University of Nevada

Reno

The Geology of the Northern Butte Mountains
White Pine County, Nevada

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

by

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May 1985

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May 1985

Acknowledgments

Endeavors of this degree are rarely the effort of only one individual. For this reason I would like to individually thank all of the people who gave me support and assistance in my pursuit.

To my wife, Mary, for her unending support, encouragement, and understanding I dedicate this thesis. She not only undertook the responsibilities of sole supporter, but also found time to give me a beautiful daughter named Erin.

A very special thanks to Dr. Joseph Lintz for his guidance, assistance, and support. I would also like to express my appreciation to Dr. Richard Schweickert who spent an enormous amount of his time editing the final draft.

I would like to express my thanks to Gary and Leigh Luce who assisted me with my field work and opened their home to me after long weeks in the field.

And finally a very large debt of gratitude to Foster Wilson, Sharolyn Prince and Richard Louisell; their help in the final preparations of the thesis were instrumental to its quality.

In addition to the above, I would like to thank Amoco Production Company, Amerada Hess and Tenneco Oil for the support needed to complete my field research.

Abstract

The northern Butte Mountains, White Pine County, Nevada, exposes 2500 meters of fossiliferous Upper Paleozoic strata ranging in age from Chesterian to Guadalupian. The eight formations found in the study area are: Mississippian Diamond Peak, Pennsylvanian Ely Limestone, Permian Riepe Spring Limestone, Riepetown Formation, Pequop Formation and Loray Formation of the Arcturus Group, and the Permian Kaibab Limestone and Plympton Formation of the Park City Group. Each formation clearly reflects the various changes in the depositional environment created by changes in the influx of terrigenous detritus, differential subsidence within the miogeocline, and global fluctuations in sea level. Carbonates are the dominant lithology, followed by sandstones, lesser clastics, and minor conglomerates. The overall depositional environment is interpreted as shallow shelf or platform facies.

Strata in the northern Butte Mounains dip 20 to 30 degrees to the southeast, and the major structural control is a basin and range fault on the west flank.

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INTRODUCTION

Pennsylvanian and Permian shelf sediments are widely exposed in White Pine County and to the north in adjacent Elko County. The thickest sections of Permian strata occur within the Butte structural trough (Hose and Blake, 1976). The main axis of the trough extends southward from the Maverick Springs Range through the Butte Mountains, continues southeast around the southwest margin of Radar Ridge and across the Egan Range and the Schell Creek Range, where it apparently dies out. Uplifted fault block ranges expose numerous, uncomplicated, well dated sequences for complete reconstruction of Pennsylvanian and Permian stratigraphy.

The purpose of this study was to map, measure, and investigate the nearly complete section of Pennsylvanian and Permian strata in the northern Butte Mountains. The northern Butte mountains were selected for this study because they contain a well exposed, uncomplicated, structurally simple, and fossiliferous record of continuous sedimentation, broken only by the Humboldt event, from late Mississippian through late Permian time.

This study was performed to contribute to a better understanding of Pennsylvanian and Permian stratigraphy and paleogeography in eastern Nevada. Fauna and lithologies in the northern Butte Mountains described in this report substantiate work done by earlier authors. Stratigraphic thicknesses in the northern Butte Mountains also help define lateral changes in formations and contribute to a better understanding of the development of the Ely-Butte basin. The Ely basin is a depositional feature that developed in eastern White Pine County prior to the emergence of the area in Lower to Middle Pennsylvanian time. The name serves to designate an area where sediments thicken toward a depositional center near Ely Nevada (Coogan, 1964). The Butte basin (Stevens, 1965) refers to a more regional Permian depositional feature bounded on the north by the northeastern Nevada shelf, on the northeast by the Oquirrh basin, on the southeast by the western Utah shelf, and on the south by the southern Nevada shelf.

REGIONAL SETTING

The northern Butte Mountains lie within the Cordilleran miogeocline. Over 10,000 meters of sediment were deposited in east-central Nevada from late Precambrian to early Triassic time (Hose and Blake, 1976). Great thicknesses of Paleozoic sandstones and carbonate rocks accumulated in the miogeocline and can be observed in every range in the region. East of the Butte Mountains in the northern Egan

Range, Schell Creek Range, and Snake Range, lower Paleozoic quartzite and shale are widely exposed. Upper Paleozoic rocks are also widespread, but have been partially or totally removed by erosion in many local areas. Complete sections of Pennsylvanian and Permian rocks are best preserved along the axis of the Butte structural trough . A north trending feature composed of broad, open synclines that are thought to have formed during Cretaceous time, during the earlier stages of the Sevier orogeny (Armstrong, 1972). In the Pequop Mountains (Robinson, 1961), the Butte Mountains (Sides, 1966), and the Confusion Range (Hose and Repenning, 1959), complete sections of Pennsylvanian and Permian strata are exposed (Locs.,Fig. 1). The Confusion Range and central Butte Mountains have sections that extend into the Upper Permian and Lower Triassic.

Upper Pennsylvanian epeirogenic arching resulted in a regional disconformity that separates lower to middle Pennsylvanian rocks from lower Permian rocks. The disconformity occurs throughout most of White Pine County. The absence of upper Pennsylvanian strata marks the duration of the Humboldt orogenic event (Ketner, 1977) . However, north of White Pine County, and in northwestern Utah, deposition of the Oquirrh Formation continued from Pennsylvanian through Permian time and no unconformity exists. In the Elko area, 100 km north of the Butte

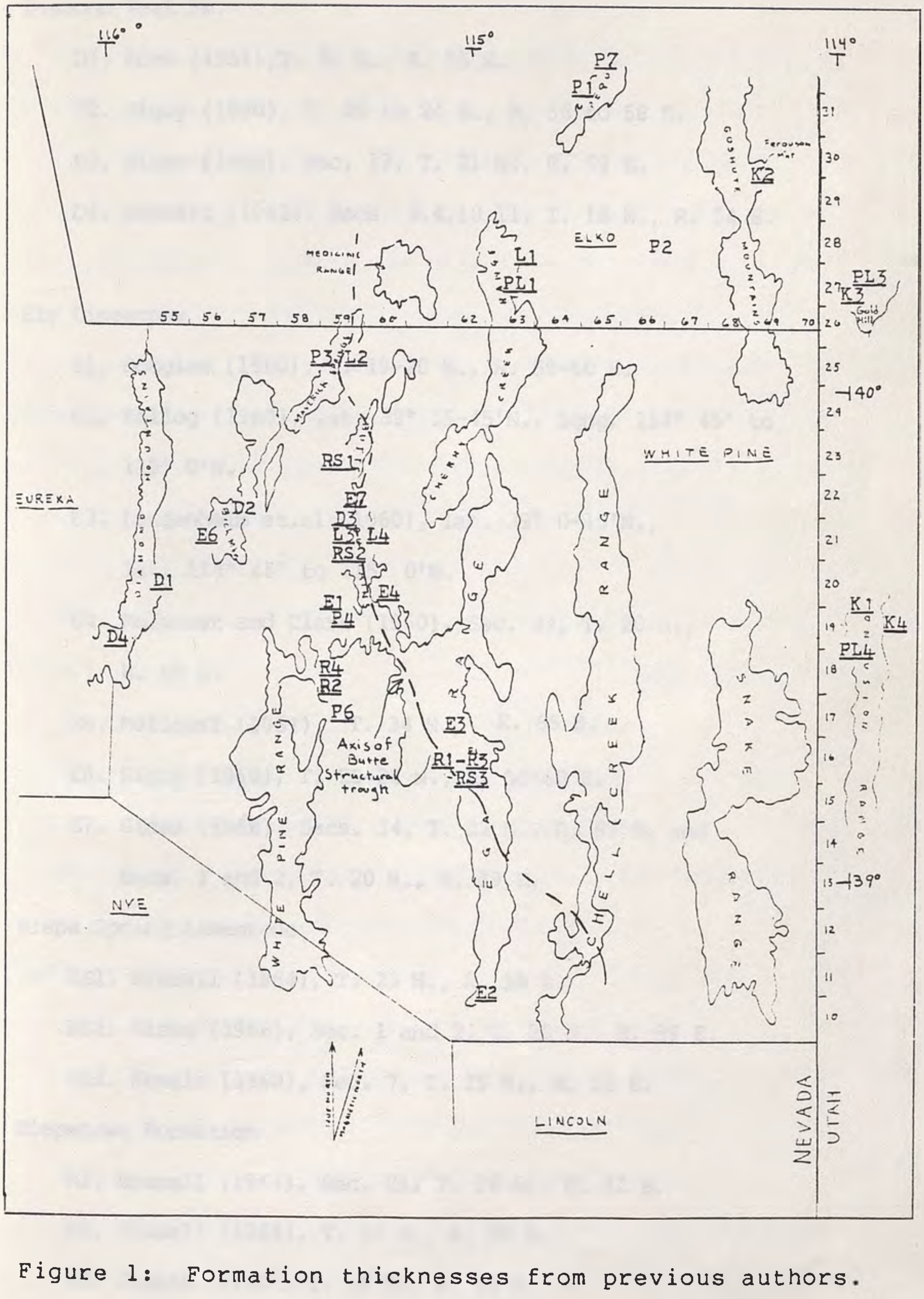


Figure 1: Formation thicknesses from previous authors.

Diamond Peak Fm.

D1. Brew (1961),T. 20 N., R. 55 E.

D2. Rigby (1960), T. 20 to 24 N., R. 56 to 58 E.

D3. Sides (1966), Sec. 17, T. 21 N., R. 59 E.

D4. Stewart (1962), Secs. 3,4,10,11, T. 18 N., R. 54 E.

Ely Limestone

E1. Douglas (1960), T. 19-20 N., R. 59-60 E.

E2. Kellog (1960), lat. 38* 15-45'N., long. 114* 45' to 115* 0'W.

E3. Langenheim et.al (1960), lat. 39* 0-15'N., lat. 114* 45' to 115* 0'W.

E4. McJannet and Clark (1960), Sec. 32, T. 20 N., R. 60 E.

E5. Mollazal (1961), T. 34 N., R. 65 E.

E6. Rigby (1960), T. 20-24 N., R. 56-60 E.

E7. Sides (1966), Secs. 34, T. 22 N., R. 59 E. and Secs. 1 and 2, T. 20 N., R. 59 E.

Riepe Spring Limestone

RS1. Bissell (1964), T. 23 N., R. 59 E.

RS2. Sides (1966), Sec. 1 and 2, T. 20 N., R. 59 E.

RS3. Steele (1960), Sec. 7, T. 15 N., R. 63 E.

Riepetown Formation

R1. Bissell (1964), Sec. 21, T. 16 N., R. 62 E.

R2. Bissell (1964), T. 17 N., R. 59 E.

R3. Steele (1960), T. 16 N., R. 62 E.

R4. Steele (1960), T. 17 N., R. 59 E.

Pequop Formation

P1. Bissell (1964), NE. 1/3, T. 31 N., R. 64 E.

P2. Bissell (1964), SE. 1/4, T. 28 N., R. 66 E.

P3. Bissell (1964), SW. 1/4, T. 25 N., R. 59 E.

P4. Brill (1963), T. 19 N., R. 59 E.

P5. Robinson (1961), Secs. 34-35, T. 34 N., R. 65 E.

P6. Steele (1960), T. 17 N., R. 59 E.

P7. Steele (1960), Sec. 3, T. 33 N., R. 65 E.

Loray Formation

L1. Bissell (1964), NE. 1/4, T. 27 N., R. 63 E.

L2. Bissell (1964), T. 25 N., R. 59 E.

L3. Brill (1963), T. 21 N., R. 59 E.

L4. Steele (1960), Secs. 27-28, T. 21 N., R. 59 E.

Kaibab

K1. Bissell (1962), T. 14 S., R. 17 N.

K2. Bissell (1964), T. 30 N., R. 69 E.

K3. Hodgkinson (1961), Secs. 5 and 8, T. 7 S., R. 19 W.

K4. Hose and Repenning (1959), lat. 39* 15-30'N., long. 113* 30' to 114* 0'W.

Plympton Formation

PL1. Bissell (1964), T. 27 N., R. 63 E.

PL2. Hodgkinson (1961), Secs. 34 and 35, T. 34 N., R. 65 E.

PL3. Hodgkinson (1961), Secs. 5 and 8, T. 7 S., R. 19 W.

PL4. Hose and Repenning (1959), lat. 39* 15-30'N., long. 113* 30' to 114* 0'W.

Mountains, an unconformity at the base of the Pennsylvanian Strathearn Formation encompassed Missouri, Virgil, and Wolfcampian time (Dott, 1955). In the Diamond Mountains, 42 km west, the Wolfcampian Carbon Ridge Formation rests on beds as young as Early Pennsylvanian and as old as Mississippian (Nolan and others, 1956).

Sides (1966) reported that lower Permian rocks rest disconformably on middle Pennsylvanian in the central Butte Mountains. The disconformity is also present in the northern Butte Mountains and is set off by a chert pebble conglomerate containing Wolfcampian age fusulinids.

Non-marine Cretaceous (Nolan and others, 1956) and Tertiary rocks (Winfrey, 1960) are present in scattered locations throughout the region. Tertiary volcanic rocks commonly overlie older rocks with angular unconformity (Cook, 1960). Large accumulations of Oligocene volcanic rocks are found in the Butte Mountains, Maverick Springs Range, Cherry Creek Range, and Buck Mountain (Hose and Blake, 1976).

The northern Butte Mountains are located at the northern portion of the Butte structural trough. Sedimentary rocks dip 15 to 30 degrees to the southeast and are interpreted as the western limb of a syncline whose axis is concealed beneath Tertiary sediments in Butte Valley (Hose and Blake, 1976). The general structure of the central Butte Mountains is that of a broad, southeast-plunging syncline complicated in the south by the Summit Springs anticline (Sides, 1966). The Butte structural trough lies at the western edge of a region in which major mid-tertiary extension created deep-seated normal faults that eventually rotated to low-angle faults. Low angle faults created by this mechanism place younger strata on older. No evidence for low-angle normal faults exists in the northern Butte Mountains. Instead, the Butte Mountains show high-angle normal faulting as is typical of nearly all major ranges in the region.

Previous Studies

Contributions to the geologic understanding of east-central Nevada were carried out sporadically from the 1860's until the early 1950's. In 1960, a volume produced by the Intermountain Association of Petroleum Geologists and the Eastern Nevada Geological Society (Guidebook to the Geology of East Central Nevada) synthesized information about earlier work done in eastern Nevada and current investigations in structure and stratigraphy. One of the most significant contributions made in this volume, with respect to eastern Nevada stratigraphy, was the reinterpretation of Pennsylvanian and Permian stratigraphic units in eastern Nevada by Grant Steele. Steele established five new stratigraphic formations: the Pennsylvanian Ferguson Springs Formation, and Permian Riepe Spring Limestone, Riepetown Formation, Pequop Formation, and Loray Formation. He gave thicknesses and general lithologic descriptions of numerous other formations identified at the surface, isopachous maps of Pennsylvanian and Permian strata, and index maps showing the traced areal extent of each formation. Steele was also the first to recognize the regional extent of an Upper Pennsylvanian unconformity and presented the distribution of Upper Pennsylvanian or younger strata above the regional unconformity. Ketner (1977) credits the Pennsylvanian disconformity to orogenic activity to the west in the Humbolt Highlands.

Bissell (1962, 1964, 1970) measured numerous stratigraphic sections of Permian marine rocks and contributed significantly to the revision of nomenclature in eastern Nevada. Stevens (1963, 1965, 1977, 1979) delineated the distribution of Permian facies and presented paleotectonic features and interpretations of Permian paleogeography.

Prior to this study , no detailed geologic work had been conducted in the northern Butte Mountains. However, the central and southern portions of the Butte Mountains have been involved in a number of geologic studies.

The only published geologic mapping of the northern Butte Mountains is by Hose and Blake (1976). Reconnaissance mapping of the area was done for the report on the Geology and Mineral Resources of White Pine County. Map scale for the report is 1:250,000. Other than the mapped portion, little reference was made to the northern Butte Mountains.

Misch (1960) commented on a thick sequence of Permian strata in the northern Butte Mountains and included a brief discussion of the structure. Steele (1960) correlated carbonate rocks of the Butte Mountains with the Pequop Formation and reported that the Loray Formation totaled 2475 feet in the central Butte Mountains (Secs. 27 and 28, T. 21 N., R. 59 E.), representing the thickest known section of the Loray Formation within the eastern Great Basin. Bissell (1964) reported that the Riepetown Formation (Steele, 1960) is present in the central and northern Butte Mountains, and "presented an interesting study in facies changes". In the central Butte Mountains (T.20 N., R. 60 E.) Bissell measured a section of the Riepetown Formation that totaled 540 feet, but could be as much as 590 feet, comprising dolomite, calcsiltite, and micritic to skeletal limestone, whereas the section measured in the northern Butte Mountains (SE. 1/4, T. 23 N., R. 59 E.) was predominantly calcsiltite, sandstone, and micritic to skeletal limestone, totaling 1138 feet in thickness. Bissell concluded that his studies were tentative and that much more detailed work remained.

Stevens (1965) identified six major lithologic units in the southern Butte basin, which included measurements taken from the southern Butte Mountains (secs. 35 and 36, T. 21 N., R. 60 E.). His overall conclusions were that only the Permian Riepe Spring Limestone is an areally extensive formation and the other five Permian lithologic units should be considered as lithosomes. However, he indicated that in part of the Butte basin the pre-Kaibab Permian section can be assigned four formational names: Riepe Spring Limestone, Riepetown Sandstone, Pequop Formation, and Loray Formation. The Permian section measured by Stevens in the southern Butte Mountains was the only complete Permian sequence in his study. Stevens' study emphasized that the application of most formational names of Lower and Middle Permian rocks to sections throughout the Butte Basin was unrealistic because different units are mappable in different regions. The number of lithosomes present in one area and the thicknesses of the lithosomes indicate that the dominant sediment source was nearby. Stevens showed that the Riepe Spring Limestone, Rib hill lithosome, Pequop lithosome, part of the Arcturus lithosome, and the Loray lithosome are all present in the southern Butte Mountains.

Sides (1966) mapped the central Butte Mountains on a scale of 1:56000, identified fauna associated with the strata , and gave thicknesses for the formations found in the area. Sides did not report the presence of the Pequop or Loray Formation in his study but did divide the Arcturus Formation into lower and upper members that are lithologically similar to the Pequop and Loray Formations, respectively. He also reported a thickness of 2537 feet for the upper member of the Arcturus Formation, which is very close to the measurement made by Steele for the Loray Formation in the very same area. Sides reported the regional unconformity recognized by Steele and others but did not apply a formational name to the Wolfcampian age carbonates above the unconformity; instead they were combined with the Ely Limestone and discussed along with the Ely Limestone.

Discrepancies among reports on geology in the Butte Basin region can probably be related to the concepts set forth by Stevens (1965). Interfingering of various facies in the Butte Mountains has undoubtedly been interpreted differently by authors; thereby leading to changes in thicknesses between the southern, central, and northern portions of the Butte mountains.

Location and Accesibility

The northern Butte Mountains are in the northwest part of White Pine County, between longitudes 115* 12.5' and 115* 20' and latitudes 39* 48' and 39* 55.5', approximately 72 km (45 miles) northwest of Ely, Nevada (Fig. 2). The area mapped is shown on four 7.5 minute, 1:24000 topographic sheets: the southeast corner of Junction Well quadrangle, the southwest corner of Ninemile Well quadrangle,the northwest corner of the Cow Camp quadrangle, and the northeast corner of the Cabin Spring quadrangle.

Access to the study area is provided by well traveled roads on each side of the Butte Range that originate from Highway 50, 26 miles south. These provide good access to the more rugged 4-wheel drive routes that end at the range front. The Ruby Marsh road through Long Valley is paved and regularly maintained by the workers of the Alligator Ridge gold mine. Thirty Mile road extends northward along the east side of the Butte Mountains through Butte Valley.

Topography

The northern Butte Mountains are part of a large, north-south trending fault block characteristic of the Basin and Range physiographic domain. They are separated from the

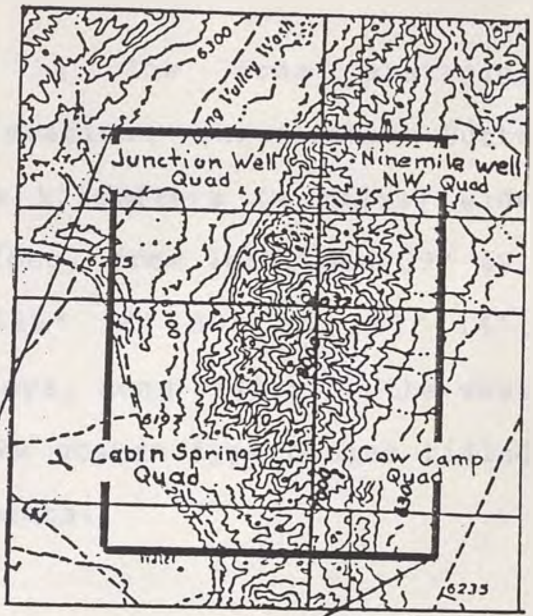


FIGURE 2b:
Northern Butte Mountains: Topography and Adjacent Valleys (Scale 1:250,000)

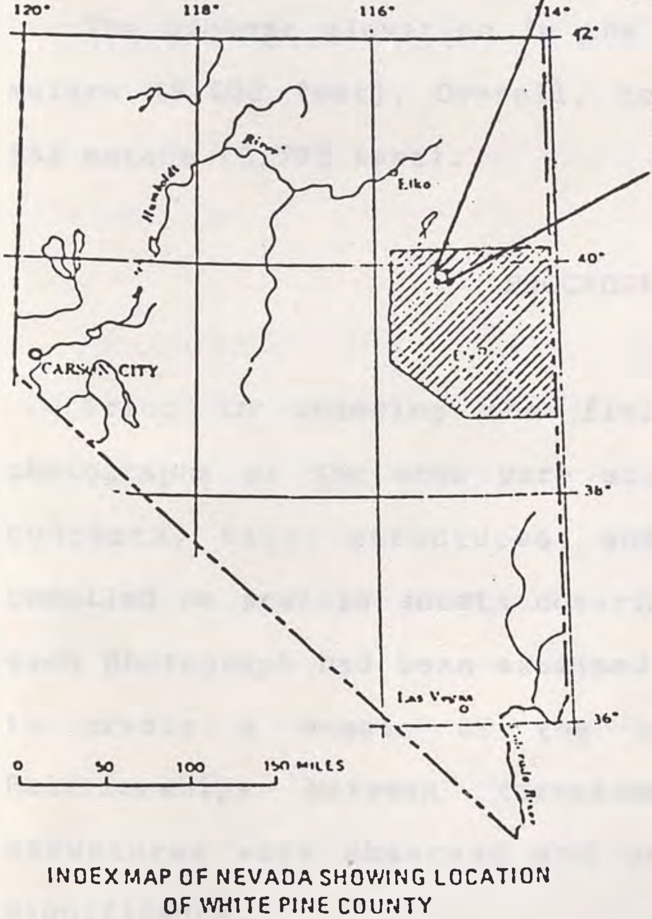


FIGURE 2a:
Location of Northern Butte Mountains, White Pine County, Nevada

central Butte Mountains by a low area averaging approximately 2,150 meters in elevation. The northern Butte Mountains are approximately 6.4 kilometers (4 miles) wide and 14.4 kilometers (9 miles) long, from latitudes 39* 48' to 39* 55', and longitudes 115* 18' 30" to 115* 14', respectively. The adjacent valleys, Long Valley on the west and Butte valley on the east, are graben type basins filled with continentally derived sediments.

The highest elevation in the area mapped reaches 2,759 meters (9,052 feet). Overall, topographic relief is about 852 meters (2,795 feet).

PROCEDURE

Prior to entering the field, 1:24000 scale aerial photographs of the area were studied. Potential formation contacts, fault structures, and areas of interest were compiled on acetate sheets covering the photographs. After each photograph had been examined, the photos were combined to create a mosaic of the northern Butte Mountains. Relationships between formation contacts and linear structures were observed and organized with respect to significance.

Field mapping and sampling were done in the summers of

1983 and 1984. Field procedure consisted primarily of traversing the mapped area, selecting rocks and fossils for geologic interpretation, and measuring stratigraphic sections.

Mapping was compiled on four 7.5 minute topographic basemaps and associated aerial photographs.

Several detailed stratigraphic sections were measured by Brunton compass and a 100 foot tape. Reference localities at Moorman Ranch (T. 17 N., R. 59 E.) and Rib Hill (T. 16 N., R. 62 E.) were also visited to examine type localities of formations.

In the laboratory, polished sections of samples of the various lithologic units were examined and classified according to the Leighton-Pendexter classification (1962) (Appendix 2). In addition, thin sections of Permian fusulinids were prepared from several formations in the area.

STRATIGRAPHY

General Statement

The most widespread Pennsylvanian and Permian stratigraphic units in White Pine County are the Pennsylvanian Ely Limestone, the Lower Permian Arcturus Group of Bissell (1964), and Hose and Repenning's (1959) Upper Permian Park City Group.

The Pennsylvanian Ely Limestone was originally named by Lawson (1906) for a regularly stratified, thick bedded limestone sequence in the Robinson (Ruth) mining District. The Ely Limestone is distributed throughout White Pine County and is disconformably overlain by the Wolfcampian Riepe Spring Limestone. The upper Pennsylvanian-lower Permian hiatus represents an upper Paleozoic tectonic event recognized by Ketner (1977) and named the Humboldt orogeny.

The Arcturus Group consists, from bottom to top, of the Riepe Spring Limestone or Ferguson Mountain Formation, Riepetown Formation, Pequop Formation or Arcturus Formation, and the Loray Formation. The Wolfcampian- Leonardian boundary occurs within the lowest part of the type sections of the Pequop and Arcturus Formations.

The Park City Group consists of three formations: Kaibab

Formation, Plympton Formation, and Gerster Formation. Work done by Baird and Collinson (1975) on conodont faunas of the Kaibab and the lower part of the Plympton Formation indicate they are of Leonardian age, and the upper part of the Plympton Formation and Gerster Formation are of Guadalupian age.

Eight Paleozoic formations totalling 2500 meters in thickness occur in the northern Butte Mountains (Plate 1). These units range in age from Late Mississippian (Chesterian) to Late Permian (Guadalupian). Stratigraphic units, in ascending order (oldest to youngest), are: Diamond Peak Formation (Mississippian-Pennsylvanian); Ely Limestone (Morrowan-Atokan), Riepe Spring Limestone (upper lower Wolfcampian), Riepetown Formation (middle to upper Wolfcampian), Pequop Formation (upper Wolfcampian to middle Leonardian), Loray Formation (middle to upper Leonardian), Kaibab Formation (Leonardian-Guadalupian), and Plympton Formation (Guadalupian). A disconformity separates the Ely Limestone and the Riepe Spring Formation. The Tertiary Kalamazoo Volcanics unconformably overlie the Paleozoic rocks.

Each formation is discussed with respect to nomenclature, lithology, depositional environment, fauna and age, and stratigraphic Relations.

DIAMOND PEAK FORMATION

Nomenclature

Hague (1883) originally coined the term Diamond Peak quartzite for a section of strata in the Eureka district having firmly cemented conglomerates at its base, followed by massive, grayish-brown quartzite, passing into laminated green and brown schists and shales. However, Hague emphasized the main lithology of the Diamond Peak and did not describe its overall heterogeneity. Nolan and others(1956), with support of other contemporary authors (Easton, 1953; Dott, 1955), formally raised the Diamond Peak to formation level.

In most of the eastern Great Basin the Diamond Peak Formation can be easily distinguished from the underlying Chainman Shale or White Pine Shale (Hague, 1883; Nolan et.al., 1956; Sadlick, 1960; Humphrey, 1960; Hose and Blake, 1976; Stewart, 1980). The Diamond Peak Formation can best be recognized and mapped as a discrete unit west of the White Pine and Butte Ranges and the northern Pancake Range. Siltstones are the dominant lithology in both sections. Sadlick (1960) described the Diamond Peak Formation as a sequence of coarse, proximal conglomerates at Carlin Canyon, Elko County (the Tonka Formation of Dott (1955)), which thinned to the southeast and graded into fine grained sandstone and shale of the Scotty Wash Quartzite near Pioche. However, the marked vertical and horizontal variability of the Diamond Peak Formation (Hague, 1883; Nolan and others, 1956; Steele, 1960; Sides, 1966; Blomquist, 1971) indicates a more complex interfingering of lithologies. Blomquist (1971) proposed that complex facies changes in the Diamond Peak are the result of intermixing of sediments from two subsea topographic highs in eastern and southeastern White Pine County, the Ely high and Currant High, respectively.

On the west side of the northern Butte Mountains, a section of conglomerate, quartzite, sandstone, limestone and shale was measured, described and assigned to the Diamond Peak Formation. The percentages of different lithologies are closely congruent to those given by Sides (1966) in the central Butte Mountains. Steele (1960), however designated these units as Scotty Wash Quartzite, but other authors (Sides, 1966; Blomquist, 1971; Hose and Blake, 1976) have considered them to be Diamond Peak Formation.

Lithology

In the northern Butte Mountains, the Diamond Peak Formation is composed chiefly of interbedded sandstone and limestone, together with minor amounts of conglomerate and shale. The relative portions of these units may vary slightly from one location to another, but it is estimated that sandstone makes up at least 50% of the formation, with limestone being the next abundant, leaving only minor percentages of conglomerate and shale.

An incomplete section of the upper portion of the Diamond Peak Formation was measured and described in detail on the western side of the study area (Appendix A, section 1, and Fig. 3 and 4). At the reference location (lat. 39* 52' N., long. 115* 18' W.), the formation is well-exposed and comprises an aggregate thickness of 259.5 m. North of the reference section (lat. 39* 52.5' N., long. 115* 18'W.), vertical and overturned beds of the Diamond Peak Formation crop out along a drainage adjacent an access road.

Sandstones are commonly yellowish-gray to light brown in color; limestones are light brown to light gray. The combination of these units gives an overall yellowish-brown color to the formation, which makes it very easy to distinguish from the bluish-gray color of the overlying Ely Limestone.

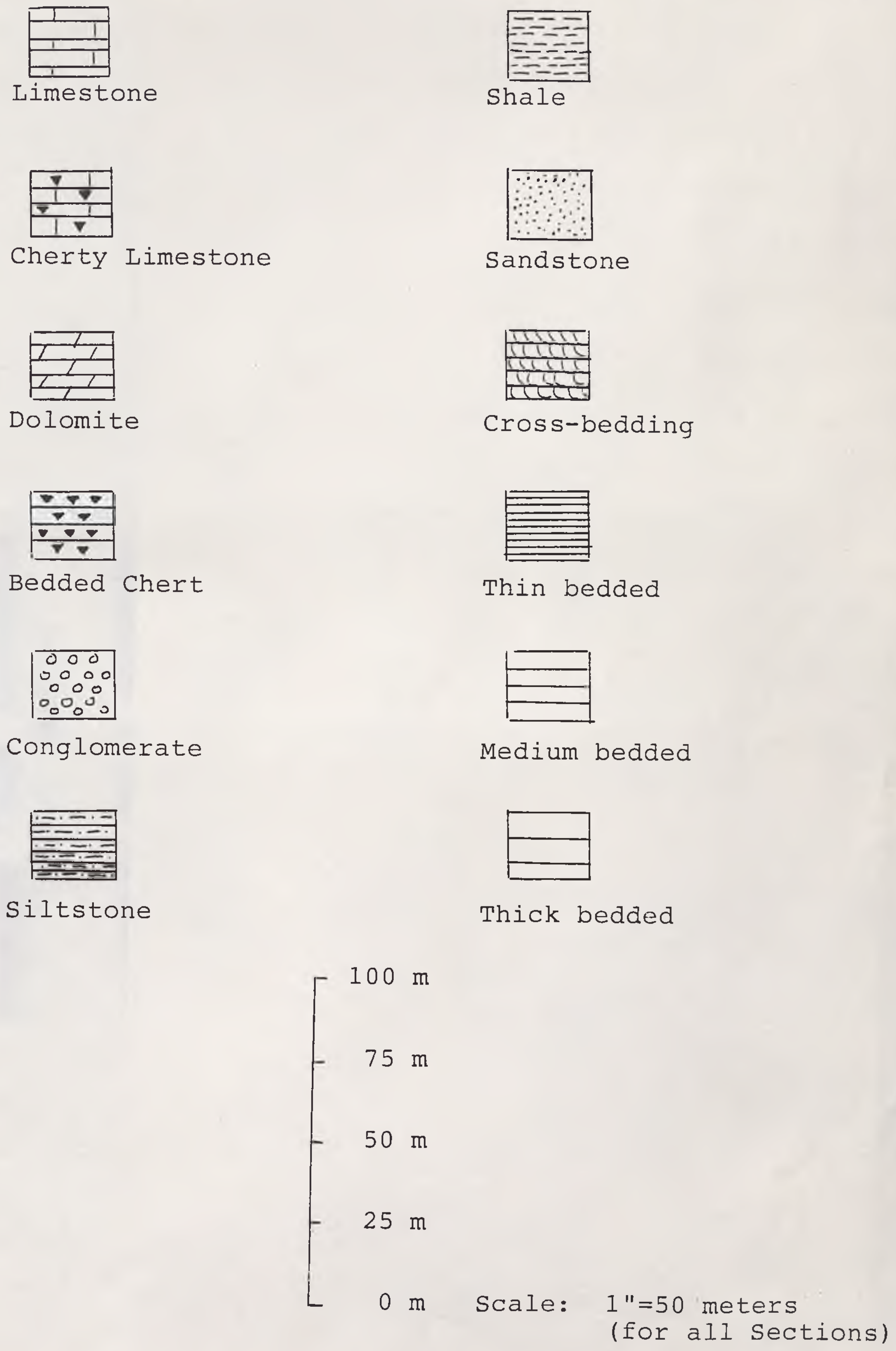
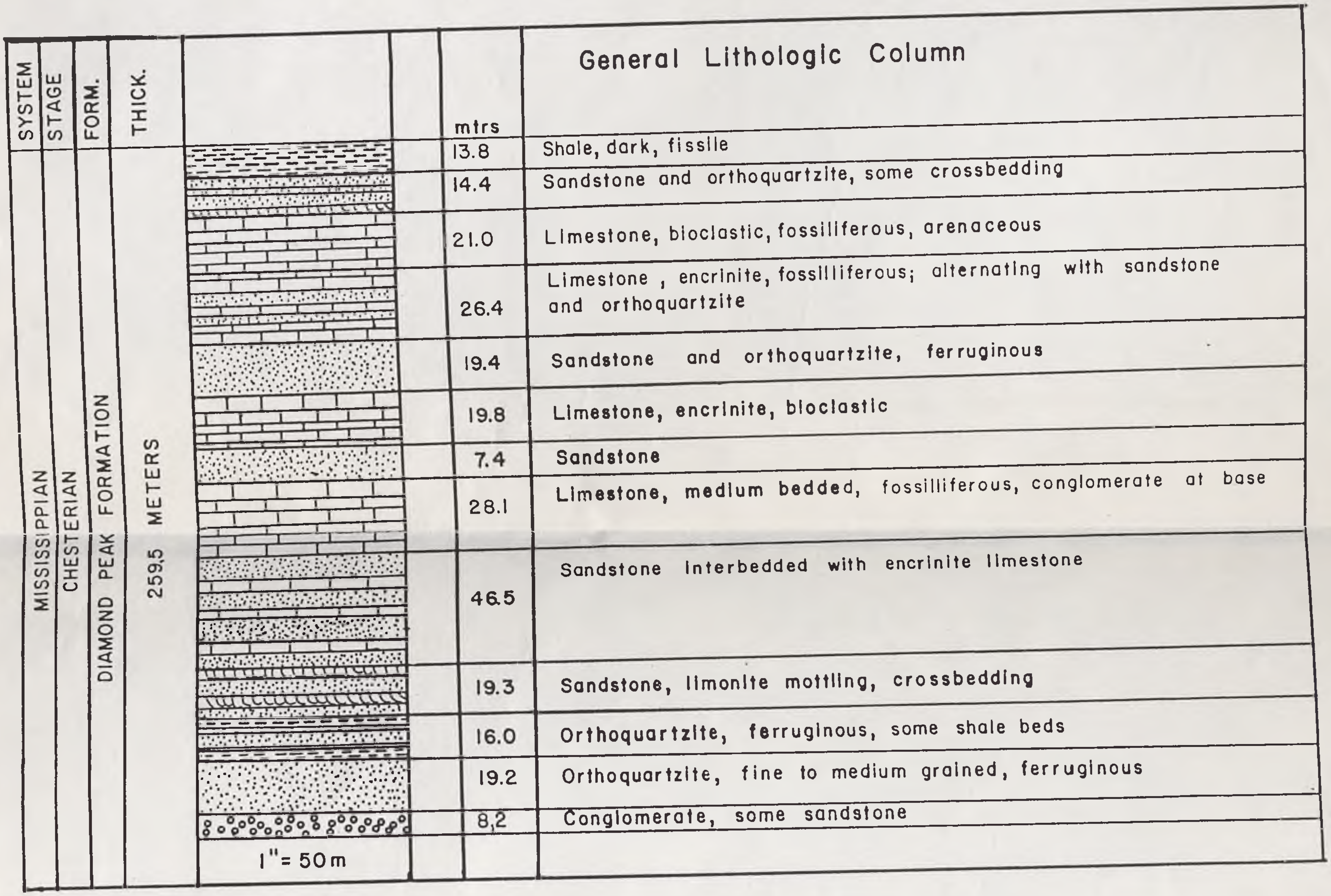


Figure 3: Lithogic Symbols for All Columnar Sections

Section 1
Diamond Peak Formation
(Partial Section)

Northern Butte Mountains
White Pine County
lat 39° 52′N., long 115° 18′ W.



mtrs	General Lithologic Column
13.8	Shale, dark, fissile
14.4	Sandstone and orthoquartzite, some crossbedding
21.0	Limestone, bioclastic, fossiliferous, arenaceous
26.4	Limestone, encrinite, fossilliferous; alternating with sandstone and orthoquartzite
19.4	Sandstone and orthoquartzite, ferruginous
19.8	Limestone, encrinite, bioclastic
7.4	Sandstone
28.1	Limestone, medium bedded, fossilliferous, conglomerate at base
46.5	Sandstone interbedded with encrinite limestone
19.3	Sandstone, limonite mottling, crossbedding
16.0	Orthoquartzite, ferruginous, some shale beds
19.2	Orthoquartzite, fine to medium grained, ferruginous
8.2	Conglomerate, some sandstone

Figure 4: Diamond Peak Formation Columnar Section and General Lithologic Descriptions (detailed descriptions of units in Appendix A, section 1)

A multicolored chert pebble conglomerate is the oldest exposed unit present in the study area. The only exposure of this unit is on the west side of the mapped area (lat. 39* 52.25' N., long. 115* 18'W.). The conglomerate is composed of 1-12 cm pebbles of red, black, green, gray, and white chert (Fig. 5). Conglomerate beds are commonly overlain by structureless sandstone units; however, gradational bedding is present where the author measured the section. Sandstone units are yellowish-gray to yellowish-brown, medium grained, quartz sand and range in thickness from approximately .12 m to 3 m.

The lower quarter (63 m) of the formation is composed entirely of terrigenous clastic rocks. Conglomerates and sandstones are overlain by resistant beds of fine-grained, light to dark brown orthoquartzites. Iron stained orthoquartzites are intermittently interbedded with finely laminated shale beds. Above the quartzite-shale interval, a thick sequence (19 m) of stacked, tabular crossbedded sandstones and associated structureless sandstone beds complete the lower clastic interval of the formation. Tabular crossbedding is enhanced by iron staining (Fig. 6).

Upsection, sandstones are interbedded with fossiliferous limestone units. Sandstone is predominant near the base of this interval at first but is replaced by medium bedded,

Figure 5a: Closeup of the Lowest Conglomerate Unit of the Diamond Peak Formation in the Northern Butte Mountains.

Figure 5b: Closeup of Conglomerate Unit Showing Vari-Colored Vinini Chert Pebbles

Figure 6a: Exposure of Cross-Bedded Sandstones in the Lower Mississippian Diamond Peak Formation

Figure 6b: Closeup of Cross-bedding. Photograph Taken from same Outcrop as Above

fossiliferous limestone units. Pelmatozoan rich carbonates commonly alternate with silty limestone containing well-preserved brachiopods and associated shelly fauna. Dominant limestone types are light gray to yellowish brown, medium bedded, fossiliferous, and commonly contain floating quartz grains.

The dominant limestone interval is overlain by over 7 m of medium bedded sandstone which is in turn overlain by nearly 20 m of medium bedded, skeletal limestone. Upsection, ferruginous, fine-grained sandstone and orthoquartzite totaling a thickness of approximately 20 m is overlain by nearly 50 m of fossiliferous, arenaceous limestone, which is interbedded with light brown, medium-grained sandstone and orthoquartzite. The upper 50 m of sandstone and limestone has a persistent light brown , weathered coloration that tends to make it look like one lithology from a distance.

The uppermost part of the formation is dominated by a sequence of pale brown, medium-grained, medium bedded sandstone and silicified sandstone, which is overlain by dark green to black, slope forming, finely laminated shale. The upper contact of the formation is set off by thick bedded, bluish-gray, cherty limestone of the Ely Limestone.

Depositional Environment

Crossbedded sandstones and shallow marine limestones in the northern Butte Mountains suggest an alternating sequence of fluvial sands, deposited upon a shallow deltaic plane, ultimately grading into shallow water carbonates. Thick sequences of stacked, tabular crossbedded sandstones are interpreted as being dominantly fluvial in origin. Low angle accretion bedding may reflect deposition at point bars by meandering streams migrating across a relatively gentle alluvial plane. Conglomerates are interpreted as being a result of reworked sediments deposited prior to the Antler orogeny.

Limestones contain a diverse indigenous shallow marine fauna dominated by well-preserved brachiopods and pelmatozoans, with corals, pelecypods, and bryozoans also present. The fossils are well preserved and give no indication of major mechanical transport. Because these limestones are interstratified with fluvial clastic rocks, the sequence appears to have been deposited near sea level.

Fauna and Age

The Diamond Peak Formation exhibits a paucity of fauna in the lower 110 meters. This is clearly the result of a greater quantity of coarse clastics in this interval. Above this interval is 50 meters of encrinite, fossiliferous limestone containing a brachiopod fauna including: *Brachythyris* sp., *Chonetes* sp., *Orthotetes keokuk*, *Pertitocardinia* sp., *Spirifer haydenianus* (Girty), *Unispirifer* sp., *Cleiothyridina orbicularis* (McChesney), and *columnal excentricus,* (Fig. 7). Approximately 22 m from the upper contact of the Diamond Peak a well preserved *Belerophon* sp. was extracted from a bedding plane.

The Pennsylvanian-Mississippian boundary occurs in the upper units of the Diamond Peak Formation (Steele, 1960; Sadlick, 1960; Brew, 1971), making the uppermost part of the formation Morrowan age.

Stratigraphic Relations

In east-central Nevada the Diamond Peak Formation occurs in a northeast-southwest trending region defining the eastern limit of the Antler orogenic highland. The formation is thickest near the Antler belt and thins rapidly to the east. The Diamond Peak Formation can easily be recognized and mapped as a discrete formational unit west of the White Pine and Butte Ranges (Hose and Blake, 1976). In areas where the coarse clastics of the Diamond Peak did not extend, the Chainman Shale continued to accumulate (Stewart, 1962). In the Ely area, Spencer (1917) reported that the Pennsylvanian Ely Limestone conformably overlies the Chainman Shale. Hose and Repenning (1959) found the same stratigraphic

Section 1
Diamond Peak Formation
(Partial Section)

Northern Butte Mountains
White Pine County
lat 39° 52′N., long 115° 18′ W.

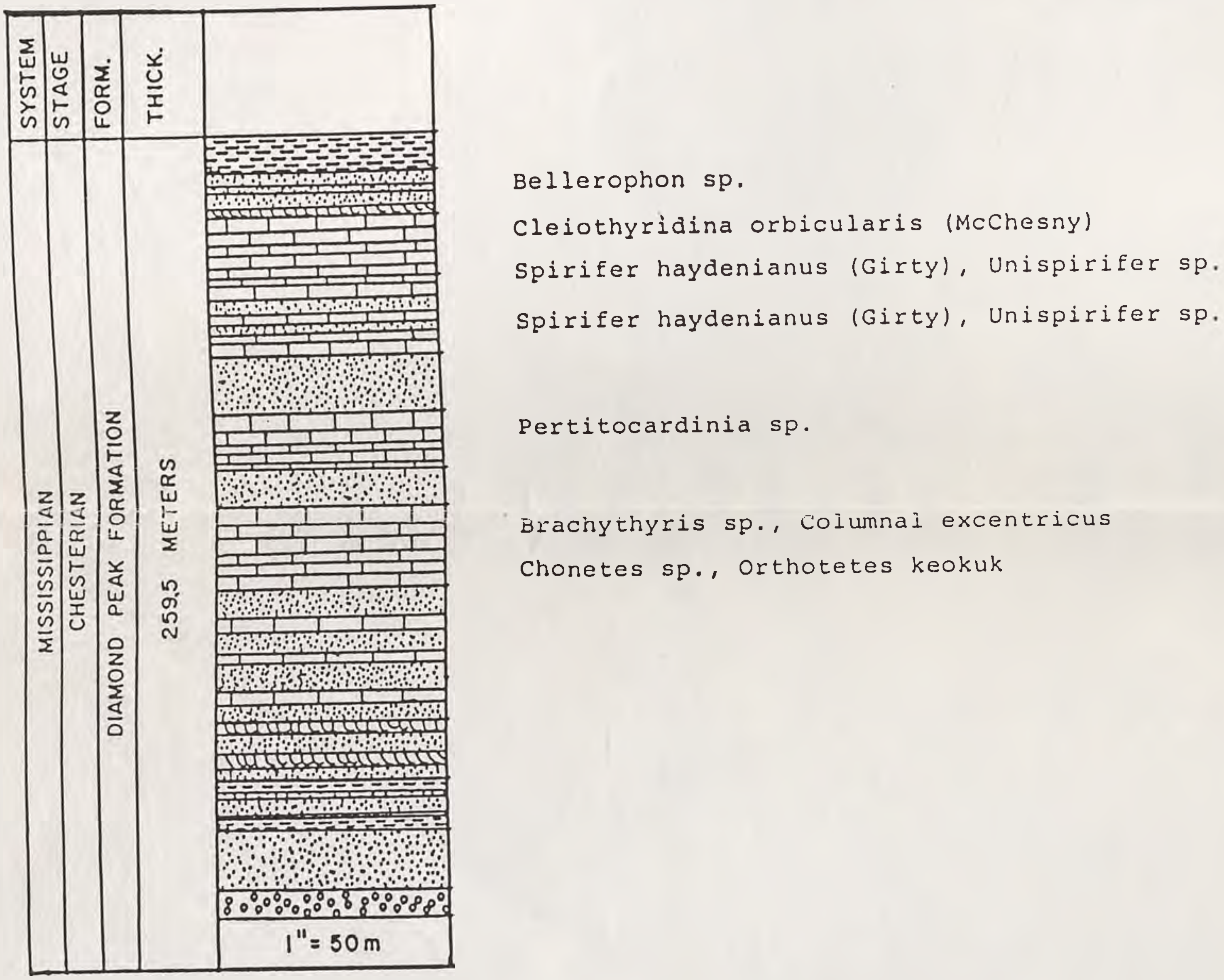


Figure 7: Diamond Peak Columnar Section and Associated Fauna

The lower boundary of the Diamond Peak Formation is not exposed in the Butte Mountains. The upper contact is conformably overlain by the Ely Limestone. The upper contact at the reference locality was chosen at the first massive outcrop of gray, cherty limestone. Similar fauna recognized across the boundary in several other areas give support to a conformable contact (Bissell, 1964).

A maximum thickneass of 1074m (Brew, 1961) on the western side of the Diamond Mountains constitutes its westernmost exposure. Stewart (1962) measured 747 m of the Diamond Peak south of the Diamond Mountains in the northern Pancake Range, where it interfingers with the Chainman Shale. East of the Diamond Mountains, in Buck Mountain, the Diamond Peak thins to 549 m , but may be as thick as 691 m (Rigby, 1960). In the central Butte Mountains, Sides (1966) reported a thickness of 242 m for an incomplete exposure of the Diamond Peak, which is consistent with the thickness described herein in the northern Butte Mountains. The formation thins eastward toward the Cherry Creek Range, where it is believed to have been deposited against a late Mississippian topographic high (Blomquist, 1971).

Stratigraphic and paleontologic features observed in the northern Butte Mountains are consistent with findings made by Wilson and Laule (1979) in adjacent ranges. Thick sequences of stacked, tabular crossbedded sandstone and shallow water fauna in interbedded limestones are present in the northern White Pine Range and Buck Mountain (Ibid). These features correlate with features found in the study area and support the interpretation that the Diamond Peak Formation was deposited in a prograding fluvial-deltaic environment (Harbaugh and Dickinson, 1981).

ELY LIMESTONE

Nomenclature

The Ely Limestone was originally named by Lawson (1906) for thick bedded, "more or less cherty" limestones which crop out in the Robinson mining district, west of Ely, Nevada. Lawson placed the lower boundary of the formation at the top of the White Pine Shale (which he misinterpreted as Devonian age) and placed the upper boundary at the base of the Permian Arcturus Formation. Spencer (1917) redefined the lower boundary by placing the base of the Ely Limestone at the top of the Mississippian Chainman Shale. He retained Lawson's upper boundary. Pennebaker (1932) proposed that the upper boundary of the Ely Limestone be placed at the base of a sequence of "medium and fine-grained sandstone weathering yellow and buff with Indian red patches," which Blanchard (in Pennebaker, 1932) recognized and designated as the Rib Hill Formation. Later, Ehring (1957) noted that the uppermost beds of the Ely Limestone are of Permian age and referred to the Permian rocks as "unnamed limestone." Ehring also noted that the name "Rib Hill" had been applied to Precambrian quartzites in Wisconsin and proposed the name Murry Sandstone for the unit above his Ely Limestone.

Steele (1960) separated the 426.5 m section of Ely Limestone, measured by Pennebaker (1932) at Rib Hill, into a lower 335 m of Atokan-Desmoinesian age cherty limestone, which was overlain disconformably by 92 m of Permian age massive coralline limestone. Steele retained the name Ely Limestone for the lower 335 m, and proposed the name Riepe Spring Limestone be used for the upper 92 m of massive coralline and fusulinid-bearing limestone. He restricted the Ely Limestone to "those limestones lying stratigraphically above the Chainman Shale or Scotty Wash Quartzite, which ever is present, and below the regional Pennsylvanian unconformity." Steele also established a reference section (Sec. 7 and 8, T. 1 N., R. 59 E., White Pine County, Nevada) exposed along U.S. Highway 50 between Illipah Creek and Moorman Ranch, where the Ely Limestone is continuously exposed between the Illipah Sandstone and Riepe Spring Limestone.

Dott (1955) elevated the Ely Limestone to group status in the Elko-Northern Diamond region equating it with his two new formations, the Moleen (older) and the Tomera (younger). Dott noted that southward and eastward the two formations become less distinct and grade into the more homogeneous Ely Limestone. Rigby (1960) evidently found enough evidence in the Buck Mountain-Bald Mountain area, 19 km west of the Butte Mountains, to extend the Moleen and Tomera Formations into east-central Nevada.

Because of the lithologic similarity of the Pennsylvanian Ely Limestone and the Permian Riepe Spring Limestone many authors recognize the Permian limestone section in their reports but combine the two when mapping and reporting thicknesses (Hose and Repenning, 1959; Langenheim and others, 1960; Playford, 1961; Sides, 1966; Hose and Blake, 1976).However, in this paper the Riepe Spring Limestone is described separately from the Ely Limestone and is mapped with the Permian Riepetown Formation. The separation of the Ely and Riepe Spring Formations is important because the unconformity between them represents an important tectonic event.

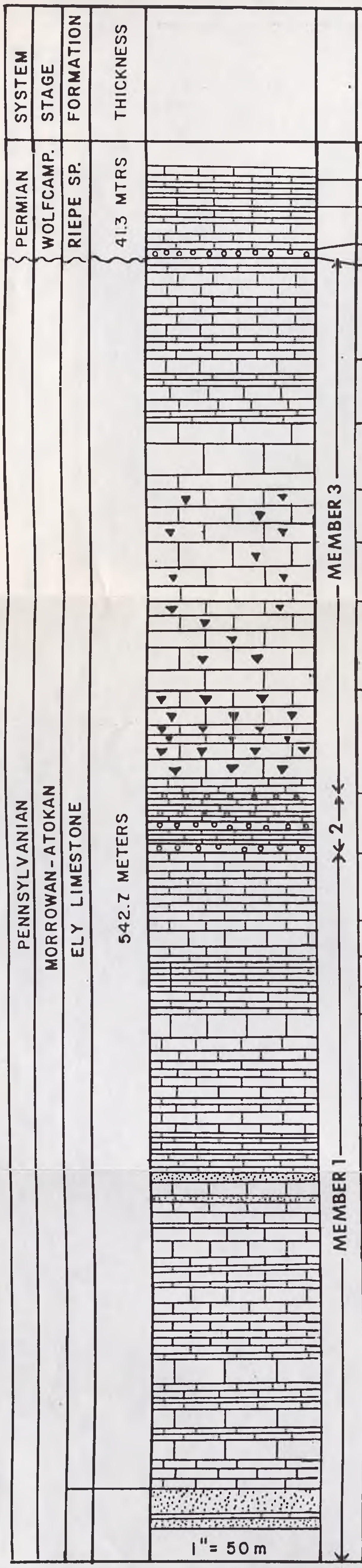
Lithology

In the northern Butte Mountains, the Ely Limestone consists of medium to thick bedded, fossiliferous, somewhat cherty limestone sequences ranging from 5 to 60 meters in thickness. Less common units include coquinoid limestone, conglomerate, calcarenite and calcsiltite. Dominant limestone types are commonly light to medium gray on weathered surfaces and olive gray to dark gray on fresh surfaces. Limestones containing moderate amounts of sand and silt weather light gray to brown and are olive gray on fresh surfaces. Partially silicified limestone units weather dark brown to black and have a striped or banded appearance. Chert, typified by spherical, irregular, and planar forms, is widespread in all sections.

Ely Limestone is well exposed along the western flank of the northern Butte Mountains (Plate I). A continuous section of well-exposed, fossiliferous Ely limestone with an aggregate thickness of 543 m was measured and described in the southwestern part of the study area (lat. 39* 50.25' N., long. 115* 18.25'W.). The contact between the Ely Limestone and the underlying Diamond Peak Formation is conformable and is placed at the base of the first massive limestone bed as one proceeds upsection. At a distance the contact between the Ely Limestone and the Diamond Peak Formation is easily detected by a distinctive color change. The underlying Diamond Peak Formation weathers to an overall yellowish-brown color while the overlying Ely limestones exhibit a more uniform gray to olive gray coloration. The contact indicates a sudden decrease in the influx of terrigenous detritus. The upper contact is placed at a chert-pebble conglomerate containing fusulinids of Wolfcampian age. Three members were recognized at this location and can also be identified throughout the study area.

Member 1 of the Ely Limestone is approximately 276 meters thick (Fig. 8). This member consists of chert-free limestone alternating with impure, resistant limestone beds, that weather to a striped or banded appearance. Less cherty, bioclastic beds usually contain scattered chert nodules and irregularly shaped chert blebs. Diagenic replacement of calcite by silica is exhibited in large, partially silicified, spherical nodules (Fig. 9) that look similar to the surrounding rock and contain the same type of fossil material. In the middle portion of the member the limestones contain quartz and chert sand. The upper portion of the member contains several brachiopod rich horizons. Whole and broken fossil material is associated with finer grained limestone interbedded with inhomogeneous chert layering or irregularly shaped chert nodules. Well-preserved silicified brachiopods weather out along bedding planes (Fig. 10) in the uppermost parts of member 1.

Northern Butte Mountains
White Pine County
lat 39°50'N., long 115° 18'W.



	General Lithologic Column
3.5	Limestone, thin to medium bedded, bioclastic
12.8	Limestone, thin to medium bedded, argillaceous
16.0	Limestone, thin to medium bedded, fossilliferous
3.44	Conglomerate; chert and limestone pebbles
41.1	Limestone, thin to thick bedded, micritic, bioclastic
30.4	Limestone, thin to medium bedded, somewhat cherty
29.2	Limestone, medium to thick bedded, bioclastic, chert clasts
23.5	Limestone, medium to thick bedded, bioclastic, cherty
26.5	Limestone, thick to massive, bioclastic, cherty
41.3	Limestone, thick to massive, cherty
46.5	Limestone, thin to thick beddea, very cherty
26.8	Conglomerate intercalated with argillaceous limestone, lenticular jasperoids
30.9	Limestone, argillaceous, cherty
18.0	Limestone, medium to thick bedded, bioclastic, arenaceous
13.6	Limestone, thin to medium bedded, fossilliferous
10.7	Limestone, thin to medium, 2 brachiopod horizons
35.8	Limestone, thin to thick bedded, fossilliferous, irregular and impure chert
6.0	Limestone, thin to medium bedded, very fossilliferous
20.3	Limestone, thin bedded, arenaceous, argillaceous, fossilliferous
25.5	Limestone, medium bedded, bioclastic; interbedded with coarse grained sandstone
22.0	Limestone, thin to medium bedded, bioclastic, slightly arenaceous, "wackestone"
33.8	Limestone, thin to medium bedded; interbedded with impure case hardened chert horizons
59.0	Limestone, thin alternating to thick bedded, bioclastic
16.0	Sandstone, coarse grained, subrouned to rounded

Figure 8: Pennsylvanian Ely Limestone and Permian Riepe Spring Limestone Columnar Section and General Lithologic Descriptions

Figure 9a: Outcrop of Ely Limestone With Large Spherical Ellipsoid Partially Replaced By Silica

Figure 9b: Closeup of Spheroid in Above Outcrop Demonstrating the Selective Replacement of Whole Brachiopod Surrounded by Limestone Matrix

Figure 10: Photographs of Silicified Spirifers sp. and Composita sp. Weathering Out Along Bedding Planes of Ely Limestone

In several locations selected silica replacement of shelly fauna and carbonate types appear to support Dott's (1958) arguments for secondary diagenic replacement. Dott argued that variable replacement of material by chalcedonic silica, replacement of fossils with respect to their size and impenetrability, and the random replacement of fossils associated with chert nodules clearly indicates a secondary, metasomatic replacement of original calcareous sediment.

Member 2 of the Ely Limestone has approximately 27 meters of chert and limestone pebble conglomerate grading into sandstones and finer grained calcsiltites. Lenticular, silicified (jasperoid) conglomerate beds crop out along the section and occur laterally throughout this zone (Fig. 11).

Member 3 is dominantly medium to thick bedded, light gray, bioclastic limestone which weathers to a rough elephant skin texture, and has an overall cliff forming or step-like topographic profile. The greater percentage of limestone in this member contains either large, spheroidal chert nodules near the tops of beds or smaller, irregularly shaped forms randomly spaced throughout the beds. Lesser quantities of fossiliferous, thin bedded, partially silicified , argillaceous limestone are interbedded with the bioclastic limestone.

Figure 11: Outcrop of Chert and Limestone Pebble Conglomerate in Member 2 of the Ely Limestone

Laboratory examination of polished sections of the dominant carbonate rocks of the Ely Limestone reveals that the commonest limestones contain abundant broken skeletal particles, usually grain bound, and cemented by micrite. Less common carbonate rocks contain varying percentages of ovoid particles (pellets), oolites, limestone intraclasts, and detrital quartz (Appendix B). Particle size is commonly 1 to 3 mm. In some limestone units, fully intact fossils are associated with finer grained skeletal particles and micrite. In member 2 of the Ely Limestone, several beds containing limestone intraclasts are interbedded with skeletal limestones. Skeletal limestones dominate member 3 and are commonly associated with large nodules of replacement chert.

Depositional Environment

The Ely Limestone can be classified as a shallow shelf or platform deposit. As noted earlier, skeletal particles are the most abundant constituents found within the Ely Limestone. Skeletal limestones and micritic-skeletal limestones are similar to the types of carbonate sediments forming today in the Gulf of Batabano on the southwest coast of Cuba (Daetwyler and Kidwell, 1959) and are analagous to shelf carbonates studied by Wilson and Jordan (1983). By analogy, the bioclastic limestones of the Ely Formation are interpreted as shallow water limestones deposited in a shallow shelf sea with water depths of a few tens of meters.

The abrupt transition from skeletal limestone to detrital (intraclast) limestone, observed in member 2, suggests a shallowing of the local area. Periodic exposure and desiccation of intertidal lime muds may have produced limestone and chert intraclasts.

Fauna and Age

Member 1 of the Ely Limestone at the reference locality is extremely fossiliferous. Brachiopods are by far the most abundant fossils, but corals and bryozoa are also found in this interval. Approximately 216 meters from the base, partially silicified brachiopods consisting of Brachythyrina sp. and Composita sp. weather out on the surfaces of limestone beds. These brachiopods have long time ranges making it difficult to associate any specific time interval with the fauna.

Approximately 93 meters above the base of the formation, the first brachiopod fauna was encountered (Fig. 12). The overlying 126 meters contains a rich brachiopod fauna. Brachiopods found in this interval, from bottom to top, include:

Rhipidomella nevadensis (Meek)

Spirifer haydenianus (Girty)

Derbyia crassa

Schuchertella sp.

Punctospirifer sp.

Lissochonetes sp.

Chonetes sp.

Megachonetes sp.

Unispirifer sp.

Crenispirifer reticularia ?

Orthotetes sp.

Dictyoclostus americanus

Antiquatonia sp.

Dictyoclostus sp.

Linoproductus sp.

Neospirifer sp.

Brachythyrina sp.

Buxtonia sp.

Marginifera sp.

Megalinoproductus sp.

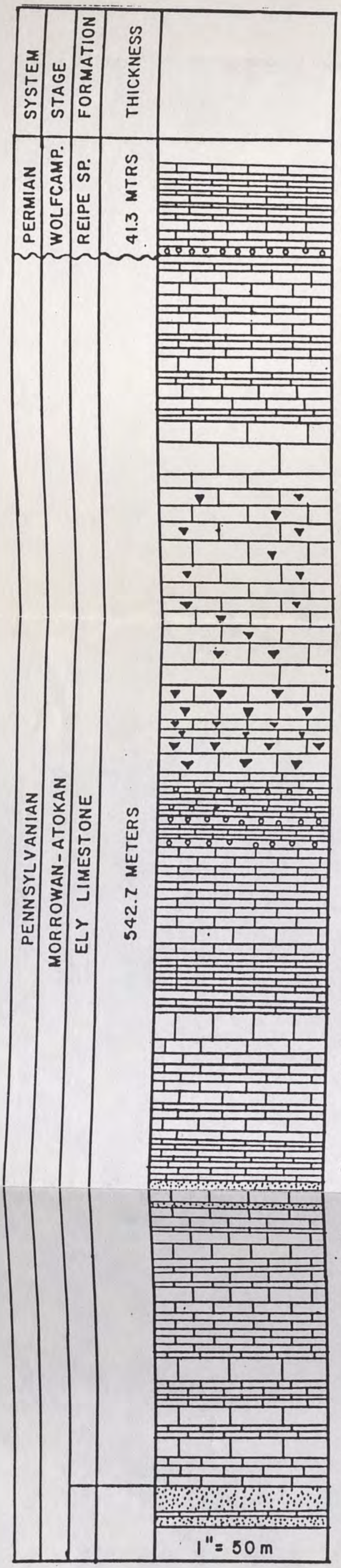
Anthrocospirifer birdspringensis

Composita subtilita

In addition to the brachiopod fauna, bryozoan fragments and rare solitary corals were found about midway through member 1.

Section 3 and 4
Ely Limestone and Riepe Spring Limestone

Northern Butte Mountains
White Pine County
lat 39°50′N., long 115° 18′W.



Neospirifer sp., Fusulinids:
Cleiothyridina sp., Composita sp., Punctospirifer sp.
Cleiothyridina orbicularis, Derbyia sp.?
Bryozoa: Ramose (Sulcoretepora) and reticulate

Composita sp., Bryozoa: ramose

Dictoclostus sp., Composita sp., Archimedes sp.?

Lophophyllidium sp.
Spirifer rockymontanus

Spirifer occiduus?, Chaetetes sp., Bryozoa

Buxtonia sp., Marginifera sp., Megalinoproductus sp., Anthrocospirifer birdspringensis, Composita subtilita
Linoproductus sp., Brachythyrina sp., Neospirifer sp., Unispirifer sp.
Antiquatonia sp., Dictoclostus sp., Unispirifer sp.
Megachonetes sp., Unispirifer sp., Crenispirifer sp., Reticularina sp.?, Dictoclostus americanus, Orthotetes sp., solitary corals

Schuchertella sp., Punctospirifer sp., Lissochonetes sp., Chonetes sp., Bryozoa

Derbyia crassa
Rhipidomella sp., Spirifer haydenianus (Girty)

Figure 12: Pennsylvanian Ely Limestone and Permian Riepe Spring Limestone Columnar Section and Associated Fauna

Steele (1959, 1960) used foraminifera to date the Ely Limestone in a number of areas, including Moorman Ranch, Rib Hill, and the Pequop Range. At these localities the lower boundary is dated upper Morrowan by the presence of Millerella marblensis and Millerella inflecta.

Bissell (1964) measured and made thin sections of units in the Ely Limestone at the reference section established by Steele (1960),at Moorman Ranch. In the upper part of his lower member he found Millerella marblensis and Eoshubertella. Downsection he found Millerella inflecta, Nankinetla sp., with Plectogyra and possibly Paraplectogyra occurring in the basal limestone units. The presence of these foraminifera led Bissell to conclude that the lower 302 m (993 feet) of the Ely Limestone is Morrowan in age.

Coogan (1964) suggested that where fossils are absent, lithology can be used to identify strata. He stated that "distinctive features of the Morrowan....are the sandpaper beds (limestone with coarse quartz sand)." He continued by saying "The stratigraphic interval that contains these beds is greatest in the Moorman Ranch section." Sandpaper beds as described by Brill (1963) occur in member 1 at the reference locality in the northern Butte Mountains. The presence of this distinctive lithologic feature leads the author to believe that the lower limestones of this locality are Morrowan age.

Member 2 at the reference locality lacks fossils. In member 3 fossils are less abundant than in the lower member, corals are dominant. Brachiopods through this interval include:

- Spirifer occiduus (Sadlick)
- Spirifer rockymontanus
- Dictyoclostus sp.
- Composita subtilita (Marcou)

The colonial corals Lophophyllidium sp. and Caninia torquia occur in abundance near the middle and at the top in laterally extensive horizons. The colonial coral Chaetetes sp., which is commonly a significant part of Atokan fauna, occurs midway through the upper member. Fragments of ramose and reticulate bryozoa were also found throughout this member.

The younger age limit of the Ely Limestone varies regionally due to differential erosion during the Humboldt event. Steele (1960) recorded the presence of Middle Atokan Fusulinella accuminata at Moorman Ranch and found Fusulinella iowensis in the northern Butte Mountains suggesting a late Atokan age for upper Ely Limestone. Sides (1966) reported Atokan fauna in the central Butte Mountains and reported that Bissell identified _Profusilinella_ _regia_ Thompson, _P._ _spicata_ Thompson, _Climacammina_ sp., and _Kamic_ in the central Butte Mountains and regarded the upper part of the Ely Limestone as late Atokan. Stevens (1965) supported a Middle Pennsylvanian age for limestones in the Butte Mountains.

Based on the observations made by previous authors and the presence of the colonial coral _Chaetetes_ sp., the author considers the upper limestone units of the Ely Limestone in the northern Butte Mountains to be late Atokan in age.

Stratigraphic Relations

Steele (1960) reported that the Ely Limestone (restricted) could be identified in an area covering approximately 7031 sq. km. This area includes all of White Pine County, and extends north into most of eastern Elko County, and toward the east to Millard County, Utah. Overall,the thickness of the Ely Limestone is fairly consistent throughout White Pine County. The Ely Limestone is thickest in the Egan Range (762 m) and thins to the north and west (Hose and Blake, 1976).

In ranges surrounding the Butte Mountains, the Ely

Limestone shows marked thickness variations (See Plate III and IV). To the east of the Butte Mountains, in the Egan range, Langenheim and others (1960) reported 914 m in the northern part of the range, and Kellogg (1960) reported 917 m in the southern Egan Range, both about twice the thickness in the northern Butte Mountains and surrounding areas. West of the Butte Mountains, in Buck Mountain and Bald Mountain, Rigby (1960) measured 455 m, and to the north, in the Pequop Mountains, Mollazal measured 488 m (1,600 feet). Douglas (1960) measured 610 to 701 m (2,000 to 2,300 feet) of Ely Limestone in the south-central portion of the Butte Mountains. The Summit Springs unit No. 1 well, drilled by Continental and Standard, enountered 730 m (2,394 feet) of gray, dense, finely crystalline limestone with some chert, representing the Ely Limestone (McJannet and Clark, 1960). In the north-central part of the Butte Mountains, Sides (1966) recorded 756 m (2,480 feet) from a composite section using coralline horizons containing <u>Chaetetes</u> sp. corals.

Northeast of the Butte Mountains the Ely Formation interfingers with the Ely Group (Dott, 1955). The two members of the Ely Group include the Moleen and Tomera Formations of the Elko-Eureka area.

During Atokan time, while the study area was emergent, deposition continued to the north in the Pequop Mountains.

Here, Robinson (1961) proposed the name Hogan Formation for thin to medium bedded, silty to sandy and platy limestones, calcareous siltstones, calcareous shale, and argillaceous limestone totaling 76 meters (250 feet) thick. He also reported that the formation is present at Moorman Ranch, south of the study area. The age of the Hogan Formation at the type locality (sec. 34 T. 34 N., R. 65 W.) is middle to late Desmoinesian. Although Bissell (1960) reported the presence of the Hogan Formation in the northern Butte Mountains (T. 25 N., R. 59 E.), the writer did not recognize any rock exposures fitting the description given for the Hogan Formation. Parts of the Riepe Spring Limestone are similar to the description given for the Hogan, but fusulinids in the basal conglomerate clearly indicates that these units are of Permian age.

To recapitulate, the Ely Limestone varies in thickness in east central Nevada. In the study area, the uppermost part of the Ely Limestone is probably of late Atokan age. At Rib Hill, Moorman Ranch, the Gold Hill district, the Confusion Range and Pequop Mountains, the Desmoinesian Hogan Formation is preserved and is overlain unconformably by the Permian Riepe Spring Limestone or Ferguson Mountain Formation (Bissell, 1964). Sedimentation continued through late Pennsylvanian time in the Carlin Canyon area and at Ferguson Mountain, where the Strathearn Formation conformably (?) over the Hogan Formation.

Pennsylvanian Tectonism-Sedimentation

Pennsylvanian time in the eastern Great Basin was one of instability and epeirogenic warping. During the Late Mississippian and Early Pennsylvanian, the Ely basin developed, with its depocenter west of Ely, Nevada, near Ward Mountain (Coogan, 1964). Ward Mountain remained the depocenter until early Atokan time when differential subsidence ceased and deposition was more uniform throughout the basin. The Ely basin was only one depocenter characterizing the eastern Great Basin during Pennsylvanian time; during part of that time it was connected with the Oquirrh Basin to the east by the Gold Hill Accessway (Bissell, 1960), and to the southwest it connected with the Bird Spring Basin (Coogan, 1964). Sediments were provided by elevated areas to the east (Western Utah Highland; Bissell, 1960) and northeast (Northeast Nevada High; Steele, 1960). The Antler orogenic highlands to the west were still active during early Pennsylvanian time and influenced the deposition of the Moleen and Tomera Formations in the Elko area (Dott, 1955).

An extensive unconformity, originally pointed out by Steele (1960, Fig. 13) and subsequently recognized by other authors, developed during the Middle Pennsylvanian and continued until the early Wolfcampian. During this

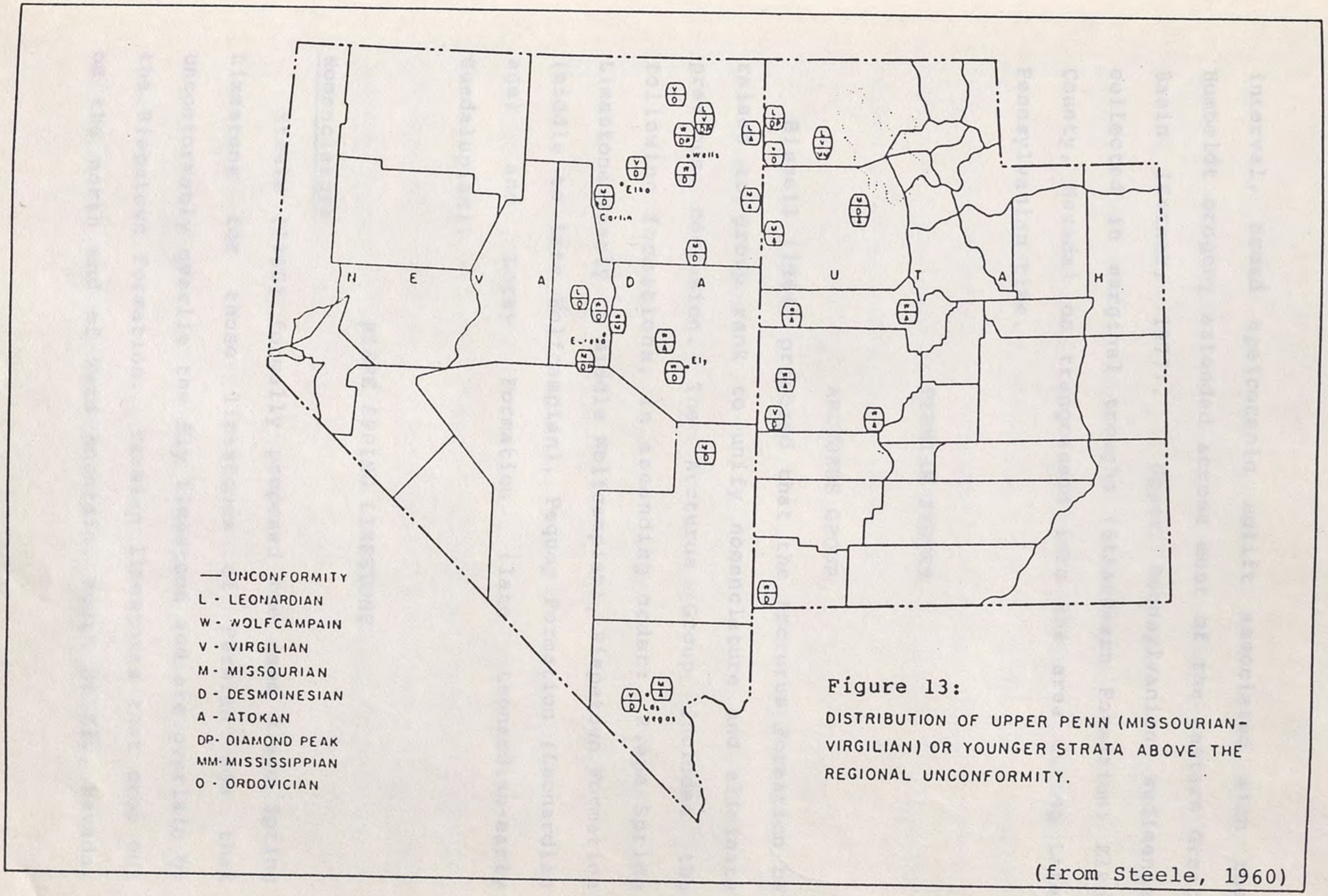


Figure 13:

DISTRIBUTION OF UPPER PENN (MISSOURIAN-VIRGILIAN) OR YOUNGER STRATA ABOVE THE REGIONAL UNCONFORMITY.

(from Steele, 1960)

interval, broad epeirogenic uplift associated with the Humboldt orogeny extended across most of the eastern Great Basin (Ketner, 1977). Upper Pennsylvanian sediments collected in marginal troughs (Strathearn Formation: Elko County, Nevada) or trangressed into the area during Late Pennsylvanian time.

PERMIAN SYSTEM

ARCTURUS GROUP

Bissell (1964) proposed that the Arcturus Formation be raised to group rank to unify nomenclature and eliminate previous confusion. The Arcturus Group includes the following formations, in ascending order: Riepe Spring Limestone (early to middle Wolfcampian), Riepetown Formation (middle to late Wolfcampian), Pequop Formation (Leonardian age) and Loray Formation (late Leonardian-early Guadalupian).

RIEPE SPRING LIMESTONE

Nomenclature

Steele (1960) formally proposed the name Riepe Spring Limestone for those limestones of Permian age that unconformably overlie the Ely Limestone and are overlain by the Riepetown Formation. Permian limestones that crop out on the north end of Ward Mountain, south of Ely, Nevada, were designated the type section. At this location the upper section is well exposed, but the contact with the Ely Limestone is difficult to find. At Rib Hill, south of Ruth, Nevada, the contact between the Riepe Spring Limestone and the Ely Limestone is well exposed in one outcrop and marked by a chert-pebble conglomerate. Its upper contact with the Riepetown Formation is exhibited in a number of different outcrops. The section at Rib Hill is very well exposed and serves as an excellent reference section.

Stevens (1963) isolated the chert-pebble conglomerate as the boundary because of its position within a well dated five foot interval. Beneath the conglomerate are limestones with the early to medial Pennsylvanian brachiopod Anthrocospirifer occiduus. Above the conglomerate are limestones with the Permian fusulinid Oketaella, thus proving the systematic boundary lies within this thin interval. Steele (1960) identified the fusulinids Schwagerina aculeata, Pseudofusulina huecoensis, and Pseudoschwagerina defining the Riepe Spring Limestone as middle Wolfcampian in age.

Lithology

In the northern Butte Mountains the Riepe Spring Limestone is lithologically similar to the older Ely Limestone and the two can easily be confused in areas where the contact is covered. The Riepe Spring Limestone consists predominantly of thin to medium bedded, light gray to light brown, fossiliferous limestone with lesser pelmatozoan packstones near the upper contact (Appendix A and B, Section 4, Fig. 8).

At the reference locality (Plate I, lat. 39* 50.25'N., long. 115* 17.75'W.), the formation is 41 m thick. The lower contact is marked by a white chert and limestone pebble conglomerate approximately .5 meters thick. Subangular to subrounded chert pebbles are encased in a fine grained, light colored, sandy matrix. A sample of the conglomerate from a locality south of the reference section contains fusulinids that date the conglomerate as Wolfcampian age.

Thin bedded micritic-detrital limestone and micrite limestone with skeletal fragments alternate with skeletal limestones in the lower parts of the Riepe Spring Limestone (Appendix B). Partially intact and fully preserved fossils are commonly held in a silty to sandy matrix. Medium bedded, skeletal limestones alternate with thin bedded argillaceous limestones. Skeletal particles consist predominantly of comminuted crinoid columnals. A fossiliferous horizon of ramose bryozoa, Composita sp., and solitary corals occurs 22 meters above the chert pebble conglomerate.

Upsection, clastic constituents of the limestone decrease and skeletal particles increase. The upper limestone units are predominantly thin to medium bedded, light gray to medium gray, skeletal micritic limestone. Skeletal particles are predominantly shell fragments in the lower portion with crinoid fragments increasing in abundance toward the top. Crinoid rich limestone units ranging from 15 to 30 cm thick are interbedded with bioclastic limestones near the top of the formation. Minor amounts of crinoid columnals are associated with skeletal fusulinids near the upper contact.

Depositional Environment

The Riepe Spring Limestone was deposited in a shallow water, marginal marine environment. The occurrence of brachiopods, bryozoans, crinoids and fusulinids indicate a shallow water, relatively stenohaline, low to intermediate energy depositional environment.

The basal chert-pebble conglomerate of the Riepe Spring Limestone is the only significant detrital material found in the section. The chert pebbles were derived from the underlying Ely Limestone.

The lower argillaceous, fossiliferous horizons contain an abundance of bryozoa and Composita sp., suggesting a water depth ranging between 3 and 10 meters, too shallow to sustain growth of corals or crinoid columnals (Stevens, 1963).

Water depth increases in the upper portion of the section. This is indicated by the presence of crinoid columnals and fusulinids. The presence of fusulinids, articulate brachiopods, and crinoid columnals suggests water depth ranging between 20 and 30 meters, associated with a low to intermediate energy environment needed to aerate the water and suspend food (Stevens, 1963).

Deposition during the Wolfcampian can best be examined from Ferguson Mountain toward the south. Sedimentation was apparently unbroken from Pennsylvanian through Permian time in the Ferguson Mountain area (Robinson, 1961), thereby representing an incomplete withdrawal of the Pennsylvanian sea during post Desmoinesian regional uplift.

By middle Wolfcampian, downwarping allowed the sea to spread outward from the Ferguson Mountain depocenter across shallow shelf-like areas to the south. Zabriskie (1970) proposed that crinoid rich facies in the upper beds of the Riepe Spring Limestone spread laterally from the Ferguson Basin upon continued deepening of the sea in this area. The crinoid rich facies gradually extended as far southwest as Moorman Ranch in the central Butte Mountains.

Fauna and Age

Fossils occur throughout the 41 meters of the Riepe Spring Limestone. Fusulinids occur in the lower conglomerate, and also in the upper limestone beds near the contact with the Riepetown Formation.

A one meter thick brachiopod coquina consisting mostly of Neospirifer sp., occurs 36 meters above the basal conglomerate. Fully intact Neospirifer sp. fossils are encased in a micritic to skeletal-micritic matrix.

The following fossils are contained in the Riepe Spring Formation in ascending order:

Fusulinids
Cleiothyridina orbicularis
Derbyia?
Sulcoretepora
Punctospirifer sp.
Composita sp.
Cleiothyridina sp.
Lophophyllidium
Neospirifer sp.

Eoperschwagerina linearis

Pseudofusulina huecoensis

Fusulinids found in the lower part of the Riepe Spring limestone are of middle Wolfcampian age.

Stratigraphic Relations

The Riepe Spring Limestone is widespread and has fairly consistent thickness throughout eastern Nevada and western Utah (Plate III and IV). Steele (1960) reported that the Riepe Spring Limestone is distributed over an area of 20,480 sq. km. (8000 sq. mi.); Bissell (1962) suggested that Steele's approximation was in excess of 5,120 to 7,680 km.sq. (2,000 to 3,000 sq. mi.). Stevens (1963) noted that the Riepe Spring Limestone was present in every section measured from the Confusion Range in western Utah to Dry Mountain in western White Pine County. The Riepe Spring Limestone extends northward into the Butte Mountains and surrounding ranges and as far south as the southern Egan Range. Stevens reported uniform thinning from 147.5 m (487 feet) in the east, to 18.0 m. (60 feet), in the west.

The author measured 41 m of Riepe Spring Limestone in the northern Butte mountains, which is similar to the measurement given by Bissell (56 m) for this area and for the thickness recorded by Sides (1966, secs. 1 and 2, T. 20

N., R. 59 E.) for the Permian limestone section overlying the Ely Limestone in the central Butte Mountains.

At the type section , at the north end of Ward Mountain, SE 1/4 sec. 7, T. 15 N., R. 63 E., White Pine County, Nevada, the formation thickens to 125 m (410 feet).On the north side of Rib Hill, overlooking the Robinson pit of the Ruth mining district, the formation is 91 meters (300 feet) thick.

The Riepe Spring Limestone is predominantly early Wolfcampian in age. Regional submergence followed the Humboldt event and created a platform depocenter bordered on the west by the Humboldt highlands. The importance of the Western Utah highland (to the east) as a source is still debatable and may just have been a submarine welt (Bissell, 1970).

To the northeast of the Riepe Spring platform, sediments continued to accumulate in the Ferguson Basin (Ferguson Mountain Formation). These sediments contain a greater percentage of organic material (Bissell, 1964), suggesting less agitation in this basin than across the Riepe Spring platform. In northwestern Utah, the most negative depression of the miogeocline, the Oquirrh Basin, collected a variety of sandy facies during the Wolfcampian.

RIEPETOWN FORMATION

Nomenclature

The name Riepetown Sandstone was proposed by Steele (1960) for the basal sandstone member of Blanchard's (Blanchard in Pennebaker, 1932) Rib Hill Formation. The lower part of Blanchard's Rib Hill Formation consisted of 335 meters (1100 feet) of "medium and fine grained sandstone weathering yellow and buff with Indian red patches." The type section for the Riepetown coincides with that originally designated for the lower part of the Rib Hill Formation: Rib Hill (NW 1/4 Sec. 21, T. 16 N., R. 62 E.). At the type locality the Riepetown Sandstone is represented by 307 meters (1008 feet) of sandstone as described by Blanchard with interbeds of limestone containing late Wolfcampian fusulinids.

Hose and Repenning (1959) included the Riepetown Sandstone, along with the Riepe Spring Limestone, in the 825 meters (2700 feet) of strata they assigned to the Arcturus Formation in the Confusion Range. Stevens (1963) applied the name Riepetown Formation to very fine-grained sandstones and siltstones in the eastern and southern parts of the Butte Basin, but noted that different stratigraphic names should be employed for rocks in the Confusion Range and at Divide Spring (Sec. 12, T. 18 N., R. 58 E.) that have different lithologic characteristics. Stevens (1965) applied the name Rib Hill lithosome to areas encompassing lithologies similar to Pennebaker's (1932) Rib Hill sandstone. Bissell (1964) agreed with the name Riepetown but proposed that the word "sandstone" be replaced by the word "formation" because "sandstone is not the most characteristic lithic unit at the type locality or in numerous other surface exposures." Sides (1966) applied the name Riepetown Sandstone to a 219 m thickness of limestone and sandstone in the central Butte Mountains.

The author has chosen the name Riepetown Formation for varicolored fine-grained sandstone, siltstone, and interbedded limestone exposed in the northern Butte Mountains. The name Rib Hill Sandstone is inappropriate because of its earlier application to Precambrian quartzite in Wisconsin (Ehring, 1957), and the name Riepetown Sandstone does not fully recognize the other significant lithologies that this section comprises.

Lithology

The Riepetown Formation consists predominantly of medium- to fine-grained, pale yellowish-orange to moderate reddish-orange sandstone and grayish-orange to yellowish-gray calcsiltite, with interbeds of thin to medium bedded, light gray to olive gray, micritic to bioclastic, fossiliferous limestone. The sandstones and siltstones alternate with ledge forming bioclastic and micritic limestone units (Appendix A, Section 5, Fig. 14).

The contact between the underlying Riepe Spring Limestone and the Riepetown Formation is set off sharply by orange to reddish-orange sandstone and siltstone overlying the more subdued grayish tones of the bioclastic limestone (Fig 15). At the reference locality (Plate I, lat. 39* 50.6'N., long. 115* 16.75'-17.25'W.) a fusuline rich bioclastic limestone marks the top of the Riepe Spring Limestone. The upper contact of the Riepetown Formation was placed at the top of highest interval of intercalated sandstone, calcsiltite, and limestone at the base of a fusuline rich limestone.

The most common lithologic unit in the Riepetown Formation is very fine-grained quartz sandstone. Sandstone beds commonly grade into siltstone beds. Sandstones are composed predominantly of well-sorted, quartz sand grains with a hematite or limonite speckling. Weathering of the iron constituents gives the units their orange and red color. Sandstones are predominantly cemented by calcite. Siltstones associated with sandstones often contain minor amounts of detrital quartz.

Section 5
Riepetown Formation

Northern Butte Mountains
White Pine County
lat 39°50.6′N., long 115°17′W.

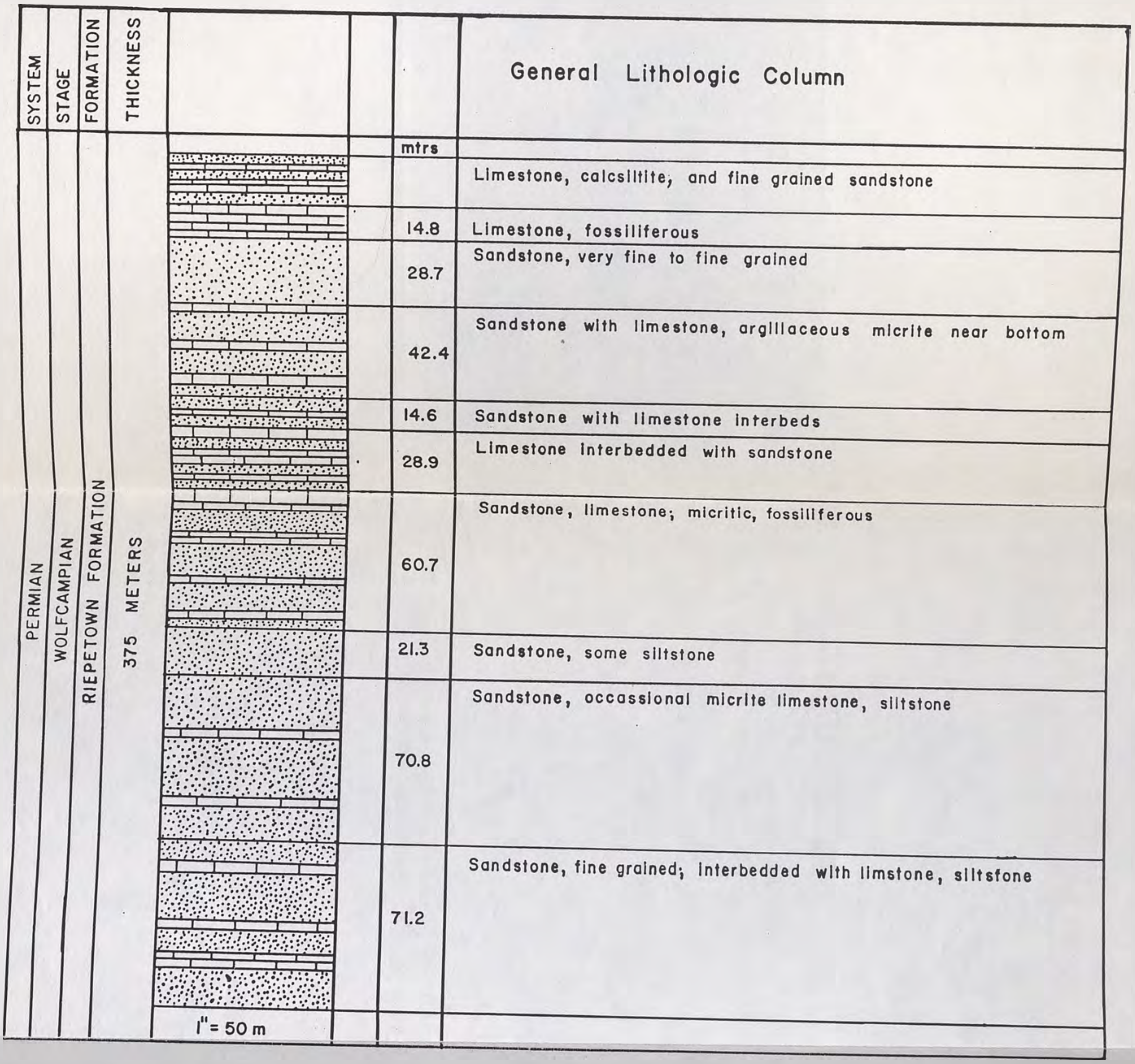


Figure 14: Riepetown Formation Columnar Section and General Lithologic Descriptions

Figure 15: Photograph showing the Contact Between the Younger, Orange-Red Sandstones of the Riepetown Formation and Cliff Forming Limestones of the Riepe Spring limestone

Interbedded with the sandstones and siltstones are a number of different carbonate types. The most common carbonate rock consists of fine grained limestone with varying amounts of skeletal material floating in a micrite cement (Appendix B). These units commonly contain minor amounts of quartz sand. Partial and fully intact fossils are commonly found in a matrix of fine-grained skeletal material and micrite. Ledge forming, crinoid-rich skeletal limestones also occur throughout the section. Broken and abraded crinoid columnals constitute the greater percentage of skeletal particles. Fusulinid tests, broken shells and Bryozoan fragments also occur in the limestone. Crinoid-rich skeletal limestones increase in quantity near the top of the Riepetown Formation.

Depositional Environment

Lithologies comprising the Riepetown Formation indicate an increase in the influx of terrigenous detrital material, from the emergent highlands to the east. Siltstone and fine-grained sandstone were apparently deposited along a broad shallow shelf east of the emergent Deep Creek-Tintic uplift (Stevens, 1979). The presence of crinoid-rich limestone and fusulinids indicate that water depths ranged between 20 and 30 meters (Stevens, 1963). During periods when the supply of clastics decreased, organic detritus collected locally across the shallow platform forming crinoid shoals and bioclastic veneers.

Fauna and Age

Fossils in the Riepetown are fairly limited except for abundant fusulinids associated with interbedded bioclastic limestones and adjacent lithic units. *Crurithyris* sp. occurs sporadically near the bottom and top of the section. Broken crinoid columnals and Bryozoa fragments are common constituents of the bioclastic horizons.

The following fusulinids were found in the Riepetown Formation in ascending order (Fig. 16):

Schwagerina *aculeata* var *plena?*
Schwagerina *elkoensis*
Schwagerina *aculeata*
Schwagerina *wellsensis*
Eoparafusulina *linearis*

At the type locality, Steele (1960) noted the presence of *Schwagerina* *linearis* and *Pseudoschwagerina* aff. *Potexana.* He concluded that these specimens date the lower 91 meters (300 feet) as late Wolfcampian. Although the remaining 213 meters (700 feet) were barren of fossils, he noted that the remaining units are also late Wolfcampian because they are

Section 5
Riepetown Formation

Northern Butte Mountains
White Pine County
lat 39°50.6′N., long 115°17′W.

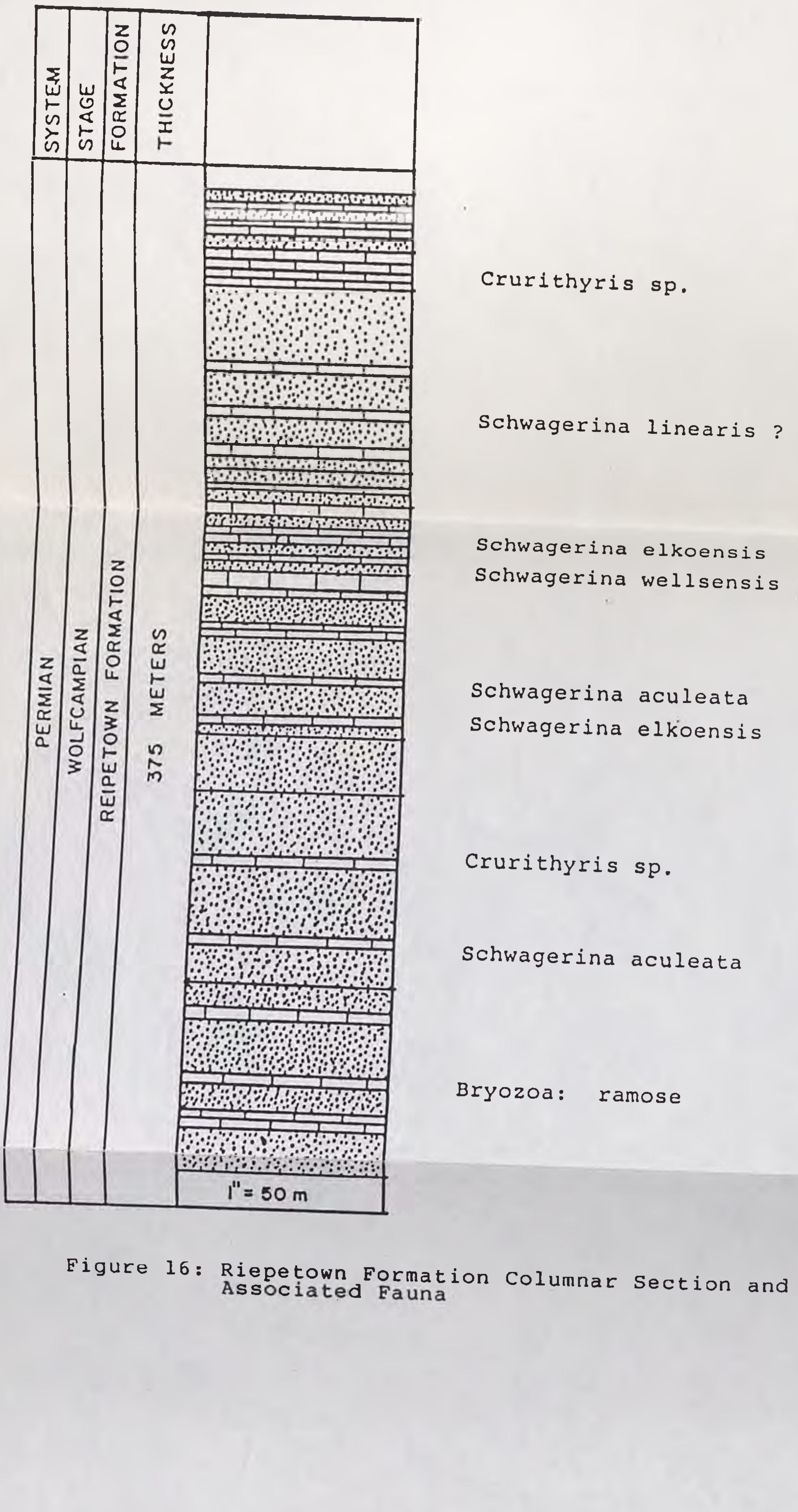


Figure 16: Riepetown Formation Columnar Section and Associated Fauna

overlain by fossiliferous Leonardian Arcturus limestone. Bissell (1964) found Schwagerina wellsensis approximately 28 meters (92 feet) from the base of the type Riepetown, dating it as middle Wolfcampian. At 71.5 m (235 feet) he reported the presence of Pseudoschwagerina sp., aff. P. texana. At Moorman Ranch, Bissell (1964) reported that the lower 53 meters (175 feet) contain middle Wolfcampian fusulinids Schwagerina aculeata and S. elkoensis. His next unit contained Schwagerina aculeata followed by Eoparafusulina linearis 4 meters (135 feet) upsection, suggesting late Wolfcampian age. Cline (1967) found Schwagerina aculeata and Schwagerina elkoensis at Carbon Ridge, which is consistent with what Bissell reported. S. aculeata and S. elkoensis are also present in the Riepetown in the Cherry Creek Mountains, Southern Pequop Mountains, Southern Egan Range and Ward Mountain.

Stevens and others (1979), found that Lower Permian rocks in northeastern Nevada and northwestern Utah can be correlated by twelve distinct fusuline zones. The zone of Eoparafusulina linearis was named for the species originally called Schwagerina linearis by Dunbar and Skinner (1937). This zone occurs in middle to upper Wolfcampian Riepetown from Ferguson Mountain to the Pequop Mountains and south to Carbon Ridge. The author believes that this correlation is also applicable in the northern Butte Mountains and the surrounding ranges. Based on the above information, the Riepetown Formation in the northern Butte Mountains ranges in age from middle to late Wolfcampian.

Stratigraphic Relations

Steele (1960) reported that outcrops of the Riepetown Formation extend over approximately 64000 sq. km. (25000 sq. mi.) in eastern Nevada and western Utah, making it the most widespread Permian formation within the eastern Great Basin.

The thickness of the Riepetown Formation is fairly consistent across White Pine County (Plate III and IV). Thicknesses range from 305 m (Steele,1960 ; Bissell, 1964) at the type locality, Rib Hill (sec. 21, T. 16 N., R. 62 E.), to approximately 360 m (Steele, 1960, Bissell,1964) at Moorman Ranch (T. 17 N., R. 59 E.). To the north in the Pequop Mountains, Elko County, thickness increases to approximately 400 m. The author measured a thickness of 375 m in the northern Butte Mountains which is consistent with thickening to the north.

In the eastern part of White Pine County, the formation consists predominantly of fine-grained sandstone and siltstone with a few beds of limestone. To the west, sandstone and siltstone remain dominant but the percentage of limestone increases, with greater percentages of crinoidal rich limestone (Stevens, 1965).

The Riepetown Formation is correlative with more organic-rich carbonates of the Ferguson Mountain Formation in northeastern Nevada. Tongues of the Riepetown Formation interfinger with the Ferguson Mountain Formation in the southern Goshute Mountains (Zabriskie, 1967). Sediments of the Oquirrh Formation continued to accumulate during middle to late Wolfcampian farther to the northeast in the Oquirrh Basin. To the west in the Diamond Range, carbonates of the Carbon Ridge Formation accumulated throughout the Wolfcampian (Strawson, 1971).

PEQUOP FORMATION

Nomenclature

The Pequop Formation was originally named by Steele (1959) for a thick sequence of thinly-bedded, fusulinid-bearing limestone 2.4 km (1.5 miles) north of Jasper railroad tunnel in the Pequop Range, Sec. 3, T. 33 N., R. 65 E., Elko County, Nevada. The name was presented in an abstract and therefore was not formally designated a new formation until 1960 when it was formally named in the Guidebook to the Geology of East Central Nevada (IAPG-ENGS). Steele (1960) dated the Pequop Formation "by a prolific fusulinid fauna" and assigned it an early Leonardian to early Guadalupian age. Robinson (1961) pointed out that in designating the type section, Steele made two errors: one in locating the type setion accurately and another in measuring the section. Robinson corrected these errors by designating a proper reference section (Sec. 34-35, T. 34 N., R. 65 E., Elko County, Nevada), north of Steele's type section. Robinson's measurement of the Pequop Formation totaled 941 m (3087 feet): 337 m (1,105 feet) is early Leonardian age, and 445 m (1460 feet) is late Leonardian age. Robinson (1961) described the Pequop as thinly bedded and platy, fine to medium-grained, silty and sandy limestone which is interbedded with medium to thick-bedded and locally massive fusulinid coquinite, encrinite, and micritic to bioclastic limestones that form a ledge and bench topography. Bissell (1962) agreed with Robinson's measurements and conclusions of the type locality and extended the usage of the name throughout the Butte Basin.

Bissell (1964) pointed out significant facies changes in the Pequop as it extends from the type locality to the south and southwest. Bissell also noted that the three part subdivision of the Pequop has utility but not necessarily at all localities. In addition, he stated, "some localities contain sections of the Pequop formation which are best left undivided."

Stevens (1965) illustrated the eastward interfingering of the Pequop Formation with the Arcturus Formation.

Lithology

In the northern Butte Mountains, the Pequop Formation consists of thinly bedded, platy, pale yellowish-orange, silty and sandy limestone interbedded with medium to thick bedded, pale yellowish-brown, fusuline rich, micritic to bioclastic and locally oolitic limestone. Bench and bluff forming limestones are interbedded with grayish-orange to pale yellowish-orange, fine-grained, thinly bedded, platy sandstone. Smaller amounts of calcsiltite are also associated with minor sandstone. A thickness of 365 m (1197 feet)was measured by the author at lat. 39* 63.25'N., long. 115* 16.25'W..

The Pequop Formation conformably overlies the Riepetown Formation. The upper portion of the formation grades into the more clastic dominated units of the Loray Formation. The upper contact of the Pequop was placed at the top of the highest fusuline-rich limestone bed about 40 m above a distictive bed of white to mottled gray chert and directly below a thick sequence of sandstone and siltstone containing a distinctive euryhaline fauna. The chert ocurs throughout the mapped area and is very useful as a marker bed for mapping.

The major carbonate type of the Pequop Formation is skeletal limestone. Skeletal particles include whole and fragmented crinoid columnals, large fusulinid tests, brachiopods, bryozoa, pelecypods, and gastropods (Appendix B). Nonskeletal units containing pelloids and oolites also occur in the section. Other carbonate types occurring in the section in lesser amounts include micritic limestone with 1 to 2 mm comminuted skeletal fragments and micrite with fully intact skeletal fossils.

Very fine-grained, quartz sandstone interbeds contain minor amounts of abraded crinoid and skeletal material. Adjacent limestone units usually contain small amounts of fine sand grains.

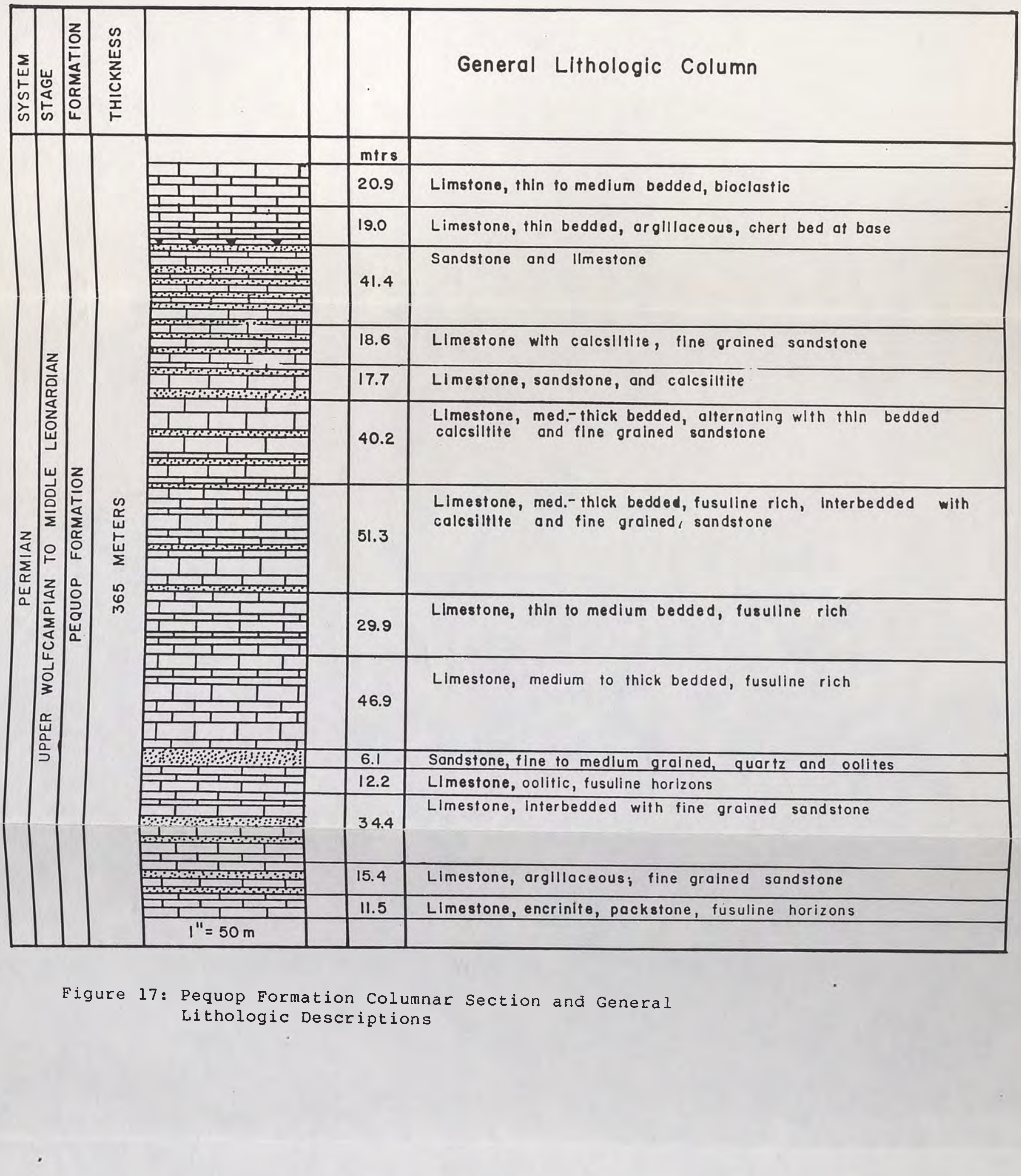
Limestone is the dominant lithology making up approximately 72% of the total thickness. Sandstone represents 19% and siltstones, make up the remainder of the sequence. Clastics rocks are distributed fairly evenly throughout the section. Finer grained lithologies are more dominant toward the top (Appendix B, Section 6, Fig. 17).

Depositional Environment

The Pequop Formation represents a decrease in the influx of terrigenous detritus associated with the submergence of the Deep Creek-Tintic uplift to the east.

Section 6
Pequop Formation

Northern Butte Mountains
White Pine County
lat 39°53.7'N., long 115°17'W.



mtrs	General Lithologic Column
20.9	Limstone, thin to medium bedded, bioclastic
19.0	Limestone, thin bedded, argillaceous, chert bed at base
41.4	Sandstone and limestone
18.6	Limestone with calcsiltite, fine grained sandstone
17.7	Limestone, sandstone, and calcsiltite
40.2	Limestone, med.-thick bedded, alternating with thin bedded calcsiltite and fine grained sandstone
51.3	Limestone, med.-thick bedded, fusuline rich, interbedded with calcsiltite and fine grained, sandstone
29.9	Limestone, thin to medium bedded, fusuline rich
46.9	Limestone, medium to thick bedded, fusuline rich
6.1	Sandstone, fine to medium grained, quartz and oolites
12.2	Limestone, oolitic, fusuline horizons
34.4	Limestone, interbedded with fine grained sandstone
15.4	Limestone, argillaceous; fine grained sandstone
11.5	Limestone, encrinite, packstone, fusuline horizons

Figure 17: Pequop Formation Columnar Section and General Lithologic Descriptions

Skeletal limestone containing an abundance of whole and fragmented skeletal material and large fusulinids closely resembles the Wolfcampian Hueco Limestone in southern New Mexico and west Texas (Wilson and Jordan, 1983). The Hueco Limestone is a good example of middle shelf carbonate sediments deposited along a gently inclined ramp profile across the Orogrande Basin (Jordan and Wilson, 1971).

The different carbonate types in the Pequop Formaton suggest deposition along a broad and open shoal environment. Rounding and abrasion of skeletal grains indicates high energy, shallow water conditions. Normal marine skeletal limestones (skeletal wackestones and packstones) form the bulk of middle shelf sediments. Fossil material including whole and fragmented crinoids, brachiopods, foraminifera (especially fusulinids), bryozoa, pelecypods and gastropods are common constituents of middle shelf carbonates (Wilson and Jordan, 1983).

Upper lithologies indicate shallow water deposition concomitant with an increase of fine terrigenous material. Fusulinids are less common in the upper units and ultimately were extinguished by shallowing water and an increase of terrigenous material.

Fauna and Age

The Pequop Formation contains an abundant fusulinid fauna (Fig. 18). The author sampled the most obvious intervals containing fusulinid coquinas. It is suggested that a more detailed sampling of this formation should be done to correlate more adequately the species in the unit.

Fusulinids extracted from the Pequop Formation in ascending order are:

Schwagerina sp.
Schwagerina modica
Schwagerina youngquisti
Pseudofusulina lativentra
Parafusulina leonardensis
Parafusulina communis
Parafusulina sp.

Steele (1960) dated the Pequop Formation as early Leonardian to early Guadalupian by its prolific fusulinid fauna. Bissell (1964) found an abundance of fusulinids in the Pequop Formation throughout the Butte Mountains. In the Robbers Roost area (Moorman Ranch) he noted the presence of *Parafusulina gracilis, Paraschwagerina* sp., *Schwagerina guembel:* and *Pseudoregularis* sp. in the lower member, which he dated as early Leonardian. In the upper member he

Section 6
Pequop Formation

Northern Butte Mountains
White Pine County
lat 39°53.7'N., long 115°17'W.

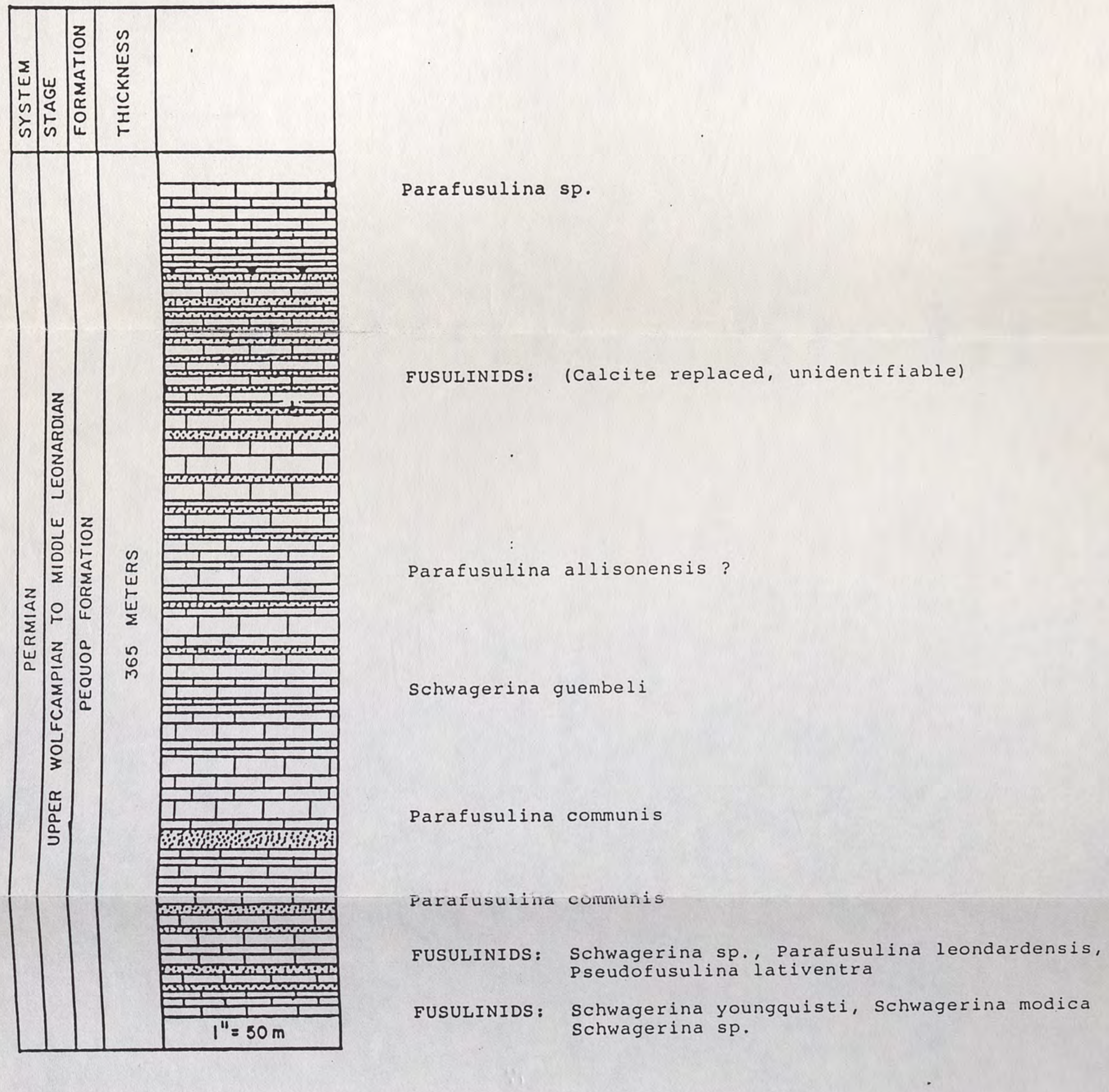


Figure 18: Pequop Formation Columnar Section and Associated Fauna

reported middle Leonardian fusulinids: Parafusulina visseri, Schwagerina moormanensis and early late Leonardian Parafusulina superlata, Skinnerella communis, and Schwagerina subinflata.

Fusulinids found in this study correlate closely with fusulinid assemblage zones proposed by Stevens and others (1979). An early Leonardian to early late Leonardian age is assigned to the Pequop Formation.

Stratigraphic Relations

The deposition of the Pequop Formation in northwestern White Pine County and southern Elko County was coeval with the deposition of the Arcturus Formation in east-central Nevada and western Utah. The Pequop Formation is thickest along the axis of the Ferguson trough and thins to the southwest in the Maverick Springs range and Butte Mountains (Plate IV). Outcrops of the Pequop Formation cover all of western White Pine County. To the southeast, deltaic sediments continued to be deposited in the Confusion Range, where water depths remained shallow and marine fauna is limited to rare occurrences of euryhaline species (Stevens, 1963). Steele (1960) reported that outcrops of the Pequop Formation are distributed over 46080 sq. km. of northeastern Nevada and northwestern Utah.

The Pequop Formation is thickest in the Pequop Mountains (plate III and IV). In the southern Pequop Mountains, Bissell (1964) reported a thickness of 1094 m for the formation, which is consistent with the measurement given by Robinson (1961) for the northern Pequop Mountains. To the southeast, in the Dolly Varden Range, Bissell measured 1163 m (3815 feet) of Pequop, and to the southwest, in the Maverick Springs Range, he gave a thickness of 1345 m for the Pequop Formation. The formation thins to the east, at Ferguson Mountain, and to the south, in the Butte Mountains and Cherry Creek Range. At the northern end of the Cherry Creek Range, the formation is 687 m thick and in the northern Butte Range (Plate I, lat. 39* 53.25'N., long. 115* 16.75'W.), the author measured 365 m of Pequop.

In the southern Butte Mountains, at Moorman Ranch, the Pequop Formation was divided into three members by Steele (1960). The three members aggregate a thickness of approximately 900 m (Bissell, 1962). Brill (1963) measured 1311 m (4300 feet) at this locality (T. 17 N., R. 59 E). Bissell (1964) remeasured Brill's section and reported 1126 m (3695 feet).

To the east of the Butte Mountains, the Pequop Formation thins and interfingers with the Arcturus Formation (Stevens, 1965). The Arcturus Formation is composed of a greater proportion of fine grained terrigenous sedimentary rocks (Stevens, 1965; Hose and Repenning, 1959). The Arcturus Formation interfingers to the north with the Oquirrh Formation in northwestern Utah.

LORAY FORMATION

Nomenclature

Steele (1960) proposed the name Loray Formation for a sequence of "yellow-tan, gypsiferous silts and thin bioclastic limestones" that underlie the Kaibab Limestone in central to eastern White Pine County, most of eastern Elko County, and parts of western Utah. The type area is at the head of the Loray Wash in Sec. 28, T. 38 N., R. 68 E., Elko County, Nevada. Steele did not report a thickness for the type section, but did report that the thickest known section of Loray (754 m) in the eastern Great Basin is in the Butte Mountains (Sec. 27 and 28, T. 21 N., R. 59 E., White Pine County). He reports that at this locality the lithology is "dominantly sand and siltstone which weathers to pale yellowish-orange, very fine to fine grained, and thinly bedded; the limestones and dolomites are yellowish-gray to olive in color, micro to very fine sucrosic and slightly silty."

Brill (1963) reported that "about 2200 feet (670 m) of clastic sediments, evaporitic dolomite, and gypsiferous strata overlie the Pequop" north of Summit Springs in the Butte Mountains. Stevens (1963, 1965) used the name Loray Formation for red and yellow sandstones and molluscan rich limestones in the Illipah quadrangle (Sec. 6, T. 17 N., R. 59 E.). Bissell (1964) commented on the disagreement between authors concerning the status of the Arcturus and the Loray. However, he recognized Steele's Loray Formation, placing it into the Arcturus Group together with the underlying Pequop, Riepetown, and Riepe Spring Formations.

The author has designated as Loray Formation a sequence of pale yellow to reddish-brown, very fine to fine-grained, thinly bedded sandstone interbedded with yellowish-gray calcsiltite and olive- gray, molluscan limestone. The name Loray is more appropriate for this sequence than the name Arcturus because it contains a greater percentage of shallow water red beds than the Arcturus and contains no significant thicknesses of marine limestone.

Lithology

The lower and upper contacts of the Loray Formation are considered to be conformable. The lower contact of the Loray was placed at the top of the highest fusuline bearing limestone of the Pequop Formation, 40 meters above a distinctive bed of white to mottled gray chert. The upper contact is placed at the base of cliff forming bioclastic limestone of the Kaibab Limestone.

From a distance the contact between the Loray and Pequop Formations can be easily detected, as is true with the upper contact of the younger Kaibab Limestone. The ledge and bench forming nature of the predominantly limestone Pequop Formation easily sets it apart from the slope forming, yellow and orange Loray.

The Loray Formation is dominated by fine-grained clastic rock that alternate with thin to medium-bedded, micritic-skeletal limestone. Sandstones are commonly very fine-grained and contain hematite and limonite speckling, which produces a characteristic orange and red coloration. Occasionally, sandstones contain abraded fossil material usually consisting of fragmented mollusca and gastropods. Both sandstones and siltstones contain calcite cement and commonly contain fossils replaced by calcite.

Micritic limestone and micritic-skeletal limestone are second in abundance. Gastropods are commonly associated with thinly bedded carbonates intercalated with finer-grained clastic rocks. Skeletal limestone containing well preserved bryozoa, corals, and brachiopods occur in the lower portion of the measured section (Plate I, lat. 39* 55.25'N., long. 115* 15.5'W.).

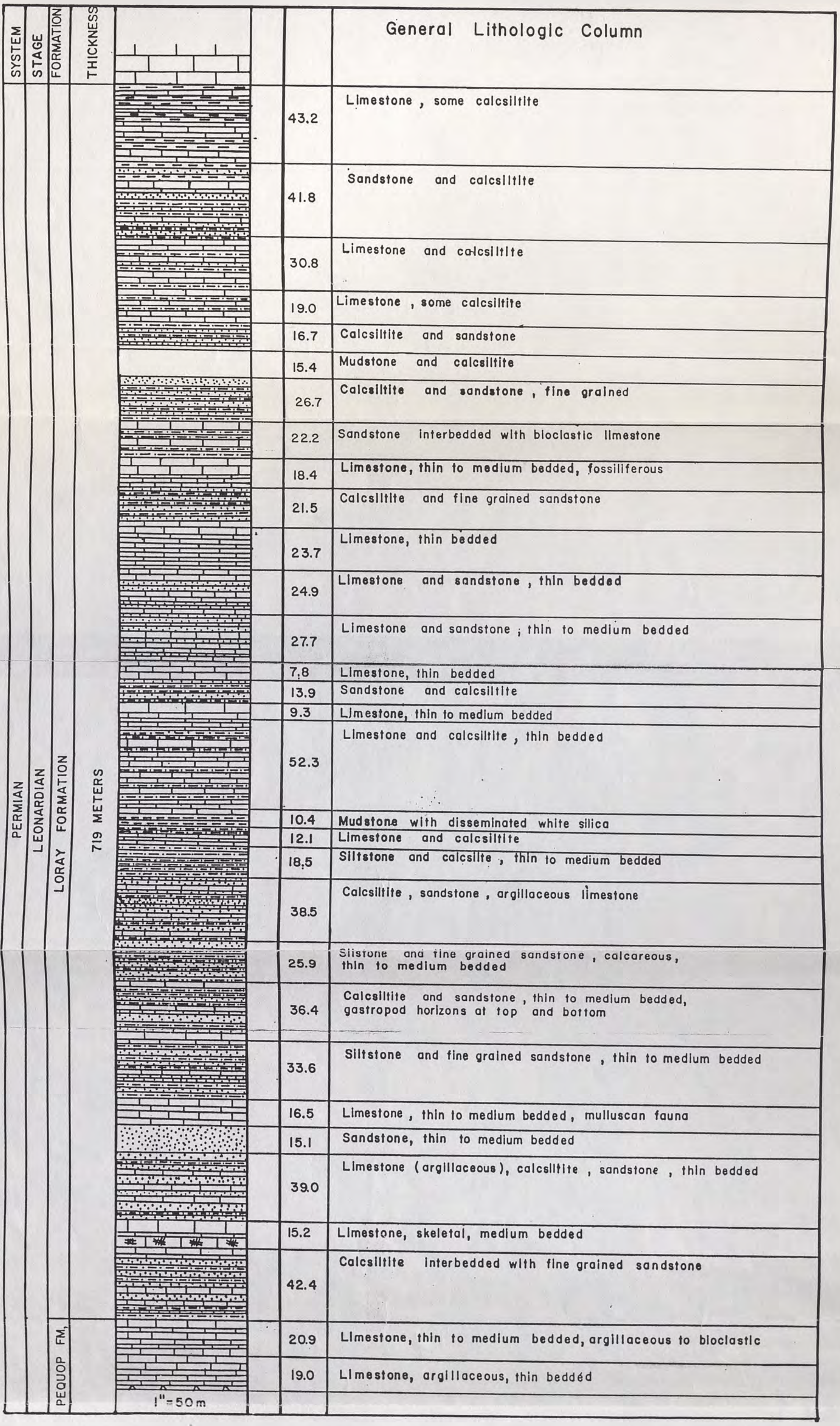
In the upper part of the measured section, fine-grained mudstone contain layers of anhydrite and gypsiferous-anhydrite nodules. In addition, yellowish, gypsiferous soils commonly occur in covered areas. Gypsiferous siltstone and anhydritic claystone are common in the upper third of the section (See Appendix 4, Section 7, Fig. 19).

Depositional Environment

The Loray Formation was deposited in a restricted environment. Evaporites, mudcracks, and animal trails indicate that water depths were very shallow and sediments were deposited in supratidal to intertidal environments. Deposition of the Loray Formation is time equivalent with a eustatic sea level drop recognized by Vail and others (1977). Euryhaline gastropod genera like Bellerophon, Euomphalus, and Euphemites lived in brackish or highly saline water (Stevens, 1963). The Permian pelecypod Nuculana is believed to have lived in similar environments as its modern day ancestor, which lives off the Gulf Coast on muddy bottoms 1 to 50 meters deep in water of variable salinity, on prodelta slopes, and in bays (Parker, 1956 and 1959).

Section 7
Loray Formation

Northern Butte Mountains
White Pine County
lat 39°55.3′N., long 115°15.5′W.



	General Lithologic Column
43.2	Limestone , some calcsiltite
41.8	Sandstone and calcsiltite
30.8	Limestone and calcsiltite
19.0	Limestone , some calcsiltite
16.7	Calcsiltite and sandstone
15.4	Mudstone and calcsiltite
26.7	Calcsiltite and sandstone , fine grained
22.2	Sandstone interbedded with bioclastic limestone
18.4	Limestone, thin to medium bedded, fossiliferous
21.5	Calcsiltite and fine grained sandstone
23.7	Limestone, thin bedded
24.9	Limestone and sandstone , thin bedded
27.7	Limestone and sandstone ; thin to medium bedded
7.8	Limestone, thin bedded
13.9	Sandstone and calcsiltite
9.3	Limestone, thin to medium bedded
52.3	Limestone and calcsiltite , thin bedded
10.4	Mudstone with disseminated white silica
12.1	Limestone and calcsiltite
18.5	Siltstone and calcsilte , thin to medium bedded
38.5	Calcsiltite , sandstone , argillaceous limestone
25.9	Siltstone and fine grained sandstone , calcareous, thin to medium bedded
36.4	Calcsiltite and sandstone , thin to medium bedded, gastropod horizons at top and bottom
33.6	Siltstone and fine grained sandstone , thin to medium bedded
16.5	Limestone , thin to medium bedded , mulluscan fauna
15.1	Sandstone, thin to medium bedded
39.0	Limestone (argillaceous), calcsiltite , sandstone , thin bedded
15.2	Limestone, skeletal, medium bedded
42.4	Calcsiltite interbedded with fine grained sandstone
20.9	Limestone, thin to medium bedded, argillaceous to bioclastic
19.0	Limestone, argillaceous, thin bedded

Figure 19: Loray Formation Columnar section and General Lithologic Descriptions

Fauna and Age

In the northern Butte Mountains the Loray Formation contains an abundant Molluscan fauna. The fauna occur most commonly in thin argillaceous limestone beds or adjacent siltstone. Nuculana sp. and Amphiscapha sp. persist throughout the section. Approximately 263 m from the base of the reference section a laterally extensive horizon of well preserved Plagioglypta sp. occurs. The horizon also crops out in various other parts of the map area and is very useful as a marker horizon.

The following molluscan fossils were collected at the reference locality (Fig. 20):

Dentalium sp.
Nuculana sp.
Myalina sp.
Euphemites vittatus
Amphiscapha sp.
Plagioglypta sp.
Bellerophon crassus
Edmondia sp.

42.4 m from the base of the formation fully intact reticulate bryozoa in a micritic matrix is overlain by

Section 7
Loray Formation

Northern Butte Mountains
White Pine County
lat 39°55.3′N., long 115°15.5′W.

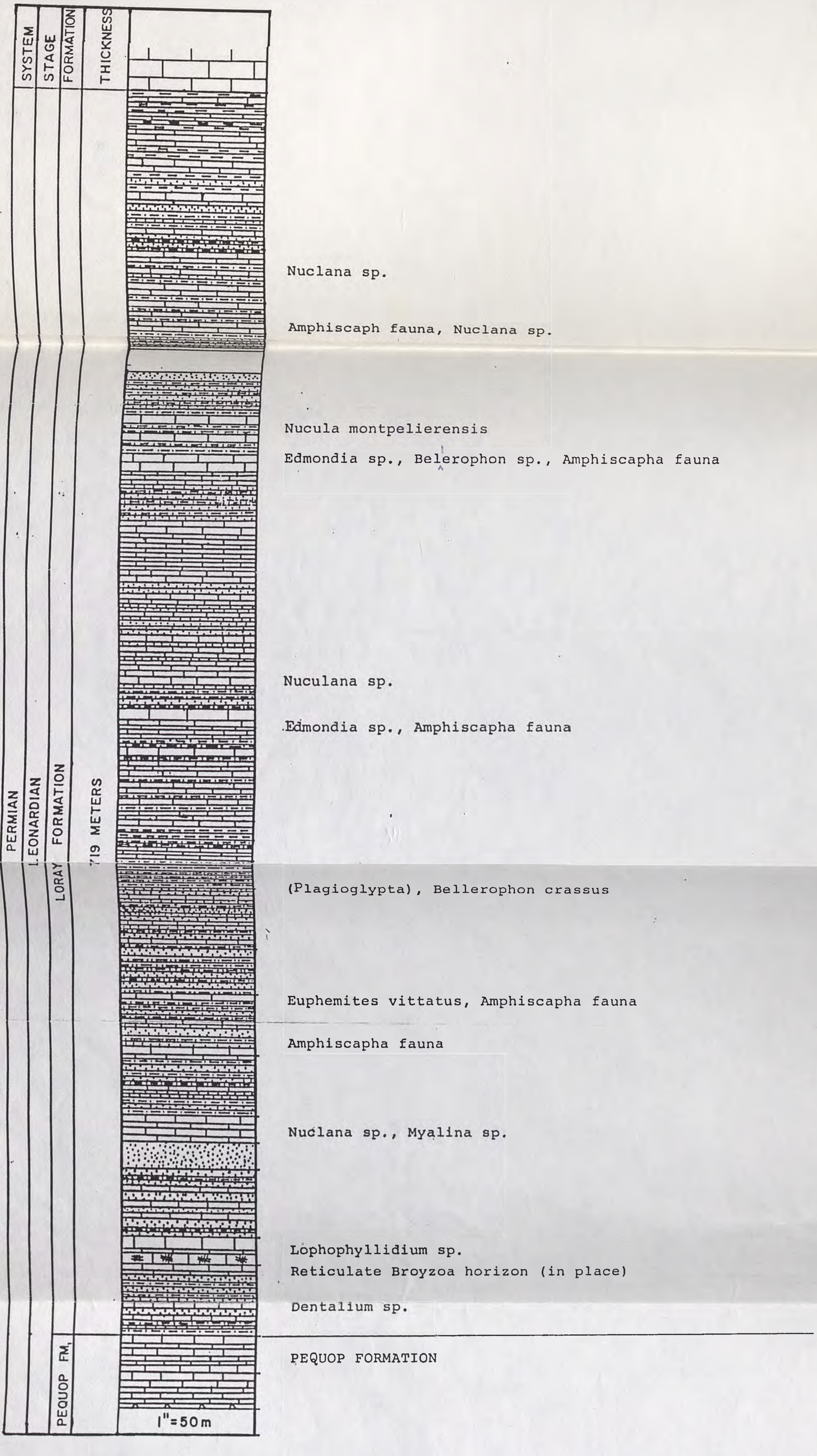


Figure 20: Loray Formation Columnar section and Associated Fauna

coquinoid horizons of brachiopod fragments, solitary corals, and molluscan fauna.

Bissell (1964) studied the Loray Formation at various locations in eastern Nevada and concluded that the Loray is a distinctive lithofacies above the Pequop Formation and beneath the Kaibab Limestone. The Loray was not considered to be a lateral facies of the upper member of the Pequop. With the discovery of diagnostic cephalopods in the Moorman Ranch area, the Loray was determined by Furnish and Glenister (1964, in Bissell) to be late Leonardian to early Guadalupian.

Stratigraphic Relations

The Loray Formation crops out in northwestern White Pine County, eastern Elko County, and westernmost Utah (Steele, 1960). Steele identified the Loray at Ferguson Springs Mountain, Gold Hill, Cherry Creek Mountains, and the Pequop Mountains.

The Loray Formation is thickest in the Butte Mountains, and thins to the north, south, east, and west (Plate IV). Steele (1960) reported that the thickest section of Loray, totaling 754 m, is in the central Butte Mountains (T. 21 N., R. 59 E.). Brill (1963) reported about 670 m of Loray north of Summit Springs , approximately 13 km southeast of the locality measured by Steele. Bissell (1964) measured 590 m (1937 feet) of Loray at the same locality in the Butte Mountains where Steele reported his thickness, but admitted that the contact between the Pequop and Loray was difficult to draw. Stevens (1963) divided the Arcturus Formation into three members within the Butte Mountains. His middle and upper Arcturus members are lateraly equivalent to the Loray Formation and consist of yellow and red sandstone and siltsone and light gray limestone comprising a total thicness of 684 m (2244 feet). Sides (1966) reported a thickness of 773 m (2537 feet) for his upper Arcturus member, which is equivalent to the Loray Formation and consists of yellow, orange and red sandstone interbedded with thin gray to brown-gray limestone.

In the northern Butte Mountains (Plate I, lat. 39* 55.25'N., long. 115* 15.5'W.), the author measured 719 m (2358 feet) of Loray Formation, which is consist with the measurements made by Sides and Stevens for their Arcturus members in the central and southern parts of the Butte Mountains, respectively.

To the northeast of the Butte Mountains, in the northern Cherry Creek Range and southern Pequop Range, the Loray Formation decreases to 457 m and 307 m (Bissell, 1964), respectively. North of the Butte Mountains, the formation thins considerably. Bissell (1963), in his study of the Loray, found only 145 m (476 feet) of Loray in the central Maverick Springs Range and 13.4 m (439 feet) to the north in the Medicine Range.

The Loray Formation is equivalent to the Arcturus Formation in Ely and farther to the east in the Confusion Range (Plate IV). In southern Elko county the Loray formation is believed to intertongue with the Pequop Formation in the northern Cherry Creek Range (Steele, 1960, Bissell, 1970). West of the Butte Mountains, in the Sulphur Springs Range, the upper part of the Garden Valley Formation accumulated during late Leonardian time (Bissell, 1970).

KAIBAB FORMATION

(Lower Formation of the Park City Group)

Nomenclature

Darton (1910) originally introduced the name Kaibab Formation for the upper member of the Aubrey Group in northern Arizona. A type section for the formation was proposed by Noble (1928) in Kaibab Gulch, Utah, 8 miles southwest of the abandoned settlement of Paria, 6 miles north of the Arizona line. The Kaibab is conformably underlain by the Hermit Shale and overlain by the Moenkopi Formation. Newell (1948) recognized the presence of the

Kaibab in the Confusion Range (Millard County, Utah), which was also reported by Hose and Repenning (1959) and included in their Park City Group. Hose and Repenning found that the carbonates in the Confusion Range were distictive enough to divide into three individual formations. In order to depict the gross lithologic characteristics of these formations, as well as their genetic correlations, Hose and Repenning applied the term Park City in a group sense and appropriately named these formations Kaibab Limestone, Plympton Formation, and Gerster Limestone in ascending order. The Park City Group in the Confusion Range is considered a correlative of the Park City Formation in other areas.

Lithology

The contacts for the Kaibab Limestone in the northern Butte Range are conformable. The lower contact forms a distinctive topographic break above the slope forming siltstones of the Loray Formation making it easy to detect in the field as well as on aerial photographs. The upper contact was placed directly below a 2 meter thick bed of white to gray chert marking the base of the Plympton Formation.

The Kaibab Limestone is predominantly thick to massive bedded, light olive-gray to pale yellowish-brown, cliff forming, bioclastic limestone, overlain by medium to thick bedded, white to yellowish-white, medium-grained, calcareous dolomite. Chert nodules are intermittently spaced throughout the section, with dark colored chert dominating the lower bioclastic limestone and white to light gray, larger ellipsoids occurring in the upper dolomite units (Appendix A, Section 8, Fig. 21).

To the north of the reference locality, at lat. 39* 48.5'N.,and long. 115* 15'W., dolomite units are locally highly brecciated and contain large angular clasts outlined by hematite cement. Localized breccias suggest collapse of solution cavities, possibly formed during dolomitization or by fluid transport through more porous dolomites after dolomitization.

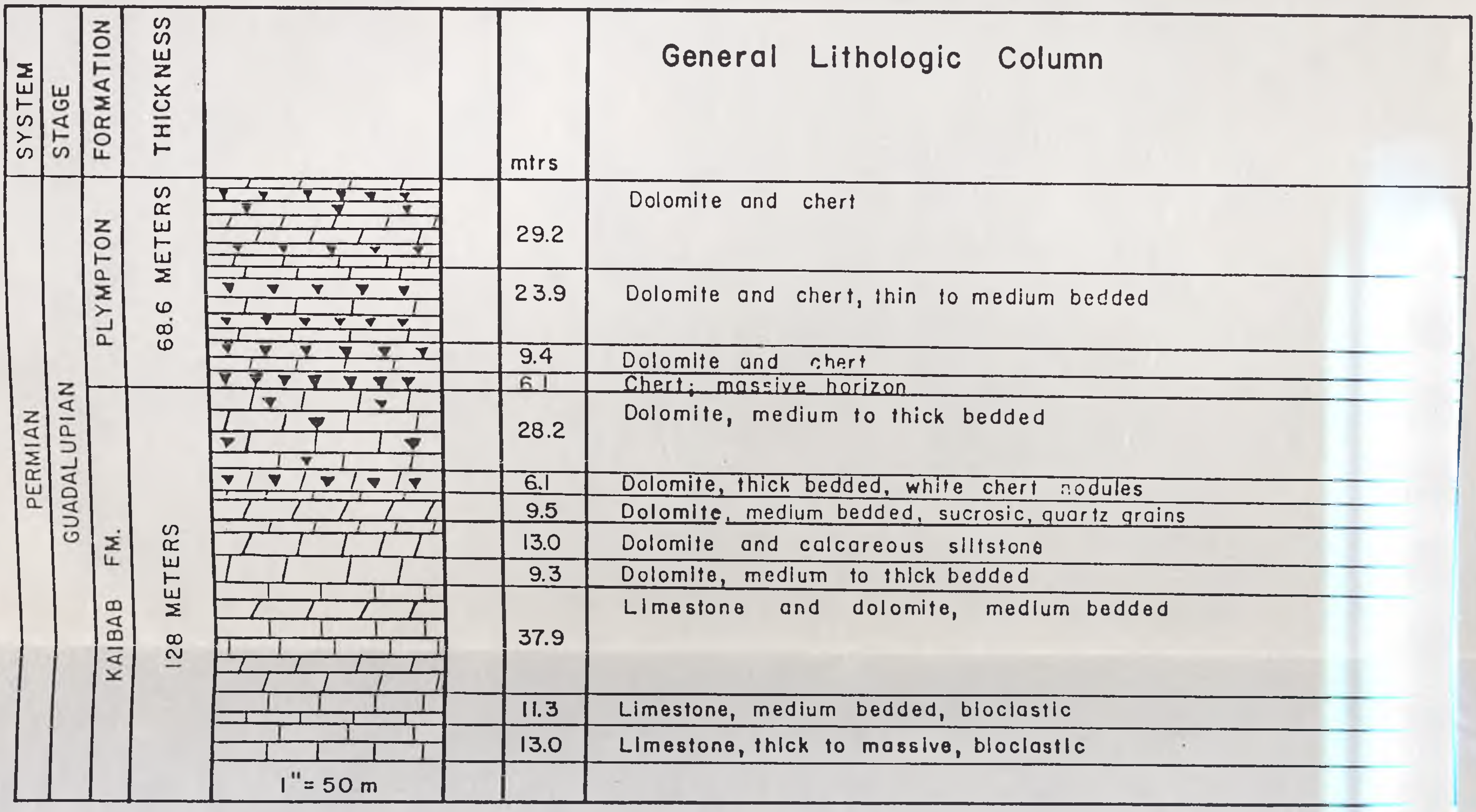
Depositional Environment

Stable marine conditions returned to White Pine County following the shallowing of seas during late Leonardian. Thick bedded, bioclastic limestones of the Kaibab Limestone are representative of middle shelf facies deposited at depths of a few tens of meters (Wilson and Jordan, 1983).

The underlying Loray Formation represents a withdrawal of the sea from the area during late Leonardian and the Kaibab Limestone indicates that an inundation took place

Sections 8 and 9
Kaibab Fm. and Plympton Fm.

Northern Butte Mountains
White Pine County
lat 39°48.3′N., long 115°15.5′W.



SYSTEM	STAGE	FORMATION	THICKNESS	mtrs	General Lithologic Column
PERMIAN	GUADALUPIAN	PLYMPTON	68.6 METERS	29.2	Dolomite and chert
				23.9	Dolomite and chert, thin to medium bedded
				9.4	Dolomite and chert
				6.1	Chert; massive horizon
		KAIBAB FM.	128 METERS	28.2	Dolomite, medium to thick bedded
				6.1	Dolomite, thick bedded, white chert nodules
				9.5	Dolomite, medium bedded, sucrosic, quartz grains
				13.0	Dolomite and calcareous siltstone
				9.3	Dolomite, medium to thick bedded
				37.9	Limestone and dolomite, medium bedded
				11.3	Limestone, medium bedded, bioclastic
				13.0	Limestone, thick to massive, bioclastic

Figure 21: Kaibab Limestone and Plympton Formation Columnar Section and General Lithologic Descriptions

during ensuing trangression of the Kaibab sea to the north.

Fauna and Age

The lower bioclastic limestone of the Kaibab consists predominantly of broken fossil material. Partially exposed shells outlined at the surface are not detailed enough to identify. One productid, *Avonia* sp., was broken loose from its matrix in the basal bioclastic unit. Other productids, *Peniculauris bassi* (McKee), *Squamaria ivesi* (Newberry), and *Rugatia paraindica* (McKee) were found by Sides (1966) in the Kaibab Limestone in the central Butte Mountains.

Steele (1960) regarded the age of the Kaibab Limestone as ranging from early Guadalupian to early-late Guadalupian in southern Utah and Nevada. Hodgkinson (1963) arbitrarily placed the Leonardian-Guadalupian boundary at the base of the Kaibab Limestone. Bissell (1964) assigned the Kaibab Limestone a Guadalupian age because ammonoids found in the underlying Loray Formation were dated as late Leonardian-early Guadalupian.

The scarcity of fossils in the northern Butte Mountains prevents any direct faunal correlation with other areas. The Leonardian-Guadalupian boundary has been arbitrarily placed at the contact between the Loray Formation and the Kaibab Limestone for convenience.

Stratigraphic Relations

The Kaibab Limestone is best known in northern Arizona, southern Utah, and southern Nevada. With the advance of the Kaibab sea during Guadalupian time the Kaibab Limestone was deposited farther north. The Kaibab has been recognized in west-central Utah (Hose and Repenning, 1959), east-central Nevada (Misch, 1960; Bissell, 1962; Sides, 1966), and in northwestern Utah and northeastern Nevada (Berge, 1960; Hodgkinson, 1961).

In White Pine County and adjacent Utah, the thickness of the Kaibab formation is fairly consistent. In west-central Utah (Confusion Range), Hose and Repenning (1959) assigned 146 m (480 feet) of massive limestone and dolomite to the Kaibab Limestone (Plates III and IV). In the northern Confusion Range, Bissell (1962) measured 136 m (445 feet) of thick to massive bedded, micritic to bioclastic limestone and dolomite belonging to the Kaibab Limestone.

At the reference locality (Plate I, lat. 39* 48.3' N., long. 115* 15.5'W.) in the northern Butte Mountains, the author measured 128 m (420 feet) of Kaibab Limestone.

North of the Confusion Range, at Gold Hill, the Kaibab pinches out into the Oquirrh Formation. North of Ferguson Mountain, in eastern Elko County, it thins to 40 m (130 feet) (Bissell, 1964). In the southern Pequop Mountains, Bissell (1964) measured 75 m (245 feet) of Kaibab.

PLYMPTON FORMATION

(Middle Formation of the Park City Group)

Nomenclature

Hose and Repenning (1959) proposed the name Plympton Formation for a sequence of rocks in the Confusion Range that were earlier regarded as Phosphoria by Newell (1948). The name for the formation was derived from a ridge in the Confusion Range where it has extensive areal exposure.

The Plympton Formation is lithologically different from the lower and upper formations of the Park City Group in that it consists predominantly of dolomite and chert, whereas the other formations are predominantly limestone.

Five distinctive lithic zones can be differentiated in the Confusion Range. The basal zone "consists of hackly medium to dark gray bedded chert, that weathers to medium gray, and small amounts of yellowish-gray dolomite in thin lenticular beds" (Hose and Repenning, 1959). Zones two and three are comprosed of yellowish gray dolomite and smaller amounts of nodular and bedded chert.

In the northern Butte Range, a partial sequence of dolomite with bedded and nodular chert and a 2 m thick basal unit of white to light gray chert has been designated by the author as belonging to the Plympton Formation.

Lithology

A partial section of the Plympton Formation, totaling 68.6 meters, was measured in the northern Butte Mountains(Plate I, lat. 39* 48.25'N., long. 115* 15.45'W.). The lower contact of the Plympton Formation is conformable with the underlying Kaibab Limestone. The upper part of the formation is terminated by an east-west trending fault.

The basal 6 meters of Plympton is set off at the bottom from the underlying Kaibab by a 2 meter thick bed of light gray chert. The remaining 4 meters of this unit consist of medium bedded, white to light gray chert and smaller amounts of thin, lenticular, intercalated yellowish-white dolomite.

Succeeding the basal chert unit is 8 meters of chert free, white to light gray, fine to medium-grained crystalline, sucrosic dolomite. Above this unit chert is the predominant lithology. Nodular and irregular forms of chert occur most commonly in the lower 6 meters of the unit, whereas the uppermost 19 meters contains mostly thin to medium bedded light gray chert beds alternating with yellowish white to light gray dolomite.

The uppermost exposed unit is predominantly white to light gray dolomite interbedded with light to medium gray, thin to medium bedded chert (Appendix A,Section 9, Fig. 21).

North of the reference locality dolomite beds contain sparse to abundant, subangular to subrounded, gray to black chert and light gray quartzite pebbles. These units are believed to be upper beds of the Plympton Formation. Due to structural complexities these units could not be correlated with the measured section.

However, in the central Butte Mountains, Sides (1966) reported a chert and quartzite pebble bearing dolomite 73.5 meters (241 feet) above a thick basal chert unit. This suggests that the similar unit in the northern Buttes directly overlies the highest unit measured.

In the drainage adjacent to the pebbly-dolomite, well-rounded, loose cobbles to boulders of Mississippian Diamond Peak conglomerate with Vinini chert pebbles, were observed. The aberrant nature of the clasts was investigated but no unit containing similar size clasts was found in the study area. The nearest exposure of Diamond

Peak conglomerate is approximately 6.7 kilometers to the northwest on the west side of the range at a relatively low elevation. Because these clasts are a long distance from any other possible source, the author believes that they are reworked Tertiary sediments.

Depositional Environment

The Plympton Formation was probably deposited under the same conditions as the Kaibab Limestone. Age of dolomitization is unknown. Bissell (1964) noted that "long-continued dolomitization typified the history of the Plympton Formation; positive and negative relics within some of the carbonates indicate that original sediment contained less magnesium."

Fauna and Age

Fossils in the Plympton Formation are rare and poorly preserved. The only fossil recovered was a dolomitized solitary coral. The specimen was only partially recovered from the rock matrix and was too altered to identify positively. In the central Butte Mountains Sides (1966) collected two specimens of Squamari vesi from float associated with the lower part of the formation. Steele (1960) cited the age of the Plympton as early Guadalupian.

Hodgkinson (1961) noted that the stratigraphic position of the Plympton indicates that it is Guadalupian in age. Brill (1963) also indicated a Guadalupian age for the Plympton. Bissell (1964) gave a middle Guadalupian age for the Plympton based on late Leonardian ammonoids in the Loray Formation and late Guadalupian ammonoids in the overlying Gerster Formation.

Stratigraphic Relations

The Plympton Formation is the middle formation of the Park City Group and conformably overlies the Kaibab Limestone in the study area. The Plympton Formation is distributed throughout White Pine County, eastern Elko County, and western Utah. The formation has been recognized in the Confusion Range, the Gold Hill District, Ferguson Mountains, Pequop Mountains, Cherry Creek Range and the Butte Mountains (Steele, 1960; Hodgkinson, 1961; Bissell, 1962). Bissell (1964) reported thicknesses of the Plympton Formation in the Medicine Range (91 m), Maverick Springs Range (55 m) and the Shell Creek Range (31 m). Steele (1960) reported that known outcrops of the Plympton Formation extend over 23,040 sq. km. (9000 sq. mi.) of eastern Nevada and western Utah.

Hodgkinson (1961) reported that the formation is thickest in the Gold Hill District, aggregating 286 m in thickness; Nolan (1935) did not find a similar thickness for the Plympton. The Plympton thins south to the Confusion Range (Hose and Repenning, 1959), where it is 210 m thick (Plates III and IV) and to the north, in the the Pequop Range, where it is 164 m thick (Hodgkinson, 1961). Southwest of the Pequop Range, the Plympton thins to 93.5 m in the Cherry Creek Range and 83 m in the Medicine Range (Bissell, 1964).

Measurements given for the Butte Mountains vary from 58 m at Robber's Roost (T. 19 N., R. 59 E.) to 133.5 m in the central Buttes, thinning again in the northern Buttes (SE 1/4, T. 23 N., R. 59 E.) to 48 m (Bissell, 1964). Sides (1966) reported 157 m of Plympton at his reference locality in the central Butte Mountains (Sec. 15, T. 20 N., R. 59 E.). In the northern Butte Mountains the author measured an incomplete section of the Plympton Formation totaling 68.6 m.

The Plympton Formation is correlative with the Phosphoria Formation of southeastern Idaho and northeastern Nevada (Hose and Repenning, 1959). Steele (1960) recognized the three formations of the Park City Group in the Cherry Creek Range. He believed that it was here that the Phosphoria Formation interfingered with the Park City Group. Hodgkinson (1961) reported that the lower 67 meters of Plympton in the Pequop Mountains consists of phosphatic bedded chert. A similar phosphatic unit occurs at Gold Hill but is underlain by finely crystalline dolomite of the Plympton Formation (Hodgkinson, 1961). He suggested an intertonguing of the Meade Peak Member of the Phosphoria and Plympton Formation.

PERMIAN TECTONICS-SEDIMENTATION

During Permian time, the eastern Great Basin was part of an intricate network of tectonic uplands, negative basinal depocenters, elongated trough like depressions, positive highlands, platforms, and shelves (Stevens, 1965). Thicknesses and distribution of units indicate that this part of the miogeocline was a downwarped region (Roberts et. al., 1965; Armstrong, 1968; Bissell, 1970) which varied in tectonism in time and place. Rapidly subsiding basins such as the Oquirrh Basin in Utah (5,182 meters thick), Wood River Basin in south-central Idaho (4,480 meters thick) and to a lesser degree the Butte Basin (2,830 meters thick) are characteristic of the Cordilleran miogeocline during the Permian period. The area was separated from the open ocean on the west by the remnant highlands of the Humboldt orogenic belt during the early Permian.

During the late Pennsylvanian, the Ely Basin was epeirogenically uplifted (Bissell, 1962b) so that no Upper Pennsylvanian sediments were deposited. In Early Permian time the Butte Basin began to subside assuming a shape similar to that of the Early to Middle Pennsylvanian Ely Basin (Stevens, 1963). During Permian time the Butte Basin was delineated by the Humboldt highlands to the north and west (Ketner, 1977) and the Deep Creek-Tintic highland to the east (Stevens, 1979). To the south, in southern Nevada, the Bird Spring Basin was separated from the Butte Basin by an oscillating negative which connected the two basins (Bissell, 1970).

In middle Wolfcampian time the Deep Creek-Tintic highland emerged shedding terrigenous clastics into the Butte Basin area. Subsidence of the highland returned eastern Nevada to an open shelf, carbonate depositional environment until the Leonardian. Near the onset of the Leonardian, eustatic sea level drops decreased water depths. Evaporites and intertidal to supratidal sediments collected in the Butte Basin until the end of the Leonardian. Trangression of the Kaibab sea during early Guadalupian restored shelf carbonate deposition to eastern Nevada. Shelf carbonates continued to collect in eastern Nevada until the emergence of eastern Nevada during Early Triassic time.

TERTIARY ROCKS

KALAMAZOO VOLCANICS

In the southeastern part of the northern Butte Mountains, Tertiary volcanic rocks overlie the Plympton Formation. In the southeast corner of the study area (lat. 39* 48.75'N., long. 115* 14.75'W., Plate I), a basal white unit of tuffaceous sandstone, of which only a few feet is exposed, is overlain by approximately 50 m of andesite. The andesite exhibits well-developed columnar jointing, weathers dark brown (Fig. 22), and has a fine-grained ground mass containing approximately 10% plagioclase phenocrysts. This description is consistent with that given by Young (1960) for the lowest member of the Kalamazoo volcanics.

Young (1960) applied the name "Kalamazoo Volcanics" to a thick sequence of volcanic rocks in the Schell Creek Range in White Pine County. This sequence consists mostly of andesitic flows and lesser amounts of tuff and sedimentary rock. The thickness of the sequence ranges from approximately 610 to 1067 meters (200 to 3500 feet). Young believed that the volcanics were contemporaneous with other widespread volcanics of southeastern Nevada and western Utah. A potassium-argon date reported by Winfrey (1958) indicates that volcanic rocks in Sheep Pass Canyon in the

Figure 22: Columnar Jointed Andesite from the Kalamazoo Volcanics

southern Egan Range are approximately 34 m.y. old (early Oligocene), thus suggesting an Eocene-Oligocene age for the contemporaneous Kalamazoo volcanics. Stewart (1980) and Hose and Blake (1976) both reported an age of 43 to 34 m.y. for older volcanic rocks found in White Pine County.

STRUCTURE

General Statement

The northern Butte Mountains lie on the west limb of the Butte structural trough (Armstrong, 1968), or Butte synclinorium . By Late Jurassic time, deformation associated with the Sevier orogeny was well underway within eastern Nevada and western Utah (Ibid). In eastern Nevada, large gentle folds like the Butte and Confusion structural troughs (Hose and Blake, 1976) developed at this time (Armstrong, 1968). Thrust faults in central Utah probably existed at depth in eastern Nevada and never breached the surface. The Butte structural trough and Confusion structural trough are also boundaries of the area affected by Oligocene-Miocene low-angle extensional faulting which encompasses the Egan, Shell Creek, and Snake Ranges (Gans and Miller, 1983). Imbricate low-angle faults and large stratal rotations are the characteristic geometric elements of the mid-Tertiary extensional domain.

In the northern Egan Range and southern Cherry Creek Range, rotation of stratal blocks and rotation of originally high angle faults have exposed upper Precambrian rocks that were as much as 10 km deep prior to the Oligocene, whereas they remain at mid-crustal levels beneath the Butte Mountains (Gans and Miller, 1983). The enormous differential uplift is considered to be a direct consequence of the much greater amount of extension east of the Butte Mountains. According to Gans and Miller (1983) the eastern limb of a broad, open syncline in the central Butte Mountains was rotated to a much steeper, westward dip due to differential uplift of the northern Egan Range with respect to the Butte Mountains.

Structural styles characteristic of mid-Tertiary low-angle faults and extension do not occur in the northern Butte Mountains. Two orders of high-angle faults have been observed in the northern Butte Mountains, first-order north-south trending normal and second-order transverse faults.

The northern Butte Mountains are bound on their west flank by a north-south trending Basin and Range Tertiary normal fault. The overall topographic profile is asymmetric, the west side being steeper than the east.

Methodology

Structures in the northern Butte Mountains were initially examined on black and white 1:24000 aerial photographs ordered from the United States Geological Survey, project VDWL. Prior to entering into the field, linear features were mapped on clear acetate overlays. These features were then examined in the field to determine if they represent faults or fractures. Most of these features are marked by fault related structures such as: slickensides, juxtaposed strata, breccia zones, and discordant bedding attitudes.

Marker horizons were also used to define structural features during the mapping of the northern Butte Mountains. The oldest marker horizon used was the basal chert-pebble conglomerate of the Permian Riepe Spring Limestone. A white chert horizon 1 m thick in the upper part of the Pequop Formation was instrumental in recognizing the repeated section of the Pequop Formation on the eastern side of the northern Butte Mountains (Plate 1). A fossiliferous unit approximately 281 m above the base of the Loray Formation was a third marker unit. This laterally extensive horizon contained a unique species of <u>Plagioplypta</u> sp..

Faults

Faults in the map area are predominantly north-south trending normal faults and east-west transverse faults (Plate I). Faulting is concentrated more on the west flank. North-trending faults on the west side are associated with slickensides on fractures that cut vertically through bedding and dip steeply to the west (Fig. 23). All of the east-west trending faults in the northern Butte Mountains either die out or are terminated by north-south trending faults.

The major fault in the study area is the range front fault bounding the western side of the mountain (Plate I). The fault follows an approximate north-south sinuous trace. The minimum vertical displacement on the fault is approximately 2500 m, the thickness of the Paleozoic rocks exposed in the northern Butte Mountains. In the southwest portion of the map area, the range front fault is transected by an east-west transverse fault, which is in turn terminated by a younger fault to the west. The younger fault parallels the range front fault and is outlined by a fault scarp in the southwestern portion of the study area. This feature can clearly be defined on aerial photographs. In the northwest corner of the study area, aerial photographs

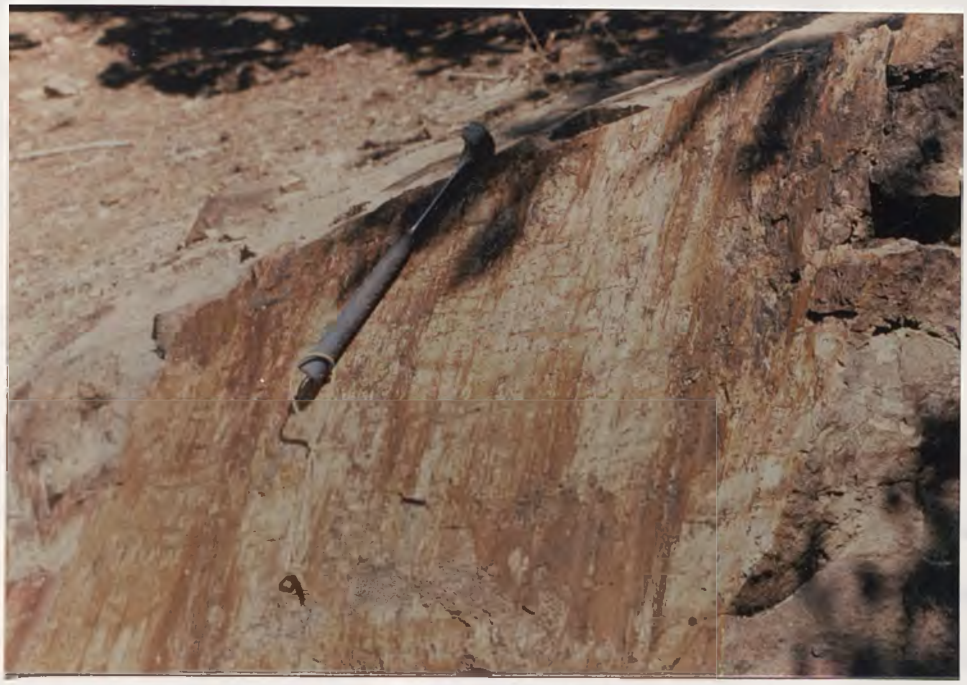


Figure 23: Outcrops of Diamond Peak Quartzite Exhibiting Slickensides on Fault Surface (Sec. 22, T. 23 N., R. 59 E.)

show that the range front fault is offset by a northwest trending fault.

The next obvious feature is a northeast trending fault in the north-central portion of the map area. This fault is clearly defined on aerial photographs . Steeply plunging slickensides and discordant strata occur along the zone at latitude 39* 52.5'N and longitude 115* 17.25'W.

At latitude 39* 51.25'N and longitude 115* 18.5'W the basal conglomerate of the Riepe Spring Limestone is juxtaposed with the lower part of the Diamond Peak Formation to the east. Slickensides on the Ely limestone to the west and Diamond Peak orthoquartzite to the east plunge between 50 and 60 degrees to the west. Minimum displacement on this fault is 543 meters, the thickness of the Ely Limestone.

A low angle normal fault within the Ely Limestone at latitude 39* 50.75'N and longitude 115* 17.6'W places sandy limestone beds that strike north-northeast and dip between 35 and 39 degrees north-west in contact with bioclastic limestone that strikes in the same direction but dips 42 degrees to the southeast (Fig. 24).

On the east side of the map area at latitude 39* 52.5'N.

Figure 24: Fault contact Between Opposite Dipping Beds in the Ely Limestone. Underlying Beds Dip to the Southeast; Overlying Limestone Beds Dip to the Northwest

Figure 24: Fault contact Between Opposite Dipping Beds in the Ely Limestone. Underlying Beds Dip to the Southeast; Overlying Limestone Beds Dip to the Northwest

and longitude 115* 15'W., a distinctive marker horizon of grayish- white chert was mapped. The very same horizon was mapped to the west at latitude 39* 53.25'N. and longitude 115* 16'W. Repetition of this marker bed gives support to a normal, north-trending fault, where the western exposure was downfaulted with relation to the eastern. This fault was originally observed on aerial photographs. This feature continues northward until it is terminated by the more distinctive northeast trending fault.

Unconformities

Two unconformities were recognized in the northern Butte Mountains: a disconformity within the Ely Limestone which places Wolfcampian Riepe Spring Limestone in contact with Atokan Ely Limestone; and an angular unconformity between the Permian Plympton Formation and Tertiary Kalamazoo Volcanics. The disconformity between the Pennsylvanian Ely Limestone and the Riepe Spring Limestone is marked by an 0.5 meter thick chert-pebble conglomerate containing Wolfcampian fusulinids. In areas where the conglomerate is not exposed the unconformity is difficult to define. The Atokan-Wolfcampian unconformity can be observed at latitude 39* 50.25'N. and longitude 115* 17.75'W. and latitude 39* 52'N. and longitude 115* 17'W..

The angular unconformity between the Plympton Formation and the Kalamazoo volcanics is exposed in the southeast corner of the map area at latitude 39* 48'N. and longitude 115* 15'W..

Folds

In contrast to the central Butte Mountains, the northern Butte Mountains contain few folds. Structural features believed to be related to folding were observed in two locations, latitude 39* 50.25'N. and longitude 115* 18.25'W. and latitude 39* 50.5'N. and longitude 115* 18'W.. At the first location, divergent dips on the north side of the canyon define a broad, open, symmetric, upright, anticlinal fold plunging to the southeast and trending northwest (Fig. 25).

On the northern ridge, adjacent the canyon, a fold which appears to be associated with the low angle fault 100 m to the west, consists of a highly fractured, competent limestone bed above a highly contorted shale lamination (Fig. 26).

Interpretation

North-south faults mapped in the northern Butte

Figure 25: Open, Symmetric, Anticlinal Fold in Ely Limestone
Plunging in the Direction of the Reader
(Plunging South)

Figure 25: Open, Symmetric, Anticlinal Fold in Ely Limestone
Plunging in the Direction of the Reader
(Plunging South)

Figure 26a: Outcrop Exhibiting Fold Produce by Movement of more Competent Limestone Bed over Less Competent Shale Bed

Figure 26b: Contorted Shale Laminations Beneath Limestone Bed

Mountains all are high-angle normal faults that dip steeply to the west. East-west faults commonly cut north-south faults and are inferred to be steeply dipping from their relation to topography (Plate II). Displacement is greatest along the rangefront fault flanking the west side of the map area.

Folds noted above may be related to minor low angle faulting or bedding plane faults. East of the Butte Mountains, several authors support low angle denudation caused by late Cenozoic extension (Armstrong, 1972; Gans and Miller, 1983).

Structural features mapped in the northern Butte Mountains are thought to be associated with Tertiary extension.

DEPOSITIONAL HISTORY OF THE NORTHERN BUTTE MOUNTAINS

The northern Butte Mountains contain eight Paleozoic formations that reflect the changes in the depositional environment caused by fluctuations in the influx of terrigenous detritus from source areas, differential subsidence within the miogeocline, and global fluctuations in sea level.

During Mississippian time the Antler orogenic highland in central Nevada shed large amounts of terrigenous detritus into its eastern foreland basin producing progradational deltaic deposits represented by the Diamond Peak Formation (Wilson and Laule, 1979). Clastic sediments of the Diamond Peak were apparently funneled between two subsea topographic highs, the Ely high, north of Ely, and the Currant high, in northeastern Nye County (Blomquist, 1971). The Diamond Peak has a maximum thickness of 1074 m on the western side of the Diamond Mountains at its westernmost exposure, and thins from this location to the southeast. In the northern Butte Mountains, exposed thickness of the Diamond Peak is 259 m. Crossbedded sandstones and shallow marine limestones in the northern Butte Mountains suggest an alternating sequence of fluvial sands, deposited upon a shallow deltaic plain, ultimately grading into shallow water carbonates.

By Early Pennsylvanian time the Antler orogenic belt had been reduced to a chain of low islands (Dott, 1955). The decrease in the supply of clastic sediment led to the deposition of limestone in eastern Nevada. The relatively uniform thickness of the Pennsylvanian Ely Limestone throughout White Pine County (Plate IV) indicates that an areally extensive carbonate platform developed. Chert and limestone pebble conglomerates within the Ely within the northern Butte Mountains and to the north in Elko County indicate periods of unrest and local uplift during the Early

Pennsylvanian. Such clastic detritus in the Ely can possibly be linked to vertical displacement during the time of deposition (Stevens, 1979) along an east-trending, crustal flaw, known as the Wells fault, which trends southeast from northwest of Wells, Nevada, through Wendover, Utah to Delta (Thorman and Ketner, 1979). As noted, the Ely has relatively constant thickness in White Pine County and southern Elko County, thins dramatically in the vicinity of the Wells fault, and is absent farther north in areas such as the Leach Range, Nevada (LeCompte, 1978). According to Ketner (1977), deposition of the Ely Limestone continued into Middle Pennsylvanian time in a tranquil sea, broken by small, sparse insular remnants of the Antler orogenic belt.

In late Middle Pennsylvanian time, uplifts in the Antler belt created a barrier between the open ocean to the west and shelf sedimentation to the east (Ketner, 1977). In addition, most of eastern Nevada was emergent by late Pennsylvanian time. This event was referred to as the Humboldt orogeny by Ketner (1977). In the northern Butte Mountains this event is represented by a disconformity between the Ely Limestone and the Riepe Spring Limestone.

Marcantel (1975) and Stevens (1979) have shown that truncated Pennsylvanian rocks in the region of the Oquirrh-Uinta uplift (Fig. 27), north of Wendover, Utah,

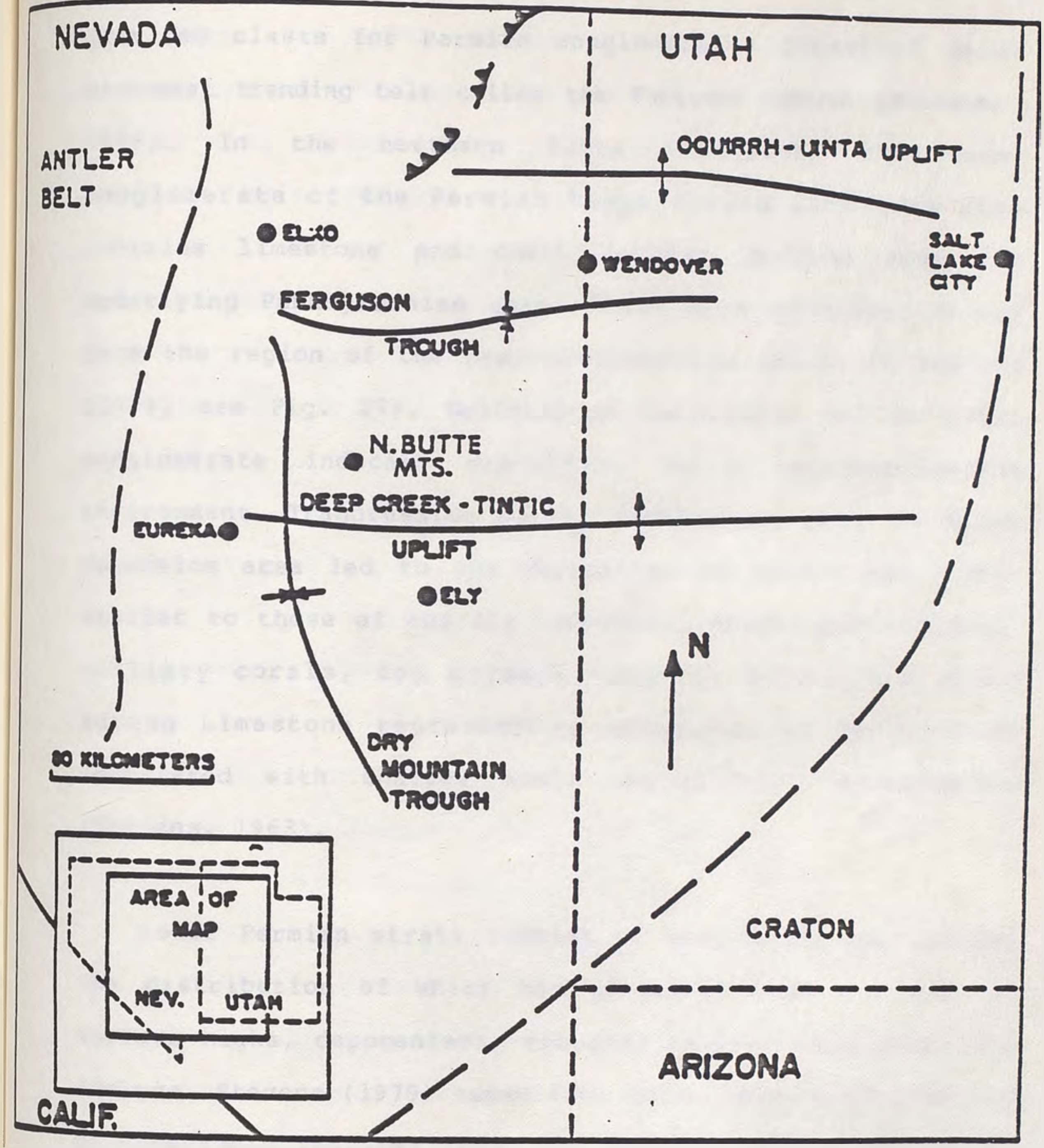


Figure 27: Lower Permian Paleotectonic Features in the Central Cordilleran Miogeocline. (From Stevens, 1979)

provided clasts for Permian conglomerates deposited in an east-west trending belt called the Ferguson trough (Stevens, 1979). In the northern Butte Mountains, the basal conglomerate of the Permian Riepe Spring Limestone also contains limestone and chert pebbles derived from the underlying Pennsylvanian unit. These were probably derived from the region of the Deep Creek-Tintic uplift of Stevens (1979, see Fig. 27). Wolfcampian fusulinids in the basal conglomerate indicate deposition in a nearshore-marine environment. Trangression of the Permian sea into the Butte Mountains area led to the deposition of marine carbonates similar to those of the Ely Limestone. Brachiopod coquinas, solitary corals, and bryozoa horizons within the Riepe Spring Limestone represent an abundance of marine life associated with shallow shelf depositional environments (Stevens, 1963).

Lower Permian strata consist of many different facies, the distribution of which has generally been credited to various highs, depocenters, troughs, basins, highlands, and shelves. Stevens (1979) named four major paleogeographic and paleotectonic features (Fig. 27) that influenced sedimentation in eastern Nevada and western Utah. Shallow shelf sedimentation was restricted to narrow bands between the uplifted areas throughout the early Wolfcampian (Stevens, 1979). By middle Wolfcampian time complete submergence of the Deep Creek-Tintic uplift allowed shallow shelf carbonates of the Riepe Spring Limestone to spread out across most of east-central White Pine county, into the northern Butte Mountains, and into southern Elko county (Plate IV). Deeper marine sediments collected in western White Pine County (Stevens, 1965). To the north along the southern border of the Oquirrh-Uinta uplift carbonate deposition occurred in quiescent lagoon environments (Fig. 28).

Reemergence of the Deep Creek-Tintic uplift in middle Wolfcampian time produced an influx of terrigenous detritus into eastern Nevada. Supratidal-intertidal fine- grained sand and silt of the Riepetown Formation (Plate IV) spread as far west as the Butte Mountains. To the north, deposition of the Ferguson Mountain Formation continued in the deeper waters of the Ferguson trough (Marcantel, 1975).

A decrease in sediment supply and an increase in water depths, probably associated with downwarping of the paleotectonic troughs adjacent the Butte Mountains, renewed shallow shelf carbonate deposition in the northern Butte Mountains during late Wolfcampian-early Leonardian time. Fusulinid rich carbonates and interbedded fine grained sandstones of the Pequop Formation intertongue to the east with more clastic rich limestones of the Arcturus Formation.

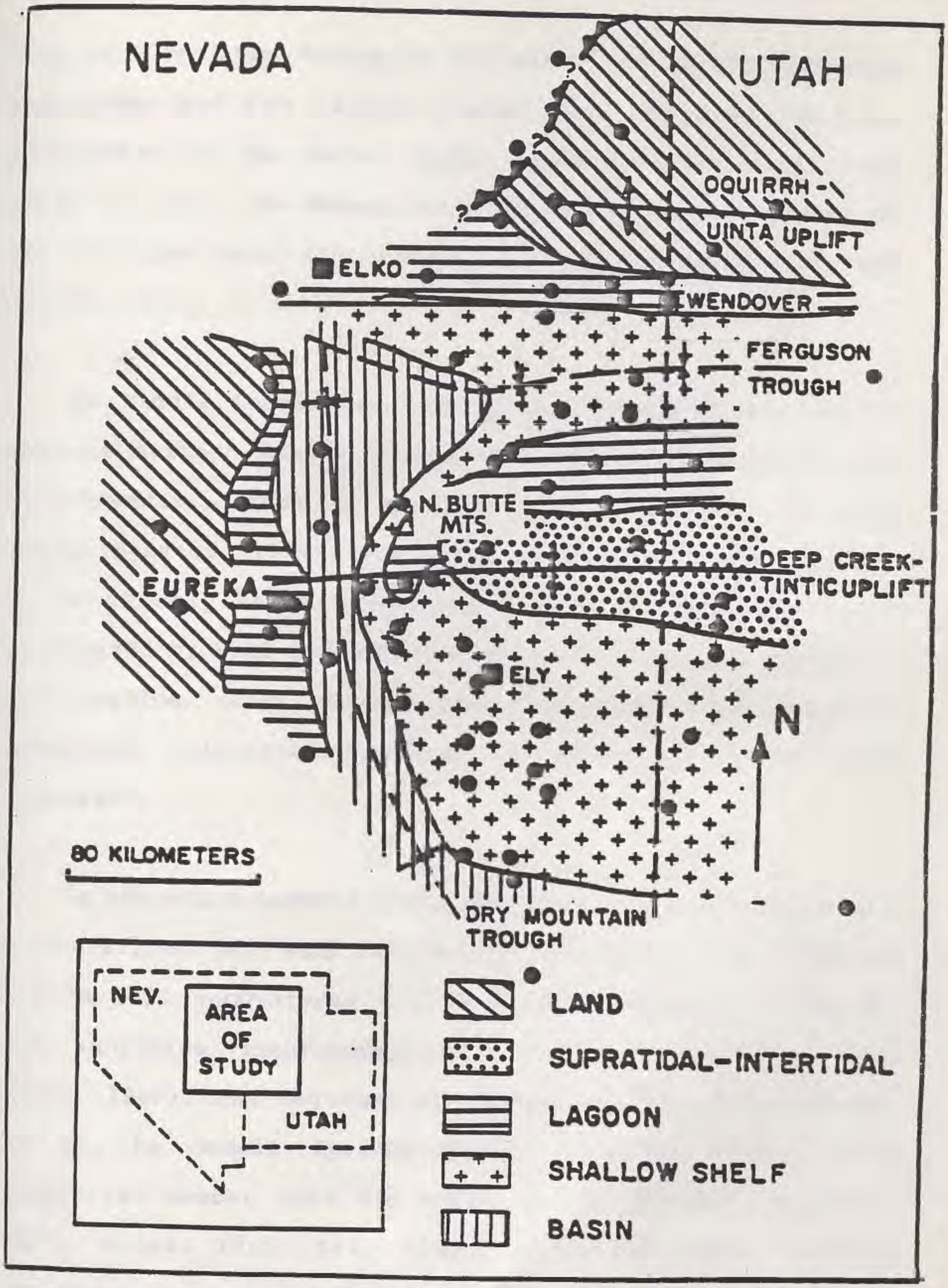


Figure 28: Paleogeography during lower middle Wolfcampian (from Stevens, 1979)

West of the Butte Mountains the amount of clastic material decreases and the Pequop grades into the fusuline rich carbonates of the Carbon Ridge Formation (Plate IV). The shelf on which the Pequop accumulated extended northward to the Medicine Range and eastward through the Ferguson trough (Plate IV).

In middle Leonardian time a shallowing of the sea in most of eastern Nevada generated a number of shallow water environments , such as shallow bays, ponds, and subtidal flats (Stevens, 1979). The decrease in water depths appears to be closely associated with a eustatic sea level drop recognized by Vail and others (1977). Restricted circulation and shallow water depths produced supratidal-intertidal sandstone, siltstone, dolomite, and evaporites of the Loray Formation.

In the south-central Butte Mountains, sec. 32, T. 20 N., R. 59 E., an oil well drilled by Continental and Standard Oil in 1951 encountered a 1332 m thick sequence of gypsum and anhydrite interbedded with siltstone (McJannet and Clark, 1960). The sequence of evaporites has been referred to as the Summit Springs Member (Steele, 1960). This evaporitic member does not occur at the surface (Stevens, 1965; Sides, 1966, this study). Complete Lower Permian stratigraphic sections now known on both sides of the Butte

Mountains (Stevens,1979), only 6 to 8 km from Continental-Standard's unit No. 1 well, do not contain the evaporite member. This suggests that the evaporites were deposited in a locally restricted basin.

The Loray Formation is equivalent to lithologies in the upper member of the Arcturus Formation in eastern White Pine county and adjacent Utah (Bissel, 1964; Stevens, 1965). Euryhaline fauna in the Loray and Arcturus, like the Euphemitid-Nuculanid, represent near-shore, open and restricted bay, and lagoonal environments (Stevens, 1963).

Trangression of the Kaibab sea into eastern Nevada during late Leonardian time reestablished open-marine carbonate deposition in eastern White Pine county and northern Elko County (Fig. 29). The sharp contact between shallow water, intertidal sediments of the Loray Formation and open-marine shelf carbonates of the Kaibab Limestone in the northern Butte Mountains suggests a rapid increase in water depth. Carbonates were deposited along an open-marine shelf that gradually deepened toward the relatively deep-water center of the Phosphoria basin in southeastern Idaho (Wardlaw and others, 1979).

Carbonate deposition in the Late Permian was influenced by two depositional basins, one centered in the south near

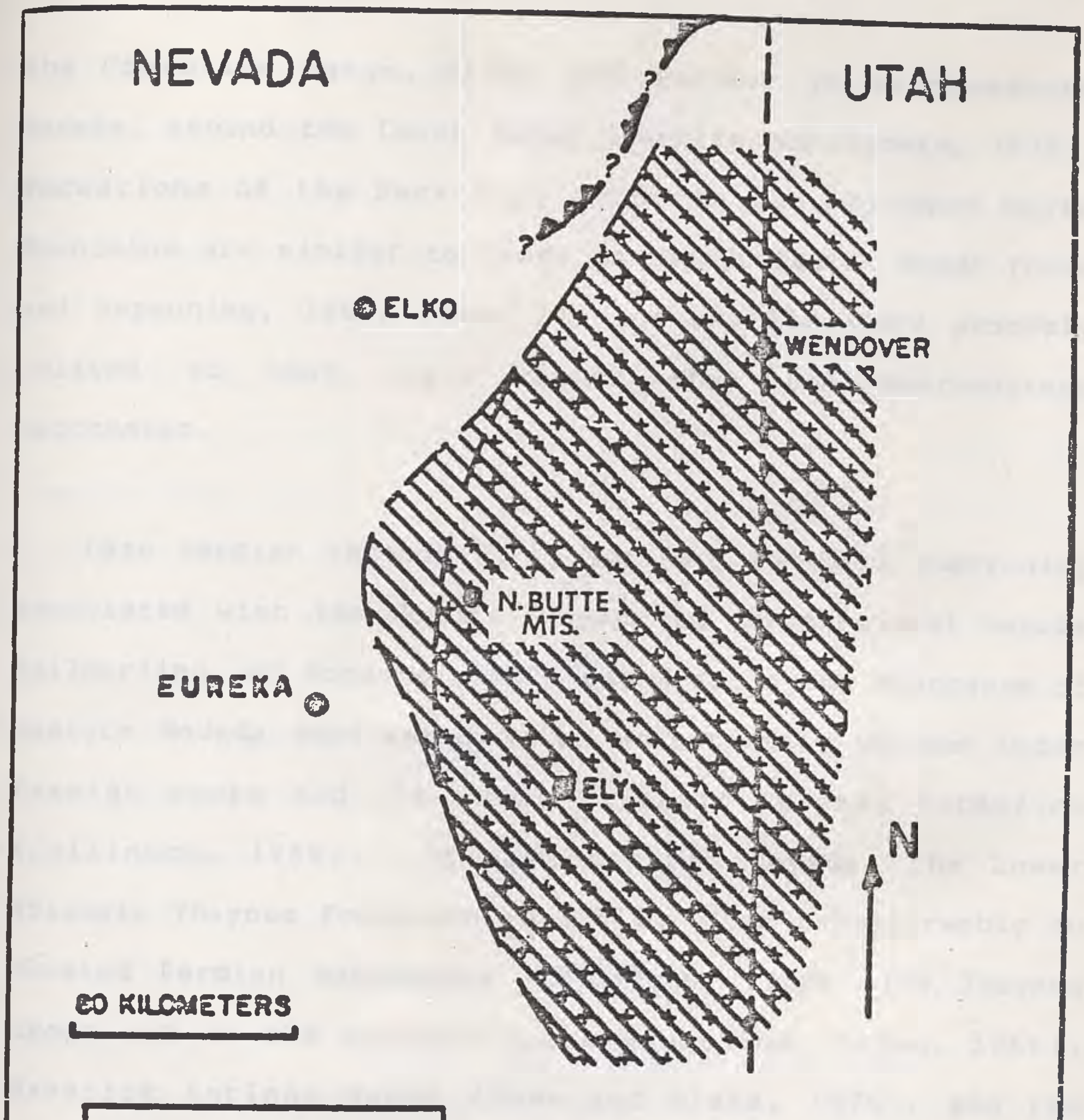


Figure 29: Geographic Distribution of the Loray lithosome and Kaibab Formation (from Stevens, 1979)

the Confusion Range, Utah, and another in northeastern Nevada, around the Leach Range (Wardlaw and others, 1979). Formations of the Park City Group in the northern Butte Mountains are similar to those in the Confusion Range (Hose and Repenning, 1959; Plate IV) and are therefore probably related to that basin rather than the northeastern depocenter.

Late Permian through Early Triassic tectonic shortening associated with the Sonoma orogeny in north-central Nevada (Silberling and Roberts, 1962) resulted in the emergence of eastern Nevada manifested in an unconformity between Upper Permian rocks and the Lower Triassic Thaynes Formation (Collinson, 1968). In east central Nevada, the Lower Triassic Thaynes Formation (Spathian) lies unconformably on beveled Permian carbonates (Collinson, 1968). The Thaynes crops out in the central Butte Mountains (Sides, 1966), Maverick Springs Range (Hose and Blake, 1976), and the Medicine Range (Collinson, 1968) providing evidence for an Early Triassic carbonate platform (Stevens, 1977).

Shortening of supracrustal rocks in eastern Nevada is thought to have occurred throughout most of the Mesozoic. In northeastern Nevada, Riva (1970) demonstrated early Mesozoic thrusting and folding which could range in age from Middle Triassic to Early Jurassic. In south-central Nevada and adjacent California large thrusts are cut by plutons ranging in age from 180 m.y. to 200m.y. old (Burchfiel and Davis, 1971). Data suggests a period of early Mesozoic deformation that ranged from the Middle Triassic to Middle Jurassic.

By Late Jurassic time, deformation associated with the Sevier orogeny was well underway within eastern Nevada and western Utah and the area was sufficiently uplifted to be a clastic source (Armstrong, 1968). In eastern Nevada, shortening of supracrustal rocks is exhibited by large gentle folds in the Butte structural trough and Confusion structural trough (Armstrong, 1968). Thrusts in central Utah apparently remained deep seated in eastern Nevada and never breached the surface.

Mid-Tertiary extension between the Butte structural trough and the Confusion structural trough created major normal faults that eventually rotated into low-angle faults and placed younger strata on older. Concomitant with this extensional rotation, horizontal extension in the Snake Range placed nonmetamorphosed rocks in contact with ductilely deformed rocks (Gans and Miller, 1983). Possible low angle faults were observed in 2 places in the northern Butte Mountains , but these appear to be of minor importance.The most apparent Cenozoic tectonic event in the

Mountains is Late Tertiary extension on high angle normal faults.

Recommendations for Future Work

The major emphasis of this thesis was to define and describe the Paleozoic stratigraphy of the northern Butte Mountains. To describe the stratigraphic units in the area, a significant amount of work was also performed to understand the structure. However, the relationship between local structural details (local low-angle bedding-plane faults) and larger-scale structure is still unclear and needs more investigation. Further investigation of these structures may provide a better understanding of the relationship of the Butte Mountains to the mid-Tertiary structural regime presented by Gans and Miller (1983).

Additional work should also be done on the fusulinid-rich limestones of the Pequop Formation. Sampling of this formation at regular intervals will provide a better zonation of the formation, which in turn, will allow a more accurate correlation with other areas.

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Appendix A - Measured Stratigraphic Sections

Section 1
Partial Section of the Diamond Peak Formation

Age: Mississippian-Pennsylvanian

Location: NW 1/4 Section 14, T. 23 N., R. 59 E.

Stratigraphic Relationship: The lower units of the Diamond Peak are in fault contact with Pennsylvanian Ely Limestone; the upper units are conformably overlain by Pennsylvanian Ely Limestone.

Description: From top to bottom.

Total Thickness: 259.55 m (851.5 ft.)

Cumulative Thickness	Unit Thickness	Unit Description
(259.55 m)	13.82 m	Shale, light olive gray (5Y 5/2)* to olive black, (5Y 2/1) fissile, slope former
(247.73 m)	14.38	Santstone and silicified sandstone, ferruginous, grayish orange (10YR 7/4) to pale brown (5YR 5/2) on weathered surface, white crystalline quartz with limonite speckling on fresh, grain sizes range from very fine to medium, medium to thick bedded, some cross-bedding. Gastropod Bellerophon (at base)
(231.35 m)	21.0	Limestone arenaceous limestone, bioclastic, ferruginous, fossil hash, moderate yellowish-brown (10YR 5/2) to dark yellowish-orange (10 Y 6/6) on weathered, light olive gray (5Y 5/2) to light olive brown (5Y 5/6) on

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*Numerical representation of hue, value, and chroma. Correlates with G.S.A. rock-color chart (1980).

		fresh, medium bedded brachiopods. *Brachiopods* *Spirifer* *Keokuk* *Anthrocospirifer* sp. (at top).
(210.35)	26.4	Limestone alternating with sandstone, 6 to 1 ratio limestone/sandstone, limestone: moderate yellowish brown (10YR 5/4) to dark yellowish-orange (10YR 6/6) on weathered surface, light olive brown (5Y 5/2) to light olive brown (5Y 5/6) on fresh surface, ferruginous, encrinite, fossil hash, Brachiopods; silicified sandstone and sandstone, light brown (5YR 5/6) to moderate brown (5YR 4/4) on both fresh and weathered surface, ferruginous, white silicified quartz grained mottled by limonite, limestone and sandstone grade interchangebly throughout. *Crinoids*. *Anthrocospirifer* *birdspringensis* *Unispirifer* sp. (near top)
(183.95 m)	9 m	Sandstone, silicified, ferruginous, olive gray (5Y 4/1) to grayish-brown (5YR 3/2) on weathered, very light gray (N8) with brown spotting (limonite) on fresh surface, fine grained, breaks along existing fractures, difficult to obtain fresh surface.
(174.95 m)	10.43	Sandstone and silicified sandstones with sandstones same as above, limestones similar to below.
(164.52 m)	3.83 m	Skeletal-detrital limestone, medium grain limestone pebbles in recrystallized bioclastic limestone matrix; olive gray (5Y 4/1) on weathered, very light gray (N8) to light gray (N7) on fresh medium bedded.

(160.69 m)	16 m	Limestone, encrinite, bioclastic, medium gray (N5) to olive gray (5Y 4/1) on weathered surface, light gray (N7) to light olive gray (5Y 6/1) on fresh surface, thin to medium bedded bryozoan (Lacy) and Brachiopods. *Pertitocardina* sp.
(144.69 m)	7.4 m	Sandstone, calcareous, slightly ferruginous, very fine grained, grayish orange (10YR 7/4) to dark yellowish-orange (10YR 6/6) on weathered surface, very light gray (N8) with limonite specks on fresh surface, thin to medium bedded.
(137.29 m)	6.54 m	Limestone, recrystallized, coarse texture, slightly ferruginous, light olive gray (5Y 6/1) to pale yellowish-brown (10YR 6/2) on weathered surface, very light gray (N8) to very pale orange (10YR 8/2) on fresh surface, medium bedded, occassional green spotting may indicate glauconite grains.
(130.75 m)	4.84 m	Limestone, bioclastic, medium light gray (N6) to moderate yellowish-brown (10YR 5/4) on weathered and fresh, fossil fragments of Brachiopods, crinoids, byrozoans, thin to medium bedded. At top *Orthotetes keokuk* horizon.
(125.91 m)	5.41 m	Limestone encrinite bioclastic, ferruginous, medium light gray (N6) to medium dark gray (N4) on weathered surface, medium dark gray (N4) mottled with light brown (5YR 5/6) from oxidized Fe (limonite) slightly fetid thin to medium bedded, upper beds contain brachipods. *Spirifers.*

(120.05)	4.27 m	Shale, medium dark gray (N7) to brownish gray (5YR 4/1), very thin laminae, very fissile, ferruginous.
(116.23 m)	.30 m	Limestone, encrinite bioclastic, crinoids, shell fragments, brachipod spines, all weathered out on surface overall color is dark yellowish-brown (10YR 4/2), thin bedded. Columnal Excentricus (Penn.) Chonetes. sp.
(115.93)	3.86 m	Limestone, light brown (5YR 5/6) to moderate brown (5YR 3/4) on weathered surface, medium dark gray (N4) to olive gray (5Y 4/1) on fresh, finely crystalline, medium bedded.
(112.07 m)	2.9 m	Conglomerate, sandstone, conglomerate, bioclastic; fine to coarse size pebbles of moderate brown (10YR 4/4) chert, pebbles floating in a matrix of coarse to very coarse sand rounded quartz grains, crinoid columnals and skeletal fragments, moderate yellowish brown (10YR 5/4) overall.
(109.17 m)	1.93 m	Limestone, encrinite, arenaceous, ferruginous, medium light gray (n6) to pale brown (5YR 5/2) on weathered surface, medium light gray (N6) with mottled limonite on fresh, medium bedded. Brachiopod Spirifer, sp. Crinoids, Eomarginifera sp.
(107.24 m)	35.75 m	Predominantly covered, suboutcrop, exposures indicate intercalation of sandstones, silicified sandstones (orthoquartzites) and encrinite limestones.

(71.49 m)	8.8 m	Covered, float consists dominantly of sandstone and quartiztes, rare limestone portions.
(62.69 m)	19.33 m	Quartzitic sandstone, resistant outcrop, alternating medium beds of yellowish-gray (5Y 7/2) to light olive gray (5Y 6/1), iron spotted, fine to medium grained quartzite (>5% quartz) and very light gray (N8) to light greenish-gray (5GY 8/1) crossbedded quartzitic, fine to medium size sandstone crossbedded portions weather a light brownish-gray (5YR 6/1) to a grayish red purple (5RP 4/1) outlining the crossbedding, spotted iron oxide portions weather yellowish-gray (5Y 7/2) to dark yellowish-brown (10YR 4/2).
(43.36 m)	8.2 m	Orthoquartzite, same as below, top of bed marked where float ends.
(35.16 m)	1.6 m	Shale extremely fissile, dark greenish gray (5GY 4/1) to grayish-black.
(33.56 m)	6.29 m	Slope covered, float indicates bedrock is similar to rock described below and above, orthoquartzite (like below) and dark greenish-gray (5GY 4/1) to grayish-black.
(27.27 m)	14.29 m	Orthoquartzite, ferruginous, olive gray (5Y 4/1) to brownish-gray (5YR 4/1) on weathered, dark greenish-gray (5GY 4/1) mottled with oxidized iron specks on fresh, fine to medium grained texture, breaks along existing fractures.

(12.98 m)	4.85	Sandstone, ferruginous, moderate brown (5YR 3/4) to dusky brown (5YR 2/2) on weathered surface, light brown (5YR 5/6) on fresh due to iron oxide, fine to medium grain, difficult to obtain fresh surface, breaks along pre-existing fractures.
(8.13 m)	2.33 m	Conglomerate, multicolored chert pebble conglomerate; red, orange, gray, black, green, and white pebble clasts, ranging in size from very fine to medium rounded, similar to conglomerates below.
(5.8 m)	2.2 m	Sandstone, yellowish gray (5Y 7/2) to dusky yellow (5Y 6/4) on weathered and fresh surfaces, fine to medium size grains of subrounded to rounded quartz sand.
(3.6 m)	1.7 m	Conglomerate, multicolored chert pebble conglomerate, red, orange, gray, black, green and white pebbles varying in size from very fine to medium sized pebbles, Ordovician Vinini chert.
(1.9 m)	1.9 m	Covered interval, slope cover contains float of conglomerate bed found above.
Bottom		In fault contact with Ely Limestone (Plate I)

Section 2

Partial Section of Ely Limestone

Age: Pennsylvanian

Location: lat. 39* 50.6'N., long. 115* 18.25'W.

Stratigraphic Relationship: Believed to be underlain conformably by Diamond Peak; upper units are in fault contact with west dipping Ely Limestone.

Description: From fault contact to basal units Detailed rock description made from polished rock sections using Leighton-Pendexter classiication. Appenxid B, Section 2)

Total Thickness: 365.12 m (1197 feet)

Cumulative Thickness	Unit Thickness	Unit Description
Contact Between East Dipping and West Dipping Limestone		
(365.12 m)	11.5 m	Calcarenite, 30% coarse sand size grains, sand grains are two types 1) rounded, frosted quartz and 2) subangular to subrounded chert, shell fragments also present in micritic matrix, medium gray (N5) to medium dark gray (N4) on weathered, medium gray (N4) to olive gray (5Y 4/1) on fresh, thick bedded.
(353.62 m)	17.7 m	Limestone, skeletal limestone, encrinite, crinoid colunals average 1-2 mm in size, interbedded with impure irregular chert beds that weather white (N9) to moderate brown (5YR 4/4), thick bedded limestone, smells slightly fetid on fracture, bluff former.

(335.92 m)	13.7 m	Limestone, skeletal limestone, encrinite, light gray (N7) to medium light gray (N6) on weathered surface, lght olive gray (5Y 6/1) to olive gray (5Y 4/1) on fresh fracture, thick bedded.
(322.22 m)	5.3 m	Limestone, micritic limestone, light gray (N7) on weathered and fracture, bedding, thin to medium bedded, impure chert weathers light brown (5YR 5/6) to moderate brown (5YR 3/4) every three feet.
(316.92 m)	15.85 m	Limestone, micritic limestone, interbedded with impure chert layers, olive gray (5Y 4/1) on weathered and fresh surface, bluff forming beds.
(301.07)	22.0 m	Limestone, micritic limestone, light gray (N7) to light olive gray (5Y 5/2) on weathered surface, olive gray (5Y 4/1) on weathered surface, olive gray (5Y 4/1) on fresh surface, thick bedded micritic and micritic skeletal limestone interbedded with thin impure chert.
(297.07 m)	19.2 m	Limestone, micritic and skeletal micritic limestone interlayered with impure chert layers, limestones are medium gray (N5) on weathered surface, olive gray (5Y 4/1) fresh, impure chert is irregular and weather yellowish-gray (5Y 6/1) to moderate brown 5YR 4/4), slope former.
(259. 87 m)	4.44 m.	Limestone, skeletal micritic limestone, white (N9) to very light gray (N8) on weathered surface, medium gray (N5) to medium dark gray (N4) on fresh fracture, smells fetid on fresh fracture, thin to medium bedding with abundant grayish

		black chert nodules, encrinite (both matrix and grayish nodules average size of crinoid columnals 1-2 mm.
(255.43 m)	7.0 m	Limestone, micrite, medium light gray (N6) on weathered surface, olive gray (5Y 4/1) on fresh fracture, dusky yellowish brown (10YR 2/2), chert nodules L/6" x W/4" x H/2.5" are at the top, thick to massive beds (nodules indicate unusual abundance of silica, Krauskopf, 1959).
(248.43 m)	8.9 m	Limestone, limestone interlayered with impure chert, case hardened siliceous limestone weathers moderate brown (5YR 4/4) to grayish brown (5YR 3/2), coarse sized sand irregularly distribted through limestone, impure chert increasess near top chert nodules a top.
(239.53 m)	6.7 m	Same as below.
(232.83 m)	13.8 m	Limestone, micritic limestone interlayered with impure siliceous limestone (impure chert) with case hardened surface that weathers grayish-brown (5YR 3/2) to brownish-black (5YR 2/1).
(219.03 m)	13.8 m	Limestone, slope forming, thin bedded limestone.
(205.23 m)	10.7 m	Limestone, detrital-skeletal-pelletoid limestone 15% quartz grains, light gray (N7) to medium light gray (N6) on weathered surface, light olive gray (5Y 6/1) on fresh surface, skeletal fragments on weathered surface, thick to massive bedding, 10" diameter nodules.

(194.53 m)	4.0 m	Limestone, detrital-skeletal-micritic limestone, very light gray (N8) to light gray (N7) on weathered, medium to light gray (N6) on fresh, thin to medium bedded, noncalcareous nodules 6' from bottom, microfossils.
(190.53 m)	4.1 m	Slope covered brachiopod coquina petroliferus midway. *Spirifer* *Neospirifer* *Linusproductus.*
(186.43 m)	4.9 m	Limestone, alternating laminations of micrite and fine to medium sand sized skeletal and quartz sand particles; noncalcareous, resistant stringers near bottom, nodules near top, very light gray (N8) on weathered, light olive gray (5Y 5/2) on fresh, thin to medium bedded.
(181.53 m)	4.3 m	Weathered, olive gray (5Y 4/1) on fresh noncalcareous nodules near base of unit, weather pale yellowish-brown (10YR 6/2) to pale brown (5YR 5/2), fetid on fracture, nodules 2.5" x 3", thick large massive beds.
(177.23 m)	57.9 m	Limestone, skeletal micritic, arenaceous, interbedded with limestones, *Linoproductus prattenianus, Lophophyllidium.*
(119.33 m)	4.22 m	Sandstone, rounded coarse to very coarse sandsize, calcareous, light olive gray (5Y 5/2) to dusky yellow (5Y 6/4) to brownish-gray (5YR 4/1), fossiliferous. *Spirifer*, *Chonetes*, *Tabulipora?*
(115.11 m)	.60 m	Limestone, skeletal-detrital-pelletoid limestone, dark yellowish-orange (10YR 6/6) to dark yellowish-brown (10YR 4/2) to olive gray (5Y 4/1) on

		weathered surface, olive gray (5Y 4/1) on fresh, medium bedded, highly fossiliferous. *Spirifer.*
(114.51 m)	2.0 m	Limestones micritic limestone, light gray (N7) on weathered, medium light gray on fresh (N6), slope forming.
(112.51 m)	2.0 m	Limestone, skeletal micritic, macro fossils along bedding planes, medium light gray (N6) on weathered, medium dark gray on fresh, thick bedded, chert beds on top.
(110.51 m)	3.66 m	Limestone and chert beds, chert veneer, medium gray (N5) on weathered, medium dark gray (N6) on fresh, alternating very thin to thin beds of chert and micrite limestone chert weathers pale yellowish brown (10YR 6/2) to dusky brown (5YR 2/2), distinctive bed.
(106.85 m)	5.5 m	Limestone, micritic limestone, chert nodules every .60 m, (2') medium light gray (N6) on weathered, dark gray (N3) to grayish black (N2) on fresh, thin bedded.
(101.35 m)	1.2 m	Limestone, skeletal micritic limestone, medium gray (N5) on weathered, dark gray (N3) on fresh, medium bedded, fossiliferous (macro). *Michelinia.*
(100.15 m)	2.4 m	Limestone, detrital-skeletal-pelletoid micritic limestone, medium to coarse sand detritus, echinoid spine fragments, light olive gray (5Y 5/2) with subordinate light brown (5YR 5/6) coloring on weathered suface, more olive gray (5Y 4/1) on fresh thin-medium bedded.

(97.75 m)	.46 m	Limestone skeletal-oolitic-detrital-pelletic limestone, 10% coarse sandsize grains of frosted quartz and angular chert detritus, light olive gray (5Y 6/1) on weathered, olive gray (5Y 4/1) on fresh, medium bedded.
(97.29 m)	6.0 m	Limestone, skeletal-micritic, macro-fragments on limestone surface, grayish-orange (10YR 7/1) to light gray (N7) on weathered surface, medium light gray (N6) to medium gray (N5) on fresh, very pale orange calcareous nodules (weathered). <u>Fusulinids.</u>
(91.29 m)	15.6 m	Limestones, skeletal-micritic limestone, macroscopic skeletal fragments on weathered surface, microscopic on polished, grayish-orange (10YR 7/1) to light bluish-gray (5B 7/1) on weathered surface, olive gray (5Y 4/1) to pale yellowish-brown (10YR 4/2) on fresh, thin to medium bedded, grayish-orange (10YR 7/4) chert on surface. <u>Fuslinids.</u>
(75.69 m)	60.63 m	Limestone, detrital-pelletoid micitic limestone, fine to medium grained sand size detritus, yellowish gray (5Y 8/1) to light olive gray 5Y 6/1), thin bedded, slope forming, minor outcrop exposures.
(15.06 m)	2.8 m	Limestone, slope covered, thin bedded.
(12.26 m)	12.26 m	Quartzitic sandstone, ravine marks contact of, moderate orange-pink (5YR 8/4) to dark yellowish-orange (10YR 6/6), thin to thick bedded.

Section 3

Ely Limestone
Complete Section

Age: Pennsylvanian

Location: lat. 39* 50.25'N., long. 115* 18.25'W.

Stratigraphic Relationship: Underlain conformably by Mississippian-Pennsylvanian Diamond Peak Formation; Overlain unconformably by Permian Riepe Spring Limestone.

Description: From top to bottom.

Total Thickness: 545.0 m (1788').

Cumulative Thickness	Unit Thickness	Unit Description
(545.0 m)	2.27 m	Limestone, bioclastic, medium to thick bedded, light gray (N7) to medium gray (N5), large elliptical impure chert nodules (15 cm to 30 cm diameter), weather dark yellowish-brown (10YR 4/2).
(542.73 m)	1.22 m	Limestone, fossiliferous, light gray (N7) on both fresh and weathered, coralline biostrome, laterally extensive. *Lophophyllidium* sp., *Caninia?* sp.
(541.51 m)	17.03 M	Limestone, micritic, thin to medium bedded, light gray (N7) to pale yellowish-brown (10YR 6/2) on weathered, medium gray (N5) to olive gray (5Y 4/1) on fresh, irregular chert, nodular chert, large elliptical clasts (25 to 40 cm diameter) at top.
(524.48 m)	24.09 m	Limestone, thin to medium bedded, pale yellowish-orange (10YR 8/6) to olive gray (5Y 4/1), layered chert horizons

		with intermittent bioclastic horizons. *Composita* sp., *Byrozoan.*
(500.39 m)	30.43 m	Limestone, bioclastic, fine grained, thin to medium bedded, light gray (N7) to medium gray (N5), medium gray (N5) to olive gray (5Y 4/1) on fresh, interlayered chert, chert nodules, irregular chert, chert ranges from light olive gray (5Y 6/1) to dark gray (N3). *Dictyoclasts* sp., *Composita* sp., *Archimedes?*sp.
(469.96 m)	29.2 m	Limestone, medium to thick bedded, bioclastic, medium light gray (N6) to pale yellowish-orange (10YR 8/6) on weathered surface, medium gray (N5) on fresh surface, bench former, large (45 cm diameter), elliptical, arenaeous, resistent clasts near top.
(440.76 m)	5.87 m	Limestone, thick bedded, fossiliferous, light gray (N7) to light brownish-gray (5YR 6/1) on weathered, chert nodules near top. Solitary Coals: *Lophophyllidium* sp., *Bryozoans.*
(434.89 m)	17.64 m	Limestone, bioclastic, light gray (N7) to light olive gray (5Y 6/1), medium to thick bedded fetid, medium dark gray (N4) to olive gray (5Y 4/1) on fresh surface, nodular and irregular chert, chert is dark gray (N3) near top.
(417.25 m)	26.48 m	Limestone, bioclastic, shell fragment weather out on exposed surface, fetid, light gray (N7) to light olive gray (5Y 6/1) on weathered suface, medium gray (N5) to olive gray (5Y 4/1) on fresh surface, thick to massive bedding, nodular and irregular chert, chert weathers dark

		yellowish brown (10YR 4/2) to moderate yellowish-brown (10YR 5/4) difficult to break from matrix. Spirifer Occiduus? Chaetetes, Bryozoans.
(390.77 m)	41.31 m	Limestone, finegrained and bioclastic, thick to massive bedding, light gray (N7) to medium gray (N5) on weathered surface, olive gray (5Y 4/1) to medium gray (N5) on fresh fracture, irregular chert, chert nodles, chert weathers brownish-gray (5YR 4/1) to moderately yellowish-brown (10YR 4/2) giving surface dark appearance.
(349.46 m)	23.71 m	Limestone, light gray (N7) to light olive gray (5Y 611), thin to thick bedded, chert nodules and layering, impure chert layering, chert weathers light brownish gray (5YR 6/1) to moderate brown (5YR 4/4), dark gray (N3) on fresh fracture.
(325.75 m)	22.73	Covered, float indicates thin to medium bedded limestone, interbedded-interlayered with impure chert and irregular chert, overall very pale orange (10YR 8/2) to dark yellowish-orange (10YR 6/6) soil coloration.
(303.02 m)	.50 m	Conglomerate, like below, calcareous matrix.
(302.52 m)	2.9 m	Limestone, argillaceous thin to medium bedded, interlayered with impure chert and white layered, irregular chert.
(299.62 m)	4.07 m	Jasperoid, silicified breccia, moderate brown (5YR 4/4) to dusky yellowish-brown (10YR 2/2).

(295.55 m)	6.28 m	Suboutcrop and float, limestone, thin to medium bedded, argillaceous, fine grained, alternating with limestone-chert pebble conglomerates.
(289.27 m)	.30 m	Conglomerate, like below, white and medium gray chert and limestone clasts, subangular to subrounded in fine grained calcareous matrix.
(288.97 m)	2.0 m	Limestone, thin to medium, bedded, pinkish-gray (5YR 8/1) to light gray (N7), argillaceous.
(286.97 m)	.25 m	Conglomerate, white and medium gray chert and limestone clasts in calcareous, micritic matrix, subangular to subrounded, pebble size, similar to below.
(286.72 m)	9.58 m	Float, limestone, micritic, slightly calcareous, light gray (N7) on both weathered and fresh surface, iron rich, light brown (5YR 5/6) to moderate brown (5YR 3/4), silicified conglomerate (?), jasperoid lenses crop out laterally from section line.
(277.14 m)	1 m	Conglomerate, limestone-chert pebble conglomerate, subangular to subrounded, very light gray (N8) to dark gray (N3) clasts are slightly calcareous, light gray (N7), micritic matrix.
(276.14 m)	30.9 m	Suboutcrop, limestone, argillaceous limestone interlayered wth impure chert and angular chert fragments, overall areal slope color is grayish-orange (10YR 7/4) to pale yellowish-orange (10YR 8/6), suboutcrops indicate thin to medium bedding thickness.

(245.24 m)	18.0 m	Limestone, bioclastic, arenaceous, medium to thick bedded, medium gray (N5) on weatherd surface, medium gray (N5) to dark gray (N3) on fresh surface, large elleptical arenaceous, resistant nodules at top.
(227.24 m)	6.55 m	Limestone, argillaceous, thin bedded, interlayered with case hardened impure chert, light gray (N7) to medium gray (N5), chert weathers moderate yellowish-brown (10YR 5/4).
(220.69 m)	1.52 m	Limestone, bioclastic, skeletal, light gray (N7) to medium gray (N5) on both surfaces, medium to thick bedded, bench former.
(219.17 m)	3.043 m	Limestone, fossiliferous, white (N6) to light gray (N7), interlayered with case hardened impure chert; weathers moderate brown, silica replaced brachiopods weather out on exposed surfaces, thin to medium bedded. *Megalinoproductus* sp. *Marginifera* sp. *Composita subtilita* *Anthrocospirifer birdspringensis.*
(216.13 m)	2.53 m	Limestone, fossiliferous, brachiopod coquinas, medium to thick bedded, brachiopods weather out on exposed surfaces, light gray (N7) to medium gray (N5) on weathered surface, olive gray (5Y 4/1) on fresh surface, bioclastic, encrinite, limestone alternate with brachiopod horizons. *Buxtonia,* sp. *Marginifera,* sp. *Spirifer.* sp.
(213.60 m)	10.73 m	Limestone, thin to medium bedded, fossiliferous, bioclastic, very light gray

		(N8) to light gray (N7) on both weathered and fresh surfaces, horizon of *Linoproductus* sp. associated with impure chert 1.0 m from bottom, followed by Spirifer sp. horizon 2.0 m up section. *Linoproductus* sp. *Orthotetes* sp. *Neospirifer,* sp. *Unispirifer.*
(202.87 m)	15.52 m	Limestone, bioclastic, arenaceous, medium to thick bedded, medium light gray (N6) on weathered surface, olive gray (5Y 4/1) on fresh, small chert nodules halfway through. *Dictyoclostus,* sp. *Unispirifer?,* sp. *Antiquatonia.* sp.
(187.35 m)	20.32 m	Limestone, thin to medium bedded micritic limestone with nodules, layered, and irregularly shaped impure chert, matrix is light gray (N7) to medium gray (N5), impure chert weathers grayish-orange (10YR 7/4) to moderate yellowish-brown (10YR 5/4), fetid. Solitary corals, *Megachonetes* sp. *Unispirifers* sp. *Crenispirifer* sp. *Reticularia?* sp. *Orthotetes* sp. *Dictyoclostus* sp. *americanus*
(167.03 m)	6 m	Limestone, thin bedded argillaceous limestone interlayered with case hardened impure chert, lichens on rock surface give distinctive dark yellowish-brown (10YR 5/4) to dark yellowish-brown (10YR 4/2) on both surfaces, lower arenaceous units contain fossils, brachiopods and ichnofossils, upper unit contains impure chert ellipses with brachiopod fauna.

(140.31 m)	18.2 m	Limestone, bioclastic packstone, medium bedded, arenaceous, ferruginous, encrinite, moderate yellowish brown (10YR 5/4) on weathered, medium dark gray (N4) to olive gray (5Y 4/1) with limonite on fresh, grades into and out of calcarenites with higher percentages of coarse grained quartz.
(122.11 m)	7.27 m	Limestone, thin to thick bedded, lower thin bedded unit interlayered with impure chert, weathers to distinctive dark yellowish-brown, upper unit is medium to massive bedded calcarenite, fine to medium sand grains, elongated chert nodules at top. *Derbyia crassa.*
(114.84 m)	22.14 m	Limestone, arenaceous, bioclastic, wackestone, thin to medium bedded, slightly ferruginous, grayish-orange (10YR 7/4) to light gray (N7) on weathered, medium light gray (N6) on fresh. *Rhipidomella,* sp. *Neospirifer.* sp.
(92.7 m)	2.8 m	Limestone, thin bedded argillaceous limestone interlayered with impure chert, chert weathers white on the surface.
(89.9 m)	7.9 m	Limestone, medium bedded wackestone, light gray (N7) to medium light gray (N6) on weathered, light olive gray (5Y 6/1) to medium dark gray (N4) on fresh surfaces, interbedded with thin argillaceous limestones.
(82 m)	23 m	Limestone, thin bedded micritic limestone, interlayered with impure chert, light gray (N7) to medium light gray (N6) on

		weathered and fresh surfaces, impure chert layers weather to a pale yellowish-brown (10YR 6/2) medium dark gray (N4) chert nodules near top.
(59 m)	59 m	Limestone, thin bedded, very light gray (N8), argillaceous limestone interbedded with medium to thick bedded bioclastic, arenaceous, light gray (N7) limestone, crinoid columnals, shell fragments (wackestone).

Ely Limestone

Diamond Peak Fm

	5.7 m	sandstone, same as below.
	3.0 m	Sandstone, coarse grained, calcareous, grayish-orange (10YR 7/4) to pale yellowish-orange (10YR 8/6) on weathered, white subrounded to rounded grains with intermittent limonite specks on fresh, some silicified portions. Coral in lower limestone.
	8.3 m	Sandstone (like below) alternating/grading into arenaceous, fossiliferous, ferruginous limestone, overall color varies from grayish orange (10YR 7/4) to pale yellowish-brown (10YR 6/2), brachiopod coquinas contain: *Echinoconchus alternatus*, *Spirifer Keokuk*, *Dictyoclostus inflatus*, *Punctospirifer.* sp.

Section 4

Reipe Spring Limestone

Age: Lower Permian

Location: lat. 39* 50.25'N., long. 115* 17.75'W.

Stratagraphic Relationship: Underlain unconformably by Pennsylvanian Ely limestone; overlain conformably by Permian Riepetown Formation.

Description: Top to Bottom (See Appendix B)

Total Thickness: 41.24 m (135.3 feet)

Cumulative Thickness	Unit Thickness	Unit Description
(41.24 m)	.84 m	Limestone, thin to medium bedded, bioclastic, medium beds encrinite, light olive gray (54Y 6/1) on both weathered and fresh surfaces. *Fusulinids.*
(40.4 m)	2.16 m	Limestone, bioclastic, thin to medium bedded, thin interbeds of argillaceous limestone, light gray (N7) to light olive gray (5Y 6/1) on weathered and fresh surfaces.
(38.24 m)	.98 m	Limestone, biostrome, brachiopod coquina, light gray (N7) on both weathered and fresh surfaces, medium bedded. *Neospirifer.* sp.
(37.26 m)	7.98 m	Limestone, thin to medium bedded, very pale orange (10YR 8/2) on weathered and fresh surfaces, argillaceous, bioclastic, impure chert, breaks platy.
(29.29 m)	12.82 m	Limestone, thin to thick bedded, light olive gray (5Y

		6/1) to pale yellowish-brown (10YR 6/2) on weathered surface, brownish-gray (5YR 4/1) to olive gray 5Y 4/1) on fresh surface, fetid, fossiliferous horizon 6 m from base, nodular and irregular chert throughout. Punctospirifer, Composita, Cleiothyridina, Bryozoa, (Ramose and Reticulate) Lephophyllidim.
(16.46 m)	16 m	Limestone, thin bedded, argillaceous, fossiliferous, platy grayish-orange (10YR 7/4) limestone interbedded with medium to thick bedded, medium light gray (N6) to medum gray (N5) limestone. Cleiothyridina orbicularis, Derbyia?, Bryozoa: (ramose) (Sulcoretepora) and reticulate
(.46 m)	.46 m	Conglomerate, white chert and limestone pebbles, subangular to subrounded, in a very pale orange (10YR 8/2) to grayish-orange (10YR 7/4) fine-grained, calcareous, sandy matrix. Fusulinids.

Section 5

Riepetown Formation

Age: Lower Permian

Location: lat. 39* 50.6'N., long. 115* 16.75-17.25'W.

Stratigraphic Relationship:
Sharply overlies the Permian Riepe Spring Limestone and has a gradational boundary with the Permian Pequop Formation.

Description: Top to Bottom
Begins with lower beds of the Permian which grade into the upper sandstone units of the Riepetown.

Total Thickness: 374.9 m (1230 feet)

Cumulative Thickness	Unit Thickness	Unit Description
Pequop Fm	6.25 m	Bioclastic limestone interbedded with arenaceous limestone, same coloration as below, middle 6' section of skeletal packstone contains Lophophyllidum, brachiopods, large crinoid columnals. Bryozoa.
Pequop Fm	41.4	Limestone interbedded with very fine grained sandstone, yellowish gray (5Y 7/2) to dusky yellow (5Y 6/4), pale red (10Y 6/2) to pale reddish-brown (10YR 5/4), calcareous, thin bedded, breaks platey, thick bedded encrinite limestone, packstone, midway through unit: fusulinids, bryozoa, crinoid columnals of bottom, Fusulinids: Schwagerina ef. S. crebrisepta

Pequop Fm		Calcsiltites, arenaceous limestone, thin bedded, 2 foot encrinite-fusuline packstone midway through unit, medium light gray (N6) to medium gray (N5) on weathered and fresh. Fusulinids: Schwagerina youngquisti
Riepetown Fm		
(374.9 m)	21.5 m	Sandstone interbedded with calciltites and argillaceous limestones, light brown (5YR 6/4) to grayish-orange (10YR 7/4) on weathered, grayish-orange (10YR 7/4) to yellowish-gray (5Y 7/2) on fresh, calcareous, slope former.
(353.4 m)	14.8 m	Limestone, micritic limestone interbedded by platey fossiliferous argillaceous limestone, yellowish-gray (5Y 8/1) to light olive gray (5Y 6/1) on both weathered and fractured surface, thin to medium bedded, fossiliferous: Cryrithyris sp., brachiopod fragments.
(338.6 m)	28.7 m	Sandstone, very fine grained, argillaceous, fossiliferous calcsiltites, yellowish-gray (5Y 7/2) to light olive gray (5Y 6/1), pale yellowish-orange (10YR 8/6), light brown (5YR 6/4) to moderate reddish-brown, calcareous, thin bedded.
(309.9 m)	42.37 m	Sandstone interbedded with argillaceous limestone, very fine grained, argillaceous, sandstone, light brown (5YR 6/1), moderate reddish-orange (10R 6/6), light olive gray (5Y 6/4), calcareous, thin to medium bedded, argillaceous, subordinate, platey limestones, light gray (N7) to light olive

		gray (5Y 6/1) thin bedded fusulinids found in lenticular pods near contacts between limestone and sandstones. Crinoid columnals, Fusulinids: *Eoparafusulina linearis?*
(267.53 m)	14.6 m	Sandstone interbedded with limestone, argillaceous, very fine grained sandstone, pale yellowish-orange (10YR 8/6), moderate orange pink (5YR 8/4) to moderate reddish-brown; calcareous, thin to medium bedded, interbeds of medium gray (N5), petroliferous limestone.
(252.93 m)	28.9 m	Limestone interbedded with sandstone, thin to medium bedded argillaceous limestone, approximately 20 feet of skeletal micritic limestone, encrinite, fusulinid, medium gray (N5) on weathered surface, more olive gray (Y 4/1) on fresh, petroliferous; sandstone: very fine grained, argillaceous, pale yellowish-orange (10YR 8/6), pale yellowish-brown (10YR 6/2), and moderate reddish-brown (10YR 4/6, thin bedded, calcareous. *Fusulinids*: *Schwagerina wellsensis*, *Schwagerina elkoensis*
(224.03 m)	60.7 m	Sandstone (60%) interbedded with limestone, argillaceous very fined grained sandstones, pale yellowish-brown (10YR 6/2), yellowish gray (5Y 7/2), dusky yellow (5Y 6/4), and light brown (5Y 6/4), calcareous, thin to medium bedded, arenaceous micritic limestone, light gray (N7) on weathered, medium gray (N5) on fresh, thin to medium bedded, skeletal limestone, packstone, encrinite, Fusulinid

		rich, light gray (N2) to medium gray (N5) on weathered, same on fresh, medium bedded.
(163.33 m)	21.3 m	Sandstone, moderate reddish-orange (10R 6/6) to moderate reddish-brown (10R 4/6) sandstone interlayered with dark yellowish-orange (10YR 6/6), silty, fine grained sandstones, very thin to thin bedded; calcareous, slope forming.
(142.03 m)	70.8 m	Sandstone, occasional resistant outcrop of bioclastic, encrinite limestone, mostly slope covered, float contains 40% moderate reddish-orange (10R 6/6) to moderate reddish-brown (10R 4/6) very thin to thin bedded, very fine grained sandstone, 40% grayish-orange (10YR 7/4) to dark yellowish orange (10YR 6/6), very thin to thin bedded, very fine grained sandstone, 15% light olive gray (5Y 6/1) to dusky yellow (5Y 6/4) calsiltites, 5% bioclastic, encrinite, light gray (N7) to light olive gray (5Y 6/1) to grayish-orange pink (5YR 7/2), medium bedded, limestone. *Crurithyris* sp. *Fuslinids:* *Schwagerina aculeata?*
(71.23 m)	71.23 m	Sandstone interbedded with limestone: sandstones varicolored ranging from moderate reddish-orange (10R 6/6) to moderate reddish-brown (10R 4/6) to moderate yellowish-brown (10YR 5/4) on weathered surfaces, similar coloration on fresh fracture, calcareous, fossiliferous zones, very thin to thin bedded, very fine grained sand, fossiliferous portion contains more silt. Limestone brownish

gray (5YR 4/1) to olive gray (5Y 4/1), light gray (N7) to medium light gray (N6) on weathered surface, same on fracture, very thin to thin bedded. Fusulinids increase towards top, float covered up section.Horizons of fusulinids associated with fine grained sandstone, some partial silicification. *Fusulinids:*
Pseudofusulina huecoensis
Eoparafusulina linearis

Bottom

Section 6

Permian Pequop Formation

Age: Lower to Middle Permian

Location: lat. 39* 52.25'N., long. 115* 16.25'W.

Described: From Top to Bottom

Stratigraphic Relationship: Conformably overlies the Riepetown Formation and is conformably overlain by the Loray Formation.

Total Thickness: 364.97 m (1197 feet)

General Description: Fossiliferous rich skeletal limestone typical of middle shelf environment

Cumulative Thickness	Unit Thickness	Unit Description
(364.97 m)	6.88 m	Limestones, skeletal - bioclastic, grayish-orange (10YR 7/4) to pale yellowish-orange (10YR 8/6), medium bedded. Fusulinids, Gastropods?
(358.09 m)	13.98 m	Limestone, olive gray (5Y 4/1), medium bedded, resistant, interbedded with less resistant platey calcsiltites and fine grained sandstones, grayish-orange pink (5YR 7/2) to pale red (5Y 6/2).
(344.11 m)	18.06 m	Limestone, argillaceous, skeletal, yellowish gray (5Y 7/2) to light gray (N7) to light olive gray (5Y 6/1), thin bedded, platey, suboutcrop.
(326.05 m)	.91 m	Chert, white (N9) to very light gray, laterally extensive, good marker bed.

(325.15 m)	31.93 m	Sandstone and limestone, sandstone, same coloration as below interbedded with fine grained limestone, limestone is resistant and forms ledges between slope forming sandstones and calcsiltites.
(293.21 m)	9.48 m	Sandstones and limestone, sandstones; pale yellowish-orange (10YR 8/6) to moderate reddish-orange (10R 6/6), interbedded with calcsiltites and thick bedded dusky yellow (5Y 6/4) fine grained limestones. Terrigenous clastics noticeably increasing.
(283.73 m)	18.58 m	Limestone, bioclastic, fetid odor, pale yellowish-brown (10YR 6/2), medium bedded, bench former, interbedded with argillaceous limestones, platey, thin bedded, slope forming and fine graind quartz sandstones, limestone in greater proportion than clastic units.
(265.15 m)	17.73 m	Limestone, same as below.
(247.42 m)	40.2 m	Limestone, light olive gray (5Y 6/1) to pale yellowish-brown (10YR 6/2), 2 to 3 m bench forming, thicknesses alternating with 1 m thick thin bedded, talus forming calcsiltites and fine grained quartz sandstones, pale yellowish-orange.
(207.2 m)	20.11 m	Limestone, same as below, medium to thick bedded, pale yellowish-brown (10YR 6/2), bench forming limestone interbedded with yellowish-orange calcsiltites and fine grained quartz sandstones.

(187.09 m)	22.02 m	Limestone, pale yellowish-brown (10YR 6/2) on both fresh and weathered surfaces, medium to thick bedded, Fusulinids; interbedded with fine grained sandstones and calcsiltites, pale yellowish-orange (10YR 8/6) to light brown (5YR 6/4) moderate reddish-orange (10YR 6/6) coloration.
(165.07 m)	9.14 m	Limestone, light olive gray (5Y 6/1) to pale yellowish-brown (10YR 6/2), medium to thick bedded; interbeds of thin, argillaceous, very pale orange (10YR 8/2) to pale yellowish-orange (10YR 8/6) limestone, sparse fusulinids, Bluff former.
(155.93 m)	29.90 m	Limestone, fossiliferous, fetid odor, medium bedded, light olive gray (5Y 6/1) on both fresh and weathered surfaces, interbedded with argillaceous limestone, pale yellowish-orange (10YR 8/6) on weathered surface, dark yellowish brown (10YR 4/2) on fresh fracture, thin bedded, platey, fossiliferous, Fusulinids throughout, (greater abundance toward top).
(126.03 m)	12.19 m	Limestone, light olive gray (5Y 6/1) like below, fusuline rich, bluff former, medium to thick bedded. Fusulinids: *Parafusulina communis.*
(113.84 m)	33.97 m	Limestone, fusuline coquina, interbedded with arenaceous limestones, light olive gray (5Y 6/1) to dark olive gray (5Y 4/1) on both fresh and weathered surfaces, interbeds contain large crinoid columnals as well as fusulinids, medium to thick bedded, thin interbeds. Fusulinids.

(79.87 m)	6.1 m	Sandstone, fine to coarse grained, calcareous quartz and oolites, very pale orange (10YR 8/2) to moderate orange pink (5YR 8/4) on the weathered surface, very pale orange on fresh fracture, thin to medium bedded, edges weather round.
(73.77 m)	1.22 m	Limestone, oolitic, dark yellowish-brown (10YR 6/2) to light olive gray (5Y 6/1) on both fresh and weathered surface, medium bedded, cross bedding, fetid odor on fracture.
(72.55 m)	7.92 m	Limestone, bioclastic, fusuline rich, medium bedded, yellowish gray (5Y 8/1) to light olive gray 95Y 6/1) on both fresh and weathered surfaces, breaks blocky. Fusulinids: Parafusulina communis.
(64.63 m)	3.05 m	Limestone, oolitic, pale yellowish brown (10YR 6/2) on weathered surface, dark yellowish-brown (10YR 6/2) oolites are fine to medium grain size, visible with naked eye.
(61.58 m)	6.7 m	Limestone, bioclastic, fossiliferous, shell and bryozoan fragments, rock fragments, quartz sand, thin bedded, breaks platey, pale yellowish brown (10YR 6/2) to light olive gray (5Y 6/1).
(54.88 m)	5.18 m	Limestone, skeletal, light olive gray (5Y 6/1) on both fresh and weathered surfaces, packstone fusuline rich, medium bedded, fetid odor on fresh fracture, fusuline rich horizons. Fusulinids: Pseudofusulina lativentra.

(49.7 m)	9.6 m	Limestone interbedded with quartz sandstone, limestone brownish-gray (5YR 4/1) to olive gray %y 4/1), medium bedded, Fusulinids. Sandstone: Grayish-orange pink (5YR 7/2) to very pale orange (10YR 8/2) on both fresh and weathered surfaces, calcareous, fine grained.
(39.8 m)	5.5 m	Limestone, argillaceous interbedded with very fine grained sandstones, limestone: skeletal micritic, light olive gray (5y 6/1), medium bedded, Fusulinids. Sandstone: calcareous, grayish-orange pink (5YR 7/2) to grayish orange (10YR 7/4). Fuslinids, crinoid columnals.
(34.3 m)	1.6 m	Limestone, skeletal-micritic, light olive gray (5Y 6/1) on both fresh and weathered surfaces, medium bedded, chert nodules and impure chert stringers, fusulinids in silicified portions (metasomatism). Fusulinids. (Unidentifiable)
(32.7 m)	5.8 m	Limestone, detrital-pelletic-skeletal, packstone, encrinite, light olive gray (5Y 6/1) on both fresh and weathered surface, thin to medium bedded, interbeds of fusuline coquinas. Fusulinids: *Schwagerina* sp..
(26.9 m)	7.9 m	Sandstone, interbedded with occassional argillaceous layers, fine grained, some coarse (10%) sand, calcareous, pinkish-gray (5YR 8/1) to white (N9) on weathered, very light gray (N8) to light gray (N7) on fresh, bedding weathers round on edges, medium bedded at bottom thinning toward top, bench former.

(19.0 m)	7.5 m	Limestone, argillaceous, interbedded with very fine grained sandstones, color similar to below, slope former.
(11.50 m)	6.5 m	Limestone, argillaceous, skeletal micritic, grayish orange (10YR 7/4) to light gray (N7), medium bedded, bench former, contains large crinoid columnals; fusuline rich interbeds are light gray (N7) to pale yellowish brown (10YR 6/2), thin to medium bedded. Fusulinids: Schwagerina sp.
(5.0 m)	5.0m	Limestone, detrital-skeletal, packstone, crinoid rich beds interlayered with fusuline coquinas encrinite beds are medium light gray (N6) to light olive gray (5Y 6/.1), medium bedded; fusuline rich layers are yellowish-gray (5Y 8/1), thin bedded. Fusulinids: Schwagerina youngquisti, Schwagerina modica.
	12.5 m	Limestone, argillaceous, skeletal, very light gray (N8) to yellowish gray (5Y 7/2) on weathered, dark yellowish brown (10YR 4/2) off fresh, thin bedded breaks platey, fauna exceptionally preserved at base. Bryozoa: Reticulate (Polypora) Anastamosing (Sulcoretepara). spined Brachiopods,

Section 7

Permian Loray Formation

Age: Late Leonardian to Early Guadalupian

Location: lat. 39* 55.25'N., long. 115* 15.5'W.

Described: Top to Bottom

Stratigraphic Relationship: Comformably overlies the Pequop formation; believed to be conformable with overlying Kaibab

Total Thickness: 718.87 m (2358.5 feet)

Cumulative Thickness	Unit Thickness	Unit Description
(718.87 m)	43.23 m	Limestone, light olive gray (5Y 6/1) to light brownish gray (5YR 6/1) thin to medium bedded, interbedded with very pale orange (10YR 8/2) to grayish orange (10YR 7/4) calcsiltites.
(675.64 m)	41.79 m	Covered, float suggests predominance of fine grained sandstone, calcareous, pale yellowish-orange (10YR 8/6) to pale reddish-brown (10R 5/4).
(633.85 m)	16.09 m	Limestone, light olive gray (5Y 6/1) to light brownish-gray (5YR 6/1), medium bedded interbedded with thin bedded calcsiltites. *Nuculana* sp.
(617.76 m)	14.71 m	Covered, same as below.
(603.05 m)	19.03 m	Limestone, light olive gray (5Y 6/1) to olive gray (5Y 4/1) on both weathered and fresh fracture, medium bedded interbedded with calcsiltites. *Amphiscapha* sp., *Nuculana* sp.

(584.02 m)	16.78 m	Covered, calcsiltites and fine grained sandstones, very light gray (N8) to light olive gray (5Y 6/1) coloration.
(567.24 m)	15.4 m	Mudstones and calcsiltites, very light gray (N8) to light olive gray on weathered, darker on fresh, thin to medium bedded, siltstones very fissile, slope former.
(551.84 m)	26.7 m	Calcsiltites, and fine grained sandstones light olive gray (5Y 6/1) to pinkish gray (5YR 8/1) to grayish-orange (10YR 7/4), thin bedded, slope former.
(525.14 m)	22.22 m	Siltstone (calcareous) and fine grained sandstone, pale yellowish-orange (10YR 6/6) to pale reddish-brown (10R 5/4), thin bedded; interbedded with bioclastic limestone, medium bedded, light olive gray (5Y 6/1). Nucula Montpelierensis.
(502.92 m)	18.36 m	Limestone, bioclastic, skeletal, light olive gray (5Y 6/1) to grayish-orange (10YR 7/4), medium bedded at top, interbedded in siltstones, Molluscan fauna. Amphiscapha sp., Edmondia sp., Belerophon fauna.
(484.56 m)	7.8 m	Calcsiltities and very fine grained sandstones, pale yellowish-orange (10YR 8/6) to pale reddish-brown (10R 5/4), thin bedded, platey.
(476.76 m)	13.73 m	Covered, float indicates thin bedded, argillaceous limestones, calcsiltites, and very fine grained sandstones.
(463.03 m)	23.73 m	Limestone, argillaceous, light olive gray (5Y 6/1), platey, thin to medium bedded, slope former.

(439.30 m)	16.6 m	Limestone, argillaceous, light olive gray (5Y 6/1) to olive gray (5Y 4/1), platey, interbedded with pale yellowish-orange (10YR 8/6), sandstones, very fine grained, calcareous.
(422.70 m)	8.25 m	Limestones and fine grained sandstones like below.
(414.45 m)	27.67 m	Limestone, light olive gray (5Y 6/1) on weathered and fresh surfaces, thin to medium bedded interbedded with grayish-orange (10YR 7/4) to yellowish gray (5Y 7/2), very fine grained sandstones, calcareous.
(386.78 m)	7.85 m	Limestone, light olive gray (5Y 6/1) to olive gray (5 Y 4/1) on both weathered and fresh surfaces, thin to medium bedded, molluscan fauna. Belerophon sp., Nuculana sp.
(378.93 m)	13.88 m	Partially covered, float consists of fine grained sandstones and clacsiltites, pale yellowish-orange (10YR 8/6) to pale reddish-brown (10R 5/4).
(365.05 m)	9.27 m	Limestone, fossiliferous, light olive gray (5Y 6/1) on weathered and fresh surfaces, thin to medium bedded, interbedded siltstones, grayish-orange pink (5YR 7/2), molluscan fauna. Amphiscapha fauna, Belerophon sp., Edmondia sp.
(355.78 m)	32.83 m	Limestone, argillaceous, light olive gray (5Y 6/1) to olive gray (5Y 4/1), thin bedded, platey, interbedded with sandy calcsiltites, very pale orange (10YR 8/2), ledge forming limestones, medium bedded, light brownish-gray (5YR 6/1).

(322.95 m)	19.47 m	Covered, saddle, float contains light olive gray (5Y 6/1), thin bedded limestone, and yellowish gray (5Y 8/1) siltstones and calcsiltites.
(303.48 m)	10.37 m	Mudstone, fine grained, intercalated with white disseminated silica, weathers moderate orange pink (5YR 8/4) against the very pale orange (10YR 8/2) surface of the mudstone (distinctive horizon).
(293.11 m)	12.08 m	Limestone, argillaceous interbedded with sandy calcsiltites, light olive gray (5Y 6/1) to grayish-orange (10YR 7/4), thin bedded, gastropod horizons associated with limestones.
(281.03 m)	18.45 m	Calcsiltites, dusky yellow (5Y 6/4) on both weathered and fresh surfaces, thin to medium bedded. *Plagioglypta* sp.
(262.58 m)	38.47 m	Covered, float indicates calcsiltites (yellowish gray (5Y 7/2)), fine grained sandstones, pale yellow to reddish-brown, and thin argillaceous limestone.
(224.11 m)	25.86 m	Siltstones and fine grained sandstones, calcareous, grayish-yellow (5Y 8/4) with intermittent pale reddish-brown (10R 5/4) spots, thin to medium bedded, platey.
(198.25 m)	1.44 m	Limestone, grayish-yellow (5Y 8/4) to yellowish-gray (5Y 7/2), argillaceos, thin bedded. *Gastropods.*
(196.81 m)	9.34 m	Calcsiltites and fine grained sandstones, gypsiferous siltstones, coarse grained quartz sand floating in silt matrix at top, grayish orange pink (5YR 7/2).

(187.47 m)	8.3 m	Calcsiltites and fine grained sandstones, pale yellowish orange (10YR 8/6) to pale reddish-brown (10R 5/4), thin to medium bedded, platey, slope former.
(179.17 m)	14.09 m	Siltstone, very pale orange (10YR 8/2) to yellowish-gray (5Y 8/1), thin bedded, platey, slope former.
(165.08 m)	3.28 m	Limestone, light olive gray (5Y 5/2) to medium dark gray (N7) on weathered, olive gray (5Y 4/1) on fresh surface, thin to medium bedded, fetid odor on fracture, abundant gastropod fauna.
(161.80 m)	18.05 m	Siltstones and fine grained sandstones, pale yellowish-orange (10YR 8/6) to pale reddish-brown (10R 5/4), platey.
(143.75 m)	15.58 m	Covered, available float consists of pale yellowish-orange (10YR 8/0), fine grained, silty sandstones and light olive gray (5y 6/1) calcsiltites.
(128.17 m)	16.49 m	Limestone, bioclastic, fossil hash, pinkish-gray (5YR 8/1) to light olive gray (5Y 6/1), thin to medium bedded, molluscan fauna horizons at bottom, beds at top intercalated with anhydrite layering (in fine grained limestone).
(111.68 m)	15.08 m	Sandstone, fine to medium quartz grains, pale yellowish-orange (10YR 8/6) to pale reddish-brown 910R 5/4), thin bedded, platey, slope former, some calcsiltite (low %).
(96.6 m)	39.0 m	Limestone (argillaceous), calcsiltites and fine grained sandstones, limestones: grayish-orange (10YR 7/4) to

		light olive gray (5Y 6/1) thin to medium bedded, sandstones: Pale yellowish-orange (10YR 8/6) with spots of pale reddish-brown (10R 5/4) to moderate reddish-brown (10R 4/6), minor outcrops, talus and slope forming.
(57.60 m)	12.44 m	Limestone, pale yellowish-brown (10YR 6/2) on weathered surface, olive gray (5Y 4/1) on fresh, medium bedded, interlayered with skeletal coquinas: grayish-orange (10YR 7/4) to pale yellowish-brown (10YR 6/2). Brachiopods, Lophophyllidium sp., Solitary Corals.
(45.16 m)	2.79 m	Limestone, biostrome, light olive gray (5Y 6/1) to brownish gray (5YR 4/1) on weathered surface, brownish-gray (5YR 4/1) on fresh, medium to thick bedded, reticulate bryozoans preserved in place.
(42.37 m)	42.37 m	Calcsiltites, and fine grained quartz sandstones, skeletal, yellowish-gray (5YR 7/2) to pale reddish-brown (10R 5/4), thin to medium bedded, platey, poor exposure, molluscan fauna. Gastropods in lower part.
Loray Fm		
Pequop Fm		
	6.88 m	Limestone, skeletal, bioclastic, grayish-orange (10YR 7/4) to pale yellowish-orange (10YR 8/6), medium bedded. Fusulinids, Gastropods?.
	13.98 m	Limestone, olive gray (5Y 4/1), medium bedded, resistant, interbedded with less resistant, platey calcsiltites and fine grained sandstones, grayish-orange pink (5YR 7/2) to pale red (5Y 6/2).

18.06 m	limestone, agillaceous, skeletal, yellowish-gray (5Y 7/2) to light gray (N7) to light olive gray (5Y 6/1), thin bedded platey, suboutcrop.
.91 m	Chert bed, white (N9) to light gray (N7) to light olive gray (5Y 6/1), thin bedded, platey, suboutcrop.
2.8 m	Limestone, skeletal fragments, light brownish-gray (5YR 6/1) to light olive gray (5Y 6/1), thin to medium bedded, breaks platey, argillaceous, slope former, small gastropods (near shore environment).

Section 8

Kaibab

Age: Guadalupian

Location: lat. 39* 48.5'N., long. 115* 15'W.

Description: Top to Bottom

Stratigraphic Relationship: Comformably overlies Loray Formation Conformable with overlying Pequop Formation

Total Thickness: 128.14 m (420 feet)

Cumulative Thickness	Unit Thickness	Unit Description
(128.14 m)	28.15 m	Dolomite, white (N0) to pinkish-gray (5YR 8/1), fine to medium grained texture, sucrosic, medium to thick bedded, associated with white chert nodules.
(99.99 m)	6.13 m	Dolomite, white (N9) to grayish orange (10YR 7/4), medium grained texture, sucrosic, associated with large chert nodules (20 cm diamenter), white.
(93.86 m)	9.45 m	Dolomite, grayish-orange (10YR 7/4) to very pale orange (10YR 8/2), sucrosic, fine to medium size quartz grains floating in matrix, medium bedded.
(84.41)	13.02 m	Dolomite, white to pinkish-gray (5YR 8/1) on both weathered and fresh, finely crystalline, no effervescence, resistant, dense, medium to thick bedded.
(62.09 m)	37.9 m	Covered, float indicates light olive gray limestone (5Y 6/1) and grayish-orange (10YR 7/4), slightly dolomitic limestone, thin to medium bedded.

(24.19 m)	11.25 m	Limestone, bioclastic, light gray (N7) to light olive gray (5Y 6/1), medium bedded, interbedded with ocassional calcsiltite, grayish-orange (10YR 7/4), thin bedded.
(12.94 m)	12.94 m	Limestone, skeletal, bioclastic, light olive gray (5Y 6/1) to pale yellowish-brown (10YR 6/2), thick to massive bedded, bluff former, chert nodules along bedding planes. Brachiopod: *Avonia* sp.

Section 9

Permian Plympton

Age: Guadalupian Age

Location: lat. 39* 48.25'N., long. 115* 15.45'W.

Description: Top to Bottom

Stratigraphic Relationship: Comformably overlies Kaibab Limestone, unconformably overlain by Tertiary volcanics

Total Thickness: 68.60 m (225 feet)

Cumulative Thickness	Unit Thickness	Unit Description
(68.60 m)	29.16 m	Dolomite and chert, dolomite: white (N9) to very pale orange (10YR 8/2), medium to thick bedded, chert ranges from white to medium gray in color, from bedded to nodular.
(39.44 m)	19.1 m	Dolomite and chert, alternating sequences of chert and dolomite, dolomite very similar to that described below, angular chert fragments in limestone suggest unstable conditions.
(20.34 m)	4.84 m	Dolomite, white (N9) to pale orange (10YR 8/2), medium to thick bedded, sucrosic, fine grained texture, upper beds contain 15 cm thick chert bedding and chert nodules, (White (N9)) to light gray (N7).
(15.5 m)	1.13 m	Dolomite and chert, interlayered chert and dolomite, same as below.
(14.37 m)	8.27 m	Dolomite, yellowish-gray (5Y 8/1) to very pale orange (10YR 8/2), sucrosic, fine grained texture, medium to thick bedded.

(6.1 m)	6.1 m	Massive chert beds, white (N9) to medium light gray (N6), 2 meter thick basal chert bed followed by alternating beds of dolomite (white, N9) to pale grayish-orange (10YR 7/4), and chert, medium bedded.

Appendix B

Microscopic identification of limestone constituents and carbonate classification

Field samples taken of limestone units characterizing the individual Formations were described from polished sections. The Leighton-Pendexter classification was used to describe and name the carbonate units. According to this classification scheme, limestones contain coarse particles, generally of sand and clay size (when lithified, micrite). The coarse particles include detrital and skeletal particles, pellets, lumps, and coated particles.

Terms used in the classification:

detrital	fragments derived from older limestones (i.e. terrigenous sediment and from intraclasts
skeletal partilces	whole or broken tests of organisms
pellets	fecal or pelloids or former intraclasts that have been comminuted and rounded to take on the appearance of fecal pellets

lumps	composite grains and include grape stones and oncolite
coated particles	ooids and pisolites

If more than one kind of particle is present in a limestone, each may be included in naming the rock. The order is in terms of relative amounts, with the more abundant kinds of particles cited first, with lesser amount following separated by a hyphen.

Example: limestone containing:

60% ooids

40% skeletal fragments

would be called a:

Oolitic-skeletal limestone

If the kind of skeletal material present in the rock can be identified, it can replace the term skeletal.

Limestones consisting of rigid framework builders, such as corals, bryozoa, and algae, are given a seperate category (See table on next page).

TEXTURAL CLASSIFICATION OF LIMESTONES

GRAIN TO MICRITE RATIO	% GRAINS	GRAIN TYPE					Organic Frame-Builders	No Organic Frame-Builders
		Detrital Grains	Skeletal Grains	Pellets	Lumps	Coated Grains		
		Detrital Ls.	Skeletal Ls.	Pellet Ls.	Lump Ls.	Oolitic Ls. Pisolitic Ls. Algal encr. Ls.	Coralline Ls. Algal Ls. Etc.	Caliche Travertine Tufa
9:1	90%							
		Detrital-Micritic Ls.	Skeletal-Micritic Ls.	Pellet-Micritic Ls.	Lump-Micritic Ls.	Oolitic - (Pisolitic-) etc. Micritic Ls.	Coralline-Micritic Ls. Agal-Micr. Ls. Etc.	
1:1	50%							
		Micritic-Detrital Ls.	Micritic-Skeletal Ls.	Micritic-Pellet Ls.	Micritic-Lump Ls.	Micritic-Oolitic (Pisolitic) ect. Ls.	Micritic-Coarralline Ls. Micritic-Agal Ls. etc.	
1:9	10%							
		← Micritic Limestone →						

Ely Limestone

Section 2

Note: Major Component first separated from minor components with hyphen.

Location Within Section	Classification Name	Additional Comments
322 m to 328 m	micritic-skeletal-intra limestone	pin-point solution cavaties, broken fragments comprise skeletal material
314 m to 316 m	skeletal limestone	whole and broken shell fragments
290 m to 295 m	skeletal-micritic limestone	broken shell material
267 m to 270 m	skeletal-micritic limestone	broken shell fragments in fine grained matrix
251 m to 253 m	micritic limestone	homogeneously fine grained
194.5 m to 200 m	detrital-skeletal limestone	skeletal fragments <3%, coarse grained quartz sand floating in fine matrix
190.5 m to 194.5	micritic-skeletal-detrital limestone	
184.5 m to 186.5	micritic-skeletal-detrital limestone	laminations and graded bedding
181.5 m to 183 m	pelletic-detrital, limestone (very little micrite) (Shelf Margin Skeletal sand)	detrital is coarse grained quartz, all constituents well sorted and coarse grained size
125 m to 130 m	skeletal-micritic limestone	whole and broken shell fragments

120 m to 122 m	detrital limestone	coarse grained chert and quartz detritus
115 m to 117 m	skeletal-detrital-pelletic limestone	whole and broken fragments, very fine pebble size matrix constituents >50%
104.5 m to 103 m	skeletal-micritic limestone	
100 m to 101 m	micritic-skeletal limestone	whole and broken bryozoa remnants
98 m to 100 m	skeletal-detrital-pelletic limestone	echinoid spines and medium to coarse grained chert and quartz sand
97 m to 98 m	pelletoid-oolitic limestone	constituents well sorted, .5 mm to 1 mm in diameter.
92 m to 97 m	skeletal-micritic limestone	broken shell fragments
76 m to 80 m	skeletal-micritic limestone	broken bryozoa and shell fragments
50 m to 55 m	detrital-pelletic-micritic limestone	
0 m to 10 m	micritic-skeletal limestone	

Riepe Spring Limestone

Section 4

Location Within Section	Classification Name	Additional Comments
40.5 m to 41 m	skeletal-micritic limestone	crinoid columnals and fusulinids
39.5 m to 40 m	skeletal-micritic limestone	broken shell fragments
30 m to 32 m	micritic limestone	
22 m to 23 m	skeletal-detrital-micritic limestone	whole and broken shell fragments
5 m to 6 m	skeletal-micritic limestone	whole and broken shell fragments

Riepetown Formation

Section 5

Location Within Section	Classification Name	Additional Comments
350 m to 352 m	skeletal limestone	crinoid columnals comprise greater percentage of skeletal material, lesser amounts of fusulinids and bryozoans
287 m to 289 m	micritic-detrital limestone	fine to medium grained quartz detritus
279 m to 280 m	micritic limestone	
271 m to 271.5 m	micritic-skeletal limestone	fusulinids floating in fine grained matrix
245 m to 247 m	micritic-skeletal-detrital limestone	fusulinids and crinoid columnals make up skeletal portion 20%, intraclasts and fine grained quartz sand make up detritus portion
164 m to 166 m	micritic-detrital limestone	
136 m to 137 m	micritic-skeletal limestone	crinoid columnals and shell fragments crinoid columnals and fusulinids
68 m to 69 m	micritic limestone	
27 m to 27.5 m	micritic-skeletal limestone	shell fragments and crinoids
0 m to 1.5 m	micritic-skeletal limestone	fusulinids

Pequop Formation

Section 6

Location Within Section	Classification Name	Additional Comments
358 m to 365 m	skeletal-micritic limestone	skeletal particles >4 mm, fusulinids and molluscan
326 m to 344 m	micritic-skeletal limestone	fine grained limestone with occassional broken skeletal fragments
265 m to 283 m	skeletal limestone	broken skeletal fragments
184 m to 187 m	skeletal-detrital limestone	fusulinids and medium size quartz sand
126 m to 156 m	micritic-skeletal limestone	skeletal constituent mainly fusulinids and shell fragments <10%
108 m to 110 m	micritic-skeletal limestone	fusulinids comprise about 30%
94 m to 97 m	skeletal-oolitic-detrital limestone	fusulinids: 5 mm, oolites and detrital .3 mm to 1 mm and comprise 50% of rock
72.5 m to 74 m	oolitic-pelletoid limestone	cross bedded, medium grained
68 m to 70 m	skeletal limestone	skeletal constituent is fusulinids
61.5 m to 64.5 m	oolitic-limestone	oolites are medium to coarse sand size
55 m to 61.5 m	skeletal-pelletic limestone	shell and bryozoan fragments, quartz sand
50 m to 51 m	skeletal micritic limestone	fusulinids comprise >50% of the rock

37 m to 40 m	ovoid-skeletal limestone	skeletal particles are fusulinids and broken crinoid columnals
27 m to 32 m	skeletal-pelloid-intra limestone	skeletal constituents are mostly fusulinids
7 m to 9.5 m	detrital-oolitic limestone	intraclasts (1 mm) and fine to medium quartz sand comprise >90% of rock
0 m to 2 m	skeletal-detrital limestone	crinoid columnals, fusulinids, bryozoan fragments in fine grained quartz matrix