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THE GEOLOGIC HISTORY OF SOUTHERN IDAHO
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Men study geologic history, as they do human history, because of curiosity. A knowledge of geologic events helps locate phosphate deposits of great value to Idaho, but such results are actually by-products of man's efforts to locate himself in time and the universe. Early geologists like Hutton and Darwin were gentlemen adventurers in intellectual realms, intent on learning the history of the globe and its inhabitants, not in tracing coal seams. Others were clergy like Sedgwick, who searched the geologic record with religious intent, to find the divine plan. All felt the suspicion that Melville expressed in Moby Dick, that "some certain significance lurks in all things, else all things are little worth, and the round world itself but an empty cipher except to sell by the cartload, as they do hills about Boston, to fill up some morass in the Milky Way." Geologic history may also offer some glimpses into the future, for man generally believes that the patterns of the past may be repeated.

Rocks preserve the record of the past in writing that anyone can learn to read, but this record lay unread until about one hundred years ago. Earlier, only a few dreamers like Leonardo saw that the pebbles of an ancient conglomerate were evidence of ancient streams or waves striking on coasts, that ripple marks on hard stone told of currents like those that form the ripples underfoot on a beach today, and that sea shells high in the Alps revealed uplift of ancient sea floors. Shale was once mud, which in turn was soil before being eroded from lands, and limestone is usually just the accumulated shells and skeletons of humble creatures that lived in clear seas. Rocks like granite puzzled the early geologists for a longer time. Werner, the great German mineralogist who dominated the mining school at Freiburg through his life, died thinking that granite was the hardening salt of a primeval ocean. But now the freshman is shown on his first field trip how granite has baked and discolored the other rocks and has pushed them aside, and sees that granite was once molten and tells of heat at depth in the crust.

However, the rocks you may see in one canyon or mountain range tell only an anecdote. The fragments must be gathered together and related to each other before history can be written.

The British surveyor William Smith found out in the early 1800's how to relate the pieces of history. Working in the canal cuts, he saw that each bed of limestone or shale had fossils of a particular kind, and different from the fossils in the beds above and below. Using such guide fossils, he traced single beds through large parts of England, and showed the extent of ancient seas and coal forests. The older and the younger strata covered different areas, and so the patterns of ancient geography and events began to appear. Smith's key fossils turned up in strata in the Alps and Juras, so a more universal history came to light. Even formation on opposite sides of the globe are the same age if they have the same kind of fossils.

So we can tell that lavas were poured out in the Seven Devils country in Idaho while there were deep and clear seas in eastern Idaho, because the fossils in a few beds of sediment amid the lavas are like those in the limestones hundreds of miles to the east. We also know that the formations in both areas are of Permian age, because the fossils in them are like those in the strata of the Russian province of Perm, whence the name was derived.

As the events fell into order, the questing mind of man began to guess how long ago these things happened. First the geologists guessed that it took perhaps a hundred years for a foot of sandstone or mud to accumulate, and multiplied by the thousands or even tens of thousands of feet of strata they could measure in the mountains. The figures were inaccurate, but infinitely disturbing to those who believed that the world was only a few thousand years old. Then the Astronomer Royal Halley calculated how old the ocean was, supposing that it had been fresh to start with and had become salty because of the salts that the rivers of the world yearly brought in.

Such guesswork ended when Rutherford and his fellow scientists learned to tell time by the radioactive clocks. A radioactive mineral like pitchblende decays eventually to lead and helium gas. If you can determine how fast it decays, and also how much of a specimen is still pitchblende and how much is products of decomposition, you can calculate how old the mineral is, and how old the formation it was found in.

The geologists recognized and gave names to the larger chapters of geologic history, the eras, long before they had dates for them. The names describe the character of the living things of the eras. The boundaries fall where revolutionary events occurred, where strata were crumpled into mountains and ancient families died out to be replaced by new ones.

The Cenozoic or era modern life is the youngest of the great chapters of earth's history. It opened about 70 million years ago. Before it was the Mesozoic era of middle life forms, about 150 million years long. The Paleozoic era of ancient life lasted about 375 million years. Geologists might invent better names if they could have a second chance, for it is now obvious that the

Mesozoic era is no more the middle part of geologic time than the Middle Ages are the middle part of human history.

The longest division of geologic time is the Precambrian, which takes in all the time before the beginning of the Paleozoic era. Perhaps Precambrian time is four and a half billion years long, because the astronomers now think the world to be about five billion years old. There are no good divisions of Precambrian time because the records are so obscure; the rocks are jumbled up by repeated episodes of mountain-making, and almost wholly barren of fossils. Geologic events grow dimmer, the more remote they are from us, just as do records of human events. Thick volumes describe the first world war in detail, but only a few clay tablets tell all we will ever know of ancient wars when a thousand villages went up in smoke. The Irish geologist Charlesworth wrote a book of 1700 pages to summarize what went on in the last million years, but only a few pages would cover all that we know of much longer periods in the remote past.

PRECAMBRIAN TIME

Perhaps the rusty gneisses and schists of the mountains around Henrys Lake in Fremont County provide the earliest record of happenings in Idaho. Gneiss is an old German word for banded granite-like rock, and schist, from the Greek word meaning to split, is a rock that parts readily along the layers of mica in it. The question is, what do such rocks signify?

Early European geologists like Barrande in Bohemia knew that the gneiss and schist were very old. They cropped out in deep gorges and the cores of mountains, underneath the Cambrian strata that held the oldest known fossils, of primordial type. Such rocks might be the once-molten crust of the earth.

In Fennoscandia, however, the glaciers had cleaned the rocks off so well that it was easy to study them over vast areas, and the Swedish geologists saw another story written. Gneiss and schist were once common rocks like shale and sandstone, now transformed by heat. As the geologists traced a bed of shale toward some ancient center of heat, they saw how it underwent a change to hard slate, then to micaceous schist, and finally to granite-like gneiss. Also, about this time the geologist Logan, traversing lonely Canada by foot and canoe, discovered that immense thicknesses of waterlain strata and even volcanic rocks lay beneath the Cambrian formations. So it became clear that the seas were greatly older than the lower Paleozoic Cambrian strata.

Only the trained eye can see that the gneiss and schist of Fremont County were once loose sand and mud on a sea floor. But elsewhere in Idaho there are rocks just about as old that escaped recrystallization and still show their original nature clearly. Precambrian quartzites with clear ripple marks form the crumbling pinnacles about Mount Hyndman in the Pioneer Mountains north of

Ketchum. Precambrian quartzites, and marbles that once were limestones crop out in the Albion Range south of the Snake River. Near Pocatello there are Precambrian lavas as well as sedimentary strata, and also a bouldery formation that is suspected to be an ancient glacial deposit.

Something is added when you realize that some of these rocks are really old, in terms of the age of the universe itself. As the astronomer Shapley points out, the precambrian rocks are older than the Pleiades, and some of the older ones have rested unchanged throughout most of the development of the Milky Way and the expansion of the universe.

In Idaho as everywhere else, the oldest rocks show no signs of a beginning. The oldest rock yet found is made of pebbles from some still-older rock. We will never know more than a fraction of the events of the first nine-tenths of the history of the earth. Some of the rocks that might have recorded ancient events have been eroded away.Others have been utterly transformed, and now are a palimpset, the geologists say, borrowing a word the scholars use for parchment written upon and then scraped clean, and written on again.

The rocks tell of ancient seas and shores, but what about the kinds of creatures that crawled on the sandy flats of the Precambrian seas near Boise, or that lay warming on the muds now turned to gneiss above Henrys Lake?

Here we enter a shadowy field of knowledge where only a few candles burn. The lowermost beds of the Cambrian period preserve traces of complex animals that surely had a long train of ancestors. Yet the Precambrian rocks seem almost barren of life. Walcott of our National Museum spent long seasons in the field searching the Precambrian strata, but all he found were the spines of some sponge-like creatures, a few worm trails, and curious objects that might possibly be colonies of algae.

The discouraging search finally slacked off. Raymond of Harvard believed that animals were free-floating and jelly-like at first, and that only in Cambrian time did some of them become sluggards, and begin to grow the hard parts likely to be preserved, with the excess calcium carbonate in their systems--a kind of hardening of the arteries even in what we think of as early times. This educated guess now turns out to be correct. In 1947, a great find of Precambrian fossils turned up in the Edicara Hills of Australia. The fossils are only shadows, the impressions of soft-bodied creatures who had been stranded on muddy flats and then covered by sand that the next tide washed in.

Several kinds of jellyfish lived on that ancient shore, and with them, soft, frond-like corrals without hard parts, and worms, and a few other lowly animals unlike anything seen before. Because life was very much the same all over the world in those dawning days, such were the earliest known residents of Idaho. Some floated idly with the currents. Some stuck to the bottom, sucking in the protozoans that must have swarmed in the water. A few had become hunters or scavengers, and crawled about in the mud looking for something to eat. When people come to believe them as exciting as arrowheads, they will look for them and eventually find them in the Belt Series of marine strata in Idaho.

THE PALEOZOIC ERA

No momentous event ushered in the Paleozoic era in Idaho some 600 million years ago. At about this time the seas began to creep into the state from the southeast, drowning lands that had been worn low through ages of erosion. The waters rose stealthily, beaches advanced and storm waves threw gravels against the headlands and fretted them away. Then, while the earth made almost 400 million trips about the sun, sea covered most of southeastern Idaho.

During the Cambrian period, the first hundred million years of the era, the seas became deep and clear in the southeastern part of the state. Sea creatures more numerous than all the sand grains on earth's shores bred and died in those clear seas, and in dying left their shells to form the thousands of feet of limestones now upturned in the mountains of Bannock and Bear Lake counties. Farther west, in Custer County, there are beds of sandstone amid the limestones, and also shales, the sand and mud from some lands still being eroded to the west.

In the Ordovician period, that lasted for 60 million years, the seas reigned as before. The sands of the Kinnikinic quartzite and the muds of the Ramshorn slate gathered near the lands, and limestones far offshore to the east. The time marked off on the geologic calendar as Silurian began, and still the western highlands shed mud and sand, that the geologist would call the Trail Creek formation.

Then, although the strata lie smoothly upon each other, there is a gap in the record. The fossils characteristic of late Silurian and early Devonian times are missing. This means that the floor of the sea rose above water level. This undulation of the crust was the only sign here that the Appalachian Mountains had begun to rise far to the east.

Next, in Devonian time, the seas again spread over the lands. The soil swept from those lands settled in layers, to become the Milligen shale. In the seas farther to the east, limy oozes and fragments of shells continued to accumulate for 40 million years, and hardened to become the Madison and Brazer limestones, a mile thick, that form the creamy-colored cliffs of the higher mountains north of the Snake River Plain.

Finally, the end of the era drew near. Tranquillity had reigned here for hundreds of millions of years, and signs of unrest began. The seas first shallowed, and new land appeared. The sands worn from these new lands were spread as the Tensleep sandstone in the shallow seas that were left in eastern Idaho.

In western Idaho the crust sagged and waves overran lands that had been above sea level since the beginning of the era. Then the crust stirred more strongly, for a world revolution had begun. In western Idaho the inner heat broke through and the Seven Devils volcanics poured out, and then the whole southern part of the state rose high above the water level.

The seas that had spread over Idaho at the beginning of the Paleozoic era swarmed with animals, inheritors of long evolutionary developments. How long, for example, had it taken to develop such an extraordinary structure as the eye?

Still, the number of species amounted to only a tiny fraction of the present multitude. Years ago the paleontologist Raymond took a census and found that only about 455 species had been identified. Of course, many tiny and jelly-like animals were not preserved, but even the occasional new finds that are made will not greatly increase Raymond's count.

Really great variety had not developed yet. There were corals and sponges, the colonial animals fixed to the bottom, who had recently learned to build protective cases of calcium carbonate. Drifters moved with the currents, like the sea anemones, the flowers of the water, colored as brightly as their descendants, no doubt. The armored shellfish, mollusks of various kinds, lived in the sand and mud. The greatest animal on earth was an early relative of the squids, living in a pipe-like shell fifteen feet long.Large sea worms crawled about and left only their trails. Lumpy sea urchins or starfish were scavenging--not to be underestimated, since it appears that they were our ancestors.

The trilobites ruled this primitive society. These armored, segmented creatures, vaguely resembling horseshoe crabs, were faster than anything else on earth at the time, because they had legs, and as yet there were no swimmers. Some of the early ones were very simple, and one paleontologist is said to have made a reputation by distinguishing the front from the rear of certain trilobites that lived in the mud and lacked the great compound eyes the others had.

The life of the sea changed very slowly for almost 200 million years. Then, late in the Ordovician period, the first great innovation appeared, a true swimmer. The little crusty-skinned ostracoderm fishes were only a few inches at first. The plates that cover them are the first sign of their existence; they must be waiting in the Kinnikinic quartzite, for they lie in strata of Ordovician age in Colorado.

Next, some kinds of the ostracoderms became organized, for their remains show traces of a bundle of fibers running from a brain to a tail. This was the notochord. The next improvement was the armoring and strengthening of this vital organ with segments of bone, and then the backbone had appeared.

So there appeared on the scene a much improved animal, the fish, who could both pursue and flee faster than anything else on earth, who was aggressive rather than retired from competition like shellfish, and who was not defenseless from time to time as the trilobites were when molting their shells in order to grow bigger.

The young are adaptable and can handle trouble and change when they come better than their elders. So when the sea floor rose in the Devonian period in Idaho, leaving only lagoons that grew shallow and stagnant in summers, some of the fish learned to gulp air, and even to live for a while on it alone. The lungfish was one of these, and this creature, far from being primitive, is a triumph of adaptation to special conditions and thus hangs on to this day in tropical lakes.

But there was another more restless fish who learned to breathe air in late Devonian time, and who apparently would crawl out on the flats even when it did not have to, and could crawl from one puddle to another. This was the stout-finned crossopterygian fish, thought extinct for 60 million years, until a stray specimen was found in the catch of the fishermen off the coast of South Africa.

One of the most treasured fossils in the world is a single footprint on shale of upper Devonian age from Pennsylvania. The paleontologist who identified it must have felt like Robinson Crusoe when he saw a footprint not his own on the desert isle, telling him that someone else was there. This footprint shows that by then the fins of some branch of the crossopterygian fish had become legs, and amphibians were about.

The intermediate links still are hiding from the fossil hunters. However, the enfolded enamel of their teeth that gives the first amphibians their name, the labyrinthodonts, also shows their kinship to the crossopterygian fishes.

Why was there a drive to leave the mothering waters? The waters had long been dangerous with predators, but perhaps more important, the lands now offered something to eat, for the first time in history. For great ages such old lands as those of central Idaho had born nothing but low, mossy plants. But the scraps of vegetation in the Milligen shales, laid in muddy seas to the east of those lands, showed that something different now clothed those lands. These were the coal forests, with the fern-like trees as much as a hundred feet tall. The trunks and stumps show no growth rings, hence we picture a land that had no winter, nor any droughts.

These forests had not been in existence long before they rang with the cries of innumerable insects. The oldest insects known, full-fledged mites, sprang into the view of a British paleobotanist, as he focused his microscope on a transparent slice of stone from a fossilized peat bog of mid-Devonian age from Scotland. About this time, some 375 million years ago, the Grandview dolomite and the Three Forks formation were piling up in southern Idaho.

Exulting in a virgin world, where no animals or birds existed to prey on them, the insects rapidly evolved to about the condition they are in today. Nature experimented wildly; the cockroaches may have been lords of the land temporarily, for there were hundreds of species, some several inches long. Their greatest enemies might have been the dragonflies, also of ancient lineage, now much fallen, for some of those of the coal forest had a wingspread of thirty inches.

Delighted by all the luscious plants and bugs, some amphibians took to spending less time in the water and more on those ancient shores west of Sun Valley. A few found how to avoid the troublesome trip to water to lay their eggs, such as frogs still make. They developed the egg with a shell, that safely enclosed the embryo, food to start it off, and a little bit of the sea itself as watery fluid. These, which then were reptiles, no longer had to stay near more water than they needed to drink, and were in a position to explore the lands. And this they did toward the end of the Paleozoic era. The disasters of the Permian period, the spreading of ash and volcanics and the poisoning of the seas that killed the fish and made the phosphate beds, did not affect the reptiles seriously. The uplift and glacial cold only stimulated the youthful reptile clan to become diverse and to flourish in any environment, as long as it was not too cold.

THE MESOZOIC ERA

The Mesozoic era in some ways is like the Middle Ages of human history. It stands between a really ancient world and a modern one. It began after changes as great as the fall of the Roman Empire, and ended in a Renaissance-like freshening. Most of the time Idaho was above sea level. The record comes from strata laid in valleys and lakes. The great reptiles dominated the stage, but the small ones turned out to be the stayers in the long run.

When the Mesozoic era began, with the Triassic period, most of southern Idaho was land, and a few volcanoes were still pouring out lavas in the west. Eventually these volcanoes died out. Streams gradually eroded the uplands and later when the crust sagged a little, seas moved in over most of southern Idaho. The first deposits were mostly shale, the soils eroded from the lands. Far from shore, limestone gathered. These seas were shallow, and layer after layer of the thousands of feet of strata show mudcracks and ripple marks, and even the prints of raindrops, made on the broad muddy flats the tides left bare when they went out. The incoming tide swept more sediment in, burying and preserving the marks, and such alterations show that the moon was then pursuing its course through the sky, as it has done as far back as we know.

The sea floor rose to become land toward the end of Triassic time, and thereafter, for perhaps 100 million years, southern

Idaho was a land of hills, low mountains, and wide lowlands. Mountains had risen to the west, and had cut off much of the rainfall. Nevertheless, it still rained enough on the uplands for forests to grow, and for streams to run and to erode the hilly country and dump sand and silt in the basins. It was fairly dry in the basins, and sometimes arid, for beds of salt show where lakes existed and then dried out.

When more than two-thirds of the Mesozoic era had passed, heat began to rise from depth. For hundreds of millions of years the crust had undulated from time to time but there had been little fire, except on the western border of the state. Now the inner heat rose broadly through western Idaho, from the Owyhees northward into Canada. Where the heat was the greatest, the older rocks melted and became the granite of the Idaho batholith--the "deep rock"--that forms the mountains and wilderness. The rocks farther out were only recrystallized, to slate or gneiss.

The time-keeping radioactive minerals in the granite, like those mined along the Bear River east of Lowman, tell that these granites are about 100 million years old. Many of the ore deposits of Idaho were born at this time. Hot fluids escaped from the masses of cooling granite into the surrounding rocks, and these fluids bore with them gold and silver and lead and zinc and many other metals that were deposited in cracks to form veins as the fluids cooled.

The granite cooled off slowly, thousands of feet below the surface. Perhaps because of so much hot rock at depth, the region rose majestically. Such bouldery formations as the Ephraim conglomerate tell of steep and well-watered mountains and streams swift enough to carry boulders several feet in diameter out onto the lowlands.

The streams worked through much of the Cretaceous period to destroy these primitive Rocky Mountains. At last they succeeded, and only low hills rose above valleys floored with the debris from the mountains. Southeastern Idaho was so low that it held for a while an arm of the sea that spread in from the Arctic Ocean and the Gulf of Mexico late in Cretaceous time.

Finally some inner forces awoke at the end of the Cretaceous time and the Rocky Mountain revolution began in earnest. Now the crust was squeezed, and all the strata that had accumulated since the dawn of the Paleozoic--nine miles thick in some places--were folded into colossal wrinkles extending to the north and northwest. About the same time the lands again rose on a grand scale, and some geologists guess that the mountains then formed were as high as the Himalayas.

The Swiss geologist Agassiz, who came to America to teach in the last century, noted with surprise that "the appearance of chains of mountains and the inequalities of the surface resulting from it, seem to have coincided generally with the epochs of renewal of organized beings." If we are not as surprised as he was, it is because, standing on the shoulders of Agassiz and others, it now seems plain that when the face of the earth is remade, and the climate changed, so must all the creatures change also.

So, when uplift of the lowlands at the end of the Paleozoic era brought coolness and broke the long tropic calm, the coal forests disappeared forever. In the club moss of the forest floor we see the last relative of the 100-foot scale trees, and in the horsetail reed all that is left of tree-sized ancestors. Now a primitive ancestor of the palms, the cycads, made up the forests. These cycads bore the largest flowers yet seen on the face of the earth, but the crumpled tissues on layers of shale give no clue to what colors or perfumes adorned them. The ginko was then in its prime, too.

Not so strange would have been the forests of sequoia and cypress and the thickets of cedar and juniper. These evergreens rose from obscure beginnings sometime in the Triassic, and therefore are the most ancient of the elements of the earth's forests.

Later, in the foothills and ravines of the mountains, and in the basins where the debris from the mountains was being laid, in Jurassic and Cretaceous time, the modern plants slowly triumphed over the cycads. Those landscapes saw the slow evolution of the grasses and lilies, the shrubs we know today, and all the multitude of broad-leaved trees.

When the swampy coal forests shrank, the army of amphibians thinned out and the reptiles rose to supremacy. We think of the main characters, the dinosaurs, as a symbol of failure. This is curious, because they reigned for 150 million years. They abounded in western North America. Tyrannosaurus, the largest carnivore that ever moved on land, possessor of the most savage mouth the surface of the earth has ever seen, ranged through the Idaho valleys. The immense Diplodocus, with legs too weak to sustain his weight out of water, moved half-submerged in the weedy slough.

The greater reptiles were an experiment in the survival value of size or ferocity. The experiment with brain power lay far in the future. The spiny-finned Stegosaurus had two accessory knots of controlling nerves along its spine, as well as its brain, but the brain weighed about two-and-a-half ounces; a man has about two pounds of brain per hundred pounds of body weight.

The various kinds of reptiles filled every environment from desert to swamp. When the land was overfull, especially with predators, some reptiles retired into the waters. Limbs that had been fins now grew membranes and became paddles, and the tail became like that of a fish, although the internal structures were quite different; the ichthyosaur is a fish to anyone but the anatomist who sees that it is a reptile masquerading as a fish. Swimming reptiles culminated in the mososaur, who was 40 feet long and certainly a terror to the largest of his old cousins, the fish.

Where could such prolific creatures go when land and sea were fully populated? In 1784 a workman in a Bavarian quarry turned over a slab of Jurassic limestone and was the first man to see a flying reptile, the pterodactyl or wing-fingered one, with membranous wings like a bat, and teeth like a fox. The pterodactyls also lie in the chalks of Kansas and must have glided over the Mesozoic lakes of Idaho. The earliest ones found have all the proper equipment for flying, the keeled breastbone for attachment of wing muscles and light hollow bones. What were the intermediate steps? Patience, say the paleontologist, they are waiting for us to find them in the Triassic rock, like the Thaynes limestone in the Caribou Mountains.

Having succeeded in launching a reptile into a new environment--the insects there already for 100 million years offered no competition--nature played again with size and produced the pteranodon, whose wings, twisted in the Kansas chalks, once spanned 27 feet and made it the largest flying animal known.

What is a world without birds however? They must have come to Idaho about the time the pine trees did, early in the Mesozoic. Bird fossils are excessively rare, for birds get eaten quickly, bones and all. But the impression of a solitary feather on a slab in the Solenhofen quarry would show that birds were around in Jurassic time, even if by luck one complete skeleton had not been found. Archaeopteryx is a bird because it had feathers, even if it did not get rid of its reptilian teeth. The birds evolved so rapidly that some of them had grown tired of flying by Cretaceous time, and the penguin-like Hesperonis hunted fish in the seas of eastern Idaho.

Only a few fragments of shattered skulls tell that the first mammals lurked in the forests and foothill brush of Idaho in the Mesozoic era. Some small groups on the fringes of reptilian society had by then developed three kinds of teeth, with which to cut and tear and grind, and eat anything handy. Their blood had also warmed, so they could forage in heat and cold that incapacitated the reptiles. The first of them laid eggs and fed milk to the young, as the platypus still does.

No mammals larger than cats prowled in Idaho during the Mesozoic era. Kept down by the reptiles, they hid in the forests or inhospitable places, gleaning a living where others could not, chasing insects in the trees, eating plants and fruits, perhaps robbing eggs from the nests of the dinosaurs. It was not meekness, however, that was to give them a glorious destiny, but the adaptability and the cunning that was forced on them.

Even as the reptiles were in their heyday, the frosts drew on, to end the Indian summer of the Mesozoic era. By subtle analysis of the minerals that form the shells of mollusks, the geochemists now find that the temperature of the world dropped about six degrees at the end of the Cretaceous period. Then came the time of the great dying, as the German paleontologist Walther exclaimed. The lowland forests and marshes shrank, and the herbivores dependent on this vegetation died off. The carnivores vanished as their prey disappeared, until a last Tyhrannosaurus once could find no mate in a lonely valley. Those who did survive were the small and the hardy and the adaptable, and the birds and insects, and the ancient and conservative dwellers in the little-changing oceans.

THE CENOZOIC ERA

In the Cenozoic era, which was about 70 million years long, the scenery of Idaho was gradually sculptured to its present form. The mammals rose to dominance, and then passed their prime.

The smaller divisions of Cenozoic time, the epochs, and their names, come from the work of an English geologist, Charles Lyell, who saw how modern creatures became more numerous in the younger strata.Pliocene means many of the recent forms, Miocene means less of them, Oligocene only a few, and Eocene, dawn of the recent forms. Later he added on the Pleistocene, which has most of the recent forms; it is also called the ice age. Geologists of an earlier generation had recognized but two divisions; a fourth or Quatenary chapter in the earth's history, recorded by soils and loose sands and gravels that we now assign to Pleistocene time, and a third or Tertiary chapter recorded by the little-hardened deposits laid from Eocene through Pliocene time. Some geologists, like Moore of the University of Kansas, prefer to use the names Paleogene and Neogene instead of the antiquated Tertiary and Quaternary.

The mountains raised by the Rocky Mountain revolution were still very high in the first part of Eocene times, and carried snowfields and glaciers. But no mountains last long, as geologic time goes. Frost and the weather and rills and streams wasted them, and the debris was spread in the lowlands as the sands and gravels of the Wasatch formation. Before half of Eocene time was past, the mountains were mostly leveled and the valleys filled, and the landscape was in old age, as geologists say. The climate of the lowlands was then almost tropical.

One day very late in Eocene time, volcanic ash began to fall in eastern Idaho. Volcanoes had begun the long series of eruptions that continued till the present day. The eruptions were only part of a general unrest, and the land grew higher in Oligocene time. Quickened streams cut deep valleys, but they worked in vain, because then the Challis volcanics poured out and completely filled the valleys.

Again the streams set to work, on lands very high above sea level. But the earth trembled again in Miocene time, and fissures opened, and lavas spread over eastern Idaho and the

Yellowstone country. These lavas burst forth at intervals of hundreds of years, each time burying forests that had grown old. The artist Holmes, accompanying an early exploring party, was the first to see these buried forests, in a cliff where fossil stumps show twenty-seven successive forests, sandwiched between lava layers.

Along the western border of Idaho, and in Oregon and Washington, the crust broke now to those depths where basalt lies as a shell encircling the world. The dark lavas of the Columbia River basalt oozed out, flooding the valleys and piling up about the knees of the mountains.

Streams had another chance to work in early Pliocene time. Now they were cutting into the granite of the central mountain mass. The thousands of feet of silt and clay they dumped in valleys are called the Salt Lake formation in southeastern Idaho, and the Idaho formation farther west. No wide Snake River Plain stretched from one side of Idaho to the other until late in Pliocene time; where it lies there were only mountains and valleys. Only this late in history did the deep cracks spread this far eastward into the continent. The area that is the plain sank along these cracks or faults, and the mountains rose to the north and south. Some lava rose to the surface and spread out; the Banbury basalt crops out in the canyon of the Snake River near Bliss. Then something happened to cool off the climate of the whole world, and here the geologist recognizes the end of the Pliocene epoch and the Tertiary period, and the beginning of the Pleistocene ice age.

The palm-like cycads had become old-fashioned by the beginning of the Cenozoic era; and flowering plants much like present ones, though not the exact species, had taken over. Plants changed less in the next 70 million years than the landscape did where mountain ranges were repeatedly raised and then eroded away. Because plants change slowly and flourish only in that climate which suits them, fossil plants tell more about ancient climate than anything else that can be found in the rocks.

So, the fronds of palms in the Eocene strata show that it was warm and damp here after the mountains of early Eocene time had been worn down. Fig trees and even the breadfruit tree grew here. The whole world was warmer than it has been since, and even in Greenland there was a forest of trees like those growing in Virginia now.

The plants show that it began to get a little cooler in Oligocene, no doubt because the land had risen. The mountains were damp enough for sequoias to grow, and trunks and stumps fifteen feet thick lie under the Challis volcanics up in the Salmon River country. At the same time, the lowlands grew drier as well as colder and the trees shrank back; a relatively new plant, the grasses, commenced their first real expansion over the plains of the world.

In Miocene time, when the Columbia River basalts poured out to dam rivers and back up lakes, the hills surrounding those lowland lakes bore a forest such as now grows in a warm and wet state like Maryland. The paleobotanist Berry found leaves of oak and hickory and hazel and sassafras and even persimmon in the lakebed clays, which are known as the Latah formation. Many people know these beds, and pause to look for leaves in them where they crop out on the Whitebird Hill. Altogether about 150 kinds of plants have been found in them. Lastly, in the Pliocene era at the end of Tertiary time it grew cooler still. The floodplain silts of this age in the Hagerman Valley show traces of poplar and alder, and some of the evergreens.

The warm Eocene was the springtime of the mammals. Already there were a number of different kinds, and everything was prepared for more. The world provided more vegetable food than it ever had before. The great reptiles had died out. Some alligators and crocodiles lurked in swamps, but there was nothing left of the rest except their bones, which stuck out here and there where streams cut gullies in the older formations.

Like creations of the dawn, the earliest Tertiary mammals were all small. The horses were smaller than hunting dogs; the camels, the size of jackrabbits; and the primitive rhinos, about as big as sheep. Their smallness and helplessness shows how peaceful this time was. But soon the first mammal flesh-eaters, the dog-like creodonts, appeared to make life dangerous for the little vegetarians.

Enormous variety developed soon, as nature worked to fill the vacuum left by the passing of the reptiles. Tribes of tree-living animals populated the forest, eating fruits, nuts, bugs, and eggs of the birds, who had been nesting there relatively unmolested for millions of years. Ancestral beavers and muskrats lived in the wet lands, and bears who had developed heavy fur and the habit of hibernating took over the cool regions. Mammals like the seals and dolphins and whales entered the oceans west of Idaho, for the savage mososaurs were gone, even if harks were there to give trouble. A few animals like the flying squirrels learned to glide through the air, and a few scraps of bond show that mammals had become truly airborne, as bats, even in Eocene time.

Next came the experiments with size that nature never wearies of trying, in spite of the repeated failures, when her creatures find open spaces. The elephant-sized Uintatherium roamed Idaho as well as the flanks of the Unitas where their bones first turned up. A dull animal, it had three pairs of horns to fight with, but a brain no bigger than a baseball. A peccary six feet high rooted and grubbed in the forests and perhaps ate acorns. Only a book on paleontology has room to describe the multitude.

The forest shrank in the cooler climate of Oligocene time, and the grasslands expanded. The little horses were adaptable enough to change instead of becoming extinct; they gradually learned to eat grass instead of browsing on twigs. Perhaps they kept growing bigger all the time because grass is so nutritious, and also learned to run fast, on their front toes, to get away from the packs of dogs and wolves that had appeared.

Without the record of the rocks, who would suspect that today is not the prime of the mammals? Variety was much greater in Miocene time. Whole families then alive are utterly gone without trace, unmissed because there is nothing like them left; and so their names are completely strange. Others that we take for granted, like the elephants, are only pitiful remnants of what they once were. A multitude of elephants flourished here and on all the other continents except Australia. With the increasing coolness of Pliocene time, all the mammals declined, except for one tribe, that of the primates.

The upward climb of the primates, ancestors of monkeys and men, latest great experiment of nature, is obscurely recorded in the rocks of the Tertiary period. They did not often get drowned and buried in sediment to become fossils for two reasons. Firstly, they were forest-dwellers; and secondly, they were growing too intelligent to get drowned easily.

We can take some pride in the fact that primates apparently developed in these regions, for the oldest fossils of primates come from Wyoming. A little lemur, Notharctus, lived in the Eocene valleys here. His head was about three inches long and looked very much like that of a rock chuck. However, its long paws foreshadowed our versatile hands; and it had better stereoscopic vision than any other animal, because the snout was shorter and the eyes were set well forward. A little higher in the Eocene strata, and so a little younger, lie the remains of tarsiers. The nose is still dog-like, but has become shorter, because the brows have expanded forward to make room for an enlarged brain.

The record of primates falls silent in this hemisphere after Eocene time. Some of the creatures migrated to the old world; those that remained more or less died out. The near-ape Parapithecus, small as an organ-grinder's monkey, was scouring the old world forests for bugs and nuts when the Lost River ranges were first sculptured and then half-buried by lavas in Oligocene time. Proconsul and his relatives, ancestors of the greater apes and man, separated from the monkey line about when the Columbia River basalts were spreading and cooling. A million and a half years ago, before the Snake River basalts flooded the plain, the nut-cracker man, Zinjanthropus, first of the toolmakers, began to learn how to produce a sharp edge on flint pebbles in southern Africa, in the Olduvai gorge where Leakey has dug him out.

THE PLEISTOCENE ICE AGE

About a million years ago, the climate of Idaho, like that of the rest of the world, became distinctly cooler. Both fossils and the character of the formations tell of this event. The Pliocene basalts of the Hagerman Valley are deeply rotted, which shows that after they were laid down it was wet and probably not too cold. On the basalts lie drab-colored clays, which are the soils stripped from uplands as the climate grew much wetter and cooler. These clays, of the Glenns Ferry formation, hold the bones of bears and the imprints of hemlock fronds, a tree of the cool wet mountains; and the camels that left their bones in the Pliocene strata below are missing.

After a century of guessing by all kinds of scientists, from meteorologists to astronomers, the reason for the cooling of the climate is a little more obvious than it used to be. The Pleistocene cooling is not the only one the rocks reveal. Two or three other times in the past, at intervals of hundreds of millions of years, glaciers have formed, scratched the rocks, and left their characteristic rubbly deposits. Each time glaciers formed, the lands were high and there were mountains. Thus the cooling is probably due to raising of the lands, because every thousand feet of increased elevation lowers temperatures about three degrees.

Anyone who looks down into the canyons of the Snake River or the Salmon River can see for himself that these are young valleys, cut into land that has been raised thousands of feet. Right now the mountains of Idaho are so high that only a slight cooling would bring the ice back. If winter snows were only a little heavier, or the summers only a little shorter, the patches of snow that now linger through most of the summer would not all melt by fall; and so they would grow larger year by year. When they became about 200 feet thick, the pressure would make ice of the lower layers; and this ice would flow down the valleys sluggishly as glaciers.

The question that remains to be answered is why ice gathered and then melted away four times, as one can tell from the successive layers of glacial debris in midwestern states like Iowa. The best explanation, as Professor Flint of Yale says, is that the lands and the mountains are in a high and marginal climatic zone, where a little cooling brings on ice, and a little warming melts it away: for reasons not yet understood, there are long-range changes in the amount of heat received from the sun.

In southern Idaho, ice lay on all highlands that are more than 7,500 feet high. Mountains barely that high, like the Owyhees, had only small glaciers that scooped out basins near the summits, but did not have the energy to flow down to the valleys. A high range, like the Sawtooths, had enormous snowfields; these fed great tongues of ice that flowed to the floor of the Stanley Basin and partly filled it up. The airport at Stanley perches on a remnant of a glacial moraine, a dump of the material the ice eroded from the steep mountain valleys.

During the million years when ice fields grew and then melted away repeatedly, floods of basalt were breaking out on the lowlands, especially on the Snake River plain. The basalt rose along many that cut down through the crust. The Russian geologist, Bellousov, sees something ominous in this process; a breaking up of the continents and the foundering of the crust, finally to make new ocean floor.

In the wetter glacial times the streams spread gravels down the valleys and far out onto the plains. Lakes formed where lavas dammed streams, and then more lava spilled out and displaced the lakes. Snake River, which once may have run westward along the center of the plain, was pushed southward, and dammed repeatedly. But it always overtopped the lava dams and cut canyons through them, like the canyon it has cut below American Falls.

About 20,000 years ago, in a wet glacial stage, Lake Bonneville filled the basin of the Great Salt Lake in Utah to overflowing. The flood waters spilled northward, and down the valley of the Portneuf River. Near Pocatello, the rushing waters moved boulders as big as cottages and dropped them helter-skelter where the current slackened. Small boulders were rolled far downstream and became well rounded, like large melons. A geologist searching for a name for the flood deposits called them the Melon Gravels.

Plants and animals could not adapt to the rapid changes of climate during the Pleistocene, so they migrated instead. In glacial times they moved southward to warmer areas, and in interglacial times they moved northward again to escape from too much heat and dryness. Time-lapse pictures at intervals of a thousand years during the last million would show the spectacular changes. As climate cooled and grew wetter here, the seedling pines and furs spread down the mountain slopes and out onto the plains, where the sage and rabbit brush were dying out. Then as a glacial stage waned, the bitterbrush thickets invaded the thinning forests of old trees, where no seedlings prospered on a drying forest floor. At several times there was a cool grassy steppe where there now is desert. Near the Snake River are traces of frost-churned soils like those now found in the permafrost regions of Alaska. As the European botanists, we in the northern hemisphere live on a fossil tundra.

The mammals who had reached their prime in Miocene time and had lost ground in the Pliocene, now thinned out still more. Most of the really large ones vanished, overcome by trials they never had to face in the previous 70 million years of their existence.

The most impressive creature in Idaho in the ice age was the mammoth, or mastodon. There must have been lots of them, considering that there is scarcely a small museum in Idaho, not to speak of the large ones, that does not have a few mastodon teeth lying around. The teeth turn up mostly in bottomland--the gold mines have found most of them--along the Snake River and many other streams. Herds of mammoths must have grazed in the wet bottoms, using their trunks, as do modern elephants, to pluck bunches of tall grass and stuff it into their mouths. There were several kinds, but the biggest was the great hairy Emperor Mammoth, fourteen feet high.

Back from the rivers in the short grass country the royal bison grazed. It is known as Latifrons, because the horn spread was six feet. Some drank from and died near a large lake not far from Pocatello, where lavas had dammed the Snake River. From the American Falls lake beds has come a magnificent skull of one of these giant bison, so complete that its tooth troubles are plain to be seen.

A large sloth then wandered into the warmer southern valleys of Idaho, perhaps on the sunny side of Juniper Mountain. Such lumbering creatures were the prey of sabre-toothed tigers, who at times may have ranged this far from the warmer valleys they preferred in California.

Now all these animals are gone. They did not die of cold, for most of them lived through four glacial stages, only to disappear after the last. The mammoths survived here longer than in Europe; it seems certain a few stragglers were left at the time of Christ. Man was in at the death of the last of them here, chasing them into bogs where stone lances could do their work at short range. But he was only harrying the remnants of population thinned to the vanishing point by something else, whatever it may have been.

Even the horse vanished late in Pleistocene time. When Cortez unloaded his horses in Mexico, the natives were staggered by an animal completely new to them. Horses had thrived here since Eocene time; why did they not survive on some of the plains and pampas which existed somewhere all the time? How could disease have ravaged them all, scattered as they were through North and South America in groups separated by an isthmus, by jungles, mountains, and deserts? Whatever the causes of disaster, neither the size of the mammoths nor the ferocity of the large cats, nor the mobility of the horses saved them.

Those who have thought longest about it now believe that the hard times promoted the brainy animal. In the long 70 million years of the Tertiary period the brain case has slowly expanded over the snout.The eyes have come far forward, and posture became erect. Very late in the Pliocene someone began fooling around with flint tools. But the development of the brain and of consciousness in just the last million years has been so fast that it deserves to be called explosive, and has made some geologists want to name this time the Psychozoic epoch.

Brainy man rose somewhere in the eastern hemisphere. Saddened archaeologists and geologists here in America are now reconciled never to find traces of really ancient man, or the eoliths, the dawn stones crudely chipped by the half-men who went drifting from the forests out into the clearings to live. When ice first spread in Idaho, only beasts shifted their feeding grounds. But in Europe some kind of men were forced southward and driven to learn to use fire, to make clothes, and to cooperate in hunting cave bears along the ice front. Late in Pleistocene time, when no one in this hemisphere was thinking any harder than squirrels and birds do when storing nuts for the winter, homo sapiens had arisen--and by virtue of his larger and more convoluted brain, had begun to paint pictures, to worry about a hereafter, and to make better weapons with which he may have exterminated his cousin, the neanderthal man, as some think.

Idaho is not old country for man. Only about 30,000 years ago did the population pressures become great enough in Asia to force men northward through bleak Siberia, and then eastward through fog-shrouded lands in search of more hunting and fishing territory. Thus man came here about the time that ice tongues in the Sawtooths were building the horseshoe moraines that hem in Redfish Lake. Doubtless he saw the colossal flood that poured down the Snake River when Lake Bonneville spilled northward past Pocatello.