, 9) Toquima Range.

Antelope Peak in the southern Snake Mountains was discussed by Peterson (1968). Hintze (1952), Webb (1958), Fritz (1968), Ross (1970), Hose and Blake (1976) and Harris and others (1979) have discussed the geology of the northern Egan Range. Merriam (1940), Ross (1970), Dunham (1977), Dunham and Olson (1980), Murphy and others (1977) discussed the geology of Lone Mountain. At Martin Ridge and Copenhagen Canyon in the Monitor Range, the geology was discussed by Merriam (1963), Ross and Berry (1963), Ross (1964, 1970), Ethington and Schumacher (1969), Ross and Shaw (1972), Dunham (1977), Dunham and Olson (1981), Matti and others (1975), Harris and others (1979), Murphy and others (1977), and Ross and others (1979). The Toquima Range geology has been described by Kay (1962), Kay and Crawford (1964), McKee (1976), Ross (1970), and Harris and others (1979).

## Methods

Field work in the eastern Great Basin was conducted during the summer of 1980. Sections were measured with a 30 m tape and Brunton compass. Thicknesses were determined using a programmable calculator with trigonometric procedures described by Mertie (1922). Bedding descriptions follow the system of Ingram (1954). Colors of weathered and fresh rock units were determined with the use of the Rock Color Chart of the Geological Society of America (Goddard, 1970).

Oriented lithologic samples were analyzed in thin sections and polished slabs. The staining method of Katz and Friedman (1965) was used to determine dolomite and limestone content. Rock textures were described using the carbonate classification system of Dunham (1962) as modified by Embry and Klovan (1971).

## Lithostratigraphy

The approximate geographic distributon of the Upper Ordovician formations studied is shown in Figure 2. Names and correlation of units are shown on Fig. 3 and discussed in the following section.

### Eureka and Swan Peak Quartzites

The Eureka and Swan Peak Quartzites form distinctive marker horizons in the study area. Hague (1883) proposed the name Eureka Quartzite for a white quartzite found in the Eureka mining district of Nevada. Because of poor exposure in the Eureka district, Kirk (1933) redefined the Eureka Quartzite, with the 107 m thick type section, located on the west side of Lone Mountain, near Eureka, Nevada. The formation is composed of cross-bedded quartz sandstone and dense, white, vitreous quartzite, with associated sandy dolomite (Kirk, 1933).

Ketner (1968) and M. F. Miller (1977) interpreted the Eureka and Swan Peak quartzites as shallow subtidal to supratidal marine deposits. The quartzites are considered to be Middle Ordovician in the eastern part of the Great Basin and Middle to lower Upper Ordovician in central Nevada (Ross, 1977). The contact with the Upper Ordovician carbonates is disconformable (Harris and others, 1979).

The Swan Peak Quartzite is at the base of sections in the Lakeside Mountains. The Eureka Quartzite is present in the Silver Island, Pilot, northern Egan and Monitor ranges, Antelope Peak and Lone Mountain.

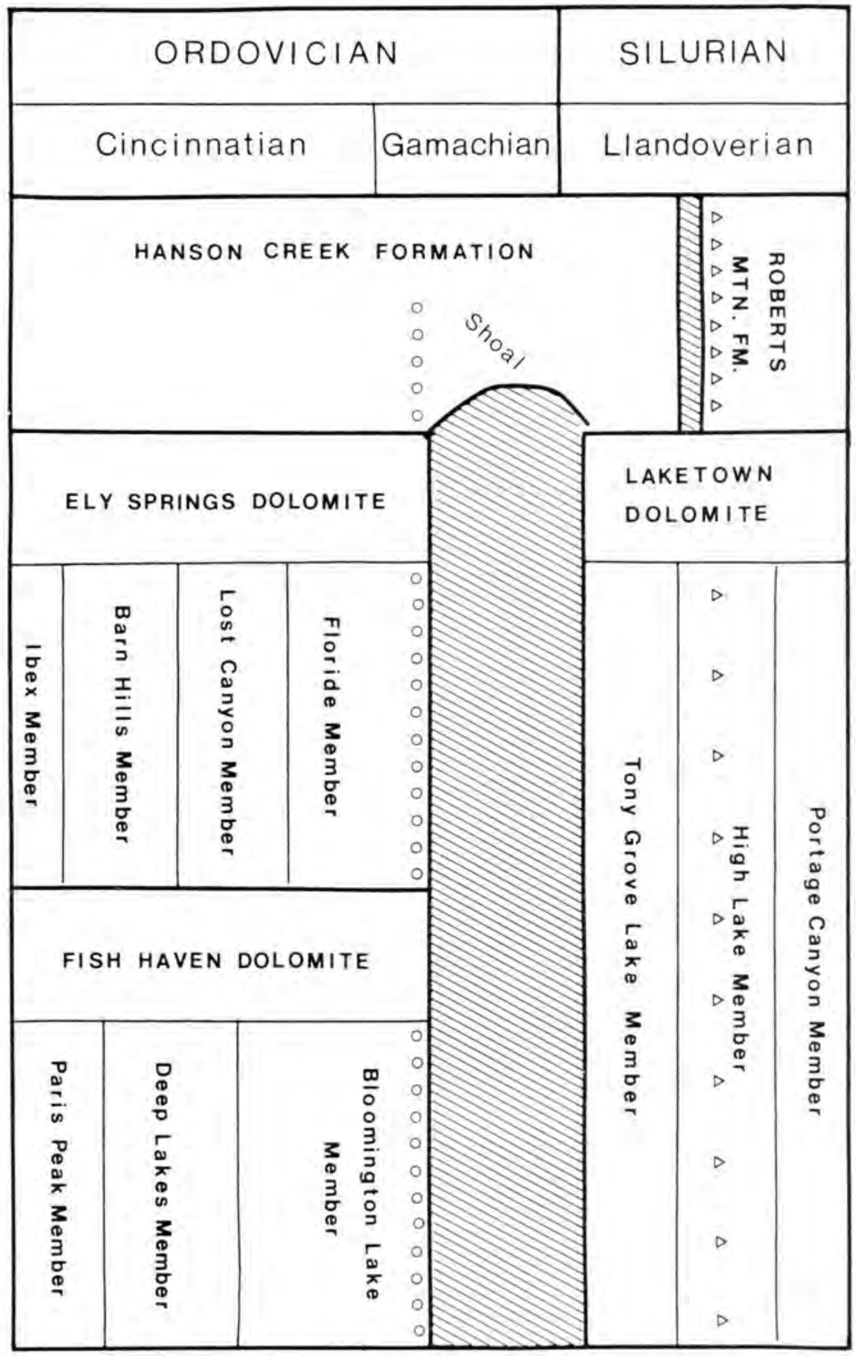


Figure 3. Upper Ordovician and Lower Silurian stratigraphic units.

## Fish Haven Dolomite

Richardson (1913) named the Fish Haven Dolomite for Upper Ordovician strata in north-central Utah and southeast Idaho. The type section is in Fish Haven Canyon, west of Fish Haven, Idaho. Keller (1963), followed by Budge and Sheehan (1980a), divided the formation into three members which are, from bottom to top, the Paris Peak Member, the Deep Lakes Member, and the Bloomington Lake Member. The Paris Peak Member overlies the Swan Peak Quartzite and is a dark gray, very fine-crystalline, thick-bedded dolomite (Budge and Sheehan, 1980a). The Deep Lakes Member is light gray, distinctly burrow mottled and contains interbeds of light and dark gray, medium- to thick-bedded dolomite in the upper part (Budge and Sheehan, 1980a). The Bloomington Lake Member is a light gray, medium- to very thick-bedded dolomite (Budge and Sheehan, 1980a). The contact with the overlying Silurian Laketown Dolomite is placed at a change to dark gray, fine- to coarse-crystalline, laminated, bioclastic dolomite (Budge and Sheehan, 1980a). A marker horizon with quartz sand grains, recognized by Mullens and Poole (1972), is near the contact with the Laketown Dolomite.

The Fish Haven Dolomite was examined in the Lakeside Mountains (Fig. 2). Another section, which includes the Paris Peak and Deep Lakes Members, was sampled by Sweet (1979) in Green Canyon east of Logan, Utah. Sweet, using "graphic correlation," assigned an upper Edenian-Maysvillian (Conodont Fauna 11 and the lower part of Fauna 12) age to this stratigraphic interval. Sweet did not sample the Bloomington Lake Member as he considered this interval to be part of the Laketown Dolomite. The Bloomington Lake Member is, at least in part, of Richmondian Age (Budge and Sheehan, 1980a).

## Ely Springs Dolomite

Westgate and Knopf (1932) named the Ely Springs Dolomite for Ordovician strata in east-central Nevada. The type section is in the Ely Springs Range, near Pioche, Nevada. The formation is Upper Ordovician in age (Budge and Sheehan, 1980a). Some strata in southeastern California and southwestern Nevada assigned to the formation are lower Silurian (Harris and others, 1979; Miller and Walch, 1977). Mullens and Poole (1972) recognized the quartz sand horizon near the contact with the Silurian Laketown Dolomite. Conodonts of Fauna 11-12 age have been recovered from the base of the formation near Steptoe in the northern Egan Range (Harris and others, 1979). The formation is divided into the Ibex, Lost Canyon, Barn Hills, and Floride Members.

The basal Ibex Member is dark- to brownish-gray, thin- to very thick-bedded dolomite, with quartz sand grains (Budge and Sheehan, 1980a). The Barn Hills Member is dark brownish-gray to medium light-gray, thin to very thick, well-bedded dolomite, without quartz sand grains (Budge and Sheehan, 1980a). The Lost Canyon Member consists of interbeds of light and dark gray dolomite (Budge and Sheehan, 1980a). The Floride Member consists of light brown to light olive gray, argillaceous dolomite that is so intensely burrow mottled that bedding is obscure (Budge and Sheehan, 1980a). Disconformably overlying the Ely Springs Dolomite is the Silurian Laketown Dolomite. The Ely Springs Dolomite was examined in the Silver Island, Pilot and northern Egan ranges.

### Hanson Creek Formation

The Hanson Creek Formation, named by Merriam (1940), overlies the Eureka Quartzite west of the Ely Springs Dolomite (Fig. 2). Over most of its areal distribution the formation underlies a chert horizon at the base of the Roberts Mountains Formation. The type section at Pete Hanson Creek on Roberts Creek Mountain is about 166 m thick and consists primarily of limestone with dolomite near the top (Merriam, 1940; Dunham, 1977; Dunham and Olson, 1980; Harris and others, 1979; Nichols and Silberling, 1980).

The section at Lone Mountain is entirely dolomitic (Merriam, 1940, 1963; Ross, 1970; Dunham, 1977; Dunham and Olson, 1980). In the Monitor Range the lower part of the formation is a laminated, thin-bedded, graptolitic limestone, which is overlain by lime mudstones and packstones and interbedded chert.

In the upper part of the formation Mullens and Poole (1972) recognized a widespread quartz-sand horizon which lies very close to the Ordovician-Silurian boundary. This age was substantiated by Harris and others (1979) who found *Gamachignathus* in the stratigraphic position of the sand horizon in the Mountain Boy Section. This conodont is common in Conodont Fauna 13 (McCracken and Barnes, 1981). The sand horizon has been found in the Ely Springs and Fish Haven dolomites.

Ross and others (1979) defined three members of the Hanson Creek Formation in the Mahogany Hills, Nevada. These members are a lower, dark dolomite member, a middle limestone and dolomite member and the upper, dark Combs Canyon Dolomite Member. *Gamachignathus* was found in the middle of these three members.

In the Mountain Boy Range, Ross and others (1979) report pentamerid brachiopods in the Combs Canyon Member. Field work in this area with D. R. J. Schiefelbein revealed the presence of *Virgiana* in the Combs Canyon Member. Lithologically and faunally the Combs Canyon Member is identical to the Tony Grove Lake Member of the Laketown Dolomite (Budge and Sheehan, 1980a). It is proposed here to retain the name Tony Grove Lake Member for these beds because of the clear resemblance of the beds with the Tony Grove Lake Member of the Laketown Dolomite at Tony Grove Lake, Utah, which is the reference section of the formation. In addition, a reconnaissance examination of the section at Pete Hanson Creek suggests the Combs Canyon Member is not present in the type section of the Hanson Creek Formation. The lithology of the Combs Canyon Member is more in accord with the widespread basal Laketown Dolomite to the east than with the Hanson Creek Formation to the west. This terminology follows Budge and Sheehan (1980b) who recognized the Tony Grove Lake Member in the Mahogany Hills.

The base of the Tony Grove Lake Member (= Combs Canyon Member) in the Mountain Boy Section is just above Zone 13 conodonts (Ross and others, 1979). The presence of *Virgiana* in the basal part of the member provides a late Early Llandovery or Middle Llandovery age.

In the Lone Mountain section there are 14 m of strata between the top of the quartz-sand horizon and the base of the Tony Grove Lake Member. These 14 m of strata may be equivalent to the middle limestone and dolomite member of the Hanson Creek Formation in the Mountain Boy Section. The three members of Ross and others (1979) cannot be recognized in the Monitor Range.

Murphy and others (1977) suggest the strata at Lone Mountain and in the Monitor Range should be referred to as the "Hanson Creek interval" since the lithology is quite distinct from that at the type section. In this report we do not use Hanson Creek Formation in the restricted sense. The Hanson Creek Formation was examined at Lone Mountain, Antelope Peak and in the Monitor Range.

### Unnamed Limestone of McKee (1976)

Overlying the Antelope Valley Limestone in Ikes Canyon in the Toquima Range is a calcarenitic to fine-grained, unnamed limestone mapped by Kay and Crawford (1964) and McKee (1976). The fauna of the unnamed limestone was dated as Upper Ordovician by Ross (1970), McKee (1976) and Harris and others (1979), making it correlative with the Hanson Creek Formation and the Ely Springs and Fish Haven Dolomites. The unnamed limestone is probably a transitional shelf-to-slope deposit that contains reworked sediment and faunas (Harris and others, 1979).

### Western Assemblage

West of the ramp are sediments, reviewed by Ketner (1977), consisting of dolomitic or calcareous siltstones, graptolitic shales, graded beds, chert and pillow lavas, known as the Western Assemblage. The strata, which include Ordovician formations, are preserved only in thrust sheets.

### Laketown Dolomite

The Silurian Laketown Dolomite was named by Richardson (1913) and is divided into six members (Budge and Sheehan, 1980a). The Laketown Dolomite was examined in the Lakeside, Silver Island and northern Egan ranges.

### Roberts Mountains Formation

The Roberts Mountains Formation was named by Merriam (1940), with the type section in the Roberts Mountains, Eureka County, Nevada. The age of the formation is Late Llandovery to Early Devonian. The lithology varies considerably from section to section. An eastern facies is thick-bedded with a shelly fauna. A western facies is platy, graptolitic limestone, interpreted as having been deposited in deeper water than the eastern facies (Berry and Boucot, 1970). The Roberts Mountains Formation was examined in the Silver Island, Pilot and Toquima ranges, Lone Mountain and Antelope Peak.

### Lone Mountain Dolomite

At Lone Mountain, Nevada, Merriam (1940) subdivided the Lone Mountain Limestone of Hague (1883) into the Hanson Creek Formation, the Silurian Roberts Mountains Formation and the Silurian-Devonian Lone Mountain Dolomite. The type section of the Lone Mountain Dolomite is at Lone Mountain, Eureka County, Nevada. The formation is Llandovery to Early Devonian and overlies the lower member of the Laketown Dolomite in some sections in central Nevada (Sheehan, 1979). In most areas, the Lone Mountain Dolomite stratigraphically overlies the Roberts Mountains Formation. The Lone Mountain Dolomite is distinguished in the field by a massive, blocky weathering pattern. The depositional environment has been interpreted as a shallow water, prograding bank at the edge of the continental margin (Nichols and Silberling, 1977, 1980; Sheehan, 1979).

## Carbonate Ramp Model

A carbonate ramp model was developed by Ahr (1973), to explain facies patterns which result from regional carbonate deposition on a gently sloping continental boundary, without a well-defined shelf margin (Fig. 1b). Ahr (1973) established the carbonate ramp model as an alternative to the shelf model (Fig. 1a). Read (1980, p. 1579) established the following definitions:

Carbonate Ramp — Shallow, gently sloping platform (slopes typically less than 1°) that lacks a marked break in slope. Grainstones are commonly in updip position, and may also be associated with local buildups downdip. Continuous reef trends are absent; buildups typically are separate and discrete; downslope, sediment-gravity flow deposits containing clasts of shallow platform rocks are absent, except adjacent to local buildups. This contrasts to:

Carbonate Shelf — A shallow platform whose outer edge is marked by a pronounced increase in slope (commonly a few degrees to over 45°) into deep water. Shelf edge is dominated by carbonate sands, and reefs that may form continuous trends. Abundant sediment gravity flow deposits contain platform-derived material (turbidites, megabreccias) downslope from the shelf edge.

Carbonate Platform — This term was used by Ahr (1973) to include both shelves and ramps.

## Depositional Environments

Depositional environments encountered in the carbonate platform of the Upper Ordovician of the eastern Great Basin are characteristic of a ramp-to-basin transition. The five major lithofacies observed are interpreted to have been deposited in: 1) supratidal, 2) intertidal, 3) subtidal, within wave base, 4) subtidal, below wave base, and 5) slope and basin environments. Subdivisions within these major lithofacies are comparable to those recognized by Sodero and Hobson (1979) in partially time equivalent rocks of northern Canada.

### Supratidal

The characteristic lithology of supratidal deposits is thin-bedded, crypt-algal laminated, light gray, primary dolomite mudstone (Fig. 12), with desiccation features, such as mud cracks and birds-eye structure. Biota is restricted primarily to blue-green algal laminates in mudstone.

### Intertidal

Light gray, algal laminated to bioturbated carbonate mudstones and wackestones (Fig. 4) are characteristic of intertidal to peritidal deposits. Interbeds of skeletal pack/grainstone, with erosion surfaces, are concentrated in tidal channels and storm deposits, with intraformational carbonate pebble conglomerate formed as a lag deposit in tidal channels and storm scours. The biota is restricted, consisting mainly of gastropods, ostracods, calcareous algae, tabulate corals, nautiloids and blue-green algae.

Algal stromatolites are most commonly simple domes (Fig. 5) up to 20 cm in diameter and up to 10 cm high, but there are some laterally-linked hemispheroids (LLH structure of Logan and others, 1964). No vertically-stacked columnar stromatolites were found.

### Subtidal, Within Wave Base

The subtidal, wave agitated environment is characterized by bioclastic, lithoclastic grainstone, with skeletal intraclast lenses. Commonly, the tops of beds have been scoured. Wave agitated sediments (Fig. 6) were deposited in this environment. Medium dark gray, thin- to medium-bedded deposits, with parallel and low angle cross-laminations as well as wave ripples are common. Coarse grained, completely redolomitized units are common (Fig. 7). The biota is restricted, consisting of pelmatozoans, ostracodes, algal oncolites and tabulate corals. Some bioclasts were coated by algae (Fig. 8).

Dasycladacean algae are common in the eastern sections (Johnson and Sheehan, 1984). Recent dasycladacean algae inhabit warm, shallow, subtidal environments with variable salinity, with a depth range from just below tide level (3-5 m) to a maximum depth of 12-15 m (Ginsburg and others, 1971). Possible fruiting cases of dasyclad algae are preserved as calcispheres.

### Subtidal, Below Normal Wave Base

In the subtidal environment, below normal wave base, the characteristic lithology is thick-bedded, cherty, bioturbated, skeletal wacke/packstone (Fig. 9). Bioclastic wackestone occurs at or just below wave base, whereas whole fossil wackestone, with preserved infauna and epifauna, occurs in quiet water, below normal wave base (Flugel, 1972). Storm scouring becomes increasingly less common with increasing depth on the ramp. The environment has open circulation, with an unrestricted fauna consisting of pelmatozoans, rugose and tabulate corals, bryozoans, brachiopods and trilobites.

Hardgrounds were commonly bored, such as those in the Lakeside Mountains (Fig. 10). Sediments commonly became semi-lithified, forming a substrate soft enough to allow burrowing organisms to form burrow networks, yet firm enough to prevent burrow collapse. *Thalassinoides* burrows are common in this environment (Sheehan and Schiefelbein, 1984), and the presence of one to three m thick galleries suggest that the environment was deep enough to be protected from storms which would have scoured the galleries.

Planar corrosion surfaces were identified in most sections. Abrasion or truncation of sediment surfaces caused by unusually strong storms are characteristic of corrosion surfaces (Wilson, 1975).

### Slope and Basin

The transition from shelf to slope to basin is accompanied by a decrease in the optimum conditions for carbonate production. As the aerobic zone grades to the dysaerobic zone, followed by the anaerobic zone, there is a change in the lithology from bioturbated, subtidal deposits with shelly fauna to bioturbated lithology lacking an abundant shelly fauna, followed by laminated, unbioturbated sediments (Byers, 1977).

As dissolved oxygen decreases, the fauna progressively becomes less diverse, less abundant, smaller in body size, dominated by infauna, and less heavily calcified (Byers, 1977). Berry and Wilde (1978) have suggested that an oxygenated zone created by glacially-induced currents, may have been present beneath the anaerobic zone in Paleozoic seas.

In the Great Basin limestone becomes more common than dolomite down the ramp.

Non-carbonate argillaceous content of limestones also increases down the ramp. Shales and calcareous mudstones are common lithologies in the deep ramp and basin. The abundance of trilobites increases toward deeper water.

In the study area, graptolite carbonate mudstone, suggestive of anoxic conditions, is present in the lower part of the Hanson Creek Formation in the Monitor Range, and at Antelope Peak. These units may have been in the dysaerobic zone (see Berry and Wilde, 1978).

## The Transects

In the following section the facies are described and depositional environments are interpreted for sections in the two transects (Fig. 2). The discussion of each transect begins in the shallow, eastern sections and proceeds sequentially to deeper water, first in the northern and then in the southern transect. Details of newly measured sections are in the Appendix.

## Northern Transect

### Lakeside Mountains

The Fish Haven Dolomite in the Lakeside Mountains, Utah, was deposited in the shallowest part of the northern transect. Geographically it is in the carbonate platform. The section was described in Part 2 of this series (Budge and Sheehan, 1980b). They assigned 15 units in the section to the Fish Haven Dolomite (total thickness 65.9 m). A sediment log is presented in Figure 11.

The thickness of the Paris Peak Member (Unit 1) was incorrectly described as 10 feet (3 m) by Budge and Sheehan (1980b). Their measurements included only the upper part of the member. A newly measured section of the Paris Peak Member is described in the Appendix. The Paris Peak Member is divided into 21 units in this study with a total thickness of 41.1 m.

Units 2-15 of Budge and Sheehan (1980b) are herein reassigned to the Deep Lake Member of the Fish Haven Dolomite. The member is 61.9 m thick.

Budge and Sheehan (1980b) placed the contact between the Fish Haven Dolomite and the Laketown Dolomite at the contact between Units 15 and 16 of Budge and Sheehan (1980b). The contact is changed herein to the contact between Units 18 and 19 of Budge and Sheehan (1980b), because the upper part of Unit 18 of Budge and Sheehan (1980b) is burrow mottled wackestone similar to the upper part of the Bloomington Lake Member of the Fish Haven Dolomite at the type section in the Bear River Range, Idaho. Unit 19 of Budge and Sheehan (1980b) contains the Silurian brachiopod, *Virgiana utahensis*, which is common in the Tony Grove Lake Member.

Units 16, 17, and 18 of Budge and Sheehan (1980b) are assigned herein to the Bloomington Lake Member and divided into seven informal units (16a-16g). Thicknesses of the informal units were estimated, not measured. The Bloomington Lake Member is 73.4 m thick. The revised Fish Haven Dolomite has a total thickness of 177.4 m.

#### Depositional Interpretation

The Fish Haven Dolomite in the Lakeside Mountains has the greatest proportion of restricted, tidal flat lithofacies encountered in the transects. Unit 1 of this study (10.0 m thick, estimated) is a covered interval, which includes the contact with the

Swan Peak Quartzite. The lower two members are characterized by four shallowing-upward cycles.

An idealized cycle began with a relatively rapid basal transgression above a sharp disconformity. Edgewise clasts of the underlying tidal flat sediments are present in the lower several meters of the cycle. The basal part of the cycle is dark gray secondary dolomite with a bioturbated wacke/packstone texture (Figure 9), which was deposited subtidally, below wave base. Higher in an idealized section, a greater proportion of bioclastic wackestone, with abraded fossils, indicates shallowing to subtidal conditions, at or just below wave base, with increased storm wave influence (Wilson, 1975). A gradational change to tidal flat deposition in the upper part of the cycle is indicated by light gray, dense, primary dolomite with cryptalgal laminates (Fig. 12), desiccation features (Fig. 4), birdseye, spongiostrome texture (tuffeted algal fabric, Fig. 13), and stromatolites (Fig. 5). Within cycles, the thickness of the tidal flat deposits is generally less than the subtidal deposits. Cycles were probably caused by progradation of tidal flat environments seaward over subtidal environments, following subsidence and/or eustatic rise of sea level (Wilson, 1975).

Bioturbated, whole fossil wackestone deposited below wave base is more common in the lower two than in the upper two cycles, indicating that the lower depositional cycles were initiated at greater depths than the two upper cycles. The fourth cycle was probably not below wave base when it began.

Units 1 through 12 of the newly measured section in the Paris Peak Member are 20.8 m thick and comprise the first cycle. Units 2, 3, 5 and 7 are whole fossil and bioclastic wackestone (Figs. 8 & 9), with lenses of bioclastic wackestone. The units are interpreted to have been deposited in a subtidal environment, below wave base. Unit 4 of this study is a bioclastic pack/grainstone lens that has rip-up clasts and a sharp, undulating contact (Fig. 14). The unit was deposited in a storm scoured channel and was affected by soft sediment deformation.

Units 8 and 9 of this study (0.2 m thick) are light gray, dense, pelleted, nonlaminated mudstone, with ostracodes (Fig. 15). The contact with Unit 7 is a sharp and irregular discontinuity surface. The unit formed in quiet-water, after storms or current activity eroded the top of the underlying subtidal deposits.

Units 10 through 12 of this study (2.2 m thick) are alternating bands, 0.5 to 1.0 m thick, of cryptalgal laminated mudstone and bioclastic packstone, deposited in a predominantly intertidal environment, which alternated with subtidal conditions, at or just below wave base.

The second cycle is about 50 m thick. The cycle includes Units 13 through 21 of this study and Units 2 through 10 of Budge and Sheehan (1980b). Units 13 through 20 of this study (17.5 m thick) are bioturbated, cherty, bioclastic wackestone, with a diverse marine fauna dominated by tabulate and rugose corals, and pelmatozoans and burrowers. Many beds have several generations of bioturbation. Storm layers of bioclastic wackestone 3-5 cm thick with abraded fossils occur throughout the interval. Discontinuity surfaces occur at the contact between units. The interval was deposited in a subtidal environment, below wave base, with periodic storm wave activity which concentrated fossiliferous debris in occasional layers.

Unit 21 of this study (0.4 m thick), is an interval with alternating light and dark gray, unfossiliferous, pelleted mudstone. The interval is bounded by continuous dark gray chert beds. Incomplete silicification of the laminated mudstone is indicated by case-hardened, reddish-brown siliceous surface stains (Fig. 16). Some of the strata with incomplete silicification have a grapestone to pelleted grainstone texture. Light gray, cryptalgal laminated mudstone was deposited in the intertidal zone. Dark gray, unfossiliferous, parallel laminated mudstone was deposited below wave base, because it lacks evidence of wave agitation.

Units 2 and 3 of Budge and Sheehan (1980b) (0.4 m thick) are dense, light gray mudstone which is overlain by light gray, cryptalgal laminated mudstone, which was deposited in the intertidal zone. Unit 4 of Budge and Sheehan (1980b) (10.6 m thick) is covered.

Unit 5 of Budge and Sheehan (1980b) (0.8 m thick) is an intraclastic, bioturbated, pelleted grainstone or grapestone (Fig. 17), which was deposited in a restricted, shallow marine shoal with moderate water movement (Wilson, 1975). Unit 6 of Budge and Sheehan (1980b) (0.3 m thick) overlies Unit 5 along a sharp, irregular contact, with up to 7 cm relief. The unit is intraclastic, unfossiliferous mud/wackestone and is interpreted to have been deposited in a shallow subtidal environment with periods of moderate to high energy. The sediment of Unit 5 evidently had been semi-lithified before being eroded by storm waves, which created an angular contact and generated angular clasts incorporated in Unit 6. Unit 7 of Budge and Sheehan (1980b) (3.2 m thick) is covered.

Units 8, 9 and the lower 9.1 m of Unit 10 of Budge and Sheehan (1980b) (20.3 m thick) are cryptalgal laminated, stromatolitic, peloidal mudstone (Figs. 4 and 18). Cross laminated bioclastic wacke/packstones in Unit 9 have teepee structures (Fig. 19). In Unit 10, the mudstone is dark brownish gray, as compared to the light gray mudstone of Units 8 and 9. The algal laminates associated with desiccation structures indicate that the interval was deposited in tidal flat and intertidal environments and is the shallowest phase of the second cycle.

The third cycle is 13 m thick. It includes the upper 2.7 m of Unit 10 and Units 11 (covered) and 12 of Budge and Sheehan (1980b). The upper 2.7 m of Unit 10 and the lower 5.3 m of Unit 12 are bioclastic, *Thalassinoides*-burrowed wackestone (Fig. 20), with packstone layers, which suggests that, initially, the cycle was not as deep as the first two cycles. Because one to three m thick *Thalassinoides* galleries are preserved, the interval is interpreted to have been deposited in a subtidal environment, below wave base. The upper meter of Unit 12 is cryptalgal laminated mudstone, with *Chondrites* burrows in the upper 10 cm of the unit (Figs. 10 and 21). The unit was deposited in tidal flats and a restricted intertidal environment. *Chondrites* burrows suggest a hiatus before deposition of the overlying subtidal deposits of Unit 13.

The fourth cycle is 13.6 m thick and includes Units 13, 14, 15 and the basal 0.3 m of Unit 16 of Budge and Sheehan (1980b). Unit 13 (3.1 m thick) is bioclastic, burrowed wackestone and is interpreted to have been deposited in a subtidal environment, below wave base, which is the initial deep part of the cycle. Units 14, 15 and the basal 0.3 m of Unit 16 are algal laminated, fenestral, pelleted mudstone and formed in tidal flat and restricted intertidal environments, in the shallow phase of the cycle.

The Bloomington Lake Member (Units 16, 17 and 18 of Budge and Sheehan, 1980b) is divided herein into seven unmeasured subunits (16a-16g). Units 16, 17 and 18 could not be recognized separately when we reexamined the section. Units 16a through 16f include about 25.5 m of Unit 16 of Budge and Sheehan (1980b). Unit 16g includes the remainder of Unit 16, 17 and 18.

Subunit 16a includes the basal 0.3 m of Unit 16 of Budge and Sheehan (1980b). As discussed above, Unit 16a is algal laminated mudstone and is the top of the fourth shallowing-upward cycle.

Overlying the algal laminated mudstone is Subunit 16b which is 6.0 m thick. The basal part is fossiliferous wackestone, about 5.3 m thick, interbedded with 20 cm thick bioclastic pack/grainstone layers (Fig. 22). Burrow mottling is common. The unit was deposited in a shallow subtidal environment, at or below normal wave base, with frequent storm activity represented by the grainstone layers. Cryptalgal laminated mudstone in the upper 0.7 m of Subunit 16b formed in an intertidal environment. The interval is interpreted as a shallowing upward sequence that is 6.0 m thick.

Subunit 16c of this study (about 5.2 m thick) is dark gray, *Thalassinoides*-burrowed, cherty wackestone with a sparse fauna (Figs. 23 & 24). The unit weathers to light-colored cliffs. Fenestral algal laminated mudstone is in the upper 0.4 m of the unit. The subunit was deposited in a restricted subtidal environment, below wave base, that shallowed to restricted intertidal conditions when the fenestral mudstone was deposited.

Subunit 16d of this study (about 8.6 m thick) is *Thalassinoides*-burrowed wackestone. The burrow mottles are in distinct horizontal layers with some vertical connections (Fig. 25). The unit formed in a subtidal environment, below wave base. Subunit 16e (about 2.7 m thick) is bioclastic (commonly coral clasts), burrow-mottled, light olive-gray (5Y6/1) weathering wackestone and was deposited in a subtidal environment within or just below wave base, where storm deposits were occasionally introduced.

Subunit 16f of this study (3.1 m thick) is very fossiliferous pack/grainstone (Fig. 26). Fossils include tabulate and rugose corals, pelmatozoans, stromatoporoids and stromatolite fragments. The unit was deposited in a subtidal environment, within wave base and in proximity to an intertidal environment.

Unit 16g of this study (47.4 m thick) includes the upper 13.7 m of Unit 16 and Units 17 and 18 of Budge and Sheehan (1980b). The unit is bioclastic, *Thalassinoides* burrow mottled wackestone (Figs. 27 and 28), with lenses and layers of bioclastic packstone. The unit is interpreted to have been deposited in a subtidal environment, below wave base, where storm deposits were occasionally introduced.

The quartz sand horizon of Mullens and Poole (1972) was not found but could have been removed by erosion. Abundant quartz sand in the lower part of the Tony Grove Lake Member (Unit 19) may have been derived from the initial phase of the predominantly Late Devonian "Stansbury Orogeny," which produced the early Llandovery sand sequences exposed in the Stansbury Mountains and Stansbury Island to the east of the Lakeside Mountains (Stokes and Arnold, 1958).

### Northeastern Silver Island Range

The Ely Springs Dolomite (Fish Haven Dolomite of Schaeffer, 1960) was examined in Cave Canyon on the northeast side of Silver Island Range, northern Tooele County, Utah. The location is NW 1/2, NW 1/2, sec. 9, T. 2 N., R. 17 W. (unsurveyed). The section was measured by Schaeffer (1960), and we use his unit designations and thicknesses. The formation is 175.7 m thick. A sediment log is presented in Figure 29.

Schaeffer recognized 9 units in the southeastern Silver Island Range. Units 1 through 3 of Schaeffer (1960), are the Ibex Member of the Ely Springs Dolomite and are 29.5 m thick. Unit 3 is 11.9 m thick and is similar to the quartz sand layer near the top of the Ibex Member of the Ely Springs Dolomite in the northwest Silver Island Range (Unit 6 of Budge and Sheehan (1980b), and to quartz sand in a similar stratigraphic position in the Pilot Range and at Antelope Peak.

The Barn Hills Member is not found in this section. The Lost Canyon Member includes Units 4 through the basal 25.7 m of Unit 9 of Schaeffer (1960), and is 110.8 m thick.

The Floride Member is 35.4 m thick. The upper 13.2 m of Unit 9 of Schaeffer (1960) is unfossilliferous, cream-colored marl/mudstone of the basal Floride Member. As in other sections, the marl/mudstone forms a topographic saddle and has ferruginous red stains. Unit 1 of the Laketown Dolomite of Schaeffer (1960) is the *Thalassinoides*-burrowed, massively bedded part of the Floride Member of the Ely Springs Dolomite. The burrow mottled part of the Floride is 22.2 m thick.

Unit 2 of the Laketown Dolomite of Schaeffer (1960) is the Tony Grove Lake Member of the Laketown Dolomite. It is overlain by the Roberts Mountains Formation.

**Depositional Interpretation**

Unit 1 of Schaeffer (1960) is 1.5 m thick and is fossiliferous wackestone, with quartz sand grains in the basal meter of the unit. A transgression at the beginning of the depositional cycle incorporated reworked sand grains from the underlying Eureka Quartzite. Unit 2 of Schaeffer (1960) is 16.1 m thick and is a covered slope, with float consisting of bioclastic wackestone. Unit 2 formed in a subtidal environment, below wave base. Unit 3 of Schaeffer (1960) is grain/packstone with quartz sand grains. The unit formed in a shoal environment, with currents adequate to transport sand grains.

At the base of the Lost Canyon Member, Units 4, 5 and 6 of Schaeffer (1960), are cherty, fossiliferous, burrow mottled wackestones. The units were deposited in a shallow, subtidal ramp environment, below normal wave base.

Unit 7 of Schaeffer (1960) is 17.0 m thick and has a banded appearance, created by light gray, dense cryptalgal laminated carbonate mudstone, in layers about 1 m thick, which alternate with meter thick layers of dark gray, burrow mottled bioclastic wackestone. Multigenerational burrowing, with *Thalassinoides* and *Chondrites*, occurs near the top of the unit. The unit resembles Unit 16 in the northwest Silver Island section. The unit was deposited in an environment which fluctuated between subtidal, quiet conditions and low intertidal conditions. An undetermined amount of the section between Units 7 and 8 was eliminated by faulting. Unit 8 (28.9 m thick) and the lower 25.7 m of Unit 9 of Schaeffer (1960) are cherty, very thick-bedded, burrow mottled bioclastic wackestone deposited in a subtidal environment below wave base.

In the slope-forming lower part of the Floride Member layers of carbonate grainstone, 5-15 cm thick, with blackened, phosphatic(?) peloids, are interbedded with the cream-colored marl/mudstone (Figs. 30 and 31). The grain-stone was deposited in scours with up to 5 cm relief and is burrow mottled. Lithoclasts of cream-colored marl/mudstone are in the grainstone. *Trypanites* borings (see Bromley, 1972) filled with grainstone, extend down as much as 7 cm into the upper portion of the cream-colored marl/mudstone layers (Fig. 32). The upper part of the basal Floride is medium dark gray, carbonate mudstone with 2-3 mm thick seams of red clay. Thin sections indicate that bioclastic, lithoclastic layers are associated with the red clay seams. The grainstone with blackened peloids may represent lag deposits, which "are characteristically thin deposits, representing slow accumulation of coarse material in the zone of winnowing" (Wilson, 1975, p. 66). The depositional environment is interpreted to have been quiet-water possibly related to a widespread relative increase in sea level. Occasional storms may have winnowed carbonate mud and eroded the marl/mudstone. The marl/mudstone was lithified prior to boring by *Trypanites* and prior to the erosional event which produced lithoclasts of the marl in the grainstone. Bioturbation in the grainstone and blackened, phosphatic(?) peloids suggest that the erosion was not due to a single storm. Red non-carbonate clay seams between bioclastic and lithoclastic layers were deposited when quiet water conditions prevailed. This is one of the few Upper Ordovician units on the carbonate platform with substantial non-carbonate content.

The Floride Member is light- to medium-gray, argillaceous, burrow mottled wacke-stone. The contact with the cream-colored, basal part of the Floride Member is gradational. The unit, together with the upper 13.2 m of the underlying Unit 9, is equivalent to Unit 22 of Budge and Sheehan (1980b) in the northwest Silver Island Range. The unit was deposited in a shallow, subtidal environment, below wave base.

The quartz sand horizon of Mullens and Poole (1972) is a bioclastic, litho-clastic grainstone, with quartz sand grains, found in isolated outcrops above the medium gray wackestone of the upper Floride Member (Fig. 33). The grain-stone was deposited in a shallow environment. The sand horizon is probably just below the Ordovician-Silurian boundary.

Lithoclasts of the upper Floride Member are incorporated into the base of the Tony Grove Lake Member (Fig. 34). Erosion of the Floride Member prior to deposition of the Silurian Laketown Dolomite has been associated with glacio-eustatic drop in sea level at the systemic boundary (Sheehan, 1979).

## Northwestern Silver Island Range

The Ely Springs Dolomite in the northwestern Silver Island Range is about 135 m thick (Budge and Sheehan, 1980b). The depositional environment is interpreted to have been deeper on the carbonate ramp than the Lakeside Mountains to the east, as suggested by the absence of regressives cycles, and less common shallow water sediments, especially cryptalgal laminates and stromatolites. A sediment log is presented in Figure 35.

The Barn Hills Member (Units 8-12) was recognized by Budge and Sheehan (1980b), but these units are assigned herein to the Lost Canyon Member. The Lost Canyon Member is redefined to include Units 8 through 21 of Budge and Sheehan (1980b) and is 78.2 m thick. This reassignment is made because the characteristic well-bed-ded, alternating light and dark gray beds of the Barn Hills Member are not present, and the entire sequence is similar to the units originally assigned to the Lost Canyon Member.

The Floride Member (Unit 22 of Budge and Sheehan, 1980b) is 28.7 m thick and consists of two parts. The basal 5 m forms a saddle and is composed of cream-colored marl/mudstone. This is the only Upper Ordovician on the platform with a substantial non-carbonate argillacous content. Cliff forming, massive *Thalassinoides*-burrowed, medium gray wackestone (Fig. 36) with a diverse fauna comprises most of the Floride Member. The upper 2 m of the Floride Member grades into laminated, bioclastic, lithoclastic pack/grainstone (Fig. 37) which is followed by a grainstone with sub-rounded quartz sand grains, which is the sand horizon of Mullens and Poole (1972).

The section was measured by Budge and Sheehan (1980b), north of Lost Canyon in the northwestern Silver Island Range, Utah. The section begins in the NE 1/4 of unsurveyed sec. 25, T. 3 N., R. 18 W. and ends in the NE 1/4 of unsurveyed sec. 30, T. 3 N., R. 17 W. Units and unit thicknesses referred to below are from Budge and Sheehan (1980b).

### Depositional Interpretation

The basal meter of the Ibex Member (Unit 1 of Budge and Sheehan, 1980b) is a grainstone with subrounded quartz sand grains (Fig. 38), and is interpreted to have been deposited during a transgression that initiated the depositional cycle. Reworked sand was incorporated from the underlying Eureka Quartzite.

Above the arenaceous grainstone, bioclastic wackestone persists to 16.9 m (Units 1-5 of Budge and Sheehan, 1980b). The interval formed in a subtidal environment, below normal wave base.

Unit 6 of Budge and Sheehan (1980b) is a 1.2 m thick, low-angle cross-laminated, arenaceous grainstone and dolomitic sandstone that was deposited in a high energy environment within wave base. Unit 7 has very little quartz sand and was deposited subtidally near or below normal wave base.

Units 8-15 (about 38 m thick) of the Lost Canyon Member are dark-gray, burrow mottled, cherty, bioclastic wackestone with abundant pelmatozoan and rugose coral debris. The interval is interpreted to have formed below normal wave base, with open circulation which allowed development of a diverse marine fauna.

Unit 16 (4.6 m thick), is a medium light- to light-gray, burrow mottled wackestone, with interbeds and lenses of bioclastic packstone. *Chondrites* burrows are at discontinuity surfaces, in dark gray layers in the middle of the unit. The upper meter of Unit 16 is interbedded light- and dark-gray dolomite, with beds having burrowed upper surfaces. Algal laminated mudstone with stromatolites is in the upper 0.6 m of the unit. The unit is interpreted to have formed during a shallowing of the environment from quiet-water, below wave base to intertidal conditions. Some stromatolites are isolated domes with tidal channels on the sides.

Unit 17 (2.3 m thick) is bioclastic wackestone and is interpreted to have formed during return to quiet-water conditions. Multiple generations of burrowing are indicated by *Thalassinoides* burrows which in turn contain *Chondrites* burrows.

Units 18 and 19 of Budge and Sheehan (1980b) are a transgressive sequence 3.0 m thick. Transgression is suggested by intertidal algal laminated mudstone which is overlain by burrowed wackestone with discontinuity surfaces, interpreted to have formed in a subtidal environment.

Unit 20 of Budge and Sheehan (1980b) (9.7 m thick) has light-gray, pelleted mudstone with algal laminates and stromatolites, interbedded with dark-gray, bioclastic, burrow mottled wacke/packstone. The sediments are interpreted to have formed when intertidal deposition alternated with deposition in quiet water. Cryptalgal laminations were disrupted repeatedly and followed by recolonizations in the same location after each disturbance (Fig. 39).

Unit 21 (20.8 m thick), at the top of the Lost Canyon Member, consists of cherty wacke/packstone (Fig. 40), with interbeds, up to 15 cm thick, of fossiliferous packstone. Oncolites are in the packstone about 6 m above the base of the unit. The oncolites are concentrated in burrows, and apparently they rolled into the burrows. Above the oncolitic zone is a 0.7 m thick layer with multigenerational burrowing of *Chondrites* burrows within *Thalassinoides* burrows (Figs. 41 and 42). Above the burrowed interval are 2 m of pelleted mudstone with algal laminates and stromatolites. Above the algal laminates is a fossiliferous, current cross-laminated sequence, which is followed by another oncolitic zone.

The first oncolites in the unit are interpreted to have formed in a subtidal environment, near wave base, with enough water movement to create circumrotary algal growth on corals. The interval in Unit 21 with oncolites in burrows is interpreted to have formed during a shallowing to a high subtidal to low intertidal environment, with conditions alternating between water agitated enough to move the oncolites and quiet water conditions which did not disturb burrowers. Further shallowing by progradation, or uplift, to intertidal conditions resulted in deposition of algal laminated mudstone. A similar shallowing, from subtidal conditions, below wave base, to high subtidal or low intertidal conditions, is suggested for the upper part of the unit. The basal 5 m of the Floride Member weathers to a saddle consisting of cream-colored marl/mudstone. This is the only Upper Ordovician unit on the platform with a substantial non-carbonate argillacous content. The wide spread unit may record a rise in sea level. The upper 23.7 m of Unit 22 is cliff forming, massive, argillaceous, *Thalassinoides*-burrowed, medium gray wackestone (Fig. 36), with a diverse marine fauna. The environment of deposition is interpreted as quiet-water, deep enough on the ramp to escape most storm activity.

The upper 2 m of the Floride Member grades to laminated, bioclastic, lithoclastic pack/grainstone (Fig. 37), which is followed by a grainstone with subrounded quartz sand grains. The upper grainstone formed during shallowing to a shoal environment.

The 59 m thick Tony Grove Lake member of the Laketown Dolomite is a mottled, peloidal packstone with cross-bedded interbeds of laminated grainstone formed in a wave agitated environment. The Roberts Mountains Formation overlies the Tony Grove Lake Member of the Laketown Dolomite. The Roberts Mountains Formation is composed of allodapic bands of dolomite and chert. Slump structures are common (Fig. 43).

## Pilot Range

The Ely Springs Dolomite (Fish Haven Dolomite of O'Neill, 1968) was examined in the southern Pilot Range in northeastern Elko County, Nevada (Fig. 2), Miners Canyon 7.5′ quadrangle. The section was mapped by O'Neill (1968). The lower part of the formation was examined in the NE 1/4, sec. 6, T. 35 N., R. 70 E., on the west slope of Hill 5907. The upper part of the formation and the Silurian dolomites were examined on Hill 6220 and Hill 6140, in the SE 1/4, SE 1/4, sec. 26 (unsurveyed) T. 36 N., R. 59 E. A sediment log is presented in Figure 44.

O'Neill (1968) reported the section to be 137 m thick. However, the region is severely disrupted by faulting, and no complete section is present. The formation was divided into three informal members and nine units by O'Neill (1968). Unit thicknesses are from O'Neill (1968).

The lower seven units of O'Neill are tentatively included in the Ely Springs Dolomite, but aside from the Ibex Member the units are not assigned to a member as they are lithologically unlike members of the formation. The units are transitional with the Hanson Creek Formation which was deposited deeper on the ramp. However, the Floride Member at the top of the Ely Springs Dolomite can be recognized.

O'Neill recognized a lower member (his Units 1 - 7) reported to be 59.6 m thick. His Units 1 and 2 are capped by a quartz sand horizon which is equivalent to the sand at the top of the Ibex Member in the Silver Island Range. Units 3 to 7 have some lithologic resemblance with the middle part of the Hanson Creek Formation. The Middle member of O'Neill has *Thalassinoides* burrows and is assigned to the Floride Member.

Faulting disrupts this sequence in numerous places making thicknesses and even the sequence of units above Unit 5 doubtful. In the measured section the presumed base of the Floride Member is in contact with the dark underlying Unit 7, along what may be a dolomite front (compare Fig. 45 with Nichols and Silberling 1980, Fig. 4B). However, higher on the ridge the massive Floride Member with *Thalassinoides* burrows is underlain by an argillaceous dolomite that resembles the regionally developed unit at the base of the Floride. In his text (p.41) O'Neill describes his middle member as being "thin bedded", but in his stratigraphic section (p.95) the interval is described as "thick bedded". Strata assigned here to the Floride Member are very thick to massively bedded. The "Upper Member" of O'Neill (his 36.5 m thick Unit 9) is platy, laminated dolomite. This unit may be a fault block of Upper Silurian rock, because that is the age of the only rock we found resembling the description. The Floride Member of the Ely Springs Dolomite, with a basal, cream-colored marl/mudstone interval, overlain by argillaceous, *Thalassinoides* burrow mottled wackestone was found 200 m south of Hill 6140. The basal cream-colored unit is present in the saddle. The sequence is disrupted by faulting. Beds resembling the Tony Grove Lake Member of the Laketown Dolomite are present west of Hill 6220 on a northeast trending ridge in the southeasternmost corner of Sec. 26 (unsurveyed).

The Laketown Dolomite of O'Neill (1968) is present in several separate fault blocks exposed on the ridge crest of the section. It resembles the Lone Mountain Dolomite and the unnamed Silurian dolomite in Cave Canyon in the southeastern Silver Island Range (see Sheehan, 1976).

### Depositional Environment

This section was located deeper on the ramp than sections in the Silver Island Range. No cryptalgal laminates or stromatolites were found. Most of the section was deposited below normal wave base as cross laminations are uncommon, and the units are argillaceous.

Unit 1 of O'Neill (1968) is 9.1 m thick, with the basal 6 m of the unit unexposed, except immediately above the Eureka Quartzite. Subrounded, fine-grained, quartz sand is incorporated in the basal meter thick grainstone.

Lithologic samples of Unit 1 are bioclastic, lithoclastic packstone. The only obvious macrofauna on weathered surfaces is pelmatozoan debris. Thin sections and polished slabs have graded and ungraded layers, up to 10 cm thick. The basal portion of a typical gravity flow consists of up to 40 percent rounded to elongated lithoclasts, 0.5 to 1.0 cm in diameter, suspended in a mud/wackestone matrix (Fig. 46). The matrix has indistinct laminae. The lithoclasts also contain rounded lithoclasts, are fractured and exhibit an umbrella effect, with spar under some clasts where mud was apparently not deposited during settling. Vertically, the beds grade to laminated, wacke/packstone, with isolated, flat-lying lithoclasts (Fig. 47), followed by cross laminated mudstone. Purple silt seams are on bedding planes and between some laminae (Fig. 48). Also, in Unit 1 of O'Neill (1968) are coquina layers of bioclastic pack/grainstone (fig. 49). Shells and bioclasts are oriented horizontally and interbedded with 1-2 mm layers of wackestone. Scour marks are at the base of some bioclastic layers.

Unit 2 of O'Neill (1968) is a 2.1 m thick, brownish gray quartz-sand grainstone, with rounded, elongated clasts or tubes, 3-5 mm in diameter. The sand clasts have a predominantly horizontal orientation. The unit forms a marker horizon which was also found in the Silver Island Range and at Antelope Peak. Thin sections show irregular mudstone stringers. Units 1 and 2 are assigned to the Ibex Member.

Units 3-7 of O'Neill (1968) (48.4 m thick) are bioclastic, bioturbated pack/wackestone with lithoclasts of peloidal grainstone and mudstone. This interval is not assigned to a member because it is lithologically distinct from recognized members. Bedding is indistinct, and undulating parallel current laminations are common. Thin wine-colored argillaceous films cover many bedding planes. These films are pelagic sediments deposited during intervals of calm water. Fossil debris in bioclastic layers and burrow mottles are more abundant than below, with the degree of abrasion less intense, towards the top of the interval. Distinct, circular burrows, 3-4 mm in diameter, are found about 3 m below the top of the interval. The unit was deposited near storm wave base.

Unit 8 of O'Neill (1968), which is his unnamed middle member, is 41 + m thick. It is assigned to the Floride Member. It consists of medium gray, argillaceous, thick-bedded wacke/packstone, with unoriented bioclasts and lithoclasts. The contact with Unit 7 has chert nodules, is irregular, with relief up to 20 cm (Fig. 45). The Floride Member has distinct burrow mottles, 1-3 cm in diameter. The upper contact was not exposed in the section examined. The unit was deposited below wave base.

### Antelope Peak, Snake Mountains

This section is the deepest part of the ramp examined in the northern transect. The Hanson Creek Formation was examined in the area mapped and measured by Peterson (1968) and Smith and others (1983). The section is in the crest of the northwest faulted limb of the Trout Creek anticline of Antelope Peak in the Snake Mountains, Elko County, Nevada. The location on the Summer Camp 7.5' quadrangle is the southwest corner of sec. 31, T. 40 N., R. 62 E. A sediment log is presented in Figure 47. The section is in Structural Plate III of Smith and others (1983), and was thrust into this area from the north or northwest.

Peterson (1968) recognized seven units in the Hanson Creek Formation at Antelope Peak. These units (numbered 3-9 in *descending* order) were examined in the field. Unit 2 of the Roberts Mountains Formation of Peterson (1968) is the uppermost interval of the Hanson Creek Formation depositional cycle and is herein included in the Hanson Creek Formation. Unit thicknesses are from Peterson (1968).

Unit 9 of Peterson (1968) begins above the Eureka Quarzite and is 83.8 m thick. Thicknesses of subdivisions within Unit 9 were estimated, because structure precludes reliable thickness measurements. The basal contact with the Eureka Quartzite is in a covered interval about 10 m thick. At the crest of Petersons's Trout Creek Anticline numerous faults and fractures, most numerous near the formation base, disrupt the continuity of the strata, making interpretation difficult.

In unit 9 of Peterson (1968), the basal 2-3 m above the covered interval are sandy grainstone to dolomitic sandstone, with subrounded, fine-sand sized quartz grains. Indistinct 1 cm clasts of sandstone could be rounded rip-up clasts or burrow mottles. A second quartz sand horizon, about 3 m thick, with very coarse-crystalline dolomite grains is about 20 m above the first sand layer. This interval was included in Unit 9 by Peterson (1968). The exposed strata of Unit 9, aside from the arenaceous grainstone intervals, is medium dark gray, bioturbated wackestone (Fig. 51). The bioturbated wackestone has many pelmatozoan columnals, with some articulated columnals up to 1 cm in length. A massive, poorly bedded appearance may have been created by fracturing, which obscures the bedding. Low angle cross-laminations are present in some beds. Scattered large (2-4 cm), rounded clasts of grainstone are in the wackestone, near the base of the formation. The unit is extensively fractured.

Units 7 and 8 of Peterson (1968) are 32.0 m thick. They are unfossiliferous dolomite with mudstone texture. The units are darker gray and finer grained than the underlying Unit 9. The interval is bioturbated, with no macrofauna on weathered surfaces. THe unit is thin- to medium-bedded (10-40 cm) and is intensely fractured, with numerous quartz veins.

Unit 6 of Peterson (1968) is 45.7 m thick. At the base of the unit is a covered slope about 5 m thick, with thin-bedded (2-4 cm), gray to cream-colored, argillaceous dolomite mudstone float, with red ferruginous stains.

The upper 40.6 m of unit 6 and the overlying unit 5 of Peterson (1968), which is 4.6 m thick, are light-to-medium gray, argillaceous, thin-bedded lime mudstone (Fig. 52) with rubbly weathering. The interval is burrowed, with horizontal, argillaceous, yellow to tan mottles. Thin sections indicate that the mudstone is not laminated and contains silt-size calcispheres, as well as bioclasts. Trilobites are the most common fossils in the lower portion of the interval, with silicified brachiopods, corals, pelmatozoan debris, bryozoans, nautiloids and trilobites found in abundance in MPM loc. 2932 near the top of Unit 5.

Unit 4 of Peterson (1968) is 6.1 m thick. The unit is iron-stained, reddish, argillaceous, lime mudstone, which is thin-bedded and platy. Unit 3 of Peterson (1968) is 10.7 m thick and forms a covered slope.

Unit 2 (in the Roberts Mountains Formation of Peterson, 1968) is assigned to the upper Hanson Creek Formation. The unit is 7.6 m thick and is light gray, massive dolomite grainstone, with quartz sand grains. This unit resembles the upper part of the Hanson Creek Formation in its type section and is the sand horizon of Mullens and Poole (1972).

Unit 1 of Peterson (1968) is poorly exposed in the lower part. The lowest part may correlate with the upper-most Hanson Creek Formation in the type section. The unit is well-bedded, platy, argillaceous limestone.

The upper part of the Hanson Creek Formation is well exposed immediately south of the crest of Antelope Peak (SW1/4, Sec. 28, T. 40 N., R. 62 E.). There Unit 3 of Peterson's measured section is exposed as massive cliffs of *Thalassinoides* burrowed dolomite. Unit 2 of Peterson is cross-laminated dolostones and has several intervals with quartz sand. At the top of Unit 2 laminations are no longer present and the unit is bioturbated. Unit 2 is overlain by 5 m of alternating 5 cm thick calcareous beds and 1 cm thick black chert beds. This interval is poorly exposed, and could be equivalent to the interval immediately below the Roberts Mounntain Formation in the type section. A 1.5 m cliff of black, laminated chert follows. The laminae are disrupted by slump structues. Limestones with 1 to 3 cm thick turbidite sequences overlie the chert. The base of the Roberts Mountain Formation is placed provisionally at the base of the 1.5 m thick chert bed which we believe is the basal Roberts Mountains chert.

### Depositional Environment

A transgression probably incorporated reworked sand grains of the Eureka Quartzite during the initial Hanson Creek Formation depositional cycle. Possible bioturbation is indicated by the clasts which resemble the *Chondrites* trace fossils of Miller (1977). The second quartz sand bearing interval in Unit 9 is interpreted to have been deposited during a minor regression or by severe storms. This unit corresponds to a sand horizon in the upper part of the Ibex Member at Pilot Peak and the Silver Island Range.

Burrowing by deposit feeders and a diverse fauna including articulated crinoid stems suggests that the basal 83.6 m of the formation (Unit 9), except for the arenaceous grainstone intervals, was deposited in an oxygenated, subtidal environment, below wave base. The carbonate mud matrix, together with the absence of large fossil fragments or bioclastic layers, indicates that the environment was probably located seaward of the optimum zone of carbonate production. The water was probably deep enough to be unaffected by all but the most severe storm activity, which produced rare layers of low angle cross-laminae. The transition to unfossiliferous, dense mud/wackestone (Units 7 and 8) is interpreted as a change to deep water, with only small bioclasts and muds winnowed from areas of greater current activity.

Gray to cream-colored dolomite mudstone (basal 5 m of Unit 6) resembles the basal cream-colored unit of the Floride Member of the Ely Springs Dolomite. The unit is interpreted as a below wave base, quiet-water deposit, possibly recording a widespread transgression, coupled with fine-grained terrigenous input from the western basin.

The upper 40.6 m of Unit 6 and Unit 5 are rubbly, argillaceous lime mudstone with burrows, and was deposited in quiet water, below wave base. The interval is more argillaceous, with more distinct bedding than the upper Floride Member of the Ely Springs Dolomite to the east, and could represent a deeper water facies of the Upper Floride Member. The abundant fossils near the top of the interval suggest that conditions became more favorable for marine life; possibly it was shallower and better oxygenated than the lower part of the interval. The overlying dolomite grainstone (Units 3 and 2) reflects continuing shallowing first to below wave base with *Thalassinoides* burrowing, then to shoals, within wave base. The cross-laminated, quartz sand horizon of Mullens and Poole (1972) marks the Ordovician-Silurian boundary regionally. The shallowing event may have been caused by glacio-eustatic drop in sea level. The top of the cliffy beds are bioturbated, reflecting deposition below wave base. The 5 m thick unit above the dolomite cliffs may have been deposited on a ramp, prior to down-dropping of the shelf margin (Johnson and Potter, 1975) in the Upper Llandovery. The 1.5 m chert has slump structures and overlying beds are turbidites deposited deep on the slope distal to the recently created carbonate shelf margin.

## Southern Transect

### Northern Egan Range

The northern Egan Range section is the easternmost and shallowest section in the southern transect. It was located on the carbonate platform about 100 km from the shelf margin. The section was measured on the west side of the northern Egan Range in central White Pine County, Nevada. Lithologic descriptions of the measured section are in the Appendix. Conodonts from the lower Ely Springs Dolomite near Steptoe on the eastern side of the range are of Conodont Fauna 11-12 age (Harris and others, 1979).

A measured section is described in Appendix I. There are several gravity fault blocks of probable Tertiary age in the study area. Blocks of the upper Floride Member and the overlying Laketown Dolomite, tens of meters in length, slid downslope (to the west) on the underlying marl/mudstone at the base of the Floride Member. A sediment log is presented in Figure 53.

The Ibex Member (Units 1 and 2 of Appendix I), 14.7 m thick, is medium light gray, bioturbated wackestone with a diverse fauna of corals and brachiopods. The basal m of the formation has grainstone with subrounded quartz sand grains.

The overlying Barn Hills Member (units 3-33 and 20a-33a) is 59.6 m thick and consists of alternating bands, from several centimeters to several meters thick, of light- and dark-gray dolomite. The Barn Hills Member has well developed bedding.

Jnits are discontinuous laterally, and they pinch-out over a distance of a few hundred neters. Detailed comparison of sections of the Barn Hills Member measured in djacent canyons about 1 km apart (Units 3-33 and Units 20a-33a) reveals very ifferent patterns of alternating light- and dark-gray bands.

The Barn Hills Member consists of a variety of alternating facies (Fig. 7) with a parse macrofauna. Irregular surfaces between some units may have been formed y submarine erosion (Fig. 55). The light gray dolomite bands are low- angle cross-aminated or nonlaminated grainstones (Fig. 7) and pelleted dolomite.

The dark bands of the member are of six varieties. (1) Pelleted mudstone (Unit !, for example). (2) Indistinctly laminated packstone, with *Chondrites* burrows (Unit :6a for example). (3) Parallel-laminated to low-angle cross-laminated pelleted nudstone, with argillaceous seams. (4) Intensely bioturbated, pelleted mud/wackes-one with pelmatozoan columnals, and some *Chondrites* burrows (Unit 7 for example). 5) Alternating light and dark laminae to 1 cm thickness (Figs. 56 and 57). (6) ;ryptalgal laminites and low stromatolite domes (Unit 22 for example).

The Lost Canyon Member (Units 34-38) is 38.6 m thick and has a gradational ontact with the underlying Barn Hills Member. The relatively homogeneous dark olored member is indistinctly bedded, burrow-mottled wacke/packstone, with a di-erse fauna. This member contrasts with the underlying member which has well lefined beds of alternating light and dark color.

The Floride Member (Units 39-49) is 29.1 m thick. The basal part of the Floride Aember (Unit 39-43) is 8.3 m thick. Unit 39 is brownish-yellow or cream-colored, laty marl/mudstone, with red, ferrugenous stains (Fig. 58). Unit 40 is an argillaceous arbonate mudstone. Unit 41 is a coarse encrinitic grainstone (Fig. 6), 0.8 m thick, vith micrite rinds on clasts (Fig. 59). Unit 42 (4.4 m thick) is covered. From Units .3 to 44, argillaceous content decreases from the very argillaceous, 1.2 m thick Unit .3, which is the top of the basal Floride Member, to wacke/packstone with silicified ossils and distinctive mottles. Units 44 to 48 are the distictive *Thalassinoides*-burrowed liff-forming interval with massive bedding that has been disrupted by bioturbation.

Unit 49 (0.8 m thick), at the top of the formation, is well-sorted, light-gray ;rainstone composed of micritized oolites (Fig. 60). The unit has low-angle cross amination and in places very fine quartz sand is interspersed in the oolite. This is he sand horizon of Mullens and Poole (1972).

### )epositional Environment

The Ibex Member records an initial transgresssion which deposited reworked sand rom the Eureka Quartzite. Subtidal deposition followed which supported an open narine fauna with extensive infaunal bioturbation.

The Barn Hills Member was deposited in a more variable environment than the bex Member. Quiet water deposits with an open marine fauna and intense bioturba-ion alternate with cross-laminated storm deposits, and cryptalgal laminates. Deposi-ion was above wave base much of the time. The Lost Canyon Member was deposited n a deeper environment than the Barn Hills Member. An open marine fauna is reserved in intensely bioturbated wacke/packstone that was protected from rework-ng by waves. Bedding is indistinct rather than sharply defined as is characteristic f wave agitated environments. Current-laminated beds are uncommon.

The basal part of the Floride Member is the regionally distributed argillaceous narl/mudstone deposited during a transgression. A single, 0.3 m thick, homogeneous ;rainstone in this unit was probably deposited during a major storm. The overlying cliff-forming *Thalassinoides*-burrowed part of the member was deposited below wave base, where the burrow galleries were protected from disruption by waves. The cross-laminated oolite with quartz sand at the top of the formation was probably deposited during glacio-eustatic regression at the systemic boundary.

The base of the overlying Tony Grove Lake Member of the Silurian Laketown Dolomite has current cross-laminated pack/grainstone with numerous bioclastic lenses. Bases of beds are commonly scoured.

## Lone Mountain

### Location and Description

The Hanson Creek Formation at Lone Mountain is located in southern Eureka County, Nevada, Bartin Ranch quadrangle, at Nevada coordinates (east zone), E. 304, 800 ft., N. 1, 761, 920 ft. (Fig. 2). The section is located beyond the carbonate platform margin but high on the ramp. Because the lithology consists of dolomite at Lone Mountain, the formation is also referred to the Ely Springs Dolomite by some authors (Ross, 1970).

The following description generally agrees with that presented by Dunham (1977), Dunham and Olson (1980) and Ross (1970). The interpretation of depositional environments in the upper part of the section differs from that of Dunham (1977) and Dunham and Olson (1980). The section was measured by Ross (1970), who recognized 10 units. A sediment log is presented in Figure 61.

### Depositional Interpretation

Unit 1 of Ross (1970) (20.4 m thick) is grainstone with abundant quartz sand in the basal meter of the unit, with a transition to dark-gray, fossiliferous, bioturbated, encrinitic packstone in the upper part of the unit. The packstone contains numerous rugose and tabulate corals (Dunham and Olson, 1980, Fig. 5) commonly in bioclastic layers. Current cross-lamination is common and the bases of beds are commonly scoured. Deposition of the unit began with an initial transgression which incorporated quartz sand grains of the underlying Eureka Quartzite. As the transgression continued the remainder of the unit was deposited within wave base.

Unit 2 of Ross (1970) (19.2 m thick) is light-gray, cross-laminated or bioturbated pack/grainstone with pelmatozoan debris in gradational contact with Unit 1. Unit 2 was deposited within wavebase.

Unit 3 of Ross (1970) (7.6 m thick) is a covered slope, with float consisting of very thin-bedded, argillaceous, nonlaminated mudstone, with red iron stains. On the southernmost ridge, Unit 3 is eliminated by a fault. The unit resembles the cream-colored base of the Floride Member of the Ely Springs Dolomite, and was deposited in quiet water below normal wave base. At the contact between Units 2 and 3 rounded clasts of Unit 3 lithology to 3 cm in diameter are incorporated in the upper part of Unit 2. Sediments of Unit 3 lithology must have been deposited and lithified nearby, subsequently eroded and deposited by storms prior to beginning of deposition in the immediate area.

Unit 4 of Ross (1970) (11.8 m thick) is mostly covered, with blocky outcrops. In thin section, the rock is indistinctly parallel-laminated, bioclastic wacke/packstone. The unit was deposited in a quiet environment below wave base. Ashgillian conodonts were recovered from this unit by Dunham (1977, p. 161).

Unit 5 of Ross (1970) (10.6 m thick) is fossiliferous, bioturbated wacke/mudstone vith a diverse fauna. Seams of argillaceous material are common as is parallel amination. Corals are relatively unabraded, possibly having been tilted by deposit-eeding burrowers. Brachiopods are locally abundant. Crinoid stems are articulated o lengths of 1 cm, suggesting an absence of currents. Our interpretation places Jnits 4 and 5 below wave base on a ramp rather than in a protected position behind shoal as proposed by Dunham (1977).

Unit 6 of Ross (1970) (0.2 m thick) is yellow-orange mudstone, with mudstone thoclasts (Dunham and Olson, 1980, Fig. 6). The upper contact of Unit 6 is irregular, ith burrows or cracks, up to 10 cm deep, filled with grainstone of Unit 7. Ross 970) considered this unit to be formed on a corrasion surface, possibly formed by ıbaerial erosion of the top of Unit 5. This interval of subaerial exposure may reflect glacio-eustatic drop in sea level.

Unit 7 of Ross (1970) (4.0 m thick) is a peloidal, lithoclastic grainstone with ıbrounded, quartz sand grains (Fig. 62 and Dunham and Olson, 1980, Fig. 7). The ıit has intervals of parallel laminae, low angle cross-laminae and possible herring ne structures. The unit was deposited in a shoal. This is the quartz sand horizon Mullens and Poole (1972) and, based on regional relationships, records a regression ar the Ordovician-Silurian boundary. Mudstone lithoclasts may have been eroded m nearby carbonate mud mounds (Dunham, 1977).

Unit 8 of Ross (1970) is 9.1 m thick, light-gray, pelleted, unfossiliferous mud/wacke-ne with parallel laminations and argillaceous seams. This unit forms the top of e Hanson Creek Formation as redefined here. The unit is interpreted to have been posited in a subtidal environment, below wave base. This unit is in the stratigraphic sition of the light colored dolomite in the Mountain Boy Range from which Ross d others (1979) collected *Gamachignathus* of probable Conodont Fauna 13 age. It tentatively correlated with that unit, but it could also be placed at the base of the ny Grove Lake Member. Dunham (1977, p. 162) reports the Bereich I conodont *iodina irregularis* 9 m above Unit 7. This conodont horizon could be in either it 8 or Unit 9. Bereich I of Walliser (1964) is of early Silurian age.

Jnit 9 of Ross (1970) begins 82.9 m above the Eureka Quartzite and is either 3 thick (Ross, 1970) or 5 m thick (Dunham and Olson, 1980). Unit 9 is dark-gray, rent-laminated, pelleted, bioclastic packstone, with breccias at the lower and er contacts. The breccias are enigmatic. The remainder of the unit is interpreted ıave been deposited in a subtidal environment, at or just below wave base, and s affected by storm waves and currents. Stromatolites reported by Dunham (1977) l Dunham and Olson (1980) were not found.

Init 10 of Ross (1970) is 7.3 m thick, light-gray wacke/packstone, with lithoclasts elleted mudstone. The basal contact has irregular relief of about 10 cm. There angular clasts of dark dolomite to about 10 cm diameter at the base of Unit 10. unit is interpreted to have been deposited in a subtidal environment, within e base.

nits 9 and 10 of Ross (1970) are assigned to the Tony Grove Lake Member of Laketown Dolomite. This is equivalent to the Combs Canyon Dolomite Member ıe Hanson Creek Formation of Ross and others (1979). Virgianid brachiopods, ch are characteristic of the member, were not found at Lone Mountain, although are common in the Mountain Boy Range. Regionally the location of Lone Moun- is at the western limit of the member, and the absence of virgianids may be ted ecologically to the deep position on the carbonate ramp.

Above unit 10 is the Roberts Mountains Formation with alternating 3-10 cm thick layers of dark-gray chert and dolomite (Murphy and others, 1977, fig. 8). Structures attributed to stromatolites in this unit are deformed (probably slumped) current laminae. We follow Matti and others (1975, fig. 23a) inbelieving the Roberts Mountains Formation was deposited on a slope rather than intertidally.

The interpretation of depositional environments in this section differs substantially from that of Dunham (1977) and Dunham and Olson (1980). Most of these differences are because a regional model of a ramp, rather than a carbonate shelf, has been applied. Units 3 and 4 were deposited in relatively quiet water. On a basis of regional trends we interpret the environment to have been quiet because the section had a position relatively deep on the ramp, rather than being protected by a shoal.

Shallowing to exposure in Unit 6 may be due to a world-wide glacio-eustatic drop in sea level near the Ordovician-Silurian boundary. Similarly, the sand horizon is associated with the regression. Light colored dolomite containing probable Zone 13 conodonts in the Mountain Boy Range (Ross and others, 1979) may correlate with Unit 8. This unit is interpreted to have been laid down during the low stand in sea level when sections to the east were above water. The Tony Grove Lake Member of the Laketown Dolomite was deposited after the Silurian transgression.

## Martin Ridge and Copenhagen Canyon, Monitor Range

Two outcrops of the Hanson Creek Formation were examined in the Monitor Range in southern Eureka County, Nevada. The sections are located deeper on the ramp than was the section at Lone Mountain. A poorly exposed, complete section was described by Dunham (1977) and Dunham and Olson (1980) at Martin Ridge. On the west side of Copenhagen Canyon, the upper part of the Hanson Creek Formation was mapped by Matti and others (1975) and discussed by Murphy and others (1979). Locations on the USGS Horse Heaven Mountain 7.5′ quadrangle are in the SW 1/2, sec. 36, T. 16 N., R. 49 E. for the Copenhagen Canyon section and in the NW 1/4, sec. 30, T. 16 N., R. 50 E. for the Martin Ridge Section. A sediment log is presented in Figure 63.

### Description

The description of the section at Martin Ridge by Dunham (1977), Dunham and Olson (1980) and Matti and others (1975) is summarized below, with additional comments based on our examination of the 175.4 m thick section.

The Eureka Quartzite is overlain by 90 m of thin to medium bedded, dark-gray, shaly, argillaceous, parallel laminated, graptolitic limemudstone (Dunham and Olson, 1980, fig. 20). Graptolites from the base of the section are either Zone 13 or 14 age (high Eden-Maysville) according to Berry (in Dunham, 1977, p. 161). Harris and others (1979) report collections of Conodont Fauna 11 or 12 near the base of the section.

Between 90 m and 113 m in the section are thin to medium bedded (5 to 40 cm), dark-brown, parallel-laminated lime mudstones with argillaceous partings about 5 cm thick (Dunham and Olson, 1980, fig. 21). Occasional beds are bioturbated.

From 113 m to 130 m is an encrinitic wackestone with abundant bioturbation in the lower part. There is cross-lamination and hummocky cross-lamination in the upper part of the unit. Bedding is thin to medium.

At 130 m is an oolite bed which also contains quartz sand grains (Dunham and )lson, 1980, fig. 22). This is the sand horizon of Mullens and Poole (1972). From 30 m to 135 m broken fossil shells are in a brown, bioturbated lime mudstone.

At 135 m is a cliff-forming, cherty, lime mudstone which Dunham (1977) and )unham and Olson (1980) assign to the Roberts Mountains Formation. Matti and thers (1975) and Murphy and others (1977) assign this cherty unit, which they ecord as being 30-35 m thick, to the Hanson Creek Formation. We measured 35.6 ı at Copenhagen Canyon. The unit is composed of parallel-laminated alternating ıert and lime mudstones that are 2 to 15 cm thick. Laminae are better preserved ı the chert than in the limestone. Parallel laminations dominate, but possible umped beds are present also.

The cherty, cliff-forming interval is overlain at 170.6 m by 4.8 m of thin bedded, oclastic lime mudstone and wackestone. Some low-angle, cross- laminated beds ith scoured bases are present. There is no fauna and no bioturbation. Regionally ıis interval is part of the Hanson Creek Formation.

The Roberts Mountains Formation follows. It is a laminated, argillaceous lime udstone and wackestone and allodapic packstone (Matti and others, 1975). Early andovery Zone 18 graptolites have been recovered near the top of the cherty terval of the Hanson Creek Formation and Upper Llandovery graptolites (Zone :-25) have been recovered at the top of the formation (Murphy and others, 1977).

The Hanson Creek Formation at Copenhagen Canyon is similar in lithology and :atigraphic relationships to the Martin Ridge section. The base of the section is t exposed. Midway through the basal graptolitic mudstone, *Laevicyclus* trace fossils ːre found on bedding planes (Fig. 65). Thirty meters of bioturbated, fossiliferous ıckestone overlies the graptolitic mudstone. Above the wackestone is about 7 m laminated, cross-bedded pack/grainstone, with quartz sand and scours to 5 cm in pth. Bioturbated wackestone, about 5 m thick, overlies the laminated limestone, d continues to the contact with the upper cherty, cliff forming unit at the top of ؛ formation.

## positional Interpretation

n the first 90 m of the section at Martin Ridge the absence of both a shelly fauna l burrowers, together with a graptolitic mudstone lithology, suggests that the iments were deposited in anoxic, quiet water that was well below wave base. The *:vicyclus* in this unit could be either a feeding trace similar to structures made some modern polychaetes or a gas expulsion structure (Frey, 1970). Deposition ın isolated deep water basin has been suggested by Dunham (1977). Alternatively, osition could have been on a ramp well below wave base. The presence of oxyge- ed water in a lower slope environment in the Toquima Range to the west, with xic conditions in the upper slope of the Monitor Range to the east, during the ɔer Ordovician, can be explained by a model for oceanic ventilation suggested by ry and Wilde (1978). These authors proposed a glacio-oceanographic model for variation of dissolved oxygen with depth in the oceans as a function of climate time. Three zones of differing oxygen content were suggested: 1) an upper zone ı turbulent mixing created by winds, resulting in well-oxygenated surface water; middle anoxic zone not affected by surface conditions, with oxygen depleted by ınic decay; and 3) a bottom layer of aerobic to dysaerobic water created by dense, -oxygenated water formed at cold latitudes, which sank and moved to mid and latitudes. The Monitor Range may have been in the anoxic zone, while the

Toquima Range, lower on the ramp than the Monitor Range, received oxygenated water from high latitudes.

The gradual increase in lime mudstone, with an increase in bed thickness, a decrease in argillaceous content, and development of some bioturbation from 90 m to 113 m, reflects a shallowing which could have been caused by progradation of shelf deposits westward over the slope deposits, or a lowering of sea level, bringing the area into the oxygenated zone.

From 113 m to 130 m in Dunham's section, a change from laminated wackestone to bioturbated packstone, followed by hummocky cross-laminated grainstone, suggests a shallowing-upward sequence with increasing current energy. Environments are interpreted to have changed from subtidal to within wave base. This may reflect glacio-eustatic drop in sea level at the systemic boundary, which culminated at Martin Ridge in the oolite and sand horizon at 130 m, which is the regionally developed sand horizon of Mullens and Poole (1972). A bioturbated, bioclastic wackestone lithology, which persists to 135 m, suggests deposition near wave base.

The cherty unit between 135 m and the top of the formation closely resembles the lowest part of this formation and probably was deposited below wave base also (Matti and others, 1975). The abrupt change in facies reflects an abrupt deepening of the environment. The cherty, cliff-forming unit overlies the sand zone of Mullens and Poole (1972) and is dated as early Silurian (Mullens and Poole, 1972; Murphy and others, 1977). The interval is in the stratigraphic position of the Middle Dolomite Member of the Hanson Creek Formation in the Mahogany Hills (Ross and others, 1979). The unit could be in part Conodont Fauna 13 age and in part early and middle Llandovery. As such, there may have been continual deposition across the Ordovician-Silurian boundary, in a position that was deep enough on the ramp that it was not exposed during the terminal Ordovician glacio-eustatic drop in sea level. At this stratigraphic position higher on the ramp there is a break in sedimentation, (for example the soil horizon at Lone Mountain).

The Roberts Mountains Formation is laminated lime mud and wackestone and allodapic grainstone, deposited by turbidity currents on a slope (Matti and others, 1975). Matti and others (1975) and Murphy and others (1977) suggest that a significant disconformity exists at their contact between the Roberts Mountains and Hanson Creek formations. They suggest an erosional contact. Note the cobble-boulder conglomerate at the base of the Roberts Mountains Formation (Murphy and others, 1977, fig. 5). They also note a major change in depositional environments at this horizon. We suggest that this change in depositional environments corresponds to the down-dropping of the shelf margin described by Johnson and Potter (1975). Conglomerates would be expected to be shed from the scarps, and at the same stratigraphic horizon in the Toano Range Sheehan and Pandolfi (1983) found clasts in debris flows which they believe were derived from fault scarps produced during the down-dropping event.

### Ikes Canyon, Toquima Range

The Upper Ordovician unnamed limestone of McKee (1976) is found in northern Nye County at Ikes Canyon in the northern Toquima Range (Fig. 1). On the USGS Dianas Punch Bowl 1:62,500 quadrangle, the section examined is in the NE 1/4, Sec. 13, T. 14 N., R. 46 E., a half mile northwest of the mouth of Ikes Canyon (Kay and Crawford, 1964). Nevada coordinates are E. 173,700 ft., N. 1,569,200 ft. The section studied is the same as that described by Kay (1962) and Ross (1970). The unnamed limestone is of Conodont Fauna 11-12 age (Harris and others, 1979).

## Description

The outcrop is 25 m thick (Harris and others, 1979) and is medium dark-gray, 'eathering medium- to light-gray, fine-grained to calcarenitic, thin-bedded (3-10 m), trilobite-rich argillaceous limestone, with clay partings. The clay partings weather iore rapidly than the limestone, imparting a rubbly appearance. Indistinct, small-:ale (to 0.5 cm diameter), light-gray mottles are in a gray matrix. A phosphatic lag eposit, several cm thick and of variable thickness is at the base of the formation. he unnamed limestone lies with apparent unconformity above the Antelope Valley imestone and with apparent unconformity above the Roberts Mountains Formation, hich is thin-bedded, with platy weathering (McKee, 1976). The boundaries of the rmation may be unconformities that are either erosional or non-depositional (rep-:senting intervals of sedimentary bypassing on the slope). Also the boundaries ight not be unconformities, but rather low angle faults which have eliminated arts of the section (see Harris and others, 1979).

A diverse faunal assemblage is dominated by trilobites, ostracodes, brachiopods specially plectambonetids), and pelmatozoans. Molluscs and one rugose coral were so identified. The fossils were disarticulated, broken and abraded, with many agments silicified. Burrow mottles were filled with bioclastic debris. Harris and hers (1979) identified a mixture of indigenous Upper Ordovician conodonts, as ell as transported Middle Ordovician conodonts in this formation.

Three interbedded lithologies were identified in the Toquima Range: 1) microbio-astic calcisiltite or peloidal grainstone; 2) microbreccia or bioclastic, lithoclastic ickstone; 3) bioturbated lime wackestone. The microbioclastic calcisiltite is a edium dark-gray mixture of fine, well-sorted bioclasts and peloids, with a ainstone texture and calcite cement (Fig. 61). The deposits are finely laminated, ith parallel and wavy cross-laminations. Subrounded quartz silt grains make up out 20 percent of the rock volume. Vertical, unbranched burrows, 1-2 mm in ameter (Fig. 65) are common.

The microbreccia is allodapic, bioclastic, lithoclastic packstone consisting of unded to angular, unsorted lithoclasts, from two mm to one cm in diameter, sepa-ted by irregular argillaceous seams (Fig. 66). An umbrella effect is found beneath me clasts. Lithoclasts, with trilobite debris to several cm in length, are scattered roughout the rock.

The bioturbated lime wackestone is medium dark-gray, very thin-bedded (2-3 cm), th up to 20 percent quartz silt grains, and argillaceous seams. Irregular burrow ottles, up to 0.5 cm in diameter, are common and contain concentrations of bioclastic bris.

## positional Interpretation

The Upper Ordovician strata in the Toquima Range are lower ramp deposits isisting of allochthonous, allodapic material, interbedded with *in situ* deeper water posits. The sediments were deposited in an aerobic to dysaerobic environment, as licated by an abundance of burrows and bioturbation and a diverse macro-fauna.

Reworking and redeposition of older sediments is indicated by conodont studies Harris and others (1979). The mixture of conodonts from different time intervals ludes indigenous Upper Ordovician conodonts as well as reworked conodonts, ssibly from the Middle Ordovician Antelope Valley Limestone, Copenhagen For-ition and/or the Eureka Quartzite.

The thin phosphatic limestone at the base of the formation (Harris and others, 1979) is a lag deposit (Wilson, 1975), representing coarse material slowly deposited in a winnowing zone during initiation of the unnamed limestone's depositional cycle.

Allochthonous gravity flow processes produced the microbreccia (bioclastic, lithoclastic packstone), and the microbioclastic calcisiltite. Downslope turbidity currents moved shelf and upper ramp sediments, as well as locally derived lower ramp deposits down the ramp, forming thin sheet deposits and the parallel and wavy cross-laminated calcisiltite. The presence of turbidites on the distal slope suggests that this was a distally steepened ramp (Read, 1982).

The burrow mottled lime wackestone is a possible *in situ* deposit, derived from local deep water carbonate production, with burrowing deposit feeders reworking the sediments. Alternatively, it may be an intensely reworked allodapic sediment.

## Regional Synthesis

The Upper Ordovician and Early Silurian carbonate platform in eastern Nevada and western Utah was the site of shallow-water carbonate deposition which produced widespread, monotonous dolomite sequences. The widespread, uniform nature of the dolomite facies permits a simple stratigraphic nomenclature with geographically wide ranging formations and members. Beyond the western margin of the dolomite platform was a distally steepened ramp where the seafloor sloped gradually into a deep basin in central Nevada. On the ramp, facies vary significantly over short distances. In contrast with the platform, the rapid lithofacies changes down the ramp will require a complex stratigraphic nomenclature to accomodate the many facies present on the ramp.

Previously, the Ordovician platform margin has been interpreted as a carbonate shelf margin presumably because this was the only model available. Patterns of sedimentation along the two transects are in accord with the carbonate ramp model of Ahr (1973). The ramp model differs significantly from the carbonate shelf model. In fact Ahr (1973) presented the ramp model as an alternative to the carbonate shelf model (see summary by Wilson, 1975), which at the time was the only model in wide-spread use. The carbonate shelf model was based on modern carbonate platforms which in nearly all modern examples have steep margins, and reefs or shallow carbonate buildups at the shelf edge. Ahr recognized that many examples of carbonate margins in the stratigraphic record have gentle slopes and his examples of the ramps are closely comparable to the units under study here. Notably absent are reef or shelf edge carbonate buildups. As noted by Read (1980), carbonate ramps characteristically lack down-slope sediment-gravity flow deposits, and these are rare in the Hanson Creek Formation. Not until a carbonate shelf edge was established by faulting in the Late Llandovery did allodapic sedimentation become common.

Two relatively brief events had a profound effect on sedimentation along the ramp. The latest Ordovician glaciation, which eustatically depressed global sea level, drained the shallow carbonate platform, resulting in a widespread disconformity. Areas deeper on the ramp received continuous deposition during the drop in sea level, but these areas (Antelope Peak, Lone Mountain, Monitor Range) show distinct shallowing at this time. Glaciation ended at the beginning of the Silurian, and deposition resumed on the shallow carbonate platform. Sediments in the deeper parts of the ramp received deep-water deposition once more.

The second event involved down-faulting of a strip at the edge of the carbonate platform. The Middle Llandovery or Early Late Llandovery down- faulting, which ccurred along the shelf margin in central and northern Nevada and possibly central daho, produced a steep slope at the western edge of the platform (Johnson and 'otter, 1975). The down faulting was probably along listric normal growth faults which are common along modern passive margins. This faulting terminated the arbonte ramp which had persisted through the Ordovician. The faulting initiated carbonate shelf with an abrupt slope into the western basin. The abrupt shelf edge nitiated generation of carbonate buildups (see Wilson, 1975). Deposition of the llodapic deposits of the Roberts Mountains Formation began. The Lone Mountain Dolomite is a shallow, shelf-edge deposit which prograded westward during the ilurian and early Devonian (Johnson, 1974). This general pattern, typical of a arbonate shelf margin, persisted until the beginning of the Antler Orogeny in the 'evonian.

In the two transects, the Lakeside Mountains and the northern Egan Range sections were located centrally on the platform. The Silver Island and Lone Mountain ections were located high on the ramp, just west of the transition from platform to amp. The Pilot Range, Copenhagen Canyon, Martin Ridge and Antelope Peak sections were located centrally on the ramp. The Ikes Canyon section in the Toquima ange was deep on the ramp.

An initial transgression at the beginning of the Upper Ordovician depositional cle incorporated quartz sand grains of the underlying Middle Ordovician quartzites to the basal part of the Ely Springs Dolomite, Fish Haven Dolomite and parts of e Hanson Creek Formation. Quartz sand grains do not occur in the basal graptolitic ne mudstone of the Hanson Creek Formation in the Monitor Range. The Eureka uartzite is not present in the Toquima Range.

The lower part of the depositional cycle in the Lakeside Mountains, Silver Island ange, northern Egan Range and Lone Mountain is characterized by bioclastic ackestone which formed in a subtidal environment, below wave base. In the Pilot ange and Antelope Peak, the lower parts of the sections are characterized by slope posits with laminated pack/grainstone and graded and platy ungraded floatstone yers. On Martin Ridge and at Copenhagen Canyon graptolite lime mudstone in is stratigraphic position were lower slope deposits. Both transects record progresve westward deepening of environments.

The Lakeside Mountains section preserves the shallowest deposits in either trans-:. Algal laminates, stromatolites, and evidence of storm activity were common to ese shallow subtidal environments. Shallowing upward cycles some tens of meters ick are easily recognized because shallow, subtidal rocks are easily differentiated m the shallower algal laminates. A generalized cycle consists of several meters open marine, below wave base deposits above a discontinuity surface. Rip-up clasts underlying tidal flat deposits are incorporated into the base of the subtidal deposits. gradual transition, tens of centimeters to a few meters thick, into intertidal/supraal deposits, reflects a relative regression of sea level due to seaward progradation environments, tectonic activity or eustatic sea level changes. Back-barrier, quietter, lagoonal deposits may be present near the top of a cycle. The upper cycles thinner and initially are not as deep as the lower cycles.

n the northern Egan Range section the Lost Canyon and Barn Hills Members of Ely Springs Dolomite include fewer intertidal deposits than were found in the keside Mountains. However, the area was also located centrally on the carbonate tform, more than 50 km from the edge of the ramp. The Barn Hills Member sists of tidally dominated subtidal to intertidal deposits. A variable, shallow environment of deposition produced pellet grainstone, carbonate mudstone units with lenticular bedding, and algal laminates.

The Lost Canyon Member in both the northern Egan Range and the Silver Island Range has few algal laminated sediments. The Silver Island Range section lacks the shallow deposits of the Barn Hills Member, and the section was located in a deeper position on the ramp than was the northern Egan Range section.

Still deeper on the ramp (Pilot Range, Antelope Peak, Lone Mountain) algal laminates were uncommon or absent prior to the glacio-eustatic decline in sea level. Most deposition was below wave base. Fine grained, non-carbonate terrigenous content is high. Limestones are present, whereas dolomite is ubiquitous to the east. Beyond these sections, to the west, limestone predominates, and terrigenous silt and clay are even more common.

Ramp deposits in the Monitor Range were initially deep graptolitic limestones, deposited in an anoxic, quiet-water environment. The anoxic sediments may have been deposited in an oxygen minimum layer of the ocean (Berry and Wilde, 1978). Deeper water deposits to the west (in the Toquima Range) were apparently beneath the oxygen minimum layer, since they contain a diverse, relatively deep-water fauna. The deepest part of the ramp examined in our transects was in the Toquima Range, where bioclastic, lithoclastic packstone, laminated calcisiltite with cross-bedding, and carbonate grainstone are interpreted to have been deposited in a lower slope environment that was oxygenated.

In the upper parts of the sections are the Bloomington Lake Member of the Fish Haven Dolomite and the Floride Member of the Ely Springs Dolomite. These members are widespread, massive, intensively burrowed units deposited below wave base. At the base of the Floride Member of the Ely Springs Dolomite is a regionally developed, cream-colored, argillaceous, platy carbonate mudstone with ferruginous stains. This unit is also present in the Hanson Creek Formation at Lone Mountain and in the Fish Haven Dolomite in northern Utah. The interval is recessively weathered and was deposited in a quiet-water, subtidal environment. The unit is distinctive because it is the only argillaceous unit in the shallow parts of the shelf. The regional extent suggests that the environment may have been the initial clastic dominated phase of a shallowing upward cycle. It was not present in the Lakeside Mountains which is the shallowest of the sections examined and environments may not have been deep enough for deposition of the cream-colored unit.

In the Silver Island, Pilot and northern Egan ranges and at Lone Mountain, the interval between the basal cream-colored, argillaceous interval and the top of the formation is argillaceous, bioclastic wacke/packstone with intense *Thalassinoides* burrow mottling. The Bloomington Lake Member of the Fish Haven Dolomite in the Lakeside Mountains is a similar unit. The interval was deposited in a shallow subtidal environment, below wave base. This interval may be correlative with the Hanson Creek Formation above the graptolitic lime mudstone and below the bedded cherts in the Monitor Range. At Antelope Peak lime mud/wackestone in a similar stratigraphic position may reflect a facies change, with deposition in a deeper subtidal environment than was present in the Pilot and Silver Island Ranges.

In the northern Egan Range and the Silver Island Range the quartz sand horizon of Mullens and Poole (1972) is the uppermost Ordovician deposit. The horizon is overlain by the Silurian Laketown Dolomite in these sections. In the Lakeside mountains the sand horizon is missing beneath the Laketown. A depositional hiatus at the Ordovician-Silurian boundary is present in these three sections.

In the Lone Mountain, Monitor Range and Antelope Peak sections the upper parts of the Ordovician section overlie the sand horizon and record a shallowing to a shoal environment, within wave base. The shoaling was probably related to the latest Ordovician glacio-eustatic lowering of sea level. At Lone Mountain the Hanson Creek Formation is overlain by the Tony Grove Lake Member of the Laketown Dolomite.

In sections in the transect that are relatively deeper on the ramp the Hanson Creek Formation (in the Antelope Peak and Monitor Range section) and the unnamed limestone (in the Toquima Range section) are overlain by allodapic deposits of the Roberts Mountains Formation.

Sedimentation was apparently continuous across the Ordovician-Silurian in the western (deeper) sections, but there is a clear indication of shallowing which could be due to the glacio-eustatic drop in sea level.

After the glaciation, sea level rose rapidly,and sedimentation was initiated once more on the carbonate platform. These deposits belong to the Tony Grove Lake Member of the Laketown Dolomite. Shallow water deposition continued into the Late Llandoverian or Wenlockian in the Lakeside and northern Egan Range sections.

On the transects, at points just east of the northern Silver Island Range and Lone Mountain, Middle or early Late Llandovery block faulting dropped a segment of the margin downward. A sharp break in slope was created. East of this faulting, shallow water deposition continued. West of the fault the allodapic Roberts Mountains Formation (Matti and others, 1975) was deposited on a steep slope. The Roberts Mountains Formation is allodapic dolomite in the northern Silver Island Range and at Lone Mountain but is platy limestone and shale at Antelope Peak and in the Monitor Range. The Roberts Mountains Formation is largely shale at Ikes Canyon (see Matti and McKee, 1977).

## Conclusions

Two transects across the Upper Ordovician carbonate platform margin were examined in western Utah and eastern Nevada. A broad carbonate platform in Utah and east central Nevada is dominated by intertidal and shallow subtidal dolomites. A carbonate ramp (Ahr, 1973), which descended into the basin in central Nevada, is characterized by shallow subtidal dolomite sequences on the east which grade westward into deeper water limestones. The limestones in turn grade westward into more terrigenous units down the ramp. The ramp model more adequately explains Upper Ordovician and Lower Silurian facies patterns than does the carbonate shelf model which was the only model available to earlier workers.

Interposed on the ramp pattern is a regional shallowing caused by latest Orodvician glacio-eustatic drop in seal level. Sections to the east became emergent. Deeper water sections on the west received continouus sedimentation but are characterized by latest Ordovician regressive patterns which brought shallow water dolomites into late Ordovician parts of these sections.

The carbonate ramp was terminated in the Middle or Early Upper Llandovery when the upper part of the ramp was down-faulted, producing an abrupt break in slope. Along the break in slope a typical carbonate shelf (Wilson, 1975) developed. Immediately west of the shelf-edge, stratigraphic sequences are made up of Upper Ordovician and lowest Silurian relatively shallow ramp facies overlain by deep water Silurian slope facies. The abrupt break in slope initiated carbonate production, and a carbonate bank (Lone Mountain Dolomite) at the shelf edge prograded westward over deeper water rocks during the Silurian and Devonian. In the area east of the carbonate shelf margin, shallow-water deposition (Laketown Dolomite) persisted into the Late Llandovery or Wenlock and was followed by cryptalgal laminites of the Water Canyon and Sevy Dolomites.

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## Appendix

## Description of Measured Sections

### Lakeside Mountains Section

[he Fish Haven Dolomite was examined in the southern Lakeside Mountains )ut six miles north northeast of Delle, Utah, in the NE 1/4, SE 1/4, sec 32, T. 2 R. 8 W. The section was described by Budge and Sheehan (1980b). The area was pped by Young (1955). The basal Paris Peak Member has been remeasured and lescribed below. Budge and Sheehan (1980b) did not recognize members in the tion, but our reexamination permits recognition of three members.

3udge and Sheehan (1980b) incorrectly estimated the Paris Peak Member (their it 1) to be 10 feet (3 m) thick. Reexamination of the section revealed that 41.1 m trata below Unit 2 of Budge and Sheehan (1980b) should be assigned to the Paris ık Member.

Jnits 2-15 of Budge and Sheehan (1980b) are assigned herein to the Deep Lakes mber, which is 62.9 m thick. Units 16-18 of Budge and Sheehan (1980b) are nsferred from the Tony Grove Lake Member of the Laketown Dolomite to the omington Lake Member of the Fish Haven Dolomite. The latter member is 73.4 hick. The total thickness of the redefined Fish Haven Dolomite is 177.4 m.

!emoving Units 16-18 from the Laketown Dolomite reduces the thickness of the ıy Grove Lake Member from 188.0 m to 114.5 m, and the total thickness of the ɩetown Dolomite from 311.3 m to 237.9 m (Budge and Sheehan, 1980b).

### Fish Haven Dolomite

| | Unit Thickness (meters) |
|---|---|
| is Peak Member. Thickness: 41.1 m. | |
| Dolomite, medium gray (N5), weathers light gray (N7) to medium gray (N5); microcrystallne, thin- to medium-bedded; continuous yellow-brown chert bed, 2-4 cm thick, at base of unit; laminated in part; chert lenses and nodules present; silica stain on surface of dolomite, with stain medium yellowish orange (10YR6/4) on weathered surfaces; chert layer, black, overlies stained interval, with irregular thickness, varying from 1 to 10 cm; dark gray (N3), weathered and fresh, dolomite at top of unit; light and dark gray dolomite layers interfinger, with layers overlain by dark gray (N3) dolomite layer of varying thickness; dark gray chert layer at top of unit (Cherty, unfossiliferous, laminated mudstone) | 0.4 |
| Dolomite, dark gray (N3), fresh and weathered surface; very finely to finely crystalline, thick- to very thick-bedded; lithology similar to Unit 17; yellow-brown chert bands common; burrow mottled; diverse fauna, with rugose, tabulate and halysitid corals common; some coral colonies in life position; pelmatozoan debris. (Bioturbated, fossiliferous, cherty wackestone) | 0.9 |
| Dolomite, dark gray (N3), weathers medium dark gray (N4); very finely to finely crystalline, thick-bedded; chert rare; thin bioclastic zone at base; nonlaminated; burrow mottled; gastropods and rare corals. (Bioturbated, bioclastic wackestone) | 0.3 |

| | Unit Thickness (meters) |
|---|---|
| 18. Dolomite, medium dark gray (N4), weathers medium gray (N5); very finely to finely crystalline, thick-bedded; lighter color than Unit 17; current laminations and cross-bedding; silicified fossils. (Laminated, cross-bedded pack/grainstone) | 0.6 |
| 17. Dolomite, dark gray (N3), weathers medium dark gray (N4); very finely to finely crystalline, very thick-bedded; start of yellow-brown chert nodules; indistinct bedding; fossils more abundant than Unit 18; fossils include tabulates, rugose corals and pelmatozoann debris; fossils in layers, but not as bioclastic lenses; fossils silicified, large and unbroken, with large coral colonies in upright position, as well as tilted; bioclastic beds begin towards top of unit, with abraded shells; becomes less fossiliferous, without bedding change, towards top of unit, with possible rip-up clasts and abraded shells; fossils rare at top of unit, with extensive burrow mottling. (Bioturbated, cherty, bioclastic crinoidal wackestone, with packstone layers) | 7.1 |
| 16. Dolomite, dark gray (N3), weathers medium dark gray (N4); very finely to finely crystalline, very thick-bedded; contact with unit 15 sharp; meringue weathering, unlike smooth, pitted surface of Unit 15; burrow mottles, mainly horizontal, with light areas coarser grained than the dark mottles; halysitid and rugose corals, pelmatozoan debris; upper light gray layer of similar rocks separated by discontinuity surface. (Bioturbated, fossiliferous, pelmatozoan wackestone) | 3.8 |
| 15. Dolomite, medium dark gray (N4), weathers medium gray (N5); very finely to finely crystalline, very thick-bedded; contact with Unit 14 sharp, with subtle color change; 3-6 cm bioclastic beds throughout unit, with densely packed, very abraded skeletal fragments, including gastropods, rugose and tabulate corals; large, poorly preserved halysitid coral colonies throughout interval; 1 mm pits in smooth surface of unit. (Fossiliferous, vuggy, coralline wackestone, with bioclastic packstone beds) | 3.8 |
| 14. Dolomite, medium dark gray (N4), weathers medium gray (N5); very finely crystalline to finely crystalline, very thick-bedded; dense; massive; structureless, with 1 m burrow mottled layer in center of unit; one rugose coral at top of unit; discontinuity surface at top. (Bioturbated wackestone) | 1.8 |
| 13. Dolomite, medium gray (N5), fresh and weathered; medium light gray (N6) burrow mottles; light gray band within unit has irregular contacts, light mottling, dasyclad algae and rugose corals; upper contact of light band sharper than lower contact; *Chondrites* burrows just below contact of light gray band; light gray band followed by dark interval with elongated mottles; top 30 cm is well-laminated light gray band with irregular lower contact; discontinuity surfaces present. (Bioturbated, bioclastic wackestone and laminated, bioclastic packstone) | 1.0 |
| 12. Dolomite, medium gray (N5), weathers medium light gray (N6); very finely to finely crystalline, thick-bedded; meringue weathering; unfossiliferous; faintly laminated and burrow mottled. (Laminated, bioturbated, pelletal pack/ wackestone) | 0.6 |

| | Unit Thickness (meters) |
|---|---|
| . Dolomite, medium gray (N5), fresh and weathered, at bottom of unit, becoming lighter, medium light gray (N6) at top of unit; rip-up clasts of Unit 10 at base of unit; basal 2 cm has lithology similar to platy bed at top of Unit 10, but separated by sharp discontinuity surface; faint burrow mottles, with faint laminae passing through the mottles; upper 30 cm is medium gray (N5), with elongated mottles; dark band, medium gray (N5), also within unit. (Intraclastic, bioturbated, laminated, pelletal pack/wackestone) | 1.1 |
| Dolomite, medium gray (N5), weathers light gray (N7); microcrystalline, thin-bedded; similar to Units 8 and 9, but not burrow mottled; indistinct algal (?) laminae; bedding of Units 8-10 thicken and thin up to 25 percent along strike; platy bed, 5 cm thick, at top of unit. (Laminated, pelleted mudstone) | 0.5 |
| Dolomite, medium gray (N5), weathers light gray (N7); microcrystalline, very thin-bedded, lighter than Unit 8; burrow mottled; ostracodes. (Bioturbated, ostracodal, pelletal mudstone) | 0.1 |
| Dolomite, medium gray (N5), weathers light gray (N7); microcrystalline to very finely crystalline, medium-bedded (15-30 cm); dense, light colored; lower contact uneven; upper contact burrowed, with infilling of lithology of overlying unit; burrows are vertical. (Bioturbated, pelleted mud/wackestone) | 0.1 |
| Dolomite, grayish-black (N2), weathers dark gray (N3), finely crystalline, very thin-bedded; much darker than units below; pelmatozoan debris; upper contact sharp and irregular, with relief up to 10 cm. (Bioclastic, pelmatozoan wackestone) | 0.2 |
| Dolomite, dark gray (N3), weathers medium dark gray (N4); finely crystalline, thick-bedded; bioclastic lens has inverted coral colonies; channel fills with pelmatozoan debris, rugose and tabulate corals, rare brachiopods and dasyclad algae; rip-up intraclasts of Unit 5 incorporated into base of unit. (Bioclastic, intraclastic pack/grainstone | 2.1 |
| Dolomite, same lithology as Unit 3. MPM loc. 3201 at base | 0.7 |
| Dolomite, medium light gray (N6), fresh and weathered; finely to medium crystalline; bioclastic lens with abraded fossils not in life position; black chert at top of unit has stromatolitic (?), laminated structure. (Bioclastic pack/wackestone) | 0.5 |
| Dolomite, dark gray (N3), weathers medium dark gray (N4); very finely crystalline, very thick-bedded; meringue weathering surface; bioclastic lenses; colonial (?) and solitary rugose corals, dasyclad algae, and pelmatozoan debris; black chert nodules; burrow mottled. (Skeletal, bioclastic, pelletal, bioturbated wackestone) | 3.2 |
| Dolomite, dark gray (N3), weathers medium dark gray (N4); very finely crystalline, very thick-bedded; light medium gray chert in stringers and nodules; faint burrow mottles; small rugose and dasyclad algae most abundant near top of unit; pelmatozoan debris common. (Skeletal, bioturbated, pelletal wackestone) | 2.3 |
| Covered; contact with Swan Peak Quartzite not exposed | 10.0 (est.) |
| Swan Peak Quartzite | |

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# Contributions

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# The Late Ordovician and Silurian of the Eastern Great Basin, Part 6: The Upper Ordovician Carbonate Ramp

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## Northern Egan Range Section

The section was measured in two parts on the west side of the northern Egan Range in the E 1/2, sec. 34, T. 20 N., R. 62 E., central White Pine County, Nevada. The lower part of the section was measured beginning in the first ravine south of the northern-most outcrop of the Eureka Quartzite. The upper part of the section was measured beginning in a major canyon which is the third ravine north of the ravine in which the lower part of the section was measured. The primary access road is a jeep trail which leads to the first ridge south of the major canyon.

### Ely Springs Dolomite

Thickness: 142.0 m.
Floride Member
Thickness: 29.1 m.

Unit Thickness (meters)

49. Dolomite, medium gray (N5), weathers medium light gray (N6); very finely crystalline, thick-bedded; low-angle cross-laminaed, very-well sorted micritized oolites. Very fine quartz sand is common in some parts of the unit. (Oolitic grainstone) .......... 0.8
48. Covered, gray dolomite float, possible faults .......... 9.6
47. Dolomite, medium gray (N5), weathers medium brownish gray (5YR5/1); very finely to finely crystalline, very thick-bedded; *Thalassinoides* burrows; chert nodules in upper part of unit. (Bioturbated wacke/packstone) .......... 6.1
46. Dolomite, medium dark gray (N4), weathers yellowish gray (5Y7/2); microcrystalline to finely crystalline, thick-bedded (30-50 cm); sharp contact with Unit 45; well-laminated; *Thalassinoides*. (Bioturbated wacke/packstone) .......... 1.5

TRAVERSE MOVED DOWN CANYON ABOUT 20 METERS

45. Dolomite, medium gray (N5), weathers medium brownish gray (5YR5/1); very finely to finely crystalline, very thick-bedded; vuggy, infilled with dolomite crystals; silicified fossils at base of unit; *Thalassinoides;* fossils include gastropods, nautiloids, and tabulate and rugose corals. (Bioturbated wacke/packstone). MPM loc. 3229 .......... 1.1

TRAVERSE MOVED DOWN CANYON ABOUT 20 METERS

44. Dolomite, pale yellowish brown (10YR6/2), weathers yellowish gray (5Y7/2); very finely to finely crystalline, very thick-bedded; argillaceous mottles, decreasing in intensity towards top of unit; vuggy, infilled with dolomite crystals; recessive weathering. (Argillaceous, bioturbated wacke/packstone) .......... 1.7
43. Dolomite, medium gray (N5), weathers medium light to light gray (N6-7); with argillaceous, burrow mottled areas, pale orange (10YR7/2), weather grayish orange (10YR7/4); microcrystalline to finely crystalline, thin- to medium-bedded (5-20 cm); blocky; argillaceous; very large (20 x 20 cm) chert nodules at base; red iron stains throughout unit. (Argillaceous wackestone) .......... 1.2

| | Unit Thickness (meters) |
|---|---|
| 2. Covered, gray dolomite float | 4.4 |
| 1. Dolomite, medium light gray (N6), weathers light gray (N7); silicified encrinite; dark gray-brown silicification near top of unit; stylolites common; sharp contact with Unit 40. (encrinitic grainstone) | 0.3 |
| 0. Dolomite, pale yellowish brown (10YR6/2), weathers yellowish gray (5Y7/2); microcrystalline to finely crystalline, thin-bedded; blocky; very argillaceous; red iron stains. (Argillaceous wackestone) | 0.6 |
| 9. Covered, argillaceous, platy mudstone float; basal cream-colored Floride Member (exposed 100 m northwest of section) | 1.8 |
| ,ost Canyon Member<br>Thickness: 38.6 m. | |
| 8. Dolomite, medium gray (N5), weathers pale yellowish brown (10YR6/2); finely to medium crystalline, medium- to thick-bedded (20-50 cm); burrow mottled; abundant silicified stromatoporoids, rugose and tabulate corals; forms cliff. (Fossiliferous wacke/packstone). MPM loc. 3231 collected through this interval | 2.3 |
| 7. Dolomite, medium gray (N5), weathers medium brownish gray (5YR5/1); finely crystalline, very thick-bedded; bioclastic unit with abraded tabulate and rugose corals, encrinite; stringy, laminated mottles are probably dolomitized stromatoporoids. (Bioclastic wacke/packstone) | 4.8 |
| 6. Dolomite, same lithology as Unit No. 34 | 8.7 |
| 5. Dolomite, medium dark gray (N4), weathers medium brownish gray (5YR5/1); very finely to finely crystalline, very thick-bedded; indistinctly bedded; argillaceous burrow mottles (0.5 cm diameter); sparse halysitids, rugose corals, syringoporids, and pelmatozoan debris. (Bioclastic, cherty wacke/packstone) | 10.4 |
| 4. Dolomite, medium dark gray (N4), weathers medium brownish gray (5YR5/1); finely to medium crystalline, very thick-bedded; intense bioturbation; poorly bedded; scattered chert nodules; oriented nautiloids in middle of unit with apicies directed to N20W; coarser texture than Barn Hills Member; contact with Unit 33a is gradational with some cross-lamination in lower part of unit; sparse abraded tabulate and rugose corals, encrinite debris, and syringoporids. (Bioclastic wacke/packstone) MPM loc. 3230 at 6.0 m | 12.4 |

;arn Hills Member (alternate section, upper part of member) (Units 20a-33a ,ere measured in the same location as the Lost Canyon Member. The units re the top of the Barn Hills Member, and were measured because the upper art of the Barn Hills Member is poorly exposed in the area that Units 3-33 ,ere measured. The remeasurement reveals the lateral discontinuity of nits in the Barn Hills Member.)

3a. Dolomite, alternating 0.5 to 1.0 cm laminae are dark- to medium dark-gray (N3-4), weather brownish gray (5YR4/1), and medium brownish gray (5YR5/1); very finely crystalline, light gray storm laminae have pelmatozoan debris and are coarser grained on weathered surfaces than dark gray mud/wackestone laminae; laminae discontinuous laterally; undulating corrasion surfaces between some

Unit Thickness (meters)

laminae; unit not laterally persistent. (Alternating laminae of mud/ wackestone and laminated packstone and pelleted grainstone) . . . . . . . . . 0.9

32a. Covered, dark gray dolomite float . . . . . . . . . . 2.4

31a. Dolomite, same lithology as Unit 3 . . . . . . . . . . 1.8

30a. Dolomite, same lithology as Unit 31 . . . . . . . . . . 0.1

29a. Dolomite, same lithology as Unit 3 . . . . . . . . . . 0.6

28a. Dolomite, same lithology as Unit 26a . . . . . . . . . . 2.3

27a. Dolomite, same lithology as Unit 3 . . . . . . . . . . 0.3

26a. Dolomite, dark gray (N3), weathers medium brownish gray (5YR5/1); very finely to finely crystalline, thin- to medium-bedded (5-15 cm); *Chondrites* burrows in upper 2 cm of beds; blocky meringue weathering; indistinct current laminations. (Laminated, lithoclastic, peloidal packstone) . . . . . . . . . . 0.2

25a. Dolomite, same lithology as Unit 3; lower part of unit very thin-bedded (1-2 cm), platy; upper part of unit thin- to medium-bedded (5-12 cm) . . . . . . . . . . 0.5

24a. Dolomite, same lithology as Unit 3; some low-angle current cross-laminations; platy beds, 0.1 cm thick, within unit; wave ripples, with up to 5 cm relief, at top of unit . . . . . . . . . . 2.1

23a. Dolomite, same lithology as Unit 3; current laminated with planar laminae at top of unit and unlaminated depression fillings at base of unit; some laminae at base of unit draped over raised, burrow mottled wackestone; burrow mottles present . . . . . . . . . . 0.4

22a. Dolomite, same lithology as Unit 3; angular rip-up clasts, 1-2 cm thick and 2-15 cm in length, at base of unit; unit varies in thickness from 20-40 cm; discontinuity surface at top of unit . . . . . . . . . . 0.3

21a. Dolomite, same lithology as Unit 31 . . . . . . . . . . 0.3

20a. Dolomite, same lithology as Unit 3; low angle cross-laminations, with burrow mottles at top of unit . . . . . . . . . . 1.1

TRAVERSE MOVED TWO CANYONS (ABOUT 1 KM) NORTH AND REPEATING UPPER 13.3 M OF THE BARN HILLS MEMBER.

Barn Hills Member (complete)
Thickness: 59.6 m.

33. Dolomite, same lithology as Unit 3; indistinct weathering laminae . . . . . . 2.5

32. Covered, gray dolomite float (probable faults) . . . . . . . . . . 16.0

31. Dolomite, parallel-laminated in part, with more intense bioturbation than other units . . . . . . . . . . 1.6

30. Covered, gray dolomite float . . . . . . . . . . 3.6

29. Dolomite, same lithology as Unit 3; laminated, similar to Unit No. 26 . . . 1.3

28. Covered, gray dolomite float . . . . . . . . . . 1.3

27. Dolomite, same lithology as Unit 5; sparse black chert nodules in layers; bioturbation includes *Chrondrites* burrows . . . . . . . . . . 0.9

26. Dolomite, same lithology as Unit 3; 15 cm thick beds poorly exposed . . . . . 1.8

25. Covered, gray dolomite float . . . . . . . . . . 0.1

24. Dolomite, same lithology as Unit 3 . . . . . . . . . . 0.2

23. Covered, gray dolomite float . . . . . . . . . . 9.0

| Unit | Description | Unit Thickness (meters) |
|---|---|---|
| 22. | Dolomite, medium dark gray (N4), weathers medium brownish gray (5YR5/1). (Cryptalgal laminated, argillaceous pelleted mudstone) | 0.3 |
| 21. | Dolomite, same lithology as Unit 6; unit is one bed | 0.6 |
| 20. | Dolomite, same lithology as Unit 5; burrow mottled, some cryptalgal laminates; base with flame structures | 3.3 |
| 19. | Dolomite, thick-bedded; dark band in middle of unit; cryptalgal laminates; contact with Unit 20 sharp and burrowed to 2 cm depth | 0.5 |
| 18. | Dolomite, same lithology as Unit 3 | 2.0 |
| 17. | Dolomite, same lithology as Unit 9; thick-bedded; mm scale, low-angle current cross-laminae in alternating light and dark gray bands, 0.5-1.0 cm thick | 0.3 |
| 16. | Dolomite, same lithology as Unit 3 | 0.3 |
| 15. | Dolomite, same lithology as Unit 9; talus covers upper two-thirds of unit; unfossiliferous | 0.8 |
| 14. | Dolomite, same lithology as Unit 6; thin- to medium-bedded, blocky weathering | 0.9 |
| 13. | Dolomite, same lithology as Unit 5; thin-bedded | 0.3 |
| 12. | Covered, gray dolomite float | 3.4 |
| 11. | Dolomite, same lithology as Unit 5; dark gray bed in middle of unit; burrow mottled; undulating laminae at top of unit | 0.8 |
| 10. | Dolomite, same lithology as Unit 6; thick-bedded | 1.1 |
| 9. | Dolomite, medium gray (N5), weathers medium brownish gray (5YR5/1); microcrystalline, very thick-bedded; alternating 1 to 4 cm thick bands have low angle cross-laminae; or are bioturbated. (Peloidal mud/wackestone) | 0.9 |
| 8. | Dolomite, medium dark gray (N4), weathers medium gray (N5) to brownish gray (5YR4/1); very finely crystalline, very thin- to thin-bedded; blocky; small (4 mm), cylindrical burrows. (Bioturbated, peloidal mud/wackestone) | 0.5 |
| 7. | Dolomite, same lithology as Unit 5; contact with Unit 6 sharp, with relief of 5 cm, but without rip-up clasts | 0.7 |
| 6. | Dolomite, medium gray (N5), weathers medium light- to light-gray (N6-7); very finely to finely crystalline, thick-bedded; bioturbated; base poorly exposed; lithology similar to Unit 3, but coarser grained. (Bioturbated peloidal mudstone) | 0.6 |
| | POSSIBLE FAULT | |
| 5. | Dolomite, medium dark gray (N4), weathers medium gray (N5) to brownish gray (5YR4/1); very finely to finely crystalline, thick-bedded (40 cm); bioturbated, horizontal burrows 1 to 2 cm in diameter; pelmatozoan and other fossil debris concentrated in burrows; meringue weathering surface; low-angle current cross-laminations. (Laminated, peloidal mud/wackestone) | 2.4 |
| 4. | Covered, gray dolomite float | 1.1 |
| 3. | Dolomite, medium gray (N5), weathers medium light- to light-gray (N6-7); very finely to finely crystalline, medium-bedded (20 cm); chert nodules in lower 5 cm only; chert uncommon in remainder of unit, color change sharp | |

Unit Thickness (meters)

at contact, but chert is gradational; bioturbated, but some faint parallel laminae preserved. (Bioturbated or laminated peloidal mudstone) ....... 0.5

TRAVERSE MOVED 300 METERS UP CANYON BECAUSE OF FAULTS

Ibex Member

Thickness: 14.7 m.

2. Dolomite, medium gray (N5), weathers medium gray (N5) to brownish gray (5YR4/1); very finely to finely crystalline, thick-bedded (40 cm) in lower part, medium bedded (7 - 20 cm) in upper part; bioturbated with 1 cm diameter horizontal burrows common in upper half of unit; pelmatozoan and other fossil debris concentrated in burrows; silicified rugose corals and brachiopods common at some horizons; brown chert nodules in upper part; meringue weathering surface; low angle cross-laminae and parallel current laminations present. MPM loc. 3223, 0-0.7 m.; MPM loc. 3224, 0.7-1.6 m.; MPM loc. 3225, 1.6-1.9 m.; MPM loc. 3226, 4.3-4.4 m.; MPM loc. 3227, 4.7-5.1 m.; MPM loc. 3228, 7.2-7.4 m. (Laminated, peloidal mud/wackestone) ............................ 14.2
1. Dolomite, medium gray (N5), weathers dark yellow orange (10YR6/6); finely to medium crystalline, thick-bedded; well-rounded, fine to medium-sized quartz sand grains floating in dolomite matrix, abundant in part; extensive bioturbation. (Arenaceous grainstone) ............... 0.5

Eureka Quartzite

## Fossil Locality Register

Fossils collected during this study have been placed in the Milwaukee Public Museum. Localities bear the designation MPM loc. Field numbers had the prefix SP and a number corresponding to the last two digits of the MPM locality number.

MPM loc. 3201. Lakeside Mountains, Utah. From the base of Unit 5 in the Paris Peak Member, Fish Haven Dolomite.

MPM loc. 3202. Lakeside Mountains, Utah. From low in Unit 17 of Budge and Sheehan (1980) in the Tony Grove Lake Member of the Laketown Dolomite.

MPM loc. 3203. Northwest Silver Island Range, Utah. From the basal 1 m of the Ely Springs Dolomite, in the Ibex Member. From a quartz-sand rich layer.

MPM loc. 3204. Northwest Silver Island Range, Utah. From 1 m above the base of the Ely Springs Dolomite in the Ibex Member. Much less quartz sand is present than in the underlying MPM loc. 3203. This is the same horizon as USNM loc. 19105 of Budge and Sheehan (1980b).

MPM loc. 3205. Northwest Silver Island Range, Utah. From Unit 2 of Budge and Sheehan (1980b) from float in a covered interval of the Ibex Member of the Ely Springs Dolomite.

MPM loc. 3206. Northwest Silver Island Range, Utah. From Unit 7 of Budge and Sheehan (1980b), in the Ibex Member of the Ely Springs Dolomite.

MPM loc. 3207. Northwest Silver Island Range, Utah. From Unit 16 of Budge and Sheehan (1980b) in the Lost Canyon Member of the Ely Springs Dolomite.

MPM loc. 3208. Northwest Silver Island Range, Utah. From several meters above the base of Unit 21 of Budge and Sheehan (1980b) in the Lost Canyon Member of the Ely Springs Dolomite.

MPM loc. 3209. Northwest Silver Island Range, Utah. From approximately 2 m below MPM loc. 3208, near the base of Unit 21 of Budge and Sheehan (1980b) in the Lost Canyon Member of the Ely Springs Dolomite.

MPM loc. 3210. Northwest Silver Island Range, Utah. From near the top of Unit 21 of Budge and Sheehan (1980b) in the Lost Canyon Member of the Ely Springs Dolomite.

MPM loc. 3211. Northwest Silver Island Range, Utah. From about 1 m above the base of the Tony Grove Lake Member of the Laketown Dolomite.

MPM loc. 3212. Northwest Silver Island Range, Utah. From about 1 m above the base of the Tony Grove Lake Member of the Laketown Dolomite.

MPM loc. 3213. Cave Canyon, northeast Silver Island Range, Utah. From near the base of the Tony Grove Lake Member of the Laketown Dolomite.

MPM loc. 3214. Cave Canyon, northeast Side of the Silver Island Range, Utah. From the base of Unit 13 of Schaeffer (1960) of the Roberts Mountains Formation.

MPM loc. 3215. South side of Ikes Canyon, Toquima Range, Nevada, from about 5 m below the top of the unnamed limestone of McKee (1976).

MPM loc. 3216. South Side of Ikes Canyon, Toquima Range, Nevada, from about 7 m below the top of the unnamed limestone of McKee (1976).

MPM loc. 3217. West side of Copenhagen Canyon, Nevada (SW 1/2 sec. 36, T16N, R49E.) From the upper part of the Hanson Creek formation, below the chert that has been variably assigned to the Hanson Creek

Formation or to the Roberts Mountains Formation.

MPM loc. 3219. Lone Mountain, Nevada. From Unit 1 of Ross (1970) in the basal Hanson Creek Formation.

MPM loc. 3220. Northern Egan Range, Nevada. From upper third of the Barn Hills Member of the Ely Springs Dolomite on the first ridge north of the measured section.

MPM loc. 3221. Northern Egan Range, Nevada. From a 0.5 m interval beginning 0.7 m above the base of Unit 2, Ibex Member, Ely Springs Dolomite. Collected 100 m east of the line of section.

MPM loc. 3222. Northern Egan Range, Nevada. Basal 0.5 m interval of Unit 2, of the Ibex Member, Ely Springs Dolomite. Collected 50 m east (up canyon) of the line of section.

MPM loc. 3223. Northern Egan Range, Nevada. From base of unit to 0.7 m in Unit 2, Ibex Member, Ely Springs Dolomite.

MPM loc. 3224. Northern Egan Range, Nevada. From 0.7 to 1.6 m in Unit 2, Ibex Member, Ely Springs Dolomite.

MPM loc. 3225. Northern Egan Range, Nevada. From 1.6 to 1.9 m in Unit 2, Ibex Member, Ely Springs Dolomite (just below chert nodules).

MPM loc. 3226. Northern Egan Range, Nevada. From 4.3 to 4.4 m in Unit 2, Ibex Member, Ely Springs Dolomite.

MPM loc. 3227. Northern Egan Range, Nevada. From 4.7 to 5.1 m in Unit 2, Ibex Member, Ely Springs Dolomite.

MPM loc. 3228. Northern Egan Range, Nevada. From 7.2 to 7.4 m, Unit 2, Ibex Member, Ely Springs Dolomite.

MPM loc. 3229. Northern Egan Range, Nevada. From Unit 45, Floride Member, Ely Springs Dolomite.

MPM loc. 3230. Northern Egan Range, Nevada. At 6.0 m in Unit 34, Lost Canyon Member, Ely Springs Dolomite.

MPM loc. 3231. Northern Egan Range, Nevada. Collected through Unit 38, Lost Canyon Member, Ely Springs Dolomite.

MPM loc. 3232. Antelope Peak, Elko County, Nevada. Collected in the upper part of Unit 5 of Peterson (1968) from the upper "Hanson Creek Formation."

MPM loc. 3333. Ridge above measured section, Pilot Peak, Nevada. Collected in the Roberts Mountains Formation.

MPM loc. 3334. Ridge above measured section, Pilot Peak, Nevada. Collected in the Roberts Mountains Formation.

Figure 4. Photomicrograph of cryptalgal-laminated, peloidal mudstone, with convex-upward structure and desiccation cracks. Unit 4 of Budge and Sheehan (1980b), Deep Lakes Member, Fish Haven Dolomite, Lakeside Mountains. Bar is 1 mm.

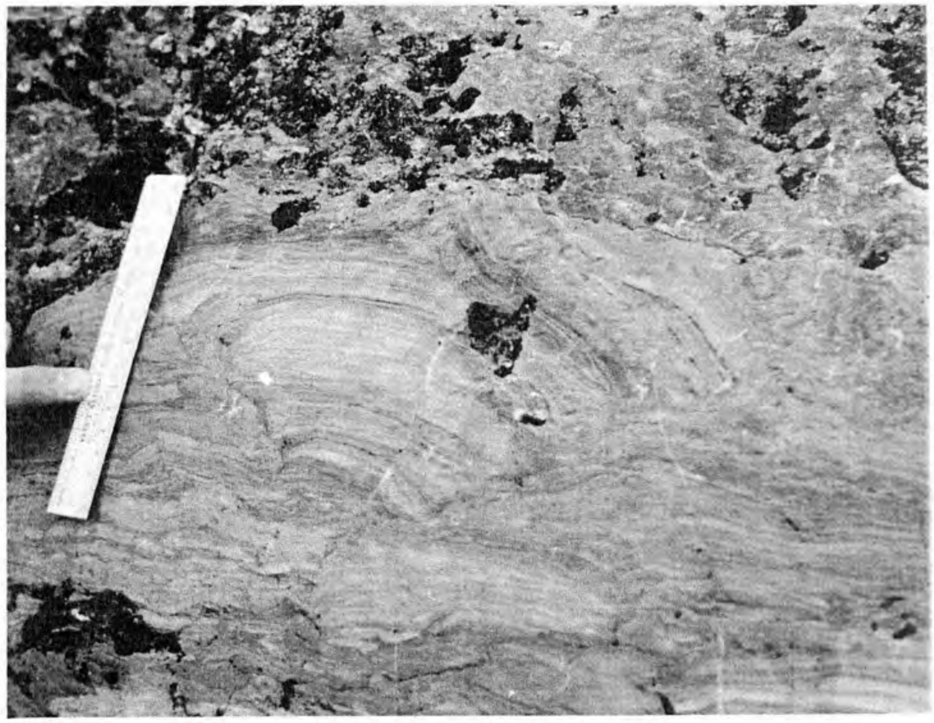


**Figure 5.** High intertidal stromatolite in cryptalgal laminated mudstone. Unit 10 of Budge and Sheehan (1980b), Deep Lakes Member, Fish Haven Dolomite, Lakeside Mountains. Scale is 15 cm.

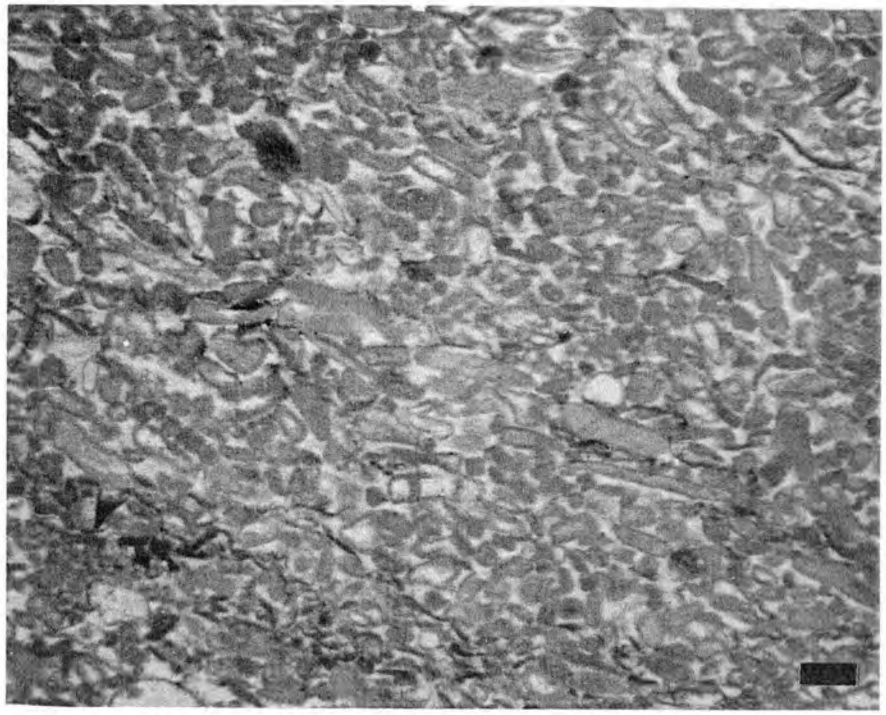


**Figure 6.** Photomicrograph of bioclastic, lithoclastic grainstone from subtidal, wave agitated environment. Unit 41, Floride Member, Ely Springs Dolomite, northern Egan Range. Bar is 1 mm.

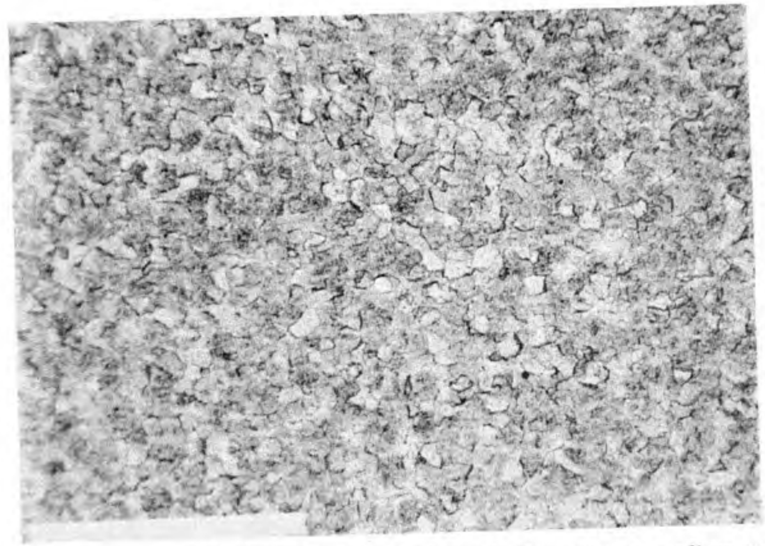
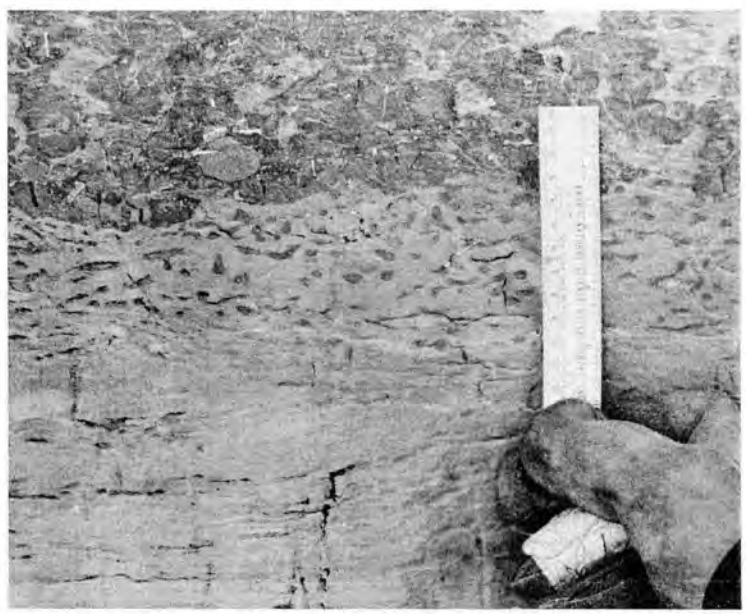


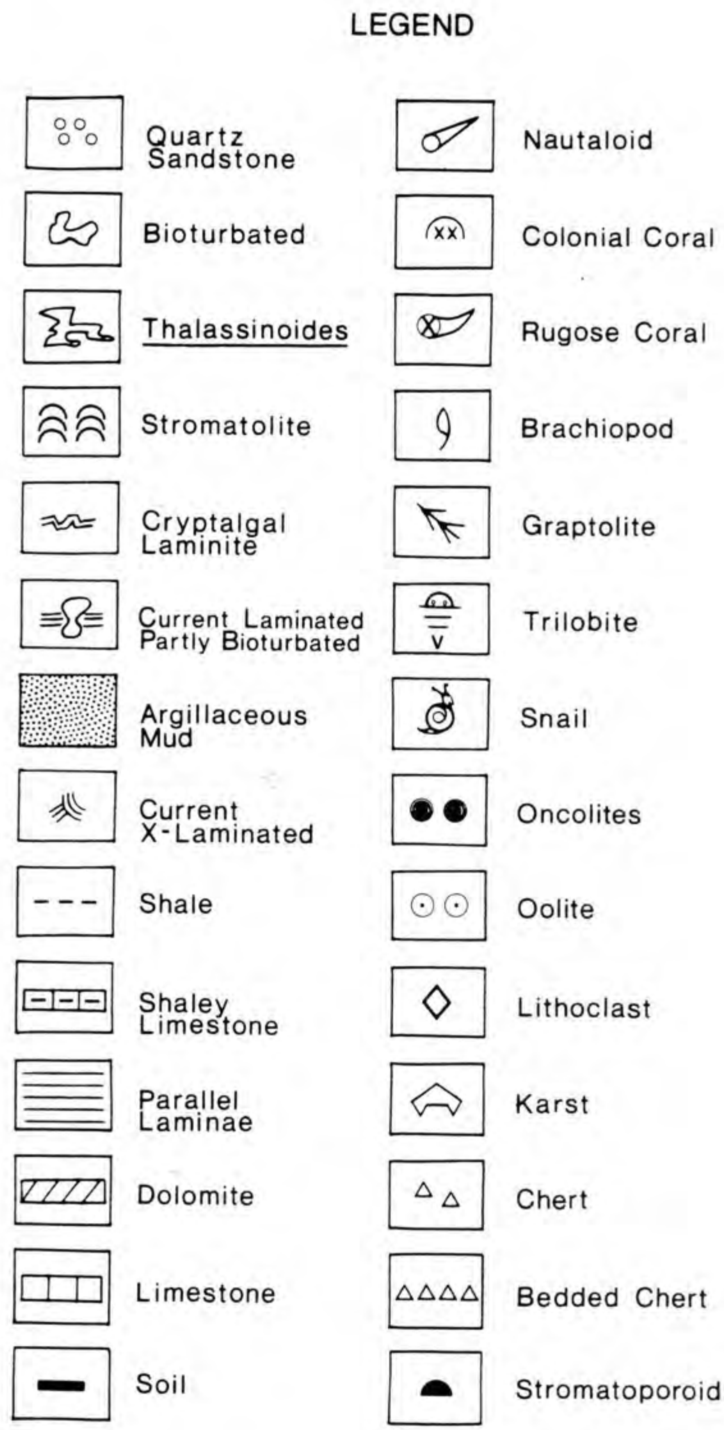
**Figure 7.** Photomicrograph of anhedral to subhedral mosaic of very fine- to medium-crystalline, secondary, sucrosic dolomite. Unit 6, Barn Hills Member, Ely Springs Dolomite, northern Egan Range. Bar is 1 mm.


**Figure 8.** Algal-coated crinoid columnal in bioclastic wackestone. MPM loc. 2901, from Unit 5 of this study, Paris Peak Member, Fish Haven Dolomite, Lakeside Mountains.

igure 9. Photomicrograph of dolomitized bioclastic, bioturbated wackestone from a subtidal, below wave base environment. Unit 2 of this study, Paris Peak Member, Fish Haven Dolomite, Lakeside Mountains. Bar is 1 mm.



gure 10. *Chrondrites* burrows in light gray, algal laminated mudstone. Subtidal, dark gray wackestone, with *Thalassinoides* burrows, is above the discontinuity surface. Unit 12 of Budge and Sheehan (1980b), Deep Lakes Member, Fish Haven Dolomite, Lakeside Mountains. Scale is 15 cm.




gure 11a. (Legend for figure 11)

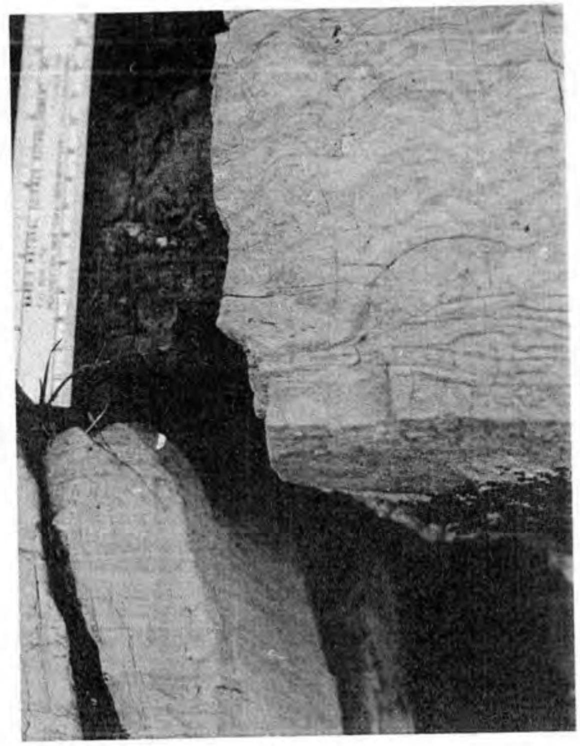


**Figure 12.** Light gray, primary dolomite, with cryptalgal laminites and stromatolites. Unit 8 of Budge and Sheehan (1980b), Deep Lakes Member, Fish Haven Dolomite, Lakeside Mountains. Scale is 15 cm.

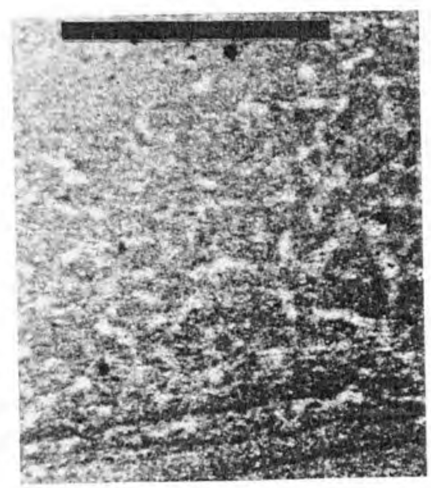


**Figure 13.** Photomicrograph of tuffeted algal fabric (spongiostrome texture) in algal laminated, peloidal mudstone. Unit 12 of Budge and Sheehan (1980b), Deep Lakes Member, Fish Haven Dolomite, Lakeside Mountains. Bar is 1 mm.

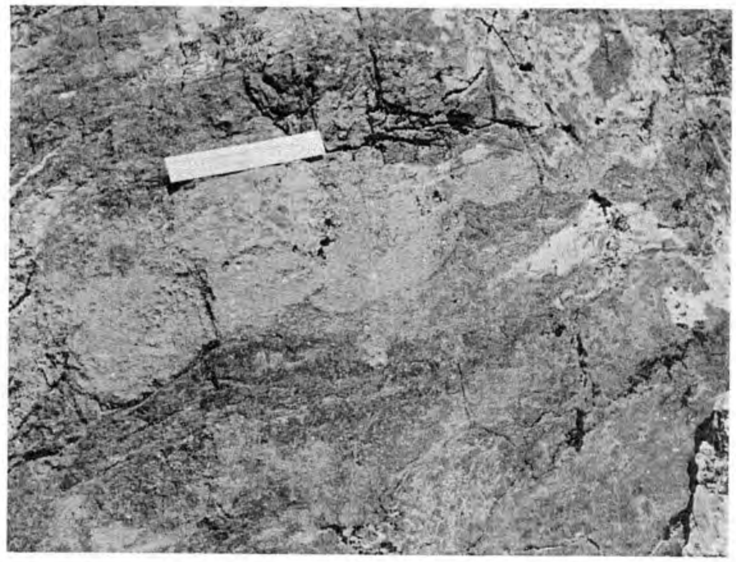


**Figure 14.** Bioclastic pack/grainstone lens with flame structures at lower contact, in whole fossil wackestone. Unit 4 of this study, Paris Peak Member. Fish Haven Dolomite, Lakeside Mountains. Scale is 15 cm.

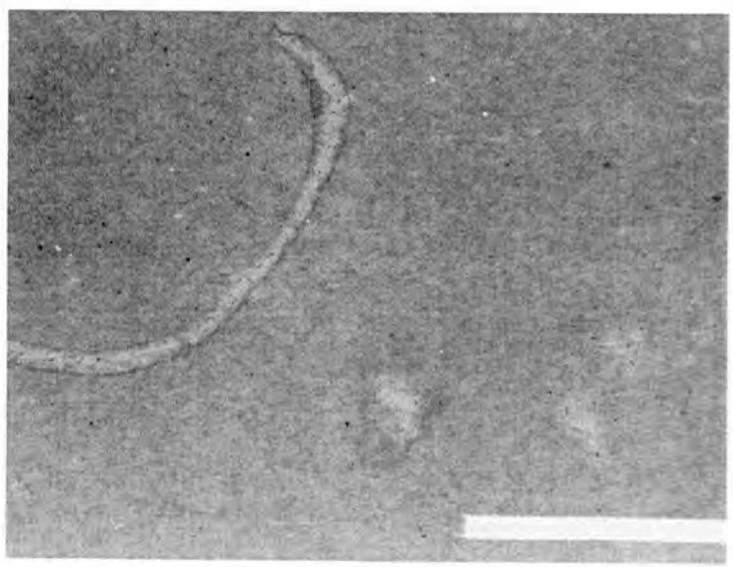


**Figure 15.** Photomicrograph of ostracode valves in nonlaminated, pelleted mudstone. Unit 9 of this study, Paris Peak Memer, Fish Haven Dolomite, Lakeside Mountains. Bar is 1 mm.

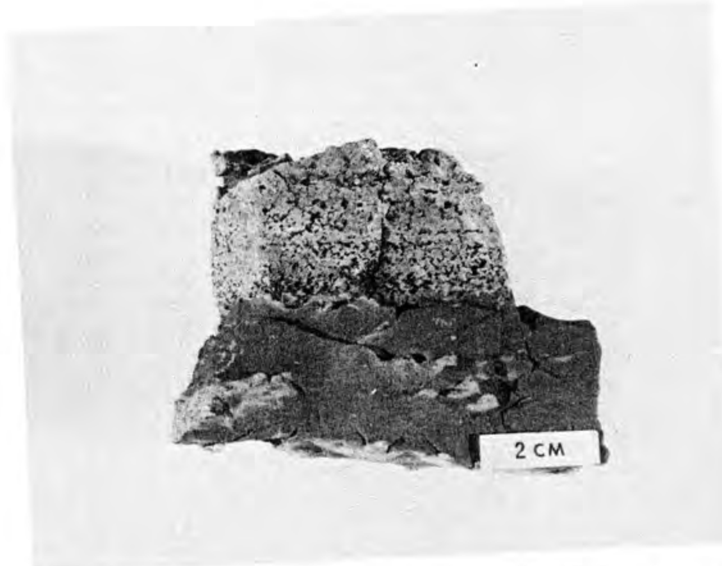


**Figure 16.** Incompletely silicified, case hardened grapestone overlying carbonate mud/wackestone. Unit 21 of this study, Paris Peak Member, Fish Haven Dolomite, Lakeside Mountains.

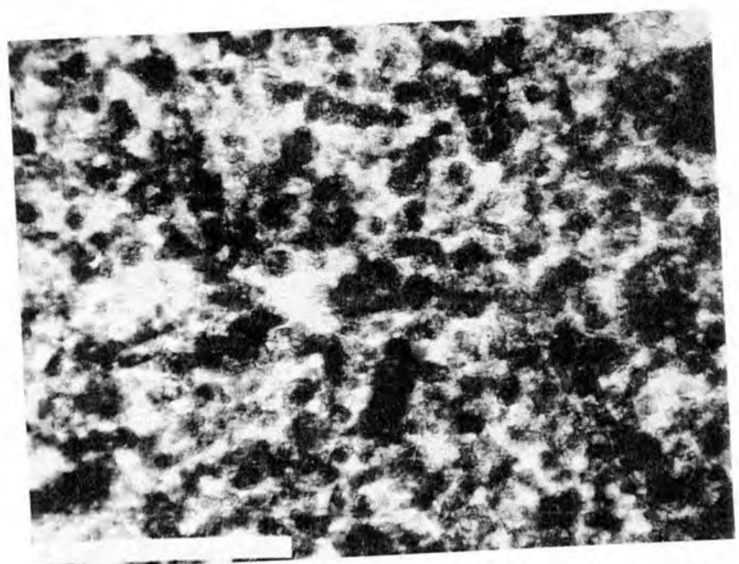


**Figure 17.** Photomicrograph of pelleted or grapestone texture in siliceous dolomite. Unit 5 o Budge and Sheehan (1980b), Deep Lakes Member, Fish Haven Dolomite, Lakeside Moun tains. Bar is 1 mm.

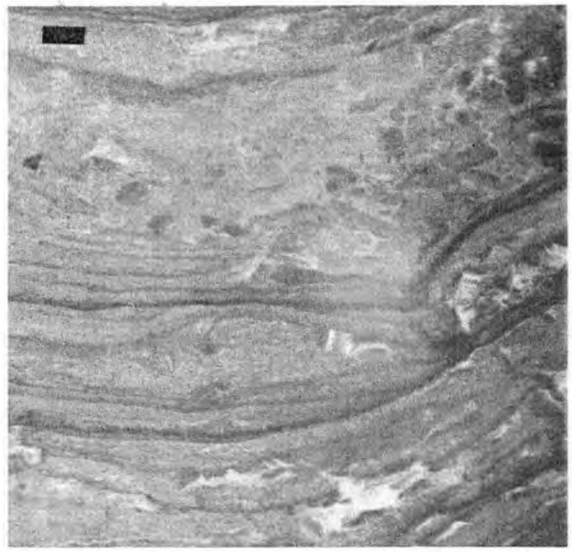
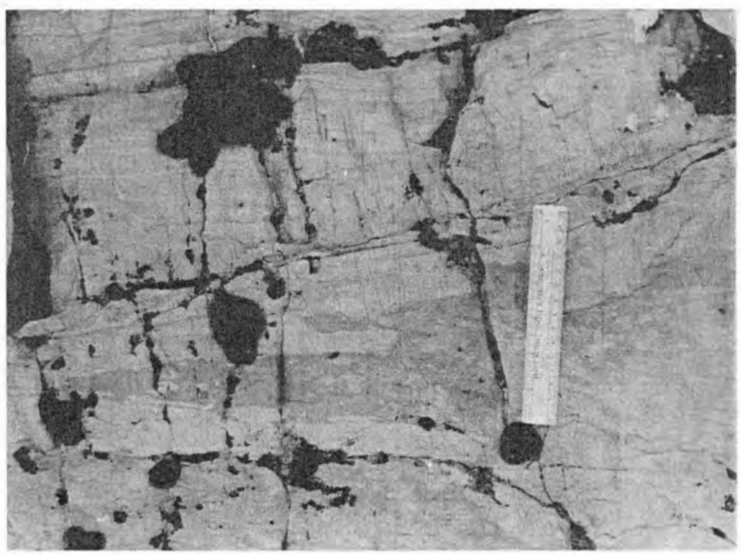


**Figure 18.** Photomicrograph of brecciated, cryptalgal laminated, peloidal mudstone, with convex-upward structure. Unit 8 of Budge and Sheehan (1980b), Deep Lakes Member, Fish Haven Dolomite, Lakeside Mountains. Bar is 1 mm.



**igure 19.** Cryptalgal laminated mudstone, with teepee structures. Unit 9 of Budge and Sheehan (1980b), Deep Lakes Member, Fish Haven Dolomite, Lakeside Mountains. Scale is 15 cm.

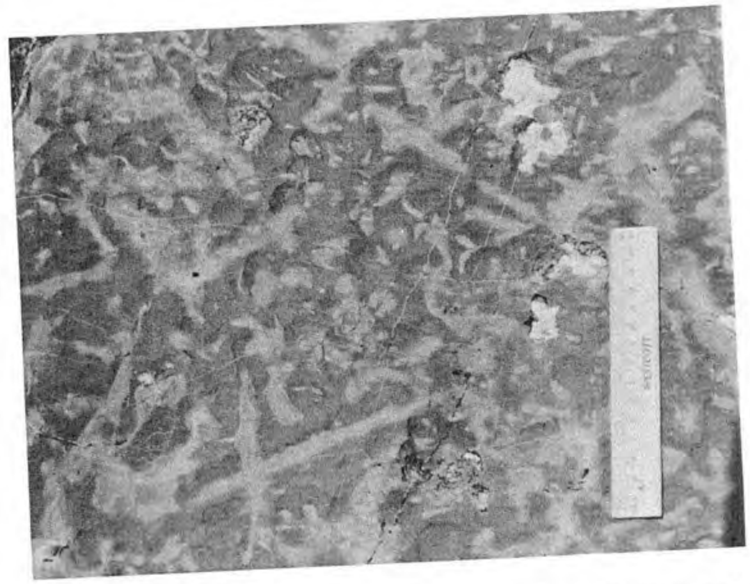


**Figure 20.** Bedding plane view of *Thalassinoides* burrow mottles in bioclastic wackestone. Unit 10 of Budge and Sheehan (1980b), Deep Lakes Member, Fish Haven Dolomite, Lakeside Mountains. Scale is 15 cm.

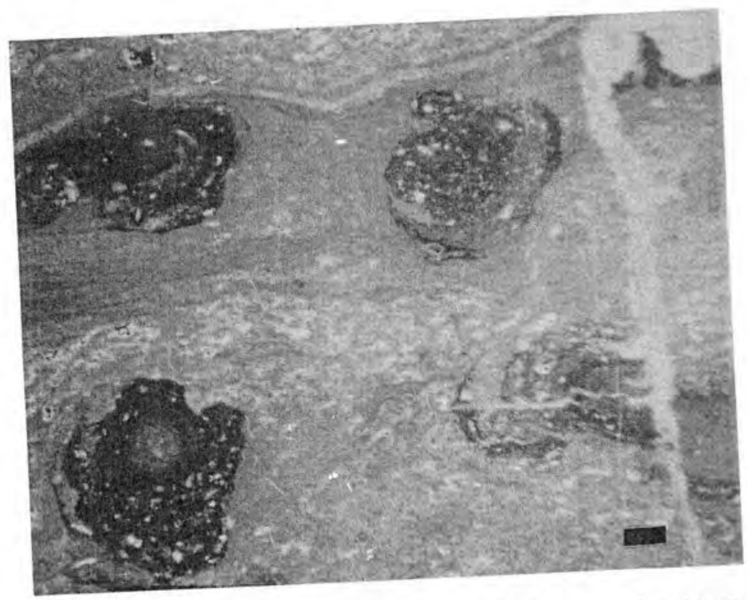


**Figure 21.** Photomicrograph of *Chrondrites* burrows in algal laminated, peloidal mudstone. Unit 12 of Budge and Sheehan (1980b), Deep Lakes Member, Fish Haven Dolomite, Lakeside Mountains. Bar is 1 mm.

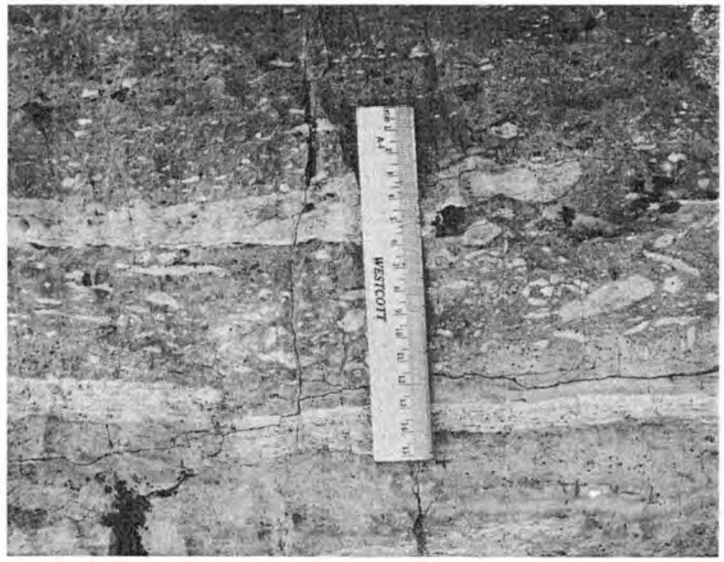



**Figure 22.** Bioclastic packstone layer, with light gray, laminated mudstone clasts. Interpreted as a storm deposit. Subunit 16b of this study, Bloomington Lake Member, Fish Haven Dolomite, Lakeside Mountains. Scale is 15 cm.


**Figure 23.** Dark *Thalassinoides* burrows on a bedding plane surface. Subunit 16c, Bloomington-Lake Member, Fish Haven Dolomite, Lakeside Mountains, Utah. Scale is 15 cm.

**Figure 24.** Bedding plane view of light-colored *Thalassinoides* burrow mottles in bioclastic wackestone. Subunit 16c of this study, Bloomington Lake Member, Fish Haven Dolomite, Lakeside Mountains. Scale is 15 cm.

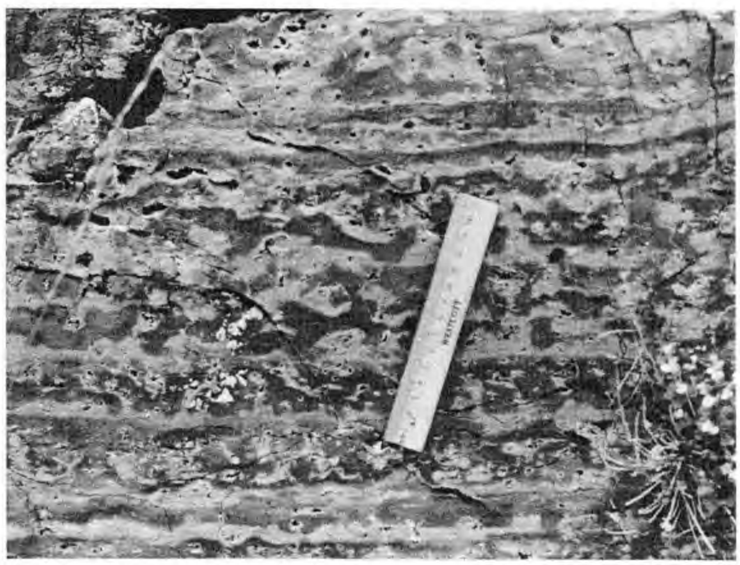


**Figure 25.** Hardgrounds and *Thalassinoides* in bioclastic wackestone, with view perpendicular to bedding. Layers with early lithification apparently prevented development of complete galleries. Subunit 16d of this study, Bloomington Lake Member, Fish Haven Dolomite, Lakeside Mountains. Scale is 15 cm.


**Figure 26.** Bioclastic packstone layers, interpreted as having been formed as storm deposits. Subunit 16f of this study, Bloomington Lake Member, Fish Haven Dolomite, Lakeside Mountains. Scale is 15 cm.

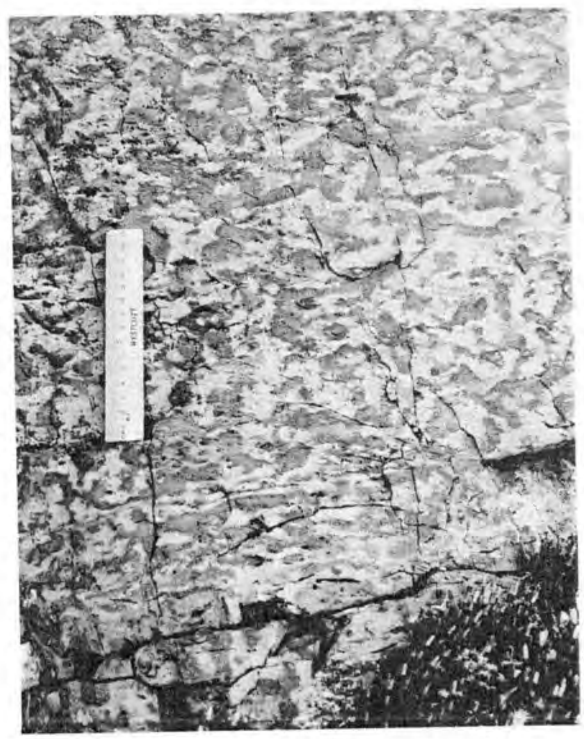


**Figure 27.** *Thalassinoides* burrow mottles in bioclastic wackestone, viewed perpendicular to bedding. Subunit 16g of this study, Bloomington Lake Member, Fish Haven Dolomite, Lakeside Mountains. Scale is 15 cm.

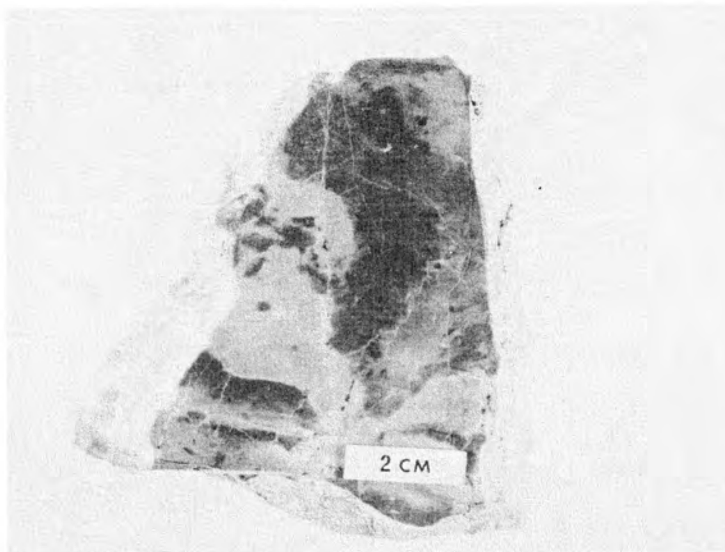



**Figure 28.** *Thalassinoides* burrows mottles in dark gray wackestone. Sub-unit 16g of this study, Bloomington Lake Member, Fish Haven Dolomite, Lakeside Mountains.

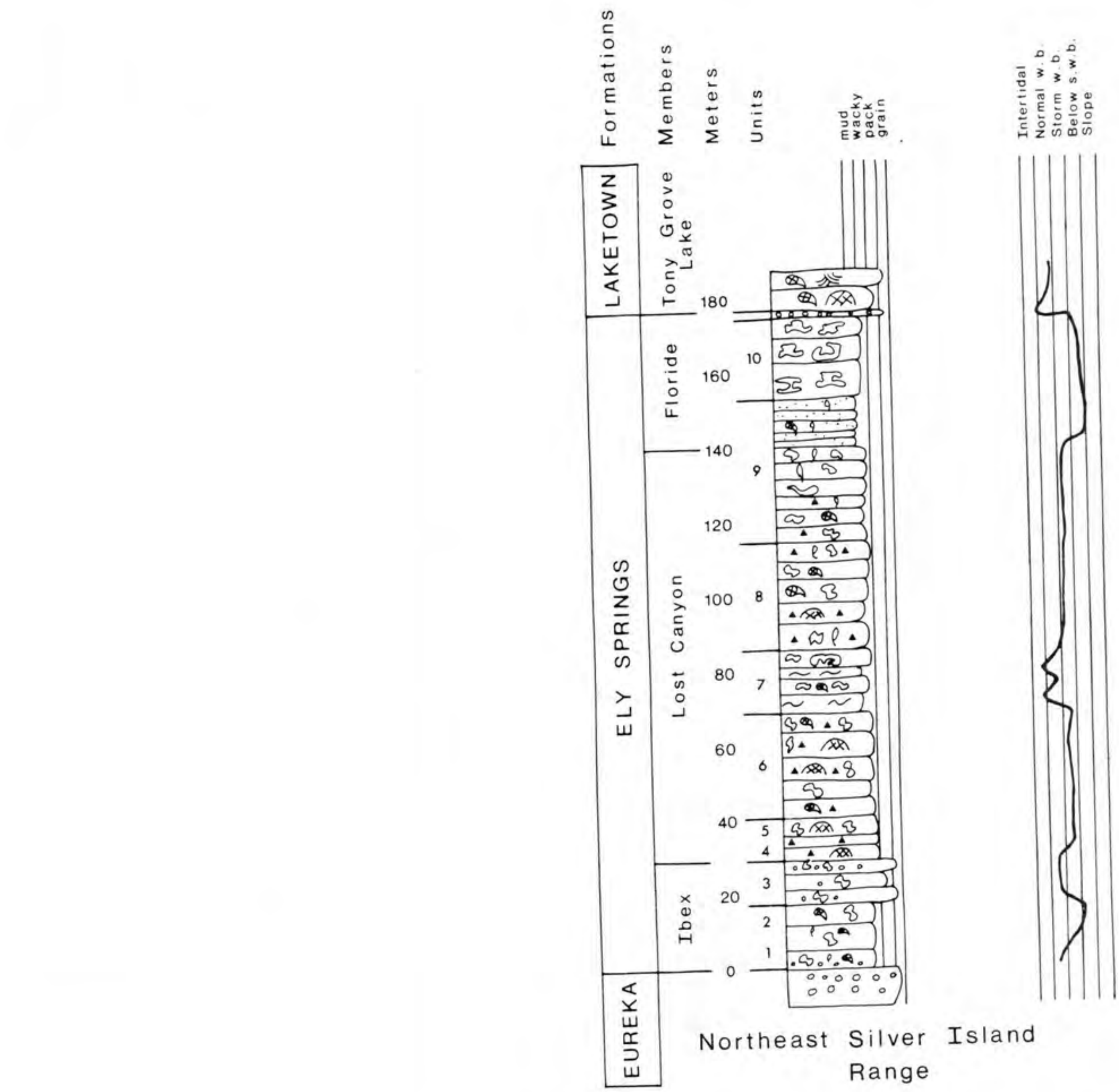



**Figure 29.** Sediment log of Cave Canyon Section in northeastern Silver Island Range. For explanation of symbols see Fig. 11.

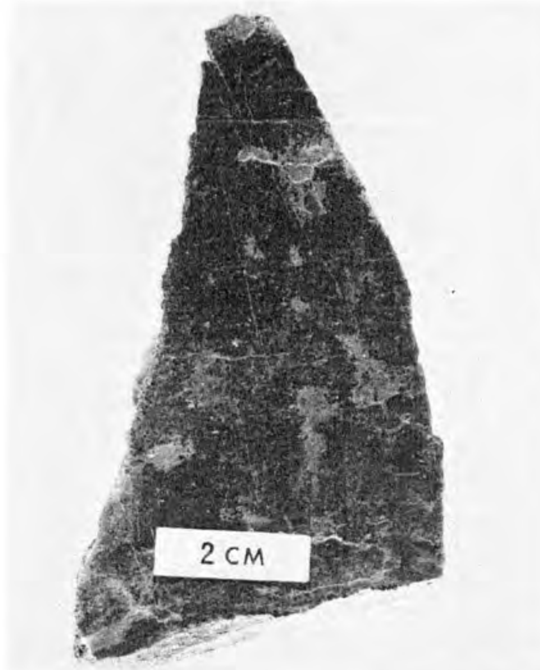
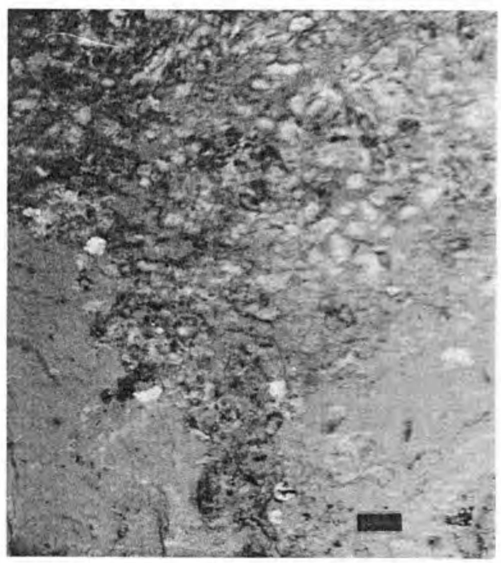



**Figure 30.** Grainstone, with rounded, blackened, peloidal intraclasts and mudstone lithoclasts, interbedded with argillaceous, cream-colored mudstone (not shown) of basal Floride Member. Unit 9 of Schaeffer (1960), Ely Springs Dolomite, southeastern Silver Island Range.



**igure 31.** Photomicrograph of grainstone with blackened, peloidal intraclasts and mudstone lithoclasts. Unit 9 of Schaffer (1960), Floride Member, Ely Springs Dolomite, southeastern Silver Island Range. Bar is 1 mm.

**Figure 32.** *Trypanites* boring. Unit 9 of Schaeffer (1960), basal cream- colored part of Floride Member, Ely Springs Dolomite, southeastern Silver Island Range. Scale is in cm.

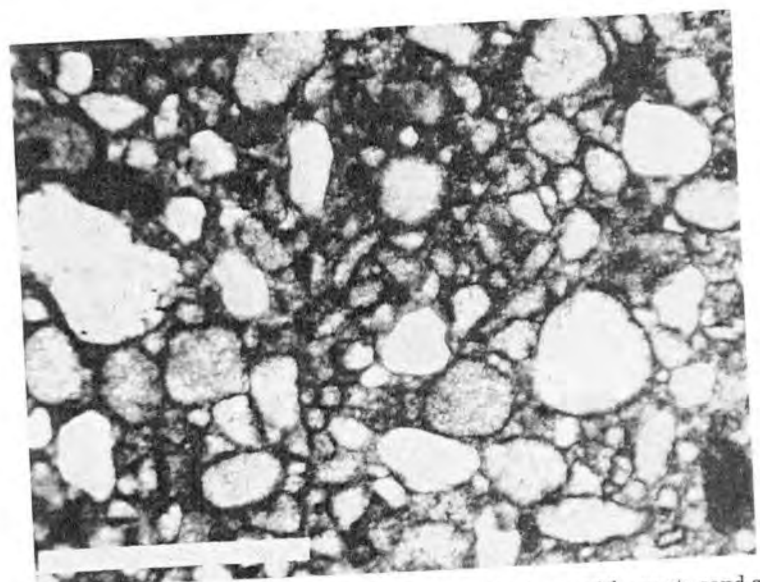
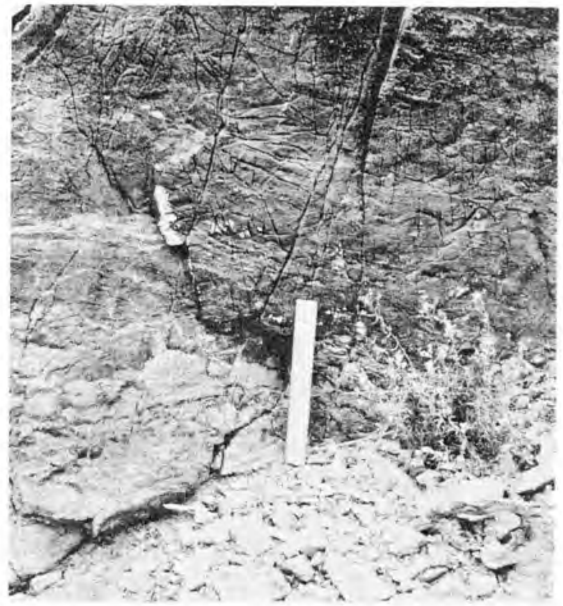


**Figure 33.** Photomicrograph of bioclastic, lithoclastic grainstone, with quartz sand grains from the sand horizon of Mullens and Poole (1972). Unit 1 of the Laketown Dolomite of Schaeffer (1960), which is herein assigned to the Floride Member of the Ely Springs Dolomite, southeastern Silver Island Range. Bar is 1 mm.



**igure 34.** Unconformable contact of Ely Springs Dolomite (Floride Member) and Laketown Dolomite (Tony Grove Lake Member), southeastern Silver Island Range. Clasts of Floride Member lithology are in the base of the Tony Grove Lake Member. Scale is 15 cm.

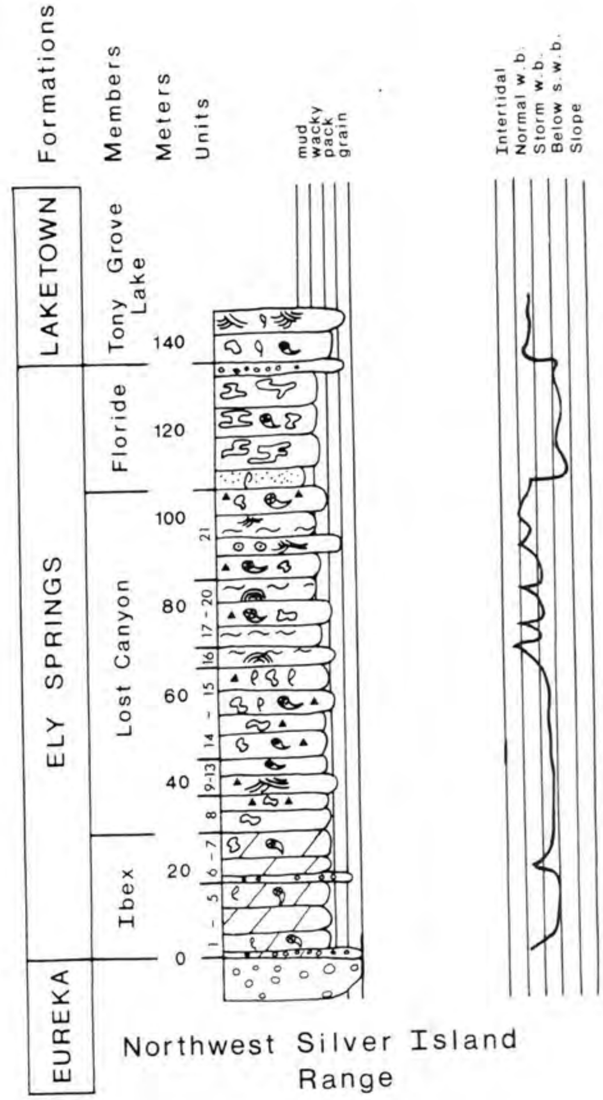



**Figure 35.** Sediment log of Northwestern Silver Island Range Section. For explanation of symbols see Fig. 11.

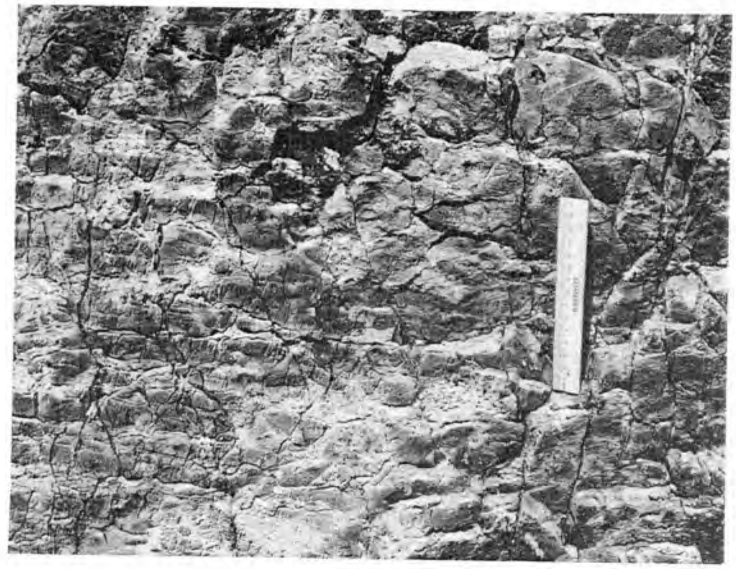
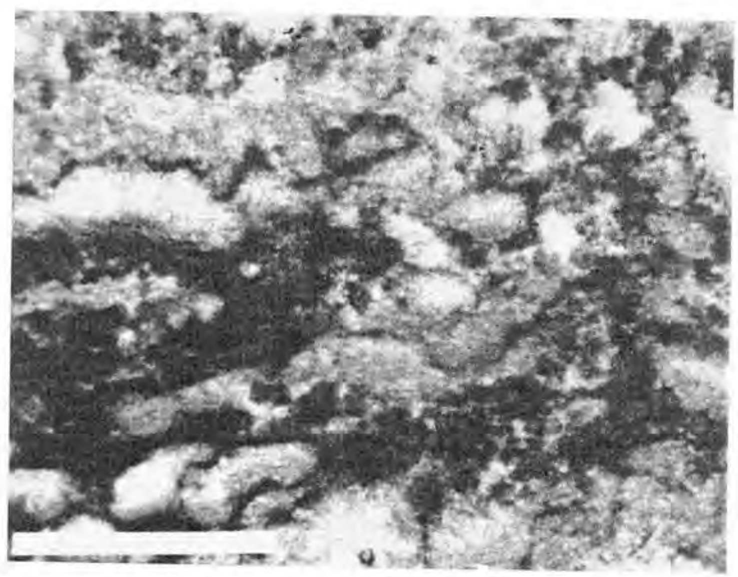


**Figure 36.** *Thalassinoides* burrows, with view perpendicular to bedding. Unit 22 of Budge and Sheehan (1980b), Floride Member, Ely Springs Dolomite, northwestern Silver Island. Scale is 15 cm.



**gure 37.** Photomicrograph of laminated, bioclastic, lithoclastic pack/grainstone. In upper 2 m of Unit 22 of Budge and Sheehan (1980b), Floride Member, Ely Springs Dolomite, northwestern Silver Island Range. Bar is 1 mm.

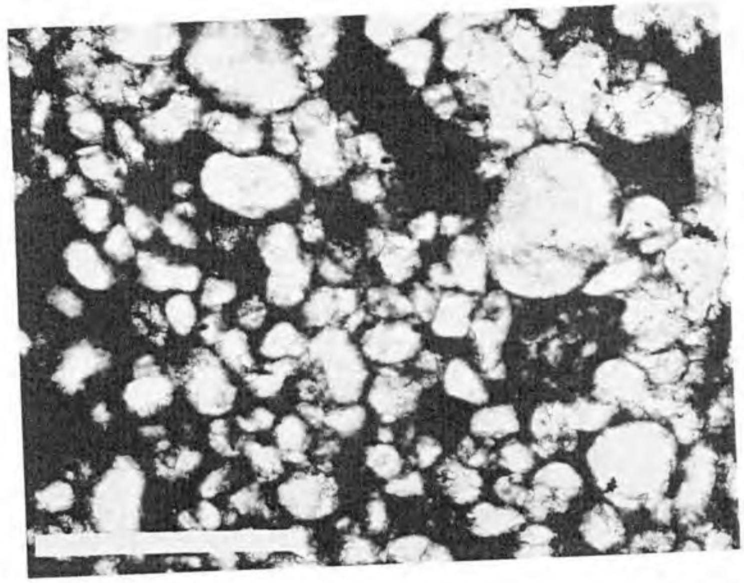
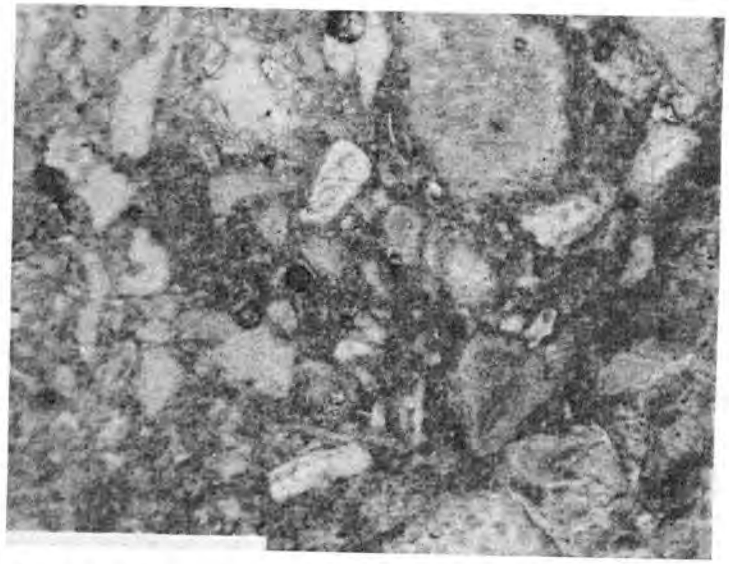


**Figure 38.** Photomicrograph of dolomitic sandstone, with reworked sand from the Eureka Quartzite. Unit 1 of Budge and Sheehan (1980b), Ibex Member, Ely Springs Dolomite, northwestern Silver Island Range. Bar is 1 mm.

**Figure 39.** Stromatolite, with second episode of growth, after disruption by currents or desica tion. Unit 20 of Budge and Sheehan (1980b), Lost Canyon Member, Ely Springs Dolomite northwestern Silver Island Range. Scale is 15 cm.



'igure 40. Photomicrograph of bioclastic packstone. Unit 21 of Budge and Sheehan (1980b), Lost Canyon Member, Ely Springs Dolomite, northwestern Silver Island Range. Bar is 1 mm.

ure 41. Multiple generation burrowing, with *Chondrites* burrows within *Thalassinoides* ›urrows. Unit 21 of Budge and Sheehan (1980b), Lost Canyon Member, Ely Springs Dolomite, ıorthwestern Silver Island Range. Scale is 15 cm.


**Figure 42.** *Chondrites* burrows within light gray *Thalassinoides* burrows. Some *Chondrites* burrows have dolomite spar in centers. Unit 21 of Budge and Sheehan (1980b), Lost Canyon Member, Ely Springs Dolomite, northwestern Silver Island Range.

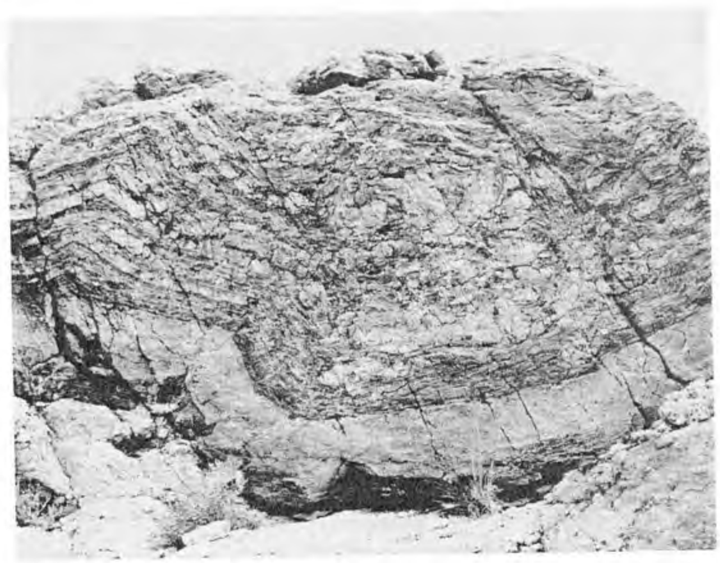


**Figure 43.** Translational slump in lower Roberts Mountains Formation, with alternating chert and dolomite bands. Height of photo is about 1.5 m. Northwestern Silver Island Range.

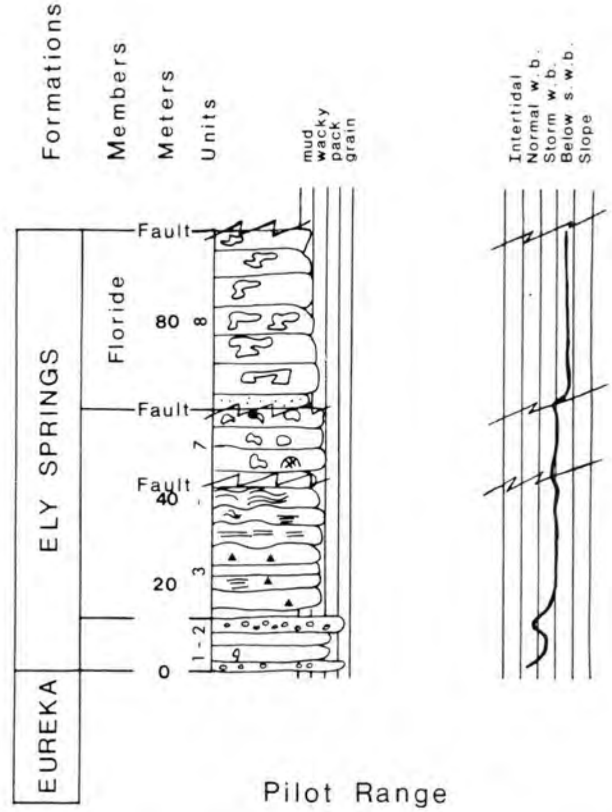



**Figure 44.** Sediment log of Pilot Range section. For explanation see Fig. 11.

45. Irregular contact of dark dolomite below and light above, with chert concentration, king possible extent of episode of dolomitization. Units 7 & 8 of O'Neill (1968), Ely ings Dolomite, southern Pilot Range. Pen is 16 cm long.

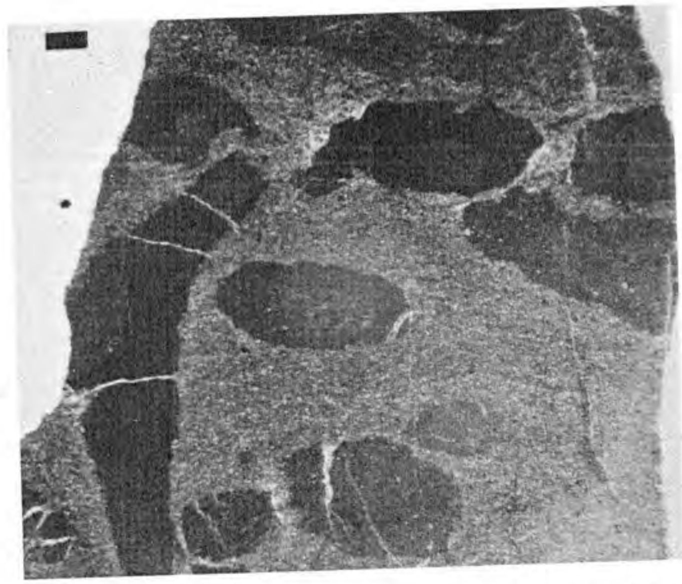


**Figure 46.** Photomicrograph of floatstone, with fractured lithoclasts in mudstone matrix. Unit 1 of O'Neill (1968), Ely Springs Dolomite, southern Pilot Range. Bar is 1 mm.

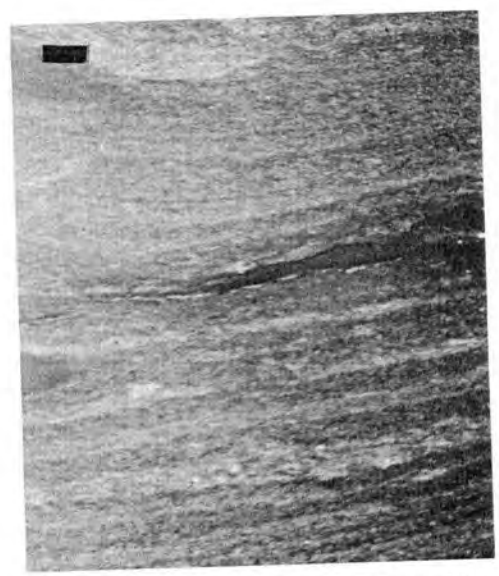
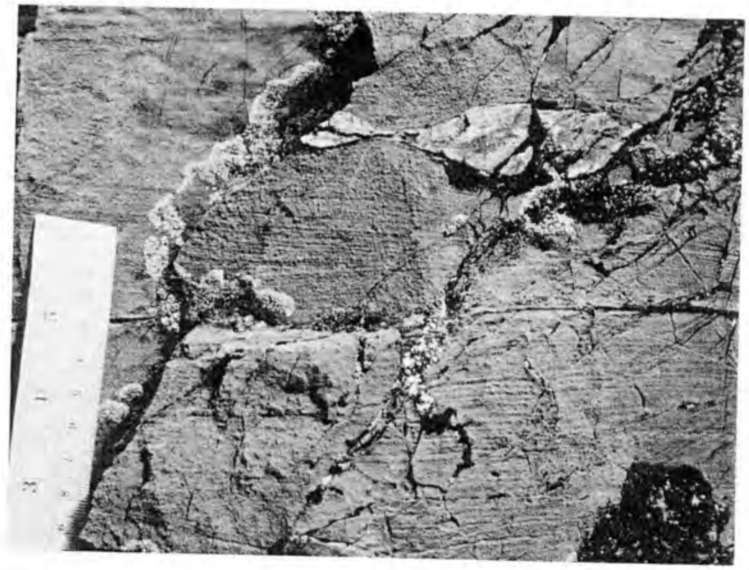


**Figure 47.** Photomicrograph of laminated mudstone, with sparse lithoclasts. Unit 1 of O'Neil (1968), Ely Springs Dolomite, southern Pilot Range. Bar is 1 mm.



re 48. Low angle cross-laminated packstone with argillaceous seams. Unit 1 of O'Neill 968), Ely Springs Dolomite, southern Pilot Range. Scale is 15 cm.

: 49. Photomicrograph of fossiliferous grainstone and wackestone, showing imbrication. t 1 of O'Neill (1968), Ely Springs Dolomite, southern Pilot Range. Bar is 1 mm.

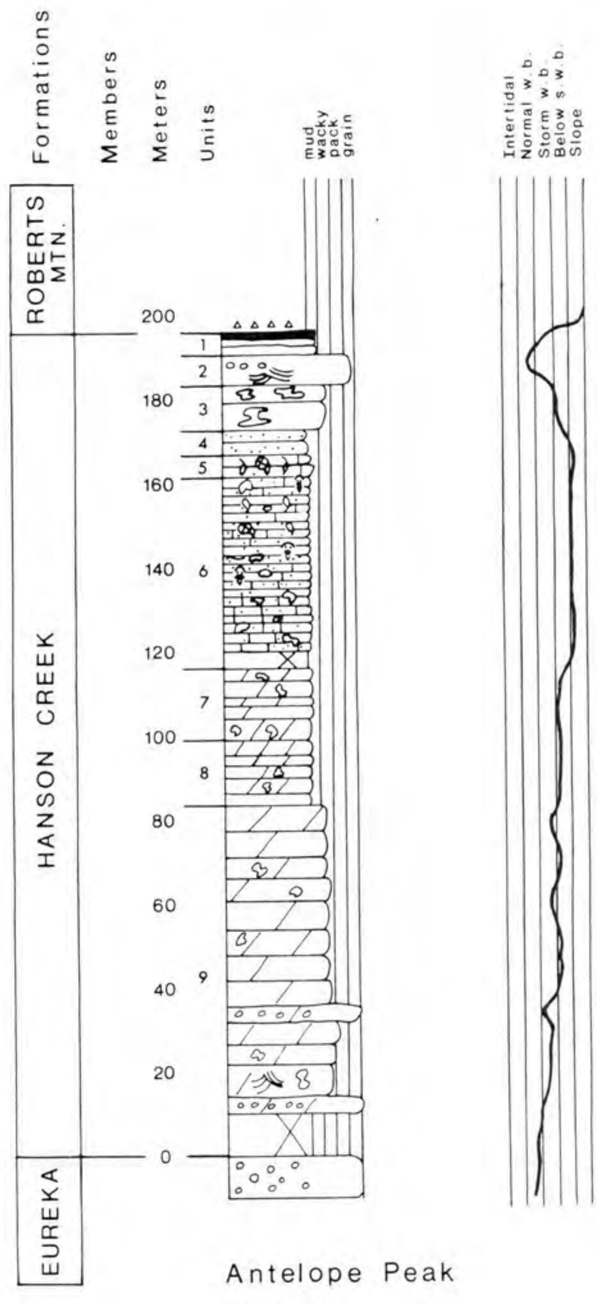



**Figure 50.** Sediment log of Antelope Peak section. For explanation of symbols see Fig. 11.

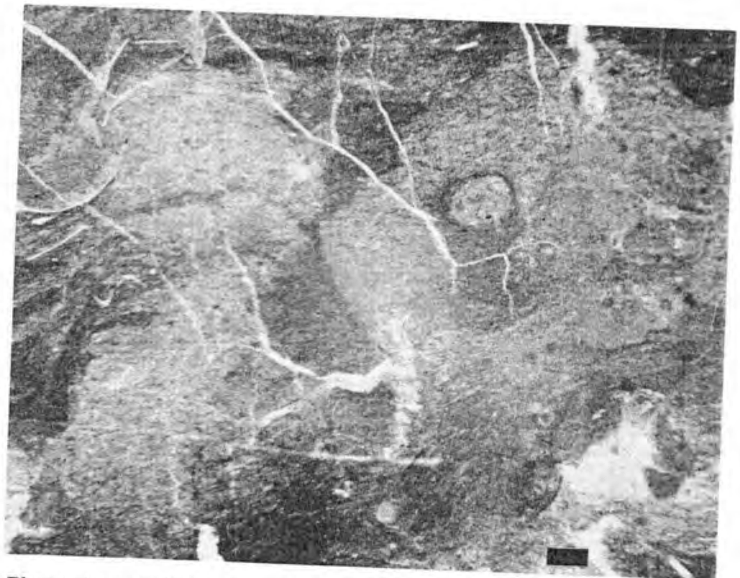
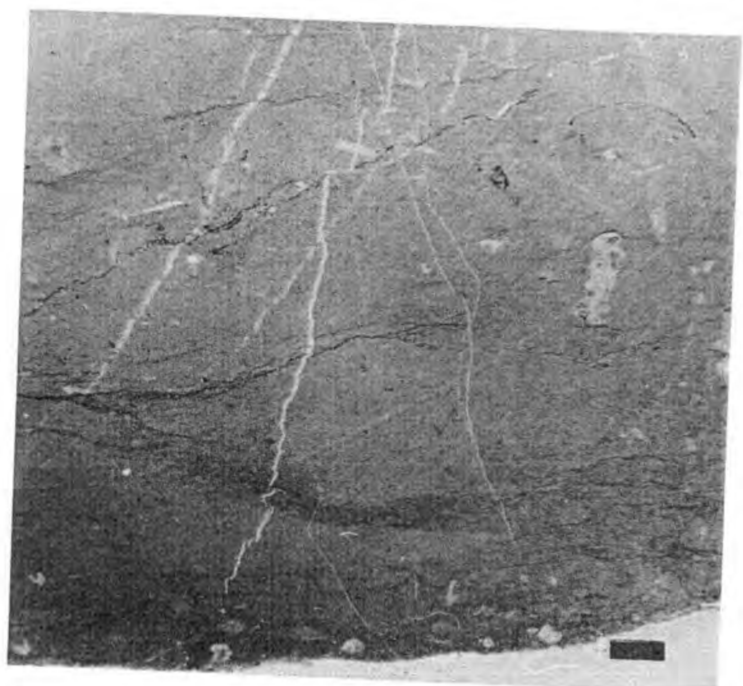


**Figure 51.** Photomicrograph of burrowed, bioclastic-lithoclastic wackestone, with wavy laminae. Unit 9 of Peterson (1968), Hanson Creek Formation, Antelope Peak. Bar is 1 mm.



**ure 52.** Photomicrograph of pelleted lime mudstone with bioclasts. Unit 6 of Peterson (1968), ·Ianson Creek Formation, Antelope Peak. Bar is 1 mm.

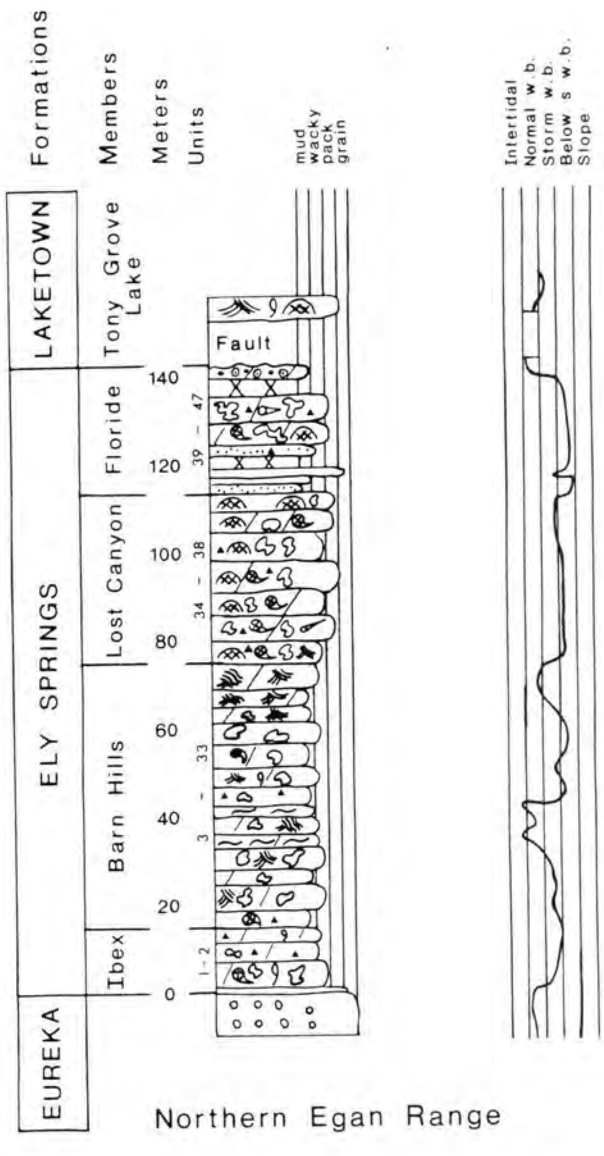
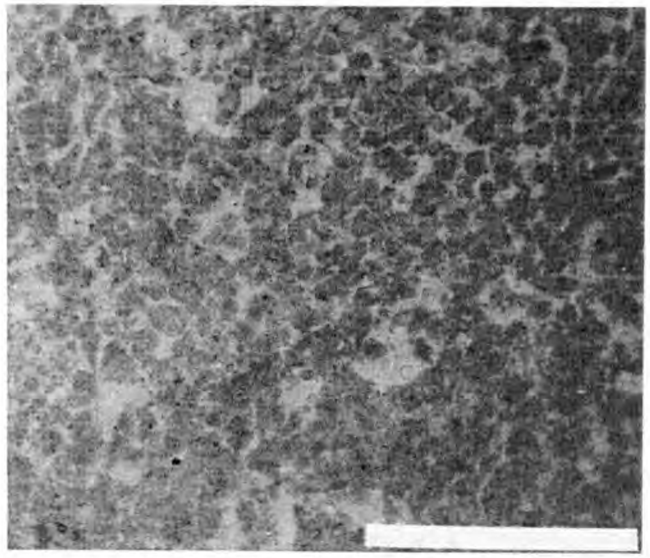



**Figure 53.** Sediment log of northern Egan Range Section. For explanation of symbols see Fig. 11.



micrograph of pelleted grainstone. Unit 5, Barn Hills Member, Ely Springs
hern Egan Range. Bar is 1 mm.

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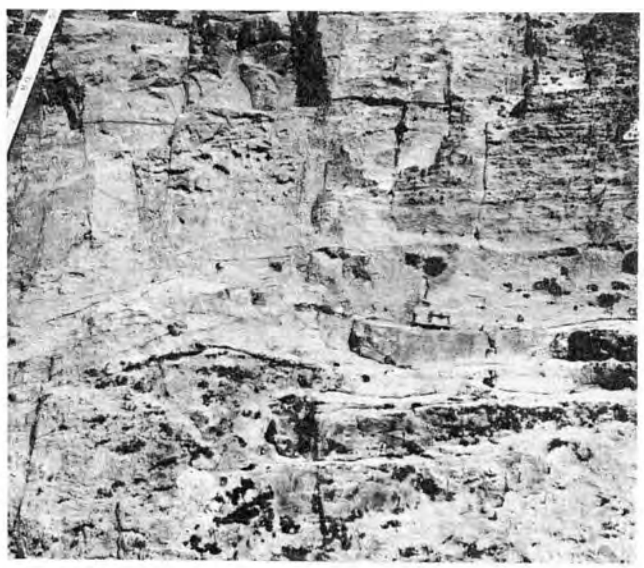
36



lar contact, interpreted as having been formed by scouring. Unit 23a, Barn
Ely Springs Dolomite, northern Egan Range. Tape is divided into 10 cm

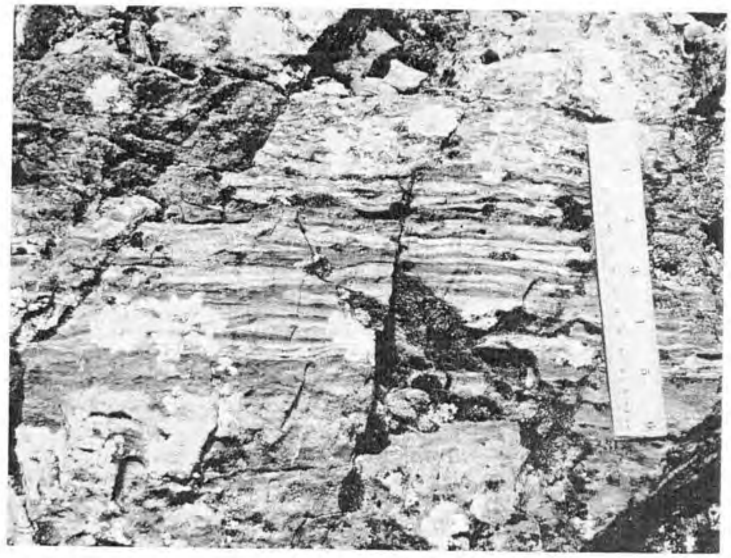


**Figure 56.** Lenticular bedding, with alternating layers of argillaceous mud/wackestone and pack/grainstone. Unit 33a, Barn Hills Member, Ely Springs Dolomite, northern Egan Range. Scale is 15 cm.

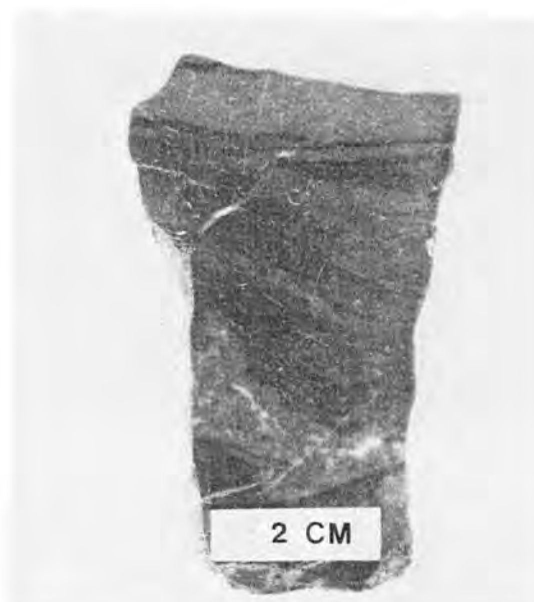
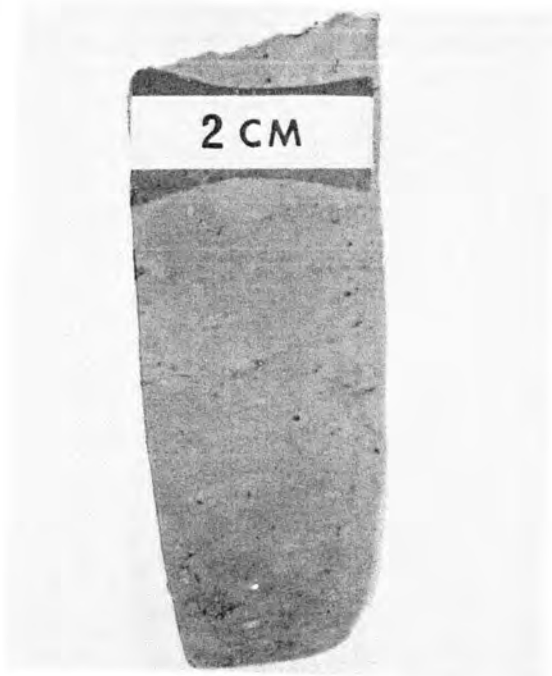
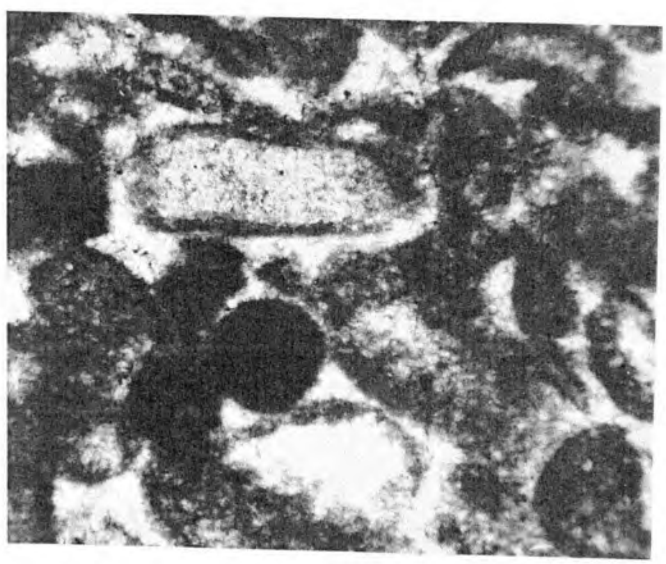



**Figure 57.** Lenticular bedding, with argillaceous mud/wackestone layers draped over pack/ grainstone layers. Unit 33a, Barn Hills Member, Ely Springs Dolomite, northern Egan Range.



cream-colored part of Floride Member (unit 39), Ely Springs Dolomite, northern



micrograph of bioclastic, lithoclastic grainstone, with clasts with micritized
'loride Member, Ely Springs Dolomite, northern Egan Range. Bar is 1 mm.

36

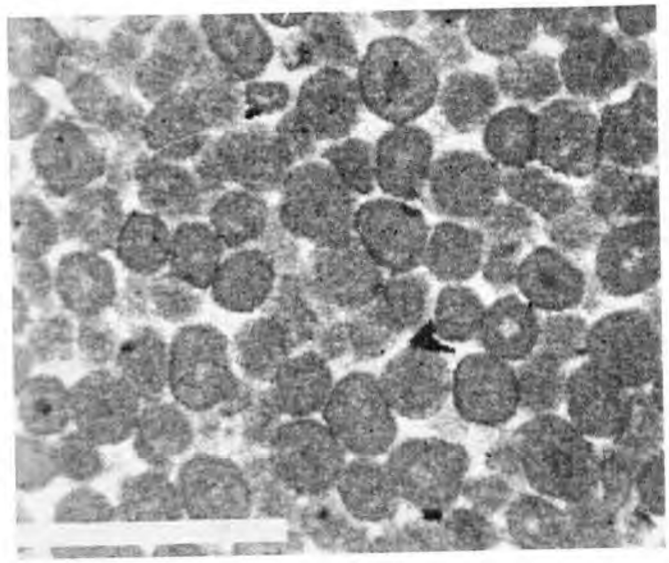


**Figure 60.** Photomicrograph of grainstone, consisting of micritized oolites with nuclei. Unit 49, Floride Member, Ely Springs Dolomite, northern Egan Range. Bar is 1 mm.

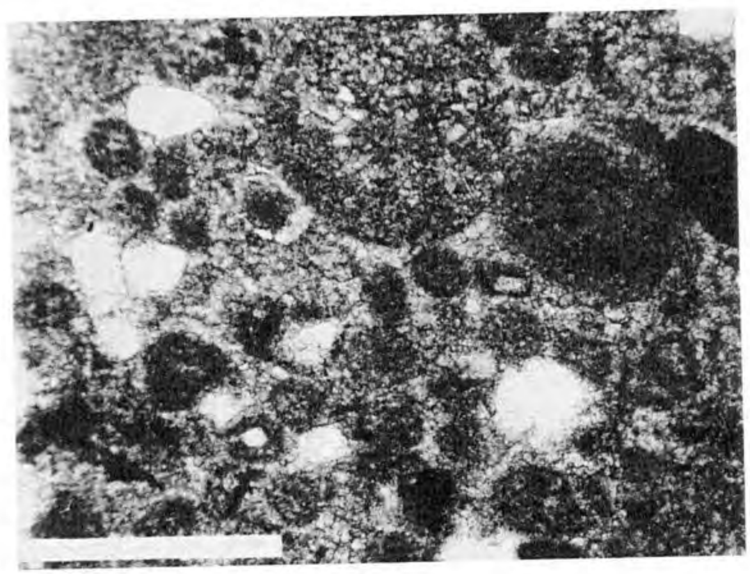
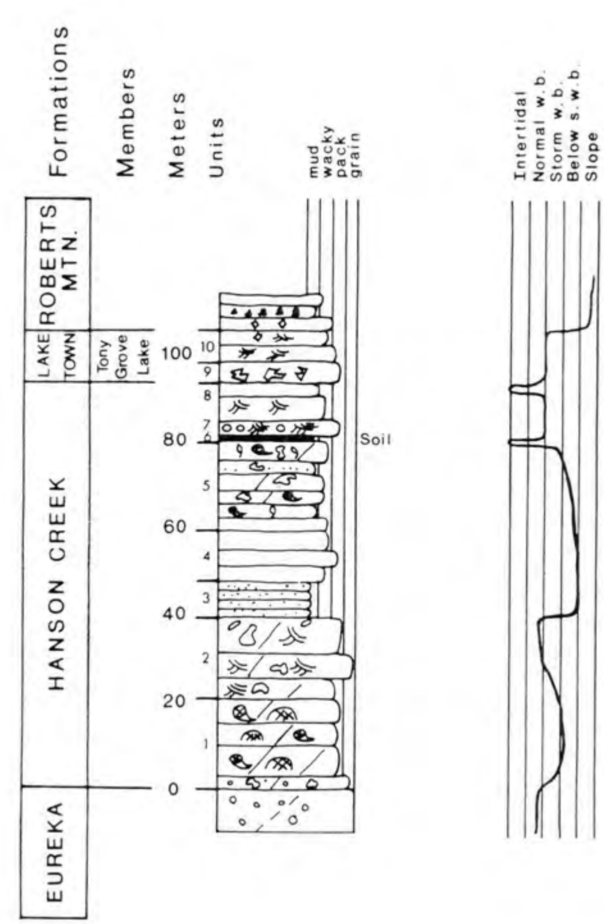


**Figure 62.** Photomicrograph of grainstone with micritized clasts and quartz sand grains from the sand horizon of Mullens and Poole (1972). Unit 7 of Ross (1970), Hanson Creek Formation, Lone Mountain. Bar is 1 mm.




ediment log of Lone Mountain section. Symbols are explained in Fig. 11.

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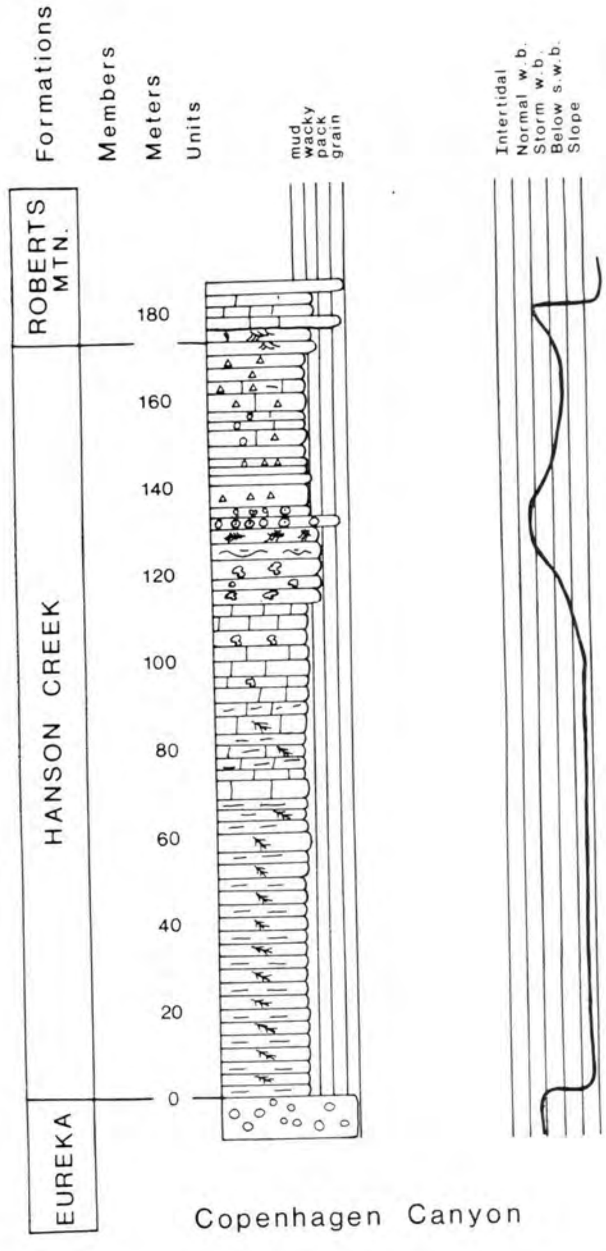
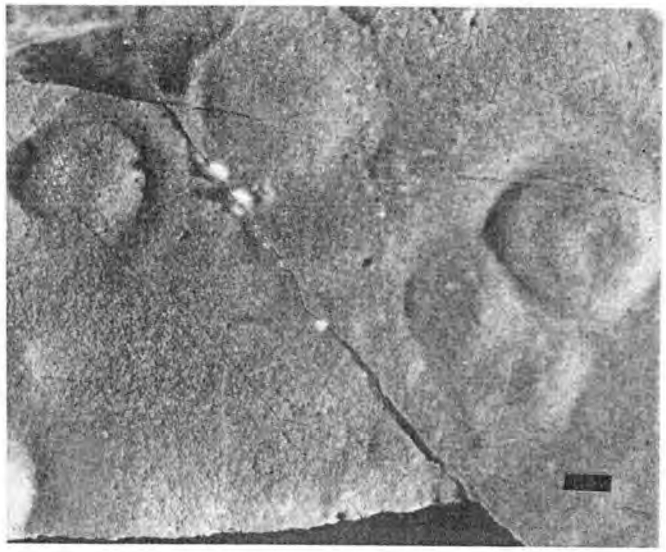



**Figure 63.** Sediment log of Monitor Range Section. Symbols are explained in Fig. 11.



ɪclus trace fossil in graptolitic mudstone. Bedding plane view. Hanson Creek
ɔenhagen Canyon, Monitor Range. Bar is 1 mm.

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icrograph of pelletal lime grainstone, (Tc) current ripple laminations (lower)
) laminations (upper). Vertical burrow is about 2 mm in diameter. Unnamed
Kee (1976), Toquima Range. Bar is 1 mm.

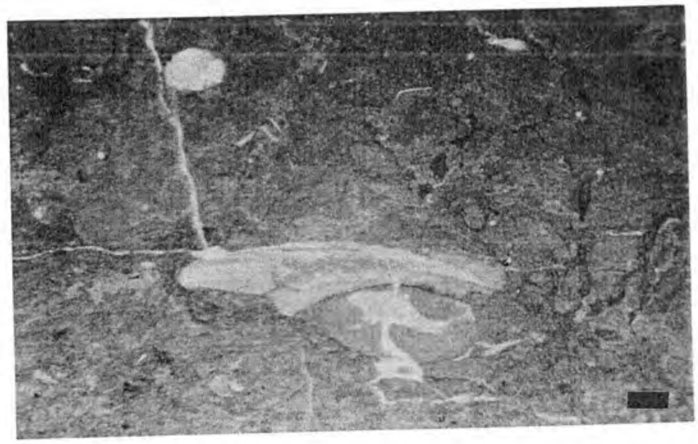

**Figure 66.** Photomicrograph of bioturbated, argillaceous, bioclastic, lithoclastic limestone. Unnamed limestone of McKee (1976). Bar is 1 mm.