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Paleontology of the Permian Loray Formation in White Pine County, Nevada*

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ABSTRACT.—The Loray Formation contains one of the most profuse molluscan faunas in the Great Basin. The Loray Formation is well exposed in the ranges of White Pine County, Nevada, and exceptional exposures are found in the Butte Mountains approximately 50 miles northwest of Ely, Nevada, where the formation is approximately 1900 feet thick. Basal beds of the formation contain a normal marine fauna consisting mainly of small productid brachiopods; a few crinoid ossicles and fenestellid bryozoans are also present. Middle and upper fossiliferous beds, however, contain an abundant mollusk fauna. Ostracods are abundant in acid residues of the fossiliferous units throughout the formation.

Twenty-one species are described; eight of these are gastropods; four are pelecypods; two, nautiloid cephalopods; two, bryozoans; one, productid brachiopod; one, echinoid spine; one, scaphopod, and two, ophiuroids, one of which is a new genus and species.

Productid brachiopods and bryozoans occur only near the base of the formation. Mollusks, including gastropods, nuculid pelecypods, and scaphopods, are the dominant fossils above the brachiopod horizon. The formation contains five fossiliferous units included within barren or nearly barren dolomite and limestone. All of the fossils are well preserved and some are partially silicified. The mollusk-rich unit seems to be lag-gravel accumulations of both infaunal and epifaunal organisms. The finer material in which infaunal burrowing pelecypods and scaphopods lived was apparently winnowed away, leaving skeletons of these burrowers and surface-dwelling gastropods, crinoids, and nautiloids intermixed at the same level.

The Loray Formation in the Butte Mountains section is interpreted as showing a change from a normal marine environment to a hypersaline, shallow-water environment.

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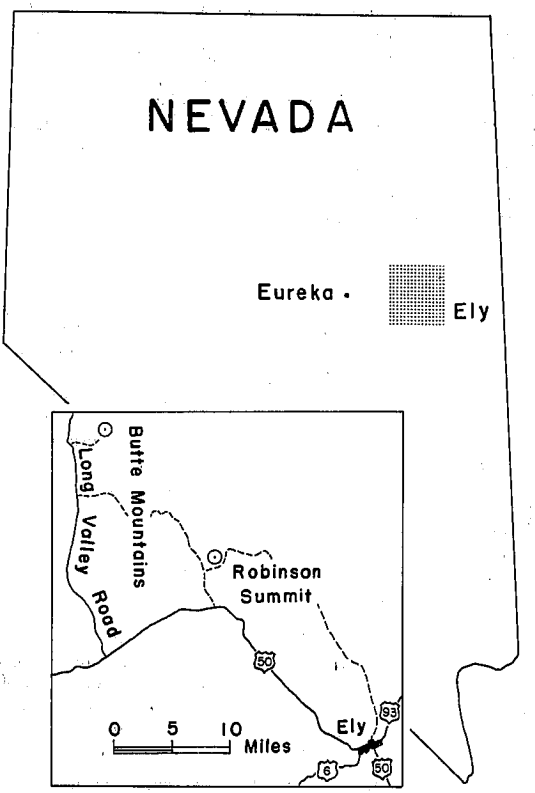
*A thesis submitted to the faculty of the Department of Geology, Brigham Young University in partial fulfillment of the requirements for the degree Master of Science, June 2, 1967.

INTRODUCTION

The Leonardian Loray Formation contains one of the most profuse molluscan and ophiuroid faunas in the Great Basin. The Loray Formation crops out in ranges of White Pine County, Nevada, and of these the most exceptional exposures occur in the Butte Mountains (Text-fig. 1).

Basal beds of the formation contain a normal marine fauna consisting mainly of small productid brachiopods, a few echinoderm fragments, and fenestellid bryozoans. Middle and upper beds, however, contain an abundant mollusk fauna of gastropods, nuculid pelecypods, and scaphopods. Crinoid ossicles, nautiloid cephalpods, and trilobites are present in small numbers. Abundant silicified ostracods are found in acid residue of fossiliferous horizons. The profuse molluscan fauna occurs above the brachiopod unit and throughout the rest of the formation (Text-figs. 2, 3).

The formation is approximately 1900 feet thick in the Butte Mountains and contains five richly fossiliferous units. The lowest is a ten-foot thick productid zone near the base. The other four fossiliferous units, each about 150 feet thick, are mollusk-rich and occur in the middle and upper parts of the formation. The lower mollusk unit begins approximately 280 feet above the Loray-



TEXT-FIGURE 1.—Index and locality map.

Pequop contact, while the next three begin 520, 700 and 1580 feet above the contact. Number and diversity of fossils decrease upward from the second mollusk unit through the remainder of the formation.

The beds of abundant mollusks seem to be a lag-gravel accumulation, for burrowing pelecypods and scaphopods are now in close association with surface-dwelling gastropods, crinoids, and nautiloids. All of the fossils are well preserved and some are partially silicified. Rocks between the fossiliferous horizons are nearly barren. Barren beds make up approximately 60% of the formation and are as much as 290 feet thick.

Location

The two sections studied are in White Pine County, 30 to 50 miles northwest of Ely, Nevada (Text-fig. 1). The thickest and most complete section is in the Butte Mountains in Sec. 34, T. 21 N., R. 59 E. This section may be reached by traveling 20 miles north of U.S. Highway 50 on Long Valley Road, then turning east onto a poorly defined primitive road and following it approximately three miles to the end at the top of a hill. The section is exposed to the north on the north side of the canyon. Section numbers are painted about halfway up the slope. This section of the formation is complete and is richly fossiliferous, particularly in the lower part.

The second section is near Robinson Summit in Sec. 29, T. 19 N., R. 61 E., five miles north of U. S. Highway 50 on the east side of 30-Mile Road (Text-fig. 1). The section may be reached by traveling approximately three miles on 30-Mile Road, then taking the right fork in the road and following it about two miles. The yellow-tan rubbly slope of the formation makes the section easy to locate in the volcanic area on the north side of the road. Only the lower portion of the Loray Formation is exposed here. The section was used, however, because of the excellent preservation and abundance of fossils. Section numbers are located about halfway up the slope. Both sections can be reached by car. A pickup truck or similar vehicle is best for reaching the Butte Mountains section, however.

Methods of Study

Both sections of the formation were collected during the summer of 1966; field work was completed in the spring of 1967. Collections from the Butte Mountains were made from a section measured by H. J. Bissell and tied to his unit numbers. The Robinson Summit section was collected, then measured with a tape and Brunton compass.

Collections were made at each fossiliferous horizon in both sections. Hydrochloric acid was used to remove matrix from some of the well-silicified specimens, and an Airdent, a miniature sand blaster, was used for removing and cleaning partially silicified mollusks. Unsilicified specimens were prepared with a Vibra Tool.

Previous Work

Rocks now included in the Loray Formation were first defined by Lawson (1906, p. 294) as part of the Arcturus Formation in exposures in the Ruth copper mining area. The Arcturus Formation has since been raised to group rank and includes the Riepetown, Pequop, and Loray Formations (Bissell, 1964, p. 603).

The Loray Formation was named by Steele (1960, p. 106-107) for a series of yellow-tan, gypsiferous siltstones and thin, bioclastic limestones exposed at the head of Loray Wash on the southwest side of Montello Valley, S.W. ¼, N.E. ¼, Sec. 28, T. 38 N., R. 68 E., Elko County, Nevada.

G. B. Robinson, Jr. (1961, p. 93-145), and K. A. Hodgkinson (1961, p. 167-196) both discussed distribution and lithology of the Loray Formation but did not discuss the fauna.

H. J. Bissell (1964, p. 565-636) has studied the Pennsylvanian-Permian in White Pine County and has measured sections of the Loray Formation throughout the area. His works have dealt mainly with carbonate petrology, but he has also listed the general types of fossils present (Bissell, 1964, p. 614-620).

C. H. Stevens (1966, p. 1121-1129) has recently published a regional paleoecologic study of Early Permian units in eastern Nevada and western Utah. His general study included the Loray Formation.

Acknowledgments

The writer would like to thank Dr. J. Keith Rigby, who suggested the Loray Formation as a thesis problem, supervised field and laboratory work, criticized the manuscript, and acted as committee chairman.

Gratitude is also expressed to Dr. Harold J. Bissell for the use of his measured section and for accompanying the writer in the field.

PALEOECOLOGY

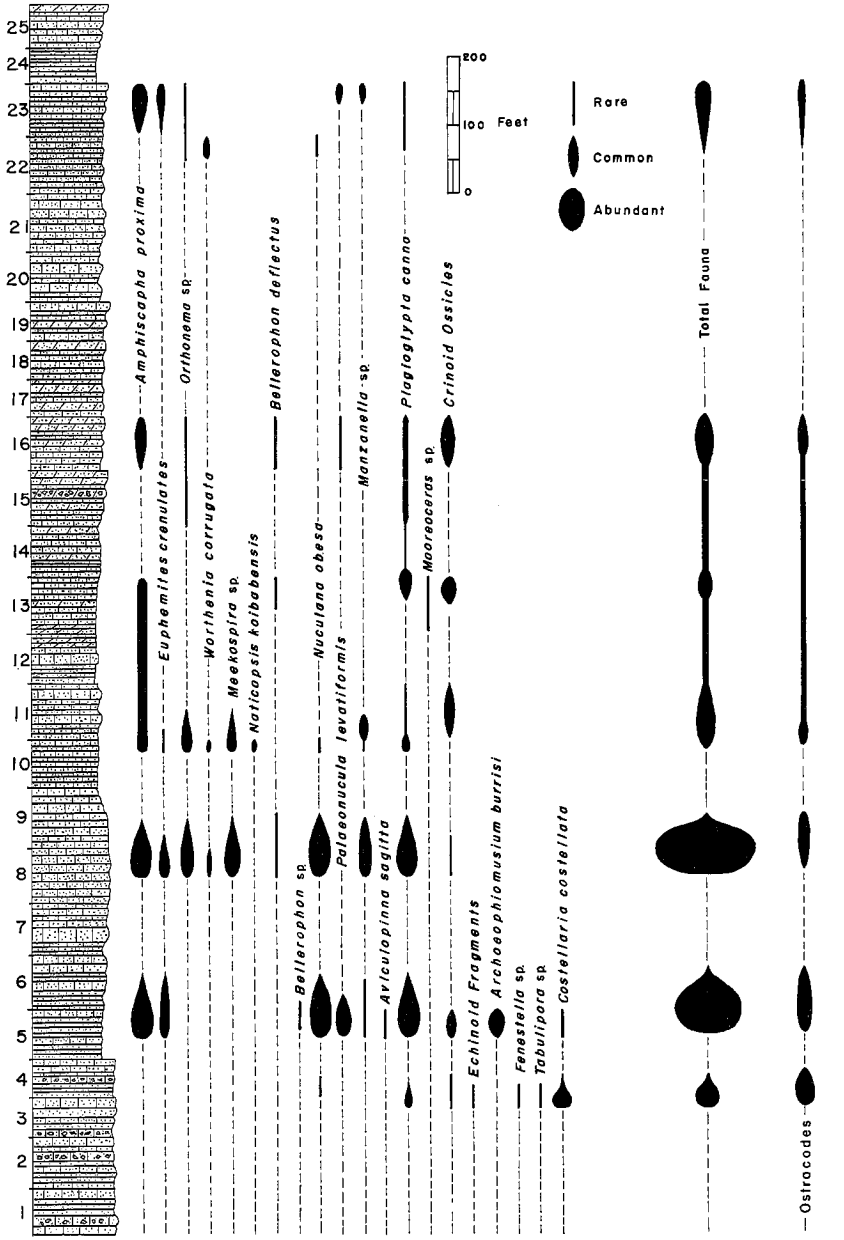
The Loray Formation is approximately 1900 feet thick in the Butte Mountains and contains five fossiliferous units included within barren or nearly barren dolomite and limestone (Text-fig. 2). Barren units make up slightly more than one-half of the formation. Fauna, rock composition, and texture in the formation indicate that the sequence accumulated in a shallow sea. The vertical shift from a normal marine environment in which productid brachiopods, crinoids, and echinoids flourished, to one of elevated salinity in which mollusks were abundant is recorded in the sequence. Upper beds of the formation are barren and grade laterally into an evaporite sequence.

Approximately the lower 180 feet of the formation is barren and consists of thin, medium- to thick-bedded, sandy limestone. Collapse breccias are also common in this unit.

The overlying 35 to 40 feet contain a normal marine fauna. The most abundant fossil is the small, spiney, productid brachiopod, *Costellaria costellata* Muir-Wood and Cooper. Specimens are well preserved, with long, delicate spines, and most are in growth position (Plate 1, fig. 9). Preservation of the delicate spines suggests deposition in a low energy environment near normal wave base.

Crinoid ossicles, fenestellid and tabuliporid bryozoans also occur but are rare. Bryozoans occur only in this lower fossiliferous unit. Ostracods are abundant in acid residues from this unit and in overlying fossiliferous units throughout the formation.

The four fossiliferous units above the productid unit are mollusk-rich (Text-fig. 2). Dominant forms are gastropods, nuculid pelecypods, and scaphopods.



TEXT-FIGURE 2.—Stratigraphic section and relative abundance of the fauna in the Loray Formation, the Butte Mountains section, White Pine County, Nevada. Unit 1 corresponds with unit 79 in the field.

The first mollusk unit begins approximately 280 feet above the base of the formation and is about 100 feet thick (Text-fig. 2). Representative blocks (BYU 1327, 1328) (Plate 3, figs. 1, 2) from this unit contain *Meekospira* sp,. *Orthonema* sp., *Bellerophon deflectus* Chronic, *Euphemites crenulates* Yochelson, *Amphiscapha proxima* Yochelson, and *Plagioglypta canna* White. The dominant fossil forms are *Amphiscapha proxima* Yochelson, *Euphemites crenulates* Yochelson, *Nuculana obesa* White, *Palaeonucula levatiformis* Walcott, *Plagioglypta canna* White. *Bellerophon* sp., *Bellerophon deflectus* Chronic, *Manzanella* sp., *Aviculopinna sagitta* Chronic, *Meekospira* sp., *Orthonema* sp., and crinoid ossicles are rare to common. *Costellaria costellata* Muir-Wood and Cooper is rare in the basal part of this unit but is unknown above here in the formation.

The second mollusk-rich unit begins approximately 500 feet from the base of the formation and is also 100 feet thick (Text-fig. 2). This unit has the greatest abundance of fossils in both sections, and number and diversity decrease upward from this unit throughout the remainder of the formation. The fauna in this molluscan unit is essentially the same as the previous one, except for the absence of *Costellaria costellata* Muir-Wood and Cooper, *Aviculopinna sagitta* Chronic, and *Bellerophon* sp. A representative block (BYU 1325) from this unit (Plate 3, fig. 3), 18 by 27 cm, contains a total of 181 fossils on the surface. Of these 10% are *Plagioglypta canna* White, 4% are *Euphemites crenulates* Yochelson, 57% are *Amphiscapha proxima* Yochelson, 22% are *Orthonema* sp., 3% are *Meekospira* sp., and 4% are *Worthenia corrugata* Chronic. Thirteen specimens of a new Permian ophiuroid were also collected from this zone.

The third mollusk unit begins 700 feet from the base of the formation and is approximately 580 feet thick. In this unit, the number and kinds of fossils are greatly reduced and are scattered throughout the unit in thin beds rather than concentrated in thick sequences, as in the lower three fossiliferous units.

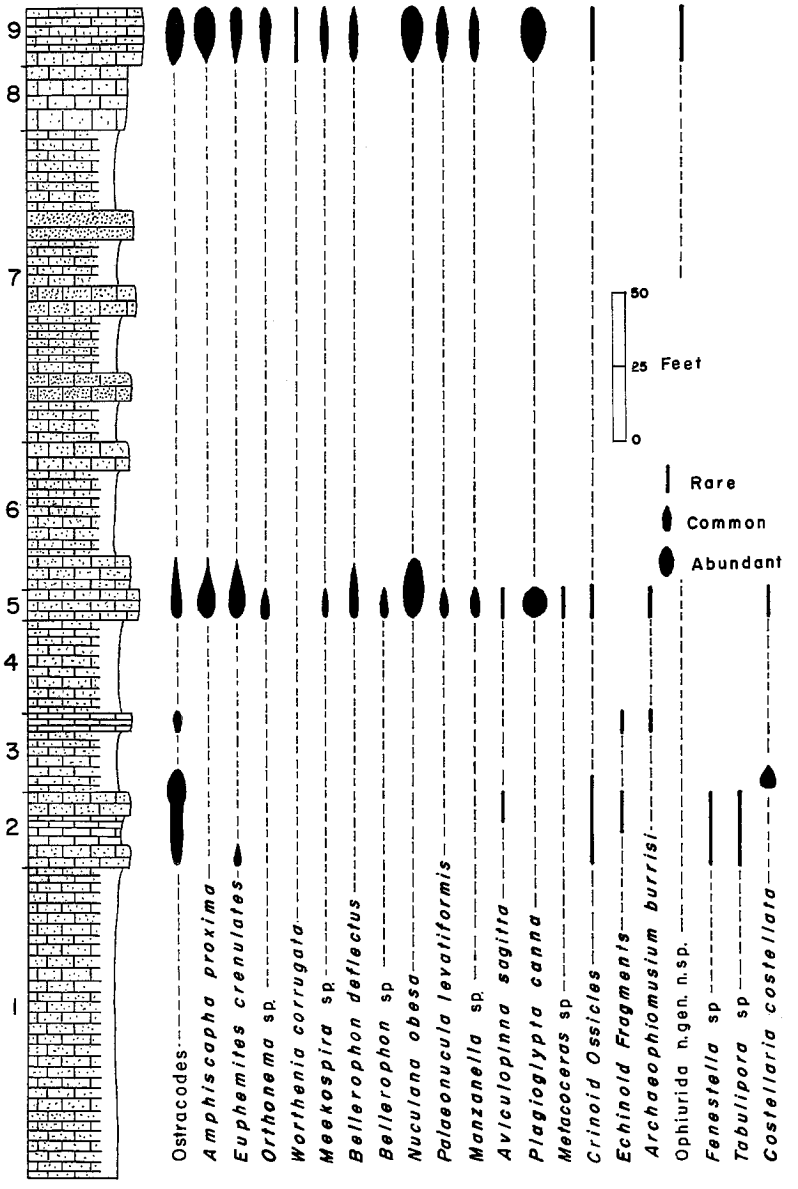
Fossil forms present in this unit include abundant *Meekospira* sp. and *Orthonema* sp., with common to rare *Amphiscapha proxima* Yochelson, *Euphemites crenulates* Yochelson, *Worthenia corrugata* Chronic, *Naticopsis kaibabensis* Chronic, *Nuculana obesa* White, *Manzanella* sp., *Plagioglypta canna* White, and crinoid ossicles in the lower part of the unit.

The middle and upper parts of this unit contain common to rare *Amphiscapha proxima* Yochelson, *Orthonema* sp., *Bellerophon deflectus* Chronic, *Palaeonucula levatiformis* Walcott, *Plagioglypta canna* White, nautiloid cephalopods, and abundant crinoid ossicles.

Plate 3, fig. 4 is a block (BYU 1326) from the lower part of this unit. The block is 15 by 20 cm and contains a total of 127 fossils on the surface. Of these 3% are *Plagioglypta canna* White, 47% are *Orthonema* sp., 40% are *Meekospira* sp., 7% are *Worthenia corrugata* Chronic, and 3% are *Nuculana obesa* White.

Above this zone the rocks become more dolomitic and intraformational conglomerate and collapse breccias are common. This change in the character of the rocks, along with a decline in the abundance of fossils, is interpreted to indicate an increase in salinity.

The highest fossiliferous unit within the formation begins approximately 1580 feet above the base of the formation and is approximately 100 feet thick.



TEXT-FIGURE 3.—Stratigraphic section and relative abundance of the fauna in the Loray Formation, the Robinson Summit section, White Pine County, Nevada.

This unit has a limited fauna consisting of common to abundant *Amphiscapha proxima* Yochelson, *Euphemites crenulates* Yochelson, and rare to common *Orthonema* sp., *Worthenia corrugata* Chronic, *Nuculana obesa* White, *Palaeonucula levatiformis* Walcott, *Manzanella* sp., and *Plagioglypta canna* White. Many of these fossils appear to be broken and washed. The shells may have been broken by predators and burrowers or by wave action. The fossiliferous lag-gravel accumulation is not well sorted as would be expected from wave action. This unit apparently accumulated as a result of the last freshening of the water before deposition of the evaporite sequence began.

Conclusions

The Loray Formation in the Butte Mountains sections is interpreted as showing a change from a normal marine environment to a hypersaline shallow-water environment. Periodic freshening of the sea is suggested by mollusk zones. The mollusk-rich units seem to be lag-gravel accumulations of both infaunal and epifaunal organisms. The finer material in which infaunal burrowing pelecypods and scaphopods lived was apparently winnowed away, leaving skeletons of these burrowers and surface-dwelling gastropods, crinoids, and nautiloids intermixed at the same level.

The abrupt change in character of the fauna from productid brachiopods and bryozoans to mollusks may have been caused by an increase in salinity. The sea also became more shallow, with the mollusks living in a higher energy environment, probably above normal wave base. Shallow depth of water is also indicated by mud cracks and well-sorted sandstone beds. Character of the rocks and presence of burrowing animals such as *Plagioglypta canna* White, *Aviculopinna sagitta* Chronic, and nuculid pelecypods, indicate that the bottom was probably calcareous silty mud.

SYSTEMATIC PALEONTOLOGY

Phylum BRYOZOA

Order CRYPTOSTOMATA
Family FENESTELLIDAE
FENESTELLA sp.

Description.—Bryozoans with a fan-shaped zoarium. Each branch in the zoarium contains two rows of zooecia. Dissepiments occur approximately every millimeter. Three to four apertures occur in each row between the dissepiments. Fenestrules have a length and width of 0.5 mm.

Occurrence.—*Fenestella* sp. is rare in both sections and occurs only in the lower parts of the section. *Fenestella* sp. occurs in units 3 and 4 in the Butte Mountains section, and in unit 2 in the Robinson Summit section.

Repository.—Measured specimen BYU 1322.

Order TREPOSTOMATA
Family STENOPORIDAE
TABULIPORA sp.

Description.—Ramose bryozoans with medium- to thick-walled zooecia. Micracanthopores occur at the zooecial angles. Monilae are indistinct; zooecial pores are 0.1 to 0.2 mm wide.

Discussion.—*Tabulipora* sp. is rare in both sections and preservation is not adequate for complete description. *Tabulipora* sp. occurs in units 3 and 4 in the Butte Mountains section and in unit 2 in the Robinson Summit section.

Repository.—Measured specimen BYU 1323.

Phylum BRACHIOPODA

One form of productid brachiopod occurs near the base of the Loray Formation. It is the dominant form in the lower fossiliferous unit where these fossils are in growth position, with long, delicate spines well preserved.

Order STROPHOMENIDA
Suborder PRODUCTIDINA
Superfamily STROPHALOSIACEA
Family AULOSTEGIDAE
Subfamily COSTELLARIINAE
COSTELLARIA COSTELLATA Muir-Wood and Cooper, 1960

Costellaria costellata MUIR-WOOD AND COOPER, 1960, Geol. Soc. Amer. Memoir 81, p. 123-124, pl. 56, figs. 1-12.

Pl. 1, figs. 4, 6, 7, 9

Description.—Small, spiney, attached productid brachiopods with concavo-convex shells with a cicatrix cutting the umbo. Cicatrix comprises from one-fourth to one-half of the width of the shell. Fine costellae, about three per mm, ornament both valves. Pedicle valve has two kinds of spines: (1) long, slender, suberect spines which occur over most of the valve, and (2) a concentration of rhizoid spines which occur around the ears and umbo. Spines are lacking on the brachial valve.

TABLE I

Measurements in mm of *Costellaria costellata* Muir-Wood and Cooper

Specimen	*BYU No.*	*Length*	*Width*	*Hinge Width*
1	1291	10 mm	13.5 mm	10.6 mm
2	1292	10.7	13	8.5
3	1293	8.5-9.5	11.3	7
4	1294	7.5-8.5	10.3	7
5	1295	10.7	13	

The convex pedicle valve has a short, slightly curved inter-area with a medial, triangular-shaped delthyrium. The delthyrium is plugged by the cardinal process. Brachial valve concave with no interarea, and with a small bilobed cardinal process, each lobe of which has a median slit. The valves have no articulating teeth and sockets.

Discussion.—Specimens are excellently silicified, and etching uncovers the shells in living position. Slender supporting spines, as much as 10 mm in length, occur on the pedicle valve.

Productid brachiopods are the most abundant form in the lower fossiliferous horizon, associated with common ostracods and relatively rare crinoid ossicles and fenestellid bryozoan colonies.

Occurrence.—Costellaria costellata occurs in units 3, 4, and 5 in the Butte Mountains section, and in units 3 and 5 in the Robinson Summit section.

Repository.—Figured specimens BYU 1291, 1296.

Phylum MOLLUSCA
Class GASTROPODA

The gastropod fauna of the Loray Formation is similar to that described from the Permian Kaibab Limestone of the Grand Canyon by H. Chronic in 1952. Seven forms are discussed from the Loray Formation and a chart of relative abundance from both sections is presented.

Order ARCHAEOGASTROPODA
Superfamily BELLEROPHONTACEA
Family BELLEROPHONTIDAE
Subfamily CARINAROPSINAE
BELLEROPHON DEFLECTUS Chronic 1952

Bellerophon deflectus CHRONIC, 1952, Geol. Soc. Amer. Bull., v. 63, p. 111, pl. 1, fig. 2, 3, 4 and 5.

Pl. 2, figs. 13, 14, 18

Description.—Involute gastropods with a planispirally coiled shell on which height and width are about equal, giving the shell a sub-rounded appearance. Whorls are slightly flattened laterally with the peripheral area strongly arched. The final whorl expands at the aperture. A narrow, fairly deep umbilicus is present, as well as a selenizone in the median dorsal region of the shell. The lateral lip flares and recurves back over part of the umbilicus. The shell is thick and without ornamentation. Where growth lines are preserved they are unevenly developed and outline the well-defined anal notch.

TABLE II

Measurements in mm for *Bellerophon deflectus* Chronic

Specimen	*BYU No.*	*h*	*w*	*ha*	*wa*
1	1257	30	29	11	21
2	1258	28	25	10	17
3	1259	23	21	9	15

Abbreviations used in the tables are h=height, w=width, ha=height of aperture, wa=width of aperture, Ø=pleural angle.

Occurrence.—Bellerophon deflectus is rare to common in both sections. Some are silicified and well preserved. This species occurs in units 8, 9, 13, and 16 in the Butte Mountains section and in units 5, 6, and 9 in the Robinson Summit section.

Repository.—Figured specimen BYU 1258.

BELLEROPHON sp.
Pl. 2, figs. 16, 17

Description.—Involute gastropods with a planispirally coiled shell. Height and width are about equal, giving the shell a sub-rounded appearance. Whorls are slightly flattened laterally, with the peripheral area strongly arched. The final whorl expands at the aperture. Umbilicus is narrow and fairly deep; the lateral lip flares slightly and recurves back over part of the umbilicus. Shell has a large, flattened selenizone marked by two lateral ridges with a slightly depressed medial portion. Shell is thick and without obvious ornamentation.

Discussion.—This form is similar to *Bellerophon deflectus* Chronic, but differs from it in having a much wider and flattened selenizone and a lateral lip which does not flare as much. Specimens of this form on hand are not silicified and are difficult to compare with the well-preserved specimens of *Bellerophon deflectus* Chronic.

TABLE III
Measurements in mm for *Bellerophon* sp.

Specimen	*BYU No.*	*h*	*w*	*ha*	*wa*
1	1262	40	45		
2	1263	39	40		
3	1264	36	40		
4	1265	34	32	13	25

Occurrence.—*Bellerophon* sp. is rare is both sections. One specimen was collected from unit 5 in the Butte Mountains section and three from unit 5 in the Robinson Summit section.

Repository.—Figured specimen BYU 1265.

Family SINUITIDAE
Subfamily EUPHEMITINAE
EUPHEMITES CRENULATES Yochelson 1960

Euphemites crenulates YOCHELSON, 1960, Bull. Amer. Mus. Nat. History, v. 119, art. 3, p. 249, pl. 47, figs. 22-28.
Pl. 2, figs. 11, 12, 15

Description.—Involute, planispirally coiled gastropods, whorls are evenly rounded; umbilicus is closed by an outer lip; sinus, slit, and selenizone are not

TABLE IV
Measurements in mm of *Euphemites crenulates* Yochelson

Specimen	*BYU No.*	*h*	*w*	*ha*	*wa*
1	1266	13	14	3	9
2	1267	11±	12	2±	8
3	1268	9	10±	2	7
4	1269	8	9	1½	6±
5	1270	3.7	3.8±	1±	2

EXPLANATION OF PLATE 1

FOSSILS OF THE LORAY FORMATION

FIG. 1.—*Echinocrinus* spine, occurs in unit 4 in the Butte Mountains, X1, BYU 1308.

FIGS. 2, 5.—*Mooreoceras* sp. *2.* view of siphuncle, x4. *5.* view of conch, x 1. Occurs in unit 13 in the Butte Mountains section, BYU 1309.

FIG. 3.—*Manzanella* sp., occurs in units 5, 6, 8, 9, 10, 11, and 23 in the Butte Mountains section and in units 5, 6, and 9 in the Robinson Summit section, X1, BYU 1307.

FIGS. 4, 6, 7, 9.—*Costellaria costellata* Muir-Wood and Cooper. *4.* view of concave brachial valve, X1, BYU 1291. *6.* pedicle valve, with cicatrix and slender spines, X1, BYU 1291. 7. brachial valve with bilobed cardinal process, X1, BYU 1296. *9. Costellaria costellata* Muir-Wood and Cooper in growth position, X1, BYU 1329. Occurs in units 3, 4, and 5 in the Butte Mountains section and in units 3 and 5 in the Robinson Summit section.

FIG. 8.—*Aviculopinna sagitta* Chronic, occurs in unit 5 in the Butte Mountains section and in units 2 and 5 in the Robinson Summit section, X1, BYU 1310.

FIG. 10.—*Palaeonucula levatiformis* Walcott, occurs in units 5, 6, 19, and 23 in the Butte Mountains section and in units 5 and 9 in the Robinson Summit section, X2, BYU 1316.

FIG. 11.—*Nuculana obesa* White, occurs in units 4, 5, 6, 8, 9, 10, and 22 in the Butte Mountains section and in units 5, 6, and 9 in the Robinson Summit section, X2, BYU 1315.

EXPLANATION OF PLATE 2

SCAPHOPOD AND GASTROPODS OF THE LORAY FORMATION

FIGS. 1-3.—*Naticopsis kaibabensis* Chronic. *1.* top view. *2.* apertural view. *3.* adapertural view. Occurs in unit 10 in the Butte Mountains section, X1, BYU 1271.

FIGS. 4, 8.—*Amphiscapha* (*Amphiscapha*) *proxima* Yochelson. *4.* top view. *8.* basal view. Occurs in units 5, 6, 8, 9, 11, 12, 13, 16, and 23 in the Butte Mountains section and in units 5, 6, and 9 in the Robinson Summit section, X1, BYU 1299.

FIG. 5.—*Orthonema* sp., apertural view, occurs in units 8, 9, 10, 11, 15, 16, 22, and 23 in the Butte Mountains section and in units 5 and 9 in the Robinson Summit section, X1, BYU 1311.

FIGS. 6, 7.—*Meekospira* sp. *6.* adapertural view. *7.* apertural view. Occurs in units 8, 9, 10, and 11 in the Butte Mountains and in units 5 and 9 in the Robinson Summit section, X1, BYU 1279.

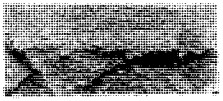
FIG. 9.—*Plagioglypta canna* White, occurs in units 3, 4, 5, 6, 8, 9, 10, 11, 13, 14, 15, 16, 22, and 23 in the Butte Mountains section and in units 2, 3, 5, 6, and 9 in the Robinson Summit section, X1, BYU 1281.

FIG. 10.—*Worthenia corrugata* Chronic, occurs in units 8, 10, and 22 in the Butte Mountains section and in unit 9 in the Robinson Summit section, X1, BYU 1314.

FIGS. 11, 12, 15.—*Euphemites crenulates* Yochelson. *11.* top view, BYU 1269. *12.* lateral view, 1266. *15.* apertural view, BYU 1266. Occurs in units 5, 6, 8, 9, 10, and 23 in the Butte Mountains section and in units 2, 5, 6, and 9 in the Robinson Summit section, all specimens X1.

FIGS. 13, 14, 18.—*Bellerophon deflectus* Chronic. *31.* apertural view. *14.* adapertural view. *18.* lateral view. Occurs in units 8, 9, 13, and 16 in the Butte Mountains section and in units 5, 6, and 9 in the Robinson Summit section, all specimens X1, BYU 1258.

FIGS. 16, 17.—*Bellerophon* sp. *16.* adapertural view. *17.* apertural view. Occurs in unit 5 in the Butte Mountains section and in unit 5 in the Robinson Summit section, X1, BYU 1265.



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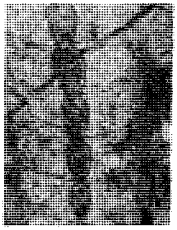

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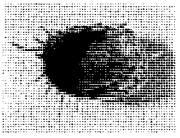

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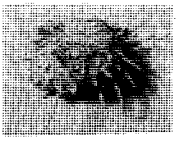

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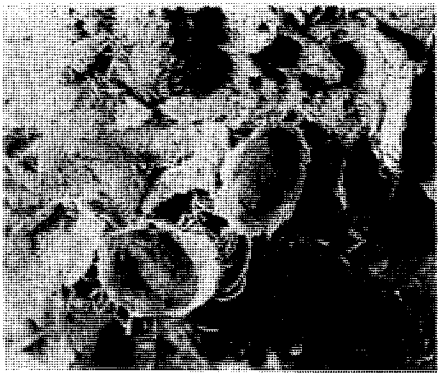

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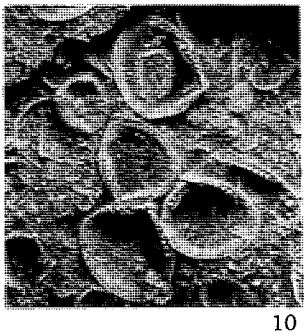

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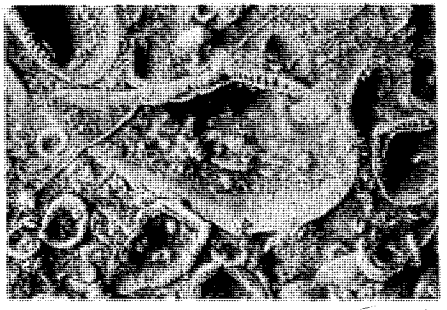

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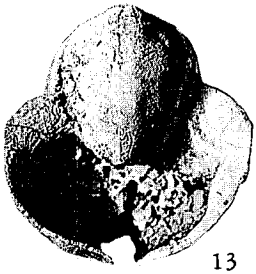
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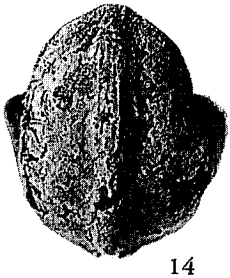
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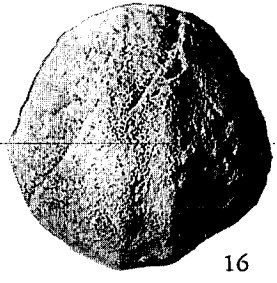
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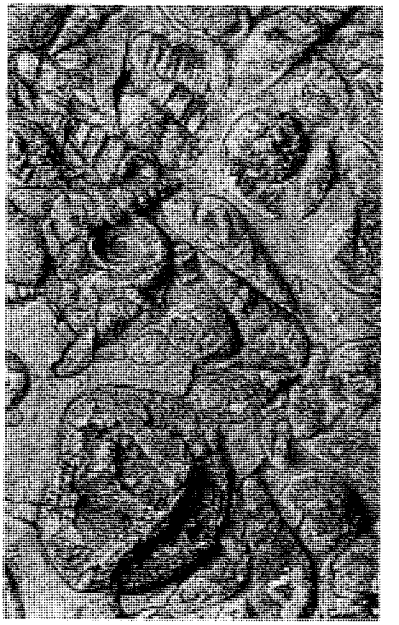

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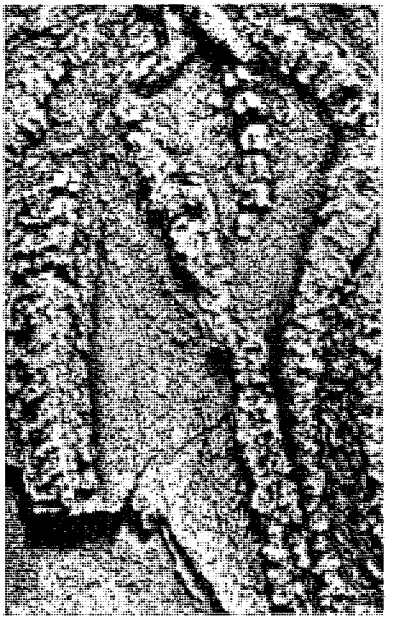

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EXPLANATION OF PLATE 3

HANDSPECIMENS OF FOSSILIFEROUS LORAY FORMATION

FIG. 1.—Representative block from unit 5 in the Robinson Summit section, X1, BYU 1328.

FIG. 2.—Representative block from unit 5 in the Robinson Summit section, X1, BYU 1327.

FIG. 3.—Representative block from unit 8 in the Butte Mountains section, X1, BYU 1325.

FIG. 4.—Representative block from unit 10 in the Butte Mountains section, X1, BYU 1326.

EXPLANATION OF PLATE 4

OPHIUROIDS OF THE LORAY FORMATION

FIGS. 1-3.—Ophiuroid n. gen. n. sp., *1.* oral view showing half-jaw plates, X6. *2.* oral view of arms showing the tentacle pores and spines, X6. c. portion of the block containing the ophiuroids, X2, BYU 1324. Occurs in unit 9 in the Robinson Summit section.

apparent. Ornamentation consists of 10 to 14 equally spaced, thin lirae. Questionable nodes superimposed on the lirae are evident on the body whorl but are covered on earlier whorls. Spaces between the lirae are approximately three times the width of the lirae.

Occurrence.—Euphemites crenulates Yochelson occurs in units 5, 6, 8, 9, 10, and 23 in the Butte Mountains section and in units 2, 5, 6, and 9 in the Robinson Summit section.

Repository.—Figured specimen BYU 1266, 1269.

Superfamily PLEUROTOMARIACEA
Family NEILSONIIDAE
Subfamily RUEDEMANNINAE
WORTHENIA CORRUGATA Chronic 1952

Worthenia corrugata CHRONIC, 1952, Geol. Soc. Amer. Bull., v. 63, p. 122, pl. 4, fig. 1.

Pl. 2, fig. 10

Description.—Small gastropods with a turbinate shell consisting of about five whorls; suture impressed. Aperture circular; parietal inductura absent; outer lip thin; selenizone present on shoulder. Ornamentation consists of revolving carinae. The nucleus is small and without ornamentation.

Discussion.—Worthenia corrugata Chronic occurs in units 8, 10, and 22 in the Butte Mountains section and in unit 9 in the Robinson Summit section.

Repository.—Figured specimen BYU 1314.

Superfamily NERITACEA
Family NERITOPSIDEA
Subfamily NATICOPSINAE
NATICOPSIS KAIBABENSIS Chronic 1952

Naticopsis kaibabensis CHRONIC, 1952, Geol. Soc. Amer. Bull., v. 63, p. 133, pl. 5, figs. 10, 11.

Pl. 2, figs. 1, 2, 3

Description.—Small, low-spired gastropods; shell has three rapidly expanding whorls with each whorl almost completely covering the one preceding it. Height and width are about equal, giving the shell a globose appearance. Spire is low and does not extend more than a millimeter about the body whorl. Aperture is semicircular to teardrop shaped; parietal lip has a thickened inductura which extends beyond the aperture; shell lacks an umbilicus; ornamentation consists of fine irregular growth lines.

TABLE V

Measurements in mm of *Naticopsis kaibabensis* Chronic

Specimen	*BYU No.*	*h*	*w*	*ha*	*wa*
1	1271	8	7	5	4.5
2	1272	6.3	6	4	3
3	1273	7.2	5	5.9	2
4	1274	5.3	6	2.5	2.5
5	1275	3.8	4	3.5	2

Occurrence.—*Naticopsis kaibabensis* Chronic is relatively rare in the formation occurring only in unit 10 in the Butte Mountains section.

Repository.—Figured specimen BYU 1271.

Superfamily EUOMPHALACEA
Family EUOMPHALIDAE
AMPHISCAPHA (AMPHISCAPHA) PROXIMA Yochelson 1956

Amphiscapha (Amphiscapha) proxima YOCHELSON, 1956, Bull. Amer. Mus. Nat. History, v. 110, art. 3, p. 223-224, pl. 12, figs. 17-26.

Pl. 2, figs. 4, 8

Description.—Discoidal, pseudoplanispirally coiled, nearly smooth gastropods. A prominent, smooth, rounded keel occurs on the outer edge of the upper whorl surface. Sutures on the upper whorl surface are distinct and slightly impressed. Upper whorl is gently arched; outer whorl face is slightly rounded to nearly vertical, and the basal whorl surface is arched slightly to nearly flat. The basal whorl surface has a distinct angulation, but is without a keel; umbilicus is phaneromphalous; umbilical angle from 150 to 170 degrees.

TABLE VI

Measurements in mm of *Amphiscapha (Amphiscapha) proxima* Yochelson

Specimen	*BYU No.*	*Height*	*Width*
1	1297	9	26
2	1298	5.8	19
3	1299	5	16
4	1300	5	13.4
5	1301	2	5.5

Occurrence.—*Amphiscapha (Amphiscapha) proxima* Yochelson occurs in units 5, 6, 8, 9, 11, 12, 13, 16, and 23 in the Butte Mountains section and in units 5, 6, and 9 in the Robinson Summit section.

Repository.—Figured specimen BYU 1299.

Order CAENOGASTROPODA
Superfamily SUBULITACEA
Family MEEKOSPIRIDAE
MEEKOSPIRA sp.
Pl. 2, figs. 6, 7

Description.—High-spired gastropods with many gradually expanding rounded whorls. Body whorl height is approximately half of shell height. Aperture is oval shaped with the upper portion coming to a point and is widest near the base. Outer lip thin; suture impressed; nucleus unknown; ornamentation not preserved.

TABLE VII
Measurements in mm for *Meekospira* sp.

Specimen	*BYU No.*	*h*	*w*	*ha*	*wa*	Ø
1	1276	19	6	4	3.5	22°
2	1277	11.2	4	3.5	1.6	25°
3	1278	8.9	3.5	2.5	1.8	28°
4	1279	10	3.5	3	2	24°
5	1280	4	1.6	1.1	0.8	17°

Occurrence.—*Meekospira* sp. is abundant in both sections, and many are well silicified. *Meekospira* sp. occurs in units 8, 9, 10, and 11 in the Butte Mountains section and in units 5 and 9 in the Robinson Summit section.

Repository.—Figured specimen BYU 1279.

Superfamily CERITHIACEA
Family TURRITELLIDAE
ORTHONEMA sp.
Pl. 2, fig. 5

Description.—Small, high-spired, many whorled gastropods. Shell has about seven whorls; whorls expand evenly; impressed suture. Body whorl is about

TABLE VIII
Measurements in mm for *Orthonema* sp.

Specimen	*BYU No.*	*h*	*w*	*ha*	*wa*	Ø
1	1302	9.5	3.5	2	1.5	18°
2	1303	7.4	2.8	1.2	1	24°
3	1304	7.2	2.7	1	1	18°
4	1305	8.5	3.5	1.5	1.2	16°
5	1306	7.7	2.5	1.5	1	22°

two-fifths the height of the shell. Shoulder narrow and steeply inclined; aperture oval shaped; outer lip thin; selenizone located in the middle of whorl.

Occurrence.—*Orthonema* sp. is abundant in both sections, and many specimens are well silicified. *Orthonema* sp. occurs in units 8, 9, 10, 11, 15, 16, 22, and 23 in the Butte Mountains section and in units 5 and 9 in the Robinson Summit section.

Repository.—Figured specimen BYU 1311.

Class CEPHALOPODA
Subclass NAUTILOIDEA
Order ORTHOCERIDA
Family PSEUDORTHOCERATIDAE
MOOREOCERAS sp.
Pl. 1, figs. 2, 5

Description.—Orthoconic nautiloid cephalopods with smooth conchs. Siphuncle is central to subcentral with approximately seven camerae per cm of conch. Suture is simple and transverse; siphuncular and cameral deposits are absent; diameter of the siphuncle is approximately one-fourth of the conch diameter (Plate 1, fig. 2). Septal necks are short and strongly cyrtochoanitic. Thin connecting rings outline a siphuncular segment which is assymetrically inflated; the adoral portion being broader than adapically. The single complete specimen collected has a length of 57 mm and maximum diameter of 8 mm.

Occurrence.—*Mocreoceras* sp. occurs in the Butte Mountains section only in unit 13.

Repository.—Figured specimen BYU 1309.

Order NAUTILIDA
Family TAINOCERATIDAE
METACOCERAS (?) sp.

Description.—A single, moderately evolute conch measuring 14 cm in diameter is questionably referred to the genus *Metacoceras*. The poor preservation of the nautiloid precludes confident taxonomic identification. The conch is broadest along the ventral lateral shoulder sloping inward dorsally. The external suture is simple, having a broadly rounded lateral lobe and an extremely shallow ventral lobe.

Occurrence.—The single specimen of *Metacoceras* (?) sp. was collected from unit 5 in the Robinson Summit section.

Repository.—Measured specimen BYU 1312.

Class PELECYPODA

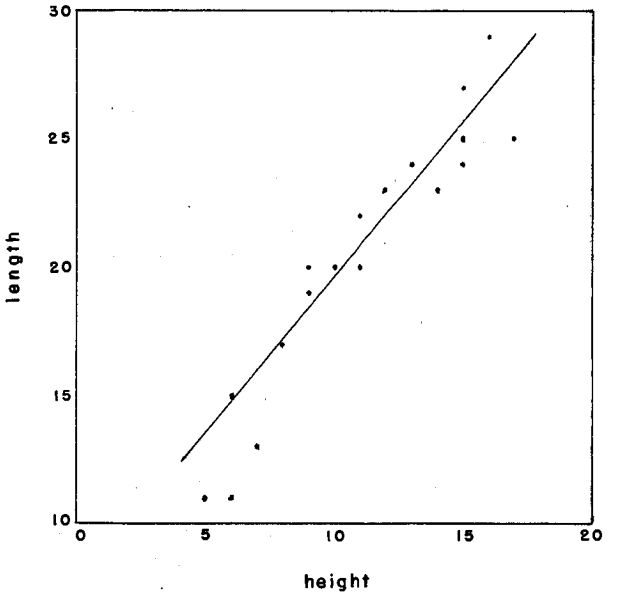
Four pelecypods occur in the Loray Formation and are similar to forms described from the Kaibab Formation (Chronic, 1952). However, the Kaibab Formation has a more varied fauna. All of the forms present in the Loray Formation were burrowers. Perservation of most of the pelecypods is not adequate for detailed measurement.

Order TAXODONTA
Superfamily NUCULACEA
Family NUCULANIDAE
NUCULANA OBESA White 1879

Leda obesa, GIRTY, 1909, U. S. Geol. Survey, Bull. 389, p. 76; GIRTY, 1910, U. S. Geol. Survey, Bull. 436, p. 40, pl. 4, figs. 7, 8; BRANSON, 1930, Missouri Univ. Studies, v. 5, no. 2, p. 43, pl. 10, figs. 21, 22.
Nuculana obesa, WHITE, 1879, U. S. Geol. and Geog. Survey Terr., Bull. 5, p. 216; WHITE, 1883, U. S. Geol. and Geog. Survey Terr. Wyo. and Idaho, Ann. Repts., v. 12, pt. 1, p. 136, pl. 34, figs. 2a-c; CHRONIC, 1952, Geol. Soc. Amer. Bull., v. 63, p. 137, pl. 6, figs. 1a-3.

Pl. 1, fig. 11

Description.—Nuculid pelecypods with an extended posterior margin; escutcheon elongate; beak small and posteriorly directed; dentition taxodont with 9-14 teeth posterior to beak, and 10-15 teeth anterior to beak. Teeth become chevron-shaped away from beak. Muscle scars and the pallial line are not preserved on the specimens at hand. Ornamentation consists of fine concentric lirae, 2 to 3 per mm, increasing in number per mm toward the umbo. Height-



TEXT-FIGURE 4.—Relation of height and length in mm in *Nuculana obesa* White.

length ratio is shown in Text-fig. 4. Posterior margin is curved upward; cardinal margin is arched anteriorly and concave posteriorly; ventral margin is gently arched.

Occurrence.—*Nuculana obesa* White occurs in units 4, 5, 6, 8, 9, 10, and 22 in the Butte Mountains section and in units 5, 6, and 9 in the Robinson Summit section.

Repository.—Figured specimen BYU 1315.

PALAEONUCULA LEVATIFORMIS (Walcott) 1884

Nucula levatiforme, WALCOTT, 1884, U. S. Geol. Survey, Mon. 8, p. 241, pl. 22, figs. 1, 1a.
Nucula levatiformis, GIRTY, 1909, U. S. Geol. Survey, Bull. 389, p. 74, pl. 10, figs 7, 8; CLIFTON, 1942, Jour. Paleont., v. 16, p. 693.
Palaeonucula levatiformis, CHRONIC, 1952, Geol. Soc. Amer. Bull., v. 63, p. 138-139, pl. 6, figs. 4-9.

Pl. 1, fig. 10

Description.—Small, biconvex, subtriangular nuculid pelecypods; shell is slightly longer than high; dentition taxodont with 13 posterior teeth and 9 anterior teeth. Teeth increase in size away from beak. Ornamentation is not preserved, although a few growth lines are present near the ventral margin of the shell. Muscle scars and the pallial line are not preserved because of coarse silicification.

TABLE IX

Measurements in mm of *Palaeonucula levatiformis* (Walcott)

Specimen	*BYU No.*	*l*	*h*	*t*
1	1286	6	4	3.7
2	1287	5.8	4.9	4
3	1288	7	5.5	5
4	1289	6.5	5.5	2.5
5	1290	4.5	4.5	3.3

Abbreviations used in the tables are l=length, h=height, t=thickness.

Occurrence.—*Palaeonucula levatiformis* (Walcott) occurs in units 5, 6, 19, and 23 in the Butte Mountains section and in units 5 and 9 in the Robinson Summit section.

Repository.—Figured specimen BYU 1316.

Superfamily ?
Family MANZANELLIDAE
MANZANELLA sp.
Pl. 1, fig. 3

Description.—Small to medium, strongly convex, thick-shelled pelecypods. Shell oval-shaped with rounded margins; cardinal margin flattened slightly; beak prosogyre. Ornamentation is lacking; growth lines are fine and irregular. Dentition is actinodont with one short cardinal tooth. Muscle scars are not preserved.

Discussion.—Preservation of this form is poor in both sections, and few are preserved well enough for measuring. Length of shell ranges from 10 to 25 mm and height from 9 to 20 mm. Internal structures are not shown. *Manzanella* sp. is similar to *Manzanella cryptodentata* Chronic; however, preservation is not adequate for certain specific identification.

Occurrence.—*Manzanella* sp. occurs in units 5, 6, 8, 9, 10, 11, and 23 in the Butte Mountains section and in units 5, 6, and 9 in the Robinson Summit section.

Repository.—Figured specimen BYU 1307.

Order DYSODONTA
Superfamily PTERIACEA
Family PINNIDAE
AVICULOPINNA SAGITTA Chronic 1952

Aviculopinna sagitta, CHRONIC, 1952, Geol. Soc. Amer. Bull., v. 63, p. 141, pl. 6, fig. 10.

Pl. 1, fig. 8

Description.—Large, elongate pelecypods; shell has a straight hinge line. Growth lines are prominent and irregular, becoming finer and more closely spaced near the ventral margin of the shell. Height of the largest specimen is 29 mm. The longest available fragment is 50 mm. No complete specimen was found.

Discussion.—This form is rare in both sections, and only fragments of the large pelecypod were collected. Identification is based on the size and shape of the shell and the pattern of the growth lines.

Occurrence.—Fragments of *Aviculopina sagitta* Chronic occur only in unit 5 in the Butte Mountains section and in units 2 and 5 in the Robinson Summit section.

Repository.—Figured specimen BYU 1310.

Class SCAPHOPODA
Family DENTALIIDAE
PLAGIOGLYPTA CANNA (White) 1874

Dentalium canna WHITE, 1874, U. S. Geog. Geol. Survey W. 100th Mer., p. 23.
Plagioglypta canna GIRTY, 1903, U. S. Geol. Survey, Prof. Paper 16, p. 452; BRANSON, 1930, Univ. Missouri Studies, v. 5, p. 58, pl. 15, fig. 6; CHRONIC, 1952, Geol. Soc. Amer. Bull., v. 63, no. 2, p. 153.

Pl. 2, fig. 9

Description.—Scaphopods with a gradually tapering cylindrical to subcylindrical shell. *Plagioglypta canna* is common to abundant throughout most of the formation, with length of shells ranging from 4 to 140 mm and diameter from 0.6 to 21 mm. Shells are relatively thick, about 2 mm at large end of largest specimens, with irregular transverse growth lines. Longitudinal ornamentation is absent.

TABLE X

Measurements in mm of *Plagioglypta canna* (White)

Specimen	*BYU No.*	*l*	*dp*	*da*
1	1281	54	2.5	7.5
2	1282	30	18	21
3	1283	41	12	14
4	1284	13	7	2.3
5	1285	10.5	0.6	2

Abbreviations used in the table are l=length, dp=diameter of the posterior end, da=diameter of the anterior end.

Occurrence.—*Plagioglypta canna* (White) occurs in units 3, 4, 5, 6, 8, 9, 10, 11, 13, 14, 15, 16, 22, and 23 in the Butte Mountains section and in units 2, 3, 5, 6, and 9 in the Robinson Summit section.

Repository.—Figured specimen 1281.

Phylum ECHINODERMATA
Class STELLEROIDEA
Order OPHIURIDA
Family OPHIURIDAE
ARCHAEOPHIOMUSIUM BURRISI (Miller) 1958

Ophiuraster burrisi MILLER, 1958, Jour. Paleont., v. 32, p. 357-361; HATTIN, 1959, Jour. Paleont., v. 33, p. 1125-1128, 1 Text-fig.
Archaeophiomusium burrisi HATTIN, 1967, Jour. Paleont., v. 41, p. 489-492, 3 Text-figs.

Description.—Small ophiuroids with 30 aboral disk plates arranged concentrically around a centro dorsal plate. Disk plates are roughly pentagonal, thin, overlapping and have a smooth surface. Central disk diameter of the ophiuroids varies from 1.6 to 5 mm. *Archaeophiomusium burrisi* (Miller) has five, thin, radially oriented arms attached to the disk at the paired radial shields. The arms are completely covered by thick plates. Each arm segment contains two side plates, one small dorsal shield, one small ventral shield, and two short spines. The side plates join on the oral and aboral surfaces, and the dorsal and ventral arm shields fill in the spaces at the distal end of each arm segment. A single arm spine is attached at the distal end of each side plate.

Discussion.—Eight ophiuroids, as well as many disarticulated arm segments, were collected from units 3 and 5 in the Robinson Summit section. One specimen is preserved well enough for identification while the others are badly eroded.

Occurrence.—*Archaeophiomusium burrisi* (Miller) and disarticulated arm segments occur in unit 5 in the Butte Mountains section and in units 3 and 5 in the Robinson Summit section.

Repository.—Measured specimens 1317, 1318, 1319, 1320, and 1321.

Order OEGOPHIURIDA
Suborder ZEUGOPHIURINA
n. gen n. sp.
Pl. 4, figs. 1, 2, 3

Description.—Thirteen badly eroded ophiuroids were found on a single, small limestone block. All specimens have their oral surfaces exposed, and some have the jaw plates preserved. The remainder of the central disks have been eroded. A central disk diameter of 4 to 5 mm is estimated from the size of the jaw plates and residue of the badly eroded disk plates. Paired half jaws are 1.5 mm long and 0.5 mm wide.

The five radially oriented arms taper evenly away from the disk, and are as much as 20 mm long. They appear to have been completely covered by long slender spines, up to 0.8 mm long. Arm width is 2 mm next to the half-jaw plates, and tapers to 0.5 mm at the arm tip. Halves of arm vertebra are opposite, and appear to be fused; tentacle pores approximately 0.5 mm in diameter are formed between the vertebra and the lateral plates (Plate 4, fig. 2).

Discussion.—This form is different from the ophiuroids previously described from the Permian of North America. On the basis of the arm structure, this new form has been placed in the suborder Zeugophiurina. The different arm structure indicates that this form is a new genus. However, specimens are not well enough preserved to describe this new form.

Occurrence.—This form occurs in unit 9 in the Robinson Summit section.

Repository.—Figured specimen BYU 1324.

Phylum ECHINODERMATA
Class ECHINOIDEA
Pl. 1, fig. 1

Echinoid fragments are rare to common near the base of the formation in both sections. Fragments consist of ambulacral plates, some showing boss and mamelon, and primary spines. One large broken spine 21 mm long and 2.5 mm wide was collected from unit 4 in the Butte Mountains section. The spine has small nodes and appears to be a form of *Echinocrinus* Agassiz, 1841. Smooth echinoid spines up to 12 mm long and 0.5 mm wide were collected from units 2 and 3 in the Robinson Summit section. These latter fragments are probably from a regular echinoid.

Repository.—Figured specimen BYU 1308.

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