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Contents

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Paleoecology of the Guilmette Formation in Eastern Nevada and Western Utah*

ROGER D. HOGGAN
Ricks College, Rexburg, Idaho

ABSTRACT.—The Devonian Guilmette Formation in eastern Nevada and western Utah consists of limestone, dolomite, and sandstone deposited in a shallow north-south trending miogeosyncline which contained two separate basins of accumulation. Locally, high-energy conditions due to a fluctuating sea level and varied bottom topography allowed massive stromatoporoids, algal mats, and algal mounds to develop. At other times lower energy or deeper water conditions were hospitable for prolific brachiopod accumulations. Sandstone deposition in the upper part of the Guilmette was probably derived from cratonic sources to the east. Massive carbonate buildups in the Guilmette are not reefs as referred to by some workers but are carbonate bank deposits. The fossils present are similar to those found in the Devonian of Australia and Alberta but do not reflect the same reef facies. On the basis of conodont occurrences, the upper Guilmette is in the upper "gigas" conodont zone, the middle portion is in the middle "dubia" conodont zone, and the lower Guilmette is in the *Stringocephalus* brachiopod zone.

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*A dissertation presented to the Department of Geology, Brigham Young University, in partial fulfillment of the requirements for the degree Doctor of Philosophy, August 1971. Dissertation chairman, Morris S. Petersen.

INTRODUCTION

Location and Geologic Setting

The Guilmette Formation has been interpreted in the past in terms of reefs and reef environments. Previous workers who have studied the Guilmette Formation have usually obtained some background in the Devonian reef complexes of Alberta and attempted to project similar environments southward into western United States. The purpose of this study was to determine whether reefs and reef environments exist in the Guilmette and what similarities, if any, the Guilmette has with the Devonian of Alberta and Australia.

Reef terminology, as applied to the Guilmette, has entered the literature primarily due to Reso's work in the Pahranagat Range of southeastern Nevada (Reso, 1959, p. 1661; 1963, p. 903). Reso reported a "reef" on the east slopes of Mount Irish associated with off-reef facies. He interpreted the lower units in the Guilmette in the Pahranagat Range to be equivalent to the Beaverhill Lake Formation and the upper units to be equivalent in age and depositional environment to the Cook Lake biostromal shoal foundation upon which the Leduc reef growth developed. Carbonate buildups in the lower part of the upper Guilmette were considered by Reso to be correlative with the Leduc reef. My conclusions are that the carbonate buildups in the Guilmette are not related, except possibly in age, to the reef facies of Alberta. Lowenstam (1950) defined reefs in terms of frame-building organisms which erect rigid topographic structures on the sea floor. The Guilmette does not contain reefs, according to this definition.

Fossils that are present in the Guilmette Formation are characteristic of Devonian rocks in other parts of the world. Many of the Guilmette stromatoporoids, brachiopods, foraminifera, conodonts, and algae have been reported from western Australia (Playford and Lowry, 1966), western Alberta (Fischbuch, 1968; Leavitt, 1968; Stearn, 1963; and others), and Belgium (Lecompte, 1968).

An energy index applied to the Guilmette indicates a fluctuating sea level in the miogeosyncline during Guilmette time. Generally the occurrence of high-energy organisms such as massive stromatoporoids and tabulate corals corresponds to high-energy levels in the energy index. Lower-energy organisms such as brachiopods, tetracorals, *Amphipora,* and bulbous stromatoporoids correlate fairly well with lower-energy levels in the index.

During the summers of 1969 and 1970 while employed by a petroleum company in eastern Nevada, the writer measured over twenty sections in the South Egan Range, Snake Range, Schell Creek Range, Grant Range, White Pine Range, and Douglas Hills in the Guilmette Formation. These sections totaled over 45,000 feet of sediments. Even though detailed information on the sections was not made available, field observations have greatly contributed to the writer's knowledge of the formation. In addition, eight sections that are used in this paper as representative of the Guilmette Formation were measured and studied. The incorporated sections include a partial section 765 feet thick, measured in the Pequop Mountains north of Interstate Highway

I-80, approximately 20 miles east of Wells, Elko County, Nevada; a complete section 2,115 feet thick in the Leppy Range north of Wendover, Utah-Nevada; a partial section 300 feet thick in the Confusion Range, north of Highway 50, Millard County, Utah; a partial section 975 feet thick in the south end of the Snake Range, Lincoln County, Nevada; two partial sections 1,100 feet and 143 feet thick in the Douglas Hills west of Lund, White Pine County, Nevada; a complete section 1,360 feet thick in the Egan Range at Sunnyside, Nye, and Lincoln counties, Nevada; and a partial section 905 feet thick in the Pahranagat Range south of Highway 25, Lincoln County, Nevada, as shown on Text-figure 1. In all, over 50,000 feet of the Guilmette Formation were measured and studied to form the basis of this study.

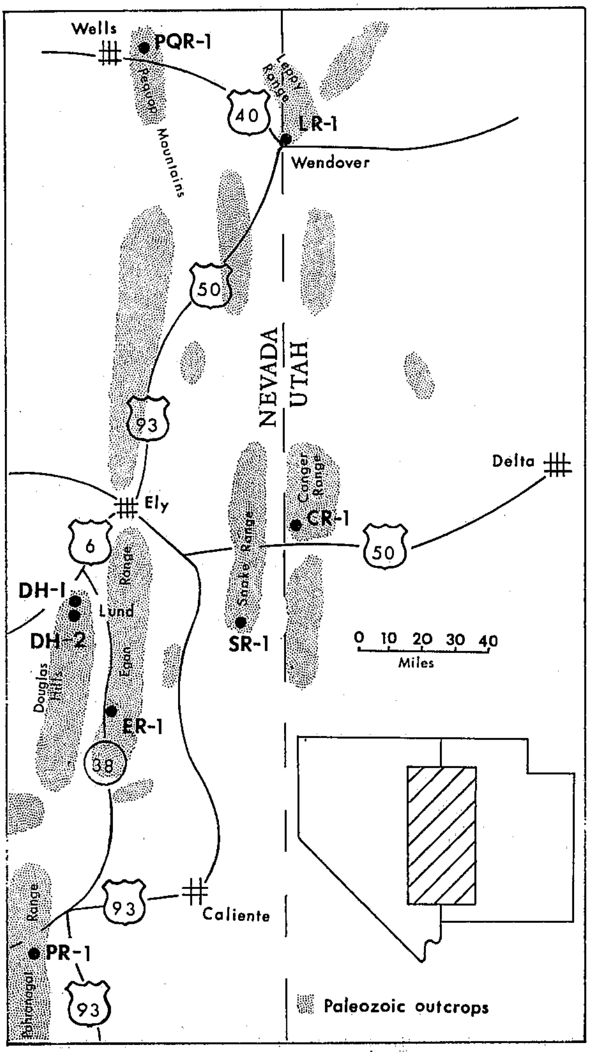
Guilmette Formation represents the marine sediments deposited in the miogeosyncline during part of the Middle and Upper Devonian epochs. The lower part of the formation is included in the Upper Givetian *Stringocephalus* brachiopod zone according to Boucot, Johnson, and Struve (1966, p. 1361). *Manticoceras,* the world wide indicator of Frasnian Age, has been collected from the top of the Guilmette in the Confusion Range by Hose (1966, p. B40). Guilmette strata are correlated with the Devil's Gate Limestone near Eureka, Nevada; Lost Burrow Formation in southern California; Arrow Canyon Limestone and Moapa Formation in southeastern Nevada; Sultan Limestone in southwestern Nevada; Silverhorn Dolomite in the Pioche District, Nevada; Bluebell Dolomite in central Utah; Hyrum Dolomite in northern Utah; and the Jefferson Group and Three Forks Formation of Idaho, Wyoming, and Montana (Poole et al., 1968, p. 852-55; Sandberg and Mapel, 1968, p. 846-47) (Text-fig. 4).

The Guilmette conformably overlies the Middle Devonian Simonson Dolomite in the study area and is distinguished from it on the basis of the first occurrence of limestone: the Guilmette is limestone at the base, and the Simonson is entirely dolomitic in lithology. The overlying formations in the area include either the West Range Limestone or the Pilot Shale, both of which are considered Upper Devonian (Fammenian) in age. In west central Utah, Mississippian-age rocks lie unconformably in the Guilmette.

Previous Work

In his early work of 1870 in the Great Basin, Hague called all Devonian carbonate sequences Nevada Limestone. Since then much stratigraphic work has been done with subsequent subdivisions of the Devonian carbonates resulting. The Guilmette Formation was designated by Nolan (1935, p. 20) for outcrops in Guilmette Gulch, Gold Hill region, where the formation consists of dolomite with some thick limestone beds and several lenticular siltstones. "Tubular" corals were noted in the 80 to 1,200 feet thickness measured in the area, but no environmental interpretation was made.

Westgate and Knopf (1932, p. 18) divided the Guilmette into the Silverhorn Dolomite and West Range Limestone in their study of the Pioche District. Merriam (1940, p. 39-40) subdivided the formation into zones A, B, and C at Dutch John Mountain on the basis of fossil assemblages of brachiopods and corals. Cooper (1943, p. 1729-94) correlated the Devonian formations of North America on the basis of *Stringocephalus* noting its occurrence near the base of the Guilmette in the Great Basin. Boucot, Johnson, and Struve (1966, p. 1361) have refined Cooper's work to include world-



TEXT-FIGURE 1.—Index map of Guilmette Formation study area with reference section location.

wide correlation and have given some information on the environmental occurrences of *Stringocephalus.*

Bissell (1955, p. 1634) related the Guilmette Formation to the paleotectonics of the Great Basin and urged the use of the term Guilmette Formation instead of the host of other terms used. Later Roberts (1956, p. 1781) proposed the term Sultan Limestone in southern Nevada; and Nolan, Merriam, and Williams (1956) used Nevada Formation and Devil's Gate Limestone as Guilmette equivalents in the Eureka District, Nevada.

Petersen (1956, p. 14-18) offered some interpretation for the environment of deposition of the formation in central Utah. Interpretations or detailed analyses of the faunal associations or paleoecological relationships were not discussed in his paper.

Langenheim, Hill, and Waines (1960, p. 63-71) described the Guilmette in the Ely area at the same time that Kellogg (1960, p. 192) reported on the Guilmette in the South Egan Range. Tschanz (1960, p. 198-208) described the Guilmette in Lincoln County, Nevada, but none of these workers offered any suggestion concerning the environment of deposition of the Guilmette in eastern Nevada.

Reso (1959, p. 1661; 1963, p. 909-10) discussed "reefs" in the Pahranagat Range of southeastern Nevada and offered some environmental interpretations. He believed the lower units of the Guilmette in the Pahranagat Range to be equivalent to the Beaverhill Lake Formation in Alberta. Upper units of the lower Guilmette were considered to be equivalent in age and environment of deposition to the Cook Lake biostromal shoal foundation upon which the Leduc reef growth developed. Carbonate buildups in the lower part of the upper Guilmette were considered by Reso to be correlative with the Leduc reef. With the prospect of petroleum reserves in the Great Basin, geologists sampled intensely and studied the nature of the reef buildups, but their findings were not published (Reso, pers. comm., 1970). Stanton (pers. comm., 1970) worked with the reef buildups for Shell Development Research in the 1960s and attempted to show a relationship of the buildups of the Guilmette to the Leduc reefs of central Alberta, Canada. Stanton believes there is little similarity in detail between the carbonate buildups in the Pahranagats and the Leduc reefs of Alberta with which he is familiar. Stanton (1963, p. 467) and Waines (1962, p. 283) have described microfossils from the Guilmette equivalents in southern Nevada. Waines (1964, p. 230) described stromatoporoid faunas of the Guilmette and other Devonian formations in Nevada. Nadjmabadi (1967) studied a measured section of the Guilmette Formation at Wendover, Utah, and described the fossil occurrences and paleoenvironment for the formation in that area.

Boucot, Johnson, and Talent (1968, p. 1239-54) have done much with the biostratigraphy of the Guilmette using brachiopods. Johnson (pers. comm., 1971) is presently working on the Givetian-Frasnian boundary in Nevada using brachiopod zonation. Conodont zonation is also useful for regional correlation as shown by Clark and Ethington (1967).

Paleoecological studies have been made on the Devonian System in many areas. Lecompte (1968) discussed the sedimentary history of the Devonian rocks in Belgium and northern France. Several authors including Leavitt (1968), Fischbuch (1968), and Dolphin and Klovan (1970), have reconstructed depositional histories and paleoecological conditions for the Devonian present in Alberta. Playford and Lowry (1966) described and reconstructed the development of the Devonian reef complexes of western Australia. Although some paleoecological studies have been made in the Devonian rocks of the eastern United States, few paleoecological studies have been made in the West.

Methods of Study

Field methods consisted of measuring and describing representative sections in the study area. Samples were collected at five-foot intervals or at lithologic breaks in each section, with extra collecting in highly fossiliferous units. Stratigraphic columns were constructed for each section.

Laboratory methods included making 550 thin sections and 150 polished sections of rock samples collected in the field for petrographic analysis. A petrographic checklist, which included color, form (i.e., homogeneous, laminated, etc.), lithology, grain size, total rock composition (including percentages of allochems and matrix), energy index, and fossil content, was used in analyzing the prepared specimens.

The energy index used was similar to the index proposed by Plumley, Risley, Graves, and Kaley (1962, p. 85-107) with slight modifications. The table below illustrates the classification used.

	Energy	% Clasts	Size of clasts in mm.
V	Strongly agitated	>75%	detrital quartz gravel or 2mm.
IV	Moderately agitated	50-75%	.25 to 2 mm.
III	Slightly agitated	26-50%	.06 to .25 mm.
II	Intermittently agitated	10-25%	.06 to .25 mm. 75% matrix with clasts from .25 to 2 mm. or inter-bedded; fine coarse material
I	Quiet water	<10%	.06 mm. to mostly silt to clay size

The index is primarily designed for carbonate clastic particles, but detrital quartz was used as an indicator of the highest category, assuming quartz sandstones were deposited in high-energy conditions. In highly fossiliferous units containing coarse carbonate particles, the size of the matrix particles was used to determine the appropriate energy category. Although the categorization of the samples tends to be subjective, a trend in energy fluctuations can be determined.

Approximately 600 samples were leached in 10 percent acetic or 20 percent monochloroacetic acid solutions to recover conodonts. The residues were further concentrated by filtering through tetrabromoethane. The conodont fossils of each sample were classified, related to the stratigraphic column, and photographed. Thin sections were also photographed.

Acknowledgments

I would like to thank Dr. Morris S. Petersen for serving as chairman of my committee and for his constant assistance and encouragement. Drs. Harold J. Bissell and J. K. Rigby are acknowledged for serving on my committee.

Mr. Jeffrey R. Orgill and my brother, Grant Hoggan, were most helpful with their assistance in the fieldwork as was Mr. Orgill with his assistance and constructive criticism during the writing of this paper.

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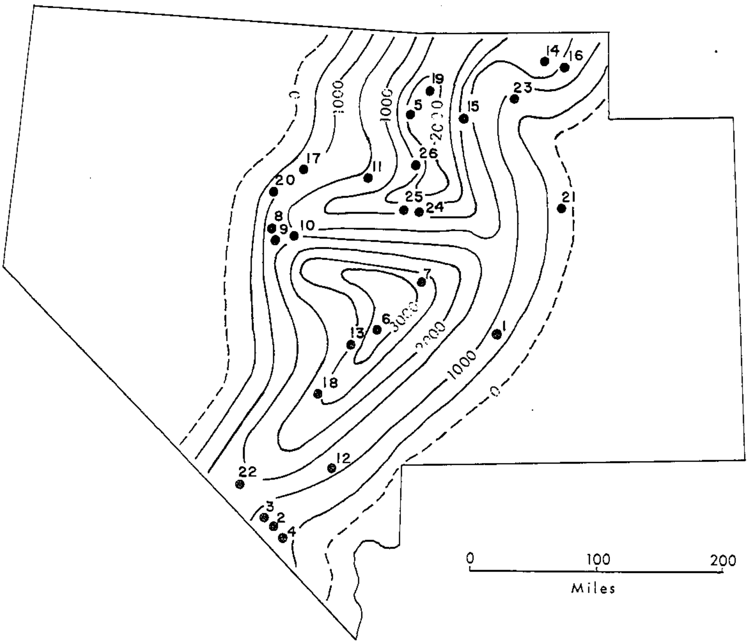

TEXT-FIGURE 2.—Isopach map of Guilmette Formation and equivalent units.

The field study was aided financially by an NDEA (Title IV) fellowship. Transportation for the fieldwork was furnished by Sun Oil Company during the summer of 1970.

SEDIMENTATION

Petrology

The following measured sections illustrate the dominant lithologies present in the Guilmette Formation. (See Appendix for detailed sections.) PQR-1 was measured at the north end of the Pequop Mountains approximately 500 yards north of Interstate Highway I-80 (Text-fig. 1). The Pequop Mountains section is 765 feet thick and is composed predominantly of limestone. The limestone units form resistant ledges or massive cliffs. Limestone ledges two to three feet thick in the lower 600 feet of the section are made up of fossiliferous fine-grained limestones or fine-grained pelletal limestones with pellets from 0.1 to 0.5 mm in diameter. Stromatoporoids, tetracorals, foraminifera, and calcispheres are present in these ledges.

A massive cliff 165 feet thick forms the upper part of the section. The cliff is formed by bedded limestones containing fine-grained pellet clasts ranging in size from .25 to 1 mm. The pellets appear to be fecal pellets or mud lumps. Fossils are rare or not apparent in the massive cliff unit. Occurring near the top, however, are tetracorals, brachiopods, crinoids, foraminifera, and calcispheres.

Dolomite units form slopes. These laminated microcrystalline or fine crystalline dolomites are present in the middle of the section. Many of the covered slopes in the lower 500 feet of the section are probably produced by non-resistant dolomite.

Thin sandstone units approximately 5 feet thick are present in the upper 400 feet. The sandstones are composed of buff colored, fine- to medium-sized, rounded, well-sorted, quartz clasts. Cross-bedding is unimodal with 6-inch sets. No directional readings were available.

LR-1 was measured in the Leppy Range approximately two miles north of Wendover, Utah (Text-fig. 1). Limestone units constitute 90 percent of the rocks in the section and appear to be much darker than the limestone observed in the other sections studied. Higher percentages of organic material account for the darker coloration in these strata. Thin- to thick-bedded, fine- to coarse-grained limestones are stromatolitic in the lower part of the section. Lenticular algal mounds up to three feet thick are present in some of the stromatolitic units (Pl. 1, figs. 3, 4). Many limestone units in the lower part are highly fossiliferous with tetracorals, brachiopods, and gastropods. Limestones in the upper part of the section are thin- to medium-bedded, fine-grained pelletal units consisting of stromatoporoids, tetracorals, brachiopods, gastropods, crinoids, bivalves, and shell debris (Pl. 5, fig. 5).

Dolomite is present primarily in the lower part of the section as laminated to thin-bedded slope-forming units. Often the dolomites occur as microcrystalline stromatolitic units interbedded with fine-grained limestones. Brecciated, laminated dolomite 15 feet thick occurs approximately 770 feet from the base of the section (Pl. 1, fig. 6).

Sandstones and sandy limestones up to 25 feet thick are composed of fine, rounded, well-sorted quartz grains similar to those in the Pequops. No cross-bedding was observed. A 25-foot sandy unit near the top of the section contained ripple marks which indicated a northwest-southwest trend for the current direction (Pl. 1, fig. 5).

SR-1 was measured at the south end of the Snake Range approximately 20 miles south of Wheeler Peak near Shoshone, Nevada (Text-fig. 1). Limestone predominates in the lower part of the section as massive brecciated fine-grained, pelletal units. The beds appear to be collapse breccia cemented with sparry calcite. Approximately 750 feet from the base a thick cliff-forming unit containing bedded chert and silicified stromatoporoids is present. Overlying this unit a slope-forming, highly fossiliferous, thin-bedded limestone containing a prolific brachiopod fauna occurs. Near the top of the section, a cliff of thick-bedded, fine- to coarse-grained limestone containing stromatoporoids and tetracorals apparently is bound together with silicified corals. A unit

EXPLANATION OF PLATE 1

SEDIMENTARY STRUCTURES AND FIELD VIEWS

Fig. 1.—Guilmette Formation exposed in Pahranagat Range south of Highway 25, Lincoln County, Nevada.
Fig. 2.—Massive stromatoporoid exposed at 820 feet, section PR-1.
Fig. 3.—Algal mound exposed at 587 feet, section LR-1.
Fig. 4.—Algal mound exposed at 528 feet, section LR-1.
Fig. 5.—Sandstone unit showing ripple marks at 1,805 feet, section LR-1.
Fig. 6.—Collapse breccia present at 772 feet, section LR-1.

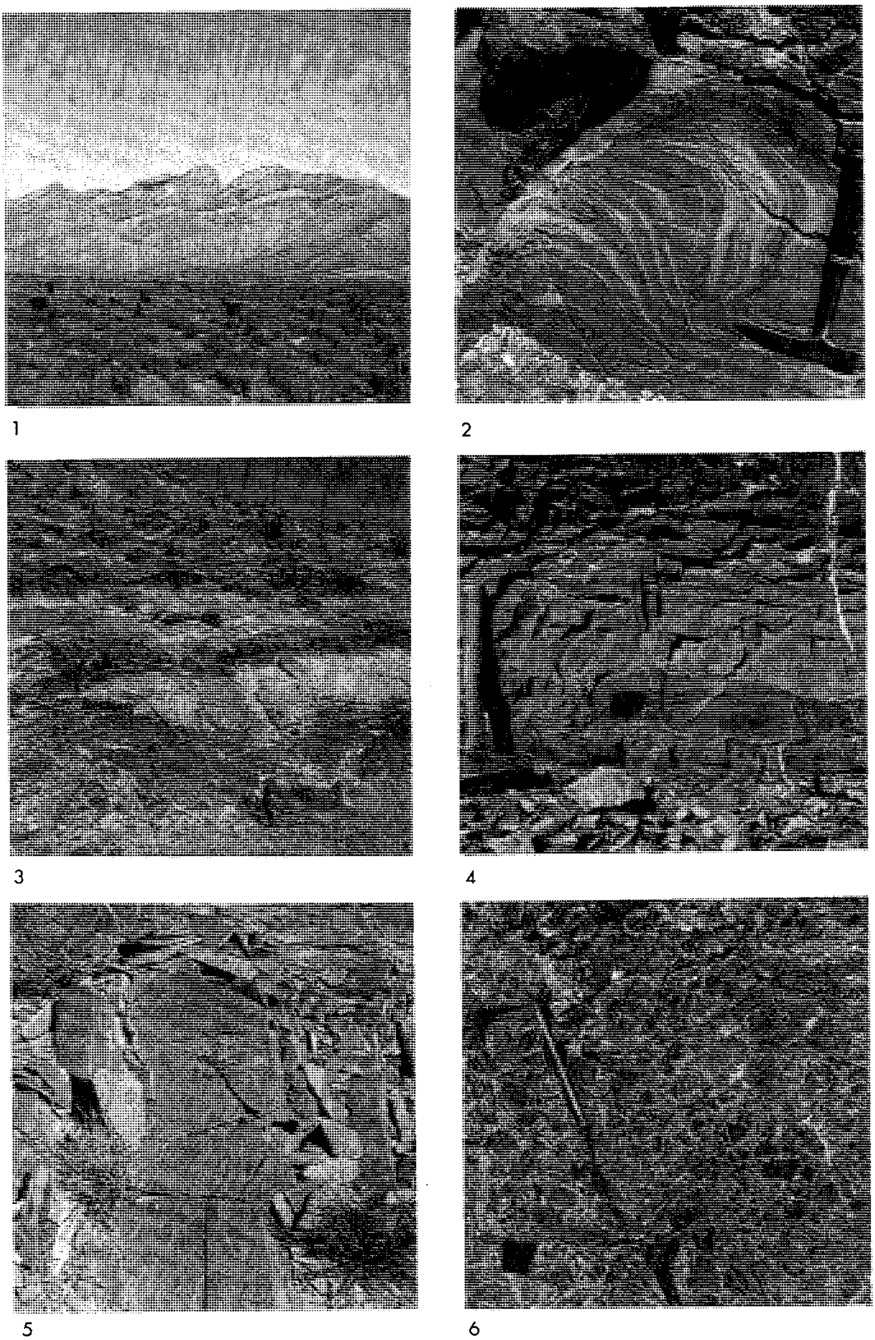

PLATE 1

of platy dolomicrite is present at the top. Two well-sorted five-foot sandstone units composed of fine, angular to subangular quartz grains are present in the upper part of the section, but no current directions were available.

Section DH-1, 1,100 feet thick, was measured approximately five miles west of Lund, Nevada, at the north end of the Douglas Hills (Text-fig. 1). Limestone units form massive cliffs throughout most of the section. Thin-bedded limestone and dolomite units form slopes. Limestone composition ranges from fine- to coarse-grained pelletal units to fine-grained highly fossiliferous units. Several limestone units contain stromatoporoids, brachiopods, and algae. A thin-bedded fossiliferous limestone unit 170 feet thick at approximately 600 feet above the base appears to be the same brachiopod unit described in section SR-1. At the top of the thin-bedded brachiopod unit abundant stromatoporoids, tabulate corals, tetracorals, gastropods, crinoids, and algae occur. Tetracorals, brachiopods, gastropods, crinoids, and algae are present in many of the overlying limestone units. At 995 feet a sandstone unit five feet thick was noted which contained fine, subangular, well-sorted quartz grains. This unit appeared similar to the sandstone units observed in section SR-1. Near the upper part of section DH-1 interbedded fine-grained limestones and dolomites are present which contain abundant calcispheres.

Section DH-2 was measured at the south end of the Douglas Hills (Pl. 2, fig. 1). This section was not illustrated in Text-figure 4 because of its small thickness. Massive cliff-forming units predominate in this 143-foot section consisting of fine- to coarse-grained pelletal limestones or fossiliferous fine-grained limestone. Light and dark gray mottled limestone is present in a unit 15 feet thick. Mottled limestone was observed in sections LR-1, DH-1, and ER-1 and appears to be the result of bioturbation or perhaps leaching of organic material from the light colored areas (Pl 2, fig. 6). Thin-section analysis revealed no difference in the grain size between the light and dark limestone. Thick fossiliferous units consisting of various forms of stromatoporoids make up the limestone cliffs at the top of the section.

Section ER-1, 1,360 feet thick, was measured at the south end of the Egan Range at Sunnyside, Nevada (Text-fig. 1). Limestone occurs as medium-bedded, fine- to coarse-grained pelletal units or thin-bedded, fine-grained fossiliferous units. Thick brecciated limestones near the base of the section resemle collapse breccias (Pl. 5, fig. 1). An oolitic limestone bed 5 feet thick is present at 290 feet. Ooids contained in the unit are 0.5 to 1 mm in diameter, and the concentric layering on each grain indicates periods of re-

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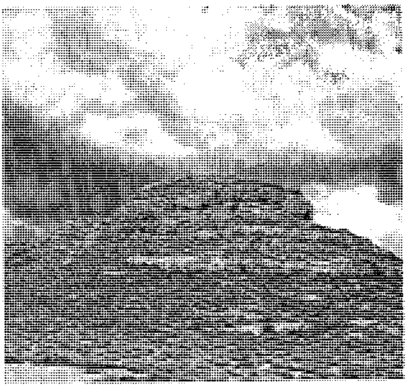
EXPLANATION OF PLATE 2

SEDIMENTARY STRUCTURES AND FIELD VIEWS

Fig. 1.—Section DH-2 showing stromatoporoid buildup near the top of the section.
Fig. 2.—Bulbous stromatoporoids in relief, associated with *Amphipora* at 132 feet, section DH-2.
Fig. 3.—Light and dark *Amphipora* rich units as a platform upon which massive stromatoporoids grew at 90 feet, section DH-2.
Fig. 4.—Stromatoporoid assemblage exposed in buildup at 132 feet, section DH-2.
Fig. 5.—Stromatoporoids and *Thamnopora* corals at 1,115 feet, section ER-1.
Fig. 6.—Mottled limestone present at 105 feet, section DH-2.



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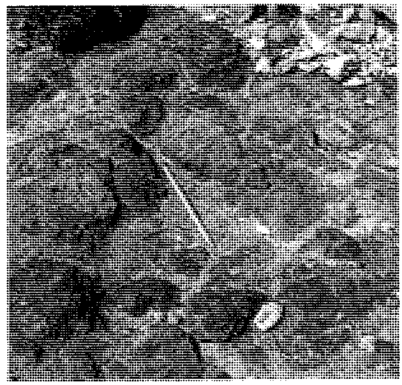

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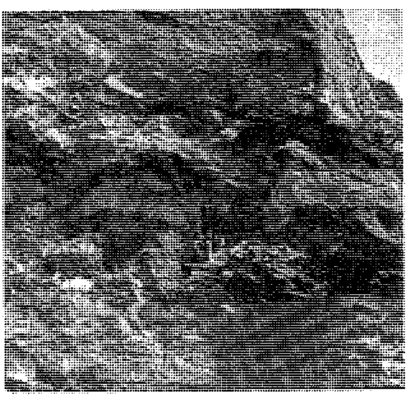

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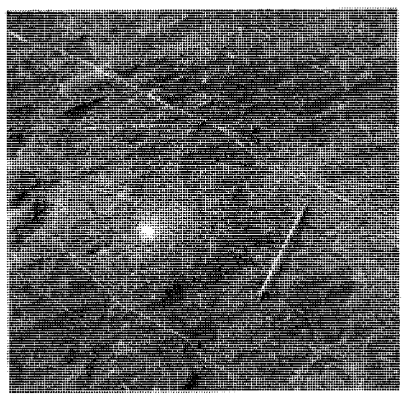

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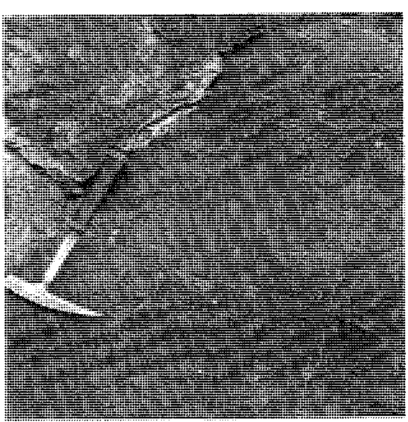

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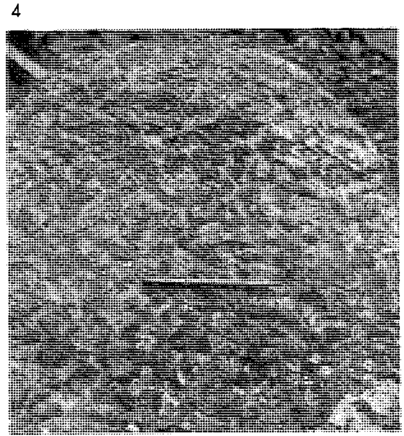

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PLATE 2

working (Pl. 5, fig. 4). The fossiliferous thin-bedded unit observed in ER-1 and DH-1 is present at approximately 850 feet and contains brachiopods, stromatoporoids, tabulate corals, tetracorals, gastropods, ostracodes, and algae.

Dolomite composes 50 percent of the rock types present in ER-1. Occurrences of dolomite range from laminated to thin-bedded dolomicrite, to fine-grained pelletal dolomite in the lower portion of the section. Massive units of coarse crystalline sucrosic dolomite predominate in the upper portion of the section and appear to be biostromes of bulbous stromatoporoids and *Amphipora*. Leaching of the fossils has resulted in abundant vuggy porosity in the units. No sandstone units were observed in ER-1.

Section PR-1, approximately 905 feet thick, was measured one mile south of Highway 25 in the Pahranagat Range southwest of Crystal Springs, Nevada (Text-fig. 1). Limestone forms massive cliffs in the upper part of the section and consists of fine- to coarse-grained fossiliferous units. Stromatoporoids, brachiopods, and gastropods are present in these units. Limestone lenses 3 to 4 feet thick occur 370 feet from the base in surrounding dolomite strata. The structureless lenses have sharp contacts with bedded dolomite on all sides.

Dolomite makes up to 60 percent of the total rock column in this section. Dark brown, coarse crystalline units with occasional "tiger striped" units of light and dark laminated, coarse crystalline dolomite predominate. Sandy dolomite is common in the lower part of the section.

Sandstone units up to 20 feet thick are common in the section. Generally they are buff colored units containing fine, well-rounded, poorly to well-sorted quartz and pellet clasts (Pl. 5, fig. 6). Bimodal cross-bedding is present in most of the sandstone units with sets from 1 to 2 feet thick.

MINERALOGY AND DIAGENESIS

Major Minerals

Calcite is by far the most abundant mineral component of the rocks in the study area, occurring as discrete material in microcrystalline limestones and as euhedral crystals in recrystallized finer carbonate sediments. Calcite also is present as cement in carbonate clastic rocks, vein fillings, concentric layers on oolites, and other coated grains and is associated with fossiliferous

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EXPLANATION OF PLATE 3

PHOTOMICROGRAPHS—STROMATOPOROIDS AND GUILMETTE FOSSILS

Fig. 1.—*Actinostroma* collected at 1,850 feet, section LR-1, vertical section, X7.

Fig. 2.—*Trupetostroma*(?) collected at 785 feet, section ER-1, vertical section, X7.

Fig. 3.—*Trupetostroma*(?) astrorhizal canals appear as elongate tubes, collected at 365 feet, section DH-1, vertical section, X8.

Fig. 4.—*Amphipora* oenostia illustrating central canal, collected at 90 feet, section DH-2, transverse section X5.

Fig. 5.—*Clathrocoilona* (?) illustrating association of algae and stromatoporoid organisms, collected at 1,290 feet, section ER-1, vertical section, X5.

Fig. 6.—*Anostylostroma,* shows tangled laminae and short pillar structure, collected at 132 feet, section DH-2, vertical section X5.

Fig. 7.—Algal filaments collected at 140 feet in algal mound structure, section LR-1, vertical section, X25.

Fig. 8.—*Alveolites* collected at 1,860 feet, section LR-1, vertical section, X5.

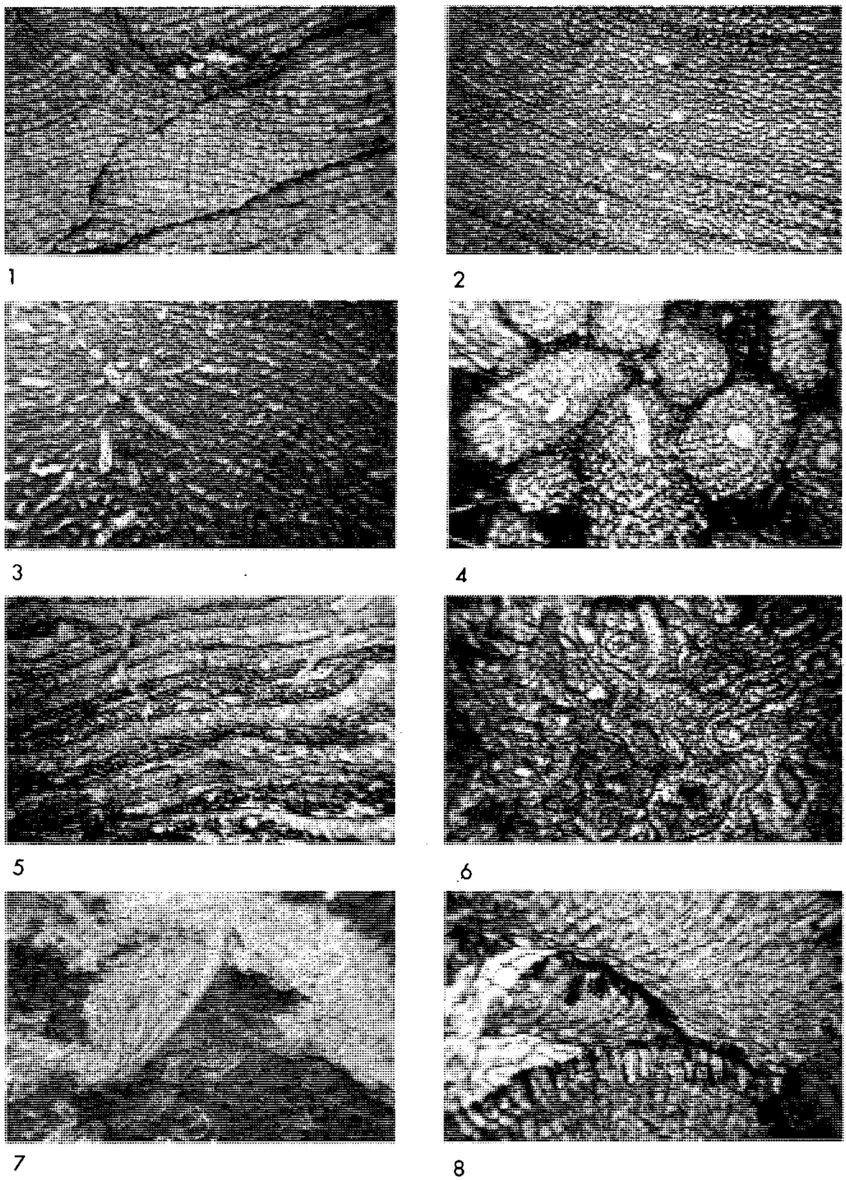

PLATE 3

sediments in the form of shells or skeletal material of brachiopods, bivalves, gastropods, and other organisms. Sparry calcite is present as recrystallized shell material, skeletal in-filling, or vein filling in fractured limestones.

Dolomite is present in many of the rocks as primary and secondary deposits. The author interprets the laminated microcrystalline dolomite as primary syngenetic deposit associated with precipitation of fine crystals from a hypersaline brine. Sanders and Friedman (1967, p. 268) state that primary dolomite deposits may form as a micrite or fine-grained crystals. They also mention that dolomitization of a fine-grained mud may result in a fine-grained dolostone that is almost indistinguishable from fine-grained primary dolomite precipitates (Sanders and Friedman, 1967, p. 298). The fine- to coarse-crystalline (sucrosic) dolomite appears to be a diagenetic secondary replacement of calcite. Commonly vuggy porosity is developed where stromatoporoids have been leached. In some instances the entire limestone units have been dolomitized with the exception of the stromatoporoids. Dolomite is present as euhedra in some of the dolomitized limestones (Pl. 5, fig. 2). Many of the algal stromatolitic units are composed of dolomite. According to Sanders and Friedman (1967, p. 315), stromatolitic dolomite may be formed in algal flat intertidal environments, but Playford and Cockbain (1969, p. 1008) observed stromatolites that formed at depths up to 135 feet. The writer interprets the occurrences of algal bodies in associated stromatolitic beds to indicate relatively shallow water, possibly an intertidal environment.

Quartz is present as fine to very fine sand grains in arenaceous limestones and dolomites and in quartz sandstones. The grains are commonly subrounded to rounded and appear to be fairly well sorted in most sections The mature nature of most of the sandstones indicates a possible reworking of the quartz clasts prior to deposition or intensive abrasion in an environment where rounding was accomplished rapidly. Pettijohn, Potter, and Siever (1965, p. 23) agree that these possibilities would produce the types of sand grains observed. The fine, angular grained sandstones in the Snake Range section do not represent the same amount of maturation as the others and possibly represent a different source.

EXPLANATION OF PLATE 4

PHOTOMICROGRAPHS—STROMATOPOROIDS AND GUILMETTE FOSSILS

Fig. 1.—*Hammatostroma* collected at 132 feet, section DH-2, vertical section, X5.

Fig. 2.—*Hammatostroma*, dark laminae illustrated arrested growth stages in massive growth form, collected at 98 feet, section DH-2, vertical section, X5.

Fig. 3.—*Stromatopora* with residual hydrocarbon material in galleries, collected at 80 feet, section DH-1, vertical section, X5.

Fig. 4.—*Hammatostroma* in tabular growth form associated with algae, collected at 775 feet, section ER-1, vertical section, X5.

Fig. 5.—*Hammatostroma* collected in bulbous growth form at 132 feet, section DH-2, vertical section, X5.

Fig. 6.—*Actinostroma* collected at 1,050 feet, section ER-1, vertical section, X5.

Fig. 7.—*Solenopora*(?) algae collected at 45 feet, section DH-2, transverse section, X25.

Fig. 8.—*Coenites* coral encrused with *Hermatostroma*(?) stromatoporoid, collected at 775 feet, section DH-1, transverse section of coral, vertical section of stromatoporoid, X5.

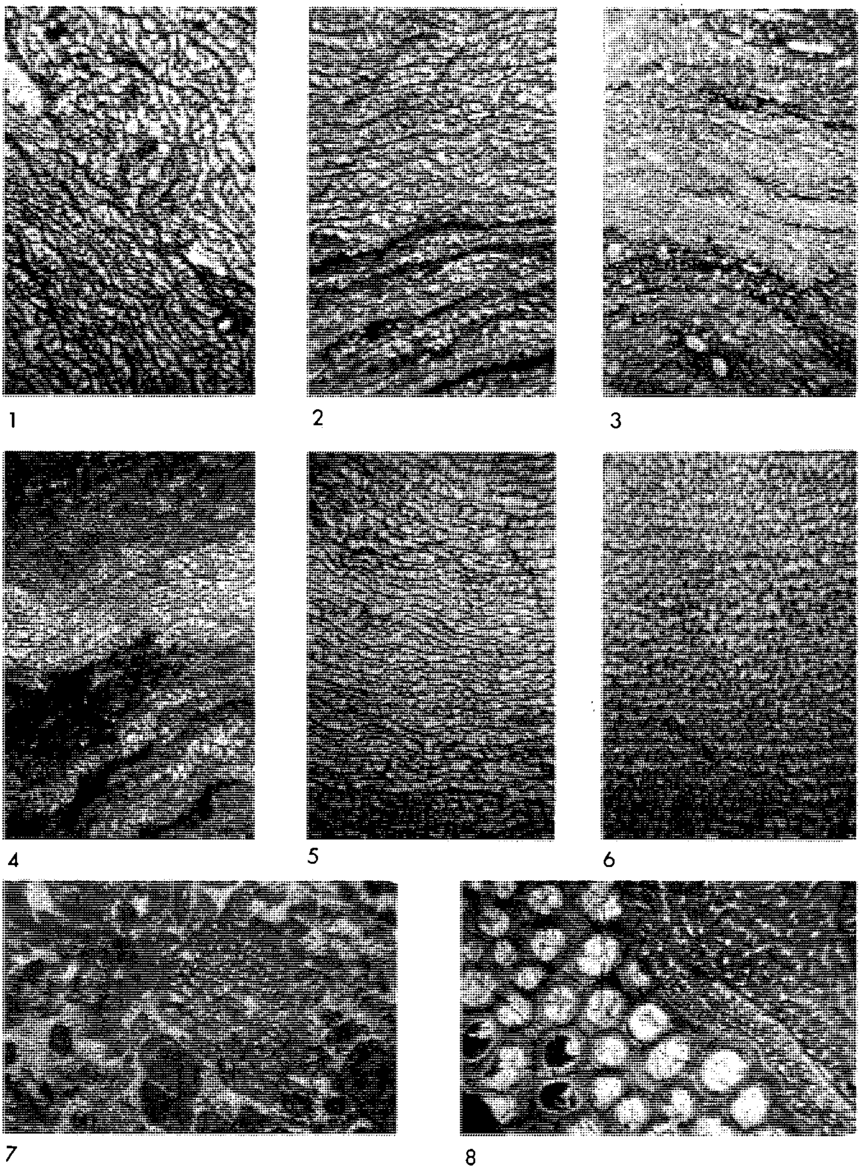

PLATE 4

		Northern Panamint Range California	Southern Spring Mountains Nevada	Arrow Canyon Range Nevada	Pioche District Nevada	Lone Mountain Devils Gate Nevada	Gold Hill District Utah	East Tintic Mountains Utah	Northern Wasatch Mountains Utah
Devonian	Frasnian	Lost Burrow	Sultan Limestone	Arrow Canyon Limestone Moapa Formation	Silverhorn Dolomite	Devils Gate Limestone	Guilmette Formation	Bluebell Dolomite	Hyrum Dolomite
	Givetian	Formation	Goodsprings Dolomite	Piute Formation	Simonson Dolomite	Nevada Formation	Simonson Dolomite		

TEXT-FIGURE 3.—Correlation chart of Guilmette Formation with equivalent units and underlying formations.

An unusual occurrence of quartz is present in most of the samples collected in the Snake Range section. Insoluble residues contain abundant doubly terminating quartz crystals. The quartz crystals may be authigenic or may be attributed to metasomatic replacement, since this area seems to be a somewhat mineralized zone with mining operations present in the region north of the studied section. Bateman (1967, p. 139-40) states that doubly terminating crystals may grow at the expense of limestone in metasomatic replacement associated with hydrothermal alteration.

Accessory Minerals

Silica is present as chert veins in the Pequop section and as bedded and nodular chert in the Snake Range section. The bedded cherts appear to have been deposited along with the limestones in a marine environment. Pettijohn (1957, p. 441) agrees with this interpretation. According to him (1957, p. 440), vein cherts in the Pequops are apparently of replacement origin.

Pyrite is present as euhedral crystals in many of the samples collected in the Leppy Range section and is associated with the high organic content of the rocks. Pettijohn (1957, p. 150) believes this is a common association in many organic-rich limestones. Although the sulphide may have been introduced by solution activity, it appears to be authigenic.

Hematite and limonite are present in small percentages in some of the units in the Snake Range section. They occur in fracture veins, stylolite veins, as pseudomorphs after pyrite, and as strains throughout some of the limestones. Their occurrence is probably due to replacement or oxidation of the original minerals.

Organic material is abundant in the limestones of the Leppy Range section and in most of the dark colored limestones and dolomites of the other sections. Apparently periods of quiescence allowed the material to accumulate along with the carbonate sediments. Water depth does not have to be deep for organic material to accumulate; organic content can vary greatly in shallow water, according to Trask (1939, p. 450).

Stylolites are abundant in many of the sections studied, especially in the finer-grained limestones and dolomites. Solution activity appears to have removed parts of clasts and bedding along stylolite zones. Most of the stylolites follow the sedimentary bedding, but instances are common where the irregular surface of the stylolites follows grain boundaries in brecciated units or follows the contacts between *Amphipora* coenostia. Many of the stylolites in the Douglas Hill sections as well as in other sections contain what appear to be hydrocarbon residues, indicating a possible avenue of migration for hydrocarbons in the limestones. Although many theories exist for the origin of stylolites, Pettijohn (1957, p. 215) believes that they represent some form of solution phenomena.

Breccias mentioned in the Leppy Range, Snake Range, and Egan Range sections are also a result of solution activity. It is difficult to tell if the brecciation is a result of evaporite removal collapse or local karst development. The breccia in the Leppy Range section contains clasts that are angular and of the same lithologic character. In the other sections the clasts are composed of several different rock types, including limestone and dolomite. In all cases the clasts resemble the superjacent rock units. Traced laterally, the structureless breccias are in contact with relatively undisturbed bedded units.

Beales and Oldershaw (1969, p. 507) state that if the clasts are largely monogenetic and predominately dolomite or if they are polygenetic and appear to be derived from thin- to medium-bedded strata that match the superjacent nonbrecciated sequence, the probability of an evaporite-solution origin increases. Brecciation with a more heterogeneous composition and grain size is more likely to be a product of cavern collapse associated with extensive carbonate rock solution. It appears from the associated dolomites that evaporite deposition may have occurred at different times in the study area and subsequently been removed through solution activity causing local collapse of overlying units. Possibly at different times subaerial exposure could have allowed ground water solution activity to develop in the carbonates followed by collapse of the overlying units.

SEDIMENTARY STRUCTURES

Sedimentary structures observed in the field or laboratory are planar cross-bedding, ripple marks, and graded bedding. Cross-bedding is apparent in a few of the sandstone units. In the Pequop section the unimodal sets are four to six inches thick. Current direction was from the southeast. The Pahranagat section bimodal cross-bedding units consist of sets one to two feet thick. Pelletal limestones often demonstrate microcross-bedding with sets less than a millimeter thick.

Ripple marks are rarely present on bedding plane surfaces in the study area. The Leppy Range section contains microcrystalline dolomites and a sandy limestone unit which reflect current ripples. Ripple marks on the sandy limestome observed at 1,800 feet are less than 0.5 inches thick (Pl. 1, fig. 5).

Graded bedding is present on a microscale in pelletal limestones and appears to be the result of normal waning current with the decline in competency taking place over a period of time, an interpretation in harmony with that of Pettijohn (1957, p. 171).

Source of Sediments

The major percentage of carbonate sediments seemingly was derived from within the basin. Carbonate sediments in the study area apparently were obtained from an abundant organic life that existed there at that time. Certainly a percentage of chemically derived carbonate sediments augmented the amount of basin-filling sediments.

Noncarbonate clastic sediments forming the almost ubiquitous sandstones in the area must have had their origin outside the basin. More than likely the quartz sediments were derived from the craton to the east or early impulses of the initial phase of the Antler Orogeny in southern and western Nevada (Poole et al., 1968, p. 902). Bissell (1955, p. 1643) also suggests the Antler Orogeny for the source of quartz sediments in the miogeosyncline.

PALEONTOLOGY AND PALEOECOLOGY

Many Devonian fossils reported from other parts of the world are found in the Devonian rocks of the Great Basin. Because many of the organisms present are restricted to particular environments, their occurrence is useful in interpreting the environments in which the Guilmette was deposited.

Stromatoporoids are the most abundant organisms preserved in the Guilmette Formation, occurring in every section studied. Ten genera were collected in the study area and appear to represent the major types present. *Hammatostroma, Trupetostroma*(?), *Anostylostroma, Actinostroma, Clathrocoilona, Stromatopora, Syringostroma*(?), *Hermatostroma, Amphipora,* and *Stachyodes* were identified. Waines (1964, p. 230) described three additional genera from Nevada that were not found in this study. Stromatoporoids are fairly good ecological indicators and with further work may be useful in correlation.

Murray (1964, p. 18-20) categorized stromatoporoids into four major groups on the basis of their gross morphology. These categories are (1) massive, which included some shaped or supspherical forms whose height or vertical dimensions are approximately equal to their width or horizontal dimensions; (2) bulbous, which includes all spherical forms from 2 to 8 cm in diameter; (3) tabular, which spread out laterally several times their thickness and less than 2 inches thick; and (4) branching or dendroid forms. In this study the author used the latter terms of tabular and branching but preferred to include in the definition of massive only those large forms which demonstrate a relatively flat base. All bulbous forms, regardless of size, were considered bulbous stromatoporoids. This was for purposes of utility, not taxonomy.

Gross morphology has little to do with the actual specific taxonomy of the organisms since a single species may occur in several growth forms according to Fischbuch (1968, p. 505). Branching forms appeared to be commonly overgrown with a different species. Stearn (1963, p. 653) found that different species may take on the same growth shape or even grow upon each other, thus producing one coenosteum from two different species. Species may also change growth form in response to environmental fluctuations (Fischbuch, 1968, p. 504). The organisms seem to be sessile benthic organisms, but the worldwide distribution of certain species indicates a possible nektonic or mobile stage in which they could migrate (Fischbuch, 1968, p. 500).

Because stromatoporoids could adapt to many ecological conditions, they are found in many types of rocks. Other organisms sharing the same ecological niches may occur with them.

Forms of Stromatoporoids

Massive Forms.— Massive stromatoporoids occur in three different localities in the study area. They occur as one-foot-diameter forms in section LR-1 approximately 1,915 feet above the base of the section in a fine-grained fossiliferous limestone. They do not appear to be in growth position and are not abundant in the unit. Associated with them are smaller bulbous stromatoporoids and crinoid columnals.

At the south end of the Douglas Hills in DH-2 there is an interesting occurrence of massive forms. Approximately 95 feet from the base of the section alternating layers of light and dark *Amphipora*-rich limestone produced a platform upon which massive forms grew (Pl. 2, fig. 3). The massive stromatoporoids are from six to eight inches wide at the base and grew from one to two feet from the platform. They occur in an upright growth pattern or in a horizontal position. Apparently upon attaining a certain height the coenostia were unable to stand, and currents or storm waves toppled them over into a horizontal attitude. Another possibility is that the pelletal substrate upon which these organisms grew may have been unable to support them. According to Newell, Purdy, and Imbrie (1960, p. 485), analogous conditions exist in the Bahamas where pelletal and oolitic sands are too unstable to support sessile forms. The massive stromatoporoids present in this occurrence are the genus *Hammatostroma* (Pl. 4, fig. 2). Note apparent arrested growth stages shown by the darkened laminae in this illustration. The author intreprets the darkened laminae to be either repair scars after waves had damaged the structure, or a reflection of seasonal or environmental changes. These massive stromatoporoids are present in fine- to coarse-grained pelletal limestone and are associated with bulbous forms such as *Syringostroma* (?) and branching forms such as *Amphipora.* Radiosphaerid calcispheres are abundant in the pelletal limestone.

At the south end of the area in PR-1, approximately 820 feet from the base, a third occurrence of massive forms is present (Pl. 1, fig. 2). These massive stromatoporoids are in growth position and average two to three feet in diameter. They occur along the bed at approximately five-foot intervals laterally. Accentuated asymmetrical growth of the stromatoporoid indicates a possible response to current flow, with the current direction from the south. *Hammatostroma* is the genus forming the massive structures in this unit. Associated bulbous forms in fine-grained limestone were deposited around the massive buildups after the structures had reached their maximum height.

All of these massive stromatoporoids appear to have grown on the sea floor in response to ideal conditions. According to Leavitt (1968, p. 324) massive stromatoporids occur commonly in the organic-reef and reef-detritus facies, characterizing the outer rim of the reef in the Carson Creek North Reef Complex of Alberta.

The massive stromatoporoids studied in the area are interpreted by the writer to have grown in clear, turbulent, shallow water environments. They appear to have been wave resistant when growing.

Bulbous Forms.— Bulbous forms are abundant in every measured section and occur with a variety of other organisms and rock types. In section PQR-1 they occur 37 feet from the base as subspherical forms with two- to three-inch diameters. They apparently are not in growth position. Associated *Amphipora* and an occasional tetracoral are present in a medium crystalline limestone.

Spherical to subspherical bulbous forms are present in many of the limestone units of LR-1, ranging in size from two to six inches in diameter. Most of these fossils are not in growth position. An occurrence 195 feet from the base appears to be in growth position associated with algae in a fine-grained, organic-rich pyritic limestone. Bulbous stromatoporoids are also found with massive and branching forms and usually associated with them are brachiopods and crinoids. Prolific fossil zones with tabulates, tetracorals, brachiopods, gastropods, crinoids, and calcispheres are often associated with bulbous and branching stromatoporoids. Associated lithologies vary from fine- to coarse-grained limestone. *Actinostroma* was identified (Pl. 3, fig. 1) in a highly fossiliferous unit 875 feet from the base. Nowhere in the section did the occurrence of bulbous stromatoporoids constitute a reefal buildup.

Section SR-1 contains bulbous forms in the upper half of the section where commonly they are from one to four inches in diameter and preserved with siliceous rines in cherty, fine- to coarse-grained limestones. The stromatoporoids are associated in growth position with brachiopods and gastropods in some units but appear to have been transported and deposited to produce an association of other stromatoporoids, tabulate corals, tetracorals, brachiopods, crinoids, ostracodes, and calcispheres in other units.

Bulbous stromatoporoids range from one to six inches in diameter and occur most frequently in growth position in section DH-1. Lithologic associations vary from fine-grained limestone to cherty, pelletal limestone. The stromatoporoids are found in simple associations with *Amphipora* but also occur with brachiopods, gastropods, crinoids, and calcispheres. Complex associations with other stromatoporoids, tabulate corals, brachiopods, gastropods, crinoids, calcispheres, and algae are common in the upper part of the section. *Stromatopora* and *Trupetostroma*(?) were collected in this section at 80 and 365 feet respectively (Pl. 3, fig. 3). *Stromatopora* has residual hydrocarbons present in the galleries (Pl. 4, fig. 3).

Section DH-2 contains some unusual occurrences of bulbous stromatoporoids. Lithologic associations are similar to those observed in section DH-1.

EXPLANATION OF PLATE 5
PHOTOMICROGRAPHS

Fig. 1.—Breccia at 40 feet, section ER-1, showing early stages of diagenesis in carbonate clasts, X5.
Fig. 2.—Dolomite crystals in limestone, section ER-1, X30.
Fig. 3.—Pelletal limestone containing foraminifera and calcispheres, section PQR-1, X25.
Fig. 4.—Oolitic limestone at 285 feet, section ER-1, X20.
Fig. 5.—Fossiliferous limestone containing shell debris at 1,265 feet, section LR-1, X10.
Fig. 6.—Sandstone containing rounded quartz and pelletal clasts at 860 feet, section PR-1, X5.
Fig. 7—Radiosphaerid calcisphere present at 103 feet, section DH-2, X60.
Fig. 8.—Nodosinelled foraminifera with lateral spines from 115 feet, section DH-2, X60.

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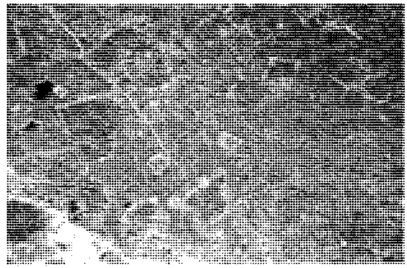

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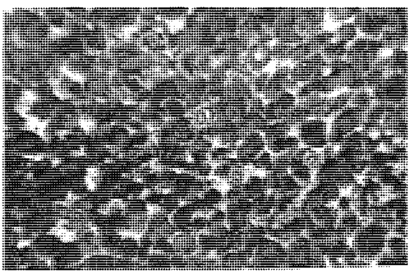

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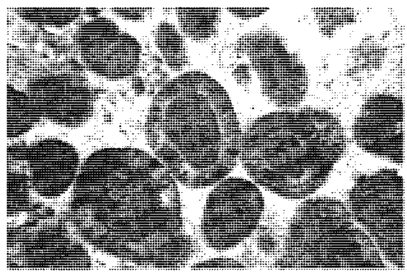

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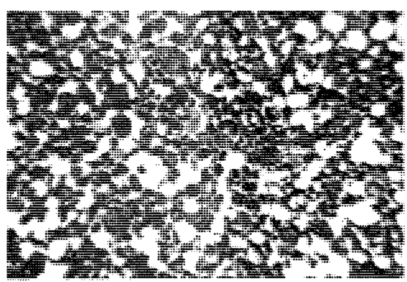

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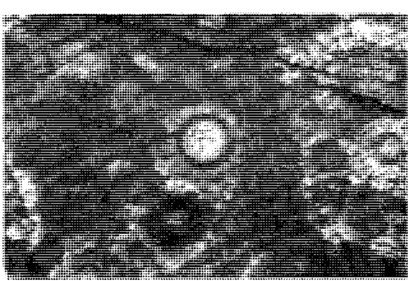

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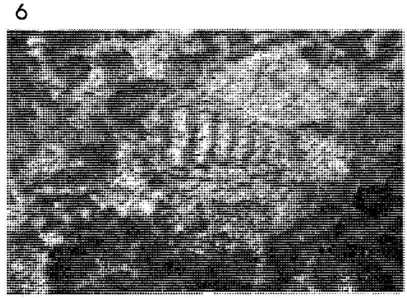

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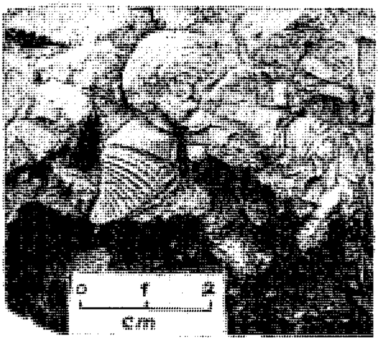
PLATE 5



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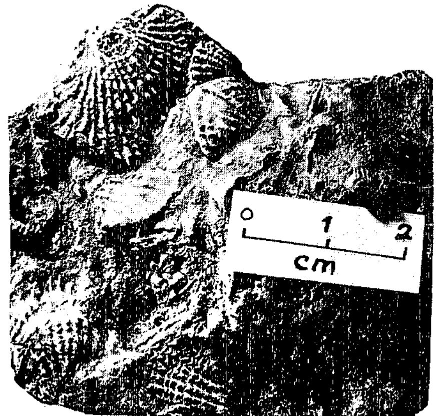

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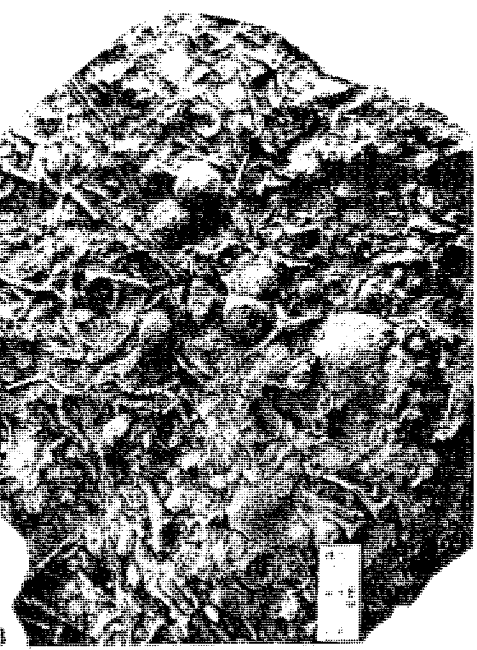

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EXPLANATION OF PLATE 6
GUILMETTE FOSSILS

Fig. 1.—Assemblage of *Allenaria*(?) and *Atrypa* brachiopods collected from the brachiopod zone, section DH-1.
Fig. 2.—Assemblage of *Spinatrypa* brachiopods from brachiopod zone, section DH-1.
Fig. 3.—Bedding plane view of brachiopod, gastropod, bryozoan, and crinoid assemblage from brachiopod zone, section DH-1.

Bulbous forms are usually found with *Amphipora* or with calcispheres and foraminifera. A specimen of *Trupetostroma*(?) three inches in diameter was collected from a unit 30 feet above the base of the section; a three-inch specimen of *Clathrocoilona*(?) was collected from a unit 120 feet above the base. Both specimens appeared to be in growth position. According to Stearn (1966, p. 46), *Clathrocoilona* probably represents a symbiotic relationship of an alga and a stromatoporoid, and variations in its form are probably due to the relative proportions of the two organisms. Approximately 120 to 132 feet from the base a 12-foot-thick reef-like buildup of bulbous and branching stromatoporoids occurs (Pl. 2, figs. 2, 4). Stromatoporoids five to seven inches in diameter appear to be in or near growth position and surrounded by the branching form *Amphipora*. Several "heads" of bulbous stromatoporoids were collected and thin sectioned. Most of the forms are of the genus *Anostylostroma*. *Anostylostroma* demonstrates tangled and nonparallel laminae, likely a response to high-energy environment, although other genera did not develop the tangled structure (Pl. 3, fig. 6). *Trupetostroma*(?) and *Hammatostroma* are present in this buildup but not as abundantly as *Anostylostroma*. The size and shape of *Trupetostroma*(?) and *Hammatostroma* are similar to that of *Anostylostroma*, showing a similar response by different species to the same environment. These bulbous stromatoporoids are associated with what appear to be the branching forms, *Stachyodes* and *Amphipora*. *Amphipora* and *Stachyodes* rarely occur together in the study area. Organisms associated with the stromatoporoids are ostracodes, foraminifera, calcispheres, and algae in fine- to coarse-grained limestone. The overlying bed produced *Hammatostroma* and *Clathrocoilona*(?) in growth position.

Section ER-1 contains abundant bulbous forms. They are occasionally associated with massive or tabular forms but are always present with the branching forms. At approximately 270 feet stromatoporoids, not in growth position, occur with brachiopods, gastropods, and calcispheres. A spherical *Trupetostroma*(?), collected at 445 feet, is three inches in diameter. From its abraded appearance the specimen probably had rolled around during transportation. *Trupetostroma*(?) collected at 790 feet was associated with tabular *stromatoporoids* (Pl. 3, fig. 2). Calcispheres were also present in this unit. *Trupetostroma*(?) and *Hammatostroma* two and three inches in diameter were collected at 955 feet in coquinoid limestones. They were present with tetracorals, brachiopods, gastropods, crinoid debris, calcispheres, and conodonts. At 1,050 feet *Trupetostroma*(?) is abundant and preserved in growth position. At 1,115 feet a 65-foot limestone unit is present containing a prolific fauna of one- to six-inch forms of *Trupetostroma*(?) and *Hammatostroma*, and *Clathrocoilona*(?). These are in growth position and silicified. Associated with them are other stromatoporoids, tabulate corals, tetracorals, brachiopods, gastropods, ostracodes, calcispheres, algae, and conodonts (Pl. 2, fig. 5). *Trupetostroma*(?) and *Clathrocoilona*(?) were also collected from approximately 1,300 feet (Pl. 3, fig. 5). Near the top of the section many bulbous forms are present with *Amphipora* in what appears to be a coarsely crystalline dolomitized biostrome. Fossils have been leached leaving vuggy porosity in the rock.

Section PR-1 contains bulbous stromatoporoids in most of the fine- to coarse-grained limestones and pelletal limestones. They are common in the coarse crystalline dolomites but are not present in the sandy lithologies.

Generic identities were not established from this section, but it is assumed they were similar to those collected in the other sections.

Occurrences of bulbous stromatoporoids in growth position associated with high-energy corals or high-energy stromatoporoid forms and occurrences of abraided stromatoporoid coenostia indicate a moderately high-energy condition for the environment in which some of the bulbous forms lived. Associations with fine-grained limestone or fine pelletal limestone and lower-energy organisms indicate that the bulbous forms were not restricted to high-energy conditions but probably flourished in low-energy environments as well. Leavitt (1968, p. 325) describes bulbous stromatoporoids in Alberta which are common in the reef platform or backreef facies and may have lived in quiet restricted waters. He also suggests that they may have lived in turbulent conditions and were transported to a quiet environment. The writer suggests that these organisms occurring in the Guilmette may have lived in both high- and low-energy environments but certainly were more successful in lower-energy environments.

Tabular Forms.— Tabular stromatoporoids are not as abundant as other stromatoporoid forms in the study area, which probably indicates a lack of suitable environmental conditions. They are associated with massive and bulbous forms in section LR-1. Section DH-1 produced an occurrence of *Hermatostroma*(?) that had grown encrusted on a fragment of the tabulate coral *Coenites*(?) (Pl. 4, fig. 8). This occurrence was associated with other stromatoporoids, colonial tetracorals, brachiopods, gastropods, crinoids, and algae. A two-inch tabular specimen of *Hammatostroma* was collected in section ER-1 (Pl 4, fig. 4). The congested appearance in the photomicrograph possibly indicates an abundance of algae growing with the stromatoporoid

EXPLANATION OF PLATE 7
GUILMETTE FOSSILS

Fig. 1.—*Polygnathus linguiformis*(?) collected 70 feet from top, section CR-1, upper view, X25.
Fig. 2.—*Icriodus* sp. from 315 feet, section SR-1, upper view, X60.
Fig. 3.—*Palmatolepis proversa* 30 feet from top, section CR-1, upper view, X45.
Fig. 4, 5.—*Icriodus nodosus* collected 70 feet from the top, section CR-1, upper and lower views, X40.
Fig. 6a, 6b.—*Palmatolepis*(?) collected at 910 feet, section ER-1, upper and lower views, X40.
Fig. 7.—*Spathagnathodus* from 1,115 feet, section LR-1, lateral view, X30.
Fig. 8, 10.—*Polygnathus webbi* collected 10 feet from top, section CR-1, upper view, X45.
Fig. 11.—*Bryantodus* sp. from 885 feet, section ER-1, lateral view, X30.
Fig. 12, 13.—*Allenaria*(?) collected from brachiopod zone, section DH-1, posterior and ventral views, X1.
Fig. 14, 15.—*Atrypa* collected from brachiopod zone section ER-1, posterior and ventral views, X1.
Fig. 16, 17.—*Spinatrypa* collected from brachiopod zone, section DH-1, posterior and ventral views, X1.
Fig. 18, 21.—*Atrypa* collected from 840 feet, section DH-1, posterior and ventral views, X1.
Fig. 19-20.—*Hypothyridina emmonsi*(?) collected from 905 feet, section ER-1, ventral and posterior views, X1.

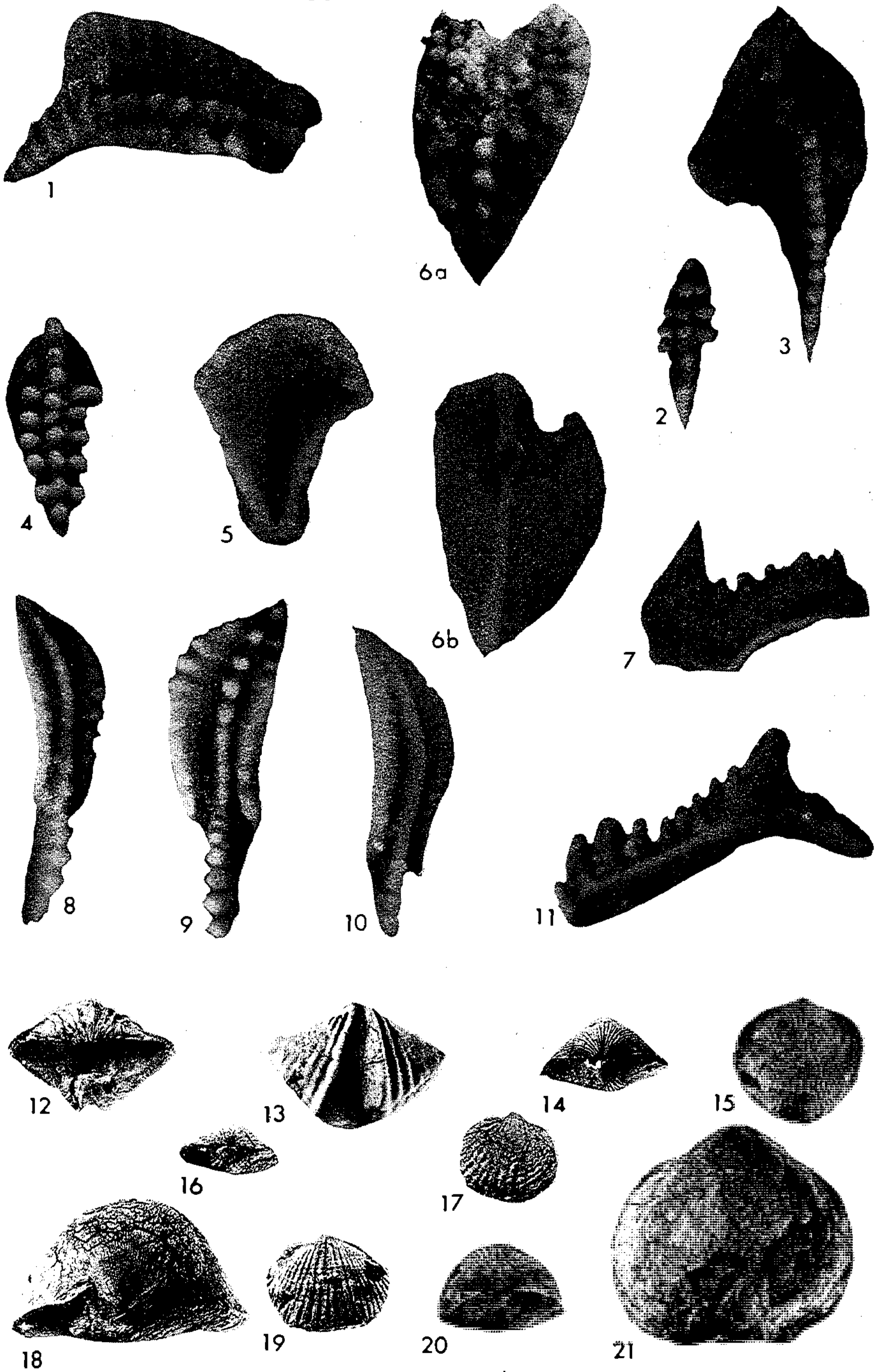


PLATE 7

organisms. It is notable that *Hammatostroma* occurs as massive, bulbous, and tabular masses, illustrating the adaptability of stromatoporoids to changes in environment. Tabular forms were also found located at 405 feet in the PR-1 section.

Tabular stromatoporoids in the Guilmette appear to be associated with moderate-energy organisms similar to tabulate corals. Associated lithologies are commonly fine-grained pelletal limestones or highly fossiliferous, fine- to coarse-grained limestones indicating both high- and low-energy conditions. The author interprets the occurrence of tabular stromatoporoids in the Guilmette as indicating moderate-energy conditions based on their association with tabulate corals and crinoids.

Perkins (1963, p. 1341) believes that the tabular forms predominated in more turbulent waters. In the Swan Hills reef complex tabular forms occur in the reef platform and encrust previously deposited sediment or are found disrupted with irregular fragments enclosed in fine-grained fossil debris (Fischbuch, 1968, p. 500). Tabulate forms in the Carson Creek North complex in the forereef slopes are associated with solenoporoid algae and apparently grew in quieter water than the massive stromatoporoids but were probably resistant to wave action. Leavitt (1968, p. 324) suggested that they could live in both turbulent and moderately quiet, clear waters but thrived best in the latter environment.

Branching Forms.— Branching forms noted in the Guilmette are *Stachyodes* and the ubiquitous *Amphipora. Stachyodes* is distinguished from *Amphipora* by its branching coenosteum, marginal pseudozooidal tubes, incipient axial canal, and variable diameter. *Amphipora* has a definite axial canal, marginal vesicles, and a relatively constant diameter along the stem fragments (Fischbuch, 1962, p. 62) (Pl. 3, fig. 4).

Stachyodes was identified in the upper units of section DH-2 associated with the reeflike buildup of bulbous stromatoporoids and *Amphipora.* In the top unit *Stachyodes* is present as stubby, cylindrical branches with diameters of less than 0.5 inches. The organisms in growth position, branching out like bushlike structures two to three feet in diameter every five to ten feet on the bedding surface. Leavitt (1968, p. 326) believes that *Stachyodes* preferred moderately turbulent, open marine waters and grew on the reef and in upper portions of forereef slopes. The writer agrees that these organisms are apparently high-energy forms due to their restricted occurrences in the reeflike buildups.

Most of the measured sections that contain fossils, particularly other forms of stromatoporoids, were found to have an abundant occurrence of *Amphipora.* Some units were approximately 90 percent *Amphipora* in bulk composition. *Amphipora* appears to have occurred with every rock type and organism in the study area.

Branches are generally preserved oriented in the same direction, in horizontal attitudes, apparently not in growth position. The reeflike buildup in DH-2 contained abundant *Amphipora* in random orientation, possibly indicating the branches of *Amphipora* have been transported and deposited between the bulbous stromatoporoids. *Amphipora,* generally less than 0.25 inches thick, probably grew in an upright position with its long axis vertical. It was probably rigid with a soft base that allowed the organisms to topple over in heavy current, storm wave activity, or death.

Genera \ Meas. Sections	ER-1 L	ER-1 M	ER-1 U	DH-1 L	DH-1 M	DH-1 U	SR-1 L	SR-1 M	SR-1 U	CR-1 L	CR-1 M	CR-1 U	LR-1 L	LR-1 M	LR-1 U	PQR-1 L	PQR-1 M	PQR-1 U
Palmatolepis linguiformis ?												X						
P. proversa												X						
Palmatolepis sp.		X																
Polygnathus linguiformis												X						
P. normalis	X	X	X					X				X						
P. foliata	X	X	X		X			X				X		X				
P. rugosa												X						
P. webbi												X						
Polygnathus sp.	X	X						X				X						
Icriodus nodosus	X	X			X			X				X		X				
I. alternata												X						
Icriodus sp.							X											
Bryantodus sp.		X					X					X		X				
Ozarkodina sp.	X	X			X							X			X			
Lonchodina sp.	X	X			X			X				X			X	X	X	
Ligonodina sp.					X													
Spathagnathodus							X								X			
Hindeodella sp.	X	X	X		X			X				X						
Roundya sp.												X				X		
Hibbardella ? sp.												X						

TEXT-FIGURE 4.—Conodont distribution in the studied sections.

From the distribution and preservation of *Amphipora* it appears to the writer that the organisms probably lived in quiet water environments. Apparently the organisms were adapted to mild currents that carried food material. Occasional strong currents broke them loose from their substrate attachment and transported them into other environments. Murray (1966, p. 19) thought that *Amphipora* may have trapped sediments, but Fischbuch (1968, p. 503) indicated that since they are rarely found in growth position it would seem they did not have that ability. Leavitt (1968, p. 326) believes that *Amphipora* thrived and grew in abundance only in relatively quiet, sheltered waters; and though they are good indicators of a backreef environment, they could grow in any place that had similar conditions.

Other Guilmette Organisms

Tetracorals.—Solitary tetracorals are present, but generally not abundant, in most of the measured sections. They were observed in growth position in A-1 Canyon of the Leppy Range (Nadjimabadi, 1967, p. 138) but are generally not in growth position elsewhere. A notable occurrence is present at the base of section LR-1 in which a three-inch unit 37 feet from the base yielded *Heliophyllum*(?) in a prolific accumulation of two- to three-inch corallites. They are oriented horizontal to the bedding plane and have undergone minor transportation as indicated by the lack of abrasion. A fairly well preserved specimen of *Zaphrenthis*(?) was collected in section ER-1, 955 feet from the base. In 21 occurrences of solitary tetracoral faunas the corals are associated with bulbous stromatoporoids in approximately 60 percent of the occurrences, *Thamnopora* 50 percent, brachiopods 70 percent, and *Amphipora* 30 percent.

Colonial tetracoral forms preserved in growth position and up to 18 inches in diameter were observed at 1,890 feet in section LR-1. They are associated with massive, bulbous, and tabular stromatoporoids and crinoid stems. They are not generically identifiable due to poor preservation. Specimens of *Pachyphyllum* one to three inches in diameter were collected in the DH-1 section 770 feet from the base. *Pachyphyllum* is associated in this unit with stromatoporoids, brachiopods, tabulate corals, gastropods, and crinoids. The tetracorals appear to have lived in moderate-energy environments but occasionally are found associated with crinoids and other high-energy organisms in death assemblages. The *Pachyphyllum*-bearing unit may be equivalent to the *Pachyphyllum* or *Phillipsastrea* zone mentioned by Merriam (1940) in the Devil's Gate Formation and other Devonian formations of western United States.

Tabulate Corals.— Tabulate corals do not seem to be as abundant as the tetracorals. *Alveolites* was collected 1,860 feet in the LR-1 section (Pl. 3, fig. 8) associated with other tabulates, tetracorals, stromatoporoids, and crinoids. *Coenites* was collected in section DH-1 at 755 feet encrusted with *Hermatostroma*(?) (Pl. 4, fig. 8). The most abundant tabulate is the branching form *Thamnopora.* One occurrence where it seems to bind other organisms together is near the top of Section SR-1. The coral is associated with stromatoporoids, tetracorals, brachiopods, and gastropods and is silicified so that the corallites of *Thamnopora* weather out in relief. In 15 occurrences of *Thamnopora,* tetracorals are associated in 73 percent of the occurrences, brachiopods 73 percent, bulbous stromatoporoids 66 percent, and *Amphipora* 40 percent.

It is noteworthy that no coral forms were found in section DH-2. Possibly the stromatoporoids *Stachyodes* and *Amphipora* filled the niches available and excluded the corals. *Coenites* was noted in Guilmette strata in the Silver Island Range with *Syringopora* and *Synaptophyllum* by Schaeffer (1960, p. 68).

According to Fischbuch (1968, p. 521), both tabulate and tetracorals are present in the Swan Hills reef complexes but did not form wave-resistant structures. The tabulate corals are interpreted by Leavitt (1968, p. 327) as having lived in well-aerated, moderately turbulent, shallow waters, while the solitary tetracorals are believed to have favored deeper and more quiet water environments. The writer finds no reason to disagree with Leavitt's interpretation of coral environments.

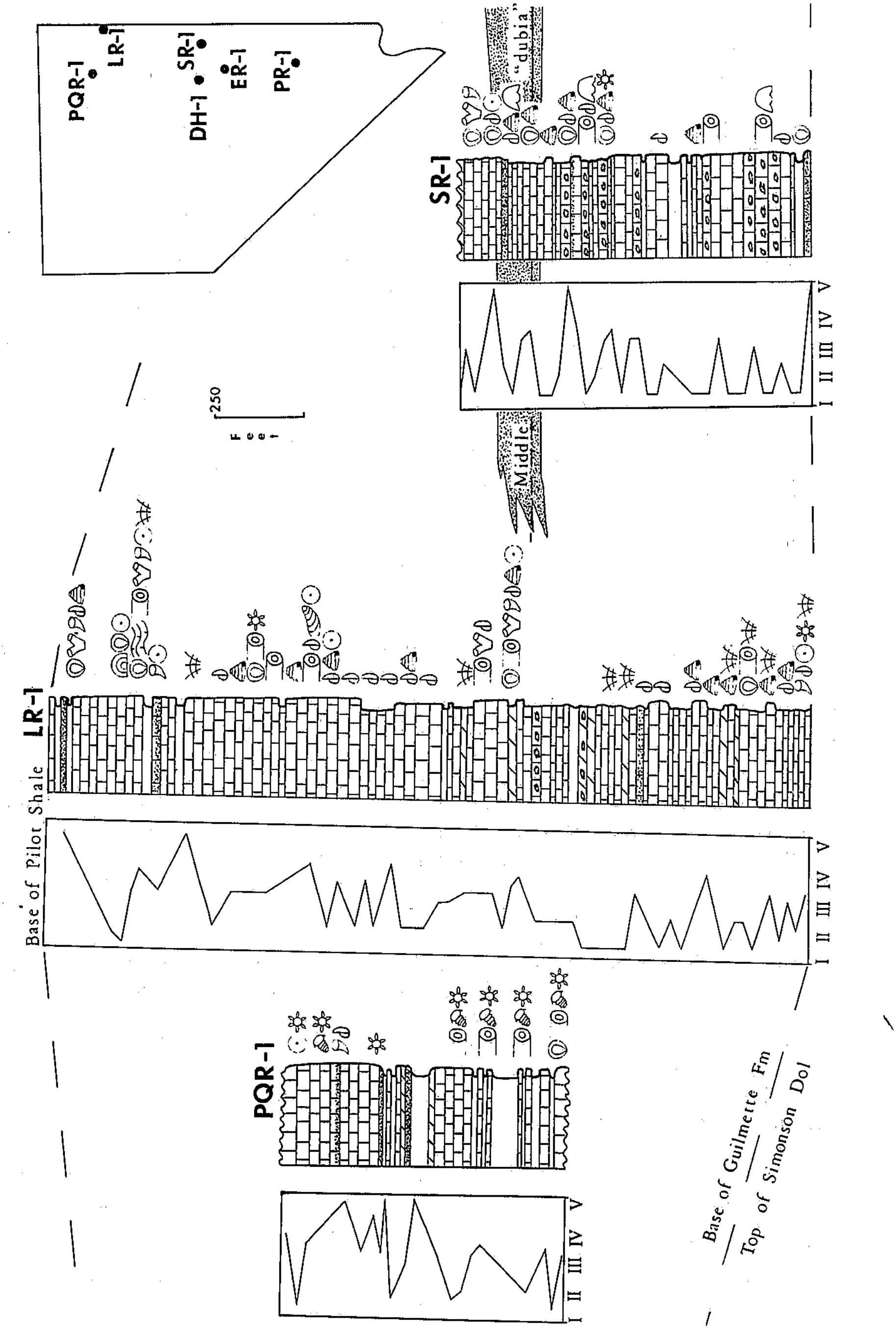
Brachiopods.— Brachiopods are present in every measured section and in some sections constitute thick, highly fossiliferous zones. Four major taxa were noted in the area: *Atrypa, Spinatrypa, Allenaria*(?), and a large brachiopod resembling *Stringocephalus*. A prolific atrypid occurrence, present at the base of section LR-1, exposes 40 feet of brachiopod coquinas associated with solitary tetracorals, foraminifera, and calcispheres. From 875 to 935 feet in the section *Stringocephalus*(?) is exposed but not weathered out in random orientation with stromatoporoids, tabulate corals, tetracorals, gastropods, crinoids, and conodonts. From 1,240 to 1,300 feet *Atrypa* is present with *Allenaria*(?) in possible growth position. Specimens of *Atrypa* 20 to 30 mm in width are oriented in growth position and resting on the pedicle valves. Most of the atrypid brachiopods in section LR-1 are fine plicate forms rather than frilly shelled forms observed in other sections.

Section SR-1 contains an interesting occurrence of brachiopods approximately 100 feet thick in which the organisms seem to occur in growth position in fine, thin-bedded, muddy limestone. *Atrypa and Allenaria*(?) were collected in that unit. Most of the atrypids possess ornate shell structures.

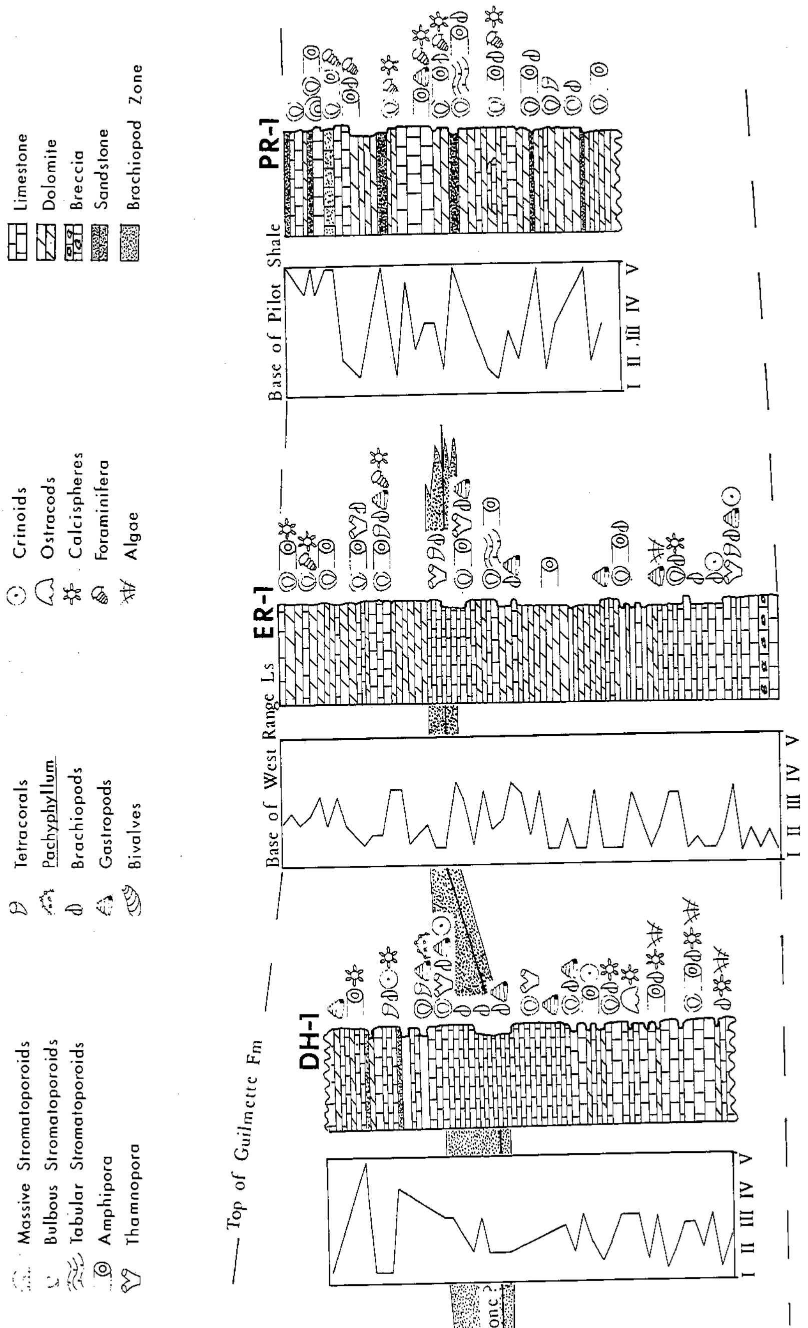
Within the same thin-bedded muddy limestones, 170 feet thick, *Atrypa, Spinatrypa,* and *Allenaria*(?) were collected in section DH-1 (Pl. 7, figs. 13, 15, 17). Most of the atrypids in this zone are 5 to 20 mm wide, frilly shelled forms (Pl. 6, fig. 2). *Allenaria*(?) collected range from 15 to 30 mm in width. Bedding plane exposures disclosed associations of brachiopods, tabulate corals, crinoids, planispiral gastropods, and bryozoans (Pl. 6, fig. 3). Above this brachiopod zone another occurrence of *Atrypa* has produced large forms from 20 to 30 mm wide with finely plicated shells (Pl. 7, fig. 21).

Section DH-2 contains *Stringocephalus*(?) at the base in random orientation. They are preserved in cross section but do not weather out. No other brachiopods were noted in the section.

Section ER-1 contains a zone 120 to 150 feet from the base which is a coquina of smooth, thin-shelled brachipods, generally 1 cm in width, apparently preserved in growth position. At approximately 950 feet, a 100-foot zone of *Atrypa, Spinatrypa, Allenaria*(?), and *Hypothyridina* was noted and collected. This zone appeared to be the same thin-bedded, muddy limestone observed in SR-1 and DH-1. The *Spinatrypa* are frilly or spinose as before and range from 10 to 20 mm in width. *Allenaria*(?) ranges from 15 to 25 mm in width. A single specimen of *Hypothryridina* 18 mm in width was col-



PQR-1
LR-1
SR-1
DH-1
ER-1
PR-1
250 Feet
"dubia"
Middle
Base of Pilot Shale
Base of Guilmette Fm
Top of Simonson Dol
I II III IV V



TEXT-FIGURES 5a and 5b.—Energy fluctuations, faunal distribution, and regional correlation of the Guilmette Formation in the study area.

lected (Pl. 7, figs. 19, 20). One section measured at Dutch John Mountain, 40 miles north of Pioche, and eight others measured north of ER-1 in the Egan Range and 12 miles south of ER-1 in other exposures, documented this same muddy limestone sequence containing frilly *Spinatrypa, Atrypa,* and *Allenaria*(?) spirifers. The writer believes that this zone is the same facies, which indicates an area approximately 2,000 square miles over which this consistent environment persisted during a part of Guilmette time.

Several limestone and dolomite units present in PR-1 contain *Stringocephalus*(?) in random orientation. Preservation is poor, and it is essentially impossible to collect from these units. All of these forms possess the hooked beak and range from 50 to 70 mm in length, characteristic of *Stringocephalus. Stringocephalus* has not been reported this high in the Guilmette previously. Since the brachiopods were not collected or identified positively, the writer suggests that this might be an area for further investigation to verify whether *Stringocephalus* exists in the upper Guilmette. If so, its occurrence could give added information concerning the depositional history of the Guilmette. Brachiopods were noted from 54 occurrences in the study area. They were found in association with gastropods in over 50 percent of the occurrences, tetracorals 40 percent, bulbous stromatoporoids 40 percent, and tabulate corals 20 percent. Lithologically they occurred in rock types from fine-grained muddy limestones and fine- to coarse-grained pelletal limestones, to coarse crystalline dolomites. However, it appears that the ornamented atrypids preferred the finer sediments and the large *Stringocephalus* preferred the coarser sediments. *Atrypa* and *Allenaria*(?) brachiopods are present in fine-grained limestones or pelletal limestones, associated with stromatoporoids and other organisms indicative of quiet conditions. During the deposition of the brachiopod faunas the sea floor consisted of muddy substrates as evidenced by the thin-bedded, fine-grained limestone associated with them. Mobile pelletal substrates made the sea bottom inhospitable for sessile benthic organisms such as stromatoporoids, corals, crinoids, or brachiopods with pedicles. These occurrences of sediments and organisms suggest that the Guilmette Formation in the study area was deposited on a moderately shallow shelf lacking high energy, turbulent conditions except along a migrating strand line.

Atrypid brachiopods adapted to different types of substrates by varying their morphology and living habits. Copper (1967, p. 367-68) states that some species of atrypids were attached with pedicles, especially those associated with corals. These types were probably elevated above the sea floor, attached but resting on the sea floor to support their weight. Most atrypids in the Guilmette appeared to be free-living forms based on the lack of large pedicle openings and associated sediments of fine-grained, muddy or pelletal limestone. Copper (1967, p. 373) mentions that atrypids without pedicles were able to stabilize themselves by developing a relatively flat pedicle valve to rest upon or ornamentation such as frills and spines to stabilize them in mobile substrates or elevate them in muddy substrates. Also, most unattached forms have a somewhat more prominent folding of the commissure, elevating the respiratory current above the muddy bottom. Copper (1967) further states that frill development is evidently best suited to clayey, nonclastic substrates and characterizes quiet, sheltered, lagoonal waters of backreef conditions (Copper, 1967, p. 374). The types of shells present on the atrypid brachiopods of the Guilmette substantiate their relationship to a quiet sheltered shelf platform. Copper (1966, 252-254) describes biotopes from Europe which indicate that the atrypid forms noted in the Guilmette Formation were living in water depths no greater than 50 meters. Leavitt (1968, p. 327) reports that *Atrypa* is present in the lower forereef limestones of the Carson Creek North Complex and in the offreef limestones of the Waterways Formation.

The thick-shelled and larger *Stringocephalus* apparently thrived in higher-energy conditions. *Stringocephalus* occurs in Europe in the center of the reef or transitional reef-backreef area (Boucot, Johnson, Struve, 1966, p. 1357). The genus has been correlated worldwide as a guide fossil for the Upper Middle Devonian or Givetian (Boucot, Johnson, Struve, 1966, p. 1349).

Bivalves.— Two occurrences of bivalves were noted in the study area, one in a unit five feet thick, approximately 1365 feet from the base of LR-1, and the second near the top of DH-1. In section LR-1 valves are disarticulated and are generally oriented convex up. The fossils appear to be *Parallelodon*(?) Meek, an Upper Devonian form. Near the top of DH-1 a single bivalve resembling *Paracyclas*(?) Hall was collected and preserved as a cast. On the basis of the associated lithologies of fine organic rich limestones and faunal associations, it would appear that these forms were deposited in moderate-energy conditions. The Carson Creek North Complex in Alberta contains occurrences of bivalves found only in reef and reef-detritus limestones, and Leavitt (1968, p. 327) concluded that bivalves were rare and favored shallow, turbulent, well-aerated water of the reef and upper forereef environment. The author interprets the occurrence of the bivalves present in the Guilmette Formation to represent a shallow-water, moderately agitated environment.

Gastropods.— Gastropods are present in limestones of varied lithologies and occur with other fossils. They appear to be restricted to limestone lithologies throughout the study area. One occurrence of importance is the LR-1 section in which gastropods form coquinoid limestone in several intervals. Both low-spiraling and high-spiraling forms are present in the coquinas.

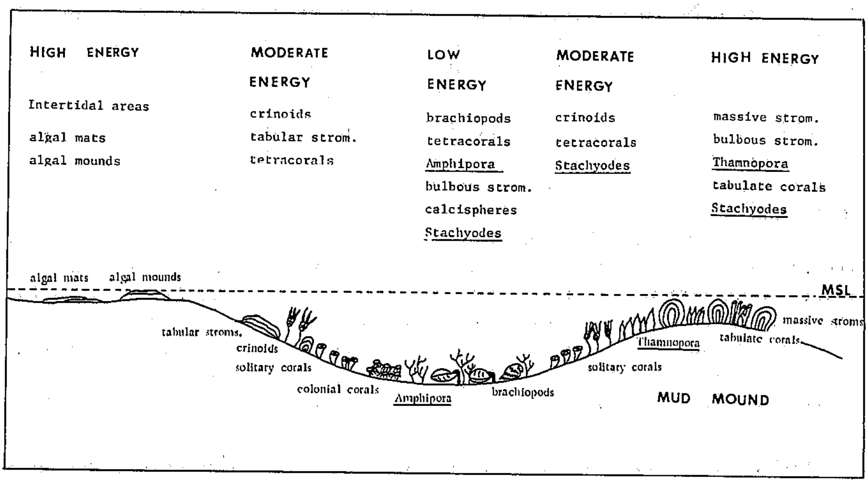
Gastropods are abundant in backreef and deep forereef areas of the Carson Creek North Complex yet are present in all of the reefal environments. The gastropods in the Guilmette appear to have been ubiquitous and tolerant of a wide range of environments ranging from quiet to rough water, which agrees with Leavitt's (1968, p. 328) findings in Alberta.

Crinoids.— Disarticulated crinoid columnals, four to five mm or less in width, are present in many of the limestones of the Guilmette. They exist in fossiliferous units in most of the sections and form coquinas in section LR-1. The small size of the columnals seems consistent in all of the sections and indicates that the crinoid species were characteristically small. Since the crinoid columnals are commonly associated with moderate-energy forms such as corals, stromatoporoids, brachiopods and ostracodes, the author believes that the animals lived on the bottom of a shallow lagoon or moderate-energy shelf environment and have been transported a short distance; this explains the disarticulated columnals. This interpretation agrees with Moore, Lalicker, and Fischer (1952, p. 604) who related the occurrence of crinoids to moderately shallow water conditions.

Ostracodes.— Ostracodes were present in many of the sections measured but were detected only in thin-section analysis. They commonly occur interbedded with finer pellets in pelletal limestones or dolomites. Generally the valves are less than one millimeter in width. Ostracodes are associated with stromatoporoids, tabulate corals, tetracorals, brachiopods, gastropods, forams, and calcispheres but did not necessarily live with any of the above since their small tests could have been transported and deposited in many environments. It would seem likely that because of the small size and living habits, the ostracodes are more successful in low-energy environments. This is substantiated by Leavitt (1968, p. 328) in Alberta where ostracodes are abundant in the backreef facies. Wolfenden (1958, p. 886), however, found that ostracodes were most abundant in reef and forereef environments in his study in England.

Foraminifera.— Only two forms of foraminifera were recognizable in thin-section analysis. One occurred in section DH-1 at 128 feet as a uniserial planispiral form, approximately 0.25 mm in diameter. A second occurrence is a more common form that appears sporadically in most of the sections, a uniserial, linear nodosinelled form (Pl. 5, fig. 8). Nodosinelled foraminifera, approximately 0.25 mm in length, are usually quite abundant in pelletal limestone but are present in some fine- to coarse-grained limestones as well (Pl. 5, fig. 3). They rarely have more than five or six chambers, and most possess lateral spines as shown in the photomicrograph. Other nodosinelleds have been reported from the equivalent formation of the Guilmette in the Arrow Canyon Range to the south by Waines (1962, p. 283). He noted three genera including *Eonodosaria* and *Tikhinella.* They resemble Late Frasnian forms found in Russia and the Kwang-si province of China. *Tikhinella* was also found in the Redwater reef of Alberta and is used to date that formation (Leavitt, 1968, p. 328).

Conodonts.— Samples were examined for conodonts in the hope of finding diagnostic time-restricted forms that could be used for regional correlation over the study area. A conodont sample section in the Cougar Springs area, CR-1, was measured and collected as a standard of reference. *Palmatolepis*



TEXT-FIGURE 6.—Intrepretive diagram of the Guilmette sea floor.

linguiformis(?) was collected by the author at the top of the Guilmette Formation in the section. The occurrence of *Palmatolepis linguiformis* is characteristic of the upper "gigas" zone of Frasnian age as reported by Clark and Ethington (1967, p. 21), who also indicated that the upper "gigas" zone is equivalent to the *Manticoceras* zone. Approximately 70 to 80 feet lower in the section, *Icriodus nodosus* was collected as well as *Polygnathus linguiformis*. The latter form is diagnostic of the middle "dubia" zone, in the lowest part of the Frasnian or *Manticoceras* zone. Other conodont forms were collected in the top 330 feet of the formation. A representative of the "dubia" zone, *Icriodus nodosus* was collected at 805 feet in the section LR-1, in the top part of the section SR-1, at 625 feet in the section DH-1, and at approximately 880 feet in the section ER-1. On this basis the interpretation is made that these occurrences likely indicate the position of the middle "dubia" zone as shown in the illustration (Text-fig. 4). Conodonts collected from measured sections are listed in the described sections.

Algae.— Algae were major contributors to carbonate sedimentation throughout much of Guilmette time. Playford and Lowry (1966, p. 36-39) and Wray (1967) have described many genera of algae from the Canning Basin of Western Australia. Algae have also been described from some reef complexes of Alberta by Wray and Playford (1970, p. 544-55).

Algae were noted from several units in the Guilmette Formation. The chlorophycophyta blue-green or green algae is represented by what is identified as *Sphaerocodium* (?) (Wray, 1967, p. 67) and is present at 170 feet and 1,735 feet in section LR-1 as microscopic branching tubular filaments. *Sphaerocodium*(?) was also noted at 1,115 feet in the section ER-1. Occurrences in both instances are associated with other algal forms such as stromatolites, algal bisquits, or algal mounds. *Girvenella,* a blue-green or green alga, occurs commonly in the Guilmette as elongate filaments associated with calcispheres in pelletal or stromatolitic limestones. *Girvenella* filaments were observed encrusted upon a gastropod shell in one instance.

Rhodophycophyta or red algae also produced carbonate sediments and are present in the Guilmette as a form resembling Solenopora (Wray, 1967, p. 50-51) (Pl. 4, fig. 7). The specimen was collected at 103 feet in section DH-2 associated with calcispheres in pelletal limestones. *Parachaetetes*(?) (Wray, 1967, p. 52-55) was also observed at 15 feet in section DH-2 associated with algal bisquits two to three inches in diameter. What appeared to be *Archaeolithothamnium,* another red algae, produced algal mounds two to three feet high at 170 feet in section LR-1 (Pl. 3, fig. 7).

Algal bisquits are present at 966 feet in the section LR-1, at 15 feet in DH-2, at 340 feet in ER-1, and at 775 feet in PR-1. The bisquits, two to six inches in diameter, are exposed in relief on bedding plane surfaces.

Algae are restricted to the photic zone since they depend on photosynthesis to maintain life. This characteristic makes them useful in interpreting environments in which they are found. Red algae prefer reef or rocky bottoms, green algae prefer sandy and muddy bottoms, and blue-green are characteristically sediment binders. Blue-green algae occurrences in the Guilmette, especially associated with stromatolites and algal structures, are believed to have formed in very shallow, possibly intertidal environments. The basis for such an interpretation is the lithologic association with primary laminated dolomites in the Guilmette and the occurrence of analogous algal growths in modern intertidal environments. Wray (1971, p. 1362) points out that even though blue-green algae is abundant in tidal flat environments, their influence may extend seaward across the backreef environment into deeper waters on forereef slopes. Some stromatolites were reported to have formed in water depths as great as 135 feet (Playford and Cockbain, 1969, p. 1008).

The most abundant and most commonly occurring algal-related fossils in the Guilmette are the radiosphaerid calcispheres (Pl. 5, fig. 7). They occur as spherical bodies ranging from 0.1 to 0.25 mm in diameter with radially arranged prismatic prisms or spines. Generally they are filled with calcite cement and associated with pelletal limestones in approximately 25 percent of the occurrences or with fine- to coarse-grained fossiliferous limestones. They have been reported from the Valentine Member of the Sultan Limestone at the south end of the Arrow Canyon Range associated with pellet, lithoclast, fossil-fragment limestone, and such organisms as stromatoporoids, ostracodes, gastropods, and foraminifera (Stanton, 1967, p. 467).

Calcisphere taxonomic affinities are problematical. They have been related to foraminifera or inorganic structures, but most authors believe them to be related to algae (Stanton, 1963, p. 415-16).

Paleoecologically, fossil calcispheres have been found in Russia in shallow water lagoonal facies and in Alberta in shallow water in shelf or backreef settings. Stanton (1967, p. 468) found them to be preserved most commonly in burrowed pelletal limestones, where they flourished in restricted marine environments. In Australia they are associated in backreef or shelf lagoon sediments (Wray, 1967, p. 48). Most of the occurrences of radiosphaerid calcispheres are in rocks of Frasnian or Fammenian age in Alberta and Australia. A shallow shelf environment was probably the environment in which the calcispheres flourished in the Guilmette Formation.

Faunal Distribution

Text-figure 4 shows the general distribution of organisms in the Guilmette Formation in the study area. Several phenomena are noticeable in the study. Bulbous stromatoporoids appear to be common only in the southern part of the area, whereas massive and tabular stromatoporoids are more restricted in their occurrence. Filamentous algae are abundant in LR-1, whereas calcisphere occurrence is negligible in that section. Apparently the environment of deposition during Guilmette time was inhospitable to bivalve faunas or competition with the abundant brachiopods was too strong. Occurrences of mixed faunas from different environments were noted. For example, in sections ER-1 and PR-1 tabulate stromatoporoids occur with bulbous forms and the branching form, *Amphipora*. The tabular forms are characteristic of forereef deposits, and the others are associated with backreef deposits in Alberta. Using reef environment terms does not confirm the existence of a reef buildup in the study area but describes ecological parameters characteristic of reef environments. Most of the fossil assemblages present in the Guilmette appear to be near the environment in which they lived or else they have been transported short distances.

By using the lithologic and fossil occurrences it is possible to reconstruct the environments that existed in the miogeosyncline during Guilmette time. Relationship factors of organisms to reef environments used in this study were obtained from Leavitt (1968, p. 298-413), who made observations in the Carson Creek North Complex of Alberta (Text-fig. 3). Tabular stromatoporoids and some branching types are indicative of a forereef environment in Alberta. Crinoids, solitary tetracorals, gastropods, and some forms of algae are present also in forereef deposits. These organisms apparently required access to marine water in moderately agitated conditions to grow. The writer suggests that such conditions could have been present in the study area in a shelf environment consisting of varied bottom topography.

Massive, bulbous, and branching stromatoporoids are normally associated in the reef environment in Alberta. Tabulate corals, bivalves, and red algae may also be present in a reef environment. These organisms thrived in well-oxygenated, turbulent conditions. A shallow shelf could contain such energy conditions near shore or possibly on local topographic highs or pelletal build-ups on the shelf.

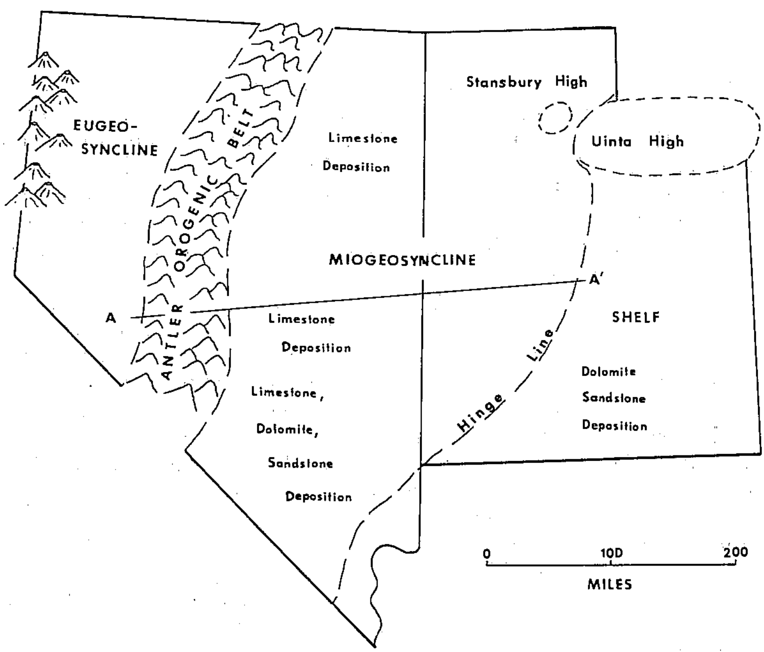
Crinoids, tetracorals, gastropods, blue-green algae, brachiopods, ostracodes, foraminifera, and calcispheres flourished in backreef environments. Crinoids and tetracorals were probably marginal backreef dwellers since they required more agitated conditions than other organisms. Bulbous and branching stromatoporoids, especially *Amphipora,* made up a large part of the epifauna. The backreef environment is characterized by quiet, clear-water conditions, generally with muddy bottoms or pelletal accumulations. Most of the fossils present in the Guilmette Formation are indicative of this environment. Quiet, clear-water conditions were probably present locally in the shelf environment in deeper water areas below normal wave base. Near the strand line or in very local intertidal areas above wave base blue-green algae were able to bind carbonate sediments together forming small mounds and algal mats.

ENERGY TRENDS

Energy levels derived by relating thin-section analysis to the energy index form the basis for interpreting energy changes in the Guilmette Formation. In studying the energy graphs in Text-fig. 4, several obvious trends can be observed. Sections LR-1, SR-1, DH-1, and ER-1 show that minor fluctuations from quiet-water conditions to moderately agitated conditions existed in relatively uniform cycles in the lower part of the section. Indications of uniform energy changes throughout the studied area of the miogeosyncline are apparent but difficult to correlate from section to section. Near the upper parts of sections PQR-1, LR-1, SR-1, DH-1, and PR-1 energy fluctuations become more extreme, with energy levels ranging from quiet or intermittently agitated to strongly agitated conditions. The high-energy or strongly agitated conditions are usually associated with the introduction of quartz clastics into the area. Section ER-1 lacks the high-energy fluctuations in the upper part of the section and also the quartz clastic units. Apparently local conditions inhibited sand deposition in that area. Faunal assemblages reflect different energy levels since brachiopods, gastropods, and some types of stromatoporoids predominate in the quieter conditions while massive and tabular stromatoporoids with *Thamnopora* and other corals seem to have flourished locally in higher-energy conditions. A notable energy peak of moderate agitation (IV) is present in the brachiopod zone of SR-1, DH-1, and ER-1. Fluctuations of energy in section PQR-1 match reasonably well with the upper part of LR-1, allowing a possible correlation between those two sections. Periods of relative stability are reflected in the lower parts of most of the sections. It may have been during one of these stable periods that the buildup in section DH-2 was able to grow to form a topographic structure on the sea floor.

CONCLUSIONS

Reso (1963, p. 909) described the upper part of the lower Guilmette in the Pahranagat Range as a massive biostromal cliff containing prolific amounts of large spheroidal and encrusting stromatoporoids and other fauna that formed a foundation upon which local bioherms developed. He describes one such "reef" on the east slopes of Mount Irish associated with off reef facies. Reso interpreted the lower units in the Guilmette in the Pahranagat Range to be equivalent to the Beaverhill Lake Formation and the upper units to be equivalent in age and depositional environment to the Cook Lake biostromal shoal foundation upon which the Leduc reef growth developed. Carbonate buildups in the lower part of the upper Guilmette were considered by Reso to be correlative with the Leduc reef. Stanton (pers. comm.) believes there is little similarity in detail between the mound on Mount Irish and the Leduc reefs he has worked with. The application of reef terminology has been a problem in the literature for many years and the term "reef" has had many interpretations. The writer prefers to use the definition proposed by Lowenstain (1950) in which he interpreted reefs in terms of the fundamental biologic potentials of organisms to erect rigid topographic structures by frame building, sediment retention, and binding, thus creating a wave-resistant structure.



TEXT-FIGURE 7.—Interpretive paleogeographic map of Nevada and Utah during Guilmette time.

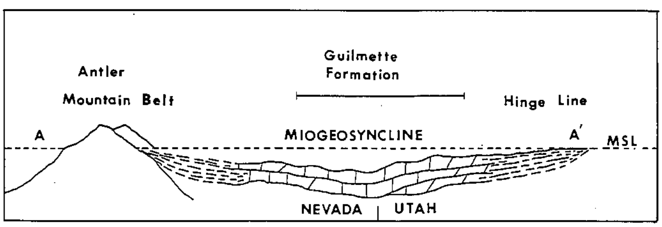
The writer has no experience with the reef trends of Alberta except for the literature. But based on his experience with the Guilmette in Nevada and Utah, he concludes that the carbonate buildups in the Guilmette are not related, except possibly in age, to the reef facies of Alberta and are not reefs in terms of Lowenstain's definition.

The writer observed only part of the Pahranagat section described by Reso, but in the South Egan Range and the adjacent areas he noted massive biostromes of bulbous stromatoporoids and *Amphipora* which did not form foundations for bioherm or reef development. The bioherms or reefs on Mount Irish must be local occurrences of such features since they have not been observed elsewhere in the area. The only reeflike buildup containing stromatoporoids in this study was one 12 feet thick observed at the south end of the Douglas Hills. Massive carbonate buildups observed in the South Egan Range represent thick pelletal or lime mud bank deposits rather than reef buildups.

Based on the occurrence of high-, moderate-, and low-energy organisms, lithologies, energy index, and the thickness trends of the Guilmette in the miogeosyncline, the writer concludes the following concerning the Guilmette depositional environment: (1) The Guilmette was deposited in a relatively shallow-shelf miogeosynclinal environment in which the miogeosyncline formed a north-south trending shallow trough.

(2) Subsidence was generally slow but appeared to be more active in two separate basins within the miogeosyncline (Text-fig. 2). One basin accumulated over 3,000 feet of Guilmette carbonate sediments north of Pioche, Nevada, and northward in the vicinity of Wendover, Utah, a second depocenter accumulated over 2,200 feet of Guilmette sediments.

(3) Water was generally not deep in the miogeosyncline during Guilmette deposition, but fluctuations in the water depth, possibly due to tectonic activity in the Antler Orogenic Belt or increased sedimentation in the area from the craton, allowed high-energy organisms to develop in turbulent oxygenated water conditions. The massive stromatoporoids, algal mats, and algal mounds attest to the effect of periodic shallowing of water depth or of a sea floor containing local positive and negative topographic relief. This would allow high-energy organisms to live on the positive mounds and low-energy organisms to survive in the surrounding lower inter areas (Text-fig. 8). Lower-energy or deeper-water conditions allowed prolific brachiopod faunas to flourish. The areal distribution of the brachopoid unit described in Text-figure 7 coincides with the thicker accumulations of Guilmette sediments in the southern part of the area.



TEXT-FIGURE 8.—Intrepretive cross section A-Á through Nevada and Utah during Guilmette time.

(4) Sandstone deposition did not occur in what may have been the deepest part of the intramiogeosynclinal basin to the south but is evidenced in most other parts of the study area. This accounts for the lack of sand in the South Egan Range and Dutch John Mountain sections.

(5) Based on the occurrence of collapse breccias in some parts of the study area, periods of subaerial exposure allowed local karst topography to develop in the limestone units of the lower part of the Guilmette Formation.

(6) The energy index used in this study indicates fluctuating energy levels during Guilmette deposition. Good correlation exists between organism occurrence and sediment energy levels. High-energy organisms occur at high sedimentary energy levels and low-energy organisms correspond with low sedimentary energy levels (Text-fig. 7).

(7) Guilmette carbonate buildups are not reefs as referred to by Reso and others and are not related in their depositional environment to the reef facies of Alberta. Even though fossils similar to those found in the Devonian of Australia and Alberta exist in the Guilmette, they do not reflect the same reef facies. The fossils do reflect similar ecological conditions present in a shallow-shelf environment similar to those noted in Belgium by Lecompte (1968).

(8) Dolomitization of the limestone units, common in the southern part of the area, was due to the restriction of marine waters by the carbonate buildups in the Guilmette. Hypersaline brines were formed, resulting in the dolomitization of the limestone by refluxion or saturation with high magnesium bearing solutions.

(9) On the basis of conodont occurrences, the top of the Guilmette is in the Upper "gigas" conodont zone and the middle portion is in the Middle "dubia" zone. The Givetian-Frasnian boundary in eastern Nevada and western Utah appears to be in the lower part of the Guilmette Formation.

APPENDIX

DESCRIPTIONS OF STRATIGRAPHIC SECTIONS

Pequop Mountains Section PQR-1

Feet/ Unit	*Total Feet*	*Description*
Guilmette Formation		
25	25	Ls, fos, f gry, wd gry; cal tmbs, pels; v tk bdd; mas; ldg; *Amphipora,* calcispheres
10	35	Cov slp
2	37	Ls, fos, m xln gry, w lt gry-buff; abd cal rnbs; Lim stns; m bdd; mas; ldg; bulb stromatoporoids, *Amphipora,* tetracorals
3	40	Cov slp
5	45	Ls, pel, f grn; gry, wd gry-buff; pel .25-.5 mm; v tk bdd; mas; ldg; nodosinellid foraminifera calcispheres
5	50	Cov slp
10	60	Ls, f grn; gry, wd lt gry; v tk bdd; mas; ldg
30	90	Cov slp

8	98	Ls, fos, f grn; gry wd lt gry; v tk bdd; mas; ldg; *Amphipora,* calcispheres
7	105	Cov slp
5	110	Ls, fos, f grn; gry, wd lt gry; v tk bdd; mas; ldg; *Amphipora,* gastropods, nodosinellid foraminifera, calcispheres
85	195	Cov slp
2	197	Ls, pel, f grn; gry, wd gry; pel. .1-.25 mm; m bdd; mas; ldg; nodosinellid foraminifera, calcispheres
8	205	Cov slp
15	220	Ls, fos, f grn; gry, wd buff; ctd grns; v tk bdd; mas; ldg; *Amphipora,* tetracorals, nodosinellid foraminifera, calcispheres
15	235	Cov slp
5	240	Ls, f grn; gry, wd gry-buff; tk bdd; mas; ldg; *Amphipora,* calcispheres
10	250	Cov slp
15	265	Ls, f grn; gry, wd lt gry-buff; tk bdd; mas; ldg *Amphipora,* Calcispheres, conodonts, *Lonchodina*
5	270	Cov slp
45	315	Ls, fos, f grn; 2 ft calc qtz ss; Cal rmbs, orgnc mat; tk bdd; mas; ldg-slp; *Amphipora,* nodosinellid foraminifera, calcispheres
45	360	Ls, f grn; gry, wd lt gry-buff; tk bdd; mas; ldg-slp; calcispheres
5	365	Dol, f grn; gry, wd yel-brn; tn bdd; slp
45	410	Cov slp
5	415	Ss, noncalc; m grn; yel, wd yel; qtz grns; sbrd; fr srtd; x bd; 4-6 in sets; tn bdd; mas; slp
5	420	Dol, f grn; gry, wd gry; tn bdd; slp
8	428	Ls, f grn; gry, wd gry-buff; tk bdd; mas; ldg; conodonts, *Roundya*(?)
5	433	Dol, f grn; gry, wd lt gry-yel; lam-tn bdd; slp
32	465	Cov slp
10	475	Ls, mot, f grn; gry, wd lt gry-buff; Cal rmbs; tk bdd; mas; ldg
15	490	Cov slp
5	495	Ss, noncalc, m grn; buff; wd buff; qtz grns; sbrd; w srtd; xbd, 4-6 in sets; tn bdd; mas; ldg
105	600	Ls, pel, f grn; gry, wd gry-buff; pel .25-.5 mm; v tk bdd; mas; clf; calcispheres
5	605	Ss, noncalc, f grn; yel, wd buff; qtz grns; subang; w srtd; m bdd; mas; ldg
120	725	Ls, fos, pel, f grn; gry, wd gry-buff; pel .25-.5 mm; tk bdd; mas; clf; tetracorals,

		brachiopods, nodosinellid foraminifera, calcispheres
40	765	Ls, fos, pel, cht, f grn; gry, wd lt gry; pel .5-1 mm; tk bdd; mas; ldg; crinoid columnals, calcispheres, conodonts, *Lonchodina*

Leppy Range Section LR-1

Middle Devonian Simonson Dolomite
Base of Guilmette Formation

37	37	Ls, fos-coq, f grn; gry, wd dk gry; orgnc mat, sp cal; tn-m bdd; slp; tetracorals, *Heliophyllum*(?), brachiopods, gastropods, crinoids, calcispheres, algae
13	50	Ls, fos, f grn; gry, wd lt gry-buff m bdd; ldg; gastropods, *Girvenella,* algal stromatolites
2	52	Ls, fos, f grn; dk gry, wd gry; m bdd; slp; brachiopods, gastropods
6	58	Ls-dol inbd, micxln; gry, wd lt gry; m bdd; slp
7	65	Ls, coq, f grn; dk gry, wd gry; m bdd; slp; gastropods
35	100	Dol, micxln; gry, wd buff-brn; m bdd; slp
5	105	Ls, f xln; dk gry, wd gry; tn bdd; slp
65	170	Ls, strmlt, brc, f grn; gry, wd lt gry-lt brn; orgnc mat; tn-tk bdd; ldg-slp; occ gastropods, algal mounds 1-2 ft tk, *Sphaerocoduim*(?) algal stromatolites
25	195	Ls, fos, f grn; dk gry, wd lt gry-gry; orgnc mat, Py; m bdd; ldg-slp; bulb stromatoporoids, algal stromatolites
5	200	Cov slp
20	220	Ls, fos, pel, f grn; gry, wd dk gry; tn bdd; slp; gastropods, algal heads, algal stromatolites
10	230	Cov slp
30	260	Dol, micxln; altntg lt-dk gry; m bdd; slp
15	275	Ls, fos, f grn; dk gry, wd lt gry; Py; tn bdd; slp; gastropods, algae
5	280	Dol, strmlt, f grn; brn, wd lt brn; nt bdd; slp; algal stromatolites
30	310	Ls, fos, f xln; gry, wd dk gry; tn bdd; mas, clf; brachiopods, gastropods
20	330	Ls-dol inbd; f xln; altntg lt-dk gry; m bdd; slp
30	360	Ls, f grn; dk gry, wd dk gry; tn bdd; slp
5	365	Cov slp
45	410	Ls, f grn; altntg lt-dk gry; m bdd; slp
5	415	Cov slp

50	465	Ls, fos, f grn; gry, wd dk gry; m bdd; mas; clf; brachiopods
10	475	Cov slp
10	485	Ls, aren, strmlt, f grn; gry, wd lt gry-buff; qtz grns; sbrd; w srtd, m bdd; clf
20	505	Ls, f grn; altntg lt-dk gry; m bdd; slp
8	513	Dol, micxln; gry, wd lt brn; lam; slp
15	528	Ls, strmlt, f grn; gry, wd dk gry; lam; ldg-slp; algal stromatolites
10	538	Ls-dol inbd; f grn; gry, wd lt-dk gry; lam; slp
6	544	Ss, noncalc, f grn; gry, wd yel-brn; qtz grns; sbrd; w srtd; m bdd; ldg
10	554	Ls, f grn; dk gry, wd dk gry; lam; slp; algae
13	567	Cov slp
15	582	Ls, f grn; gry, wd dk gry; lam-tn bdd; slp; algal stromatolites
20	642	Cov slp
5	647	Dol, brc, micxln; lt gry, wd lt-dk gry; tn bdd; slp
30	677	Ls-dol inbd, f grn; altntg lt-dk gry; ss clst 6-7 in dia, m bdd; slp bioturbated
15	692	Dol, micxln; lt gry, wd lt gry; cht nod; lam; slp; algal stromatolites
30	722	Cov slp
45	767	Ls-dol inbd, micxln, altntg lt gry dol-dk gry ls; lam-tn bdd; ldg-slp; algal stromatolites, bioturbated
5	772	Dol, brc, f grn; altntg lt-dk lam; ldg; bryozoan(?)
20	792	Ls, f grn; altntg lt-dk gry; m bdd; ldg; fos debris
24	816	Ls, fos, f-crs grn; gry, wd dk gry; orgnc mat; tk bdd; mas; ldg; bulb stromatoporoids, *Amphipora, Thammopora,* tetracorals, brachiopods, gastropods, crinoid columnals, conodonts, *Icriodus nodosus Polygnathus foliata, Bryantodus*
4	820	Ls, fos, f xln; gry, wd gry; m bdd; mas; ldg; bulb stromatoporoids, *Thamnopora,* tetracorals, fos debris
55	875	Ls, fos, f-crs grn; dk gry, wd lt gry; tk bdd; mas; ldg; bulb stromatoporoids, *Actinostroma, Amphipora, Thamnopora,* tetracorals, brachiopods, *Stringocephalus*(?), gastropods, calcispheres
10	885	Dol, micxln; lt gry, wd lt gry; tn bdd; slp
10	895	Ls, f grn; gry, wd dk gry; tn bdd; slp
10	905	Ls, fos, f-crs grn; gry, wd gry; tk bdd;

		ldg; bulb stromatoporoids, *Stringocephalus*(?)
15	920	Ls, fos, f grn; gry, wd gry; tk bdd; mas; ldg; *Thamnopora*
15	935	Ls, fos, f grn; gry, wd gry; tk bdd; mas; ldg; *Amphipora, Stringocephalus* (?), gastropods
13	948	Cov slp
8	956	Dol, aren, f grn; lt gry, wd gry-brn; qtz grns; sbrd; w srtd; m bdd; ldg
10	966	Ls, fos-dol inbd, f xln; gry, wd lt-dk gry; tn bdd; slp; brachiopods, calcispheres, algal bisquits
34	1000	Cov slp
10	1010	Ls, pel, v f grn; gry, wd dk gry; pel .06-1 mm; m bdd; ldg
15	1025	Cov slp
20	1045	Ls-dol inbd, micxln-f grn; dk gry, wd lt-dk gry; lam; clf; algal stromatolites
70	1115	Ls, fos, f-crs grn; grn; gry, wd gry; Py; tn bdd, clf-slp; brachiopods, gastropods, conodonts, *Spathagnathodus*
5	1120	Ls-dol mot, f grn; lt-dk gry, wd lt brn; tk bdd; mas; ldg; brachiopods
40	1160	Ls, fos, pel, v f grn; gry, wd gry; tn bdd; slp; shell debris, brachiopods, gastropods
80	1240	Ls, fos, pel, f-crs grn; gry, wd gry; Py; tn bdd; slp; *Atrypa, Allenaria*(?), conodonts, *Ozarkodina, Lonchodina, Spathagnathodus*
10	1250	Cov slp
50	1300	Ls, fos, pel, f-crs grn; gry, wd gry; tn bdd; ldg-slp, *Atrypa, Allenaria*(?)
20	1320	Ls, fos, f-crs grn; gry, wd gry; m bdd; clf; shell debris
10	1330	Cov slp
20	1350	Ls, fos, micxln-crs grn; gry, wd gry; tn bdd; clf; shell debris, brachiopods, gastropods, conodonts, *Spathagnathodus*
10	1360	Cov slp
35	1395	Ls, fos, f-crs, grn; gry, wd gry-brn; orgnc mat, Py; tn bdd; ldg-slp; *Amphipora,* brachiopods, bivalves, crinoid columnals
40	1435	Ls, fos, f grn; gry, wd gry; m bdd; ldg; gastropods, burrows
75	1510	Ls, fos-dol inbd, f-crs grn; gry, wd gry-brn; lam-tn bdd; ldg; *Amphipora,* bryozoans, algal stromatolites
25	1535	Ls, fos, cht, f grn; gry, wd lt gry; m bdd; ldg; *Amphipora, Thamnopora,* tetracorals, algal stromatolites

15	1550	Ls, fos, f-crs grn; gry, wd gry; tk bdd; ldg; sil bulb stromatoporoids, *Amphipora*
130	1680	Ls, fos, pel, f-crs grn; gry, wd dk gry; Py; tn-m bdd; ldg-slp; brachiopods, gastropods, algal stromatolites
15	1695	Cov slp
40	1735	Ls, f grn; gry, wd gry-brn; orgnc mat; tn bdd; mas; ldg; algae, *Sphaerocodium*(?)
5	1740	Ls, micxln; dk gry, wd dk gry; lam; slp
25	1765	Cov slp
15	1780	Ls, aren, micxln-f grn; gry, wd gry-brn; qtz grns; sbrd; w srtd; tn-m bdd; ldg
10	1790	Cov slp
25	1815	Ls, aren, f grn; gry, wd gry-brn; Py; qtz grns; subang; w srtd; crnt rpl mks; v tn bdd; ldg
15	1830	Cov slp
5	1835	Ls, f grn; gry, wd dk gry; tn bdd; ldg
20	1855	Cov slp
35	1890	Ls, fos, v f grn; gry, wd lt gry; tk bdd; mas; ldg; bulb-tab stromatoporoids; *Amphipora, Thamnopora,* colonial tetracorals, crinoid columnals
25	1915	Ls, fos, f grn; gry, wd gry; m bdd; ldg; mas, bulb stromatoporoids, crinoid columnals
25	1940	Ls, f grn; gry, wd gry; m bdd; ldg
40	1980	Cov slp
10	1990	Ls, f grn; gry, wd dk gry; tn bdd; ldg
15	2005	Cov slp
55	2060	Ls, fos, f-crs grn; gry, wd dk gry; tn-m bdd; ldg; bulb stromatoporoids, *Thamnopora,* tetracorals, brachiopods, gastropods
10	2070	Cov slp
5	2075	Ss, noncalc, f grn; gry-buff; sbrd; w srtd; tk bdd; ldg
20	2095	Cov slp
20	2115	Ls, f grn; gry, wd gry; tn bdd; mas, ldg

Top of Guilmette
Bottom of Pilot Shale

Snake Range Section SR-1

Middle Devonian Simonson Dolomite
Base of Guilmette Formation

3	3	Ls, fos, f grn; gry, wd lt gry; tk bdd; mas; reeflike buildup
2	5	Ss, calc, f grn; gry, wd gry-brn; qtz grns; ang; w srtd slp
5	10	Ls, pel, micxln-f grn; gry, wd lt gry; m bdd; slp

15	25	Ls-dol inbd, f xln; altntg lt-dk gry; tn bdd; slp
10	35	Cov slp
5	40	Ls, f grn; gry, wd gry; m bdd; slp
10	50	Cov slp
5	55	Ls, pel, f grn; gry, wd gry; pel .06-.1 mm; lam; mas; ldg
30	85	Ls, pel, f grn; gry, wd lt gry; tk bdd; mas; ldg; brachiopod debris
20	105	Ls, fos, f-crs grn; gry, wd gry; tk bdd; mas; clf; brachiopods
70	175	Ls, brc, pel, f-crs grn; gry, wd lt gry; Lim; v tk bdd; mas; clf; *Amphipora,* ostracodes
10	185	Ls, fos, pel, f-crs grn; dk gry, wd dk gry; v tk bdd; mas; clf; shell debris
95	280	Ls, pel, f xln-f grn; gry, wd lt gry; pel .1-.25 mm; Lim vns; v tk bdd; mas; clf
35	315	Ls, brc, f grn; gry, wd lt gry; Hem vns; v tk bdd; mas; clf
15	330	Ls, fos, f grn; lt gry, wd lt gry; m bdd; mas; ldg; gastropods, conodonts, *Icriodus, Polygnathus, Bryantodus, Spathagnathodus, Lonchodina*
10	340	Cov slp
5	345	Ls, f grn; gry, wd gry; m bdd; mas; ldg
60	405	Cov slp
5	410	Ls, f grn; gry, wd lt gry-buff; m bdd; ldg
5	415	Cov slp
15	430	Ls, f grn; gry, wd lt gry-buff; tk bdd; mas; ldg; conodonts, *Bryantodus*
30	460	Ls, fos, pel, f grn; gry, wd gry; Lim; v tk bdd; mas; ldg; brachiopods, ostracodes
15	475	Cov slp
80	555	Ls, brc, pel, f-crs grn; gry, wd lt gry-buff; Hem; pel .1-.25 mm; tk bdd; mas; ldg
5	560	Ls, fos, f grn; gry, wd gry-buff; m bdd; mas; ldg; bulb stromatoporoids, algae
15	595	Ls, fos, brc, pel, f-crs grn; gry, wd gry-buff; Lim vns, sp cal; m bdd; mas; ldg; bulb stromatoporoids
45	640	Ls, brc, f-crs grn; gry, wd dk gry-buff; Hem vns; v tk bdd; mas; ldg; foraminifera
25	665	Ls, fos, pel, cht, f-crs grn; gry, wd buff; Hem-Lim; v tk bdd; mas; clf; *Amphipora*
5	670	Ss, noncalc, f grn; gry, wd buff; qtz grns; ang; w srtd; m bdd; slp
10	680	Ls, f grn; gry, wd buff; m bdd; mas; ldg; ostracodes
25	705	Ls, fos, f grn; gry, wd gry-buff; v tk bdd;

		mas; ldg; bulb stromatoporoids, brachiopods, gastropods
15	720	Ls, fos, f-crs grn; gry, wd gry-buff; tn bdd; ldg; shell debris
45	765	Ls, fos, cht, f grn; gry, wd lt gry-buff; m bdd; mas; clf; bulb stromatoporoids, gastropods
40	805	Ls, fos-coq, f-crs grn; gry, wd blue gry; tn bdd; slp; brachiopods, *Atrypa, Allenaria*(?), gastropods, conodonts, *Lochodina, Hindeodella*
15	820	Cov slp
25	845	Ls, fos, pel, f-crs grn; gry, wd gry-pink; Hem; tn bdd; slp; brachiopods, gastropods, ostracodes
15	860	Ls, fos, f-crs grn; gry, wd lt gry-pink; Hem; tn bdd; ldg; bulb stromatoporoids, tetracorals, brachiopods, crinoid columnals, ostracodes, conodonts, *Polygnathus foliata,* P. normalis, Lonchodina
5	865	Dol, aren, v f grn; lt gry, wd gry-brn; qtz grns; sbrd; fr srtd; rpl mks; m bdd; slp
40	905	Ls, fos, f-crs grn; dk gry, wd dk gry-gry; tk bdd; mas; ldg; *Thamnopora,* tetracorals, brachiopods, gastropods
30	935	Ls, fos, cht, f-crs grn; gry, wd lt gry-buff; Hem; m bdd; mas; clf; bulb stromatoporoids, *Amphipora, Thamnopora,* tetracorals, brachiopods, calcispheres
10	945	Ls, fos, f grn; gry, wd lt gry; m bdd; ldg; brachiopods
5	950	Cov slp
5	955	Ss, noncalc, f grn; gry, wd gry-buff; qtz grns; sbang; w srtd; m bdd; slp
10	965	Cov slp
5	970	Ls, fos, mot, f-crs grn; gry, wd lt gry-gry; m bdd; ldg; shell debris
5	975	Dol, micxln; lt gry, wd lt gry; tn bdd; slp

Douglas Hills North Section DH-1

Guilmette Formation

20	20	Ls, pel, m-crs grn; gry, wd gry-buff; tn bdd; mas; ldg; calcispheres, algae *Girvenella*
5	25	Cov slp
5	30	Dol, micxln; gry, wd buff; tn bdd; ldg
10	40	Cov slp
5	45	Ls, pel, f grn; gry, wd gry-buff; pel .1-.25 mm; tn bdd; mas; ldg
10	55	Cov slp

35	90	Ls, fos, pel, f-crs grn; gry, wd gry-buff; tn bdd; mas; ldg; bulb stromatoporoids, *Trupetostroma*(?), *Amphipora,* calcispheres
5	95	Cov slp
35	130	Ls, fos, pel, f-crs grn; gry, wd gry-buff; pel .1-.25 mm; tn bdd; mas; clf; bulb stromatoporoids, *Amphipora,* calcispheres, *Girvenella*
5	135	Cov slp
10	145	Ls, f grn; gry, wd lt gry-buff tn bdd; slp
5	150	Cov slp
10	160	Ls, pel-dol inbd; f-m grn; gry, wd lt gry; tn bdd; rpl mks; slp; calcispheres, *Girvenella*
30	190	Ls, pel, f grn; gry, wd gry-buff; Lim; pel .1-.25 mm; tn bdd; mas; clf; algae
10	200	Ls, v f grn; gry, wd lit gry-brn; tn bdd; slp
35	235	Ls, fos, pel, f-crs grn; gry, wd gry-buff; lam-tn bdd; mas; clf; brachiopods, algae
95	330	Ls, pel dolic, f grn; dk gry, wd brn; lam-tn bdd; rpl mks, slp; *Amphipora,* ostracodes, calcispheres
10	340	Dol, micxln; pink-gry, wd buff; tn bdd; slp
15	355	Ls, micxln; gry, wd lt, gry; tn bdd; slp; calcispheres
5	360	Cov slp
15	375	Ls, fos, f grn; gry, wd pink gry-buff; tk bdd; mas; ldg; bulb-tab stromatoporoids, *Trupetostroma*(?), calcispheres
5	380	Dol, micxln; gry, wd brn; tn bdd; slp
10	390	Cov slp
25	415	Ls, fos, f-crs grn; gry, wd lt gry; tk bdd; mas; ldg; bulb stromatoporoids, brachiopods, crinoid columnals, calcispheres
20	435	Cov slp
15	450	Ls, mot, f grn; gry; wd lt gry-buff; m bdd; ldg
145	595	Ls, fos, pel, cht; f-crs grn; gry; wd gry-buff lam-tn bdd; mas; clf; bulb stromatoporoids, *Thamnopora,* brachiopods, gastropods, crinoid columnals
35	630	Ls, fos, f grn; gry, wd lt gry; tn bdd; slp; brachiopods, *Atrypa, Spinatrypa, Allenaria*(?), calcispheres, conodonts, *Icriodus nodosus*
25	655	Cov slp
115	770	Ls, fos, f grn; gry, wd lt gry; tn bdd; clf-slp; bulb-tab stromatoporoids, *Hermatostroma*(?), *Amphipora, Thamnopora, Coe-*

		nites(?), tetracorals, *Pachyphyllus,* brachiopods, *Atrypa, Spinatrypa, Allenaria* (?), gastropods, crinoid columnals, calcispheres, algae *Girvenella,* conodonts, *Polygnathus foliata, Ligonodina Hindeodella*
50	820	Ls, fos, f grn; gry, wd lt gry-buff; tn-m bdd; mas; clf; bulb stromatoporoids, tetracorals, gastropods
20	840	Cov slp
25	865	Ls, fos, f grn; gry, wd lt gry-buff; m bdd; clf; tetracorals, brachiopods, *Atrypa,* conodonts, *Ozarkodina*
40	905	Cov slp
5	910	Ls, aren, v f grn; gry, wd lt gry-brn; qtz grns; subang; fr srtd; m bdd; ldg
60	970	Ls, fos, f-crs grn; gry, wd lt gry-buff; m bdd; mas; clf; tetracorals, brachiopods, gastropods, crinoid columnals, ostracodes, calcispheres
5	975	Dol, micxln; brn, wd buff; tn bdd; slp
15	990	Ls-dol inbd, micxln-f grn; gry, wd lt gry-buff; m bdd; ldg-slp; calcispheres
5	995	Ss, noncalc, f grn; gry, wd buff; qtz grns; subang; w srtd; m bdd; ldg
105	1100	Ls-dol inbd, micxln-f grn; altntg lt gry-buff; m bdd; ldg-slp; gastropods calcispheres

Douglas Hills South Section DH-2

Guilmette Formation

15	15	Ls, fos, f grn; gry, wd gry-buff; tn bdd; mas; ldg; *Amphipora,* brachiopods, *Stringocephalus*(?), nodosinellid foraminifera, calcispheres, algal bisquits, *Parachaetetes*(?)
5	20	Ls, pel, f grn; gry, wd lt gry; tn bdd; ldg; calcispheres
10	30	Ls, fos, f-crs grn; gry, wd gry; tk bdd; mas; ldg; *Trupetostroma*(?), *Amphipora,* nodosinellid foraminifera
5	35	Ls, fos, pel, f grn; gry, wd lt gry; tk bdd; mas; ldg; gastropods, calcispheres
5	40	Ls, fos, pel, f-crs grn; dk gry, wd dk gry; tk bdd; mas; ldg; *Amphipora,* nodosinellid foraminifera
55	95	Ls, fos, f-crs grn; gry, wd lt gry-buff; m bdd; mas; ldg; bulb stromatoporoids, *Amphipora,* calcispheres, algae
5	100	Ls, fos, pel, f-crs grn; altntg lt-dk gry; m bdd; clf; mas stromatoporoids, *Hammatostroma, Amphipora,* calcispheres

15	115	Ls, fos, mot, f-crs grn; gry, wd lt-dk gry; m bdd; mas; ldg; *Amphipora,* nodosinellid foraminifera, calcispheres
5	120	Ls, fos, pel, f-crs grn; gry, wd gry; m bdd; mas; ldg; bulb stromatoporoids, *Clathrocoilona*(?), calcispheres
12	132	Ls, fos, f-crs grn; gry, wd lt gry; v tk bdd; mas; clf; reef-like buildup, bulb stromatoporoids, *Trupetostroma* (?), *Hammatostroma, Stachyodes, Amphipora,* ostracodes, nodosinellid foraminifera, calcispheres, algae
11	143	Ls, fos, f grn; lt gry, wd lt gry; v tk bdd; mas; clf; bulb stromatoporoids, *Hammatostroma, Clathrocoilona, Stachyodes, Amphipora, ostracodes,* nodosinellid foraminifera, calcispheres

Egan Range Section ER-1

Middle Devonian Simonson Dolomite
Base of Guilmette Formation

120	120	Ls, brc, f grn; gry, wd lt gry-buff; v tk bdd; mas; clf
25	145	Ls, fos, f-crs grn; gry, wd gry-buff; m bdd; ldg; *Thamnopora,* tetracorals, brachiopods, gastropods, calcispheres, conodonts, *Icriodus nodosus; Polygnathus foliata, P. normalis, Ozarkodina*
5	150	Ls, fos-coq, f-crs grn; gry, wd lt gry; tn bdd; mas; ldg; brachiopods, conodonts, *Icriodus, Polygnathus, Lonchodina, Hindeodella*
105	255	Ls, fos, f grn; gry, wd gry-buff; tn bdd; ldg-slp; brachiopods, gastropods, crinoid columnals, conodonts, *Icriodus nodosus, Polygnathus foliata*
5	260	Ls, mot, f grn; lt-dk gry; m bdd; ldg
10	270	Ls, fos, f grn; gry, wd gry; tn bdd; slp; bulb stromatoporoids, brachiopods, gastropods, calcispheres
5	275	Ls f grn; gry, wd gry; tn bdd; slp
5	280	Ls, micxln; gry, wd lt gry; tn bdd; slp
5	285	Dol, pel, f grn; gry, wd lt gry; tn bdd; slp; ostracodes
5	290	Ls, ool, crs grn; gry, wd gry; ool, .5-1 mm; tn bdd; slp
15	305	Ls, fos, pel, f-crs grn; gry, wd lt gry; m bdd; bulb stromatoporoids, gastropods
10	315	Ls, pel, f grn; gry, wd gry; m bdd; ldg
25	340	Dol, micxln; gry-brn, wd lt gry-buff; lam-tn bdd; slp; algal bisquits

35	375	Cov slp
5	380	Ls, f grn; dk gry, wd gry; tn bdd; slp
5	385	Cov slp
5	390	Dol, micxln; gry-brn, wd lt buff; lam; slp
5	395	Cov slp
5	400	Ls, pel, f-m grn; gry, wd gry; lam-tn bdd; slp
5	405	Cov slp
5	410	Dol, micxln; gry, wd pink; lam-tn bdd; slp
5	415	Ls, pel, f-crs grn; gry, wd gry; lam; slp
15	430	Cov slp
15	445	Ls, fos, f-crs grn; gry brn, wd lt gry-dk brn; orgnc mat; m bdd; ldg; bulb stromatoporoids, *Trupetostroma*(?), *Amphipora*, brachiopods
5	450	Cov slp
35	485	Ls-dol inbd, mot, micxln; lt-dk gry; tn bdd; clf
75	560	Dol. micxln-f grn; mot gry, wd lt gry-brn; tn bdd; ldg-slp
10	570	Cov slp
145	715	Dol, micxln-f grn; altntg lt-dk gry; tn bdd; ldg-slp; *Amphipora*
5	720	Ls, fos, f-crs grn; gry, wd lt gry; m bdd; ldg; brachiopods, gastropods
5	725	Cov slp
35	760	Dol, f xln; dk gry; wd brn; stng hydcb odor; lam-tn bdd; ldg-slp; *Amphipora*
30	790	Ls, fos, f-crs grn; gry, wd brn-buff; tn-m bdd; ldg; bulb stromatoporoids, *Stromatopora*(?), tab stromatoporoids, *Hammatostroma, Amphipora,* calcispheres
30	820	Dol, fos, f-crs xln; dk gry, wd brn; tk bdd; mas; ldg; *Stachyodes, Amphipora*
135	955	Ls, fos-coq, f-crs grn; gry, wd gry-buff; tn bdd; ldg-slp; bulb stromatoporoids, *Trupetostroma*(?), *Hammatostroma*(?), *Thamnopora,* tetracorals, *Zaphrenthis*(?), brachiopods, *Atrypa, Spinatrypa, Allenaria*(?), *Hypothyridina* gastropods, crinoid columnals, calcispheres, conodonts, *Palmatolepis*(?), *Icriodus nodosus, Polygnathus foliata, P. normalis, Bryantodus, Lonchodina, Ozarkodina, Hindeodella*
85	1040	Dol, mic-f xln; gry, wd lt gry; lam-tn bdd; ldg-slp
10	1050	Dol, fos, crs grn; dk gry, wd brn; stng hydcb odor; m bdd; ldg; ls bulb stromatoporoids, *Trupetostroma*(?)

65	1115	Ls, fos, f-crs grn; gry, wd gry-buff; tk bdd; mas; clf; bulb stromatoporoids, *Trupetostroma*(?), *Hammatostroma, Clathrocoilona*(?), *Amphipora, Thamnopora,* tetracorals, brachiopods, *Atrypa,* gastropods, ostracodes, calcispheres, algae, *Sphaerocodium*(?), conodonts, *Polygnathus foliata, Hindeodella*
15	1130	Dol, mic-f xln; dk gry, wd brn; m bdd; ldg
15	1145	Ls, fos, mic-f xln; gry, wd gry; tn bdd; slp; *Thamnopora,* tetracorals, brachiopods
30	1175	Cov slp
10	1185	Dol, fos, f-crs xln; gry-brn, wd lt gry; m bdd; ldg; bulb stromatoporoids, *Amphipora,* brachiopods
15	1200	Ls, fos, pel, f grn; gry, wd lt gry; tk bdd; mas; ldg; bulb stromatoporoids, *Amphipora,* calcispheres, conodonts, *Polygnathus normalis*
80	1280	Dol, f xln; gry, wd lt gry; tk bdd; ldg; *Amphipora*
20	1300	Ls, fos, f-crs grn; gry, wd gry-buff tk bdd; mas; ldg; bulb stromatoporoids, *Trupetostroma*(?), *Clathrocoilona*(?), *Amphipora,* nodosinellid foraminifera, calcispheres
30	1330	Dol, mic-f xln; dk gry, wd brn; lam-tn bdd; xbd; ldg-slp
10	1340	Dol, fos, crs xln; dk gry, wd brn; stng hydcb odor; tk bdd; mas; ldg; biostrome of bulb stromatoporoids, *Amphipora*
20	1360	Ls, fos, f-crs grn; gry, wd buff; tk bdd; mas; ldg; *Amphipora,* ostracodes, calcispheres

Top of Guilmette Formation
Base of West Range Limestone

Pahranagat Range Section PR-1

Guilmette Formation

3	3	Dol, f-m xln; lt gry, wd lt gry; tk bdd; ldg
2	5	Dol, aren, f grn; dk gry, wd dk gry; qtz grns 1 in stngs; sbrd; w srtd m bdd; ldg
10	15	Dol, crs xln; lt gry, wd lt gry; tk bdd; mas; ldg; bulb stromatoporoids
5	20	Dol, aren, f grn; gry, wd brn; qtz grns; sbrd; fr srtd; m bdd; ldg
25	45	Dol, crs grn; gry, wd lt gry; m-tk bdd; mas; ldg
5	50	Dol, fos, f-crs grn; dk gry, wd gry; tk bdd; ldg; *Amphipora*
10	60	Dol, aren, m-crs xln; dk gry, wd dk gry;

		qtz grns 6 in stngs; sbrd; fr srtd; m bdd; ldg; bulb stromatoporoids
20	80	Dol, crs xln; altntg lt-dk gry; m bdd; ldg
5	85	Dol, fos, crs xln lt gry-gry, wd lt gry; tn-in bdd; ldg; bulb stromatoporoids, *Amphipora*
12	97	Dol, aren, m-crs xln; lt brn, wd dk brn; qtz grns in 4 ft uts; m ss; sbrd; fr srtd; tn-m bdd; ldg
18	115	Dol, brc, f-crs xln; gry, wd lt gry; "tiger stripes"; tk bdd; mas; ldg
5	120	Dol, fos, aren, m-crs grn; dol lt gry, wd dk gry; ss brn, wd dk brn; qtz grns; rd; w-srtd; m bdd; bimod xbds; ldg; bulb stromatoporoids, brachiopods, *Stringocephalus*(?)
55	175	Dol, fos, crs xln gry, wd dk gry; m bdd; mas; ldg; bulb stromatoporoids, *Amphipora*
10	185	Dol, crs xln; gry, wd gry; m bdd; mas; ldg
15	200	Ls, fos, f-crs grn; lt gry, wd gry; m bdd; ldg; bulb stromatoporoids, tetracorals, bryozoans(?)
12	212	Dol, fos, mot, crs xtls, lt gry-gry; tn bdd; ldg; bulb stromatoporoids, *Amphipora*
23	235	Dol, fos, m-crs xln; gry, wd gry; tk bdd; slp; *Amphipora, Stringocephalus*(?)
5	240	Ss, noncalc, f-crs grn; lt gry; wt lt brn; qtz grns; sbrd; p srtd; tk bdd; slp
30	270	Dol, crs xln; lt gry, wd lt gry; "tiger stripes"; lam-m bdd; mas; ldg
42	312	Ls, fos, pel, f-crs grn; gry, wd lt gry; tk bdd; mas; clf; bulb stromatoporoids, *Amphipora, Stringocephalus*(?), gastropods, nodosinelled foraminifera, calcispheres
3	315	Dol, fos, crs xln; gry, wd lt gry; "tiger stripes"; m bdd; mas; ldg; *Amphipora*
15	330	Dol, fos, crs xln; gry, wd lt gry-brn; lam-tk bdd; mas; clf; *Stringocephalus*(?)
20	350	Dol w/ls lns, f-crs grn; dk gry, wd gry-brn; tk bdd; mas; clf; bulb stromatoporoids in dol, *Amphipora* in ls
10	360	Ls, m xln; gry, wd lt gry; tn bdd; mas; ldg; bulb stromatoporoids
5	365	Dol, crs xln; lt gry, wd lt gry; "tiger stripes"; tk bdd; mas; ldg
5	370	Dol w/ls lns, f-crs grn; dk gry, wd gry-brn; tk bdd; mas; clf; *Amphipora* in ls
10	380	Ls, f grn; gry wd lt gry; m bdd; mas; ldg
12	392	Dol, crs xln; lt gry, wd lt gry; "tiger stripes"; tn-m bdd; mas; clf
8	400	Dol, crs xln; lt gry, wd lt gry; "tiger stripes"; tn bdd; mas; ldg; *Amphipora*

5	405	Ls, fos, f-crs grn; gry, wd gry; m bdd; mas; ldg; tab stromatoporoids, *Amphipora, Stringocephalus*(?), gastropods, algae
3	408	Ss, noncalc, f grn; buff, wd brn; sbrd; w srtd; m bdd; mas; slp
17	425	Dol, fos, crs xln; lt gry, wd lt gry; "tiger stripes"; m bdd; mas; ldg; bulb stromatoporoids
20	445	Ss, noncalc, f grn; gry-brn, wd buff; qtz grns; sbrd; p srtd; m bdd; bimod xbds, 1-2 ft sets; mas; slp
35	480	Dol, fos, crs xln; gry, wd gry-brn; m-tk bdd; mas; clf; *Amphipora, Stringocephalus*(?)
65	545	Ls, fos, f-crs grn; gry, wd gry-lt brn; tk bdd; mas; clf; bulb stromatoporoids, *Amphipora, brachiopods, Stringocephalus* (?), gastropods, nodosinellid foraminifera, calcispheres
55	600	Ls, pel, f grn; gry, wd gry-lt brn; tk bdd; mas; clf; *Amphipora,* calcispheres
25	625	Dol, crs xln; gry, wd lt gry; tk bdd; mas; ldg; bulb stromatoporoids
20	645	Ss, noncalc, f grn; buff, wd buff; qtz grns; w rd; w srtd; m bdd; mas; slp
20	665	Dol, f-crs xln; dk gry, wd lt brn; lam-tn bdd; slp
6	671	Ss, noncalc, f grn; buff; wd buff; qtz grns; w rd; w srtd; m bdd; mas; slp
9	680	Dol, f xln; gry, wd lt gry; m bdd; slp
30	710	Dol, f-crs grn; dk gry, wd lt brn; m bdd; mas; ldg
30	740	Ls, fos, f grn; gry, wd lt gry-brn; tk bdd; mas; clf; bulb stromatoporoids, *Amphipora, Stringocephalus*(?), gastropods
20	760	Ls, fos, f-crs grn; gry, wd lt gry-grn; tk bdd; mas; clf; *Amphipora,* brachiopods
15	775	Ls, f grn; gry, wd gry; m bdd; ldg; bulb stromatoporoids, *Amphipora,* nodosinellid foraminifera, algal bisquits
30	805	Dol, aren, f grn; dk gry, wd gry, qtz grns; sbrd; w srtd; tk bdd; mas; ldg; *Amphipora*
15	820	Ls, f grn; gry, wd gry-lt brn; tk bdd; mas; clf, mas stromatoporoids 2-3 ft dia, *Hammatostroma,* bulb stromatoporoids
10	830	Dol, crs xln; lt gry, wd lt gry; m bdd; mas ldg; bulb stromatoporoids
15	845	Ss, noncalc, v f grn; buff, wd dk brn; qtz-pel grns; qtz sbrd; w srtd; m bdd; xbd 1-2 ft sets; slp

10	855	Dol, fos, crs xln; dk gry, wd gry-brn; tk bdd; mas; ldg; bulb stromatoporoids, *Amphipora*
10	865	Ls, aren, f grn; gry, wd gry; tk bdd w/.5 in ss stngs; mas; ldg
25	890	Ls, f grn; gry, wd gry; tk bdd; mas; ldg
15	905	Ss, noncalc, f grn; buff, wd dk brn; qtz grns; w rd; w srtd; tk bdd; mas; ldg

Top of Guilmette Formation
Base of Pilot Shale

Confusion Range (Conger Springs Area) CR-1* (Text-fig. 1)

Top of Guilmette Formation

Feet from top	*Genera*
0	*Palmatolepis linguiformis*(?)
	Polygnathus normalis
	P. webbi
	Hindeodella
	Ozarkodina
30	*Palmtolepis proversa*
	Polygnathus normalis
	P. foliata
	Hindeodella
60	*Hibbardella*(?)
	Ozarkodina
70	*Polygnathus linguiformis*
	Polygnathus rugosa
	Icriodus nodosus
	Icriodus alternata
80	*Polygnathus rugosa*
	P. webbi
	Polygnathus sp. (?)
	Icriodus nodosus
	Ozarkodina
120	*Polygnathus brevis*
	Polygnathus sp. (?)
	Bryantodus
	Ozarkodina
	Hindeodella
170	*Polygnathus foliata*
	Lonchodina
190	*P. foliata*
	Bryantodus
200	*P. foliata*
210	*Polygnathus* sp. (?)
220	*P. foliata*
	Polygnathus sp. (?)
	Ozarkodina
	Roundya

240	*Polygnathus* sp.
270	*Polygnathus* sp.
280	*Lonchodina*
320	*Polygnathus* sp.
	Ozarkodina
330	*Lonchodina*

*This section was not measured in detail but only for conodont zonation.

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