Transcribed lectures from Historical geology course. 1936

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[s.l.]: [s.n.], 1936

I don't know whether this class has reached the size to allow its continuance, but we will have to take a chance on that. I am going to ask you to put your name on a sheet of paper, and you write on it whether or not you have registered or intend to. In case the class does continue, I want to tell you just a little bit about the geologic treatment of the subject. The geology you have taken as a previous course, that is dynamic geology. It is a course largely of information. Historical geology is one of interpretation.

Now interpretation of necessity implies a foundation of information so inasmuch as the foundation is furnished as far as dynamic geology is concerned, we are just going to build on that. There are two books, either of which you may use for texts, one by Miller, Introduction to Historical Geology, and the other one, Chamberlain and Salisbury's College Geology, Part II. For the Historical part the revised edition is the one volume book, and I would advise that one. It is more ???, that is, if you are going to buy Chamberlain and Salisbury; the old one is published in two volumes, but this is the better form.

Now after you have bought the book, after you do you will perhaps not feel inclined to read it very much. Historical geology is just about ad dry as the rocks which we seek to interpret if you try to read it from cover to cover. I have an outline which I will give you which represents the general sequence in which the material will be considered. This outline does not follow any one of the text books. It is a list following a foundation laid by somebody else. The general treatment in historical geology is the interpretation of the earth and its peoples, that is, I should say, its population, the earth and its population.

We will begin at such a time when there was no North American continent, and determine its origin. Then, when we have a continent, we will go back and begin with the populations, not only on the population on the surface of the earth, but the forms which are entrenched in the rocks, that is, the fossil population.

Historical geology should be considered as that, and as those events which are revealed and preserved in the rocks, that is, as interpreted in the rocks. With that as a geologic start, let us say more of the geologic foundation. If you wanted to start out to interpret the history of the earth, where would we begin? If we had to do it from our own imagination, it would be a job, for several life times for a great number of individuals have been working on this job. Individuals have published and compiled volumes of interesting and valuable material.

It is then what we call sequence of events which we call historical geology. These individuals first began an examination of the surface and that's where we begin. We ordinarily speak of the rocks on the surface of the earth as outcrops. Along the river banks we have outcrops. These are surface exposures where the rocks are exposed at the surface of the earth where the mantle rock is absent.

Suppose we came to an outcrop, what is the information we would gather from it? We want such information as will tell you the environment in which that rock was laid down or formed. First we should know the class of rocks, igneous, metamorphic, or sedimentary. Each would indicate a different process of formation of that rock.

It is not enough, however, to know the kind of rock. We should also know more of the district of that rock. We can also identify a rock as the the species of rock. If you were to take that specimen of rock if you wanted to talk about the animal life included in that formation ???. For instance if we were to take dogs today, we have quite a number of kinds of dogs, so we have to further determine the class of that individual dog as to police, shepard, etc. It is important for us to know whether that rock is a sedimentary rock, and if so, is it a feldspathic rock, or is it a limestone or a sandstone or a marble.

We have to know, then, more than at least the class identification and the environment, but the species are identified by the nature of that environment. Furthermore, we must know the structure of that form, and that is a ???.

We must ??? and there are a number of them.

By structure we mean arrangement. Structure is the arrangement of the rocks recorded on the earth's surface; under ordinary conditions when diastrophism, that is, the forces which twists and turns segments of the earth, has not acted upon the rocks after they are laid down, they will lie in a horizontal position. If, however, they are in other positions, then we can interpret what the forees were which changed them to that particular position. So we must know the structures and arrangement of the rocks. Later we will have more in this course in regard to structure and arrangmment.

We must know a sequence. For instance, were to to have a sequence in which there is a sandstone, shale, and limestone, that is what we mean by sequence. In geologic history if we had that sequence, that reversed, ls, sh, and ss, a different interpretation would have to be made depending mainly upon the sequence. Later we will have more in the course in regard to that.

Not only should we know rocks, but we should know color of rocks. The color is due to the environment of the deposition. If it is red, it would be indicated through oxidation of the iron compounds, probably therefore in an arid climate. If it is black in color, it would indicate an abundance of plant and animal material, such as in coal. Carbon is abundant in coal, that is why the coal is black. Humidity gives them a dark color; that is the kind of information a granite? would give from exposure at the surface. I have paid particular attention to sedimentary rocks.

Now I have done so, because the sedimentary rocks are the great record of the earth. However, the other rocks record history to be sure, but it is largely the sediments which will concern us. In many places, however, the geology is not just limited to what we see at the surface, but there are certain artificial openings by which we can gather information. These are ordinarily such things as wells, oil and water wells, mines and tunnells. All of them are recognized as being beneath the surface of the earth.

After being in a ??? where the normal method of observation can be carried on, but any time a subsurface operation is made, a geologist is usually on hand to get all of the information available. The information gathered from these amplifies and modifies the information that he is able to obtain from the outcrops. They do not change maps for concepts as to what the geology of the subsurface? shows, but it will help the geologist in getting a better scope. Now sometimes the geologist has been studying an area; he has hints on the exposure. He has a fairly good idea as to the kind of rocks. that occur. He has a good idea as to where they occur. If there are any true lines, he has that information also. Now what does he do with it? Well, it depends upon the topography of the area; if he publishes this information, he refers to maps and various types of diagrams. It is possible for an individual without proper background to go to this source and get information which he would need for working out the geology of that area. This information is usually represented by means of areal maps.

They are maps that are concerned with the areas that are outcropping of the various formations. In other words, they represent the geographic distribution of the outcrops, in other words, the ??? geographical distribution of the outcrops of the formations at the surface of the earth, no relation with them underground, but at the surface. Now in any one area you would not have rocks continuously exposed over the surface, but you would have the outcrops scattered. Only a relatively small portion of them would be made up of ??? yet it is possible to interpret and fill in between until the final product is a map. After all, what the areal map represents is the surface as it is occupied by some of the formations. In other words there is much necessity of knowing the location of the formation.

Up here on the wall is a geologic map, and areal map. It represents the areas occupied by the various geologic formations. Now before long, I want you to become familiar with a few outlines of that map. The details you will perhaps never become

acquainted with. That is not necessary. You will notice that the map as you see it, the striking feature is the distribution of the color. That is one way we have of representing geologic formations. So then the distribution becomes quite apparent.

There is a regular system of coloring used to represent different geologic formations which appear at the surface as outcrops. That area was covered by a continuous ice sheet. The surface material is glacial drift, but none of it shows on the map for the map shows bed rock only. They may be consolidated or unconsolidated. Out in the Bad Lands they are, for the most part, sands and clays. They are not the mantle rocks.

In addition to color, another means of indicating rock formations is by pattern. This is useful where color printing becomes too expensive, and so you will find in a number of cases where geologic maps are interpreted by patterns instead of colors.

Here again, as to correct pattern, there are certain rules and regulations. You undoubtedly realize that the chief consolidated rocks are stratified, therefore you will find sedimentary formations as being represented by parallel lines; now that doesn't mean horizontal. Any areas of parallel lines on a map would indicate sedimentary rocks. Now for instance, we may have a formation represented by lines such as this. When we run out of lines we begin another pattern. When we run out of that pattern after a while, we start another, grouping the lines so that they are always parallel.

Igneous rocks are represented by intersecting lines. In other words, non-parallel lines. The intersecting lines are usually so, arranged so as to give us rhombs, or parallelograms. Nowhere will you find squares used on geologic maps. If you add a third set of lines they form a triangular pattern. Variation in the treatment of lines gives us a varied pattern.

Then the third class, metamorphic rocks, are represented by irregularly spaced short lines. Dashes, in other words. Metamorphosed rocks then would be represented by ?. All of these maps are represented by color and pattern, but still we have another way, and that is by means of symbols in which there are combinations of letters

and which indicate the age and the character of the formations. They indicate the age or the character. Now if we were to look at the areal map of, well, asuming that one had been made now with no information, The arrangement of the formations on the map may indicate the structure, and that, of course, would be of importance. If we have large areas covered by one formation, it is logical to assume that the formations are apparently horizontal. That is perfectly obvious. If we find that on the map there are bands extending across the map, if each of these represents a different series of rocks, then they are all inclined in one direction or the other, assuming, of course that the surface is not too irregular. I guess the best example of the map is the colored bands of green, yellow and gray. The gray on the coast line represents a formation of a definite geological age and we know that these formations shown here are all inclined, they are all inclined in one direction, that is, regional dip.

Those of you who have taken Geology of Minnesota know something of the formations in the southeastern part of the state. They dip to the southeast. If in a sequence as represented here we were to find that

yellow blue gray

don't pay any attention to these colors as they are imaginary. That is, if we were to interpret the geologic formation here, starting with the yellow , the formation here might represent either one of two geologic formations, a fold or a fault. A fold would be indicated by a repetition of the colors in a reverse of ? order beginning with the yellow, yellow, blue, grey, blue, yellow. If our sequence was reflected repeated in the same order, yellow, blue, gray, yellow, blue, gray, then a fault is indicated so that just by observation of the distribution of the formations we can begin to know some of the structure, that is, by the arrangement of the formations. If on a map we were to find that the series was repeated in reflected order, that the contacts were hyperbolas ? then we should know the structure was plunging. For example, these sediments might represent an anticline. So long as it remains with the axis in horizontal position, the formation will appear as parallel bands on the sides.

When the axis is on the side, however, the trend goes around an we get this sort of structure, a plunging fault?.

Well, I think now you can see what we can get from the areal maps. We can get class of rock, sed., ig., and met., and we can also get position or arrangment of the rocks. Most geologic maps have on them a time saving device which connects the structural facts. Again assuming this to be a geological map, now we want to know what the structure would be if we were going to cut through it and look at the end of it. If we wanted a cross section, we could make one. Usually there would be included in the report somewhere a section indicating the structure. Such diagrams are called structure sections. Let's make one here.

a——————b

Along this line we would lay off distances proportionate to where the line connects. We know this is gray, then blue, then yellow, etc. Now this is an anticline. I say it depends on the sequence of the rocks. If we want to stop and get the information we could tell from that, but in a report we are saved that bother by ?. This, for the most part, is fact. This interpretation that this is made from, that is, that the structure sections ordinarily are made from, are purely hypothetical, and of course, the further you go beneath the surface, the more hypothetical it becomes.

Structure sections indicate the arrangement of the rocks. They are not just like I have indicated them here in blank spaces; they are filled with a pattern which rep resents that particular formation. If the geology is a ls, then it is represented by a blocked pattern like a brick wall emphasizing the fractures present in a ls. This next is ss represented by a stippled pattern. The next is sh represented by lines parallel to the formation. The patterns of structure sections differ in that they follow the structure lines; they just stop when they get to the boundary of a formation. ? represent an area, these, however, represent structure. Structure sections are of value in interpreting the geologist's ? of the formation. He is able to ??? the surface. In this particular case it indicates diastrophism in which the rocks beneath are folded. Later on we will have more of this.

Another method of representing formations, which is used, is the columnar section. It is just what its name implies. It is a column, it is a diagram. It is a thing which is made. It does not exist except in the construction which appears on paper.  I won't stop to fill in the list of patterns provided in this structure. If we wanted to make a columnar section, we would begin by arranging the rock in the order of age. Down at the bottom would be the black, then, red, then white, green, blue, yellow. Nowhere in a cross section and no where in a line? surface would you see such a thing as this. It is a construction. It represents a generalized condition. Some one has remarked of it in this way, "It represents only the original structure and none of the subsequent structures." Now let's see what they mean. After the deposition of the rock, the surface was subjected to erosion and we have an unconformity. Wherever that line is, that would be an original structure, so that would go into the columnar section. The intersecting part is the lower series where ???.

This represents a generalized condition; the vertical scale is drawn in proportion to the thickness. If we go back to the areal map and find this section represented, we would find a, a section in which, in which we would have the same color, symbol and pattern. We would find a number of things, say if we were representing that in this formation we might represent diagramatically where the ss was, where the sh, and where the ls, but in a columnar section we would know in detail the thickness of the ls and its position in regard to top or bottom. Much better opportunity for interpreting a columnar section are the figures showing the thickness in feet given on the side of the section. It is approximately the only place on the map where we can tell the thickness.

We could get it, of course, from the areal map of your cross section, but it is easy to turn to the columnar section. We have still another method of representing formations, the well log. You undoubtedly are familiar with the word log being used in connection with the word ship. A log is a record of the progress a ship makes. The same word is used for a ? of conditions found in the drilling of a well. The well log again is a construction. It is quite like a columnar section in all its respects. It does not represent the subsequent changes that take place, but it does represent the character and the thickness of the formation.

It differs from the columnar section in being applied to a special location where it was drilled whereas a columnar section represents a general area as represented on the map.

Now I think I have given you enough to understand that there are various ways of getting geological information. You can get it from the surface and you can get it from the subsurface. It is available in published form -- it is at the disposal of the general public. In most cases, any questions of a geological nature ???. These are the methods by which the facts are accumulated. If we have the facts, the less time it takes to interpret it. It is the foundation.

(Interruption. Question: Can we get this in the text by Miller? Answer: Let me say a little about this text by Miller. It is very elementary. If you begin to read it from cover to cover, I think you will stop at the end of the third chapter; it is so well organized. However, if you want to find something in a hurry, you will know exactly where to find it in Miller, in what chapter it is going to be, so it depends on how you want your dose of historical geology. Miller, of course, is the dry toast. Chamberlain and Salisbury is a little bit more over on the interpretive side, more interpretive than Miller, but also less factual, and more interpretive, so in Chamberlain and Salisbury you are really getting all of the jam and none of the toast, so it is up to you to get what you want, all toast, all jam, or some of both. ? is less expensive. If you want a historical geology since 1900 by all means buy that. It isperfectly all right because I am not going tofollow any one of them. Other questions?)

Then let's begin now with interpretation. We have the geological information, now for interpretation. This will be nothing more now than a review of dynamic geology. I don't know what concept you have of dynamic geology, but I do know of one that it should be. Geology represents the action of the atmosphere and the hydrosphere on the lithosphere, the three states of nature which make up our earth.

Well, when did this action begin? Well, we are pretty sure it was in existance yesterday and for a number of yesterdays. We can be sure, however, that the action of the atmosphere and the hydrosphere on the Lithosphere has gone on for a long period

of time. In other words, the geologic processes which are modifying the surface of the earth today are the same as have modified it in the past -- water, wind, vulcanism, and distrophism. It is hard to think of anything else even though ???. Such things as the Devils backbone or Devil's chair, etc., and such other natural features are the result of men's work. (P.W.A. Joke) In other words these features have resulted from processes acting today. The sooner we realize this the better. Scottish geologist ? so firmly believed in that, that ??? evolved two schools of geologic thought. One school held ???; the other had erroneous ideas so we won't bother with those. But there did come into reality the more uniform one, which forms the A.B.C. foundation of geology. And if you don't understand that, I will guarantee that at least part of the time you will be lost.

Law of Uniformity. Starting from that point, let us see what we can find out. If geology is the action of the hydrosphere and the atmosphere upon the lithosphere, what is the lithosphere? I think that you know that it is the rocky portion of the earth. Well, what about the rocks? If the lithosphere is made up of rocks, then we should know something about them.

In a shell ten miles thick around the outside of the earth, it has been extimated that 95% of the rock material there is igneous. In a shell taken around the outer portion of the earth, 5% of that material is sedimentary. Most of it is metamorphosed, that is, inverted back into an original form as a rock class as metamorphic igneous or metamorphic sedimentary. Then the ??? portion of the earth is made up of sedimentary rocks, but a great volume of igneous rock. That is not so surprising to you, I don't imagine, when we consider the subsurface distribution on the continents.

75% of the continental areas is covered by sedimentary rock, and 25% is exposed at the surface of igneous rock. Now stop for just a moment to see what that means. To again begin our interpretation, this 5% covers 75% of the continents. In other words, it is just about as thick as the tarnish on this globe, or the peeling of an apple?. An exceedingly thin film about the outer portion is the sedimentary record. Yet in this sedimentary record is going to lie all of our interpretations. All will

be based on that. Not all of it, but 99.99% of it, for this is all down to approximately a distance of 4,000 miles, and is merely postulation and hypothesis. And so when I say hsitory of the earth, I should say, history of the skin of the earth.

Then back to this 5%. How is it subdivided? 4 of that 5% is sh, 3/4 of the remaining 1 is ss and the other 1/4 of the sedimentary material is ls. (Interruption. Question: What was that? Say it again. Answer: 4 of that 5% is sh, 3/4 of the 1 that is left from the 5 is ss, and the other 1/4 of the 1 that is left is ls. Is that clear?) If we have a film of sediments around the outisde, the igneous rocks beneath, the question then is, what is the source of the sediments? And the logical answer would be, the erosion of the igneous rocks.

Most of the igneous rocks would be made up of sandry things as feldspar, quartz, and acessory minerals, commonly spoken of as ferro-magnesian minerals. What would happen to such a rock such as that if it becomes weathered? The feldspar decays and forms clay. And because the quartz is next in abundance, the sandstonesare next. The ls has resulted from the calcium leached from the feldspar. Limestone is the least abundant of the sedimentary rocks. I might repeat to you that rocks are made up of minerals. We won't stop with the various minerals which make up certain rocks, but I think that you should be familiar with such as quartz, calcite, limonite, hematite, magnetite, gypsum, halite, kaolinite. Those are the predominant minerals that you will find in our sedimentary rocks. The others we will give the proper attention as they appear.

This supply of sedimentary materials is then resultant from a solution type of rock ???. However, we speak of a weathering process of decay which is known as decomposition, the process of breaking up rock. As for disintegration, I think most of you are familiar enough with your dynamic geology to remember the agents associated with each of these processes. In other words, distinguish the physical agents from the chemical agents. The physical agents break and tear down; the chemical agents dissolve and combine ???.

Later on we can look at a sediment and say, this resulted from disintegration or or decomposition, and thus interpret the environment as indicated by, indicated by the ???.

If weathering was all that we were to count on we would have a relatively uniform topography. We would not have sculptured monuments? or canyons. The process of erosion is the principal removal of loose material. This takes place by means of many agents but streams are the primary ones. We have undoubtedly become aware of the fact that an area, when it is completely eroded by streams, forms a smooth plain; such is spoken of as a peneplain. In the history of the earth various peneplains have been established by erosion. I think you can recognize what the processes are, excess drainage, and.

Rainfall of the surface runs on the surface and begins to form a stream which grows in three directions. First in length, then depth, and ten finally swinging back and forth from the middle, with the result that the rocks will be levelled, truncated, or cut off, and the channel widened. Later on then there has been an uplift that has caused rejuvenation. We have evidence of an uplifted peneplain in the Appalachian Mountains. (Tennyson verse about everlasting hills).

If you think of the process of peneplanation, he had a pretty good idea, given sufficient time, the hills will melt and flow. Well, what happens to all of the materials? Part of it is deposited along the streams, but as a results of this erosion action of the stream plus the erosion action of the waves and ??? will result ultimately in layers deposited upon the continental shelf. Well, let us stop.

What is a continental shelf? The oceans are too big for the basins; that is the simplest explanation.

This represents a cross section, this is sea level,; out here is a basin. It filled to overflow. This margin on the continent is spoken of as the continental shelf. It has a depth of 600 feet. Then there is a drop sharply. There is a drop to a depth of perhaps 6,000 feet or more. This is the continental shelf then, the material contributed by the waves and the streams -- deposited in the shallow water. Today we find continental shelves around the Gulf of Mexico and New York, out until you get To the the sharp break.

At the present time the continental shelves, the continental shelf is the area in which the marine sediment records are being formed. That has also been true in the past. If we had the opportunity to visit the various sections of the United States, we could very easily be convinced that the distribution of the land and the water has not been as it is now.

If we were to visit the Appalachian Mountains -- from the various facts that have been given you about the sequence of the rocks, you would know that they consisted of normal marine sedimentary rocks, ss, ls, and sh. We would find that a thickness of 3,000 ft. of material is represented not in any one place, for in various places, 3,000 ft. of sediments all accumulated in water not deeper than 600 ft. Now we have to explain such an accumulation.

It is believed that on the continents are sedimentary troughs, long narrow zones of weakness which represent ? of deposition. These became submerged, later areas contributed sediments, and asa result we have deposition of 3000 ft. As the sediments are deposited, the weight of the sediments caused the bottom ot go down, and such a geologic feature is called a geosyncline. They, for the most, represent negative portions of the continent. Negative portions -- they are usually below sea level. If we were to examine the rocks that occur on the North American continent, we would find areas???. We have to go no farther than the river bank. (Interruption: Question: What would say was a definition of normal marine deposits?)

In thisarea between the mountains we find normal marine sediments. They are not on the continental shelf, not geosyncline. What are they? They represent the gradual submergence of the continents. The continents really remained where they were. The sea really moved in. The ocean level could rise or the continent could sink. We had submergence of continent and sea level becomes higher and higher. It spreads from the Gulf of Mexico and it spreads until it is up to Washington Ave., with the shore line at St. Cloud. This is an area of marine deposition, and they have to be given a name. Epicontinental seas, they are spoken of a Epicontinental seas, seas on the continent. You may run across the term epeiric seas, that is one and the same thing.

They represent portions of the continent, not margins along the boundaries which have been submerged. Hudson Bay, for example, is an epicontinental sea at the present time. Tennyson was a better geologist than most of us know. I am quite sure he didn't know anything about ? but anyway he came pretty close (poetry) .

When the limestone was deposited out here, his last two lines were a perfect description. (repeat poetry). The sediments are deposited in these various areas, the continental shelf, geosynclines, and the epicontinental seas ? of course the result of later erosion, so we should think of our geological history not only as ? but read the sediments as they are recorded by erosion. It is not enough to know that the area was submerged; we want to know where the shore line was. That is asking a good bit, but I think we can know something about it.

For the most part, the composition of the sediments indicate its proximity to the shore line. On the continental shelf, the sediments are in zones, gravel, sand, mud and then from there on out we have the unconsolidated form known as ooze; the ooze later on makes ls, the mud sh, and the gravel and sand ss. These are the main marine sediments not associated with ? conditions. However, with the ??? the 500 ft. of water, that is part of the way we have to go about the interpretation. Now here isa ? in the records ???. Down on the river bank we have ss, ls, sh. Which was deposited first? First ss, next sh, next ls. We have this order when the area has not been affected by diastrophism. In other words, when the sequence hasnot been turned upside down. In other words geologic formations are not deposited in this way. We have one and the next one is deposited on top of it. If something did not disturb these pages of geologic history, they would be in the same order. (Interruption. Question: The ss on this rive bank, does that extend way downsouth? Answer: The ss on the rive bank goes way down into Arkansas. It is at the surface here, but it is far beneath the surface there.) This sequence of formations has led to another law. Law of superposition. In a series of sediments the youngest rock is always the uppermost one. Ordinarily we would have a recess, but I want to finish this intro-

duction, so I am going to try to get on. If we consider sediments as pagex in the rock history, some of the pages are torn out, that is, they have been torn by the process of erosion, and we do not have a complete story from beginning to end. Several places of the story have to be filled in else our record is not complete. These breaks or ? in the sedimentary record give rise to unconformities.

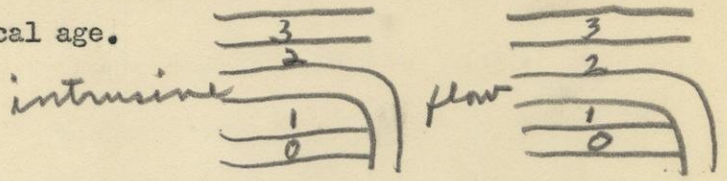
Now every time you see the word unconformity, you should have thissequence of events going through your mind ??? that is just a part of the processof interpretation. We won't say much about unconformities, but bear in mind the types of unconformities that we have, that we have. I know I shouldn't be telling you this after dynamic geology, but it probably won't hurt. Under unconformity we have the term disconformity. If the erosion resulted without any change in the position of the lower bed, stating it another way, if the strata above and below the erosion surface are parallel, that would be a disconformity.

This seriesrepresents submergence, deposition, emergence, erosion, submergence, and deposition. The beds above and below the erosion surface are parallel, and we speak of it as an unconformity. All other relations are called nonconformities. a non-conformity results when the underlying series has been displaced, and the deposition on the eroded surface is not parallel to the beds of the ? below. There may be a great variety of non-conformities, etc.

This non-conformity is spoken of as an angular unconformity. The interruption of such a equence of events is the basis for the law of unconformity. In other words the sedimentary sequence of events is the basis for the law of unconformity. the sedimentary equence being interrupted and ? resulting in an unconformable relationship.

Our geologic process still includes another type of agent, vulcanism. Let me remind you vulcanism is expressed in two ways, surface material known as extrusion and subsurface material known as intrusion. For the most part, these can be recognized by texture. Texture is again different from structure; it is size and arrangement of grains. We can tell whether a rock is intrusive or extrusive, and of course that is important in determining the sequence of events.

One of the goals in historical geology is to arrange things according to age. Now how are we going to arrange igneous rock? We date them by the time of solidification. If we have a flow rock, and an intruded rock as here indicated, in general they look alike but they are of different geological age.



Age of rock is indicated by the sediments here, this after 2 this after 1. Remember, all intrusivesare dated by time of solidification.

A nother law isthe Law of Intrusion. Simply stated thus: the intruded rock is always the younger. or perhaps it would be better to say the intruded rock is always younger than the intruding rock. Age is determined by rock intruded, but the materials that we are interested in here are the materials that came from the center of the earth. They are older, but nevertheless, the igneous rock is dated by time of solidification.

If this were all, it would be a simple job, but after this, diastrophism came along and that ???. We classdiastrophism in two different divisions, orogenetic, which is mountain making diastrophism. Orogenetic diastrophism resultsfrom sediments or movements, circumferential movements parrallelling the crust of the earth. Two ? move closer together and we have the diastrophism which forms mountains and geosynclines. The other isepirogenetic or continent making diastrophism. These movements are radial, that is, movement along the radii of the earth, with the continent moving farther from the center or toard the center along the radii. For the present we will let it go at that. Thos are the types of diastrophism given.

There isjust one thing left now, and that is the Law of Correlation. Correlation is used in a number of connections but ???. The majority of rock units, the majority of rock units with regard to geologica age ???. Later on I will tell you that the ls on the river bank is the equivalent of a lsin New York. That is what we call correlation. Correlation takes place over the entire earth and just in so far as the mapping has been done, we have a complete history of the earth'story of ??? which means we have to guess more than anything else.

This? of rock unit usually comes about by means of two typesof criteria, two things we look for when we want to map formations. I am not going to say much about them now because I am going to spend more time on them later. I have chosen to call them the geological and biological criteria; these are physical criteria and these are organic criteria. We cannot consider this one until we know something about the animal and plant kingdom, and we won't know anything about that until after the ??? but we could talk of geological criteria.

They are relatively simple, for the most part, however, an enumeration of them should suffice.

1. Continuity. Well, if ??? table top I begin on thisside and I can go along an come out on this end of the table top and there is nothing surprising about that. I know I am on the same ?. We can do the same with geological features. If you alked over an area and did not cross other formations, you would know it was the same for mation.

2. Similarity of materials. Another one that can be overlooked a little bit, but it is a fairly good thing to know. If, for example, we had a formation which contained a ???. Color, size of grain, composition, all those things ??? in other words, similarity of materials. If you postulate ??? (A sentence or two about Vermillion range and overworking).

3. Similarity of sequence isnext. In a ?we may not have the ame formation exposed over an entire area, yet we would know something about the geology. The similarity of edimentary material in an area would lead us to believe that this contact was ??? over that one, that formation over that one, etc. This of courese does not over the question, but it is the bes we can do. The mining engineer in giving hisidea of a geologis, starts out g isfor guess, e for error. Anyway, it must of necessity be interpreted. There are other ways, but they are less ???. Thee are almost ??? from the study of adjacent lands.

Such is a foundation on which we will have to build. Now providing that the class continues, and so far as I am concerned, we will meet again next week if we have enough to permit us to continue the class ??? meet next Tuesday and make arrangements.

CD/HVA

Phy in general ? through which these forms came into being. So much is of common interest to us. Therefore beginning on April 14th and 16th respectively those interested in National Parks will meet on Tuesday evening and those interested in Historiaal Geology will meet on Thursday evening. Now in order to know just where we are going to stand, I would like some expression on your part as to how this will divide us.

We are all, of course, you and I ? nature of both courses will have to be somewhat ?. I think I can organize it so that no course will suffer too much.

For this evening the general topic which I want to consider, those of you who have not had an outline, I will give you one. The topic -- origin of the earth and geologic time.

I would suggest that if you have not had previous geology courses that you had access to some kind of a book. There are going to be some things which you are going to want to look up, so I would suggest some kind of a text book. (Interruption Question: What would you suggest as a text book? Answer: Get one including both historical and dynamic geology.)

The origin of the earth would seem a little far fetched, yet I believe that you will possibly be interested a little bit in the origin of the earth. To those who are taking Historical geology, you are concerned in the origin of the earth, and are going to be influenced by some of the ideas concerning the beginning of geological time on the earth.

There are principally four hypotheses of earth origin. Let us begin with the oldest one, Laplacian. That is called the Laplacian. I am just going to hit the highlights now. The Laplacian Hypothesis was announced in about 1759, I think the date was. This French astronomer and mathemetician postulated that all of the material in our solar system ?. Now the sun and all of the planets and their satellites originally existed as a mass of gas which extended from the sun to the outermost of the planets. Now such a mass of gas must have been exceedingly rare, that is, meaning not dense. It must have been very ?. Having the mass of gas, he didn't say origin of the gas, he didn't know from whence it came, but he assumed it to

be highly heated, that is, the loss of heat from this mass of gas began to contract. As it contracted, it began to rotate. In the process of rotation, there was a tendency for an equatorial bulge to form, that is the ? diameter was shortened and the ? diameter increased. This process of losing heat, contraction, spinning, more rapidly, continued until the force which tended to draw material out in space, centrifugal force, in other words, gravity, tendended to want to ?, began to be equal and the two opposing forces balanced. There was left off then, not drawn off, a belt of gas around the equator. The main mass condensed due to the cool rotating action and a belt of gas was left off, one belt being left off for each planet.

The sun, that is, the star of our solar system, represents a mass of gas which is left after all of the planets are made. If we were to look down, say at the north pole, there, this mass, it was something like that. Then there was left off a belt or ring of gas, and here was a body which continued; another ring of gas left off, and so on until finally the material left in here was the sun.

These belts of gas here are uniformly dense. In the weak portion the belts broke. I don't know which is the weakest portion here. And the belts broke and the mass was collected in one spheroidal body. This spheroidal body began rotating, cooling. and if left off a belt for instance around its ? one, and the process again would be repeated. That would be broken; it would collect out here.

The sun is a star. The sun is a star. This mass which came from a breaking up of the rim, a planet, this a satellite or a moon.

Now Laplace was convinced of this. He looked out and saw a planet in which these rings were still around it. In other words he was looking at Saturn?. Saturn is a planet with two light rings around it. So certainly there, there is our solar system in the making.

The present day astronomers say that Laplace was mistaken, that the rings around Saturn are satellites which have come to close to Saturn and have become disrupted. In other words, Saturn represents ? of our solar system, rather than the construction of

our solar system. If we assume this to be the earth rather than any planet in particular, this is the idea. First a portion of highly heated gas, then as the gas cooled it became a liquid globe still highly heated. ? in the nature of lavas perhaps, but a molten globe still more heated. Then ? began to freeze solid; thus the solid globe, the outer portion of which would be a crust, the inner portion of which would still be molten. Consequently the ? kingdom is located beneath the ? of the earth. A true correlation if you want to think of it that way. Then too, Laplace thought that the earth originated from a mass of gas, and passed through a liquid to a solid stage. The material remaining was the source of the sun. Otherwise ??? that was Laplace's explanation. It is sometimes called the nebular hypothesis. These highly heated masses of gas still exist in the heavens are are still spoken of as spiral nebulae. They are still present, not in the form of Laplace, but in another one.

Then two men at the University of Chicago, Chamberlain, the geologist, and Moulten, a mathematician, tried to explain the arrangment of the solar system on the basis of another process. We will give you a summary then. Chamberlain and Moulten, these men considered the mathematical aspect of the solar system and they found some rather surprising things. They found that 744/745 of all the material in our solar system is still in the sun. In other words 1/745 of our solar system is in the planets, a very big volume. Further, they studied the surface of the sun and found that high fountains of flames were rising from the sun's surface for thousands of miles and they would always return to the surface of the sun. Having a velocity ??? return to us, a velocity of approximately 386,000 miles per second. These masses of flame returned to the sun's surface because of their gravitative force.

The force of gravity for anybody is dependent upon its size or mass rather and the sun has a tremendous mass, and therefore its force of gravity is enormously great. For example, if the world's Champion High Jumper were to expend his best efforts on the sun's surface, the record he would make would be three inches. The force holding to the surface of the sun is so great that you couldn't jump more than three inches.

??? these men certainly were not masses of flame. They almo t leave the sun's surface. Wouldn't it be possible to have something to help them? They knew of the tides of the surface of the earth. Well, why not? They assumed then two stars, one of which was our sun. They didn't collide, they merely came close to each other, close enough so that tidal effects of the passing pulled off from ~~it~~ the sun, 1/745 of the material. Now we will postulate that these bodies were moving ?.

We are going to consider them in three positions. Let us call this position 1, 2, and 3. This is 1, 2 and that is 3. The tidal effect? would be in the direction of the line joining the diameter of these two bodies. In other words, ?. Any material pulled from the sun's surface, therefore, is going out in that direction. Coming in, ??? any material pulled from that position is going in the direction indicated. To the third position the material would be drawn out as indicated. What happened to this? It started out in a direction as indicated by this arrow, but after this star passed, it took a ? part out into space. This did the same thing, so in the third position we would have the bodies arranged something like this, the ? of them drawn from the sun, and I have indicated that process as not being contraction. There would be an accumulation of that ?. The ? we leave for a period of time until it has ? again.

Mercury, Venus, the Earth, Mars, Asteroids, Jupiter, Saturn, Uranus, Neptune, these are the astronomical bodies other than the sun which make up our solar system. The planets and the smaller group of planet-like bodies arranged at increasing distances from the sun to the outermost planet. When Chamberlain and Moulten proposed this hypothesis. As most of us/probably know, there are two tides on the earth all the time. They are ? opposed. See this arrangement of planets, all of these small, all of these large. Why not have paired or double eruptions? When the material goes off in that direction, let's have some go off in the other direction. The smae for each of these stages. The large planets drawn from the side of the sun near the passing star, the smaller planets drawn from the side of the sun away from the passing star, therefore, paired eruptions. Well, that sort of leaves an unbalanced condition. Here was a group for which there was no corresponding ? but eventually the planet Pluto was discovered, so there they are, there is the partner for the asteroids.

Paired eruptions. There is, however, one difficulty, and that is that Pluto is possibley going to prove to be a small planet instead of a large one. They don't know much about it yet.

This material which left the sun's surface was ? more in the form of gas, more in the form of gas. As Laplace said, as it lost heat, the lithosphere then became solid. Those small bodies being small planets, planetesimals, they call them, small planets. How large are they? Some of then think the largest ones are like the asteroids, about 500 miles in diameter, and from there on down to molecules. Quite a range in size, but all of them solid bodies.

Evidently in each of these there was a large enough body to act as a nucleus or a core or knot. This body began to r volve around the sun and in so doing, it tended to sweep a part in the ?, sweep up the other planetesimal bodies. It is believed then, that there were 10 paired ? but only 9?. Each of these others had a center around which the material could accumulate (Interruption. Question: Does this mean that only 8 of these centered? Answer: Yes.)

According to this hypothesis then the material in the earth has been solid ever since the time it left the sun's surface. The planets have grown by the accumulation of planetesimals added to their outer surface. This star went out into space and has been ? ever since. The chances of it happening again, of, one and an endless number of ciphers after it. In other words, very, very remote. Chamberlain and Moulten proposed this hypothesis about 1900, so we can see that Laplace had about 150 years for his hypothesis.

Barrell. A geologist at Yale by the name of Barrell modified very slightly the planetesimal hypothesis. He believed the bodies were large rather than small, so he called them planetoids. The hypothesis, therefore, planetoidal. He thought these masses were so large that bombarding the surface of it with heat penetrated by the impace was enough to cause confusion and those ? rock masses. That is not commonly accepted at this present time.

Jeans, and English astronomer by the name of Jeans made another modification, but this time more or less of a hybrid, you might say between Chamberlain and Moulten's

and Laplaces. He believed the solar system to have resulted from the close approach of two stars. He, however, assumed all the material came off the sun at once and all on one side. This represents an accumulation of the sun. He shows and ? the material was pulled off in a cigar-shaped form. This cigar-shaped mass of gas would not be homogenous; it would tend to break up into units somewhat in that shape. These represent the planets, Mercury, Venus, earth, Mars, Asteroids, a group of bodies, Jupiter, Saturn, and the rest of the planets. The cigar, broken up into units then. Those units in the middle of the cigar formed the largest planets and as we go out they become smaller or if they go out in the other way they become smaller. That is true in general. That arrangement according to size, it ?. Jeans says these bodies that are large would remain gaseous or liquid the longest before solidifying; therefore they could hav e this smae process happen to them. The bodies which were small, began solidifying very soon, and therefore they would have little chance of having that happen to them. Mercury or Venus have no moons or satellites, Mars has two, Jupiter and Saturn both have many, one nine and the other ten. A long period for cooling and the possibility of ?.

These conditions, there is not enough known about them to say. ? gas broken up into units more or less collided into spheres still gaseous. Those spheres finally became liquid, then solid. You see this has been called the Tidal Hypothesis, and you can see there is considerable difference in opinion between ? and ? and there is considerable difference of opinion between ? and ?.

That is Jean's explanation. I haven't seen any written ? but just from my own information, I wonder why he didn't make two cigars, one large and one small. Chamberlain and Moulten postulated, postulated one large and one small, why not two cigars? I don't propose to be an astronomer, but there are some things which I want to know. If one star swished by the other one in space as I drew the original, I think Jean's cigar would have been something more like that. In other words, the attractive force of this star going out into space would ten ???. It would tend to draw the material in a curved form and it would be more crescent-shaped than cigar-shaped. That is just a ? of attractive bodies in space and I think that evidence should be included. That is about all I want to say about the origin of the earth. Any Questions?

If we explain the origin of the earth we have, however, one little speck of astronomical ?. Anyway the sun was the center of our universe until they found out there were thousands of others. They found the milky way we speak of as a galaxy. Then they found the earth was ? Nevertheless it is so. In explaining the origin of the earth, it is just one little ???

When does geologic time begin? What I have considered so far may be called cosmic geology or the pre-historic geological events. When do we begin to reckon geologic time? We should begin to reckon geologic time when the earth becamesuch a body that the processes now modifying its surface came into existence. In other words, when the rain began to fall, the streams began to run on the surface of the earth, waters began to collect on the ? to form ocean basins. We then had the three forms of matter on earth, solids, liquids, and gas. When we had three states of matter, we had an earth.

Now let's see how long we have had an earth. There are various ways of arriving at it. One way would be to consider the oldest living individual on the earth. Well, man is not a very good form to use, neither are other forms in the animal kindgom, but among the plants there are individuals where age is recorded ?. Of course I am referring to the Redwood or Sequoia that grow in the western part of the U. S. They are four or five ~~hundred~~ thousand years old; they have been determined by ring counts. If you go back four or five ~~hundred~~ thousand years from 1936, that would be 2200 B. C., way back in a time when history was being recorded by chips taken out in blocks of stone. Now the earth has been in existence during the life of these ?. We do not know how much longer, but we are sure the earth is at least four to five thousand years old.

I am going up through the gradual stages so we won't get too much of a shock Another way to tell the age of, the age of the earth would be to tell the age of the oceans if we could. The volume of water in the ocean is known. The average salt content is known, the rate at which salt is brought to the ocean by streams of the earth is known. Therefore, we should be able to make some kind of headway as to the length of time the ocean has been in existence.

Total salt in the ocean divided by the amount brought to the ocean each year. The latest figure gave 360 million years, 360 million years. That doesn't take into consideration the salt that was once deposited in the ocean and now makes up rock layers on the continents of the earth. Perhaps we could arrive at some figure by another method of calculation.

Since the rain has falllen on the surface of the earth, streams have run into the ocean carrying sediments. These sediments have been deposited in rock layers in such a way as it is possible to determine a continuous but unrepeated sequence. Rock layers from the time the sediments began to form up to the present. If by taking observation from various places so as to get all of the units, but not repeat any of them, we would find that there had been deposited along the shores of the ? oceans of th earth 529 thousand feet of material, 110 miles in other words. The average accumulation is calculated to be 1 ft. in ? years, that is, out beyond the continental shoreline, 1 ft. in 88 years on the continental shelf. In the ocean basins where they have been able to examine the records, they have found ? in ? years. That is out beyond the continental shelf.

The oceans are larger than the basins; therefore they spill out on the edge of the continent. So much is spoken of as shelf, the other is basin. This is the zone in which the 110 miles of sediments have accumulated, not here in the ocean basin, but out in the margin of the continent. 465 million years or 500 million years if you want, is allright ro 465½ million years.

Then the physicist and chemist, the exact scientists began to work on it. Remember what I said about the geologist, g stands for guess and e for error. The physicist and chemist began to help out the geologist. They found certain elements which began to disintegrate. These are of course the radioactive substances. These chemical elements are found in the minerals of some large masses of igneous rocks, Igneous rocks or intrusive rocks, that is, those which were once in a moulten state, essentially all the granites.

These minerals the chemist has analyzed then to see if he can determine how much of the material there is left as a result of this disintegration. The most common of these substances is radium which breaks down into lead, not the kind of lead used in plumbing. There is just enough difference so the chemist can recognize it. The procedure is more or less this. If a mineral has all bee n converted into lead, then we have a minimum figure. We don't know when the conversion stopped, but when the portion of the mineral there is lead and part of it is still radium, then we can determine the age of the rock. We can determine the ? in that rock. That rock. There was quite a scurry to examine masses of granite and after they did so, the fact isn't surprising that different observers, taking speicmens from the same mass, different observers taking specimens from the same mass, checked each other closely, and they were able to extablish the oldest rock mass, that is, intrusive, the oldest granite in the world. We can't lay claim to the oldest one.

The granite which is in the southern Black Hills, that is ???. The oldest determined is some of the Scandinavian masses. These computations give us figures with a ? of one billion 500 million to 1 billion 800 million years; that is a range of approximately 300 million yeafs. That is the most exact way of dating the age of the earth. It gives us also the largest figure.

Now in considering the changes which have taken place in the earth and the changes taken place in regard to the forms of life on earth. We have at our disposal approximately two billion years. That is, we are going to raise the figure just a little bit because this intrusive rock forced its way into something which existed previously. Therefore in round numbers, the age of the earth is two billion years. Well, with such a great amount of time we are going to have to do something with it. Therefore, let's subdivide it as much as possible. Someone has said that the rocks of the earth are the pages in its geologic history. If that is true, then we have the various volumes, chapters, pages and paragraphs which make up the history.

In geologic time units we have:

Time units

Era

Period

Epoch

Stage

We have these as subdivisions of geologic time in ? order. Ther era is the largest subdivision. The events have been ? by the rocks. The eras are all Greek terms which describe the character of the life which existed during that portion of geologic time. Cenozoic, Messozoic, Paleozoic, Proterozoic, Archaeozoic, well, they are the pages. They need some translation. Archaeozoic, a-r-c-h-a-e-o-z-o-i-c, Proterozoic, Paleozoic, Messozoic, Cenozoic, each of them ends in z-o-i-c, zoic;; that means life, primitive life. Old perhaps or ancient would be just as good. Messozoic, middle, Cenozoic, recent. I have purposely put this oldest at the bottom and the youngest at the top. Well, here are the subdivisions of geologic time. Now what are we going to do with these wo billion years? We are going to try to distribute it through here. Archaeozoic, 500 million years, another 500 million years, Proterozoic, 330 million years Paleozoic, 110 million years for the Messozoic, and 60 million years for the Cenozoic. That's total of 1,500 million years.

I am not using the 2 billion. I am being conservative. These two occupy, each of them occupies about ¼ of geologic time, and all the rest, the other third. That bears out.

Now so far as years are concerned, you can add a cipher or subtract one if you want to. No one can say you are not just as right as he is. These are all ?. We have to deal also with periods so let us see what some of those names are. Now in order to avoid some well justified criticism, I am going to write this backwards. I should begin at the bottom and write from here on up, but blackboard space is limited, your notebook space is not. I ? that they are arranged in the right order in your notebook.

The subdivisions of the Cenozoic are Recent, then Quaternary, q-u-a-t-e-r-n-a-r-y, Tertiary, t-e-r-t-i-a-r-y. The Messozoic has three divisions, Cretaceous, c-r-e-t-a-c-e-o-Jurassic, J-u-r-a-s-s-i-c, Triassic, t-r-i-a-s-s-i-c. The Paleozoic, first Permian, P-e-r-m-i-a-n, Pennsylvanian, Mississippian, Devonian, Silurian, Ordovician, Cambrian. Any of these which need translation?

Proterozoic. In the Proterozoic and Archaeozoic the subdivisions are not of the same rank as these due to ???; they are subdivisions which apply to the Lake Superior ares. As we consider other areas, I will give you those as well. Keweetin and Huronian for the Proterozoic, for the Archaeozoic, Keweenawan. Unfortunately the periods, the period names doe not have a uniformity in the basis on which the name was chosen. In part they are geographic terms to discern character of rock; they are not subdivisions to time. In other words, there is no system to is. I will tell you what these mean as we go along. Geologic time used to be divided into four parts. This, incidentally, is not necessary for your understanding, but I am telling you why they have such names as they do.

Geologic time was divided into ??? four-fold subdivisions. This was the primary, this the secondary, this the tertiary, this the quaternary. Now you can see how the ideas have changed, but some of the subdivisions that have retained these two names, those are based on time. Cretaceous, cretaceous means chalk, so this is descriptive of the characteristics of this system, chalky. Jurassic, the Jura Mountains in ?. Triasic because it has three different kinds of formations in it. Permian, the province of ? in Russia, Pennsylvanian, anmed from the state. Mississippian Devonian maned for the valley, not the state. Devonian, named for Devonshite, England, where the rocks were first recognized. Keweenawan, named for the upper portion of Michigan which sticks out into Lake Superior. Huronian because of the rock first studied on the shoreline of Lake Huron. Keweetin isa general term included in the area sw of Hudson Bay. You can see there was no system at all. Now your job is to keep these names in the

right order.

There are three things which you must know. There is no way to get around it. It is just necessary. One is geologic time, the other one is geography and later on it will be character of the rocks. Insofar as you have a historical foundation in any one of these things, so historical geology is going to be just that ? to you. If you are ? on your geography, you had better get out some kind of a geography book and begin looking at it. Any questions on this material? (Interruption. Question: What do you do about the Laurentian? I have included it in the series on the ? rocks. I have left out intrusive rocks. Those will be added at a later date.)

That is one thing we are going to start next time, the geologic pattern of the U. S. In preparation for that, I am lost so far as telling you where to go and get it. There is only one place where ~~it~~ it is all gathered together and that is a book about 500 pages in which you can find it if you scratch hard enough. Bowman is the author, Forest Physiography is the name of the book. Rather a peculiar title for the name of a geology book, but that is what it is. About 99pages in it are devoted to ? and the rest is about the geology of the U. S.

I will tell you the places you can get it if you want to begin scratching. Let me know and I will help you find it in our library.

Now as to maps. Lobeck Physiographic Diagram of the U. S. with text is the best one unless you know all about the ?. This describes the surface formations of the U. S. It should be available at all campus book stores for 35¢ I think. At the University of Cincinnati they have put out a general outline covering somewhat these features of the ? of the U. S. Last year I ordered them for the group and I think it would be well worth again the price of the book, 25¢ or 30¢. That is about the most condensed source of material I know. If you want one I will order them and try to have them here as soon as possible.

(Dutton's top for Lobeck.)

I told you I would have some maps heres so you could see some of the things you can get. They are not very expensive, so I think most of you will be willing to have one.

Tonight we are going to start the subject of the geologic pattern of the U. S. Thi is, of course, a repetition of what you will have when you get the Lobeck diagram. The map represents, as I said, the physiographic features as they occur in the U. S. You will notice that they have the coastal plains along the Atlantic and the Gulf of Mexico. We have in here a mountainous region, the Appalachian Mountain region. Then the next mountainous region occurs way over here. This broad expanse in between is known as the Interior Lowland. Then we come to this region which is a region of ? and then the mountains as they occur on the Pacific coast.

On your Lobeck diagram I should like you to become familiar with these formations. Know these rather than the states because the physiographic forms of the states of course, are relative to the rocks. Inasmuch as the surface units are greater than the ? units, it is better to know the ? boundaried, but it is well to know the geographic boundaries as well. With that in mind, we want to call your attention to this one.

This is just a little differently represented. In the main you can see well the similarity of the two maps. The legend to the right gives you the explanation as to what the surface forms are. Notice the area occupied by plains, the areas occupied by mountains, the areas occupied by plateau.

The mountainous region they have indicated here asetwo types of mountains, not a particularly good representation because too much has been included. The complex mountains # ? and the complex mountains # ? and ? and ?, and area folded in the Appalachian Mountains and the block mountains which are of course folded mountains ???. Now you see the general pattern of structure.

Strucrues is arragnement of rocks. We think similarity exists between ? and geologic structure. Tonight we want to take the coastal plains and the Appalachian Mountain system. That is the same (map) as the one up above. I can reach this on,

hoverer, and I can't the other. The area which we are going to go over this evening begins in Texas, comes over through Arkansas, Louisiana, ???, and back to the south, and then from here we shall subdivide the Appalachian Mountains where my left hand is and this along the Atlantic Coast. It is going to be, thenm a a relatively large portion of the U. S. which we are going to consider this evening.

First is the coastal plains. We should recognize that the coastal plains are ? and unconsolidated materials of relatively recent geological age. They primarily belong to the Messozoic and Cretaceous eras. Now I want you to become familiar with the colors on the map so the colors will mean geologic ages to you. Messozoic is in green, Cretaceous for the most part will be in yellow. Well, perhaps I should tell you the truth rather than the half-truth while I am about it.
The Cenozoic is divided into Quaternary and Tertiary, the Quaternary is in gray stippling and the Tertiary is in yellow and the Messozoic is in green. The Tertiary is in yellow and so all the yellow you see on the map here is Tertiary and the gray stippling of which I spoke also, largely along the coastal areas. These materials are largely sands and clays. They were deposited similar to the deposition which is going on today upon the continental shelf.

In other words, when these rocks were being deposited, the North American continent was changed to such an extent that the shore line was at the inner edge of the (gray or green?) or yellow there the (gray or green?) is absent. Where I have just traced my finger. Since the deposition of that material the shoreline has moved out to its present position because of an uplift because of the rising of the central portion of the continent. As a result of the lack of any more severe deformation, the rocks are inclined seaward, gently inclined toward the sea. If we were to try to represent a cross section through such an area the surface would be a plain sloping toward the sea.

the rock inclined seaward at a fairly steep angle.

Both of these angles here are greatly exaggerated. This would be a cross section. If we were to put a number here to represent age of rock, say this was 1, 2, 3, 4, then as one might travel toward the coast, they would pass successively over younger and younger formations. In other words, this would be on the inner boundary and until you get (Dutton's chalk slipping.) There is a storm at sea, until you get

to sea level. Mor or less of a shingle structure, more or less of a shingle structure. If we could look down on such an arrangement, we would find that these areas occur as belts, this being the ocean out here. The oldest formation would be the inner belt, and then the younger belts would occur as you get close to the ocean. If you observe the colors here you can see a banded and concentric arrangment.

This is the general outline to keep in mind with regard to the coastal plain. I am going to try to explain the geologic age, the nature of the materials and the geologic structure, in other words, the arrangement of the rocks. I am doing it primarily so you will understand something of the ? I am going to explain. If, for example, I tried to explain the general appearance of a cat I would have to spend some time regarding its physical form before I could give you the details. The same is true of the U. S. We have to know something about it before we can begin our explanation.

The coastal plain perhaps represents the simplest geology there is in the U. S. One of the reasons for its being the simplest, it was formed ~~after~~ as one of the most recent of records. If, for example, we say the layers designated as 2 here, 2 is softer than 3. Then in the process of erosion valleys would develop in 2 and hills? in 3. This would be a relatively steep slope and this a relatively gentle slope. These regions are spoken of as cuestas, cuestas, they are the only conspicuous land formd develope on the coastal plains.

If a series of streams are going accross into the ocean, then the tributaries would look as the streams are diagrammed here. That is one of the characteristics of streams. These two characteristics are to be found in ???. Well, the coastal plains being simple, we shouldn't spend any more time on it.

Coming in from the Atlantic coastal plain the first subdivision or rather the next subdivision I should say, it the Appalachian Mountain system. If you will remember the diagram which I showed you, the Appalachian Mountain system is made up of a variety of formations. The Piedmont Plateau. The first one is called the Piedmont Plateau. To continue the diagram, this represents the Atlantic area and rising above the inner edge of the coastal plain there is a seaward sloping surface

the product of erosion, that is, being cut down, all ancient rocks of complex structure. These, for the most part, consist of schists, and gneisses which are metamorphic rocks that is, the result of heat and pressure as well as large intrusive masses of granite. Collectively these may be called crystalline rocks. Most of them are of Pre-Cambrain age, that is, Archaeozoic and Proterozoic. Some of the granites are of carboniferous age.

Then the Piedmont. Unfortunately what I was talking about was the Piedmont upland. These all apply to the Piedmont upland, the crystalline rocks of ancient age and the complex structure.

Another sub/division is called the Piedmont lowland. That represents a basin, that is, lower than the areas around it, a fault basin, the rocks of which are Triassic in age and consist of ss and sh and both intrusives and extrusvie rocks. Now let us stop for just a minute to get the geography. Piedmont upland begins in Alabama, through Georgia, South Carolina, North Carolina, Virginia, through Maryland, and int Pennsylvania. At the Pennsylvania-Maryland boundary we have this area which represents Triassic ? . The most part of it is in Pennsylvanian and New Jersey, there are other basins on the upland of the same character, but they are not large enough to make individual units.

The ss and sh are less resistant than the ? rocks, thereby making a basin or lowland. (Interruption: Question: What or where is it which is called the lobe? Answer: In pennsylvania and ?. Most of it stops in northern Maryland. The main portion of it is in Pennsylvania and New Jersey.)

The next subdivision to the west is the Blue Ridge country. Continuing our profile we come to the highest portion of the Appalachian Mountain system. The highest point in the eastern part of the U. S. is found in the southern portion of the Blue Ridge. This area is a ridge only in its northern half. In the southern half it it quite broad. The general form on the map would be more or less spindle-shaped and the true ridge characteristics are in the northern half. This being a region of complex land forms. Some of the most inaccessible portionf of the U. S. are in the southern portion of the Blue Ridge.

The rocks are chiefly igneous rocks, but also some sediments are present. These sediments are of lower Paleozoic age. Pre-Cambrian rocks have the most unusual complexity as described in the Piedmont. The lower Paleozoic rocks folded and faulted; they form a range of complex mountains and range of complex mountains. These two subdivisions are sometimes referred to as the Older Appalachians. They are a part of the mountain system, but they are of a greater geologic age than the other areas, but they are also included in the system.

Valley and Ridge. The next subdivision is the Valley and Ridge province. This is going to be the last subdivision here. The Valley and Ridge province is this area. It is a range which is lower than the subdivisions both to the east of it and in the west. This range is as much occupied by valleys as it is by ridges or vice versa. Most of the Appalachian Mountains are here present. This diagram is becoming lengthy. If we are to take a portion of the Appalachian Mountains we would find this to be more or less the conditions present there in the Valley and Ridge Province. We have the entire Paleozoic represented. ???. Nothing like making geology the way you want it. I am trying to get some carboniferous in there. I guess I am not going to make it. (Interruption: You are substituting then here carboniferous for Pennsylvanian? Answer: Yes, for the last three.)

I will tell you about this after I get it drawn. The telling will probably mean a lot more than the drawing. Well, now let's start. Along the eastern side of the Valley and Ridge province we have blocks which were thrust far to the nw so that they, now this is all backwards. The Appalachian structure is becoming more complex than I have known it before. (Interruption. Something happened there with your Ordovician. Answer: It did. Well, I will draw you one before the eveing is over.

(Slide shown) Here is what I have been trying to put on the blackboard. To the east we have thrust faults and as you go west we have ? and as we go farther west we have ? and still farther to the west the folds become undulating. Keep that in mind for the structure of the Valley and Ridge province. The eastern side has the thrust faults and as you go farther west the ? become less and less. The rock there is, for the most part, ls, ss, and sh.

(Interruption. Question: In the eastern portion? Answer: All of it.)

The mountains are in general of two kinds, mountain ridges which respresnt the truncated, the resistant edge of the ss, and mountains which represent the remainder of a geologic structure which was lifted higher on two sides of the mountain. That is, these were the anticlines at the time the faults were formed, those here, the upward anticlines and because they were upward anticlines, they broke across the crest and when erosion began to cutt off this ???. In most cases a thick ls. That was when conditions ??? are represented by that level.

Then, when erosion began the next time, it began cutting valleys in this region and now the cutting has proceeded and left a mountain in the form of a synclinal mountain. This is one instance when ? and geologic structure are just the reverse. The Valley and Ridge province is characterized by structures that are ne sw direction and so most of the ridges have the same trend, ne sw. We

West of the Valley and Ridge province the Appalachian plateaus -- that would be out in this region, a truly plateau area that is not af great topographic ???, rugged, I mean. The rocks are carboniferous in age and in horizontal position, that is, essentially horizontal. The region still farther to the north and east is the New England. This region is characterized again by complex structure, byt rocks which range in age from Pre-Cambrain through the entire Paleozoic. Most of them are crystalline although a few sediments are present, that is, unmetamorphosed, sediments.

There are two general mountain axes here, the White Mountains through New Hampshire and the Green Mountains through Vermont. The area is essentially an upland above which are rising a few areas that represent the unreduced remnants of the cycle of erosion which produced the upland surface. Such is about the general outline of the later forms and now I am going to give you a recess while I draw this section. It is important and you have to have it. This will probably be so small you won't be able to see it. Now, I think that is about what it should be. This over here is the Pre-Cambrian rock, this block moved to the nw; this block moved to the ?/ The other/did not ? them. Then as they come west, they pass into symetrical folds

and finally come out into the flat lying sturcture of the ?. That then, is the general form of the mountain structure of the eastern part of the U. S. I am going to get a map and I want you to look at those on the all, and we will continue after recess. I want you all to take a good look at these maps because I want you to become familiar with the patterns and you can't do it back there.

(Recess)

Do you have the general idea you want about these units? This geosyncline about which some members of the class have asked is a trough of all sediments from which the Appalachian Mountains have formed. That is the frough of sediments. Any other questions? All that I am trying to do this first time is to get you acquainted with the U. S. Some of the tings are going to have to be explained and this introduction may seem as though we are hitting just the high spots. That is all we intend to do, but we are going back to them.

I spoke of the older Appalachian and in here the Valley and Ridge province and these are the newer Appalachians, Then, in other words, they came into being at another time and the New England came at still a third time so in the ? they will follow. We are showing the different things of which the Appalachian system was made. Any other questions? I

I want to consider two other areas this evening. In some respects quite alike and yet in many respects quite different. They are alike in being outposts. You might say of the region which occurs in southern ?; they contain much the same kind of rocks and much the same geologic structure. Here in New York the Adirondacks are. The Adirondacks I have not included in the Appalachian Mountain system although sometimes they are included there.

The Adirondacks consist of a circular mountainous area in ne New York and are composed of complex Pre-Cambrian rocks, again characteristically crystalline. In this region, for instance we have marbles quite in abundance of marbles, not very many commercial marbles, not the kind of marbles which occur ?, but there are marbles present. The area is so complex and so little work has been done on it, so there is relatively little to say about it. There are no land forms except ?. The area is almost completely ? with sediments of Paleozoic age. It stands as a neck of ?

formed by blocks around which is a collar of other rocks. (Interruption: Question: Is it sort of an eroded dome? Answer: It probably never was covered with sediments. It was probably an island when the sediments were being deposited all the way around.)

The other area is known as the Superior Upland. It includes northern Michigan, northern Wisconsin, and northern Minnesota. The Superior Upland. Now these two units which lie in the U. S. are ? and still a larger subdivision of the N. A. continent known as the Laurentian Shield.

This map is so badly worn that I don't know whether or not you can see it here, it being the pink area which occurs throughout most of Canada. This is the shield of which I am speaking. It extends across into the U. S. in the vicinity of Lake Superior. On both sides of it we have rocks of such a nature as to put them in the Laurentian shield. The Superior Upland is somewhat of another bad region to explain in geological terms.

In the main, it represents a huge syncline or better, a synclinorium, that is, a folded syncline. That is a syncline or synclinorium. It is a structure in which we have both anticlines and synclines, but the general strucute results in a downward trough-like form. The ? is a trough-like syncline. It is not a true synclinorium. In general terms we will have to know the area as a syncline or cynclinorium whose axis passes approximately along and through the center of Lake Superior. In other words, the two sides are spoken of as limbs. These two limbs lie along the opposite sides of Lake Superior. Now, the lake basin is only a small portion of this geologic structure. So far as structure is concerned, the rock on the north side of Lake Superior dips beneath the lake and the rocks on the south side dip beneath the lake so we have geologic evidence of a trough in the rocks.

It is not as diagrammatic as I have indicated on the blackboard, but it does have that general form. The axis goes through Duluth, through Lake Superior and into Canada. It is not known just how far, perhaps 200 miles into Canada and it becomes obscure. That would be, let's modify this, make it a little more nearer fact. All I am going to indicate here is a general trend. I am not going to complete the diagram. The rocks on the north side dip so as to pass beneath the

lake basin and the rocks on the south side are dipping so as to pass beneath the lake basin. We are putting some ? on these rocks. On the south side there is a fault in here and again we have a repetition of the same type of structure. These rocks lying in the vicinity of Lake Superior are Proterozoic in age and the rocks in these two areas are Archaeozoic in age. This one example in Minnesota would be the Vermillion range and this over in Michigan would be the Marquette range. Those would be the ? ranges. I have tired to put this structure along with those in these two areas, tried to give you a concept of the whole thing..

On thing I think is worthwhile. It would imply that these rocks which occur here passed underneath here and here joined with these on that side so our postulated geologic structure of these basement rocks all completed is more of a synclinorium in form. Within the old structure which is of Archaeozoic age there has formed more ? materials and a more recentstructure, a geologic basin in which Lake Superior itself lies.. But then the geologic basin was a result of the ice moving along a ? valley. The glacier here happened to gauge out that basin and ??? so there in northern Minnesota we have a geologic recordwhich is interesting, but it is as I said before, complex, and such a general impression will serve as much as anything to try to get something driven in which will stick. If I tried to describe it in detail it would be worse than water on a ducks back. Any questions about this? I know there must be millions of questions which you feel are not explained. This is an introduction, and later on I am going back and try to explain further. That is about the extent of the material which I intended to cover this evening.

(Slide shown) This is the geologic map of Pennsylvania as it says and represents the surface distribution of rocks in that area. Those of you who are being introduced to geology perhaps think it is undoubtedly the worst thing with which you can come in contact (explanation of shale)

(Slide - diagram of basin in cross section of Triassic through Manassaus, Prince Wm. County.)

(Slide - Lobeck map)

The region which I have attempted to describe tonight, the coastal plain area, along here a region of unconsolidated ss and clay of relatively recent age and the Appalachian Mountain system which includes the area through here. The region of the Blue Ridge you see the spindle shape of the Blue Ridge. Then the Valley and Ridge province and then to the northward we see ? In the plateaus to the west in here, the Adirondacks. This, the Superion Uplands as it occurs in Minnesota, northern Wisconsin, and northern Michigan. This vicinity has a great number of intrusions. (Slide - Index map showing the physiographic provinces of the U. S.)

You have seen the land forms. Now remember the age of the yellow wich is Tertiary, next, the ?, and the quaternary; around the outer region, the entire portion of Pre-Cambrian. The Valley and Ridge province is Paleozoic, late Paleozoic being in the ?. The Adirondacks are principally Paleozoic although there is some Pre-Cambrian. ???. I have tired to give you the surface structures and geologic ages. Any questions? Now I am sorry this material is not collected in one place so I can say where to go and get it. There is no place. The best one is ???.

(Lobeck slide)

Before proceeding this evening to new material, let's briefly go over waht we considered last time. I tried to give you some general impressions as to the nature of the subject, nature of the rocks and arrangement of the rocks in this area known as the Gulf Coastal Plain and this area known as the Atlantic Coastal Plain. Then the next unit we discussed was the Appalachian Mountain system beginning with the Piedmont Plateau westward and then the Blue Ridge area and still farther westward the Valley and Ridge Province, which begins in Alabama and extends ~~up~~ to the St. Lawrence.

We learned that the first two provinces ~~here~~ are areas of complex structure. In the Valley and Ridge Province it is less complex ? . Then to the west the Appalachian Plateau, an area of ~~Appalachian basin~~ late Paleo rocks and the ??? horiz. structure. The Adirondacks next, more or less of a complex area of ancient crystalline rocks of Pre-Cambrain age. Then we jumped over here to the Lake Superior area and found again ancient rocks of complex structure.

This evening I want to cover the area which lies between the Appalachian Mountain systen and the Rocky Mountain system. This entire unit is known as the Interior Plains Area. The portion labelled Interior Lowland we are calling Central Plains ???. Then we are also considering this region known as the Interior Highlands, and then the Rocky Mountain system, and for the next time, we will take the rest of the United States. You now should have the general area then which we are going to consider.

This area lies north of the Gulf Coastal Plain and west of the Appalchian system and south of the Superior region. Let us again renew our acquaintance with the structures represented. The areas of complex mountains mean they are folded and faulted; they are broken up by structures known as faults; and they have been invaded by great masses of molten material. As we see it here on the map, I will outline or give you the territory which is included in this area ??? Texas, eastern New Mexico, Oklahoma, eastern Colorado, Kansas, western Nebraska, North Dakota, South Dakota, montana. You see the extent of this area which I am going to call the Central Plains.

Then we will consider the area of the Central Lowlands which includes this general area here, ??? Southern + western Minnesota, all of Illinois, all of Indiana, most of Michigan; it even goes across ??? Ohio, NW. Penn, and in N.Y. along Lake Ontario;-that is the area of the Central Lowlands.

Now then we have the Interior Highlands which include portions of Arkansas, Oklahoma and Missouri. The area, as it says, is a plateau; it is in some respects ? almost mts praticularly in regard to the conspicuous relief. The Central Plains is the district I first mentioned; ~~This~~ Westward is a district of Great Plains. ???. As for these areas in the west, 12 and 13, although they are represented here as complex mountains, this is someone elses interpretation, but if I were going to make this map I would have considered them as ~~?. ???.~~ anticlinal mts.

First I want to introduce to you the extent of the last glaciation in the North American continent. Now the glaciation which was represented or is represented by the surface materials of the area you see, does not represent the only glaciation or the only glacial period on the North American continent. There are older ones, but this is the area affected the most recent one you see here. ~~This is the most recent one.~~ You will notice it covers a large area of the portion we are going to consider in the Central Lowlands. You will note one area was not covered, the driftless area; that is called the Driftless Area. The Ohio River ? makes one boundary and the Missouri River makes another boundary. That being the case, we can go ahead with some of the details.

Since it has been dark and you haven't been able to do much writing, let's get these areas straight. First the Interior Plains, called the Interior Plains; its distribution then is this area here, the area north of the Gulf Coastal Plains and w west of this area, the Interior or Central Plains. The Central Lowland, the largest area, the Central Lowland. Then the Great Plains, the other subdivision, the Great Plains.

Let us now turn our attention to the Central Lowland. Its present surface forms are the result of glacial deposition, therefore, little bed rock is exposed

and exerts practically no influence on the land forms. They are largely, then, those of accumulation, glacial accumulation, and so far as age of rocks is concerned, we might spend just a moment here again. The more firmly built the foundation, the better the superstructure will be. Cenozoic, Messozoic, Paleozoic, Proterozoic, Archaeozoic, this you will recall is the geologic time scale. ~~The~~

The Central Lowland is characterized by a Piedmont, the Piedmont being almost all Mexsozoic and Cenozoic. These rocks which now occur over the Central Lowland are for the most part marine sediments, being deposited in, of course, water. They are made up of ss, ls and sh, what we speak of then, as normal marine sediments, the same kind of sediments that are accumulating along the shorelines today. The Cenozoic is the portion which is represented by the glacial deposits. On this map if we were to ? the surface materials, the area approximately along the Ohio River, yes north of the Ohio and Missouri Rivers, would have to be ???.

We would have the rock structure as represented here, but for the most part we have Paleozoic and that is what we are concerned with. In most cases to the ? plain areas represent a lack of deformation. That is true. Mountain making forces have, for the most part, been absent from this area. You remember in speaking of the Appalachian Mountain system, the great amount of deformation is on the east side and as we pass farther to the west, it becomes ??? less intense.

We find throughout the Central Lowlands they are approximately horizontal. They are modified by great broad ? (open) structures, afew of them we should name. One is an arch which straddles the Ohio ? (-ind) line. It is known as the Cincinnati Arch. It is an arch (in) which the rocks have been bowed up into an arch. Another structure we should mention is the Illinois Basin. All right, the state of Illinois represents a spoon-shaped basin, that is, the spoon without the handle. ~~??? the rocks in the center of Illinois are all, well,~~ (Thus) the rocks are inclined toward the center of the state. Michigan also has a basin; it, however, is uniformly circular.

The western portion of the Central Lowlands has a structure inwhich the

the rocks are gently inclined west or southwest, ~~west or southwest~~. That then should give us somewhat of a general view of what a cross section through this area would be. I said before, it is an area devoid of intense deformation and yet the rocks have been exposed because it was high and subject to erosion. The formations of the Cincinnati Arch went down into the basin, then rise in an arch only to dip again westward ~~and here are going into the west~~?. (Interruption. Question: They slope down? Answer: Yes, they slope downward.)

This would be a general cross-section diagram ??? across the Central lowland ~~Plateau~~?, but for the most part, we are ?, but the rocks formerly went into the arch into the Illinois Basin and then into a smaller arch and they they dip to the west. This area would be eastern Ohio. The next basin would be Illinois ? and the next arch would straddle the Mississippi River. ???. The rocks, of course, in general follow the same general profile, just indicate then one layer and we would know the general form of the others. We know now the age of the rocks and we know the character.

Now let's say more about the surface formations. Dynamic geology, for the most part, is that portion of geology which considers the surface forms; historical geology cannot be concerned with that, but inasmuch as this course is more or less of a hybrid, let us mix in some physiography ???. The surface forms characterizing the Central Lowlands are, for the most part, a result of glacial deposition. The whole region can be subdivided on the basis of this agent, the presence of absence of this particular geological agent. This area in here was never covered by glaciers; it is one which begins in Texas, goes through Oklahoma and Kansas, up through Missouri. This area is known as the Osage Plains. It was beyond the boundary of glaciation. In this region the topographic forms, that is, the land forms are a direct reflection of the structure.

This is exaggerated in order to bring out the idea in general. The region consists of two erosion levels, one is the top of the ridges, the other is the bottom of the valleys. The unusual thing about these erosion surface ~~valleys~~, it is ~~they are~~ inclined to the east, but is ~~they are~~ formed on rocks which are inclined westward, giving rise to forms which we mentioned last time, cuestas. A ridge, one slope steep and the other gentle. If you go across the Osage Plains, if you go through

Oklahoma or Kansas. If I remember I will get a map of Kansas. You will cross a series of ridges, over one ridge to a valley, and over another ???.

The other region is ~~affected~~ located among features of by glaciation ???, most of ~~which~~ it lies in Wisconsin, but extends into se Minnesota, ne Iowa and nw Illinois, and area then, for the most part located in sw Wisconsin, ~~yes sw Wisconsin~~, but in the other states I mentioned as well; never completely covered by glaciars and never completely surrounded. The glaciers would go to one side, to the east and the west, but they would never go completely around it.

If you think of se Minnesota, sw Wisconsin, you know how diagramatically that section has been dissected by streams. There are large bluffs along the streams. They have never been ~~?~~ modified by ice, however, thus having developed for the most part what might be called a mature area, a region practically all in slope, a region very very poor agriculturally. It would be an area in which erosion remnants abound. If you are acquainted with Camp Douglas in Wisconsin, you know the masses of rock on the plains. It would be impossible for them to stand, had the glacier come across them. They would be knocked down like so many bowling pins. This is spoken of as the driftless area, no drift. This region perhaps contains some of the most spectacular ~~?~~ scenery in the Central Lowlands. It is about the only region ~~which~~ in which you get much relief. In the Great Plains you do, but we are talking about the Central Lowlands. These Osage Plains + Driftless Area are, therefore, characterized by the absence of glaciation.

The next subdivision would include the southern ⅔ of Ohio, Indiana, Illinois, northern portion of Missouri and Iowa extending on out, well, the boundary here becomes rather indefinite. This region if you think of it, think of the region. As you know, it is just about as monotonous as any place could be unless it is the next subdivision, the Great Plains. It is a flat region, a good region agriculturally. It is a region which which there was a great amount of glacial deposition and it is older than the region which we are considering next.

We also use the term till for glacial deposits, particularly of the clay type where they have been dropped by the ice and not sorted by water action. The designated area That is known as the till plains, plains which have been constructed as a result of glacial deposition. Ohio, Indiana, and Illinois contain younger till deposits than those in the west because of the greater age of those deposits in the west. They have been subjected to stream erosion for a longer period of time; therefore, those have been cut up so ? Iowa and Missouri would be a region of dissected till plains but by stream erosion whereas the eastern states, Indiana, Ohio and Illinois would be less dissected.

That portion of New York along Lake Ontario, Lake Erie, through Pennsylvania, northern Ohio, all of the state of Michigan, northern Indiana, all of Illinois, over into this Driftless Area, is a region in which there are about as many lakes as there are in Minnesota. Because of its physiographic form, that it is known as the Eastern Lake Section, the region of young glacial deposition, a region in which the drainage systems have not had time yet to develop to such an extent that they drain the lakes, an area, therefore, of young glacial deposits.

Wisconsin, northern Wisconsin being in part of the Superior Upland, and Minnesota are the two typical states in the Western Lake Section, an area of great glacial deposits, and the stream action has not been able to drain the lakes as yet.

We have then, in the Central Lowland, six subdivisions, two of which were never covered by the ice, two that were not covered by the older sheets of glacial deposition, and the eastern and western sections, areas that were covered by younger glacial deposits. This ice age did not result in one sheet of ice, but several They moved down over the continent and then melted back. Sometimes we wish it would be just as simple as that. Really there was a succession of ice invasions, Wisconsin, Illinoisan, Kansan, Nebraskan. We usually subdivide these into four stages and the last one, the Wisconsin stage, into five substages. I have represented the

oldest on the bottom. These you will recognize as geographic names taken from areas in which glacial deposition was typically exposed. You will recognize the oldest depositions as being the farthest south, so far as area is concerned, and then the next oldest less farther southward. These sets of glacial deposition are the ones which give us the till plains and the lake sections.

(slide)

First pay attention to where the state boundaries are, boundaries between Ohio and Indiana, southern boundary of Missouri, boundary between Illinois and Indiana, southern boundary of Wisconsin, etc. (Interruption. Question: ??? to the west of the Driftless Area? Answer : ???.)

I should like to call your attention to the fact that the drift areas were ? than the areas which contained drift deposits. This is a region of glacial till plains. You can see why it has that character. ???. Therefore, having had streams upon that surface for the longest period of time ???.

Next in age, but uncovered for a shorter period of time, this area to the west, therefore less cut out. The last atages of the Wisconsin, the very last stages of the Wisconsin, therefore, gave rise to the lake areas. You will also recognize that the greatest share of lakes ? north of the third ice sheet.

The Great Lakes are very definitely related to the ice lobes or perhaps I should put it the other way, the ice lobes are very definitely related to the Great Lakes. Here is Lake Michigan ???. Here is the outline of Lake Superior, and notice how it has come down here as a lobe into that ?. As some of you know, the Great Lakes were a direct result of glaciation. (Interruption. Question: Which has more to do with the boundary of Illinois, the structure of the rock underlying or the drift? Answer: For the most part it is a drift boundary.) Are there any questions about the Central Lowlands? (Interruption: Question: Do these glacial deposits show on this Lobeck map? Answer: No, they do not show on the Lobeck map. I don't know where I could tell you to get those. If you are interested in them I could give you the sources from which the slides were taken.)

(Interruption Question: Are these bluffs along the Mississippi down between the two states? Were they formed as a result of the erosion of the Mississippi or is that or does that structure run through back from the river? Answer: ???.) (Interruption: Question: Will you repeat what you said about the till plains? Answer: ???) Other questions? Well, we will go on with the Great Plains then.

Perhaps while we have light so we can write, let us again get them placed geographically. I know the ? but quite so bad. In Minnesota there is a series of rocks called theSt. Croix or Croixan series, so I take little for granted in the way of geology.

The Great Plains begin in Texas then occur through Oklahoma, Colorado, Kansas, Nebraska, Wyoming, North Dakotam South Dakota, Montana, and then keep right on going up to Canada. Of course we stop at the international boundary, a great strip at the western portion of the Interior Plains. Topographically you might call the area that portion where you can see farther and see less than in any other region. It is a rather ? ?. It consists of an eastern sloping ?, the western margin of which is almost one mile then above sea level, but the eastern edge for the most part is in the neighborhood of ?. You have then, a difference in elevation of about 300 feet. The eastern and western edges of the Great Plains are marked by escarpments, cliffs, bluffs, they all mean the same thing.

Going west from the Central Lowlands we would have to rise to get on the general surface of the Great Plains. However, in travelling over this area following roads and railroads, you do not come to a distinct bump in the rocks; as you go westward you would drop again before you got to the Rocky Mountains. Again the roads and railroads follow the ? so there is no pronounced drop. (Interruption. Question: There is a drop then in the rock? Answer: Yes, in the topography. Question: Does that continue the length? Answer: Yes, practically so.)

Only very very exceptionally do we find a rather sharp contact between the Rocky Mountains. For the most part there is always a lower area between. It may not be conspicuous, you see it such a small area, but taken over a large area, it is true. (Interruption.) The materials in the Great Plains are also inclined wastward. The surface materials, they are of early Cenozoic age, early Cenozoic, but the Tertiary, the late Cenozoic, but the Quaternary contains of course the glacial deposits of which we have been speaking previously, but this would be in the Great Plains, that s, the age of the materials. (Interruption. Question: What is the structure under there? Answer: I will come to that in just a minute.)

The surface materials incline to the east; it is Tertiary in age. Now for the age of the material. They are composed for the most part of sands and clays which were deposited by streams flowing eastward from the Rocky Mountains. Alluvial. Such stream deposition is given the name alluvium or is called alluvial deposits. Because this material lies to the east of the mountains we attach the term Piedmont to it. Piedmont, at the foot of the mountains, and because the final product is a plain, we add that to it, and so the entire feature is called Piedmont alluvial plain.

Think of it in terms of an apron if you want to, and apron of streams was carried out from the Rocky Mountains. ???, therefore they have to drop the load of material they were carrying and thus deposit this material out here. Since then, that material next to the mountain has been cut out. So much for the Great Plains. We find other kinds of material. We find a ? of the western sloping rocks.

Here in this portion they are dipping westward; here in this portion they are dipping southwest so that they pass beneath the Great Plains and then rise sharply as they approach the mountains. They don't vary much in thickness that but I am not going to start out as I did last week. This structure is spoken of as a syncline; this is assymetrical on the eastern side. It dips to the mountains, but near the mountains they are very very steep. Those of you who have seen the Garden of the Gods know how steep they can be. Erosion of

those vertical forms has given rise to the Garden of theGods. The rocks are principally Messozoic but the Paleozoic is also represented. The structure the age and then the character; for the most part they are marine sediments, normal marine sediments. (Interruption. Question: They are Messozoic and Paleozoic? Answer: Yes, they are.) I think that perhaps by this time you are beginning to realize that a large part of the United States has been under water for I have spoken of marine sediments so much, marine through here, marine through here and here. ???. So much for the general character of the Great Plains.

Now it is also subdivided, subdivided for the most part on the basis of amount of dissection, amount of cutting up that has taken place where this apron was formed. ??? that apron has been removed, giving rise to these subdivisions. This part was glaciated and so it is known as the Missouri section glaciated. It is merely a region in which the surface forms are the result of ice action. We won't say any more about it at this time.

The next is the Missouri section unglaciated, never covered by ice. The particular significance then about this Missouri section unglaciated is the development of the Badlands. The Missouri and its tributaries have in some places so effectively frayed this outer margin that it has become rather worthless, and because of that fraying of the outer margin, the region is spoken of as the Badlands. You are familiar with the Badlands of ?, the Badlands of ?, the Badlands of ?. The Badlands of the Great Plains then are merely a very thorough cutting up along the streams of what was formerly a uniform surface . (More explanation of Badlands.) And this portion which is left makes the pinnacles and needles of the Badlands. (Interruption.)

We have two possibilities of course in the Badlands. If you look down on these rocks which form the foundation, then the Badlands are the features of elevation. If, however, you approach the Badlands on the top, on the Great Plains, then

the features are those ? of depression and you can see that quite well ? at the present time in the Badlands because of the road being constructed there. (More explanation.) (Interruption. Question: The Badlands continue how far? Answer: ???.) (Interruption.)

Sometime when you get ahold of a railroad map I would like to call your attention to the branch lines. The eastern boundary of the great Plains more or less determines the ends of the branch lines which come out in this region. This eastern boundary has less than 20 inches of rainfall per year, consequently this is poor agricultural land and one can pretty well tell by the branch lines the extent of the rainfall in that region. They go so far and stop.

The Black Hills should go in here, but I am going to save that until last. I hope we have some time so I can show you some pictures of the Black Hills. Next to the south through Nebraska particularly we have a portion of the largest undissected portion of the Great Plains. Down through Nebraska there is only one stream cutting through it and that stream has not been able to cut through that territory. This region is known as the high plains area; the high plains are typical of what the Great Plains used to be. It is praticularly well represented in Nebraska. (Interruption.) In Colorado we have a portion which has been mentioned before, the Colorado Piedmont, the Colorad Piedmont.

Just as the streams coming from the Black Hills area had sufficient velocity to strip off the apron here in front, the streams coming from ? had sufficient velocity to strip this apron off in front. It is not so conspicuous over the low area between the Great Plains and the Rocky Mountains proper. Oklahoma and Texas have another very large undissected remnant of ?. I don't know where they got the name for it. Llamo estacado and that's the name. Sometimes it is spoken of as steaked plains, not because they raise steaks on the plains, but if you put a steak out there ???. There is not much to say about it. It represents an undissected portion of this ? apron. T

The boundary here to the south then brings us in contact with another plateau region, brings us in contact with ???. It is a region in which all the ? material has been stripped off. The surface follows ???. It is a plain then which we speak of as a stratum plain, that is the Edwards Plateau. All the ? material has been stripped off and in the stripping process it stopped, for at the present time here is one layer over one wide area. It is therefore called a stripped plain, material stripped off the top. (Interruption. Question: Where was that? Answer: ???.)

Now before I get to the ? before I have to talk too fast, I want to show you the Black Hills, show you some of the pictures. The Black Hills represents an elongated dome approximately 125 miles long and about one-half as wide. As a result of the uplift which formed, the dome rock layers are inclined ? around the entire ? of the done, so we have in this region not cuestas, but hogbacks, formed in the same way, except that the rocks are more steeply inclined. These are conspicuous features seen on entering or leaving the Black Hills, These hogbacks surround the Hills.

Within these there rises the central region, the western half of it is a ls plateau, did I say the western half or northernhalf? Excuse me, I should have said the ~~northern~~ western half, the ~~northern~~ western half is a ls plateau, the southern portion of the eastern half is made up of granite intrusives, masses of granite that forced its way into the rocks. This granite has been very badly jointed, very intricately jointed, that is, broken and jointed. Along the planes of fracture, the rock has decayed more rapidly. As a result, the ??? in this way, then we have formation of pinnacles or needles, a system of joints.

Supposing we were looking down from on top of the Black Hills, we might see a joint pattern something like that. As a result of this jointing, the material eroded around the edges like thin, each edge like this and this erosion kept on and finally therefore we have then the spires or needles, and each represents a spire; this would be its neighbor, here another one and here another one.

The northern half of the eastern area is composed of rock which we call a schist. It is a rock which has resulted from intense deformation. It is characterized by a cremulated lamination. Lamination means layer and cremulated means wrinkled; it is rock characterized by wrinkled layers. This is the region of Lead and Deadwood, the mining area of the Black Hills .

With the exception then, of these granite areas and these schist areas, the surrounding rocks are all of normal marine sediments or marine sedimentary type with one exception. Within the first hogback as you come from the east. ??? there is a region spoken of as the Red Valley. The rocks are of ?, Triassic in age; they are red ss and sh, softer than the materials with which they are associated and therefore they make a valley and the Black Hills is known as the ?. It completely surround the Black Hills; it is the chief route of transportation in the Black Hills following around inside the valley. This is one of the hogbacksm dakota ss. This ss is drilled into for artesian water, it is a water bearing horizon. (Comment on fresh water of Chicago entering the ss 300 years ago) (Interruption. Question: ??? minerals of Black Hills. Answer: ???.) Other questions? The Black Hills represents one of the regions of the most concentrated geology in North America. You can get plenty of concentrated geology in Minnesota, but you can't understand it as well as you can that of the Black Hills. (Black Hills pictures.)

CD/HVA

I thought I would pass these maps around so we coulb become better acquainted with some of the divisions of which we have been speaking, so I have prepared the mimeographed outline maps which you have just received. I think you will be able to label that so that you will have in mind the proper names and the proper areas.

This evening I am going to consider the Interior Highlands. It is the region you will find in the southern portion of Missouri, the adjoining portion of Arkansas and Oklahoma. Now locate that on your diagram there on your map. Lines which are marked thus are boundaries between the regional subdivisions. Within the major subdivisions you will find just plain lines which divide the sections. For example, you can follow the extent of the boundary of the Great Plains which we had last time. Through the southern portion of this Interior Highlands there is a dotted line. It should be made a full line. It is a division of the physiographic provinces; it runs east-west across ???.

Let us first consider the area north of that line, the Interior Highlands. I would suggest a method somewhat similar to this in order to avoid having so many names on the map for it means nothing to us. Beginning with the major subdivisions ???. Then we would have the Ozark Plateaus. We label the Coastal plains. You can label these later on. Then, second the Appalachian plateaus and the Appalachian Mountain system; 3, the Superior Upland and 4, the Interior Plains and 5 would be the Interior Highland, so you can put a ? to the north of the line which I have just completed.

The geographical location of the area you can get from the map. It is principally southern Missouri, nw Oklahoma and nw Arkansas. The land form there, as the name implies, is a plateau, rather a series of plateaus. If I was to draw a north-south, no excuse me, if I was to begin in se Missouri and draw a profile through to the sw corner of Missouri and then turn south to the southern boundary of the Ozark Plains, the profile would be such as this upper line. Then in the very corner ??? is a region known as the St. Francis Mountains. It is a region in which the ancient crystalline rocks are exposed. It therefore represents a dome,

the central rocks or core of which has been exposed by erosion.

Then to the west there is a plateau, the result of stream erosion which ? the lower Paleozoic formations; that is, the surface is not related to the ?. It is a distinct erosion level cutting across a series of sediments exposing the ends. This is one of the plateaus. This is the Salem Plateau.

Then we come to the Mississippi? rocks which temselves form a distinct plateau; it is the Springfield Plateau. This is down here is lower and middle Paleozoic. The Springfield Plateau has resulted from the resistant character of the ls in it. Then the next one here is the Boston Mountains made up of the Pennsylvania formations, not particularly very thick ss layers. Now I don't know which part of this you are going to call the Ozark Mountains, but some place in the group lies the Ozark Mountains. That is, there is no such thing as the Ozark Mountains. The areas which are mountainous are ??? and of the dissected ? of each of these plateaus. Due to stream erosion the margin is cut by valleys; in such areas this takes on a mountainous appearance ???. Between the Springfield Plateau and the Boston Mountains, locally they can speak of any of these regions as mountains, ???.

In general then, remember principally a region of Paleozoic formations for the most part undeformed. That is, they have a plateau character due to uplift, but that portion which lies south of the boundary you draw just a little higher.

Across is the Ouachita Province, the Ouachita Province. It is an Indian name. I will have to ? these names. We will then continue (Interruption. Question: This now is south of that dash line which we changed? Answer: That's right.) And the line which I am now drawing on the blackboard is due south. This is sw and this over here is ene and now we are going to bend the line of section and go into the Ouachita Province. The surface forms first which we will draw is a wide valley and then we get into a region of folds ??? where we come in contact with the Coastal Plains of the west coast. This region is the Arkansas Valley, the mountainous area is the Ouachita Mountains. So much then for the surface forms, and now then the rock structures.

The formations beingin down from the Boston Mountains are here folded, rather complex, but in a general strucutre known as a synclinorium. That is, it is a structure made up of anticline and synclines, but the general structure is that of a syncline, a downward folding trough, a synclinorium. Then, coming to the Ouachita Mountains the same complex ? conditions but it becomes arched into a strucutre which, for the most part, is an upward fold, therefore called an anticlinorium, a series of folds but the general trend is upward like an anticline. Then we would have a synclinorium and this the anticlinorium. These words merely mean series of folds, but in general, as I said before, the series of folds with an upward trend iscalled an anticlinorium and a system of folds which has the general form of a trough is a synclinorium.

Now in order that we don't have too many details to keep in mind, these two areas are quite comparable to the folded region of the Appalachian Mountains. They do not have the same topographic expression but they ? the same as the Valley and Ridge Province of the Appalachian Mountains and just as we had in the Appalachian Mountains a plateau to the west, here we have a plateau to the north. ???. The system of folds go to the sw making up the Appalachian Mountain folds, go beneath the Gulf Coastal Plain, but they turn as they go beneath here and go out that way, so it is believed there is a direct connection ???. Some of the oil field development is dependent on ???, with the folds present here in the Ouachita region ???.

This particular area, that is, the Ouachita Mountains, is a region of rather rugged topography, rather heavily timbered; it has been one of the popular resort areas in the United States ??? Hot Springs, Arkansas. The Hot Springs themselves indicate, of course, some source of uncooled heat down beneath the surface. As yet it has not been recognized what that source is.

The setting aside of that region of Hot Springs was the beginning of the national park regions. Inasmuch as this is c combination of courses, I suppose I

should bring in some of the facts of interest of both courses. Yellowstone was actually the first National Park, but the Hot Springs area was set aside by governmental action to be preserved for the public and this, as I said, was the initiation of the idea; it did not bear fruit until 40 years later when Yellowstone was created as the first National Park. Any questions? (Interruption. Question: You said the Ouachita region is heavily wooded? Answer: Reasonably so, yes; it is a region which gangsters used for hideouts.) (Interruption. Question: Have the strata been changed from a flat to a curlycue; have they been hardened much? Answer: Not essentially so. There is one formation in the Ouachita Mountains, and if we were to look at these ? from above you would find that they plunged and here the surface has been cut through them to get zig-zag ???, and gives rise to regions on a map which would look about like that.) (Interruption. Question: Are diamonds associated with igneous rocks? Answer: ???.)

This particular rock is a noaulite?. I don't expect you to remember it; it is a fine grained ? rock and makes an excellent whetstone. (Interruption. Question: Is this region undeformed? Answer: Well, ??? .) (Interruption. Question: The Arkansas valley, does the St. Francis Mountains seem to be a compensation or what? Answer: ???) (Interruption.) Other questions? (Interruption. Question: These much-folded mountains were deformed the same time as that deformation of the Appalachian Mountains? Answer: Yes, maybe earlier. We will begin explanation later on.) Other questions?

Then we come next to the largest subdivision known as the Rocky Mountain system. As the map indicates, the Rocky Mountain system begins in northern New Mexico and extends northwestward to the Canadian boundary crossing the Canadian boundary in the states of Montana and Idaho and also eastern Washington; it is subdivided into four parts, the first of which we are calling the Southern Rockies. This area includes the mountains of southern Wyoming, and from there south to the end of the major subdivision. It is a region of linear mountains, that is, the mountains are in lines and they are not distinct ?; they are separated from each other by lower areas.

Almost every mountain in this group is an anticline, and anticlinal range.

In general the areas are folded, trending slightly east of south, giving rise, therefore to an arrangement such as this, an arrangement in which the mountain folding overlaps, that is, the various lines of folding are not continuous. You begin with one mountain group and it gradually disappears out here; another one starts here just before the other one disappears; another one starts here and so on. If sometimes you are ??? you will see this general arrangement of this mountain axis through this region. Of course we cannot take up the details with regard to each of these areas. If we were to take the Laramie Range of southern Wyoming? or the ? range of ?, neither of then would serve ???; you would find in general that all of them have the same general cross section. Individaully they are quite different, yet almost each one of them will have this, a crystalline base, that is, of igneous and metamorphic rocks.

We will have an inclined series out here on the limb, the lower one Paleozoic and the upper one Messozoic formations.  The mountains themselves usually consist of this core, the foothills usually being rocks of Paleozoic and Messozoic age, thefoothills, the end of the foothill belt, of course, comes into this region of tertiary alluvial plains, that is, the Great Plains on the east for example.

Some of the other subdivisions run west. These sedimentary rocks, of course, extended over the top at one time. Since the formation of the Rocky Mountains, that material has been stripped away; it is quite logical that that would be done. After the formation of the mountains that was the high area, therefore subject to the most erosion and therefore the stripping of these sediments, and these rocks were so hard thaty they have retarded ??? whereas the foothills between occur on the sides.

There are many regions where you can see these rocks as I have drawn them and sometimes they can be seen even more ???. They stand up in regions as I showed you last time like in the Black Hills region ??? and this then becomes a typical form spoken of as a hogback (Interruption. Question: Is that what we have in Denver Park? Answer: ???) These rocks which occur in the center of the anticline

for example, Pikes Peak, usually are igneous, from an igneous mass. The erosion surface was cut down through the granite. If I were to draw more of the details of this region I would have to change the general form of this mountain to a surface a little more like that. Inother words, not all of the ? is here and part of it has been removed to the extent that a peneplained region has been formed.

At the time it was formed the streams had eroded into the area as deeply as they could. Probably then the old surface was like that; uplift of the area, and as a result all the material on the sides was stripped sway. These isolated remnants which occurred above the erosion surface, were called monadnocks. Pikes Peak, Longs Peak, which occur ??? is another such monadnock. If you take the ? road in ? National Park you come up on this erosion surface and you look quite a distance over this surface and as you do so, you see these ???. They are remnants; The streams were able to ? at the time these were formed. This is characteristic of the front ranges from the Laramie Range on the north to the crystal? range on the south end. All of them are characteristically ???; there are a few of them ???, that is, in the region of the mountains the pressure was from this line and down here acted as a plunger, and in so doing, arched up the sediments over the top. In some places it actually rose ???; in such cases then, the foothills belt disappears. These are eroded out here. Such you have for example, south of Colorado Springs. These formations which have been mentioned, the bedrock? ??? or whatever else you want to call them, disappeared just south of ? and are present south of that (Interruption. Question: Was that an overthrust? Answer: No. uplift, uplift.)

Once getting beyond the ? range bends into a syncline and repeats the process of an anticline, so there are ??? the front ranges and the western belt made up of a ? series, but there is a distinct mountain axis over here, and this area between here is a cyncline. This is the area in which in Colorado they call the Parks?. We're not speaking of National Parks now but ???. The result of the wearing off of the material on the mountains and being dumped off here ???.

Going northward out of the mountainous area we come to the Wyoming basin, excuse me, I want to add one thing yet about this other area. The topographic form

or central core has been modified by glaciation in central Nevada. As far as scenery is concerned ???.

Now for the southern? rockies. It is a region of Tertiary alluvial material, again a repetition of the same thing we have out here on the Great Plains. The mountains are not interrupted in the sense that the structure is interrupted. The topographic form is of course changed but these mountain area which ? north or slightly west of north, merely bend to the northwest, trend through the Wyoming basin and then ???, so if you will look at the diagram I gave you, just imagine that those fingers which you see sticking out continue with a ? to the nw ??? which lies in the region to the north.

The folds such as this occur in the region but they are so low that the Tertiary material have for the most part, covered them up. Now we change the diagram to the extent that we put a tertiary cover up about that far. In other places if we put the Tertiary cover up there, then we would have the ??? so extensive that if covered over everything ???;in some places the streams have been able to ???, in other words, uplift and stream erosion have exposed the ???. This is another one of the regions of badlands in western United States.

As a matter of fact, this is a region which in terms of Paul Bunyan, ???. It is a region in which stream dissection has produced an infinite erosion pattern. That is true of any of these regions. The continental divide is so low that it contains salt marshes of ? lakes, lakes that appear after a rain, and then the next day disappear. The Continental Divide.

I think that is enough and now next, the Middle Rockies. This is the mountainous area in the vicinity of Yellowstone. Yellowstone lies in the nw corner of Wyoming. This region has a rather peculiar shape as you will notice on your maps. It includes the mountainous area of nw Wyoming, then a group of mountains which extends along the ? boundary and then along the ? boundary and then make a right angle turn to include the mountains along the Wyoming-Utah border, a rather peculiar shaped area and made up of a different kind of rock structure.

Let's begin with Yellowstone. The Yellowstone area consists of a volcanic plateau and the predominance of this volcanic material is the reason for the hot water phenomena we have at Yellowstone. In other words, the underground source is undoubtedly the same source which gave rise to the volcanic material, and it gives heat to the underground water. That region would be here in nw Wyoming.

This plateau is surrounded by mountains, first the mountain on the east of Yellowstone; at the north of this group, the mountains are of this general character, anticlinal for the most part, anticlinal without a foothill belt on either side, a rather rapid ascent from the plains into the mountainous region in which the rocks are these ancient crystalline rocks which we have described before. These are the Beartooth Mountains. East and just a little bit north of Yellowstone, you can see you can see them, the Beartooth Mountains. It is a region of volcanic accumulation, both flows and explosive material all of Tertiary age, all Tertiary Age.

The plateau has been dissected to the extent that it gives a mountainous design. That is, the streams have ? into it so effectively then that we have the Absaroka Mountains. Alongg this general trend, the lava and volcanic materials disappeared and again we have anticlinal mountains which make up the Shoshone Mts. I don't expect you to remember these mountains, but this seems to be the only way in which I can explain this material to you effectively, It is also an anticlinal range, but not so thoroughly stripped of materials over the top. In other words, it is an anticline in which the sedimentary rocks go almost over the top. Now isn't that what you would expect? I said the Beartooth Mountains expose igneous rocks and I said these ??? therefore being low. Here is a ? between the Wyoming Basin and the uplift ??? and then taking a great swing here back to the nw, in general, the Big Horn Mountains.

It is an ? area which goes out and turns almost? a circle where ??? and this portion out in here is the Big Horn Mountains. (Interruption: Question: In Wyoming? Answer: Yes, in Wyoming, and that extends into Montana just a bit.) Now I have to restore the diagram to its ?. Again we are back to the Big Horn, a mountain range stripped ??? a mountainous region in which some of the best features of glaciation are best developed. It is a region of beautiful cirques, that is, broad ???; it gorged out bowl-shaped areas in the mountains; these are so widely separated and do not interfere with each other and can do a beautiful job of cutting up the surface.

If you cross the mountains from the eastern side you see how the cirques have developed. Then the Big Horn, that's another story. Taking the mountains which extend along the Idaho Wyoming border we have ??? are quite different, Just south of Yellowstone we have the Teton Mountains, characterized many times as the American Alps. The structure of the Teton Mountains consists of an uplifted bolck, the eastern side having risen, giving rise to a ?. It slopes to the west; then this was glaciated, giving rise to the sawtooth skyline. Off on this side we are in the Wyoming basin and so we have plateau ? topography. ??? full blocks and this is one of the Teton Mountains just south of Yellowstone.

Then we have the Wasatch Mountains just across in Utah in a ns direction, We have the Wasatch Mountains, another block, but tilted in the other direction, so the general relation is somewhat as indicated here ??? and this on which the Great Salt Lake is situated. The faulting along the Wasatch has been so recent that all of the spires? of the mountain, that is just what they are, nothing more than spires?. The interstream areas all have triangular ? sections that are shaped like that. The ? is rising so rapidly that in so doing it left the end of the ? area cut off. ??? and in so doing it has been so recent and so persistent that you still have the fault along which the slipping took place. That is characteristic of ???. Then we come to the largest east west mountain range of the North American Continent.

They ? in Utah, the Uinta Mountains. It is estimated that the Uinta

Mountains represent one of the largest single uplifts in the ?. We are still in the Rockies and it is still an anticline, differing in this sense, these formations were steeply tilted and then ? over in a form like that, a flat topped arch and therefore the formations which came ??? and then have been cut off since the uplift. It has been estimated that the uplift here has amounted to 30,000 ft, 30,000 ft. of uplift. The mountains there are 12 or 13 thousand feet high. That means that the material stripped off the top was somewhere in the neighborhood of 18,000 ft., 18,000 ft, of material has been removed. (Interruption).

Well, let's stop for a moment. Any other questions about the Middle Rockies? (Interruption. Question: The Tertiary deposition was largely workings over of the two previous periods? Answer: Of everything previously.) Other questions?

Then we are going to the Northern Rockies. The Northern Rockies extend nw from Yellowstone, the mountains which are present in sw Wyoming and ne Idaho, that is, just north of the Snake River, are for the most part again folded and are Paleozoic and Messozoic formations. The folds are smaller but we have again anticlines and synclines, a group of folds through this region, and the rest of the Northern Rockies are entirely different.

This region of the Northern Rockies consists of ??? several areas in the North American continent which are more or less headaches. Let's begin with the area represented by Glacier National Park. The mountains of Glacier National Parl consist of ancient marine formations. You haven't heard me say that very often, ancient marine formations. They are slightly deformed. The mountains are portions of a great fault block, not like I have described before, but another kind of fault. Now the topographic forms would be something like I have indicated here, great plains to the east and then the mountains of which GlacierPark only represents a part, and then a trough , the result of ? then later the erosion. This mass of rock here is a portion of the rocks of the earth which have been shoved out and over the rocks which were here. The shoving has been of such a nature that the formations up in this area, if we were to try to find them in this ? they would be down in such

a region as this. In other words, these formations were the continuation of these over here and as a result of the movement, they have been ? up and out. In some cases, a matter of 25 miles shortening of the crust of the earth, 25 miles shortening, one block of the earth moving out over the other. Such movement is spoken of as overthrust and that in Glacier National Park is known as the Lewis Overthrust.

And we have then ls, ss and sh which here as I said, are only gently deformed, just slight waves in the rock. I said that they were ancient, more specifically they are Proterozoic in age. (Interruption. Question: Would the overthrust appear to the eye? Answer: Yes, in some places ??? it extends from Montana to Idaho) Other questions? (Interruption. Question: Proterozoic on which side of the fault plane, Cretaceous on which side? Answer: That's the sequence as I have written here.) (Interruption.)

As we continue westward from the Glacier National Park region these formations continue into Idaho and from there on west to ne Washington. We have rather abundant intrusive rocks, so throughout most of this portion, it is a repetition of this separated by structure troughs. The reason for these throughs is not recognized as yer. ??? streams one of the unsolved problems of that region, but in the ne area of Washington, as I said, there is a group of intrusives; to the se here is the area of folded Paleozoic and Messozoic.

That leaves jusr one region we have not discussed and that is Central Odaho. It is made up of a batholith of a huge mass of intrusive material from which the sediments which used to be above it have eroded away and there is left a land form developed upon this uniform mass of granite. It is therefor a mountain range, not system to it, no arrangement at all. It is merely the way the streams have left it. It is practically impassable, valleys too irregular to follow, ridges too irregular to follow, little habitation and across it there is practically no transportation. It's the Salmon River country of which I am speaking, the Salmon River Mountains of Central Idaho. I think that's probably enough and maybe even too much on the Rocky Mountain system.

Let's take just a minute to summarize what I have tried to give you. This region which we described, that is the Rocky Mountain system, for the most part, consisting of areas or lines of folding in the south and in the middle and southern portions of the northern subdivision, the ranges mark the areas of folding. In most cases the crystalline cores of the Mountain ranges are exposed. The sedimentary material is of Messozoic and Paleozoic age flanking the crystalline cores and makeing up the foothills. ??? is a region in which deposition has almost or ??? completely covered the lines of folding and are graduâlly being uncovered as erosion proceeds and the very northern portion of the Rockies consists of this series of very ancient marine formations which I have also ???.

One other region, that of Central Idaho, a region of large intrusive masses. Any questions? (Interruption: Are they of about the same period of formation. Did they all come into existance at about the same geological time? Answer : ???.) (Interruption. Question: How can we determine the age of the intrusives? Answer: By the youngest deformed rock. That is one thing that will stand you in good stead, regardless of what course of geology you take, by the youngest deformed rock. ??? marks the time the mountain range cane into existence.) (Interruption. Question: The quakes of that region recently were the result of what? Answer: ???)

Next time we will finish these physiographic features of the United States and then we will begin to tell you how they all happened.

(Slide. Lobeck Map. Here is the region which we have just discussed. Here is the region etc., etc.)

I guess that's almost in focus. Once again we will get acquainted with the geography before we go much farther. Last time we considered the Rocky Mountain system which included the areas approximately where the pointer is traced. This evening I want to try to finish the western portion of the United States. As major subdivisions, the remaining portion of the United States us made up of two parts, this portion just west of the Rocky Mountain system, known as the Intermontane Plateaus, then the mountainous area and the valleys which are spoken of as the Pacific Mountain System.

In the Intermontane Plateaus we find three subdivisions, the Columbia Plateau, lying here through the Snake River area ???, the Basin and Range Province, mostly in the state of Nevada, from the Wasatch Mountains down into ??? across southern Arizona, sw New Mexico and extending across the international boundary. Third, the Colorado Plateau lies to the west of the Southern Rockies and south of the Northern Rockies in the Wyoming Basin.

In the Pacific Mountain System are the Sierras and the Cascades which make up one province. I will name all of these again so you can get them later; then the Pacific Coast Ranges, this the Puget Trough, and this the Great Valley of California. (Interruption. Question: What trough did you call that? Answer: The Puget Trough.)

Back again to the structure represented. We are dealing this evening with 14, 15, and 16, 14 and 16, plateau areas and 15 an area of, as the name implies, of basins and ranges, and 17 is a complex mountain area. We hope to dissolve some of the complexity during the course of the evening. Had we called the Rocky Mountains number 7 in our provinces in our major subdivisions (Class answer : Number 6). 6 the Rocky Mountains. All right, then 7 is the Intermontane Plateaus.

As the name states, this is a plateau region between the mountains; within the major subdivisions, mountains are essentially absent ot are limited to isolated ranges, separated by desert plains. 7A then we ill call the Columbia Plateau, 7B the Basin and Range Province and 7C the Colorado Plateau.

Let's begin with the Columbia Plateau as the first province, the first subdivision of the Intermontane Plateaus. First let's get the boundaries. It lies west of the Northern and Middle Rockies; it lies east of the Cascades. Remember that the Northern Rockies come up through Idaho and then join with the Cascades in northern Washington so that actually we can hardly speak of a northern boundary of the Columbia Plateau because ??? lies to the west of the Columbia Plateau. The southern extent is approximately the southern boundary of Oregon and Idaho as well. It is lower than its neighboring provinces except the one to the south. That is the Basin and Range country.

The Columbia Plateau is characterized by flat lying, that is, it has lava flows of a dark color which have accumulated in this region to a thickness of 4,000 feet. (Interruption. Question: Is that average or does it vary? Answer : ???) I have some specimens of lava from the Columbia Plateau which I shall pass around the room. One specimen you will notice is very porous. It contained abundant gas which blew bubbles in the rock and thus the rock solidified. The other one was more fluid, less gas content in it and therefore it flowed forward more smoothly in rolls. I was able to bring home only a small roll, some of them are as high as I am ??? flowed forward slowly and cooled. (Interruption. Question: This piece here, is this considered scoria? Answer: Yes, that would be scoria. Scoria is the porous dark colored solidified lava.)

In general the rock is spoken of as a basalt, as a basalt. Where the streams have cut through the various portions of the Columbia Plateau, these layers of basalt, the ancient lava flows, you can see them there one after the other just like so many sheets of paper or so many pieces of wood arranged one above the other. Where we have a large area such as this covered by lava flows, it is believed that the manner of eruption was ??? slowly moved up along the fractures and then being very fluid, spread out like a flood from these fractures. Throughout the region of the Columbia Plateau we find fissures or fractures. Throughout the Region of the Columbia Plateau we find fissures or fractures, numerous fractures from which these dark

colored lavas came. It is evident that from 50 to 60 thousand cubic miles of lavas are found in the Columbia Plateau. On the map this area which is colored a rose or pink, that's all lavas; 50 to 60 thousand cubic miles of material came up from the interior of the earth and was poured out on the surface. In the succession of floods of molten paterial which came out from the fractures; they flowed out and we find them encountering a pre-lava surface which was very irregular. When the lava flows came to a hill, they just surrounded it and during this time we have a hill of older rocks surrounded by younger lava flows. The next flood covered more of the hill, and the next one still more and so on until the later flows covered the entire hill and irregular pre-lava surface, and today the monotonous surface of the Columbia Plateau is due to the accumulation of these lava flows.

All the irregularity of the pre-lava surface is covered. These lavas are said to be Tertiary in age. Remember, the Tertiary is the oldest of the last two subdivisions of geologic time. The Tertiary just prededed the ice age in other words. Rather inconsistent that we should have such a change in temperatures from lava flows to the spread of continental ice sheets. (Interruption. Question: Is there drift over these lavas? Answer: ???) For the most part the lavas are undeformed. That is, they remained in this horizontal position. The variations from this horizontal structure, are largely two. (Interruption. Question: The variations are largely what? Answer : Two, just two kinds or variations.)

First, a tilting or warping of the layers as they slowly slumped to occupy the space from which the materials had been brought to the surface. That is, we can hardly say that there would be ??? beneath the surface of the earth if 50 or 60 thousand cubic miles of material had been removed, but rather the upper surface would tend to slump inasmuch as all that material on top, the lava flows, had formerly come from the interior of the earth. ??? not in one direction because the slumping was not uniform. The other change is found along the western margin where due to later uplift in the Cascade Mountains the lavas which flank the eastern side of the Cascades became uplifted as I will describe later.

One other thing should be included in here. This repeated eruption of volcanic material was not quite so continuous and uninterrupted as what I have drawn. More correctly between certain of these lava flows are lake sediments, andoccasionally a lava flow may have a weathered zone at the top, a soil zone. These two characteristics the, the weathered surface of some lava flows and the presence of lake sediments between some lava flows indicate that the periods between lava flows were long. There are regions in which the lava flows are ?, practically no vegetation? on them. That condition would arise ??? the weathering is going to produce a soil horizon and later lava flows will bury it. (Interruption. Question: Those lakes, are they or were they fresh water lakes? Answer: ???) Other questions? (Interruption. Question: How deep down do you find some of those weathered surfaces? Answer: Well, you find them at the bottom of the series which would be at least 3 or 4 thousand feet of material.)

The greatest section of these materials is along the Snake River and there are some places in which the Snake River, let's say that the profile of the Snake River is this line. In some places it flows right through lavas and in other places it goes through the pre-lava indicating that in some places there are at least one half mile of materials which have been accumulated above, and they believe these low ? below the ??? they have about 800 feet shown right there and of course it would be between these two where we would get the lava flows. (Interruption. Question: Does that indicate then as a whole this river has had a continuous chance to dig through or are there places where the river valleys has been flooded or an I making no sense? Answer: If I get what you mean, the Snake River has done a large share of cutting since the lava flows. I will speak of that later if I don't forget it.)

The first section is the Snake River Plateau. This represents some of the youngest surface of the Columbia Plateau. It is a region in which the lava flows are practically unweathered. It contains a national monument which is called the Crators of the Moon. These craters are associated with the recent rather late volcanic eruptions, probably of the age which I have just erased, Quaternary. The

lava specimen which I passed around came from the Craters of the Moon National Monument. In this region not only did the lavas come up along fractures, but there was sufficient gas associated with it to create a??? thus creating the spatter cones which have remained Craters of the Moon. A portion of the Snake River Plains is practically desert because of the absence of weathered material, the two principal products being sagebrush and jack rabbits.

Through this region the Snake River has been able to cut a valley about a mile deep along the Idaho-Oregon boundary line, north south. The Snake River comes west to the Oregon boundary and where it turns it is over one mile deep. Along the Snake River Plains, if you were to look at the morth side, in many places you would find ???. For example the Thousand Springs of Idaho. A cross section of the Snake River Canyon would be something like that. It is a very steep walled canyon, ??? and so whatever precipitation takes place out here if it gets into one of these proous lavas, it percolates along ??? until it comes to the water horizon and then it comes out as a spring. Some places here you have countless springs as far as the eye can see. and they are all ? of these porous portions of the lava flows.

The se portion of Idaho contains more late materials than the other parts of the Columbia Plateau. To this section is given the name Payette. It is, of course, a geographical name, maned for Payette, Idaho. The only difference we have more accumulation of lake sediments. The Payette Section is the present representation of what we had represented in the past lava flows. (Interruption. Question: Sw section was it? Answer: Yes, the sw section.)

In ne Oregon there is one mountainous area in the plateau. It is called here the Blue Mountain Section. The mountainous area trends in a ne-sw direction, and it is directed just about just about the ne corner of Oregon. Here we have at present a representation of what was ? of this region, a pretion of the pre-lava surface, lavas with the mountainous areas not completely covered. The lava never went over the Blue Mountains. This gives you an idea of what the pre-lava surface was composed of, folded and metamorphosed ancient rocks. We won't say any more about the age of that. They are much older, much older than the lavas which surround it.

In Washington we have the ??? Walla walla section. Wait, I don't know if both Wallas are capitalized. I guess I had better capitalize both so as not to slight anyone. The Walla Walla section is characterized by its coulees, steep sided valleys, steep sided canyons, I should say, without streams. A typical profile diagram, of course, through one of these coulees would indicate horizontal lava flows with steep walled canyons. This might even be an island in the canyon with the sides standing vertically. Occasionally it might be a lake basin. As a matter of fact, quite commonly lake basins might be formed. If the line which I have drawn represents approximately the boundary of the Columbia Plateau, then the Columbia River comes down across this way, and then crosses the Cascades. It follows along the north boundary and then turns south and then across the Cascade Mountains, That's the direction of the river.

In the explanation of these coulees a geologist of the University of Chicago has explained them in this way. During the ice age the northern portion of the Columbia was covered by a glacial lake; therefore the Columbia's course was ?, no drainage in it, so it is perfectly ? but drainage which comes from the northern Rockies in this direction toward the Columbia, drainage which comes down the Snake River; my geography is a little bit off here, now, more like that. This drainage would continue to flow; this drainage, however, was blocked and directed along the ice front. It got out about so far and then took a short cut. At another time and for some other reason not known, it took another short cut over here. This longer one is Grand Coulee and this shorter one, Moses Coulee. They represent abandoned stream channels, having formed as a result of diversion of water which should go to the Columbia River, until it found a short cut.

In all respects then, these coulees are structural channels except they were probably eroded in a short period of time by a large amount of water. A normal valley should develop a profile more like this. They should not be steep sided valleys, therefore this University of Chicago geologist thinks ??? and must have been of large volume. (Interruption. Question: Aren't those rocks hard? Answer: Yes, but they would be weathered.)

In this region are relatively late lava flows; in this region are, however, ice lobes. Why not have a lava flow take place ? the glacier? That would furnish a large amount of water. This is a possibility for that does happen on islands?. Lava flows come out ??? those are the conditions which have been postulated fro the formation of the Grand Coulee and the Moses Coulee. At the time these coulees were in existence, one of the greatest water falls that ever existed on the earth was in this Grand Coulee. It was 400 ft, high and over one mile wide. Today there are great plunge basins below this region spoken of as dry falls, now a state park in Washington.

Since the formation of these coulees ??? the Columbia has ??? and so these coulees lie at an elevation above the Columbia. I see I have drawn the ice boundary down here too far when I come to explain this. You all have heard of Grand Coulee Dam. Grand Coulee just happens to be a location; it has nothing to do with the dam, but it is located ???. The particular engineering problem involved there is a damming of the Columbia River and creation of a reservoir which will be used for irrigation purposes down throughout ??? but as I say, the Coulee itself has nothing to do with the dam.

Well, we probably have spent a little too much time on the Coulee District but within the Walla Walla section there is also the Yakima District. It is of importance only because it represents some of the lava flows which are not horizontal. The uplift of the Cascade mountains to the west brought up some of the lavas on its eastern flank ans as it did so, it twisted and turned these lavas in such a~~s~~ way ??? that you get a line of folding diagonal to the main trend, and in the Yakima District, the lavas are faulted or folded as a result of being ? and that's the only place in this plateau where the lavas are in other than horizontal position. (Interruption. Question: What region does the Cascades cover? Answer: ???)

Harney Section and then we are through with the Columbia Plateau. This section is in se Oregon; it is a region known as the Oregon Desert. For the most part it is a pummice desert, a pummice desert; pummice you will recall is nothing

more than rock froth resultant of lavas coming ??? interval ???. The rain that falls there leaves only by evaporation or by percolating in the ground. No streams leave the area. They almost did. As a matter of fact, they lack only about two geet of rise ??? and then they would have flowed out, but as the lake got higher and higher, the amount of evaporation was equal to the percipitation and then of course the lake level has remained constant. Any questions about the Columbia Plateau and its subdivisions?

Next we will take the Basin and Range province then. I have them in that order here. Again let us recall the boundary of theBasin and Range Province. It lies west of the Middle Rockies, west and south of the Colorado Plateau and east of the Sierra Nevadas. It includes the entire state of Nevada, western Utah and se California, southern Arizona and sw New Mexico. As for general characteristics -- it should be described as an area of isolated sub parallel north south mountain ranges, surrounded by desert basins. I will repeat that, not that you have to get it in the same words, but the idea -- an area of isolated sub parallel north south mountain ranges surrounded by desert basins. They ranges are composed of a great variety of rocks, so much so that we won't try to name any of them in general, I mean in detail. The ne portion is an area in which the ranges are primarily of Paleozoic rocks; the nw area, the ranges are primarily of Messozoic formations and the southern portion, the ranges are primarily of Pre-Cambrian formations. In these areas and elsewhere as well, the ranges are composed of Tertiary lavas.

Now perhaps you can see why the complexities. The basins lie normally at elevations of about 3 to 6 thousand feet, yet the area contains the lowest elevation in the United States. Salton Sea in se California is 273½ feet below sea level. (Interruption. Question: What is the name of that? Answer: Salton Sea.) The Death Valley is between 200 and 300.

For the most part, Death Valley has been land for some time; this used to be the Gulf of California. The ranges are about 7 to 10 thousand feet, fairly respectable mountains then, and the greatest elevation is 12,000 ft., so from this

12,000 to the bottom of the Salton Sea we have the greatest relief in continental United States. Mt. Whitney is the highest, to be sure, but you have to go some distance from Mt. Whitney to get such relief.

The ranges are spoken of as fault blocks and depending upon the particular slope of the fault plane you may have one side of the mountain steep and the other gentle, or it is just as possible you should have a condition like that; the sides of the mountain would be symmetrical. But every mountain crest represents the edge of a block; every mountain crest represents the edge of a block. For the most part, the movements have been such as to cause a lengthening of the earth's surface.

In a region where we have step faulting as indicated here and found in the Basin and Range Country, then, half of these faults is the result of tension and half faulting. The two points at the ends of the series are farther apart then, than before the faulting began. These are spoken of a normal faults.

Many of the faults are this kind, but there are some also which are spoken of as reverse or thrust faults, being ones in which the earth's circumference is shortened as a result of compression. Within the individual block, the formations may have any structure. I have indicated them here as being horizontal. That need not be true; they may be folded into anticlines; the rocks may just be a tilted series. You can have any portion of structure if you look long enough. Around each of these ranges there is a basin filled with the debris which has come from the adjacent mountains. The basins, therefore, are all covered ~~with~~ all floored with alluvium. The streams carried and deposited material. Here we have on a small scale what I have once before described as the Great Plains, plains construction at the foot of the mountains as a result of streams coming down and spreading their material ???.

Take this map. I would ask you to look at it at the close of the hour. The gray stippling is this alluvium as you can see the distribution of the basins. Such are desert basins. The other spots are the ranges of which I have spoken. Any questions? (Interruption. Question: What caused them? What caused the whole batch of them? Did they come before of after the Rockies? Answer: ???)

(Interruption. Question: I sthat rock alluvium igneous or sedimentary? Answer: They are the result of the erosion of all of these varieties. As you see them now they are sedimentary material, but they have come from the weathering of igneous, metamorphic and sedimentary rocks.)

The first section here is the Breat Basin. It includes most of the state of Nevada and the adjoining portion of ?. It was named the Breat Basin because of the characteristics as observed by the early ???; they came across ??? and therefore its name. It is very typical of the general character which I have described. It is an exception for we ? ancient lakes which ??? ancestorof which Great Salt Lake is a pygme? desert. During the ice age Great Salt Lake rose until it was approximately 100 ft. deeper than it is now. At that time it emptied into the Snake River. ???. The climatic conditions changed ans the lake level dropped and water did not flow out assuming more or less the present salt conditions. Again the climate changed and it rose, but this time it found an altitude about 60 feet above the present level and so it flowed out. Along the area formerly covered by the Great Salt Lake are some of the desert ranges and you can see the general ? of these ranges in the mountains. Locally they are spoken of as terraced mountains, and these terraces represent old lake levels.

Of course since the last one, water has not been flowing out. It has been concentrated as a result of evaporation. It is still a region of Playa lakes, lakes which exist after a rain or heavy dew and then disappear. (Interruption. Question: Where are those lakes in the Columbia Plateau? Answer: ???) These are saline water lakes, not suitable for drinking purposes.

Then Lake Bonneville, there is no relation to the Donneville Dam or the Columbia River. Another section is the Sonoral Desert. It is actually composed of two desert regions, the Mohave Desert of ? and the Gila Desert of sw Arizona. It is a region of greater aridity than in the Great Basin and also a region in which the desert plains are more extensive, covering a larger area.

Salton Trough, another one of the subdivisions of the Basin and Range Province represents a portion of the Gulf of lower California, which was cut off by the deposition of a delta. This represents the gulf and this would be land out here. The Colorado River with all of its cutting through the canyon area comes down ??? and built a delta here. The delta continued to grow until finally it has flanked this area to the north. This became a region of evaporation and what was originally ocean water began to evaporate to form a relatively small body of water. The present body of water is primarily due to a decision of the Colorado River to again go in that direction. It was largely the flooding of an irregular ?, but the present one was primarily the result of that condition. I don't think it merits more discussion than that. There are two other sections, but we have some interesting things, so I will go on. Any questions about the Basin and Range Province? (Interruption.

Let's begin with the Colorado Plateau, lying west of the Southern Rockies, south of the Middle Rockies and surrounded by the Basin and Range Province. It is a region of horizontal sediments where elevations in the plateau are not below 5000 and may be as high as 11,000, almost two miles above sea level. It represents an area of some of the greatest canyon cutting not only in the United States and North America, but actually in the world in a single canyon or series of canyons rather or maze of canyons.

The cause of the canyons in thi particular region is due to the through flowing streams, that is, the streams receiving their water from melting snows and rains from the mountains to the east and north. They receive practically no contributions as they flow through the plateau. Therefore the streams can cut deeply before they reach the level where they will not cut. Therefore we have the pronounced canyon characteristics of the Colorado Plateaus. (Interruption. Question: I don't understand stream cutting. What do you mean here? Answer: ???.)

The area is largely one of plateaus. Think of it in terms of rock terraces far and wide throughout the region, the conspicuous form of a terrace or series of terraces. Particularly is this character noticeable in southern Utah. Two of these terraces are very conspicuous so much so that we should know more

about them. One is Triassic red ss. Above it is a Jurassic white ss. In one region even though I should say elsewhere, you hav e this step like characteristic, but in one region the rocks have been worn until you have almost a ? face with a canyon cutting down through it.

Then you come to this canyon. This edge here would be the face, this describes the general condition of Zion National Park, an area of res ss at the base and white ss at the summit, an area represented by this photograph. If you want, you can stop at the close of the hour and see the general character of these land forms. (Interruption. Question: How thick are the strata? Answer: The canyon is cutting about 2500 feet deep and I don't include ???).

If we were to get back on this plateau series we come to another terrace or whatever you want to call it. On this one we have Tertiary alluvium. Instead of a single canyon being cut as represented for Zion, again don't forget this one, this face is not this face. Here we have pinks , yellows, and whites, alluvium sands and clays for the most part, and instead of having a single stream, we had another stream which came in and more or less branched out and eroded a gulf, eroded a gulf. This region, therefore, in here would become pinnacles and spired. This is the region of Brice National Park. We will have more of that at a later time.

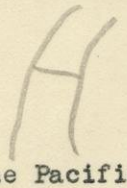
Another region of which I should speak is known as the Canyon Lands of Utah, a region of entrenched meanders. It is a region in which the streams ???. (Interruption. Question: I didn't hear that name. Answer: Entrenched meanders. They develop when a region has almost reached the end of its erosion cycle.) To become entrenched ??? and therefore it maintains its widding course, but it becomes ? into a gorge and so we speak of them as entrenched meanders. This would be a cross section through a region such as that. If the swinging gets to such a stage as that you have favorable conditions for a natural bridge. The riven eventually wears through the rocks underneath and then the water would come down, swing underneath the bridge and go like that. As a result, we would then have a bridge which would look more or less like that and erosion here cuts that portion

ou

out and we would have a rock arch going across the stream in this direction. The water flows at right angles to it, the water here cutting underneath it. So far as the Grand Canyon is concerned, I will draw a generalized diagram and then consider it in more detail at a later time. I guess that's generalized enough.

The river is flowing in Archaeozoic rocks which have been badly deformed, and the walls of the canyon and stair steps are of Paleozoic marine sediments, ss, sh and ls. On the north the elevation of the plateau is 10,000 feet, yet the upper plateau is formed on a ls which was once deposited in the ocean. We have the area uplifted 10,000 feet without disturbing the position. I apologize for slighting the Colorado Plateaus in this way, but those of you who are taking National Parks will hear more of the Colorado Plateaus later on. (Interruption.)

Next is the Pacific Mountain System. A Sierra Cascades is the eastern subdivision, B, the Pacific Coast Ranges, the western subdivision, and C. the Great Valley which lies between A. and B, and D, the Klamath Mountains which join A and B and separate the portions of C. The Pacific Mountain System should be thought of in terms of as a badly cripples letter H.



The Sierras are here, then the Cascades, and the Pacific Coast Range, the Klamath Mountains, the Great Valley of California and Puget Trough. I'll repeat that. First the Sierras here, then the Cascades, the Pacific Coast Ranges along this side, the Klamath Mountains through here and the Great Valley of California and Puget Trough. Is that clear? Now I think that perhaps is a little better than all that black area we had in the structure diagram.

Let's begin with the Sierra Cascades. The Sierra Cascades include the eastern mountain chain. We will first take up the Sierra Nevadas which represents a fault block, the upper surface sloping gently to the west, the eastern slope is steep down to the Great Basin, not as steep as I have drawn it, yet there are places where the descent from the top of the Sierra Nevada block to the bottom is 10,000 feet in 10 miles.

This is not a straight road. It is essentially a block made up of a huge intrusive which we call a batholith, a large mass of rock. There are a few places in it where the sediments which formerly were more extensive over the top, still hang down within the batholith. They are spoken of a pendants. These are the portions which are mineralized, and form the gold belt of California. Otherwise it is made up of this uniform mass of granite. It is not actually granite, but we will call it that nevertheless.

The details of the ? area is due to glaciation so we have the jagged skyline and we have such areas as Yosemite, a glacially gorged valley. Next the Cascade Mountains. I hope you don't take notes on the wrong lecture. The Cascades are essentially the result of vulcanism acting extrusively, rather than intrusively. The southern end of the Cascades is the locality of Mt. Lassen, the most recently active volcano in the United States, and from there north, we have an increase of volcanic comes and then the accumulation is replaced with accumulated lava flows with ???. As you pass north, the lava ???/basin characteristics becomes less and less and the range characteristics more and more due to uplift.

I might take time to diagram this while describing the Cascades down here. There were fissures, fractures through which the lavas came up and later lavas came up through another fracture, and still another fracture gave rise to still more lava flows and so the Cascades represent a zone of faults through which the lavas came out. They were not so fluid as those of the Columbia Plateau. And after the lava had been poured out, there was the formation of the volcanic cones on top of the plateau. The steep side of the cone is a composite cone, lava plus ash and cinder. Ash and cinder won't stand. Lava makes a low flat cone, but when you get the two of them together, you get the composite cone, the steep cone which I have described.

You will notice on this map you cannot tell where the Columbia Plateau ends and the Cascades begins. Next, let's take the Pacific Coastal Ranges. The Pacific Coastal Ranges of Oregon are made up of marine Tertiary rocks. They are in broad open folds more or less like that, only arches and troughs, no very intense

deformation. The Coast Ranges of northern California down at San Francisco Bay are made up of folded Messozoic rocks; the folds in general are in a nw direction passing out into the Pacific Ocean; consequently in this region the mountain ranges also are nw along the lines of folding. Between the mountains we have valleys which are open ended which go right out to the sea.

South of San Francisco the ranges consist of faulted blocks, fault blocks which are very recent in age, so recent, in fact, that it is still in the process of being formed or ??? and occasionally the Californians get wakened up by the shaking or quakes. This is the youngest mountain range in the North American continent, so young that it is still in the process of being formed.

The Coastal Ranges south of San Francisco they were. Now the Great Valley. The mountains to the east and the mountains to the west are being eroded and materials are being contributed, and that should explain the origin. Valley between the mountains here and valley between the mountains here with this floor of recently deposited stream material.

Now there is an interruption here, the Klamath Mountains. They are a combination of the complexities which I have described. It is a region of folding and intrusives. It resembles the Sierra Nevadas except that we have little more folding and little more intrusives, but the complexities are just about as great. The ranges between the Klamath Mountains ?? and in no way related to rock structure. The area between them becomes a mountain range, giving it a local name. I might put in just a word regarding the north end of the Puget Trough. The north end has become submerged and has become Puget Sound. Its particular branching form is largely due to glacial agents and we won't stop to consider those. AnyQuestions? (Interruption. Question: What is the relation of those Olympian Mountains? Answer: Almost a repetition of the Klamath Mountains, and they connect with the mountains on Vancouver Island ???)

Well, we have therefore completed a grand tour of the United States and from it I hope you have gotten some ideas as to the ages of the rocks , the character that is, whether they are lavas, intrusives, and the structure, where are the zones

of deformation, etc. That last material is what is called the geologic pattern of the United Staees, the character of the rocks and the position and structure. If you have this in mind, the things which are to follow are going to be simplified. Next time we will have the Pre-Cambrian, the rocks that are ?. I suggest that you read trying to follow the outline. It is merely an outline, however. Next time I will take up the physiographic features, or in other words, the rocks and records of the first two periods, the Archaeozoic and the Proterozoic, covering about two-thirds of geologic time in one lecture.

CD/HVA

From the material which we have donsidered so far I hope that you have formed a general idea as to what I have tried to give you, that is, the geologic pattern of the United States, a general idea regarding the surface forms, the land forms, the relation of the land forms to the underlying structures. In other words, ???, and the particular geologic age of the materials of those regions. For the next two evening sessions I am going to try to explain these things in chronological order, that is, I am going to try to explain the development of the physical features of the United States.

You realize that geologic time is subdivided into five ersa, the oldest of these eras is called the Archaeozoic, so we will begin with the consideration of the Archaeozoic rocks and records. What I am going to try to do in considering the development of the physiographic forms of the United States, is to tell you the facts and then try to make an interpretation for you which will create a general picture as to the conditions of the continent during that portion of geologic time. It would be hopeless to try to explain everything, not only for your point of view, but mine as well. Therefore, I am going to try to choose things which would be representative. Understand, they are to be selections. In no sense would the geologic record be complete. We hope to get a very, very general impression and from that starting point, you can go on if you are interested in the details.

One thing which you must know, of course, I should say, there are three things you must know. You must know the geographic distribution; you must know the rock character, which includes, of course, structure as well; and you must know the ages of the rocks considered. That will then be more or less the general outline which we will consider of each of the eras.

The Archaeozoic and Proterozoic are sometimes classed as the Pre-Cambrian, or in other words, the Pre-Paleozoic. You remember that geologic time is subdivided into these eras, Cenozoic, Messozoic, Paleozoic, Proterozoic and Archaeozoic, the youngest one being the Cenozoic and the Archaeozoic being the oldest Below

this here we would be in the cosmic stages, in the formation stages of the development of the earth. We, of course, have no records of the ? until the Archaeozoic, so we are going to begin an explanation of the record of the rocks of the Archaeozoic. I said sometimes those are referred to as the Pre-Cambrian. If you were to make the subdivisions you would remember that the oldest one in the Paleozoic is the Cambrian and the reocks before it are Pre-Cambrian or Pre-Paleozoic. These are the portions of the geologic time scale which we are going to consider this evening.

Let's begin with the Archaeozoic forst. Where do you find Archaeozoic rocks? Where are they exposed? There is one area here in the Adirondacks and the adjoining portion of eastern Ontario. If you want to, you can call that the St. Lawrence area, the St. Lawrence area. There is another one in the general vicinity north of Lake Superior; there are comparable formations also on the south side, but we are not going to pay any attention to that area. On the north you can speak of that if you want to as the Superior Area. Archaeozoic rocks are found in the Grand Canyon; some Archaeozoic rocks are also found in the Piedmont Plateau. Now there are other small areas in which Archaeozoic rocks are at the surface of the earth, but we are not going to bother with those.

Of these occurrences which I have mentioned, we know most about the Lake Superior area. We can make the best interpretation of Archaeozoic events from the Lake Superior formations. I will go ahead and speak concerning those and then fill in just a bit with regard to some of the other areas. In the Lake Superior region it is normally subdivided, I should not say normally, because it depends upon whom you are reading or who is teaching it. In the igneous series, well, that isn't a good classification either. In the upper series, it is spoken of a Laurentian and the lower series is quite generally referred to as the Keewatin. Both of these are represented in Minn. We will speak of the Minn. occurrences at a later time. If that represents the Minnesota or the Lake Superior

regions of the Archaeozoic formations. Then in some place there should be the oldest known rock on the N. A. continent, the oldest known rock on the N. A. continent. This one is intrusive, therfore it cannot be this rock, because by the Law of Intrusion, the intruding rock is always younger than the rock which it intrudes. The oldest known rock in the N. A. continent then, must lie in this part some place.

If we were to examine some of the ??? as we find them, we would find that what is called the Keewatin may be further subdivided in Minn. It consists of two subdivisions, called the Soudan and the Ely formations. There is another one which is sometimes used, but it has less and less of a geologic ? as more and more work is done. It is called the Koochiching. Now these are names and of course they mean little to you. Let's try to explain the names as we go along ans we will try to realize why the names were applied. The Koochiching, is, of course, an Indian name. We use it for a county in Minnesota. It refers to a portion of the boundary area between Minnesota and Canada. Most of the geologic names are from geographical localities. The Koochiching consists of schist at the present time. They are calcareous quartzose schists. They occur primarily on the north side of Rainy Lake I say the north side because Minnesota geologists do not recognize the Koochiching, so when you come to a boundary as far as names of formations are concerned, they usually are different. (Interruption. Question: You say it consists of these various kinds of formations, the rocks at the present time? Why not at all times? Answer: It has been changed from something. Previously it was originally something else and its character has now been changed.)

The Ely formation is, of course, named from Ely, Minnesota. As a formation it consists normally of green rocks, many of which are characterized by elipsoidal structures. Cross sections, that is, in a horizontal or vertical or any other plane will show the rocks to be composed of masses such as this, elipsoids, and of course, the solid form is called elipsoidal. It is also referred to as pillow structure. Associated with these green elipsoidal masses there are also layers composed of

erupted volcanic fragments. Only very very sparingly do we have anything which might represent a sediment. There are very few. The Minnesota geologist would classify the Koochiching as one of the representative layers, in Minnesota, represented by the Keewatin. They say the Koochiching is a sedimentary portion in the base of the Keewatin.

Let's go on to the Soudan. The Soudan is, of course, the formation is named for the town of Soudan on the Vermillion Range. It is interesting perhaps to know that the town there got its name as a result of the time keeper's request. After the mine had been established, ??? in the spring when the order went out for supplies, he requested a thermometer with zero at the top so he could find out how cold it got ???. There the rock formation is justt about as hot as we would be likely to have it. It is brilliant red banded, some of the bands, bright red and some of them bluish black. It is a rock which is ca led jasper. It is entirely chert or flint which has been stained red or discolored if you want to call it that. It is stained that way by hematite which is the brightest red material which we use in the coloring of rouge and lipstick. There are layers of this red material interbedded with blues and blacks. (Interruption. Question: How thick are the layers. Answer: Varying thicknesses. In some places the hematite, it gets about so thick and in other places it is about as thin as paper.)

These rocks are intruded in ne Minnesota by granite to which the name Laurentian has been given. They are very conspicuous granites, very coarse grained. They have in them very large grains of quartz which virtually stand out as knobs and are sometimes spoken of as quartz eyes. It is a very unusual characteristic and can be used to distinguish the granite itself. (Interruption.)

These are the ? of the Archaeozoic era in Minnesota. We might stop here for a little bit and rather survey it and get it all together. It is interesting at least to me to know that the Koochiching which is the oldest known formation at the surface of the North American continent, was originally a sediment. It is an example of the Law of Uniformity, that the oldest known rock formation was the result of normal processes of erosion and deposition. I said that it was a calcareous

quartzose schist. Calcareous means that it contains $CaCO_3$ and quartz means that it contains silica or quartz and since it is a schist, it must have contained mica whichis AlSi? It perhaps won't help you any if I write it out. This was originally ls; this was perhaps originally sand or ss and this was perhaps originally clay or shale. The deposition of the Koochiching, therefore, records the products of decomposition and disintegration, for these materials are the products of such processes today and the oldest known rock was formed by the same processes which are acting on the surfacd of the earth today. Now I imagine that the next logical question would be: If these are the ? material, then what was the source of the materials for the Koochiching? The only answer to that is that we do not know. There is nothing older so far known, nothing older than the Koochiching. Now it is also logical to ask: Well, wasn't the Koochiching deposited on older rocks? The older rocks have since been destroyed, not by magic, but they perhaps have been assimilated by younger intrusive rocks. The older rocks have since been involved in a process which has resulted in its disappearance from the ? that area from the Rainy Lake district. It may be covered up boy some of the other formations, but it is not exposed in this area.

Now with regard to the Ely formation, I spole of those elipsoidal characteristics. It is believed that such structures are formed as a result of submarine lava flows. The lavas may actually have flowed out underneath the sea under an area of water or it may have poured out on the land and then have flowed into a body of water. Today in Hawaiian volcanoes, where we have lava flows which reach the sea, the material moves in ? and it goes out there; the edge ??? and it in turn becomes crusted. More materials ??? and so the flow goes forward in rolls. These elipsoids are more or less the result of the crustification of the adjoining edge. The lava flow then does not move forward as a wall and we therefore have these masses breaking out into these elipsoidal units. The best example I can think of is the testing of sugar solutions in water when making frosting or candy. A drop of the solution is dropped into a vessel of water. The surface all around the drop cools

on the outside as it falls to the bottom of the cup and tends to flatten out when it reaches the bottom. Now the same process may have happened in the formation of the Ely formation. This is commonly called the Ely greenstone. (Interruption. Question: How big are these elipsoids? Answer: Well, all sizes from several inches up to 23 feet. That is the length, and the diameter is about one-fourth of that.) Now greenstone is one of the numerous geologic thrash piles. That is, when you do not know what to ca l it, ???. Greenstone is such a term. It is green, so that word is perfectly all right and it is stone so that word is perfectly all right, and the two words together are all right, but it actually means metamorphism whose original equivalent is uncertain.

Now with regard to the elipsoids. We are rather certain about the origin, but there are other materials in the Ely formation of which they are not too certain of the origin. Some of these are spoken of as tuffs. Tuffs are layers composed of volcanic fragments. In other words, they are a sedimentary rock composed of volcanic materials. Explosive volcanoes blew the materials into the air and then they settled and formed layers so in the Ely formation we have a record of both quiet and explosive volcanic action. The flows are the quiet action and the tuffs the explosive volcanic action. The accumulation of such materials as these indicates an area of submergence. The sediments were accumulated; they accumulated in a submerged area, otherwise we would not have ls. The elipsoids of the Ely formation also indicated an area of submergence.

Now for the Soudan formation. It is not positively known what the environment was in which the Soudan accumulated. It is most probable, that it was a submerged area, because of the strata characteristics and furthermore because it contains a ? jasper, whose modern equivalent forms only in areas of submergence. The Soudan came into existence as a result of solutions heavily charged with silica and iron. Now whether those solutions came from normal processes of erosion from the surface or whether they were direct contributions from volcanic sources is not known, but because of the abundance of silica and iron it is probably similar to that which I have described. Each of these various subdivisions points to an area

of submergence. The characteristic structures indicate that during the Archaeozoic, an area of submergence must have existed.

Now let's leave this region and consider the St. Lawrence area. In the St. Lawrence area we find only two subdivisions of the rock, Laurentian and Grenville. The Grenville, of course, named for the Englishman who was associated with the early exploration in eastern Canada and the Laurentian from the occurrence along the St. Lawrence River. That's the origin of the two names. (Interruption. Question: Is it comparable to the Laurentian of Minnesota? Answer: ???)

The Grenville consists of metamorphic sediments which cannot be less than two miles in thickness and full half of that consists of marble, marble which was originally ls. Now that means that there was an area of submergence. Some of the other characteristics regarding the Grenville will come up at a later time. but we are interested in the abundance of ls. It represents, of course, the thickest accumulation of ls known on the North American contientn, if not in the world, one of the thickest accumulations. (Interruption. Question: What did you say the thickness was? Answer: ???)

The area of occurrence is here, the other region is in here. Have you the geography straight now? The Laurentian intrudes the rock of this area. Other intrusive rocks also called Laurentian are flound in ne Minnesota; they are both granites and are believed to be ? although as I said before, we cannot be sure. Throughout our consideration of these events we are going to find something which youymight as well get acquainted with at the present time and that is intense deformation and large igneous intrusions are contemporary. I will repeat that, intense deformation, both with regard to geography and geological time, that is, intense deformation and large igneous intrusions are contemporary. Now which is the cause and which the effect? It is not known. That is, we are not sure whether the intrusion produced the deformation, or as a result of the deformation, igneous rocks were ?. But the two of them today occur in the same areas at approximately the same geological time.

If we were to examine the geological maps or field experiments? we would

find that the rocks uniformly trend east, not exactly, but about N70°E. So uniform are they that you would hardly need a compass in these areas. You could just take a look at the edge of the rocks and those edges would trend in a N70°E direction. (Interruption. Question: I want to get those two areas again. Answer: ???) (Interruption. Question: Is that area in Minnesota along the Rainy River? Answer: ???) (Interruption. Question: They wouldn't be exposed along that river then? Answer: ???) Now this trend of which I have spoken is referred to as the strike of the rocks, in other words, the trend of the rocks. (Interruption. Question: Is that true in both areas? Answer: ???) That's the strike of the formations, the axes of the folds, also trend N70°E, and the strike of the faults also trend N70°E. What does it mean? It is interpreted that these things represent the roots of an ancient mountain range. These are the grain, we might say the geological grain, much as you would have grain in wood. At the present time, the surface is worn down to a relatively level surface and with the formula for geologic structure, the geologist can restore some such observations that a mountain range once existed in this area.

Now we know that mountain ranges normally result from the destruction of troughs in which sediments have accumulated. We speak of such troughs as geosynclines. Now this is, of course, inference from now on. We know these various things. It is inferred that there existed in Archaeozoic time a trough which at least extended from Rainy Lake east far enough to include this area of the Adirondacks and se Ontario. This trough had sides which spread toward the east, so we had a trough submerged as indicated by my hands. It was a trough like that  whose axis was N70°E. Neat the western end where the sides converged, we had predominantly the deposition of clastic materials, the product of disintegration. Farther east, the land areas were a greater distance from the edge, and so here we have the formation of the Grenville and therefore abundant ls.

Now this conception is like the railroad schedules, subject to change without notice. Any time a geologist finds any additional information, the schedule will have to be changed, so much so that geology which was proposed about five years ago ??? anything more about it.

This is called the Quebec syncline. But you might as well ? the concept even though it has to be changed at a later time. Now the Quebec geosyncline was destroyed at the close of the ?. The close of each geologic era is marked by the destruction of a geosyncline. This one was evidently destroyed by the forces which were compression? and as these sides ??? the rocks were folded and faulted in lines which today indicate the general trend of the axes of that region. The strike of the formation, the strike of faulting, the area of formation will indicate the areas showing where the transformation took place here as I have indicated. With this deformation which destroyed the trough, came the Laurentian granite ? surrounding large blocks of sediments and incorporating them into the granite, a process which is called stoping. They incorporated them into themselves, melting them up and making igneous rocks of them. There lies the answer to what happened to the material below the Koochiching. The basement rocks on which these materials were deposited, have disappeared because of the intrusion of younger materials, so the oldest rocks of the Keewatin lie upon something younger than itself.

Remember the Law of Superposition and the Law of Intrusion. That's about all we can say in regard to the general appearance of the North American continent in Archaeozoic time. I hope you are not disappointed. I said there were some rocks in the Grand Canyon, but from there to Rainy Lake is rather a long distance for any ?. I also said there were some rocks in the Piedmont Plateau, but they are quite different from the rocks in the Adirondacks, so if you were able to strip off this younger material, we would find that extending to this region and underneath all of this, in other words, the foundation of all younger rocks must, of necessity, be Archaeozoic, because the Archaeozoic was the oldest.

According again to our present concepts of historical geology, when, as more and more information is gained, of course, our concepts will have to be changed. Any questions? (Interruption. Question: According to that idea then, it might be possible for Archaeozoic or Pre-Archaeozoic material to be there? Answer: It may cover this whole region in here, in which case, we would have to have still another

subdivision of geologic time.) (Interuption. Question: There might be material comparable to the Laurentian granites elsewhere then? Answer: ???) By the way, the destruction of the Quebec geosyncline is referred to as the Laurentian Revolution. The destruction of geosynclines will always be called revolutions. (Interruption. Question: What about the rocks along the North Shore, are they Laurentian? Answer: ???) (Interruption: Question: What is meant by the Canadian Shield, is that both Archaeozoic and Proterozoic or what? Answer: ???). While I think of it I will get some of these rocks from Minnesota and let you see what they are.

This is one of the elipsoids of which I spoke. You can see the eliptical cross section. Many of them are more perfect than this one. All cross sections would be eliptical. The back part of this tends to be rounded off, but it has been broken. This is some of the Soudan Iron formation. You can see the black and blue and red bands in it. The black is the ? and the bluish red is hematite. This is a mass of hematite; this is what they mine. Don't let this one drop on your toes. Any questions before we go on to the Proterozoic?

Perhaps you might be interested with a note here in regard to the Vermillion Range. The Vermillion Range is made up of an ore body or ore bodies which are the Soudan formation as ? in the Ely Greenstone. The Vermillion Range was visited in 1878 and again in 1880. In 1878, Prof. ? from Hamilton College in New York ? this for a group of financiers and turned in a favorable report and two years later they began to verify this report and they began to acquire property in the Vermillion Range. The first ore was shipped in 1884. The ore rax was 1¢ a ton. You might be interested in that. ??? 17,000 acres acquired for $41,000.00. They did such a good job that no extensions of the iron range have ever been found. It gives you some idea of the thoroughness of their work. The same man passed over the eastern end of the Meaaabi Range and of course, turned in a negative report and he was, of course, justified in his report. The eastern end of the Messabi Range ??? and they went in by canoe.

Now we will go on to the Proterozoic. The distribution is agian important. It is quite simple and yet a little more difficult than that which we had for the

Archaeozoic. The Canadian occurrence lies north and east of Lake Huron. The Superior Upland is again an important area for Proterozoic rocks. The Grand Canyon will give us a little more information. Proterozoic rocks are also exposed in Glacier National Park. They are also present in the Blue Ridge. We will stay close to home with the Lake Superior Section an then go out from that. The subdivision of the Lake Superior section would be as follows: I am going to write them from the youngest to the oldest which would be upside down geologically, but it will be all right when you have them in your notebook then. Killarney, intrusive, Keweenawan series, Huronian series, Upper, Algoman intrusive, Lower Middle Huronian. Perhaps I had better stop to do some explaining. As I have written, Killarney is intrusive, then the Keweenawan series, the Huronian series, the Upper portion which is made up of, I guess I had better make an addition here, the Upper portion which is made up of the Virginia Slate, the Biwabik Iron formation and the Pokegama quartzite. Then the Algoman intrusive and the Lower Middle Huronian which is composed of the Knife Lake slates and the Ogishke conglomerate. Now I will try to describe the character and the geologic record which may be interpreted. T

The Ogishke conglomerate, as you can well suppose, it is an Indian name; it is taken from alake in ne Minnesota which means kingfisher. Along the shores of the lake there outcrops a conglomerate which means it is a cemented gravel. This conglomerate contains boulders of granite, a granite in which there are large quartz eyes. This conglomerate also contains boulders of greenstone; and it also contains boulders of the iron formation. I don't think it requires very much logic to interpret the source of the Ogishke conglomerate. It was derived from Archaeozoic rocks which were exposed. The significant thing or interesting thing is this: There are boulders of the Laurentian granite present in this old gravel pit.

Now granites solidify at great depths beneath the surface of the earth. Yet in otder to furnish boulders to the conglomerate, that mile or two of material above the granite must have been eroded, so between the Archaeozoic below and the beginning of the Proterozoic rock record, there must have been a very profound

interval of erosion, so much so that there has eroded a mile or two of sediments which were carried then into areas which as yet are not recognized. So far we do not know them. This is referred to, this type of formation, as a basal conglomerate. It is at the base of the beginning of the sedimentary cycle as the product of the various ??? a long period of erosion. It indicates further that the old Laurentian mountains were peneplaned. Thye were cut down until in this area we could have the spreading of a ? trough over conglomerate rocks of Archaeozoic age.

The Ogishke conglomerate was followed by the Knife Lake Slates. In northern Minnesota, you can walk across a mile of them and never repeat a formation. The slates are not typical of those which you would use for roofing or blackboards, but theybreak with sharp angles and edges. They do have a ringing sound when broken. The early explorers named the lake from the rocks that cut their canoes and shoes and the geologist turned around and named the formation from the lake. They are very sharp and if you skid down very many of these you will have to buy a new pair of boots. This is composed of fine granular material. Much of it was originally mud; part of it had resulted from erosion and part of it represents very fine-grained volcanic dust and ash. The thickness, as I said, is over one mile indicating deposition in an area of continued submergence. The deposition was interrupted by the Algoman intrusion . That is named for a Canadian ? . As I said before, diastrophism and intrusion are contemporaneous, so we find that these materials below here are deformed.

The Algoman granite was intruded and then another period of erosion set in, for upon the eroded edges of the Ogishke conglomerate and the Knife Lake Slates, there began the deposition for the Messabi Range, and so on the eroded edges of these two we had the deposition of the materials which are in the Messabi Range.

This is a geologic cross section which is taken from the Minnesota Geological State Map. The Ely greenstone is this area in here, intruded by the Laurentian granite and then on top of that, they just call them the Lower Huronian

slates here. Those were intruded by the Algoman granite and those rocks were here deposited on the eroded edges of the folded Lower Middle Huronian slates and the granite, so this granite exposed at the surface shows a profound period of erosion before the deposition of that series.

The Messabi Range series consist of three types of formations. We are interested only in one, that is the Biwabik formation. It is the iron formation. This here was originally a ss of course and is now a quartzite. The Indian name for iron is Biwabik. They named the formation and then they named the town after the formation. The Biwabik Iron formation, then. If it were translated, it would really be the iron iron formation. It is quite different from the Vermillion Range. That is a hard ore. They mine it by underground methods, shafts, and of course in the Messabi range, they do it like they are mining out here on the parade. They dig a hole. It is called a soft ore, mined by steam shovel. When they first discovered the Messabi Range, they thought they couldn't mine it because they couldn't sink a shaft, and that kept them from mining it that year ???. The Biwabik iron formation was originally a cherty iron carbonate, that is, a flinty iron carbonate. Now it is quite different at the present time because the silica and the carbonate have been removed and the iron has remained behind to be concentrated. It is spoken of as negative enrichment, enrichment, not by something being added, but by something being taken away, negative enrichment.

This sedimentary series adds nothing to the general picture of the conditions. It, of course, shows submergence. I have included it in here because of the local interest. If I were teaching geology somewhere else I might not even have talked about it, and for instance, being at Minnesota, I teach the hot water theory but if I were at Wisconsin, I would advocate a cold water theory, but personally, as far as I am concerned, I do think I believe a little more in the hot water origin.

This is the Huronian record. The following the Huronian, we have the deposition of rocks which are called the ~~Kewootin~~ Keweenawan series. It begins with the

pouring out of lava flows. These are the lavas which occur on the north and south shores of Lake Superior. (Interruption. Question: Was there an unconformity between the Upper Huronian and the Keweenawan? Answer: Not a conspicuous one.) These lava flows poured out on the surface until it has been estimated that 24,000 cubic ~~feet~~ miles of material was poured out. Such an area would be comparable to the Columbia Plateau.

It is believed the material came to the surface and passed through structure faults or fissures and then spread as a flood over the region. As the material was transferred from a magmatic chamber beneath the surface of the earth on the the surface, there would be a tendency to be a cavity; the flows tend to accumulate in an area above the cavity and there seems to be a compensation. The extreme weight of the surface material tends to collapse the chamber below it. ??? and the lavas are more or less horizontal, but go beneath the lake, Lake Superior, to form the lake basin. On the north they dip south and go beneath the lake and on the south they dip north and go beneath the lake so a trough is formed.

As the lava flows formed, the inclination? that you see here probably resulted from the collapse of that roof of that magmatic chamber. The bottom of the Keweenawan is lava flows, but as you get near the top, it is more sedimentary and on the top, you have almost a ss. I might say that the rocks at Taylors Falls are these Keweenawan lava flows.

The next rock in Minnesota was an intrusive. It is a dark colored rock. It is a gabbro and is spoken of as the Duluth Gabbro. The hills of Duluth are composed of this rock. In the area north and east of Lake Huron, is a region whidh is spoken of as the Killarney region, and that is where they get this name. There the intrusives are granite. It is believed that the granite intrusives of the Killarney district and the granite intrusives of northern Michigan and Wisconsin as well as the gabbro intrusives of northern Minnesota are all of the same geological age and all came from the same magmatic reservoir. There was also a separation of the materials. The intrusives began with the granite materials coming off and the last intrusive was the material which had settled at the bottom, the heavy rocks,

which came out here are now on the north shore. So much for the occurrences in the vicinity of Lake Superior. (Interruption.)

I think we have probably spent enough time on the Lake Superior region to convince you that there must have been an area of submergence here. If we were to go to the Grand Canyoh, here is where the Columbia River is, it is flowing in a series of schists, Archaeozoic in age; above them lies a tilted series of Proterozoic rocks in which we find such things as, for example, ls, and because of the thickness here up to 12,000 ft, it is believed that this Grand Canyon series is also indicative of an area of submergence. It is hard to imagine a series of two miles of sediments in other than a geologic ? when you have ls there.

In the rocks of Glacier National Park we have also an accumulation of Proterozoic material of even greater thickness in which there are ???. I speak also of the occurrences of rocks in the western part of the Piedmont Plateau and of the Blue Ridge, another area of submergence. First I spent quite considerable time on that which extended through the Lake Superior region and on into the next, an area north of Georgian? Bay. It extends at least that far east. To the southwest it extended down to the Grand Canyon area. This region was joined by another trough more or less north-south which went up into the region of Glacier National Park and another region over here in the vicinity of the Blue Ridge and the Piedmont areas.

These four areas were named as follows: This one is the Cordellaran. I guess I had better write horizontally. Cordellaran the name is. It is used for the mountainous region of the Americas. This was the Appalachian trough and this one is called the Ontario and this one the Sonoran. That was the general distribution of the lands and seas during the Proterozoic. These are the areas in which the sediments have accumulated.

Now that I have you convinced of that, In Indiana they drilled a well 4000 feet deep and they drilled into Proterozoic ss. On the basis of the previous information those are the areas of submergence for the Proterozoic. I think you will realiz8 the geologic evidence for them. The Lake Superior region would be in here

on the north side of the Ontario geosyncline. The Grand Canyon would be here, then Glacier National Park in here and of course the Piedmont and the Blue Ridge.

You you come to the ? of the Proterozoic; it was characterized by intrusion. We have learned that ??? I have said that geologic diastrophism was accompanied by mountain making. The area of submergence became on of emergence and in place of submergence there were mountainous folds which are traced by means of underground structures even into this portion of Kansas and Oklahoma. Under all this material these mountain folds are found and then they turn and go ne in a direction like this. The range is indicated in the same way as previously. The strike of the formation, the axes of the folds and the strike of the faults.

These have been called the Killarney mountains or the lost mountains of Wisconsin. The Proterozoic rocks of the Grand Canyon region are also deformed. In this region there was some deformation which had to do with the shifting of the trough forming like this. This period of deformation, closing the Proterozoic, is often referred to as the Grand Canyon-Penokee Revolution. Penokee from this district on the Wisconsin-Michigan boundary line where I have erased these ?. The Grand Canyon deformation which took place in the Sonoran trough and the Penokee in the Ontario trough ???. Any questions about this? (Interruption. Question: The Quebec geosyncline you said has a vast deposit of ls, which would indicate what? Answer: ???)

I know these won't be clear to you, but you can think about these things and what isn't clear to you, you can check with me next time. Next time I am going to cover the Paleazoic and this covers a lot of pages in your books, but you can be sure I am going to hit only the high spots.

CD/HVA

Some of you were asking about when you might expect a quiz. It will be at the conclusion of the part at which we are now, part 3. We will probably spend one evening on the Paleozoic, and one on the Messozoic and one on the Cenozoic, or I should say, we will probably spend one evening on the Messozoic and the Cenozoic together, and the following week we will have a quiz.

Are there any questions concerning the material which we have covered so far, that is the Pre-Cambrian or perhaps better, the Pre-Paleozoic? The next in this outline is what is called the Lapalian interval. Now that is different than the French mathematician and astronomre. The term Lapalian means gone or missing, gone or missing. It refers to the fact that wherever Paleozoic and Pre-Paleozoic rocks are found, there is always a gap in the sedimentary record between these two different ages. That is, as represented by the geologic record.

If we were to go over to Taylors Falls and go up on the bluffs near the school house, a road leading down past an exposure, there you would find, in that area you have lavas, the Keweenawan lava land, Proterozoic in age. Right on top of those lavas, there are boulders which themselves are composed of lavas, but we find that ? from these boulders the particles become smaller and then you get out here into a region of, a region of still finer grains, and so you are now here in a region of ss. Such a structure as that indicates an erosion interval, a period in which deposition ceased because these lavas here formed on the surface of the land. They were eroded into the profile which you see there and at a later time as the seas moved into that area, there was more and more that condition along the erosion surface. Such an erosion surface is spoken of as an unconformity. That is one of the examples of a geologic record of this group.

If we were to go to the Black Hills, let us say, there at Deadwood, South Dakota, on the south side of an exposure there we would find the badly altered rocks changed into mica schists. Over the top of that we would find

a conglomerate or ancient gravel layer composed of quartz pebbles and from there on up until we get to finer material, first a ss and then sh and there occurs a layer of ls.

Here again is marked an erosion surface, an unconformity, the geologic record of a gap. (Interruption. Question: What would that be following the straight line there? Answer: Mica schist, a metamorphosed rock. It is a solid piece, yes. Question: What is above the ss and sh and ls? Answer: ???)

If we were to go to the Grand Canyon, again we would find a basement rock composed of these crumbled rocks. We would find above that a tilted series and above that a series which is horizontal, the surface of which I am marking at the present time. We could repeat these examples indefinitely, not only for the United States, but for the rest of the continents, all the continents. Wherever we have post Paleozoic rocks in contact with pre-Paleozoic rocks, they are always separated by an unconformity.

What does it mean? Those are the geologic facts. Now I want to try to interpret that record. It indicates that at the close of the Proterozoic, the continents were involved in diastrophism which resulted in all of the basins of deposition becoming emergent. On the basis of that, then, all the basins of deposition became emergent, and therefore those areas were subject to erosion and we find that unconformity or gap existing between the pre-Paleozoic and the post-Paleozoic rocks. In other words, up to the present time, there are no rocks known which represent a transition from pre-Paleozoic to Paleozoic time.

Now in all this I am trying to create pictures as to what would happen to the North American continent. We should picture the North American continent during this interval as being larger, more emergent that at any other time so far recorded. All of the geosynclines were dry, all of the seas of the continent, that is, in the central part of the continent, were gone, but insofar as we have no other records, it was an emergent North America. It was being eroded to be sure, but the materials were being carried beyond the present shore line. The continent was in an uplifted condition, more uplifted than at the present time, no basins

of deposition.

I would like you to carry that concept then as to the Lapalian Interval. Now after I have you fully convinced that that is the truth, I will tell you that in Minnesota we have a series of rocks ??? but until they decide, the concept will still hold, the concept is still worth while as an intorduction. That is true or was true for all the continents, not only the North American continent, but for all the continents.

The close of the Paleozoic resulted in wide spread diastrophism, and the continents were subject to emergence and erosion. The next is the introduction to the Paleozoic. Consideration of the Paleozoic is going to involve such a large geographical area that it is impossible to treat it as we have the previous periods of geologic time. I have to give you the shock gradually. Let's begin with the general distribution of the Paleozoic formations. Let's learn, however, a little bit about the geography concerning the Paleozoic rocks.

On the geologic map of the United States there are certain areas which stand out as exposing large areas large amounts of Paleozoic rocks. For the most part, they are represented on here in blues, greys and whatever color you want to call this in here, so we will find that Paleozoic rocks are distributed from the Blue Rigge of the Appalachian Mountain system thnoggh the Central Lowlands, the Inerhor Highlands, but of course, excluding the Superior Highland which we considered last time. Then they occur along the foothills of the ranges in the Southern and Middle Rockies and in scattered exposures in the Northern Rockies and broadly exposed through the Colorado Plateau, and scattered exposures through the ne Basin and Range Country. From there on west, exposures are again scattered So. geologically speaking, let's think of the Paleozoic rocks as not occurring east of the Blue Ridge and as occurring only in scattered areas west of the Rocky Mountains and the Colorado Plateau. That still gives us quite a large portion of the United States covered by Paleozoic rocks.

If you have been reading in your books, and I hope you find a little time to read occasionally, you have found that the general character of the Paleozoic

rocks seems to be an endless succession of ss sh and ls and the topic here is the general lithology of the group which means study of the rock characteristics. It refers to what I have described whether they are marine or non-marine, whether they refer to clastic or non-clastic. If, in this endless succession we try to interpret the condition which it indicates, both you and I would be hopelessly lost.

Wherever there is no particular ? or exceptional conditions, indicated that is, where there is a series of ls, ss, and sh which are in no way unusual, we are going to refer to those as a normal marine sequence. When I use that term or use those words, it means, of course, that the area was submerged, that it was receiving sediments, but there was nothing exceptional about it or that condition of sedimentation, nothing unusual which we should attempt to remember. (Interruption. Question: Do you have to follow that order necessarily? Answer: No, just as long as the three of them are there, not that order.) Yet while we are recognizing that there is this normal sequence, we are going to choose or select certain formations which would indicate what the conditions of the continent was.

I have adopted this system of choosing formation principally because it emphasizes the interpretation. It probably would be just as easy for me to go ahead and tell you what the land and sea distribution was for the Paleozoic, but you would not know the ? on which it was based, you would not know how the interpretation was based, so I will try to show you can work out what the physical conditions of the continent were. We are going to recognize a normal marine sequence, and yet we are going to ? the variation from this condition to indicate the abnormal cases and consider them in the line of the facts which are given us and the interpretation which can be made from those facts.

If, for example, a ss is red in color, that is significant. Why? Because red color means hematite, an iron oxide, it means an iron oxide in which there is no water. If water were present, instead of the ss being red, it would be yellow or brown indicating that the color was produced by the iron compound known as limonite, a compound, I don't care if you remember these formulas, but a compound

in which there is water. It is under very unusual conditions that no ? would be absent in any basin of deposition. If that basin is ??? arid climate, water is going to be absent and the ss is going to be red. If the deposition nasin had sufficient water, the ss would be yellow. If the ss is crossbedded, it indicated an entirely different condition, sometimes spoken of as false bedding. Such a structure results from the deposition of sand on the front of a delta, or on the front of a sand dune. It's when we find cross-bedded ss that we begin to get suspicious and look for other characteristics which might intidate whether this was a delta or a desert, and there are ways in which we can determine that. If we had a rock in which there were mud cracks, it indicates that at the time this rock was being deposited, at least once it was exposed to the drying action of the sun, that there was more or less of a mud bottom, probably along a shor zone, and as it dried up, the cracks formed. This one came from Pipestone. Here there is another one from Pipestone in which there are ripple marks. There are waves in the ss. Those marks are caused by waves driving along the shallow water zone at the time this ss was being deposited. So we have a number of different characteristics we can use. Some exceptions may be distribution or it may be thickness. Well, we will have plenty of that before the evening is over.

If we were able to have a magic carpet as well as a magic drill, let us say, and we wanted to find out some information about the United States in Paleozoic time, and we started in Minneapolis and started to drill down through the Paleozoic series, you would find that in less than 1,000 feet you would be through the Paleozoic rocks. If we went further down the Mississippi Valley, you would find that the thickness increases; it, however, would never exceed four digits. In other words it would never get over ? thousand feet. That is true for the Paleozoic through the ?. We would find that characteristic all through the Central Lowland. If we went to the Appalachian Mountains and tried that, what do you thick the thickness of sediments would be, Paleozoic in age? 30,000 feet, 30,000 feet of sediments in the Appalachian Mountains. In other words, you would have to go down six miles before you come to Pre-Paleozoic rocks. If you tried it in certain regions in the west

I could pick out any one for you, you would again find thicknesses measured in terms of five digits, and yet all of those sediments or, for the most part, the majority of them, have accumulated in water never deeper than 600 feet.

Now we have some physiographic geology, certain ideas concerning these basins of deposition. In those areas where we have great thicknesses of sediments, it indicates that they have accumulated under shallow water conditions. We speak of those areas as geosynclines. I spoke of the geosynclines, for example, of the Proterozoic last time, but that is nore or less an introduction. We want to consider what might be called continental structure.

This applies particularly to Paleozoic, although it is not necessarily restricted entirely to Paleozoic. Every continent, and the North American continent is no exception, is made up of what might be called a nuclear portion. It represents that portion of the continent in which pre-Paleozoic rocks predominate. If you don't want to use that term, we will call it the old rock platform. These old rock platforms in every continent consist of pre-Paleozoic rocks. They have all been badly deformed so the rocks are badly crippled and broken. We find that in addition to, I should say we find that the old rock platform may be subdivided, that there is an emergent portion which throughout geologic time seems to have remained more or less above sea level, not continually so, but its general tendency has been to remain above sea level.

You likewise find a portion whose general history through a large portion of geologic time has been submerged. It has been subjected to floods and therefore it has on its surface, marine deposition. Lying at the borders, excuse me, I will mkae this a different outline. If we have a central portion, then it is obvious that we must have a border portion to the continent. These are more or less found in the present border area of the continent and they may likewise be subdivided into emergent areas and submergent areas.

With regard to the North American continent I am not going to stop to draw a map; you know the North American continent, but you would find that the region which includes the Canadian Shield, about the northern one-fourth of the North American continent, the area over all this region which is pink in here, represents the emergent portion of the old rock platform. It is now spoken of as the Shield, largely because it ??? liek the surface of the shield. With regard to the North American continent, since it lies in Canada, is spoken of as the Canadian Shield.

The submergent portion of the continental border areas lie along the margins of this shield area. Again I am applying it to the North American continent, but in general, it is true for the other areas. These submergent areas are spoken of as geosynclines. They are areas which were periodically or continuously depressed, and thus allowed the accumulation of great thicknesses of sediments.

Seaward from these geosynclines there were areas which were periodically or continuously elevated, thus furnishing sediments to the adjacent troughs. These are spoken of as border lands. Now let's, well, now the details of that continental pattern are going to change during Paleozoic time. It is quite obvious that they should and yet all the time we should have this general pattern in mind for the North American continent.

This region here which I haven't named is the submergent portion of the old rock platform. Any questions about the continental structure? (Interruption. Question: Were the materials from the borderlands constantly going into the geosynclines? Answer: ???) (Interruption. Question: Are those geosynclines deeper than the middle portion there? Answer: ???) (Interruption: Where would the geosynclines be geographically? Answer: ???)

This is very much exaggerated on a vertical scale. That would be the general cross section. That would be the cross section in general. This would be the western geosyncline; this would be the eastern one; that would be the western borderland; that would be the eastern borderland; that would be Appalachia and this would be Cascadia. (Interruption. Question: The southern part of the Ozarks would

be an indication of what? Answer: ???) (Interruption. Question: The two troughs indicated by arrows are the geosynclines? Answer:???) (Interruption. Question: The sediments from the borderlands and Canadian Shield help to make up the Paleozoic formations? Answer: ???) These were the main source of materials because they were high. In this area relatively few materials were brought in. (Interruption: Question: To what extent would those glacial periods previous to the Quaternary/do they seem to be coming from the Shield area too? Answer: ???)

I think you have heard the statement before, diastrophism is the ultimate basis for the subdivision of all geologic time. Now we have seen how mountain making diastrophism closed the Proterozoic and also closed the Archaeozoic. With regard to the Paleozoic, there is going to be continued uplift, that is epeirogenetic diastrophism, which is going to separate period from period. Remember the era is the largest period of geologic time and they are separated by orogenetic diastrophism. The periods are the shorter subdivisions and they are separated by epeirogenetic diastrophism. Let's postulate and then I will try to prove it to you.

At the beginning of the Paleozoic or during the Lapalian Interval, that represents the profile of the North American continent, and then sea level was so low that the thoughs were not flooded. The continent was entirely emergent. Now let it be subjected to epeirogenetic diastrophism, and the continent begins to decrease in elevation, and as it begins to fall, the sea level rises. Now remember this is not a barracks excluding the sea. As the sea level rises, then, the trough becomes flooded, but after the submergence, both troughs contain water. Successive or continued submergence results in a flood from borderland to borderland. That ought to be the middle of a period then. That should be the middle of a period. As the continent begins to be uplifted then, the waters recede. They go back so that they are just in the troughs, and after continued or with continued uplift, they may be completely withdrawn from the continent and we have the end of a Paleozoic period. The next period the same sequence would be repeated, a cycle then, a cycle in which the continent is emergent between the periods and during the passage of a period, the continent becomes more and more submergent and then with uplift

of the continent the seaa retreat and the continent becomes emergent.

I am trying to introduce some system to all these changes. That is going to be then what we call the paleographical cycle. I don't know whether that is going to save any words or not. Paleographic then, paleo means old and graphic means land and sea distribution. So we have a cycle in these changes in land and sea distribution which I am postulating. Now follow the pattern which I have given you. Of course this inferred cycle is as yet a postulation. You have no evidence for it. I think you have evidence for this ? of what the sediments were and where the thick sediments were and where there was absence of sedimentation. You just have to accept my word for the paleographic cycle until I ???. Let's make another postulation or inference.

If a Paleographic cycle is present, what would we expect to find in the middle of the sediments which were deposited. When the seas were such that this represents a submergent condition of the continent, the borderlands were contributing sediments to those troughs. There was no sedimentation in the central part of the continent. We would than expect to find ??? and we would expect them to be ss and sh. They are close to the source of sedimentation, therefore, the materials in the trough should largely reflect the proximity to such areas . If now we change the picture to maximum submergence, the troughs are still going to carry on their clastic deposition, but the non clastic material is going to spread out over the central part of the continent. Materials will be coming from the borderlands and Shield, but being removed, the ss and sh will be in least abundance and there will be more ls.

In any Paleozoic period represented by this cycle we should expect to find evidence of it as existing as a relatively thin widespread non-clastic formation in the middle of the period. Then as the period begins to close, maximum submergent conditions pas into one in which the troughs only are occupied. Then we again return to an emergent continent. (Interruption. Question: During each one of these intervals, do these geosynclines drop a little more so this nice balance can be maintained? Answer: ???) (Interruption. Question: Does the bottom of the geosyncline falling down, maintain the rule if you push a string down in the middle, the sides come

closer together. Does that push Cascadia and Appalachia closer together or what? Answer: That is the theory of isostacy for which there is some basis of foundation, but it is not proven.) (Interruption. Question: Does that cycle take place then in every era in only the Paleozoic or what? Answer: ???) Any questions, other questions about this introduction? (Interruption. Question: Did this occur before the ide age? Answer: ???) (Interruption. Question: I don't quite understand the distribution of the sediments. Answer: ???) Any other questions? (Interruption. Question: Is that the best geologic record for those three or four eras or is that postulation? Answer: ???)

I will try to show you that there are geologic evidences, but so far this is just a postulation. (Discussion of sediments in the ocean basin and on the continental shelves.) Other questions? (Interruption. Question: That's pretty much like building a road on the side of a peat bog, the marle comes up so no ? from the marle can ? over? Answer: ???)

Well, I am going to cover the Paleozoic in terms of this paleographic cycle, and what I am going to say is going to be abbreviated considerably. There are pages and pages in the text books, and when you finish with them, you won't have a very concrete idea of it all. In terms of this paleographic cycle, if it conforms to the postulated condition, if it is a widespread ls approximately in the middle , then we are going to say this represents an ideal period. With that in mind, let's begin the classification of the Paleozoic periods based on geologic evidence.

The first period is the Cambrian. Where are we going to put it? With the ideal periods or with the non ideal periods? We have to go to the geologic record. These rocks which I had on the blackboard ? ? the lava flows of Taylors Falls are upper ~~Cambrian~~ Keweenawan in age. They constitute the ~~Upper Cambrian~~ Croixan Series, named for the type exposure along the St. Croix River. Of the materials included in the St. Croix series, they are marine sediments, now I didn't say normal marine sediments, I said they were marine sediments. Out of these three, ss, sh, and ls, which occur most abundantly in the St. Croix series? Dresbach, Franconia, St. Lawrence and

Jordan, those are the four formations. Only one of those is ls and that has a lot of sand in it. Abundant ss and sh in the St. Croix series. That means that the area contributing sediments to this region was relatively high. The streams were flowing with sufficient velocity to transport the sand and mud particles, and the clastic materials lie up against the edge of the ???. On the basis of that would you say it was ideal or non-ideal, the period I mean. (Interruption. Question: I don't know what you mean by ideal or nonideal periods? Answer: ???) (Interruption. Question: If you had this at DesMoines, Iowa, couldn't it then be ideal? Answer: ???)

You recall the physiographic conditions of the continent in the Lapalian Interval. The continent was emergent. Now, as the Cambrian period begins, the water invades the geosynclines; the borderlands are high; they contribute clastic materials into the troughs and after it spreads into the central part of the continent.. What is this region? The Superior Highland you recall. ??? the region of the Killarney Mountains and it is quite probable that in terms of Paleozoic seas, there were still mountain ranges bordering on the edge of that sea, the Killarney Mountains were not eroded completely and were contributing sediments to that region.

I will show you that this isn't something I have thought up in a night mare. This is the interpretation of Schuchert of Yale, who perhaps knows more about the paleophysiographic conditions of the North American continent than any other man. Paleophysiographic means ancient land forms. This is Cambrian. You will notice the troughs are the only part of the continent flooded. Here is the Cordellaran geosyncline, and here is the Appalachian geosyncline split into two at its northern end. Here are the Killarney Mountains which he believed were present as land forms in the Cambrian. They were the result of diastrophism at the close of the Proterozoic and were still present in the Cambrian, so that is pretty good evidence. This is, of course, interpretation. There was no one here to draw that map. It is based entirely on geologic interpretation.

One other thing yet regarding this Cambrian series of the St. Croix. The St. Croix series is definitely Cambrian in age. Maximum submergence of the continent in Cambrian time came in the upper part, not in the middle. Why? Again

probably related to this uplifted condition of the continent. The continent was still of a sufficiently elevated character so maximum submergence did not cross the continent, so there are two things which don't permit the inclusion of the Cambrian as an ideal period. ??? it is sometimes spoken os as a delayed flood. It was behind schedule so far as the Cambrian is concerned. That is the important thing. about the Cambrian. Let's not say any more about it and go on to the Ordovician.

If you think of the Ordovician rocks represented in Minnesota, the closest one to us would be straight down on the river bank where there is exposed the Platteville. ls ss and sh follow it. If you examine Ordovician rocks, we find that they are just the reverse of the Cambrian. They are dominantly non-clastic. Ls occurs in abundance. They may not necessarily all be ls. As you know, Minnesota has abundant dolomite which you may think of as magnesium bearing ls. That results in the same way. This predominance of the non-clastic material is just as significant to us as was the reverse relationship in the Cambrian. The lw which you find out on the river bank is geologic evidence of maximum submergence of the middle Ordovician. When I mention of the North American continent, how much of it? About two-thirds of the present North American continent was submerged at the time of this maximum flood. (Interruption. Question: Why does it represent a maximum flood? Answer: ???) (Interruption. Question: Which seems to have been the center of the Ordovician or closer to the center, the Shakopee of the Platteville? Answer: ???. Question: What I am getting at, the St. Peter ss between that is clastic isn't it? What does it indicate? Answer: ???).

The St. Peter ss is ? elsewhere, would be found to be more or less something like that. Now here in Minnesota we call this ls the Platteville, named for a type location in Wisconsin, but generally speaking the widespread ls of Ordovician Age is the Trenton, not Trenton, New Jersey, we will have another one in New Jersey, but named from Trenton Falls, New York. The Trenton ls occurs east of the Blue Ridge, and we have no Paleozoic rocks east of the Blue Ridge, so none of these rocks are comparable to the Trenton ls, so I would suggest that in order to keep an example in mind of this maximum flood of the North American Continent during

Paleozoic time, you remember the Trenton ls and the correlated ls elsewhere which happens to be Platteville in Minnesota. Why did they choose the Trenton? Because many names are apread from the east to the west, and the heathens in this section of the land have to accept the names proposed for eastern areas. The Ordovician then represents the first of our ideal periods. This flood of the middle Ordovician is the maximum flood during Paleozoic time.

Next the Silurian. The Silurian contains quite a variety of rocks which would be ? in here as a normal marine sequence. That is true of the Cambrian and Ordovician as well. After an examination of the Silurian rocks, we want to pay particular attention to the distribution and character. We would find that the water of the Niagara River dropped over a brink of ls of middle Silurian age, and if we traced out this formation or its ?, the ones with the same general age, we would find were also widely distributed. We would find that the North American continent was submerged to the extent of about 50%. About one-half of the continent was submerged during middle Siluruan time.

I will put down the names of the formations used for geologic evidence. The Trenton is the geologic evidence that the Silurian belongs to ??? because in the middle the continent was submerged, not as much as in the Ordovician, but enough so that we had widespread ls forming in that time. The close of the Silurian wasn't quite according to Hoyle, but we have in certain regions, some rocks known as the Salina series. They cover more or less of a boomerang or elbow shaped area, well in the central portion of Michigan and this area over in New York. In this region we find salt beds associated with a normal marine series. Now salt, we know, as a rock layer results from deposition in an area where there is concentration by evaporation. At the present time we have then, formation of salt deposits in the playa lakes. They exist in the west. We have deposition in the Great Salt Lake, of course, but it is not there as a rock layer. However, in such a region as found on the eastern side of the Caspian sea, we have a Bay in which salt is being deposited at the present time, so much so that it is one of the natural resources of the ? ?. The waters flow from the Caspian Sea into the Gulf and evaporate so rapidly that there is a constant

current from the bay into the gulf and ???. Now in order to have salt deposits of such a region, it is reasonable that we should postulate the existance of some such gulf or lagoon cut off arm of the sea which would ? such an area. It is usually referred to as a lagoon or basin of deposition which is periodically or continuously replenished from the ocean, and then as the water evaporates, you have a deposition of salt. There is then continued replenishment or continued or repeated deposition. There are times when streams from the surround areas continued to drop sand or mud, and so, for a time, we have the deposition of those materials, and that decreases and the salt was deposited again, and so we have a series of salt deposits and marine sediments. (Interruption. Question: Does that boomerang go into Lake Erie? Answer: ???)

Now in the case of the present Caspain which I have described, the evaporation rate is so high that the flow is constant. Where we have just a continent, it is subject to movements up and down. It is possible that salt water to such an area as this ??? tottered back and forth and if it did so, you would have alternate or intermittant ???. I am not saying that is true, but we will try to explain it later on.

Next the Devonian. If we were to examine the rock history of the Devonian, we would find again a ls occurring in the middle of the period. It represents about a 40% submergence of the North American continent. As I have said before, the amount of submergence is indicated by the present distribution. It is a ls as I have already described. Therefore the Devonian is also to be classed as one of these ideal periods. It so happens that it is the last. None of the others which we will consider will be classed in this group. Now the close of the Devonian like the close of the Silurian, was not entirely normal. Across New York there are sediments which are of the same geologic age and yet are quite different in the character. They are quite commonly spoken of as the Chemung-Catskill series. Of course named for the New York locality, the Catskill is on the east and of course is exposed in the Catskill Mountains. To the west we have the Chemung. Get these geologic relations straight. The Chemung is a marine sh, but the Catskill is a red ss, conglomerate and sh. We find that westward the Catskill is interfingered with

the Chemung. They are dovetailed. One lenses out between the other. Now that red color as well as some of the fossils which occur in the Catskill show it to be of non marine origin. The Chemung is definitely marine.

What does it mean? These materials were being deposited in the northern portion of the Appalachian geosyncline. The Catskill material is a delta or alluvial plain built out into the waters of the Appalachian geosyncline and the Chemung is the material which was deposited beyond the face of the delta, beyond the region where the iron could be oxidized. The deposition of a delta, the size of the Catskill delta implies a large source of sediments and of course that source of sediments could be only in one place. It was being deposited in this trough, therefore Appalachian must have been the source of those sediments.

That represents the contour lines which indicate the thickness of the sediments. Here in the black is the profile of it indicating that it gets thicker to the west, thinner to the east. That was the old shore line. Here it was 100 ft. thick, 100, 200, 300, 400, 500, 600, 700, 800 feet thick then grading back, 700, 600, 500, 400, 300, 200, and 100 feet thick again. Wells have been drilled and they know the thickness of it. This also is a restoration with regard to the conditions there. These streams are present today, streams which flow east.

At the time the delta was being formed, the streams were coming from Appalachia. Placed geographically it is se ? which represents the center of that delta, and from there the sediments get thinner. (Interruption. Question: What is the topographic expression of it now? Answer: ???) Now in order to have such a high accumulation as that Devonian delta, there is only one thing logically to postulate, and that is that Appalachia must have been rejuvenated, and as it was uplifted, the velocity of the streams was increased. They could carry more and they did carry more, and as a result of this periodic uplift of Appalachia, there began this delta. By the close of the Devonian the ??? that the waters were completely entrenched by the Appalachian geosyncline. That is Schuchert's interpretation of the geologic facts which I have given you.

Now this uplift of Appalachia was a diastrophic event; it involved ??? which is known as Acadia, in other words, New England and a portion of Canada, and it is spoken of as the Acadian disturbance. We are going to call this a disturbance and reserve the term revolution for ???. This is the Acadian district. It is actually, of course, represented by an unconformity between the Devonian rocks and younger rocks. The Acadian disturbance deformed rocks of Devonian and older ages and of course, it could not deform rocks which were not present yet, so when they came into existence an unconformable relationship resulted.

The next is the Mississippian. The Mississippian is not an ideal period because it had two floods. In other words, there were two extensive submergences, and if we are to abide by our ??? we would have to say that the Mississippian is really two periods, but the fossils do not substantiate it. The Mississipian had two floods. There are three formations which have three names, such as the Madison-Kinderhook-Ponoco. The Madison occurs in the Rocky Mountain region and it is a thick la, the Kinderhook occurs across the Central Lowland and is a thin ls and the Ponoco occurs in the Appalachian Mountains and is a thick ss. Coudl you relate that now to this condition of the continent?, The Madison ls being thick out here in the Rocky Mountain area, suggesting that Cascadia was not as high as it had been previously, so continued deposition gave us ls; the Kinderhook ls was thin because it was in the central part of the continent. The Appalachian, you remember, had just been uplifted, so strems which had just formed the delta, were bringing materials out here so we have the formation of the Ponoco ss. Therefore, we have three formations, this is ls, being thick; this is ls being thin, and this is thick ss, each of them definitely related to a physical condition of the continent.

Now the closing of the Mississippian is ? in the central part of the continent. That is just where the Missouri, and Ohio Rivers join the Mississippi by a series known as the Chester series. It is composed of alternating ls and ss. It begins with a ss and after that, they alternate to give us eight pairs or clastic and non clastic materials. The materials occur primarily in Missouri, Kentucky, and

Illinois. I always think of Edna Ferber's "Showboat" in connection with this. Kim, called Kim for Kentucky, Illinois and Missouri. ??? very unstable condition. You remember as a result of materials along a shoreline, the ss indicates shallow water conditions, the ls represents deeper water conditions. If these occur one on top of the other, it means the water has been shallow and then deep. In terms of changing geography, it means the shoreline has moved up on the continent and then moved back. In terms of sea level, it means the Continent was uplifted, and so it got to almost bouncing back and forth. It became so unstable that it actually wobbled back and forth between shallow and deet water deposition. (Interruption. Question: The ss is a result of what kind of deposition? Answer: ???)

Well, we have rum seven minuted over time and I haven't finished the Paleozoic, but I guess it will wait until we get back to it. If you haven't read it, there is a lot for you to read. Now we are through with the Mississippian, saying nothing, of course, about the fossils, nothing about the life during any one of these periods. Later on we will come back to these areas.

CD#HVA

During the last class meeting we had considered some of the changes which had taken place in the land and sea distribution during the Paleozoic. You remember that we had postulated certain conditions which we will call ideal periods and were attempting to classify the Paleozoic periods on the basis of conformity to this ideal condition. The Cambrian had not been classified as an ideal period because of a predominance of clastic materials as well as the fact that the flood come late in the period and also ??? clastic rocks formed in of the center of the continent. The Ordovician, Silurian and Devonian were ideal periods, each of them having a widespread ls, approximately at the middle of the period indicating widespread submergence. The Mississippian was not an ideal period because of two submergences and that was about where we closed.

The period following the Mississippian, that is known as the Pennsylvanian. The outstanding characteristic of the Pennsylvanian rocks could be very easily remembered by ~~really~~ recalling the principal economic product of the state for which the system is named. You think of the coal and that is the diagnostic characteristic of the Pennsylvanian series or I should say the Psnnsylvanian system throughout the eastern half of the continent. There are various formations which we can choose to represent this carboniferous character. The one you will find in your outline being emphasized in the Monongahela, the Monongehela series. I have chosen that one because it contains the largest sincle coal bed in the United States. The Pittsburgh ?, seam the largest individual coal layer in the United States.

Now the Monongehela series contains in addition to the coal, normal marine sediments. You remember those are sandstones, limestones and shales. The normal marine sediments indicate submergence; that's quite obvious. The thing which is diagnostic is the interpretation of the coal horizons. This can be best brought out by telling you more of the details of one of the series of coal layers. This information has been worked out by the Geological Survey of the State of Illinois where they have studied it most intensively, It applies to other regions as well.

If we begin with the series that is relatively complete, we would begin with the ss, followed by a sandy sh, a fresh water ls, then under clay, coal, black shale, calcareous shale, ls, and sh and then an unconformity at the top and bottom of the series. These formations are normal associates of a coal seam. They would normally be related to coal in the order in which I have listed them here. Now such repeated associations mean that there must be a reoccurrence of the physical conditions in which the coal is the diagnostic or characteristic rock layer.

Now let's see if we can postulate what would be the conditions. The ~~matter~~ nature of ss, that begins the series indicating that it is non-marine, non-marine. Evidently then, the conditions of deposition are somewhat similar to an alluvial plain, because these are going to cover large areas and you would have to consider it in terms of alluvial deposition. Then the condition of elevation is changed so the streams have decreased ~~gradually~~ gradients, have decreased ~~gradually~~ velocities. They can no longer bring just sand, but they bring mud with the sand. In other words, the region is one of less relief and therefore the velocity of the streams is lessened and the deposition is finer. Now finally this decreases and the relief changes so greatly that the streams can bring in only material in dissolved conditions and then in the basin we have ls; it gives rise to fresh water ls lenses which are discontinuous ??? they are just local. (Interruption. Question: Is that the same as the marle that we have today? Answer: Somewhat similar to it, yes.) The area has now become so low, so poorly drained that we have what is called then, a poorly drained soil profile. Leaching has been so great that the clay which was called underclay is gone under thorough weathering. ~~???~~. I said it was leached and oxidized. That means that the iron minerals have been taken out; it means that the calcareous content has been removed and you have left a material similar to kaolin, something like kaoiln, highly ~~???~~ refractory i.e., heat resistant. A part of this leaching was probably done by organic acids from vegetation, contributed by organic ~~grounds~~.

You realize that such extensive vegetation gave rise to swamp lands. I don't mean now, tropical vegetation, not necessarily tropical vegetation for in

tropical areas, decay is too rapid. The material would be decayed before it would be buried, and thus you would not have favorable conditions for coal accumulation.

So far this has been all with the changing relief of the land. First of all, alluvial plain, then basins, then swamp soil and then swamp vegetation. The area continues to decrease in elevation with the result that the sea begins to move over the swamp. In other words, the sea moves in over them, the carboniferous material becomes a part of the mud, so you have a black or carbonaceous shale. As the area continues to be submerged, the shoreline moves in and you are farther away from the source of the sediments and you have calcareous shale. Finally the region is so thoroughly submerged that you have the clearing of the waters, and ~~marine,~~ marine ls is deposited. The uplift starts and it shifts back to the mud deposition and then the area becomes emergent. This is spoken of as a coal cycle. Repeated occurrence of this cycle justifies its acceptance.

Time and again in the study of Illinois coal basins, they find such a sequence. Erosion may stop any place down in the coal cycle. The cycle may be complete or incomplete. Occasionally, for example, you may find one coal seam on top of the other indicating that this portion did not develop and you have the succession of one coal after the other. Think of this as an ideal condition, all parts of which may or may not be present.

Now the coal of Pennsylvanian age is found largely in these areas. The Appalachian Plateaus, usually known as the Appalachian Coal Field; Michigan, here it occurs in a basin, almost a circular basin; Indiana, where it is on the west side of the Cincinnati Arch and is going toward the Illinois Basin, which is a spoon-shaped area like the ladle portion of a spoon; it next occurs then west of the Mississippi, north of the Missouri River and South of the Missouri River.

You will see that coal deposition took place over the eastern half of eastern two-thirds of the United States. Let's translate this coal cycle into physical conditions, into paleographical conditions, if you will. Repeated occurrence of the coal cycle would then seem to indicate repeated oscillation, an oscillatory

condition of the continent and the coal represents a swampy condition in each of these oscillations. The coal then, is the result of the dombination of those forces which gave rise to the Chester series in the Upper Mississippian. You remember you had eigh series of ls and ss. The continent was wobbling back and forth, but always below sea level. In the Pennsylvanian, the unstable condition of the continent existed, but the continent was slightly higher, so in the area of coal deposition, the oscillations between marine and non-marine conditions, if we were to try to diagram it by means of a chart or graph, we will say this line represents sea level, I will start this now and finish it later.

Then in the Mississippian, the general oscillations of the continent would be of that nature, always below sea level. When the water was shallow, we had the ss; then when the water was deep, we had the ls. Then in the Pennsylvanian, we had oscillation which was like that. This would be the dividing line; this would be the Mississippian and that would be the Pennsylvanian. Later on we will complete that.

In the region west of the coal deposits which I have described, we had a continuance of ~~non~~ normal marine deposition, so we don't have to say any more about that. In other words, the Cordellaran geosyncline as well as the Pacific trough contained normal floods in which there was being deposited ls, ss and sh. There is nothing particularly different about that area.

The next period is the Permian. The Permian of the United States can be rather easily summarized in this way. In eastern United States, only the lower Permian was represented by deposits centering in West Virginia. In the western part of the United States, we had two geologic records which are red beds along the eastern side of the Cordellaran geosyncline, but there is a marine deposit in the southern part of that geosyncline and on the Pacific Coast. I am going to say more about that ar a later time, so we won't stop for it now. It is significant that in eastern United States on the side occupied by the Appalachian geosyncline there are no rocks ~~? than younger Permian, no rocks~~ deposited after ~~youngest~~ earliest Permian.

Now according to our foundation of earth history we want to date the disappearance of that geosyncline. I think we are justified in assuming the geosyncline became destroyed during Permian. Heretofore we have called those diastrophic forces which closed eras, revolutions, and in each case, a revolution has destroyed a geosyncline and given rise to a mountain range. The Paleozoic was closed by a revolution; it destroyed the Appalachian geosyncline and gave us the rock structures of the Appalachian mountains. Notice I didn't say land forms -- they are the result of later history. The rock structures are Paleozoic in age. This unstable condition, if we were to continue it into the Permian, would be characterized by an oscillatory condition above sea level. The rest of this would be Permian and the emergence of the trough.

Now let's review for just a moment. You will remember the geologic pattern of the Appalachian Mountain system. The Appalachian Plateaus are essentially horizontal. Some broad waves are present in the rocks, however. The Valley and Ridge Province contains anticlines and synclines, with the most intensely deformed rocks on the east side where ~~???~~ thrust faults + overturned folds are present. For the most part Paleozoic rocks are absent in the Piedmont. There are a few present there, but more abundantly present in the Blue Ridge.

I think you will recognize as a general fact ~~the~~ that deformation is greatest near the applied force. For example, if you put your finger on a rubber ball or loaf of bread, right where the pressure is applied, that's where the deformation, the greatest deformation takes place. We can say the force ~~takes~~ took place along the eastern side. The folds and thrust faults are more abundant there. Well, then, what was the nature of the force? It was compression. Two segments of the earth moved together and squeezed the ~~some~~ zone between. Now that could take place by both sides changing positions or either one of them doing so. On the eastern side we have the borderland Appalachia. Now the trough is between them; the trough is destroyed by Appalchia moving toward the nw, toward the Canadian Shield, crowding the zone in between. What made Appalchia move, is of course unknown.

I think you can see quite easily how this can be interpreted from rock

structure. We know how long the Appalachian geosyncline was in existence by the series of rocks deformed. We know the nature of the deformation ~~? ? of~~ by overturning of anticlines and synclines and thrust faults and that Appalachia moved from east to west because ~~???~~ of the symmetry of folds. This resulted in the joining of Appalachia to the continent. Such were the closing events of the Paleozoic all of which should have been covered last time but wasn't.

I will take just a moment to show you the condition of the continent after the geosyncline has become dry. Here we have the ridges where the Appalachian Mountains came into existence, from Alabama to the Gulf of St. Lawrence/and they are in the region now occupied by the Vallye and Ridge Privince. I will call your attention to a penninsula here in the ~~east~~ west. That is an area in which the red beds were being deposited. Here are the ~~???~~ Ouachita Mts completed at the same time as the App. Mts. ~~???~~. These are based on pretty good geology. Now these do not ~~???~~ connect under the Costal Plain strata. They are probably of the same geological period, but the rock structures are not ~~?~~ continuous. Any questions about the Paleozoic? (Interruption. Question: Would the Permian be an ideal period then? Answer: No, only three, the Ordovician, Silurian and Devonian were ideal periods. We can't say that the Pennsylvanian was ideal because it is non-marine, coal. The Permian is not ideal because the geosyncline was destroyed and there was no widespread flood.

The next is the Messozoic era. The first period of this era is the Triassic. First I would like to call your attention to the distribution of Triassic rocks. They occur in basins in the Piedmont Plateau, North Carolina, to New Jersey in a basin along the Connecticut River and similar areas in Nova Scotia and Halifax. There are also Triassic rocks in the Rockey Mountain system, Colorado Plateau and the Pacific Mountain system. Let's begin backwards. The Pacific Mountain System is continued marine deposition, the Colorado Plateau and Rocky Mountains contain red beds deposited in a basin which you just saw on the projected map, deposited in a lagoon, a cut off portion of the sea, in an area of arid climate.

The eastern region is the most significant to us. Almost without exception the Triassic rocks lie upon pre-Paleozoic rocks. The pre-Paleozoic rocks are crystalline materials containing abundant feldspar, liek this pink mineral. The Triassic contains a material which is called arkose. It is a feldspathic ss, a granular rock made up of fragments of feldspar. There are as well red ss and shales. Now let's see if we can build a picture from that information. We should have learned that the srystalline pre-Paleozoic rocks of the eastern part of the United States were to be found in the borderland which we call Appalachia. We know that Appalachia was a land area, no marine rocks on it. We now find these Triassic materials deposited on top of the pre-Paleozoic crystalline rocks and they contain arkose. What is the source of the arkose? Obviously the rocks right beneath this series. The Newark series is the name of it, named from a type exposure at Newark, N. J.

The gneisses which occur abundantly in the Piedmont Plateau represent the type of rock which ~~?~~ predominated in the old land mass Appalachia. These gneisses were broken down. Then the feldspar grains became fragments. That breakdown took place by disintegration. If decomposition had caused the rock to break down, the feldspar would have been kaolin. So the evidence of feldspar grains indicated that Appalachia was subjected to intense physical breakdown. That condition was brought about by the Appalachian Revolution which not only destroyed the trough but uplifted Appalachia as well.

The streams were rejuvenated and had increased velocity and began to erode Appalchia. They carried large volumes of material into the ocean but in the low portions of Appalachia, the materials became trapped. The streams could not carry them out and so we have this Newark series, non-marine, deposited on the land mass Appalachia. We commonly speak of it as intermontane deposition, the kind of deposition going on at the present time in the state of Nevada, an area without a through-flowing stream. ~~??? and~~ The rainfall permits erosion of the mts. but there is deposition under desert conditions. in the basins.

The gneisses contain various iron minerals. Under such conditions the materials are converted into hematite and we have red ss and sh, so I would like for you to think of the Triassic in eastern United States as being a time when due

to the previous Appalachian Revolution, this land mass was standing high; then the streams were cutting through its surface rapidly attempting to carry the material out to the sea but resulting in the deposition of that basin. If we were to examine one of those basins at the present time we would find a condition somewhat as I am diagramming. For the most part the red ss and sh have been softer than the surrounding material so they have been worn into lowlands, but in the lowlands we have conspicuous ridges which are either one of two things, indicating igneous activity in this region. These were fed by underground sources and formed flows, dikes, + sills. ~~???~~.

Now in the highlands of New Jersey, for example, the region formed from igneous rock, either intrusive or extrusive igneous rock. (Interruption. Question: Why couldn't the streams carry the material to the sea? Answer. ???) These are the general geological conditions today indicating that the basins have since been deformed. They have dropped. This period of deformation affected all of the area in which Triassic rocks occur. Therefore, it must have affected most of Appalachia. It is called the Palisade disturbance. The Palisades would be somewhat comparable to what I have drawn there. If I modified it to this extent, make that come up to the surface and spread out there with the Hudson River ? at the east end. (Interruption. Question: Are the Palisades only one side of the River? Answer:???)

This, of course, does not give us a very complete picture of the Triassic, but it gives us the fundamental picture. The Appalachian geosyncline is gone; the Rocky Mountain geosyncline is an area largely of lagoonal deposition and the Pacific Coast continued as normal marine sediments. Let's go on the ~~the~~ next one, the Jurassic.

The most significant thing in the Jurassic is the area east of the Mississippi River. There we have the absence of Jurassic sediments, not the absence of a Jurassic record, but the absence of Jurassic sediments. Now this absence can be explained in one of two ways: either the materials were deposited and then completely eroded away, or during Jurassic time, eastern United States was subjected to erosion and the deposits which formed as a result of that erosion

were carried beyond the present borders of the continent. At a later time I will try to show you that the materials were probably never deposited.

For the present just assume that to be the case and we will go back to it. Western United States, well, to be more specific, in the Rocky Mountain region during Jurassic time, the area was flooded, not throughout the length of the geosyncline, but the southern part, well, northern Utah, about northern Utah, little bit farther south but not as far south as southern Utah. This was a submergence which came in from the Arctic ocean. It is indicated by the widespread ss.

While this area was submerged or probably just previous, in southern Utah, there began a desert condition which has continued up to the present time. The desert condition is represented by a formation which is called the Navajo formation. I think you will recognize the region in which a formation would get such a name, essentialy ne Arizona, with the adjoining portion of Colorado, Utah, and New Mexico, the only place in the United States where four states come together in one place. The Navajo formation is significant because of its splendid cross bedding. This is represented in almost all exposures of Jurassic rocks in the region which I have described. It is particularly significant in Zion National Park. These corss-bedded layers, remember I showed you last time something about cross-bedding; in the case of the Navajo formation, these indicate layers in the neighborhood of some fifteen to twenty feet long. That would be the length of this segment. They are the results of advancing fronts of a sand dune. You undoubtedly know that sand dunes migrate, move forward and in so doing, they build successive fronts. The angle of inclination in these successive fronts here now represents this angle of inclination in the Navajo formation. It is a relatively thin widespread ss through the Rocky Mountain region, north of southern Utah. This was succeeded by a swampy condition, not in a swampy condition, but in an emergent condition in which lakes and streams were abundant.

Then the Sundance submergence gave way to an emergent condition of still sufficiently low elevation to give you lake and stream deposits known as the Morrison formation. This formation has more reptiles of dinausaurs than all

the others in the world put together, more dinasaurs and their related reptiles thanks to the courtesy of the Sinclair Oil Company, than all the rest of the formations put together. We will say more about that later. These are the high lights or significant things concerning the Jurassic.

Now let's go to the Cretaceous. The Cretaceous brings about a condition which is very significant in that the continent begins to assume its present configuration, its present outline. On the geological map of the United States we remember that the green is Cretaceous. During the Cretaceous time the shorelines of the Gulf of Mexico took the course which I am tracing with the pointer at the present time. You can see that the Atlantic and Gulf Coastal shore lines were established at this time. In order to interpret this we will have to know more about the conditions. If I modify this diagram a bit we will ~~have~~ find that these are Cretaceous rocks. The Cretaceous rocks lie on top of an eroded surface, across Triassic rocks.

The lowermost Cretaceous is non-marine and the upper Cretaceous is marine. This geologic evidence indicates than that Appalachia became tilted. The eastern side was submerged beneath the Cretaceous seas, beneath Cretaceous seas and the shoreline moved in Appalachia to the eastern boundary of the United States. How far it came in we do not know, but we are sure that in upper Cretaceous time the shoreline of the Atlantic was very similar to what it is at the present time. The fact that the Cretaceous always lies on a well eroded surface is the geological fact that the Jurassic has always been absent in this area.

After Appalachia was rejuvenated with the Palisade disturbance, it took the entire Jurassic period and probably a portion of the Cretaceous to reduce it to a plain of which ??? as the Cretaceous came was tilted, thus producing a striking unconformity. Just remember the general process rather than clutter up your notebook with names. That extensive erosion was going on was indicated by the Selna-Austin, Selna named for a locality in Alabama, Austin named for a Texas locality. The Selna-Austin chalk formation. Notice where it is, just across the end of the Appalachian Mountain system. What

was the condition of the Appalachian Mountain system in order to have chalk deposited over the end of it? ??? These areal relations are further evidence of pre-Cretaceous erosion. We have chalk layers, and remember chalk is ls, ls deposited under very favorable conditions, and here we have chalk deposited on the Appalachian Mountains indicating that they were worn down so low that the streams were unable to contribute sands or mud to that region. (Interruption. Question: That's the Old Appalachian Mountains, isn't it? Answer: ???) So during Cretaceous in eastern United States, I should like for you to think of the Atlantic coastline assuming its approximate present condition and then ???. It is not of Mississippian age, but it is a Mississippian embayment. ??? and so it came up in the valley as far as southern Illinois.

the Gulf coastline marked by extensive flooding of Miss. Valleys

The water spread over Coastal Plain

In the Rocky Mountain region we have a different geological condition. If we were to consider the rock record in geosynclines of the Rocky Mountain region and ?, we would only need to take the two end members of the series. The Colorado series is principally marine, whereas the Fort Union is entirely non-marine. The Colorado series includes such formations as the Dakota ss, a very important water bearing horizon in the Rocky Mountains and Great Plains region.

Great Plains

The distribution of the Colorado series is such as to indicate maximum submergence of the continent during Messozoic time. The Rocky Mountain or Cordellaran geosyncline was flooded from one end to the other, and it spread ~~over~~ the waters to the east continuing until the green which you see here on the state of Minnesota, not the green, but the formation resulted from this widespread submergence. We have a flood of the Cordellaran trough, quite comparable to the widespread submergence of the Paleozoic period. Get a general picture as to what it was.

The Atlantic coastal plain was under water and the Gulf coastal plain was under water and there there was this great area submerged in the west and now in this Cretaceous system as it occurred in the west end of the Rocky Mountain region, we begin with a marine and end with a non-marine formation. Some place in here if the conditions were such that they area became unstable, we might

expect to find coal layers and there are coal deposits between the top and the bottom, but in between the two of them there are coal layers.

Let's recall what happened in eastern United States. The coal was the forerunner or geologic evidence of ~~accumulation~~ oscillation. The continent was fluctuating, it was changing and in these changes the physical conditions were such as to give you coal horizons. The same thing was true in the Cordellaran geosyncline. At the clost of the Messozoic, the Cordellaran geosyncline became so unstable that it was ? formed in which coal layers indicate oscillatory conditions. Now such oscillation should lead to deformation and in the case of the Cordellaran geosyncline it was destroyed at the end of the Messozoic. Again let's recall how it is dated. It was destroyed at the end of the Messozoic. The youngest marine materials to be deposited in the geosyncline fall within the Cretaceous. After this,
Cretaceous time, after/the area was no longer an area of marine deposition, therefore we know that the trough was destroyed between the bottom and the top of the Cretaceous system. This has been called the Cordellaran Revolution. I would prefer to call it the Rocky Mountain revolution. Each revolution is related to mountain formation. We get back again to the same thing, diastrophism is the ultimate basis for the subdivision of geologic time. So it is represented here again closing the Messozoic. (Interruption. Question: What's the difference between that and the Laramide Revolution? Answer: ???)

In my haste to get over this I forgot one thing. You will have to insert it here and then put it where it belongs in your notes. At the close of the Jurassic there were huge igneous intrusions which today are present in the Sierra Nevadas and the mountains of central Idaho and along the coast of British Columbia. This batholith or one of these batholiths was responsible for the present rocks that make up the Sierra Nevadas. Since it is, the deformation associated with the period is called the Sierra Nevada disturbance.

Intrusion is always accompanied by deformation. This intrusion was accompanied by the formation of an arch which separates the Pacific waters from

those of the Cordellaran geosyncline. (Interruption. Question: That makes the great basin in the west? Answer: ???) (Interruption: Question: The Great Basin is on the east side of this arch then? Answer: ???) Any questions about the Messozoic? As I said, I am just trying to outline it in such a way so that you can add to the skeleton if you want to from your reading. Just try to picture the general conditions and how we know what it was.

The next is the Cenozoic. The Cenozoic is subdivided into two parts which we call periods; the older of these is the Tertiary. On the geologic map the yellow and orange represent Tertiary rocks. You can see where they are, Tertiary sediments I should say, represent Tertiary sediments.

The Atlantic and the Gulf coastal plains were submerged during Tertiary time and received for the most part marine clastic material, ss and sands, clays and shales. During Tertiary time the Atlantic and Gulf coastal plains were continental shelves. The succession of rock formation in the coastal plains indicates that the continent has successively risen, increased its elevation and the shoreline moved out and out until its present condition. Simply stated then, we can say that the Atlantic and Gulf coastal plains resulted from enlargement of the continent. During the Tertiary the coast has gotten larger and as it came up there was less and less area submerged for Tertiary deposition. One of the other significant records of Tertiary time, this distribution of materials through the Great Plains and in the basins and the plateaus of the Rocky Mountains. All of that material is alluvial. That is, it is fresh water, in contrast to this other material which was all marine. The oldest Tertiary materials are found at the present time only in the basins between the mountains. The younger materials are found in the basins between the mountains and out across the Great Plains. These alluvial materials are composed of sands and clays, some conglomerate with essentially calcareous content.

Let's begin the interpretation. Those are the facts, Let's begin the interpretation. What is the source of all this material? The newly made Rocky Mountains had come into existence at the close of the Cretaceous period.

They were elevated, areas in which streams could erode rapidly. As the streams began to cut down the newly made mountains, there first began a process of intermontane materials so the older materials are found between the mountains. When the basins became filled, the streams carried sediments beyond the basins of the mountains and then spread out this alluvial apron in the Great Plains which we have now.

One other thing during Tertiary, a large share of the Rocky Mountains were buried underneath sediments which they themselves contributed. We had a plain extended across the Rocky Mountains, a plain as a result of both deposition and erosion, erosion of mountain area, deposition of basin area, a graded plain, neither the result wholly of deposition or erosion, but of these two processes together, known as gradation. That was the general condition which prevailed to about the middle of the Tertiary and then things began to happen.

The area began to be rejuvenated, rather I should say the area began to be uplifted and the streams were rejuvenated. They then began to cut new courses through the basins. They began to cut new courses through the plains and as a result of erosion and rejuvenation the alluvial apron has been cut up into the frayed form you see on the map. It once was continuous, but now it is all cut up. Streams which were able to flow across the mountain ranges due to the fact that it was buried have continued to flow across the mountain ranges so you have, for example, the Royal Gorge of the Arkansas, a river so narrow that at the bottom of it the railroad tracks are above the stream etc. follows the ??? In Wyo. a canyon such as that crosses the Big Horn Mountains. It misses the end of the mountains about 25 miles, yet it flows through a canyon 2000 feet deep to get out of it and all of this, a result of entrenchment by uplift. ???. (Interruption. Question: Have the Cretaceous sediments been all cut down to make up that condition? Answer: ???)

That's the alluvial Tertiary record through the Rocky Mountains and Great Plains. These red areas are Tertiary igneous rock. All of the Columbia Plateau or most of it and this portion of the Columbia Plateau known as the Snake River. Many of the mountain ranges are Tertiary volcanics. Here in Arizona and New Mexico there are two kinds of vulcanism exposed. As the lava

flows of the Columbia plateaus, successive floods of dark colored lava so fluid ~~sh~~ liquid ~~???~~ that they flowed to surround or cover all the irregularity of that region. Such a formation may be very well seen at Yakima and one of the series of lava flows at Washington is the Yakima flow. These flows were not continuous but interrupted, interrupted by periods sufficiently long to have the formation of lake sediments as seen at the town of ? Ellensburg so we have some of the lake materials interbedded with lavas known as the ~~Helmshnery~~ Ellensburg formation.

Going through the Columbia plateau we have lava flows, tier on tier of lava flows that are conspicuous. Occasionally it would be interrupted by a zone of colored materials, the lake sediments. Such strata often contain vertebrate ??? fossils, one in Oregon known as the Day formation, the John Day river (description of John Day River). These two types of formations are the conspicuous thing in the Columbia plateau. You find practically nothing else. I spoke of another type of eruptive materials being represented. That is volcanic ash and dust. Some of that occurred early enough to be included in the materials on the Great Plains. It is present, but not abundantly. In some regions of western United States the ash beds are quite thick. Some of the beds in this John Day formation are ash. (Interruption. Question: Are these aasociated with potash formations? Answer: ???)

One of the most famous localities for these ash and dust beds, I should say famous for the fossils it contains, is found in Colorado west of Pikes Peak near a little town of Florrisant, so it is called the Florrisant bed. It was an intermontane region in which there was sufficient water so these materials became stratified. They became bedded or as it fell in this area it entombed insects and leaves. This, the Yakima would be the flows and the Florrisant would be the eruptive materials. As I said before, we are merely choosing types to represent these conditions.

Now here on the Pacific Coast Ranges south of San Francisco and in the Washington and Oregon coast regions we have Tertiary sediments. I haven't said very much about these regions on the west coast. You remember I pointed out

~~the Pacific Coast Cordilleran trough~~

an arch separating ??? this one commonly known as the California trough and this one known as the ~~Colorado~~ Columbia trough. These were areas of normal marine deposition during Tertiary. During Tertiary these were the only geosynclines which were left. We had Tertiary sediments, Tertiary clastics, sands, sandstones, clays and shales. The youngest material of marine origin in these areas is about just a little bit later than middle Tertiary. That means that the trough began to be deformed, began to be emergent in Tertiary time. Now you remember our principle of diastrophism. Diastrophism is the ultimate basis for the subdivision of all geologic time.

Applied to the west coast the destruction of these troughs is still going on. When it is completed we will probably have the end of the Cenozoic. The continued deformation of the region is repponsible for the earth quakes which we have in southern California. The forces have not occurred sufficiently to cause the rocks to fracture in Washington and Oregon. It may be that ~~they~~ it may never occur to that extent. So I should like to have you think of the destruction of these troughs on the Pacific coast as being related to the close of the Tertiary and extending through the Quaternary which is the youngest subdivision of the Cenozoic.

Now for the Quaternary. So far as geological records are concerned, it is a repetition of present conditions with one exception and that is, of course, glaciation. Continental glaciers spread from centers east and west of Hudson Bay until they came as far as the Ohio and Missouri Rivers. The particular features of continental glaciation we are not going into at the present time. I think most of you know the type of record we have as a result of glaciation, otherwise the Quaternary is a repetition of what is going on today, marine deposition along the Atlantic and Gulf coasts. The grey on the map indicates that the continent has been enlarged since Tertiary time. They grey in the Great Basin indicated deposition of alluvial character. We have then, at the present time, the same processes going on which formed the geologic records of the past, except for one exception, that is geosynclinal deposition. ~~It certainly comes~~

That may even be represented now by the Gulf of California. That may be a geosyncline. It certainly comes close to our idea of a geosyncline, an area submerged with high areas to the east and west contributing sediments to that region. Perhaps that is the next section which will become uplifted and become a part of the North American continent. (Interruption. Question: Why didn't you include the Gulf of Mexico? Answer:???)

Just to recall to you now that we ~~?~~ had five land masses, the Canadian Shield, I hope there are five, Appalachia, Cascadia, and Lanoria, four land masses, four land masses, a central one and border areas with troughs, but the general process has been the destruction of the troughs and the addition of the borderland to the continent. In each case it has been the adding of a borderland to the continent.

You can see that we are getting to a place where we ~~will~~ could talk about some interesting geology and we are also at present where we are about half through. From now on we part company and shift dates. Next week the Historical Section will meet on Thursday and meet on Thursday from then on, accordding to our pre-arranged schedule. The group interested in National Parks will meet on Tuesday. Those who come next Thursday will spend the first hour telling me something about what they have learned.

CD/HVA

April 23, 1936

Now that we have started on the second half of our interest is going to be centered primarily on the forms of life. Last time in addition to the quiz I added a few remarks with regard to the processes and environment of fossils. That was putting the cart before the horse, so this evening I am going to talk about the various characteristics of animals and plants. If we understand so mething about these organisms while they are living, then the preserved remains which we call fossils mean more than just impressions in rock, for they really did exist at one time. Most of the time will be spent on the animal forms because they are better preserved, but we will briefly summarize the characteristics concerning the plant kingdom.

First a few words with regard to the classification. Inasmuch as confusion is apt to arise depending upon the nationalities of the individuals doing scientific work, the naming of organisms is based on the Latin and Greek, Latin and Greek names, so we should become acquainted with these terms. In English the classifications would be written this way, Kingdom, Phylum, Class, Order, Family, Genus, Species, Variety, Individual. These last two are not strictly for the purpose of classification. Each higher subdivision is made up of units of the lower subdivisions. We have two kingdoms, the animal and plant kingdoms. The subdivisions within these two kingdoms are then called the Phyla, as the plural form, Phyla.

With this classification in mind, let's talk about the plant kingdom. This will be a one-way conversation really, not let's talk about it, but I will tell you about it. What is usually considered as the most primitive plants are included in the subdivision called Thallophytes, Thallophytes. The translation of the term would be, that is, a literal translation, shoot and plant, shoot and plant. These forms are characterized by an absence of stems, roots, and leaves. Common forms are such as bacteria, algae. They are the most common forms of Thallophytes. From those two examples you realize the presence of the character-

istics which I have given you. Mildew, yeast, toadstools are other known varieties of these forms. Some of them manufacture their own food from other substances, others live on decaying substances, thereby being parasitic or saprophytic.

I think it would be well to know something about the physiologic processes typical of Thallophytes. The simplest type of plant you could have would be a single cell, a single celled plant, and there are such plants, a uniform mass of protoplasm which absorbs food through the cell wall. It grows and when it has reached an appropriate size, the cell is constricted and you have two cells resulting from the subdivision. This represents the regeneration or the new generation of that plant. That's the simplest type of growth or reproduction that there is possible to have.

Still among these forms there are other single cells in which a portion of the substance which is known as protoplasm, is most concerned. There are usually, two, two parts to this protoplasm, one is called the nucleus and the other is the chloroplast, chloroplast meaning color body. It contains chlorophyll which is fesponsible for the coloring in plants. Now in such a cell the work, that is, the physiological work of keeping the cell alive is subdivided; the chloroplast manufactures food for the cell, supplies food to the cell. When the cell divides we find that the nucleus splits and the chlo roplast splits, the two subdivisions migrate to opposite poles and then the protoplasm between constricts so you have two individual bodies. Each cell then, begins fully equipped with chloroplast and nucleus. The nucleus distributes the hereditary qualities, so in addition to the protoplasm, the nucleus and chloroplast first divide and migrate and then the cell creates a new generation.

About the next most complex form would have to have units of cells, an individual plant made up of a number of cells, and each cell independent. When reproduction takes place the protoplasm shrinks away from the cell wall and it subdivides into a certain number of units, four let us say. When the cell wall breaks, the units are freed into the surrounding water. Remember now these are all

water forms. Wherever they come to rest in favorable environment, they grow into new plants. These bodies are called spores, these subdivisions which can make new plants. Subdivision takes place inside the cell. When reproduction takes place in this way the old individual them becomes a ? of lifeless cells. Still among the Thallophytes and among the water plants we have another change. When the protoplasm chrinks away from the cell wall ??? and if one is smaller, it is impossible for these units to grow into new plants, but we find them fusing with each other. This fused form is given the name zygots. The units are like spores in all physical characteristics except size -- they are smaller than spores. There is no way of telling them from spores except by size.

There is still one other change among the Thallophytes. They are getting more and more complex and these units which form the zygote are not the same size; one is large and loses its power of motion and the other is small and retains its power of motion. These bodies which form the zygots, we are going to use the same scheme later on, the large one becomes the egg and the smaller one becomes the sperm and they are both produced by the same plant. All of these methods of reproducing species are present in primitive plandts and these are water plants. The important thing is their environment, their water environment. The matter of reproduction will be important at a later time.

Bryophyte is the next one. The term means moss plant and it indicates one of the commonest forms present in this subdivision, the mosses and another less commone one, the liverwort. Many do not see them unless they are on the lookout for them. The characteristics of this group can best be described or indicated by the despription of one plant. Perhaps you are familiar with the cap moss which exists as a sort of fringy clumpy bit of vegetation. In the fall when the plant becomes mature, from this clump, this fringy clump of material, there will arise a slender brown stalk, the top of which has a little cap. It looks something like that and there is a lid on the bottom here. Now that general

form you undoubtedly will recall seeing, a form like that. Let's try to describe it.

The generation which is feathery-like, manufactures its own food. When in the reproduction period when the zygote is formed, it grows into a form which is dependent upon the food manufacturing generation, but since it is a plant which manufactures spores, it is called the sporophyte. From the sporophyte then, there are produced spores. The spores grow into new plants as we described previously. Those plants are capable of making gametes. Gametes would be just like spores except for size. The spores grow into gametes, gametes produce the eggs and sperm which unite and form zygotes ??? this one, this is the green one; it is the one which manufactures food. This one is the sporophyte and it is in a sense a parasitic generation; it lives on this small green clump. Now when the plant has reached maturity, this little lid on this capsule falls off. On the inside are the spores and when the wind blows, this bell is shaken by the wind and they fall out and are carried away.

Of course you can see that they won't go very far. Reproduction takes place quite close by. You undoubtedly have seen the smoke or cloud of a puff ball when it is squeezed. That cloud which you see consists of the thousands and thousands of spores. Such bodies are released from the cap. Now as this generation is only several inches high you can see that the spores will not be blown a very great distance, so the clump moss grows in clumps close together, all resulting from these spores which I have described. If a great gust of wind comes along, of course it will be spread farther. (Interuption. Question: How long does it take for one of these generations to occur? Answer: ???) Now this is called alternation of generations and it is characteristic of all plants except the Thallophytes. It is a very important process.

Pteridophytes. The next phylum is the Pteridophytes. The term pterid means feather, feather plant, because the commonest form is the fern. Now you will realize why it is called the feather plant. Other varieties are the horsetails; they are also called scouring rushes. They may also have the name Equisitae --

that's the generic name for them, Equisitae. The ground pine is another one that belongs here. It is sometimes used for Christmas decoration and they are also called lycopods. These forms were important during the Carboniferous. during the time the Pennsylvania coals were being formed. They grew to tree-like proportions and were important in the formation of the coal. The ferns are so common that I am going to spend a little time talking about them, but I want to call your attention to this difference. In the fern the gametophyte generation is so small that most of you have never seen it. The showy part of the fern ?? and is independent so far as habitation? is concerned. In general the gametophyte generation would not be quite as big as my little finger, and not thicker than a few sheets of paper. This is the dependent generation and the sporophyte generation has become the independent form.

Now when the ferns begin to have brown dots on the underneath side, that is nothing more than the cases which contain spores and when the spores are ripe, the cases break. The spores fall into favorable environment and produce the gametophyte generation and the process is repeated. (Interruption. Question: In the case of a perennial plant, is the process the same or repeated or what? Answer: ???) There there is a subdivision of rather questionable rank which is known as the pteridosperms. They are on fossils if they exist at all. The botanists are not sure how to class them. They are forms which are intermediate between flowering plants and plants that ???. That is all we are going to say about them.

The flowering plants have been given the name Spermatophytes. I don't know why they chose that name for them, Spermatophytes, flowering plants. These are further subdivided into, I can think of the second one but I can't think of the first one now. Gymnosperms, gymnosperms. I don't remember what the translation of it is now. These are the evergreen or pine trees or forms related to the pines. They are related to the flowering plants in the sense that the

cones are the flowers. They are not abundant on the earth today, but they are the large sequoias and redwoods, examples of the gymnosperms. The Spermatophytes in addition to being called flowering plants are also called seed plants. In the case of the gymnosperm, the seeds are born at the base of the scales of the cone, and in some of them the scales have to turn way back before these seeds are loose, and drop out.

The other subdivision is the Angiosperms. These are characterized by the seeds being coated. The seeds are coated usually giving rise to some sort of a fruit although not all of them have that property. Among these Angiosperms it is interesting to know the changes taking place in this alternation of generations. A flower exists soley for the purpose of perpetuation of the species. It consists of certain reproductive structures and other things to aid this process, for instance, colorful petals to attrace insects. The petals are to attract the attention of the insects; the nectar is to pay them for their visit to the plant.

Let's see what happens when they do visit the plant. An ordinary flower would consist of these parts, the central portion or the vase or vase, depending whether or not you got it in the ten cent store or tea shop, known as the pistol. Around that there should be some thin shaft-like structures known as the stamen. As that is a flower, it may have some petals, and they would be around the outside. In some cases, if petals are present these structures are green and act as a protective coat around the bud; these are known as sepals. In many cases the sepals take on all the functions of the petals. When the plant has reached maturity, in the stamens there will be produced pollen grains. The pollen grains are that portion of the alternation of generations which ???. In the base of the pistol there are generated the other portion, the eggs. The visit of the insect from one flower to the other is usually so manipulated in the plant that in entering the plant it does not get pollen from this individual, but any brought with it from another neighboring plant is deposited on the sticky fluid

of the pistol. If that is of the same species or comparable species, then the pollen grains begins to grow and sends down a tube and then we have ???. In the base of the pistol these are ? into the form which is the zygote which grows into a sporophytic generation and this produces spores within the base. These are usually encased in a fruit or comparable structure and when it falls into a favorable environment, the seeds produce and the process begins again.

From a structure in which the sporophyte generation was this small cap such as we saw here at the beginning of the sporophyte generation, which we saw in here, excuse me, I made a mistake, and from this sporophytic generation which we see here, we come to this. These are the gametophyte generations so from the relatively small sporophyte generation we come into a ? here which ???.

Plant growth covers most of the surface of the earth. And now I think you have a few more ideas concerning plants and their characteristics than you knew before, unless you have had some botany and know then more thoroughly what I have just given to you. There is one thing I forgot. These plants begin to have wood. These have wood from here on. The Thallophytes and Brypphytes have no wood. Wood has a transporting system; it takes moisture from the roots to the leaves; another system takes food from the leaves to the roots. It is a system of tubes resulting from the ends of the cells being dissolved out. They are in a straight line, that being their general form.

The essential characteristic which I want you to get from this is something with regard to the complexity of the organism and then one other thing. In giving you my notes I neglected the various environments. Let's call this one the water plants. Most of them grow in water; these in areas of moisture, the mosses if you keep those in mind; the Petridophytes still in moist environment, but getting above the surface of the earth, swampy environment; and then the Spermatophytes, the land forms. Increasing complexity of organization is related to different environments, the simple plants existing in a uniform environment, and the more complex plants in an environment which is not uniform. We can take a moment now for questions about the plants as long as we don't run into an involved discussion

of botany. (Interruption. Question: The seed, isn't that essentially a new plant? Answer: ???)

From what I said last time I think you will realize why plantsare not as important as animals for fossilization. They can only be fossilized if the wood is preserved and you know how wood decays and that is the reason for that. (Int erruption. Question: What is that stuff which grows on the sides of trees and boulders, lichen, I guess, where does that fit into this? Answer: ???)

Now let's try the animals and see howwe get along with those. Now the Animal Kingdom. Protozoa, the first phylum is the Protozoa; it means first animal, and like the first phylum of plants these are single cells. We are going to dispense with zoological classification nowand make two further subdivisions. We are going to know that the Protozoa are divided into Foraminifera and Radiolaria Now there are no other wordsfor some of these things. I think I have told you about the woman who visited the museum. She was not so surprised that anybody found all these things, but how they knew what to call them. Most of you know what foram means and this means to bear, so these are ? bearing forms. The skeleton is calcareous carbonate. It may consist of one or a number of chambers although the animal is only a single cell. The number of chambers result from the animal's growing so large that it cannot be encased in the shell and when the protoplasm begins to extrude, it grows another compartment and all of these animals make shells of $CaCO_3$. They have been, for the most part, external. Now the perforated character applies to only a part of them. The protoplasm extends out through these perforations in threads, and these threads entangle other protoplasm and in so entangling then, the protoplasm, it extracts the food; those in which there are perforations, they feed in that way, otherwise they feed much like an amoeba. They merely engulf their food; they digest that portion of it which is digestible and them move on leaving the undigested part of the food.

Now then, Radiolaria. Radiolaria has nothing to do with ?. The term

means little ray. It refers to the fact that the external shall is quite usually ornamented with radiating spines which are the rays and that's the origin of the name, these radiating pines on the surface. These skeletons are always made of silica and I think it isinteresting to note here that these simplest forms of organismsliving in an environment where there were two compounds they could use forskeletons, have been able to make use of both. The foraminifera have been important forms making up chalk deposits. Radiolaria have been recognized as fossil forms that do not make up rock formations. I would like to pass some Protozoa around, but they are microscopic in size and you would perhaps not be able to see them. One is about the size of a dime, another about the size of half a wheat grain, another form, the size of a pin head. It is just a globular form. If you want to see them I will get some (books) from the office and show you.

The next Phylum, the Porifera. The term Porifera means just what it ays pore bearing in the sense that the pores are larger than in the foraminifera. These are of the sponges. The sponges belong to this Phylum. Sponges are ordinarily of three varieties, those with a skeleton of silica, known as the siliceous sponge, those with a skeleton of $CaCO_3$, known of course as the calcareous sponge, and then one, well it isthe bath sponge which iscomposed of spongin. Spongin is a substance which is an organic compound, essentially carbon, oxygen, hydrogen, nitrogen, as most organic compounds are. (Interruption. Question: Is it something like chitin? Answer: ???)

The calcareous and siliceous spongeshave skeletons which are made up of units called spicules. They are more or less rod-like, that is, for example, with these pieces of chalk, they would have a form something uch as this which I am holding now, three rods at right angles to each other. Another form is one in which the lower bar does not develop andso you have a form something like that. Still another form is one in which the bars are arranged so, three of them in the

plane and one at right angles. These are so arranged that you have them end to end leaving much space between the spicules. They act as stiffening bars or rods through the protoplasm.. When the animal dies, protoplasm begins to decay, the sponges begin to decay and are not preserved as fosssils, and thus we do no t have ~~p~~ sponges preserved. The one I passed around is the most common and that's its name, receptaculites. This is sometimes called the sunflower sponge, I think you can see why. (Interruption. Question: Are those extinct now or what? Answer: ???) Any more questions about sponges?

I haven't said much about the organization of them. They represent aggragates of cells. If you take the protoplasm of a sponge, separate it from the skeleton, strain it through silk and put it in a favorable environment, it will go right back into a sponge. This is also characteristic of a collection of the cells. If you take two sponges, strain them through silk, you will get one sponge. If you take three animals and do the same putting them in favorable conditions you will get one sponge, so it seems to have a loose form of organization in the individual. (Interruption. Question: Are those holes in the sponge devices where the inner or older portions still eat or what? Answer: ???)

The next Phylum is the Coelenterata, c-o-e-l-e-n-t-e-r-a-t-a. If we translate it the term would mean nothing so we won't bother with it. The corals are the most common variety of the coelenterata. The term coelenterata means that these forms have a body cavity and that was not true of the previous forms. The coelenterata can perhaps best be understood by describing the characteristics of the sea anemone, sea anemoniew are like corals but they do not secrete a skeleton; corals secrete a skeleton of $CaCO_3$. A sea anemone may be thought of as a sack, the top portion of which has been turned in and the margins of which hasebeen brought or drawn out into tentacles or projections. I will try to draw one although it will be rather crude when it is drawn. I am drawing just a section so I will cut through some of these tentacles. If this went around and joined like that there would be other of these. Something like that. This represents a cross section through the edge of the sack where the

portion is turned down. In here it is quite intricately wrinkled and this is the digestive cavity. The animal feeds in thiw way. These tentacles possess stinging cells which causes them to ??? and if it becomes entwined about it, it is paralyzed and then that tentacle will move over in such a way as to put it inside this gullet. In the process of moving these tentacles, they encounter food and that is the way it lives -- it captures these food particles as I have described and releases them inside the gullet. This form is all tissue, no skeleton. They are interesting to watch on the shore when the tide comes in ???, too much agitation will cause them to constrict that cavity and if you get too close ???.

In the case of corals they have built a cup for themselves. The cup would be like this area which I have drawn now. Inasmuch as the animal increases in size and the deposition of the material at the bottom results in the moving of the animal up when it is grown, the shape of the shell is quite often cone-like. This material would all be $CaCO_3$ and it would be like this with the animal at the small end and so you get a form such as this or this, distinctly cone-shaped like a cow's horn. (Interruption. Question: Those horn corals, are they to be found in the sea today? Answer: ???).

If you look at a wide end of the coral you would find radiating lines known as septae. They represent portions where the tissues folded up into a wrinkle and $CaCO_3$ was deposited in there and so in each one of these there was a fold in the tissue. In other words it is just the framework, just the strengthening of these tissues and those are built right inside of this cup. In the forms which I am going to pass around about the small one you can still see the cup in this for which has been fossilized, for the most part, the cup has been broken although here you can see the edge. I will call your attention also to this specimen. When you see it, look for structures which resemble some zigsaw plates. These are graptolites. They a re extinct forms which resemble zigsaw plates and are classed with the coelenterates. The term graptolite means written stone and they were though to represent writing in wedge shaped characters. Anatomically

they are like the coaras and the sea anemone but they had a different habit of like. Instead of building $CaCO_3$ shells for themselves they built an encasement which was shaped like that, blast-furnace shaped, or mortal shaped. This would be the enlarged portion of that. When they were feeding, their tentacles would be out like that. They have skeletons of chitin like the material in your finger nails or hair. They are normally found in shales and existed in colonies. They went out here from a central bulb like plant and these floated at the surface of the water and so at times they were practically world-wide in their distribution over the seas. As they drifted into a stagnant area then that would be a favorable place for them to fall and also a stagnant area would be favorable for shales so that is where you find them. What was originally corners have been flattened so you get a sharp point here instead of a round point. Of course, as I said these are extinct. (Interruption. Question: How was the growth added, below or what? Answer: ???) These are all extinct and we will have specimens of them.

Four, the Echinodermata. The next phylum is the Echinodermata. The term means hedge-hog skin because some of the forms had spines. A very common form is the starfish. First the general characteristics, pentagonal symmetry. That is the symmetry of a star, a plated skeleton, that is, a skeleton made up of a series of plates. Cystoid, one subdivision and again I am not talking about classes. This is an ideal ???. Cystoids were bladder like forms. We won't say more about them. The next subdivsiion, Blastoids. They are nut like, like a hickory nut. All of you are acquainted with the starfish so let's talk about this in terms of a starfish.

Turn a starfish upside down and bend the arms back, then we sould have an anatomy comparable to a blastoid. We would have five grooves and tube feet. These grooves were food grooves. The space in between was merely filled with plates to make the grooves solid. The blastoids are extinct, but they have been important fossils. (Interruption. Question: Are they from the Paleozoic? Answer: ???)

They were stemmed or stalked and have the appearance of rods or circular plates. Crinoids, they are lily-like. That is the best description of them, sometimes spoken of as sea-lilies. If we continue the deformation of the starfish, turning it upside down ??? then we would have an animal comparable to a crinoid. They are always in multiples of five, five,ten, twenty, twenty-five and so on. Each arm had a groove and in these grooves are projections, where in the case of the starfish, all these tube feet have cilia which create the currents carrying food with it going into the mouth and into the digestive cavity. The starfish has an obnoxious habit of feeding and the crinoid being a little more delicate in its habits, builds more room for its digestive process. The crinoid would consist of the cup and the arms. The starfish would be included in what is known as the Asterozoa, and we can't call them Asteroids, because they would be celestial bodies, and there would be confusion, so they are classed as Asterozoa. Then one more group, the Echinoids.

This grou gives its name to the entire phylum. The sea urchins or sand dollars are excellent examples. These forms are so different from the starfish that it is hard to compare them although there are some similarities. If you kept the starfish on its back, filled up the space between the arms, they it would be something like the chinoid. It may be flat or like the sea urchin. Somehow or other the mouth got underneath on the other side. Don't ask me how it happened because I don't know. Most likely this is what happend. ??? bend back until they meet in the back and them some of them became atrified. The grooves are no longer in use. (Interruption. Question: How did these things manage to get from here to there or did they stay put? Answer: ???)

Five is Molluscoidea. Again the translation of the term means nothing so we will dispense with it. There are two subdivsions. Bryozoa. That ought to be easy for you to translate, for we have just had it in the plant kingdom. Moss animals, that is what the name means and that is what they are commonly called. They are of a variety of forms. They are colonial, a number of

individuals living together. They are some of the most important ls making animals that have ever been in existence. They have made large volumes of ls and the only way you can recognize them is by their porous character. The surface has pores. They may be twig-like, they may be encrusing mosses over rocks and other shells, taking a variety of forms. They may be anyy shape. They are still living today and they have lived ever since the Cambrian. Of course the individuals are microscopi in size. Their actual classification is somewhat in doubt but we will use.it. There is no necessity to say anything about the physiology, they are so small anyway.

And here is one of the most important fossil groups, Brachiopod. The term means arm-footed. A number of these names of course have been based on mi sconceptions. This is an example of a brachiopod, somewhat mutilated, the inside of it. They have a ? structure which they thought were the arms by which the animal walked, but that is not true ???. These are sometimes spoken of as lampshells. The one I am passing around is on to which the name ? is applied.

That would be the shape on one valve. If you had a wick there and a handle here you would have a form like a Roman lamp. That which represents the wick there is the pedicle. The animal consists of two valves or shells. We have names for them; the one which contains the pedicle is the pedicle valve and it can always be recognized by this perforation through which this tissue protruded. The other one is the brachial valve; it contains the supports for the gills. The brachippods are characterized by a symmetry in which the valves are of unequal size, but may be divided into two equal halves. If I were to draw a brachiopod, then the brachial valve of the animal would have a shape or form something like that, this projections being represented by this area and here would be the opening. You can see the pedicle valve is larger than the brachial valve and if I had drawn it correctly there would have been a plane of symmetry through each valve, dividing it into symmetrical halves.

Brachiopods are opened by two muscles, one for opening and one for closing. That is the difference between those and another form which I will mention at a later time. Such projections are commonly spoken of as beaks. The organism opens at right angles, the valves drawing away from each one and the area opposite the portion opened is spoken of as a hinge area and there may in some cases, be a hinge line so we have hinge areas and hinge lines. This portion here is a hinge area; this one is a brachiopod with a rounded hinge area. Later on we are going to have some with extended hinges like that. Some of them meet absolutely straight and they become shield shaped. We have a variety of styles, but don't let that scare you. This one would be biconvex, both shells convex. This would be biconvex planoconvex, and this concavoconvex. As to surface ornamentation, it may have radiating ridges, plications; they are nothing more than corrugations on the animal. There may be concentric rings which represent stages of growth, known as growth lines. I think that's plenty with regard to the brachiopod with the exception of size; they are from a dimension of 1/8 of an inch to two feet. (Interruption. Question: Those things in the South Sea Islands are ??? Answer: ???) (Interruption. Question: These brachiopods stay put don't they? Do they have a swimming stage? Answer: ???)

Well we are very short of ???. I would have like to have finished the animal kingdom tonight but we will have to let it go until next time.

April 30, 1936

At the previous meeting of the class we considered the first five phyla of the animal kingdom and stopped with the Molluscoidea, so the sixth one would be the Mollusca. Ther term Mollusca means soft-bodied animal, soft-bodied animal. When I tell you that this division of the animal kingdom includes such animals as clams, mussels, and snails, then you have some idea as to what I mean by soft-bodied animals. Within the phylum the subdivisions are these, Pelecypod, Gastropod and the Cephalopod. Now each of these terms refer to the type of locomotion of the animal and almost all of them are misnomers.

Pelecypod means ax-footed, ax-footed. These forms are the clams or mussels. The oyster also belongs to this group. As I discuss more fully their characteristics their name will become apparent. Pelecypods are forms consiting of two valves, or at least have two external shells composed of $CaCO_3$, the shells themselves each of them being of equal size and having a plane of symmetry between them so that one shell is the mirror image of the other, each one being exactly alike. Therefore the plane of symmetry passes between them, between the valves. Last time we had the Brachiopod. You will remember that the Brachiopod was the animal in which the plane of symmetry passed through each valve and the valves were of unequal size. We are not interested in the anatomy of these forms because they, of course, are not ever preserved, but we should be able to recognize the external forms, the classification of these forms.

The Pelecypod in its normal living condition is up on edge whereas the Brachiopod in its normal living condtion has one of the valves down against the surface of the environment in which it is living. As I said, the normal position of the Pelecypod, at least this fresh water variety, is on edge so the valves become right and left instead of top and bottom. This animal moves by means of a mass of muscle that protrudes or is able to be protruded from about this portion of the shell, that is, from the posterior portion of the shell.

That represents the side view of the shell. It is in a position such as you see here. Then in here is this mass of muscle which can alternately be protruded and retracted and as it is protruded it is shoved into the mud and more or less uses this muscle as a pry and is shoved ahead. This process is repeated and the animal moves ahead or wherever it is going. The animal moves in that way thus the name ax-footed. Someone thought this portion here represented an ax, perhaps an old stone ax ??? that is, well, those are the general characteristics. These forms had a variety of shapes, the same as the Brachiopods had. Some had plicated surfaces, others had concentric lines of growth marking the stages in the growth of the organism. The Pelecypods do not become important members of the fossil communities until the Messozoic, until the Messozoic, and from the Messozoic on. A few are present in the Paleozoic, but they are not very abundant.

The Gastropods are represented by the snails and slugs. The term means stomach-footed. The name was applied when it was believed that the animal walked on its stomach, that portion of the body outside of the shell which has the property of locomotion and ???/ Slugs are also classed here. Of course the slug is merely a snail without a shell. The most common snails are characterized by an unchambered or undivided coiled shell. The next group, the Cephalopods, are going to have a shell that is divided into chambers and that is why I stress that this one is undivided. It is a tapering tube, tapering tube in a spiral form in which side of is the animal and as it has grown and increased in size it has wound the house about itself. There are both right and left-handed spirals within the same species. This is not the common fresh water snail that you find in rivers. It is not quite as common as the ? snail you find about here.

Here is another one of the fresh water snails that I ground through so you can see the sections. It is a continuous tube ? where I have ground through it. Sometimes these forms can be easily recognized and sometimes there is some

difficulty. That is particularly true when you have a cast of the inside, that is, sedimentary materials fill the tube and retain the shape of the tube, and sometimes the outer shell is all or partly destroyed. You would, of course, recognize the spiral form, but you would not be able to identify the fossil form.

This form is living today and in many respects it resembles some of the first gastropods which appeared. It has started to coil but it has not as yet completed one revolution. An individual revolution is called a whorl and in this form there is a cavity for living tissue; the other acts as a cap to protect it. This is representative of some you will hear about. We speak of the Gastropod in the following terms, as low or high spired, depending upon just what it describes, the height of the spiral. We speak of the whorl as being circular or angular. In the form which I am passing around, that would be an example of a circular whorl. That is, the cross section of the tube is circular, so it is a circular tube wound in a spiral. Others are angular. The one I had in mind was of a cross section in which the whorl has that general shape so you can see it is far from being circular. These forms may be ornamented with lines extending to the ?. They may be spiral lines which wrap around the shell and some of them may be very spiny, particularly some of the modern forms. With regard to the history of this group, they have never made important contributions, so far as abundance is concerned, to the communities in which they have existed and they are probably at the height of their development at this time. There are probably more snails in waters now at this time than at any other time.

The Cephalopods are represented by the nautilus, the octapus and the squid, cuttle-fish if you want. All of these forms move or can move at least, by ejecting streams of water from tentacles which surround the head. Now the

octapus can use these tentacles as great arms, and yet it is possible for it to move by expectorating these streams of water. These are probably the first animals to use this principle of locomotion. Their locomotion is a little more successful than man's attempt in the same process. The water is drawn into a bladder-like compartment and is forced out of the tentacles, and the animal moves in the opposite direction.

Under the Cephalopod we are going to have to say a little more concerning the subdivisions, subdivisions based on the number of gills which they have. There are two divisions, first the Tetrabranchs which have four gills, and the Dibranchs which have two gills. Now the gills were never preserved. Among the Tetrabranchs we have two further subdivisions into the Nautiloid and the Ammonoid. The Tetrabranchs are characterized by cylindrical shells or shells coiled in a plane. It is subdivided by transverse partitions into units which are called chambers. Here is a fossil Cephalopod of the Nautiloid subdivision and around it you would find marks, marks, going around as these chalk lines which I am putting on now. They represent the sutures wher the internal part joins the external portion of the animal. As the animal grew and increased in size, it grew up into the portion of the shell with a greater diameter and then built a floor for itself; as it grew still larger, it moved up again and as it continued to grow, it moved up and up and up, and so you have those lines fomed which I have marked here with chalk, marking a partition in the original form.

Now these particular lines are spoken of as sutures. Nautiloids have straight sutures and yet when we say straight sutures, we recognize that if the animal was complete these sutures would form a circle. (Interruption. Question: Is the animal as big as the distance between the two sutures? Answer: ???) (Interruption. Question: Are there any today? Answer: ???)

(Interruption. Question: Could it have anything to do with the habit some of them have of temporarily leaving their shells? Answer: ???) (Interruption. Question: Some of the species as I understand it, can, well they find their shells are baggage and they leave them and if danger comes they scurry back only to their own shells instead of somebody elses. Answer: ???)

In these forms there exists a tube which permits the animal to fill the chambers with water or air, thus it can float or sink, and in order to do that it must have some tissue attached so it can go back into it. That is why I say I don't think they are able to leave it and go back into it at a leter time.

These nautiloids represent some of the largest forms of Cephalopods during the Ordovician. They were about a foot in diameter and twelve feet long. If you are very ambitious you may be able to find some around the Twin Cities, or at least a specimen of it. Incidentally they were the straight froms but there were also the curved ones like the present nautiloid which is living today.

The ammonoids have sutures which are not straight and they may be wavy, have undulating sutures or they may be completely wrinkled. The external form of the nautiloid may be straight as in some of these specimens which I passed around. They have more or less of an oval cross section, or they may be coiled in a plane instead of in a spiral so there again, external form is indicative of classification.

One of them included in here is included in the dibranchs. It is a cigar-shaped from whose generic name is Belemnites. It is the Messozoic ancestor of the cuttle fish or squid. That portion which is preserved is cigar-shaped. Now at the light end of the cigar there was a conical depression. In this conical depression there was fitted a structure which today is the cuttle bone of the cuttle fish, a thin spear-shaped mass. If you look down on it from

the top you will find it was shaped something like that. The tissue of the animal surrounds this mass and this was the cavity for the animal. Here were the tentacles or its mouth, a circle of tentacles with the mouth as the central portion of it. This is commonly spoken of as a guard. That at least is an intorduction to these forms and we will have more of them at a later date. Any questions on this subdivision?

The next phylum is the Arthropoda. We have been introduced to this end of the word so we know the name refers to a method of locomotion. If you have not been introduced to arthritis, you are lucky. The term arthro means point, joint-footed is the explanation of the term. These are the first animals which we can say have such a thing as lobes or legs for locomotion. Among the Arthropoda, I am not going to follow the zoological classification, for many forms are not preserved, and they do not have a geological recod so there is no reason to bother with them.

One subdivision we are going to use we will call the Trilobites. These are fascinating fossils and a rather important group. I will try to reproduce a likeness here. Not only were the limbs segmented, but the body was segmented as well, and there were a pair of appendages for each segment of the body. The trilobites probably wouldn't be very enthusiastic about this ancestor of theirs, but that's somewhat the general form which they had. I think you can see where they get the name Trilobite. It had three divisions, both longitudinal and transversal, the head, body, and tail which are also the cephalon, thorax, and pygidium, but the name Trilobite has such ? from this which is the axial lobe and these two portions are the pleural lobes. Some of these forms had the head extending actually into these ? although there was an infinite variety of forms. They eyes were set on bumps protruding from the top of the head. These had multiple lenses so the animal saw thousands of images instead of one. Because the body was segmented they were abel to toll up into a ball, putting head and tail together. Therefore everything was ???. The animal had a ? or ? the same as the crayfish or lobster,

which belong to the Arthropods,and thus was able to ? quite effectively. There is one of these Trilobites rolled up as the last act, I presume, on earth, and if you look on one side you can see the multiple lenses of the eyes.

The Trilobites varied in size from one-fourth inch in length to twenty-seven inches in length. They are exceedingly interesting to find and they did constitute a rather important geological record. (Interruption. Question: Is that a fossil you have there? Answer: No, this is a cast of a form which was molded, modelled I mean into a cast. I think this was the natural size, no, this particular form did not get as large as this. Some of these forms had a variety of shapes. The heads and tails were sometimes almost ? in form. Some forms were ? shaped; certain forms were perhaps adapted to burrowing and perhaps could move just as well in one direction as in the other. All of the Trilobites were scavangers. They lived on the bottom of the sea and lived on deceased organic material. You will hear more of the Trilobites at a later time.

About the only other group here which I think we will need to include are the insects, that is, ? the Arthropods considered, but under the circumstances I think it is justified. The term insect means cut in two and you know the abdomen of the insect is almost separated from the body. There is a considerable constriction between the abdomen and the body. Most of you would recognize an insect if you saw one so there is no reason for my describing them to you. When you get dragon flies with a wing spread of 27 inches and cockroaches with a spread of ? inches ???.

Again I am going to avoid zoological classification and call the eighth phylum the Vertebrates. These are the forms which are quite commonly thought of when the word animal is mentioned. To most people the workd is populated with bugs, worms, and animals, and anything beyond that, there is no classification.

The vertebrates include an extinct form of certain principal characteristics known as the Ostracoderms. Ostracoderm means ???. These lived for a very short period of time. They are important because they were the first vertebrates to live. Next, the fishes, which need no description; then the amphibians which are adapted to two environments; they can live on either land or water. Their eggs are laid in the water; their young hatch in the water and grow there, but the adults can inhabit either land or water environment, as for example, the frog. Well, they need no further description.

Next the reptiles, the lowest form of animal life which is entirely adapted to land environment, as for example the snake, which also can live in the water, not permanently, but temporarily. Turtles are reptiles, but of course they live in the water or on land. The term reptile means creeping.

Next the birds, a form characterized by warm blood and a body covering of feathers, and then the mammals, the great group of animals which suckle their young and are considered to be the highest type of animal on the surface of the earth. Of course man made the classification of the group so it would have to be up there. Any questions about this survey of the animal and plant kindgoms? Let me repeat -- all I have tired to do is to introduce you to a few of the characteristics so you won't think of them in terms of just something found in the rocks and that they did exist, did live on this earth at one time.

One lady who was viewing the fossils in an exhibit at ??? remarked to the man in charge that she couldn't see how these forms could live without any flesh. I want you to do a little better than that with regard to fossils. Now in order to keep to the schedule, we want to go on and consider the successive development which has taken place. This has been with regard to zoological classification. Let's try to see what changes took place in order that the earth might have the population that it has at the present time. As previous, we have hit the high spots and then have gone back over them more thoroughly.

The oldest group of rocks, the Archaeozoic, contains no actual fossils. There are certain evidences that life was probably in existence, but there are no fossils. The evidences consist of graphite horizons and abundant graphite can only result from accumulation of plant or animal material and also the presence of iron formations, for it is believed the presence of iron precipitating bacteria which are quite abundant today ???. That is a complete statement about the life in the Archaeozoic. That is 500 million years of history, and we have covered that quite rapidly.

In the next group of rocks, the Proterozoic, which also took another 500 million years, we find fossil remains. They are essentially unicellular organisms, that is, single celled forms. Foraminifera and radiolaria have been found in the Proterozoic rocks. Of course they would have to be found in areas where the rocks are undeformed and in the North American continant, those two areas would be the Grand Canyon and the Bell series of northern, no western Montana. Sponge spicules have also been found. These rods of silica which were the internal framework of the sponge. Such was the record of life for the first two-thirds of geologic time. You can see we have to go rather rapidly to get the earth populated in the remaining one-third of geologic time.

Beginning with the Cambrian all of the Phyla are reppesented except the vertebrates. Now that was almost a phenomenal advance. In the Proterozoic we had two represented, the Protozoa and the foraminifera, and then in the Cambrian, every Phylum was represented by some form. Note that I say, some form, except the vertebrates. From here on the succession of introduction follows almost exactly the zoological classification.

In the Ordovician we have the appearance of the first vertebrat, the Ostracoderm; in the Silurian, the first fish appear in the form of sharks. In the Devonian the Ammonoids appear -- they have not been present previously, the

Ammonoids appear. We find that certain forms have reached the end of their racial history and so extinction began. The last of the Ostracoderms lived in the Devonian, only three periods for them. The ancestral forms of the echinodermata, the cystoid was extinct so the population of the earth is changing. During the Mississippian we have introduced the insects. Up to that time the world was free of them. The next, the vertebrates, also appeared. The Amphibian appears in the Messozoic, and the last graptolite lived in the ocean waters. In the Pennsylvanian the coal plants reached the height of their development and in the marine waters the last blastoid was in existence. Blastoids you remember are those nut-like forms along with the Echinodermata. In the Pennsylvanian there was also the appearance of reptiles so you see that they are being introduced in just the order in which they were here. The next is the Permian and we have modern corals, the appearance of modern corals, having septae arranged in sixes rather than in fours, that is, six, or multiples of six. The time has come for the end of the Trilobites. If you ever find a Trilobite, you can be sure that it came from the Paleozoic, for none lived before and none lived after the Paleozoic. The same is true of others of these in this summary which I am giving you. ??? Blastoid during Paleozoic time. In the Messozoic, during the Triassic, the last straight nautiloid lived. The ruling reptiles, that is, as distinguished from the modern, the ruling reptiles began their modern history. (Interruption. Question: What was that, the end of the Triassic? Answer: ???) In the Jurassix the first birds and the first mammals lived and this was the climax of the reptilian development. It is the Jurassic which has been made famous through the courtesy of the Sinclair Oil Co., that is, all the reptiles come from the Jurassic. A few come from other rocks, Cretaceous, for example. The Cretaceous was the chalk-forming age of the world. Practically all the chalk deposits of the earth were formed in Cretaceous. Modern plants, or I should say, flowering plants, make their appearance. The Ammonoids have disappeared from the waters of the earth, the Ammonoids. The ruling reptiles are gone after the Cretaceous. In the next era, the Tertiary communities are

characterized by the development of mammals. First they are primitive, unspecialized forms, but as you come closer and closer to the present, forms assume more and more modern characteristics. The primitive and archaic and out-of-date ancestors die out; they become extinct. Man as a form of animal life is known from the Pleistocene, but not earlier than the Pleistocene, the ice age.

A nd so in this brief summary I have tried to show you how the animals of the earth have changed, that is, how to take a composite view of the animals living on the earth during each portion of geologic time. Each portion of geologic time has been diagnostic because of the animal or plant life during that time. A ny questions over this material?

Perhaps just a word can be added as a summary to what I have geven you. It may help you to orient yourself when we get into it a little bit deeper. The Proterozoic we can call the age of unicellular life. The Paleozoic, let's divide the Paleozoic -- the early Paleozoic would be the age of invertebrates and the late Paleozoic would be the age of primitive vertebrated. The Mesozoic we could call the age of reptiles and the Cenozoic, the age of mammals. Those would be more or less the high points along the way.

One very commom misconception which I would like to remove before it is too firmly established is that all I am trying to do is mention the changes, and it is up to you to accept the ideas as we go along otherwise we could never cover the material.

Now when we say the Paleozoic is the age of invertebrate and primitive vertebrate life and the Mesozoic is the age of reptiles, of course you realize that the unicellular forms would continue and then as we go on, the invertebrates would continue and then the primitive vertebrates would also continue. All I am trying to do is give you a skeleton.

I will take just a little time to show you some illustrations of these forms. These are the foraminifera; they are unicellular. You can see the variety of forms these animals can build. Notice that many consist of a number of chambers

such as that form and it is all constructed by one single cell. In this form, groups of sand grains have been cemented into a house and these spiral forms. These graptolites are supposed to have started their geologic history by first growing up from the bottom and then floating downward from some floating body. Then there was the construction of the float and the construction of the feathery like extensions and then that is the final reconstruction of them.

These are bryozoans, moss-like animals usually. These lace-like pa terns, these threads in the lace wo ld be the calcium carbonate in the individual. By these you can imagine the size of the individual. Notice this one in the corner. This is the one with the spiral central support. (Interruption. Question: You can get that one in the Glenwood series, can't you? Answer: ???) Notice these with the projected hinge areas, this being the hinge across the top, extreme extension of the hinge area. Other forms here show the hinge area more rounded. That would be in the right-hand corner. There are still others which are not represented.

Here are some representative pelecypods and some cephalopods. The name ammonite or ammonoid comes from the Greek God Ammon who was a goat, so they named these forms from the coiled shell which resembled a ram's horn. These dark portions represent the sutures of the ammonoid. This would be a side view and this would be an end view so you can get an idea. This will show you where I got some of my thunder. A. would be a normal nautiloid; B. in here is jurassic, belemnites, which were particularly characteristic of the Jurassic. You can see from this that projection which comes out of the animal here. That shaded portion is the only part that is preserved and is the fossil, and the bone shrinks away. (Interruption. Question: That tube on the side, that isn't a feeler, is it? Answer: ???)

Some gastropods or snails, quite a variety of them. Trilobites. (Interruption. Question: That one up on the top must have been a pretty prickly mouthful for any who wanted to eat it.) This one I won't have to name

for you. This is some of which I haven't as yet spoken, the family tree of man, I want to find out something now before we go any farther. There is about one-half hour left of this evening's period and I want to find out how much these names mean to you. Do you have a definite impression of an organism when it is named? Would you know it if you saw it? I think personally the time would be well spent if I turned you loose on some specimens. We can spend part of the time doing that and then maybe go downstairs into the museum after. Next time I am going to try to cover the changing populations, and that is going to be a pretty big job.

CD:HVA

This evening I want to try to tell you something concerning the various populations which have inhabited the earth. I speak of these in the plural largely because from time to time they had characteristic individuals living in the various communities and for that reason, one population was not the same as the other even though they were ?, that is, groups of animals, yet the individuals as well as the varieties were different at different portions of geologic time. We will take them up in chronological order.

I have told you something about the evidences of life in the Archaeozoic, and that is an algae or alga, I should say. It was found in the rocks of northern Minnesota and identified by Miss Tilden of the Botany Department, who, if anybody can identify algae, it is she. She says there is no question about the identity of this form, but it is the only fossil known from the Archaeozoic. Other evidences of life consisted of the graphite in the Grenville series. You remember the Grenville is the series of ? rocks found in northern New York and the adjacent provinces of Canada. Thus for the first one-third of geologic time, the record of life is conspicuous by its obscurity if not by its absence. There is no place in the world where Archaeozoic rocks are unmetamorphosed, undeformed, and that universal characteristic undoubtedly explains a large part of the lack of recognizable forms in the Archaeozoic rocks.

Now I should like to postulate that the life that existed on the earth during the Archaeozoic was similar to that which exists today in larval forms found in fresh water as well as marine water. During the Archaeozoic few forms had gone beyond this rather primitive state, yet today they are, of course, the primitive forms of the earth. If we want to characterize the various portions of geologic time by the ~~port~~ types of life which prevailed, I think we should do that in order to get some conception of continuity, then we should call the Archaeozoic the age of larval life. Another reason which we might introduce here in considering it to be larval -- these forms have no skeletons and therefore they would not be preserved in the rocks, so therefore it is not a matter of imagination. There is some basis to that.

Now for the next third of geologic time, the Proterozoic. Fossils which have been found in the Proterozoic have been recognized in areas where the rocks are little deformed. With respect to such areas on the North American continent, you will recall that they are largely found in the Northern Rockies, in the vicinity of Glacier National Park, and in the Grand Canyon, the rocks at the top of the narrow gorge in which the river flows and at the rim of the Canyon wall. The forms which have been found in these rocks include radiolaria, foraminifera, (Interruption. Question: What was the last? Answer: Foraminifera.) and spicules of sponges.

In addition to these animal forms, there are also found again, masses of ls deposited by algae. The precipitation of ls by these plants which we call algae is an involuntary process. They extract CO_2 from the water and use it in the manufacture of food. In the water surrounding them where the CO_2 is extracted, the$CaCO_3$ is precipitated and that is the derivation of the solid material which exists as a fossil. It's like this: $Ca(HCO_3)_2 \rightarrow CO_2$ and H_2 , $\rightarrow CaCO_3$. It is the $CaCO_3$ precipitated around the plant masses.

With regard to animal forms you recognize the presence of the protozoan, the unicellular animals, the single-celled animals. This has led to the designation of the Proterozoic as the age of unicellular life, indicating that the forms had gone beyond the larval stage and that in their maturity they still consisted of a single cell, but they had advanced or developed sufficiently far so that they possessed skeletons, and thus left a record of their existence. As to the possible reason for the absence of other forms during the Proterozoic, I think it can be left until we come at it from another point of view. In such a way we have disposed of the biological record of the first two-thirds of geologic time.

Thus we come to the Paleozoic. Quite often you will hear the term pre-Cambrian used. It has been so sued because the Cambrian represents the oldest series of rock formations in which there are well-preserved remains of animals.

That has been taken ¢¢¢ then, more or less as a standard to which rocks can be referred. Pre-Cambrian means that the rocks are essentially deformed and characterized by absence of fossils, whereas Post-Cambrian time does not exclude deformation, but it does mean that the rocks contain more fossils. I think Cambrianis to geology or I should say geologic time what the birth of C hrist is to the designation of time under the present circumstances.

Among the Cambrian individuals or the groups of animals in the Cambrian, the most important form because of its abundance, is the trilobite family or group or class or whatever you want to call them, the trilobites. By and large considering the Cambrian forms of the entire earth, the trilobites make up about 60% of the population. (Interruption. Question: At that time you mean? Answer: Yes:) Now there are a few areas in which trilobites are abundantly preserved and in almost all Cambrian rocks you will find some fragments of trilobites. The St. Croix series along the eastern boundary of Minnesota has trilobites in it. They are not especially well-preserved, that is, whole specimens aren't, although the heads and tails are beautifully preserved. Just in case you have run out of names, that will be one to add to your vocabulary, Discellocephalus Minnesotensis. That is the trilobite that designates the rocks of the upper Cambrian, Discellocephalus Minnesotensis, that's it's name. We had another relative by the name of ? but Discellocephalus Minnesotensis is the horizon marker, the index of the upper Cambrian age of the rocks.

In the various outcrops of the Cambrian rocks as exposed on the North American continent, you can usually find some fragments of trilobites. Perhaps one of the most outstanding regions in which you find trilobites is located in eastern British Columbia. It is Mr. Stephen, S-t-e-p-h-e-n, Mr. Stephen, about the village of Field, Field, British Columbia. It is just a short distance west of Lake Louise and if you ever get as far as Lake Louise, by all means go over into British Columbia and Mt. Stephen and hunt for trilobites. The locality is east of Field about a mile, although you go out of the south boundary of the

town. There is a trail which leads up the mountain side, a climb somewhere in the neighborhood of ? feet, and the last part of it is stiff going ??? but after you get up above the timberline, you get to this talus slope, just rock fragments from there up to the top of the mountain. As soon as you get to the place where there are no trees you find trilobites and from there on up, everywhere you go, walk, stand or sit, you will be on trilobites. There are so many, one may get sackfuls.

My personal experience in the vicinity resulted in rather an amusing incident. Finding such an abundance of trilobites, it was of course, very greedy on my part to try to bring back most of the mountain. I collected as many as I possibly could with the help I had with me. When we started down I found I had more trilobites than I could carry. The collecting bag was full, the lunch bag full, breech and jacket pockets full, and yet I wanted to bring back more of them so there was only one thing to do. My wife had on two paid or socks in her boots and she came down the mountain side with but one paid and the other paid full of trilobites dangled around my neck. That was one day's collecting. If you want trilobites, that is where to get them. They are mid-Cambrian, so they are of a different variety from that one I had on the blackboard.

("Adventures in Molluscoidea" read.)

The trilobites of the Cambrian period reached a maximum length of 15 inches so they would be from that size on downward to forms, oh, 1/8 of an inch , which would be the maximum size of some of the smaller forms. That will just give you an idea as to their size.

Next in abundance in the inhabitants of the Cambrian seas were the brachiopods. Although two types of brachiopods were present, one was especially charagteristic. It was hingeless, or said to be inarticulate, that is, the valves or the shells did not open by moving in opposite directions from each other, that is, by moving up and down. They moved by rotating the valves. ??? and by rotation, the long axis of the ??? and it left an open space whereby the animal could

feed. These forms had long and pointed beaks, by beaks we refer to the portion where the valves normally remained constant, where the shell ??? if it did hinge. The form which is being passed around has a shape somewhat like that, more or less ? shaped. This would be the larger valve. The other valve was less long at the beak and thus there was this projection beyond where there was an opening through which came the pedicle which held the animal to the mass of rocks or to whatever it was attached. This particular form which you have is characteristic od the St. Croix series. It represents the Cambrian and its name is Lingulepis. I am not interested in your remembering these names. If you want to, all right, but anyway I should like to have you remember it is a pointed hingeless, smooth-surfaced brachiopod. The only markings on the shells would be some very find concentric growth lines. (Interruption. Question: Would you find those over at Burkhardt's Mills? Answer: ???)

There is another one, well, I don't think we will put it in here. So in the Cambrian, there were these pointed hingeless somooth-surfaced forms. (Interruption. Question: Those rocks where you find them, do they belong to the Cambrian series? Answer: ???).

Now at the same time we had these forms and all others which were hinged. They had a straight hingeline, and they were slightly plicated, so the animal looked somewhat like I sketched here. This would be about one-half inch for the height. This is always spoken of as the height of the brachiopod. I am not going to stop to mention that one. I am just indicating that there were other forms. The first one, the inarticulate one, was the ? form. I should mention one more thing. The inarticulate forms have phosphate shells whereas all of the hinged forms have calcareous shells. (Interruption: Question: Is that the type of shell that makes the phosphate deposits of the Tennessee Valley? Answer: ???) (Interruption. Question:Which one was inarticulate? Answer: ???)

Other inhabitants of the Cambrian seas were some simply coiled gastropods. There is one form that looks something like that, like a cap, like a liberty cap of France. The animal had begun to coil but it is only about one-half way around.

There are others in which the whorl is complete. They are never high-spired, never very many revolutions to the forms.

Another form in the Cambrian seas were the cephalopod. They were represented by the cylindrical nautiloid, the Cambrian ancestors of these forms. They were relatively small compared to the Ordovician descendants, but they were present in the Cambrian seas and all of then were these cylindrical types. They are commonly spoken of as Orthoceras. The term means a straight cone in the sense that these tapered and may have looked like a cone. They are not abundant.

There is another form present, but not abundant. Those are the graptolites, the graptolites which grew up more or less as a plant would grow, attached to the sea bottom. You can see that the number of forms of life lifing in the Cambrian were not particularly abundant, that is, not so many varieties, yet the development which had taken place was advanced, far advanced over the previous ers. And in the forms present we would probably have to say that as much development took place previous to the Cambrian as has taken place since. We have one of the most highly developed of the invertebrate forms ??? insects, which are competing with man for the possession of the earth at the present time. In these Cambrian fossils, all the ? phyla were present. They had means of capturing food and digesting it. They had organs of idgestion and ?, in fact, every organ which was necessary for life was in these Cambrian forms. Since the Cambrian only one other addition has been made to the animals, and that is the internal skeleton. None of the Cambrian forms had internal skeletons. That is the only fundamental difference, that has taken place since Cambrian time.

Gowing on to the Ordovician we come to the forms which you would expect to find along the river bank here on the Campus. If you went out here to the outcrops and began to look for fossils, possibly one of the first things that you would find would be a bryozoan - they are so abundant in the Ordovician rocks. They were so abundant that one man who was working on them was accused of being paid by piece work in the naming of them. He found such a number of varieties of them. His book on them is about so thick. ??? has been written about

them forms of the Twin City region.

For the most part there are three varieties, twig-like encrusting meases, crust-like masses and some hemispherice forms; although these forms were abundant and varied in the Ordovidian I should like for you to remember them as a form which existed throughout geologic time with very little change. They are just about as simple today as when they first appeared as fossils. Perhaps the second form you would find out here in the rocks on the river bank would be the brachiopod. The brachiopods of the Ordovician period were usually one of two kinds. They are concavo-convex with straight hing lines and slightly plicated surfaces, more or less shield-shaped. This is one case where competition is illustrated by the fossils. As soon as some manufacturing concern markets something for which they think there will be a market, as soon as they put it out their competitors put out something just as good, or so their salesmen say. Well, here are two brachiopods who did the same thing. This one ??? so in one form the pedicle valve is convex and in the rival form the pedicle valve is concave, otherwise they are quite alike. This one is Rafinesquina and this one is Strophomena. This type of brachiopod is so characteristic that I should like you to think of it as the concavo-convex straight-hinged brachiopod. It is characteristic, or they are characteristic of the Ordovician, these two. These are demonstration models which were made for the purpose which I will use them now.

There are the two valves. It is rather impossible to believe that you could have a concavo-convex organism and have any living material in between and yet when you put the two shells together there was room enough for the animal itself. (Interruption. Question: Which side did the animal rest on? Answer: ???) This one is a model of this one and this one is the concave valve and this one is the convex valve. If, in making this, they had split it along the other edge, they would have had the other brachiopod. That is the only difference.

The brachiopods were becoming such abundant forms that we begin to find in the Ordovician the introduction of new varieties and this is one of those forms. We will speak of these as the round-hinged plicated forms,

these ribs being the plications. They are the corrugations. They serve the same purpose an this animal as the corrugations do. They are for strengthening the shell. If we were to take a cross section of the shell we would find that these corrugations would be something like that. They strengthen the shell without adding thickness to the shell. These forms had two sets of muscles, one for closing and one for opening. If the shell was constructed properly the ? goes underneath and the center or pivot point ???. It is rather hard to demonstrate. It was a matter of two purposes, one was to strengthen the shell. You will notice this brachiopod has one other feature. It is quite probable that, well, it has this depression called a sinus and this hump called a fold. It has an interlocking feature. It is quite probable that this brachiopod was being preyed upon by some other animal and the Cambrian forms such as these could be very easily opened or cracked and as soonas they were, they were exposed to being eaten.

Now in this model, well, the shells of the organism were about that far apart then they were eating and if something did try to eat them, not a chance. As to why this type developed, purely foolishness. As I have heard this was a Scotch brachiopod ??? to pay him for this effort. That is endowing him with a little too much intelligence but nevertheless that's the evidence. Now there were other types of brachiopods. I don't mean to say these were the only two but these are the characteristic forms. Now there were other forms.

They were biconvex forms. This very fat one of this model is biconvex. There were others which had this general outline and yet both the shells were biconvex. These two forms, however, are the characteristic forms in the Ordovician. ¶ You will remember that these organisms were able to go wherever there was open water, because they were able to be widely distributed; the graptolites are an excellent horizon marker, an index to Ordovician rocks. There are other graptolites, but if you know graptolites, then these are the best horizon markers that you can use in the Ordovician.

The corals were characteristic forms although they became more abundant at a later date. Out in the rocks of the river bank you would find maybe

some horn corals. This is a model of the horn coral. These are the ridges or septa of the horn coral. I think most of you would recognize a horn coral when you see it so there is no reason why we should burden you with names.

The masters of the Ordovician seas were straight cephalopods and straight nautiloids. They got to be 15 feet long and were about one foot in diameter. They were carniverous forms and therefore they must have been quite ? inhabitants of th Ordovician seas. Although these straight forms are more abundantly represented, there are others in the Ordovician which are bent, curved, and coiled. If you can recognize the difference in these fours terms, straight, bent, curved, and coiled, so at the time of the greatest abundance we also have the greatest variety of these nautiloids.

They are rather abundantly found in the Twin City region as well.

Then we come to the trilobite. Although the trilobite represents the most abundant form of the Cambrian, yet the greatest abundance of trilobites came in the Ordovician. That is, if we were to consider just the racial hsitory of the trilobite, we would find the greatest number and the greatest variety in the Ordovician than at any other time. Unfortunately in the Twin City area they are not especially characteristic of the Twin City rocks. One particular habit of these was to roll up so as to put head and tail together and thus protected themselves by the ? on the outer portion of the back. Many are found fossilized in that condition, and adaptation to ~~s~~ perhaps such a forms as the cephalopod. (Interruption. Question: Is this an evidence of social organization of these forms? Answer: ???) (Interruption: These fossil examples over here, they are all going in the same direction indicating that that might be a suggestion of a social organization like in the schools of fishes? Answer: ???)

The next, the Silurian, which is characterized by the chain coral. You remember that they are colonial forms in which wach individual builds a cylindrical case and these cylinders are one attached to the other, and when seen in cross section, resemble a chain. Honeycomb corals were also present, but

they were not so abundant as the chain corals. Among the brachiopods we have the appearance of still another form. I have found that students usually refer to this as the butterfly brachiopod. It think it is rather an apt term. It is rather biconvex, it is plicated and has a fold and sinus, but differs from the others in the hinge line. The hingeline is prolonged or extended so as to produce these wing-like structures. Spirifer, that's the generic name. On the ? side of these valves, the ? were supported on spiral calcareous supports and that's where they get the name. It is on the spiral internal supports. You remember the ending ifer which means to bear, so this would be a spire bearing form. These ??? and lived through the rest of the Paleozoic. You can see from what I have told you about brachiopods so far that you can tell the age of a series of rocks by the variety of forms present. If we find these we know the age of the rock; if we find this one, even though this one lived through the entire Paleozoic and either of these two, we could tell the age of the rock, and if we found this one ??? we could still tell the age and so on. I might add that in the Silurian we had descendents from these forms, the straight-hinged-concavo-convex shell with this difference, not as flattened an area which we call the ? area. In the Silurian descendants, there are transverse lines going across here. That is essentially the only difference. We will see what happens to that in a very short time. Among the trilobites we find a rather interesting thing. When forms approach the end of their racial history they begin to do all sorts of peculiar things and that was true of the Silurian trilobite. They began to oh, grow spines or nodes and they get rather peculiar shapes and things which were as useless as a fifth leg on a dog. In the modern slang, they are best described by calling them sport models. They existed for a short period of time and then they went out of style so far as the community was concerned, and then they were gone.

I don t mean to imply that the conservative forms were not present, for that is not true. (Interruption. Question: Wouldn't that be an effort on the part of the species to protect themselves? Answer: ???)

In your text book, if and when you read it, you will find probably mention of the form eurypterid in the Silurian. The eurypterid was a fresh water form. It is commonly described as a water scorpion. It belongs to the Phylum Arthropoda. (Interruption. Question: What is the life span of the individual in days, months or what? Answer: ???) The eurypterids are mentioned quite frequently in the book. That's largely due to done reason. The best specimens have been found in the state of New York and most anybody who makes a ? at wriging a book has done work in New York or has visited the New York museum and gets in these eurypterids.

Going back to he marine forms we should mention the sharks, the first successful vertebrate. They lived in the Silurian and of course as sharks, have continued to live to the present.

The next period, the Devonian. The Devonian is important because of the introduction of a new subdivision of the Cephalopods, the Ammonoids, the forms which are characterized by sutures which are not straight. This is the interesting thing to know concerning these ammonoids, that they began with an externalform which is a most complex development from the nautiloid. The nautiloids began straight, then bent, then carved, then coiled and even in the coiled form they had straight sutures. When the ammonoid form began they are straight but the sutures are not straight. ??? and again let me say that even though the ammonoid is characteristic of the Devonian, the nautiloids continue and all the varieties are still present and living in the Devonian.

In the Devonian among the brachiopods the spirifer becomes a very important form. A great number of varieties of this form were present. There were probably more Spirifers present in the Devonian than at any other time, that is, not spirifers because there were more brachiopods living during Devonian than at any other time. The Devonian would then be the zenith or climac of the racial history of the brachiopod. They were great in abundance at that time. Then they began to do some rather peculiar things.

I spoke of the Silurian descendant of this form that had lived on. In the Devonian they began to have little spines which stick up along the edge of the hinges. The spines are usually poorly preserved and so on this form I don't know if you can even see them. If we had a good specimen, we could. This form becomes Chonetes. It is concavo-convex, straigh hinge-line, slight plicated and begins to have spines along the edge. I will draw it for you so if you could see it, you would; you can see it on the drawing however. That's the way it would begin to look. Then, not content with that because of the abundance and the varieties, the spines begin to move over this surface and the plications become less apparent and less pronounced and so you have little protrusions over the surface. The form is still more or less semicircular and then these spines begin at the hingeline. As you go farther and farther into the Devonian, the spines go farther and farther on the valve. That one is Productella.

During the Silurian I spoke of some honeycomb corals being present. This one which I am passing around is one of the honeycombed corals of the Silurian. This next form is a small nautiloid from the Ordovician. One other thing with regard to the Devonian. It is commonly spoken of as the age of Fishes. Every variety of fishes except the modern forms were present. There were more of them during Devonian than at any other time. There were sharks of which we have already spoken in the Silurian. There were lung-fish forms in which there was an outgrowth from the alimentary tract which served as a lung. There are still three species living on the earth today, one each in Africa, Austrialia, and ?. These lung fish live in an environment which fails seasonally. The lakes dry up. During the drouth the fish secrete themselves in a coat of slime and then stay that way until the wet season comes again when the cocoon disintegrates and the fish feed enough for the next time and the process is repeated. Most of the lung fishes were fresh water forms. During the Devonian we also had enamel scaled fish like the garpike or the sturgeon which live today, and there is still another variety which we won't bother to name, a joint-necked fish, a fish which could move its head up and down

in a vertical direction. If you had it in a fish bowl, it could nod good-morning to you. These were the most savage forms of the Devonian environments and these were marine. They had very massive crushing jaws. The coincidence of these fish with the crushing jaws and the brachiopod is rather interesting.

The next is the Mississippian, when we have as one of the outstanding things, the abundance of echinoderms, and abundance of blastoids and crinoids. Some limestones such as, for example, the Chester series of which you have heard before, are made up largely of the remains of blastoids and crinoids. In Iowa is probably the richest area for Mississippian crinoids in the world. There are others -- one is in ? Indiana. Most of the Mississippian specimens of crinoids come from that Iowan locality. Out in the Chester series in a little gully that wasn't over two feet long in shale, some of the very few shale horizons which occur in the Chester series, I have gathered all the blastoids that you could hold in your two hands. That gives you some idea of the abundance. Some places in the Chester where it is fractured, these forms drop to the bottom of the crack and you can take out as much as a cigar-box full of perfect specimens. The stems of these forms are quite similar ~~to~~ and they ~~are~~ are very abundant in almost all Mississippian rocks.

There is one coral which is an index to the Mississippian. I think you are beginning to realize that the only thing I am beginning to refer to is or are the indices. This coral is a colonial forms. Each individual built a hexagonal prism, but it lives in a cup at the top. Now we speak of a form such as that one as a cup coral and also as a horn coral. We are going to/at present describe this one which is characteristic of the Mississippian as the colonial cup coral in order not to confuse it with this one which is a solitary form. They are entirely different. That form is designated as Lithostrotion. (Interruption. Question: Is that a magnesian discoloration on this specimen or is it iron? Answer: ???).

Another index or horizon marker for the Mississippian is this spiral shaped support for the bryozoan. If you want to remember it that way, all right. It's name is Archimedes. Archimedes was a very smart man in that he made the first pump, and he was the first one to realize the value of the spiral. That is

how he made the pump. He put the lower end of the spiral into the water and as he turned it, the water wound 'round and 'round and came out of the top. This fossil archimedes is an index fossil in the Mississippian. That is the only place it is found. In the brachiopods, the spirifer form continues and then we begin to have forms in which the spines appear on both surfaces and the form is larger. If you don't want to remember the name of this one, it is known as the spiny brachiopod. Perhaps I should add that it is plano-convex, one valve plane and one valve convex. Now you prob ably want to see the spines on these. All you will see is slight projections from the surface. The spines have broken in recovering the fossils, but if you find them in place, you will see the spines.

Then another brachiopod more or less combines the good characteristics of many of them. It is called the Composita. It is a composite form, in other words. This is its model and the from is being passed around. It is round hinged. You cal also use the term short-hinged if you want to; they mean the same. It is a smooth-surfaced biconvex form with a fold and sinus and thereby differes from these other forms which we have described. I spoke of the interlocking edge. These forms have an interlocking edge without the necessity of plications, but when the animal is feeding ??? and yet the valves cannot be twisted apart and so the folds of the sinus interlock to give us that characteristic.

The fishes of the Mississippian then. The most abundant forms are the sharks, the shell-eating shark. At the present time we have the man-eating shark, but in the Mississippian time there were no men, so they fed on brachiopods. These forms had pavements of crushing teeth. Today the sharks have a pavement of cutting teeth. Here again a coincidence, the shell eating sharks follow the abundance of brachiopods. It is well worthy of note that the forms feeding on brachiopods lived in greater abundance at the same time as the brachiopod.

Now we should pay attention to a protozoan of the Mississippian, more or less of a shperical form that is found abundantly in the rocks known as the Bedford ls, Indiana Stone, the ? building stone or whatever name you want to give it. This animal was very abundant at that time.

The last period is the Pennsylvanian, when of course we had the coal plants. I haven't said much about the plant kingdom, but during the Pennsylvanian there were coal forming plants and regarding that material, I am going to ask you to go to your tests. The pictures of these plants are important.

In the Pennsylvanian swamps there were significant insects, particularly if size means anything -- dragon flies with a wing spread of 29 inches. Dragon flies were also called snake feeders, frying darning needles or whatever you want to name them. Insofar as insects are oncerned, you might call the Pennsylvanian the age of cockroaches, for they were unusually large. ??? you had to tie your shoes to the bed posts if you wanted them in the morning. During the Pennsylvanian, the Productus and Composita are very abundant and characteristic. They are about the only two brachiopods you will find in the Pannsylvanian rocks. It is not surprising that you find quite a num ber of amphibians. They first appear in the Mississippian, but were not significant forms, but in the Pennsylvanian coal swamps they were. They were similar to an over-grown salamander or mud puppy. They were not particularly graceful? indicating that they more or less ? themselves through the slime of these swamps. In general, these amphibians were spoken of as stegocephalians. Of course you recognize this, and the first part means ???. They had a kind of ? on their heads. Reptiles were all present, but not very abundant.

Then in the next period of the Paleozoic, the Permian, we have the appearance of the appearance of the modern corals, the corals of the six-fold symmetry. The trilobites are present for the last time. The blastoids are not even present here. They dies out at the end of the Pennsylvanian. The amphibians are approximately like those of the Pennsylvanian, and some of the reptiles begin to grow useless structures, the most conspicuous one of which is a vertical fin down the back, and that's all that we have time for except just a word with regard to a summary now.

The Archaeozoic was the age of larval life; the Proterozoic, you will remember was the age of unicellular life, and the Paleozoic is dominantly the

age of invertebrates. Other forms are present as you can see, but as you think, by and large, of the Paleozoic rocks, it is the age of the invertebrates. That is the conspicuous form of life in the Paleozoic. Next time we will finish the Mesozoic and the Cenozoic in relation to the biological and geological changes.

CD/HVA

May 15, 1936

Last time we considered the communities of the Paleozoic and before proceeding, I think we should take enough time to summarize. I have forgotten whether or not I did, therefore we will. Now it is a little diffiecult to keep these changes in mind, therefore it is well for us to emphasize certain of the mileposts among these various changes and we do that best by describing various portions of geologic time as being the age of such and such, for example, we call the Cambrian the age of trilobites because of the abundance of those forms in the Cambrian communities. Now that doesn't mean that they were the most abundant in their racial history, but it does mean in the Cambrian, the trilobites were the most conspicuous forms.

The Ordovician we would designate as the age of Nautiloids. We use that designation because they were large, because they were abundant and because they were the most ? and therefore probably the most ferocious animal pf the Ordovician time. They have been characterized as the masters or the rulers of the Ordovician seas.

For the Silurian it would perhaps be best known for its chain and honeycomb corals although the appearance of the first vertebrates in the form of sharks is significant. The Devonian would be known as the age of fishes and possibley the age of brachiopods. It represents, this period represents the climax in the racial history of the brachiopod.

The Mississippian would be the age of blastoids and crinoids. The Pennsylvanian would be designated as the age of coal and amphibians. The Permian has no characteristic life forms by means of which we can designate it. Perhaps if we want to emphasize one thing in the Permian that occurred during no other time, it was the presence of fin-backed reptiles. So much then for review in summarizing the Paleozoic. Any questions over that material?

Beginning then, the Mesozoic. The first period of the Mesozoic would be the Triassic. A mong the Triassic forms attention should be called to the beginning of plant life of a higher type. For example, the Triassic

contains abundant representatives of the group known as gymnosperms. The most common of these living forms at the present time are the evergreens trees and the petrified forest of Arizona which is Triassic in age and is made up exclusively of conifers, that is, cone-bearing trees, evergreen trees. Other gymnosperms were present, but the petrified forest represents the greatest abundance of these forms. You will perhaps recall that the modern corals were introduced in the Permian. By modern corals I refer to those forms in which the septae are introduced in multiples of six. For example, those would be the early or primitive forms.  Then the next ones would still be in sixes  A nd now another group is introduced, and that would be in twelves, in twelves,  If another group is introduced, then of course that would be in 24's and so the animal has an entirely differeny symmetry than those corals which had been living through the previous periods of the Paliozoic.

Paleozoic corals diagrammatically seem to be divided into four sets with the partitions radiating from the center or converging at the center.  Actually they don't quite to that, but along the side, well it is like this.  so just at a glance one would say it was radial, but closer examination would show that it was actually divided into four partitions. It is therefore spoken of as the tetracoral and that is the characteristic coral of the Paleozoic This one is divided into six parts and therefore is spoken of as the hexacoral. The last tetracoral lived in the Triassic. Now here again, if we closely examine the arrangment of septae in a coral we can approximately tell its age; we can tell if it is either younger or older than the end of the Paleozoic. Before the Permian only the tetracorals lived. After the Triassic, only the hexacorals lived. That is an illustration of the use of these forms as indices to the age of the rock.

When we were considering the various communities of the Paleozoic I mentioned a great variety of brachiopods. Now when we come to the Mexozoic rocks we find the brachiopods very very inconspicuous, another instance of

the way in which we can recognize the age of the rocks, by the fossils in them. I wonder what brachiopod we would choose to have lived on the Mexozoic generation? (Interruption. That Composita, that one.) Yes one that is similar to the Composita. It had a short rounded hinge line and a smooth surface. The top view of the valves would be like that  whereas the other view would indicate that it was biconvex.  and where the valves came together, there was this fold and sinus interlocking. The brachiopod of the Triassic is the descendant of this particular form which I have here on the desk, and again I am not interested in the name, but if you want it, it is Terebratula. Terebratula is the form which is still living today, not the same individual and of course not the same species, but the same type of shell is living at the present time and began its geologic history at the beginning of the Mesozoic.

There is one other form that lived during this time in which the fold and sinus were absent and the surface was marked by plications. It wasn't quite as round as this one, but there was a brachiopod with some sort of a surface ornament. These two brachiopods are practically the only forms that are quite abundant in the Triassic. The other forms which we considered were for the Paleozoic. The Paleosoic, then, is the time of the brachiopods and since then they have been relatively inconspicuous. The

The cephalopod of the Triassic also shows some significant changes. The last straight nautiloid lived during the Triassic. They began their geologic history in the upper Cambrian, at least that is the oldest fossil form that has been found. They lived through to the first of the Mesozoic period. Since that time only the curved variety has lived and we call them the chambered nautilus of which you have seen specimens.

Another variety of ammonoids is present in the Triassic. In the Pennsylvanian, the ammonoids were introduced and the form present was one which was coiled and in which the suture lines were all in broad waves such as something like that  These with the broad waves, all of them are known as goniatites.

If is merely a variety or subdivision of the ammonoids. In the carboniferous other a mmonoids appeared in which the forward lobe of the suture was complicated by a series of wrinkles such as this  That loop is known as ceratite. In the Mesozoic during the Triassic, now as I stated you wee thre apppars a form in which the entire suture is cerrated.  This one is the ammonite, a group of the ammonoids. (Interruption. Question: What was that, did you say? Answer: A mmonite, a group of the ammonoids.) All portions of the cutures are cerrated, as I said. The ammonite is the characteristic form of the entire Mesozoic. A form was also present, well let's skipit.

By far the most important fossil of the Triassic are the reptiles. In the Triassic the reptiles were so abundant and so well represented that we find them divided into three groups. These forms were sometimes designated as the ruling reptiles to distinguish them from the modern reptiles. ??? thanks to the courtesy of the Sinclair Oil co, a form known as the dinasaur and another form known as the enaliosaur and the third subdivision known as the pterosaur. This inhabited the land, the dinasaur, the enaliosaur the sea and this one, the pterosaur, the air. A ll three subdivisions were present in the Triassic, but the variety of the forms in the subdivisions was not as important as at a later portion of the Mesozoic. You will perhaps recall that one of the formations of the Triassic was the Newark series deposited in intermontane basins on the land mass Appalachia. (Interruption. Question: What did you ca ll that one? Answer: Newark series, N-e-w-a-r-k) The specimens of the Dinasaur tracks which you saw in the museum were taken from the Newark series. You remember that they were shaped more or less like a bird's foot, of course there are other resemblances between the birds and the reptiles. (Geologic story of footprints in the Newark series). I think we can let the dinasaurs go until we come to them at a later time. There will be more for consideration The mammals were present in the Triassic. These were, however, small and very primitive and more or less like reptilian associates.

Now for the Jurassic. Among the plants we should mention for the

Jurassic a local abundance of cycads, c-y-c-a-d-s. These were forms, well there were, there are some of them still living. They are sometimes used as hotel decorations. They resembled palms, which belong, however, to another classification of the plant kingdom. As a fossil form, I can't think of anything that would resemble a cycad more than a pineapple, somewhat larger than a pineapple. W here the scars are on the pineapple, that represents the bases of the stems to which was attached a ? like leaf. These have been found in abundance in a certain number of place. They are found in the Black Hills. There is a place there which is known as Cycad Monument. A geologist went into this territory and collected all the cycads he could possibly get and in his zea l, he became a paleobotanist and he gathered up all the specimens there were I guess and brought them back with him. Apparently his conscience bothered him afterwards and ??? to see to it that this territory was set aside a s a national monument. The cycads are all in the Smithsonian Institute.

In the marine Jurassic, now by tht of course, you recall it would be related to the west coast. In the marine rocks of Jurassic age there are found abundant crinoids. The European Jurassic is particularly prolific in crinoids. Some of the specimens contain 6000,000 individual segments. You remember they had plated skeletons; that would give you an idea as to the complexity of the form. (Interrutpion. Question: That would be one skeleton? Answer: Yes, that would be one skeleton.) That would be worse than taking apart a grandfather clock.

You will recall having seen specimens of echinoids. Some were radially symmetrial. They looked like small cantaloupes or japanese lanters. Those forms first appeared in the Mesozoic and are still living and yet in the Jurassic there begins to appear another variety of echinoderm, one that is more or less heart-shaped, and if you look down on it, the symmetrical form appears circular. These forms which begin in the Jurassic, begin by developing assymmetry, such as that, thus producing a form which is at least crudely bilaterally symmetrical. You know the meaning of the term symmetrical. For

example, a brachiopod woukd be a bilatterally symmetrical form. Those bilateral symmetrical echinoderms appear for the first timein the Jurassic and are still living. The cephalopods of the Jurassice are more diagnostic in the abundance of the belemnitem the ancestor of the squid or cu ttle fish, the form that looks like a cigar although the specimens commonly are three or four inches long. The maximum size of the individuals went up to two feer. Squids or cuttle fish were as large as two feet. (Interruption. Question: Was that the size of the whole animal? Answer: Yes) Right at the time that the ruling reptiles were very abundant I think it is interesting to note the appearance of modern reptiles. Of course by appearance, I mean the first appearance in the fossil record. We don't know how long they lived before that. Turtles, lizards, crocodiles and snakes were all introduced in the Jurassic.

Now if you will recall the general plan by means of which the communities have changed to many forms through geologic time, what would be the next one you would expect? There is only one of which we haven't spoken. The birds appear in the Jurassic. The oldest specimens come from a limestone in Bavaria or what was Bavaria before they began juggling politically. The form was found in a ls which accumulated on the inside of a coral atol. Therefore the sediment was very fine and the delicate features of the bird were preserved. Two specimens have been found and they are of two different species. That means that the birds have a previous geologic record. The Jurassic bird is the Archeopteryx, the ancient winged forms, that is what it means. Archeopteryx was a rather peculiar looking bird. It has claws on the wing because the wings had developed from fore limbs, that is, from the front limbs, and had digits which had become atrified and thus were present. It is doubtful that Archeopteryx could fly. It is most probably that he could climb and fly like a flying squirrel. He had ??? which refers to the tail which was fully as long as the body. It existed as the extension of the backbone and from that tail the feathers stuck out radially. Of course no bird at the present time

has such. Archeopteryx had teeth in his jaw, teeth which were set in individual sockets and they did not touch each other thus indicating the reptilian ancestry of Archeopteryx. The feathers were not the thoroughly developed feathers which adorn modern birds, but they were what you might speak of as fringed scales. The birds at the present time have not as yet completely gotten away from some of the reptilian characteristics. If you examine the leg of a chicken or bird, you will see their feet and the bottom part of their legs are covered with scales which are merely a modification of the feathers. The modern bifds still have that characteristic and the feathers are just more or less modified scales. (Interruption. Question: Do the reptiles have some sort of a stop so they don't shove the teeth into their gums? Answer: I don't know.)

I am going to pass by the ruling reptiles in the Jurassic and speak of them in the Cretaceous when I can speak of the varieties of all of these forms. Perhaps I shouldn't pass them by completely, but I can emphasize the geologic history this way. (Reading) Wyoming of course has contributed more dinasaur remains than all the rest of the world together. Excuse, me, I should say Wyoming and Utah, and most of them have come from the Morrison formation. (Interruption. Question: When did you say they disappeared. Answer: At the end of the Cretaceous.) I don't mean to slight these vertebrates but you can go out and hunt a lifetime and frind probably just a few fragments and then spend a lifetime putting them together. You can go out and find a brachiopod, on the other hand, in its entirety, but if you went out and found a bone or some such remains of the vertebrates, you probably wouldn't know what it was anyway, so we will deal with the reconstruction of these forms.

Going on to the Cretaceous, here again the plants make significant advances. Flowering plants are present. The oldest flowering plant had been found in ~~non-marine sediment~~ the lower Cretaceous on the Atlantic Gulf Coastal Plains. Those of course obviously were found in non-marine sediments,

growing on land; they would be found in non-marine sediments. The animals which are characteristic of the Cretaceous would include such forms as for example an abundance of foraminifera. They make the chalk beds. Practially all the representative chalk deposits in the world are in the Cretaceous. This is why the system is given that name, creta, meaning chalk — the chalk deposits of Dover, the chalk deposits of Brittony. Those of the Gulf Coast are all Cretaceous in age and resulted from the abundance of these unicellular forms that secrete Ca CO_3 (Interruption: Question: Was the water deep or shallow? Answer : ???) Going on there is a heavy shelled pelecypod; it is named ?; it is the form which you saw down in the museum which had a shell several inches in ? and that had begun to twist on the end. It is known that pelecypods prefer shallow water and the pelecypod and pelecypods with then indicate shallow water deposition. The cephalopods of the Cretaceous are wuite interesting and are found with considerable abundance in the Pierre sh, named for Pierre, S. D. In this sh. there are mumerous concretions of $CaCO_3$ in which these fossils a re found. There are found both the coiled forms such as this one, for example, and anothr one which is an index to the Cretaceous, a cylindrical form, the sutures of which are characteristic of the ammonites. The fossil is cylindrical yet internally the sutures are like that of the ammonite.

You have heard this, but it won't hurt to hear it again. In the Cambrian, only straight nautiloids were present. In the Ordovician, straight and bent. These are horribly drawn, but nevertheless , straight, bent, curved and coiled ones were all present in th Ordovician. They are represented by forms, the stages by means of which we arrive at the coiled nautiloid which has live on to the present time. The first ammonoid which appears takes on the external form of the coiled ammonoid, but it has a different kind of suture. They lived from the Devonian to the Cretaceous and then in the Cretaceous we get just a reversal of the geologic history and which one marks the end of the ammonoids, so here we have two subdivisions of the cephalopods, one

begins its history and increases the complexity of the exterior form and lives on and the other begins its history with a complicated exterior form and a complicated interior and in its final stages resumes a simple exterior and retains the complicated interior. Rather an interesting line of development there in the cephalopod. Perhaps the cephalopods are the best forms to be used in the representation of development. (Interruption. Question: Was there any reversal in type of environment? Answer : ???) (Interruption. Question: What do you call the straight one? Answer: Baculites and th s one is scaphites. These are pictured in your text books and you can look them over more thoroughly there.)

Then we come to the reptiles. Now again I am going to try to describe a few of these forms and yet all the time I will spend in describing them here won't do as much as looking in the book. I will point out a few of the characteristics of these forms, starting with this one. This one is, or was one of the largest beasts as has ever been on the surface of the earth, Brontosaurus. That means thunder lizard. The form has been described as more representing an elephant's body with a snake-like head and tail. These forms were inhabitants of the swamps and concentrated the heavy bones in the lower part of the body, and when walking in swamps were thus buoyed by the water. This form was vegetarian. It got up to 90 feet long. The best explantation of 90 feet is to tell you that if you put him on the steps of Northrop A uditorium, his head and tail would reach the ends of th steps. This was one of the very characteristic forms that lived in the Mesozoic, particularly Jurassic and Cretaceous.

Here is another beats. Was it, yes it was King Kong in which this animal was reconstructed. It is characterized by two rows of triangular shaped plates down the back. Stegosaurus. Its name was Stegosaurus. Stegosaurus was a vegetarian. He was sort of a docile creature not being able to ? himself because of his great size and yet bery able to take care of himself because of his spiked tail. There were prongs or spikes porjecting from the tail of this animal. The forelimbs were short and the hind limbs were high. It is believed that this animal when protecting itself turned its slashing tail toward

the enemy. This animal had to have two brains in order to make the back part go where the front part wanted to go. He had an enlargement of the spine in the back portion of his hip which controlled his tail. Stegosaurus was about 25 feet in length.

This is an illustration of two different forms of dinasaurs, this one is Tricerotops. Tricerotops was a vegetarian and had spikes on his face and in order to increase the effectiveness, the head was balanced by a boney frill and the head was so pivoted so the animal could bend its head up and down so it dould use it for protection. There is an excellent skull of this animal in the museum at Rapid City, S. D., so if you ever go there, don't fail to see it.

King of the lizards, or rather tyrant of the lizards. This was one of the most destructive machines of that age. Tyrannosaurus. The front limbs were atrified. The animal walked on two feet; this was because of the heavy tail. The head was large; the teeth were dagger-like. It was about 47 feet in length and about 20 feet in heighth. This one is a form which was made famous by Roy Chapman Andrews in the Gobi Desert. He has made a statement about the eggs of dinasaurs.... they average about one inch in length to one foot of dinasaur. This one was the vrested dinasaur, an aquatic form living in the waters of the land. A restoration of this form is found in the museum at San Diego. Well, that's all of the dinasaurs. I think you realize some of the variety of these forms and their huge size.

Among the enaliosaurs there are such forms as Plesiosaur which can best be described by a turtle strung on a snake. The body was shaped like a turtle. It had no shell; it was rather tub-like, with a long head and a long tail and paddle like limbs, so when it sent about in theseas, it used its limbs as oars. It is known that this form was vegetarian from the environment in which it lived. If is found with round smooth stones, andit is believed these were used for purposes of mastication if the animal did not have time to chew its

food, they merely swallowed the stones and then the food was masticated by the grinding action of the stones.

Another form was the mosasaur. This was distinctly more lizard-like than any other form we hve considered. It was adapted to swimming and the fore part of the body was pointed. These forms lived largely upon fish as indicated by sharp teeth for catching the slippery form.

Another one is Icthyosaur, Icthyosaur. This one was adapted to swimming even more so than the mosasaur. He probably had more fish in his diet. He had more teeth and sharper teeth so a fish diest was more convenient for him.

Then we have the Pterosaurs. These forms were built for ?. It was generally accepted that he could not fly. They nested in high places. When they wanted to fly they would fall off the cliff and glide and then crawl back to the cliff again. The largest of these forms had a wing-spread of 25 feet. It was almost ?. Yet it was one of these flying reptiles like Archeopteryx that had claws on its wings. They had three fingers on the ends of their wings and a fold of flesh was ???. Some had very ? shaped bodies, not particularly beautiful. I can best describe them as a flying telegraph pole. Some of them had long slender bodies and ???.

Now you have an idea of some of these forms of the Mesozoic. Your text books will tell you much more and they have fine pictures of them. Look them over anyway if you don't read about them.

Next time I think we will be able to finish up with the Cenozoic.

(Pictures) I forgot my speech. Tonight the general topic which I want to try to consider is the relation of biologic changes to geologic events. This is going to be an attempt to correlate these two sorts of records, a geologic record and a biologic record. Now the geologic record is that which was formed by the deposition or the formation of different kinds of rocks and the biological record is that which is found in the rocks as fossils. I should like for you to think in terms of correlating rocks as records of earth history and the successive changes that have taken place in the earth. Now we have considered previously both of these topics so what I say shouldn't be too new.

First with regard to the Pre-Paleozoic records. You perhaps will recall that the forms of life present during that time were exclusively unicellular so among those unicellular forms they had already established the habit of building two kinds of skeletons, one of $CaCO_3$ and the other of silica. When we think of the Pre-Paleozoic rocks in addition to the presence of these unicellular forms we usually think of them because of the scarcity of them. Now the scarcity or sparcity of this population is often explained in terms of deformation. It has been suggested that the rocks are so deformed that the fossils have been destroyed. Seemingly that is a rather logical suggestion and yet there are not many rocks severely deformed, not of Pre-Paleozoic age but of the Paleozoic age and yet the fossils have not been destroyed; the fossils have merely also been deformed so the absence of fossils from the Pre-Paleozoic rocks cannot be explained on the basis of the severe deformation to which the rocks have been subjected.

Another suggestion has been made that the lack of abundant fossils in the Pre-Paleozoic rocks is due to the composition of the oceans. You see the oceans had existed for only about 200 million years and during that time it has been suggested there had not been enough material carrier into the oceans from the continents to give it the composition necessary so the forms couldn't extract their skeletons from the dissolved material in the oceans. In other

words, there were not enough dissolved subststances in the ocean waters to furnish material for the animals to make thier selections. This seems improbable when you consider such forms as the Grenville series which are 50,000 feet of ls, and when we consider the Belt Series of the Northern Rockies where there is abundant ls and only, with only the unicellular forms of like preserved in it, or the ls. of the Grand Canyon region. Seemingly then, there was plenty of ls or dissolved $CaCO_3$ in the ocean waters. Anothe suggestion was made that perhaps the forms were unable to use this material in the construction of skeletons.

The first suggestion is less likely. In the process of development then, most of them found no need and therefore no ability to use the $CaCO_3$. They were unicellular forms, floating organisms and skeletons were of no particular value to them. In some such terms as these we have to explain the lack of fossils in the Pre-Cambrian rocks. Now which of these suggestions, which one of these suggestions should be used in this explanation? It is merely a matter of choice. If you have better suggestions, it is up to you to use or produce them. It is just a matter of choice.

Here in the outline the term limeless seas is used. That is a little bit misleading. It should be seas with less lime. That is, the oceans of the Pre-Paleozoic contained less dissolved salts than they have at the present time. That is the meaning of the statement,

In the line of these suggestions let us contine the geologic record a nd the next event is the Lapalian Interval. You will recall that the geologic record of the Lapalian Interval was a world wide unconformity which separates the Paleozoic rocks and the rocks on which they lie, the older rocks on which they lie, a world-wide unconformity.

Now let's interpret that in terms of land and sea distribution. If everywhere on the continent there exists this unconformity, then it is logical to say the continents were all larger than what they are now. We also know that at the present time all the continents or practically all of the continents are surrounded

by a submerged margin in which the ocean waters have flooded onto the continent, making an outer zone, the continental shelves with a depth a maximum depth of about 600 feet out here with a sharp break then to a depth of about 6000 feet. This is the fundamental formation of the earth, that is, the continental shelf results from that flooding of the ocean waters onto the continents.

Let us suppose that we go back to the time of the Lapalian Interval. The shorelines were farther out at that time; the continentw ere thus larger, much larger, but the continental shelves were smaller, considerably smaller. Before the Lapalian Interval, the animals were in a zone that wide, During the Lapalian interval they were limited to a zone less than half that wide. You maybe realize that the unicellular forms which were in this coastal zone, normally they prefer to live in the shallow water end of this zone, but under entirely different conditions, some may exist in deeper water or even float in water over the ocean basins.

Supposing we start with the single celled forms. Now if those forms had more or less attempted to congregate along the shore zones, then the uplifted condition of the continent means that the forms distributed over a wide zone would have to be concentrated over a small zone. In other words the density of the population was considerably changed. That is, all these conditions prevail. The density of the population is going to be increased, so we are not speaking of that increased density of population. Up to this time the unicellular forms had been free to feed from the surface all around them, that is, they were surrounded by water and therefore there was no particular object in their going through any changed, and some keep that form up to the present time. Yet those animals which found themselves in that crowded zone, eventually came to a place where in order to protect themselves from overcrowding, they built a house or skeleton around themselves. Furthermore it is postulated that due to the aggregation the cells the external skeleton was built around a group of cells which constitute

an individual. Suppose we have an aggregate of cells, the cells on the outside are going to do the feeding job most likely for they are closest to the source of food supply. In some forms living today even though the cells are aggregated, each one performs its own particular or individual function. In an aggregate such as the sponge, that goes one step farther and there is a division in this job of living. Some of them get food, some of them digest it, some of them make a skeleton, some of them perform other functions, and then we are on the road to a multicellular animal. Now because there is thie great difference in the population before and after the Lapalian Interval, it seems plausible that the Lapalian Interval was that portion of geologic time in which the animals adapted themselves to a littoral condition, that is, to this inner portion of the continental shelf, and we might add as an additional statement that by aggregation of cells, more complex groupd of animals appear in the population succeeding this interval. (Interruption. Question: Then you feel that according to that, that would be the period in which they became aware of the use of the dissolved materials in the water? Answer: I think it is more than just that. It is not only that they learned to make shells but there was more material there from which to make the shells.)

I have postulated that the Lapalian Interval was a worldwide unconformity. Unconformity means extensive erosion, worldwide erosion and it is therefore entirely possible that the composition of the oceans was changed to a considerable extent, changed as a result of the erosion that took place in the Lapalian Interval. What are the contentions for that? We have abundant animals. The animals find themselves in a more crowded condition and they can protect themselves from overcrowding by an external skeleton. That much space is staked out so that they can accommodate themselves individually. Whether or not you want to accept that postulation is up to you. (Interruption. Question: How do you explain that the slugs came though without having any shells in all these ages. Answer: I can't explain it.) Of course there are many things which cannot be explained,

and that would be one of them. (Interruption. Question: Has it come through all the other ages that the gastropods did? Answer: That would be hard to say; they have no skeleton and we have no fossils of them.)

In mot of these cases, you have to keep a system such as this in mind starting from any form of life, animal, plant, unicellular, multicellular, you are going to go along so far and you will find that there is going to be a variation and that variation is going to be to an advantage or to a disadvantage; if it is to their advantage, they continue and if it is to their disadvantage, they will probably discontinue. If it is to their disadvantage, the line will go on from here and the same thing will probably happen again. Here are we well out here on the ends; that is where the g for guess comes in geology. As you see, the end product is entirely of a different nature. One is fact; the other is postulation.

Just a summary now, the general physiological changes brought about during the Lapalian Interval I would like to stress again. The character of the Cambiran animals. You remember that each Phylum of the animal kingdom was represented by some form except the vertebrates. The fundamental plan of the animals has already been developed when Cambrian time began. If you take such a form as the trilobite, we have later a highly specialized organism, one in which were the fundamental physiological organs developed, organs for digestion, organs for secretion, and excretion, organs for locomotion, organs for mastication, the sense of smell, sight, nerve system developed, etc.

The fundamental plan of the animal kingdom was present at the beginning of the Cambrian. It certainly was not present before the Lapalian Interval. If you want a yardstick for measuring the Lapalian Interval, I would suggest that you get some conception as to the length of that time.

Let's leave the Lapalian Interval and see what succeeding events bring. (Interruption. Question: Following that Lapalian Interval, is that

basal conglomerate, isn't it? Answer: ???) Any other questions?

Let's see some of the events that took place after the Lapalian Interval. Now again that is a survey so let us take the first half of the Paleozoic. Recall if you can, some of the physical conditions which were present in the Cambrian, Ordovicia, and Silurian, the first three periods of the Paleozoic. Recall if you can, some of the physical conditions which were present in the Paleozoic. Now I will grant that there were successive emergences and submergences, that there were periods of clastic and non-clastic deposition, but the first hald of the Paleozoic time passed on the North American continent without any orogenetic diastrophism, so here was a portion of the Paleozoic ere in which there was no stress, no physically adverse conditions superimposed upon the organisms. Now after the flood advanced, the successive generations of snimal life advanced with it; as the flood receded, successive generations receded. Those that didn't, we find in the rocks as fossils, we find them in the younger rocks as fossils.

So the shifting of the floods of the Cambrian, Ordovician, and Silurian, had little effect on the organisms of the sea. The conditions of temperature, composition of the ocean, so far as we know were quite uniform, so where there was a flood, we could have organisms living of some kind. I like to think of the fossil communities as compared to human communities which we have at the present time. If you can remember the time when everybody who wanted a job could have on, that was what we called boom days and everybody was doing just about as much as he could. During such a period production is normally high, production of all things including humans. During such periods there is a tendency for over population, that is, because conditions were favorable. Then with adverse conditions begin to appear the forms that were head and shoulders above the rest of them. Now the animals are no different in power of adaptation and also development. They had just about as much control as man has over finance and economic environment at the present time.

So far as the marine organisms were concerned, we find animals developing not along conservative lines, but along radical lines. We find them beginning to seek new advantages, trying one direction and succeeding and then there begins to be a variety of forms, for instance, the plicated brachiopod, the concavo-convex brachiopod. I don't see that there was any logical explanation for them. There were new conditions and they just competed with the other organisms. The same is true of the corals. In the Silurian there was an abundance of corals, individual corals, and coral reefs. There was no particular stress to bring it on, but there were ideal conditions in which to develop ra idly and abundantly. I think the trilobites are the most interesting of all in this connection.

The Cambrian trilobite had much the same habits as the crayfish at the present time, crawling at the bottom, seeking out food that they could get without much trouble. They were scavengers feeding on material at the bottom of the continental shelves. In the Cambrian the trilobites were in abundance and thus the food supply was beginning to get short. In a region of sedimentation it is probably that a large part of their food became covered up in this process of sedimentation. A group of enterprising trilobites began to make miners of themselves burrowing down in under to get their food and they developed shield like heads and tails thus indicating that they could burrow underneath theunconsolidated sands, muds, and clays of the continental shelves, and once beneath the surface, it didn't make much difference which way they went, forward or backward. (Interruption. Question: Sort of a streamlined affair?) Now again the eye itself on the head was modified because it was set up on a standard. I don't know that there was any particular reason for developing such an eye, but it would be possible for these forms to be beneath the surface and let their eyes protrude so that they could watch for danger or see what was going on. The crocodile does nothing more than that, for that is how he stays at the present time, right in the water with only his nose and

two eyes out. These forms of course just protrude from the bottom.

Then in the Silurian we find in this general line of development another wide break in the trilobites. The trilobites found that the food supply on the bottom was inadequate so they began to burrow down and use that food supply covered up by the sediments. There was only one other place left to get a food supply now and tht was before they get to the bottom. Then we find trilobites which start to swim. They came up and swam from the bottom to the top. We find that the trilobites had developed various cases of spine projections, not of great weight or of considerable volume. In other words they acted as water wings, buoys, so the animal could live in the neighborhood on the bottom and come up and get its food supply up above. (Interruption. Question: Were they gliding fins or hollow floats? Answer: ???)

Now again I hope that these postulations don't obscure the facts. There are certain facts and certain interpretations that I am trying to make for them. Then on to the later portion of the Paleozoic. As the geologic record indicates, about hald of the Paleozoic period was characterized by the absence of stress, then the geologic records of the latter half certainly indicated the reverse conditions.

In the Devonian we had the construction of the Catskill delta and the northern portion of the A ppalachian geosyncline. The delta resulted from the rejuvenation of the land mass A ppalachia so there was some diastrophism in the northern portion of the Appalachian trough. It was folded and we named it the Acadian disturbance. In the Mississippian we had the Chester series, a series of alternating ls and ss indicating a wobbling of the continent with respect to sea level. Toward the close of the Mississippian an east-west trough in the southern portion of the United States began to be deformed and finally the Ouachita Mountains began to appear. This you have had before. Then in the Pennsylvanian we had the coal cycles which include both marine and non-marine phases which indicates the oscillation of the continent. Then the Appalachian trough was destroyed and then we had the formation

of the Appalachian mountains.

Now what does the whole thing mean? The physical conditions were just the reverse in the latter half of the Paleozoic than they were in the first half. Things were calm and peaceful in the first half of the Paleozoic and were quite the other way around during the latter half. Organismz living in the marine environment might find that environment rather quickly changed. The various changes which took place were such as probably would not affect the invertebrates. That is, the various types of invertebrates had their choice of either migrating with the shifting seas or becoming fossils, but they were living with organisms that had no choice. Y

You remember in the Silurian there were sharks, then in the Devonian there appears an abundance of fishes, now why an abundance of fishes? I think it rather due to the fact that they could move effectively and rapidly with the various bodies of water. Supposing that one of these areas began to be uplifted. Forms which could move swiftly and effectively, they will move as the shoreline moves and thus the fluctuation of the shoreline means no adverse condition for them. They merely migrate as the shoreline does and that was true of relatively few other forms.

The brachiopods reached the climax of its development in the Devonian. Thery were a particular food supply for the fishes, abundant food for the fishes. It is only like saying 2 and 2 is four, rather 2 and 2 are four, it is so obvious. Yet the abundance of brachiopods is not so important in the latter part ofthe Paleozoic. It is believed that not all of these fish forms got away. In other words as the shorelines began to go down, some of them tarries in pools and shallow water pockets and many fish were trapped.

It is believed that in the Devonian some such process existed and some of these trapped fishes attempted to leave this basin in which they were trapped and doomed to die. At that time then there perhaps developed the lung fish, which could most likely migrate to another body of water. Today a fish can do that providing the distance isn't too far. Probably you have caught a fish

a nd have had it flop back into the water. That is its way of locomotion on land. In the Devonian one form of fish developed lungs. There was another form which had a peculiar fin which consists of a boney girdle with radiating appendages and that boney girdle and appendages were the foundation for limbs and did not develop without any alteration or changes.

Well, supposing we had along this line of development a form which had both a boney girdle plus the lungs. That form attempting to migrate from one place to another would have relatively little difficulty. It would not have to use its gills but could use its lungs during the migration and so it is believed that the amphibian appeared as a biological response to this unstable condition during the latter part of the Paleozoic.

We see the amphibian is a form which spent part of its time on land and part in the water and it is not entirely free from either of them. Even though it stays on land, the eggs have to be laid in water and have to be hatched in water, and when it becomes an adult, it can move on land, yet its body is always moist, therefore you find amphibians in areas where there is at least water periodically. It seems they have always been near areas where there is water, moist areas; you will find them there at the present time.

The oldest possible record of any amphibian is a foot print in the Devonian, a single foot print in the Devonian. At least it is believed to be the oldest trace of the amphibians. This fossil foot print is in the museum at Yale and if I were teaching geology at Yale, I would have to say that is the oldest record. They reached their racial climax in the Pennsylvanian. Here we have a geologic condition which is an unstable continent, Response to that condition is abundant growth of swamp or coal plants. Contemporaneous with that development of amphibious plants there appears the amphibious animals which are not particular as to whether they are on land or in the water. They are not specialized with their habits and so you could realize that between the biological record and the geological record there is a correlation. As

As we continue the consideration of the Paleozoic, we find that during that period eastern United States was subjected to more arid conditions indicated by the red color in the sands, and the mud cracks, rain drop impressions, cross-bedding, and it is not surprising that the forms which developed so abundantly with the destruction of the swamps, their racial history has the same decline. They drop off very suddenly at the close of the Paleozoic. Why didn't they go some place else to live? They did. They have given rise to the inconspicuous reptiles which we have at the present time. They were not entirely killed off. The favoralbe conditions merely passed, and once past, they began to go toward the inconspicuous place they have at the present time. The best phrase which would summarize these events at the cloase of the Paleozoic is one taken from a rather popular treatment of geology, "The friendly slime was turned to dust." "The friendly slime was turned to dust," the slime in which the coal plants grew, the slime through which the amphibians moved. Turning to dust reptiles, the drying out of the materials was brought about and with that the contemporary discontinuance of the forms.

Let's go on to the Mesozoic. As before, a consideration of the geological records as represented in the Newark series of the eastern United States, should convince us that the dry conditions of the eastern United States, continued into the Mesozoic, red ss, and shale, mud cracks, raindrop impressions — all such geologic records can be used to determine climatic conditions. Back in those Paleozoic coal swamps there were a few reptiles that are very important as far as compared to the huge thick-skulled amphibians that slithered through the Pennsylvanian coal swamps. Yet when they began to decline, the arid condition was not unfavorable to the reptiles.

At the present time the reptiles are concentrated in arid regions, but it was through that that the reptiles learned to protect their eggs from drying out, by putting a shell around them and inside of that shell, putting a membraneous coat. Now the shell is porous enough to allow ariation, and yet the membrane around it protects it from drying out. Now I don't know, and no one else knows either, the beginning of this form which built shells around their eggs, but when they did, those forms were reptiles. A nother suggestion that developed was the reptile offsrping

passed through the tadpole stage inside of the egg. Now then the continuation of this arid condition merely was an advantage to reptiles in that the amphibians decreased, but it had no particular effect on the reptiles.

Then as soon as competition is removed, the source of food sullpy is more and that is the foundation of the reptilian dynasty of the Paleozoic in the destruction of the swamps, in the absence of any form that could compete with the reptiles. Remember these reptiles were so successful that they could inhabit water, lad and air. Their climax was one of the milestones in the earth's population. They were so successful living upon the earth that they established all time records in size of animals that walked. This is, of cou se, more or less a summary of these Mesozoic reptiles. It is to be thought of in terms of these conditions in which there was relatively little competition except among themselves. These reptiles, take for example, the dinasaur -- these reptiles came out on land. What do they find? Perhaps a few snails, a few insects, a few amphi bians, and all of their reptilian ancestors, and they found a land surface clothes with vegetation.

I forgot one thing which should have been obvious to you. The land surfaces began to have a development of land plants in the Devonian. The plants migrated onto the land and began to be food supply for the animals. Then in the Mesozoic these reptiles came out on the land. The plants had been preceded by the gymosperms, the cone-bearing trees, the needle or scale trees. Why had those developed? The needle of the pine tree or the scale of the cedar tree is one of the most economic structures for the preservation of moisture. A leaf from a maple or elm or ash has enough spore space in it from which water is evaporated in almost unbelievable amounts. The tree exists from the moisture which it takes from the ground and it is given into the air through the leaves. Now in reducing the surface of the leaf down to the needle or scale, you reduce the transpiring surface and the ratio of intake and output is decreased.

(Interruption. Question: What furnished the food to the reptiles? Answer: Mainly

the vegetation.)

These succeeding developments, the arid conditions, with the gymnosperms and the dominance of the reptiles, and here again we have to introduce a thing which cannot be explaine and that is, before the decline of the reptiles there is the appearance of the mammals. The oldest form of mammals can only be described by the tooth structure, for the oldest mammalian fossils are merely jaws and that gives us little else so we put that down to one of the unsolved problems of geology. Perhaps some day somebody will have an inspiration and go ahead and explain it. Befor

Before the close of the Cretaceous another thing, another important thing, happened...the angiosperms appeared, the flowering plants. And with this I am going to try to show you something else. Heretofore I had suggested that most of the development had been due to physiological changes. The facts about the angiosperms would lead us to believe that their development depended upon the stability of the continent. In the non-marine lower cretaceous rocks of the Atlantic Coastal plains the oldest angiosperm fossils are found. Examination of the Cretaceous and succeeding plant fossils seems to indicate that from these regions the angiosperms spread until they were over the entire North American continent. Now other continents also had more or less centers in which these forms originated. These angiosperms gradually spread throughout the United States. Thatis the fossil evidence. What is it at the present time?

What is the distribution of the hardwood areas of the United States? They are concentrated in the southeastern mountainous regions of the United States, and as you go out from that region you find less and less hardwoods. There is that parallel development of the fossil records spreading across the North American continent as well as their present distribution, distribution of the present type. From lower Cretaceous up to the present, the angiosperms spread farther and farther. The appearance of these angiosperms in the Cretaceous brings up another rather interesting point. A large share of the angiosperms depended upon the insect for fertilization. Now here is the same problem, the hen and the egg, which came first? The insects get their food from the flowers and the flowers are polinated by the insects.

As soon as the flowering plants appear that is when the insects appear in abundance. There were of course, lizards and crocodiles, etc. At the close of the Cretaceous you will recall that the Cordellaran geosyncline was destroyed, that is, a geological condition, the destruction. We are having a geosynclinal disturbance. It implies considerable diastrophism; it should mean a period of considerable instability. Instability should mean oscillating conditions in which there would be swamps and accumulation of vegetable reamins to form coal. You know of the lignite deposits of the great plains and you know of the coal deposits of the Rocky Mountain states. The Paleozoic coals were pteridophytic, the Cretaceous cols are essentially angiosperms, some gymnosperms, but essentially angiosperms. Here we have two different types of plants and yet both of them can respond to similar conditions, both of them respond to swamp conditions and both of them can give rise to coal deposits. As

As soon as the troughs began to be destroyed/~~###~~ mountains began to rise here. That is a record of the world, it is a record of the North American continent. Similar events are in the South American continent. Other continents also suffered diastrophic forces. Now the accumulated effect of all this diastrophism was shifting of the currents of the ocean which independently of independently shifted the winds belts of the earth. These climatic changes wherem well as far as the land goes, we find a very very rapid decline of the ruling reptiles.

Now I don't know that one can see his way through all these distur bances, yet the ultimate cause of the extinction of the ruling reptiles was diastrophism. You can say it was temperature or you can say it was moisture, yet everyone one of those actually means diastrophism. It is rather unfortunate that with such a significant geologic history you cannot attach a more definite cause to their disappearance.

Now let's go on to the Cenozoic. We begin with the Tertiary when perhaps the most significant event was the appearance or at least the dominance of the grasses. In other words, there began the construction of areas known as prairies. Now the grasses are angiosperms, flowering plants. If we are to go back to the

time that Columbus discovered America and be able to know something about the plant geography of the continent at the time, I think you would realize that it was essentially wooded. The great area that was not woods we now call the Great Plains, the area east of the Rocky Mountains.

Is there any particular reason for that being grassland instead of woodland? That portion is in the rain shadow of the Rocky Mountains. That is, the rain has dropped before it gets over the mountainous area. It descends across the Great Plains then as a drying wind and tends to gather moisture, takr moisture away from the soil. (Interruption. Question: What good will a shelter belt to do his area? A nswer: Well, it's a matter of dispute now, really no good at all.) It is an area in which the rainfall was so low that it would support only grasses.

The Rockey Mountain revolution still had its effect on this territory and that effect was felt by the construction of this plains area and that in turn affected the life, the animal life. The ruling reptiles had become extinct; the modern reptiles were present, the inconspicuous amphibians were present, then later competition, and the answer is like 2 and 2 are 4 again. You get considerable development of the mammals and they certainly do develop during the Tertiary.

You recall the general development of the mammals during the Tertiary. There were three things to remember. 1. The increase in size which directly reflects on the abundance of food. 2. The changes in limbs directly relative to the environment in which the forms lived. 3. The tooth structure whose development reflects their diet.

By taking one form that can best be illustrated, th horse for example, we can see this development. It began ts geologic history with a form about as large as a fox terrior, running on five toes with teeth possessing conical knobby projections, The line of development was its increas in size, running. more and more on its toes until at the present time we have its present size and it is running on one toe. The development of the flat tooth bounded by ridges which could grind the food is noticeable. The Tertiary forms passed from browsing forms to grazing forms and when these animals got big enough, the

carnivors appear. They do not appear until the other animals have appeared, have lived long enough so that they can feed on them. Following this outline, we leave the hoffed mammals of various kinds and then we have the rodents, the gnawing animals, and the trunked forms, and the flying animals such as the bat and the marine animals such as the whale, and now we have a great number and we can find only traces of this development. We don't have the whole story.

During the Tertiary all of the subdivisions of the Anthropoids, that is, the man-like group of animals, were represented except man himself. We had such forms as the lumur, orang-utan, the chimpanzee, the gorilla, all of these various subdivisions except man-kind.

What was the physiological event that brought about man? It is generally considered by anthropologists that the advent of man is due to the correlation of the increased coolness of the world. In other words, due to the correlation with glaciation. As the mean temperature dropped, the forest habitat of the anthropoids was destroyed and like the forms which lived in the various submergences, they had their choice of moving to areas of idential environment and some of them did, and some of them changed to new environemnts. The latter group by successful generations gave rise to mankind. That, of course, is a bare suggestion. The last topic is the history of mankind so we will let that go until a later time. The stress of the ice therefore we think brought about the appearance of man.

This evening one of the topics in the outline which I will consider briefly is entitled " ? ? Changes". The general record of the fossils and the variety of forms that exist on the surface of the earth today seems to indicate that the general direction toward which all like is trending is to occupy a variety of environments. This can be best understood by considering a few samples.

If we were to take up a group such as the arthropods, those forms with the segmented external skeleton and jointed appendages, we have a group in which will be found the cray fish inhabiting fresh water, the lobster inhabiting marine waters, the thousand legged worms, which are really not worms - they inhabit the land surfaces, and the insects, which are rather serious competitors in almost any environment. Those forms have so diversified themselves so that they occupy different environments and do it successfully.

The snails have done a good job of diversification as well. There are abundant marine snails, a fair representation of fresh water snails, and rather numerous land snails. The forms thus can live either in a submerged environment or in one in which submergence does not exist. I should like for you to recall the classes of the ruling reptiles. The classes are based on the environment. The enaliosaurs lived in the water, the dinasaurs on land and the pterosaurs in the air.

Taking such a group as the vertebrates, we are taking a little larger group now, we find very successful adaptation — fish, both marine and fresh water, birds in the air, and the mammals most conspicuously on land, the whale in the sea and the bat flies in the air. Among the vertebrates then, there has been this spreading out with the final result that the forms dominate practically every environment in which life can be sustained.

The plants have done just as well. We have the aquatic plants of various types, from the unicellular form which makes up the pond skum to such beautiful but complex examples as the water lily — from the unicellular then to the flowering plants. We have those plants that like a moist environment — we call them swamp or amphibious plants. And there are also the plants living on the land such as trees, for example,

that is, the, of course I mean the common trees not related to the swamp as would be the difference between an oak, which would prefer the field, to a cypress which lives with its roots in a submerged state. Further representation in the plant kingdom are the grasses which/~~live~~ inhabit some of the driest portions of the continent.

Thus we see that the plants and the animals have attempted to occupy the sea, the land, and all the gradational zones. The plants have only one place in which they haven't been successful, and that of course is the air. We have relatively few plants in the air. There are a few plants that grow in the air where they are subjected to wind and air currents.

In this general tendency of spreading out we must not confuse cause and effect. The ability to produce all these changes resides in the organisms themselves. It is only the environment that brings out that ability. It has been stated in this way, "Environment permits and directs, but does not cause development." "Environment permits and directs, but does not cause development." That's the crystallization of the idea which I have tried to present here from these illustrations. In each case the physiological conditions surrounding the organism, permitted and directed the development, but did not cause it.

The next topic is probably a little more ? than some of the other aspects of earth history which we have considered so far. It has to do with the succession of faunas. A fauna is any community of animals. Now we may qualify those communities; we may limit them by time or we may limit them by geographical boundaries. That is, for example, we may have the succession of fauna in Minnesota -- the animal communities existing in Minnesota in the summer wo ld be quite different from those existing here in the winter. Therefore, though we use the term quite broadly, it can also be used in a restricted sense. When we use it in earth history, we are interested in the time limits. The geological limits are not so distinct, so we speak of the Devonian fauna or of the Silurian fauna or the Platteville fauna. The subdivisiona determine just hou much of the racial history of the inhabitant is to be included in our grouping.

Now by succession of fauna, it implies that there were changes and I hope you realize that changes did take place. The term succession of faunas does not mean that each period had those specific creations of animals and then they dissapeared in~~to~~ the next period. Rather it means that the complexion, the general character of the communities was changed, not the entire group. Those changes could be brought about in a variety of ways.

Let us first consider adaptation. Adaptation would be the response of the organisms to their habitats. (Interruption. Question: What did you say just now, will you repeat it? Answer: Adaptation would be the response of the organisms to their habitat.) Let's limit ourselves now to a consideration of marine environment. In marine environment the organisms would attempt to adapt themselves to such things as temperature, currents, abundance of sediments, food supply, and other factors. Geological history recorded the fact that much adaptation took place at the beginning or the end of a geological period. If you will recall what the geological conditions of the continent were, you will remember that the beginning or the end of a period was characterized by a restruction of the submergences. In other words, the continent was more or less emergent.

During such restructed conditions there seems to be a great tendency for the organisms to adapt themselves to the local conditions in which they reside. These restructional portions develop individual communities whose characteristics are not uniform because the environments are not similar. There are barriers which separate one community from the other. These barriers I have just mentioned -- those are the barriers that keep the animals from moving out of one local area. These organisms in these particular provinces develop their own particular characteristics. These communities are called provincial fauna. Provincial fauna, then, are the response which animals make to the restruction of the sea.

Now let's consider the opposite ?. The middle of a period is normally characterized by an expansion of the submergence. The continent becomes widely submerged, uniform conditions prevail, the barrier is removed. Now we find the

forms migrating, that is, inhabitants of different communities move out; they intermigrate and thus instead of having a group of animals having characteristics of only one local area, we have communities of animals in which there are imigrants coming in from numerous provinces. Such a group of animals is referred to as cosmopolitan fauna, a group of animals in which there are a number of imigrants.

Now after we have these two types of fauna, I mean just after we have these two fauna, we have two types of organisms, we have the provincial type which retains its characteristics and whose resident area can re recognized by its characteristics. As for example you would have relatively little difficulty recognizing a human homing from another country. You could be sure of the country from which they came ???. The same is true of fossils, that is, when you get so you can understand it. In the same way in which we have groups of individuals made up from imigrants, excuse me, that is all wrong. In the same way in which we have an individual who has v isited many provinces and had gotten someth ng from those many visits and is called a cosmopolitan person, so the snimals have done the same thing and are spoken of as cosmopolitan types.

If you read the Devonian chapter or the chapter on the Silurian you will find illustrations concerning these provincial and cosmopolitan characteristics. I can speak of thes of them, one for example, is a group of animals which seemingly prefer sandy bottoms on which to live. Now those particular individuals appear in the central part of the ~~Devonian~~ North American continent in the Devonian, but their provincial characteristics indicate that they migrated from a resident ? in Brazil. During the Devonian they migrated to that extent. That would be an example of a cosmopolitan type, no it would be a provincial type.

As for an example of a cosmopolitan type, there is a brachiopod which first appears in the lower Devonian of western Europe and then it successively appears in younger and younger Devonian rocks as you go east across Europe and Asia and finally it appears in younger Devonian on the North American continent, about middle Devonian. In younger rocks it appears in ? valley and in the vicinity of the Great Lakes and in

late Devonian time it appears in the Devonian of New York. That particular brachiopod is only capable of moving during the first few weeks in its life and yet during its life it was able to migrate around the world in one geological period. That would be a cosmopolitan type, the brachiopod which in one geological period encircled the earth. (Interruption. Question: That would be exceptionally subject to drift? Answer: ???)

Not only do we have the rise of new fauna due to changes but we may also have the disapp arance of forms, in other words, extinction. Now those are largely the two features which produce the changes in the communities. Extinction is primarily due to biological and geological factors. So far as the biological features are concerned, I will have to refer you to the zoologists in order to understand it completely We can say that in a number of ways. Such things as for example, disease, will cause extinction of organisms, and then racial old age, in which the race merely becomes less and less able to survive and finally disappears; a third way is mutation. I don't know any other word for it, mutation. Mutation would be the process in which changed descendants live on, their ancestral forms becoming extinct. Notice that I said the changed forms live on. (Interruption. Question: Survival of the fittest, is that?. Answer: ???). I had in mind the horse, the one-toed form coming from the three-toed form. That is exactly the meaning of mutation. Those are the biological factors and I gave them to you as ???.

The geological factors can be primarily related to diastrophic forces, that is, ultimately we would come to diastrophism as the cause of much of the extinction. It depends upon these things for example. It will remove barriers and surround invading froms, overwhelm resident communities; it will permit rivalry for the same food supply and the one better able to get it lives on. It will permit intermigration and in many cases, a decrease in the food available per capita, th t is, zoologically speaking. It will change the current of the oceans; the changes in the shorelines may mean a greater abundance of sediments and ? the physiological conditions which surround the organisms and are primarily arlated to the balance of the conditions which have been and which are going to be with relation to the ? conditions of that

one particular area. You can blame it on these two things if you want to. You can say it was the change in temperature or moisture. In the case of the land animals you can say it was lack of food/or supply ??? yet all those things are related to diastrophic changes.

Now I suppose we should make some use of all of that. The goal of historical geology is to arrange the events of the earth in their correct sequence. In order to do this we have to be able to determine the relative age of the formations, not their actual or absolute age in number of years, but the relative age. At the first part of the course I spoke concerning the geological criteria for correlation, that is, the basic method by means of which we can map a known unti with another rock unit and say that they are of the same geological age.

If you have forgotten them, then let me repeat First the continuity of the deposit. I think I could explain it in this way. If I go from here to there on this board and there is no ? between, I am certain that I am on the same board. The same thing is true in geology. Next, similarity of materials, granting that the materials are characteristic, of course. If you have two sandstones, that does not mean that they are of the same geological age — it depends upon the character of the sand grains. A third way is the similarity of sequence, ss, ls, and sh, ss, ls, and sh. in that order in two localities does not mean they are of the same geological age unless there is something distinctive about their thickness or character of the formations. The fourth one is the attitude of the structures. It is somewhat negative in character. You would never call the series of A and B of the same geological age because a geological event separates them, one of tilting and erosion; therefore they cannot be the same geological age. Those are the geological criteria.

Now let's go to the biological criteria, the various ways in which fossils may be used to correlate rock units. The best way is perhaps the identity of special forms. These are usually referred to as guide fossils or index fossils or key fossils These forms of course are only recognized as being guide fossils after considerable study, but once they have been recognized as guide fossils, then of course they are of great value in attempting to correlate rocks. The use of fossils for the correlation

of rocks first came about in the Jurassic, thatis, I mean not in Jurassic time, but in using Jurassic fossils, when the ammonites were so abundant and in such a variety of forms that they were used as guide fossils for the Jurassic. I think I have spoken of the trilobites which occurred in the St. Croix series under the horrible name of Dis. Minnesotensis. That generally is a guide fossil for the upper Cambrian. It has never been found any place else than in the upper Cambrian. Now Dis. Minnesotensis is the form which is found in the St. Croix series, but applying another species name to it such as for example, Dis. Pepinensis. It is the trilobite of the upper Cambrian of the Black Hills, yet the genus is characteristic of the upper Cambrian. Perhaps you will recall the spiral axial support of the bryozoan Archimedes. Archimedes is a guide fossil to the Mississippian. Whenever it is found, the age of the rocks you know is Mississippian. (Interruption. Question: What was that again? Answer: The fossil Archimedes, is a guide fossil to the Mississippian.) Now I have given you examples. What are these? They are fossils of wide distribution, that is wide geographical distribution and of short geologic r nge. That is, they lived only a short portion of geologic time and they when they were living they were practically world wide in their distribution. What kind of a fossil would that be? A cosmopolitan fossil. All guide fossils must, of necessity, be cosmopolitan types found in widely separated areas in the rocks of the earth. I think you need no more than that to indicate the way in which we correlate rocks by the identity of specific forms.

Second. This next one is the aggregation of forms. That is, this would be the general complex of the community, not taking a single individual, but taking all the enighbors in the area. Maybe there is no guide fossil in the community and yet by knowing ~~///~~ something concerning the general group of the organisms there, we can say approximately what the geologic age would be. Some of these overlap, so don't be ?. With regard to aggregation of forms, let me refer you to the cross section of the city dump that they had at the World's Fair at Chicago. There was no particular article in the dump that identified the date of the horizon, rather it was an aggregate of the discarded articles. Well, suppose these was a wardrobe. If you looked only at the men's things, you wouldn't know where you were, whether it was 1900 or 1875, but if

you looked at the women's wardrobes, you could just about tell the date. In other words, the men were conservative in their dress; the women were not. The smae is true of fossils. Other organisms change readily and those changes are the significant things in trying to date geological events. Now conservatism has its place, well granted, but for arranging things in order, it is the changes that are of value. The trilobite lived from the Cambrian up to the present and had perhaps few changes, therefore it is not a very good guide fossil. One lived from the Ordovician to the present and it is about the same. It would be ? to try to use that to determine the age of the rock.

And the third way would be the formation in the development of the organism. In other words, you have to know their racial history. If you know when the form began, the stages through which it passed and when it became extinct, the finding of any one of these forms could be ? with this racial history and you could tell where the form belongs.

The fourth way is the percentage of living specimens represented in the communities. If, for example, you had a rock in which there were only, oh, maybe two or three organisms in the rock and they are still living whereas if you have another rock in which there are a dozen species in the rock in which they are still living, I hink you would find the younger geologic age in the second rocks. There are more forms in that rock which live in the present, therefore, it must be closer to the present. The tertiary is an example of th t on the basis of cephalopods, gastropods and snails. The first subdivision contains 5% or less of forms which live on to the present; the next one is aboud 20% and the l st one is around 40%, and so forth up until you get to the Pleistocene and most of them live on to the present; only a few have not. Occasionally people say things in other ways and if it is easier to remember them when said the other way, then if you are more, I don't know what the word should be, more, more exact, you say it. This one I came across lately (poem) Any questions concerning the biological changes?

As in the next topic concerning proofs, and ? and development -- they could just as well be examples of development. I am going to choose certain forms to illustrate lines of development. It is quite obvious that I couldn't follow all of them out but there are a few which I think are significant. Let's start with the classic one which you find in all the text books, the cephalopod. This is going to be our geologic time scale. As you review, recall that the cephalopod began its geologic history in the upper Cambrian with a form externa ly straight. Its geologic history continues up to the Triassic, then they become extinct. In the Ordovician there were forms which were bent and forms which were coiled and these bent forms go about to the Devonian and become extinct and the coiled forms go on to May 28, 1936. These three then are the nautiloids and that is their geologic history. The form began externally straight; new forms were added in the Ordovician, one of which was unsuccessful and the other one is the survivor of the nautiloids of the present time. The other subdivision of the cephalopods is the ammonoid which began its history in the Devonian as a coiled form with undulating or wavy sutures and that form was gradually replaced in the Pennsylvanian by a form in which the forward undulations show the sutures were cerrated and that form was replaced in the Triassic by a form in which the forward and backward undulations were cerrated and then, it, in turn, was replaced by a form in which the entire suture became wrinkled. Then the Cretaceous -- they continue into the Cretaceous and become extinct. And from that there are forms which are bent and straight and all of them become extinct at the end of Cretaceous.

Now these changes have been successively gradual indicating/that the appearance of the Ammonoids here came about by stages from this form and then in turn came about the development of the ???, so the line of development would go like this with increasing complexity of the sutures and when the form comes about to the end, it reverses its previous history; it is coiled, bent, and straight, and all of them are extinct. It is the same ? ?; it is straight, bent, and coiled in the beginning and before that there were none. This change in the Cephalopods is one

of the classic examples which you will find in almost every text book as an example of the changes that have taken place in the organism.

While I am explaining that I will call your attention to other changes which are not quite so common, such as for example, the snail. They began their geologic history with forms which were not coiled; later they had begun to coil but had not completed one coil. These forms were very low in their spirals and the general record through geologic time is the decreased diameter and the increased height. Now there are exceptions, but if you take the majority of the Gastropods, you would find that to be the general tendency. The Gastropods are more complex, have more varieties and are in greater abun ance on the surface of the earth today than they ever were in the past. In ohher words, it may be the climax of the hsitory of thegastropod. Many animals when they reach the zenith of their racial history begin to ornament themselves. If you are acquainted with marine gastropods, you know what they are now — they have all sorts of projections from the surface. There is an extension at the one end called the siphon?; it has been prolonged in some cases to several times the length of the shell. I don't know what the reason is for these ornamentations, but a great many animals show them.

Let's try another one, a more common form now such as the brachiopod. The brachiopod appears in the Cambrian in a form which is more or less pear-shaped and inarticulate, a brachiopod that is biconvex; it still ? today. Also present in the Cambrian is the shield-shaped brachiopod, articulate, very lightly plicated, slightly concavo-convex. In the Devonian there arises from this form a brachiopod, but it is more h avily plicated and it is biconvex and rather fat. From that same line of development there arose some ? shaped ? and plicated and concavo-convex forms. Some place in between these two forms in the Ordovician, there arose a brachiopod thathad a round hinge, very, very ?, very, very biconvex, very, very strongly plicated. In the Silurian from this last form there came one in which the hinge area was much more pointed, otherwise quite similar to it. Oh, back in this one you remember there were two forms that were concavo-convex. These forms go on into the Silurian and if we take a form like the concavo-convex

and if you take the edge of the concavo-convex shell, you find that the edges were slightly ?. Then in the Devonian, a brachiopod app ared with the extended hingeline; the butterfly brachiopod undoubtedly developed from this one. This last one does not live on. This form appears in the Devonian with these ridges now becoming projections or spines. This one down here goes on to the Permian and becomes extinct. This also becomes extinct at the end of the Devonian. From here between these two in the Pennsylvanian, there developed a form which is articulate, has a hinge here ??? has a well-developed convexity and has a fold in the sinue. I don't know how I am going to do this, They lived up to the Permian, and from that it goes off to this form and from this one, these are merely modified descendants. They are not identical. Now I hope you can trace through that. I can point out some of the significant things. The spined forms are characteristic of the Carboniferous; the forms with the extended-hingelines developed the greatest extension in the Devonian. The forms with the ridges along the hinge line are limited entirely to the Silurian. Now we have to use negative results. If you find none of the spiny form of this one or none with the extended hinge area or non of these, theny you have only your choice of these two. In the Ordovician, the forms were convex or barely convex - neither of them developed very great complexity. We are not particularly interested in the details, but from that I think you can get some idea as to the changes in the forms.

Now for the vertebrates. We don't want to forget about those. In considering the development of the vertebrates, I should like to review very sketchily the successive geologic changes. You remember the first successful vertebrate was a fish that appeared in the Silurian. The amphibians are first definitely known in the Mississippian and undoubtedly came from a fish ancestry and the development of limbs and lungs are the important structures which made amphibian life possible. After the climax or during the climax of the amphibians there appeared also a reptile in which the significant chage was the ? or the tadpole formation within the egg, an adjustment to arid condtions.

Following the reptiles was the development of the mammals. The mammals

are subdivided into the monotremes and the marsupials and the placentals. Each of these subdivisions is characterized by a ? complex especially with regard to the reproduction of a new generation. In each case there is a greater opportunity for development and training of the offspring. That may or may not be of significanc but a greater period of development is there. The primary mammals are present in the Cretaceous, and today the greatest collection of marsupail forms are found in Australia. The marsupials are the forms which are born in an immature state and are carried in pouches by the mother. Australia has a number of forms ??? ~~than~~ than the rest of the world. It is thought that this distribution was dependant upon the isolation of Australia at a tim when the marsupial mammals were developed. With the isolation they did not have to compete with the placental mammals. The Tertiary history concerns largely the placental forms.

There are great numbers as well as almost infinite varieties. Again we have to choose. I am going to choose the one in the text book, the horse. The horse is represented by the odd-toed hoofed mammals. The horse began its geologic history in the Eocene as a relatively small form about the size of a fox terrier, possessing five toes. Now briefly summarizing the history of the horse. Through the Tertiary it increased in size which is illustrative of the abundance of food and his ability to use it. Inasmuch as he lived on the prairies, he had to range fro food as well as to run for his life. He had to come up on his toes and first there were three functioning and then only two and eventually only one toe functioning and finally the horse got way up on one toe protected by the hoof. The other change was in the teeth. The small forms were browsers and had knobby teeth and later forms were grazers and therefore had grinding teeth. In such cases where forms have passed through the stages I have represented, occasionally there will be evidences in the living forms today, that the changes had taken place. This is a ? bone of a horse which lived in South Dakota. ??? and here there are two fossil toes still attached to the main one. The hing legs were not as well preserved.

Now we have not mentioned the even-toed forms, cows, sheep, camels, ?

and like forms which rise from ?; instead of walking on the foot they way they should walk, they came up on two toes and they are still on two as illustrated by the cloven hoof. If you want to ? see a fossil form, I want you to look closely at the foot of a pig the next time you get a chance -- there are two functional and two almost rouching the ground, but not quite.

That is the general history of all of the mammals and there is no particular reason why we should go any farther into the discussion of it now -- increase in size as a result of the change in the tooth structure as a change of habit and the other, the modification if the hoof ???. Rodents and carivors had a modification of teeth and limbs. Dogs and cats have claws. Some of the claws are ?, some are dependant upon the habit of the form. As soon as the mammals became carnivorour, we find a difference in the teeth. The back teeth are fro gringind and the fr nt teeth are fron biting and the canine teeth are for tearing. In the dog the canine teeth are developed; the rodents have no canine teeth, but in order to be able to gnaw, the second incisor took on the function of being prolonged and they are the gnawing teeth of the rodent. In the case of the elephant, the second incisor was prolonged into a trunk, nothing more than a tooth. (Poem)

One group of animals which I have not considered sufficiently is the group to which man belongs, so I will spend a few minutes on the geologic history of mankind. This is getting into the field of anthropology. A geologist has to be many things among which anthropology is included. In order to avoid certain elements of confusion, let's get our foundation properly constructed. This group of animals belongs to that group or subdivision known as mammalia. That would be the class, the order is known as primated. Man first because Man is the ? and made th order, so he should be first. Then we have the families among which are the lemurs, tarsiers, monkeys, apes and mankind. The apes are further subdivided into the gibbon, the orang utan and the gorilla and the chimpanzee.

Comparable to these subdivisions of the apes, mankind would be divided into one solitary genus known as homo. Now let's briefly trace the geoligic history of

these forms. The primates first appeared in the Eocene where fossils of the first three groups appear, lemurs, tarsiers, and monkeys; they are all present as fossils in the Eocene. The lemurs and tarsiers are four-footed walkers and living forms do not have stereoscopic vision, that is, they cannot see an object with both eyes at one time. The sense of smell is more important thatn the sense of sight and they have more of a muzzle than a face.

The monkeys are also four-footed walkers; they have stereoscopic vision; they sit on their haunches and in that position the front limbs serve for other than locomotive functions. They have stereoscopic vision, therefore the front limbs pick up the objects and bring them to the eye for vision. The thumb is opposed to the four fingers and they have a grasping hand. They didn't have Model T Fords in those days so ???. The accuracy in the vision of a monkey is of great importance to them in order to be able to judge the strength of a limb to which they are going. Those that judged successfully gave rise to the present monkey, and those that judged inaccurately are fossils. (Interruption. Question: What do you call that kind of vision? Answer: Stereoscopic, stereoscopic vision.)

The lower anthropoid, that group, appears at the close of the Eocene. Their geologic history does not become significant until the following period, the Oligocene. Then in the next subdivision, the Miocene, we have these forms appearing; and the gibbon, orang utan and the gorilla and the chimpanzee at the present time have the habits and characteristics that they do because they lived in different areas. For example, the gibbon and the orang utan move through forest areas by walking on one limb and reaching overhead for the other one and they distribute their weight over two limbs; they are larger than the monkey. The others, the gorilla and the chimpanzee do not move through the trees; they live in forest areas, but they move on the ground in an erect posture. //

Mankind does not appear until the ice age, until the Pleistocene. That would be the oldest form that is, in the Pleistocene, wo which the name mankind can be given. At this point it is proper that we consider the origin of man. As an organism, he had the same ancestry as the other primates. This ancestry, however,

is not to be confused with the pseudo scientific explanation that man has come from the ape and that some pl ce there is a missing link. I know of no one with a scientific reputation worth having who has said any such thing. Rather put the apes up here with man because they are both living. That is, they maybe have developed from the same parental stock, may have developed from the same primate stock, but have gone off in different directions and have arrived at different goals. It is believed that the place of this separation was in Central Asia and took place or occurred as a result of the ice age. It has been diagnosed somewhat in this way. There are found in the Tertiary tocks of this region other forms of fossil primates. We will say that this represents an area in which the primates were living in that region. At the close of the Tertiary, the area was subjected to diastrophism and there rose through here a mountainous chain, the Himalayas. The chain of mountains served as a barrier not only the mountains changed the life, but the temperature was decreasing. The ice age was in the office; the trees were being destroyed. Before this mountain barrier rose to such an extent that the forms could not migrate, the apes moved out -- they went to the east to areas of similar environment where they are found today and one group went to the west into the areas ??? and those that were left behind made the best of the conditions where they lived. The trees were going; erect posture became the method of locomotion. It was cold; these forms needed food. It was cold; the skins kept the animals warm, why shouldn't they keep man warm? So that's the beginning of what we call man.

We can read about it in books. So far as the geology of it is concerned, we stop with the advent of man on the surface of the earth. From there on it is anthropology. Man did live dnring the ice ages. We have good records from Europe and in North America, but here they have not been as complete. There has been one record of a form belonging to the Pleistocene and that was found here in Minnesota,, the Minnesota Maid, found up here at Pelican Rapids?. It is five minutes after eight, so I think we had better stop now. Next time we will finish this up and then for the last hour or so, I will let you tell me all about what you have learned.

I believe last time we had gotten as far as the appearance of what might be called mankind, on the surface of the earth, in what might be called the Pleistocene. What I have to say this evening is largely anthropology, so what I have to say with regard to these forms is, of course, merely what I have gotten from reading and no actual experience in the field. I think it is primarily of interest to us to arrange the forms more or less in order ? to mankind or rather to the present forms of man, would be a better way of stating it.

Pithecanthropus; one of the rather old forms that has been found has been given this name, Pithecanthropus. It was found in Java and is sometimes called or known as the Java Man. Perhaps this form has received greater attention than all of the other forms put together and yet actually there was so little of it found that the actual classification of it is somewhat questionable. They found part of the head, skull cap, three teeth and one thigh bone, the femur. Now from those fragments they have attempted to reconstruct an individual. It is of course apparent that the reconstruction will imply considerable interpretation, so much interpretation that many anthropologists say it is a man-like ape, a highly developed type of ape.

The general process of reconstruction is more or less in this form. The teeth indicate somewhat the matter of the diet of the form; the size of the teeth and the general arrrangement would give some indication as to the dentition, the arrangement of the teeth. The size of the teeth would give some indication as to the probable size of the jaw. The skull cap would give some indication as to the relative size of the head. The convolutions on the inside of the skull would give some indication as to the brain capacity of the individual. The femur bone would approximate a human size. The general shape and projections on the bone indicate that the form was rather massively built, a rather muscular individual, walking probably with a stoop. That is true of some forms later known and that is probably true of Pithecanthropus as well.

Now this I say, is interpretation. I have given you the facts of those things found and the rest is merely reconstruction of the things found. ??? lies in

the fact that it was found in stream gravels and it is hard to say what the geologic age of those gravels might be. Some geologists have called it Tertiary, Pleiocene; others have called it Pleistocene, belonging to the ice age. Choose whichever side you want to. I think the anthropologists themselves are divided, so you will be in good company on either side.

The next form in the anthropological sequence, Sinanthropus, sometimes spoken of as the Peking Man, found near Peking, China, or what was Peking before they changed its name. They found the upper portion of the skull, several teeth and two lower jaws, of course belonging to different individuals. Of this form, no culture is known, that is, noth ng which they made or used. There is still considerable work to be done on these forms.

The next form is Eoanthropus, sometimes referred to as Piltdown Man or Dawn Man. Eo means "the beginning", of course, not true of mankind. This is called the Piltdown Man because the fragments were found at Piltdown, Sussex, England. I think one of the important things about these forms is the distribution they have, one in Java, one in China, and this in England. The Piltdown Man is one of the most questionalbe of all anthropoid finds. They found the skull and jaw fragments , the question is whether the skull and jaw belong together. Again these were associated with gravels; the age has been determined as belonging to the first or second interglacial stages, so these forms were living in Europe during the ice age. These forms are then the more or less primitive and ancestral forms to that group spoken of as mankind.

The next one would be the beginning of the genus homo. Now there were fossils or extinct races of man and one of the most primitive would be the Homoheidelbergensis, known as the Heidelberg Man. In these you might do this, this would give them some distinction. These forms are primitive and are not mankind. With these fragments of Heidelberg Man there is also found artifacts, that is, they found chipped flint implements; they found them in caves indicating that they were learning to make implements and had learned to use shelter. These

forms also belonged to the first or second interglacial stages of Europe. Wisconsin, Illinoian, Nebraskan, Kansas, that would be the glacial succession in North America; that is subdivided into four parts. I have purposely left out one because there is a tendency to correlate North American glaciation with European glaciation. I

In Europe there were four well-defined periods of glaciation. In North American glaciation there is a tendency to include the Iowan, but that is now being considered as the beginning stages of the Wisconsin glaciation. This is the European succession with the apparent correlation, apparent relations of these, Wurm, Riss, Mindel, Gunz. Now an interglacial stage would be any place in here, when the ice was absent from the area. Of course man could not live in an area when it was covered by a glacier, but after the glacier had receded, man could migrate into the region and the artifacts and the skeletons would be ? in the ? between the periods of glaciation. These two forms belong in either one of these two periods. (Interruption. Question: Will the French accept those names for European glaciation? Answer: ???) (Interruption. Question: Are the names selected in the same manner as they are in North America? That is, did the glaciation get only as far as Germany and no farther? Answer: ???) (Explanation of word drift)

The next is homoneanderthalensis, being a true man and known of course as the Neanderthal Man. There have been a great number of specimens found of this particular form. Up to about ten years ago they had found 53 skeletons, so there is a complete record of these forms associated with caves, rock shelters and artifacts. With regard to Neanderthal Man, ~~with~~ in the restoration at the Field Museum at Chicago; there is a family group and it shows family life rather vividly. The man is a muscular individual, rather short in stature, heavily built, shoulders somewhat hunched, knees slightly bent and in this group he had just been successful in killing a deer. The implement with which he killed it is in his hand. The prize was not won without a scuffle because his knee has been cut as indicated by the restoration. The mother is sitting by the campfire.

If I remember, she is working on the skin of an animal. A youngster 10 or 12 years old is having what you might call a feast, I suppose. He has a bone and is chewing on it; it is uncooked. The group is shown as being at the entrance to a cave, shelter. It is rather an interesting group. If you go there I think it is well worth your while to stop to see it.

After these then there are some others and all of them are known as homo sapiens, and from there on thr is, of course, a continual condition of man and his existence and his development. In this group there would be the various principal races of man, under it, Cromagnon and other races of man that have become extinct. From homo sapiens, man had become diversified and has taken up different environments and ? and thuse we hve them distributed over the surface of the earth and they have ? just as we have them at the present time. /// Anything more than that would be an encroachment on the subject of anthropology.

I have said nothing about the types of culture for that is not geology. That is anthropology, that is, as I said, another field in this general history of the development. I th nk you will recall that the first successful vertebrate was a fish and that there formed from fish-like ancestors, amphibians that could move about temporarily on land, and from forms with amphibian-like characteristics, there developed an organism known as the reptile and/from again stock probably characteristic of all thes three thre appeared a form known as mammals, and from mammal stock, there appears what we call man. Yet man's appearance and his ? are quite similar to that of the other animals. Perhaps there are objections to man's(primitive primate) ancestry, but that isn't as bad as it seems. ??? reptile, amphibian, and aquatic ancestry rather than this anthropoid ancestry. As I said before there are other ways of saying that, but I think th s is one of the best ways, so if you object to primate ancestry, then keep this in mind.

With regard to one topic I have avoided intentionally, that is the subject of evolution. Evolution means nothing more than development. Now I have tried to show you the development of the complex organism from simple ancestry. I have

also purposely left ? ? until the very last one. If through several hundred million years, the general biological plan has been the development of complex forms from simple ancestry, then it seems rather surprising that in the last million years the plan should be changed, that all the rest of man's associates, animal and plant associates, should develop from more primitive forms and yet not apply the same geologic history to man. You don't need to if you don't want to. That is up to you. Evolution should be thought of, at least I like to think of it, in the same way as thousands consider the origin of the earth. The development of man is ???, the question is merely how you are going to explain it. Evolution is merely one way. Now if you prefer special creation for each geologic period, that is up to you. If you prefer an explanation of uniform ? (Interruption. Question: What do you mean by that? Answer: Once they were created they were never changed, that is what I mean). Evolution is nothing more than the explanation that we have in the same sense, the explanation for the origin of the earth. Rather few people doubt that the earth is in existence, the only question is how it got to its present state. The same is applied to animals. They are here; they are diversified; they are adjusted to their environment -- it is simply a matter of what you want to choose. I think nothing more need be said. In fact it should not be aid in a course in geology with regard to those particular features.

Now I do want to take time to have you record some things which I consider to be, I find, important. I don't remember whether I gave them to you during the first part ot not. First I will give you the ten fundamentsls, the ten commandments, so to speak, concerning the geological history of the earth.

1. The continent has been subjected to successive submergences and emergences as recorded by superposition and unconformity. If these things are not clear, ask me about them. As a matter of fact, all the things I hav tried to teach you have been about these things.

2. The reconstruction of successive geographies is based upon the distribution and correlation of marine strata.

3. The reconstruction of ancient physiography is based upon the

composition and structure, no, texture, composition and texture of shallow water sediments.

4. The postulation of geosynclines is based upon great thicknesses of shallow water sediments.

5. The absence of geosynclines in the central lowland is indicated by the thinnes of the samine sequence.

6. All deformation of rocks is dated by the youngest formation involved. (Interruption. Question: What does that mean, the last one? Answer: ???)

7. The present mountain ranges of the continent have resulted from the deformation of geosynclines and their consequent disappearance. (Interruption. Question: Does thatapply to all mountain ranges? Answer: ???)

8. Where a mountain range h s been peneoplaned, its former presence may be determined by its roots. (Interruption. Question: Its what? Answer: Its roots -- strike of fold, strike of formations, strike of schistocity, and strike of faults, those zre spoken of as roots of mountains.)

9. Diastrophism is the ultimate basis for the subdivision of all geologic time.

10. Igneous activity is usually contemporaneous with severe diastrophism.

Now perhaps in this list of ten you would put some others, but to me that seems to be more or less the ? on which the geologic history of the earth is based.

Now let's take th econd ten. These will be the fundamentals of the biological history of the earth.

1. Changes in the life of the earth have been toward increasing complexity.

2. Successive changes in life apparently have been ~~related~~ related to geologic events.

3. Decline or extinction of organisms was primarily caused by changes resulting from diastrophism. Now with regard to this third one, you might say it was climate or you might say it was the change in temperature or the change

in moisture; it might have been the removal of barriers -- it might hav been any of those things, but primarily the cause was diastrophism.

4. Diversification of organisms results from adaptation to environment. Now in some of these there is going to be an overlap. If the forms did not adapt themselves to the environment, then of course they became extinct and whether or not that environment was suitable ???. That is of course overlap.

5. The character of a fauna or flora is determined by a restriction or intermigration.

6. Sedimentary strata may be correlated by the use of biological criteria. Now like the roots of the mountains, if you have forgotten what those are, there would be such things as identity of species, in other words, guide fossils. ? of the forms, in other words, cosmopolitan or provincian communities. It should be in the hsitory represented by the organism being studied, and the last one, the percentage of living species.

7. The order in which vertebrate animals appeared is the same as the zoological order. That is, when the scientists began to study the back-boned animals, they began to arrange them in increasing complexity. Then when they began to work out the geologic history, they found that they appeared in exactly the same way in which the living forms had been arranged. Someone suggested that the scientists got the order from the geologic history, and that is n't true; they got it from the character of living organisms, and yet it coincided with the geological record.

8. The vertebrate animals have dominated the earth in the same order as that in which they appeared. First we have amphibians, then the reptiles, and then the mammals, and the rest of the mammals was ? an undoubtedly inhabit the earth today.

9. This one is not written out so I will have to stop to think how to say it. The histories of the animals and plants have followed parallel developments. Perhaps a word of explanation is needed. The plants, aquatic,

amphibian, and terrestrial. The animals started aquatic, amphibian, and terrestrial. The animals always follow the plants because that is the meaning of the statement.

10. Mankind was the most recent form to appear. Perhaps that is lending too much emphasis to the last one, but we are all egotistical enough to want to know when man arrived, and we want some place to put him. (Interruption. Question: Where do bacteria come in? Answer: ???) Any other questions?

Well, we will let you get started on your part of the ? tonight.