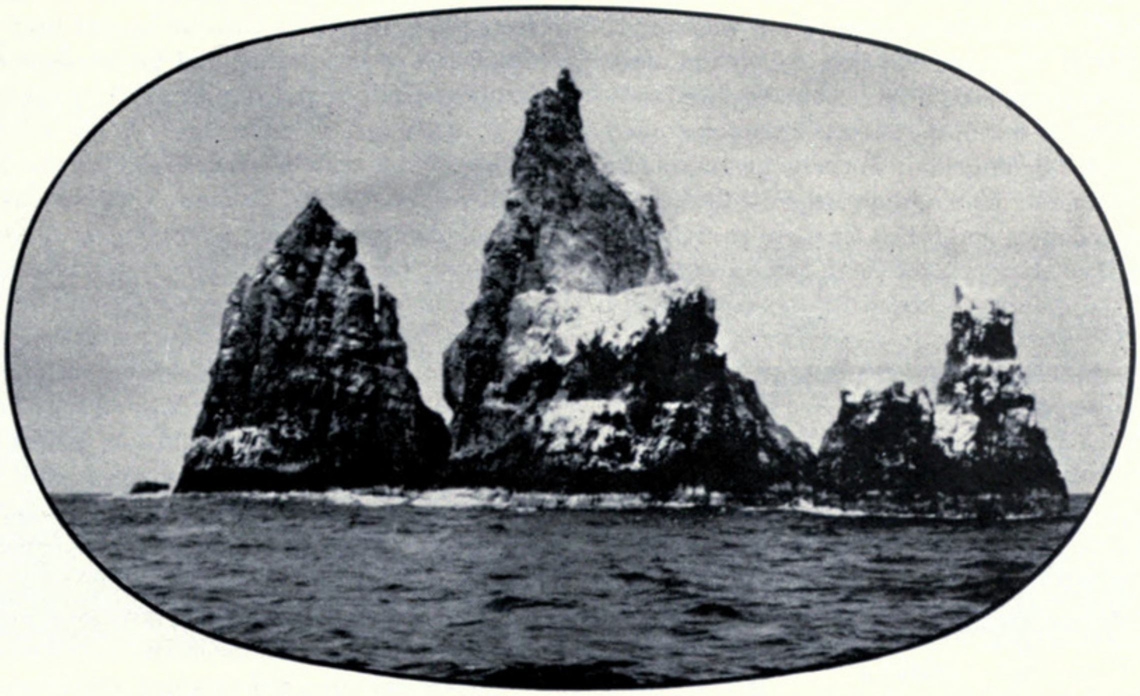


A VOYAGE of the ANTON BRUUN

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.

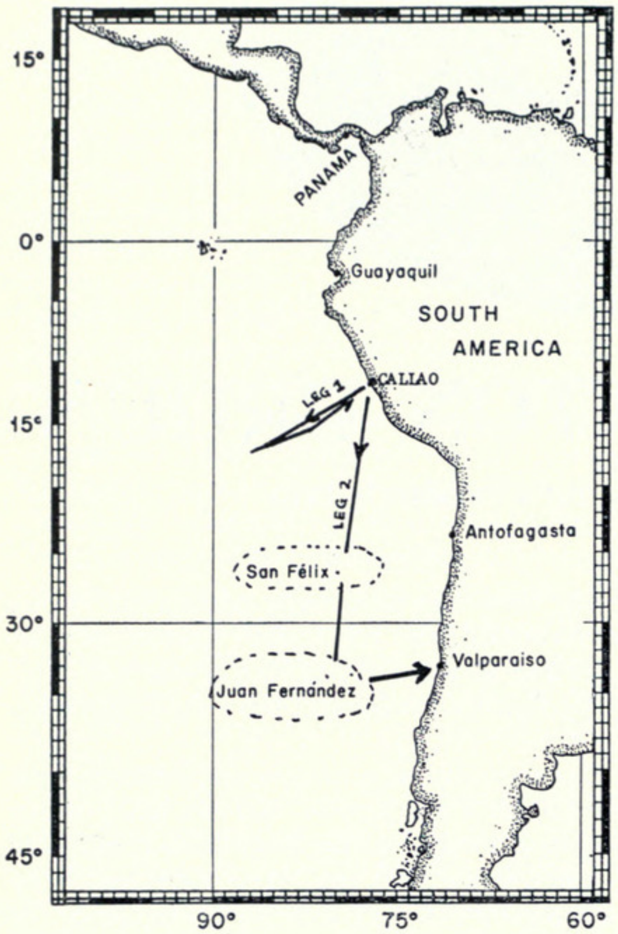
Along the western coast of South America, the continental shelf of shallow water is very narrow, and fifty to a hundred miles off the coast it plunges into the Peru–Chile Trench with its depths of more than 20,000 feet. West of the trench, off central Peru, is a great plateau 12,000–14,000 feet deep. 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

...recent acquisitions—anthropology...

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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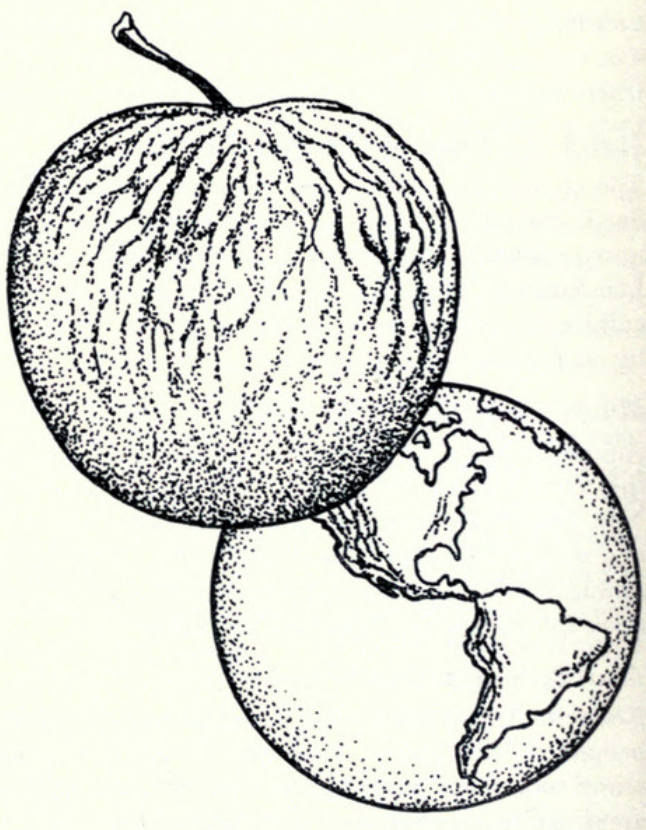
WHEN one considers various theories of mountain building that have been proposed, one discerns a fundamental problem:—is it necessary to consider all the major features of the earth now known and so to strive after one mechanism that fits them all? Or should one try to elaborate a process that appears 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-



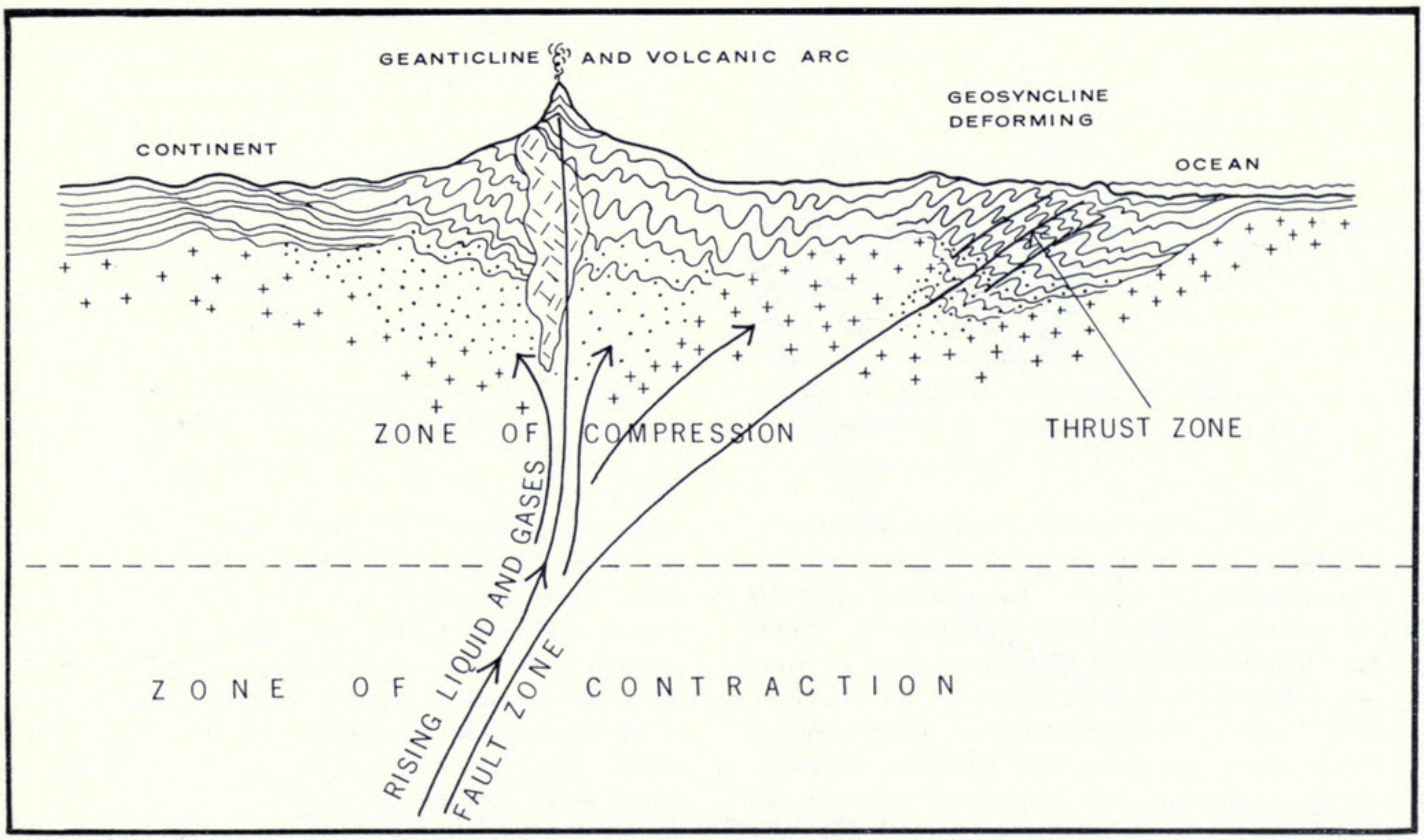
The wrinkled skin of a dried (shrunk) apple compares with mountain ranges (wrinkles) on a contracting earth.

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.



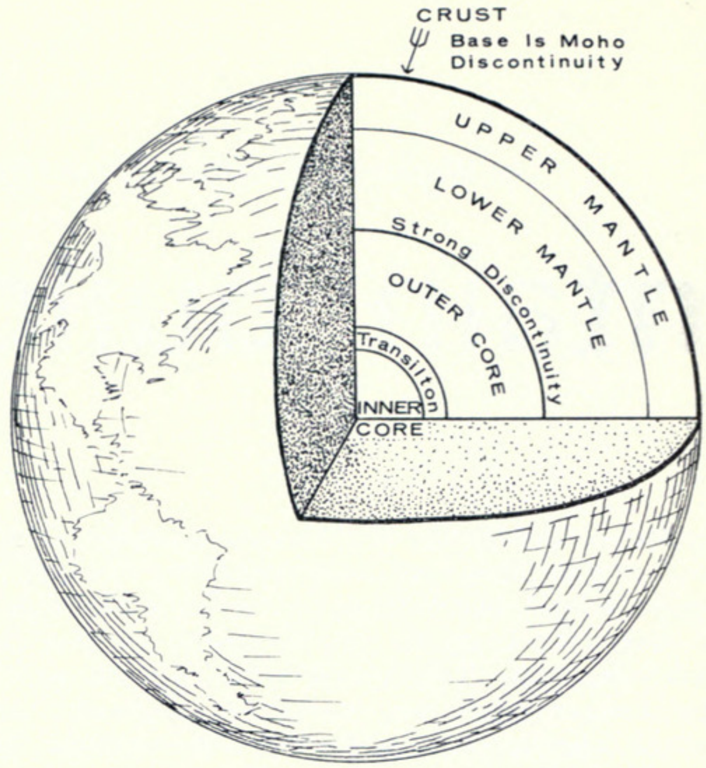
Vertical section of the crust and upper mantle at right angles to an orogenic belt according to the contraction theory.

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.

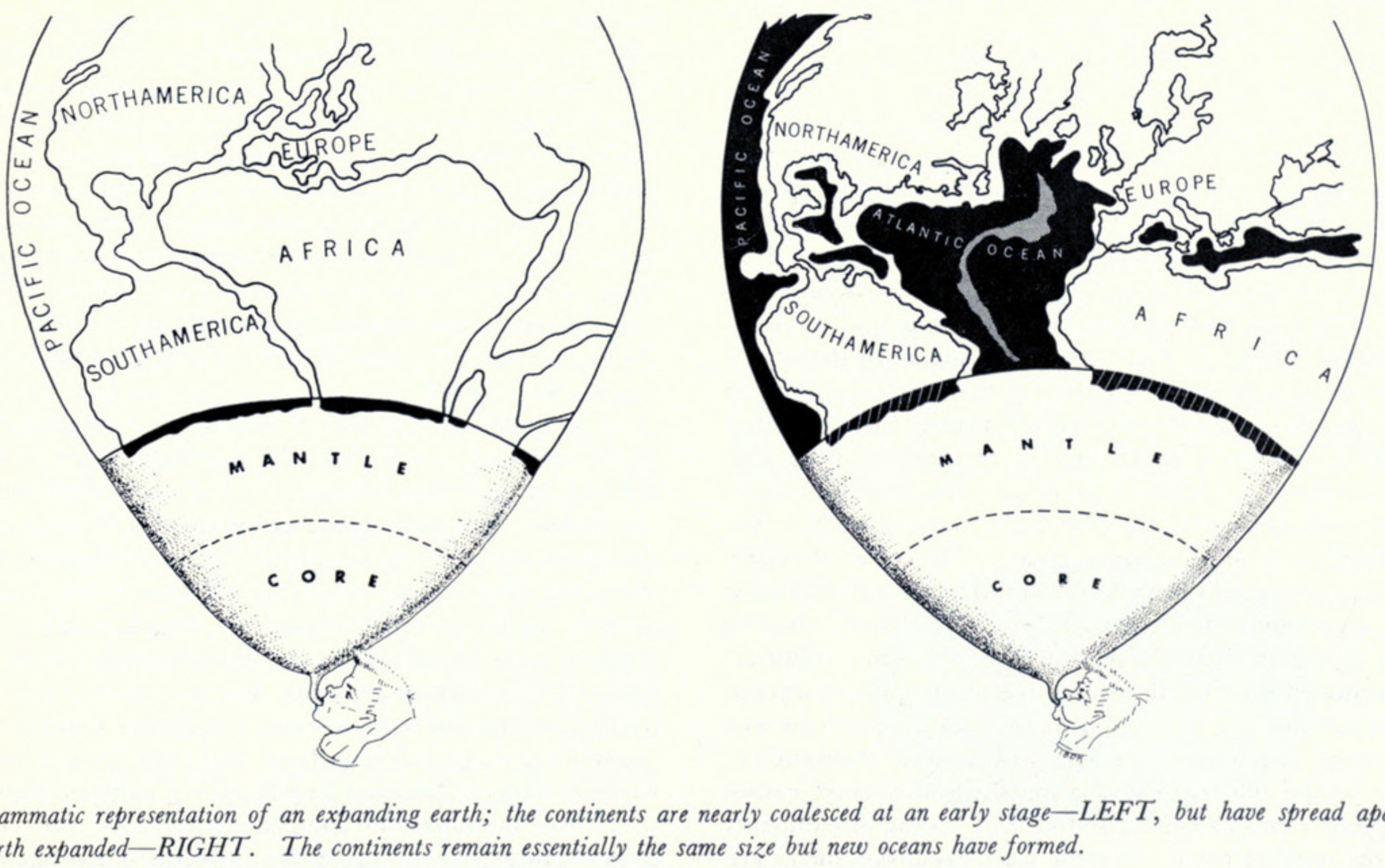
An alternative but highly controversial theory postulates core growth by an entirely different mechanism. Instead of being composed of iron-nickel, the core is considered to have the same chemical composition as the mantle but to be changed in physical state by the very high pressures and temperatures 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