BULLETIN CHICAGO NATURAL HISTORY MUSEUM

Volume 37, Number 1 *January, 1966*

MUSEUM NEWS

COBURN APPOINTMENT SPURS MUSEUM DEVELOPMENT

A new Department of Planning and Development was established by the Museum on January 1. Mr. Robert E. Coburn has joined the Staff as Development Officer to coordinate various phases of institutional development, including public relations, membership, and all other activities which communicate the Museum's program to the public. Our experience in recent years has clearly demonstrated that Chicago Natural History Museum must develop a broader base of financial support if it is to maintain and heighten its past distinction. The development department will aid in defining financial needs and in making them known to the community.

Mr. Coburn attended Northwestern University and has spent 43 years in development work. He joined the Community Fund of Chicago in 1943 as Associate Executive Director. He has served as Campaign Director of the Crusade of Mercy and the Community Fund campaigns each year since that time. He retired from the Community Fund-Crusade of Mercy at the end of December.

Mr. Coburn has been actively associated with one hundred and fifty fund-raising programs which produced over $300,000,000 for many non-profit educational, health, and charitable organizations. He has served as President of the Indiana Society of Chicago, South Shore Country Club, and Bryn Mawr Community Church Board of Trustees, and as Director and Chairman of the Executive Committee of the Chicago Theological Seminary. Mr. Coburn was also one of the founders of the Chicago Society of Fund-Raising Executives. He lives at 6700 Oglesby Avenue in the South Shore section of Chicago.

NEW BOTANY CURATOR STUDIES TROPICAL PLANTS

Dr. William C. Burger has just been appointed Assistant Curator of Vascular Plants. He will be concerned with the plants of tropical North America. His special field will be floristics of Costa Rica.

Dr. Burger was born in New York City where he attended Columbia College. He served in Germany and France, in the Army, after graduation. On his return he worked for a short while at the New York Botanical Garden and then moved to Cornell University where he began graduate work. He studied there under the direction of Professor Robert T. Clausen and received his M.S. degree for a thesis based on a statistical study of several populations of the Swamp White Oak, the Bur Oak and their putative hybrids. Dr. Burger received his doctorate from Washington University in St. Louis, where he studied at the Missouri Botanical Garden under Professor Robert E. Woodson, Jr., an outstanding American systematist. A study of several new-world genera of the mulberry family was the basis of his thesis—and subsequent contribution to the *Flora of Panama*.

Dr. Burger joined the Agricultural College staff of Haile Selassie I University at Alemaya in eastern Ethiopia and worked on a USAID project administered by the University of Oklahoma. During his four years there he collected extensively in Ethiopia, especially in the Harar highlands. He prepared illustrations and text for a manual of the woody plants of the Harar highlands and for a text on the identification of the families of seed plants in Ethiopia.

His recent return from Ethiopia took him through India, Thailand, Malaysia, and Australia where he investigated the many varieties of tropical vegetation. He will go to Central America in January to begin field work in tropical America. He will be joined by Chief Curator Louis Williams later in the season.

NATURE PHOTOGRAPHY EXHIBIT

Outstanding nature photographs, selected from thousands of national and international entries, will go on display at the Museum during the 21st CHICAGO INTERNATIONAL EXHIBITION OF NATURE PHOTOGRAPHY to be held February 4 through February 27.

Animal, plant, landscape and other nature photographs will be shown in the competitive exhibition, which is sponsored jointly by Chicago Natural History Museum and the Chicago Nature Camera Club.

More than one hundred prints in both black-and-white and color, and approximately 700 color transparencies will be exhibited. The color slides will be projected on two Sunday afternoons, February 13 and February 20, at 2:30 P.M. in the Museum's James Simpson Theatre.

mountain building II

by Bertram G. Woodland, Curator, Igneous and Metamorphic Petrology

After dealing with the types of mountains, and the tools of the geologist in dealing with theories of mountain building (see November, 1964, BULLETIN) in Part I, Dr. Woodland turns, in this article, to aspects of the general structure of the earth as they relate to mountain building. He examines the crust and the mantle of the earth, the topography of the ocean floor and the continental crust.

The Crust of the Earth

The field of study called *geophysics* has provided much information particularly about the deeper parts of the crust in orogenic belts and the way it differs from the present day stable platforms and oceanic crust. Thus, the study of earthquakes themselves is beginning to shed light on the nature of the movements in the crust which produce the quakes, while the geographical and depth distribution and periodicity of earthquakes throughout the world provides information on the relationship of unstable zones to crustal structures. The velocity of earthquake waves which varies with depth zones of the earth also enables us to infer conditions within the earth below the crust, data which must be consistent with any ideas of the mechanism and sources of energy for mountain building. Small explosive charges set off in the ocean or on land produce man-made seismic waves, which can be received and analyzed to give data on variations in crustal thickness and rock density. The base of the crust is now defined by a change in velocity of seismic waves; this is called the *Mohorovivic discontinuity* (Moho for short). The accumulation of information on variations of gravity in different parts of the world also adds to our understanding of the nature of the deep parts of the crusts and the region below the base of the crust, called the *mantle*.

Results from such investigations show that the thickness of the continental crust averages nearly 25 miles but increases to 35 miles or more under high mountain ranges. The crust is composed of granitic type rocks in its upper portion and somewhat denser, presumed basaltic types below, immediately above the Moho discontinuity. Oceanic crust, however, averages less than four miles in thickness, not including the water depth, and is essentially composed of material similar to the basaltic layer of the continental crust.

Measurement of variations in the magnetic field has also been rewarding in indicating crustal displacements on a large scale, for example, in the eastern Pacific floor. Another type of work based on the earth's magnetic field is the determination of the direction of magnetism which was sealed into the rocks at the time they were formed. It is believed that this provides information on the ancient magnetic fields (thus the name *Paleomagnetism*) and analyses of these are interpreted by some earth scientists as showing that the continents have not always been in the same position relative to the poles or even to one another. If such movements are accepted, it is necessary to integrate them into any theory of mountain building.

Gravity determinations are, thus, an important source of data about crustal structure. A concept which receives much support from these studies is the generally accepted theory of *isostasy*. Isostasy holds that the earth's crust acts as if it is in a floating equilibrium on a very viscous, but nevertheless yielding, substratum. It is thus analogous to an iceberg floating in the ocean—in general, the higher the land, the thicker the crust, and therefore the deeper the Moho discontinuity. That is, high mountains have deep roots and conversely the depressed crust of ocean basins is just a thin skin.

On the basis of isostasy it would be predicted that an area of the crust should sink if subjected to a substantial additional load, and rise again if relieved of that load. In a number of instances this seems actually to have been the case. Scandinavia and the Hudson's Bay region show evidence of a slow but persistent uplift during the last several thousand years. This is interpreted as recovery from the depressed levels caused when they were loaded with tremendously thick ice sheets during the Ice Age. In the Glacial Epoch also, a much larger lake existed on the site of Great Salt Lake. In the past 16,000 years it has gradually been reduced to its present size. In response to this decrease of load, there has been uplift of the crust to a maximum of over 200 feet, as can be seen in the warped elevated form of the old shoreline around the lake.

Gravity and seismic studies, however, indicate that a straight relationship of height of land to crustal thickness is oversimplified; lateral variations of density occur both within the crust and below the Moho, in the upper part of the mantle. Thus, areas of thin crust can stand relatively high, if their densities are abnormally low. To illustrate: a three-inch column of light balsa wood stands as high in the water as a six-inch column of heavier maple. Anomalous regions of thin crust are present in a large portion of the western United States, particularly west of the Colorado plateau, as well as along the mid-Atlantic undersea mountain range. Seismic wave studies indicate that the crust and the upper mantle have unusually low densities in these areas. These low densities have a direct bearing on the mountain building process.

The Oceanic Crust

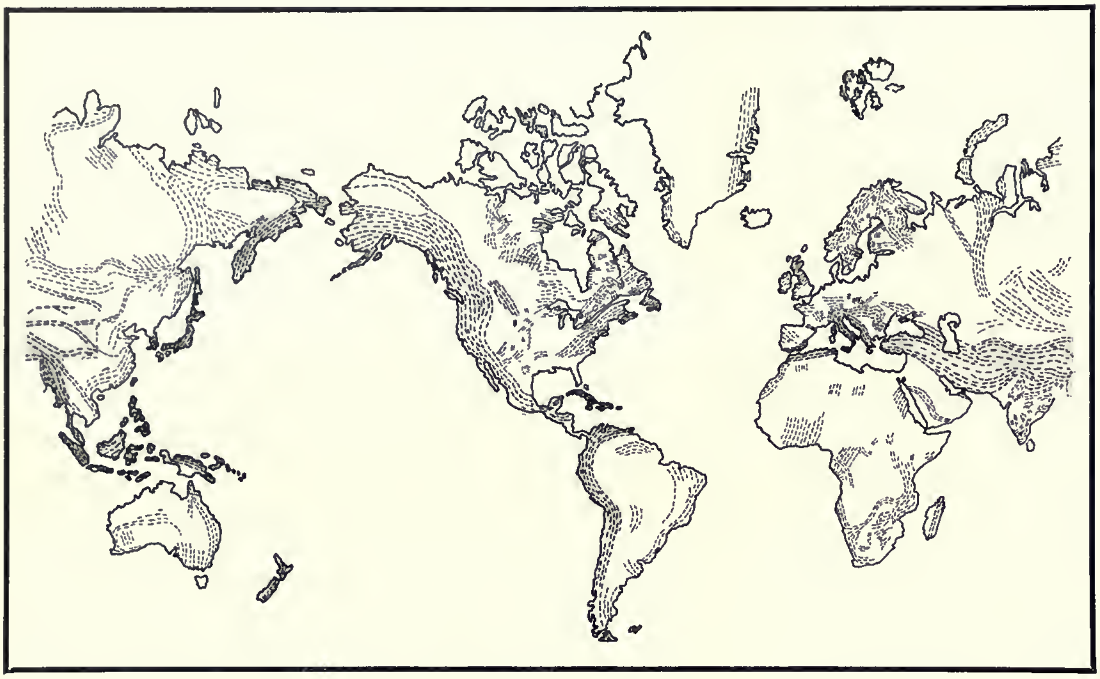
Within the last two decades our knowledge of the ocean basins has greatly expanded. The ocean floor is now known to have a very varied relief. Its major feature is a world-girdling system of mid-oceanic ridges that rise one to two and a half miles above the average ocean depth of three miles. These ridges vary in width from a few hundred to 2500 miles. In many places the summit zone has a median rift valley, sometimes 30 miles wide, along which earthquake shocks originate.

Iceland, which is noted for its active volcanoes, stands on the Mid-Atlantic ridge. A median rift passes through the island in the form of a down-faulted zone marked by active vertical fissures along which the crust is slowly being torn apart. Other volcanic islands, such as Tristan da Cunha, also rise from the ridge system. Along the crests of the ridges the flow of heat from inside the earth is well above the average for the rest of the ocean floors and continents. In many places the ridges are offset along transecting faults.

A rifted ridge in the Indian Ocean connects with the Red Sea rift and thence to the Zambesi River, via the great East African rift valleys. In the current view, these African rift valleys were produced as the result of tension which stretched and fractured the crust along existing faults. The resulting linear troughs formed by the sinking of crustal rocks show lower than average gravity values. (In the same way, the crustal rocks of the Arabian peninsula are believed to have separated from Africa to form the Red Sea; dense rock from the mantle welled up to form the sea floor which has higher than average gravity value.) Recent earthquake tremors originating along the rift valleys, and much active volcanism, indicate that these stresses continue today.

The East Pacific ridge runs into the Gulf of California and up into the line of the great San Andreas fault zone, reappearing off the northernmost coast of California. The 1906 San Francisco earthquake is a result of movement along the San Andreas Fault.

The Pacific Ocean has a number of other interesting features that concern us. It is more or less ringed with geologically young mountain systems, such as those on the west coast of the Americas, and also with an almost complete ring of active volcanoes, the circum-Pacific "ring of fire." Many of these volcanoes form islands arranged in arcs, such as the Aleutians, the Kuriles and the Marianas. Other volcanic arcs occur in Indonesia, which are a continuation of the young mountain ranges of Malaya, Burma and the Himalayas. The lavas and ashes emitted by these circum-Pacific volcanoes are characterized by an interesting type called andesite. The composition of andesite and its violent manner of eruption distinguish it from the basaltic lava emitted by the mid-Pacific volcanoes such as Hawaii. Associated with these island arcs and with the west coast of Central and South America are amazingly deep oceanic trenches, whose depth below sea level commonly exceeds the height of Everest. The deepest sounding ever made, over 36,000 feet, occurred in the Marianas Trench.



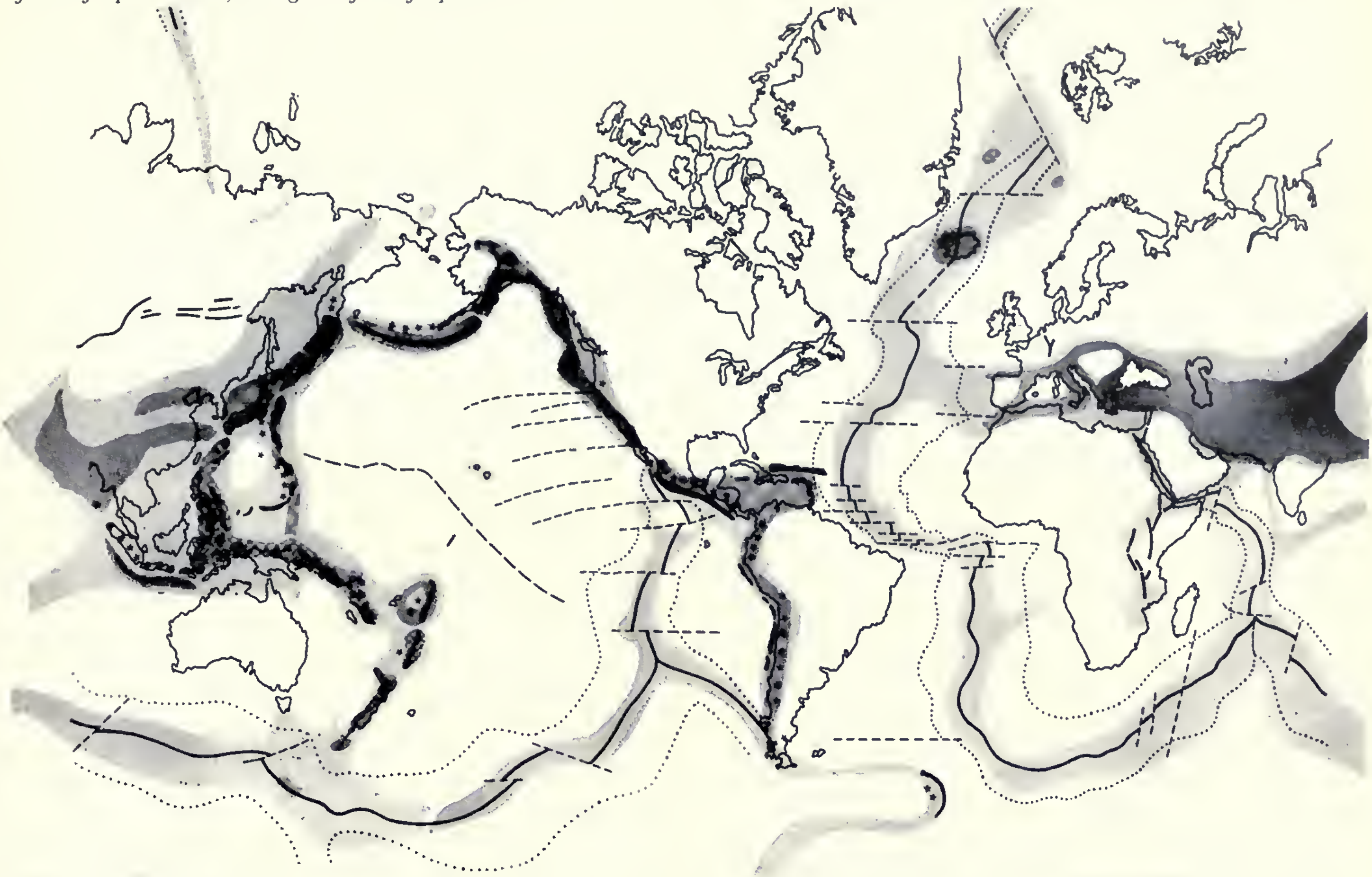
Structural trends of the rocks in orogenic belts. Blank areas include those where there is insufficient data and also where flat lying strata cover the deformed rocks of the crust, such as in Illinois. Greenland is nearly all under ice. The shaded areas are the young mountain ranges formed within the last 100 million years, mainly during the latter half of this period.

This circum-Pacific belt is by far the most seismically active area in the world. It is significant that earthquake shocks originate at different depths in various areas of this belt. Along the line of the trenches, they occur at shallow depths, down to about 40 miles. Beneath the volcanic islands they originate between 40 and 180 miles below the surface. Deeper quakes, some more than 430 miles down, occur on the continental side of the island arcs. Thus, there seems to be an active zone of slippage around the Pacific, which dips away from the ocean and under the continents.

It might be mentioned here that studies of circum-Pacific earthquakes have revealed a puzzling phenomenon. Analysis of waves generated by earthquakes suggests that the crustal movements responsible are preponderantly of the type where one block slides along a vertical fault in an essentially horizontal manner. This movement does not fit the structural and dynamic models favored by many people, which require relative vertical movement thrusting an upper block up and over a lower one along an inclined fault zone.

It is noteworthy that there is no trench off the west coast of the United States, the line of great volcanoes in the Cascade Mountains is inactive, and there is no inclined earthquake zone beneath the coast. The earthquakes of the American west are related to other features such as the San Andreas

● *Mid-ocean ridges (dotted) and median rifts (thick line).* ● *Dashed lines represent faulted offsets of ridges and fault scarps of the eastern Pacific.* ● *The thick, dashed line in the central Pacific is a subsided old ridge.* ● *Rift valleys are shown in east Africa, Siberia and Europe.* ● *Deep sea trenches are shown in solid black.* ● *Lines of stars are Volcanic arcs.* ● *Shaded areas are zones of earthquakes, the darker areas of more frequent shocks, the lighter of less frequent.*



fault, along which the movement of the crust is such as to move the area to the west of the fault in a northwesterly direction relative to the area to the east. All these features of the Pacific are in strong contrast to those of the Atlantic Ocean, whose surrounding coasts are not seismic, and have no festoons of volcanic islands, or rims of young mountains.

Another relatively recent discovery is that the ocean floors, particularly of the Pacific, are dotted with volcanoes which rise many thousands of feet above the ocean floor, only some breaking the surface to appear as volcanic islands or atolls. Many of these submerged volcanoes, or sea mounts, occur in linear trends with nearby volcanic islands and atolls, both active and extinct. When the ages of the individual volcanoes in a given chain are compared, they show a progressive increase in age in one direction; for example, the Hawaiian islands are older toward the northwest. This suggests that the magma source (responsible for the building of volcanoes) has migrated over the years. Because of the distribution of the linear chains relative to the mid-oceanic ridges, it has recently been suggested that it is not the magma source, but the crust itself which has migrated, carrying the volcanoes with it.

Many of the submerged volcanoes have flat tops which were formed by the planing off of the peaks by wave action. With the subsequent subsidence of the volcanoes, these flat-topped occurrences, called *guyots* are now submerged under 3,000 to 6,000 feet of water. Guyots emphasize that the ocean floors are not stable but have been subjected to considerable subsidence and uplift.

Formation of Continental Crust

Closely connected to the problem of mountain building are questions about the origin of continents and the permanence of oceans. Continental crust is characterized by the prevalence of low-density "granitic" type rock or *sial* as it is called. Originally it was thought that this formed when the earth passed through a molten stage much like the slag that floats on molten iron in a furnace. This may have occurred in the initial period of earth evolution or later, when an originally cold earth was warmed up as a result of internal reactions, including that produced by radioactive elements such as uranium.

Nowadays, it is generally held that the earth was never completely molten and that the crust evolved by chemical and gravitational differentiation from the mantle as the earth's internal temperature increased. However, there is disagreement about the time involved in producing the crust, and about whether the crust was formed over only certain parts of the earth's surface (the continents) or over the entire surface and subsequently concentrated into the present continents.

Some data have been interpreted as indicating that the bulk of the sial was differentiated very early in the earth's history, say at least by 3½ billion years ago, and that little has been added since. Other results suggest that the sial has grown throughout geologic time, primarily by welding of new material to the margins of the continents. Granitic type rocks have been produced in recent geologic times which appear to have been derived by differentiation from the mantle (or from basalt which originated in the mantle), thus supporting the idea of continuous growth. However, many other "granitic" type volcanic and intrusive rocks, particularly those associated with the orogenic belts, seem rather to have been derived by melting of pre-existing sial or at least by mixing of such a source with basalt from the mantle.

Assuming that the bulk of the sial was formed early in the earth's evolution, it has been claimed that it did so on the sites of the present continents as a result of inhomogeneities in the mantle; this implies that the oceans and continents have been permanently in their present position, the continents ever changing their shape and relief as a consequence of orogenesis and erosion and changes in sea level. Alternatively, the sial may have formed over the entire earth's surface. Then vast outpourings of basalt along weaker zones may have caused the foundering and oceanization of large areas, the sial being squeezed out laterally in the process and thickening the continents as the oceans grew in size. Concentration and thickening of the sial may also have been produced by the action of slow-moving currents in the mantle which would sweep the sial together into the zone or zones where the currents turn downward. Continued action of such currents is believed to cause continental drift.

Hypotheses that the continents have not always occupied the same positions relative to each other or to the poles have been put forward for many years with supporting evidence based on the distribution of fossils, on past climate indications (particularly glaciation in the Southern Hemisphere continents some 250 to 300 million years ago), and on the fit of the opposite Atlantic coasts. During recent years, studies of paleomagnetism in rocks have given strong support to the idea of drift. Drift, of course, is antagonistic to the idea of permanence of the oceans. It is worth noting that investigations of the ocean bottoms so far have revealed no sediments older than about 100 million years, which is a short part of the total earth's history, while the rocks of the mid-Atlantic ridge are also relatively young (the oldest tested to date is 20 million years old). We shall return later to the questions of continental drift, oceanization of continents and the opposite phenomenon, accretion of oceanic crust to the continents, which are all pertinent to mountain-building theories.

Folded Zones and Crustal Shortening

There are a number of controversies among geologists over the interpretation of geological evidence about the mechanism of the mountain-building process. Foremost among these is the question of *lateral compression*. The severe folding of originally horizontal beds of sediments in orogenic belts, commonly accompanied by recrystallization and development of new structures such as slate and schist, led to the idea that the forces responsible had acted in a more or less horizontal direction, producing a lateral compression. This resulted in the shortening and thickening of the section of the crust affected: the greater the folding and piling of folds or slices of rock on top of each other the greater the shortening. Arising out of such an interpretation, mechanisms to produce lateral compression have been sought. These ideas have dominated thought on orogenic processes for the last century as the complex nature of the linear folded belts became more and more known from geologic studies.

However, during the last 30 years the importance of *vertical movements* has again been stressed (they were prominent in geological writings over 150 years ago). There can be no doubt as to the reality of large vertical movements of parts of the crust. The accumulation of thousands of feet of sediment, the bottommost beds of which were laid down in shallow water as was the sequence to the very top, demands a considerable sinking of the area to accommodate the deposits which isostasy by itself cannot explain. For example, taking a basin with an initial water depth of 500 feet, filling it with sediment, and allowing for isostatic settling would permit only the accumulation of about 1200 feet. Sinking would then cease and the basin would be full of sediment to sea level. Likewise, the presence in surface rocks of metamorphic minerals that must have formed at high temperatures and pressures found only at considerable depths in the crust (e.g., 5 to 20 miles) indicates the extent of vertical uplift and erosion that has occurred. Of course, the proponents of lateral compression as the basic cause of orogenic structures recognize that considerable vertical movement is a necessity to explain the elevation of mountain ranges as well as many other geological phenomena. But the tendency is to regard uplift as a consequence of initial thickening of the crust followed by isostatic rise, which continues as erosion removes the load from the top. Implicit in this is the idea that the uplift mainly follows the folding and thickening of the crust. Geologists who consider that vertical movement is the primary deformation mechanism hold that folding and lateral compression structures are a resultant; in many cases they thus suggest that uplift precedes folding. We shall take up these aspects later and discuss how perhaps the two views can be reconciled.

Geosynclines and Oceanic Trenches

Yet another problem relating to the circum-Pacific region is the question of whether the deep ocean trenches associated with volcanic island arcs are modern examples of geosynclines in their early stages, that is, before being filled with sediment. There used to be strong opinion against their equivalence based particularly on the fact that the rocks of orogenic belts were regarded as having been essentially deposited in relatively shallow seas. The geosynclines would then be similar to areas of sedimentary deposition off the east coast of the United States and the area off the Gulf Coast where over 40,000 feet of mainly shallow water sediments have accumulated. (It is possible that the lower parts of the sedimentary

The author, Dr. Bertram G. Woodland, at work in the field. This photo shows Dr. Woodland collecting rock samples in central Vermont. He has traveled extensively in Great Britain, Norway, France, and the United States observing, and collecting samples for later interpretation. The dark diagonal lines in this photograph are an excellent illustration of folded rock strata.

column were deposited in water of oceanic depths.) However, in these areas there is no evidence of particular crustal unrest and volcanism is, of course, absent. Thus there is no sign that these areas are destined to be future orogenic zones, although they may.

On the other hand, there is some support for the opposite view. Deep sea deposits are known, for example, in the young mountains of Cuba and Timor (Indonesia). Although previously not thought possible, it is now believed that great thicknesses of alternating sandy and shaly rock types, characteristic of many complex mountain belts, may have been deposited in deep water; the sediments that formed them were released from unstable slopes near to land and were transported to greater depths in dense sediment-charged bottom currents called *turbidity currents.* So it is possible that the geosynclines which later gave rise to mountain systems were, at least at some stages in their history, deep-water troughs similar to the modern oceanic trenches. The modern trench, over 25,000 feet deep, just north of Puerto Rico contains an estimated 6,000 to 20,000 feet of sediment probably deposited by turbidity currents. Future uplift of the area could produce island structures much like Barbados, for example.

Considerations of Time

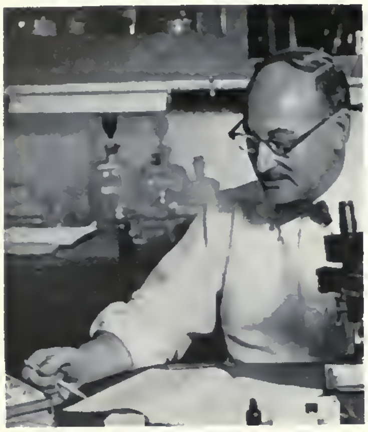
Before turning our attention to the various hypotheses of mountain-building mechanisms we must consider one last aspect—the important one of *time.* It was recognized many years ago that the processes involved in mountain building are very long, taking several hundreds of millions of years from the inception of a geosyncline to its final deformation and consolidation as a relatively quiescent part of a continent. But the paroxysmal orogenic phase was believed to occur over a few tens of millions of years near the end of the whole sequence of events and to occur more or less synchronously in a number of geosynclines in various parts of the earth's crust. Thus arose the idea of relatively short periods of widespread crustal unrest and mountain building; these periodic events were called *revolutions.*

Continued and more detailed study now shows that the history of even one geosyncline is more complex than previously believed and that the time span of deposition, volcanicity and deformation varied from place to place. Uplift and folding migrated in time, both along the geosyncline axis and at right angles to it. Orogenic movement was active over hundreds of millions of years and individual events were not world-wide. Events in one geosynclinal complex may even have overlapped in time those in another complex considered to belong to a different "revolution." In any one particular region, however, it is possible to make out a periodicity: deposition, volcanicity, folding, metamorphism, and uplift are repeated in adjacent zones which migrate in time.

When the crustal history is examined on a broader time scale (over the last 3½ billion years) a crude cyclical arrangement of activity seems to emerge. Ages of crystallization of mineral components of rocks (established by measurement of the time necessary for the breakdown of certain radioactive elements) are assumed to represent periods of metamorphic recrystallization and consolidation of molten material in the crust. These events are broadly interpreted as marking periods of orogenesis. Pertinently dated minerals from all the continents show ages which cluster in periods centered around 2,600, 2,100, 1,750, 1,400, 1,000, 500, 350, and 100 million years ago. These data have tended to revive the idea of a cyclical mechanism controlling the evolution of the crust. It has also been suggested that between the major periods of orogenesis a different type of activity can be discerned—the outpouring of great quantities of basaltic lava on the continents, possibly related to periods of tension in the crust.

This article will be continued in subsequent issues of the BULLETIN.

CHARLES HAMILTON SEEVERS
1907-1965



Prof. Charles Hamilton Seevers, Research Associate in the Division of Insects, Chicago Natural History Museum, and Chairman of the Department of Biology of Roosevelt University, died on December 12, following a brief illness. He was an internationally recognized authority on the classification, biology, and evolution of the Staphylinidae or rove beetles, whose more than 30,000 described species constitute one of the largest families of living things.

Prof. Seevers was born in Topeka, Kansas, April 19, 1907. He received his bachelor's degree in chemistry from Washburn College, Kansas, in 1928, and his doctorate in Zoology from the University of Chicago in 1932. He was an instructor at the Northwestern Missouri State Teachers College in 1933. In 1934, he was appointed Associate Professor, and later, Professor and Chairman of the Department of Zoology of Central Y.M.C.A. College, Chicago, where he remained until 1945. In that year he became Chairman of the Department of Biology of Roosevelt University, a school he helped establish.

Although he did his doctoral research in experimental embryology, he later turned to the study of the rove beetles that live with termites. One of his two major monographs, published by the Museum, deals with the classification and evolution of these species, the other with those that are guests of army and driver ants. A third large monograph, revising the classification of 200 North American genera of one subfamily, was brought to a conclusion shortly before his death.

In recognition of his outstanding research, he was appointed a Research Associate by Chicago Natural History Museum in 1943. He was later elected a Contributor, for his gift to the Museum of his valuable personal collection.

Prof. Seevers made several collecting trips to Mexico and one to Colombia. He also made two extended trips to Europe to study type-specimens, and on one of these he made an inventory of the Knirsch and Brancsik collections of beetles, which were later purchased by the Museum.

As a teacher, Prof. Seevers was outstanding. The lucidity and currency of his lectures in such diverse fields as embryology, genetics, parasitology, histology, and comparative anatomy will long be remembered by his thousands of students, many of them now doctors, dentists, and biologists.

Prof. Seevers is survived by his widow, Frances B. Seevers, Curator of the Biology Department at Roosevelt University, and by his only brother, Dr. Maurice H. Seevers, Chairman of the Department of Pharmacology at the University of Michigan Medical School.

New Grants to Anthropology

National Science Foundation has awarded the Department of Anthropology of the Museum two grants: (1) for the support of research entitled "Evolution of Social Organization in Prehistoric Arizona" for a period of two years; and (2) for support of an "Undergraduate Research Participation Program" for 1966. The latter grant will be used to provide increased opportunities for the scholarly development of eight outstanding undergraduates. Both grants will be under the direction of Dr. Paul S. Martin, Chief Curator Emeritus, Department of Anthropology.

The grant for archaeological research in Arizona is the fifth one to be awarded the Museum; and the grant for training undergraduate students is the second one.

Dr. Martin's undergraduate program, typical of a number of new Museum programs in education, acquaints prospective students in archaeology with theoretical and practical field work during the summer digs at the Museum's Field Station in Vernon, Arizona. The result, it is hoped, will be a clearer, more rounded view of archaeological anthropology for the undergraduate planning to make this field his life's work.

COVER: Mount Kangchenjunga on the Nepal-Sikkim border, the third highest mountain in the world (28,146 feet). This photograph was made from Darjeeling, India, some 50 miles away, by John Moyer of the Museum staff, while he was serving as a United States Consul in India.

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BULLETIN **CHICAGO NATURAL HISTORY MUSEUM**

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NSF Aids New Programs

MUSEUM TEACHING ARM PLANS SUMMER COURSES

The Raymond Foundation, one of the Museum's educational divisions, will offer this summer two six-week programs: a course in anthropology for high-ability high school students; and an institute in geology for elementary teachers and supervisors. Applications for both courses are now being accepted.

Supported by two recent grants from the National Science Foundation, the courses are representative of new Museum efforts to fill specific educational needs.

Training in anthropology is not offered in high schools of the Chicago area. The Museum course, which will be held from June 27 to August 5, will provide high school students with an intensive introduction to the study of man. It will explore the scope of anthropology, the evolution of man, and the rise of civilizations in both the Old and New Worlds. Lectures by outstanding authorities, seminars, workshops, and a week-long dig on a local archaeological site are planned to give the students a sound foundation in anthropology and an opportunity to test a possible career interest in the science.

Students from Chicago area public and private high schools who have completed the 10th or 11th grade by June are eligible. Selection will be based on academic achievement, recommendation of teachers, and personal interviews. Application forms are available by writing Miss Miram Wood, Chief of the Raymond Foundation, at the Museum.

The program is under the direction of Miss Wood; it was planned and will be conducted by Miss Harriet Smith and Miss Edith Fleming, lecturers in anthropology in the Raymond Foundation.

In recent years, geology has been introduced into many elementary schools. A good number of the grade school teachers, however, have had little or no training in the subject. To meet this need, the Museum is offering an institute in geology for elementary teachers and supervisors in Chicago and suburban public and private schools. The institute, which is under the direction of Mr. Ernest Roscoe, lecturer in geology in the Raymond Foundation, will run from June 27 to August 5.

The program will deal with the fundamental concepts and principles of physical and historical geology, with emphasis on the geology of the Chicago area, and will include work on mineral, rock and fossil identification, lectures and research work in the laboratory and library. Several full-day field trips are planned to enable the participants to study local geology first hand and to apply basic principles in the field. The field trips will be led by Mr. Harry Changnon, Curator of Exhibits, Department of Geology.

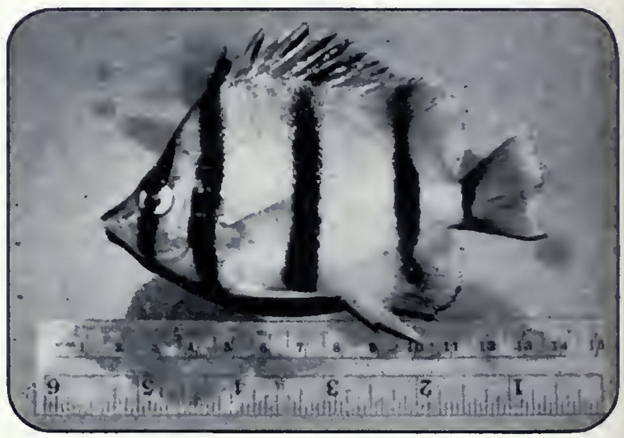
Applicants for the geology institute must have primary assignments to grades 4, 5 or 6 and a minimum of three years' teaching and/or supervisory experience. Those interested in the program may obtain applications by writing Mr. Roscoe.

March 31 is the deadline for applicants in the geology institute, March 25 for the anthropology course.

Slime eels—taken in trap at 4500 meters

Pinecone fish—named for its thick, spiny, bony scales

Examining gills of dolphin fish for parasites



Butterfly fish—an undescribed species from San Felix

A VOYAGE of the ANTON BRUUN

Loren Woods, Curator of Fishes, reports on a research trip

The waters from Panama to southern Chile, from the coast to the islands several hundred miles out at sea, are greatly in need of thorough biological exploration. Not that this region has been completely neglected. The *Beagle*, with Charles Darwin aboard, stopped in Chile and Peru and collected shore fishes in the 1830's. Ninety years ago the *Challenger*, equipped with trawls and dredges for bottom collecting, visited the Juan Fernandez Islands and fished the deep waters between these islands and mainland Chile. Several recent cruises have studied physical oceanography.

To this corner of the Pacific has come the *Anton Bruun*, the National Science Foundation research ship, formerly the presidential yacht *Williamsburg*. After two years exploring the Indian Ocean, the *Anton Bruun* is being used to carry on biological and oceanographic research in the southeastern Pacific. The scientific staff, as in the Indian Ocean Expedition (see BULLETIN, July 1964), is composed of scientists from many institutions and several countries. I participated in a cruise in November and December of last year; on board were scientists and students from Scripps Institution of Oceanography, University of California at Los Angeles, Cape Haze Marine Laboratory, Smithsonian Oceanographic Sorting Center and the Marine Institute of Peru.

The cool Peru Current, flowing northward just off the coasts of Chile and Peru until it is deflected westward to the Galapagos Islands, dominates the southeastern Pacific. The volume of water in the current, which is also called Humboldt Current, is not very great but there is considerable upwelling of colder deep water, which brings nutrient materials to the surface and produces a varied and abundant marine life. These favorable conditions have made possible the famous guano industries of Chile and Peru. More recently, by eliminating the middleman, and catching the fish before the birds do, the Peruvian fish fertilizer industry has become the largest in the world.

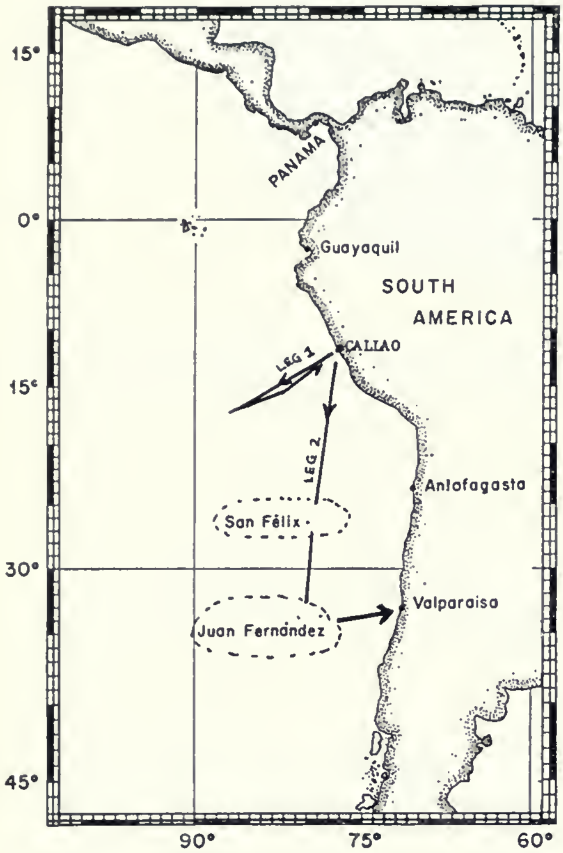
Along the western coast of South America, the continental shelf of shallow water is very narrow, and fifty to a hundred miles off the coast it plunges into the Peru–Chile Trench with its depths of more than 20,000 feet. West of the trench, off central Peru, is a great plateau 12,000–14,000 feet deep. To the south of the plateau are broken ranges of submerged mountains (Nazca Ridge). The valleys of these mountains are at 14,000 feet or so, but many of the peaks reach to within one or two thousand feet of the surface. Still further south four peaks actually break the surface, rising as enormous volcanic cones from the great depths to more than 6,500 feet above sea level. These are *San Ambrosio*, 1,570 feet high and *San Felix*, 630 feet high, 500 miles off the mainland, and the two Juan Fernandez Islands, *Mas a Tierra*, 3,040 feet, 350 miles off Chile and *Mas Afuera*, 6,562 feet, 430 miles out.

The objective of this particular cruise, one of a number the ship will make as the project goes on, was to collect specimens of plants and animals, particularly fish life, at all levels from tidepools to the deepest parts of the Peru–Chile trench, using different kinds of nets, traps, setlines and diving gear for the various levels.

At our starting port, Callao, Peru, there was a delay of two days because the deep set lines, air freighted from the States, had not arrived. We spent the time shore-collecting at San Lorenzo Island, about five miles off Callao Harbor.

Here were steep sandy beaches separated by rocky headlands. Collecting was difficult because the water was rough, murky, and cold (60°). The area was rich in kelp and other algae, and the rocks were covered by sea cucumbers and starfishes. Fishes were rather few in species but there were many blennies, sea basses, and demoiselles. Surprisingly, no sharks were seen or collected either here or anywhere else though we constantly watched for them and fished for them at night.

With the arrival of the deep set lines, we set out from Callao. The first ten days we fished with midwater trawls,



Route of the ANTON BRUUN

bottom trawls and deep set lines and traps on the continental shelf, across the Peru Trench and about 300 miles farther west over the oceanic plateau. The remaining time we worked southwest from Callao to San Felix Island and the Juan Fernandez Islands. At these islands fishes and invertebrates were collected with otter trawls, poison, handlines and a light at night. Midwater and bottom trawling continued in the deep waters east of Juan Fernandez. We ended the cruise at Valparaiso, Chile.

Deep ocean trawling, either in midwater or on the bottom is a time-consuming operation. The cable must be paid out and hauled back slowly. Bottom trawling was usually done during the day and midwater trawling at night. In the great depths it is always dark on the bottom. Anyway, the animals stay there regardless of the surface light. In midwaters the animals migrate toward the surface at night concentrating in a broad layer. Our objective was to put our net in, or at least through, this layer and sample the concentration. The net would be lowered about 5–600 feet at a time and dragged 15–30 minutes at each depth until it had gone down 6–10,000 feet. The net would then be hauled back to within 1,000–2,000 feet of the surface and the process repeated. Such a haul generally took from 8 o'clock at night until 4 or 5 the next morning.

A night's work produced from one to 5 gallons of specimens. There would be many kinds of jellyfishes and a variety of shrimps ranging from tiny transparent larvae to 6-inch-long bright red specimens. The fishes most often taken were lantern fishes, with rows of luminous spots along their sides; deep-bodied, silvery hatchet fishes; very slender, elongate snipe eels; and viper fish with slender, curved teeth as long as their jaws. Every haul brought something not caught before, often species we could not find in the literature, so they were identified only to family in our records.

The specimens were transferred from the net into deep trays and sorted, photographed and preserved immediately. Usually the ship was rolling and tossing so our problem was to get them swiftly and safely into covered containers before they were spilled over the deck.

While the all-night trawling operation was proceeding, the deep set line and trap were fishing on the bottom. This apparatus consisted of a weighted buoy and trap and a line with 50–100 baited hooks on leaders. This gear was put over early in the evening and would sink to the bottom and lie there all night. By next morning a 12-hour fuse would have burned through, releasing the weight and allowing the line and trap to rise to the surface. Then the buoy could be located on the radar screen. Since the buoys were only 10 feet above the water, radar didn't help much if the waves were higher than 10 feet, which was frequent, but we could usually sight the buoy since it was painted bright red. If there were any fishes floating on the hooks, the gathering birds showed us the location.

A standard set of hydrographic data was collected at each station where the nets were to be hauled. Water samples were collected at intervals to the bottom and temperatures noted. Each sample was chemically analyzed and the amount of plankton measured. This work was done by three ship staff technicians who also helped with handling of the fishing gear. The Peruvian scientists were particularly interested in surface plankton and so the ship was stopped every four hours wherever we cruised so a plankton sample could be collected.

When we reached San Felix Island, the emphasis was shifted to inshore collecting. San Felix is only 1½ miles long, and is very barren black cinder lava and weathered yellow sandy clay. Because of its distance from the mainland, 500 miles, and difficult anchorage, no fish collections had ever been made here. We spent several days collecting in the tidepools and open shallow sea-caves to depths of 110 feet, using scuba gear and poison. Fishes were abundant but, as at Callao, the variety was not great. While the diving party was off in small boats, the crew fished with handlines in the deeper waters of the anchorage.

Some diving was done at night to collect pine-cone fishes. This species was previously known from only one dried specimen, so several were kept alive in aquaria and observations made on their behavior. *(Continued on page 11)*

Spring Lecture Series

This year's Spring Lecture Series offers film studies on the people, the history, and the natural riches of many areas around the world. The nine films, all in color and all with personal commentary by well-known lecturers, are presented by the Museum as the 125th Series of Illustrated Free Lectures. They will be held in the James Simpson Theatre of Chicago Natural History Museum at 2:30 p.m. on successive Saturday afternoons from March 5 through April 30. Reserved seats for Museum members will be held until 2:25.

Paris

Arctic

Puerto Rico

March 5, **Paris**

Paris has for centuries enjoyed an aura of romance and fantasy. It holds charm for people of many interests, from *haute couture* to medieval history, from Left Bank bistros to the elegant *Table du Roy*. Veteran film maker Eric Pavel presents the storied city with authority and style, shows its complexity and variety, its seamy side as well as its grandeur.

March 12, **Mexico's California**

A beautifully photographed study of the flora and fauna of Lower California and the tropical islands along its shores. Laurel Reynolds and Mindy Willis, the film-makers, also present some of the historical landmarks of this part of Mexico, where ancient customs still flourish beside the ways of today.

March 19, **Tales of the Mid-Pacific**

The capture of a whale and its subsequent performance at Sea Life Park—tracking a 65-mile-wide whirlpool—a descent into a volcanic crater; these are some of the highlights of this Len Suttman film. He uses Hawaii, with its "crossroads" culture of east and west, as the base from which to explore life in the surrounding seas.

March 26, **Egypt—The Golden Land**

Animated maps, an innovation by Clifford J. Kamen, trace the route followed in his film. Starting at the mouth of the Nile, beautifully composed film sequences show the ancient and modern sights of Alexandria, Cairo, the Sahara, Luxor, Aswan, the Suez Canal, and Mount Sinai. Remarkable shots *inside* the Pyramids distinguish this movie.

April 2, **South Viet Nam**

Kenneth Armstrong presents in-depth observations on the people of Viet Nam. With the understanding gained in many months of reporting in Viet Namese cities, in rural areas, and in combat areas, he is able to show the bearing of history, custom and religion on the present struggle in this crucial area.

April 9, **Australia**

A real life study of the people "down under," and the relatively untouched natural wealth of their continent. Presented by Charles Forbes Taylor, longtime lecturer on platforms all over the world.

April 16, **High Arctic**

An intimate documentary on the life of the northernmost Eskimos, by noted explorer Lewis Cotlow. Shows how their survival in an almost Ice-Age environment depends on their ingenious use of the few natural resources available to them.

April 23, **Timeless Turkey**

Turkey in the sense of a bridge—between the East and the West, and between its historical-legendary past and its future of progress in agriculture, industry and education. Commentary by Arthur Dewey, experienced lecturer-film-maker.

April 30, **Puerto Rico**

Fran William Hall conducts a tour with the help of native Puerto Ricans; from the fern-tree forests to the residence of the lady-mayor of San Juan, from a steel band practice session to Pablo Casals in rehearsal, the island is presented through the eyes of its inhabitants.

Egypt

PRE-COLUMBIAN POTTERY FIGURES

THIS POTTERY FIGURE from the Nicoya Peninsula of Costa Rica was presented to the Museum as the gift of Raymond Wielgus Product Models, Inc. It stands nine inches high, is made of reddish-buff pottery painted with designs in red, black and gray and represents a female figure.

A polychrome style of pottery flourished for 1300 years on the northwest coast of Costa Rica in the province of Guanacaste, including the Nicoya Peninsula, and in adjacent Nicaragua. Recent archaeological work has distinguished three periods in Nicoya Polychrome pottery: early, dating from A.D. 200 to A.D. 800; middle, A.D. 800 to 1175; and late, from 1175 to 1560. This figurine falls in the style of Early Polychrome B and thus dates from A.D. 600 to 800. The development of the Early Polychrome style seems to have been influenced by the Classic Mayas. The nature of this relationship will not be understood until more is known about the archaeology of the area lying between northwestern Costa Rica and the eastern Maya frontier in Honduras and Salvador.

THE COLIMA STYLE of ceramic sculpture flourished on the west coast of Mexico from about 100 B.C. to A.D. 600. Colima-style figures are naturalistic, refined and elegant. They have highly burnished red, brown or black surfaces without textural or painted elaboration. The men and women have strong, tranquil faces and a peasant solidity.

This new acquisition shows a seated man holding a large pot on his lap. He is naked save for a breech cloth, ornaments on his upper arms, and a headdress consisting of a fillet around the head held by a strap under the chin. The hair is long and hangs down his back. This specimen, made of red pottery with incised design is 14½ inches high, and dates from about A.D. 600. It is the gift of Julian R. Goldsmith.

The Colima sculptors also depicted mammals, birds, reptiles, fish and shellfish. Their favorite animal was the dog, of which they made a great variety of hollow effigies. Dogs were raised by the ancient Mexicans both for food and sacrificial offerings. It is not clear whether the Colima clay dogs were placed in tombs as food offerings or to represent dogs sacrificed at the funerals to assist their masters in the difficult journey to the land of the dead.

Many other fine Colima pieces, including three dogs, are on display in Hall 8 (Indians of Mexico and Central America).

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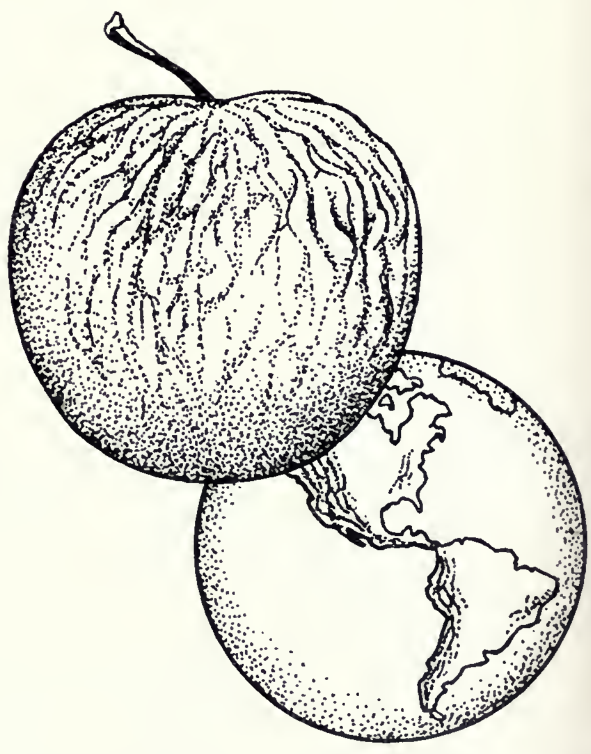
WHEN one considers various theories of mountain building that have been proposed, one discerns a fundamental problem:—is it necessary to consider all the major features of the earth now known and so to strive after one mechanism that fits them all? Or should one try to elaborate a process that appears to explain mountain building without conflicting with other features, thus leaving the explanation of these features to other processes? A similar dilemma concerns the source of the energy that drives the one or more mechanisms, although as will be noted at the end, the energy problem seems a little more circumscribed than the problem of the possible mechanisms of mountain building.

The Contraction Theory

The gradual accumulation of knowledge about the distribution of folded strata, particularly of the linear belts of com-



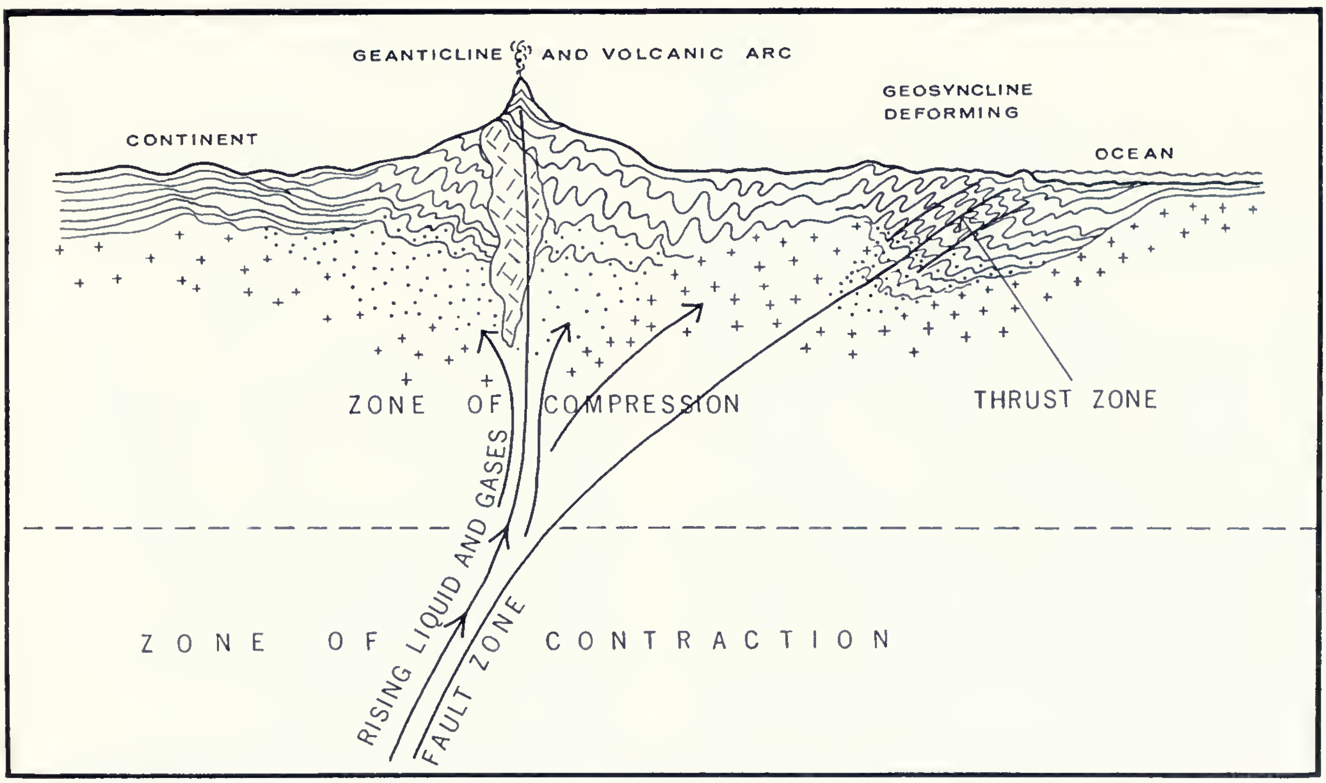
The wrinkled skin of a dried (shrunk) apple compares with mountain ranges (wrinkles) on a contracting earth.

by Bertram G. Woodland, Curator, Igneous and Metamorphic Petrology

untain building III

plex folds, led to the idea of horizontal compression in the crust as the operating force which caused the crumpling. A French geologist, Elie de Beaumont, in 1829 proposed that the compression originated through the contraction of the earth as it cooled. The hypothesis received much support about the turn of the century when it was recognized that in the Alps large slices of the earth's crust had been folded, dislocated, and thrust over others for distances up to tens of miles. Such overthrusting of masses thousands of feet thick was interpreted as proof of considerable crustal shortening by compression as a result of contraction. The fact that the folded zones occurred in restricted parts of the crust was explained by the crust's heterogeneity, certain sections behaving more plastically than the rest, which acted as rigid blocks. The geosynclines, in which large thicknesses of sediment accumulated prior to their conversion to folded mountain belts, were also believed to have formed as large crustal downbuckles produced by lateral compressive forces in the crust.

Contraction of the earth by cooling was an attractive idea as the earth was believed to have originated by condensation from hot nebular gases. It would have passed through a completely molten stage and on further cooling its mantle would have gradually solidified. An earthquake wave discontinuity at a depth of about 1,800 miles has been interpreted as the boundary between the solid mantle and the still liquid core of iron-nickel which is supposed to have settled inward under the influence of gravity. The crust formed as an early crystallized layer, likened to the slag floating on the iron in a blast furnace. The zone of cooling in the upper mantle is a region of contraction, while above this layer the already cooled crust and uppermost mantle are under compressional forces as they adjust to a smaller area.



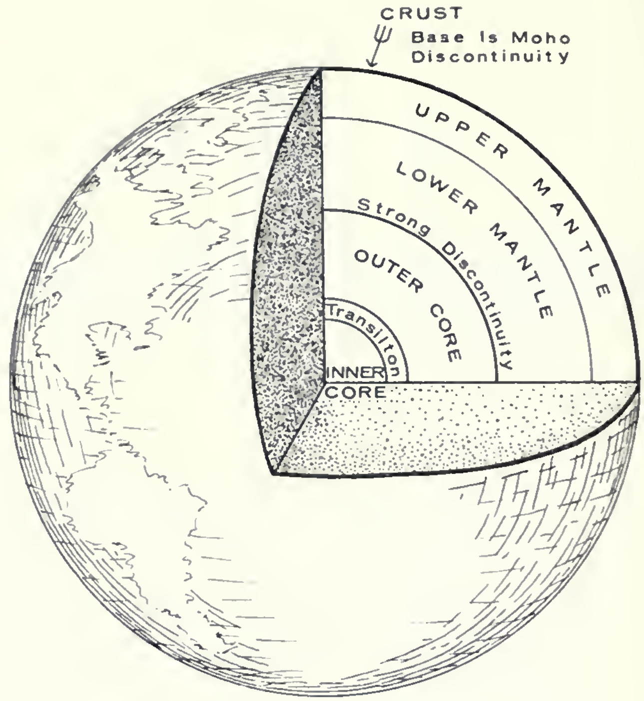
Vertical section of the crust and upper mantle at right angles to an orogenic belt according to the contraction theory.

One version of the mechanism of orogenesis suggests that the crust is pulled down to form a trough which becomes a geosyncline and is filled with sediment. Further compression of the crust leads to deformation of the thick deposits, metamorphism of the deep roots, production of magma and intrusion of granitic material; concomitant uplift is produced by the compressional thickening of the crust and isostatic response.

Another version attempts to relate the operation of the forces arising from contraction more directly to the large scale structures of the present active belts and their associated volcanic and seismic activity. Thus, continental margins with their thick load of sediment constitute a 'weak' zone which serves to focus rupture in both the contracting and the crustal compressional zones. Failure by faulting would take place along inclined planes which intersect the earth's surface as arcs. The inclined fault planes are equated with the inclined zones of earthquake origin which dip from the oceanic trenches toward and under the neighboring continents. Arcuate volcanic islands are formed by magma produced along the fault zone. The fault zone within the zone of compression is manifested by thrusting, which eventually affects the folded and altered sediments of the trough. Uplift of these transforms the trough into a geanticline, a new deep trough forms on the oceanward side, and the process is repeated.

There are a number of strong objections to the contraction theory. Today, the evolution of the earth from a hot gas cloud through a completely molten stage is not considered likely. Instead, it is believed the earth evolved by the agglomeration of many small cold bodies that formed in an orbit around the sun. The earth would gradually become heated, however, as a consequence of the great pressures developed internally and also from the energy released by the breakdown of radioactive elements. There is dispute about how much heat would be developed. Some hold that it would have been sufficient to largely melt the earth at an early stage and so aid the formation of the metallic core and sialic crust. Solidification of the mantle and further cooling would have ensued, allowing the application of the contraction hypothesis for mountain building as outlined above. Others consider that the rise in temperature has never been enough to bring about anything like complete melting and, further, that the earth may still be warming up rather than cooling. These different interpretations arise because, as yet, we do not have enough criteria on which to establish a generally acceptable set of calculations of the thermal history of the earth.

There are three modifications of the contraction theory that do not depend on cooling as the underlying cause. One suggests that the production of magma by partial melting of the upper mantle and its extrusion to the surface would result in contraction of the mantle. The contraction would provide the forces for mountain building as described. Additionally, the magma produced throughout geologic time would form the basaltic crust of the oceans and the sialic continental crust. The magma for the latter would originate at greater depths and be extruded at the margins of the continents (volcanic island arcs); the continents thus grow in size marginally. There is no evidence that volcanism is quantitatively adequate to produce contractional forces in the mantle



Section of the earth showing internal structure.

and, as mentioned earlier, calculations suggest it is also inadequate to explain continental accretion in the time available.

The other variants of the contraction theory postulate that the core of the earth has been increasing in size throughout the earth's history. Generally, it is considered that the core is composed of iron-nickel; this is in accord with the overall density of the earth and with the iron-nickel meteorites that are presumed to have formed deep within a now fragmented planet. In contrast to the mantle, the greater part of the core behaves as a liquid with respect to the transmission of seismic waves. (A smaller inner core with a radius of about 750 miles is believed to be solid.)

Some earth scientists believe the core has grown continuously by gravitative settling of iron after radioactive heating had warmed the mantle sufficiently to aid the process. The growth of the core would cause contraction because of increase in the volume of the denser material, but it would also release gravitational energy in the form of heat at the mantle-core boundary. The heat would raise the temperature of the mantle and cause thermal expansion and changes in mineralogical constitution to less dense forms. These would only partly offset the general contraction by core growth. If the effects were periodic, however, it may explain periods of greater heat flow and tension in the crust (produced by expansion in the mantle) alternating with periods of contraction. Additionally, the heat may cause circulation of matter in the mantle, but we will return to this aspect later. Ultimately, when the core reaches its maximum size, cooling would set in as a general condition.

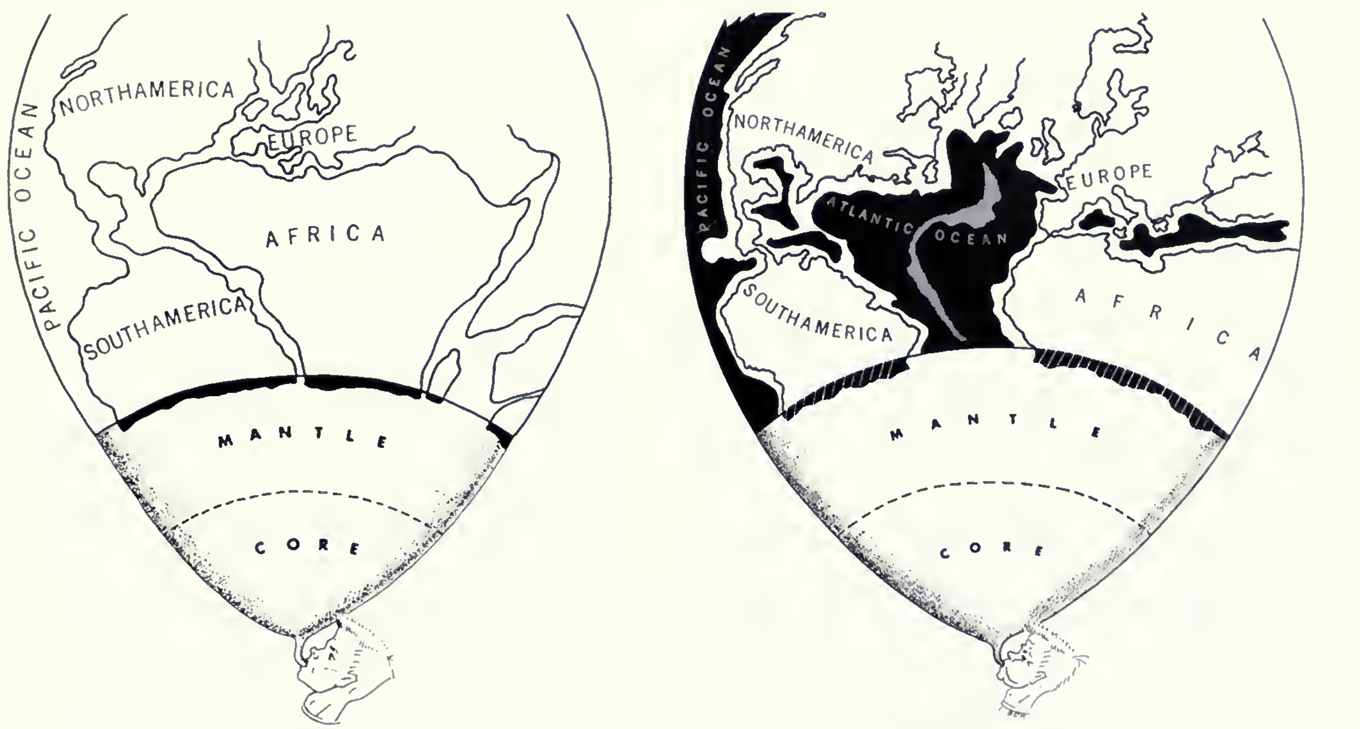
An alternative but highly controversial theory postulates core growth by an entirely different mechanism. Instead of being composed of iron-nickel, the core is considered to have the same chemical composition as the mantle but to be changed in physical state by the very high pressures and temperatures that exist deep in the earth. The minerals have broken down into simpler constituents and the atoms have been *ionized*, that is, electrons have been stripped off the outer shells that surround the atomic nucleii. The electrons are free to wander and the material is then in a metallic state (i.e., a good conductor of electricity). The breakdown of the crystalline state would mean also that the core behaves as a liquid. Thus, flow in this metallic-state core could equally well generate the earth's magnetic field as it would in a liquid iron-nickel core. Continuing increase in size of such a core would again lead to shrinkage of the earth's radius and also to release of gravitational energy as heat, with the attendant effects described above.

The major difficulties that have been placed in the way of the acceptance of any contraction hypothesis are the extensive system of mid-ocean ridges with their median rifts and transcurrent faults with evidence of large horizontal movements such as the San Andreas of California and the Alpine fault of South Island, New Zealand. The median rifts and their extension in the Red Sea and East African rift valleys imply major tensional forces pulling the crust apart. This is contrary to the state of compression which should reign in the crust if the earth is contracting. Likewise, it is difficult to explain large horizontal crustal shifts and also the movements and crustal tension deduced for many earthquakes of the circum-Pacific region if the crust is subject to compression.

However, it may be argued that there is another internal process to explain the crustal rifting, while orogenesis may still arise mainly through contraction, particularly if the two effects should operate more or less alternatively and periodically as noted above. Some geologists maintain that the earth is not contracting and is, in fact, expanding and that major earth structures can be better understood in an earth of gradually increasing radius. So we shall now turn to an examination of these ideas.

Expanding Earth Hypotheses

The concept of an expanding earth was first suggested about the turn of the century but has received more attention during the last ten years. It was put forward by some as an explanation of the theory of continental drift, i.e., the separation of the Americas from Europe and Africa was brought about by the expansion of the mantle and the rupturing of the crust and its separation to form the Atlantic Ocean. Carried to the extreme, some even advocate that the area of the present sialic crust (area of the continents plus the area of the surrounding seas down to an arbitrary depth) equals the area of the earth at the time when the crust was largely formed. This means the surface area was then a little under a third of what it is at present and the radius would have been only just over half of that of today's earth. The mantle and core would have expanded while the cooled thin sialic crust remained about the same in size; the crust was thus rent into pieces and dispersed into the pattern of the existing continents. The great system of median rifts along the mid-ocean ridges has been cited as evidence for expansion of the earth with the rifts representing the tearing apart of the crust and the development of new oceanic crust by extrusion of magma



Diagrammatic representation of an expanding earth; the continents are nearly coalesced at an early stage—LEFT, but have spread apart as the earth expanded—RIGHT. The continents remain essentially the same size but new oceans have formed.

from the mantle. Rifting of the continental crust would be marked by the African and Red Sea rifts, with the formation of a new ocean in the case of the latter.

Theoretical considerations of the evolution of the earth's interior have led some to postulate expansion. Thus, heat produced by decay of radioactive elements has been suggested as a source of thermal expansion; in general, calculations indicate, however, that this source is insufficient to explain any notable increase in volume. Another idea is that the earth's core is composed of matter in a very dense state and that this is unstable and changing slowly but continually into a less dense form. The volume increases, but in addition the energy released would cause thermal expansion and further mineralogic changes in the mantle. Contrary to this is the hypothesis of gradual core growth, during which the release of gravitational energy may suffice to cause enough expansion of the mantle to more than compensate for the contraction inherent in the increase of the dense core. Lastly, there is the very interesting postulate that the value of the universal gravitational constant is decreasing with time; this is related to the theory of the expanding universe. If gravity is decreasing, then the pressures within the earth are decreasing; this would cause expansion and also changes in the mineral structures to less dense forms and perhaps change of dense core material to less dense mantle material (assuming a non-iron core).

Geological data on the extent of the seas that have periodically inundated the continents during the last 600 million years have been interpreted as showing that the area of the incursions has steadily diminished to the present. This is taken to indicate earth expansion on the assumption that the continental sial area has remained much the same while the oceanic areas have increased.

Expansion has been utilized not only as the underlying force for continental drift but also for mountain building. The crust ruptures along the median rifts of the mid-oceanic ridges, and new crust is formed from the upper mantle. According to one view, deep sea trenches are formed by tension associated with deep mantle fractures (deep earthquake zones) which occur at the boundary of oceans and continents. Filling of the trenches produces geosynclines and hot volatile material, differentiated from the deep mantle, migrates up the fractures resulting in volcanism and melting of the deep crust and production of granite; increased temperature and deep burial cause metamorphism of the sediments. Compressional folding and thrusting are effected by the granite masses and by the increase in radius of the crust consequent on expansion, as well as possibly by crustal rotation arising from the development of new oceanic areas. Thus, the Pyrenees Mountains between France and Spain were supposed to have been formed by compression as the present North Coast of Spain separated from France forming the Bay of Biscay. Spain rotated southward around a pivot at the west end of the mountains and the region to the east of the pivot was compressed and folded forming the Pyrenees. Isostatic response to the thickened and granite-intruded crust causes emergence accompanied by sliding and folding of sediments from the uplifted mass. In these ways expansion forces are

Compression of mountain range during twisting movement of a crustal block during earth expansion and formation of the Bay of Biscay.

used to explain the process of mountain building and all the attendant phenomena which traditionally had been explained as caused by a regime of contraction in the earth. Previously we have seen that the contraction theories have problems, particularly in the existence of the world-wide oceanic ridge-rift system. How then can the expansion theories be assessed?

There is little concrete evidence available on which to base estimates of possible earth expansion independent of geological interpretations. Calculations based on the postulated decrease of the gravitational constant suggest that the earth may have increased its area by some 5.5 to 6% during its total history (this means an increase in radius of only 0.002 of an inch per year). Estimates of radius increase over the last 200 million years based on paleomagnetic measurements on rocks of that age from widely separated localities on the same continent are not yet good enough to be used with confidence; it is suggested, however, that they do indicate a slow increase of between about 0.01 and 0.07 of an inch per year, depending on the data used.

Another possible source of information depends on the earth's rotation. If the earth was smaller in the past, it would have rotated more rapidly and there would have been more days in the year. Study of the growth pattern of corals that lived some 350 to 400 million years ago indicates that there were then about 400 days in the year. Assuming that the increase in the length of day since then is entirely due to expansion, the earth's radius has been increasing at a rate of about 0.026 of an inch per year. Unfortunately, tides caused by the moon's and sun's gravitational fields also affect the speed of rotation, rendering it very difficult to disentangle the various effects. Calculations have been made that attempt to separate the lunar tide component, and these still support a very slow expansion, rather than contraction, of the earth.

Expansion on a scale large enough to explain the drift of continents and the production of the Atlantic and Indian Oceans during the last 200 million years (amounting to an increase of about 36% of the present surface area, or an increase in radius of 0.2 of an inch per year) is apparently unexplainable by any possible means. Slow expansion over 3½ to 4 billion years, assuming the present sialic crust area was once the total surface area and requiring an increase of 70% of the present surface area and of 0.03 of an inch per year in radius, remains a possibility on the basis of existing data. It is regarded as unlikely by some and certainly there is no evidence that the sial ever completely covered the earth.

The suggestion has also been made that the area of the mid-ocean ridges represents new crust formed during expansion. The ridges cover about 12% of the total area and, if this is averaged over the greater part of the earth's history, the necessary expansion (a radius increase of only 0.004 of an inch per year) is very reasonable. However, the data available about the ridges indicate that they are geologically young features. If it is assumed they developed during the last 200 million years, then the amount of expansion becomes excessive.

It thus seems possible that the earth may have slowly expanded, but probably not at the rate some theories demand. Other causes are needed to explain features such as mid-ocean ridges and complex mountain ranges. While crustal rifting may be plausibly explained by an expanding earth, it does not seem possible to explain the totality of effects which are involved in the development of an orogenic belt, particularly the early subsiding geosynclinal stage.

This article will be continued in a subsequent issue of the BULLETIN.

ANTON BRUUN *(continued from page 4)*

The deepest dive was along the base of the spectacular pinnacle pictured on page 3, named Peterborough Cathedral. The water was quite clear. The bottom consisted of huge rounded boulders piled together, black and bare or gray-green when covered with algae and encrusting invertebrates. Long-spined sea urchins were scattered everywhere on the rocks and not together in clumps as is so often the case on a coral reef. The largest fishes here were moray eels but there were also bright red scorpion fishes, a brilliant pink sea bass, and a beautiful yellow butterfly fish boldly marked with black transverse bands. Most of the fishes were red, green or black and had to be searched out in the crevices or under the kelps.

Mas a Tierra, the island of the Juan Fernandez Islands nearest the mainland, is strikingly different from San Felix. Mas a Tierra has 3,000-foot ridges, sufficiently high for clouds to gather. This produces abundant rainfall on at least part of the island so the valleys have trees and most of the slopes dark green shrubbery. There are also barren ridges where the soil is thin; even these usually have some grass. About 600 people, mostly Chilean fishermen, live in one village; their main occupation is tending spring-lobster traps. The lobsters are kept alive in floats and once a week a seaplane calls to carry them to the Chilean market.

The water around Mas a Tierra was several degrees colder than at San Felix. The pine-cone and butterfly fishes were absent but otherwise the varieties of fishes at these two isolated, widely-separated localities were very much alike.

Perhaps half of the species of shore fishes around these islands are the same as those found on the mainland. Most of the remainder appear to be endemic species. Some of these, such as the pine-cone fish and deep-bodied snipe-fish, have their nearest relatives in New Zealand, Southern Australia or South Africa. The nearest relative of the strange butterfly fish has not been determined, but certainly it is very different from any American species.

The specimens have been sent to the Smithsonian Sorting Center and to Scripps Institute of Oceanography where they will be sorted and labeled. Certain groups are to be sent to specialists for study and eventual publication. The remainder will be available in institutions like Chicago Natural History Museum, for study by staff, visitors and students. The *Anton Bruun*, returned to its labors, still criss-crosses the sea, gathering the evidence which will in the years to come contribute to a fuller portrait of the Pacific.

The Anton Bruun

FOUR TRUSTEES ELECTED TO MUSEUM BOARD

After a recent trustees' meeting, James L. Palmer, President of Chicago Natural History Museum, announced the election of four new trustees to the Museum's board. They are Harry O. Bercher, President of International Harvester Company, Paul W. Goodrich, President of Chicago Title and Trust Company, Remick McDowell, Chairman of The Peoples Gas Light and Coke Company, and E. Leland Webber, Director of Chicago Natural History Museum.

Mr. Bercher has been president and chief executive officer of International Harvester Company since 1962. He has been associated with the company for 37 years, having joined the firm immediately after his graduation from the University of Illinois. He serves on the boards of a number of civic and cultural organizations.

Harry O. Bercher

Paul W. Goodrich

Remick McDowell

E. Leland Webber

Mr. Goodrich, who has been president of Chicago Title and Trust since 1952, is a trustee of the Metropolitan Crusade of Mercy, Chicago Wesley Memorial Hospital, and Drake University. He is also vice president of the Chicago Central Area Committee.

Mr. McDowell, a graduate of the University of Chicago, joined Peoples Gas in 1940, and has been a corporate officer since 1942. He was elected chairman of the company in 1961. He is also a director of the Chicago Central Area Committee and chairman of the board of trustees of the Institute of Gas Technology, a research affiliate of the Illinois Institute of Technology, and chairman of its executive committee.

Mr. Webber graduated from the University of Cincinnati in 1942, joined the staff of the Museum in 1950, and was elected Director in 1962. He is a member of the Board of the Illinois State Museum, the Council of the American Association of Museums, and of the Board of Directors of the Y.M.C.A. Hotel of Chicago.

This month's cover is a photograph entitled "Tempting Food" taken by Mr. T. S. Lal, of Quilon, India and selected for showing in the 21st Chicago International Exhibition of Nature Photography, on view in Stanley Field Hall through February 27th. The south Indian fruit bat, about to land on its lunch, some small "finger" bananas, was photographed on an Indian farm. An examination of skull and teeth characters would be required for an accurate scientific identification of Mr. Lal's bat, since there are several similar species in India. The photograph does show, however, that it is a handsome animal—for a bat.

CHICAGO NATURAL HISTORY MUSEUM

Founded by Marshall Field, 1893

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BULLETIN

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