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WALTER WARD NIEBUHR II for the MASTER OF SCIENCE
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Title: PALEOECOLOGY OF THE <u>EUREKASPIRIFER</u> <u>PINYONENSIS</u> ZONE, EUREKA COUNTY, NEVADA

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J. G. Johnson

Five measured sections serve as the source of data in studying the community structure and depositional history of the <u>Eurekaspirifer pinyonensis</u> Zone in Eureka County, Nevada. Sections were established at McColley Canyon in the Sulphur Springs Range, Coal Canyon in the Simpson Park Range, Cooper Peak in the northern Roberts Mountains, and at Lone Mountain in order to collect large paleontological samples keyed to measured sections. The research is essentially confined to the Bartine Member of the McColley Canyon Formation. The Bartine is characteristically an argillaceous, slope-forming limestone. Samples were taken from the measured sections wherever significant faunal or lithologic changes were observed.

Detailed study of the measured sections allows certain trends within the Bartine to be recognized. Progressively increasing water depth is indicated by the lithologies and faunas in all sections. The

McColley Canyon section shows shallowing in the Bartine after initial deepening. The lower Bartine at Coal Canyon is indicative of an environment different from those elsewhere on the shelf. As the trend toward deeper water continued, the Coal Canyon section became increasingly like that of Lone Mountain.

A time line has been established through the Bartine on the basis of the last appearance of the coarsely costate Atrypa sp. and the first appearance of Atrypa nevadana. The Atrypa time line demonstrates that the Bartine Member is a transgressive unit, older in the west than in the east. The oldest Bartine is at Coal Canyon. The Bartine Member is believed to intertongue with the Kobeh Member between Coal Canyon and Cooper Peak and between Lone Mountain and McColley Canyon.

Communities defined in the Bartine are the Eurekaspirifer pinyonensis Community, the Atrypa nevadana Community and its homolog the Atrypa sp. Community, the G-A-S Community, the Leptocoelia infrequens Community, and the Restricted Leptocoelia infrequens Community. The Eurekaspirifer pinyonensis, A. nevadana, and G-A-S Communities occupy positions on the shelf progressively farther from shore. The Restricted Leptocoelia infrequens and Leptocoelia infrequens Communities are characteristic of special environmental conditions at Coal Canyon. All communities are believed to lie within benthic assemblage 3.

Paleoecology of the *Eurekaspirifer pinyonensis* Zone, Eureka County, Nevada

by

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Acting Chairman of Department of Geology

Redacted for privacy

Dean of Graduate School

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Finally, I should like to give a special acknowledgement to my wife, Claire, without whose unfailing moral and financial support this project probably never would have been completed.

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PALEOECOLOGY OF THE *EUREKASPIRIFER PINYONENSIS* ZONE, EUREKA COUNTY, NEVADA

INTRODUCTION

Purpose and Scope

During the Spring of 1972 the writer was engaged in a small-scale research problem involving the Early Devonian brachiopods in the J. G. Johnson collection. Attention was centered around the brachiopods from the *Eurekaspirifer pinyonensis* Zone of Eureka County, Nevada.

Certain patterns of associations between the brachiopod species which intimated at community structures were recognized in the course of this research. The collections were not keyed to measured sections, however, so communities could neither be defined with certainty nor related in time and space. The strata of the *Eurekaspirifer pinyonensis* Zone were known to be abundantly fossiliferous and the writer and Dr. Johnson agreed that the fauna of this biostratiographic zone would provide an excellent subject for a Master of Science thesis in Paleontology. The primary goal of the research was to define brachiopod communities within the zone and to determine their vertical and lateral distribution. A secondary goal was to learn something about the depositional environment and history of the strata containing the *Eurekaspirifer pinyonensis* fauna.

The *Eurekaspirifer pinyonensis* Zone is contained almost entirely within the Bartine Member of the McColley Canyon Formation. The problematic overlying *Elythyna* beds of the Coils Creek Member, once included within the *E. pinyonensis* Zone, are beyond the scope of this project.

Location and Accessibility

The study area is located in north-central Nevada north of the town of Eureka in Eureka County. From north to south, measured sections were established at McColley Canyon in the northern Sulphur Springs Range, Coal Canyon in the Simpson Park Range, Cooper Peak in the northern Roberts Mountains, and at Lone Mountain, as shown on the index map as Figure 1.

The general study area is well-served by two-lane paved roads. All of the section localities are approachable by single-lane dirt roads to within one or two miles. Off-road travel, even with four-wheel drive vehicles, is difficult due to the rugged, blocky terrain and the high, dense sagebrush.

Previous Work

The pioneering biostratigraphy in Eureka County was done by C. W. Merriam who first defined and established the relative position of the *Eurekaspirifer pinyonensis* Zone and the *Acrospirifer kobehana*

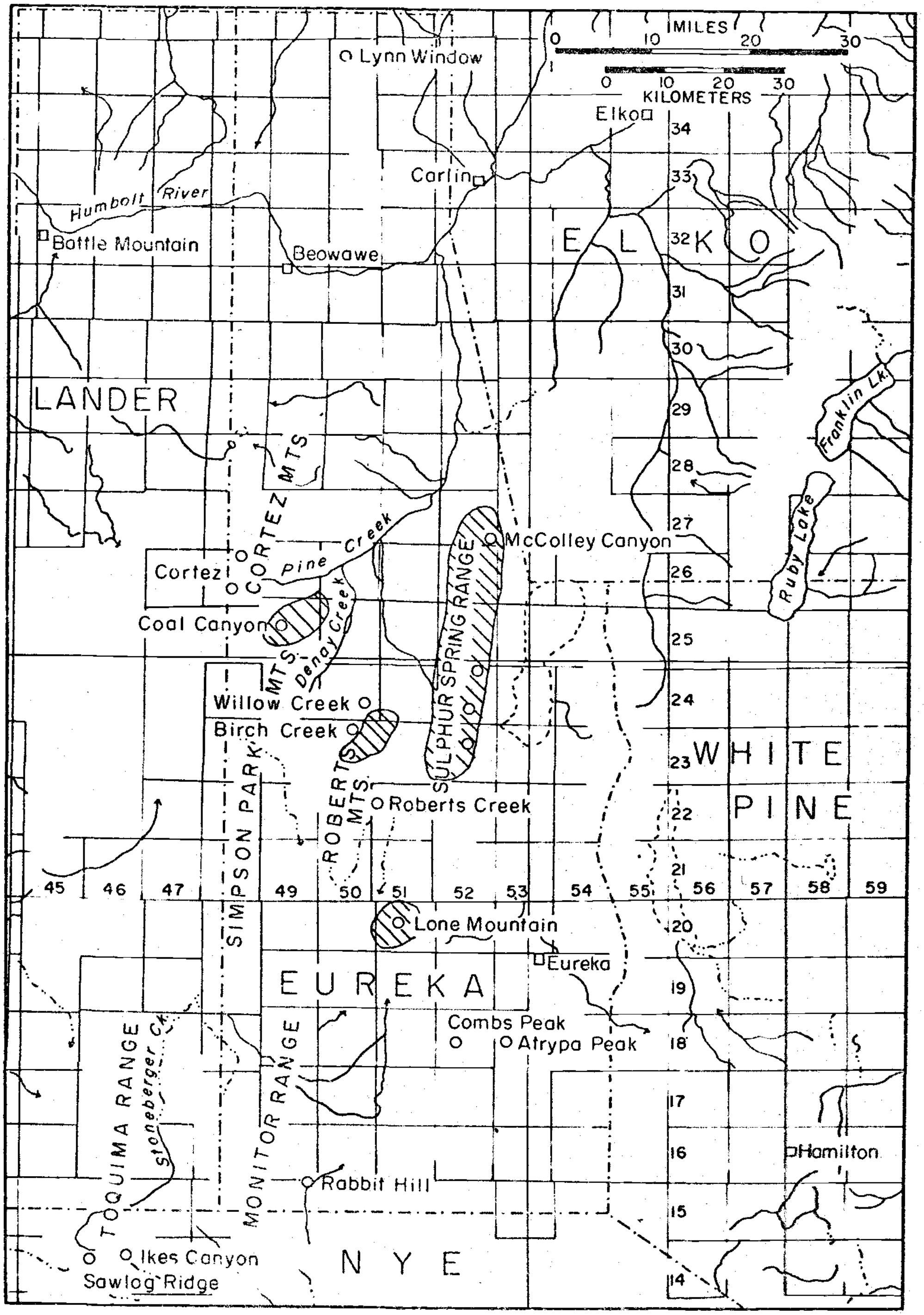

Fig. 1 INDEX MAP OF STUDY AREA

Zone (Merriam, 1940). The E. pinyonensis Zone was later recognized in the Sulphur Springs Range by Carlisle and others (1957), and in the Simpson Park Range by Johnson (1965). Johnson also recognized and named the unique Leptocoelia infrequens Subzone in the Simpson Park Range (Johnson, 1965).

The three-fold lithologic character of the McColley Canyon Formation was recognized by Gronberg (1967), who defined and described the Kobeh, Bartine and Coils Creek Members at Lone Mountain. Murphy and Gronberg (1970) later recognized and mapped the Bartine and Kobeh Members in the Roberts Mountains and Sulphur Springs Range.

The systematic paleontology for the Lower Devonian brachiopods, including the Eurekaspirifer pinyonensis Zone, has primarily been the work of J. G. Johnson (1970).

Geological Setting

During the Emsian Stage of the Early Devonian the area in which Eureka County is now located was the site of a shallow continental-margin marine shelf (Johnson, 1971). This shelf environment was the site of deposition of a great thickness of carbonate sediment, much of it very fine-grained. Reefs are not known from this period of Nevada's earth history, although at some intervals thickets of tabulate coral colonies reached patch reef proportions. The shelf was the home of a prolific benthic fauna, of which brachiopods were an important component in terms of numbers and, one may assume, biomass.

During the Late Devonian-Early Mississippian the Early Devonian shelf carbonates were involved in the Antler Orogeny as the lower plate of the Roberts Mountain thrust (Johnson, 1971). The tectonism associated with the Antler Orogeny is responsible for the complex structure and numerous fault slivers associated with these strata (Carlisle et al., 1957). Superimposed upon the earlier fault structure is the middle Tertiary block faulting which produced the present-day Basin-and-Range topography. The Basin-and-Range topography provides for extensive exposures of Devonian and earlier limestones and dolomites, many ranges rising up to 3000 feet above the adjoining basins. Complete sections through the Lower Devonian strata are the exception rather than the rule, however, due to the structural complexities imposed on the lower plate rocks by the Antler Orogeny.

The Bartine Member is an argillaceous, thin to medium bedded, limestone characteristically medium grey to brownish orange or very pale yellow at outcrop. At all localities where the basal contact of the Bartine may be observed, it is seen to conformably overlie the Kobeh Member. In the Roberts Mountains and at Lone Mountain the Bartine is overlain by the Coils Creek Member. In the Sulphur Springs Range the Bartine is overlain by the basal clastic dolomite of the Union Mountain Formation.

The argillaceous limestone of the Bartine Member almost always crops out as a rubbly slope-forming unit between the more resistant clean carbonates or clastics with which it is in contact. The problems of structural complexity described above are compounded by the weathering characteristics of the Bartine with regard to finding outcrops suitable for establishing measured sections. At many Bartine localities, outcrops are widely dispersed with intervening slopes covered with a rubble of weathered Bartine material.

Methods of Investigation

Five sections measured by the writer are the primary source of data for this project. These sections are located at Coal Canyon in the Simpson Park Range, where two sections were measured, Lone Mountain, Cooper Peak in the northern Roberts Mountains, and McColley Canyon in the Sulphur Springs Range. The locations of the sections are plotted on the index map in Figure 1. The dispersal of the measured sections reflects the writer's desire to obtain a representative collection of lithological and paleontological samples across the breadth of the preserved shelf sediments.

A number of criteria were considered in choosing sites for measured sections. The primary considerations were completeness of section and the nature of the top and bottom contacts of the section. The sections measured, with the exception of the two at Coal Canyon, were chosen because they show a minimum of faulting, are complete, and have well-defined stratigraphic contacts at the top and bottom of the Bartine Member. The sections at Coal Canyon did not meet all of these qualifications, but were selected anyway on the basis of geographical location and faunal content as will be discussed in further detail below.

All of the localities used in this report had been visited by previous workers. The Coal Canyon locality had been collected and the McColley Canyon and Lone Mountain localities had been measured and collected (Murphy and Gronberg, 1970). Revisiting and remeasuring the sections at these localities was justified in view of the fact that many of the previous collections were reconnaissance collections and not suitable for paleoecological work. The localities were therefore remeasured and collected in order to obtain detailed, large, paleontological samples suitable for paleoecological studies which were tied to measured sections.

A final consideration in locating measured sections was outcrop accessibility. In view of the size of samples that were to be collected section locations generally were restricted to those outcrops which could be reached within an hour of walking or climbing.

Samples were taken from the measured sections wherever significant faunal or lithologic changes were observed. Faunal changes such as the first or last appearance of certain brachiopod species, an apparent change in community make-up, the prolific appearance of faunal elements such as corals or bryozoans, or the occurrence of particularly highly fossiliferous beds were regarded as significant. Significant lithologic changes included visible change in grain size, changes in hue or weathering characteristics, the occurrence of environmentally significant or unique sedimentary structures, the occurrence of quantitatively important allocthonous sedimentary particles such as crinoid columnals or quartz sand grains, or abrupt changes in the amount of bioclastic material present.

Samples taken for the purpose of collecting paleontological specimens were usually collected as large blocks of limestone. The aggregate weight of paleontological collections averaged about 30 pounds. Smaller hand specimens were taken as lithological samples. In the laboratory, those samples which contained silicified fossils were treated with hydrochloric acid to free the shells from the carbonate matrix. Non-silicified fossils were separated from the limestone using a hydraulic rock splitter. After separation from the limestone the specimens were sorted and identified. All identifications were checked by Dr. Johnson. The brachiopod species in each sample were listed both as number of specimens and as a percentage of the total brachiopod fauna for the sample. The communities defined in this paper are the result of the study of 9,795 brachiopod specimens.

A lithologic specimen was set aside from each paleontological sample. These specimens were cut and polished in order to observe the possible trace fossils or sedimentary structures present and to observe the orientation of the shells with regard to the substrate. Thin sections were prepared from those lithologic samples taken from horizons where significant faunal or lithologic changes were believed to have occurred. The thin sections were studied with a petrographic microscope to determine constituency, presence of microfossils, or sedimentary structures.

In the text which follows, certain descriptive adjectives have been keyed to standard schemes. In the paragraphs describing the relative abundance of individual species in the fossil collections those species whose relative abundance is greater than 10% of the collection are referred to as "abundant," those which constitute 5 to 10% are referred to as "common," and those which constitute less than 5% of the collections are referred to as "rare."

In the lithologic descriptions, all rock color descriptions are referred to the Rock Color Chart distributed by the Geological Society of America. The carbonate classification followed is that of Folk (1962). In describing bedding thickness the following scale was used; 1-4 inches was referred to as thin-bedded, 4 inches to 1 foot was considered medium-bedded, and 1 foot to 3 feet was considered thick-bedded. Bedding thicknesses greater than 3 feet were considered very thick-bedded.

ANALYSIS OF MEASURED SECTIONS

McColley Canyon Section

Section Description

The section at McColley Canyon, designated MCN-1, is located in the saddle above the head of McColley Canyon in the NE1/4, NW1/4, NE1/4 of Sec. 1, T26N, R52E, Mineral Hill Quadrangle. The line of section bears S70E. At this location 221 feet of McColley Canyon Formation were measured. The basal 50 feet of section is considered to belong to the Kobeh Member of the McColley Canyon Formation and the upper 171 feet to the Bartine Member on the basis of lithology.

Section MCN-1 begins at the contact between a light gray (N7), fine-grained, thick bedded, unfossiliferous dolomite and a medium light gray (N6), very fine-grained, thin bedded, fossiliferous limestone. The dolomite has been assigned to the Lone Mountain Dolomite by Carlisle and others (1957). The limestone may be assigned to the McColley Canyon Formation on the basis of its lithology and its stratigraphic position between the Lone Mountain Dolomite and overlying Union Mountain Formation. The writer assigns the lower 50 feet of the McColley Canyon Formation on section MCN-1 to the Kobeh Member. The assignment is based on the color and composition of the limestone and on its weathering characteristics. The contrast with the yellow-weathering, rubbly Bartine just upslope is immediately apparent. The contact between the Kobeh and Bartine Members is abrupt, but apparently conformable.

At the Kobeh-Bartine contact the lithology changes from a medium light gray (N 6), bioclastic very fine-grained limestone to a sparsely fossiliferous, thin bedded, light bluish gray (5 B 7/1), weathering argillaceous micrite. The basal Bartine evinces the rubbly, grainy weathered texture which is typical of the rock unit wherever it is found. On a fresh, polished surface, however, the argillaceous limestone of the lower 15 feet of Bartine (50 to 65 feet on section MCN-1) shows an olive black (5 Y 2/1) color. Compositionally, equal amounts of micrite/microspar and clay make up 94% of the rock. The remaining 6% consists of bioclasts. The basal Bartine at McColley Canyon is very similar to the basal Bartine at Coal Canyon with regard to color and composition.

The biotic component at this level of MCN-1 is sparse, both with regard to whole shells and disarticulated valves, and with regard to comminuted bioclastic material. There is no evidence of burrowing or other biogenic activity. Such bioclasts as are present, in the form of brachiopod and gastropod shell fragments, ostracods and miscellaneous spines, are angular with freshly broken edges. The presence of angular bioclasts in such a fine-grained sediment argues for the possibility of the shells being broken by the actions of scavengers and the sediment being so thoroughly churned by burrowing organisms that all traces of burrows and small-scale sedimentary structures were destroyed.

The fauna preserved consists entirely of brachiopods with the exception of the small gastropods and ostracods viewed in thin section. The brachiopod fauna is of moderate diversity with six forms, Chonetes sp., Parachonetes macrostriatus (Walcott), Atrypa nevadana Merriam, Meristella cf. robertsensis Merriam and a possible Howellella sp., represented. Atrypa nevadana is preserved articulated and with frills intact and may be assumed to have lived in the immediate vicinity, if not actually in the spot where final burial took place. The other brachiopod species present also probably lived in the immediate vicinity in view of the quiet water environment and the unbroken, unabraded condition of the shells.

On the basis of the high percentage of clay and microcrystalline carbonate, the angular nature of the bioclasts, and the barren fossil assemblage, the basal Bartine may be considered to have been deposited in quiet water, undisturbed by wave or current action.

At 65 feet above the base of section MCN-1, or 15 feet above the base of the Bartine Member, the lithology changes abruptly to a fossiliferous, thin bedded, grayish orange (10 YR 7/4) to pale yellowish brown (10 YR 6/2) weathering, argillaceous biomicrite. This lithology occurs throughout the middle 130 feet of the Bartine

Member at McColley Canyon with slight variances in color and amount of bioclastic content.

Sample MCN-14 taken from 82 feet above the base of the section exhibits an olive gray (5 Y 4/1) color and does not appear as organic-rich as samples from the basal Bartine. Compositionally, this limestone is 89% very fine-grained material with micrite/microspar accounting for approximately 60% and clay approximately 29% of the total constituents. A small amount (1%) of very fine quartz sand is also found. The remaining 10% of the sample is composed of bioclastic material.

The bioclastic material, in addition to whole shells and valves of brachiopods, includes ostracods, crinoid columnals, pieces of tabulate corals, trilobite fragments, and miscellaneous spines. The angular, fragmented, bioclastic material and the disarticulated brachiopod valves are distributed among the clumps and stalks of the branching and massive tabulate colonies which are abundant and in growth position. The fauna is much more diverse than that found lower in the section and includes 12 brachiopod genera in addition to fenestellid bryozoans, solitary tetracorals, tabulate corals, gastropods, and calcareous algae. Numerically important brachiopods include Parachonetes macrostriatus, Dalejina sp., Atrypa nevadana, Nucleospira subsphaerica Johnson, and Eurekaspirifer pinyonensis (Meek). Parachonetes macrostriatus is the only species which appears articulated and unworn. Of the others all are disarticulated and the specimens of Atrypa nevadana and Eurekaspirifer pinyonensis especially show the affects of abrasion and wear.

On the basis of the percentages of micrite and clay, and the abundance and condition of the bioclasts, the lithology at 82 feet on section MCN-1 is considered to have been deposited in intermittently agitated water. The situation of quiet water, occasionally disturbed by wave action or laminar flowing bottom currents, is sufficient to explain the relationship between the disarticulated brachiopod valves and other bioclasts and the tabulate coral colonies. The tabulate coral colonies and probably the coralline algae and Parachonetes macrostriatus grew during periods of quiet water when carbonate mud was being deposited. Periodic episodes of higher energy would wash bioclastic material downslope along the bottom where it would be trapped among the tabulate colonies and algal stalks. These periodic influxes of mud and bioclastic material probably resulted in the death and disarticulation of many of those brachiopods actually living in the area at the time and the introduction of at least some of the Atrypa nevadana specimens and the Eurekaspirifer specimens into the developing thanatocoenose. Atrypa nevadana is represented by equal proportions of brachial and pedicle valves, while Eurekaspirifer pinyonensis is represented by pedicle valves only.

Between 82 and 97 feet the lithology is essentially unchanged. At 87 feet above the base of the section a sample (SSN-1-571) was collected which is noteworthy for the diversity and excellent preservation of its brachiopod fauna. Numerically important forms include Dalejina sp., Megastrophia sp., Phragmostrophia merriami Harper, Johnson, and Boucot, "Strophochonetes" filistriata Walcott, Trigonirhynchia occidens (Walcott), Atrypa nevadana, Nucleospira subsphaerica, Eurekaspirifer pinyonensis, and Ambocoelia sp. Atrypa nevadana is the most abundant species.

The A. nevadana collection is composed for the most part of broken, articulated, delicately preserved specimens in a wide range of sizes. The size distribution of the collection ranges from juvenile individuals 2 mm wide to a maximum of 25 mm for mature individuals. The orientation of the shells at the outcrop and those shells which exhibit geopetal structure indicate that the life-orientation of the animals was with the pedicle valve down. Smaller shells have the pedicle foramen and the deltidial plates well-developed. Shells broader than 20 mm generally show encroachment of the dorsal beak into the delthyrium and partial resorption of the deltidial plates. These individuals may have lived free upon the bottom. Many individuals show long, relatively deep, round-bottomed indentations in either valve. These indentations are most frequently found on the brachial valve and are believed to be the scars of healed injuries

(Fenton and Fenton, 1932a). DuBois (1916) noted similar injuries to those specimens of Terebratalia obsoleta Sowerby which lived in rough water. Crowding in closely settled colonies is also known to cause such irregularities in the shell form. Judging from the many articulated shells of Nucleospira and Phragmostrophia as well as A. nevadana, and the unworn, unbroken condition of most of the shells, this collection is considered to be representative of a life assemblage.

At 97 feet above the base of the section the lithology of sample MCN-15 reflects an apparent slight increase in environmental energy. Very fine-grained particles still dominate, with micrite and microspar composing approximately 40% and clay 22% of the rock. The remaining 38% if composed of coarse-grained, angular bioclasts. These bioclasts are oriented with the long axes of the clasts parallel to the bedding and are composed of tabulate corals, ostracods, trilobites, gastropods, and bryozoans. The bryozoans are of the delicate, amphiporid variety, are particularly profuse, and are oriented parallel to the bedding planes.

Numerically important brachiopod species include Dalejina sp., Phragmostrophia merriami, Parachonetes macrostriatus, Atrypa nevadana, Eurekaspirifer pinyonensis, and Ambocoelia sp. Almost all the shells are disarticulated, although Phragmostrophia, Atrypa, and Ambocoelia are represented by some articulated individuals. Other faunal constituents include numerous trilobite fragments, bryozoans, solitary tetracorals, and Tentaculites sp. Also present are several varieties of tabulate corals, including Aulopora sp., Syringopora sp., and Favosites sp. These corals were found in growth position, including one Favosites colony growing on the exterior of an Atrypa pedicle valve.

Sample MCN-15 is another example of a mixed environment of deposition, a very fine-grained carbonate mud with a considerable admixture of angular and broken shell fragments. The former element infers quiet water deposition and the latter the work of either currents or biotic agents. Biotic agents are ruled out as the degrading mechanists in the case of sample MCN-15 for several reasons. The sample itself, and the outcrop from which it was collected, shows zones, lenses, and washes of concentrated bioclasts, just as one would expect to find distributed by currents. Biotic agents on the other hand, would tend to mix the fragmented shell material evenly throughout the sediment. Another consideration is the mixture of delicate Amphipora and shell fragments. It is not logical to assume deposit feeding organisms burrowing through an original mixture of Amphipora and whole brachiopod shells and selectively crunching the brachiopod shells while leaving the fragile bryozoans undisturbed.

In view of the arguments against burrowing organisms or other biotic agents as the direct cause of the bioclastic element in sample MCN-15, it seems most logical to appeal to periodic, weak currents as a transporting agent to bring the shell fragments down slope and introduce them into the quiet water community. During periods of quiet water the site was occupied by brachiopods such as Phragmostrophia, Atrypa, and Ambocoelia and by certain tabulates and the amphiporid bryozoans. Periodic episodes of quickened current temporarily destroyed the quiet water community, as increased sedimentation and turbidity served to kill, and currents uproot, the prior inhabitants. The currents must have been strong enough to uproot the Amphipora colonies, but generally must have been weak, laminar currents. The bryozoans, although uprooted and current oriented, have not been fragmented. The presence of many juvenile A. nevadana in growth position further argues for weak currents. The lithology at MCN-15 is characteristic of sediment deposited in alternately agitated and quiet water.

Between 97 and 120 feet there is an alternation of sediment types reflecting fluctuating depositional conditions. Very fine-grained bioclastic limestone of the type found at 97 feet alternates with very fine-grained, non-bioclastic limestone in zones 8 to 10 inches thick. The bioclastic limestone is characterized by a fauna like that in sample MCN-15 while the non-bioclastic limestone is characterized by abundant bryozoans such as Amphipora sp. and various dichotomously branching forms, but has few brachiopods. This alternating lithology is believed by the writer to reflect shelf-wide fluctuations in depositional regime rather than the common and pronounced lateral variations in depositional environment that is regarded as usual on shallow carbonate shelves (Newell and Rigby, 1957). This opinion is based on the regular alternation between just two types of lithology, the thickness of the zones of the two lithology types indicating depositional conditions of some duration, and the fact that the lithologies persist along strike within their zones. It is thus concluded that the lithology exposed between 97 feet and 120 feet on section MCN-1 represents a somewhat regular fluctuation between conditions of deposition in quiet water and conditions in intermittently agitated water.

At 120 feet above the base of the section samples MCN-16b and SSN-1-871 show a different lithology, representing a new variation on the depositional theme. At this point the lithology is a highly fossiliferous, medium bedded, medium light gray (N 6) weathering biopelmicrite. On a fresh surface the color is medium dark gray (N 4). Compositionally, the samples are 62% fine-grained material, 20% pellets in the size range of very fine sand, and 18% coarse bioclastic debris. The fine-grained component breaks down to be 10% clay and 52% micrite of the total sample. The pellets are very well-sorted. The bioclasts are mostly represented by disarticulated valves and fragments of valves of thick-shelled brachiopods, although favositid colonies and pieces of trilobites are also present. The fragmented shell material is subangular to subrounded.

The fauna at this level is essentially composed of two species, Atrypa nevadana and Eurekaspirifer pinyonensis. The specimens of A. nevadana are larger and thicker shelled than those found lower in the section, the largest individuals are 35 mm across the widest part of the pedicle valve. The valves are quite thick, approximately 2 mm at the thicker, posterior end. Many of the specimens are broken and most are disarticulated. Those specimens which are whole show evidence of twisting of the shell and healed injuries to the shell which must have involved the mantle (DuBois, 1916). All A. nevadana specimens show wear and abrasion of the shells manifested in smoothing of the costae and peripheral corrugations. Such environmentally produced modifications to the shell exterior are typical of shells which grew or were transported in at least moderately turbulent water.

The articulated specimens of A. nevadana are convexo-plane with the brachial valves strongly convex and the pedicle valves essentially flat. The dorsal beak blocks the pedicle foramen either partially or, in some specimens, completely. Those specimens in which the delthyrium may be observed show partial resorption of the deltidial plates. It is assumed on the basis of shell convexity and the condition of the pedicle foramen that the individuals lived unattached on the shelf bottom on the pedicle valve as suggested by Copper (1967).

The *Eurekaspirifer pinyonensis* collection from 120 feet consists of relatively small, disarticulated valves 15-25 mm wide. The mix of pedicle valves and brachial valves is essentially equal, 21 pedicle valves and 19 brachial valves. Not only is the number of pedicle and brachial valves essentially equal, but they also have parallel size distributions. The *E. pinyonensis* valves do show some effects of abrasion and rounding, but are in general well-preserved.

The sample taken at 120 feet is the lowest pelletiferous limestone in the Bartine Member at McColley Canyon. The pellets found in the sample are well-rounded, and sorted. Their composition is essentially very fine-grained calcium carbonate with little or no organic matter. On the basis of the composition, these pellets are believed to be small intraclasts rather than coprolitic in the sense of Folk (1962). The pellets are visible on a polished section as discrete, very fine sand-sized particles set in a matrix of microgranular calcite. When viewed under high magnification, the pellets are seen to be composed of microgranular calcium carbonate. They are tightly compacted and are clastic units unto themselves.

The fossils included within the micritic-pelletiferous matrix are a mixture of unabraded articulated brachiopod shells, disarticulated valves and broken and rounded shell fragments. The shells and shell fragments are variably oriented, convex up, concave up, and at right angles to the bedding planes. The random orientation of the shells indicates an environment which experienced periodic currents strong enough to move large, heavy brachiopod shells, but which were ephemeral in nature (Menard and Boucot, 1951), episodically disturbing and carrying for short distances as clastic particles the shells available in the area.

The environment of deposition of sample 871 is believed to have been one of generally quiet water in which micrograined carbonate mud was being deposited. Periodically, higher energy conditions existed which disturbed and disarticulated some of the Atrypa nevadana which lived there and introduced disarticulated and broken E. pinyonensis into the area along with pellets of semi-consolidated limestone. The lithology at this level indicates a sediment which was deposited in intermittently agitated water.

At 195 feet the lithology becomes that of an abundantly fossiliferous, thin-bedded, grayish orange (10 YR 7/4) weathering biopelmicrite. A sample, MCN-17, taken from this level is composed of 50% micrite/microspar, 10% clay, 14% bioclasts, and 26% pellets. The pellets are similar if not identical to those described above and must be considered the result of erosion of a semi-consolidated carbonate mud bottom with subsequent rounding and deposition farther downslope. Further evidence of current action is the presence of small-scale rip-ups and ripple marks indicating that currents disturbed the unconsolidated mud of the shelf floor. The argillaceous content of sample MCN-17 is reduced and some of the void space filled with sparry calcite after the clay was winnowed away.

The bioclasts present consist of shell debris from brachiopods, tabulate corals, trilobite fragments, and crinoid columnals. Some of the bioclasts are quite coarse, consisting of thick Atrypa pedicle valves 30 mm in width. The disarticulated shells are found both convex up and convex down. Tabulate coral colonies are found apparently uprooted and lying horizontal to the bedding planes.

The fauna at 195 feet is dominated by Eurekaspirifer pinyonensis, with Atrypa nevadana and "Strophochonetes" filistriata as common associates. Phragmostrophia merriami, Nucleospira subsphaerica, and Hysterolites sp. are rare species in this collection. At this point, E. pinyonensis becomes the dominant species for the first time. The E. pinyonensis collection is primarily represented by disarticulated pedicle and brachial valves with the ratio of pedicle valves to brachial valves 2.5:1. There are some articulated individuals with the delicate spiralia intact. Further, the E. pinyonensis collection is characterized by shells of adult individuals, indicating that the remains of once living individuals were subjected to current sorting with subsequent destruction and/or downslope transport of the smaller shells. It is the writer's contention that E. pinyonensis lived in or near the area where the shells were ultimately buried, considering the excellent state of preservation of the articulated shells and due to the fact that the disarticulated shells do not show evidence of rounding or breakage. Previous research on the subject of shell transport indicates that although the net transport distance of brachiopod shells may be high, in shallow water environments they are usually not transported far from their original living place (Middlemiss, 1962) and that in general shells are not usually transported far in environments where fine-grained sediments are being deposited (Speden, 1966).

The two other brachiopod genera found in this assemblage, _A. nevadana_ and "_Strophochonetes_" _filistriata_ occur in almost equal abundance, but in different modes. _A. nevadana_ is found in the same state of preservation as _E. pinyonensis_ except that more of the shells are still articulated. The size distribution is skewed toward the larger size valves and, as with the _E. pinyonensis_ collection, it is assumed that the shells of juvenile individuals were destroyed and/or transported downslope. "_Strophochonetes_" _filistriata_ is represented by disarticulated pedicle valves almost to the total exclusion of brachial valves. The pedicle valves are well-preserved, as silicified specimens of this genus go, and do not show signs of wear or breakage from transport. The preponderance of pedicle valves _re_ brachial valves is not significant of transport as the order Strophomenida is subject to such disproportionate representation as an accident of preservation (Boucot, oral communication, July, 1973).

The mixture of small (10 mm width, maximum) "Strophochonetes" pedicle valves with well-sorted valves of A. nevadana and E. pinyonensis two or three times as large in a transported thanatocoenose is explainable in terms of the hydrodynamic properties of the respective shells. A "Strophochonetes" pedicle valve, lying flat upon the substrate, convex exterior up is a very close approximation to an airfoil and, as indicated by R. G. Johnson's (1957) work with shell transport, would tend to remain at rest in spite of current action. Thus, the "Strophochonetes" valves would tend to remain stable upon the bottom in an environment where the larger A. nevadana and E. pinyonensis valves were being transported. The same argument may be offered to explain the unequal proportions of Eurekaspirifer pedicle and brachial valves. The brachial valves of Eurekaspirifer are relatively planar and would lie flat on the mud bottom and would resist the attempt of currents or wave action to move them. The pedicle valves, on the other hand, are quite convex and would be easier to transport until such time as they reached a stable, i. e., convex up, position. Although the mixture of brachiopod remains found in this assemblage has been attributed to differences in hydrodynamic characteristics with concomitant variable reaction to transportive agents, the writer does not mean to imply that these three brachiopod species are ecologically mutually exclusive. The mosaic distribution of the sessile benthos within communities on the bottom of the modern seas has been discussed by a number of researchers, and the patchy distribution of colonies of modern brachiopods in an overall hospitable environment has been observed by Rudwick (1962a). It is the writer's conclusion that these three species, A. nevadana, E. pinyonensis, and "S." filistriata were inhabitants of the same community in the general sense and that the thanatocoenose preserved in the limestones at McColley Canyon represents the result of current action which has transported and mixed inhabitants of adjacent colonies of different species of brachiopods. A second possibility is that only the large A. nevadana and E. pinyonensis shells have been transported into the area and that "Strophochonetes" filistriata lived there using the larger shells as a substrate to which they could attach.

The overall aspect of the lithology at 195 feet is indicative of a higher energy environment than has been previously encountered in section MCN-1, although microgranular and microcrystalline carbonate still predominate. Some of the argillaceous material has apparently been winnowed from the sediment, indicating active current sorting. The presence of clastic carbonate pellets and the very coarse, obviously transported, bioclastic material are further indications of active transport by marine currents.

It is apparent from the nature of the bioclasts that currents of moderately high energy were present at least periodically. Many of the large, articulated _A. nevadana_ are found oriented with the commissure normal or at an angle greater than 45 degrees to the bedding plane. Studies by Copper (1967) and Fenton and Fenton (1932a), plus the writer's own observations and collections of _A. nevadana_, indicate that large, frilled, convexo-plane atrypids were oriented with the pedicle valve down in life position, as shown in Figure 2. The orientation of the articulated specimens of _A. nevadana_ at the site of sample MCN-17 indicate that there were currents at least strong enough to roll articulated _Atrypa_ shells which were 30 mm wide. This fact in itself, however, does not indicate currents of particularly high energy. As Menard and Boucot (1951) have pointed out, the effective density of water-filled, articulated brachiopod shells is relatively low.

The relationships of the bioclasts in sample MCN-17 give other clues to the nature of the currents present. An interesting relationship is that of the tabulate coral colony and the _A. nevadana_ brachial valve as shown in Figure 3. The tabulate coral colony has been dislodged from the substrate and transported, coming to rest with the long axis of the colony parallel to the bedding plane. The _Atrypa_ brachial valve has subsequently come to rest capping what was the apex of the living colony. Studies of movement of disarticulated brachiopod shells by Menard and Boucot (1951) and by Johnson (1957) indicate that currents tend to slide shells along the bottom. The

Figure 2. Atrypa nevadana in life position from the Bartine Member, Telegraph Canyon, Sulphur Springs Range, Eureka County, Nevada. Approximately 1/2 life size.

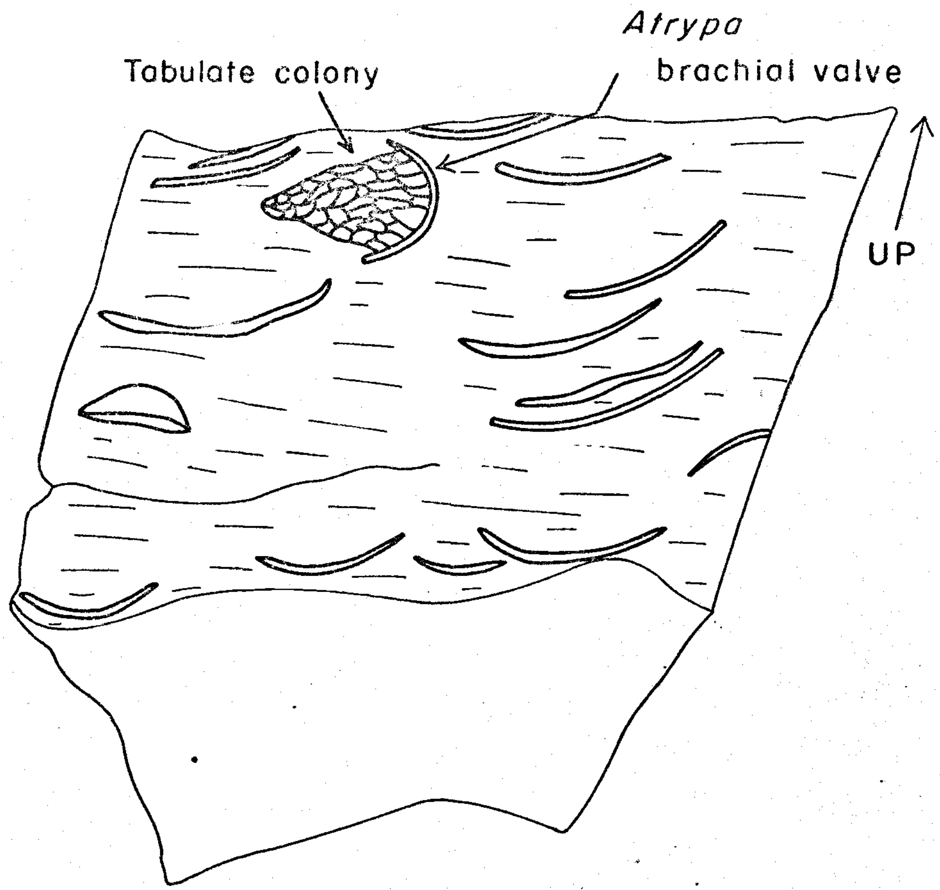

Fig. 3. Relationship between transported tabulate coral colony and disarticulated *Atrypa nevadana* brachial valve indicating vigorous transport of disarticulated brachiopod valves. From Bartine Member at McColley Canyon, Sulphur Springs Range. Approximately 3/4 life size.

writer believes that the relationship described above indicates that in this case the shells were being at least tumbled and perhaps even saltated along the bottom. In any event, it appears necessary to get the *Atrypa* brachial valve up on its edge, perpendicular to the bottom, so that it could snag on the coral colony and establish the orientation in which it was preserved. To the writer this implies a current of some velocity.

The large brachiopods are somewhat randomly oriented in the beds under discussion, parallel to and oblique to the bedding planes. Menard and Boucot attribute such randomly oriented clumps of shells to transport by currents which have suddenly ceased and more or less "dumped" their bioclastic load.

The appearance on many of the *Eurekaspirifer* and *Atrypa* shells of indentations, creases, and other irregularities which indicate subsequently repaired life-time injuries or the affects of crowding is of further interest. Such injuries were described by Fenton and Fenton (1932a) in atrypids from the mid-continent. They did not, however, offer an explanation for their origin. The irregularities are particularly interesting in view of the fact that they are strikingly similar to those figured and discussed by DuBois (1916) in his studies of *Terebratalia obsoleta* from Puget Sound. DuBois found similarly scarred shells in those examples of *T. obsoleta* which lived in current agitated waters and he attributed them to injuries to the mantle suffered when the animal was impacted against the substrate as a result of turbulent or oscillating current. Figure 4 shows an excellent specimen of Eurekaspirifer pinyonensis exhibiting the scars of injuries to the shell which occurred during the animal's life-time and subsequently repaired.

The composite picture arises from the evidence indicating an environment in which the water was constantly agitated by weak currents depositing very fine-grained carbonate mud, with episodic, moderately strong currents which winnowed some of the finest material from the sediment and redistributed the dead shells which lay on the shelf floor.

At 197 feet above the base of section MCN-1 the lithology of the Bartine Member changes from limestone to dolomite. The lithology at 197 feet, represented by sample MCN-17d, has the same outward appearance as the lithology at 195 feet, only closer inspection and the application of hydrochloric acid reveals that it is dolomite. The dolomite on MCN-1 is particularly interesting when compared to the lithology at Telegraph Canyon, six miles to the south. Here the Bartine lithology at the same stratigraphic level and even higher is still limestone. The color and texture of the rock is the same as at McColley Canyon, only the composition is different. The Lower Devonian carbonate rocks are known to become increasingly dolomitized as one proceeds north from the Sulphur Springs Range into the

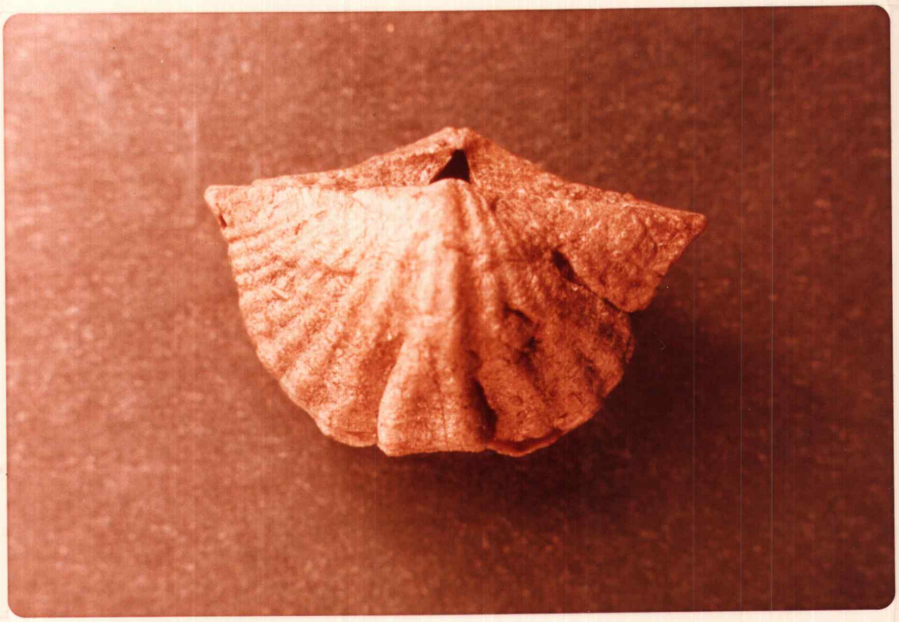

Figure 4. Shell of Eurekaspirifer pinyonensis showing injuries incurred and subsequently repaired during the animal's lifetime. Approximately life size.

Pinyon Mountains (Carlisle et al., 1957). It is the writer's opinion that the dolomite present at 195 feet on MCN-1 is secondary dolomite after alteration of the original micritic limestone. The primary lithologic type at the site of sample MCN-17d is a fossiliferous, medium bedded, pale yellowish brown (10 YR 6/2), quartzose dolomitic pelmicrite. Interbedded with the dolomitic pelmicrite are sporadic lenses and occasionally thin beds 1-1/2 inches thick of unfossiliferous moderate brown (5 YR 3/4) dolomitic pelsparite. Figure 5 is a photograph from this lithology. These lenses and bands of dolomitic pelsparite are the bands of secondary chert referred to by Murphy and Gronberg (1970). In the field the interbeds stand out as a result of differential weathering, and in this aspect and in color have very much the appearance of chert. Their clastic nature is revealed in thin section or polished section, however.

The composition of the primary lithology is microcrystalline dolomite 55%, pellets 30%, and fine quartz sand 15%. The pellets are of clastic origin, well-rounded and well-sorted, and are of the size of fine sand. The quartz grains are angular and well-sorted. The interbeds are composed of 90% pellets in a dolomitic sparry matrix. These pellets are clastic in origin, well-sorted and well-rounded. The composition and appearance in thin section of the interbeds is very similar to that of the basal beds of the overlying Union Mountain Formation. The writer considers these interbeds to be the first

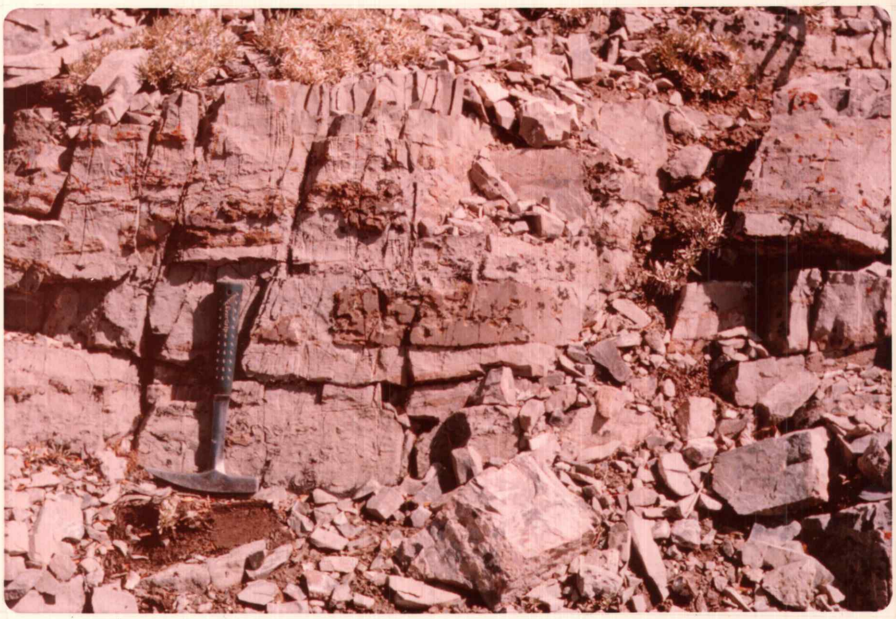

Figure 5. Lithology at 197 feet on section MCN-1. The light gray rock is quartzose dolomitic pelmicrite, the moderate brown lenses are dolomitic pelsparite.

transitory manifestations of Union Mountain sedimentary conditions at McColley Canyon, implying that Union Mountain conditions were already established somewhere to the east. Despite the appearance of a presumed Union Mountain element the unquestionably dominant lithology at this point in the section is more typical of what the writer considers to be a dolomitized Bartine and so the strata are still considered to belong to that member.

The fauna of the primary lithology is composed of Atrypa nevadana and Eurekaspirifer pinyonensis with the latter most prevalent. The shells lay in the rock oriented parallel to the bedding convex down. Figure 6 shows shells from the same stratigraphic level at Telegraph Canyon. The shells are all abraded and disarticulated and obviously represent a thanatocoenose. The interbeds and lenses are unfossiliferous.

The abundance of very fine sand-sized pellets in a microcrystalline calcite matrix, in conjunction with the presence of angular quartz grains is indicative of deposition in slightly agitated water (Plumley et al., 1962). Microscale foresets are visible in thin section near the contact between the primary lithology and the interbed in sample MCN-17d, presaging the slightly higher energy conditions represented by the interbeds.

At 212 feet the lithology is characterized by a moderately fossiliferous, thin bedded, medium gray (N 5), quartzose dolomitic

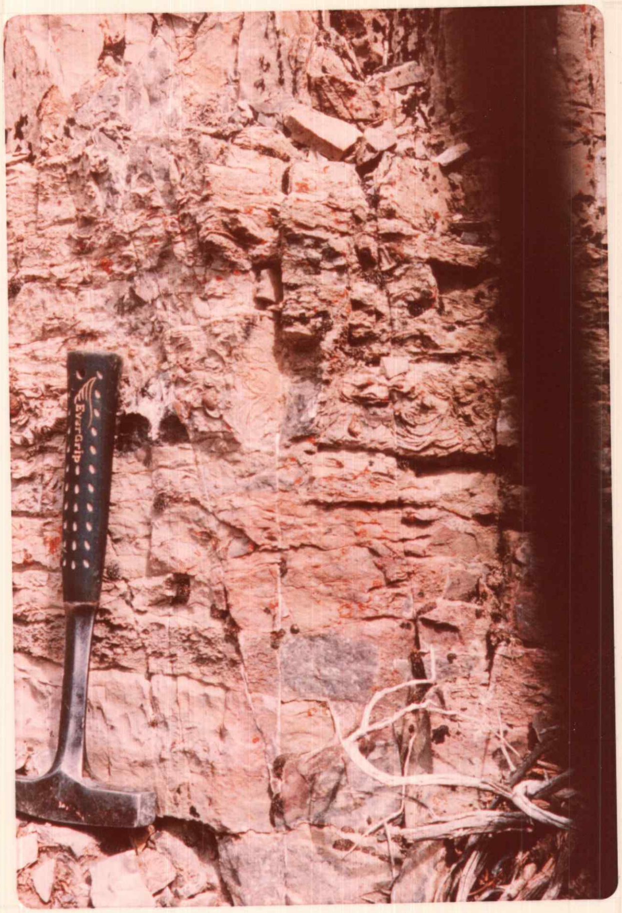

Figure 6. Lithology at Telegraph Canyon from the same stratigraphic horizon as sample MCN-17b. Note how the shells have been stacked into nests and oriented convex down.

pelsparite with washes and lenses of pale yellowish brown quartzose dolomitic pelmicrite as at 197 feet. The fossils present are disarticulated and abraded valves of A. nevadana and E. pinyonensis, but they are much less in evidence than at 197 feet.

The environment of deposition at this locality may be described as variable. The lenses of pale yellowish brown dolomitic pelmicrite and the quartzose dolomitic pelsparite both indicate deposition in slightly agitated water, the latter representing slightly higher energy conditions than the former on the basis of a lower proportion of microgranular constituents.

Between 212 feet and 221 feet above the base of section MCN-1 the lithology represents a highly variable depositional environment. The lithology shifts back and forth between pale yellowish brown, quartzose dolomitic pelsparite to medium gray quartzose dolomitic pelsparite to moderate brown dolomitic pelsparite within and between beds. The variation within beds is manifested in small scour channels several inches across and on the average an inch deep, back-filled in a contrasting manner with one of the other lithology types described above. This interval of the section is sparsely fossiliferous with abraded shells of Eurekaspirifer pinyonensis. These three lithologies are considered to represent conditions of fluctuating energy on the basis of the proportions of microgranular and fine-grained clastic constituents. The pale yellowish brown facies has the highest proportion of microgranular material, the medium gray facies and moderate brown facies have successively less microgranular material.

At 221 feet the moderate brown pelletal dolomite becomes the sole sediment type. The writer considers this to be the contact between the McColley Canyon Formation and the Union Mountain Formation at McColley Canyon. Considering the distribution of sediment types from 197 feet to the top of the section it is apparent that the change from Bartine to Union Mountain sedimentation is transitional and not abrupt. The sporadic incursion of Union Mountain type sediment first apparent at 197 feet indicates to the writer that the Union Mountain depositional environment must have been established to the east while Bartine sedimentation still prevailed at McColley Canyon. Consistent with this conclusion is the opinion here expressed that the Union Mountain Formation in the Sulphur Springs Range represents a westward facies shift rather than the onset of an entirely new depositional regime.

Interpretation of Fauna and Lithology

The lithology on section MCN-1 reflects environments of increasing energy as one proceeds upward from the base of the section. The increase in energy is manifested in the increasing proportion of clastic pellets and coarse to very coarse bioclasts vs.

the fine-grained fraction of the limestones although the lithology is predominately micrograined at all levels. It has been pointed out in the preceding discussion that the lithology at the base of the section is interpreted as representing quiet water sedimentation. Toward the top of the section sediments interpreted as deposited in agitated water become increasingly prevalent, until at the top of the section agitated water prevails. The Bartine Member at McColley Canyon is interpreted as giving evidence of a shallowing trend toward the end of Bartine time. The occurrence of a succession of limestones representing environments of increasing energy, followed by cross-bedded intraclastic dolomites, and ultimately by the terrigenous clastics of the Union Mountain Formation is cited as evidence of shallowing.

The brachiopod assemblages in section MCN-1 reflect the changing energy levels of the paleoenvironments, and are separable into a high-energy and a low-energy fauna. These faunas are sufficiently distinct from one another both in their paleontological and sedimentological aspects to be regarded as communities. The high-energy fauna will hereinafter be referred to as the *Eurekaspirifer pinyonensis* Community and the low-energy fauna will hereinafter be referred to as the *Atrypa nevadana* Community. The *Eurekaspirifer pinyonensis* Community is found in the strata from 120 feet to the top of the section. Its lowest occurrence coincides with the lowest occurrence of pelletiferous limestones in the section. The community is characterized by Eurekaspirifer pinyonensis and Atrypa nevadana as abundant species and "Strophochonetes" filistriata and Phragmostrophia merriami as common species. Nucleospira subsphaerica and Hysterolites sp. are rare species within the community.

The Atrypa nevadana specimens are large (greater than 35 mm in width), prominently convexo-plane, and thick-shelled (2-3 mm in valve thickness) when compared to individuals of the same species which inhabited quiet water environments. The Eurekaspirifer specimens are also large and assume an increasingly higher proportion of the fossil fauna as one proceeds up section from 120 feet. As the lithology represents sediments of an increasingly higher energy environment, Eurekaspirifer becomes the dominant species and at any one time Eurekaspirifer occupies habitats extending closer to shore than any of the other members of the Eurekaspirifer pinyonensis Community. Thus, some of the E. pinyonensis shells mixed in with the A. nevadana were probably transported in from upslope. The habitats of the two species must be regarded as overlapping.

The orientation and condition of the shells of the Eurekaspirifer pinyonensis Community attest to the agitated water conditions in which the animals must have lived. Reference has already been made above to the inferences that can be made about the energy conditions in which the shells of samples MCN-16b and MCN-17 were deposited. Evidence has been cited which indicates that in some collections the dead shells have been saltated or at least rolled along the bottom as part of the traction load. Field observations of the shells at outcrop between 120 feet and the top of the section reveal that they are often randomly oriented or oriented convex down. The stable orientation for single disarticulated valves is convex up (Menard and Boucot, 1951; Johnson, 1957), thus the beds with shells oriented convex down or randomly oriented are indicative of transport by currents which were powerful enough to pick the shells up and move them, but which were transitory in nature and dropped the shells in a sudden waning of transportive capability such that the shells were not able to assume a stable orientation. These currents were also capable of winnowing a portion of the fine mud from the sediment, indicating currents with turbulent flow, and concomitant turbid water conditions.

In the studies made of shell transport by Menard and Boucot and by Johnson the substrate selected was in the range of fine to medium sand. Both of these studies indicated that scouring of the sediment from around the shell was of primary importance in final burial and that it was possible for shells to be buried in an environment in which erosion and transportation rather than deposition was taking place. This mechanism for burial is ruled out for the case of the disarticulated shells of the Eurekaspirifer pinyonensis Community. Those shells rested on a very fine-grained substrate with mean particle size less than 0.18 mm in diameter. As Inman (1949) demonstrated, for sediments composed of grains less than 0.18 mm the threshold velocity for movement of the particles increases as a function of reduced bottom drag. It is empirically evident that in the situation under discussion the shells would be more easily transported than the substrate on which they rested in the face of laminar bottom currents. It is therefore reasoned that the disarticulated valves were buried by periodic influx of sediment, rather than by scouring. This condition holds true for all the collections described from all sections.

Speden (1966) has observed that in a typical shallow benthic marine habitat the hard-shelled biotic constituency at any one time consists of both living and dead specimens, with dead specimens in greatest numbers and widest areal distribution. Speden also observed that except in special conditions, shells are not transported out of their gross environment. The mix of articulated and disarticulated shells in the *Eurekaspirifer pinyonensis* Community may be regarded as a preserved example of the habitats observed by Speden. A recapitulation of the environment of the *Eurekaspirifer pinyonensis* Community envisions shallow, turbid waters less than 100 feet deep over a bottom littered with the empty shells and disarticulated valves of *A. nevadana* and *E. pinyonensis*. Turbidity is postulated as a result of the turbulent flow which is evidenced by the partial winnowing of mud, the orientation of the shells and the presence of small scale asymmetrical ripple marks at some horizons. The presence of microscale and larger scour marks is further evidence for turbulent flow (Sanders, 1965).

In this turbid, current-agitated environment, A. nevadana lived unattached on its flat pedicle valve, while Eurekaspirifer pinyonensis lived attached by what was probably a stout pedicle judging from the size of the delthyrium. Periodic fluctuations in the current strength would disarticulate and scatter the shells of the dead animals. During these periods of current flow some of the fine material would be lifted into suspension and carried downslope along with some of the smaller shells into deeper water. At irregular intervals alterations of the local depositional patterns would result in sedimentation which, if in sufficient quantity, would bury and preserve the bottom fauna. Small amounts of sediment might have been insufficient to bury the bioclastic debris on the bottom, but might have been sufficient to kill the local brachiopod faunas thus providing more shells for the bottom currents to rework as well as solid substrates onto which subsequent generations could attach. Sediment would probably have been particularly lethal to Atrypa nevadana as this species lived with its commissure parallel and very close to the substrate.

The other community recognizable at McColley Canyon is the Atrypa nevadana Community, characteristic of the quiet water sediments between 50 and 120 feet at section MCN-1. The most common species in this community is Atrypa nevadana which is found in substantial numbers in all collections between 50 and 100 feet. In comparison with the Atrypa nevadana specimens of the Eureka-spirifer pinyonensis Community, those of the Atrypa nevadana Community tend to be smaller (25 vs. 35 mm width for the largest specimens) and dorsi-biconvex to biconvex instead of convexo-plane. Other common species associated with Atrypa in this community are Dalejina sp., Megastrophia iddingsi (Merriam), Phragmostrophia merriami, "Strophochontetes" filistriata, Chonetes sp., Parachonetes macrostriatus, Meristella cf. robertsensis, Nucleospira subsphaerica, and Ambocoelia sp. Rare species in most collections are Trigoni-rhynchia occidens and Howellella sp. The associated species are present in varying proportions from 0 to 50% in the collections between 50 and 120 feet. These varying frequencies are believed to represent a sampling bias reflecting the mosaic distribution of adjacent colonies of brachiopod species. There is no environmental factor evident to explain the different proportions of species from collection to collection. Eurekaspirifer pinyonensis is present in all Bartine collections except sample MCN-12 from 50 feet above the base of the section. Eurekaspirifer pinyonensis appears as small disarticulated valves, predominantly pedicle valves averaging 15 mm in width. The size of the valves and their condition suggests that these examples of

E. pinyonensis have been transported in from the *Eurekaspirifer pinyonensis* Community located farther upslope. The *Atrypa nevadana* Community differs further from the *Eurekaspirifer pinyonensis* Community in the abundance and diversity of its fauna aside from the brachiopods. Common faunal elements are solitary tetracorals, gastropods, bryozoans, tentaculites, trilobites and coralline algae.

Most of the brachiopod fossils observed between 50 and 120 feet were either in life position or in the stable, convex up orientation in the case of disarticulated valves. The presence of convex-up oriented shells on a very fine-grained substrate is suggestive of gentle currents or non-turbulent flow. The absence of any winnowing of the finest sediments is also an indication that such currents as were normally present were not turbulent, and thus below wave base. The presence of diverse and prolific faunas in the *Atrypa nevadana* Community argues for good circulation, even though the sediments are characteristic of quiet water. The presence of gentle, but steady, currents along the bottom in the manner of tidal currents or the epeiric currents suggested by Shaw (1964) is indicated.

The question of the mechanism of final burial of the shells in the *Atrypa nevadana* Community may be treated in the same manner as for the *Eurekaspirifer pinyonensis* Community. In the face of the very fine-grained nature of the bottom sediments, deposition is appealed to as the mechanism for burial. The presence of coral colonies in growth position shows how influxes of sediment periodically overwhelmed and buried the benthos in a layer of micrite and bioclasts.

A summary of the conditions in which the Atrypa nevadana Community lived provides a picture of an environment in clear, quiet water below wave base. The benthic assemblage was dominated by adjacent settlements of brachiopods with interspersed colonies of corals and coralline algae. Table 1 gives relative abundances for brachiopod species on section MCN-1.

Lone Mountain Section

Section Description

The Lone Mountain section, LMN-1, is located in T20N, R51E, of the Bartine Ranch Quadrangle and follows Gronberg's FF section (Gronberg, 1967). The base of the section is located in a saddle in the main southwest-trending ridge of Lone Mountain and follows the ridge up the mountain to the northeast. Five hundred and eighty-three feet of section was examined, of which 457 were of Bartine lithology. The footages recorded are keyed to a series of numbers painted on the section by Dr. Gilbert Klapper of the University of Iowa. The basal contact of the Bartine Member with the Kobeh Member is marked by a change from a thin bedded, moderately fossiliferous, light olive gray (5 Y 6/1), quartzose biomicrite to a thin bedded fossiliferous grayish orange (10 YR 7/4) argillaceous biomicrite with orange silty interbeds. The orange silty interbeds are the special distinguishing characteristic of the Bartine.

From the Kobeh-Bartine contact to 104 feet above the base of the Bartine the lithology is described as a thin bedded, grayish orange ((10 YR 7/4) weathering fossiliferous, argillaceous biomicrite. Sample LMN-15 comes from this interval. The limestone is light olive gray (5 Y 6/1) on a fresh surface and is composed of 80% micrite/microspar and clay, 19% bioclasts, and 1% coarse quartz silt and very fine quartz sand. Bioclasts are composed of fragments of brachiopods and ostracods with many indeterminate acicular fragments. The bioclasts tend to be oriented with the long axes parallel to the bedding plane.

The brachiopod fauna present in sample LMN-15 includes "Strophochonetes" filistriata and Anoplia sp. as abundant species, the latter as transported shells. Rare species include Leptaena sp., Strophonella cf. punctulifera (Conrad), an indeterminate parvicostellate stropheodontid, Phragmostrophia merriami, Nymphorhynchia cf. pseudolivonica, the coarsely costate species of Atrypa and Meristella robertsensis. The fauna is typical of what the writer has defined as the Atrypa sp. homolog of the Atrypa nevadana Community. The

Atrypa sp. homolog is much better expressed at Coal Canyon and section CCN-1 and will be more fully treated in the discussion of that section. The Atrypa sp. Community succeeds the shallow water Acrospirifer kobehana fauna (Johnson, 1974) of the Kobeh Member and is considered by the writer to indicate a deeper water habitat.

Other faunal elements present include Conocardium sp., Phacops sp., a number of indeterminate pelecypods and loxonemid gastropods. Horizontal burrows are common, a fact which may be interpreted as meaning that deposit feeders were common.

The lithology in sample LMN-15 represents a very fine-grained sediment deposited in a low energy environment. There are no current-produced sedimentary structures nor is there any winnowed sediment evident save that of the sparry, thin interlaminae. The orientation of the enclosed bioclasts indicates gentle currents, however the random orientation of the unbroken brachiopod valves is indicative of turbulent eddies in the bottom currents (Menard and Boucot, 1951). The original environment may be pictured as a level carbonate mud bottom below wave base. The water was normally clear with periodic turbidity as eddying bottom currents brought sediment and bioclastic debris downslope. On this mud bottom the geniculate stropheodontids lived, perhaps semi-infaunally (Rudwick, 1970). Meristella and Atrypa lived on the bottom, while Anoplia, which is associated with the biosparite interlaminae, may be presumed to have been transported in from farther up slope. The original habitat of the preserved Anoplia specimens must have been immediately upslope, however, for the small, fragile Anoplia shells are delicately preserved even though disarticulated.

At 101 feet above the basal contact of the Bartine Member the lithology remains unchanged, but the fauna has changed significantly. The fauna, collected as sample LMN-16, has Chonetes sp., Atrypa nevadana, Anoplia sp., and Ambocoelia sp. as abundant species. Rare species from this sample include Nucleospira sp., Brachyspirifer pinyonoides, Cyrtina sp. and an indeterminate strophomenid. All brachiopod shells and valves are oriented parallel to the bedding planes with exception of Anoplia which represents a transported element. This fauna is representative of the Atrypa nevadana Community. Faunal elements other than brachiopods include a diverse assemblage of loxonemid, bellerophontid, and platycerid gastropods, indeterminate pelecypods, orthoceritids, some questionable scaphopods, fragments of dalmanitid and phacopinid trilobites and prolific large ostracods.

At 104 feet above the Kobeh-Bartine contact the lithology is a thin bedded, grayish orange (10 YR 7/4), fossiliferous biopelmicrite. Sample LMN-17 was collected as representative of this lithology. On a fresh surface the rock is light olive gray (5 Y 6/1) and in thin section may be seen to be composed of 44% micrite/microspar and clay, 21% pellets, 19% bioclasts and 16% sparry calcite void filler. The pellets are clastic with regard to their occurrence in this sample and are of coarse silt size. The micrite and clay have been partially winnowed from between the pellets. The bioclasts are current-oriented with the long axis parallel to the bedding plane, and are composed of brachiopods, gastropods, ostracods, and indeterminate tabular fragments.

The fauna collected in sample LMN-17 includes "Strophochonetes" filistriata, Parachonetes macrostriatus, and Atrypa nevadana as abundant species; Phragmostrophia? sp. as a common species and Anoplia sp., Dalejina? sp., Cyrtina sp. and an indeterminate stropheodontid as rare species. These are genera and species which are characteristic of the Atrypa nevadana Community. Other faunal elements present include fragments of the trilobite genera Phacops and Dalmanites, Tentaculites sp., molluscs in the form of pelecypods, gastropods, and an orthoceritid and prolific large ostracods. Horizontal burrows are also present.

The disarticulated brachiopod valves in these strata are oriented convex up and parallel to the bedding planes. The fine bioclasts are distributed evenly throughout the beds in a hash of ostracods, small gastropods, and comminuted fragments.

In general aspect, the lithology at 104 feet represents a very poorly sorted sediment with carbonate and terrigenous clay particles mixed with silt sized pellets and a hash of very coarse sand-sized bioclasts. The partially winnowed texture of the sediment, the presence of bioclasts and shells which have obviously been transported and the orientation of the brachiopod valves in a current-stable position are all evidence of current action. The environment of deposition was evidently in moderately agitated water as indicated by the partially winnowed sediments and the size of the bioclasts. In the Bahamas, Newell and Rigby (1957) found such sediments associated with tidal currents and deeper water sediments circa 60 feet in depth. Shaw (1964) associated such sediments with that area on the shelf where oceanic wave energy is dissipated. The latter model is appealed to here as the sediments described above were deposited in sheets rather than restricted to channels as in the case of the Bahama sediments.

At 118 feet sample LMN-18 shows a virtually identical lithology as that found at 104 feet. The fauna is also similar with two important exceptions. One exception is the appearance of one specimen of Leptocoelia infrequens (Walcott), the only collection at Lone Mountain in which the writer found this species. Gronberg (1967) reported Leptocoelia infrequens in his samples UCR 4530 and 4531 which came from the interval between 157 and 257 feet above the Kobeh-Bartine contact. The species must be in very low frequency, as the writer did not find any examples in his investigation of this interval. The second distinguishing characteristic of this sample is the abundance of burrow structures. These trace fossils, when viewed in polished section along the plane of a bed have a configuration typical of the fodichnia of the Zoophychos facies as defined by Seilacher (1964). Seilacher states that the presence of such biogenic structures represents the action of crawling deposit feeders living in water at least as deep as the sublittoral zone.

At 371 feet above the Kobeh-Bartine contact the lithology has again become very fine-grained, cropping out as a medium bedded moderate yellowish brown (10 YR 5/4) weathering fossiliferous micrite. Sample LMN-111 taken from this level is dark yellowish brown (10 YR 4/2) on a fresh surface. The rock is 95% micrite/microspar and clay with a high clay content. The remaining 5% of the constituents is composed of very fine-grained bioclasts concentrated in layers 1/4 inch thick. The bioclasts are sparse even where most concentrated.

The fauna associated with this sample is of the Atrypa nevadana Community with G-A-S biofacies elements. The G-A-S biofacies as defined by Johnson (1974) is a relatively deep water biofacies encompassing the benthic life zones occupied by the Pentamerus, Stricklandia, and Clorinda communities of Ziegler (1968), or benthic assemblage 3, 4, and 5 as defined by Boucot (1974). Sloss and others (1949) have defined a biofacies as composed of one or more biotopes differing in biologic aspect from laterally equivalent biotic assemblages. A biotope is the living space of a community. As implied by the initials, the G-A-S biofacies is characterized by the presence of Gypidula, Schizophoria, and Atrypa. The only aspect of the fully developed biofacies that the writer has observed in the Bartine is a recurrent assemblage including abundant to common Schizophoria, Brachyspirifer, Atrypa and Carinagypa. This assemblage will be hereinafter referred to as the G-A-S Community.

Johnson has stated that the G-A-S biofacies is succeeded by the shallow water Acrospirifer-Leptocoelid biofacies in a regressive sequence. It, therefore, stands to reason that to have the Acrospirifer-Leptocoelid biofacies ultimately succeeded by the G-A-S biofacies indicates deepening conditions. Such is the case at Lone Mountain.

The writer has observed that where the Atrypa nevadana Community is succeeded by the G-A-S Community within the Pinyonensis Zone there is a transitional fauna which includes Atrypa nevadana, Brachyspirifer pinyonoides, and Schizophoria nevadaensis, but without Carinagypa loweryi (formerly Gypidula loweryi Merriam). Carinagypa loweryi is the last species to appear in a deepening sequence. The writer will refer to this transitional fauna as the Atrypa nevadana Community with G-A-S elements.

Abundant species in sample LMN-111 are Chonetes sp. and Atrypa nevadana. The specimens of Atrypa nevadana are present in sizes ranging from juveniles 5 mm wide to adults 40 mm wide. The specimens are beautifully preserved with prominent frills in the strongly convexo-plane adults. Common species in this assemblage include Hysterolites sp., and Brachyspirifer pinyonoides. Rare species are Levenea sp., Schizophoria sp., Leptostrophia sp., Megastrophia sp., Leptaena sp., Phragmostrophia merriami, "Strophochonetes" sp., Parachonetes macrostriatus, Cyrtina sp., and Trigonirhyncia occidens. The individuals present in this collection are for the most part articulated and do not show signs of wear or breakage. Other faunal elements present are fragments of trilobites of the genus Phacops, indeterminate pelecypods and gastropods, Tentaculites sp., lamellar stromatoporoids, and trace fossils in the form of horizontal burrows as described in sample LMN-18 above. The brachiopods present in the sample are all oriented parallel to the bedding planes with Atrypa nevadana always lying on the pedicle valve and Chonetes occurring in irregularly spaced clusters.

The environment of deposition for this interval was in quiet water as evident from the very fine-grained nature of the sediment and the abundance of clay, in short, a very low energy environment. The lithology at this level probably represents the beginning of a deepening trend. The fauna has elements of the G-A-S Community and 43 feet higher in the section, at 414 feet, the Atrypa nevadana Community is succeeded by the typical G-A-S Community with Schizophoria, Brachyspirifer, and Carinagypa loweryi in a similarly very fine-grained lithology. The G-A-S Community persists until a level 457 feet up in the Bartine is reached. Above that point is a 34 foot covered interval which ends at an outcrop of the Coils Creek Member. The contact between the Bartine and the Coils Creek is covered and cannot be observed, but there is no reason to believe that the G-A-S Community is succeeded by another faunal assemblage between 457 feet and the top of the Bartine.

Interpretation of Fauna and Lithology

The Bartine Member as exposed at Lone Mountain evinces a recognizable cycle of sediment types which the writer interprets as representing a continuous deepening trend up to the Coils Creek Member contact. This interpretation is supported by the sequence of faunas found in the Bartine at Lone Mountain. The community succession supports this interpretation. At the base of the Bartine the shallow water Atrypa sp. Community succeeds the shallower water Acrospirifer kobehana Community of the Kobeh Member. The Atrypa sp. fauna is succeeded by the Atrypa nevadana fauna with G-A-S Community elements. This transitional community is in turn succeeded by the deep water G-A-S Community. Table 2 gives the relative abundances for the brachiopod species in section LMN-1.

Cooper Peak Section

Section Description

The Cooper Peak section, designated CPN-1, is located in T23N, R50E of the Roberts Creek Mountain Quadrangle. The strata measured for the section have been thrust and overturned. Section CPN-1 begins in the middle of a saddle north of Cooper Peak at the stratigraphic contact between the Bartine Member of the McColley Canyon Formation and the Coils Creek Member. The section extends upslope bearing S18E. Due to the attitude of the beds, the rocks become older going upslope. Figure 7 shows the location of section CPN-1 on Cooper Peak.

The thickness of the Bartine Member was measured as 202 feet. The basal contact of the Bartine Member with the Kobeh Member is immediately recognizable by a color change from the light olive gray (5 Y 6/1) to medium light gray (N 6) of the Kobeh to the yellowish gray (5 Y 7/2) of the Bartine. The highest Kobeh Member is a very fine-grained, medium bedded fossiliferous limestone with many large horn corals. It contains a *Kobehana* Zone brachiopod fauna including *Dalejina* sp., *Anoplia* sp., *Leptocoelia* sp., *Meristella* sp. and a large

Figure 7. Cooper Peak showing location of section CPN-1.

spirifer which may questionably be regarded as Acrospirifer kobehana (Merriam). The general aspect at outcrop is of typical Kobeh lithology. The basal Bartine is a thin to medium bedded, yellowish gray (5 Y 7/2) argillaceous biopelmicrite with a Pinyonensis Zone fauna which will be discussed below. The lithology is typical Bartine.

The Kobeh-Bartine contact is abrupt and in complexly folded strata. The Bartine lithology is brecciated with secondary calcite as vein filling. The contact is judged to be a fault contact. An unknown amount of the lower Bartine at Cooper Peak has been removed by this fault.

From the basal contact to 175 feet above the contact with the Kobeh, the Bartine is of rather uniform lithologic appearance, although there are faunal variances easily recognizable at outcrop. Such lithologic changes as do occur are recognizable only in thin section and polished section. At 56 feet above the contact the Bartine is a thin to medium bedded, yellowish gray (5 Y 7/2) weathering argillaceous biopelmicrite. Sample CPN-14 is from this level. The limestone is olive gray (5 Y 4/1) on a fresh surface, composed of 66% microgranular constituents, 17% pellets, and 17% bioclasts. The micr-ogranular component is the sum of 46% micrite/microspar and 20% clay. The pellets are well-sorted and of uniform coarse silt size. They have indistinct margins and appear to be fecal pellets. The bioclasts are uniformly oriented with long axes parallel to the bedding. Disarticulated brachiopod valves are oriented convex up. Variously broken pieces of brachiopods, trilobites, ostracods, bryozoans, gastropods, and assorted echinoderm fragments comprise the bioclasts.

The fauna of CPN-14 consists of very poorly preserved examples of Dalejina sp., Nucleospira sp., Atrypa nevadana, and Eurekaspirifer pinyonensis. The tabulate coral Favosites sp. is also present. The collection is poorly preserved, but is unique enough to establish its identity as part of the shallow extremity of the Atrypa nevadana Community. This conclusion is based on the size of the specimens of E. pinyonensis and the appearance of Dalejina, Atrypa, and Eureka-spirifer in the same collection.

The environment of deposition of Sample CPN-14 is believed to be one of quiet water with periodic episodes of sedimentation brought about by shifting of local patterns of deposition. The limestone is composed of microgranular carbonate and has a high clay content. The bioclasts are angular and oriented in a stable position. There is no evident current winnowing. Between the base of the section and 124 feet on CPN-1 are alternating zones of bioclastic debris and zones with fossils in life position similar to the lithology between 101 and 120 feet on MCN-1.

At 124 feet above the base of the section the Bartine is a thin to medium bedded, light olive gray (5 Y 6/1) weathering argillaceous biomicrite. On a fresh surface the rock is medium dark gray (N 4) and is composed of 87% micrite and clay, 12% bioclasts, and 1% fine to medium quartz sand. The bioclasts include brachiopods, crinoid columnals, bryozoans, ostracods, and tentaculites. As a whole the bioclasts are angular fragments, poorly sorted and oriented parallel to bedding. The disarticulated brachiopod shells are oriented convex up.

The fauna, represented in sample CPN-13, includes Trigonirhynchia occidens, "Strophochonetes" sp., and Megastrophia sp. as abundant species. Common species include Spinulicosta? sp., Ambocoelia sp., and Brachyspirifer pinyonoides. The collection is unique in that it is the only sample collected by the writer which contains an inferred life assemblage of T. occidens. Trigonirhynchia occidens is a widely occurring species, although usually in very low abundance and often disarticulated. In sample CPN-13 this brachiopod makes up 38% of the brachiopod fauna and is made up of articulated individuals with a full range of sizes in a normal frequency distribution. There is no immediately recognizable environmental factor to explain this assemblage. Other faunal constituents include amphiporid bryozoans, ramose bryozoans, trilobite fragments, and many large tabulate coral colonies in growth position.

The environment of deposition at this level in the section was that of quiet water in which a microgranular carbonate with a high clay content was deposited. There is no evidence of winnowing which indicates that such currents as were present were not of sufficient velocity or turbulence to initiate movement in the bottom mud (Inman, 1949). Currents laden with clay and carbonate mud periodically overwhelmed the benthos, as indicated by the unfossiliferous micrite layers interbedded with fossiliferous bioclastic layers. These currents must have been very gentle in nature, however, as the delicate bryozoans enclosed in the sediment deposited are unbroken although current-oriented.

The benthic fauna at any one time in this interval would have been visible as large, closely spaced tabulate coral colonies in between which the bottom would be thickly settled with bryozoans either attached directly to the bottom or to whatever hard surfaces offered themselves as substrates on which to attach (Shrock and Twenhofel, 1953). Clustered here and there, lying either directly on the bottom or attached to hard substrates were colonies of Megastrophia or "Strophochonetes." Trigonirhynchia occidens also occurred as scattered clusters, probably attached by the pedicle to old shells or other hard surfaces such as the tabulate colonies.

At 138 feet the lithology is a thin to medium bedded, grayish orange (10 YR 7/4) weathering, fossiliferous argillaceous micrite with interbeds 1 inch thick of graded pelletal biomicrite. On a fresh surface the limestone is medium gray (N 5). The argillaceous micrite is 97% micrite and clay with a high clay content and 3% bioclasts. Horizontal burrow structures are present in the micrite. The bioclasts are finely comminuted and are composed mostly of tests and fragmented tests of ostracods and a few miscellaneous spines.

The pelletal biomicrite may be observed in thin section overlying one bed of bioclastic micrite with a slight scour contact and grading upward into the next bed of argillaceous biomicrite (Figure 8). It is composed of 60% micrite/microspar and clay, 29% bioclasts, 9% pellets and 2% very fine quartz sand. The fine fraction of the pelletal biomicrite contains less clay and organic matter than does the finer grained sediment with which it was in contact. The bioclasts include fragments of brachiopods, calcareous algae and tabulate corals, and many whole brachiopod valves, ostracods, and small gastropods. Coarse silt to fine sand-sized pellets compose the pelletal component of the rock. These are clastic pellets, some of which were deposited as an aggregate and are bordering on intraclasts in size.

The bioclasts in the pelletal biomicrite interbeds exhibit normal grading from medium to very fine grained. The pellets grade from fine sand to coarse silt and are less numerous in the upper one-third of the interbed. The contact with the overlying bioclastic micrite is transitional, indicating deposition by waning currents from farther up the slope. Within the graded beds are horizontal burrows.

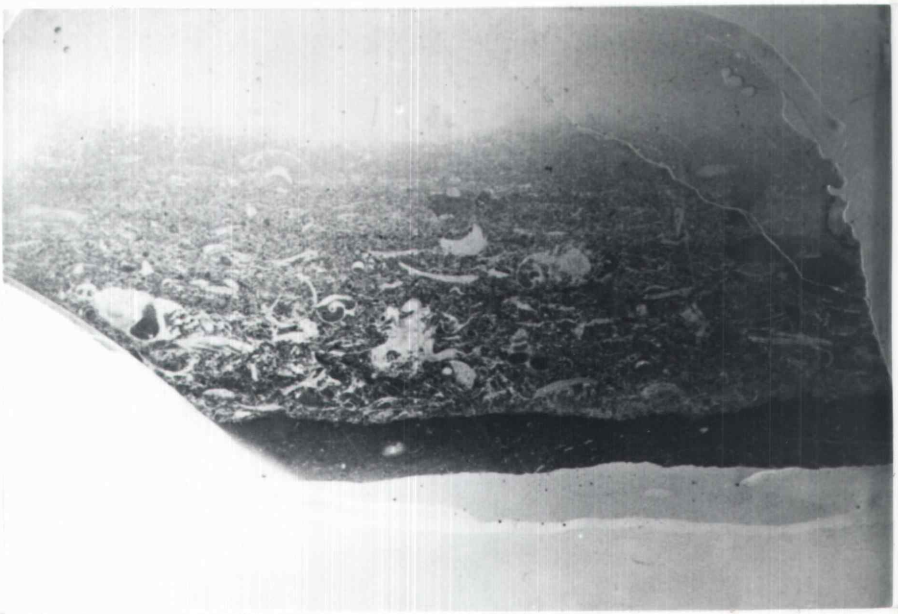

Figure 8. Photomicrograph showing graded bedding in sample CPN-13a.

The fauna at this level, represented by sample CPN-13a, is characterized by abundant Cymostrophia sp., Phragmostrophia merriami, Spinulicosta? sp., and Atrypa nevadana. Rare species are Trigonirhynchia sp. and Leptocoelia sp. Other faunal elements are as described above in the discussion of the bioclastic constituents.

The presence of the genus Cymostrophia makes the collection unusual. In the Devonian System of Nevada, Cymostrophia is only known from the northern Roberts Mountains. Johnson (1970) has reported Cymostrophia from a float collection at Willow Creek. To the writer's knowledge sample CPN-13a is the only collection from Nevada in which Cymostrophia is reported from a measured section. The mode of occurrence of the genus in the Bartine Member is also noteworthy. The only other collections of Cymostrophia from North America come from well-washed, reef-associated limestones in Canada. Cymostrophia occurs in a similar mode in the Koneprusy limestones of Czechoslovakia (Havlicek, 1967). These modes of occurrence contrast with the occurrence of Cymostrophia in the fine-grained muddy limestones of the Bartine.

Transport of the Cymostrophia shells from an environment such as they occur in Canada and Czechoslovakia into the environment in which they are found at Cooper Peak is ruled out for several reasons. Fundamental to this opinion is the fact that well-washed reef-associated limestones of Bartine age are unknown in Nevada. The condition of the shells argues against transport as they are articulated and the ornamentation is well-preserved with no signs of abrasion. The shells are also much larger than the next coarsest bioclasts present in the graded pelletal limestones and there is no indication of currents capable of transporting the massive Cymostrophia shells.

The occurrence of the Cymostrophia assemblage and the Trigonirhynchia assemblage discussed above must be regarded as environmentally significant in the light of their singular appearance at Cooper Peak among the many faunal horizons sampled by the writer. Their limited occurrence in one section, however, does not allow their position in the vertical or horizontal faunal distribution within the Pinyonensis Zone to be understood. Therefore, no rigorous community definition will be applied to these assemblages at this time.

The environment of deposition represented by sample CPN-13a is envisioned as a quiet water environment below wave base with interludes of turbid currents which deposited the graded pelletal biomicrite. The word turbid is used advisedly and the writer has no intention of conjuring turbidity currents of the eugeosynclinal scale in the mind of the reader. There is no evidence to suggest that slopes of sufficient gradient to set such movements of sediment in motion ever existed on the Bartine shelf. The sediment laden currents were of sufficient turbulence and velocity to carry pellets and small, thin-shelled bioclasts but not large, heavy brachiopod shells such as those of Cymostrophia or Atrypa nevadana. The writer believes that the graded beds represent the waning of density currents flowing downslope from the shallower reaches of the shelf and depositing their sediment load in deeper water. The fine-grained nature of the limestone coupled with the restriction of bioclasts and pellets to the graded beds suggests that the beds from which sample CPN-13a was taken were deposited in deeper water than any of the sediment of Bartine time at McColley Canyon.

At 152 feet above the Kobeh-Bartine contact the beds show an obvious two-phased depositional character. The lithology is thin-bedded, grayish orange (10 YR 7/4) weathering, argillaceous biomicrite with pods and lensoidal interbeds of bioclastic pelsparite as represented in sample CPN-12. The beds are an overall dark gray (N 3) on a fresh surface. The argillaceous biomicrite is 75% micrite/microspar and clay and 25% bioclasts. The bioclasts consist of unsorted brachiopod shells oriented convex up with layers and pods of finer bioclasts distributed vertically and laterally between the larger brachiopod shells. The bioclastic pelsparite is confined to these pods and interbeds. It is often found as small bodies beneath the disarticulated brachiopod valves as though currents had been transporting both the fine bioclasts and pellets and the larger brachiopod valves. When the brachiopod valves settled out and came to rest they trapped small amounts of fine bioclasts and pellets underneath them after which carbonate mud was deposited over the lot. Figure 9 is a photograph of a thin section which illustrates this relationship.

Compositionally the bioclastic pelsparite represents a well-winnowed sediment consisting of 66% pellets, 26% bioclasts, and 8% micrite/microspar. The pellets are in the very fine sand-size range and are supported by sparry calcite. The bioclasts are pieces of brachiopods, ostracods, and gastropods. Many of the bioclasts are slab-like fragments averaging 0.7 mm in length.

The fauna from CPN-12 is representative of the Atrypa nevadana Community with G-A-S Community elements. Abundant species are Schizophoria nevadaensis Merriam and Brachyspirifer pinyonoides Johnson. Rare species are Phragmostrophia merriami, Trigonirhynchia sp., Atrypa nevadana, and Hysterolites sp. All the brachiopods are disarticulated and have been transported, although not heavily abraded. Other faunal elements are indeterminate pelecypods, gastropods, trilobite fragments, and fenestrinellid bryozoans. The bryozoans, gastropods, and trilobite fragments have also been transported.

The environment of deposition of these beds is believed to be similar to that of the just previously described sample, CPN-13a. The lensoidal, fan-shaped bodies of bioclastic pelsparite are believed to represent deposition by tidal or density currents flowing along the bottom in scoured channels. At the distal end of the channel the sediment-laden currents would begin to fan out and deposit their load

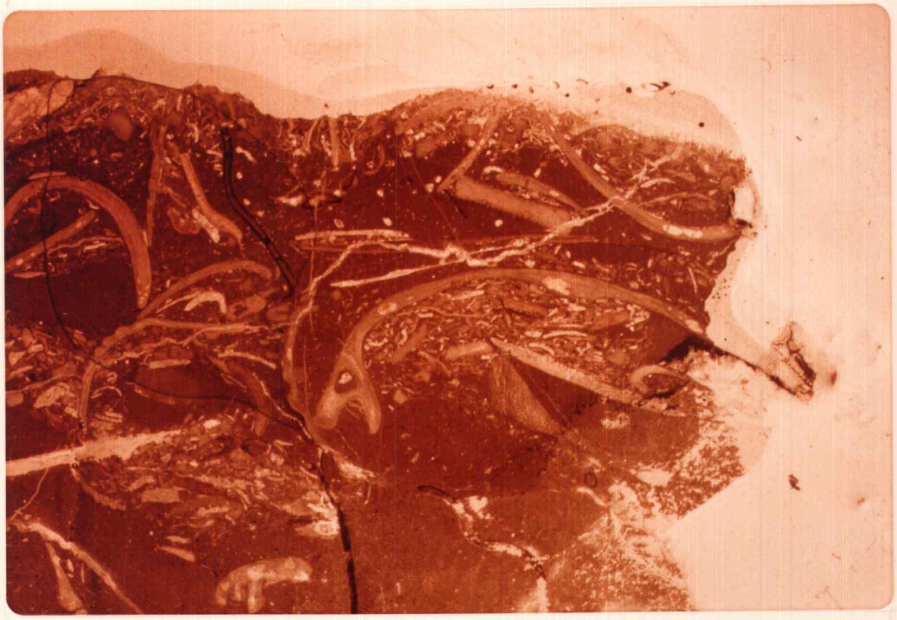

Figure 9. Photomicrograph of lithology at CPN-12. Note concentration of fine bioclasts and lack of micrite under large shell in center.

as their speed was reduced. The lensoidal bodies at CPN-12 represent the initial fanning out of the currents and the deposition of the coarser bioclasts being carried. As the currents continued to spread out over the bottom and as their velocity and competence steadily diminished they deposited a continuously finer sediment, culminating in the graded beds such as present in sample CPN-13a.

The conditions just described for sample CPN-12 persist until the beds 175 feet above the base of the Bartine. At this point quartz sand makes its first significant appearance, becoming proportionally more important toward the top of the section. The lithology is a medium bedded, medium light gray (N 6) weathering, fossiliferous quartzose biomicrite. Sample CPN-11c is taken ftom this lithology. The sample lithology is medium dark gray (N 4) on a fresh surface and is composed of 62% micrite/microspar and clay, 28% very fine to medium quartz sand, and 10% bioclasts. The quartz sand is poorly sorted, subangular to subrounded, and is matrix supported by micrite. The quartz is concentrated in interbeds which are in scour contact with the bioclastic micrite layers. The sandy layers become thicker and more quartzose toward the top of the Bartine, becoming 3 to 4 inches thick interbedded with bioclastic micrite beds which contain little or no sand. The bioclasts, where present, are finely comminuted, most of them being on the order of 0. 4 mm across. They are most numerous in the nonquartzose layers.

The fauna is essentially the same as that from CPN-12 with the exception that the bryozoans do not appear. The orientation of the shells is much like that in CPN-12, except that the fossils are not as numerous. There are some horizontal burrows present in the micrite layers. The fauna is still typical of that of the Atrypa nevadana Community with G-A-S elements.

On the surface, the abundance of quartz grains indicates an environmental shift to an environment of increasing energy in comparison with those previously described in this section. The sandy interbeds do not display cross-beds or foresets and are crudely stratified. However, the rocks are still predominantly microgranular so that quiet water conditions must have prevailed much of the time. Further, the fauna present indicates that relatively deep water conditions still existed.

The source of the quartz grains is also problematic. The most obvious place to look is eastward, toward the ancient continent. However, there is no evidence of sand in any quantity in the shallow water sediments of the Bartine at McColley Canyon. The first sand occurs 255 feet above the Bartine-Union Mountain contact in sedimentary rocks which must be regarded as much younger than those at the top of the Bartine at Cooper Peak. The writer cannot envision transportation of medium sand-sized clastics across an environment where carbonate muds are being deposited and into deeper water without some deposition of clastic material in the intervening shallow water. The question of the source of the sand must remain unanswered until more information is available about the paleogeography of Bartine time.

At 202 feet above the base of the Bartine is the contact between the Bartine Member and the Coils Creek Member of the McColley Canyon Formation. The contact is sharp but there is no evidence of faulting or erosion. The sandy limestone of the Bartine Member is succeeded by a medium dark gray (N 4) very fine-grained limestone with a Pentamerella brachiopod fauna. The basal Coils Creek at Cooper Peak matches very closely Murphy's description of the basal Coils Creek at Willow Creek (Murphy and Gronberg, 1970).

Interpretation of Fauna and Lithology

A recapitulation of the section at Cooper Peak shows evidence for initial deepening followed by shallowing toward the top of the section. The sedimentary rocks representative of shallowest water are those from sample CPN-14. This sample is very similar faunally to sample MCN-14 and lithologically to sample SSN-871 at 50 feet and 137 feet respectively on section MCN-1. Thus the basal Bartine at Cooper Peak is compared to the shallow water environments of the lower parts of section MCN-1. Sample CPN-12 at approximately 152 feet is representative of the sediments of the greatest water depth in the section, containing as it does the graded beds deposited in the waning stages of downslope density currents. The presence of a fauna with G-A-S Community elements testifies to the depth of the water in which the sediment was deposited, that is, deeper water than at any level of section MCN-1.

The only definitely recognizable community in section CPN-1 is the Atrypa nevadana Community with G-A-S elements which is present from 154 feet up to the Bartine-Coils Creek contact. This community inhabited a deep water environment where very fine-grained carbonate mud was being deposited on a bottom level except for the numerous narrow, shallow channels scoured by the density or tidal currents returning along the bottom from the shallower parts of the shelf. Between the channels were colonies of Schizophoria and Brachyspirifer and clumps of bryozoans standing up on the bottom. In the scoured channels were assorted fragments of the local benthos and many whole brachiopod valves. The Schizophoria-Brachyspirifer assemblage of the G-A-S community must have extended some distance upslope for its members are found in sample CPN-12 both in life position and as disarticulated valves in the bioclastic debris of the sediments deposited by the density currents.

Table 3 gives the relative abundances for brachiopod species from samples taken along section CPN-1.

Coal Canyon Section N-1

Section Description

Three sections were measured in the Bartine Member east of Coal Canyon in the Simpson Park Range. The second of these sections was discarded as of no value, and the first and third sections incorporated into the field data. Section CCN-1 is located in Sec. 16, T25N, R49E of the Horse Creek Valley Quadrangle. The section is in the second canyon east of Coal Canyon within which are four fault-bounded ridges of exposed Bartine lithology (Figure 10). The tops of the ridges become stratigraphically lower as one proceeds into the canyon to the southwest. The Coal Canyon area is structurally complex and dependable top or bottom contacts could not be established on any sections in the area.

Section CCN-1 runs up the third ridge of exposed Bartine Member which crops out prominently on the eastern side of the canyon. The top of the section bears N85E from Hill 6909, S45E from Bauman Well and S10W from the intersection at BM 5701. Three hundred feet of Bartine lithology was measured on this section. The section starts at the lowest exposed bed of limestone below which is a scree-covered slope running down into the bottom of the canyon.

The basal 72 feet of the section is in a pale yellowish brown (10 YR 6/2) to grayish orange (10 YR 7/4), platy weathering, medium

Figure 10. Looking into canyon east of Coal Canyon at sections CCN-1 and CCN-3.

bedded, burrowed argillaceous biomicrite. On a fresh surface the rock is medium dark gray (N 4) to light olive gray (5 Y 6/1). The limestone is very fine-grained and highly argillaceous. The fine-grained fraction makes up 88% of the rock and is evenly divided between clay and micrite/microspar. Bioclasts in the form of tentaculites, brachiopod fragments, pelecypod and ostracod shells, conodonts and tetraxon spicules account for 11% of the rock. The generally sparsely scattered bioclasts are oriented parallel to the bedding planes. The remaining 1% of the sample is composed of quartz silt.

The fauna from this interval of section CCN-1 is dominated by brachiopods as indicated in samples CCN-11, -12, -13, and -15. Abundant species are Levenea fagerholmi Johnson, Dalejina sp., and Leptocoelia infrequens. Rare species within this interval are Leptaena sp., Leptostrophia sp., Mclearnites sp., "Strophochonetes" filistriata, Chonetes sp., Megastrophia sp., and an indeterminate stropheodontid. This assemblage of brachiopods belongs to what the writer has defined as the Restricted Leptocoelia infrequens Community. This community is characterized by Leptocoelia infrequens and Dalejina sp. as the most abundant species. Ancillary species are Levenea sp., Leptaena sp., Strophonella cf. punctulifera, Megastrophia sp., Leptostrophia sp. and "Strophochonetes" sp. There is a noticeable lack of spiriferids in samples taken from rocks containing this fauna with the exception of the reticularid Elythyna sp. A.

Elythyna sp. A appears sporadically in the Restricted Leptocoelia infrequens Community and seems to indicate a special set of ecological circumstances which is not yet understood.

The fauna in this interval is restricted in aspects other than the brachiopod assemblage. The only other fossils which occur are a few scraps of trilobites, a small indeterminate solitary tetracoral species and infrequently occurring favositid colonies. The strata are replete with horizontal burrows, however, indicating the former presence of an active deposit feeding community. Ostracods are also abundant at some horizons and may have been responsible for some of the burrows.

The Restricted Leptocoelia infrequens Community occurs throughout the lower 72 feet of section CCN-1 and throughout section CCN-3. Elythyna occurs only in section CCN-3. This is a low diversity fauna, usually only three or four species are present in any one collection from these beds, some collections containing Dalejina sp. or Leptocoelia infrequens as the only faunal constituent. The rock in which this community is found is characterized by a high clay and organic content, and is invariably heavily burrowed. The shells found here are rarely disarticulated or showing signs of transport. All indications are that these rocks and fossils represent a very quiet water, low energy environment where sedimentation was continually taking place. Sparse isolated brachiopod colonies appeared here and there where a spatfall managed to gain a foothold.

Samples were taken at intervals from each section and analyzed for organic content. The analyses showed that the strata bearing the Restricted Leptocoelia infrequens Community fauna had the highest organic content. These rocks were the only samples tested which had an organic content higher than 2%. These organic rich rocks are marked by a dark brown color on a fresh, polished surface.

Bader (1954), in his research on the relationship between organic content in sediments and pelecypod population density, found a direct relationship between pelecypod density and organic content until a level of 2% organic content was reached, at which point the relationship became inverse. Bader attributed this reversal of trend to the environmentally toxifying action of bacteria which increases with organic content. Sanders (1958), in studies made of the invertebrate benthic assemblage at Buzzards Bay, Massachusetts, found that there was a correlation between sediment size and whether filter feeders or deposit feeders predominated in the benthic communities. Sanders found that filter feeders predominated on sand sized substrates over which the organic matter was kept in suspension and that deposit feeders were predominant on substrates of clay where weak currents allowed more, or most, of the organic matter to settle out. It would seem that this relationship could be independent of depth. Instead, it would be an example of benthic community structure being controlled by the type of sedimentation taking place.

The lithology between the base of the section and 72 feet is representative of a very fine-grained sediment with higher clay and organic content than any other interval of any other section with the exception of section CCN-3 which has a similar, where not identical, lithology.

The only evidence of current action is the distribution of the finest bioclastic fragments which have evidently been washed in among some of the whole brachiopod shells. The lack of any current-associated primary structures and the overall very fine-grained nature of the sediment argue for very weak and gentle currents. Considering the uniformity of the grain size of the argillaceous limestone and the bedding the writer envisions an environment where sedimentation was taking place at a constant, but gradual, rate. The water would have been constantly turbid, which may be a partial explanation for the generally low diversity of the fauna, as the constant sedimentation would discourage the settling, or at least the survival, of brachiopod spat (Rudwick, 1962a).

The lithology gives surficially conflicting evidence with regard to the original water depth in which the sediments were deposited. The presence of preserved sediments which are characterized by a high clay content, and high organic content, evidence for the one-time presence of prolific burrowing deposit feeders and other quiet water aspects, seems a priori as indicative of deep water. These conditions, however, are succeeded by a sequence of strata and faunas which are indicative of continually deepening water, but which do not exceed the depth range of the G-A-S Community, and which at the same time are cleaner, with less clay. The G-A-S Community as found in the Bartine is believed to lie in the intermediate part of Benthic Assemblage 3 as defined by Boucot (1974), i. e., about 100 feet. The faunal and sedimentological succession, which will be discussed in continuing detail below, suggest to the writer that the basal Bartine at CCN-1 was deposited in water no deeper than the depth zone in which the Atrypa nevadana Community is found. The occurrence of the Restricted Leptocoelia infrequens Community and the Leptocoelia infrequens Community which succeeds it in the Bartine seems indicative of special environmental circumstances, as the only place where these communities are found, in fact the only place where Leptocoelia infrequens is found in any quantity, is in the Coal Canyon sections. The Cortez Mountains to the northwest are an exception.

The occurrence of the brachiopod colonies in the interval concerned is believed to have been random and short-lived. The fossils occur in the rocks along single bedding planes and are of limited extent along any one plane. The individual colonies are believed to have been limited both in time and in space. The environment was apparently so hostile to brachiopods and most other sessile invertebrates that their occurrence was fortuitous at best and long term colonization could not take place. The occurrence of the Restricted Leptocoelia infrequens Community may be recognized in the light of the foregoing facts as the result of an environment generally unsuitable to diverse brachiopod colonization.

At 72 feet above the base of section CCN-1 the lithology suddenly changes to that of a thin bedded, light olive gray (5 Y 6/1), crinoidal micritic biosparrudite. This lithology persists until 82 feet in the section as 4 inch beds of crinoidal limestone alternating with beds of sparsely fossiliferous limestone of the type found in the basal 72 feet of the section. On a fresh surface the crinoidal limestone is olive gray (5 Y 4/1) to medium light gray (N 6) and when examined in thin section proves to be composed of 60% bioclasts, 20% micrite matrix, and 20% sparry calcite matrix. The bioclasts are the size of very coarse sand and are composed of crinoid fragments as plates, columnals, and spines. Ostracods and brachiopod fragments are also present as bioclasts.

The fauna present in the crinoidal beds includes specimens of Leptaena sp., the coarsely costate Atrypa sp., Howellella sp., and an indeterminate stropheodontid. Other faunal elements present are certain indeterminate bryozoans and fragments of what appear to be large loxonemid gastropods. All the brachiopods present in the crinoid beds show the effects of transport, being disarticulated, and considerably abraded. The condition and size of the collection is such that no satisfactory community assignment may be made.

The crinoidal beds represent a poorly sorted sediment or partially winnowed sediment as a mixture of a very fine-grained matrix (micrite) and a coarse bioclastic fraction with sparry calcite replacing micrite in some of the interstices between bioclasts. Evidence of current action is readily apparent. The crinoidal beds are in disconformable contact with the micritic interbeds. The condition and sorting of the crinoid columnals and the fact that the crinoidal beds are crudely graded is evidence that these bioclasts were deposited by a transportive agent and were removed from the site of the living animals.

The crinoid beds are believed to have been deposited in water near wave base, and represent a slight deepening over previous conditions. They appear to represent initially a medium energy environment, slackening toward the top of each crinoidal bed, until quiet water, low energy conditions again pertain above the highest crinoid bed at 82 feet. This crinoidal interval is regarded by the writer as an event, or series of events, of some importance in the depositional history of the Bartine environment(s) at Coal Canyon. The crinoidal interval is succeeded by a series of beds bearing an increasingly diverse fauna, culminating in the deepest water fauna of the faunas present in the Bartine, the Carinagypa, Schizophoria, Brachyspirifer fauna of the G-A-S Community.

Between 82 and 157 feet the lithology returns to that representative of very fine-grained sedimentation in quiet water as represented in samples CCN-18, -19, -110, and -111. The rocks are thin to thick bedded, light olive gray (5 Y 6/1) to medium dark gray (N 4), platy weathering, fossiliferous, burrowed argillaceous biomicrite. The rock is medium dark gray (N 4) on a fresh surface and is composed of 85% very fine-grained material as micrite/microspar and clay. The fine fraction is highly argillaceous. Bioclasts as scattered crinoid ossicles and columnals, ostracods, brachiopod fragments, gastropods, and trilobites, make up the remaining 15% of the rock. Where the bioclasts are brachiopod shells or valves they are oriented parallel to the bedding, convex up. Where bioclasts are finely comminuted they are scattered throughout the rock as though they settled with the mud and clay.

The brachiopod fauna in this interval features Leptocoelia infrequens and Leptostrophia sp. as abundant species, Strophonella cf. punctulifera and Atrypa sp. as common species and Dalejina sp., Levenea sp., Leptaena sp., "Strophochonetes" filistriata, Nucleospira sp., Ambocoelia sp., Schuchertella sp., Parachonetes macrostriatus, Howellella cf. textilis Talent, Megastrophia sp., and Coelospira? sp. Other faunal elements include Conularia sp., bryozoans, pelecypods, and gastropods. This fauna is representative of what the author defines as the Leptocoelia infrequens Community.

This community occurs through the middle 176 feet of CCN-1. The Leptocoelia infrequens Community, like the Restricted Leptocoelia infrequens Community, is characterized by abundant or common Leptocoelia infrequens. There are several differences between the two assemblages as they are described in this paper. The writer believes these differences are important enough to warrant the definition of two distinct communities. The Leptocoelia infrequens Community is much more diverse, having from 6 to 11 genera per collection compared to 1 to 3 genera in most collections in the Restricted community. Of these new genera, the most common are a variety of strophomenids, mostly from the superfamily Stropheodontacea (Johnson, 1970); plus the coarsely costate variety of Atrypa. Some of the strophomenids are known from the Restricted community, however, the appearance of Atrypa sp. in the Restricted community is limited to two specimens. Spiriferids, which are noticeable by their absence in the Restricted community, are present with some degree of regularity in the Leptocoelia infrequens Community. They are still a minor faunal element, however, and the one spiriferid which was found in the Restricted community, Elythyna sp. A, is not found in the Leptocoelia infrequens Community.

The Leptocoelia infrequens Community is interpreted as characteristic of a quiet water environment which was at least semi-restricted. This interpretation is supported by the lithology and the fauna. The Bartine lithology in which the Leptocoelia infrequens Community is found is much more argillaceous than any other rocks which may be considered as possibly of the same age, implying very quiet water conditions. The community succession in these beds implies that it was a very quiet water environment no deeper than the depth zone occupied by the Atrypa nevadana Community, as the Bartine is considered to be a transgressive unit.

The fossils within this interval are excellently preserved. The brachiopods are almost always articulated, Leptocoelia and the strophomenids are lying parallel to the bedding. Atrypa is also oriented parallel to the bedding with the pedicle valve down and with the frills intact. The specimens of Conularia show two "colonies" apparently attached to a common base, flattened by the sedimentary overburden, but otherwise very well-preserved. Horizontal burrows are prolific at this level as they are at the lower levels in section CCN-1.

As stated above, the lithology of this interval is representative of a very fine-grained sediment with a high argillaceous content. There is no evidence of current action within these strata, however a considerable thickness of muddy sediment was nevertheless deposited. Such a situation argues for very slow, but steady, sedimentation in turbid water conditions. The writer envisions a physical setting of cloudy water in which clay and carbonate mud were slowly being deposited over a bottom rich in organic matter. On this bottom Leptocoelia infrequens lived with its beak attached to the substrate and its commissure up off the bottom. The geniculate strophomenids may have lived semi-infaunally just below the surface of the substrate as suggested by Rudwick (1970). Many deposit feeding organisms were probably present burrowing and plowing through the organic rich bottom sediments.

Between 158 feet and 193 feet the lithology is that of a thick bedded, light gray (N 7) weathering, highly fossiliferous argillaceous biomicrite. The lithology is typically medium gray (N 5) on a fresh surface. A sample shows that the make up of the rock is 81% micrite/microspar and clay. The clay fraction is reduced compared to the lower intervals in the section. Bioclasts as tetraxons and fragments of tabulate coral and stromatoporoid colonies, trilobites, and brachiopods make up the remaining 19% of a typical sample. The bioclasts are distinctly distributed according to size. The coarse bioclasts are scattered evenly through the rock, while the very finely comminuted bioclasts are concentrated in lensoidal zones indicating the work of weak ephemeral bottom currents. Those brachiopod valves which are disarticulated are strewn evenly over the bedding planes, convex up. The lithology and fauna represented in this interval is found in samples CCN-114, -115, and -116.

The fauna within this interval is typical of the Leptocoelia infrequens Community, in fact at 193 feet is the youngest and last Leptocoelia infrequens Community collection to be found at Coal Canyon. Abundant species within this interval are "Strophochonetes" sp., Leptocoelia infrequens, and Phragmostrophia merriami. Common species are Atrypa sp., Parachonetes macrostriatus, and Mclearnites sp. Rare species are Dalejina sp., Levenea sp., Leptaena sp., Ambocoelia sp., Megastrophia iddingsi, Coelospira? sp., Chonetes sp., Meristina sp., Brachyspirifer pinyonoides, Cyrtina sp., Spinulicosta? sp., and an indeterminate stropheodontid. Other faunal constituents include trilobite fragments, loxonemid gastropods and some indeterminate pelecypods with an infaunal morphology. A faunal element of great significance is the large massive tabulate coral colonies which make their appearance at 193 feet. Sample CCN-116 comes from this level. The fossils in sample CCN-114 at 158 feet show no signs of transport, however, many of the shells from sample CCN-116 at 193 feet are disarticulated and appear to have been subjected to short-term transport. Horizontal burrows are abundant at all levels.

The interval between 158 feet and 193 feet is one of increasing current action as evidenced by the condition of the shells in CCN-114 compared to those of CCN-115 and -116. The large tabulate coral colonies which appear at 116 are further evidence of continuing improvement of circulation. Further, the contact between the bed at 193 feet and that which it overlies is a scour contact indicative of currents capable of initiating movement in , and transportation of, very fine carbonate mud. These currents were therefore probably responsible for keeping the bottom well stirred up and the water therefore turbid. The environment could be summarized as one of low to medium energy, in shallow, somewhat turbid water with good circulation. The bottom was inhabited by massive tabulate corals and a variety of brachiopods and deposit feeders. A large infaunal population is indicated by the prolificity of horizontal burrows.

The trend toward deepening and improved circulation continues through the interval 194 feet to 230 feet as represented in samples CCN-118 and -119. The lithology in this interval is an obscurely bedded, yellowish gray (5 Y 7/2), weathering, highly fossiliferous burrowed argillaceous biomicrite. A typical sample is light olive gray (5 Y 6/1) on a fresh surface and is 99% micrite/microspar and clay and 1% bioclasts. The fine fraction is increasingly free of clay compared to previous samples from CCN-1, it is almost completely carbonate mud. The bioclasts are composed of ostracods, brachiopod fragments, crinoid columnals, bryozoan fragments, and indeterminate finely comminuted slivers. Many of the finely comminuted slivers are accumulated in a radially arranged fashion in the burrows while others are concentrated in laminar washes and zones. Both modes of occurrence are indicative of the work of gentle currents.

The brachiopod fauna has "Strophochonetes" filistriata and Nucleospira subsphaerica as abundant species, "Schuchertella" sp., Megastrophia iddingsi, Atrypa sp., and Leptocoelia infrequens as common species and Phragmostrophia sp. and Parachonetes macrostriatus as rare species. Other faunal elements are fragments of Otarion and other trilobites plus cylindrical colonial and solitary tetracorals, some indeterminate infaunal pelecypods, and a single bellerophontid gastropod. The chonetids are arranged in clusters and are oriented parallel to the bedding plane in an obvious life assemblage. The Leptocoelia specimens form a transported element as disarticulated shells. Prolific horizontal burrows are present in the form of repichnia which are described by Frey (1973) as the traces left by predators, scavengers and certain deposit feeders. Figure 11 shows a polished section from sample CCN-119 with nicely preserved trace fossils. The community affinities of this assemblage are like those of the Atrypa nevadana Community with the exception that the Atrypa present is the earlier coarsely costate species rather than A. nevadana. The assemblage cannot properly be assigned to the Leptocoelia infrequens Community as Leptocoelia infrequens is no longer abundant. From 193 feet upward, Leptocoelia infrequens becomes increasingly less common, disappearing after 256 feet. The assemblage is considered to be a community homolog of the Atrypa nevadana Community, as that community was defined at McColley

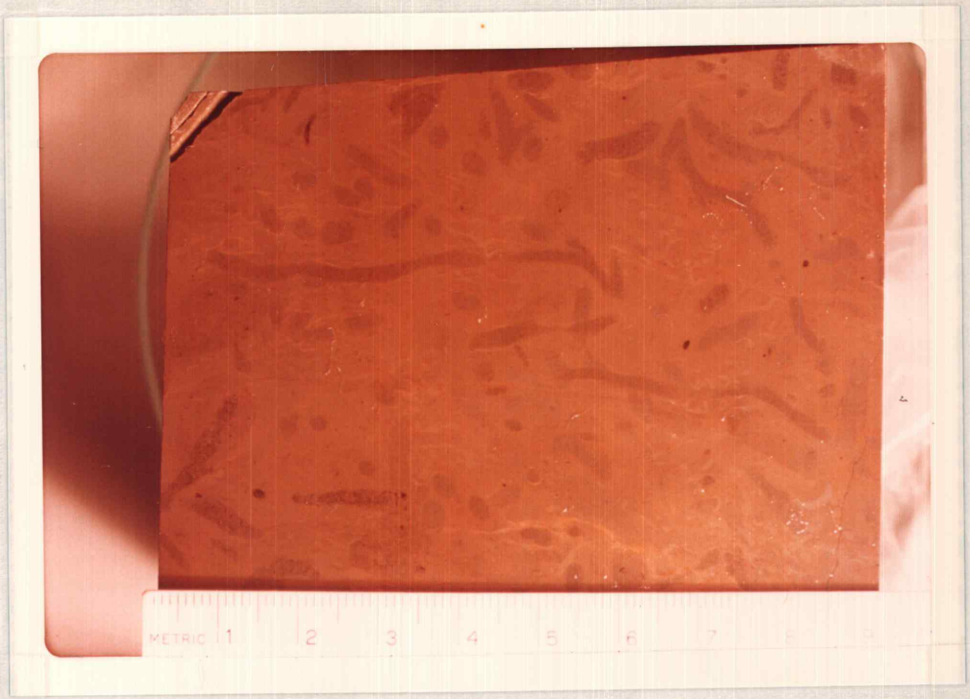

Figure 11. Illustration of burrows on polished section in sample CCN-119. Approximately life size.

Canyon. The term "homologous community" is meant here as in the sense as defined by Boucot (1974).

The sediment which was deposited in this area during the interval under discussion was even cleaner of argillaceous material than those sediments which preceded it. The region of the shelf preserved in section CCN-1 was now the scene of active laminar bottom currents. These currents left primary sedimentary structures such as the microlaminae 0.2 mm thick visible in polished section in sample CCN-19 in Figure 12. Further evidence of current action is the number of transported and current-oriented brachiopod valves and other bioclasts. The radially arranged bioclasts in the burrow structures are typical of bioclasts which have been current-drifted into open burrows and subsequently cleared out of the way by the burrow's rightful inhabitant (Frey, 1973) (Figure 13). The microlaminae and the fineness of the bioclasts indicates that such currents as were no doubt present were in fact very gentle. In the absence of turbulent current flow to keep mud in suspension it is presumed in this case that the water was probably free of turbidity. The bottom was evidently deeper than the optimum depth for Leptocoelia infrequens. The Leptocoelia infrequens found in this interval is mostly in the form of disarticulated shells drifted down from upslope.

In the interval between 230 feet and 257 feet the Bartine once again becomes a crinoidal limestone as a thick bedded, olive gray

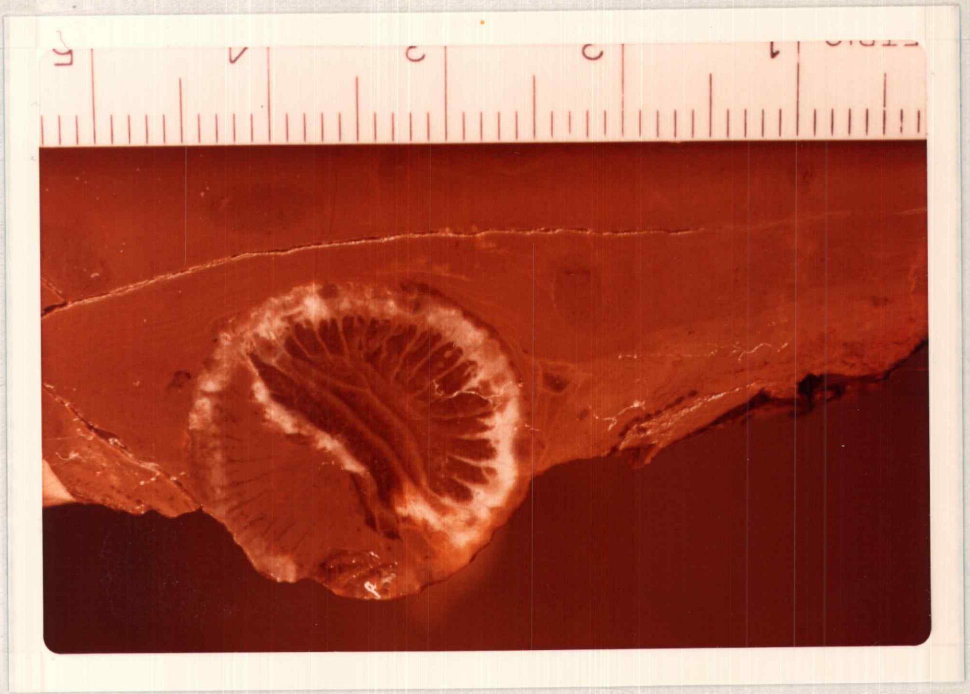

Figure 12. Illustration of microlaminae around transported horn coral on polished section of sample CCN-119.

(5 Y 4/1) weathering argillaceous crinoidal biomicrite. The rock is medium gray (N 5) to light olive gray (5 Y 6/1) on a fresh surface. A typical sample observed in thin section shows the lithology to be 69% micrite/microspar and clay, 30% bioclasts and 1% very fine quartz sand and coarse quartz silt. The bioclasts are largely composed of crinoid columnals and double-lumened crinoid ossicles, brachiopod and trilobite fragments and ostracods. The bioclasts are distributed evenly through the sediment and over the bedding planes.

The fauna collected from this interval in samples CCN-112 and CCN-125 is again representative of the Atrypa sp. homolog of the Atrypa nevadana Community. Abundant brachiopod species are Phragmostrophia merriami, Spinulicosta? sp., and Atrypa sp.; common species are "Strophochonetes" sp., Meristina sp. B, and Ambocoelia sp., while rare species are Strophonella sp., Parachonetes macrostriatus, Trigonirhynchia sp., Leptocoelia infrequens, and Nucleospira sp. Other faunal elements are trilobite fragments, colonial tetracorals, indeterminate pelecypods and bellerophontid gastropods. Most of the shells appear to have been transported. Horizontal burrows similar to those in CCN-119 are abundant. Where burrows are present the bioclasts have been removed, indicating that the burrows are the work of scavenging organisms.

The sediment preserved in this interval was a very poorly sorted mixture of coarse sand-sized bioclasts and clay-sized terrigenous and carbonate clastics. The size and distribution of the crinoid columnals and ossicles and of the bioclasts indicates suddenly waning currents of low to medium energy dumping their loads of sediment. Such a condition would result if ocean waves transited shoreward through a baffle of some nature, such as a thicket of crinoids. The transportive competency of the wave-generated currents would be drastically dampened shoreward of the baffle, resulting in the rapid deposition of a poorly sorted sediment. The effect of baffles of marine grasses in the modern Florida Bay environment and the possibilities of crinoid thickets acting as baffles have been investigated and described by Ginsberg and Lowenstam (1958). This interval is the second interval of crinoidal limestones and, like the crinoidal beds between 72 and 81 feet, the fauna changes significantly above it. Above these crinoid beds is the first appearance of Atrypa nevadana and the Atrypa nevadana Community which will be discussed in further detail below.

The lithology above the second interval of crinoidal limestone is again predominately micritic. Between 258 feet and 285 feet the lithology is a thick bedded grayish orange (10 YR 7/4) weathering, argillaceous bioclastic micrite. Samples CCN-126 and CCN-127 and -128 were collected from this interval. The rock is light olive gray (5 Y 5/2) on a fresh surface and is 75% micrite/microspar and clay, 24% bioclastic debris and 1% very fine quartz sand. The bioclasts are composed of brachiopod shell fragments, trilobite fragments, ostracods, and bryozoan fragments. The bioclasts are arranged in layers with the long axis parallel to the bedding. These layers are much more pronounced and clearly separated from the micritic interlayers in CCN-127 than in CCN-126. This contrasting texture could quite possibly be the work of burrowing organisms from the appearance of the rock. Burrowing organisms are definitely responsible for the fact that CCN-126 has a higher proportion of bioclasts than CCN-127.

There are actually two faunas to discuss as two variations on a theme in this interval. The first fauna occurs in sample CCN-126. This fauna is typical of the Atrypa nevadana Community. The second fauna occurs towards the top of the interval in samples CCN-127 and CCN-128. This fauna is like that found at the stratigraphic top of the Bartine at Cooper Peak and is representative of the Atrypa nevadana Community with G-A-S Community elements in the form of Schizophoria sp. and Brachyspirifer pinyonoides.

The brachiopod fauna from sample CCN-126 has Dalejina sp., Atrypa nevadana, and Nucleospira sp. as abundant species, Phragmostrophia merriami as a common species, and Levenea sp., Leptaena sp., Mclearnites sp., Leptostrophia sp., "Strophochonetes" sp., Parachonetes macrostriatus, Trigonirhynchia sp., Leptocoelia infrequens, Meristina sp., Hysterolites sp., and Ambocoelia sp. as rare species. This fauna is typical of the Atrypa nevadana Community as defined in the McColley Canyon discussion. Faunal elements other than brachiopods present in this sample include trilobite fragments, indeterminate colonial tetracorals, encrusting stromatoporoids, and encrusting bryozoans. This collection is made up mostly of articulated shells and may be considered a life assemblage. Horizontal burrows are numerous as in CCN-119.

The fauna contained in sample CCN-127 has Phragmostrophia merriami and Atrypa nevadana as abundant species, Dalejina sp., Schizophoria sp., Megastrophia sp., Trigonirhynchia occidens, Nucleospira sp., and Brachyspirifer pinyonoides as common species and Chonetes sp., Parachonetes macrostriatus, Meristella? sp., Howellella cf. textilis, Hysterolites sp., and Ambocoelia sp. as rare species. Other faunal elements include bryozoans, trilobite fragments, indeterminate tetracorals, lamellar stromatoporoids, Tentaculites sp., indeterminate pelecypods with infaunal morphology, bellerophontid gastropods, and large tabulate coral colonies. There are abundant horizontal burrows which obliterate the bioclasts.

The sediment represented in the lithology is typically very fine-grained, but is purer carbonate with an incremental decrease in the clay content. The coarseness of the bioclasts and their orientation indicates current action in the original environment. The size of the bioclasts is reduced in sample CCN-126, indicating decreasing current velocity commensurate with the increasing depth indicated by the fauna. The lithology and the fauna argue for quiet, clear water, in a generally low energy environment. It is noteworthy that at this point on section CCN-1 the fauna and lithology have begun to parallel those of the Lone Mountain section.

The final 14 feet of section CCN-1, 286 feet to 300 feet, are characterized by a thick bedded, light brown (5 YR 5/6), highly fossiliferous argillaceous bioclastic micrite. The limestone is a light olive gray (5 Y 6/1) on a fresh surface and in thin section is found to be composed of 99% micrite/microspar and clay and 1% bioclastic material. The proportion of clay is increased over the samples from the preceding interval. The bioclasts are widely scattered throughout the sample and are composed of bryozoans, brachiopod fragments and ostracods. The bioclasts are generally small, on the order of 1.5 to 1.0 mm. The sediment was thoroughly churned by burrowing organisms which may explain the paucity of bioclasts.

The fauna contained in this interval is typical of the G-A-S Community. Abundant species are Schizophoria nevadaensis, Megastrophia iddingsi, Parachonetes macrostriatus, and Atrypa nevadana. Common species include Carinagypa loweryi, Phragmostrophia merriami, and Nucleospira sp. Rare species present are Dalejina sp., Leptostrophia sp., Chonetes sp., Meristina? sp., Howellella, and Brachyspirifer pinyonoides. Other faunal elements include bryozoans, trilobite fragments, solitary tetracorals, lamellar stromatoporoids, indeterminate pelecypods, and platycerid gastropods. Horizontal burrows are prolific. In all aspects the fauna from this interval is considered to be a typical G-A-S Community life assemblage as that community occurs in the Bartine Member.

There is no evidence of current action within the sediments preserved in this interval, implying very quiet water. Turbidity may have been a factor as a result of the slow deposition of argillaceous material. Consideration of the fauna and lithology leads to the conclusion that these sediments were deposited in quiet, relatively deep water in Benthic Assemblage 3 (Boucot, 1974).

Just above the highest exposed Bartine at CCN-1 is a thin-bedded dark gray (N 4) weathering crinoidal micrudite (CCN-132). The rock is medium dark gray (N 4) on fresh surface and is composed of crinoid columnals and ossicles in a partially winnowed matrix of micrite and sparry calcite. There is no assignable fauna associated with this lithology. The only megafossils recovered from these beds were a single specimen of Atrypa nevadana, a few indeterminate rhynchonellids, and gastropods.

This unit was assumed to have been deposited in an environment of medium energy as evidenced by the partially winnowed matrix with the coarse sand-sized crinoid columnals. This fact is considered as evidence for shallower water than that in which the limestone at 300 feet was deposited.

The stratigraphic position of this unit is questionable. Its lithology is not that normally associated with the Bartine Member; in fact the lithology looks most like Denay Limestone. The exact nature of the contact between the youngest exposed Bartine and the crinoidal member is obscure, as the outcrops high in the section become more and more covered with scree. The crinoid unit crops out at the very brow of the ridge on which section CCN-1 is located and is the last observable outcrop. It is possible that the contact between the established Bartine and the crinoid unit is a fault contact.

Interpretation of Fauna and Lithology

A recapitulation of the faunas and lithologies at Coal Canyon shows that the two show parallel trends and ultimately become convergent with conditions at Lone Mountain. The community structure at Coal Canyon has the Restricted *Leptocoelia infrequens* Community, the *Leptocoelia infrequens* Community, the *Atrypa* sp. homolog of the *Atrypa nevadana* Community, the *Atrypa nevadana* Community, the *Atrypa nevadana* Community with G-A-S elements, and the G-A-S Community in orderly succession, punctuated by lithologic changes which indicate that the overall ecological pattern is one of improving circulation and increasing depth.

The brachiopod communities show tendencies toward ever-increasing diversity, the increased diversity being manifested in the appearance of the spiriferid genera. The community structure becomes very similar to that of Lone Mountain coincident with the appearance of A. nevadana. Table 4 gives the relative abundances of brachiopod species on section CCN-1.

The environment represented at Coal Canyon seems to signify low energy conditions in general with the exception of the crinoid beds described. The crinoidal intervals tend to punctuate marked changes in the faunal constituency. The early depositional phases at Coal Canyon in which the Restricted Leptocoelia infrequens and Leptocoelia infrequens Communities are found represent environmental conditions different from those on the other parts of the shelf which were studied. As the Bartine transgression proceeded and the water in this region continued to deepen, the cause of the apparent restriction of the Coal Canyon area was gradually negated with resultant improved circulation and the deposition of cleaner limestones which were essentially free of the large clay and organic fractions of the earlier sediments. The improved circulation enhanced the ecological potential of the local bottom habitats and encouraged the settlement of diverse benthic communities. The crinoidal unit above the G-A-S Community-bearing Bartine represents shallowing at some later date;

however, the relationship of this unit with the Bartine is uncertain. Suffice to say that the crinoidal unit is younger.

Coal Canyon Section N-3

Section Description

A third section was measured approximately one-quarter mile from the ridge on which section CCN-1 was measured. This section is located on the innermost prominent fault-rounded ridge on which the Bartine Member crops out. The top of the ridge coincides with the top of the section and bears N80W to hill 6909, N45W to Bauman Well, and N12E to the intersection at BM 5701. The section begins at the lowest Bartine outcrop and extends upslope, bearing N65E. The section totals 198 feet of Bartine lithology. Below the youngest Bartine outcrop is a covered area extending down into the floor of the canyon. Across the canyon are outcrops of what appears to be the Kobeh Member of the McColley Canyon Formation. Due to the complexity of the structure in the canyon the nature of the Kobeh-Bartine contact cannot be ascertained.

The entire 198 feet of the section is a uniform, indistinctly bedded, dark yellowish brown (10 YR 4/2) to olive gray (5 Y 4/1), sparsely fossiliferous, burrowed, argillaceous biomicrite, very reminiscent of the lithology below the first crinoid beds in section

CCN-1. On a fresh surface the rock is olive black (5 Y 2/1) to pale yellowish brown (10 YR 6/2). The lithology is representative of a very fine-grained, very argillaceous sediment, which averages 75% micrite/microspar and 25% clay. Bioclasts, where present, are generally finely comminuted, ranging from small whole bivalves 0.8 mm long to indeterminate shell fragments less than 0.1 mm long. The occurrence of the bioclasts is variable in frequency, but they are never abundant. They are mostly scattered evenly through the limestone, although they are sometimes concentrated along the bedding planes. The types of bioclasts present are tentaculites, ostracods, conodonts, brachiopods, pelecypods, bryozoans, trilobites, gastropods, sponge spicules, and echinoderm fragments.

The fauna found in this section is typical of the Restricted *Leptocoelia infrequens* Community as described above. Abundant species present in section CCN-3 are *Dalejina* sp. and *Leptocoelia infrequens*; rare species are *Levenea* sp., *Leptaena* sp., "*Schuchertella*" sp., *Strophonella* cf. *punctulifera*, "*Strophochonetes*" sp., *Atrypa* sp., and *Ambocoelia* sp. *Elythyna* sp. A is common in some beds in the lower part of the section. *Atrypa* is very rare, only two specimens being found in the entire section. Other faunal elements are small solitary tetracorals which are locally abundant, rare small favositid colonies, ostracods and trilobites. Horizontal burrows are abundant at all levels in the section and are in part the result of the activities of small bivalved animals, perhaps infaunal ostracods, which are abundant at some intervals. Figure 13 shows a photo of a thin section which shows one of these animals in the act, surrounded by argillaceous limestone, with a trail of disturbed sediment behind.

The relative abundance of brachiopod species in section CCN-3 is given in Table 5.

Interpretation of Fauna and Lithology

The sediment represented by the lithology in this section was high in clay and organic content. There is no evidence of current action. The environment of deposition is interpreted as identical to that of the basal 72 feet of section CCN-1, that is, quiet, possibly turbid, shallow water. The faunal association and distribution are likewise judged to be similar.

The tops of the fault-bounded ridges become stratigraphically older as one proceeds into the canyon, as stated above in the discussion of CCN-1. Following this reasoning, it is apparent that the top of section CCN-3 must be stratigraphically older than the top of CCN-1. The lithology of the section clearly resembles that of the basal 72 feet of CCN-1 and is totally unlike any lithology appearing above the crinoidal interval which starts at 72 feet. It is concluded that the

Figure 13. Photomicrograph of burrowing bivalve in section CCN-3.

strata in CCN-3 are for the most part older than those in CCN-1 and originally were overlain by them. If there is any overlap between the two sections it cannot be more than 23 feet, based on the last occurrence of *Elythyna* sp. A in section CCN-3. *Elythyna* does not occur in section CCN-1.

SUMMARY

Relationships Between Measured Sections

The state of the art of Bartine biostratigraphy makes correlation between sections difficult. There is not enough information to allow time lines to be drawn through all levels of the Bartine. The detailed collections made as part of this research have led to the establishment of a time line across the Bartine based on the occurrence of the two species of Atrypa. This means of correlation will be discussed below.

There are certain trends recognizable in the Bartine lithology which are common to all sections. In all sections the tendency is for the rocks to reflect sedimentation taking place in progressively increasing depth. An exception to this trend is found at McColley Canyon and will be discussed below. The trend toward deeper water is most easily recognized in the associated faunas, but is also recognizable in lithologic changes in certain instances. Faunal changes at Lone Mountain show a succession starting with the shallow water Acrospirifer-Leptocoeliid Biofacies (Johnson, 1974), passing through beds containing the fauna of the Atrypa nevadana Community and culminating in the deepest Benthic Assemblage 3 community, the G-A-S Community. There are no indications that the trend toward deeper water during the time of Bartine deposition is ever reversed, although there may have been intervals of time when little or no actual increase in water depth was occurring. The overall aspect, however, in view of the patterns of faunal change, is that the deepening trend was unidirectional. The faunal sequences at Coal Canyon and Cooper Peak reflect initial and intermediate differences from those at Lone Mountain, but both sequences culminate in the establishment of the deeper water G-A-S Community or elements thereof. The McColley Canyon section is somewhat different. At this locality the shallow water *Acrospirifer* Community is succeeded by the deeper water *Atrypa nevadana* Community which is in turn succeeded by the shallower water *Eurekaspirifer pinyonensis* Community. It is important to note that the McColley Canyon section is the only locality where a shallowing trend is noticeable within the Bartine itself. There is, however, evidence for post-Bartine shallowing in the other sections. This relationship is not inconsistent, in that the McColley Canyon section is closest to the shoreward margin of the ancient shelf. If a shallowing trend began in the latest phase of Bartine time it would be first noticeable in the McColley Canyon area and conceivably not be noticed in the westward extensions of the shelf until post-Bartine time. Post-Bartine shallowing is present at McColley Canyon in the form of clastic dolomites with foreset beds and cut-and-fill structures.

The Cooper Peak section shows gradually increasing quartz sand content in the uppermost Bartine beds, followed by Coils Creek lithology with a shallow water *Pentameralla* fauna. At Coal Canyon the beds containing the G-A-S fauna are followed by shallow water, medium energy crinoidal beds. The stratigraphic position of these beds is in doubt as the contact between them and the lower Bartine beds is almost certainly a fault contact. The fact that shallowing conditions are present in the upper Bartine beds at McColley Canyon while deeper water faunas persist in the upper Bartine beds in the western sections is evidence of the possibility that some of the upper Bartine beds at McColley Canyon may be lateral equivalents of the lower Coils Creek at such localities as Lone Mountain and possibly Cooper Peak.

Correlation is possible within the middle beds of the Bartine Member on the basis of the relationship of *Atrypa nevadana* and *Atrypa* sp. The *Atrypa* sp. referred to in the section descriptions above is a coarsely costate, dorsi-biconvex to convexo-plane atrypid very similar to *A. nevadana* in general form and mode of occurrence. The distinguishing feature between the two forms is the coarseness of the costae on *Atrypa* sp. This single external feature may be demonstrated to be a species-specific characteristic rather than a manifestation of intraspecific variation. *Atrypa nevadana* is always found stratigraphically above *Atrypa* sp., immediately following it in the faunal succession. Despite the close vertical proximity of occurrence, the two species are never found together, nor are there any transitional forms suggesting either intraspecific variation or phyletic relationship. These conclusions are based on observation of 1693 specimens of *Atrypa nevadana* and 186 specimens of *Atrypa* sp. from the writer's collections plus supplementary study of specimens in the extensive J. G. Johnson collections and discussion of the problem with Dr. Johnson. The specimens observed come from a number of widely separated localities.

The question of a phyletic relationship between these two forms remains open. Certainly, one would expect to find some transitional forms if this were the case. The two species are obviously very closely related and in the absence of transitional forms, the writer believes that the possibility of allopatric speciation from a common stock must be considered.

Regardless of what the phylogenetic relationship between the two *Atrypa* species may be, the replacement of *Atrypa* sp. by *A. nevadana* does not seem to be the result of different environmental preferences or of environmental changes. Both species occur over the entirety of the depth and energy spectra represented in Bartine and upper Kobeh Members. Both species occur in both argillaceous and "clean" limestone. The most striking example of the similar ecological amplitudes of the two species is in the *Atrypa* sp. homolog of the *Atrypa nevadana* Community which is found at Coal Canyon in samples CCN-116, -119, and -125. Many species found in this *Atrypa* sp.

Community carry through and are found in the *Atrypa nevadana* Community throughout its range. Examples of the common species found in the two communities are *Phragmostrophia merriami*, "*Strophochonetes*" *filistriata*, *Parachonetes macrostriatus*, *Nucleospira subsphaerica*, and *Ambocoelia* sp.

In the face of the arguments against environmental control for the relative distributions of *Atrypa* sp. and *Atrypa nevadana*, it is concluded that the appearance of *Atrypa nevadana* is not environmentally controlled, but time controlled, and that linking the first appearance of *Atrypa nevadana* from section to section does indeed constitute a time line. This time line occurs at 257 feet above the base of section CCN-1, which means that it occurs at least 410 feet above the base of the Bartine Member when taking in the maximum amount of overlap with section CCN-3. It must also be borne in mind that the base of the Bartine is in actuality an undetermined distance below the base of section CCN-3. The writer has found the lowest occurrence of *Atrypa nevadana* at Lone Mountain to be at 101 feet above the Kobeh-Bartine contact. Klapper, however, has found *Atrypa nevadana* at 95 feet above the Kobeh-Bartine contact. The writer's Lone Mountain footages are geared to Klapper's section numbers, therefore I am willing to agree with the 95 foot level as the first occurrence. The distance between the base of the Bartine and the first *Atrypa nevadana* at Cooper Peak cannot be determined because of the fault which cuts through the basal Bartine at that locality. At McColley Canyon the base of the Bartine and the first appearance of Atrypa nevadana coincide. Thus it may be seen that as one transits from west to east across the rocks of the ancient shelf the vertical distance between the base of the Bartine and the lowest appearance of Atrypa nevadana becomes less until it becomes concurrent in McColley Canyon. This steadily decreasing stratigraphic distance between the base of the Bartine and the Atrypa nevadana time line is a demonstration of the diachronous nature of the Kobeh-Bartine contact and reflects the transgressive nature of the event of Bartine sedimentation.

The statements in the preceding paragraph re the Atrypa time line and the base of the Bartine Member infer that the Bartine is older in the west than in the east. Supporting evidence for this position may be found in the faunal sequences at Coal Canyon and at McColley Canyon. In the Leptocoelia infrequens beds at Coal Canyon there occurs a transition from a fauna with a mixed Kobehana Zone and Pinyonensis Zone fauna to a Pinyonensis Zone fauna s. l. This changeover occurs at 157 feet above the base of section CCN-1 when the Kobehana Zone brachiopod Coelospira ? sp. finally drops out altogether, coincident with the beginning of such typically Pinyonensis Zone brachiopod species as Phragmostrophia merriami, and Brachyspirifer pinyonoides. When one considers the additional older strata in section CCN-3, this gives a total of at least 310 feet of Bartine strata which may be considered of Kobehana Zone age and therefore possibly correlative with the Kobeh Member at Lone Mountain and in the Roberts Mountains.

At McColley Canyon, Atrypa sp. occurs in the Kobeh Member with an Acrospirifer kobehana Zone fauna. The occurrence of Atrypa sp. in the Kobeh Member directly underlies the occurrence of Atrypa nevadana in the Bartine Member. The fact that at McColley Canyon the highest occurring Atrypa sp. is associated with the Kobeh Member while at Coal Canyon it is associated with elements of the Atrypa nevadana Community in the Bartine Member indicates a correlation between the youngest Kobeh at McColley Canyon and the middle Bartine at Coal Canyon. Thus, from a brief discussion of the correlative utilization of the Atrypa time line, it may be demonstrated that the oldest Bartine lithology at sections studied is at Coal Canyon, while the youngest basal Bartine is at McColley Canyon.

As superjacent rock-stratigraphic units with a diachronous interface, the Bartine and Kobeh Members must grade laterally into one another at some place or places according to Walther's principle. Two intertonguing relationships between the Kobeh and the Bartine

Members are hypothesized in this paper. It was concluded from the discussion of the relationship between the *Atrypa* time line and the stratigraphy of the Bartine at Coal Canyon that at least part of the lower Bartine at that locality was *Kobehana* Zone in age. Therefore, the Bartine must grade laterally into the Kobeh Member somewhere between Coal Canyon and the southeastern sector of the study area, for nowhere in that area does the Bartine Member contain a *Kobehana* Zone fauna. This is the first intertonguing relationship.

The second intertonguing relationship occurs between Lone Mountain and McColley Canyon. Between these two localities the stratigraphic distance between the Kobeh-Bartine contact and the *Atrypa* time line diminishes from 95 feet to 0 feet. The highest occurrence of *Atrypa* sp. at Lone Mountain is in the Bartine Member, while the highest occurrence of *Atrypa* sp. at McColley Canyon is in the Kobeh Member. These two sets of circumstances demonstrate at once the diachronous nature of the Kobeh-Bartine contact and the equivalent, and therefore intertonguing, relationship between the lower Bartine of Lone Mountain and the highest Kobeh at McColley Canyon. Figure 14 is a hypothetical cross-section showing the proposed relationship of the Kobeh Member and the Bartine Member across the shelf.

In the preceding paragraphs the correlation of the middle and lower Bartine and upper Kobeh strata has been discussed. Unfortunately, at the present time no such correlation between the beds of

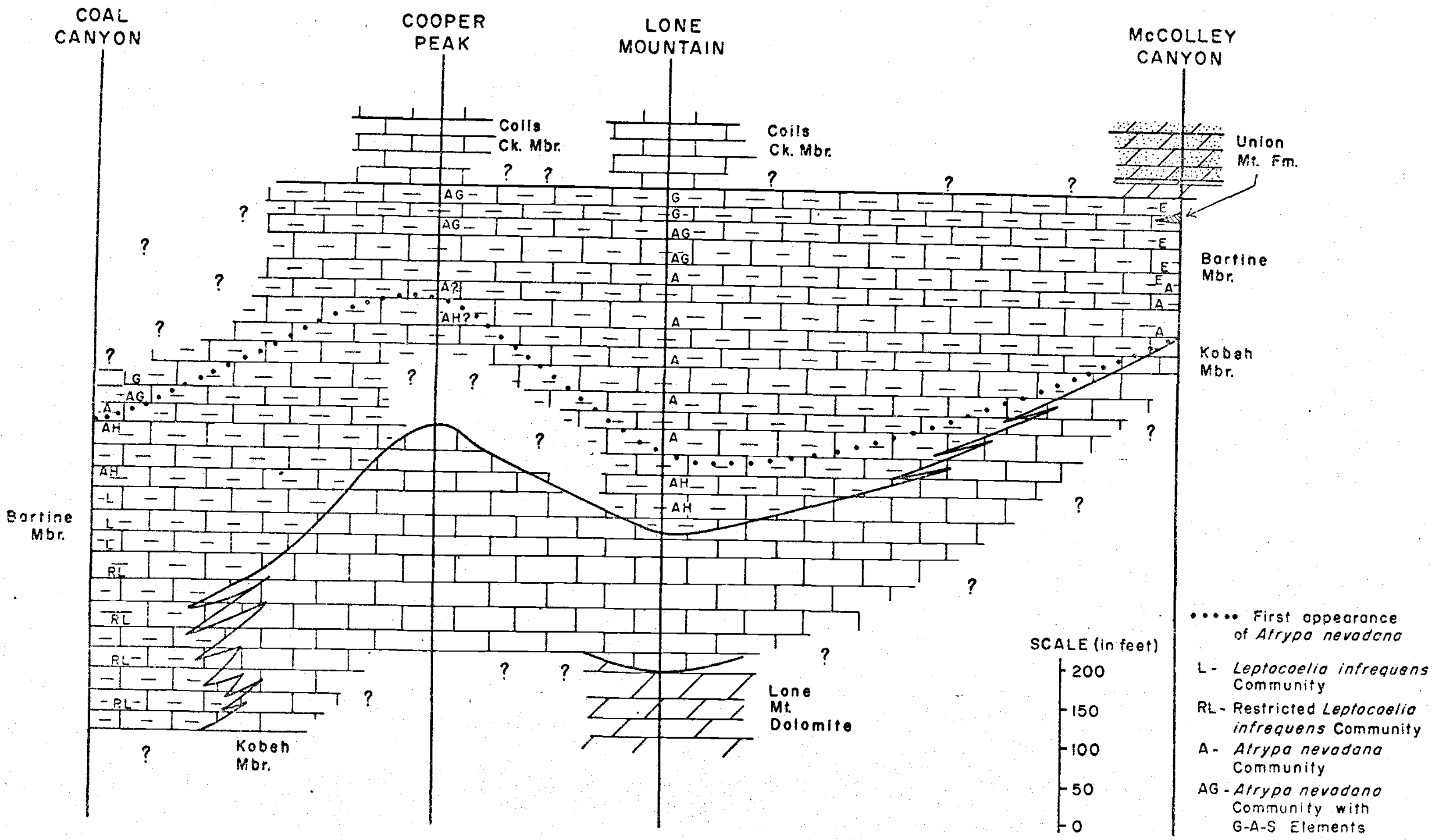

Fig. 14

DIAGRAMMATIC CROSS SECTION OF BARTINE MEMBER FROM COAL CANYON, SIMPSON PARK RANGE TO McCOLLEY CANYON, SULPHUR SPRINGS RANGE, EUREKA COUNTY, NEVADA the upper Bartine and between the upper Bartine and the rock-stratigraphic units which overlie it such as the Coils Creek Member and the Union Mountain Formation may be made. The writer has briefly alluded to the possibility of equivalence between the highest Bartine Member at McColley Canyon and the basal Coils Creek Member at Lone Mountain and Cooper Peak. This suggestion is purely conjectural, however, and awaits the establishment of more measured sections and fossil collections so that the time-stratigraphic position of the immediate post-Bartine rock-stratigraphic units might be understood.

Community Distribution Through Time and Space

There follows now a brief recapitulation of the communities which have been defined and their lateral positions on the shelf relative to shore. This summary precedes a discussion of the distribution and succession of the communities in time and space.

The *Eurekaspirifer pinyonensis* Community is in closest proximity to the shore line of any of the Bartine communities discussed in this paper. It is characterized by abundant *E. pinyonensis* and *Atrypa nevadana*. It occurs only in the easternmost beds of the Bartine in what was an eastward transgressing sea. The next community seaward was the *Atrypa nevadana* Community which was characterized by abundant *Atrypa nevadana*, *Phragmostrophia merriami*, *Dalejina* sp., "*Strophochonetes*" *filistriata*, *Chonetes* sp., *Parachonetes macrostriatus*, *Nucleospira subsphaerica*, and *Ambocoelia* sp. This community has a homolog in the *Atrypa* sp. Community of the Coal Canyon Bartine. The G-A-S Community of Johnson is the deepest or the community farthest from shore. The G-A-S Community is characterized by common to abundant *Schizophoria nevadaensis*, *Carinagypa loweryi*, *Brachyspirifer pinyonoides*, and *Atrypa nevadana*. Between the *Atrypa nevadana* Community and the G-A-S Community is a transitional fauna which has most of the elements of the *Atrypa nevadana* Community plus *Schizophoria nevadaensis* and *Brachyspirifer pinyonoides*. *Carinagypa loweryi* is missing from this fauna.

At Coal Canyon there are two communities, the *Leptocoelia infrequens* Community and the Restricted *Leptocoelia infrequens* Community which combined occur in over 300 feet of section. These communities appear to be unique to Coal Canyon and are judged to be the result of special circumstances as have already been discussed.

At the time of the deposition of the oldest Bartine, the Coal Canyon area was inhabited by scattered colonies of brachiopods which were members of what has been described as the Restricted *Leptocoelia infrequens* Community. Later in earliest Bartine time the area was occupied by the more diverse and somewhat more prolific

Leptocoelia infrequens Community. At this time, Lone Mountain, Cooper Peak and McColley Canyon were the sites of deposition of Kobeh lithology with shallow water Kobehana Zone faunas.

In middle Bartine time the Leptocoelia fauna at Coal Canyon was replaced by the Atrypa sp. Community which in turn was replaced by the Atrypa nevadana Community as diversity and abundance continued to increase in that area. At the same time, Bartine lithology had spread to the entire shelf area. At Cooper Peak the enigmatic Cymostrophia and Trigonirhynchia assemblages were living, while at Lone Mountain and McColley Canyon the brachiopods typical of the Atrypa nevadana Community held sway. The Eurekaspirifer pinyonensis Community is inferred to have lived farther to the east on the basis of E. pinyonensis shells transported into the Atrypa nevadana Community at McColley Canyon.

By late Bartine time continued deepening had resulted in the establishment of the G-A-S Community at Lone Mountain and Coal Canyon and the transitional Atrypa nevadana Community with Schizophoria and Brachyspirifer at Cooper Peak. Initially, the Atrypa nevadana Community was present at McColley Canyon; however, this community was displaced by the westward migration of the Eurekaspirifer pinyonensis Community towards the end of Bartine time as a shallowing trend had its initial effects on the eastern shelf margin. It is during this phase of the Bartine event that the full spectrum of the <u>Pinyonensis</u> Zone Community profile is visible within the study area. Figure 15 shows a profile of the community distribution during the height of the Bartine transgression.

The writer finds himself in accord with Boucot that the Bartine communities described in this paper are all confined within the subtidal Benthic Assemblage 3 (Boucot, oral communication, July, 1973). Benthic Assemblage 3 has been defined by Boucot (1974) as encompassing the depth zone between 40 and 200 feet.

Considering the distance involved between the eastern and western extremities of the study area, some 40 miles, and considering the low angle of slope associated with this continental-margin shelf, it is doubtful if the maximum depth under consideration exceeded 125 feet. Although the writer has stated his agreement with Boucot that the communities under discussion were confined to Benthic Assemblage 3, the <u>Eurekaspirifer pinyonensis</u> Community is believed to be at the shoreward margin of this depth zone, and possibly even into the outer margin of Benthic Assemblage 2. This community was definitely associated with current agitated sediments and even extended up to the very limits of the clastic dolomite facies which supercedes the Bartine at McColley Canyon.

The salient characteristics of the Bartine Member which distinguishes it from bounding rock-stratigraphic units is the argillaceous content of its limestones. This argillaceous content is dispersed

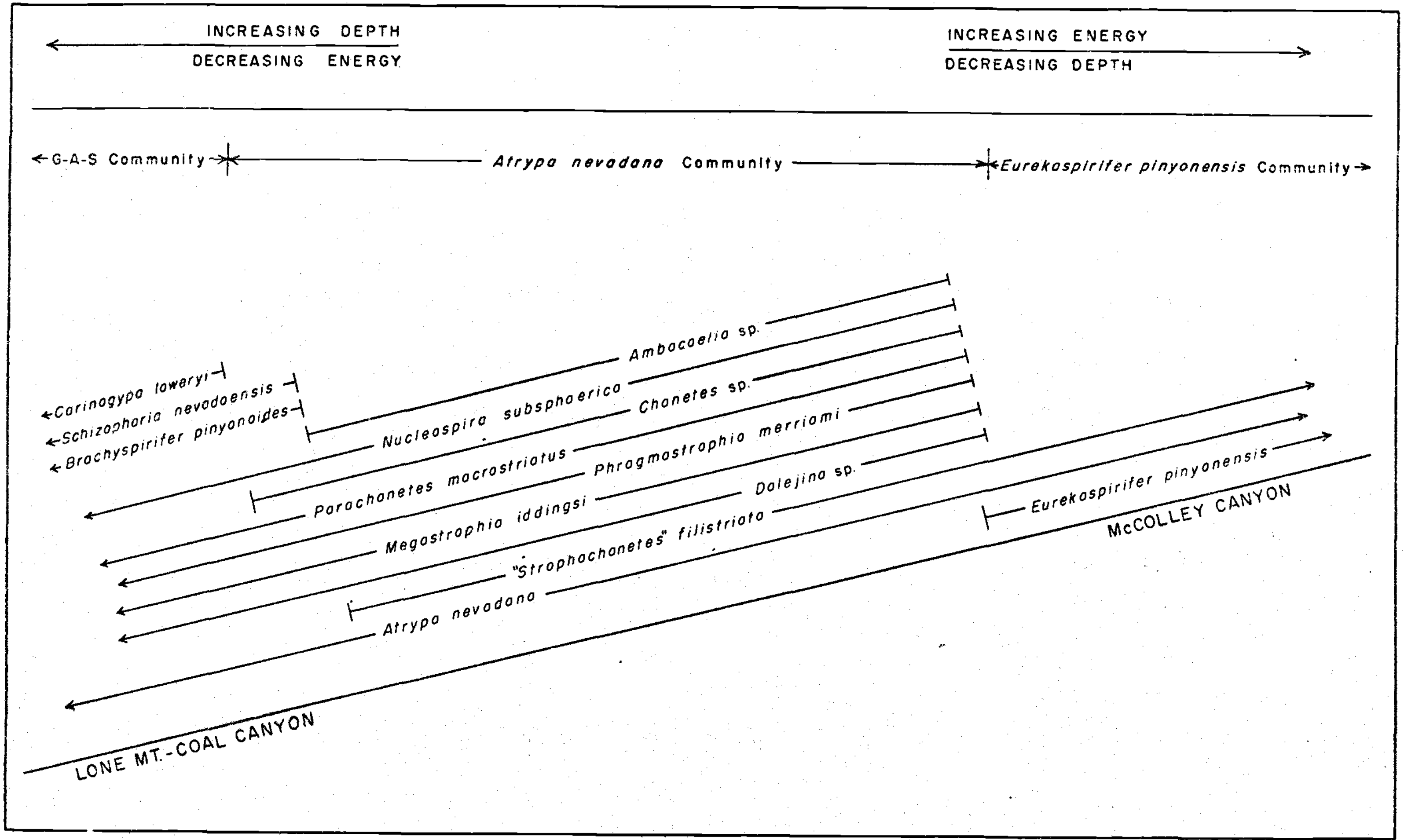

Fig. 15 DIAGRAMMATIC REPRESENTATION OF DISTRIBUTION OF BRACHIOPOD COMMUNITIES IN UPPER *E. pinyonensis* ZONE, EUREKA COUNTY, NEVADA

through all the depositional environments of the Bartine Member regardless of depth or energy level. It spreads as the Bartine seas transgress over the eastern margins of the shelf.

The hypothesis was developed that the oldest Bartine is at Coal Canyon and that the Coal Canyon locality was environmentally separated from other shelf localities to the east. This environmental separation resulted in the low diversity fauna of the Leptocoelia infrequens Community at Coal Canyon while assemblages of more normal content and diversity were living at other localities in the non-argillaceous but contemporaneous upper Kobeh Member. The writer has cited how after the crinoid beds at 72 feet in section CCN-1, the fauna at Coal Canyon reflects increased diversity and that a progression toward deeper water communities, culminating in the establishment of the G-A-S Community, was begun. It is submitted that the crinoid beds represent the transition point where increasing depth has allowed open circulation between the Coal Canyon locality and the normal carbonate depositional environments of the open shelf. It is further submitted that a corollary to the establishment of communication between these two depositional regimes was the spread of the terrigenous clay and the establishment of Bartine sedimentary conditions over the entirety of the shelf rather than being restricted to the Coal Canyon area.

The source of the clay must remain an unanswered question until more is known about the paleogeography of the Emsian of Nevada.

CONCLUSION

In the preceding sections of this paper the discussion has centered upon the nature of the distribution of the brachiopod fauna in the Bartine Member of the McColley Canyon Formation. By keying the occurrence of the various brachiopod species to measured sections located at outcrops spaced across the preserved remnants of the ancient shelf sediments, it has been possible to define or recognize five brachiopod communities in a fauna which has been previously referred to as the Eurekaspirifer pinyonensis Zone fauna. The communities defined are the Restricted Leptocoelia infrequens Community, the Leptocoelia infrequens Community, the Atrypa nevadana Community and its homolog the Atrypa sp. Community, and the Eurekaspirifer pinyonensis Community. The G-A-S Community of Johnson has been recognized. Data collected on the vertical and horizontal distribution of the brachiopods has allowed the recognition of a time line through the Bartine Member based on two species of the genus Atrypa.

Delineating the distribution of the Bartine brachiopod communities and the establishment of the Atrypa time line in conjunction with petrographic studies of Bartine lithology allows certain conclusions to be reached regarding the nature of the Bartine Member as a geological event. The significance of the Atrypa time line other than the fact that it affords correlation within the Bartine Member, is that it demonstrates conclusively that the Bartine Member is a transgressive unit, older in the west than in the east.

Study of the horizontal distribution of the brachiopod communities allows inferences to be made about the depth profile of the water over the shelf and makes possible identification of the restricted environment which existed at Coal Canyon during the time of earliest Bartine deposition. Study of the vertical distribution of the brachiopod communities not only corroborates the proposition of the Bartine as a transgressive unit, but shows that the post-Bartine regressive phase actually began during the time of Bartine deposition.

Analysis of the data gathered in the course of this investigation allows a hypothesis to be made about the possible nature of the intertonguing relationship which must exist between the Bartine and Kobeh Members. Concomitant with such conclusions is the proposal of a model of the shelf profile and the distribution and relationship of bio- and lithofacies. Finally, the conclusions reached in this paper place the diverse brachiopod fauna of the Eurekaspirifer pinyonensis Zone in an ecological perspective both in regard to community relationships within the Bartine, but also in regard to the relationship of the Bartine and the Pinyonensis Zone fauna to the upper Kobeh Member. In previous publications the Bartine Member with its Pinyonensis Zone fauna and the Kobeh Member with its Kobehana Zone fauna have been discussed as though they were mutually exclusive superposed rock-stratigraphic units with included unique biostratigraphic zones. This paper demonstrates the coeval nature, at least in part, of both the Bartine and Kobeh Members, and their associated biostratigraphic zones. Johnson's (1965) proposal of the *Leptocoelia infrequens* Subzone is a viable biostratigraphic concept in the sense of the occurrence of *Leptocoelia infrequens* at Coal Canyon. The writer would restrict the *Leptocoelia infrequens* Subzone to those strata which are characterized by the *Leptocoelia infrequens* communities at Coal Canyon and which are believed time-equivalent to the upper *Kobehana* Zone beds to the south and east.

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APPENDIX

APPENDIX A

FAUNAL LISTS AND LOCALITIES

SECTION: MCN-1

LOCATION: Section is located in saddle above the head of McColley Canyon in the NE 1/4 NW 1/4 NE 1/4 of Sec. 1, T26N, R52E, of the Mineral Hill Quadrangle. The line of section bears S70E.

Sample: SSN-1-271

Footage: 38 feet below base of Bartine, in Kobeh Member

Brachiopoda	
Dalejina sp.	7
Leptaena sp.	13
Megastrophia sp.	4
"Strophochonetes" sp.	17
Anoplia elongata	20
Atrypa sp.	17
Howellella sp.	1
Cyrtina sp. D	3
Craniops sp.	4
Coelenterata	
solitary tetracorals	18
Mollusca	
Platyceras sp.	5+

Sample: MCN-12

Footage: At Kobeh-Bartine contact

Brachiopoda	
Chonetes sp.	2
Parachonetes macrostriatus	13
Atrypa nevadana	4
Meristella cf. robertsensis	3
Howellella ? sp.	1

Sample: MCN-14 and SSN-1-471

Footage: 32 feet above base of Bartine

Brachiopoda	
Dalejina sp.	207
"*Schuchertella*" sp.	1
"*Stropheodonta*" sp.	25
Phragmostrophia merriami	8
Chonetes sp.	1
"*Strophochonetes*" *filistriata*	13
Parachonetes macrostriatus	51
Trigonirhynchia occidens	1
indet. rhynchonellids	2
Atrypa nevadana	148
Meristina sp.	8
Meristella cf. *robertsensis*	2
Nucleospira subsphaerica	173
Howellella cf. *textilis*	1
Eurekaspirifer pinyonensis	96
Ambocoelia sp.	12
Cyrtina sp. D	2
Craniops sp.	97
Coelenterata	
indet. solitary tetracorals	12
Mollusca	
platycerid gastropods	8
indet. gastropods	5
Orthoceras? sp.	1

Sample: SSN-1-571

Footage: 37 feet above base of Bartine

Brachiopoda

Dalejina sp. C	84
Megastrophia sp.	71
Phragmostrophia merriami	25
"*Strophochonetes*" *filistriata*	56
Parachonetes macrostriatus	5
Trigonirhynchia occidens	21
Atrypa nevadana	555
Meristina? sp.	3
Nucleospira subsphaerica	111
Howellella cf. *textilis*	10
Eurekaspirifer pinyonensis	23
Ambocoelia sp.	122
Cyrtina sp.	3
Craniops sp.	20

Mollusca

indet. gastropods	2

Miscellaneous

Tentaculites sp.	2

Sample: MCN-15

Footage: 47 feet above base of Bartine

Brachiopoda

Dalejina sp.	35
Stropheodonta sp.	5
Phragmostrophia merriami	100
Parachonetes macrostriatus	33
Trigonirhynchia sp.	5
Atrypa nevadana	82
Eurekaspirifer pinyonensis	23
Ambocoelia sp.	37
Craniops sp.	28

Arthropoda	
trilobite fragments	25
Bryozoa	
indet. bryozoans	9
Coelenterata	
indet. solitary tetracorals	7
Miscellaneous	
Tentaculites sp.	3

Sample: MCN-16b

Footage: 70 feet above base of Bartine

Brachiopoda	
Phragmostrophia merriami	2
Atrypa nevadana	44
Eurekaspirifer pinyonensis	43

Sample: MCN-17 and 17b

Footage: 145 feet above base of Bartine

Brachiopoda	
Phragmostrophia merriami	7
"*Strophochonetes*" *filistriata*	104
Atrypa nevadana	113
Nucleospira subsphaerica	1
Hysterolites sp.	1
Eurekaspirifer pinyonensis	275

SECTION: LMN-1

LOCATION: Section located in T20N, R51E of the Bartine Ranch Quadrangle and follows Gronberg's FF section (Gronberg, 1967). The base of the section is located in a saddle in the main southwest trending ridge of Lone Mountain and follows the ridge up the mountain to the northeast.

Sample: LMN-15

Footage: 14 feet above base of Bartine Member

Brachiopoda

Leptaena sp.	21
Strophonella cf. punctulifera	1
indet. parvicostellate stropheodontid	15
Phragmostrophia merriami	18
"Strophochonetes" filistriata	101
Anoplia sp.	434
Nymphorhynchia cf. pseudolivonica	1
Atrypa sp.	13
Meristella robertsensis	19

Mollusca

indet. pelecypods	11
indet. gastropods	9

Arthropoda

Phacops sp.	1

Miscellaneous

Conocardium sp.	1

Sample: LMN-16

Footage: 101 feet above base of the Bartine Member

Brachiopoda

"Strophochonetes" sp.	18
Anoplia sp.	20
Atrypa nevadana	44

Nucleospira? sp.	1
Brachyspirifer sp.	1
Ambocoelia sp.	24
Cyrtina sp.	2
indet. strophomenid	2
inarticulate	1
Mollusca	
bellerophontid gastropods	29
platycerid gastropods	5
loxonemid gastropods	18
pelecypods	17
orthoceritids	2
schaphopods ?	30 ?
Arthropoda	
Dalmanites sp.	3 pygidia
Phacops sp.	8 pygidia 44 cephalons
ostracods	many large ostracods

Sample: LMN-17

Footage: 105 feet above base of Bartine Member

Brachiopoda	
Dalejina? sp.	5
Phragmostrophia? sp.	25
"*Strophochonetes*" *filistriata*	68
"*Strophochonetes*" sp.	4
Parachonetes macrostriatus	77
Anoplia sp.	9
indet. stropheodontid sp.	8
Atrypa nevadana	91
Cyrtina sp.	3

Arthropoda	
Phacops sp.	45 cephalons 16 pygidia
Dalmonites sp.	28 pygidia
ostracods	many large ostracods
Mollusca	
pelecypods	4
gastropods	29
orthoceritid	1
Miscellaneous	
Tentaculites sp.	6

Sample: LMN-18

Footage: 119 feet above base of Bartine Member

Brachiopoda	
Dalejina sp.	13
Stropheodonta sp.	8
Phragmostrophia merriami	6
"*Strophochonetes*" cf. *filistriata*	22
Parachonetes macrostriatus	32
Trigonirhynchia occidens	5
Atrypa nevadana	80
Leptocoelia infrequens	1
Brachyspirifer pinyonoides	1
Cyrtina sp.	8
inarticulates	6
Mollusca	
bellerphontid gastropods	2
pelecypods	39
schaphopods ?	8

Arthropoda	
Phacops sp.	7 cephalons
ostracods	many large ostracods
Miscellaneous	
Tentaculites sp.	3

Sample: LMN-19

Footage: 130 feet above base of Bartine Member

Brachiopoda	
Dalejina sp.	1
Phragmostrophia merriami	7
Parachonetes macrostriatus	7
Atrypa nevadana	74
Nucleospira sp.	3
Brachyspirifer pinyonoides	4
Arthropoda	
Phacops sp.	14 cephalons 6 pygidia
ostracods	
Mollusca	
gastropods	6
pelecypods	10
indet. cone	1

Sample: LMN-111

Footage: 371 feet above base of Bartine Member

Brachiopoda	
Levenea sp.	1
Schizophoria sp.	2
Leptaena sp.	1
Megastrophia iddingsi	18
Leptostrophia sp.	7

Phragmostrophia merriami	2	
"*Strophochonetes*" sp.	12	
Chonetes sp.	293	
Parachonetes macrostriatus	4	
Trigonirhynchia occidens	10	
Atrypa nevadana	740	
Hysterolites sp.	79	
Brachyspirifer pinyonoides	115	
Cyrtina sp.	25	
inarticulates	2	
Arthropoda		
Phacops sp.	57	cephalons and pygidia
Mollusca		
pelecypods	7	
gastropods	4	
Miscellaneous		
Tentaculites sp.	4	
lamellar stromatoporoids		

SECTION: CPN-1

LOCATION: Section located in T23N, R50E, Roberts Creek Mountain Quadrangle. Section begins in middle of saddle north of Hill 9503 at stratigraphic contact between Bartine Member and Coils Creek Member of McColley Canyon Formation. Section runs upslope bearing S18E. Strata are overturned.

Sample: CPN-14

Footage: 56 feet above base of Bartine

Brachiopoda	
Dalejina sp.	1
Atrypa nevadana	27
Nucleospira sp.	11
Eurekaspirifer pinyonensis	8
Coelenterata	
Favosites sp.	24

Sample: CPN-13

Footage: 124 feet above base of Bartine

Brachiopoda	
Megastrophia sp.	10
"Strophochonetes" sp.	14
Spinulicosta? sp.	4
Trigonirhynchia occidens	25
Brachyspirifer pinyonoides	7
Ambocoelia sp.	4
Bryozoa	
indet. bryozoans	numerous
Arthropoda	
trilobite fragments	3

Sample: CPN-13a

Footage: 138 feet above base of Bartine

Brachiopoda	
Cymostrophia sp.	28

Phragmostrophia merriami	10
Spinulicosta? sp.	13
Trigonirhynchia sp.	1
Atrypa nevadana	21
Leptocoelia sp.	1
Bryozoa	
indet. bryozoans	numerous
Arthropoda	
trilobite fragments	18
Coelenterata	
indet. corals	3
Mollusca	
indet. gastropods	4

Sample: CPN-12

Footage: 152 feet above base of Bartine

Brachiopoda	
Schizophoria nevadaensis	239
Megastrophia? sp.	4
Phragmostrophia merriami	10
Chonetes? sp.	3
Trigonirhynchia sp.	2
Atrypa nevadana	26
Brachyspirifer pinyonoides	248
Hysterolites sp.	1
Arthropoda	
trilobite fragments	23
Mollusca	
indet. pelecypods	12
indet. gastropods	3
Bryozoans	
amphiporid bryozoans	numerous

SECTION: CCN-1

LOCATION: Section located in valley east of Coal Canyon in the eastern Simpson Park Range, Sec. 16, T25N, R49E, of the Horse Valley Quadrangle. The top of the section bears S45E from the Bauman Well, S10W from the intersection at BM 5701, and N85E from the top of Hill 6909. The section runs down the nose of the slope.

Sample: CCN-11

Footage: At base of section

Brachiopoda

Levenea fagerholmi	2
Dalejina sp. C	2
Leptocoelia infrequens	38
indet. inarticulate	1

Arthropoda

indet. trilobite fragments	

Coelenterata

indet. solitary tetracoral	1
indet. tabulate coral	1

Sample: CCN-12

Footage: 23 feet above base of section

Brachiopoda

Levenea fagerholmi	3
Dalejina sp. C	3
Leptocoelia infrequens	124
indet. brachiopod	1

Arthropoda

indet. trilobite fragments	

Coelenterata

indet. solitary tetracorals	2

Sample: CCN-13

Footage: 36 feet above base of section

Brachiopoda

Levenea fagerholmi	73
Dalejina sp. C	108
Leptaena sp.	6
Leptostrophia ? sp.	1
Mclearnites sp.	2
"*Strophochonetes*" sp.	1
Chonetes sp.	1
indet. spiriferids	2
inarticulates	4

Sample: CCN-15

Footage: 24 feet above base of section

Brachiopoda

Levenea fagerholmi	16
Dalejina sp. C	40
Megastrophia iddingsi	1
indet. stropheodontid	4
"*Strophochonetes*" *filistriata*	23
Leptocoelia infrequens	20

Arthropoda

indet. trilobite fragments

Coelenterata

indet. tabulate coral	1

Sample: CCN-16

Footage: 72 feet above base of section

Brachiopoda

Leptaena sp.	1
indet. stropheodontid	2

Atrypa sp.	12
Howellella? sp.	1
Miscellaneous	
indet. bryozoans	1
indet. gastropod	1

Sample: CCN-18

Footage: 81 feet above base of section

Brachiopoda	
Levenea? sp.	7
Dalejina? sp.	7
Leptaena sp.	8
Strophonella aff. *punctulifera*	5
Leptostrophia sp.	56
"*Strophochonetes*" *filistriata*	1
"*Strophochonetes*" sp.	1
Atrypa sp. (coarsely costate)	6
Leptocoelia infrequens	49
Nucleospira sp.	12
Ambocoelia sp.	2
Coelenterata	
Conularia sp.	2

Sample: CCN-19

Footage: 95 feet above base of section

Brachiopoda	
Levenea sp.	8
Dalejina sp.	1
Leptocoelia infrequens	13
indet. inarticulate	1

Sample: CCN-110

Footage: 105 feet above base of section

Brachiopoda	
Levenea fagerholmi	3
Dalejina sp.	11
Leptaena sp.	5
"Schuchertella"? sp.	2
Strophonella cf. punctulifera	34
Leptostrophia sp.	86
"Strophochonetes" sp.	15
Parachonetes macrostriatus	3
Atrypa sp. (coarsely costate)	20
Leptocoelia infrequens	318
Nucleospira? sp.	9
Howellella cf. textilis	4
Coelenterata	
indet. favositid	
Bryozoan	
stick-like bryozoan	1
Mollusca	
indet. pelecypods	2
indet. gastropods	2

Sample: CCN-111

Footage: 109 feet above base of section

Brachiopoda	
Levenea sp.	3
Dalejina sp.	2
Strophonella? sp.	1
Megastrophia? sp.	1
"Strophochonetes" sp.	5

Parachonetes macrostriatus	2
Atrypa sp. (coarsely costellate)	14
Coelospira? sp.	6
Leptocoelia infrequens	8
Nucleospira? sp.	4
Howellella cf. *textilis*	1
indet. inarticulate	1

Sample: CCN-114

Footage: 157 feet above section

Brachiopoda

Levenea sp.	2
Leptaena sp.	1
Mclearnites sp.	27
Megastrophia iddingsi	19
Phragmostrophia merriami	153
"*Strophochonetes*" sp.	151
Chonetes? sp.	12
Parachonetes macrostriatus	77
Atrypa sp. (coarsely costate)	43
Coelospira? sp.	5
Leptocoelia infrequens	218
Meristina? sp.	1
Nucleospira sp.	3
Brachyspirifer pinyonoides	14
Ambocoelia sp.	3
Cyrtina sp.	2

Arthropoda

trilobite fragments

Mollusca

indet. pelecypods	3
indet. gastropods	3

Sample: CCN-115

Footage: 167 feet above base of section

Brachiopoda

Dalejina sp.	1
Leptaena sp.	1
Mclearnites sp.	8
Megastrophia sp.	1
Phragmostrophia merriami	8
"Strophochonetes" filistriata	57
Leptocoelia infrequens	2

Arthropoda

trilobite fragments

Sample: CCN-116

Footage: 176 feet above vase of section

Brachiopoda

Leptaena sp.	2
Mclearnites sp.	19
indet. stropheodontid sp.	21
"Strophochonetes" sp.	85
Parachonetes macrostriatus	15
Spinulicosta ? sp.	6
Atrypa sp. (coarsely costate)	33
Leptocoelia infrequens	23
Meristina ? sp.	1
Ambocoelia sp.	11
Cyrtina sp.	3
indet. spiriferid sp.	2
indet. inarticulate	1

Arthropoda

trilobite fragments

Mollusca

indet. bivalves	6
orthoceritid?	1
indet. gastropods	2

Sample: CCN-119

Footage: 223 feet above base of section

Brachiopoda

"Schuchertella" sp.	15
Megastrophia iddingsi	12
Phragmostrophia? sp.	2
"Strophochonetes" filistriata	77
Parachonetes macrostriatus	8
Atrypa sp. (coarsely costate)	14
Leptocoelia infrequens	12
Nucleospira subsphaerica	42
indet. spirifer with radial ornament	1
Lingula sp.	2
Craniops sp.	1

Arthropoda

Otarion? sp.

trilobite fragments

Coelenterata

cylindrical tetracorals	48

Mollusca

indet. pelecypods	12
indet. gastropod	1

Sample: CCN-125

Footage: 251 feet above base of section

Brachiopoda

Strophonella sp.	3

Phragmostrophia merriami	8
"Strophochonetes" sp.	5
Parachonetes macrostriatus	2
Spinulicosta ? sp.	34
Trigonirhynchia sp.	1
Atrypa sp.	12
Leptocoelia infrequens	2
Meristina sp. B	4
Nucleospira sp.	1
Ambocoelia sp.	5
Arthropoda	
trilobite fragments	
Coelenterata	
indet. corals	7
Mollusca	
indet. pelecypod	1
indet. gastropods	7

Sample: CCN-126

Footage: 257 feet above base of section

Brachiopoda

Levenea ? sp.	6
Dalejina sp.	74
Leptaena sp.	1
Mclearnites sp.	8
Leptostrophia sp.	1
Phragmostrophia merriami	14
"Strophochonetes" sp.	1
Parachonetes macrostriatus	4
Trigonirhynchia sp.	1
Atrypa nevadana	84

Leptocoelia infrequens	1
Meristina sp.	2
Nucleospira sp.	74
Hysterolites sp.	1
Ambocoelia sp.	5
indet. spirifers	2
indet. inarticulate sp.	1
Arthropoda	
trilobite fragments	
Coelenterata	
encrusting stromatoporoids	
Mollusca	
indet. molluscs	4
Bryozoa	
encrusting bryozoans	

Sample: CCN-127

Footage: 270 feet above base of section

Brachiopoda	
Dalejina sp.	18
Schizophoria sp.	18
Megastrophia ? sp.	13
Phragmostrophia merriami	48
indet. stropheodontids	4
Chonetes sp.	6
Parachonetes macrostriatus	4
Trigonirhynchia occidens	12
Atrypa nevadana	101
Meristella ? sp.	1
Nucleospira sp.	18
Howellella cf. *textilis*	4

Brachyspirifer pinyonoides	15
Hysterolites sp.	5
Ambocoelia sp.	2
Lingula sp.	1
Bryozoa	
indet. bryozoans	36
Arthropoda	
trilobite fragments	
Coelenterata	
lamellar stromatoporoids	
Mollusca	
indet. pelecypods	10
indet. gastropod	1
Miscellaneous	
Tentaculites sp.	2

Sample: CCN-130

Footage: 300 feet above base of section

Brachiopoda	
Dalejina sp.	2
Schizophoria nevadaensis	39
Carinagypa loweryi	8
Megastrophia iddingsi	16
Phragmostrophia merriami	8
Leptostrophia sp.	5
Chonetes ? sp.	3
Parachonetes macrostriatus	37
indet. rhynchonellid sp.	1
Atrypa nevadana	14
Meristina ? sp.	2
Nucleospira sp.	7

Howellella sp.	1
Brachyspirifer pinyonoides	2
inarticulate	1
Bryozoa	
indet. bryozoans	11
Arthropoda	
trilobite fragments	
Coelenterata	
indet. solitary tetracorals	3
stromatoporoid, indet.	
Mollusca	
indet. pelecypods	5
Platyceras sp.	7
indet. gastropods	4

SECTION: CCN-3

LOCATION: Section located on innermost prominent fault-bounded ridge in valley east of Coal Canyon in eastern Simpson Park Range, Sec. 16, T25N, R49E of the Horse Valley Quadrangle. The top of the section bears N80W to Hill 6909, N45W to Bauman Well, and N12E to the intersection at BM 5701.

Sample: CCN-34

Footage: 23 feet above base of section

Brachiopoda

Levenea ? sp.	1
"Schuchertella" sp.	1
Leptocoelia infrequens	39
inarticulate	1

Sample: CCN-35

Footage: 38 feet above base of section

Brachiopoda

Dalejina sp.	1
Leptocoelia infrequens	44
Elythyna sp. A	16

Sample: CCN-37

Footage: 144 feet above base of section

Brachiopoda

Dalejina sp.	32

Coelenterata

indet. solitary tetracorals	2

Sample: CCN-38

Footage: 157 feet above base of section

Brachiopoda

Dalejina sp.	60
Leptocoelia infrequens	1

Sample: CCN-39

Footage: 175 feet above base of section

Brachiopoda

Dalejina sp.	10
Leptaena sp.	4
"Strophochonetes" sp.	4
Leptocoelia infrequens	20
Elythyna sp. A	1
Ambocoelia sp.	1

Arthropoda

trilobite fragments	2

Coelenterata

indet. solitary tetracorals	6
Favosites sp.	1

Sample: CCN-310

Footage: 189 feet above base of section

Brachiopoda

Dalejina sp.	8
Atrypa sp.	1

Arthropoda

trilobite fragments	1

Coelenterata

indet. corals	2

Sample: CCN-311

Footage: 198 feet above base of section

Brachiopoda

Dalejina sp.	19
Leptaena sp.	1
Strophonella cf. punctulifera	9
Ambocoelia ? sp.	2

Coelenterata	
indet. coral	1

Table I: RELATIVE ABUNDANCES OF BRACHIOPOD SPECIES ON SECTION MCN-1
abundances expressed as percent of fauna

footage on section	12'	50'	82'	87'	97'	120'	195'
MCN number	271	12	471	571	15	16 b	17
Dalejina sp. C				7.7	10.9		
Dalejina sp.	8.1		30.0				
Leptaena sp.	15.1						
Megastrophia sp.	4.7		6.5				
Stropheodonta sp.	19.8			1.6			
Phragmostrophia merriami			1.0	2.3	31.3	2.3	1.4
"Strophochonetes" filistriata			2.0	5.1			20.8
"Strophochonetes" sp.			4.0				
Chonetes sp.		8.7					
Parachonetes macrostriatus		56.5	5.0	0.4	10.3		
Anoplia elongata	23.3						
Trigonirhynchia occidens				1.9			
Trigonirhynchia sp.					1.6		
Atrypa sp.	19.7						
Atrypa nevadana		17.4	18.0	51.0	25.6	49.4	22.6
Meristina sp.			1.0				
Meristella cf. *robertsensis*		13.0					
Nucleospira subsphaerica			23.0	10.2			0.2
Howellella cf. *textilis*				0.9			
Howellella sp.	1.2	4.3					
Hysterolites sp.							0.2
Eurekaspirifer pinyonensis			14.0	2.1	7.2	48.3	54.9
Ambocoelia sp.			2.0	11.2	11.6		
Cyrtina sp. D	3.5						
Cyrtina sp.				0.3			
solitary tetracorals	X		X		X		
Gastropods	X		X	X			
Orthoceritids			X				
Bryozoans				X	X		
Tentaculites				X	X		
Trilobites					X		

Table II: RELATIVE ABUNDANCES OF BRACHIOPOD SPECIES ON SECTION LMN-1
abundances expressed as percent of fauna

footage on section	14'	101'	104'	118'	128'	371'
LMN number	15	16	17	18	19	111
Levenea sp.						0.1
Dalejina sp.				7.1	1.0	
Schizophoria sp.						0.15
Leptaena sp.	3.2					0.1
Strophonella cf. *punctulifera*	0.2					
Megastrophia iddingsi						1.4
Stropheodonta sp.				4.4		
Leptostrophia sp.						0.53
Phragmostrophia merriami	2.7			3.3	7.3	0.15
indet. stropheodontid		1.8	2.8			0.92
"Strophochonetes" filistriata	15.3		23.4	12.1		
Chonetes sp.		15.9				22.3
Parachonetes macrostriatus		1.0	26.6	17.6	7.3	0.31
Anoplia sp.	65.9	17.7	3.1			
Trigonirhynchia occidens				2.7		0.76
Nymphorhynchia pseudolivonica	0.2					
Atrypa sp.	2.0					
Atrypa nevadana		38.9	31.4	44.0	77.1	56.5
Leptocoelia infrequens				0.5		
Meristella cf. *robertsensis*	2.9					
Nucleospira sp.					3.1	
Hysterolites sp. A						6.03
Brachyspirifer pinyonoides		0.9		0.5	4.2	87.7
Ambocoelia sp.		21.2				
Cyrtina sp.		1.8	1.0	4.4		1.9
Conacardium sp.	X					
Pelecypods	X	X	X	X	X	X
Gastropods	X	X	X	X	X	X
Trilobites	X	X	X	X	X	X
Orthoceritids		X	X			
Ostracods		X	X	X		
Tentaculites			X	X		X
lamellar stromatoporoides						X

Table III: RELATIVE ABUNDANCES OF BRACHIOPOD SPECIES ON SECTION CPN-1
abundances expressed as percent of fauna

footage on section	0'	15'	124'	138'	152'
CPN number	15	14	13	13a	12
Dalejina sp.	33.3	2.1			
Schizophoria nevadaensis					44.8
Cymostrophia sp.				32.8	
Megastrophia sp.			15.2		
Phragmostrophia merriami				13.5	1.9
"Strophochonetes" sp.			21.2		
Anoplia sp.	13.3				
Spinulicosta ? sp.			6.1	17.6	
Trigonirhynchia occidens			37.9		
Trigonirhynchia sp.				1.4	0.4
Atrypa nevadana		57.4		28.4	4.9
Leptocoelia sp.	6.7			1.4	
Meristella sp.	6.7				
Nucleospira sp.		23.4			
Hysterolites sp.					0.2
Brachyspirifer pinyonoides			10.6		46.5
Eurekaspirifer pinyonensis		17.0			
Ambocoelia sp.			6.1		
Acrospirifer kobehana ?	40.0				
solitary tetracorals	X				
trilobites	X		X	X	X
Gastropods	X			X	X
Bryozoans			X	X	
Pelecypods					X

Table IV: RELATIVE ABUNDANCES OF BRACHIOPOD SPECIES ON SECTION CCN-1
abundances expressed as percent of fauna

footage on section	0'	23'	36'	—	72'	81'	95'	105'	109'	167'	176'	223'	251'	257'	270'	300'
CCN number	11	12	13	15	16	18	19	110	111	115	116	119	125	126	127	130
Levenea fagerholmi	5.0	2.0	28.0	15.4				0.6								
Levenea sp.							4.3		6.3					2.2		
Dalejina sp. C	5.0	2.0	41.0	38.5						1.3				26.6		
Dalejina sp.							34.8	2.2	4.2						6.7	1.3
Schizophoria nevadaensis																26.7
Schizophoria sp.															6.7	
Carinagypa loweryi																5.5
Leptaena sp.			3.0		6.3	5.2		1.0		1.3	0.9			0.4		
"*Schuchertella*" sp.								0.4				8.1				
Strophonella cf. *punctulifera*						3.2		6.7								
Strophonella sp.									2.1				3.9			
Mclearnites sp.			0.8							10.3	8.6			2.9		
Megastrophia sp.									2.1	1.3						
Megastrophia iddingsi				1.0								6.5				11.0
indet. stropheodontid				3.8	12.5						9.5				1.5	
Leptostrophia sp.						36.4		16.9						0.4		3.4
Phragmostrophia merriami										10.3			10.4	5.0	17.8	5.5
"*Strophochonetes*" *filistriata*				22.1		0.6				73.1		41.4				
"*Strophochonetes*" sp.			0.4			0.6		2.9	10.4		38.6		6.5	0.4		
Chonetes sp.			0.4												2.2	2.1
Parachonetes macrostriatus								0.6	4.2		6.8	4.3	2.6	1.4	1.5	25.3
Spinulicosta? sp.											2.7		44.2			

Trigonirhynchia sp.													1.3	0.4		
Trigonirhynchia occidens															4.4	
Atrypa sp.					75.0	3.9		3.9	29.2		15.0	7.5	15.6			
Atrypa nevadana														30.2	37.4	9.6
Leptocoelia infrequens	88.0	95.0	26.0	19.2		31.8	56.5	62.4	16.7	2.6	10.5	6.5	2.6	0.4		
Meristina sp. B													5.2			
Meristina sp.											0.5			0.7		1.4
Coelospira sp.									12.5							
Nucleospira subsphaerica												22.6				
Nucleospira sp.						7.8		1.8	8.3				1.3	26.6	6.7	4.8
Howellella cf. *textilis*								0.8	2.1						1.5	
Hysterolites sp.														0.4	1.9	
Brachyspirifer pinyonoides															5.6	1.3
Ambocoelia sp.						1.3					5.0		6.5	1.8	0.7	
Cyrtina sp.											1.4					
trilobites	X			X						X	X	X	X	X	X	X
cylindrical tetracorals												X	X	X	X	
solitary tetracorals	X	X		X												X
Bryozoans					X			X							X	X
Gastropods											X	X	X			X
Conularia sp.						X										
Pelecypods								X			X	X	X	X		X
Orthoceritid											X					
lamellar stromatoporoids														X	X	X

Table V: RELATIVE ABUNDANCES OF BRACHIOPOD SPECIES ON SECTION CCN-3

abundances expressed as percent of fauna

footage on section	23'	38'	144'	157'	175'	184'	198'
CCN number	34	35	37	38	39	310	311
Levenea sp.	2.4						
Dalejina sp.		1.6	100	98.4	25	88.9	61.3
Leptaena sp.					10.0		3.2
"*Schuchertella*" sp.	2.4						
Strophonella cf. *punctulifera*							29.0
"*Strophochonetes*" sp.					10.0		
Atrypa sp.						11.1	
Leptocoelia infrequens	92.9	72.1		1.6	50.0		
Elythyna sp. A		26.2			2.5		
Ambocoelia sp.					2.5		6.5
solitary tetracorals			X		X	X	
trilobites					X	X	X