11: The Williston Basin

What Is the Geologic Column?

Let us consider the geologic column once more, this time from a very specific perspective.

Imagine a great pillar of the Earth's crust, made by boring straight down from the topsoil into the mantle. As you examine this pillar from top to bottom, you see horizontal sections of different kinds of rock, some very fine slivers, others extending for hundreds of feet. Each type of rock is there for a reason, and represents a moment or an eon of the history of this very place. Can we piece it together?

What will it mean, for example, if we find quartzite, grains of ordinary sand, which have been squashed into a single unit of stone? Where did the sand come from? How much pressure did it suffer?

Or we may find shale formed when the mud of some long-lost lake bottom was pressed until the water ran away and the grains finally bound into stone. Was there once a lake here? Or was there some kind of quiet, shallow sea?

As we answer these questions, we will be considering the local geologic column.

For a moment, let us look at the Earth as a whole. Are there events so widespread that Earth has a common history from Australia to Alaska? We have learned the names of some of the geologic eras, and we know that several are related to events such as impacts from objects from outer space, or movements of the continents. These must contribute to an intercontinental similarity in geologic history.

Is there, then, a place on Earth which has deposits that we can identify from each one of these eras: Cambrian, Ordovician, Silurian, Devonian, Carboniferous, Permian; then Triassic, Jurassic, Cretaceous; and then on through the Cenozoic epochs right up to the Pleistocene? Geologists certainly speak of "the geologic column" as if the geologic eras were of international significance, and as if such pillars might be dug anywhere, although they might have been damaged in many places.

But is the column intact in any location?

Local Variations

In southeastern South Dakota, glaciers have removed practically everything right down to the Cambrian. Here, Pleistocene deposits, glacial till, and loess from periglacial winds, lie right on top of the Cambrian quartzite, which has no fossils at all. Nothing in this place is over 2 million years old except the stuff that is over 500 million years old. A pillar of Earth and stone bored from this locality would have none of the chalks of the Cretaceous or the redbeds of the Permian, no coal, no limestone, no volcanic ash—just glacial till and pre-Cambrian quartzite.

If you were to go to the Grand Canyon, on the other hand, you could see deposits from many more geologic eras, and because of the river erosion, the evidence would be right in front of your eyes as you walked through the canyon. You would not need to dig for it. Even so, several eras are missing. Geologists say that there was a long period of erosion; of course, there can be no record of the deposits that were eroded. Skeptics say that the rocks are completely different everywhere and the geologic column is just a fiction.

But in North Dakota, there is an area in which one can find deposits from each of the major eras recognized by geologists, even though many of those eras got their names in Europe. One cannot see them here on a day's hike, as in the Grand Canyon, but in the course of drilling 14,945 feet—or about 3 miles—for oil, the oil companies have found rock types and identified them. They have a good reason to be very careful in their work because it is money in their pockets; if you want to find oil, you must identify your rock

Focus Questions

The purpose of these questions is to help you stay attentive to the text. If you mind starts to wander, answer these, or find fossil or appropriate landscape images and paste into the margin.

The margins are retained on the left so that the colored column may be cut and pasted into a single piece if desired.

1. The geologic column is
    a. A pillar in a temple in Greece
    b. A stone record of the Earth's history
    c. The stone that holds up the world
    d. A marching band in Germany

2. What kinds of rock can be found in the geologic column?
    a. Quartzites and sandstones
    b. Shales and slates
    c. Schists and clays
    d. All of the above
    e. All but shales because they are too weak

3. The geologic column is
    a. Complete and intact throughout the world
    b. Complete in at least 2 dozen locations
    c. Never complete
    d. Complete only in the Grand Canyon

4. The original purpose of Glenn Morton's essay was
    a. To remind people of Noah's Flood
    b. To teach creationists about Noah's Flood
    c. To teach christians to think clearly about geology when they consider Noah's Flood
    d. As a primer in geology

5. The approximate depth of the drill work in the Williston Basin is
    a. 12 feet
    b. 1000 feet
    c. 3 miles
    d. 10 miles

types correctly.

Williston North Dakota

In the following pages, you will find a description of the geologic column as found in the Williston Basin of North Dakota and as described by geologist Glenn Morton, to show that the geologic column is not just an idea, but something that really exists, even though the Earth presents it in many different ways.

I have not included the introduction to Morton's paper, which is an argument with specific creationists; nor have I kept the footnotes that are too technical for our present purpose. You can find them on his website.

Furthermore, I have edited his work to place the topmost (and thus the most recent) layers at the beginning of the chapter, instead of the earliest (and most ancient) ones which I have placed at the end. This way, we can imagine ourselves digging down through history.

In the margin, I have sketched representations of the soil types and fossils so that if you lay the images end to end, you can see a tall pillar -- a kind of lively diagram of the very column we speak of. The sketches are simple and suggestive, and though they are less than a thousandth of the actual depth of the sediments they record, they do convey some impression of this impressive sequence.

Resources

Along the way, I have explained a number of geologic terms and fossil names, in an effort to make the whole more readable.

I have asked Glen Morton's permission to use his work in this way, and he has kindly agreed, but you may be interested to find his original work at the following web address:

http://www.glenn.morton.btinternet.co.uk/geo.htm

In case it should be moved, it is called *The Geologic Column and Its Implications to the Flood.*

Why He Wrote It

Glenn Morton wrote this description to alert Christians to the evidence for a long geologic history of the Earth and a long and complex history of its sediments, many of which are clearly not flood material. Some Christians are promoting the idea that all these sediments were laid down by a single flood at the time of Noah. Not wanting us to look foolish or to lose our faith, Morton explains why geologists do not think that all, or even most, of the sediments in the world could have been laid down in a single, worldwide flood; most, indeed, cannot belong to any flood at all.

Glenn Morton himself used to think that all of geology was a deposit from the time of Noah, and was deeply troubled in his Christian faith when he learned that the people who had taught him were not interested in helping him to examine any evidence to the contrary. They only criticized him, forcing him into an intellectual and spiritual solitude that could have destroyed his faith.

It was his intent to protect the faith of others by writing this work; and that is also my reason for presenting it.

Our Catholic faith does not teach that we must believe that the Flood of Noah actually covered the entire Earth, only that there was a flood of very great extent, that it was God's doing, that it changed real history, and that God saved some number of men who "walked with Him" for the purpose of deepening His covenant with mankind. I have, in another place,* discussed a flood that seems to me the most likely biblical flood scenario. In any case, we are certain that reason and faith cannot quarrel because:

Truth is One.

* See Bibliography.

6. The Holocene is the epoch of men as farmers. It extends back in time
   a. 6,000 years
   b. 10,000 years
   c. 150,000 years
   d. Since the creation of man

7. Glacial till refers to
   a. Soil that was burrowed and turned by a glacier
   b. Rocky soil dropped by a glacier
   c. Icy soil
   d. Soil that was soft until the coming of the glaciers

8. An abundance of gravel implies
   a. A former river
   b. A former sea
   c. A former glacier
   d. A former lake

9. A sandstone lens
   a. Helps us to see the rocks below
   b. Is a field of sandstone, thicker in the middle than at the sides
   c. Is composed of translucent quartz sand
   d. Is a shattered mountain
   e. All of the above

10. Fossils of the Tertiary include
   a. Trilobites and bears
   b. Ammonites and crows
   c. Crocodiles and rodents
   d. Hyracotherium

11. Water ferns
   a. Include the ancient form salvinia preauriculata, presumably related to the modern form Water Spangles
   b. No longer exist
   c. Have long stems and grow in dry soils
   d. Did not exist until the Pleistocene

The Williston Basin

Holocene—Last 10,000 Years

Our drill begins to work in rural North Dakota. Right on top, we find the rich soil of the American prairie. "Holocene" means "recent" and refers to the last 10,000 years.

Pleistocene—Last 2 Million Years

Below the topsoil, we find glacial tills, typical of the Pleistocene. Glacial till is composed of mixed sand, clay, and rocks of different sizes, all carried along by a glacier and then dropped when the glacier melted. No other soil type is so mixed up and so unrelated to bedrock of nearby mountains, hills, and plains. It is easy to recognize glacial till. The last glacier melted about 10,000 years ago.

Below the glacial till lies a gravel bed, suggesting the former presence of a river.

Tertiary 2—65 Million Years Ago

The Tertiary is the next large subdivision of geologic time. It is refers to the 63 million years before the Pleistocene. It is known as the age of mammals, because the rocks and soils carry abundant mammal fossils.

Two Golden Valley Formations *100 feet deep*

The Tertiary begins in the Williston Basin with the Golden Valley Formation. In the first layer, we find several fields of sandstone, called lenses. They are called lenses simply because they are wide fields thicker in the middle and tapering at the edges, like a lens; of course, we only know about them because there are several drill holes to compare, not just one. Between the lenses is a parallel bedding made from finer-grained materials like silt, clearly a river deposit, or a lake bottom. Many channels have been cut through the siltstones, showing that streams cut through it after it had been laid down and after it had hardened.

The Golden Valley Formation contains many plant remains and fossils including the unique water fern, Salvinia preauriculata, presumably related to the modern Water Spangles. Animal fossils include fishes, amphibians, four species of crocodile, mammals including several insectivores (insect eaters), three primates, some rodents, a pantodont (a huge, bear-like creature), Hyracotherium (a type of horse), and an artiodactyl (a type of deer). There are also fresh-water mollusks (shellfish) and two species of insects.

There are molds of tree trunks. Since the molds are filled in, we know that the trees had time to rot away before the next layer was deposited on top of them. This in turn means that all these

12. "Molds of tree trunks" means
    a. The moldy remains of old trees
    b. Hollow forms from ancient trees
    c. Petrified forests
    d. Large numbers of wooden containers

13. The clay of the Golden Valley Formation
    a. Is a breakdown product of feldspar
    b. Looks like a soap
    c. Is composed of very fine particles
    d. All of the above

14. The Fort Union Formation
    a. Does not include mammal fossils
    b. Cannot include marsupial fossils because these animals never lived in North Dakota
    c. Includes the first trilobites
    d. Includes marsupial mammals

15. Animal burrows in the Fort Union Formation
    a. Show how desperately the animals tried to escape the flood muds
    b. Are actually the remains of tree limbs
    c. Show that animals once lived peacefully in this area
    d. None of the above

16. Shale is deposited
    a. In sea beds
    b. On blackboards
    c. In forests
    c. On lake bottoms

17. Shale comprises:
    a. 14 percent of the geologic column
    b. 23 percent of the geologic column
    c. 46 percent of the geologic column
    d. 82 percent of the geologic column

objects were buried over a considerable period of time.

Below these lenses and fossil deposits, we find the second Golden Valley Formation, a hard kaolinitic claystone. Kaolin is a type of clay often produced by the breakdown of feldspar. You can tell a claystone because it doesn't look grainy. Pipestone is a type of clay, though not as hard as the Golden Valley claystone. It looks like soap. Claystone is never a flood deposit because it is so fine and even; floodwaters get everything mixed up together.

Below the Golden Valley Formation lies the Fort Union formation. It includes shale as well as sandstone and conglomerate.

The fossils record here shows marsupials—the mammals without placentas, like kangaroos and such; they only live in Australia now (remember, we're in North Dakota). We find a bat, some primitive monkeys and primitive ungulates (ungulates include elephants and tapirs); there are alligators, implying a wet environment part of the time; erosional channels suggest flowing water; and root casts witness to growing trees. Fossil leaves, spores, and pollen tell still more about the presence of ferns and flowers.

Animal burrows are quite common in these layers, indicating that animals were actually living here, burrowing about and building homes for themselves, not just dying here as they would if washed in and buried as part of a flood deposit.

There are also pyrite and siderite, minerals typically deposited in poorly drained swamps, evidence that this area was once a great swamp. This formation also has standing fossilized tree stumps.

A word about shale: Due to its very small particle size, the muds that are to become shale require very tranquil waters before they will drop out and sit on the bottom; moving waters lift such small particles and hold them suspended. The formation of shale is one of the vast unacknowledged difficulties of basing geology on Noah's Flood. All shale is evidence for still and tranquil waters, not raging or swirling floods, and shale are nearly half (46 percent) of the geologic column worldwide.

Cretaceous 145–65 Mya

Before the Tertiary was the period called the Cretaceous due to the immense chalk deposits over many parts of the world. "Cretaceous" means chalky.

The Iridium Anomaly

The Cretaceous is introduced by the Hell Creek section, which contains the famous iridium anomaly. Iridium is an element often found in materials from outer space. There is a layer of iridi-

18. "Cretaceous" means
    a. Chalky
    b. Sandy
    c. Coal-bearing
    d. Granitic
    e. All of the above

19. The iridium anomaly
    a. Refers to a criminal behavior
    b. Is an unusual concentration of the element iridium
    c. Separates the Cretaceous and Tertiary eras
    d. Implies soil from outer space
    e. All of the above except the first

20. Above the iridium anomaly
    a. Dinosaur remains are abundant
    b. Dinosaurs have been killed by the iridium
    c. There are no original fossils of dinosaurs; only recycled ones
    d. Mammal fossils disappear

21. Sand grains in the Fort Union and Hell Creek formations
    a. Differ in color and texture, showing that their origin is different
    b. Are just the same, although the fossils are different
    c. Are the same; and so are the fossil remains
    d. Are mixed with pollen

Sedimentary Representations

Sandstones are represented in a light color with grains.

Shales are represented as dark deposits with irregular wavy lines.

Limestone deposits look like block walls.

um-rich soil, just a few centimeters deep, lying between the Cretaceous and Tertiary deposits all over the world. This means that something from outer space fell upon the face of the entire Earth. Either it was a cloud in the first place, or it shattered when it fell and made a worldwide dust cloud or a ring like Saturn's rings so that when it fell, it fell everywhere, not just in one place. The concentration of iridium in this layer is about 12 nanograms/gram, which may seem pretty small, but in the rest of the geologic column, iridium cannot be detected at all. The few dinosaur remains or old-style mammals found above the iridium anomaly seem to be recycled. That is, they got into the higher formation by eroding from an old formation into a newly forming one. Of course, erosion always takes older material into new bedding, usually in tiny grains, but sometimes in chunks.

The pollen/spore proportions are interesting. Remember, spores come from ferns; pollen comes from flowers. Just below the iridium anomaly, that is, before it was spread about, pollen grains and fern spores appear in equal numbers. Right on the anomaly, we find about a hundred times more fern spores than pollen grains. It seems the flowering plants almost got wiped out. In fact, a few disappear completely; we only have their pollen.

Similar strata in Saskatchewan and New Mexico also show the iridium anomaly and the same sudden decrease in flower pollen compared to fern spores. Somehow the climate changed at this time, and many of the new flowers did not survive; they have never been seen by man. Only their pollen remains.

Hell Creek Formation

Except for the iridium anomaly and the types of animals found in it, the Hell Creek Formation, which comes next, looks just like the Fort Union Formation, being made of sands and shale, with many meandering channels incised into it—once again, the mark of multiple rivers and streams.

Indeed its fossils, however, speak volumes about the different world from which it came. It would be a very curious thing for a proponent of Noah's Flood as the source of all sediments to explain how the very grains of sand are indistinguishable in these two formations, while the fossils are completely different.

The animal fossils include *dinosaurs* and the very early mammals of the Cretaceous Era, so unlike our modern farm and zoo animals. This is the first time we have found a dinosaur fossil, for there were none in the Fort Union Formation.

Fox Hills Formation

The Fox Hills formation lies below the Hell Creek Formation.

22. Clean sands cannot be part of a flood deposit because
    a. Floods are always black
    b. Floods are always a mix of materials
    c. Flood waters never carry sand
    d. Sands are ground into silt by a flood

23. Erosional channels are
    a. Small cuts in a soft sediment
    b. Boating channels from prehistoric times
    c. Crab burrows from Erosi crabs
    d. Cuts of varying depths, even 120 feet deep, made in hardened sediments

24. In the Fox Hills Formation, there are no mammals because
    a. All the mammals of the flood times were buried in higher ground
    b. All the mammals were eaten by the dinosaurs before the days of the flood
    c. There were hardly any mammals in these ancient times

25. The Pierre Shale
    a. Is usually red in color
    b. Is mixed with shells throughout
    c. Is largely composed of fecal pellets
    d. Has fossils sorted by weight
    e. All of the above

26. Bentonite deposits
    a. Include the Kara bentonite
    b. Come from volcanic ash flows
    c. Can be hundreds of feet deep if the volcano is violent enough
    d. All of the above
    e. None of the above

Its sands are too clean to be flood deposits; its shale, as usual, are too fine. There are coal seams, which mean there had been trees that got flooded, and there are limestone sections, which mean there were shells, implying a time under the sea. Notice that these different beds are distinct, as if they implied a history; they are not tumbled together as a flood might have left them.

There are root casts, Ophiomorpha (crab) burrows, more dinosaur bones, turtle plates, shark teeth, and erosional channels over 120 feet deep. Such deep channels indicate that the sediments were laid down and hardened before eroding; else the canyon walls, cut by a river, would have collapsed before they became so high (so deep).

There are no mammals in the Fox Hills Formation, although there are land animals. We will find only one mammal, of an unfamiliar type, from here down as we drill. It is extraordinary.

Pierre Shale

The Pierre shale is rich in organic matter consisting almost entirely of fecal pellets. This means there was once a fairly tranquil lake here, with various creatures dropping their waste into the bottom. In the Sharon Springs member, we see the bones of some of the reptiles that lived around the area. These fossils are not sorted according to ecological niches, as flood creationists would lead us to expect, for we have already seen coal and limestone, one directly above the other; now we find this bed of marine fossils in the same location.

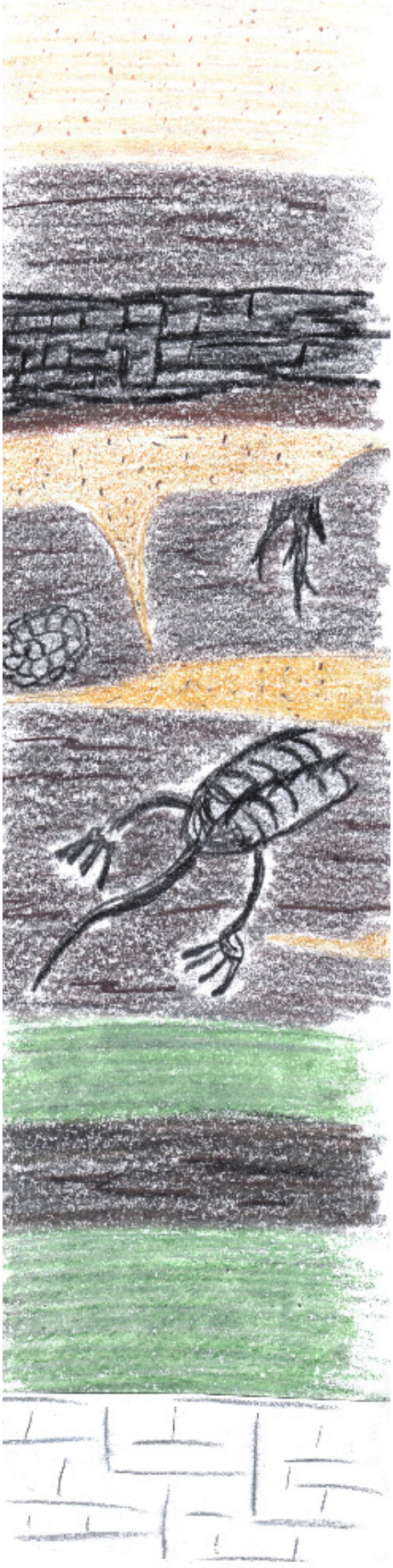
Note also that the Sharon Springs fossils are small, lying below the heavy pantodont bones, and above some much larger fossils of dinosaurs. Clearly the geologic column is not sorted by size, another claim made rather carelessly by some Christian teachers.

Kara Bentonite and Monument Hill

Two deep beds of clay made from volcanic ash are found in this section of the column. First we find the Kara bentonite, which is 100 feet thick. Bentonite is clay made from volcanic ash. Below the Kara is the Monument Hill Bentonite that is still thicker—150–220 feet deep. Nothing in modern times has left such immense deposits over such a vast area. Even the great Indonesian volcano of Krakatoa had comparable ash depth only in the immediate area.

Niobrara Chalk

The Niobrara Chalk is next. It is made up largely of coccoliths, microscopic sea plankton with a calcite shell. Ordinary sea shells such as clamshells are also calcite, but thicker. These mi-



27. The Niobrara Chalk
    a. Is a marine deposit, like any chalk
    b. Includes fragments of the Nio ferns of ancient times
    c. Was laid down during the same period as the White Cliffs of Dover
    d. Is never mixed with organic matter, including fecal pellets
    e. Both a, and c
    f. Both b and d

28. Numerous beds of bentonite in the Niobrara
    a. Killed all the fish from time to time
    b. Show that there was a volcano which repeatedly erupted
    c. Add bright colors to the chalky layers
    d. Provided nesting areas for the Portheus

29. Seasonal variations in the thickness of the Niobrara chalk
    a. Can be clearly distinguished, like tree rings
    b. Cannot be distinguished because of the turbulence of the water
    c. Confirm the time frame of the Flood
    d. Are mixed with sandstones

30. The Carlisle Shale
    a. Is mostly a freshwater deposit
    b. Includes shark teeth
    c. Both of the above
    d. Is composed of limestone

croscopic shells are the stuff of chalk, the characteristic deposit of the Cretaceous, so here we are in the American Midwest, with the same deposit type as the White Cliffs of Dover.

The chalk here is mixed with an abundance of fecal pellets, which, on examination, turn out to be the remains of plankton. Some unknown fish dined on the plankton and left his droppings behind. He also left his bones and scales.

Besides the white chalk, more than 100 beds of bentonite beds (clay from volcanic ash, remember) are found throughout the Niobrara. This interlayering of bentonite and chalk means that there was a marine environment that kept getting intensely strewn with ash from nearby volcanoes. The ash never killed all the fish, but it was thick enough to survive as layers of gray clay between layers of coccoliths.

The fossils of the Niobrara include a 14-foot Portheus (a fish) that apparently died while trying to digest a 6-foot fish! The skull of the giant marine lizard Tylosaurus and fossils of the giant flying reptile, Pterodactyl, have also been recovered from this bed. Some sediment-filled burrows have also been discovered.

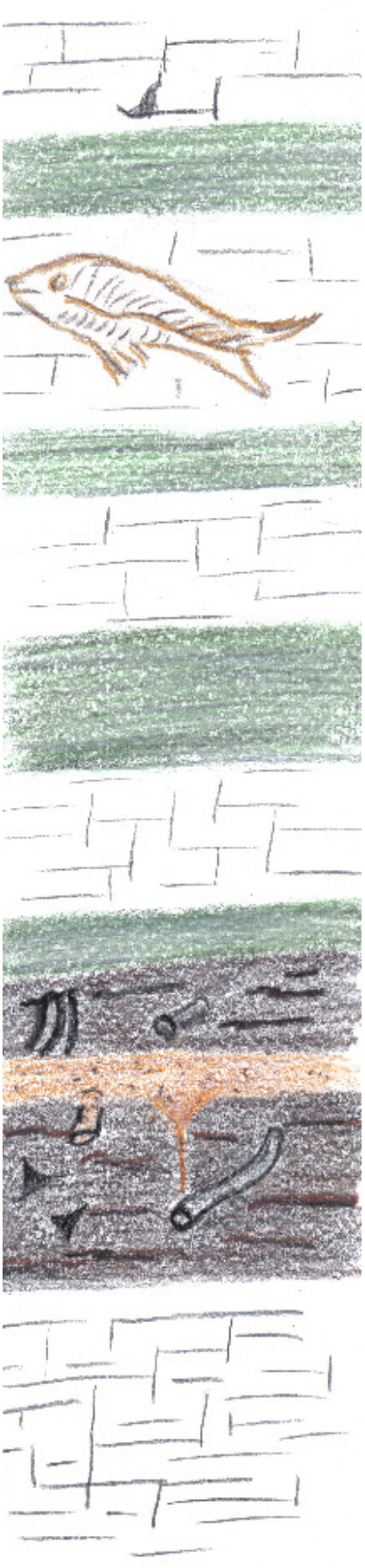
A recent analysis of the Niobrara beds reveals that the individual thin layers can be distinguished like tree rings, and like tree rings they vary in thickness. There seems to be a correlation with the orbital cycles of the Earth. In this way, the Niobrara has yielded new date markers, and once again suggests a much broader time frame than the brief year of Noah's Flood.

Carlisle Shale

The Cretaceous Carlisle Shale, a primarily freshwater deposit, appears next. Rather than being made of bentonite and coccoliths, this consists of sands and shales. Erosional channels suggest the location of ancient streams, while burrows and feeding traces testify to the animals which lived nearby and sought their food in the once-soft sands. Shark teeth and bones have also been found, so this location must actually have been flooded by the sea for a time (few sharks can survive in fresh waters).

Greenhorn Limestone *4,910 feet deep, almost a mile*

Next comes the Greenhorn limestone. Once again, the limestone is composed mostly of coccoliths, small skeletal remains approximately 3 to 5 micrometers, or 3 to 5 millionths of a meter, wide. If you look on the label of a box of plastic garbage bags, you will find that their thickness is measured in micrometers. The little planktons were about as wide as the thickness of the garbage bags. (The abbreviation for "micrometers" is a Greek letter *mu*, which looks something like an upside-down, mirrored *h*. You will



31. Cocoliths
    a. Are hardened shells of ancient seeds
    b. Are sea shells broken into small fragments
    c. Are skeletal remains of microscopic sea creatures
    d. Do not contribute to limestone formation

32. Fecal pellets
    a. Are broken up by swirling water
    b. Are always deposited with limestone
    c. Are a sign of tranquil waters and peaceful little lives
    d. Do not concern geologists, since they are not stone

33. Belle Fourche Shale
    a. Was a shoreline deposit
    b. Proves the existence of rivers in this area
    c. Is an organic deposit in tranquil waters
    d. Is characterized by volcanic ash

34. Ammonites are
    a. Creatures with coiled shells
    b. Biblical peoples who lived in this area after the Flood
    c. A species of trilobite
    d. A species of mammal

35. An index fossil
    a. Is the first of its kind
    b. Helps us to identify a geologic era
    c. Is one of those found in the British Museum of the nineteenth century
    d. Must be a shellfish

see it if you look.)

The Greenhorn coccolith formation is about 40 feet thick and consists of 16 ledge-forming, burrowed limestone beds separated by thin shales. Over a distance of 450 miles—which we know about from other drill sites—these ledges have bentonite both above and below. Because the beds are so flat, it seems certain that each ledge results from a single event or a single era. It would all be much messier if there had been a flood around. For one thing, coccoliths need clear water to grow, die, and fall neatly to the bottom.

The burrows in the ledges mean that *after* the limestone (or chalk) was formed, some little creature dug his home out of it. When the coccoliths were not as productive in the waters above, the fine muds that turn to shale were deposited, separating one limestone bed from the next. This whole sequence of events required very quiet water, and above all, lots of time. Even the little fecal pellets have their message of peace, indicating normal mealtimes for everyone!

Belle Fourche Shale

The Belle Fourche Shale is next. Once again, what sort of water motion is necessary to shales? If you said something like, "tranquil!" you are right. Once again, we are looking at an old lake bottom. Just below the Belle Fourche Shale, another layer of volcanic ash was deposited.

Dakota Group

The series of Cretaceous beds ends with the Dakota Group and its unique ammonites. One of the index fossils of the Cretaceous is the ammonite, which changes just enough to identify each era.

The Dakota is formed of sand and shales with a very soft, brown coal called lignite. Parts of the Dakota beds have ripple marks, indicating water; at the same time, we find burrows, animal tracks, and worm trails, suggesting land. Both together indicate a river mouth or delta where later (see above) there will be a lake, or perhaps the sea will come in. It is a complex history!

The Dakota Formation has numerous channels eroded into underlying strata. Some of these channels are 30 feet deep, showing that the sediments were laid down and firmly settled, then eroded, not completely, as a wind might do, but in channels, as if by streams and rivers. The layers definitely belong to distinct events, and then the channel erosion is a further event. All this requires much more than a single flood.

Volcanic ash turns up again, and the ash is strikingly pure; it

36. Pure volcanic ash
    a. Is impossible as a sediment laid down in waters, because the waters must be very tranquil not to mix with it
    b. Is unusual as a sediment laid down in waters, because the waters must be very tranquil not to mix with it
    c. Is only found as sediments of the land

37. The three geologic periods of the Mesozoic Era are
    a. The Paleozoic, the Paleocene, the Jurassic
    b. Triassic, Jurassic, Cretaceous
    c. Devonian, Carboniferous, Permian
    d. Cambrian, Triassic, Eocene

38. The Jurassic Continental Morrison Formation
    a. Is the most famous bed of dinosaur bones in the world
    b. Includes both sands and shales, from both land and sea environments
    c. Extends from Canada to Arizona
    d. Has the last mammal bones in the geologic column.
    e. All of the above

39. The Jurassic Swift Formation is composed of
    a. Shales with fossils of sea (salt water) creatures
    b. Shales with fossils of land creatures
    c. Shales with fossils of fresh water creatures
    d. Sandstones with fossils of sea creatures

40. Evaporites or evaporitic rocks
    a. Are made in the evening
    b. Are made by evaporation
    c. Are hot sandstones
    d. Are very fine warm sea deposits
    e. All of the above

must have fallen on quiet waters and sunk gently to the bottom.

Plant fragments are also found throughout the strata.

Jurassic 145–208 Mya

The three geologic periods of the Mesozoic are the Triassic, the Jurassic, and the Cretaceous. We have drilled through the Cretaceous; now we cut more deeply to find the Jurassic. We have already found several dinosaurs; more are coming.

Jurassic Continental Morrison Formation

The Upper Jurassic Continental Morrison Formation comes first. This is the most famous bed of dinosaur bones, and although we are drilling in North Dakota, we know from others' work that this bed of sands and shales extends from Canada to Arizona. It has footprints and fossil soil profiles showing what kinds of soil preceded the local stone; it has the last, strange mammal fossils; several entirely unfamiliar plants; and some coal. Huge dinosaurs as well as smaller ones have been found throughout this formation; they are not sorted by size.

Jurassic Swift Formation

Moving downward, we find the Jurassic Swift formation, which is predominantly shale, part of that 46 percent tranquil water deposit. This shale has abundant belemnites, little sea creatures with a tapering conical shape, as well as familiar oyster forms and the clam-like pelecypod. All these are salt-water creatures. As we continue, watch for salt deposits below these oceanic shales.

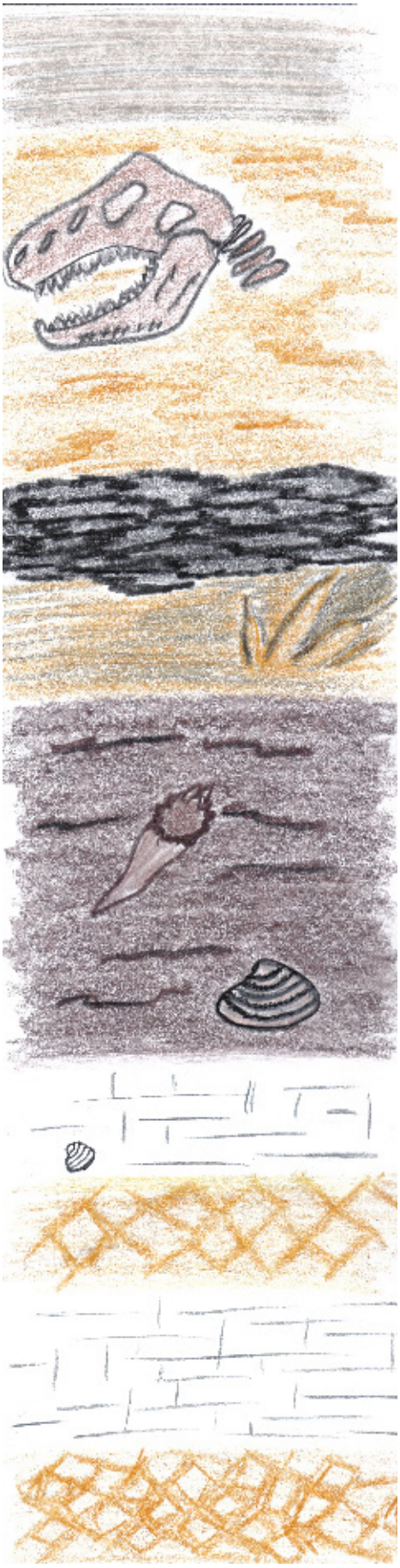
How?

Read on!

Rierdon Formation *6,690 feet deep*

The Rierdon Formation is a set of alternating marine and evaporitic rocks. If you could actually drill out a post, straight from top to bottom of the Williston Basin, you could readily pick out this section with its horizontal stripes alternating between the dark shales left by an underwater ecosystem, and pale, salty deposits made by evaporation and therefore in the air. Evidently the ocean came and went. When it came, its animals went about their business and left their shells and things; when it went, the water did not drain away quickly, but became shallow and then evaporated, leaving a broad plain of gypsum, anhydrite, and salt, minerals which are called evaporitics.

Gypsum is calcium sulfate with water in its structure. Anhydrite is a calcium sulfate without water in its structure; it does not form in water unless the water is quite warm—over 35 degrees C or 95 degrees F, which is just about your internal body tempera-



41. Three evaporitic minerals are
    a. Salt, gypsum, and granite
    b. Salt, anhydrite, and clay
    c. Salt, anhydrite, and gypsum
    d. There is only one anhydrite: salt

42. For calcium sulfate to crystallize in water, as anhydrite, water temperature must be
    a. 0 degrees C
    b. 20 degrees C
    c. Close to human body temperature
    d. It first crystalizes as gypsum

43. Oolitic limestone is formed quickly because
    a. It forms when shells are broken by the waves
    b. It forms at river mouths during spring rains
    c. Both of the above
    d. No, oolitic limestone is formed very slowly

44. The Triassic Period is the first period of
    a. The Paleozoic Era
    b. The Mesozoic Era
    c. The Cenozoic Era

45. The Pine Salt Bed has red sands and shales
    a. The red sands imply a drying environment
    b. The shales imply a mild, watery environment
    c. This means that red sands and shales cannot be found together
    d. The environment of an intertidal flat would allow both of these apparently contradictory rock formations
    e. A, b, and d above

ture. That's hot for ocean water!

The marine beds are full of fossils, including pelecypods (the clam types), and tiny ostracods and foraminifera. This formation also contains oolitic limestone, a fine limestone that looks like something made of styrofoam beads. In fact, it is composed of tiny rounded balls formed by tossing and rolling a starter fragment in calcium-saturated seawater until it is completely coated and heavy enough to drop at last. This is a slow process.

Jurassic Piper Formation

The Jurassic Piper Formation lies at the bottom of the all the Jurassic beds. Its top is a small limestone bed, but below we find red beds and gypsum. Red beds indicate a dry, continental deposit, usually a desert.

Below these lies the Dunham salt. So the ocean dried out to salt here, and then a desert with red sands was formed above the salt. Then the sea returned, bringing limestone.

Triassic 208–250 Mya *7,325 feet down*

The earliest period of the Mesozoic is the Triassic. This period, too, is represented in the Williston Basin.

The Spearfish Formation

The Triassic Spearfish Formation comes next, containing the Pine Salt Bed, which has some gypsum and some highly oxidized red sands and shales. The evidence for oxidation is the red color, a consequence of the rusting of their iron content. Gypsum, the hydrated calcium sulfate, is a mineral always and only formed by evaporation. These Spearfish deposits have the very same appearance we find in modern deposits being laid down on an arid intertidal flat. (The area between high tide and low tide is the intertidal flat. In a dry climate, the retreating tide will always leave more minerals behind than it is able to carry away.)

There are conglomerates here, stones made of other stones glued together. The glue is either silicates or carbonates dissolved in water and then deposited between the stones until they are crusted into a single chunk. The Spearfish Formation has rocks from earlier times (see the Mississippian rocks below). These older stones have been broken and dropped into the redbeds as wayward lumps that do not match their surroundings.

Once again, this type of recycling is bound to happen—everywhere that you find sediments, they have come in from somewhere else, right? Something is being recycled.

46. The Minnekahta limestone of the late (Upper) Permian is colored
    a. White
    b. Yellow
    c. Pink
    d. Black

47. The Opeche shale of the Permian is colored
    a. Black
    b. Green
    c. Red
    d. Orange

48. In the midst of the Opeche shale is the evidence of a dying sea
    a. A salt deposit 300 feet deep
    b. A limestone deposit 300 feet deep
    c. Fossils of dying clams
    d. A fossil whale, 300 feet long

49. The world ocean
    a. Is not salty enough to be hundreds of millions of years old
    b. Has left most of its salt in the Williston Basin
    c. Could not have left salt on land because it stays in the ocean beds
    d. Has left about 9 trillion cubic meters of salt in the Williston Basin and more in other places

50. The difference between limestone and dolomite is that
    a. Dolomite is brown
    b. Dolomite contains a significant amount of magnesium
    c. Dolmite collects near shale
    d. There is no difference

Paleozoic/Permian 250–290 Mya *7,740 feet deep*

The Paleozoic is the most ancient time of life forms that are readily visible in the fossil record. As we continue to dig, we cross the line into the Permian, the most recent of the long ago times.

Minnekahta Limestone

The Permian formations are introduced by the characteristically pink Minnekahta limestone, which was deposited in hypersaline (extremely salty) waters. Of course, one cannot imagine hypersaline waters in Noah's flood, since 40 days of rain should have diluted all the saltwater of the world.

Opeche Shale

The Opeche shale underlies the Minnekahta and is red. Shale is always the deposit of a quiet sea, but the Opeche shale speaks of the deep quiet of a dying sea. In the center of the basin, at its lowest point, a deposit of salt lies 300 feet deep. Evidently an immense body of water was enclosed here, cut off from the ocean so that it dried out entirely. We call it the Williston Sea, and we find Permian pollen in the salt, not the pollen of modern grasses and flowers.

Do not think that the salt was just in our little drill hole. This salt deposit covers an area larger than the state of North Dakota. A depth of 150 feet of salt (half of 300, since it tapers to the edge) means about 9 trillion cubic meters of salt! This represents the evaporation of 845 million cubic kilometers of seawater, or 1/14 of the world's oceans.

The only way that so much salt could have evaporated in such a small area is through repeated flooding with ocean water that was then allowed to evaporate. Indeed, this sort of deposit, which is not unique, explains why the oceans are not saltier, a question often raised by creationists who think the Earth is only 10,000 years old or so. The ocean has unloaded its salt into evaporation deposits, again and again.

Mississippian (Carboniferous) 290–323–360 Mya

Minnelusa Formation

Below the Opeche shale lays the Minnelusa Formation, another long piece of evidence for very dry conditions right before the sea flooding that repeatedly dried out.

First of all, it has dolomite—a magnesium calcium carbonate—with desiccation cracks. The mineral formed by evaporation, and then cracked with still further drying out. Secondly, there are two anhydrite (waterless calcium sulfate) layers with a

51. The predominance of sea creatures in the Minnelusa Formation shows
    a. That the land animals were created simultaneously with the sea creatures
    b. That the land animals left better fossils than the sea animals
    c. Both of the above
    d. There are no fossils of land animals in the Minnelusa Formation

52. Karst is limestone landscape, and includes caves
    a. Which were eroded while the limestone was still being formed under water
    b. Which were eroded after the limestone had been lifted into the air

53. Crinoids may be found in churches
    a. Because they look so much like lilies
    b. Because their fossils are encased in marble
    c. Because their forms have been carved in marble

54. The Mississippian Madison crinoid deposit is approximately
    a. 200 feet thick and 100 cubic miles
    b. 2,000 feet thick and 10,000 cubic miles
    c. 20,000 feet thick and one million cubic miles
    d. Not thick enough to measure

55. Crinoidal limestones are found
    a. Only in North Dakota
    b. In many different states and on different continents
    c. Only in Europe
    d. Crinoidal limestones cannot be distinguished from any other type of limestone

peculiar "chicken-wire" structure that only forms above 35 degrees C (95 degrees F) and near the water table. This type of anhydrite is being deposited in the Persian Gulf area today. Thirdly, the Minnelusa holds wine-red sands with the type of cross-bedding typical of modern desert dunes!

Fossils include brachiopods, cephalopods, gastropods, fish teeth, crinoids, and pelecypods—all sea creatures. There are no fossils of land animals.

Big Snowy Group

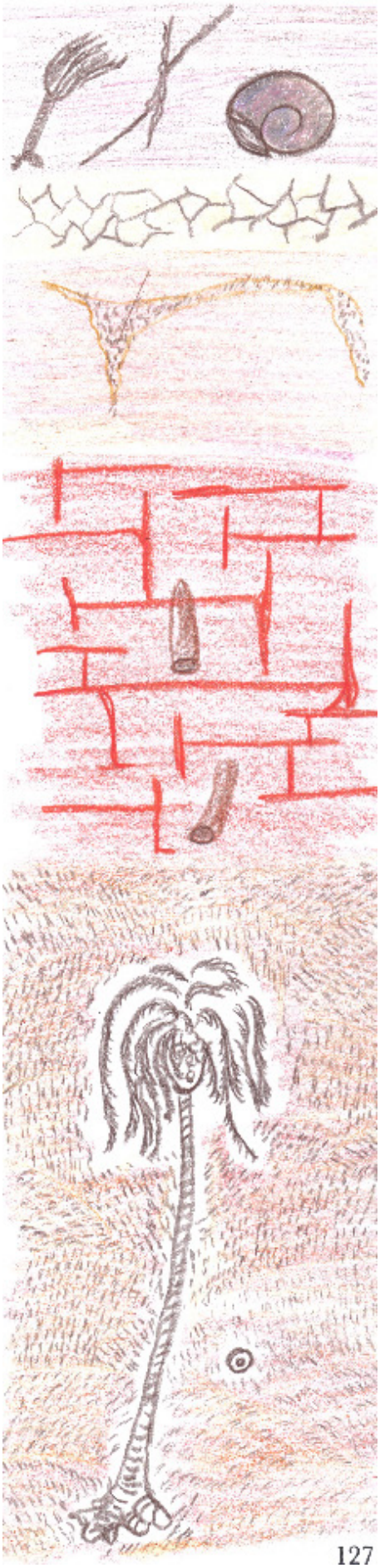
Below the Minnelusa is the Big Snowy group. Another dolomite lies here, its layers apparently glued with algae, and subjected to intense drying. Intertidal channels have been cut into this surface and then filled with sand.

Mississippian Madison

Below the Big Snowy lies the Madison group, beginning with ancient karst landscapes. Karst is limestone with occasional caverns due to subaerial erosion, meaning erosion under the free air. There are salt deposits confirming in their own way the dryness of the climate. The limestone was also heavily burrowed, meaning that there were animals living in it at every level, meaning (in turn!) that every level was once the top, close to fresh air and sunshine.

Fossils here include half-millimeter-long scolecodonts, spores, corals, ostracods, gastropods, and plants; but above all, in the Mission Canyon Formation can be found the most extraordinary deposit of crinoids, small sea creatures that look like delicate flowering plants but are sea animals with a calcified outer covering. They once populated the shallow seas of the world, living from the middle Cambrian for 250 million years, all through the Paleozoic. Most died out in the Permian, but a few are left, and thousands of their gently curving fossils are to be found in the marble of churches and public buildings all over the world.

This particular deposit of crinoids is different, however, for the shells are almost entirely broken, indicating that the sea had a strong wave action. The deposit of crumbled shells is sometimes as much as 2200 feet thick, nearly half a mile. Half a mile *thick*, not half a mile wide! Take a moment to calculate the number of crinoids needed to make such a depth. Over the area we know, there must be 10,000 cubic miles of crinoid plates, enough to cover the Earth three inches deep. Even if the whole Earth had been covered with the shallow waters they required, it would take quite a while to accumulate so many shells. Nor are these the only crinoidal limestones in the world, though they go elsewhere by



56. The Three Forks Shale
    a. Is a still-water deposit
    b. Was deposited on a river bottom
    c. Was formed under the old Atlantic Ocean
    d. Lies in three seams that join in the Williston Basin

57. Caliche is
    a. Wet soil
    b. Dry soil
    c. Another name for sand dunes
    d. Stony rubble soil

58. Stromatolites are
    a. Limestone from a shallow sea
    b. Limestone from a deep sea
    c. Limestone with Mayan calendars etched in their surfaces
    d. Never composed of limestone

59. The Dawson Bay Formation consists of carbonates that are partly cemented by
    a. Salt
    b. Sugar
    c. Magnesium
    d. Epoxy

60. The Prairie Evaporite contains oncolites which
    a. Cause cancer in shellfish
    b. Are entirely cubic, due to salt content
    c. Grow into spherical forms from successive deposits of carbonates
    d. Are domed salt deposits

other names: the Redwall in Arizona; the Leadville, in Colorado; the Rundle in Canada; the Lisburne in Alaska; and still more on every other continent, possibly excepting Antartica.

Devonian 360–408 Mya

Remember: fish became bony in the Devonian.

Bakken Formation *10,255 feet deep (nearly two miles)*

The topmost of several Devonian formations is the Bakken Formation, shale rich in organic compounds. Tranquil, even stagnant, oxygen-poor water was required for this shale.

Three Forks Shale

Below this is lies the Three Forks Shale, a still water deposit.

Birdbear Formation *11,340 feet deep*

Below this is the Birdbear Formation with desiccation, caliche development, and burrows. Caliche is a dry soil, full of carbonates.

Duperow Formation *11,422 feet deep*

Next down is the Duperow Formation. It shows signs of erosion under the open air, with salt and anhydrite deposited in the pores of the drying soil. There are also stromatolites that indicate the presence of a shallow sea. Stromatolites are limestone rocks made by a daily deposit of calcium carbonate. The daily deposit can actually give us an ancient calendar.

Dawson Bay Formation *12,089 feet deep*

The Dawson Bay Formation is another carbonate which has been eroded in the dry air. In fact, its individual grains are cemented by salt in some places. That is, salt was deposited in the fractures and crevices in the rock, and it even plugged old burrows. Dry times!

Prairie Evaporite

Next comes the Prairie Evaporite, consisting of dolomite, salt, gypsum, anhydrite, and potash, all evaporitic minerals, indicating a dry environment. There are also peculiar oncolites which begin with algal growth on shells making concentric carbonate deposits, and end with a more or less spherical object. This takes time. This type of process is still going on, and examples abound from much more recent eras. We know what we are seeing.

Winnepegosis Formation

The Winnepegosis Formation first turns up as a carbonate interbedded with anhydrite. These minerals seem to have precipitated from solution in water. Digging deeper, we find a bioclastic

61. Bioclastic limestone is
    a. Limestone that breaks easily
    b. Limestone directly composed of shells
    c. Limestone composed of shells and glued by limy deposits from the water
    d. Generally of a green color

62. Paleozoic Corals
    a. Can have four, six, or eight sides
    b. Died out in the Permian extinctions
    c. Were followed by the six and eight sided corals of the Triassic or later
    d. Are rounded and do not have sides to count

63. The Bighorn Dolomite
    a. Was once a soft sediment where little animals burrowed their homes
    b. Was once too hot to live in
    c. Has always been hard
    d. Includes a formation named after Andrew Jackson

64. Carbonates, of which concrete is a modern example
    a. Are always cured under water
    b. Kept the oceans of the world warm during Noah's Flood
    c. Are attractive to burrowing animals when they cure
    d. Give off heat when they cure

limestone, meaning limestone made directly from the shells of dead carbonate-producing animals, rather than just from dissolved and carbonate mineral. Mud cracks are also found, as are burrows. There is no sand here, and no shale. It is a seascape.

Silurian 4008–439 Mya

Silurian Interlake Formation *12,539 feet deep*

Are you tired of digging? Take heart! We are almost to the bottom of the Paleozoic.

The Silurian Interlake Formation consists of carbonates, anhydrite, and salt, with a little sand. Layered throughout this deposit we keep finding burrows where animals lived, and mud cracks from drying out of the layers. There are also intact fossils of four-sided corals such as we never see today. Most of the Paleozoic corals died out in the Permian extinction; only one type survived into the Mesozoic rocks. Modern corals of the six-sided or eight-sided kind all came after the Triassic.

Ordovician 439-490 Mya

Bighorn Dolomite *13,250 feet deep*

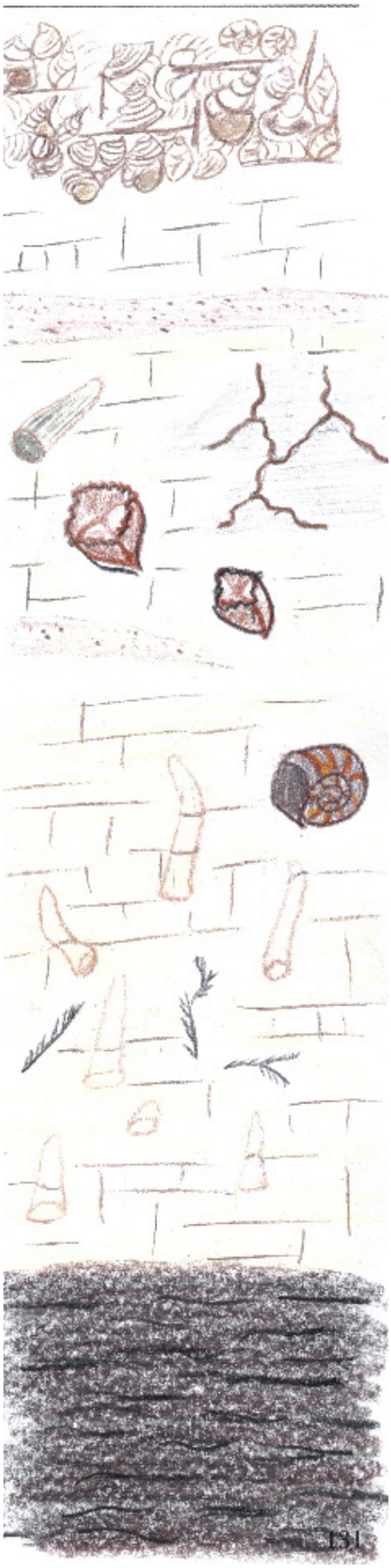
Below the Interlake Formation lies 1300 feet of Ordovician limestone and dolomite. These are the Red River, Stony Mountain, and Stonewall Formations, collectively known as the Bighorn Dolomite, all honeycombed with the tunnels of little creatures that burrowed into its soft sediments when they were new.

There is one more important fact about carbonate: when it is formed, it gives off heat. For one little crab making its shell in the sea, this heat is hardly noticeable; for one building receiving a concrete floor, it is a factor to be considered. But carbonates extending 1300 feet deep would give off enormous amounts of heat if they were deposited quickly; if formed in the single year of Noah's Flood, they would kill everything in sight, boil off the water, and roast the little animals in their burrows.

Fossils here include graptolites, gastropods, cephalopods, and corals. Below, in the Red River dolomite, new burrows indicate still another nameless burrowing creature.

Icebox Shale *14,210 feet deep*

The Icebox Shale — what a curious name! There is a shale mountain near Rifle, Colorado with caves so cool that early ranchers collected and stored all their summer ice in its recesses. Maybe it is the same geologic formation and the reason for the name.



65. The Winnepeg Sandstone
    a. Is the same as the Deadwood Sandstone
    b. Is a recycled version of the Deadwood Sandstone
    c. Cannot be related to the Deadwood Sandstone because there is a layer of shale between them
    d. Was formed in the same catastrophe as the Deadwood Sandstone

66. The Cambrian Period began
    a. 490 mya
    b. 543 mya
    c. 250 mya
    d. 6000 years ago

67. Scolithus burrows in quartzite
    a. Indicate the former presence of soft sand
    b. Require the use of powerful drills
    c. Cannot be found, since quartzite is almost as hard as diamond

68. Pure white sandstone and quartzite indicate the former presence
    a. Of a running river to carry away the organic matter
    b. Of a nearby stagnant pool to collect the fecal pellets
    c. Of salty water to bleach the sand
    d. Of water in constant, gentle motion

In any case, shale means still waters, long ago. At least it was wet for a while!

Winnipeg Formation

Below this shale is the Winnipeg Formation, sandstone that is chemically hard to distinguish from the Deadwood scolithus sand (which we will find below). It does not have worm burrows; this is a striking physical difference, but it seems likely that the Deadwood Sandstone may have eroded to create this more recent Winnipeg Sandstone. That is, some of the Deadwood sandstone—perhaps an exposed section upwind or up river—eroded and landed on top of the black shale that lies between the Deadwood and the Winnipeg Formations. This would mean that a very local episode of erosion brought the sand for the Winnipeg. Furthermore, it would mean that the Winnipeg and Deadwood Sandstones did not form as part of a worldwide catastrophe, since they are distinct local events with time for a quiet shale between.

The Cambrian 490–543 Mya

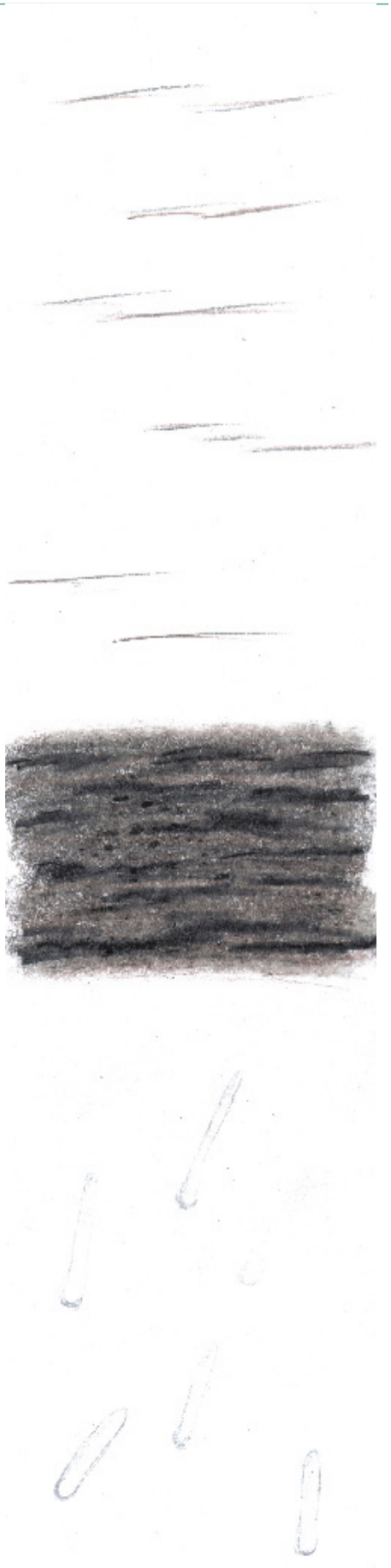
The Cambrian is the earliest of the eras of life forms that are readily recognizable in fossil form, having hard parts that fossilize well.

Deadwood Formation *14,445 feet deep*

In the depths of the Williston Basin, the Winnipeg Formation is interrupted by a dark, black shale. This means there was very tranquil water carrying organic matter, probably inhabited by little creatures, and gently dropping them or their waste products to the bottom.

Below the shale is a very pure quartzite with scolithus burrows, similar to burrows in other basement quartzites around the world. The burrows tell us that these metamorphosed sandstones, which now lie three miles below the surface of the earth, were once merely soft sand, making an ideal, tranquil home for whatever unknown worm-type animal made the homey little burrows.

When I say the sands were tranquil, however, I do not mean the water was still. In these pure quartzites, there is hardly a single streak of shale. This tells another story, for in order to keep mud from accumulating in a deposit of sand, the water must be in continuous motion, slow enough to drop the sand, while fast enough to keep the mud suspended. If the mud falls, it forms shales or at least darkens the sands. This winnowing of potential shales identifies the Deadwood deposit as a very gentle operation, continuous in motion, but leisurely nevertheless. It is not a flood



69. Trilobites
    a. Are black
    b. Lived in the seas for 250 million years
    c. Can be found in Cambrian strata
    d. None of the above
    e. All of the above (except d)

70. The mantle of the Earth
    a. Is too deep for our drills
    b. Has often been intruded by the drills of our oil companies

deposit.

There are trilobite fossils in the Cambrian strata. These fossils can be found all over the world, and come in many types and sizes—all looking a bit like sow bugs, only blacker, more fierce, and occasionally as large as a lobster. They filled the seas of the whole world for the first half of all the time since the Cambrian moment, yet they belong only to those ancient times and no survivors of their type have ever been seen alive.

Pre-Cambrian *14,945 feet (nearly three miles deep)*

No fossils are readily visible before the Cambrian explosion, about 543 mya. Only recently has it been discovered that there were many soft-bodied species in pre-Cambrian times. Their subtle imprints may be found in some stones, but apparently they never became sufficiently numerous to leave the vast organic deposits that could transform into oil and thereby finance their own discovery. The oil companies that drill in the Williston Basin and elsewhere often go "the extra mile" to serve the curiosity of their geologist friends, but the oil stops at the pre-Cambrian, and pretty soon the drilling stops as well.

The mantle is still considerably deeper than our drill. Nobody has yet cut into mantle (as of 2007) though several teams have tried. At present, efforts are underway in Iceland to drill into the volcanic mantle where it lies fairly close to the surface because Iceland sits on the mid-Atlantic rift.

Research and Review

Answer the questions on the even numbered pages beginning with page 120.

Geologists usually list the beds they discover in order from lowest to highest, which is the order of their history, not of their encounter in a dig or drill. Rewrite the Williston Basin account, or some section of it, in reverse order, and describe the history that you find.

Find images of several of the fossils mentioned and copy or paste them into the margin, perhaps on the even-numbered pages beginning on page 120.

Copy or cut the column sketches from the right-hand column and paste them into a single long image. How much of the story can you repeat by just using that image for your prompt?

In the Williston Basin, these deposits are to be found only by drilling, but many of them outcrop in other parts of the country. Find an outcrop of one of these formations and paste or file the image near its description. You may want to adjust the given coloring for a better match.