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The Status of Paleontology in North Dakota

by

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THE STATUS OF PALEONTOLOGY IN NORTH DAKOTA

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Introduction

Every once in a great while it behooves those working in a science to stop, examine their position, look backward and see where they have been, and where they are going. I propose to do this in this paper. Aristotle has said, "He who sees things grow from the beginning will have the best view of them", and so I might have entitled this paper, "The History of Paleontology in North Dakota"; however, it is hoped that more can be accomplished than just reviewing the history. Perhaps I can, indeed, chart some of the roads which must be traveled in the future.

Recently a colleague of mine from our history department

pointed out that geologists would certainly not want historians running geological surveys and that, in like manner, scientists do not do the best job of writing history. Even with this admonition, I feel constrained to plunge ahead.

To accomplish the end outlined above, I have divided the paper into three parts—a survey of the past history of paleontology in North Dakota, a partial review of the status of the science today, and a glance into the future.

A Backward Look

The fascinating field that is paleontology, the study of plants and animals of past geologic ages, has intrigued Man since he first developed imagination and curiosity.

Apparently this was equally true in North Dakota, for excavation of an Early Mandan Indian site, eight miles down river from the town of Fort Yates, Sioux County, has yielded (letter dated 2 November 1960, from W. Raymond Wood to Wilson M. Laird) an assemblage of fossil shells from the Fox Hills and Tongue River formations, or beds more than 60 million years old. The Fox Hills sandstone crops out not far from this site; but it must be nearly 40 miles to the nearest exposure of the Tongue River formation; and so the Indians must have carefully assembled these shells, some of which are commonly rather delicate and fragile. Were these Indians, then, the first fossil collectors in North Dakota? Surely they were!

Although not germane to the subject at hand it is intriguing to speculate on the use made of this cache of shells. Were these mystic objects used in an ancient rite? Were they trinkets brought home to the children? Or could the intellect have been stirred to puzzle the origin of these shells entombed in rock and to compare them with present-day shells found along the river bank?

Although numerous explorers, trappers, traders, and various entrepreneurs traversed parts of what is now North Dakota in the eighteenth centuy (La Verendrye in 1738, and his sons crossing through North Dakota in 1742 on their way to and from the Black Hills or the Big Horn Mountains; Jonathan Carver exploring the Red River valley in 1768 for the provincial government; James Mackay in 1795 penetrating as far north as the Mandan villages in the vicinity of present-day Bismarck; Charles Chaboillez establishing the first fur trading post within the boundary of North Dakota for the Northwest Company at Pembina in 1797; Alexander Henry establishing the Northwest Company post on the Red River at the mouth of the Park River and depots at the "Grandes Fourches" in 1800, and the establishment of Hudson Bay and XY Company posts at Pembina in 1801), none of these hardy souls—illustrious and lusty, romantic and daring, pioneering and roving though they were —apparently made significant scientific observations or collected

fossils to document for their more sedentary contemporaries the nature of this otherwise unexplored country.

One of them, the outstanding geographer and surveyor, David Thompson, was equipped and instructed in 1797 by the Northwest Company to determine the location of the 49th parallel and the company trading posts and the trails between them, to visit the Mandan Indians, and also to search for the fossil bones of large animals (Sheldon, 1961, p. 3). Thompson did an excellent job of surveying, especially in the vicinity of the Mouse River west of the Turtle Mountains and spent an unusually cold winter (1797-1798) with the Mandans, but I can find no record that he was successful in his search for fossils. It remained for the Lewis and Clark expedition to return with the first fossils collected by white men from North Dakota.

As you all know, perhaps one of the most significant events in early North Dakota history was the remarkable voyage of Meriwether Lewis and William Clark. Though rough and hardy men, little lettered by the standards of today, the excellence of their observations in the pursuit of their primary task, to explore the newly acquired Louisiana Purchase, in the face of grave obstacles, marks theirs as one of the truly great, scientific expeditions.

They entered (Reid, 1948) the state October 13, 1804, mapped the course of the Missouri River (Thwaites, 1959) through the state (as they had all along their route), noted the wildlife present in the area, and made what were apparently the first geological and paleontological observations. After their stay in a fort they erected near the present site of Stanton during the winter of 1804-05, they left what is now North Dakota on their westward trip on April 27, 1805, returned to North Dakota August 3, 1806, and took their final departure from the state on their way to St. Louis on August 20, 1806. Although it is a digression, perhaps, from the history of paleontology in North Dakota, their geological observations are so intriguing that they are worth recording here.

On 18 October 1804 at the Cannonball River, Lewis records,

> ". . . above the mouth of the river Great numbers of Stone perfectly round with fine Grit are in the Bluff and on the Shore, the river takes its name from those Stones which resemble Cannon Balls."[1]

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Some of the more imporant observations were those of the baked or melted and fused red shale and sandstone locally called

[1]It should be mentioned that these "cannonballs" are sandstone concretions in the Fox Hills formation of Cretaceous age not in the Cannonball formation of Paleocene age.

today "scoria" or "clinker" and so commonly employed today for road metal in the western part of the State. On March 21, 1805, as they made preparations to leave their winter camp, Clark reports:

> "Saw an emence quantity of Pumice Stone on the Sides & foot of the hills and emence beds of Pumice Stone near the Tops of the[m], with evident marks of the Hills having once been on fire. I Collected Some [of] the different [sorts] i. e. Stone Pumice Stone & a hard earth, and put them into a furnace, the hard earth melted and glazed the others two and the hard Clay became a pumice Stone Glazed."

Shortly after they left Fort Mandan (April 7) Lewis discusses the geology near the present town of Riverdale (April 9) saying,

> "the Bluffs of the river which we passed today were upwards of a hundred feet high, formed of a mixture of yellow clay and sand many horizontal stratas of carbonated wood, having every appearance of pitcoal at a distance; were seen in the face of these bluffs. these stratas are of unequal thicknesses from 1 to 5 feet, and appear at different elevations above the water some of them as much as eighty feet. the hills of the river are very broken, and many of them have the appearance of having been on fire at some former period. considerable quantities of pumice stone and lava appear in many parts of these hills where they are broken and washed Down by the rain and melting snow."

On the following day (April 10) just south of the site of Old Fort Berthold they noticed a bluff which Lewis records, ". . . is now on fire and throws out considerable quantities of smoke which has a strong sulphurious smell." This is probably the first record of a burning coal bed in North Dakota.

The voyagers continued their observation of the "clinker"-capped hills until exposures seen near the present Mountrail-McKenzie county line on 16 April led Lewis (Reid, 1948, p. 241-242) to speculate on the origin of this so-called "scoria".

> "I believe it to be the stratas of coal seen in those hills which causes the fire and birnt appearances frequently met with in this quarter. where those birnt appearances are to be seen in the face of the river bluffs, the coal is seldom seen, and when you meet with it in the neighbourhood of the stratas of birnt earth, the coal appears to be presisely at the same hight, and is nearly of the same thickness, togeter with the sand and a sulphurious substance which usually accompanys it."

The experiments of Clark, and these ideas of Lewis, antedate

the theories of George Catlin and John James Audubon by approximately 30 and 40 years respectively, and yet the interpretation is far more modern than the erroneous ideas held by the latter two. The words "pumice", "lava", and "scoria" used by early explorers were simply unfortunate choices and it is to be regretted that these technical terms connoting igneous activity have become entrenched in local modern usage for the sedimentary rock formed in the baking and fusing of shale and sandstone by burning of the underlying lignite.

Yet another significant observation was made on 16 April for Lewis (Reid, 1948, p. 241) writes,

> "I met with several stones today that had the appearance of wood first carbonated and then petrefyed by the water of the river, which I have discovered has that effect on many vegitable substances when exposed to it's influence for a length of time."

In these terms Lewis writes what is presumed to be the first record of fossils from North Dakota!

Lewis and Clark made other geological observations including "alkali" and glacial drift (without regarding it as such) and experimented with the combustion of lignite. It is interesting to note, however, that they mistook the Killdeer Mountains for the "turtle mountains". The return trip of the travelers through the state in 1806, made wih relative haste, required only 17 days, and no geological observations were recorded.

The famous botanist Thomas Nuttall visited North Dakota in 1811 as did the naturalists John Bradbury in 1811 and William Price Hunt in 1812, but they seem not to have recorded geological or paleontological observations in the state.

Many other voyageurs, trappers, and hunters crisscrossed North Dakota and plied her waterways, but the next significant records were those left by the artist George Catlin who, in 1832, was on the first steamboat to reach the Yellowstone River. Catlin wrote like the artist he was and misinterpreted the origin of "clinker" although his word pictures of the Badlands[2] are as beautiful as his brightly colored paintings. On his voyage downstream from the post at the mouth of the Yellowstone he recorded his observations of the country and the rock strata. In discussing buttes along the way he wrote (Catlin, 1913, p. 79),

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[2]As used herein, "Badlands" refers to the Badlands of North Dakota especially well developed along the Little Missouri River, but also occurring along the Missouri River and lesser tributaries. The Badlands of North Dakota are formed in the Tongue River formation (of Paleocene age) and older formations; the "Little Badlands" just southwest of Dickinson are developed in the White River formation of Oligocene age as are the Badlands of South Dakota.

". . . . the superstratum, forming the tops of these mounds (where they remain high enough to support anything of the original surface) is composed, for the depth of fifteen feet, of red pumice; terminating at its bottom, in a layer of several feet of sedimentary deposit, which is formed into endless conglomerates of basaltic crystals.

"This strange feature in the country arrests the eye of a traveller suddenly, and as instantly brings him to the conclusion, that he stands in the midst of the ruins of an extinguished volcano."

Erosion in the Badlands impressed Catlin greatly and he paused to paint and write (p. 89) less than a day's journey north of the Mandan villages,

"These stupendous works are produced by the continual washing down of the sides of these clay-formed hills; and although, in many instances, their sides, by exposure, have become so hardened, that their change is very slow; yet they are mostly subjected to continual phases, more or less, until ultimately their decomposition ceases, and their sides becoming seeded and covered with a green turf. . . ."

Thus, in spite of his "conclusion" regarding volcanoes in North Dakota, Catlin's ideas of badland erosion were relatively modern; this is remarkable since they came so hard on the heels of the catastrophic theories expounded elsewhere in the world.

One of the finest scientists and observers to reach the Upper Missouri country was the German nobleman, Alexander Philip Maximilian, Prince of Wied-Neuwied who reached Fort Clark, founded in 1831 near the present town of Stanton, on June 18, 1833. A careful observer, he too, commented (Thwaites, 1905, p. 338) on the "cannonballs" near the mouth of the Cannonball River, and he observed, in this area, the dip of the strata into what is now known as as the Williston Basin.

In the vicinity of Fort Union he wrote (p. 383),

"The strata of sand-stone occurring in the above-mentioned hills are filled, at least in part, with impressions of the leaves of phanerogammic plants, resembling the species still growing in the country."

He apparently made the first extensive fossil collection in North Dakota for in a short but touching footnote (p. 383) he says of his fossil leaves, "Unfortunately, all these interesting specimens were destroyed in the fire on board the steam-boat." This refers (**fide** Thwaites, 1905, p. 240) to the burning of the "Assiniboine" near present-day Bismarck on June 1, 1835. Maximilan's was returning separately, but the "Assiniboine" went down on her return voyage

carrying a large cargo of furs as well as all of Maximilian's biological and geological collections. A sad loss for paleontology as well as all biological science!

During the summer of 1843, John James Audubon undertook a voyage up the Missouri River to study the quadrupeds of North America. Traveling with him on this journey was geologically-inclined Edward Harris. The entourage passed the mouths of the Cannonball River and Beaver Creek (in Emmons County) on June 5; therefore, it is probable that they entered North Dakota for the first time on Sunday, June 4, 1843. Upon leaving, they passed the same landmarks on Sunday, September 1, 1843. The majority of the time spent in North Dakota was spent in the area around Fort Union, near the present site of Williston (Audubon and Coues, 1898).

As Audubon's chief interests were biological, he made only a few geological observations. After one excursion to the north of Fort Union to search for petrified wood, he (Audubon and Coues, 1898, p. 37) wrote, "though we found many specimens, they were of such indifferent quality that we brought home but one."

After another trip into the Badlands in which he observed "clinker" capping the hills, he said (p. 149), "This whole is evidently the effect of volcanic action . . ." He continued,

> ". . . in the sand at the tops of some of the highest hills I have found marine shells [they are not, for there are no marine fossils near Williston], but so soft and crumbling as to fall apart the instant they were exposed to the air. I spent some time over various lumps of sand, hoping to find some perfect ones that would be hard enough to carry back to St. Louis; but t'was 'love's labor lost', and I regretted exceedingly that only a few fragments could be gathered."

He further recorded on this trip,

> ". . . numbers of petrified stumps from one to three feet in diameter; the *Mauvais Terres* abound with them; they are to be found in all parts from the valleys to the tops of the hills, and appear to be principally of cedar."

Edward Harris (McDermott, 1951) spent much more time observing geological phenomena. He, also, observed the dipping strata in southern North Dakota. He discussed the concretions of the Cannonball River area and during his stay at Fort Union, he made trips into the surrounding country side to search for petrified wood and other fossils. On August 24, 1843, on the trip downstream he found (p. 177) ". . . Red Stones with impressions of leaves &c &c petrified wood."

Another member of the Audubon group, John G. Bell, took an extensive trip through the Badlands and, upon returning, gave an account (McDermott, 1951, p. 173) of burning lignite beds which

convinced Harris (even though it apparently did not similarily affect Audubon) that ". . . neither in the recently or more anciently burnt portions is there the least appearance of *Pumice Stone* as stated so confidently by Catlin . . . ."

During the summer of 1850, Thaddeus A. Culbertson visited North Dakota with the purpose of studying the fauna of the area. As with most of the early naturalists, he was also interested in the geological aspects of the area. He recorded (Culbertson, 1851) that he found petrified wood in the White Earth River area, but lists of his collection do not record fossils.

The 1850's witnessed the greatest expansion of scientific traffic and observation in the Upper Missouri country with the advent of vast surveys of western lands conducted by the Federal Government.

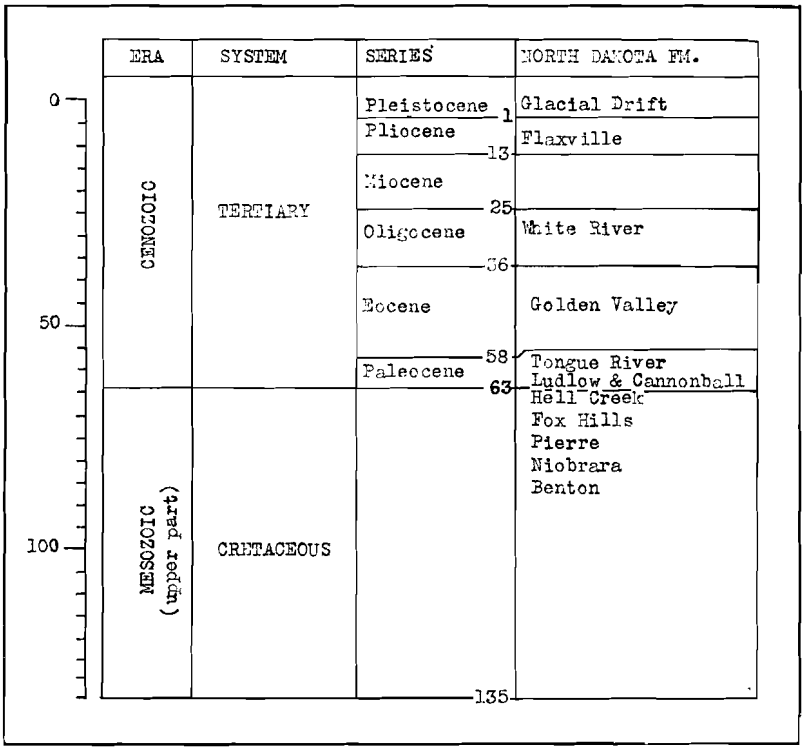

FIGURE 1. Surface formations of North Dakota and the geologic time scale. Numbers indicate millions of years ago. None of the formations of the Triassic and Jurassic Systems of the Mesozoic Era nor those of the Paleozoic or Precambrian Eras are exposed in North Dakota. They lie buried in the subsurface of the Williston Basin. (Adapted from Kulp, 1961.)

In 1853, John Evans, geologist with the Northern Pacific Railroad Survey wrote (Evans, 1854, p. 21) in his scientific instructions to Isaac I. Stevens, Governor, Washington Territory, and leader of the survey,

> "From the Sioux river to the falls of the Missouri, on both sides of the Missouri, you pass through the cretaceous and tertiary formations, perhaps as rich in fossil remains as any other region in the country, or it may be in the world."

His evaluation of the fossiliferous nature of the formations mentioned may be a little overly enthusiastic but locally would certainly be true. Thus, it seems he knew much more than the above sparse references to paleontology in North Dakota might otherwise indicate.

Much of this information came from exploration of areas that are now parts of adjacent states. Jean N. Nicolett and John C. Fremont ascended the Missouri in 1839, but apparently collected no fossils in the North Dakota portion of their trip. However, they had collected a large number of Cretaceous mollusks, south of Fort Pierre, which were described in the East by S. G. Morton in 1842 and Timothy A. Conrad in 1843.

Evans himself, had collected extensively in the Badlands of South Dakota while on a side trip from the famous trip of David Dale Owens down the Red River to Fort Gary (Winnipeg) in 1849. The vertebrate remains collected by Evans caused a sensation when studied and reported on in a series of papers by Dr. Joseph Leidy of Philadelphia. It has been said (Merrill, 1924) that, "this was the first systematic account published of the Bad Lands fossils and it might not unjustly be considered as marking the beginning in America of studies in vertebrate paleontology."

It was about this time that the two men, Dr. Frederick V. Hayden and Dr. Fielding Bradford Meek, who had the most to do with paleontology in North Dakota (and indeed with geologic and paleontologic exploration in the west) first entered these lands. Both were veritable giants in the early days of the Federal surveys; they went on to play a large part in subsequent explorations of the northern Great Plains and Rocky Mountain states and in the organization of the present U. S. Geological Survey in 1879. Hayden was the leader and administrator, a man of great physical stamina; Meek was the more scholarly, a man shy, unassuming and oftimes in ill health.

The exploits of Evans and the reports of his fossils by Leidy had whetted the interest of that most avid collector and outstanding paleontologist of his day, James Hall, State Geologist of New York. Hall dispatched Meek with Hayden as his assistant (although their positions were reversed on subsequent expeditions) to the Badlands (now in South Dakota) in 1853 by way of steamer up the Missouri

River as far as Fort Pierre. In spite of hostile Indians they collected enormous quantities of fossils. The mammalian remains were described by Leidy and the Cretaceous fossils by Hall and Meek in 1856 in a paper which gave the first geological section for the region.

The following spring (1854) Hayden severed his connections with Hall and ascended the Missouri River partly under the auspices of the American Fur Company. He remained in the Upper Missouri Country for two years supporting himself "in various ways as he went along". In 1856 he returned to explore and collect with Lt. G. F. Warren of the U. S. Topographic Engineers, from Fort Pierre to a point 60 miles north of the mouth of the Yellowstone. In 1857 Hayden was reappointed geologist by Warren on an expedition to the Black Hills. During 1858 Hayden explored Kansas with Meek, and with Capt. W. F. Raynolds of the Topographic Engineers he explored in Montana in 1859. After Civil War services as a surgeon, Hayden made some seventeen extensive expeditions in Colorado, Utah, Idaho, Montana, South Dakota and North Dakota. It was largely through the efforts of Hayden that the Yellowstone region was set aside as our first National Park.

The Sioux Indians gave to Hayden the name "The-man-who-picks-up-rocks-running"—such were his exploits in the field. It is related (Merrill, 1924, p. 527) that once while collecting alone in the Upper Missouri country, he was surprised by a band of hostile Indians. "Finding him armed only with a hammer and carrying a bag of rocks and fossils, which they emptied out and examined with much surprise and curiosity, they concluded he was insane and let him alone." A reaction experienced by most paleontologists sooner or later yet today!

Meek, when not in the field with Hayden, was busy describing the the invertebrate fossils in a series of papers jointly authored with Hayden. Although ill much of the time he worked and drove himself at a prodigious rate, writing once (in 1869) to John Strong Newberry (Merrill, 1924, footnote p. 528) "Is there any little nook or corner about your museum rooms where I could have a little cot to sleep on while I am with you? I can bring my blankets and sheets with me . . . I also prefer to spend my evenings with the books and specimens." In spite of his ill health and humbleness, he, with the exception of James Hall, is called (Merrill, 1924, p. 528), "perhaps the most widely known of American paleontologists."

Such was the nature of the two men, Meek and Hayden, who collaborated in a series of papers describing Cretaceous and Tertiary fossils from the western United States beginning with their first work in 1856 and terminating with a monumental quarto volume by Meek which was published in 1876, the year of Meek's death. In his letter of transmittal of this tome to the Secretary of the Interior, Hayden acclaims Meek's work "as one of the most important contributions ever made to the science of palaeontology in any por-

tion of the world." This is still the standard reference for invertebrate paleontology in North Dakota!

Until the activity of recent years at the University of North Dakota, the only significant additions to invertebrate paleontology in North Dakota were the publication of a great many new localities (but no taxonomic work) by Arthur Gray Leonard, State Geologist from 1902-1932; small but excellent descriptive papers by T. W. Stanton and T. W. Vaughan on mollusks and corals (respectively) from the Cannonball formation in 1920; a list of Foraminiferida from the Cannonball by Steven K. Fox, Jr., and Reuben J. Ross, Jr., in 1942; and the report of a small marine fauna in the otherwise non-marine Hell Creek formation by Wilson M. Laird and R. H. Mitchell in the same year.

The first extensive collections of North Dakota *vertebrate* fossils following the expeditions of Hayden were made in 1883 by Edwin Drinker Cope. In a letter written from his camp near Sully Springs (8.2 miles east of Medora) he described (Cope, 1884) his visit to White Butte in present Slope County and listed, with a field identification, the vertebrate fossils found. In 1883 Cope described in more detail two new species of excellently preserved fossil fish from the Percidae or perch family found in the siliceous limestones (White River formation) atop Sentinel Butte. In the same year C. A. White assigned these to a new genus. This locality has become so famous that the exposure has been absolutely minded out and no fish remains can be found there today.

The Carnegie Museum sent Earl Douglass in 1905 to collect vertebrate fossils in western North Dakota, and he reported on these from the White River formation in a charmingly descriptive, reconnaissance manner (Douglass, 1909). The material collected in North Dakota and states farther west was the subject of numerous papers by Douglass.

There are few other systematic reports of North Dakota vertebrate fossils. The vertebrate record is mostly compiled from reports of isolated finds of fragments — a mosasaur from the Pembina Escarpment (Berkey, 1905), a dinosaur from Marmarth (Leonard, 1908), a titanothere from near Buford (Gidley, 1917), a mammoth from near Watford City (Haraldson, 1952), and a few other reports by Leonard in the course of other investigations with the North Dakota Geological Survey. The American Museum of Natural History in New York and Princeton University have had collecting parties in the field in North Dakota in more recent years, but published reports of their work are unknown to me.

J. S. Newberry and F. H. Knowlton loomed large in the history of paleobotany of the western states. Early paleobotanists, however, created a large number of form genera and form species based on fragmentary remains. Therefore details of the history of the collection of fossil plants are even more difficult to obtain. The literature is

old, rare, dispersed and modern paleobotanical taxonomic revisions make such a historical study difficult in this field.

However, it is known that the now nearly treeless plains of North Dakota were once covered with splendid forests of hardwoods such as oak, elm, hickory, and walnut interspersed with conifers, gingkoes, fig trees, cypress, *Sequoia,* etc. Certainly the strata of western North Dakota (especially the Paleocene) abound with fine specimens; even the "clinker" carries delicate impressions of beautiful leaves. As early as 1922 a press release of the U. S. Geological Survey recorded that from the Fort Union group alone some 300 species had been identified.

Also interesting are the common finds of petrified wood (usually reported as *Sequoia* and recently reinterpreted by Chaney, 1951), of specimens of logs bored by shipworms, of cones of *Sequoia dakotensis* Brown, 1935) from the Cretaceous Hell Creek formation, and even of fossil amber from North Dakota (Langenheim, Smiley and Gray, 1960, p. 1356). Even more interesting is a fossil shelf fungus described and named (Brown, 1936) from the Upper Cretaceous of the Cannonball River area. Two years later the author (Brown, 1938) had the commendable scientific (or should I say intestinal?) fortitude to admit he was wrong in an article entitled "Two Fossils Misidentified as Shelf-Fungi" and to admit their more correct placement as otherwise unidentifiable fossil corals.

A View Around Us

Since I came to North Dakota, I have been working toward the preparation of a systematic catalogue of all of the fossils and fossil collecting localities reported from North Dakota. To that end I have prepared a card file with species each recorded on a key punch card containing a bibliographic citation to each locality from which the fossil has been reported. I make no claims for the completeness of this record; in fact, I consider it incomplete. I believe it to be tolerably complete as far as invertebrates go but inadequate regarding the vertebrates and especially the fossil plants. Nevertheless, some idea of the paleontological record from North Dakota can be gained from the following.

There are 703 cards in the file; eliminating the obvious synonyms, these record a total of 488 species and subspecies distributed among 294 genera and subgenera. Of this 488, 54 species occur in the subsurface only (discounting occasional finds in glacial drift). Ninety of the total are vertebrates of which 44 are conodonts (tiny tooth-like fossils of uncertain origin, perhaps an extinct order of fish) from the subsurface and but 46 are plants. One fossil bird has been reported from North Dakota, eight reptiles, no amphibians, but 10 species of fish and 27 species of mammals.

Excluding plants, 85 species have been based on specimens first described from North Dakota. These holotypes include 59 gastropods,

21 pelecypods, five corals, and two each of crustaceans (crabs), fish, and mammals.

A sidelight that is perhaps interesting is that 14 species of fossil animals and at least one plant have names utilizing North Dakota place names (five gastropods, three pelecypods, three corals and one each crustacean, cephalopod, and mammal). They are:

Cyclichnella dakotensis
Epitonium dakotense
Eriphyla? mandanensis
Eucrotaphus dickinsonensis
Fasciolaria? mandanensis
Fasciolaria dakotensis
Fusus (Serrifusus) dakotensis
Modiolus schallerensis
Paracyathus kayserensis
Ranina (?) burleighensis
Scaphites mandanensis
Sequoia dakotensis
Sterophonotrochus leithensis
Trochocyathus dakotaensis
Turricula janesburgensis

Thus even the abandoned post office of Schaller in southern Morton County is immortalized for all posterity by having a fossil clam named after it!!

A Glance into the Future

First, I think it is unfortunate that the state has so few trained paleontologists working in it. A number of oil companies have geologists who are studying fossil algae in connection with subsurface reefs and fossil spores and other microfossils in connection with subsurface correlation problems. Unfortunately, their reports are reports with a direct and immediate commercial aspect and have a habit of finding their way into company files and so do not reach the scientific public. These men are applying the knowledge gained in finding oil for their respective companies, and therefore have not (nor cannot be expected to have) a sole and abiding interest in furthering paleontological knowledge.

The greatest need, perhaps, lies in the lack of library reference material. I have compiled a bibliography of over 300 articles, books, and monographs dealing directly or not so indirectly with paleontology in North Dakota. Over half are not locally available! Most of the great monographs of the early Federal surveys and such publications as Nautilus, the Carnegie Museum Annals, and the early volumes of the Academy of Natural Science of Philadelphia, the Boston Academy of Arts and Science, and the American Journal of Science are not in our library. These cannot be bought on microfilm since it is impossible to make comparative identifications from

microfilmed plates especially when these are housed in the library and are thus not available for constant comparison in the laboratory.

Another great need is comparative collections and collections from within our own state. As implied above, the great collections are in the United States National Museum, the Carnegie Museum, the Philadelphia Natural History Museum, the American Museum of Natural History, etc. These specimens will never return to North Dakota! But it is possible, in many instances, where the specimens are not absolutely unique, to make extensive collections of many of our abundantly fossiliferous strata. We need constantly to be out searching the outcrops and building our collections.

Now, the University of North Dakota and the North Dakota Geological Survey have been cooperative, and in the Department of Geology we are rapidly expanding our facilities for storing and labelling our expanding collections. We have over 25 cases of fossils where less than a decade ago we had three. This is still a small number and we obviously need yet to grow!

But who wants to work a farm where the substance is drained from the soil and opportunity is gone? Challenges lie where there are frontiers! What direction shall we take?

My personal interest has long been in the Cannonball formation —named from a North Dakota river and cropping out almost wholly within the boundaries of the state, this deposit from the last marine invasion of the interior of the continent in a time of waning seas in front of a newly rising cordillera 60 million years ago, is yet virtually unstudied. Its surface expression and subsurface extent are not accurately known, and its fauna is largely undescribed and unfigured. Yet I have collected two large trays of tiny gastropods from one outcrop in one afternoon. Most of these are new to science or have never been reported from North Dakota. Over 70 species of foraminiferids have been listed from a few outcrops but none described or figured. The fauna of the Cannonball formation, commonly said to have Gulf Coast affinities, I believe has boreal rather than austral connections.

Another problem is the recent finds by students and members of the University staff, reported by Lee S. Clayton and S. J. Tuthill (see elsewhere in this volume of the Proceedings), of aquatic molluscan faunas in ice-contact lakes of the Pleistocene or Great Ice Age. The Pleistocene terrestrial and aquatic invertebrate faunas have not been studied in North Dakota nor in detail elsewhere in the United States. Before we can well interpret Pleistocene aquatic environments, and perhaps climate, it will be necessary to study the distribution of present day mollusks in North Dakota—an untrammeled field. Study of Pleistocene mollusks, now underway at the University of North Dakota, will come at an opportune time to help unravel the complicated glacial history of the state which is now

being undertaken in an accelerated program by the Geological Survey and the Department of Geology. This glacial geology is of prime importance in ground water studies so essential to an agricultural state like North Dakota.

Within the last month geology students have discovered abundant ostracods in the sediments of Glacial Lake Agassiz—the first invertebrates collected from these ancient lake deposits in North Dakota to my knowledge. The extent of their occurence on their usefulness in deciphering the history of this famous lake, about which so much has been written but about which we know so little, remains to be seen.

The invertebrates of the Tongue River formation (underlying all of the Little Missouri Badlands in North Dakota) have not been studied since the days of Meek and Hayden. We have not even collected topotypes of the 30 molluscan species first described from this formation in North Dakota (nor has anyone else).

The exact age and correlation of the various Pierre shale outcrops has not been determined nor has the fauna been completely described in the past 85 years. A good start has been made in this direction by the staff and graduate students of the University of North Dakota, but eastern universities are looking for new problems and have students in South Dakota who are systematically working their way north. We may be "scooped"! The fauna of the Fox Hills formation even more urgently needs work. Micropaleontology of the Niobrara formation is now in progress.

In 1959 at the Geological Society of America meetings in Pittsburgh, a paper was read on spores and pollen from the basal Paleocene lignites in South Dakota. Yet, in spite of the proven usefulness to industry of polospore analysis, this is an untouched field in North Dakota except for the work done by employees of oil companies. We have no accomplished paleobotanist at the University of North Dakota, and this has hampered studies of fossil plants; but I feel there must, and will, soon be a beginning in this direction.

The subsurface of the vast Williston Basin offers immense opportunities, especially for micropaleontology. Clarence Carlson (1960) and I (Holland and Waldren, 1955) have well advanced a study of the conodonts of the Winnipeg formation, but we have not touched its abundant bryozoan fauna. The Devonian bears spores and chitinozoans and I am confident that microformaniniferids will be found in insoluble residues of the limestones. The Mississippian carries abundant endothyroid foraminiferids and the Pennsylvanian and Permian strata will yield fusulinids. A former student of mine and I began, in a desultory way, a study of radiolarians in the Pierre formation and he has reported to me (Everett E. Wilson, oral communication) that he has since carried this "zone" of radiolarians into the subsurface and found it a useful marker for tracing on electric logs even beyond the point where he could find these tiny microfos-

sils. Serendipity? We can't tell the value of many of these things until they are tried!

The necessity for paleobotanical studies in determining paleogeography and stratigraphy of the lignite deposits will make the need for these studies even more apparent than the above paucity of file information would indicate. The fossil floras of the western part of the state are scarcely touched in a modern manner.

When the descriptive and taxonomic work on the fossils of North Dakota is completed the true paleoecological work can fairly begin. While the modern ecologist and biologist has only the Recent to deal with, the paleontologist has the accumulated record of ½ a billion years to interpret. We shan't want for things to do. The future of paleontology in North Dakota looks bright indeed!

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