THE CORRELATIVE VALUE OF FORAMINIFERA
IN THE PIERRE SHALE OF COLORADO

By

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Purpose of the Investigation

The purpose of this investigation was to determine whether or not Foraminifera have any value as horizon markers in the Pierre Formation. The drilling of oil wells in the Fort Morgan area and other parts of eastern Colorado has shown the necessity of correlating the various horizons of the Pierre and related formations penetrated by the drill. It was felt that Foraminifera and other micro-fossils might serve in making the correlations.

Acknowledgments

The writer is particularly indebted to Professor R.D. George and to the University of Colorado for making this work possible. The direction of Professor George, and his efforts in making available a University truck and other equipment are appreciated. The study has been expedited by the advice and criticism of Professor W.C. Toepelman, Professor P.G. Worcester, Mr. Harry Aurand, Mr. W.A. Waldschmidt, and Dr. C. Max Bauer, and by the assistance of Mr. R.E. Murphy in field and laboratory.

The Pierre Formation

The Pierre Formation is known to occur over nearly all of that part of Colorado which lies to the east of the Foothills belt of the Front Range. It ranges from five to seven thousand feet in thickness, and is composed of buff to dark-gray marine shales with interbedded sandstones and concretionary limestone stringers.

The Pierre lies conformably upon the Niobrara limestone, and the lower two thousand feet of the formation is very largely dark gray, carbonaceous, fissle shale with frequent interbedded stringers of ferruginous, concretionary limestone and sandstone. These concretionary beds are seldom more than six or eight inches thick, and usually are persistent only for short distances laterally, insofar as field evidence indicates. The concretions are commonly very hard, but much fractured and broken. The stringers occasionally develop into lenses more than a foot thick, and one prominent concretionary bed was noted in the Degge Mesa area which was made up of spheroidal ferruginous concretions more than two feet in diameter. The last named bed is persistent over a considerable area in the immediate vicinity of Boulder and lies about a hundred feet below the Hygiene sandstone member of the Pierre. The lowest two or three hundred feet of the Pierre shales are, in general, much harder than any of the shales found at higher levels, and that part of the formation which lies below the Hygiene much more limy than any of the higher beds.

There is a variable zone of increasingly sandy shales and alternating thin beds of sandstone and shale which grades upward into the Hygiene sandstone. The thickness of this zone may vary from a few feet to more than fifty feet, and in places the alternating layers are entirely absent; the shales become more and more sandy until they grade imperceptibly into the sandstone.

The Hygiene sandstone is the most persistent of the group of sandstones which occur in the Pierre. It is a fine grained, quartz sandstone, commonly gray in color, but often slightly green or brown, especially on the weathered surface. Inclusions of carbonaceous material are very common; parts of the bed may be locally very limy, and concretionary horizons are common within the sandstone as are shaly intervals. The Hygiene can be traced northward from Boulder to the vicinity of Fort Collins, a distance of more than forty miles.

Above the Hygiene there is a zone of alternating shales and sandstones, and sandy shales, which roughly occupies the middle third of the Pierre formation. In the immediate vicinity of Boulder the Hygiene is the only well defined sandstone in the group, but in the vicinity of Ft. Collins the group includes five well defined sandstones known from bottom to top as the Hygiene, the Terry sandstone, the Rocky Ridge sandstone, the Larimer sandstone, and the Richards sandstone. The sandstones are separated by strata of sandy shale which vary in thickness from one to four hundred feet, and the intervening sandy shales usually grade into the sandstones which are remarkably similar in texture, composition, and appearance. The sandy zone described above is variously known as the Hygiene zone and the Hygiene group. The sandstones bear an abundance of megascopic fossils, but would appear to contain very few microscopic forms. The microscopic fossils apparently are more abundant immediately above and below the sandstones.

The shales above the Hygiene sandstone are very similar to those below except that the upper beds contain less lime and more sand. The hard, ferruginous, concretionary stringers continue with more or less frequency to the top of the formation, but appear to be less continuous laterally, and are all rather limy as they are throughout the lower part of the Pierre. The higher shales of the formation are apt to be lighter in color and softer than those in the lower part, but this is not always true. In the Eldorado Springs section the shales immediately below the Fox Hills formation are hard, platy, and black.

It was found in the laboratory that shales from the upper part of the Pierre usually break down when soaked in cold water, but most of those shales in the lower part of the formation disintegrate only partially when broken by mechanical means and boiled in a lye solution.

The upper part of the Pierre seems to be in general more sandy in the northern part of the area studied than in the southern part.

The Pierre is overlaid conformably by the Fox Hills formation, which represents the last phase of marine cretaceous deposition in Colorado. The contact between the Pierre and Fox Hills is a gradational one and can not be exactly placed. It is usually marked by increasingly sandy shales and alternating thin beds of shale and sandstone.

Economic Importance

The Pierre Formation in itself is not of great economic importance now, but the Hygiene member often shows traces of oil and was the main producing horizon in the Boulder Field. Too, shale from the Pierre is used extensively in the making of brick in certain localities.

The present economic importance of the Pierre is in prospecting for oil. The Dakota formation is most frequently the oil producing horizon, but to reach it the drill must penetrate the overlying Pierre shale. The desirability of identifying the horizons penetrated, especially the Hygiene Zone, seems obvious because the Hygiene is an oil-bearing horizon in many places, and is the most persistent of the sandstones of the Pierre.

Location of sections measured and sampled

The sections measured and sampled are: Coal Creek, Eldorado Springs, Degge Mesa, Little Thompson Creek, Fossil Creek, and Big Thompson Creek. These sections traverse the following areas: The Coal Creek section--sections 19, 20, and 21 of T1S-R70W; Eldorado Springs--section 33, T1S-R70W; Degge Mesa--section 31, T2N-R70W, and sections 1, T1N-R71W, and 6,8,9, 10,13,14, T1N-R70W; Little Thompson Creek--section 36, T3N-R70W and sections 31, 32, 33, 34, and 35, T4N-R69W; Big Thompson Creek--sections, (next page)

14 and 23, T.5.N.-R.69.W.; Fossil Creek--sections 10,11, 12, T.6.N.-R.69.W.

The location of the Coal Creek Section was chosen because of the excellent outcrops of the Pierre formation in the cuts along the Denver and Salt Lake R.R. where nearly the entire thickness of the Pierre is exposed, leaving not more than two hundred feet, stratigraphically, covered with alluvium. The place at which the Eldorado Springs Section was studied was selected because it presents the greatest exposure of the Pierre formation between Coal Creek and Degge Mesa, and is located nearly midway between them. The Degge Mesa Section was studied at the place given because that location presents the best exposure of the Hygiene sandstone as well as of the lower part of the Pierre shales in the immediate vicinity of Boulder.

The Little Thompson, Big Thompson, and Fossil Creek Sections were chosen principally on the advice of Mr. H.A. Aurand who recommended the excellent exposures in those localities. Sections located farther north might have been better suited to the problem, from a regional standpoint, but time and financial considerations prevented extending the area.

Field Methods

The Field work was done during the Winter and Spring of 1932. Work during the Winter was greatly hampered by bad weather and low temperatures, and work was done mostly on week-ends and during school vacations.

The Coal Creek, Eldorado Springs, Degge Mesa, and Little Thompson Creek Sections were measured with a plane table and stadia rod. The Big Thompson and Fossil Cfeek Sections were measured by using thicknesses previously measured by Mr. H.A. Aurand as a guide, and checking the thickness of the sampled zones with a Brunton Compass and steel tape.

In those sections which were measured with the plane table, great care was taken to insure accuracy in the measurements and the position of the samples.taken. All turns in the traverse were made by using foresight and backsight readings, and in all cases an effort was made to keep the readings within 2500 feet. In those few instances where it was necessary to take longer readings, the stadia distances were rechecked with the Stebinger screw.

Some sections could not be measured in a single traverse. In such cases care was taken to break the traverse on some established survey point, such as a section corner, and to continue the new traverse from another such point.

A rod shot was taken on each exposure to be sampled, and if the exposure was large enough to require the taking of several samples, the location of the additional samples was found by running a Brunton traverse to tie them in. In exposures where samples could be taken at right angles to the strike of the beds, an effort was made to take the samples about twenty feet apart, using the rod to measure the distances. Large exposures, requiring a great number of samples were tied in with rod shots at both ends, and on any sandstones or other prominent beds which might occur within the exposure.

Sampling

Two general methods of sampling the outcrop were employed. The first method was to dig a trench across the exposure at right angles to the strike of the beds, and to take a composite sample of the bottom of the trench. The second method was to dig pits in the exposure, and to take a composite sample from the sides and bottom of the pit.

The pits and trenches were dug to a minimum depth of one foot, but the great scarcity of tests composed of agglutinated foreign material would indicate that the shales must be penetrated to a considerably greater depth. It appears that the agglutinated tests near the surface are largely destroyed by ground water and surface water leaching. It is suggested that workers securing samples for the study of foraminifera excavate trenches or pits to a depth of at least two feet in order to secure better preserved material.

Laboratory Methods

Ordinary No4 paper sacks of a good grade were used to contain the samples. The samples were numbered when collected, using the rod-station number and a numerical suffix to indicate the location of the sample. Sample 1-A-1 would be sample number 1, from the outcrop located at rod station number 1-A. The samples were filed in boxes in proper order at the end of each day's work in the field.

Various methods of preparing the material for study were tried, but the following prodedure proved most satisfactory: About fifty grams of shale are placed in an evaporating dish and covered with water. The sample is allowed to soak for twenty-four hours, and is then placed on the hot plate where it is boiled vigorously for about an hour. If the material fails to break down under this treatment, a small quantity of lye is added to the solution and the boiling is continued until the shale is at least partially broken down.

The disintegrated sample is washed by adding water, agitating the material to place the silt in suspension, and decanting. This operation is repeated until the water is no longer discolored with silt. The sample is then dried on the hot plate, and placed in small paper sacks to await examination. The samples are treated in lots of twenty or more for convenience.

Method of Examination

The following procedure was used in examining the samples: The material was passed through 16 and 115 mesh screens. That which remained on the 16 mesh screen was examined with the unaided eye for fossil material. The other two sizes of material were placed on separate parts of the tray for examination, the greater part of the tray being covered with the material retained on the 115 mesh screen. The sizing was chosen because fossil material left on the coarser screen can readily be recognized without the aid of a lens, and the greater abundance of foraminifera will be retained on the 115 mesh screen. The material which passed through the 115 mesh screen was examined to determine whether it contained foraminifera, and to study the character of the individual grains composing the sample.

A Spencer binocular microscope was used for examining the samples. An auxiliary stage and tray were devised to greatly facilitate the work. The stage was made of a piece of plate glass twelve inches square painted black on the lower side, and mounted on four legs made of cork stoppers, which were glued to the plate with Canada balsam. The tray used was constructed from a piece of plate glass five inches by three and one-half inches which was painted black on the lower side and edges. The unpainted surface was ruled in one centimeter squares with white ink, and the squares numbered. The material examined was spread thinly upon the tray which can be moved easily about on the auxiliary stage. This auxiliary stage fits over the regular stage of the microscope. The tray proved very satisfactory because it provided a hard, smooth surface over an intense black background. Artificial light was used altogether.

Mounting of specimens

The foraminifera and other material taken from the samples were mounted on slides of the type devised by Mr. W.A. Waldschmidt for use in the laboratory of the Midwest Refining Company. Canada balsam was used as a mounting medium, and the tests placed in the desired attitudes for study. A number 00 sable-hair brush and a fine needle were used for picking out the tests and mounting them.

PLATE I

Fig. 1 Nodosaria Seminuda

Fig. 2 Nodosaria soluta

Fig. 3 Sponge spicule

Figure4 Cristellaria Cultrata

Fig. 5 Haplofragmoides canariensis (d'Orbigny)

Fig. 6 Vaginulina (?)

Fig. 7 Vaginulina legumen (?)

Fig. 8 Vaginulina legumen (?)

Plate I

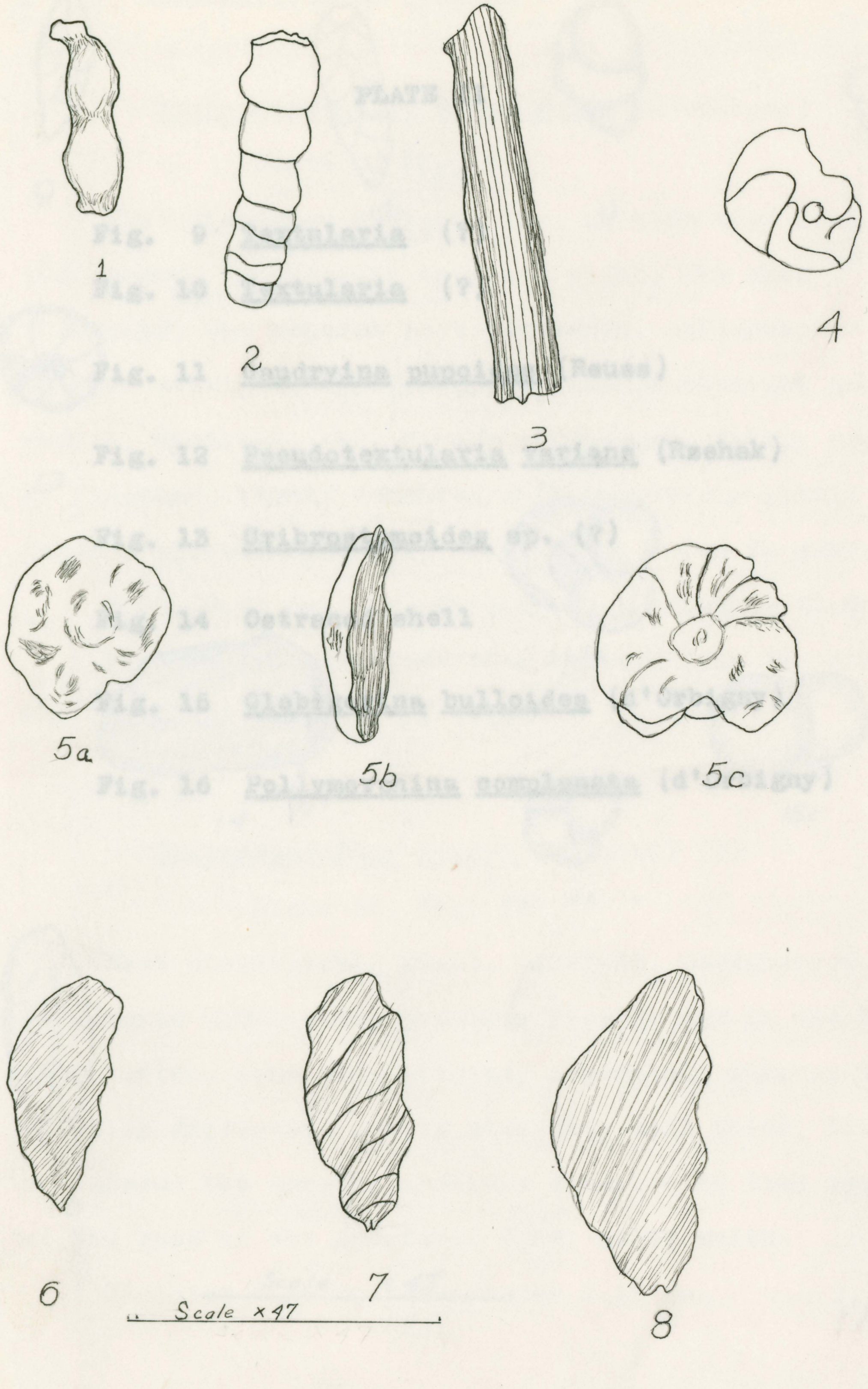


PLATE II

Fig. 9 Textularia (?)

Fig. 10 Textularia (?)

Fig. 11 Gaudryina pupoides (Reuss)

Fig. 12 Pseudotextularia varians (Rzehak)

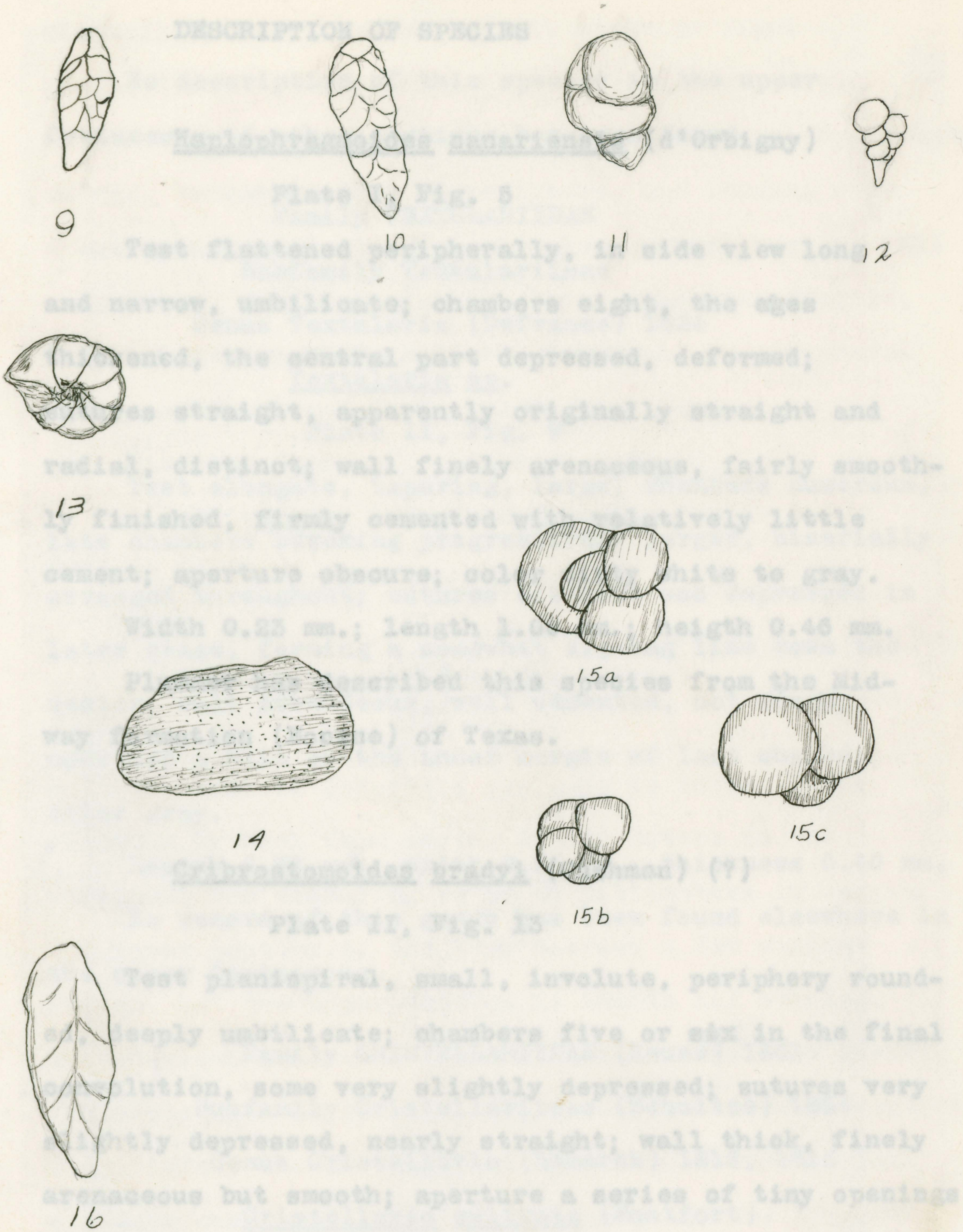
Fig. 13 Cribrostomoides sp. (?)

Fig. 14 Ostracod shell

Fig. 15 Globigerina bulloides (d'Orbigny)

Fig. 16 Pollymorphina complanata (d'Orbigny)

Plate II



DESCRIPTION OF SPECIES

<u>Haplophragmoides</u> <u>canariensis</u> (d'Orbigny)

Plate I, Fig. 5

Test flattened peripherally, in side view long and narrow, umbilicate; chambers eight, the edges thickened, the central part depressed, deformed; sutures straight, apparently originally straight and radial, distinct; wall finely arenaceous, fairly smoothly finished, firmly cemented with relatively little cement; aperture obscure; color dirty white to gray.

Width 0.23 mm.; length 1.00 mm.; heigth 0.46 mm.

Plummer has described this species from the Midway formation (Eocene) of Texas.

<u>Cribrostomoides</u> <u>bradyi</u> (Cushman) (?)

Plate II, Fig. 13

Test planispiral, small, involute, periphery rounded, deeply umbilicate; chambers five or six in the final convolution, some very slightly depressed; sutures very slightly depressed, nearly straight; wall thick, finely arenaceous but smooth; aperture a series of tiny openings at the base of the apertural face; color white.

Diameter 0.40 mm.; thickness 0.17 mm.

No description of this species in the upper Cretaceous of other sections has been found.

Family TEXTULARIIDAE

Subfamily Textulariinae

Genus Textularia (Defrance) 1824

Textularia sp.

Plate II, Fig. 9

Test elongate, tapering, large; chambers numerous, late chambers becoming progressively larger, biserially arranged throughout; sutures distinct and depressed in later stage, forming a somewhat zig-zag line down the center; wall arenaceous, well cemented, not rough; aperture a slit at the inner margin of last chamber; color gray.

Length 0.75 mm.; width 0.55 mm.; thickness 0.40 mm.

No record of this genus has been found elsewhere in the upper Cretaceous.

Family CRISTELLARIIDAE (Reuss) 1861

Subfamily Cristellariinae (Schultze) 1854

Genus Cristellaria (Lamarck) 1812, 1816

Cristellaria cultrata (Montfort)

Plate I, Fig. 4

Test planispiral, lenticular, biconvex, involute, slightly keeled; chambers six to eight in final convolution, translucent except for a narrow margin on all sides; sutures flush or slightly depressed; limbate, curved, becoming wider at periphery, and merging with a quite large and somewhat circular central region; wall calcareous, finely perforate, thin, appearing fragile, translucent; apetture radiate, terminal, on peripheral margin of apertural face; color shiny tan.

Diameter 0.60 mm.; thickness 0.20 mm.

C. cultrata is described from the Taylor and Navarro of Texas.

Nodosaria Seminuda (Reuss)

Plate I, Fig. 1

The test of Nodosaria seminuda is large, those obtained by Goes from depths of 530 meters in the Caribbean Sea measuring 18 to 22 millimeters in length. The lower portion of the test carries a few surface striae, but the upper portion is smooth and shining. The chambers are rather closely set and the form stout. The septa are not strongly depressed, nor are the segments constricted, though they tend to become so toward the ultimate chambers. Many are perfect, and the longer forms are six millimeters in length. They are not as straight as the type illustrated by Goes. The primordial chamber is less bulbous than the type, but it carries the spinous prolongation characteristic of the species.

Genus Nodosaria Lamarck 1812

Genotype by designation, Nautilus raphanistrum, Linne'

<u>Nodosaria soluta</u>

Plate I, Fig. 2

Test with the chambers in a straight linear series, the chambers distinct, not strongly embrasing; sutures normally at right angles to axis; wall calcareous, finely perforate, glassy; aperture central and terminal, radiate, often with chamberlet below with a rounded opening in the main cavity of the chamber. Shell smooth, straight or arcuate; segments inflated; septa depressed and transverse; some specimens mucronate; few chambers. The deep constrictions between the chambers make these shells fragile, and they are seldom preserved entire.

Family POLYMORPHINIDAE

Subfamily Polymorphininae

Genus Polymorphina (d'Orbigny)

<u>Polymorphina complanata</u> (d'Orbigny)

Plate II, Fig. 16

Test elongate, compressed, elliptical in end view; chambers ten to twelve, arranged biserially, compressed slightly becoming larger later, set directly opposite, giving straight central line; sutures slightly limbate, little if at all depressed, slightly curved; wall thin, calcareous; aperture radial, terminal; color light, dull tan.

Length 0.83 mm.; width 0.25 mm.; thickness 0.09 mm.

This species is hot described elsewhere in the upper Cretaceous.

Genus Vaginulina (d'Orbigny)

Vaginulina legumen

Plate I, Figs. 7 and 8.

Test compressed, usually with one side of the test straight, representing the periphery in coiled forms, the other typically convex; sutures oblique, the highest on the straight side of the test; aperture at or near the peripheral angle. The septa are oblique and somewhat depressed; the surface is smooth; the ultimate chamber is prolonged on the inner margin into a nipple shaped fissured aperture; the initial segment may be with or without spine.

Genus GLOBIGERINA (d'Orbigny)

Globigerina bulloides

Plate II, Fig. 15

Test trochoid throughout, umbillicate, chambers of the young, especially in the microspheric form in a flattened trochoid form like Discorbis. Usually smooth and the wall thin; later chambers globular; wall thick and cancellated; in well preserved, especially pelagic species, clothed with long slender spines coming from the angles of the cancellated surface areas, the base of such areas with the pores of the walls calcareous; aperture large opening into umbillicus.

Genus PSEUDOTEXTULARIA (Rzehak)

PSeudotextularia varians (Rzehak)

Test with the early chambers as in Gumbelina but in the adult having a series of globular chambers arranged in a more or less spiral manner about the upper portion of the test. Gumbelina, test with the early chambers planispiral, at least in the microspheric form, later chambers biserial; wall calcareous, perforate; aperture large and open, arched, at the base of the inner margin of the last-formed chamber, without teeth.

Ostracod shell

One specimen of Ostracod was found by the author, a shell with the characteristic markings of Ostracods and haging some minute nodes.

Sponge spicules

Many long thin tubular forms were found, some of them bearing striations; others were smooth and tapered to a fine, needle-like point.

Carbon residues

Numerous particles of what seemed to be carbon residues were found. These were about the size of sand grains. Most of them were shiny, although some are dull and granular.

Pyrite

Some spheroidal agglomerates of tiny balls of pyrite were found. It has been suggested that these are probably the product of recrystallization from ground water, and because of this origin are probably not related to the bedding.

Black balls

Some round blue-black particles were found, probably carbonaceous matter.

Conclusions

The results of this investigation have not indicated that Foraminifera have any particular value as horizon markers in the Pierre formation. It was hoped at the outset of the problem that the study would indicate definite foraminiferal zones in the shales which might be used to correlate various strata within the formation, and that the foraminifera might have commercial value as an aid to identification of well cuttings.

The failure to establish any definite zones may be due to one or both of two causes: first, that foraminifera of any particular species are not confined to any well-defined zones and therefore have no correlative value; or, second, that outcrop samples are subjected to such a high degree of leaching by surface waters and circulating ground waters that much of the foraminiferal material has been destroyed. If it is true that the tests of these microscopic animals have been removed from the outcrop samples, only the drilling of a large number of wells will furnish sufficient samples to determine the correlative value of the microscopic faunas.

The results of other microscopic studies of the Pierre indicate that foraminifera are much more abundant and that a greater variety of species are present in well cuttings than in the samples used in this work.

The distribution of foraminifera found in the Pierre would indicate that the abundance of any species or group of species at a particular horizon, see plate IV, in the formation is probably due to local environment such as temperature, velocity of current, or type of material being deposited.

The almost complete absence of recognizable foraminifera in the Hygiene and other sandstone members of the Pierre may indicate that the stronger current necessary to transport sand was not favorable to the development of microscopic faunas.

The presence of Glauconite in all the sandstones examined and in the shales immediately above and below suggests that shore conditions must have been present at no great distance, or that the water was rather shallow when the sandstones were deposited.

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Plate III Distribution of Foraminifera

Date Due

APR 2 1		MAR 25 '59 CU	
Se 13 '37F		AUG 19 '61 CU	
Oc 2			
JAN 1 7 1944			
AUG 2 9 1949			
AUG 4 1950			
OCT 7 - 1950		APR 4 '66 ES	
JAN 1 9 1952		MAY 10 '68 ES	
JUN 2 9 1953			
JUL 8 1953			
Aug 25, 1954			
JUL 2 6 1955			
NOV 1 5 1955			
JUN 9 '61 CU			