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Corrections from the Fox Hills Formation Trail City Member

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CONCRETIONS FROM THE FOX HILLS FORMATION TRAIL CITY MEMBER

by

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LIST OF FIGURES

ABSTRACT

Concretions occur as fairly continuous horizons in the Trail City Member of the Fox Hills Formation. These horizons are used as stratigraphic markers for correlation of the formation.

Two general types of concretions are found. The first is sandstone which occurs either as spherical or lenticular shaped forms. The other type has a hard blue-gray limestone core and is usually spherical in shape. Although both types may contain fossils, the unfossiliferous concretion is more abundant.

The concretions were formed either by accretion of material from the sediment, and from connate and ground waters; or by rolling, in the same manner as an armored mud ball form.

INTRODUCTION

Occurrences of concretions have been noted by several geologists who have worked on the stratigraphy and paleontology of the Fox Hills Formation of North and South Dakota. These concretions occur in the basal Trail City Member.

This paper describes the occurrence and types of concretions found and presents hypotheses on their origin.

Definition of Concretion

The term concretion, in a restricted sense, refers to a form which has been built up by the addition of material about a center, the material being progressively older inward.

According to Twenhofel (1950 p. 594), "concretions are aggregates of inorganic sedimentary materials in other sediments. Many have a nucleus and internal structure is very commonly concentric."

Concretions may be present in all unmetamorphosed sedimentary formations. The concretions found in the Fox Hills Formation agree with Twenhofel's definition of concretion, except in some instances. A minority of the concretions as they appear in outcrop are fossiliferous. The majority appear to have no organic content.

Previous Investigations of Fox Hills Concretions

Previous workers on the Fox Hills have mentioned the concretions of the formation. However, the general interest has centered on the fossiliferous type concretion in relation to stratigraphic interpretation and correlation of the formation.

Meek and Hayden in 1861 were the first to name and describe the Fox Hills Formation. Since that time, all workers have noted the concretions and the concretions are now used as stratigraphic markers for the Lower Trail City Member of the Fox Hills Formation. These concretionary zones first appear in the Lower Trail City Member and are generally nine to fifteen feet above the Pierre-Fox Hills contact.

Waage (1961) has divided the concretion-bearing portion of the Trail City Member in South Dakota into six zones based on a fossil element which dominates a particular zone. The zones are, progressing from oldest to youngest: (1) the *nicolleti* zone in which concretions contain masses of the ammonite *Discosaphites* *nicolleti*. (2) *Limopsis*-*Gervillia* zone which overlies the *nicolleti* zone is made up of two layers. The lower layer of concretions contains a small pelecypod *Limopsis* *striato-*

punctatus and a few other fossils. The upper concretion layer consists almost entirely of the pelecypod *Gervillia recta*. (3) The *Protocardia* zone, overlying the *Limopsis-Gervillia* zone, is made up of concretions which may contain two different pelecypods, *Protocardia subquadrata* and *Pteria nebrascana* and an assortment of other fossils. (4) and (5) Between the *Protocardia* and the upper *abyssinus* concretion zone are two zones which are barren of fossils. (6) Above the barren zone is the *abyssinus* concretion zone. This is just below the top of the Trail City. The most characteristic feature is the abundance of immature scaphites that appear to belong to *Discoscaphites abyssinus*.

According to Feldman (oral communication, Department of Geology, U.N.D.) the same zones are only applicable to the Trail City Member of the Fox Hills of North Dakota at certain localities. In some outcrops the faunal element does not exist in what would be a corresponding concretion zone of the type section in South Dakota. This may be explained by a change in the depositional environment, which determines the habitat of organisms.

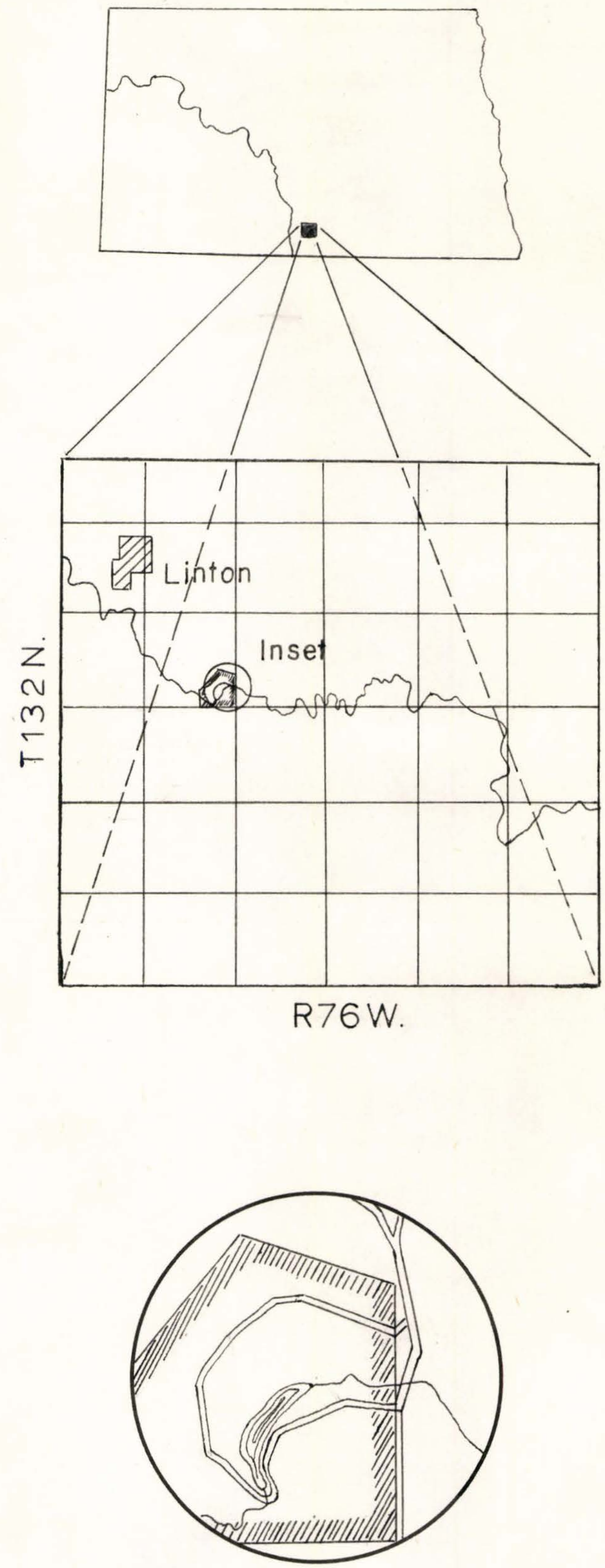
GEOLOGIC SETTING AND DESCRIPTION OF CONCRETIONS

The concretions described in this report occur in the Trail City Member sediments of the Fox Hills Formation of North Dakota. The Fox Hills Formation is made up of four members. At the base is the Trail City Member which is clayey silt and silty to sandy clay with fossiliferous and unfossiliferous concretion zones. Above the Trail City is the Timber Lake Member which consists of a fine to medium-grained dirty greenish-gray sand. Concretions occur in this member also, but are usually discontinuous,unfossiliferous layers and cannot be used as markers. Overlying the Timber Lake is the Bullhead Member which is distinctive in that banding appears as a result of alternation of thin beds of gray clay shale and light-gray siltstone. In the lower part of the member bentonitic shales are found. The Colgate Member overlies the Bullhead and is a fine to medium-grained dirty sandstone. In the type area the Fox Hills is 300-350 feet thick (Waage, 1961, p. 231).

A trip was made to Linton, North Dakota, (figure 1) to obtain and observe some concretions as they appear in outcrop. In the vicinity of Linton, located in south central North Dakota, several outcrops of the Fox Hills Formation are found.

Two miles southeast of Linton is Seaman Park (SW, SE, SE, SEC. 17, T 132 N, R 76 W, Emmons County, N.D.).

Figure 1



Inset - Seaman Park
sec. 17, T.132N., R.76W.
Emmons Co., N.D.

At the south edge of the park, a steep escarpment (figure 2) rises to a height of approximately 140 feet. Of this 140 feet approximately 100 feet is Pierre Shale. Above the Pierre is approximately 40 feet of the Lower Trail City Member of the Fox Hills Formation. The first zone of concretions appears about 10-15 feet above the Pierre Fox Hills contact. Nearly all concretions found had a gypsiferous shell encircling them. The bedding around the concretions was bowed to conform to the spherical concretion. This is probably due to growth of the concretion penecontemporaneously with sedimentation. Most of the concretions are distributed in continuous layers in the Linton area.

After preliminary examination of the concretions collected from the outcrop, it was found that there are two types: (1) The first type is a sandstone concretion which appears to be stratified bedded. This bedding is also apparent when the concretion is subject to weathering. The concretion may appear as a lenticular accretionary zone or as a spherical body. The spherical bodies perhaps began developing earlier when overlying sediment was thin, thus had a longer time to develop than the lenticular type, accounting for the difference in shape. In some cases, this type concretion is

FIGURE 2. Photo showing escarpment and Trail City Member of Fox Hills Formation at Seaman Park. **View looking southeast.**

fossiliferous, though not abundantly so. A spherical concretion about 10 inches in diameter was cut in half and a few (20-30) fossils were seen in the cross-section. All the fossils in this concretion were clustered at the top half in an area of about 2 square inches. In this concretion, it would appear that all the fossils became part of the concretion as it grew. Thus, this type should, perhaps, be called an accretion rather than a concretion, but for this investigation will be called a concretion. The sandstone concretions show no variation in grain size or color from outer edge to the center. The matrix is a fine-grained sandstone and appears to be the same as the surrounding Fox Hills lithology.

(2) The other type concretion found was in some cases fossiliferous and in other cases completely lacking in fossils. The size of these concretions ranges from 3 inches to 2 feet in diameter. The shape varies from spherical to ellipsoidal, but in general, is spherical in shape. Those lacking in fossils have a dense, hard, gray-blue, limestone core.

All of these concretions have an outer rind varying from 1/8 inch up to an inch in thickness. This outer rind in most cases contains gypsum. Sometimes the gypsum will form lenticular crystals a quarter inch in length. Those concretions with a thick outer rind show a decrease in carbonate from the center to the outside. Concretions with a thin rind are carbonaceous from the outside perimeter to the inner core.

Some of the concretions exhibit outlines of what appear to represent growth stages. The size of these bands varies, which probably indicates variation in growth. The color of the bands ranges from the gray-blue mentioned above to a brownish gray. The outside rind is always a light buff brown. This is probably due to chemical and physical weathering when the concretion is exposed at the surface by erosion of surrounding bedrock. Other concretions found show no circular bands or growth rings in cross-section, only an outer weathering rind. These also have a core of gray-blue limestone and do not show structure of any kind. In some, fractures appear that have been filled with either gypsum or calcite.

The fossiliferous concretions have the same shape, same gray-blue limestone core and gypsiferous rind around the outside as the unfossiliferous concretions mentioned above. This outer rind in all concretions found spalls off very easily and contains an assortment of ammonites and pelecypods. In some cases, as the concretions were removed from the outcrop, this layer ~~would~~ remained behind (figures 3 and 4).

The gypsiferous layers indicate one of two things:

(1) that the concretion is, because of weathering, slowly disintegrating and the outer rind is being removed. So that after a prolonged period of time this concretion would no longer exist.

(2) that this layer is probably due to accretion. This seems to be the more plausible reason, due to the fact that gypsum is frequently found in the subsoil of North Dakota. No attempt was made to determine the sedondary accretionary forces drawing the gypsum to the concretion. The force is probably quite similar to those that which caused the inner concretion to form.

The fossils found in these concretions consist of gastropods, cephalopods, and ammonites. In some of the concretions they are extremely abundant, in others, very few are seen. A count of the fossils in several of these, from a cross-section, ranges from 2 up to 208 in an area of 40 square inches.

Orientation of Fossils in Concretions

Four concretions having a fossiliferous hard gray-

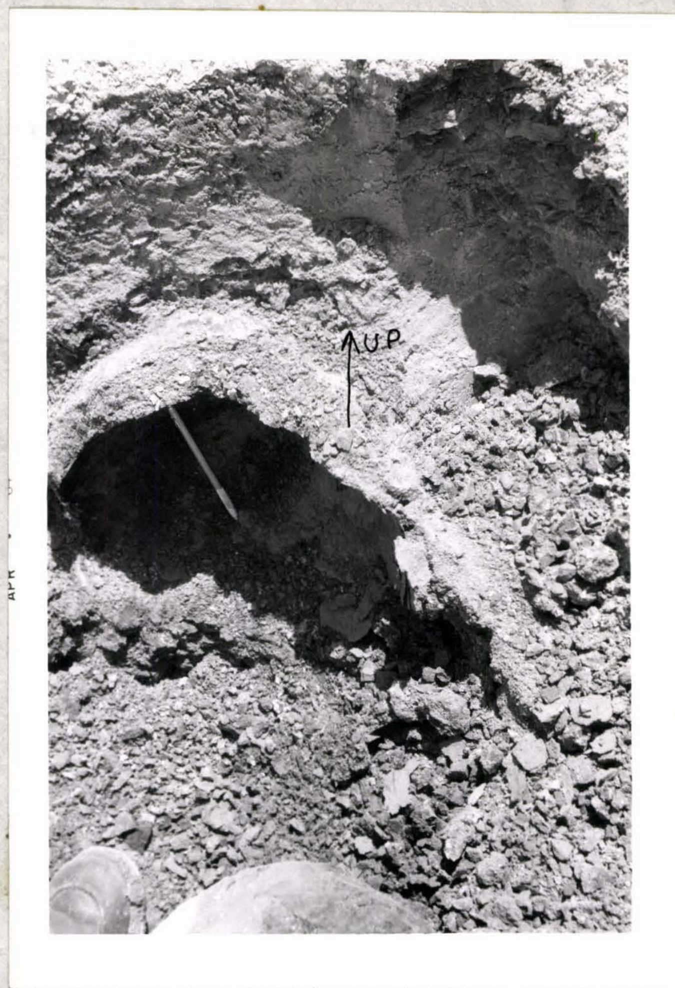


FIGURE 3. Photo showing gypsiferous rind in the outcrop after concretion was removed. Location SW, SE, SE, SEC. 17, T 132 N, R 136 W, Emmons County, N.D.

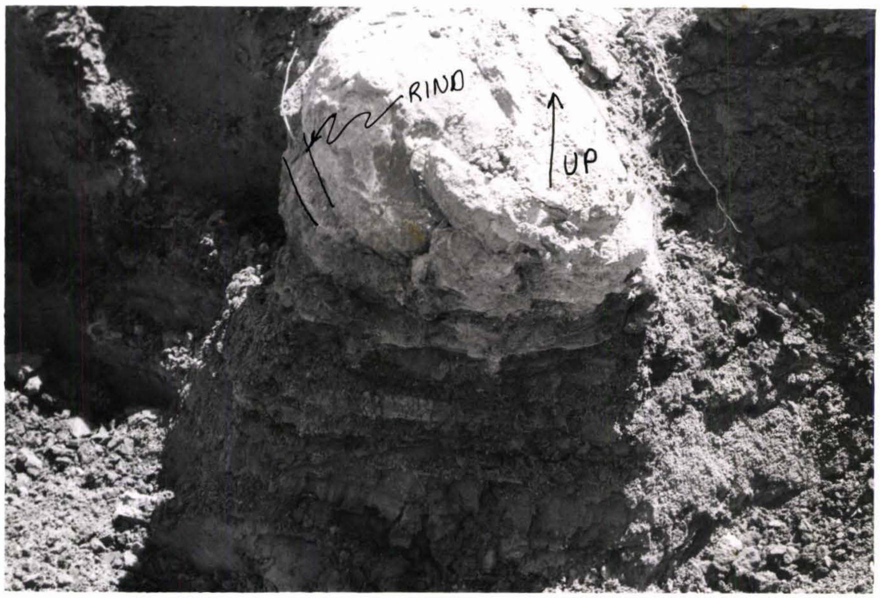


FIGURE 4. Photo showing gypsiferous rind on concretion in place in outcrop. Location SW, SE, SE, SEC. 17, T 132 N, R 136 W, Emmons County, N.D.

blue limestone core were cut in half. Orientation of the fossils in the concretion was determined in relation to the orientation of the concretion as it was found in outcrop.

Of the four concretions, one had a known orientation and the other three orientations were assumed. The orientation of the latter was unknown because at the time of collection, the collector was primarily interested in the paleontology and stratigraphy of the formation and not in the origin of the concretion. Of ten concretions collected, by the author, only one was fossiliferous.

Rose diagrams were plotted of the orientations of the fossils in the concretions (figure 5 A, B, C, D). As may be seen by the diagrams, neither a heterogeneous nor a parallel orientation is dominant. If a heterogeneous orientation of the fossils was shown by the rose diagram it would have indicated rolling had taken place as part of the origin of the concretion. On the other hand, if the shells and fragments had shown parallelism it would have indicated formation in place.

Though a strong preferred orientation is not shown, it appears that parallelism is more the tendency than a heterogeneous arrangement. The orientation of the

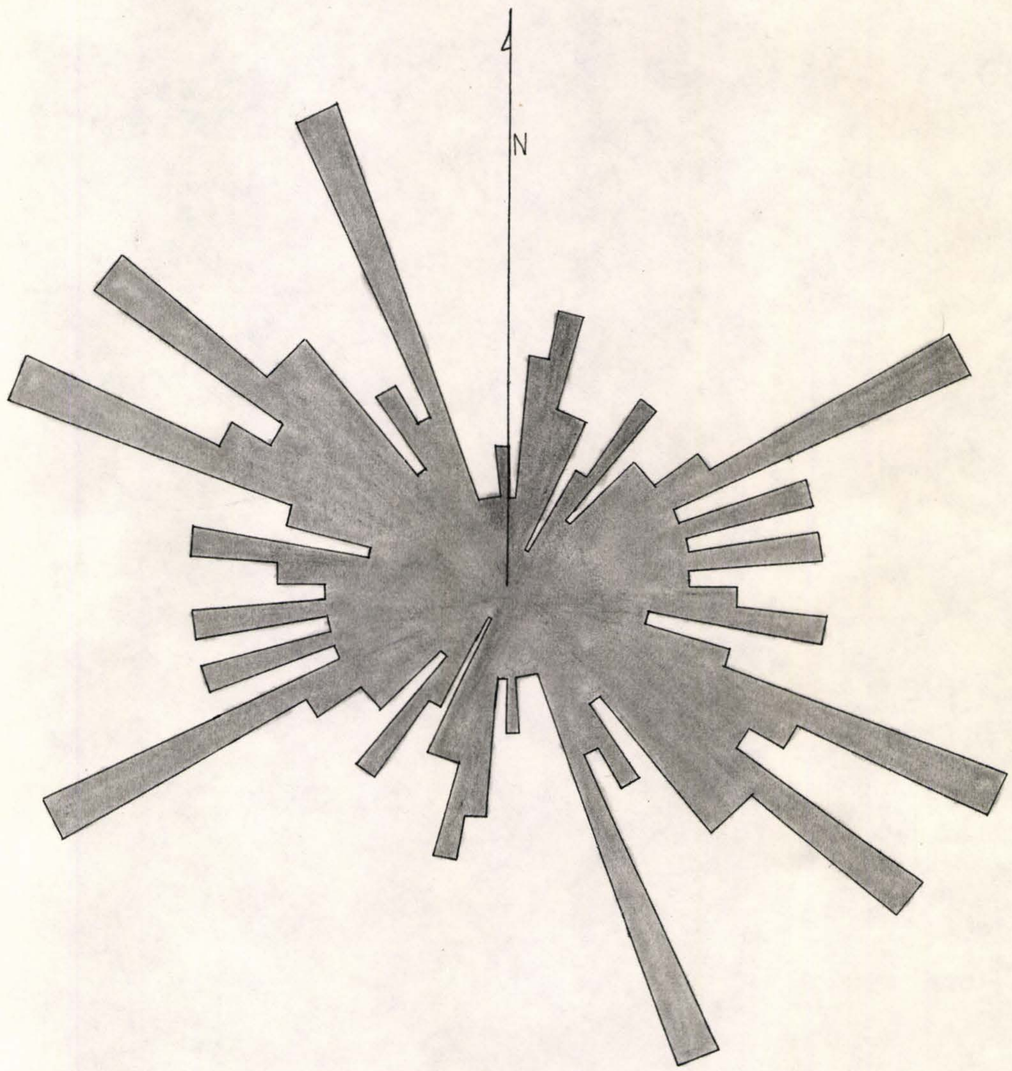


FIGURE 5 A. Rose Diagram showing orientation of fossil shells in concretion. N arrow indicates top of concretion as taken from outcrop. (208 fossils)

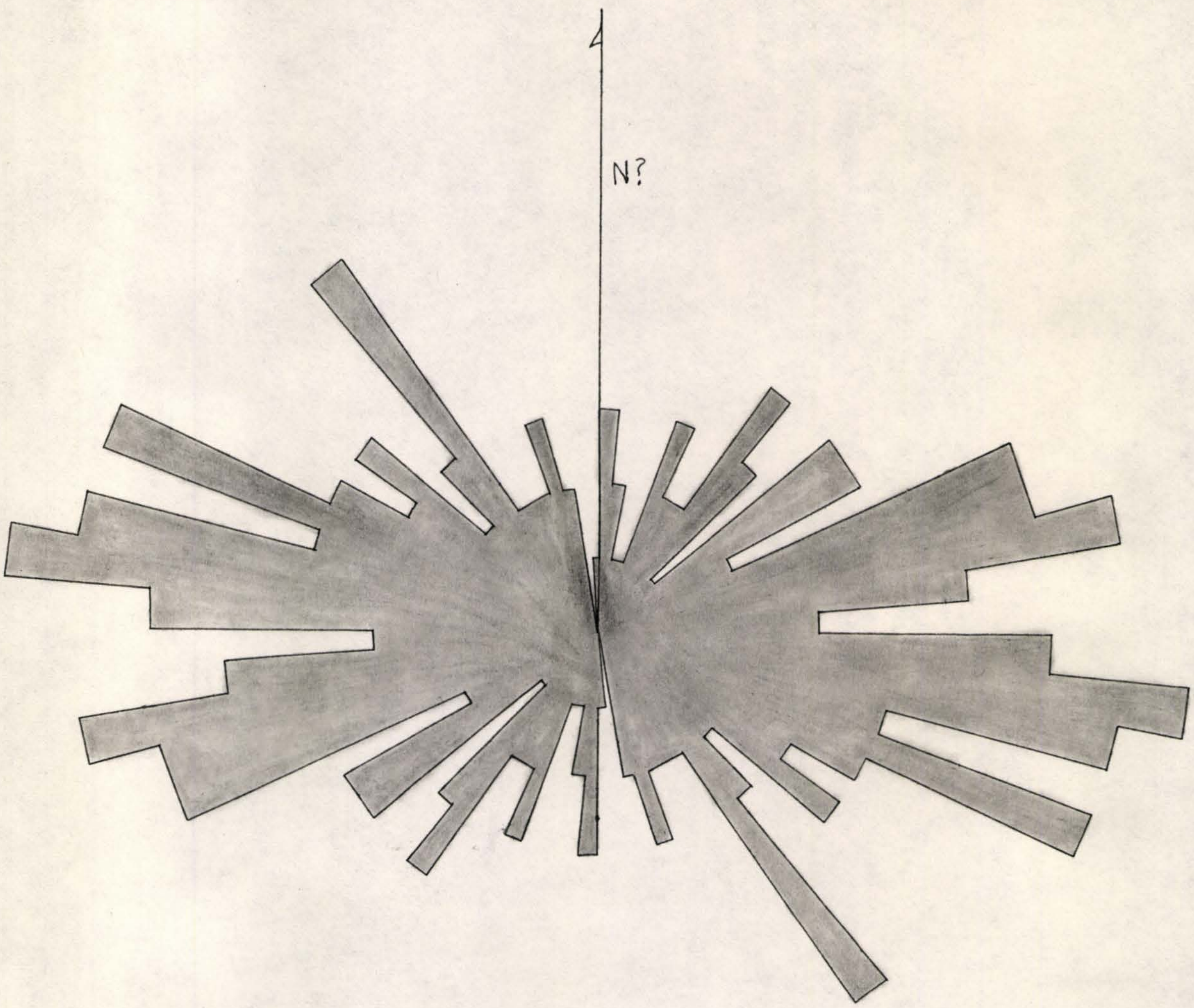


FIGURE 5 B. Rose Diagram showing orientation of fossil shells in concretion. N arrow indicates top of concretion as taken from outcrop, except true orientation in outcrop not known. Direction assumed as shown by question mark. (128 fossils)

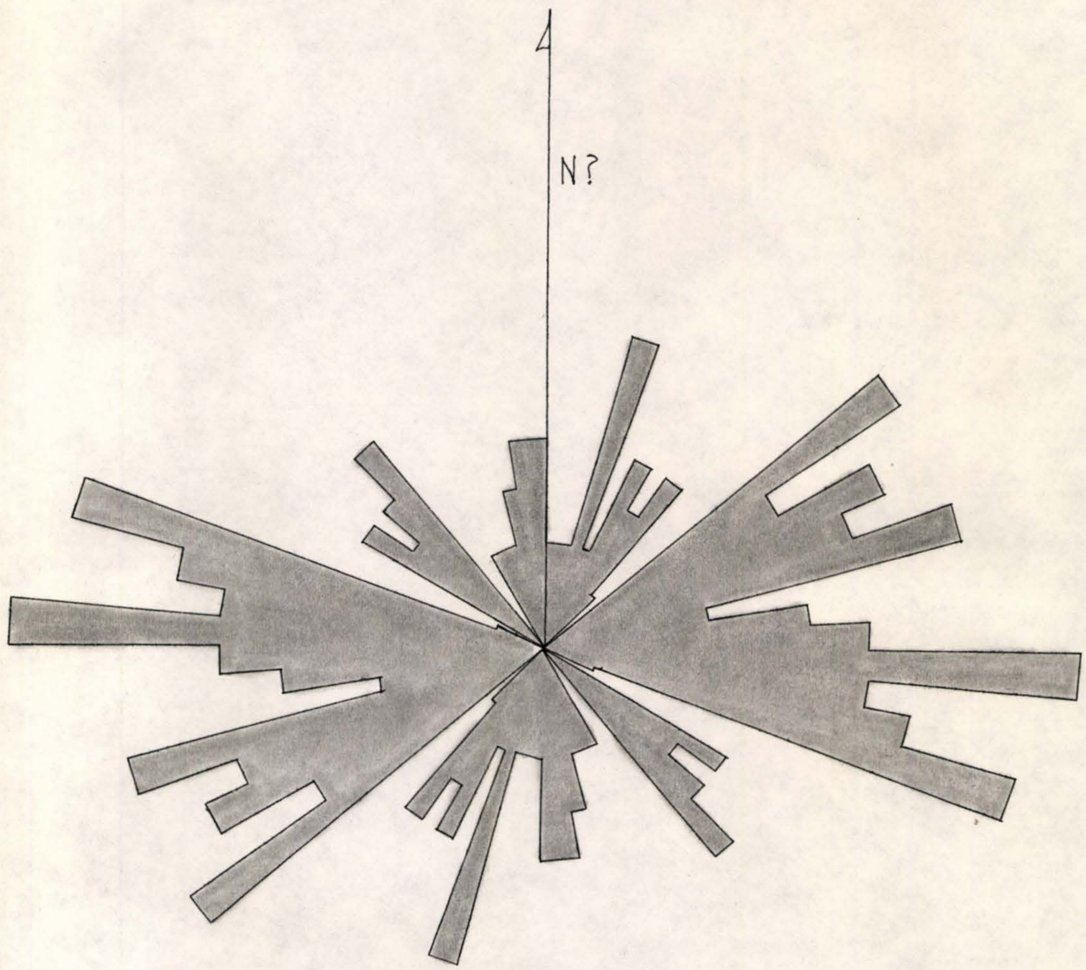


FIGURE 5 C. Rose diagram showing orientation of fossil shells in concretion. **N** arrow indicates top of concretion as taken from outcrop, except true orientation in outcrop now known. Direction assumed as shown by question mark. (178 fossils)

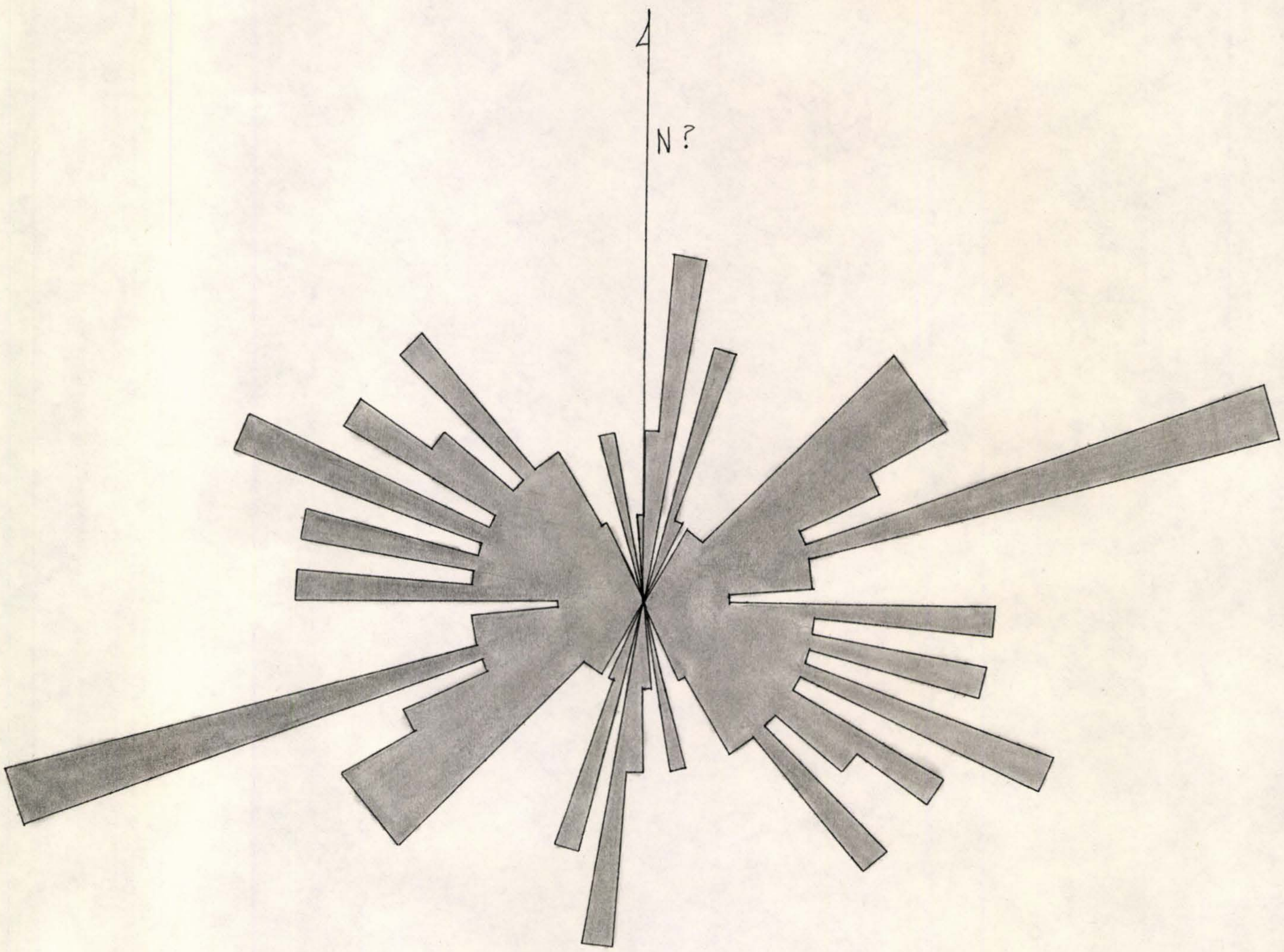


FIGURE 5 D. Rose diagram showing orientation of fossil shells in concretion. N arrow indicates top of concretion as taken from outcrop, except true orientation in outcrop not known. Direction assumed as shown by question mark. (101 fossils)

fossils enclosed within the concretions would have to be determined in many more concretions before a dominant orientation would indicate conclusively a heterogeneous or parallel orientation.

ORIGIN OF TRAIL CITY MEMBER CARBONATE CONCRETIONS

Two hypotheses regarding the origin of the concretions of the Trail City Member of the Fox Hills Formation will be brought forward. They are: (1) the concretions formed in place and are thus of epigenetic origin, and (2) the concretions are actually not concretions but mud balls and were formed by a process of rolling during sedimentation.

The idea that the concretions formed in place arises from the fact that they are widespread. They are found at the same horizon in the Trail City Member in North and South Dakota. In all exposures where bedding can be seen in relation to concretions the bedding curves over and under the concretion (figures 6 and 7). In some of the concretions it is apparent that they have grown by accretion, as several concentric bands can be seen in cross-sections.

As mentioned above, the orientation of the fossil shells was measured in the fossiliferous concretions. As can be seen by the rose diagrams (figures 5 A, B, C, D),

FIGURE 6

FIGURE 7

Photos showing bedding bowed over and under concretion in place in outcrop. Location SW, SE, SE, SEC. 17, T 132 N, R 136 W, Emmons County, N.D.

a slight preference in orientation indicates the shells more closely approach a parallel position in relation to each other, than a heterogeneous orientation within the concretions.

The latter paragraph may be far from fact because many more fossiliferous concretions should be measured before exact conclusions are drawn.

Thin sections were made of both fossiliferous and unfossiliferous concretions. The fossiliferous concretions were found to contain angular fragments of dominantly quartz and feldspar grains in a silty matrix. Besides shell and shell fragments, scattered pieces of wood (which appeared to be rotten and showed no replacement) are found in cross-section. All grains appear to be very fine sand size (Wentworth grade scale). This would indicate that the concretion formed in place. If a variable grain size had been found it would indicate that the concretion may have formed by rolling. This is considered in the second hypothesis in another part of this paper. —?—

In the unfossiliferous concretions, matrix dominates so much so that in a thin section one inch long by a half inch wide, three fourths of the section is matrix of silt-size material. The remainder consists of very fine sand size (Wentworth grade scale) quartz and feldspar grains.

In the places where coarse grained sediment is found, definite shapes are seen macroscopically, which in a cross-section appear to represent the outline of a mollusca shell. Under microscopic examination, these areas are found to contain coarse grained sediment. According to Waage (1961), the Trail City Member appears to have been thoroughly reworked by burrowing organisms. If this is so, this may indicate that certain of these concretions as described above should contain fucoid markings. These markings are not only on the periphery of the concretion but are heterogeneously scattered throughout.

If these are fucoid markings, then this would mean that the concretions were being burrowed into by organisms during formation and during a stage when they were soft enough for organisms to penetrate them. It does not seem possible that the concretion was burrowed after it had become lithified. Also, these cavities are now filled with coarse grains of mostly quartz and feldspar. This indicates that as these organisms burrowed and then abandoned the cavities, the cavities were filled by coarser sediment surrounding the concretion. Another possibility is that these areas of coarse material were simply accreted as the concretion was forming.

If the first mentioned hypothesis is valid, this would indicate a syngenetic or penecontemporaneous (with sedimentation) origin for some of the concretions found in the Trail City Member.

As mentioned before, nearly all concretions found have a gypsiferous rind encircling the outermost margin of the concretion. This indicates that all the concretions, through the thousands of years since formation, have continued to grow. This would also indicate that connate and ground water must furnish a continuous source of material to produce growth. This is variable, however, as can be seen by the variation in width of rings. Some of the concretions were in more advantageous position than others in relation to connate and percolating ground waters. This may be demonstrated by size. In one case, a concretion 3 inches in diameter shows five rings of accretion, whereas, another is 10 inches in diameter and indicates only one zone of accretion.

The second hypothesis, as stated, indicates a syngenetic origin. The origin of the concretions, if formed this way, would be much the same as that of an armored mud ball. Armored mud balls form by rolling across sediment and accreting pebbles and sediment which lie in their path. Their energy is developed in many ways, such as water or uplift which supplies energy for them to roll and thus accrete the sediments which may later become indurated and allow for preservation. The concretions of the Timber Lake Member of the Fox Hills Formation may have been formed in this manner. Another possibility is, a particle was rolled back and forth by either waves or currents and accreted the sediment and organic substances in its path.

Two particular reasons occur which cause doubt as to the reliability of this hypothesis. The first is the widespread occurrence of the concretions. They are found in central South Dakota and extend north into south central North Dakota. It does not seem plausible that the same source of energy would occur at relatively the same time over this area to form concretions which now appear at the same horizon in the Fox Hills Formation of both North and South Dakota.

The second reason is the means by which the concretions would obtain the energy needed to form by rolling. This reason depends on two variables: (1) a slope would have had to be present for the concretions to roll down. This is plausible, but what cannot be explained is the phenomenon that would cause all the concretions to begin rolling and accrete sediment and fossils and then cease movement so that several distinct layers of concretions occur at the same stratigraphic interval in both North and South Dakota. (2) The second theory, as mentioned by the author, that of wave or current action rolling a spherical mass back and forth, is more plausible. However, the fineness of the sediment contained in the concretions would indicate that if they developed in this manner they were below wave base. Above wave base is found a rough water environment in which gravels and calcarenites are found. Fine particled sediment is found below wave base in quiet water environment. Would currents here be strong and consistent enough to move a body as large as some of these concretions are?

CONCLUSIONS

It is concluded that the concretions were formed in place by accretion of material from the surrounding sediment and from connate and ground water solutions.

Fossils found in great numbers in some of the concretions may be explained by environmental factors which would account for the large numbers of fossils in some concretions with concretions barren of fossils in other areas. It is possible that a dead sea type environment existed in this Cretaceous sea, which could have brought either brackish or fluctuation of anaerobic waters into the environment of the organisms now found in the concretions. The fossils were then either covered by sediment or penecontemporaneously with sedimentation formed loci of accumulation of carbonate from connate and percolating ground waters.

This paper does not solve the problem of the formation of the concretions found in the Trail City Member of the Fox Hills Formation. However, it may help future workers who inquire into the formation and origin of these concretions.

ACKNOWLEDGMENTS

The writer is grateful to Dr. John Reid of the Geology Department of the University of North Dakota who gave encouragement and many helpful suggestions. Mr. Rod Feldman suggested this topic for a thesis and supplied concretions for study. Mr. James Hollarn accompanied the author on a field trip to a collecting locality. Also, other students and professors in the Geology Department of North Dakota assisted with ideas and discussions on some of the hypotheses presented herein.

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