Copies to: Dr. Hoeh
Mr. Herrmann
Mr. Burky

INTER-OFFICE

To: Mr. John Portune, Mr. Bob Gentet

Date: Feb.23, 1973

Department: Booklets

Subject: Genesis and Geology

From: Robert Macdonald

Your proposal that the dinosaurs lived thru into Creation week, being killed off sometime between the 3d day when the angiosperms were created, and the 6th day when man was created is both highly imaginative and highly speculative. According to this theory all deposits containing both dinosaurs and angiosperms would have to be made during this three day period. Theological considerations aside, this theory presents some enormous problems in explaining these deposits on this basis. Let us consider these points.

1. As explained in my memo, it has now been established that Angiosperms existed during the upper Jurassic, so we would have to consider upper Jurassic plus Cretaceous deposits. This would amount to a total thickness of more than a mile in some parts of the Colorado plateau (see page 34 of my memo)-a lot of material to be deposited in 3 days, especially when one considers what is in these deposits.

2. Many coal beds are included in these upper Cretaceous deposits, some of them more than 20 feet thick. The same type of pollen and spore studies as was described in my memo have been made on these coal beds as well as the strata intervening. Some upper Cretaceous formations have been studied in detail in regard to their pollen and spores as well as floral megafossils. All of these studies show changing populations of plants (as well as animals) throughout this period, an indication of a long period of time as described in my memo. There is no way to account for these thick deposits with their shifting floral assemblages in a short period of time.

3. There are many other indications of time during the deposition of these rocks. Burrows and trails are very common in these deposits and show that life was going on in a normal fashion. There are hardly any upper Cretaceous rocks in Utah that do not show extensive burrowing.

4. My memo described a recent discovery of palm trunks in growth position in the upper Jurassic in Utah. If these angiosperms were created on the third day, how did they live, die, and partially rot away before thousands of feet of material including dinosaur fossils was deposited on top of them in three days?

I have documentation for all these things I have mentioned. Your theory just does not fit the real world. The conslusion is inescapable -- There were angiosperms before Adam.

I suggest that you carefully read the enclosed memo in an attitude of prayer, asking yourself "Is it possible that I could be wrong?"

INTER-OFFICE

To: Mr Richard Burky **Date:** March 12, 1973

Department:

Subject: Geology **From:** Robert Macdonald

It has just come to my attention that the claim by Tidwell (quoted in my memo of February 22, 1973, p. 25) of the first documented pre-Cretaceous angiosperms has been refuted[1]. In addition Tidwell has retracted his claim. The palm trunks in growth position claimed by Tidwell to have been found *in situ* in the Upper Jurassic Arpaien Shale were apparently transported by the slumping of portions of a Teritary formation both stratagraphically and topographically above the Arapien Shale. Palm wood and a palm stump in growth position in a probable fossil soil were observed also in the overlying Tertiary formation (p. 892). Many other lines of evidence point to this formation as the source of the fossil palms.

This is an example of the procedures inagurated when fossils are found "out of place". In this case the fossils were contained in rocks found to be out of place because of deformation, and the range of angiosperms did not have to be extended downward (even though evolutionists would like to do so). Just yesterday I discussed this matter with the U.C.L.A. paleobotanist, Dr. William Schapf. He doubts that anigosperms even existed in pre-Cretaceous times. Their sudden appearance at the beginning of the Cretaceous certainly indicates their creation at that time.

While there are no Jurassic angiosperms, the fact remains that there are abundant angiosperms in the Cretaceous, along with dinosaur remains. In many areas of the Colorado Plateau there are over a mile of upper Cretaceous deposits alone. The upper Cretaceous Evanston formation in Wyoming contains both dinosaurs and angiosperms as well as coal beds.[2] The upper Cretaceous Edmonton formation in Alberta likewise contains both dinosaurs and angiosperms with many coal beds interspersed within it.[3] (p. 270-272) Both these and other formations have been studied extensively with respect to fossil fauna and flora (both pollen and megafossils), and shifting populations of organisms with respect to time have been observed.

The floras of several successive Cretaceous formations in Alaska have been studied in detail.[4] A few statements from the abstract of this article are pertinent.

> " The succession of florules shows a temporal change from gymnosperm-dominated vegetation in older beds to angiosperm-dominated vegetation in younger units. ... All plant taxs have limited stratographic ranges in the local section. ... Comparisions of Kuk River taxa with living analogues suggest that climates of the Cretaceous coastal plain of Arctic Alaska changed from warmer to cooler temperate during this ... late Mesozoic time.

Time is required for floral populations to shift in response to changing environments. In addition after the creation of new kinds, time is apparently required for them to become dominant.

Other indications of slow deposition during the upper Cretaceous include "Bioturbations", or borings made by animals in soft marine sediments. Much of the marine upper Cretaceous in the Colorado plateau is heavily bioturbated. In a report dealing with the structure of some of these burrows in the upper Cretaceous in Utah, James Howard writes:[5]

"One can find some evidence of animal activity which was contemporaneous or penecontemporaneous with deposition in nearly every exposure of the upper Cretaceous sandstones of east-central Utah."

Bioturbations prove slow non-catastrophic deposition. These boring animals could not carry on their daily activities under catastrophic conditions. A formation that is burrowed from bottom to top is necessarily the result of slow deposition under normal offshore marine conditions. The burrowing of marine animals has been studied in present day environments and modern burrows are identical to their fossil counterparts. It is interesting that these animals do their job of reworking sediments so well that the original bedding planes are often obliterated. This accounts for the massive, unbedded fabric of many formations.

Bioturbations as well as surface tracks, trails and organisms preserved in growth positions demonstrate that life was going on in a normal undisturbed manner during the deposition of the surrounding sediments.

I just received an article[6] by Dr. Srivastava, the author of the above paper on the Edmonton Formation. This more recent paper provides some very pertinent information on the formation.

> "On the basis of lithology, sedimentary structures, fossil content and stratigraphic relationships, Allan and Sanderson (1945) concluded that the Edmonton Formation was deposited as a long and relatively broad composite delta contributed by several distributaries on an unstable shoreline."

This brings up the rather involved subject of the interpretation of sedimentary environments on the basis of the above mentioned criteria. This subject has received much attention during the last two decades, and constitutes the bulk of a course in Sedimentology in which I am presently enrolled. Models have been set up based upon the studies of present day sedimentary environments, and the corresponding conditions can usually be observed for any given part of the stratagraphic record. I am convinced that most of these interpretations of environments of sedimentation are valid, meaning that most sedimentation is non-catastrophic in the "old" sense. That is not to say that all present day or past environments represent slow deposition. I have observed an aluminum beer can <u>in situ</u> 6 feet below the surface in a gravel pit cut into a local stream bed!

The Society of Economic Palcontologists and Mineralogists has published a series of books on this subject; their latest, "Recognition of Ancient Sedimentary Environments" is especially valuable.

Srivastava continues (p. 114):

> "Fossil tree-trunks (in situ) are common in coal seams of the lower Edmonton Formation, indicating local swamp forests ... Pollen and fossil woods identified from the strata indicate the presence of cypress-swamps."

This statement is highly significant. Tree trunks in growth position are common in coal seams (more than one).* Both angiosperms and dinosaurs (see Figure 3) are common in the Lower Edmonton Formation. Here we have several horizons during which trees were growing normally. Each forest horizon would represent a centrury or longer -- each during the time that dinosaurs and angiosperms co-existed on earth.

Srivastava goes on to describe the biotic changes and inferred climatic changes that take place during the deposition of the Edmonton Formation, and mentions the presence of "mammals": Figures 2 and 3 graphically show these changes. The author then suggests a reason for the extinction of the dinosaurs (p.117).

> "The climatic cooling, dwindling swamps and marshes, and gradual extinction of the dinosaurianfauna and Aquilapollenites-Mancicorpus flora, during Edmonton time all appear closely inter-related (Fig 3)."

There are many indications of time in the Cretaceous during which fossils of both dinosaurs and angiosperms were deposited.

1. The great thicknesses of these deposits with their many coal beds.
2. Studies showing the shifting populations of the biota.
3. Extensive bioturbated deposits.
4. Several horizons of tree stumps in growth position.

These prove that angiosperms and dionsaurs lived side by side for long periods of time. Therefore our former model of assigning angiosperms and dinosaurs to "separate creations" just does not fit the real world.

*I just phoned Dr. Srivastava who now works in the Los Angeles area. He mentioned that 500 to 600 standing tree trunks had been removed from several strip mined coal seams in the Drumheller area.

Although Tidwell did not discover a pre-Cretaceous angiosperm, his find of palm stumps in growth positions in three adjacent localities as well as the one palm trunk in growth position in the unslumped Teritary material is still very important. By itself it proves that there was at least one horizon in the Teritary during which trees were growing normally.

Many other instances of Teritary forests in growth position are well known. Successive Miocene forests of the Columbia Plateau were destroyed in turn by basalt flows. Yellowstone National Park's famous Amethyst Cliff preserves the remains of eighteen successive Miocene forests, each destroyed and buried by volcanic materials. These forest contain pines which take a minimum of 200 years to mature, and redwoods which take a minimum of 500 years. This would indicate a minimum age of these forests of from 3600 to 9000 years.

At least six successive forests are preserved in growth position in a sequence of Upper Cretaceous to Early Tertiary formations in North Dakota.[7] The largest petrified tree in North Dakota, a redwood preserved in the place in which it grew,was ten feet in diameter at its base. Fossil forests in growth position are but one of many indications of time in the Tertiary. So much time is indicated that the Tertiary has to be pre-Adamic.

How much longer is it going to be necessary to spend time and effort in continually "discovering America" as Mr. Cloud expressed it in his last sermonette in Pasadena before his death? There comes a point when we should acknowledge that America exists and has already been discovered, and then get on with more important matters. Hopefully that day will soon come.

Enclosed herewith are two pages from my memo of February 22, 1973 that have been revised, ready for insertion into the original copy.

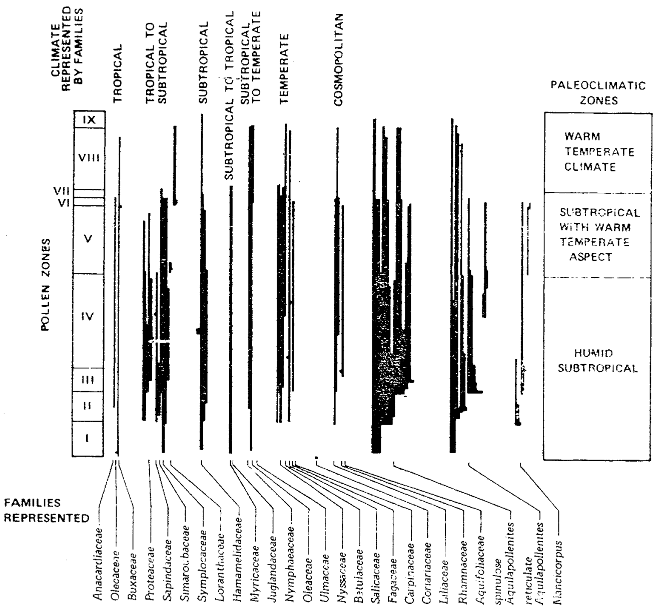


FIGURE 2 — Distribution of angiosperm families recorded in the Edmonton Formation and their correlation with the distribution of *Aquilapollenites* and *Mancicorpus*. I - IX: pollen assemblage zones of the Edmonton Formation (after Srivastava, 1970).

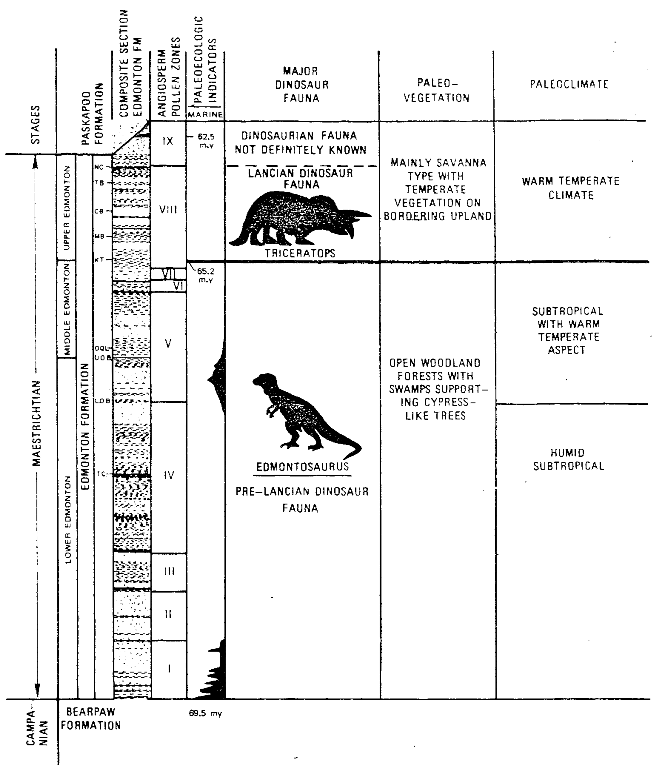


FIGURE 3 — Correlation of available lithologic, biotic, climatic and radiogenic data for the Edmonton Formation.

Abbreviations: I - IX, pollen zones (see Srivastava, 1970);
C. B., *Champsosaurus* Bed; D.Q.L., Dinosaur Quarry Level;
K. T., Kneehills Tuff; L.O.B., Lower Oyster Bed;
M. B., Mammal Bed; m.y., million years;
N. C., Nevis coal seam; T.B., *Triceratops* Bed;
T. C., Thomson coal seam; U.O.B., Upper Oyster Bed.

REFERENCES

1. Scott, Richard A. et al. 1972, "Pre-Cretaceous" Angiosperms from Utah: Evidence for Tertiary age of Palm Woods and Roots, Amer. J. Bot. 59 (9), 886-896.

2. Oriel, Steven S., and Tracey, Joshua I., 1970, Uppermost Cretaceous and Tertiary Stratigraphy of Fossil Basin, Southwestern Wyoming; U.S.G.S. Professional Paper 635, p. 12.

3. Srivastava, Satish K., 1969, Biostratigraphy and Paleoecology of the Edmonton Formation (Maestrichtian), Alberta, Canada, Palaeogeography, Palaeoclimatology, Paleoecology, 7, p. 221-276.

4. Smiley, Charles J., Cretaceous Floras from Kuk River Area, Alaska" Stratigraphic and Climatic Interpretations, 1966, Bull. G.S.A., V. 77, p. 1-14.

5. Howard, James D., 1966 Characteristic Trace Fossils in Upper Cretaceous Sandstones in the Book Cliffs and Wasatch Plateau, Utah Geological and Mineralogical Survey, Bulletin 80.

6. Srivastava, Satish K., 1972, Paleoecology of Pollen - Genera Aquilapollenites and Mancicorpus in Maestrichtian Deposits of North America, 24th IGC, Section 7, p. 111-120.

7. Bell, Gordon L. 1972, The Petrified Forests of North Dakota, Earth Science, Jan- Feb.

Earth & Life History

Examining key issues relating to the history of life on earth

Number 2 PRELIMINARY EDITION November 1998

The Geologic Record: *Understanding Its True Nature by Examining Portions of the Colorado Plateau and Great Basin*

The true history of the earth is often misinterpreted by a lack of understanding of the nature of the geologic record. A good grasp of that nature can be obtained by examining select portions of two major regions of the Western United States, the Colorado Plateau and the Great Basin. With little doubt, no other place in the world contains such a full and observable sample of the geologic record in such a compact and accessible area.

These two regions record geologic events from the oldest geologic era, well over a billion years old, to the recent sediments continuing to be deposited even as I write. Each of the major geologic time periods is represented by strata whose thicknesses are measured in miles.

We can step through the geologic history in a sequential manner moving from event to event. An "event" may be the deposition of sediment, erosion, weathering, soil formation, igneous intrusion, igneous extrusion, metamorphism, structural deformation, faulting, or other geologic processes.

Each geologic event has two components we need to consider. First is the question of sequence. When did this event occur in relation to the other events in the same area? The second item is time. How much time did it take for this event to happen? A volcanic ash fall may be deposited in a matter of hours or days while a soil might require hundreds or thousands of years to develop. By taking these two factors into consideration for each of the geologic events we can get a reasonable grasp of the geologic history of the area. Through the process we will gain an understanding of the true nature of the geologic record.

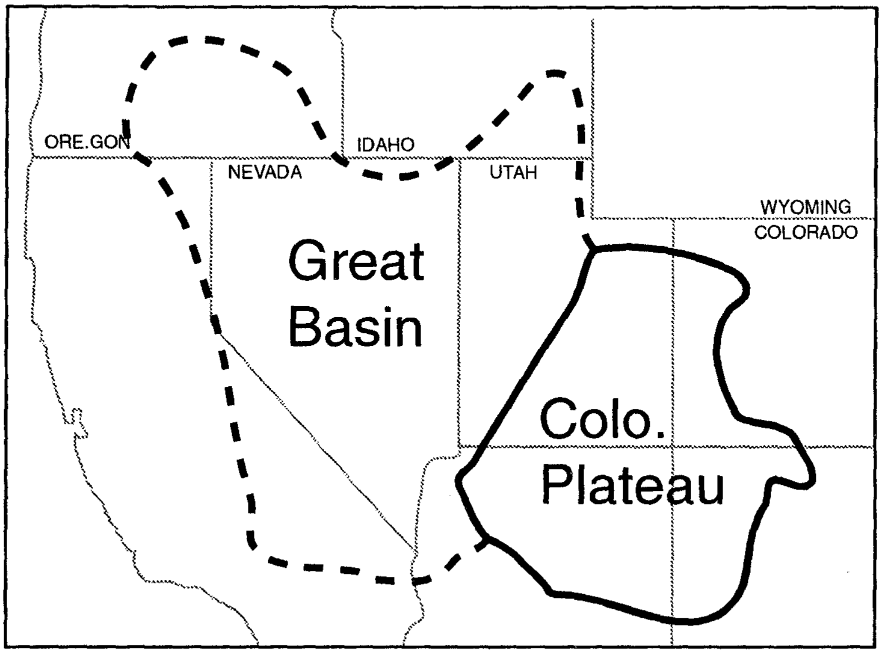


Figure 1. The general boundaries of the Colorado Plateau and the Great Basin in the Western United States.

The general location of the areas that will be examined is shown in Figure 1. The whole western half of the United States contains many areas rich in geologic interest. The Colorado Plateau and Great Basin, however, have been selected as a study area because of the completeness of record simpleness of structure, lack of cover ing vegetation, ease of access, and eas of correlating geologic events from on location to another.

Geologic Time Periods

Before getting into the specifi geology of the Colorado Plateau an Great Basin, we should examine th general worldwide picture of geologi time and the type of life forms livin during that time. This understandin

Continued on page 3

Earth & Life History

An intermittent journal that examines topics involving the origin and development of living and fossil organisms from the perspective of intelligent design and creative development as opposed to macroevolution by purely natural means.

The journal takes no exception to the traditional factual evidence from the geological, paleontological or archaeological records. It merely seeks to put that factual evidence together in a more rational manner that reveals a far greater meaning and purpose for human life than does evolution.

New topics are covered as time and financial resources permit. Copies of this issue and previous issues are available from the address below.

Editor:
Richard R. Burky, Ph.D.

Mailing address:
P.O. Box 94401
Pasadena, CA 91109-94401

About the Editor:

The editor holds a Ph.D. in anthropology with a concentration in archaeology and physical anthropology. His dissertation research focused on radiocarbon dating fossil bone. He has completed many courses in geology and paleontology as well, with special emphasis on fieldwork. During the more than 30 years he has studied and researched prehistory, his work has been published in professional as well as popular journals and magazines.

About this issue ...

For many people, even well educated ones, the geologic record is a mystery. While they may accept the geologist's conclusion that vast amounts of time have transpired since the origin of the earth, they do not understand why this is so, or the evidence upon which it is based.

Religious people often view the geologist's conclusions with great skepticism. Those of Judeo-Christian faith commonly conclude that the inspired scriptures require a young, recently created earth with a similarly young, recently created group of living and fossil organisms. On the other hand, many of Hindu faith hold that the earth is of immense age and man, in fully modern form, is of far greater antiquity than the physical record would indicate.

Individuals of both persuasions have produced evaluations of the physical record that are in striking contrast. Whitcomb and Morris (1963), among many others, present an explanation for a young earth by appealing to catastrophic mechanisms for producing much of the geologic record. Cremo and Thompson (1993) take a different approach to prove that modern human beings are of immense antiquity. They attempt to undermine confidence in modern scientific methodology to show that modern human beings have actually lived on earth far longer then scientific explanation would allow. The book's title and subtitle, *Forbidden Archaeology : The Hidden History of the Human Race*, clearly references this agenda.

There are also unorthodox approaches to prehistory presented from time to time by individuals with varying academic credentials that counter commonly held conclusions about the history of the earth. Several authors have presented such ideas in the later half of the present century. Two notable ones are Velikovsky (1950, 1952, and 1955) and Hapgood (1959, 1966 and 1970).

An overview and general understanding of the geologic record will help evaluate the validity of these contrasting approaches to prehistory and give one a better basis upon which to evaluate what has really happened in the past. Understanding what has happened in the past, how we have become what we are, greatly impacts our understanding of the reason and purpose for human life.

The geologic record is best understood by examining it in real life context. Probably one of the best places in the world for doing this is in the Western United States. Portions of two major physiographic regions, the Colorado Plateau and the Great Basin, provide a nearly ideal area for this purpose.

One cannot expect a 100% complete record of the geologic past anywhere on earth. That's simply the nature of the record. The record in this area, however, is remarkable for the amount of geologic time and for the variety of geologic processes represented.

Proper understanding of the geologic record is a major key to evaluating the history of life on earth. The area being presented is one of the finest for learning the true nature of the geologic record.

The Editor

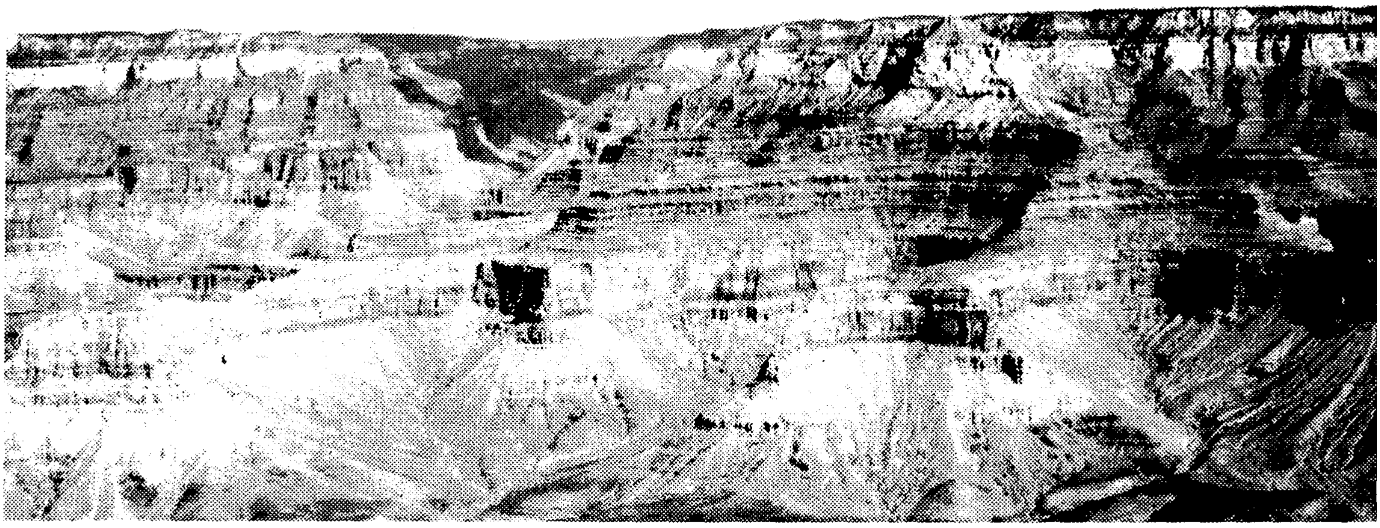


Figure 2. The magnificent Grand Canyon in northern Arizona. This is a good starting place to begin to get a grasp on the nature of the geologic record.

has been derived from more than 150 years of intensive study of the whole world. We will later see how these worldwide time periods are actually expressed in the physical record of our study area. For now this chart will help us to organize and conceptualize a large amount of data in a simple manner.

The history of the earth is divided into four major time periods. From youngest to oldest these are the Cenozoic, Mesozoic, Paleozoic, and Precambrian. The names of the first three were selected because of the type of fossil organisms found in the rocks.

The Cenozoic strata contained forms that were very much like modern living animals. At least they resembled the living animals to a far greater extent than those found in the older strata.

The Paleozoic fossils varied most dramatically from modern animals. Few of the fossil organisms looked anything like modern forms. As notable exceptions, a very few unique organisms were almost identical to the modern forms. These forms are called "living fossils." They include animals such as cockroaches, dragon flies, hermit crabs, coelacanth and opossums.

The strata of the Mesozoic time period contained fossils that were more modern in form than the Paleozoic fossils, but not as similar to modern forms as those of the Cenozoic. The Mesozoic was dominated by land animals of reptile structure such as the dinosaurs and flying reptiles. In the oceans swimming reptiles included the mosasaurs, ichthyosaurs, and plesiosaurs. The reptiles were the dominant large animals of the time period.

The Precambrian strata are almost devoid of life forms but they do contain a few fossils such as algae and bacteria.

Figure 3 on page 4 presents this picture of the geologic time periods and some of the more typical life forms found within them. Also included are some of the finer time divisions and ages attributed to them.

The more precise ages for time periods shown on the chart in figure 3 were determined by radiometric means. Decaying radioactive elements are locked inside the crystal structure of minerals contained in the rocks formed by igneous processes. They self destruct at known predictable rates into known unique "daughter" elements which are also held within the crystal structure. The amount of the daughter elements present can be measured. When this quantity is known, the amount of time required to produce it can be calculated. The radiometric dating methods will be explored in more detail in future issues of this journal. (For a good technical reference that covers all the common radiometric dating methods see Geyh and Schleicher 1990.)

The radiometric dating methods indicate very old ages for the geologic strata. While these methods give more

Geologic Time Periods

		Typical Life Forms
Cenozoic	Present to 66 mya	
		Mammals
Recent	0 - 10,000 years ago	Flowering plants*
Pleistocene	10,000 years - 1.6 mya	Modern fish
Pliocene	1.6 - 5 mya	Modern birds
Miocene	5 - 24 mya	Fewer reptiles
Oligocene	24 - 36 mya	Modern amphibians
Eocene	36 - 58 mya	A few "living fossils"
Paleocene	58 - 66 mya	
Mesozoic	66 mya to 245 mya	
		Dinosaurs
Cretaceous	66 - 144 mya	Flying reptiles
Jurassic	144 - 208 mya	Swimming reptiles
Triassic	208 - 245 mya	Nonflowering plants*
		Archaic fish
		Ammonites
Paleozoic	245 mya to 570 mya	
		Trilobites
Permian	245 - 286 mya	Archaic amphibians
Pennsylvanian	286 - 320 mya	Archaic reptiles
Mississippian	320 - 360 mya	Archaic plants
Devonian	360 - 408 mya	Clams, snails, crinoids
Silurian	408 - 438 mya	Brachiopods
Ordovician	438 - 505 mya	Early fish
Cambrian	505 - 570 mya	First insects
		Sponges, corals
Precambrian	570 mya to 3800 mya ?	Algae, bacteria, and other obscure forms

mya = million years ago
Time data from *Geology* September 1983
* The first flowering plants appear in abundance in the late Cretaceous.

Figure 3. The geologic time scale.

precise figures for the ages, they are not the only way to know that the geologic strata are extremely old. The geologic processes that formed the strata also reveal that very long time periods were involved. The two methods complement one another for understanding the time it took to produce the geologic record. These processes will be mentioned and examined as we progress through this article.

The geologic time divisions should be understood as arbitrary points along a continuum. Life forms did not necessarily change at these boundary times. In some cases some forms went extinct or changed at the boundaries while others lived on with little or no apparent change. It would be a mistake to conclude that these time boundaries always mark major worldwide changes in geology or living organisms.

Precambrian Life

Life in the Precambrian was apparently very limited, but the fossil record indicates that it was very old. There is a possibility that it was far more plentiful and complex than our present knowledge of the fossil record would indicate. Algae and bacteria type fossils are apparently older than 2,000,000,000 years! A few other obscure fossil forms of various sorts are present in some areas. Any fossils are very rare in Precambrian strata.

Even if more fossil organisms are found as these older rocks are explored more thoroughly, it is clear that they do not contain anywhere near the abundant fossil forms found in the Paleozoic strata.

Paleozoic Life

Several Paleozoic life forms are illustrated in figures 4, 5 and6 to give a brief visual impression of how different these were than modern ones. The reader is encouraged to consult a good modern paleontology text for through details of how different the Paleozoic life really was.

The whole issue of the progression of different living organisms is far

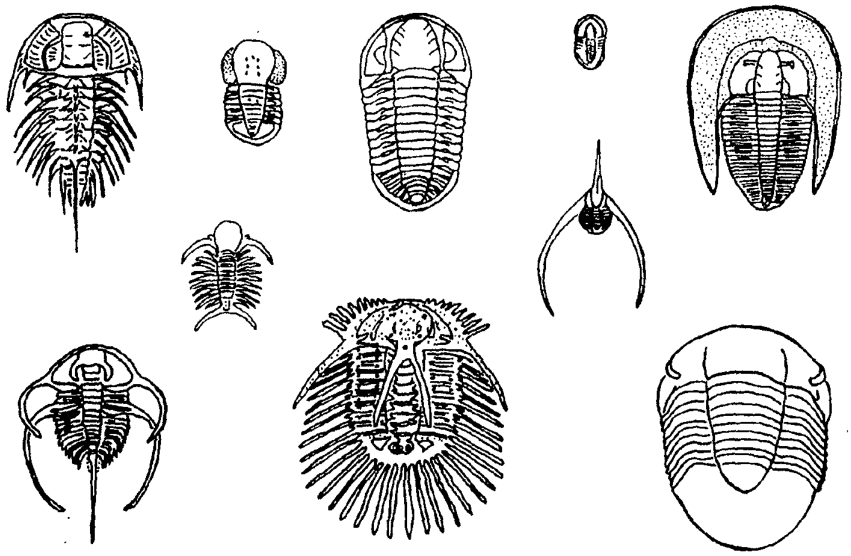


Figure 4. Examples of various types of trilobites. Trilobites were abundant in the Paleozoic time period but did not live into the Mesozoic. Most were small but some reached lengths of more than 30 inches.

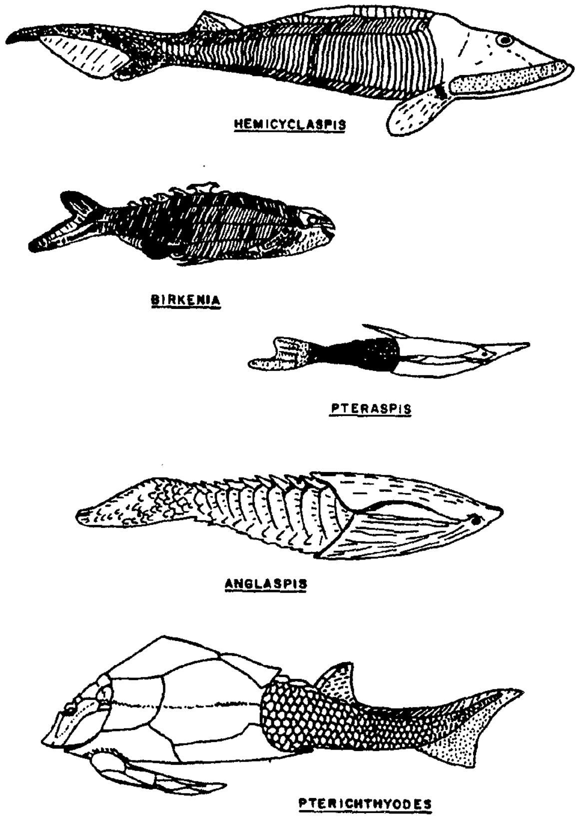


Figure 5. These common early fish are clearly much different than the ones we find alive today. They lived in the early Paleozoic.

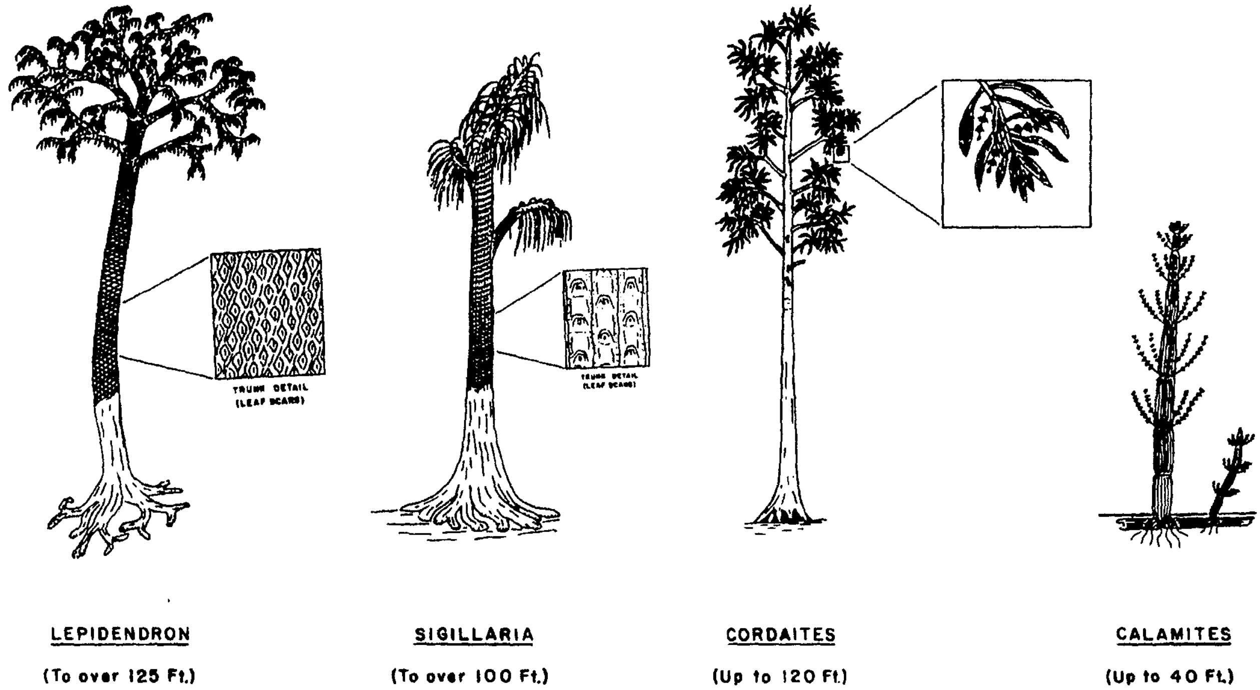


Figure 6. Trees like these were the primary contributors to Paleozoic coal beds. Most have gone extinct. Forms similar to *Calamites* are living today but the modern forms reach only about a tenth the size of those in the Paleozoic.

more complex than the simplicity that is pictured here. Early in the Paleozoic the fish similar to those pictured in figure 5 predominated. The first fish had an exterior bony armor. Later Paleozoic fish had internal bony skeletons but were still considerably different than modern fish. Sharks, which have cartilage for structural support instead of bony skeletons, first appear in Paleozoic strata but continue to live today. The Paleozoic sharks were, likewise, different than those living today.

Some organisms, e.g. the trilobites pictured in figure 4, lived in abundant variety during the Paleozoic. There was a progression and divergence of forms throughout the time period, but they all ceased to exist at the end of it. Stokes (1960, p.187) states that trilobites make up 60% of all Cambrian fossils and that brachiopods make up another 10-20% of it.

Brachiopods are a type of marine shellfish that look superficially like clams. They were extremely abundant in the Paleozoic, but have lived in continually reducing numbers ever since. 20,000 extinct species have been recorded. Even though brachiopods continue to exist today they are a very insignificant and obscure group. Just the reverse situation has occurred in the clams (Pelecypods). They were insignificant in the early Paleozoic, but now exist as 35,000 separate species (Stokes 1960, p. 443).

Late Paleozoic cockroaches and dragonflies would look familiar, but the amphibians and reptiles certainly would not. Neither would most of the land plants. Three of the most common trees of the later Paleozoic are

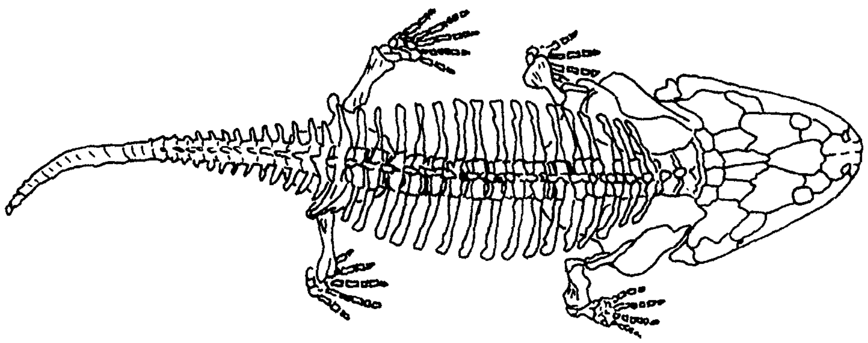


Figure 7. *Metoposaurus*, not your common frog or salamander! This early

grew to heights of 40 feet, about ten times the heights of typical modern forms.

The other large trees of the Paleozoic are long since extinct. Some types of the smaller plants, e.g. ferns, living in the Paleozoic are still thriving today, however.

Mesozoic Life

One of the most striking features of Mesozoic life is the domination of the land, sea and air by reptiles. The dinosaurs are well known by even elementary school children but they certainly are different than living animals. Almost as well known are the flying reptiles, such as *Pteranodon*, *Pterodactylus*, and *Rhamphorhynchus*. Perhaps less well known are the large dominant sea reptiles that include the plesiosaurs, mosasaurs, and ichthyosaurs.

Sea turtles were present then and continue to the present. So do the crocodiles. (A fossil crocodile skull six feet long has been found in the late Mesozoic strata in Texas. The body is estimated at 40 to 50 feet.) Lizards and snakes were present in the Mesozoic.

Of special note are the ammonites. They existed worldwide in abundance during the Mesozoic but were extinct by the end of it. They are especially useful for correlating strata from one place to another because so many different types existed and, being mobile marine organisms, were so widely distributed.

By the end of the Mesozoic, fish of modern design and feathered birds of a modern appearance were present. Also present were an abundance of modern flowering plants. This should help emphasize that the boundary lines of the geologic time periods are more of less arbitrarily set to mark off a continuum of geologic events and changes in living organisms. To better understand the nature of the geologic record and these boundaries one must keep in mind that modern fish, birds and flowering plants made their appearance before and continued after the end boundary of the Mesozoic.

On the other hand the time period boundaries do make meaningful divisions for some major animal forms.

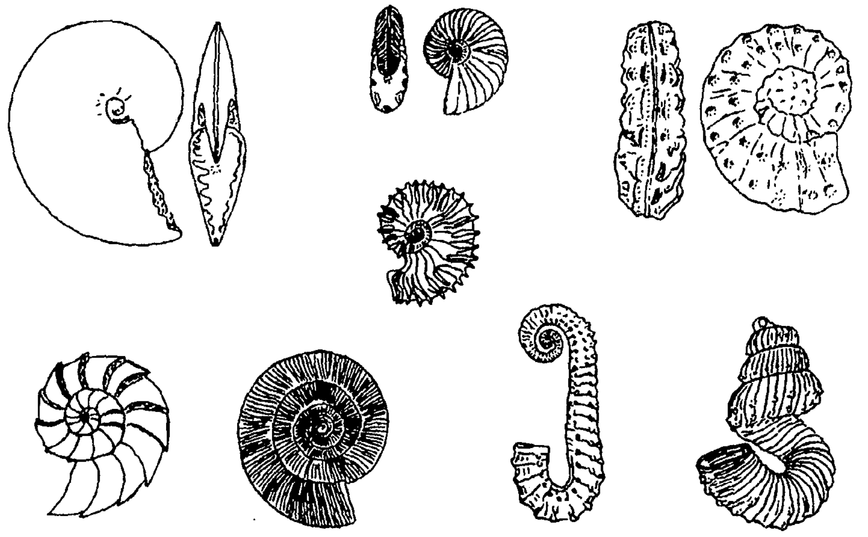


Figure 8. Ammonites were marine organisms that were abundant in numbers, diverse in form (ranging in size from less than an inch to nearly six feet in diameter), and of worldwide distribution during the Mesozoic. By the beginning of the Cenozoic they were totally extinct.

The boundary for the end of the Mesozoic marks the end of the dinosaurs, flying reptiles, plesiosaurs, mosasaurs, ichthyosaurs, and ammonites in the geologic record.

The geologic time period boundaries were set as the science of geology developed without the luxury of having the depth and overview of understanding now available. They were originally established based on imperfect, partial knowledge and local interpretations. In spite of this the time divisions provide a helpful and valuable reference framework for comprehending the geologic record. One should, however, avoid reading more into them than is there.

Cenozoic Life

With the arrival of the Cenozoi we finally find an environment o plants and animals that would be gen erally familiar to humans, althougl not completely, especially in the earli er Cenozoic. Nearly all the mammal that lived at the beginning of th Cenozoic would be strange to moderı

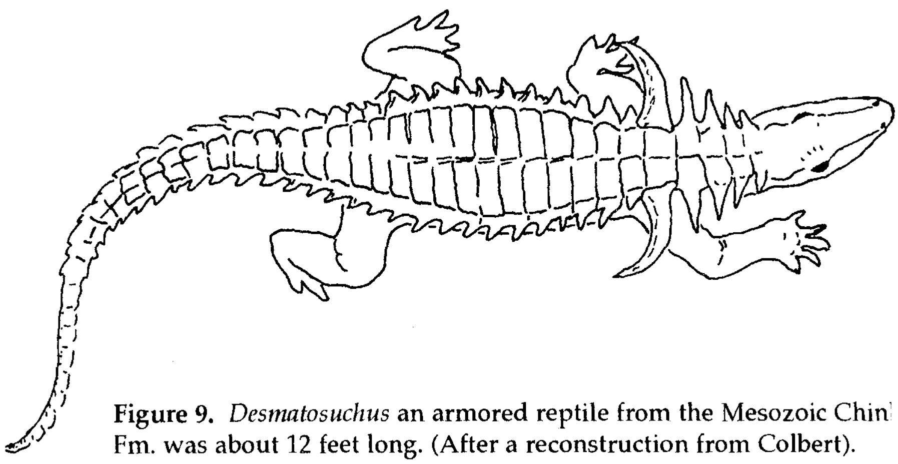


Figure 9. *Desmatosuchus* an armored reptile from the Mesozoic Chin Fm. was about 12 feet long. (After a reconstruction from Colbert).

Mesozoic Dinosaurs

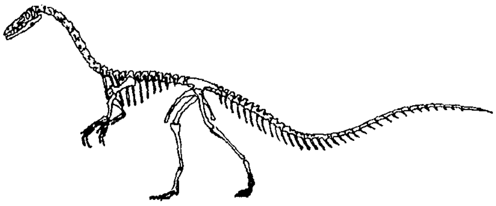


Figure 10. One of the earliest dinosaurs, *Coelophysis* is found in the Chinle Fm. of the Colorado Plateau. (About 8 ft. long.)

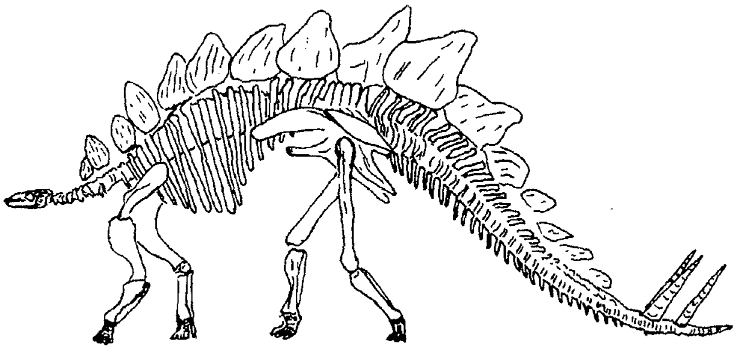


Figure 11. *Stegosaurus.* A dinosaur found in the Morrison Fm. of the Colorado Plateau. About 20 ft. long

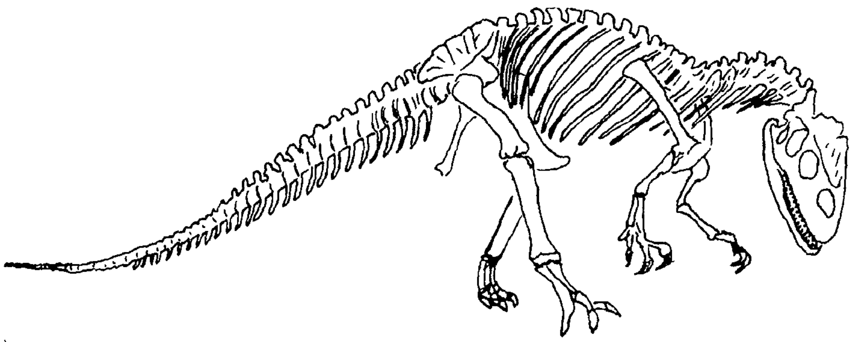


Figure 12. *Allosaurus*, another dinosaur from the Morrison Fm. of the Colorado Plateau. About 30 ft. long.

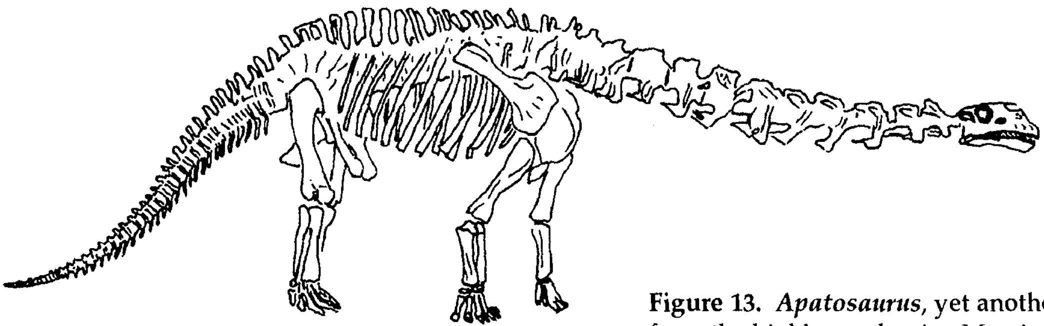


Figure 13. *Apatosaurus*, yet another dinosaur from the highly productive Morrison Fm.

Some Early Cenozoic Mammals

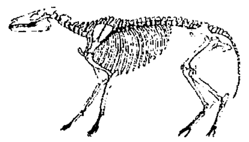
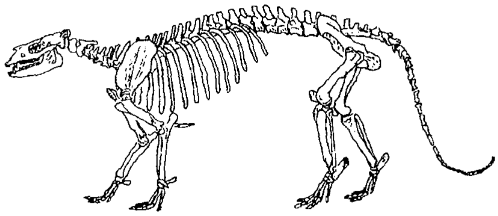


Figure 14. *Hyracotherium* or "eohippus" the diminutive "horse" of the early Cenozoic.. (Redrawn from Cope, about 15 inches tall.)

Figure 15. Early Cenozoic mammal *Phenacodus*. Superficially it may look somewhat like a modern dog but its five toes had hooves rather than claws. Its teeth differed dramatically from those of a modern dog. This animal was about five feet long. (Redrawn from Romer).



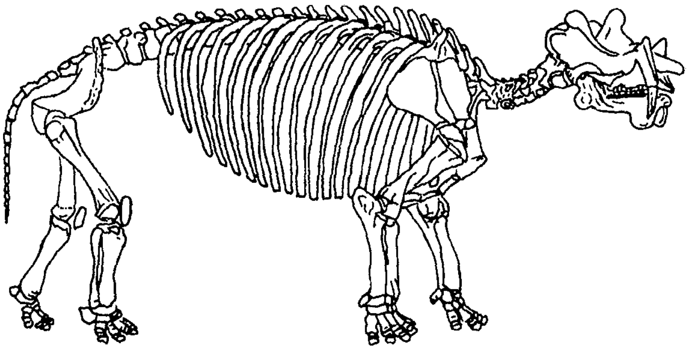
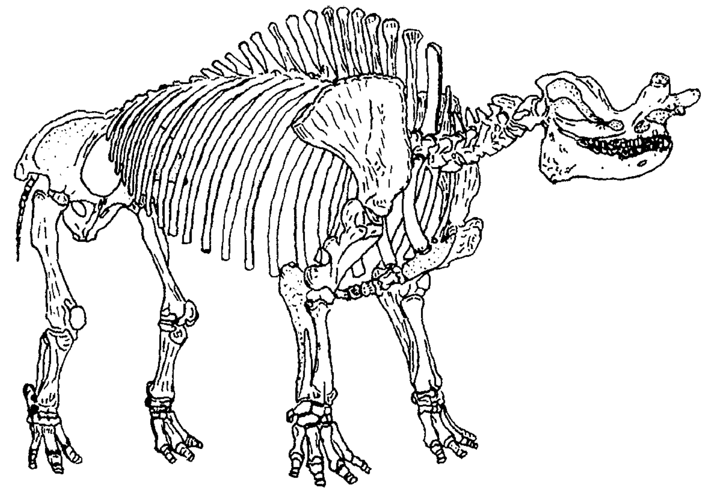


Figure 16. Another rather bizarre early Cenozoic mammal, *Uintatherium* was the size of a modern rhinoceros. It's group, the Dinocerata, went extinct in the early Cenozoic.

Figure 17. *Brontops* an early Cenozoic mammal that belonged to a group called the Titanotheres. The whole group went extinct in the early Cenozoic. 12 feet long, 8 feet high. (Redrawn from Osborn).



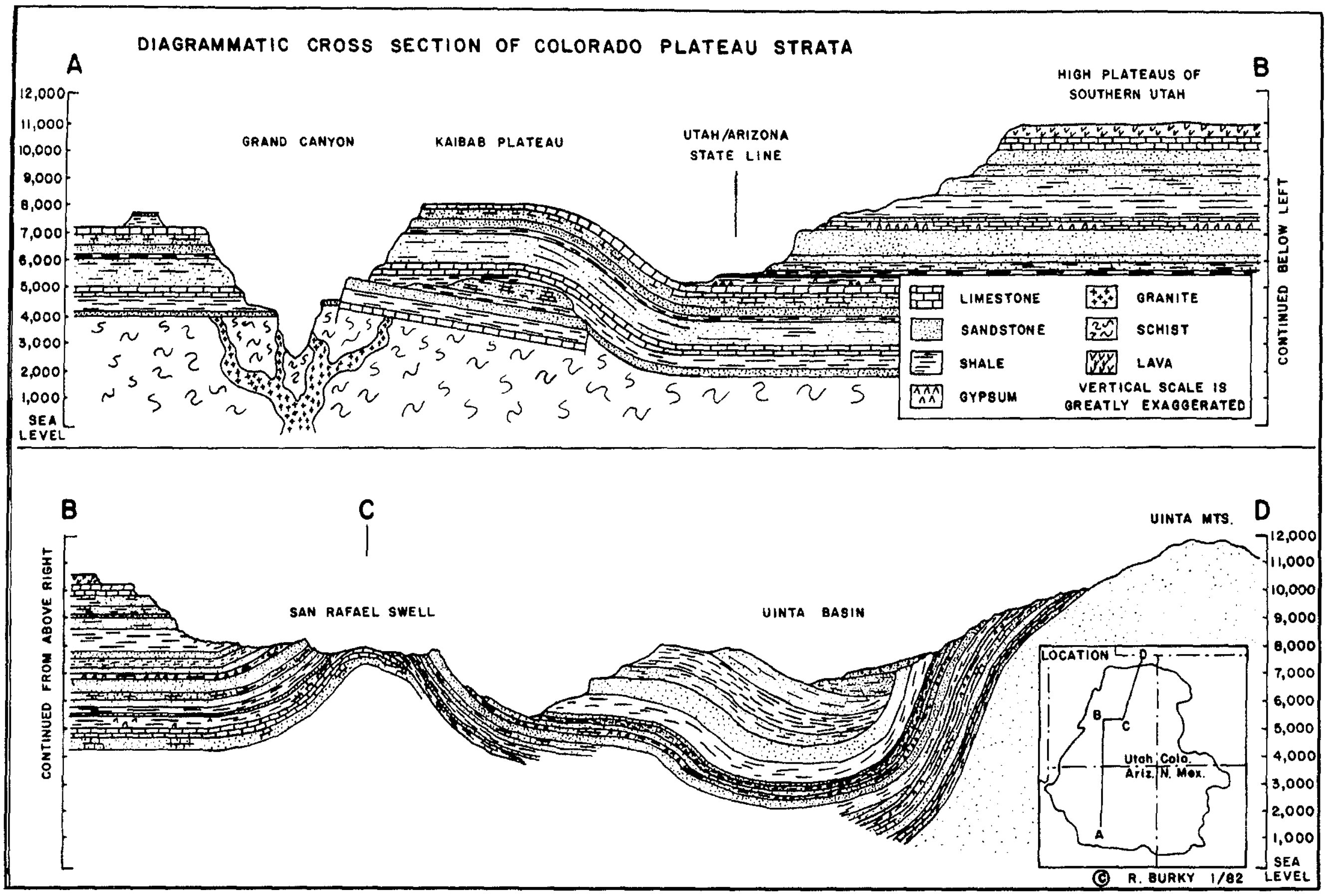


Figure 18. This diagrammatic representation of the strata of the Colorado Plateau clearly presents their relative age and relationship to one another. All important features and relationships pictured can be readily verified by visiting the area. How these strata relate to the general geologic time divisions is shown in figure 19 on the following page.

humans. They were mammals, but not ones with which people are familiar. No dogs, cats, horses, cows, monkeys, apes, elephants, giraffes, etc. The animals illustrated in figures 14 through 16 are representative of the mammals from the early Cenozoic.

The plants and fish would be less strange. Some of these, along with many seashells, would be quite familiar.

Whales and dolphins would eventually replace the extinct plesiosaurs, mosasaurs and ichthyosaurs in the seas, but not for a long time into the Cenozoic.

Colorado Plateau Strata

The strata of the Colorado Plateau provide a unique opportunity to compare the geologic history of a local area to that which has been developed for the world as a whole. The geologic history this area is remarkable for its completeness, simple and understandable structure, and availability for examination. The strata are exposed over thousands of square miles of surface area.

The four major geologic time divisions are each represented by literally miles of thicknesses of strata. Their layout clearly shows the relative age and relationship of one to another. These features are illustrated in the diagrammatic outline of the strata in figure 18. The reality of these relationships are easily observed and proven by visiting the area represented.

Figure 19 illustrates how these strata relate to the overall outline of the geologic history of the earth. The fossils found in any of the strata can be compared with those predicted by an understanding of the worldwide outline of geologic history. The fossils found compare precisely to those predicted.

Limestone structures built by algae are the most prominent fossil evidence in the Precambrian strata at the bottom of the Grand Canyon. Few other fossils occur in the sediments of these strata. Trilobites are found in the lowest and oldest Paleozoic strata in the bottom of the Grand Canyon as well as in the uppermost Paleozoic strata that form the rim of the canyon. They are not found in any of the later strata in the area.

Bony armor plates of early Paleozoic fish (see Figure 5) are also found in some of the lower Paleozoic strata here.

Although the Paleozoic strata of this area do not contain coal deposits, some fossil plants have been found. Types similar to some of those in Figure 6 are found, but none that are similar to the abundant flowering plants found in the late Mesozoic and

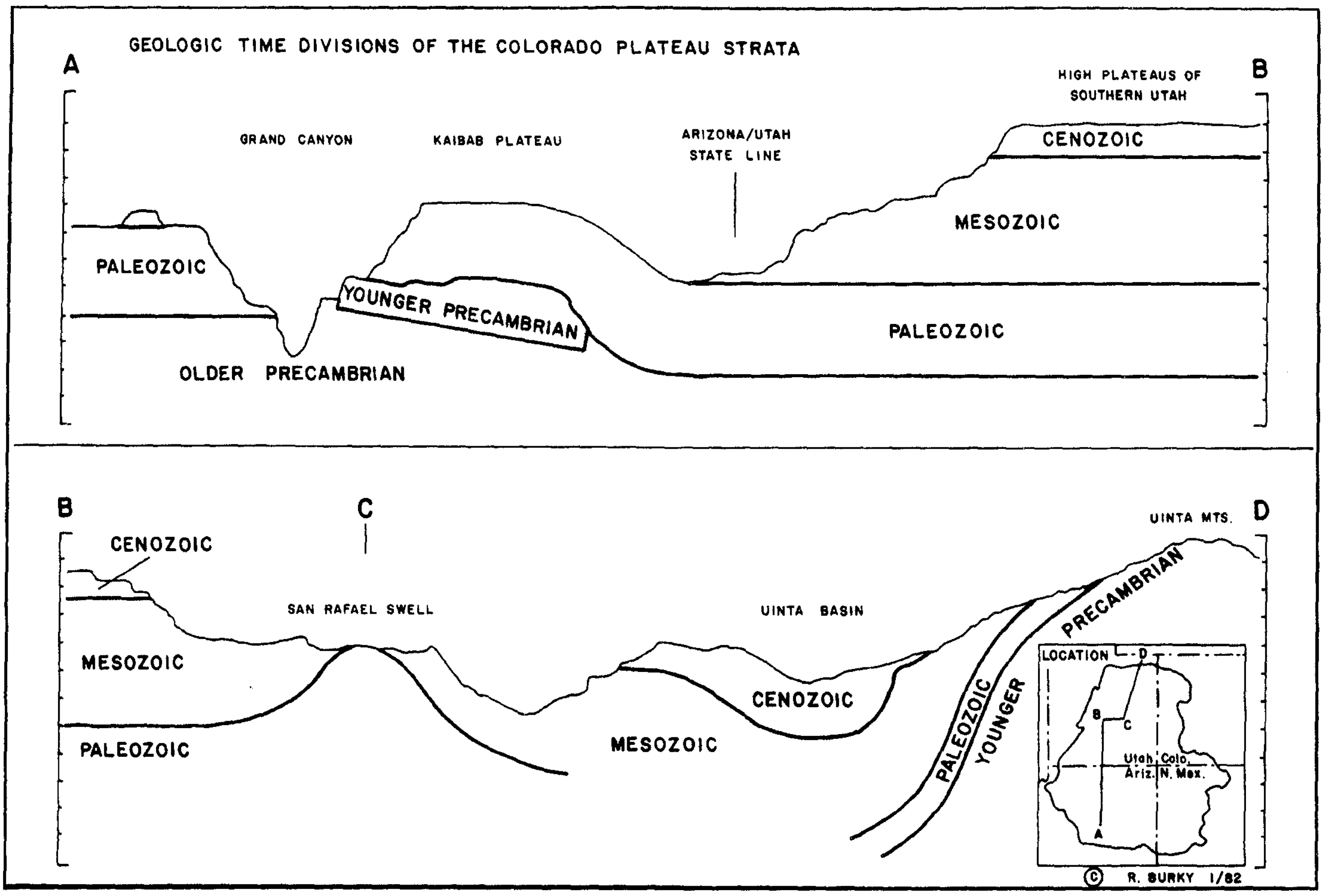


Figure 19. The outline of the strata in figure 18 has been copied in this figure with the geologic time divisions indicated. The type of fossils found in the strata of the different time divisions correspond exactly to those expected based upon the general, worldwide time scale and fossil relationships.

throughout the Cenozoic. Flowering plants are found in abundance in some of the early Cenozoic strata of this area, but not in strata older than the Mesozoic.

Note that no dinosaur fossils are found in the strata of the Grand Canyon. Such fossils are found only in those strata that occur above the rim of the canyon. Dinosaur bones are found in many of the strata that fall within the Mesozoic time period, but in none of the strata in the Cenozoic time period. Major changes in land animals have occurred in a consistent pattern over the earth.

In like manner the Mesozoic marine strata of the area produce an abundance of ammonites. These range in size from a fraction of an inch in diameter to well over a foot. The Cenozoic strata of the area does not contain any marine strata so the lack of ammonites in that time period cannot be verified. However, for those who believe the strata were deposited under worldwide catastrophic conditions in a relative short time period, the total absence of ammonite fossils from the Cenozoic strata of the Colorado Plateau is a point to consider. The total lack of dinosaur fossils from these same strata should also make one question such a conclusion.

The fossils of the early Cenozoic strata of this area clearly show a major change in type of land animal. The dominant reptiles have been replaced with new and different types of animals, the mammals.

The fossil mammals we find from this time period are not types that would be readily familiar to us. They are not modern dogs, cats, cows, bears, elephants, deer, bison, etc. They might be recognized as mammals as opposed to reptiles, but they would certainly not be familiar. One type of mammal extant in the early Cenozoi that would be familiar today is th opossum. It is the exception to th rule, one of the "living fossils."

The examples of the early mam mals illustrated in figures 14-17 ar found in the strata of the Colorad Plateau and adjacent areas.

Only in the much later Cenozoi deposits of the Colorado Plateau an the Great basin are found modern fos sil forms such as horses, camels, bisor muskox, etc.

Thus, it is found that the fossil lif forms found in this area correspond t those of the general pattern for th world as a whole. Many more exan ples could be presented and con pared. Only time and space prohib doing so.

Comparing Real Views of the Strata With the Diagrammatic Representation

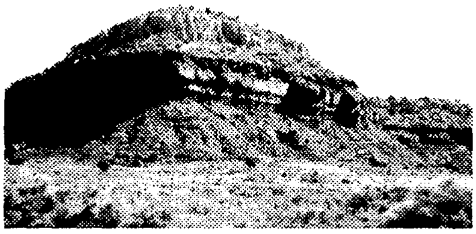


Figure 20. This is the Moenkopi Formation, the first formation above the limestone that forms the rim of the Grand Canyon. It is also found at the Grand Canyon and south of it.

Figure 21. The view northward from point X shows how the strata are stacked one on top the other. The first row of cliffs is called the Vermillion Cliffs. Next are the White Cliffs of Navajo Sandstone. On the skyline are the Pink Cliffs formed by the Cedar Breaks Formation.

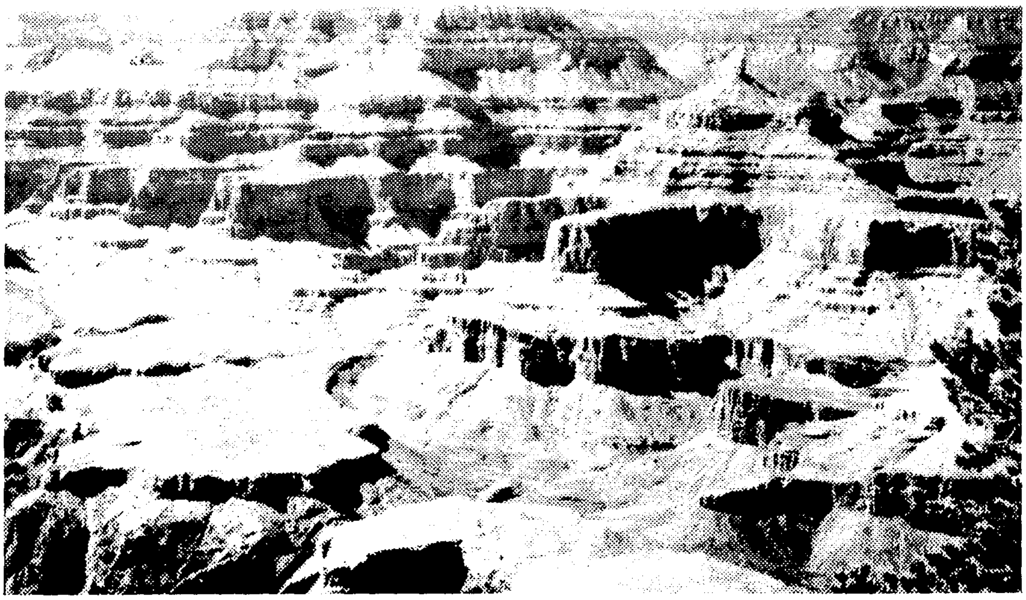


Figure 22. The horizontal strata of the Grand Canyon are the most obvious in this picture. A careful look at the right center of the picture will reveal a protruding block of underlying tilted strata deposited during a much earlier time period.

Figure 23. Strata of the Moenave and Kayenta Formations make the topographic feature known as the Vermillion Cliffs.

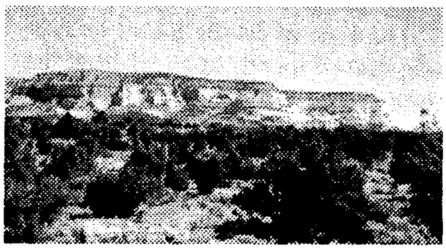


Figure 24. The white cliffs of the Navajo Fm. are shown here overlain by the Carmel Fm. The Navajo Fm. forms the majestic and dramatic scenery of Zion National Park.

Figure 25. The Cedar Breaks Fm. forms the colorful, easily eroded limestone strata of Bryce National Park and Cedar Breaks National Monument.

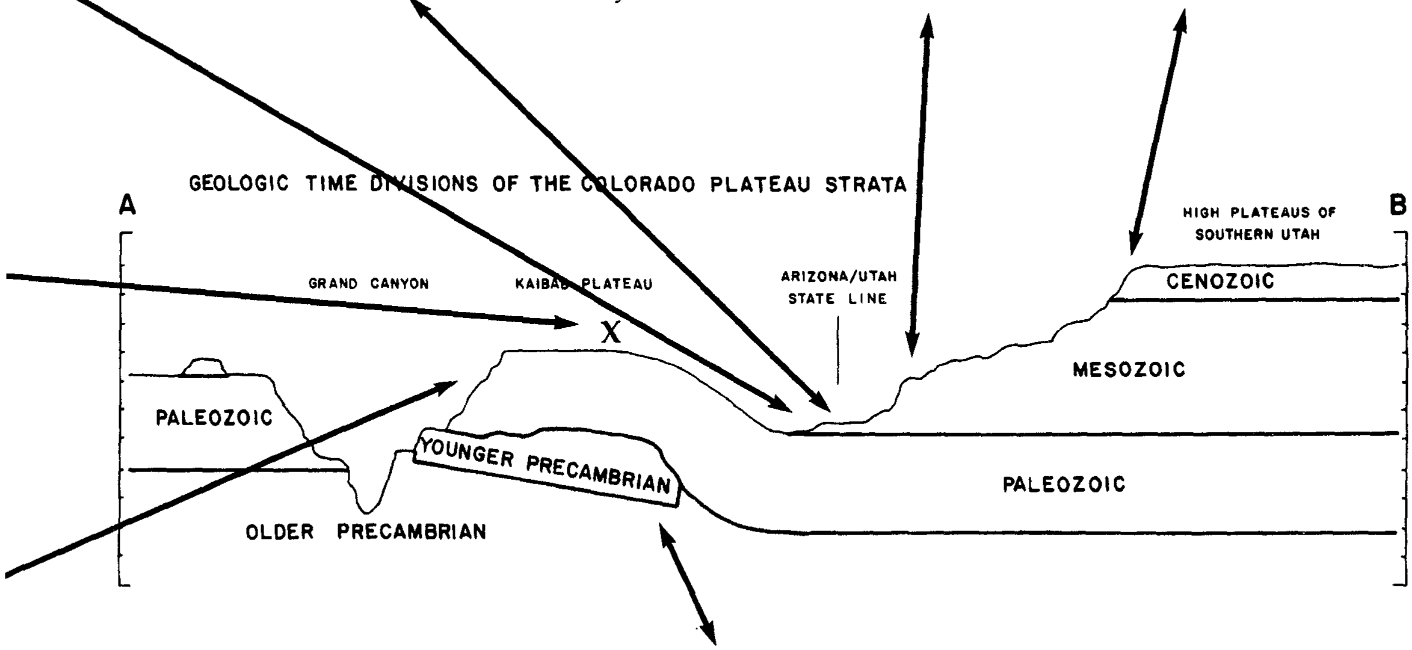
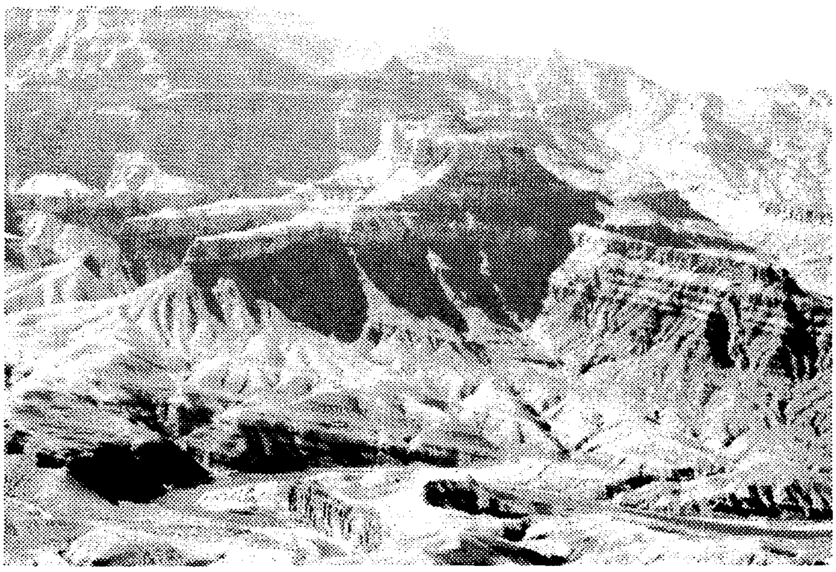


Figure 26. Tilted strata that were deposited after the deposition, metamorphosis, and erosion of the crystalline rocks at the bottom of the canyon, but long before the deposition of the horizontal strata of the Grand Canyon.



The Strata

A schematic overview of the strata of the central Colorado Plateau is shown in figure 18. How that strata relates to the geologic time periods is illustrated in figure 19. These two figures illustrate how this area is such an ideal place to examine the relationship between the world wide composite geologic record and that of a local area.

To discuss this topic it is necessary to explain the technical term "geologic formation," or as it is usually used, just "formation."

A formation is a geologic stratum, group of strata, or other rock unit that can be delineated, mapped and described. It's a basic unit used by the geologist to describe the geology of an area. After naming and describing formations the geologist can discuss and write about the geology of an area in a meaningful way.

Just as letters make up words, geologic formations make up the geology of an area. Just as individual letters can be examined to understand words, individual strata must be examined to understand the geology of an area. Geologic formations that occur one after another in a time sequence are often illustrated in a vertical column with the older on the bottom and the younger on top. This is often called the "local geologic column" of an area.

Local columns of formations for the central Colorado Plateau strata are shown in figures 27-29. In these columns the formations in the Grand Canyon are listed in the Precambrian and Paleozoic sections. The formations in central Utah and the Uinta Basin are listed in the Mesozoic and Cenozoic sections. There is no question as to the depositional sequence illustrated in Figure 18.

A detailed description of each formation is beyond the scope of this paper. Two things, however, are of primary importance to us. First is the type of fossils contained in the formations and, second, the evidence of the depositional time involved. A summary of these two items are given in the graphics of Figure 27 and 29.

The Fossils

The type of fossils found in geologic strata depends upon whether the strata were deposited in the sea (marine deposits) or on land (in lakes, streams, mudflats, or by wind) (continental deposits). Typically all geologic strata can be placed in one of these two categories based on fossil content and depositional environment factors. This separation of itself is a strong evidence against deposition under any catastrophic condition that would mix organisms from all environments together.

The Precambrian is noted for its scarcity of fossils. In the bottom of the Grand Canyon are fossil structures built by algae. Other fossils are sparse and of uncertain affinity.

The Paleozoic formations contain an abundance of marine fossils. Of special interest are the trilobites. They make their appearance in the Tapeats Fm. and last occur in the Kaibab Fm. that forms the canyon rim. There is a large variety of other marine and nonmarine organisms in the Paleozoic formations. The first early, armored fish are found in the Temple Butte Fm.

Marine animals are found in strata that have the characteristics of having been deposited in an ocean environment. Plant and land animal fossils are found in nonmarine or continental deposits. Some formations such as the Moenkopi are primarily nonmarine, but contain some strata that were deposited in a marine environment and contain marine fossils. Though most formations are either marine or nonmarine, some have strata from both depositional environments, but they are segregated units.

Dinosaur fossils are first found in the Chinle Fm. This is the second formation above the rim of the Grand Canyon. Many of the formations between the Chinle and the North Horn (This formation bridges the boundary between the Mesozoic and Cenozoic) contain fossil dinosaur bones or foot prints. Some, the Morrison for example, are abundant dinosaur producers. No primary deposits of dinosaur fossils are found in any of the strata deposited after the North Horn, even though there are strata of over two and a half miles in thickness!

Ammonites are found in the Mesozoic marine strata. Their fossils are particularly abundant in the Mancos, Curtis and marine portion of the Moenkopi. They do not occur in any of the Cenozoic strata. They were extinct by this time. However, none of the Cenozoic strata in this area were deposited in a marine environment so ammonite fossils would not be expected, even if they weren't extinct.

The first fossil mammals are found in the middle of the Mesozoic. They are small, rat-sized animals, known primarily from their teeth. Mammals did not become dominant and abundant land animals until the early Cenozoic. The strata deposited after the North Horn reflects this increased abundance of mammals.

It is not until the time of the Brown's Park deposition that most of the fossil mammals would have a look of familiarity. At that time are found early mastodons and camels. The fossil "rabbits" would also look familiar.

The fossil mammals found in the much later glacial deposits of the area are mostly extinct, but would have a familiar look.

Turtles, crocodiles and lizards have lived since Mesozoic times without significant change. Their fossils are found in many of the Mesozoic and Cenozoic strata.

Modern flowering plants are first represented in abundance in this area in the Dakota Fm. They were therefore present during the latter times of the dinosaurs. This means that major changes in the land plants and the land animals occurred during different time periods.

The fossil fish show a dramatic change in form from Paleozoic to Cenozoic and that change is represented in the strata of the Colorado Plateau area. Figure 28 graphically illustrates these changes that have occurred in fish at three stratigraphical levels. Thousands of fish fossils of many vari-

FOSSIL ORGANISMS FOUND IN COLORADO PLATEAU STRATA

Era	Geologic Formations	Fossils
CENOZOIC	GLACIAL DEP.	BISON
	BROWN'S PARK	
	DUCHESNE RIVER	EARLY MAMMALS (CARNIVORES, HERBIVORES, RODENTS AND INSECTIVORES), FISH, TURTLES, CROCODILES, LIZARDS
	UINTA	
	GREEN RIVER	EARLY MAMMALS, FRESH WATER SNAILS AND CLAMS, MANY FISH, ALGAL LIMESTONE STRUCTURES, ABUNDANT FLY LARVA, INSECTS (MOSQUITOES, BEETLES, ANTS, FLIES, BEES), LIZARDS, TURTLES, CROCODILES, OSTRACODES, LEAVES
	COLTON	EARLY MAMMALS AND "HORSES" (PHENOCODUS, CORYPHODON, "EOHIPPUS")
	FLAGSTAFF	FRESH WATER SNAILS AND CLAMS
	NORTH HORN	UPPER STRATA - EARLY MAMMALS LOWER STRATA - LAST OF THE DINOSAURS
MESOZOIC	PRICE RIVER	
	BLACKHAWK	DINOSAUR TRACKS, COAL BEDS, LEAVES (FIG, WILLOW, SEQUOIA)
	STAR POINT	
	MANCOS	SNAILS, CLAMS, OYSTERS, SHARK TEETH, FISH SCALES, CEPHALOPODS, FORAMINIFERA, OSTRACODES, COAL BEDS
	DAKOTA	500+ SPECIES OF PLANTS, INCLUDING FIG, OAK, WILLOW, PALM, SASSAFRAS, POPLAR
	CEDAR MT.	PETRIFIED WOOD
	MORRISON	FIRST MAMMALS, MANY DINOSAURS, CROCODILES, TURTLES, SNAILS, FRESH WATER CLAMS
	SUMMERVILLE	
	CURTIS	CORAL, SQUID-LIKE ANIMALS
	ENTRADA	
	CARMEL	OYSTERS, CLAMS, SNAILS, CRINOIDS
	NAVAJO	DINOSAUR TRACKS
	KAYENTA	CLAMS, DINOSAUR TRACKS (RARE)
	MOENAVE	EARLY CROCODILES
	WINGATE	
	CHINLE	FIRST DINOSAURS, EXTINCT LARGE AMPHIBIANS AND REPTILES, EARLY BONY FISH, SNAILS, CLAMS, INSECTS, MANY PLANTS AND LARGE TREES
	MOENKOPI	EXTINCT AMPHIBIANS, COELACANTHS, SNAILS, CLAMS, SEA URCHINS, CEPHALOPODS, OSTRACODES
PALEOZOIC	KAIBAB	EARLY SHARKS, SNAILS, CLAMS, SPONGES, CORALS, SEA URCHINS, TRILOBITES, CRINOIDS, BRYZOANS, BRACHIOPODS, CEPHALOPODS, FORAMINIFERS, OSTRACODES
	TOROWEAP	
	COCONINO	ANIMAL TRACKS (20 VARIETIES), INSECT TRAILS — NO ACTUAL FOSSILS FOUND
	HERMIT	PLANTS (SEED FERNS), ANIMAL TRACKS, INSECTS
	SUPAI	BARREN OF FOSSILS IN THE GRAND CANYON AREA
	REDWALL	SNAILS, CLAMS, EARLY SHARKS, CORAL, SEA CUCUMBERS, TRILOBITES, ALGAE, BRYOZOANS, BRACHIOPODS, CRINOIDS, BLASTOIDS, SPONGES, CEPHALOPODS, FORAMINIFERS, OSTRACODES
	TEMPLE BUTTE	PRIMITIVE ARMORED FISH, ALGAL LIMESTONE STRUCTURES
	MUAV	TRILOBITES, SNAILS, SPONGES, BRACHIOPODS (MARINE SHELLFISH, MOSTLY EXTINCT), EARLY CRUSTACEANS, CYSTOIDS
	BRIGHT ANGEL	
	TAPEATS	
PRECAMBRIAN	CHUAR GROUP	ALGAL LIMESTONE STRUCTURES, SOME FOSSILS OF UNCERTAIN IDENTITY
	DOX	
	SHINUMO	
	HAKATAI	
	BASS	ALGAL LIMESTONE STRUCTURES
	VISHNU	NO FOSSILS

© R. BURKY 3/82

Figure 27. Fossils found in the formations of the central Colorado Plateau strata.

eties are found. Each of the fish shown are merely representative of the type that are found at a particular stratigraphic level.

The Evidence for Time

The next major issue to examine is the evidence for the amount of time it took to deposit the material in the strata. A cursory look at the strata of the Grand Canyon may give the impression of rapid deposition. Closer examination reveals many reasons why this can not true.

A few of these reasons that would seem most evident to the lay reader are indicated in Figure 29. We will examine a few of these in detail.

Deeply weathered rock

The crystalline rocks that make up the Vishnu formation show evidence of chemical weathering many feet deep prior to the deposition of overlying strata. The chemical breakdown of the minerals in crystalline rocks take a lot of time. This time will increase or decrease depending upon the climate. However, when weathering zones are found that are many feet thick it is known that much time has elapsed. In this case the zone developed between the time the Vishnu was eroded to a level surface and the time it was covered by sediments of the Tapeats Fm.

Fossil mud cracks

Mud is rich in clay. When it drys out the clay shrinks because of water loss. This produces a very characteristic cracked surface. Such surfaces are found in abundance throughout many of the strata in the area. A few of those occurrences are indicated in Figure 29.

The significance is this. It proves that the strata were not deposited all at once under water. The mud had to be deposited, allowed to dry, than be covered by more sediment. In many cases there is layer after of mud cracks in a very short vertical distance. This shows that there was a time period with many alternate cycles of deposition and drying. The material was deposited in small increments in these situations.

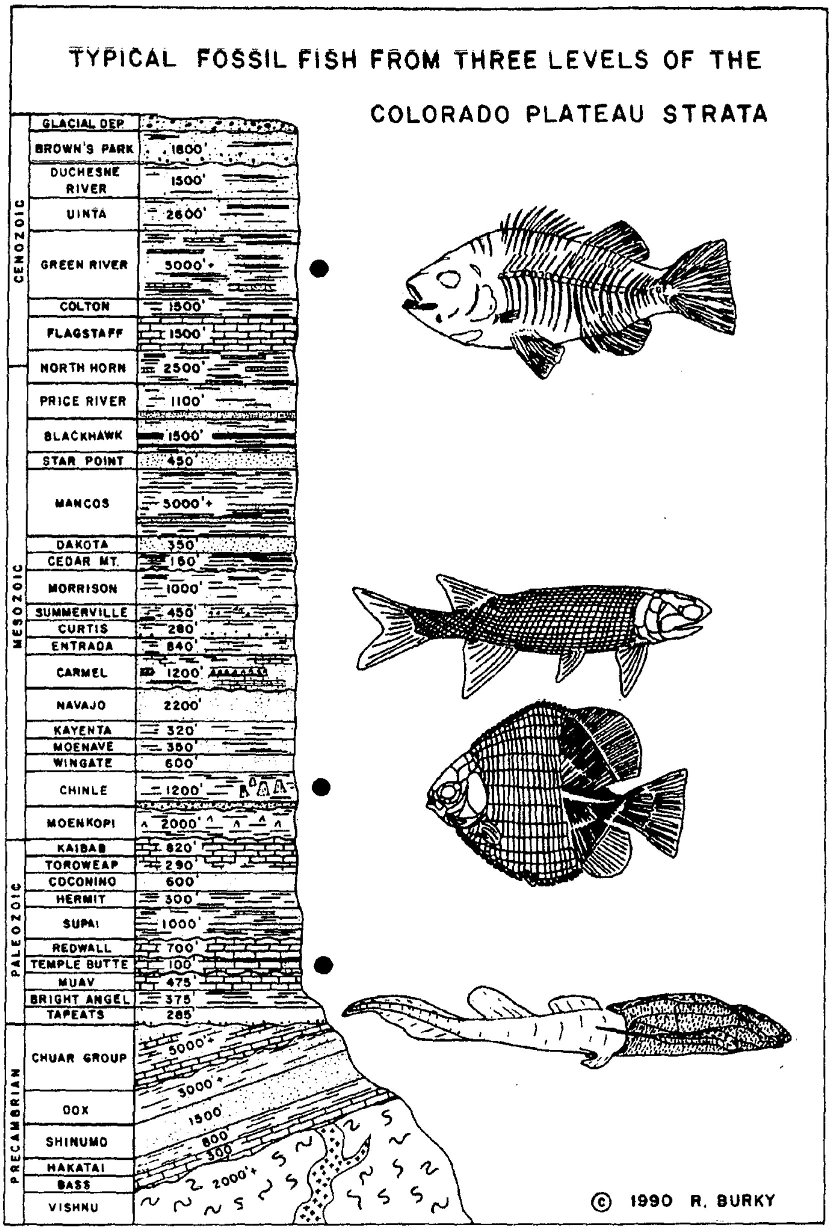


Figure 28. Fossil fish change dramatically in design from older to younger strata in the Colorado Plateau.

Fossil algal limestone structures

Another common indicator of significant lapsed time between the deposition of the strata layers is the growth of finely laminated limestone structures that are built up by algae. These structures are reminiscent of the rings of a tree. The algae slowly build up the layers one by one over time like a tree adds rings year by year. The structure are in growth location and position. They have not been deposited as large masses all at once.

This indicates that there was an on-going environment in which the algae was living and building up the structures. This definitely witnesses against rapid, catastrophic deposition of the strata.

Standing trees and oyster beds

A few strata contain fossil tree

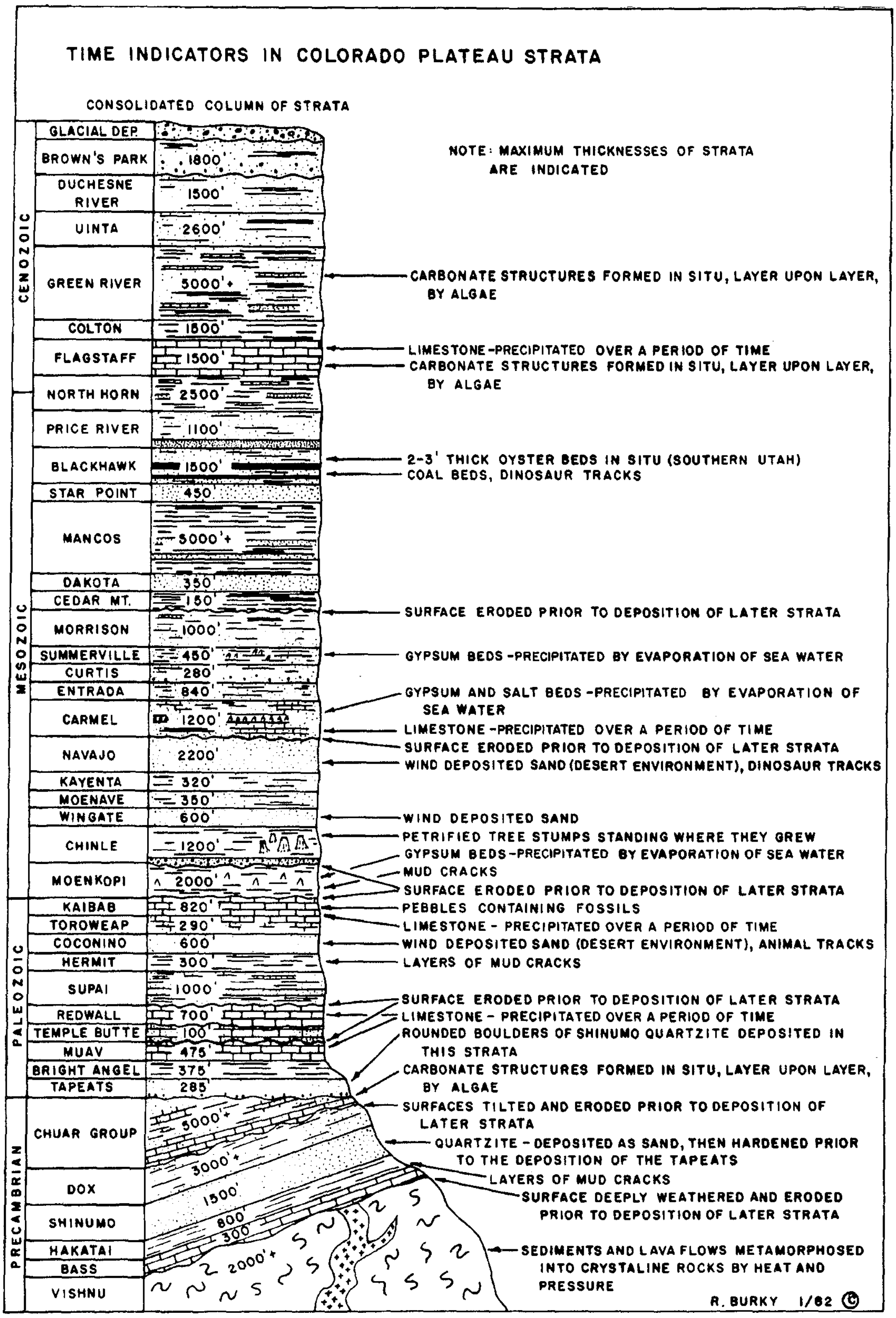


Figure 29. Evidence for prolonged time periods of deposition found in the geological formations of the central Colorado Plateau.

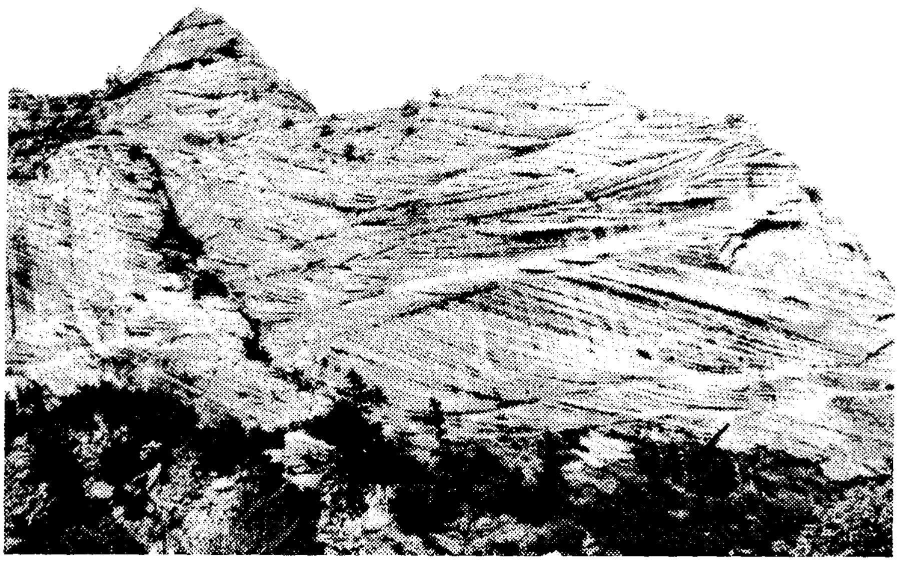


Figure 30. A fossil desert. Wind blown sandstone deposits of the Navajo Fm. in Zion Nation Park in southern Utah. This is part of one of three fossil deserts found in the strata of this area. All have the same characteristic crossbedded sandstone bedding patterns that are characteristic of sand dunes.

Figure 31. Bedded layers of limestone deposited in growth position by algae. This indicates that the sediments deposited slowly in a normal environment, not rapidly by catastrophic mechanisms. These strata are in the Green River Fm.

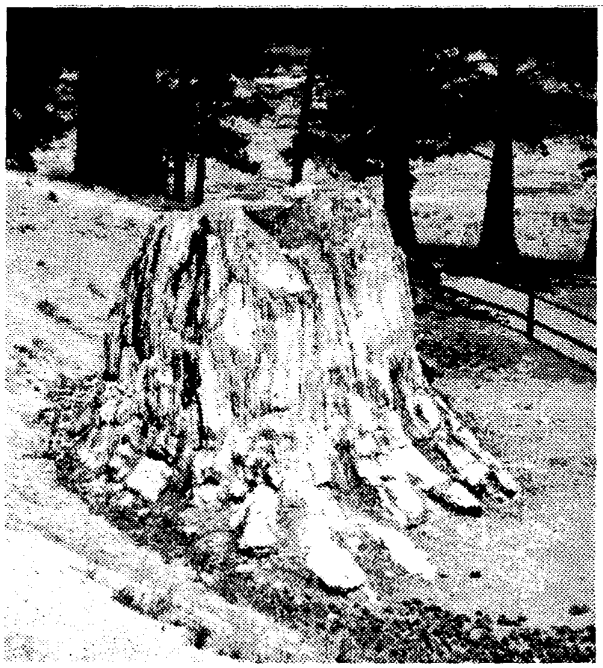


Figure 32. A petrified tree stump standing in growth position and location. This is another indicator that significant time elapsed during and between layers of strata. This tree was approximately 12 feet in diameter. Other standing petrified tree stumps up to 15 feet in diameter have been reported from the middle Cenozoic strata of the western Great Basin (Arnold 1947, p. 36).

stumps that are preserved in growth position. These are not as common as the other time evidences but they are not extremely rare either. What they show is that enough time for a tree to grow elapsed between the deposition of the strata in which their roots are growing and the deposition of the strata that covered and preserved them .

Fossil tree trunks that occur in such situations vary from a few inches to fifteen feet in diameter.

A similar type of indicator of time is reflected in the occurrence of fossil oyster beds. In some cases these beds are many feet thick and typically are made up of only one species of oyster. At one oyster bed locality in central Utah there were so many shells of one species of oyster they were quarried and used to surface roads. To conclude that they were gathered, sorted and deposited under catastrophic conditions exceeds credibility. They were clearly deposited in the environmental context where they lived and died. Many such oyster beds occur in the Mesozoic strata of the Colorado Plateau.

Fossil deserts

Three major fossil deserts are found in this area. They are indicated by the formation names: Coconino, Wingate and Navajo. The wind blown depositional structure and other environmental indicators clearly witness the conditions of deposition. This would certainly rule out the possibility of the strata being deposited in one catastrophic flood.

Evaporite deposits

Some strata are made up either in part, or entirely, of minerals that have been deposited by evaporating water. These occur at multiple levels in the local geologic column (e.g. The Moenkopi, Carmel, and Summerville formations). A mineral such as common table salt perhaps most clearly illustrates the situation. This salt stays dissolved in the water until it is evaporated and concentrated to the point of saturation. Only then does it begin

Figure 33. Structures built by algae in a boulder of limestone from the Bass Formation in the bottom of the Grand Canyon. Algal structures are one of the most typical of the rare fossil forms found in Precambrian strata. Such structures occur not only in the Precambrian, however, but are found throughout the geologic record.

to crystallize and come out of solution. Salt is the most common mineral in sea water but it stays dissolved in that water until it is evaporated. Salt deposits would not form under flood conditions.

A more common mineral deposited in this manner and present in great quantities in many Colorado Plateau strata is gypsum. It may not be recognized by most people but it is common in our modern living environments. It is the principal constituent of construction wallboard, chalk and plaster of paris.

The Carmel Fm. in one area of central Utah is estimated to contain 9.7 billion tons of gypsum (Stokes and Cohenour 1956, p. 54). That would represent a lot of evaporated water.

Colorado Plateau Summary

The Colorado Plateau is a unique area that has remained essentially stable and little disrupted for a very, very long period of geologic time. Yet it contains literally miles of strata from all four of the major geologic time periods. This combination has produced a near "textbook" perfect location for understanding the nature of the geologic record. The previous se tions have shown how the record he corresponds precisely with the con posite record developed by geologis for earth as a whole.

The Great Basin

In contrast to the Colorac Plateau, the Great Basin lacks the gre level expanses of geologic strata. has been depressed, compresse extended and faulted severely whi the Colorado Plateau was enjoying i long, stable existence. Howev because of this different geologic hi tory it can show us a different aspe of the nature of the geologic record.

In addition, the Great Basin ad detail to parts of the geologic reco that are blurred or missing in t Colorado Plateau. Fortunately, so of the strata from the Plateau exte into the Basin and provide markers make correlation of geologic eve possible between the two areas.

The Great Basin extends from Sierra Nevada Mountains in the W to the Watsatch Range in the East. brief overview of its geologic histor necessary to understand its curr geologic structure.

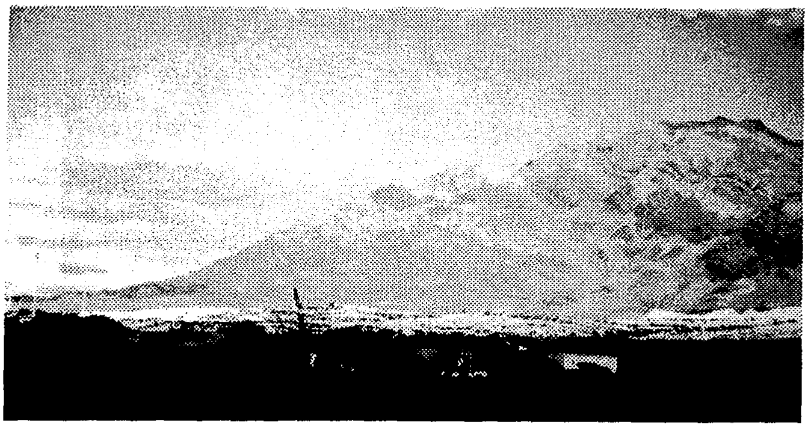
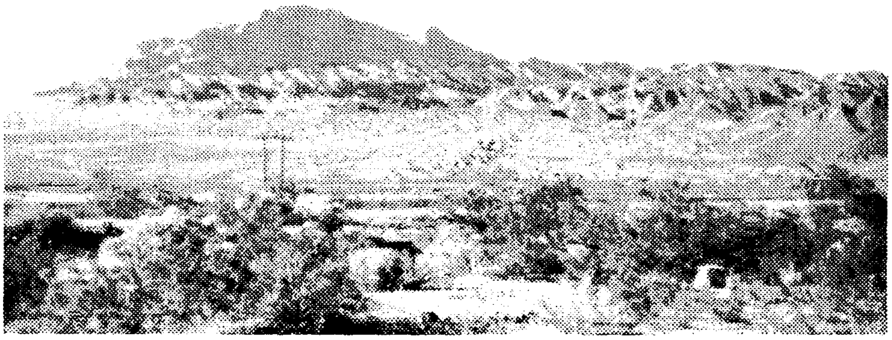


Figure 34. Frenchman Mt. immediately east of Las Vegas, NV is made up of a series of geologic strata that include those of the Grand Canyon. It provides the opportunity to compare the age of the Grand Canyon's strata to earlier and later geologic events in the Southern Nevada area. Immediately to the east these Paleozoic strata are overlain by Mesozoic and early Cenozoic strata. (View is from the southwest.)

Figure 35. This view from the southeast of Frenchman Mt. shows how the Paleozoic, Mesozoic and early Cenozoic strata lie in superposition over one another to the east of Frenchman Mt.



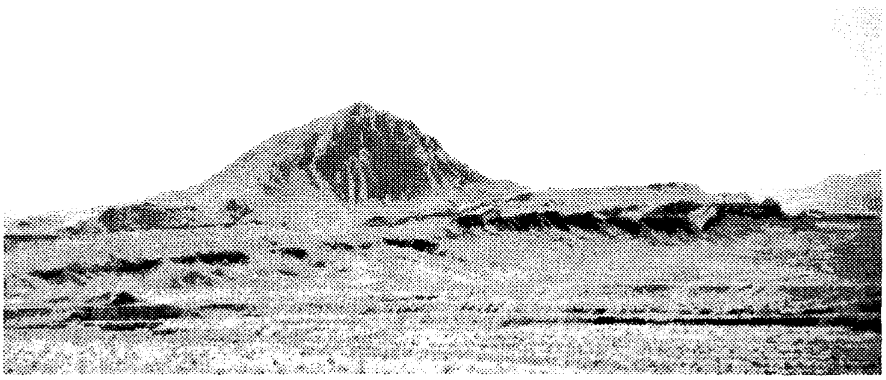


Figure 36. Lava Butte a few miles east of Frenchman Mt. is made up of extruded volcanic rock. It lies in the Horse Springs Fm. of early Cenozoic age (just off the right edge of the picture in Figure 34 above) and has been dated at approximately 13 million years old. This age is in full harmony with the estimated time of the deposition of the Horse Springs strata. (View is from the northeast.)

Figure 37. Mormon Mesa, about 40 miles northeast of Las Vegas near the town of Overton, is a remnant of the Muddy Creek Formation that filled the Las Vegas Valley after all the major structural changes pictured above had taken place. This formation is still in its original horizontal position of deposition, indicating that no structural change has occurred since it was deposited. Tremendous erosion has, however , taken place.

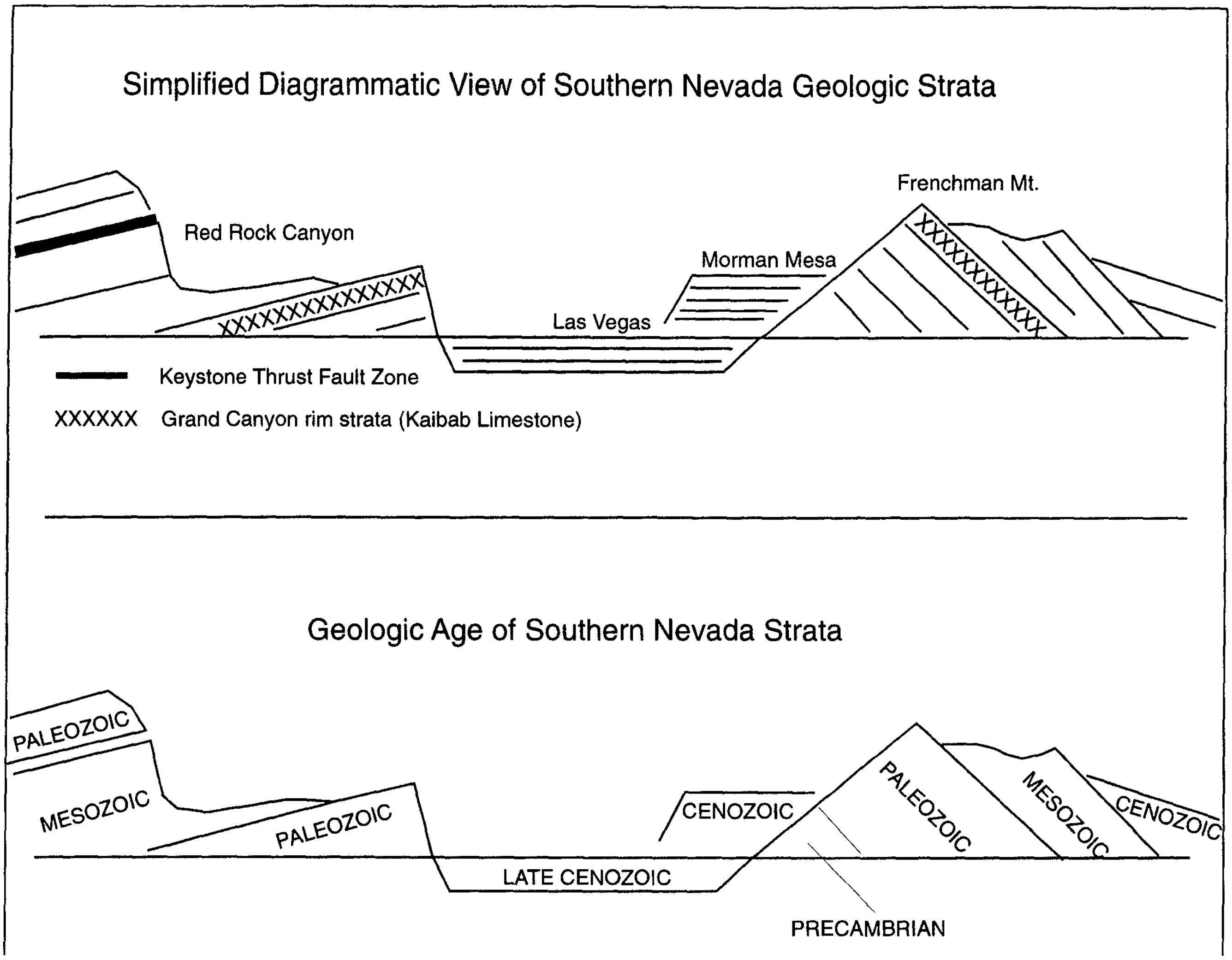


Figure 38. A diagrammatic view of the area surrounding Las Vegas in Southern Nevada. It summarizes some of the major geologic features of the Great Basin and helps correlate them with the stable Colorado Plateau to the east.

During the Paleozoic most of the area was covered with ocean and receiving vast amounts of sediment. A time period that produced strata several hundred feet thick on the Plateau, may have produced 10,000 or more feet of strata in the Great Basin. The Basin area was obviously down warping during that time to be able to receive so much additional sediment.

But, alas, things change. A great east/west compression was applied to the Basin after the Paleozoic, in the middle of the Mesozoic. This compression was possibly caused by giant convection currents within the earth's mantle in connection with continental drifting. Whatever the cause, it shortened the area, causing the sediments to be greatly lifted and in some cases metamorphosed. There are many areas where the crustal shortening caused older Paleozoic strata to be pushed over younger Mesozoic strata, in some cases for many miles.

The mountains that were created in this compression started shedding sediments eastward into the Colorado Plateau area. Probably most of the sediments that produced the Mancos, Star Point, Blackhawk, Price River, and associated formations originated in the erosion of this uplifted area.

Later, in the early Cenozoic, the Basin was subjected to stretching or extension movements in the opposite direction. These allowed the mountains to drop and rotate in great fault blocks that had their axes in a genera north/south orientation. The Sierr Nevada is the western most of thes fault block mountains. This range i made up of a huge block that rotate up in the east side along a major fau and down in the west. The west sid plunges under the Great Valley c California. Slight movements hav continued to a lesser degree on man of of the faults bounding the Gre Basin mountain blocks to the prese time.

The breakup of the Great Basi was accompanied by much volcan activity. Tremendous amounts of la was outpoured and much volcanic a distributed over the area. At oth places igneous masses were intrud

Correlation of Geologic Formations for Parts of

Southern Nevada	Grand Canyon	Southern Utah
Las Vegas		
Muddy Creek		
		Volcanic Rocks
Horse Springs		
		Claron/Cedar Breaks
		Kaiparowits
		Waweap Sandstone
		Straight Cliffs
		Tropic Shale
		Dakota Sandstone
		Carmel Limestone
Aztec Sandstone		Navajo Sandstone
		Kayenta
		Moenave
Chinle	Chinle	Chinle
Moenkopi	Moenkopi	Moenkopi
Kaibab Limestone	Kaibab Limestone	Kaibab Limestone
	Toroweap Limestone	
Supai (Callville, Pakoon,Queantoweap)	Coconino Sandstone	
	Hermit Shale	
	Supai Sandstone & Shale	
Redwall Limestone	Redwall Limestone	
Temple Butte Limestone	Temple Butte Limestone	
Muav Limestone	Muav Limestone	
Bright Angel (Pioche) Shale	Bright Angel Shale	
Tapeats Sandstone	Tapeats Sandstone	
	Chuar Group	
	Dox	
	Shinumo Quartzite	
	Hakatai Shale	
	Bass Limestone	
Schist	Vishnu Schist	

Indicates major structural disruption

the Colorado Plateau and Southern Great Basin

Central Utah	Uinta Basin & Mountains	
Green River Flagstaff North Horn	Glacial Deposits Browns Park Duchesne River Uinta Green River Wasatch (Colton) Flagstaff Limestone North Horn	**Cenozoic** (66 mya to Present)
Mesa Verde Group Mancos Shale Dakota Sandstone Cedar Mountain Morrison Summerville Curtis Entrada Sandstone Carmel Navajo Sandstone Kayenta Wingate Sandstone Chinle Moenkopi	Mesa Verde Group Mancos Shale Frontier Sandstone Mowry Shale Dakota Sandstone Morrison Curtis Entrada Sandstone Carmel Navajo Sandstone Chinle Moenkopi	**Mesozoic** (245 mya to 66 mya)
	Park City Weber Sandstone Morgan Round Valley Limestone Manning Canyon Humbug Deseret Limestone Madison Limestone Lodore Sandstone	**Paleozoic** (570 mya to 245 mya)
	Uinta Mountain Group (24,000 ft. thick) Red Creek Complex (Metamorphic Rocks)	**Precambrian** (4.5 billion to 570 mya)

into the sediments.

Valleys were formed between the mountain range blocks. Many of these valleys are filled to great depths with material that eroded from the mountains. Great alluvial fans of eroded sand and gravel can be seen extending for miles from the mountains to the center of the valleys. The deepest and most famous of these valleys has been established as Death Valley National Park.

In addition to the alluvial fans some valleys hosted extensive lakes in which were deposited hundreds of feet of sediments. In some cases the alluvial fans and lake sediments were subjected to renewed uplift and angular deformation. Such sediments can be seen in Death Valley (Furnace Creek Formation) and in Rainbow Basin National Natural Landmark, north of Barstow, CA.

Many of the valleys were structural basins with no outlet to the ocean. During the late Cenozoic glacial periods these valleys filled with water. Some became exceedingly great inland lakes. Lake Bonneville in western Utah covered about 20,000 sq. miles at its greatest extent. Lake Lahontan in western Nevada covered about 9,000 sq. miles. These lakes rose and fell, filled and evaporated many times throughout their history. Reading their record provides yet another method for examining the geologic history of the region.

Southern Nevada's Geologic Story

An excellent place to witness the sequence of major events of the geologic history of the Great Basin is in the Las Vegas area of Southern Nevada. An overview of the events is pictured diagrammatically in Figure 17.

In Frenchman Mountain immediately East of Las Vegas is preserved strata that are direct equivalents to those of the Grand Canyon. Many have the same formation names See pages 22 and23 for their specific correlation.

At the Grand Canyon the strata are still in the horizontal position in which they were deposited. The same strata at Frenchman Mountain are uplifted to high angles. Mesozoic strata similar to those overlying the Grand Canyon strata in Northern Arizona and Southern Utah are found overlying those same strata in Southern Nevada.

Figure 39. The crushed zone, in the area of the Keystone Overthrust fault, where Paleozoic limestone (dark) was pushed over the Mesozoic sandstone (lighter). Large and small fragments of each formation are ground and mixed together. This happened after each had lithified to solid rock

Another block of "Grand Canyon strata" is found further west toward Red Rock Canyon. Kaibab Formation strata, equivalent to those which form the rim of the Grand Canyon, form the crest of Blue Diamond Hill. Overlying these strata are the same Mesozoic strata that were present east of Frenchman Mountain and north of the Grand Canyon in Southern Utah.

Further west in Red Rock Canyon a very striking thing has happened. Paleozoic strata has been pushed up over Mesozoic strata. This occurred during the great compression phase of the Great Basin. Similar overthrusts of younger strata by older strata occur elsewhere in Southern Nevada and in many areas of Western Utah.

The Mesozoic formation, Aztec Sandstone, was already hardened or lithified by the time of this overthrust. Figure 39 shows the crushed zone where where the Paleozoic dark limestone slid over the lighter Mesozoic sandstone forming zone of crushed rock containing clasts from both formations. Some geologists estimate as much as 25 miles of overlap has occurred in this area. This illustrates the compressive, or shortening, phase of the Great Basin.

Since the mid-Mesozoic sandstone was deposited and lithified before the overthrust, the overthrust had to take place after the mid-Mesozoic. The other overthrusts in Western Utah occur at equivalent geologic times.

The evidence for the extension, or lengthening, phase of the Great Basin is likewise well shown by the geologic structure of Southern Nevada. The fault block structure of Frenchman Mountain and the tilted fault blocks to the west are representative of what happened all across the Great Basin. The intervening valleys are likewise representative. As the crust extended valleys formed and the mountain blocks faulted and rotated. While this is an obvious over simplification of the processes of compression and extension that took place, it illustrates that such movements did occur.

The eastward dipping Cenozoic strata of the Horse Spring Formation shown in Figure 17 provide the evidence that the extension process did not occur rapidly. This sequence is made up of many thousands of feet of strata, many of which show the results of slow depositional processes. The uplifted Paleozoic limestones are the source of limestone conglomerate lenses that occur in the sediments.

In the middle of the Cenozoic sediments is a mass of solidified lava known by the geographic name of Lava Butte. The age of its solidification has been measured by radiometric means to about 13 million years old (Purkey et.al. 1994, p. 71, Bohannon 1984, p. 11). This is in contextual agreement with the other geologic events. Later Cenozoic movements further uplifted this sequence of Paleozoic, Mesozoic and Cenozoic strata. This was the last major uplift of the area. The area has remained basically stable ever since.

This last uplift created an undrained basin in the Southern Nevada area. The Colorado River was not yet flowing through the area and draining it to the Pacific Ocean. However, streams were flowing into the area from other parts of the Basin and from Southwestern Utah. They formed a large saline lake in the valley. The sediments that were deposited in this lake are now called the Muddy Creek Formation. The greatest thicknesses of these sediments are in excess of 1,000 ft.

The Muddy Creek contains beds of gypsum and some salt, indicating deposition under evaporative conditions. Deposition of the Muddy Creek was apparently terminated when drainage to the ocean was established. After that happened the deposited sediments were subjected to erosion. Much of the original Muddy Creek sediments have now been eroded away (Bohannon 1984, p. 57). Except for local disturbance the strata are lying in horizontal position as deposited.

Figure 40. An outcropping of the Muddy Creek Formation in the Las Vegas Valley. The formation once covered most of the valley but is now nearly gone. This outcrop illustrates how little movement has occurred since its deposition. The bedding planes remain horizontal yet much of the formation has been eroded away.

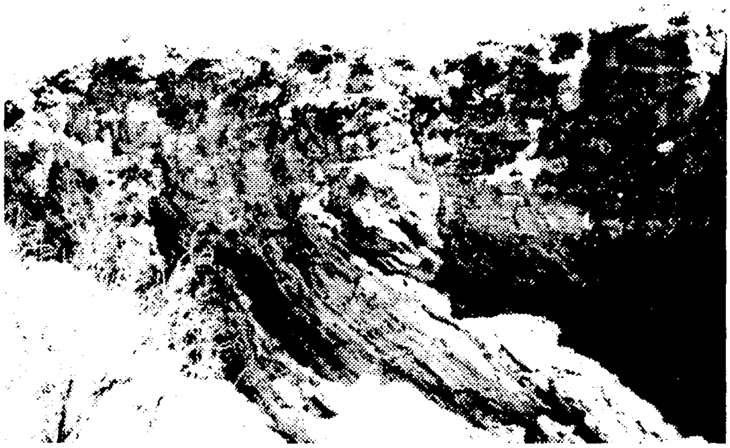


Figure 41. A gypsum bed of the Muddy Creek Fm. here lies in horizontal deposition position over the uplifted and eroded strata of the Horse Springs Fm.

Within some of the area originally covered with the Muddy Creek Fm., and extending beyond, are sediments of much later and smaller lakes along the modern water courses. Some of these lakes were filled during the latest glacial period but are now in varying stages of dryness and erosion. Examples of these latest lake sediments occur even in the Las Vegas Valley proper (Longwell et. al. 1965). These sediments form the basis of an archaeological site known as Tule Springs.

Tule Springs Archaeological Site

This is an extensive archaeological site that occurs within the upper portion of the latest lake and stream deposits in the Las Vegas valley. It is very instructive in establishing the relationship of human activity to the

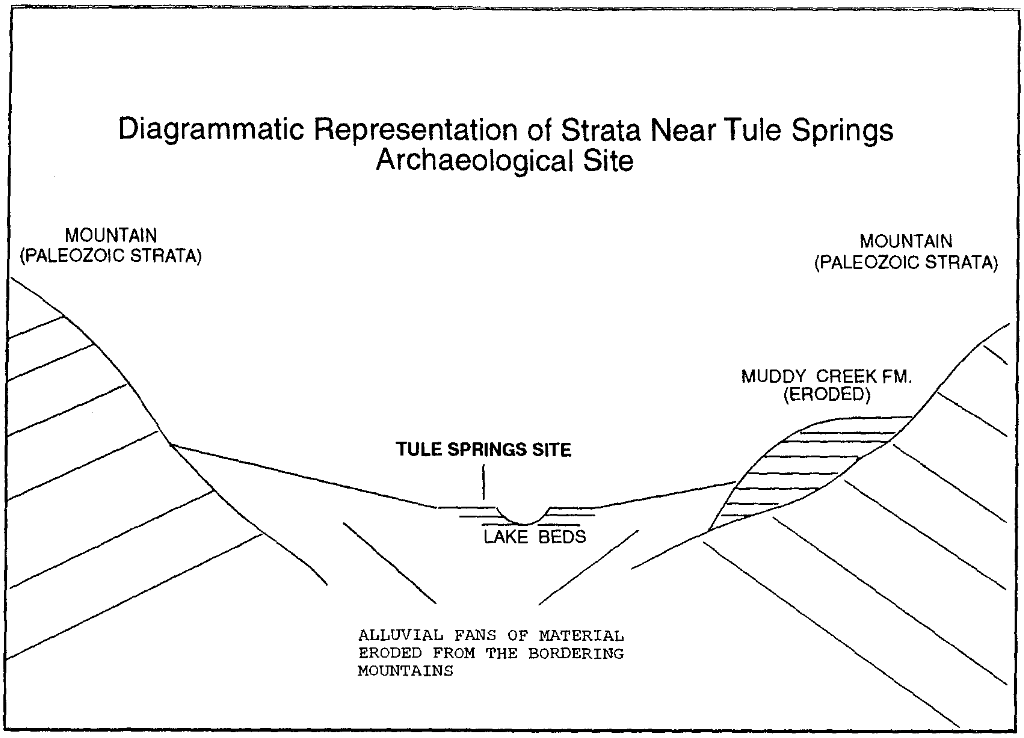


Figure 42. The geologic setting of the Tule Springs Archaeological site. While the Muddy Creek Fm. doesn't outcrop in the immediate vicinity of Tule Springs, the stratigraphic relationships pictured are correct. The lake beds of the Tule Springs site were deposited a long time after the Muddy Creek Fm was eroded from a large portion of the Las Vegas valley.

previous geologic activity. Keep in mind that the deposition of the lake beds in the Tule Springs is one of the last major geological events to take place in the area.

The fossils of the large mammals that were found there are mostly of species that are generally familiar. They include: camel, bison, large and small varieties of horses (both of the same genus as the modern horses, *Equus*), mammoth, deer, coyote, puma, lynx, giant jaguar, and ground sloth. Some of these are extinct species, however, they are very similar to living mammals and of fully modern design.

The radiocarbon dates for the site ranged in a relatively uniform sequence from around 5,000 years old for the younger strata units to over 40,000 years (the practical upper limit of the dating system at the time) for the older strata. Human artifacts were found at the site in strata dated around 10,000 years old. These time indications are in harmony with the geologic information.

The Last Million Years in the Great Basin and Colorado Plateau

The events mentioned up to this point, with the exception of the Tule Springs Site, all occurred prior to a million years ago as indicated by radiometric and geologic dating techniques. It is instructive to look at events from all over the Great Basin which date within the last one million year time period.

By a million years ago the basic geologic structure of both the Colorado Plateau and Great Basin had long since been completed. This does not mean that faulting, uplift and earth movements had totally ceased. Nor that volcanic activity had ended. There is ample evidence that such local events continue to occur. However these local events did not alter the overall structure significantly.

The great extension of the Great Basin area resulted in creating a series north-south trending fault block mountain ranges. These are separated by broad valleys or basins.

Very few of the basins have exterior drainage to the ocean. If precipitation increases, lakes form in central portion of the basins. During extended dry periods these lakes disappear. Death Valley is one prominent example. Multiple lake levels in the valley are recorded by the many wave cut terraces on Shore Line Butte at the southern end of the valley. Most of the basins in the Great Basin show similar evidence of having had lakes at various times in the past.

The Sierra Nevada Mountain range at the western edge of the Great Basin shows evidence of at least three major glacial periods within the last million years (Sheridan 1971, p. 5). This is in harmony with the vast evidence for three major periods of glacial advance for the same time period in the Midwestern U.S. (Ruhe 1969, p. 25; Morrison and Frye 1965, Fig. 6). Similar glacial evidence, especially for the last two major advances is present in the Wasatch Mountains at the eastern edge of the Great Basin (Richmond 1964, p. 1).

At the time of greatest advance of the mountain glaciers the Great Basin was filled with many lakes. The largest, Lake Bonneville in western Utah, covered an area of 20,000 sq. mi. and reached a depth of 1,000 ft. (Bissell 1963 p. 107). In northwestern Nevada was a smaller but still large lake, Lake Lahontan. It's maximum area was around 9,000 sq. mi. Both of these lakes filled and emptied a number of times in the last million years. Their histories are much better known for the last 10,000 to 100,000 years (Morrison and Frye 1965, Fig. 2).

When the lakes dried up, soil formed along the edges and on previous lake sediments that were exposed to the climate elements. Refilling of the lake formed new sediments which overlaid the soil formed on the older sediments. After that lake dried up yet another soil formed on the new sediments.

Soil takes a long time to form. The sequence of fossil soils in a series of lake sediments give a relative measure of the amount of time involved in the process. The occurrence of soil sequences have been studied for both lake areas (Morrison 1964, Morrison 1965).

Another means of dating lake deposits in the Great Basin is dating the time of ash falls from volcanic eruptions. The origin or source of an ash can usually be determined by chemical analysis of its composition. The chemical "fingerprint" of prominent ash falls of the past have been determined. The eruption of most of these ash falls have been dated by radiometric means. When an ash is detected in sediments that has a matching "fingerprint," the age of the sediments at that point can be determined.

Three prominent volcanic ash layers that occur in the Great Basin will

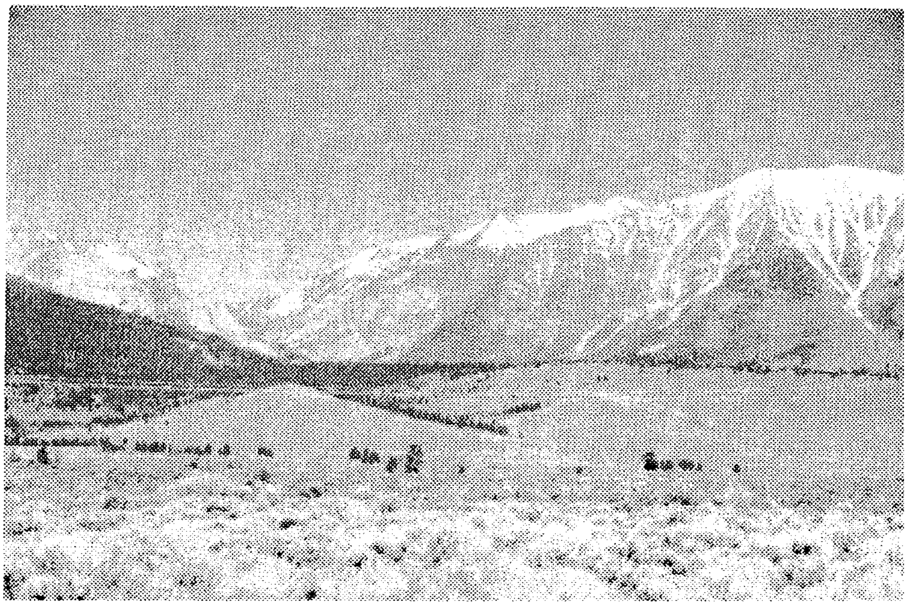


Figure 43. The two ridges in the center of the picture are the right and left lateral moraines of the Mono Basin glacial advance. The ridge behind the two that truncates them is the right lateral moraine of the larger Tahoe glaciation. Remnant moraines of the Tioga glaciation lie within the right and left lateral moraines of the Tahoe moraine. Till from the Sherwin glaciation is found on the lower mountain slopes behind the moraines in the picture.

illustrate the use of ash falls for dating sediments. The first and youngest is the Mazama ash. It was deposited as a result of the explosive eruption that destroyed Mount Mazama and left a large caldera that has become Crater Lake in Southern Oregon. The explosion is well dated at approximately 7,000 years ago. The ash from this eruption is well known from many archaeological sites. There is substantial evidence for human occupation of western North America prior to this eruption. The ash overlies many human artifacts. This ash fell after the two largest lakes of the Great Basin had dried up substantially, so it is not a good marker for the lake beds.

The two other ashes are the Pearlette "O," dated at 600,000 years, and the Bishop, dated at 700,000 years. In a 1,000 foot hole drilled in the Bonneville basin in western Utah both these ash falls were identified. The Pearlette "O" at the 283 foot level and the Bishop at the 317 foot level (Stokes 1988, p. 215). Time markers like these are very important for correlating events across the Basin.

It is also helpful to examine the source of the Bishop ash. It too originated from the explosion of a volcanc that formed a giant caldera. This caldera was much larger than that of Mt. Mazama. It is identified as the Long Valley Caldera. The caldera is located approximately 25 miles north of Bishop, CA. U.S. highway 395 crosses the bottom of the caldera Lake Crowley lies in its basin. The caldera is easy to traverse and not realize that it is a caldera, the result of the collapse of a very powerful volcano.

The volcanic material thrown ou during the explosion is found lying or glacial till (unique deposits made by glaciers) both north and south of th caldera. By dating the material fron the explosion, we can establish th youngest possible date for the forma tion of the glacial till. In this case th till has to be older than 700,000 years Other glacial till lies on top of th Bishop ejecta. We know this i younger than 700,000 years. Th Bishop ash has be identified as far eas as southern Nebraska (Izett et. al 1970).

These three ash falls have bee mentioned as examples of how as

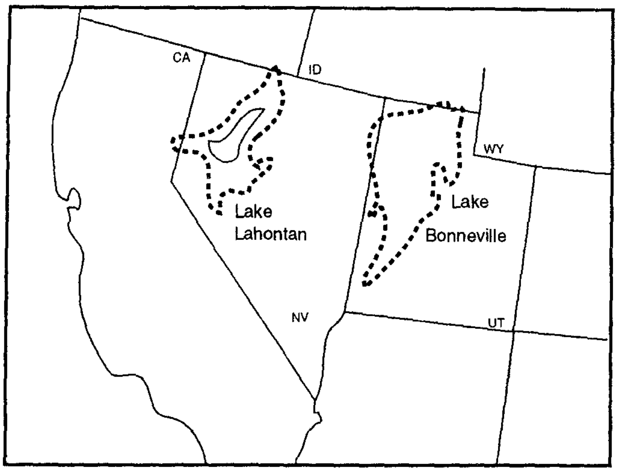


Figure 44. Location and generalized shoreline outline of the two largest lakes in the Great Basin at their maximum depth during the last major glacial advance.

layers are used to correlate and date geologic processes and archaeological sites. There are many more ash falls in the Western U.S. that are used in a similar manner.

The glacial/pluvial period

As the last one million year period opened the structure and topography of the Great Basin and Colorado Plateau was essentially what it is today. Glaciers had occurred in the Sierra Nevada prior to this time (Sheridan 1971, p. 5). A deep drill hole in the Lake Bonneville basin reveal that lake sediments were forming there as long ago as 3.5 million years (Stokes 1986, p. 215). The Grand Canyon was already deeply eroded. Lava, dated around a million years old by potassium/argon techniques, flowed over its rim and dammed the Colorado River more than once.

The evidence for the first glacial till in the Sierra Nevada Mts. younger than a million years is quite extensive. This till, called the Sherwin, is found immediately under the Bishop volcanic ash dated at 700,000 years ago. The ridges and structures originally formed by glacial ice have long since eroded away, but extensive deposits of the glacial till remain.

The mixture of large rocks, small rocks, and fine mineral material all mixed together is characteristic of glacial action and is given the name "till." Long ridges of this type of material build up on the sides and at the end of glaciers in mountain valleys. They are given the name "moraines."

After glacial ice has melted away these moraines, composed of till, stand as topographical evidence of the former presence of the glacier. Over time erosion destroys the topographical form. The crystalline rocks weather and decay. The extent to which these processes have occurred help indicate the amount of time that has passed since the glacier retreated.

In the eastern Sierra Nevada Mts. there is ample evidence of at least four glacial advances within the last million years. They have been given the names:

Sherwin
Mono Basin
Tahoe
Tioga

Of the four the Mono Basin has left the least evidence of its passing. Some scientists find evidence for additional advances, but the evidence for these four is the most obvious and understandable for the nonspecialist.

As mentioned, the Sherwin till is known to be older than 700,000 years because Bishop ash from the Long Valley Caldera was deposited on top of it. How much older it is than 700,000 years is not known. It has lost all its characteristic topographic surface form. In some areas many of its crystalline rocks are deeply weathered.

The next glacial advance, the Mono Basin was apparently a smaller one in this area. One prominent evidence for it is preserved in the Mono Basin, hence the name given to this advance. In this area a later, larger, glacier advanced down the same canyon but for some unknown reason turned and changed direction at the end of the canyon. This allowed the moraines of the earlier, smaller advance to be preserved. Its rocks are less weathered than those in the Sherwin, but more weathered than those of the following Tahoe advance. The original surface topography of the lateral glacial moraines are still well preserved (See Figure 43).

The Tahoe advance was quite extensive. Large lateral moraines remain from this glacial advance that retain most of their original topographic form. Most of their rocks show relatively little weathering. These tills lie on top of a lava that is dated between 60,000 and 90,000 years old (Dalrymple 1964). It has been associated with the North American glacial period known as the Wisconsin.

The next glacial advance, the Tioga, is also a part of the Wisconsin. It is a smaller advance than the Tahoe. Its moraines are nested inside the larger Tahoe moraines. If another glacial advance the size of the Tahoe occurred, the evidence for Tioga advance could be destroyed. Since no large glacial advances have occurred since the Tioga, its evidence is clearly visible in many areas. Many of its lateral and terminal moraines are still intact.

When the glaciers advanced in the mountains the undrained basins of the Great Basin filled with lakes. In some cases the lakes reached such high levels they cut terraces in the terminal moraines of the glaciers. Thick lake clay deposits are correlated directly

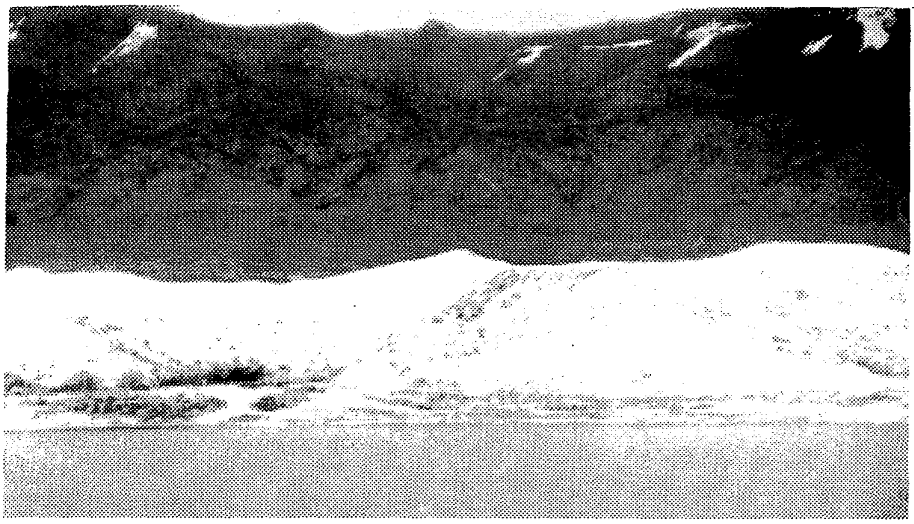


Figure 45. Lake clay sediments from Lake Lahontan at Rye Patch Reservoir in Western Nevada. The sediments represent several periods of deep water separated by periods when the sediments were exposed to weathering in a dry environment.

Figure 46. A closer view of a portion of the lake sediments shown in the previous figure. The heavy dark bands are interpreted as times when the lake dried up and soil forming processes began acting on the sediments.

with the glacial advances. The evidence is especially obvious for the Tahoe and Tioga advances (Morrison and Frye 1965). As the lakes dried up between the times of glacial advance, soils formed on the lake deposits. This happened because the deposits were exposed to subaerial soil forming processes for long periods of time.

The lakes in the Great Basin had long and complex histories of filling and drying over and over again. The latest major emptying of the lake basins took place about 10,000 years ago by many lines of evidence. This is also the approximate time of the disappearance of the major glaciers from the Sierras.

Good summaries of the glacial and pluvial periods of the Sierra Nevada and Great Basin can be found in Wright and Frey 1965.

Packrat nests - an unexpected boon for dating recent events in the Great Basin

A packrat is a wood rat of the American Southwest that gathers materials from the vicinity of its nest site and adds them to the nest. Especially common to the nests are sticks and twigs from nearby vegetation. The nests are usually built in protected or sheltered environments like under rock ledges and overhangs, in rock crevices, or in small caves.

In the dry Southwest these nests can last incredibly long times. The pieces of the nest are usually held together by a crystallized mass of rat urine that looks like like amber, hence it's given the name, amberat. The amberat preserves the nest contents because of its adhesive and chemical preservation qualities. The amberat is easily dissolved and the nest separated by soaking in water for several days (Betancourt et. al. 1990, pp. 60-61)

The vegetation and other organic contents of packrat nests can be dated by radiocarbon techniques. Dates as old as 50,000 years old have been obtained on some nests (ibid. p. 86). Many dates from nests in the walls of the Grand Canyon range between 6,000 and 20,000 years old (ibid. pp. 242-243). A multitude of dates are available for the Great Basin that range back to nearly 50,000 years old (ibid. p. 207). Many other sites in the U.S. Southwest and Northern Mexico yield similar dates.

The packrat nests show several important things. First, the erosion of the dry areas of the Southwest has been slow. If rapid erosion had taken place most of the nests would have been destroyed. They show that the area has not been covered with water for thousands of years. Had this occurred, the nests would have dissolved and washed away. They also show that the vegetation growing in the areas from which materials for the nests were gathered has slowly changed in response to the changing climate during and after the glacial advances.

Dating extinct animal dung in dry caves of the region

The conclusions obtained from

studies of packrat nests are further verified by examining another type of material in dry caves. The dry caves provided shelter for animals. Those animals deposited dung in the caves in the process of living there. Often this dung remains in its original rounded shape, called a bolus.

Because of the unique shape of the dung bolus the species producing it can often be identified. Dung found in the caves has been identified as that of bison, camel, horse, ox or musk ox, sloth, Mammoth, and mountain goat. Some of these animals have been extinct in the New World for over 9,000 years.

Dates from twenty Colorado Plateau cave sites have been reported (Mead and Agenbroad 1992). The dates range up to 40,000 years old. Most are between 10,000 and 20,000 years old. It seems clear that caves with intact dung boluses have remained relatively dry since the dung was deposited. Had they been subjected to substantial moisture or submerged in water for a period of time their structure would certainly have been destroyed.

Settings and dates for the earliest archaeological sites

In addition to the Tule Springs archaeological site, four other early sites in the Great Basin and Colorado Plateau should be noted. These are Danger Cave in western Utah, Fort Rock Cave in south central Oregon, Sudden Shelter in central Utah, and Spirit Cave in western Nevada. All except Sudden Shelter reveal human occupation around 10,000 or more years ago.

Danger Cave

In western Utah in the basin of Lake Bonneville, the large lake during the last glacial advance, is a cave that shows evidence of human occupation which dates to 10,300 years ago (Jennings 1978, p. 32). This cave would have been under water until Lake Bonneville dropped over 900 feet from its highest level during the latest glacial advance.

The first evidence of human occupation is a hearth built in a layer of sand deposited by the lake. With it was found a well-crafted lanceolate projectile point. The cave remained dry after that time. This dryness resulted in excellent preservation of perishable materials deposited there. Pieces of 1,000 millstones were found in the cave along with many other cultural artifacts. It was occupied a long, long time.

Fort Rock Cave

This cave is located in south central Oregon in the northern Great Basin. It contains a hearth that was dated 13,000 years old and woven sandals dated 10,000 years old. These were overlain by volcanic ash from Mt. Mazama (Crater Lake) that is well dated to 7,000 years ago. The cave contained many additional artifacts.

Sudden Shelter

Sudden Shelter is located in central Utah under a rock ledge of Mesozoic sandstone of the Star Point Fm. (See Figure 47). The earliest cultural level is dated at 8,000 years. There is a lower level that wasn't yet dated at the time of publication (Jennings et. al. 1980).

One importance of Sudden Shelter is showing the relative rate of erosion of rock outcrops. After 8,000 years the overlying rock shelf still covers the site. Geologic processes do indeed often move very slowly.

Spirit Cave

In western Nevada in the Lake Lahontan basin is a rock overhang or "cave" that was covered with water during the last glacial advance. After the water receded a burial was made in that "cave." The burial was mummified and extremely well preserved. It is clear it had been kept dry since burial.

Dating the bone, hair, and two mats in which the burial was wrapped yielded eight dates of approximately 9,400 years. All the dates were within 100 years of one another (Burky 1996b).

The dating and context of all five noted archaeological sites are in harmony with what we know about the geological context and dating of the region. This further confirms the time depth and sequential prehistory of the area.

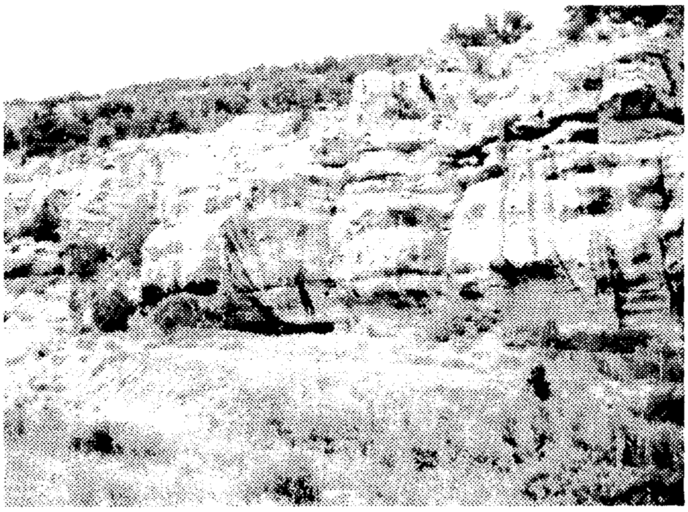


Figure 47. Sudden Shelter, an archaeological site that contains evidence of human activity over 8,000 years ago. Note that 8,000 years of erosion hasn't dramatically changed the topography of the site. The entrance is the dark area in the left center portion of the picture.

In Summary

A good overview of the nature of the geologic record has been presented. This area contains rocks dated as old as 1.5 billion years and strata that have been deposited since that are many miles thick. All the major geologic periods are represented by sizeable thicknesses of rock strata.

Further more, the structure of the area is such that the different aged strata can be sequentially related to one another. The geological events can be examined in the sequence that they occurred. The amount of time needed to produce the features found in each of the strata is thus cumulative. The depositional features of the strata provide evidence for the passage of an overwhelming amount of time.

A quantitative figure for the amount of time can be estimated by utilizing radiometric dating techniques (See Appendix II for more detailed information on these techniques). By comparing the physical features and the radiometric dates a cross check can be made on the time involved in producing the record. The two methods of evaluating time give comparable conclusions.

While there is no doubt that catastrophic events occurred from time to time in the area, the bulk of the geologic record examined reveals that long periods of time were involved in producing the geologic results observed.

The fossil life forms found at the various geologic levels correspond to those found throughout the world at similar levels. There is a definite progression of life forms throughout geologic time.

Changes in these life forms occur at various times. Changes from predominately non-flowering plants to flowering ones occurred during the later times of the dinosaurs. After that the dinosaurs and ammonites went extinct. The land animals became predominately mammals instead of reptiles. The mammals of the early Cenozoic were considerably different from modern mammals. There were major changes in their design as time progressed.

The fish of the Paleozoic are very different than modern fish. Many changes occur to fish during the Mesozoic. Modern fish, like the flowering plants, show up in the geologic record during the latter times of the dinosaurs.

Birds, even a few modern groups, occur in the Mesozoic. Most modern groups enter the record during the Cenozoic.

While many questions remain, some conclusions are clear. The earth has been around for a long, long time. The life on it is very old. Most major life forms have been changing continuously since they were introduced, at least from the broad perspective of geological time.

What caused those changes in design is quite a another story. That topic is evaluated as a separate issue.

* * *

Appendix I

A Sequential Summary of Major Geological Events of the Colorado Plateau and Great Basin

1. Deposition of the sediments and lava flows that would eventually be metamorphosed into the Vishnu Fm. at the bottom of the Grand Canyon.

2. Further deposition to bury the sediments deep enough to provide enough pressure to metamorphose the lower ones. Earth movements and injection of magma that help alter the deeper sediments and lavas into the metamorphic rocks (K/Ar dated at 1.5 billion years ago).

3. An extensive period of erosion that stripped away all overlying unmetamorphosed sediments and much of the metamorphosed rock.

4. Deposition of the limestone of the Bass Fm. over an extended time period, shown by the layer by layer buildup of calcium carbonate by algae.

5. Deposition of the mudstone and shale of the Hakatai Fm. over time shown by the layer after layer of fossil mud cracks.

6. Deposition of the Shinumo and Dox formations (4,500 feet of sediments).

7. Deposition of the Chuar group of formations (nearly a mile of sediments). Some strata show the slow buildup of calcium carbonate deposits, layer by layer, by algae.

8. Great earth movements interrupted the deposition and angularly block faulted the area. The Shinumo sandstone is metamorphosed into quartzite.

9. Extensive weathering and erosion reduced the uplifted surface to several hundred feet of relief. Deep chemical weathering profiles developed on the crystalline metamorphic rocks of the Vishnu Fm. This required an extensive time period. Some of the weathering products are incorporated into the overlying Tapeats Fm.

10. Deposition of the Tapeats Fm. Fossils of trilobites and other living organisms now begin to occur in the sedimentary rocks. The Tapeats Fm. contains boulders of the Shinumo quartzite showing that the sandstone had been metamorphosed into quartzite and then eroded into boulders prior to the deposition of the Tapeats sandstone.

11. Deposition of the Bright Angel and Muav Fms.

12. Erosion of the surface of the Muav, then the deposition of the Temple Butte Fm.

13. Deposition of the Redwall Fm. Up to 700 feet of relatively pure calcium carbonate with locally abundant marine fossils. The process of concentrating and depositing this much calcium carbonate

would require considerable time.

14. Erosion of the upper surface of the Redwall Fm. and the development of sink holes and collapsed caverns in the limestone prior to the deposition of the later formations (McKee 1982, p.157).

15. Deposition of the sandstone and mudstone of the Supai group of formations. Many land animal tracks and fossil mud cracks occur in these strata showing they were most likely deposited under normal living conditions (McKee 1982).

16. Deposition of the Hermit Fm. Layer after layer of fossil mud cracks show an extended time period of deposition.

17. Deposition of up to 600 feet of wind blown sand, now known as the Coconino Fm. A significant amount of time would be required to weather out the mineral grains for this quantity of sand and to deposit it as wind blown dunes.

18. Deposition of the Toroweap and Kaibab Fms. In the Southern Nevada area these two formations contain vast amounts the mineral gypsum. It is deposited when water containing it in solution is evaporated. This required substantial time and a warm, evaporative climate.

19. Deposition of the Moenkopi Fm. This formation also contains significant amounts of gypsum deposits and fossil mud cracks. Previously stated comments on depositional time apply.

20. Chinle Fm. deposited. This formation contains a significant number of fossil tree stumps preserved in growth position. The substrate sediments which anchored the tree roots were obviously deposited a significant number of years prior to the deposition of the sediments around the tree trunks which preserved the trunks and allowed them to be petrified.

21. The Wingate Fm., another fossil desert with wind blown sand up to 600 feet thick.

22. Moenave and Kayenta Fms. deposited. Contain dinosaur foot prints.

23. The Navajo Fm. deposited. Wind blown sand deposits accumulated to 2,200 feet thick in Southern Utah. This extensive desert stretched from the Las Vegas area eastward into western Colorado and northward into Wyoming.

24. Deposition of the Carmel Fm. which locally contains abundant marine fossils and limestone. It contains enormous deposits of gypsum, estimated at 9.7 billion tons (Stokes and Cohenour 1956, p. 54), in central Utah. This deposition required a long standing, warm, evaporative climate to deposit such extensive amounts of gypsum by the evaporation of sea water. Locally it also contains large deposits of common salt (NaCl).

25. Deposition of the Entrada, Curtis, and Summerville Fms. These contain some thick beds of gypsum in central Utah.

About this time great compressive forces acting upon the earth's crust were squeezing and uplifting the strata of the Great Basin. Eventually, as the result of significant crustal shortening, great thrust faults occurred. Many miles of older strata were thrust up over younger strata in Western and Central Utah and in Southern Nevada. The Keystone Overthrust west of Las Vegas and the Charleston-Nebo Thrust of Northern Utah are prime examples.

26. Deposition of the Morrison Fm. This formation is the major dinosaur fossil producer of the

western U.S. It extends from Northern Arizona and New Mexico northward to beyond the Canadian Border.

27. Deposition of the Mancos, Star Point, Blackhawk and Price River Fms. of Central Utah. Sediments derived from the great uplifts to the west were deposited in coastal coal swamps and shallow inland seas east of the area as sandstones and shales. These built up to well over a mile in thickness. They are the source of much of Utah's considerable coal reserves. The weathering, erosion, and deposition took an enormous amount of time. Standing tree stumps and dinosaur foot prints have been found in many of the coal mines in Utah.

28. Deposition of the North Horn Fm. This formation is unique in that it has dinosaur fossils in its lower portion and only mammals in its upper portion. It bridges the time when the dominate land animals changed from reptiles to mammals.

29. Deposition of the Flagstaff Fm. Contains algal limestone structures showing slow deposition over time.

30. Deposition of the Colton Fm.

31. Deposition of the Green River Fm. (nearly a mile in maximum thickness). This formation contains a multitude of algal limestone structures and mud cracks at many different locations and levels. It contains many additional evidences for long time periods of deposition. Extensive oil shale deposits occur within this formation.

32. Uinta, Duchesne River, and Brown's Park Fms. Contain some areas with algal limestone structures.

TRANSITION TO THE GREAT BASIN

Prior to this time East/West crustal extension had begun to take place in the Great Basin. This caused the uplifted area to sink, forming great ranges of north/south trending fault block mountains. In between these mountain ranges developed broad, undrained basin valleys. This major faulting was accompanied by wide-spread volcanic activity in the Basin. K/Ar dating of the volcanic rocks and ash falls indicate that this extension process went on for several millions of years. Since about 6 million years ago the topography of the Great Basin has basically remained about the same, with only minor alterations due to local faulting and volcanism.

There may be some time overlap with the deposition of the last several formations in the Colorado Plateau and the events that will now continued in the Great Basin. Fortunately some of the strata of the Colorado Plateau also occurs in the Great Basin and will allow direct time and sequence comparison to be made.

Immediately east of Las Vegas, NV is a large fault block mountain (Frenchman Mt.) that contains strata equivalent to that of the Grand Canyon. The strata there are lying at steep angles dipping eastward. Above these strata are those sequential strata we find in the Colorado Plateau, up to and including, the equivalent of the Navajo Fm. After this strata was faulted to a high angle, material eroded all of the older strata to form new strata. This new strata, derived from the materials of the old, is called the Horse Springs Fm. It is with the Horse Springs Fm. that the sequence of events will continue. There may be some time overlap with the deposition of the last three formations mentioned in Step 32 above.

33. Deposition of the Horse Springs Fm. The Horse Springs Fm. is a thick sequence of strata containing large lenses of boulders from the Paleozoic and Mesozoic formations from which they were eroded. This formation also contains fine sediments and beds of gypsum formed under evaporating conditions. Within the Horse Springs Fm. is a mass of volcanic material called Lava Butte (Figure 36). K/Ar dating gives it an age of about 13 million years. The Horse Springs is estimated to have been deposited between 8 and 20 million years ago (Purkey et. al. 1994, p. 70).

34. A period of faulting and erosion. This was the last major structural change of topography in the area. The Horse Springs Fm. was tilted to an impressive angle (See Figures 35, 36 and 41).

35. Deposition of the Muddy Creek Fm. Contains extensive deposits of gypsum and some salt, which is evidence for extended time and evaporative conditions. This formation was deposited in a closed basin. The Colorado River was not yet flowing through the basin.

36. Extensive erosion of the Muddy Creek Fm. after drainage from the basin was established to the Colorado River. The erosion would have required considerable time.

37. Erosion of the mountains and deposition of extensive alluvial fans into the areas from which the Muddy Creek Fm. had been eroded. Similar development of alluvial fans occurred all across the Great Basin. Lakes formed, dried up, and reformed continually in the undrained valleys. Nearly continuous deposition occurred in some parts of the Lake Bonneville basin from this time forward.

38. Earliest glaciation occurred in the Sierra Nevada Mts. (McGee and Deadman Pass, the later K/Ar dated by an overlying lava flow to over 2.5 million years ago, Sheridan 1971, p.5).

39. Sherwin glaciation in the Sierra Nevada Mts.

40. Explosion and collapse of the Long Valley Caldera (K/Ar date: 700,000 years ago).

41. Mono Basin glaciation in the Sierra Nevada Mts.

42. Tahoe glaciation in the Sierra Nevada Mts. Till lies on top of a lava flow K/Ar dated between 60 and 90,000 years ago. A period of deep lakes forming thick sediments in both the Lahontan and Bonneville basins.

43. Glaciers retreat, lakes dry, soils form on the tops of the lake sediments that are now exposed to weathering.

44. Tioga glacial advance in the Sierra Nevada Mts. Lake Lahontan and Lake Bonneville reach some of their highest levels, creating thick deposits of lake sediments that overlie the soils formed during the previous dry period. Early deposition of the Las Vegas Fm. in chain lakes or swamps in the Las Vegas Valley. The upper levels of these deposits contain the Tule Springs archaeological site.

45. Glaciers retreat. Lakes dry up.

46. First human occupation (^{14}C dated 10,300 years old, Jennings 1978, p. 32) of Danger Cave in Western Utah which was flooded when Lake Bonneville was high. First solid evidence of human occupation at the Tule Springs site was between 10 and 11,000 years ago (Wormington and Ellis 1967, p. 82). Two human skeletons from the Lake Lahontan basin dated by ^{14}C at 9,225 years old and 9,400 years old (Burky 1996). A hearth found in the Northwestern Great Basin at the Fort Rock site was dated older than 11,000 years old. At the same site sagebrush sandal dated to 10,000 years old

(D'Azevedo pps. 121, 123). Both of these items were found under a layer of volcanic ash from the explosion of Mt. Mazama. Human occupation older than 8,000 years is reported for the Sudden Shelter site in central Utah (Jennings et. al. 1980, p. 20). Oldest wood (dead) in bristlecone pine grove in the White Mts. of California dated approximately 8,500 years old.

Extinction of the "megafauna" in North America. Soon after the retreat of the last glacial advance (around 11,000 years ago) the fossil evidence indicates a significant number (35 genera) of large mammals became extinct in North America. This includes forms like the horse, mammoth, camel, and ground sloth. Some would attribute their extinction to the arrival of humans, but this is by no means a unanimous conclusion (Mead and Agenbroad 1992, p. 16).

47. Packrat nests and fossil dung in dry caves. ^{14}C dates indicate that many dry caves in the Great Basin and on the Colorado Plateau have preserved these readily perishable materials for well over 30,000 years (Mead and Agenbroad 1992, Betancourt et. al. 1990).

48. Mt. Mazama explodes and scatters ash over many archaeological sites over a wide area. Explosion dated approximately 7,000 years ago.

49. Oldest living bristlecone pine(Approximately 5,000 years) discovered (and cut down!) in Great Basin National Park (Lanner 1997, p. 27). There is no reason to believe the topography of its growing area has changed significantly in that 5,000 years.

50. There is no evidence that the lake basins of the Great Basin have been refilled to their high levels during the last 12 to 13,000 years. Rather, there is much evidence that they have not.

A Brief Description of Radiocarbon and Potassium/Argon Dating

Radiocarbon Dating

In nature atoms of the element carbon exist in three different weights. The most common form is ^{12}C. About 99% of all carbon is this form. Another 1% of carbon is in another form that is a little heavier. It is known as ^{13}C. A very small amount of carbon, much less than 1%, is in a very rare third form known as ^{14}C, or radiocarbon. While the first two forms are very stable and last indefinitely, this form is unstable. It is radioactive and thus self-destructive. The fortunate thing is that it self-destructs at a constant rate, one that is statistically stable through time.

If ^{14}C is constantly destroying itself, why is there any left?

An atom is chemically carbon because it has 6 protons in its nucleus. If it had 7 protons in its nucleus it would be nitrogen, if it had 8 protons then it would be oxygen. ^{12}C has 6 protons plus 6 neutrons giving it a total atomic weight of 12. That's why it's called ^{12}C. ^{13}C has 6 protons which makes it carbon, but it has 7 neutrons making it one unit heavier than^{12}C. ^{14}C has 6 protons and 8 neutrons, making it two units heavier. Normal nitrogen has 7 protons and 7 neutrons giving it an atomic weight of 14, the same weight as ^{14}C. Is there a connection?

In the upper atmosphere high energy cosmic rays interact with nitrogen causing the exchange of a proton for a neutron. When this is done the nitrogen atom is no longer nitrogen. It now has 6 protons in its nucleus which makes it carbon. The exchange of the proton for a neutron causes the weight to remain 14. The nitrogen atom became a radioactive ^{14}C atom. This new carbon atom quickly reacts with oxygen to become a molecule of CO_2. As CO_2 it can used by plants to build their structures and to make nutritional elements that will utilized by animals.

While plants and animals are living they are adding carbon compounds to their tissue that have the same general ratio of radiocarbon to regular carbon as that of the atmosphere. Since the ^{14}C production and decay processes are relatively uniform, the ratio of ^{14}C atoms to other carbon atoms in the atmosphere is relatively uniform through time. This uniformity of ratio follows through the living plant and animal tissue with only slight variation.

Once a living organism dies the ratio begins to change. The organism is no longer adding new tissue or maintaining existing tissue with new material. The ^{14}C in its compounds uniformly self-destruct with time, reverting back to nitrogen. Gradually the ratio of ^{14}C to other carbon diminishes. The amount it diminishes is directly proportional to the amount of time that has passed. This factor is the basis for radiocarbon dating.

Approximately every 5,700 years the amount of ^{14}C self-destructs to one half of its previous amount. Since the amount of ^{14}C in a substance can be measured, by comparing the amount present with the amount that would have been there when the tissue was formed, the age since formation can be calculated.

The current practical limit for most radiocarbon dating is about 50,000 years.

Can we verify the accuracy of this dating method?

The oldest known living species on earth is the bristlecone pine. A tree from eastern Nevada has proven to be nearly 5,000 years old. High in the White Mountains of California is a grove of bristlecone pine that has living trees over 4,000 years old. Like most trees the bristlecones add one ring each growing season which is usually part of one year. By counting the rings the approximate age of the tree can be determined. In the White Mountain grove very old dead trees were also found. By matching the rings of the dead trees with those of the living trees, it could be shown that the oldest rings of the oldest dead trees were over 8,000 years old.

Once a tree produces a growth ring the carbon compounds in that growth ring are not replaced as are the carbon compounds in the soft tissue of an animal. The ^{14}C in the growth ring immediately begins to self-destruct. The material in the growth ring is, in effect, dead tissue. Dating it is like dating the remains of a dead organism. New ^{14}C is no longer being added to it.

The approximate calendar age in years was known for each ring. By radiocarbon dating the material in the rings the results could be compared to the known calendar year date for the growth of those rings. When this was done it was found that the radiocarbon method gave dates that were a little older than the actual calendar years for the time period back to 2,000 years ago. Beyond 2,000 years the dates became progressively younger than reality. By 7,000 years ago the radiocarbon dates were nearly a thousand years younger than reality (Taylor 1987, Fig.2.5). The main cause of these differences was the variation of ^{14}C content in the atmosphere. Since this variation is now known, the dates obtained can be adjusted (calibrated) for this difference and more accurate dates estimated. Similar tree ring comparison dating has been done on fossil trees in Scotland, Ireland, England and on the European continent with similar results (See *Radiocarbon*, Vol. 28, No. 2B, 1986).

Potassium/Argon Dating

The potassium/ argon age dating method is used primarily for dating igneous rocks that are at least several hundred thousand years old. Potassium is a very abundant element in the earth's crust. It occurs in many common minerals. The presence of these potassium minerals in most igneous rocks makes this method practical for dating those rocks.

About 0.01% of natural potassium is the radioactive form ^{40}K. ^{40}K radioactively decays to argon-40 (^{40}Ar), an inert gas. Being inert, ^{40}Ar does not combine with other elements once it is formed. Also, because it is inert it does not form or become a part of other minerals in igneous rock. When ^{40}Ar is present in igneous rocks its origin and source can be consider the radioactive decay of ^{40}K.

How can a gas be held by the crystal of a mineral?

When elements form into a crystal they bind to one another in an orderly fashion. This crystal structure acts as a cage to hold things inside of it, much like a bird cage holds a bird. A small fly may pass through the spaces between the cage wires but the larger bird cannot. A similar type of thing happens in the crystal structures of minerals. The ^{40}Ar atom is quite large in size. The spaces between the elements in the crystal structure are too small for it to get through. When ^{40}Ar is created by the radioactive decay of ^{40}K it is trapped inside the crystal lattice. In the laboratory the crystal structure can be destroyed allowing the ^{40}Ar to escape so it can be measured.

It is important that the crystals did not incorporate any ^{40}Ar from the molten magma into the crystal structure when it formed. This would make a calculated date older than the true date. It is also important that the crystal was not heated excessively after it formed. Later heating can expand the crystal lattice and allow some of the ^{40}Ar to escape, making the calculated age younger than the actual age.

By measuring the amount of ^{40}K and the amount of the daughter element ^{40}Ar present in the mineral, the original amount of ^{40}K present at the time of crystallization can be calculated. By knowing the amount of time it takes for ^{40}K to transform into ^{40}Ar, the length of time since crystallization of the mineral can be determined. Minerals form when molten rock cools. Crystals form when lava solidifies. They may also form when material is erupted into the air by a volcano. Either of these activities provide a geologic activity that may be dated by the potassium/argon method.

For a more complete understanding of this dating method and some of the problems involved in using it, see Geyh and Schleicher, 1990.

Potassium/argon dating of geologic events in the Colorado Plateau and Great Basin

The oldest dates are for the Precambrian metamorphic rocks in the area of the Grand Canyon. These provide potassium/argon ages of 1.5 billion years (Cook and Bally, 1975, p. 3). Thirteen dates for Jurassic igneous intrusive rocks in the Great Basin gave ages that ranged from 140 to 170 million years (ibid., p. 201). Nine dates for the Early Cretaceous intrusive rocks in the same area ranged from 99 to 135 million years (ibid., p. 218). Eleven Upper Cretaceous igneous rocks from the same area yielded ages 67 to 95 million years (ibid., p. 237). These events all took place prior to the crustal extension that formed the current topography of the Great Basin. Remember that the crustal extension was complete about six million years ago.

During the time of the crustal extension and breakup of the Great Basin into fault block mountain ranges, many areas of the basin witnessed volcanic eruptions, lava flows, ash deposits. and igneous intrusions. These igneous activities can usually be dated by the potassium/argon method. A great many of them have been dated. Most have occurred between 34 million and six million years ago. There are only a few younger than six million years old (Stewart and Carlson, 1976).

It will be remembered (p. 25) that an igneous mass located in the Horse Springs Fm. dated to approximately 13 million years old. This is in harmony with the expected time of deposition of the Horse Springs.

At the western edge of the Great Basin, immediately east of the Sierra Nevada Mts. a giant volcanic eruption occurred that sent the Bishop Ash as far east as Nebraska (Izett et. al., 1970). Its ash overlies the geologically late glacial tills and is found in many lake sediments across the Basin. Six potassium/argon dates give an average age of 0.71 million years.

While this sampling of dates may not constitute conclusive proof that the method is absolutely reliable, it should give reasonable verification of its validity. If more evidence is desired, many more dates are available for comparison with the geologic context of the Great Basin and Colorado Plateau.

References for this issue...

Albers, J.P. and J.H. Stewart
1972 *Geology and Mineral Deposits of Esmeralda County, Nevada.*. Bulletin 78 Nevada Bureau of Mines and Geology, Univ. of Nevada, Reno.

Arnold, C.A.
1947 *An Introduction to Paleobotany.* McGraw-Hill, New York, N.Y.

Betancourt, J.L., T.R. Van Devender, and P.S. Martin
1990 *Packrat Middens: The Last 40,000 Years of Biotic Change.* Univ. of Arizona Press, Tucson.

Bissell, H.J.
1963 *Lake Bonneville: Geology of Southern Utah Valley Utah.* U.S. Geological Survey Professional Paper 257-B.

Bohannon, R.B.
1984 *Nonmarine Sedimentary Rocks of Tertiary Age in the Lake Mead Region, Southeastern Nevada and Northwestern Arizona.* U.S. Geological Survey Prof. Paper 1259.

Brigham Young University
(Undated) *Geologic History of Utah.* BYU Geology Studies, Vol. 20, Pt. 3.

Burky, R.R.
1996a *Radiocarbon Dating Archaeologically Significant Bone Using the Unique Amino Acids Gamma-Carboxyglutamic Acid (Gla) and Alpha-Carboxyglycine (Aminomalonate).* An unpub published doctoral dissertation, Univ. of Calif., Riverside.

1996b A 10,000 Year Old Inhabitant of Churchill County. *In Focus* 9:1, pp.126-133. Churchill County Museum Assoc., Fallon, NV.

Burky, R.R., D.L Kirner, R.E. Taylor, P.E. Hare and J.R. Southon
1998 ^{14}C Dating of Bone Using Gamma-carboxyglutamic Acid and Alpha-carboxyglycine (Aminomalonate). *Radiocarbon* 40:1, pp.11-20.

Carroll, R.L.
1988 *Vertebrate Paleontology and Evolution.* W.H. Freeman and Co., New York.

Cook, T.D. and A.W. Bally, editors
1975 *Stratigraphic Atlas of North and Central America.*. Princeton Univ. Press, Princeton, NJ.

Cremo, M.A. and R.L. Thompson
1993 *Forbidden Archeology.*. Bhaktivedanta Institute, San Diego, CA.

D'Azevedo, W.L. (editor)
1986 *Handbook of North American Indians, Volume 11, Great Basin.* Smithsonian Institution, Washington, D.C.

Davis, J.O. (editor)
1984 *1983 Excavations at Archeological Site 26pe670 Rye Patch Reservoir, Nevada.* Tech. Report No. 38, Desert Research Institute, Reno, NV.

Dalrymple, G.B.
1964 *Potassium-argon Dates of Three Pleistocene Interglacial Basalt Flows from the Sierra Nevada, California.* Geol. Soc. Amer. Bulletin v. 75, pp. 753-757.

Geyh, M.A. and H. Schleicher
1990 *Absolute Age Determination.* Springer-Verlag, New York.

Hapgood, C.H.
1959 *Earth's Shifting Crust.* Museum Press Limited, London.
1966 *Maps of the Ancient Sea Kings.* Chilton Books, New York, NY.
1970 *The Path of the Pole.* Chilton Book Co., New York, NY.

Hintze, L.F.
1975 *Geological Highway Map of Utah.* Brigham Young University Geology Studies, Special Publication 3, Provo, Utah.

Izett, G.A., R.E. Wilcox, H.A. Powers, and G.A. Desborough
1970 The Bishop Ash Bed, a Pleistocene Marker Bed in the Western United States. *Quaternary Research 1:121-132.*

Jennings, J.D.
1978 *Prehistory of Utah and the Eastern Great Basin.* Univ. of Utah Anthropological Paper No. 98, Univ. of Utah Press, Salt Lake City.

Jennings, J.D., A.R. Schroedl, and R.N. Holmer
1980 *Sudden Shelter.* Univ. of Utah Anthropological Paper No. 103, University of Utah Press, Salt Lake.

Lanner, R.M.
1997 Whatever Happened to the World's Oldest Tree? *Nevada,* May / June, pp. 27-30.

Longwell, C.R., E.H. Pampeyan, Ben Bowyer and R.J. Roberts
1965 *Geology and Mineral Deposits of Clark County, Nevada.* Bulletin 62, School of Mines, Univ. of Nevada, Reno.

McKee, E.D.
1982 *The Supai Group of Grand Canyon.* U.S. Geological Survey Prof. Paper 1173.

Mead, J.I. and L.D. Agenbroad
1992 Isotope Dating of Pleistocene Dung Deposits From the Colorado Plateau, Arizona and Utah. *Radiocarbon,* 34:1, pp. 1-19.

Molenaar, C.M.
1969 Lexicon of Stratigraphic Names Used in Northern Arizona and Southern Utah East of the Paleozoic Hinge Line. In *Geology and Natural History of the Grand Canyon Region*, Four Corners Geological Society.

Morrison, R.B.
1964 *Lake Lahontan: Geology of Southern Carson Desert, Nevada.* U.S. Geological Survey Professional Paper 401.

1965 *Lake Bonneville: Quaternary Stratigraphy of Eastern Jordan Valley, South of Salt Lake City, Utah.* U.S. Geological Survey Professional Paper 477.

Morrison, R.B. and J.C. Frye
1965 *Correlation of the Middle and Late Quaternary Successions of the Lake Lahontan, Lake Bonneville, Rocky Mountain (Wasatch Range), Southern Great Plains, and Eastern Midwest Areas.* Report 9, Nevada Bureau of Mines, University of Nevada, Reno.

Purkey, B.W., E.M. Duebendorfer, E.I. Smith, J.G. Price and S.B. Castor
1994 *Geologic Tours in the Las Vegas Area.* Nevada Bureau of Mines and Geology and Dept. of Geoscience, Univ. of Nevada, Las Vegas.

Richmond, G.M.
1964 *Glaciation of Little Cottonwood and Bells Canyons, Wasatch Mountains, Utah.* U.S. Geological Survey Professional Paper 454-D.

Ritzma, H.R.
1959 *Geologic Atlas of Utah, Daggett County.* Utah Geological and Mineralogical Survey, Salt Lake City, Utah.

Romer, A.S.
1966 *Vertebrate Paleontology*, Third Edition. Univ. of Chicago Press, Chicago.

Ruhe, R.V.
1969 *Quaternary Landscapes in Iowa.* Iowa State University Press, Ames, IA

Shelton, J.S.
1966 *Geology Illustrated..* W. H. Freeman and Co., San Francisco.

Sheridan, M.F.
1971 *Guidebook to the Quaternary Geology of the East-Central Sierra Nevada.* Lebeau Printing Co., Phoenix, AZ.

Stewart, J.H., and J.E. Carlson
1976 *Cenozoic Rocks of Nevada.* Map 52, Nevada Bureau of Mines and Geology, Univ. of Nevada, Reno.

Stokes, W.L.
1960 *Essentials of Earth History.* Prentice Hall, Englewood Cliffs, NJ.

1986 *Geology of Utah.* Utah Muse. of Nat. Hist., Univ. of Utah and Utah Geological and Mineral Survey, Dept. of Natural Resources, Salt Lake City.

Stokes, W.L., and R.E. Cohenour
1956 *Geologic Atlas of Utah, Emery County.* Bulletin 52, Utah Geological and Mineralogical Survey, Salt Lake City, Utah.

Taylor, R.E.
1987 *Radiocarbon Dating: An Archaeological Perspective.* Academic Press, Orlando.

Untermann, G.E., and B.R. Untermann
1964 *Geology of Uintah County.* Bulletin 72, Utah Geological and Mineralogical Survey, Salt Lake City, Utah.

Velikovsky, I.
1950 *Worlds in Collision.* Macmillan, New York, NY.
1952 *Ages in Chaos.* Doubleday, Garden City, NY.
1955 *Earth in Upheaval.* Doubleday, Garden City, NY.

Whitcomb, Jr., J.C. and H.M. Morris
1963 *The Genesis Flood.* Baker Book House, Grand Rapids, MI.

Wormington, H.M. and D. Ellis (Eds.)
1967 *Pleistocene Studies in Southern Nevada.* Nevada State Museum Anthropological Paper No. 13, Carson City.

Wright, Jr., H.E. and D. G. Frey, (Eds.
1965 *The Quaternary of the United States.* Princeton Univ. Press, Princeton.