THE MINNESOTA GEOLOGIST

OFFICIAL BULLETIN
OF
THE GEOLOGICAL SOCIETY OF MINNESOTA

VOL. XX SPRING AND SUMMER 1966 No. 1

ANCHORED TO THE INFINITE

The builder who first bridged Niagara's gorge,
Before he swung his cable, shore to shore,
Sent out across the gulf his venturing kite
Bearing a slender cord for unseen hands
To grasp upon the further cliff and draw
A greater cord, and then a greater yet;
Till at the last across the chasm swung
The cable--then the mighty bridge in air!

So we may send our little timid thought
Across the void, out to God's reaching hands--
Send out our love and faith to thread the deep
Thought after thought until the little cord
Has greatened to a chain no chance can break,
And--we are anchored to the infinite!

Edwin Markham

GEOLOGICAL SOCIETY OF MINNESOTA

Mrs. Marion S. Skahen, Editor**
The Minnesota Geologist
1812 Bryant Avenue S., Apt. 5
Minneapolis, Minnesota 55403

MEETINGS: October to May, inclusive, 7:30 p.m., every second and fourth Monday, at 155 Ford Hall, University of Minnesota, 17th and Washington Ave. S.E. Visitors welcome.

FIELD TRIPS: May until October, inclusive.

ANNUAL DUES: Residents in a 50 mile radius of the Twin Cities, $5.00, plus $2.00 additional for husband, wife, or dependent family members. Students and non-residents, $2.00.

AFFILIATE MEMBER OF: Midwest Federation of Mineralogical and Geological Societies

and

The American Federation of Mineralogical Societies

**Mailing address for Exchange Bulletins until further notice:

THE MINNESOTA GEOLOGIST
Mrs. Marion S. Skahen, Editor
5450 Bryant Avenue, N.
Minneapolis, Minnesota 55430

STANDING COMMITTEES--Chairmen:

Constitution and By-Laws	Martha M. Peterson
Parliamentarian	Grace V. Benz
Bulletin and Editorial	Marion S. Skahen
Program	Fred W. Hallberg
Field Trip	Elmer H. Brown and Dr. Bert R. Carlson, Co-chairman
Membership	Martha M. Peterson
Geologic Tablets	Lawrence W. King
Historian	Hal E. McWethy
Library*	Wilma Monserud and Elsie J. Sacia, C -chairman
Hospitality and Sunshine	Elsie J. Sacia
Property and Equipment	Dr. Henry N. Reinking
Auditor	J. Orval Engen
Banquet	Grace V. Benz and Martha Peterson, Co-chairman

*A list of informational books on Geology is included in this bulletin.

GEOLOGICAL SOCIETY OF MINNESOTA INSTALLS BRONZE TABLETS

Plans for installation of thirty-two educational bronze tablets throughout the State of Minnesota have now been completed, and the tablets have been installed. This is a project supervised and directed by Mr. Lawrence W. King, a charter member of the Society. The tablets explain the geological significance of the areas in which they are placed. If and when another location is found suitable for an additional tablet, arrangement will be made for its installation.

ANNUAL BANQUET

The twenty-seventh annual banquet of the Geological Society of Minnesota was held on Monday evening, April 25, 1966, at the Bethany Lutheran Church Hall, 2511 E. Franklin Avenue, Minneapolis.

Mr. Richard J. Dorer, formerly with the State Department of Conservation, who is the author of the volume of poetry, The Ghost Tree Speaks, was the speaker. His subject was the Minnesota Memorial Hardwood Forest.

In charge of the banquet and table decorations were Martha Peterson and Grace Benz. The event was a fine success with 110 in attendance.

MINNESOTA MINERAL CLUB

The Minnesota Mineral Club may well be proud of the response and enthusiasm shown by their members and the hundreds of visitors who came to their annual exhibit at Apache Plaza in April. This attendance is indicative of the important role that a hobby can play in the lives of individuals. Mineral and rock hunting, collecting, and polishing can be fascinating and rewarding, as is demonstrated in the collective interest and effort shown in their exhibit.

* *

A MESSAGE FROM YOUR PRESIDENT

Fellow Members:

To me, and apparently to the membership at large, the winter series of lectures was interesting and profitable. The wonderful success of the program was due entirely to your Program Chairman, Mr. Fred Hallberg. (Oh, yes, there were an even dozen speakers.)

The official "Board" was a solid plank during the past season. If I select one member of it for special mention, the help and counsel of the other members comes to mind. Thanks to each and every one for service cheerfully and thoughtfully rendered.

It seems that there are so many cycles in the natural order of life--day and night--winter and summer--deposition and orogeny--lectures and field trips--ah, yes, FIELD TRIPS!

Somewhere in this bulletin you will find a tentative list of field trips. On these trips you will find items we have read about in the books on the shelf. Those trilobites and others with strange-sounding names! And the minerals and the metallic ore deposits! Didn't someone tell us about them in the lectures?

Are our dreams going to be followed by realities? Just another enjoyable cycle. Why don't you get in on the sequel to the winter's program? The Houghton, Michigan, trip includes a lot of happy hunting grounds. And Mr. Elmer Brown, our Field Trip Chairman, has a number of shorter trips scheduled.

As I look out the window, the sun is shining, spring is beckoning, the air is full of promises. Rocks! Fossils! Field Trips! The whole outdoors is one big interesting laboratory. May your summer be an enjoyable one.

Clyde Case, President

NEW MEMBERS:

Mrs. Caroline Van Strum Derdiger, 3122-15th Ave. S., Mpls. 55407	PA4-8213
Mrs. Fred Gordon, 521-2nd Street, White Bear Lake 55110	
Miss Helen Kretchmer, 3110-4th St. S.E., Mpls. 55414	331-7772
Mr. & Mrs. Theo. Mason and son, 2437-30th Ave. S., Mpls. 55406	724-9063
Mrs. Phyllis Mullin, Box 90, 500 S.E. Essex, Mpls. 55413	336-3074
Prof. Paul W. Stor, Concordia College, 275 N. Syndicate, St. Paul	
Miss Mary E. Quinn, 4949 Beard Ave. S., Mpls. 55410	922-4815

With the 33 members listed in our Winter Bulletin, this makes 42 new members this year.

Martha M. Peterson
Membership Chairman

We on this continent should never forget that men first crossed the Atlantic not to find soil for their ploughs, but to secure liberty for their souls.

Robert J. McCracken

IN MEMORIAM

Mrs. Lulu Zalusky, 4004 Bryant Ave. S., wife of Joseph W. Zalusky, a charter member of the Geological Society of Minnesota, passed away on March 4, 1966. She is survived by her husband, a son James J. of St. Louis Park, a daughter Mrs. Palmer Thorstenson, six grandsons and one granddaughter.

Mrs. Zalusky was a fifty-year member of the Eastern Star, a life member of the Hennepin County Historical Society, Royal Neighbors, and the Audubon Society.

****

Mrs. Nellie E. Howard, 3534 Colfax Ave. S., a former member of the Society, passed away on April 14, 1966. She is survived by two sisters, Mrs. Grace Knowles, Bellingham, Washington, and Mrs. Florence A. Bailey, Elk River, Minnesota.

Mrs. Howard was an elementary school teacher in Minneapolis for 45 years, retiring in 1954.

****

Miss Ida M. Swenson, recently residing at the St. Olaf Residence, 2912 Fremont Ave. N., for many years a member of our organizztion, passed away March 7, 1966, following a long illness. She has no immediate survivors.

She was a member of the Eastern Star and Treasurer of Wenell American Legion Auxiliary 233.

****

Our heartfelt sympathy is extended to the survivors in their loss.

NEWS NOTES

Mr. George Rickert, former president of the Geological Society of Minnesota, was taken suddenly ill a few weeks ago and hospitalized for surgery. We are glad to report that he has completely recovered and shows his usual good spirit and enthusiasm to be of help whenever he can.

Illness also necessitated the hospitalization of Mr. J. Orval Engen, one of our board members. He too is at home now and has returned to teaching. We all extend our best wishes for his complete recovery so that he can resume his regular activities.

It is perhaps as fortunate to
have a desire to study the simple
rock formations, as to be born
with great wealth.

Edward P. Burch
1940

PROPOSED FIELD TRIPS--MAY 15 TO OCTOBER 2, 1966

Field trips are the key to the study of geology. As the English author, John Ruskin, wrote: "There are no natural objects out of which more can be learned than out of stones. They seem to have been created especially to reward a patient observer. For a stone, when it is examined, will be found a mountain in miniature. The surface of a stone is more interesting than the surface of an ordinary hill, more fantastic in form, and incomparably richer in color."

Providing an opportunity for the Geological Society of Minnesota to benefit from this type of observation, the following proposed field trips are being planned for the coming summer months:

Sunday, May 15	Minneapolis Building Stones Leader--Mr. Elmer Brown It will be interesting and informative to all to see how the varied and beautiful sandstones, granites, and marbles are untilized in the construction and ornamentation of our fine buildings.
Saturday & Sunday June 4 and 5	Luverne, Minnesota Leaders--Dr. Bert Carlson and Mr. Elmer Brown This field trip is planned to study the Sioux Quartzite Formation in southwestern Minnesota, and the decomposed granite and kaolinite at Redwood Falls; also to visit the Ochs Brick Plant at Springfield, Minnesota. There will be an evening dinner and lecture with slides on the quartzites we have seen in Minnesota and Wisconsin.
Tuesday, June 14 through Tuesday, June 21	Annual Field Convention of the Midwest Federation of Mineralogical and Geological Societies, June 16-19 at Houghton, Michigan. Sponsored by the Copper Country Rock and Mineral Club, with the cooperation of the Division of Continuing Education--Michigan Technological University. This is to be the outstanding field trip of the year and is expected to attract enthusiastic member groups from many states. It will take the place of our long annual field trip. (The June 14-21 dates mentioned above enclude travel to and from Houghton.) Complete details of program may be secured from Miss Martha Peterson. Telephone 825-1147.
Sunday, July 10	Taylors Falls, Minnesota and St. Croix Falls, Wisconsin This trip is to study the lava flows that form some of the spectacular vertical basalt cliffs and pot holes, as well as to view the magnificent scenery of the area.
Sunday, August 14	Annual picnic Through the perennial courtesy of Mr. and Mrs. Lawrence King, the picnic will be held at their lovely home on the St. Croix. This is always a delightful social interlude for our members.

Proposed Field Trips (cont.)

Saturday & Sunday September 10 and 11	The North Shore of Lake Superior A field trip to the North Shore has always been a favorite excursion for members, not only because of the spectacular scenery for which Minnesota is known, but for the many interesting specimens of agates, rocks and minerals to be found in that locality.
Saturday & Sunday October 1 and 2	Little Falls, Brainerd and Cuyuna Iron Range This excursion is planned to study the moraines and outwash plains, as well as the iron bearing rocks of the Cuyuna Range.

Attendance on a field trip will prove its interest and value. Bring your friends along to see the geologic wonders of this state. It will be a thrilling experience.

****

WINTER LECTURE SERIES

Correlated with our field trip program for summer months is the Winter Lecture Series of the Geological Society of Minnesota. The Society's lecture series for 1965-66 has been informative and interesting.

For the purpose of supplemental information, and as an aid to our members, we are including here for leisurely study and review a brief outline of some of the lectures presented during the fall and winter months by the Society. These outlines are mainly covered by notes taken for and by your editor and are not a complete resume. We trust they may prove helpful in clarifying the subjects in your mind.

THE HIDDEN EARTH

Professor J. Merle Harris
Lecture given in conjunction with a film by McGraw-Hill Publishers

This film summarized several aspects of the current work that is being done in the field of geophysics, as well as presenting some of the conclusions of past work. Inferences as to the nature of the interior of the earth are drawn largely from the study of natural earthquakes, much as the study of artificial earthquakes is used to interpret the layering of the earth's crust.

Earthquakes evidently occur because of the earth's crust being under stress. However, the causes of the stresses are still a matter of speculation. The film pictures an instrument set up in a long tunnel to measure rock movement. The statement that, "In the course of a year a mile of rock moves one-sixteenth of an inch" is to be taken as a measurement at a particular time and place--not as any kind of average.

The earliest known seismograph was of Chinese origin and was interesting in design. It employed several ceramic frogs arranged in a circle, looking outward, each holding a marble in its open mouth. The circle was mounted on an axis in such a way that, with a little tilting, the marble held by the frog lowest in the circle would fall from its mouth. In this way the direction of the first pulse or disturbance could be deduced.

Studies of the behavior of earthquakes led a seismologist, named Mohorovicic, to discover that the crust of the earth (now defined as the outer layer of the earth, in which earthquake waves travel relatively slowly) varies considerably in thickness from place to place. In general, it varies from 10 to 30 miles thick under the oceans. The line (really a surface) of separation of the crust from the lower layer next to it is called the "Mohorovicic discontinuity", for its discoverer, or simply "Moho" for short.

No actual drilling has as yet penetrated the Moho. However, a well-publicized project, called the "Mohole Project", is under way to do just that. From the above information regarding the thickness of the crust in different places, it is not hard to see why the best drilling site is believed to be in the ocean, in spite of certain obvious difficulties.

It has been found that when a seismograph is located too far away from the source of an earthquake, only the primary waves are received. This is interpreted to mean that if the waves dip too deeply into the earth they encounter a zone which absorbs transverse waves. Since tests show that liquids have this property, it is generally believed that below the mantle, which is about 1800 miles thick, most of the material is liquid. This portion of the earth, below 1800 miles, is called the core. From some other considerations it seems probable that the center of the core is solid. Thus the present picture of the earth is that of an outer crustal layer resting on a much thicker mantle, both of which are almost entirely solid. Below this there is an outer core, probably liquid, and near and including the center is an inner core, probably solid. It is not believed that volcanoes and lava flows derive their molten material from the core of the earth, however. It is believed to arise from pockets near the interface between the crust and mantle. Many of the deeper earthquakes also originate here.

Heat Escape

Another subject presented (by the film) is that of the study of the escape of heat from the interior of the earth. Whereas the average rate of increase of temperature with depth, called the geothermal gradient, is about one degree Centigrade for each 100 feet of depth, there are many places where it is considerably greater. This may be due to nearness to an igneous source or to a zone of weakness in the crust. In some hot springs areas commercial and industrial use is made of this energy source to generate electricity. How much of the earth's internal heat is due to the decay of radioactive substances and how much to "left-over" heat from the time when the earth was molten is a problem yet unresolved.

PRECAMBRIAN GEOLOGY

Dr. W. C. Phinney

The Precambrian period covers 81 percent of geologic time--approximately four billion years. It is present as large areas of relatively low relief on all major continents, probably a stable core around which younger portions of continents have accreted. Problems of correlation are difficult because rocks are non-fossiliferous; some are metamorphosed, reconstructed mineralogically, and complicated in structural relationship. Advent of radiometric dating has aided considerably in correlation problems over the past 15 years.

Many geographic conditions must have had similar ranges as today. For example, glaciation, volcanic action, erosion, and sediment deposition took place then as it does today. Certain details may have been different such as salinity of oceans or composition of atmosphere.

Precambrian Canadian Shield is composed of granitic rocks, gneises, schists, and volcanics, as well as slate. It extends from the Great Lakes region northward to Greenland and from the North Atlantic westward to Saskatchewan and the Northwest Territory.

In Minnesota there is anorthosite, and volcanics along the North Shore. Granitic rocks can be found near St. Cloud; gneisses and other metamorphics are present in the Minnesota River valley. The following precambrian effects can also be studied:

> Ely Greenstone (slightly metamorphosed volcanic rock) and Knife Lake formation in North Central to Northeastern Minnesota; Algoman Granite in northern Minnesota.
>
> Mesabi Iron Range--Virginia Formation. Bacteria and algae in sediments are two billion years old.
>
> Duluth Gabbro is intruded for 150 miles from Duluth to northeast tip of state.
>
> Hinckley Sandstone and Fond du Lac Sandstone in east central part of state. Sandstone in southern part of state in Sioux Quartzite.

The Cambrian period began 550 million years ago. Meteorites are 4.5 or 4.6 billion years old.

The coloring of rocks in slides is optical interference caused by polaroid lens.

Thin sections of rock three ten-thousandths of an inch in thickness are used to study textures and mineral composition under the microscope to help unravel the history of the rocks in detail.

PRECAMBRIAN GEOLOGY AND IRON FORMATIONS

Dr. Henry Lepp

The Cambrian period record as estimated here started about 600 million years ago and was originally defined as the earliest strata in which fossils could be found. Recently, however, marine animal fossils have been discovered on Victoria Island, which could indicate that complex life existed in part of the Precambrian era, but evidence is incomplete in the Precambrian because of structural metamorphism.

Iron formations in the Lake Superior region are Precambrian rocks which are partly weathered and oxidated. Taconite is a chemical precipitate like limestone. Natural precipitates form from material carried by rivers in solution and precipitated into the ocean. Iron formations in Minnesota fall into two age groups: those older than 1700 million years like the Mesabi Range, and those older than 2600 million years like the Vermillion Range.

Most of the iron formations of the world are in rocks that are older than 1500 million years. We have sedimentary rocks that are rich in iron in Europe—Alsace Lorraine, younger than 600 million years. There are also iron formations that are less than 600 million years old in North America (e.g., the Clinton Formation of Eastern United States.)

Precambrian iron formations are composed of iron minerals and silicon dioxide minerals (chert). Taconite contains very low aluminum, titanium, and phosphorus. Younger iron formations contain calcium carbonate and iron minerals. They are high in aluminum, phosphorus and titanium. In rocks younger than Cambrian we find large deposits of chert with no iron, and large bodies of iron-rich sediment with no chert.

In a temperate climate the chief weathering product is clay. Silica and aluminum form clay. In the tropics (laterite soil) silica is leached out of rocks, and all that is left behind is aluminum oxide, iron oxide, titanium oxide, and phosphorus.

Some of the oldest rocks that we know are sedimentary. Ely Greenstone is partly volcanic rock. One way of explaining the differences between the old and young iron formations is to assume that the Precambrian formations formed in an oxygen-deficient atmosphere, which would allow iron to be dissolved and thus to form chemical sediments like taconite that are low in aluminum and titanium.

Metamorphic changes take place at high temperatures. Weathering or surface leaching used to be considered a type of metamorphism.

ORIGIN OF PETROLEUM AND OTHER FUELS

Dr. F. M. Swain

In discussing petroleum, the subject may be covered under four main topics:

1. Source area
2. Source material
3. Exploration
4. Some great oil fields

Regarding source area and source material, sedimentary deltas such as the Mississippi Delta shales are a source bed for petroleum. Southern Louisiana has one of the largest source beds in the world. The estuary at Chesapeake Bay is also a rich source bed.

The Bay of Naples is 2,000 to 3,000 feet in depth. The temperature is warm, and there is much organic matter. The lagoons have a high rate of evaporation.

The bays along the rocky coast of Oregon and Washington are rich in kelp and seaweed. The kelp floats in and is preserved. On the beaches kelp accumulates with coarse material--carbonate hampers decay, and so is a good source. Coral is also an excellent source and reservoir for petroleum.

A reef of serpula worm is also a good source. There is an area and reservoir bed in Mexico. Another source is eel grass and sea anemones in Oregon.

With reference to exploration to find petroleum:

a. Surface mapping
b. Underground exploration: paleo geographic maps of Nicaragua and the Williston (N. Dak.) basin

In Western Texas most oil is in limestone rather than sandstone. Permian rocks in Texas are high carbonate rocks.

Regarding the great oil fields, Athabaska Tar Sands in Canada is one of the great future oil reserves in North America and probably in the world. The Netherlands and the North Sea probably will be one of the great gas fields of the world--mostly cretaceous. The greatest of all oil reserves, however, are the fields in the Persian Gulf area.

Coal as a fuel may be discussed under several broad areas:

1. Source areas
2. Source material
3. Where coal is found
4. Modern technique

Major sources of coal are dismal swamps in North Carolina and in lakes. In Bog Head Coal in Lake Nicaragua masses of small waxy algae form bog head coal. Cedar Creek Bog in Minnesota has 40 feet of peat and marl. Ten feet of peat will compact to one or two feet of coal.

Coal is classified as to geological age. Methane may form directly by bacterial action from carbohydrates. Crude oil comes from finely divided plant material--blue-green algae--while coal is chiefly cellulose. Usually coal and oil are not found in the same beds. Coal is made up almost entirely of ring compounds.

In crude oil, the more ring compounds there are the poorer the quality of oil. To form oil, high temperatures and high pressure are not needed. Oil is the result of interaction between the various organic material over a long period of time.

Oil forms more rapidly in salt areas and areas of high evaporation. There is a good possibility of finding much more gas and oil in the United States, but getting it is so expensive that other sources may be used.

Suggested references for a further study of this topic are Petroleum Geology by Landis (Wiley Co.) and Coal by Van Krevelen (published in the Netherlands).

AGE DETERMINATION OF ROCK FORMATIONS

Dr. J. A. Grant

Traditionally the ages of various rock formations have been determined by observing their positions relative to each other. For example:

Superposition
Dikes and Sills
Truncated cross-bedding
Fossils
Varves (glaciated material)

Ripple marks in sandstone indicate the top of their respective beds. Rates of sedimentation are very uncertain with variations of one foot in 500 years up to one foot in 2500 years.

Tree rings show seasonal variations in growth. (The oldest tree in the world is the bristle cone pine in California, which is 4,600 years old.)

However, Geologists have needed something other than the above to arrive at ages back to Precambrian times. Today, absolute ages are determined by radioactive decay.

a. This is not affected by temperature and pressures in the earth's crust.
b. The heat flow from the center of the earth is caused partly by radioactive decay.

These are the main decay schemes:

Uranium 238	changes to	lead 206	- half life:	4.5×10^9 years
Uranium 235	" "	" 207	" "	7×10^8 "
Thorium 232	" "	" 208	" "	1.4×10^{10} "
Rubidium 87	" "	Strontium 87	" "	5×10^{10} "
Potassium 40	" "	Calcium 40	" "	1.3×10^9 "
Carbon 14	" "	Nitrogen 14	" "	5700 "

It is necessary to select the decay scheme and the material to be used. Sometimes it is very important to know the number of daughter elements to start because if too many daughter elements are present the sample will appear to be much older than it is.

Gaseous products of helium and argon may escape. If the sample is open to entry or loss of either parent or daughter material, the determination will be wrong. Therefore one must be sure to get material in its original condition.

If we can date an intrusive into fossils, then we can date the fossils very accurately.

Geologists can analyze a rock as a whole or any minerals in the rock. If the rock and mineral formations are concordant events, the analyst gets only one age.

Regarding the age determination of meteorites, meteorites are thought to be primitive materials, and the age of earth and the age of meteorites are closely related. Lead from iron and stone meteorites and lead from the earth fall within the same time period, 4500 million years. Assuming that all lead came only from radioactive decay, the extreme upper limits of age of earth are 5060 million years to 5640 million years.

PALEOECOLOGY

Dr. E. J. Cushing

By the last 80 million years of geologic time (Cenozoic) the continents, ocean basins and crustal layers as we know them have been established. Mammals and flowers have evolved during the Cenozoic period.

The biological concept of complex systems acting in the universe is useful to geology.

Paleoecology (cont.)

The study of paleoecology is the study of the relationship of past plants and animals to the earth and landscape of the time. The paleoecologist is interested mainly in the following:

a. Change in species
b. Changes in the grouping of species, that is, their distribution in the landscape.
c. Climactic changes as related to landscapes--for example, glaciation

The geologist who is interested in paleoecology adopts the idea that recent life is similar to present life. To reconstruct the landscape of the past, the paleo-ecological tool he uses is the analysis of pollen of the last 10,000 years. (Rocks containing spores go back to Paleozoic and Devonian times. Pollen-producing plants developed during the Cenozoic period.) In Minnesota we are interested in the last 10,000 years and the plants of this post-glacial period.

Pollen grains falling into a lake are buried in mud and form a stratigraphic sequence. The grains may come from near or far. Pollen is a clue as to the nature of the higher plants, but very little or nothing can be known about the animals except from relationships between plants and animals today.

Pollen is obtained from lake cores bored out from frozen-over lakes. For example, the pollen core from Cedar Bog Lake indicates that about 8,000 years ago mostly pine and marsh fern were in abundance, while about 4,000 years ago there was less pine and more oak. Most recent cores show much ragweed pollen due to agricultural development.

PLEISTOCENE GEOLOGY

Dr. H. E. Wright

The Pleistocene period was the period of glaciation which affected Minnesota and most of North America. In the Pleistocene, there were either lower temperatures or more snow, or both. Mountain glaciers spread out onto piedmont and plains. During the last million years ice expanded at least four times from the Labrador center. Ice started as mountain glaciers in the mountains of Baffin Land, and spread to the base of the Rockies. The glaciers were fed by storms from the southwest. The driftless area of Minnesota and Wisconsin has been glaciated. The mountains of western Canada and the San Juan, Wind River, Glacier Park, Sangre de Cristo, Uinta, and California ranges had their own glaciers. The cirques in the Bear Tooth Mountains are now becoming lakes.

Extensive glaciers exist in Antarctica and Greenland. Antarctica is practically featureless, but mountain ranges do show, and rivers of ice are marked with crevasses. The very cold temperatures make the front edge of small ice tongues vertical. Crevasses are deep and sharp where the ice tongues fall over the valley ridge. There is very little melt water in Antarctica. By contrast, the Greenland ice sheet has outwash plains.

Certain features of glaciation can be noted. For example, moraines can be formed by debris being brought up and along glaciers. Eskers are formed by debris carried in rivers under the ice. When the ice front melts the serpentine ridges may be seen. There are thousands in Minnesota, especially in the northern part of the state. They may range from 20 to 100 feet in height. (cont. on p. 13)

Drumlins are back of the terminal moraines. These cigar-shaped deposits are formed at the same time but in different parts of the ice sheet, the drumlins forming in the lobe, and moraines at the front of the lobe.

In the Wadena and Long Prairie area there are 1200 drumlins in a fan-shaped arrangement. They are 15,000 years old. The problem of drumlin formation still remains unsolved. The pattern of deposition must be related to the fanning out of the ice near the terminus, which may permit till to be squeezed up into ridges. There is no way to get under the ice to see what is happening under the glacier to form the drumlins. There is a set of drumlins north of Two Harbors which are 50 to 100 feet high, five miles long, and have a mile between the drumlins.

At their maximum extent, glaciers reached to what is now St. Louis. The Ohio and Missouri Rivers were marginal streams, and their present channels were determined at that time. The glacial ice was perhaps 10,000 feet thick, and its weight depressed the earth hundreds of feet.

The distinct ice lobes which crossed Minnesota followed the natural lowlands which are in the original bed rock. Four major ice lobes reached central Minnesota. There is a problem in working them out. Both red and grey drift show in the Grantsburg Lobe, the grey being on top.

The Wisconsin glacial stage in Minnesota started 70,000 years ago and ended 11,000 years ago. Carbon-14 dating of organic debris in glacial drift determines the age of any particular ice lobe.

STRUCTURE OF CONTINENTS

Dr. J. C. Craddock

Continental structure is studied by the use of gravity meter and by seismic methods. The ocean basins are of heavy weight compared with continents, which are light weight. Oceanic islands are mainly basalt upon which are superimposed coral islands. There are two explanations for such islands as New Zealand and the Fiji Islands.

1. That they are separated from Australia
2. That they are growing into continents (continental accretion)

Continental accretion assumes three stages:

a. Early stage. Long zones undergo deep subsidence with accumulation of sediments in the geosyncline.
b. The tectonic stage
   (1) Folding of sediments
   (2) Thrust faulting
   (3) Intrusive granite batholiths
   (4) Metamorphism

c. Elevation
   Uplift due to isostasy or the balancing out of rocks.

By continual accretion the older rocks form the center of the continent, but a problem appears in the fact that in Africa, Brazil, and Austrailia the continental edges appear to be very ancient.

Structure of Continents (cont.)

The theory of drifting continents is based upon the following lines of evidence:

1. Stratigraphy of Australia, Africa, India, Antarctica and South America is amazingly alike.

2. Truncated belts in South America can be matched up with the same formation in Africa.

3. Magnetite crystals in lava are oriented according to magnetic field at the time they were formed. This does not correspond with the earth's present magnetic field. This indicates that both the magnetic poles and the geographic poles must have been in different places in earlier times.

The primal crust of the earth may have been similar to the crust of the ocean basins. The first orogeny may have been due to a convection cell. The down-welling convection currents form a trough and subsidence of the earth's crust, and then isostasy takes over. This convection cell theory is contravened by the rift valley system in Africa and in Nevada. Rifts indicate expansion. Present thinking is that perhaps the whole earth is expanding due to the build up of heat, and not shrinking because of cooling.

Reference: Our Wandering Continents, Alex du Toit (1937)

THE HUMAN SEASONS

Four seasons fill the measure of the year;
There are four seasons in the mind of man:
He has his lusty Spring, when fancy clear
Takes in all beauty with an easy span:
He has his summer, when luxuriously
Spring's honey'd cud of youthful thought he loves
To ruminate, and by such dreaming high
Is nearest unto heaven: quiet coves
His soul has in its Autumn, when his wings
He furleth close; contented so to look
On mists in idleness--to let fair things
Pass by unheeded as a threshold brook.
He has his Winter too of pale misfeature,
Or else he would forego his mortal nature.

John Keats

\#\#\#\#\#\#\#\#\#

THE COIN

Into my heart's treasury I slipped a coin
That time cannot take nor a thief purloin
Oh, better than the minting of a gold-crowned king
Is the safe-kept memory of a lovely thing.

Sara Teasdale

"EARTHQUAKE COUNTRY"

(The following section from the book Earthquake Country by Robert Iacopi is included in this bulletin because of its general interest to geologists and its excellence of information.) He is discussing an area in California:

The San Andreas Fault breaks into many branches in Southern California, and there is no reason to believe that the same situation could not occur in the north end.

Within California the San Andreas varies considerably in width. In places it may be less than 100 yards wide and made up of a few entangled lines of rupture. In most sections, however, it is several hundred yards to a mile or more in width and inter-laced with any number of sub-parallel fault lines. Its actual edges are indefinite because of the many old lines of activity that are now hidden under recent gravel deposits or alluvium, and because of the land-sliding that has covered several miles at a stretch. South of San Gorgonio Pass in Southern California the San Andreas zone is so wide that almost the entire width of the state falls under the spell of this great cleft and its many branches.

Despite its great variety of natural wonders, California is best known to many outsiders for just one thing--earthquakes. California is earthquake country, and the many reports and stories on its rumblings and shakings have made indelible impressions throughout the world. Only one in 10,000 California earthquakes ever does any great damage.

Bare statistics do not tell the whole story. Any Californian who knows even a few facts about the state's seismic history realizes that "earthquake" can mean many things. Most often, it refers to minor quivers of the earth that people can feel but that scarcely do more than rattle windows, crack a little plaster, or occasionally knock an older home off its foundation. The fact that California averages one earthquake of destructive magnitude per year does not mean that a city of some size is flattened. On the contrary, a great percentage of these larger earthquakes are centered far enough from population centers that the great shock intensities close to the source do nothing more than shake some sand dunes or frighten a few cattle. The large cities--far in the distance--feel nothing more than the last dying shudders.

Despite the public attention concentrated on recent earthquakes, California has had only three "monster" earthquakes during recorded history--in 1857 in Southern California; in 1872 in Owens Valley, and in 1906 along the Northern California coast.

What we know is that earthquakes are only a small part of a greater geologic process that is constantly taking place in the earth's crust. When the earth shifts along lines of weakness known as faults, the violent movement of great rock masses creates shock waves that result in earthquakes.

We can learn a great deal about the nature of earthquakes by studying the faults along which they originate and by observing the physical features that have been created by both ancient and recent movements. California's San Andreas Fault is by far the most conspicuous in the state and is so well delineated in many areas that it can be easily explored by the layman.

California has earthquakes for the same reason that it has much of its magnificent scenery. Earthquakes originating here are tectonic in nature, which means that they are caused by the very forces that are responsible for mountain building.

The state is broken into a series of crustal blocks that are separated by faults--great fractures that form lines of weakness in the masses of rock at the earth's surface. Due to the pressures that build up below the surface, these blocks are elevated, tilted, folded and depressed along the fault lines until they resemble the pattern of an old brick street. And every time two of these blocks suddenly shift past each other along a fault, California has an earthquake.

Fault movements are responsible for the development of the great Sierra Nevada, most of the ranges of Southern California and much of the Pacific coastline. There are thousands of faults located throughout the world, but there are definite concentrations in the areas that are associated with high, actively building mountains and deep oceanic belts. A great concentration of faults extends from east to west through Europe and Asia Minor. The largest seismic belt surrounds the Pacific Basin and includes the fault systems of the west coasts of South and North America, the Aleutian Islands, the complex Japan-Kurile belt, the Phillipine Islands, New Zealand and many South Pacific Islands. Master fault zones of the Pacific Basin are noted for their horizontal rather than vertical movement.

California is interlaced with hundreds of faults, among which the San Andreas is the most publicized. The most dominant fault in California today is, by far, the San Andreas Fault, a giant shear zone that extends some 650 miles through Southern California and along the Coast Range section of Central California. This huge fissure has been instrumental in the development of the topography all along its course; and it has caused two of the greatest earthquakes in California history, 1857 and 1906, plus a number of others that have excited public interest.

The fault received its name when geologist Andrew Lawson pointed out that the fault features were best exposed and typified by the straight valley on the San Francisco Peninsula that was occupied in part by San Andreas Lake.

Like all major faults, the San Andreas is not a single break in the rock, but it is a wide zone, made up of several lines of activity that are roughly parallel. It is not of a single age, but includes the remnants of ancient faults that have been quiet for countless centuries and other active breaks that form the line of most recent activity within the zone. The discontinuous movement along the fault has given rise to a confused surface appearance consisting of old features that have been heavily eroded, plus the fresher results of movements of the past few thousand years.

The depth of the San Andreas Fault is unknown. Most geologists agree that it probably extends all the way through the earth's crust, a distance of 20 to 30 miles. Most California earthquakes originate at points about 10 miles deep, and those that shake man at ground level must also vibrate the rocks for an equal distance in all directions. The fault probably dies out deep within the earth where temperatures are such that the rocks become more plastic and movements along the line of fracture can be absorbed without any rock break.

TO BE ALIVE

> Life may appear to have become a frustrating round of meaningless activities in today's complex society. But there are millions who preserve a sense of the underlying wonder of our world, who have a capacity to take a delight in everyday experience, and find intense joy in simply being alive.
>
> "Words to Live By", THIS WEEK MAGAZINE

University of Minnesota Library

FURTHER ADDITIONS TO THE GEOLOGY LIBRARY, PILLSBURY HALL

by Wilma Monserud

Lauff, G. H. --------The Bottom Sediments of the Straits of Mackinas Region. Institute of Science and Technology, Univ. of Michigan, 1961.

Lee, M. O. ----------Biology of the Antarctic Seas. (Antarctic Research Series, Vol. 7), American Geophysical Union, 1964.

Lee, W. S. ----------The California Deserts. Putnam and Sons, 1963.

Leiper, H. (ed.) ----The Agates of North America. McClure, 1961.

Liberal Geological Society -- Pre-Permian Handbook of the Hugoton Embayment. Liberal, Kansas, 1962.

Liddicoat, R. -------Handbook of Gem Identification. 6th ed. Gemological Institute of America, 1962.

Lyon, R. J. ---------Minerals in the Infrared. Stanford Research Institute, 1962.

Mason, B. -----------Meteorites. Wiley, 1962.

Maury, M. F. --------The Physical Geography of the Sea and Its Meteorology. Harvard University, 1963.

McCoy, J. W. --------The Inorganic Analysis of Petroleum. New York, Chemical Publishing Co., 1962.

Medvedev, S. V. -----Problems of Engineering Seismology. Consultants Bureau, 1963.

Menard, H. W. -------Marine Geology of the Pacific. McGraw-Hill, 1964.

Miller, D. W. -------Water Atlas of the United States. Water Information Center, Inc., Port Washington, L.I., New York, 1962.

Milner, H. B. -------Sedimentary Petrography. 4th ed. Macmillan, 1962.

Minnesota Natural Resources Council ----Minerals Task Force, Areas of Interest and Problems. (Summaries) Minneapolis, 1962.

Moore, C. A. --------Handbook of Subsurface Geology. Harper and Row, 1963.

Moore, C. B. (ed.)---Researches on Meteorites, Wiley, 1962.

Mukerjee, P. K. -----A Textbook of Geology. Calcutta. The World Press Private, LTD., 1962.

Nagata, T. N. -------Rock Magnetism. Tokyo. Maruzen, 1961.

Nelson, J. H., and others ---Magnetism of the Earth. U.S. Coast and Geodetic Survey, 1962.

N.Y. Oil Finders Convention -----The Habitat of Oil in the Sedimentary Basin. 1955.

Nichols, D. ---------Echinoderms. London, Hutchinson Univ. Library, 1962.

Northern Ohio Geological Society --------Symposium on Salt. Cleveland, 1962, 1963.

O'Keefe, J. ---------Tektites. University of Chicago, 1963.

Panhandle Geological Society -Symposium of Oil and Gas Fields of the Texas and Oklahoma Panhandle. Amarillo, Texas, 1961.

GEOLOGICAL SOCIETY OF MINNESOTA
5450 BR AVENUE NORTH
MINNEAPOLIS, MINNESOTA 55430

Return Requested

Professor J. Merle Harris,
121 Folwell Hall
University of Minnesota
Minneapolis, Minn 55414