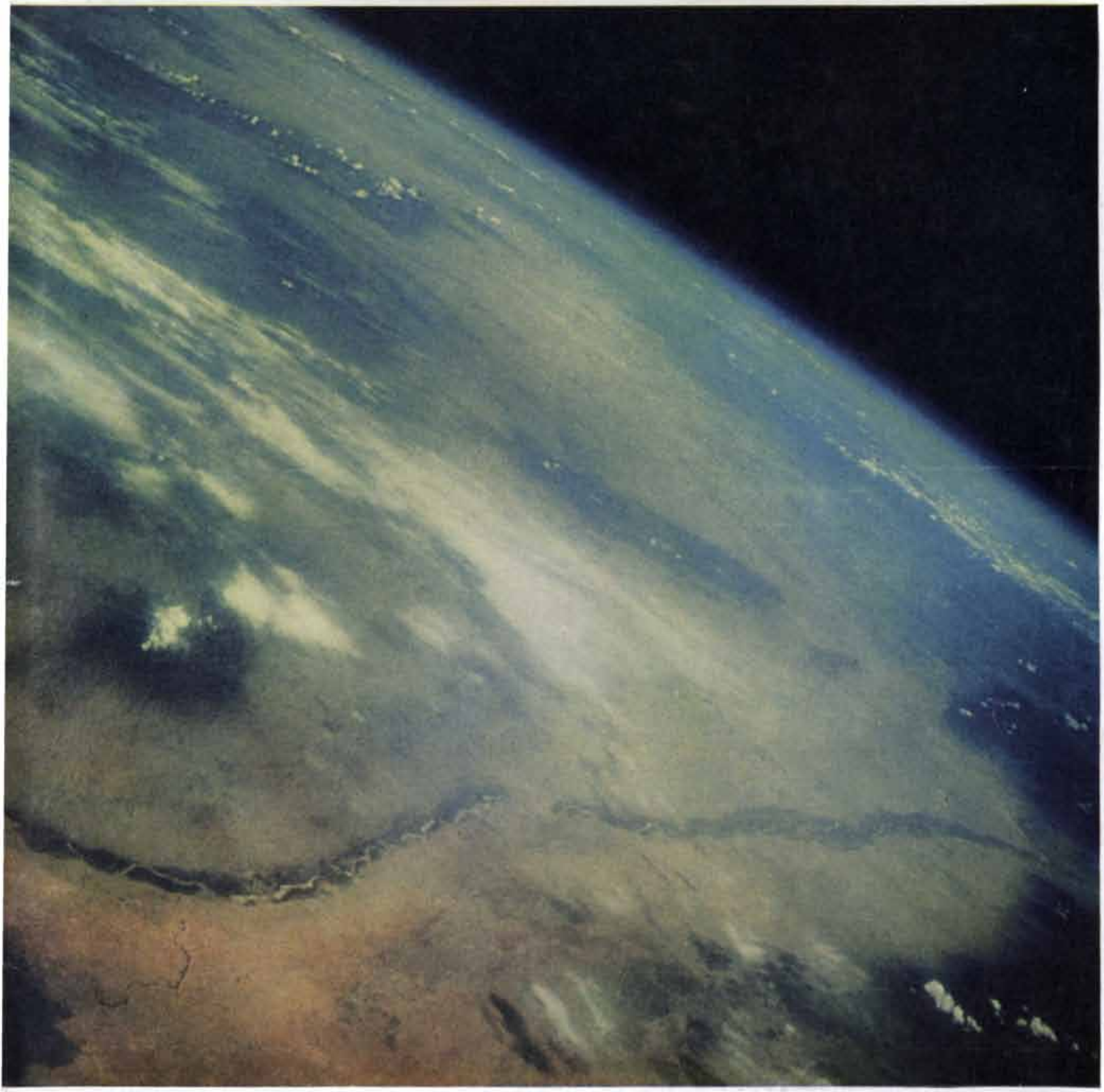
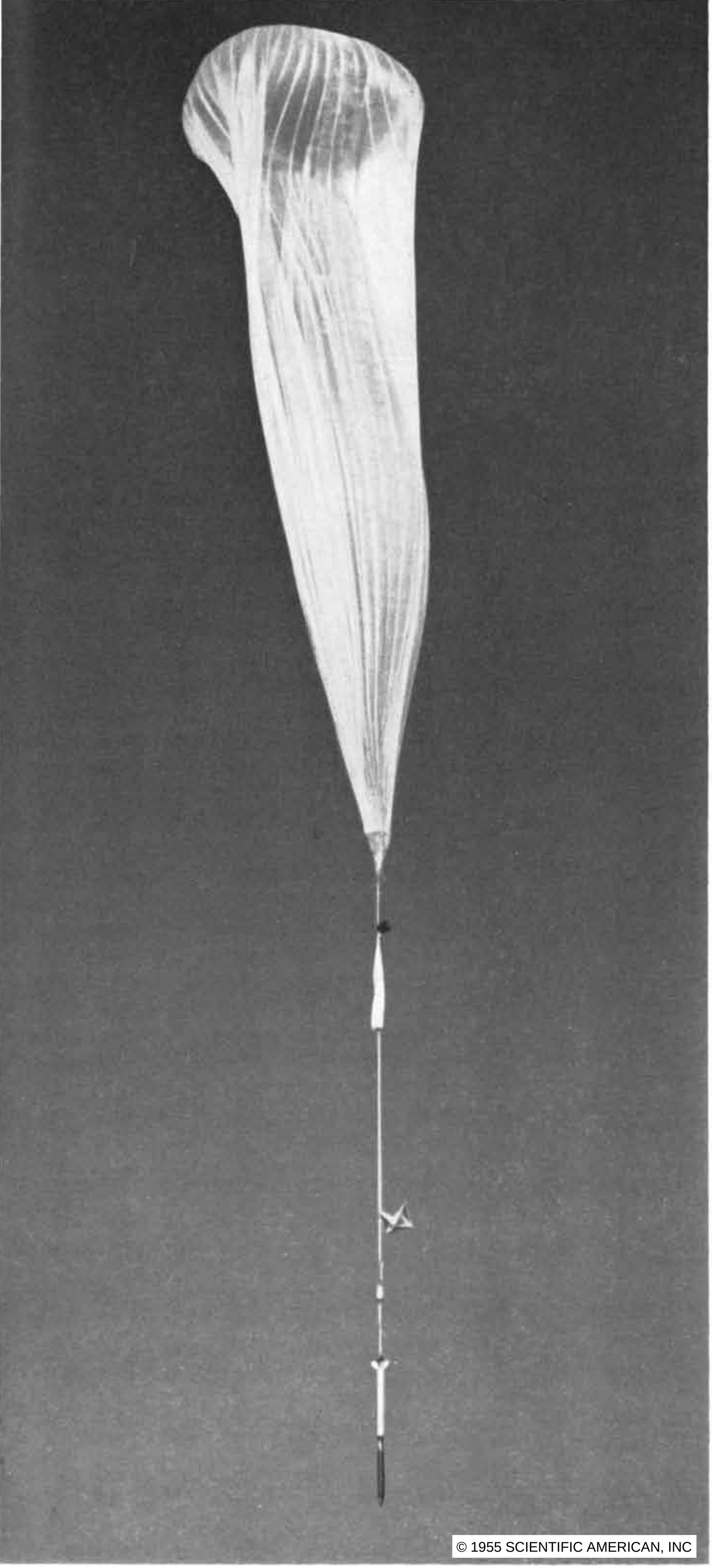
SCIENTIFIC AMERICAN



THE PLANET EARTH

FIFTY CENTS

September 1955



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General Mills builds, equips and flies balloons for upper-atmosphere study

The nation's most complete balloon facilities for collection of high-altitude data are yours at the Mechanical Division of General Mills. These polyethylene balloons carry more than 300 pounds of instruments to altitudes of 100,000 feet or more, maintaining stable altitudes for hours. This permits accurate continuous observation of the chemical and physical properties of upper air, magnetic field and cosmic ray data, motion of air, atmospheric electricity, visibility, airborne particles, and other valuable scientific data.

General Mills manufactures not only the balloons but also much of the instrumentation required, including telemetering and tracking equipment. Experienced crews are available, if you wish, to fly and track the balloons, record telemetered data, recover parachuted instruments, assemble and evaluate collected data.

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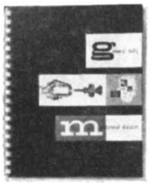
☐ Meteorological and high-altitude research ☐ automation ☐ bombing, navigation and missile control systems ☐ industrial instrumentation and control ☐ specialized precision instrumentation ☐ electro-mechanical computers ☐ remotely-controlled manipulators ☐ fine-particle technology.



FREE BOOKLET describes the complete facilities available to you at the Mechanical Division. For your copy, or help with any specific problem, write Dept. SA-1, Mechanical Division of General Mills, 1620 Central Ave., Minneapolis 13, Minn.

MECHANICAL DIVISION

OF General Mills, Inc.

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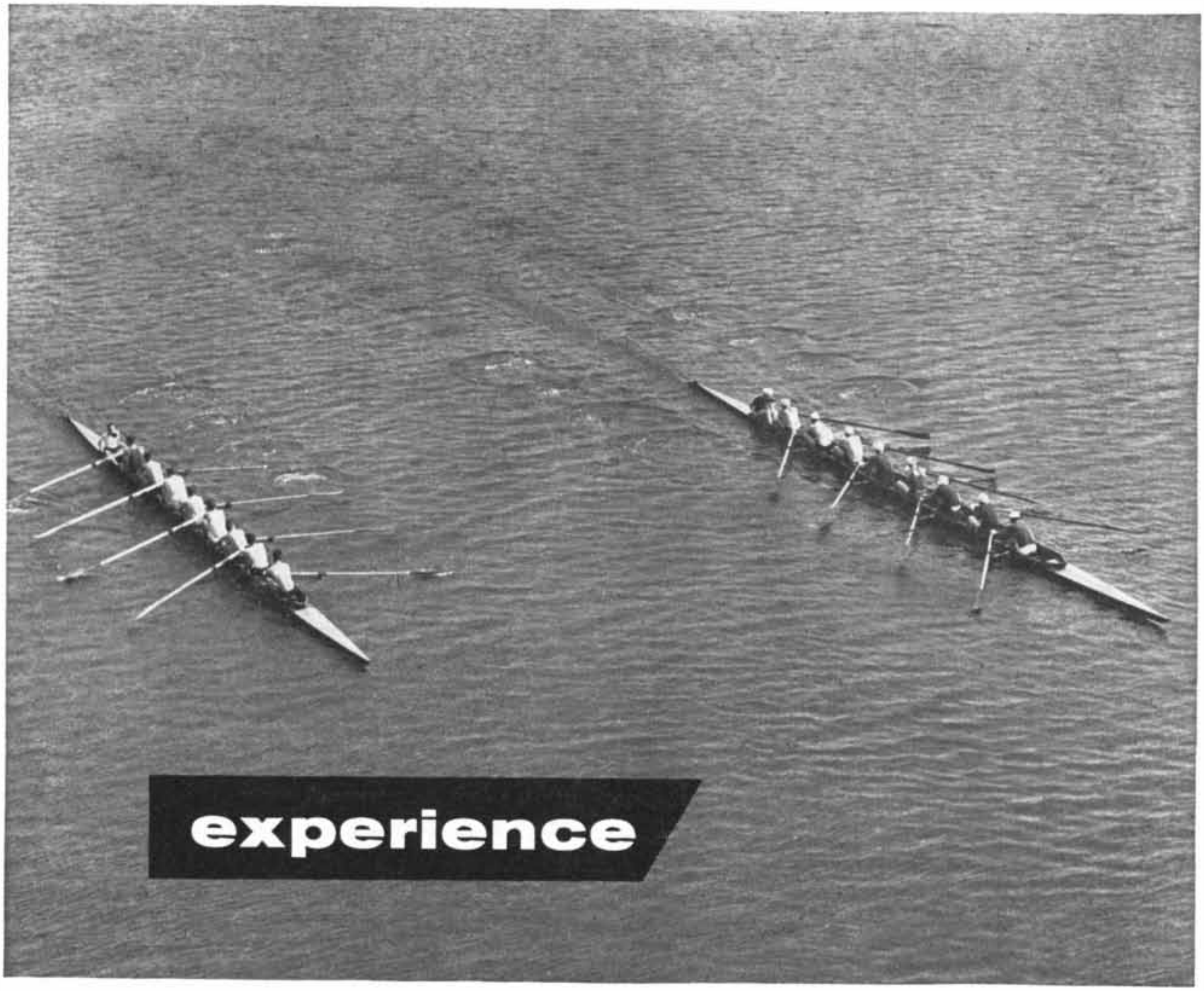
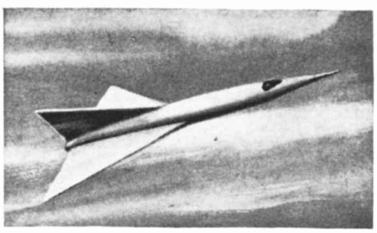
No. 3



plays a vital role in every success



Pressure actuated switches for every requirement from zero absolute to 12,000 psi. Meletron switches are used by every major manufacturer of aircraft in the United States.

Coxswains know what it takes to win crew races . . . precise coordination, sustained effort, timing. Victory goes to the crew that has mastered these arts through long, grueling experience.

At Meletron we have concentrated our efforts since 1938 on the improvement of one product—pressure actuated switches. To produce more than 1,000,000 switches requires considerable knowledge of their pressure sensing characteristics, knowledge acquired only through experience.

This experience has enabled us to build reliable precision instruments that perform better than customers' specifications.

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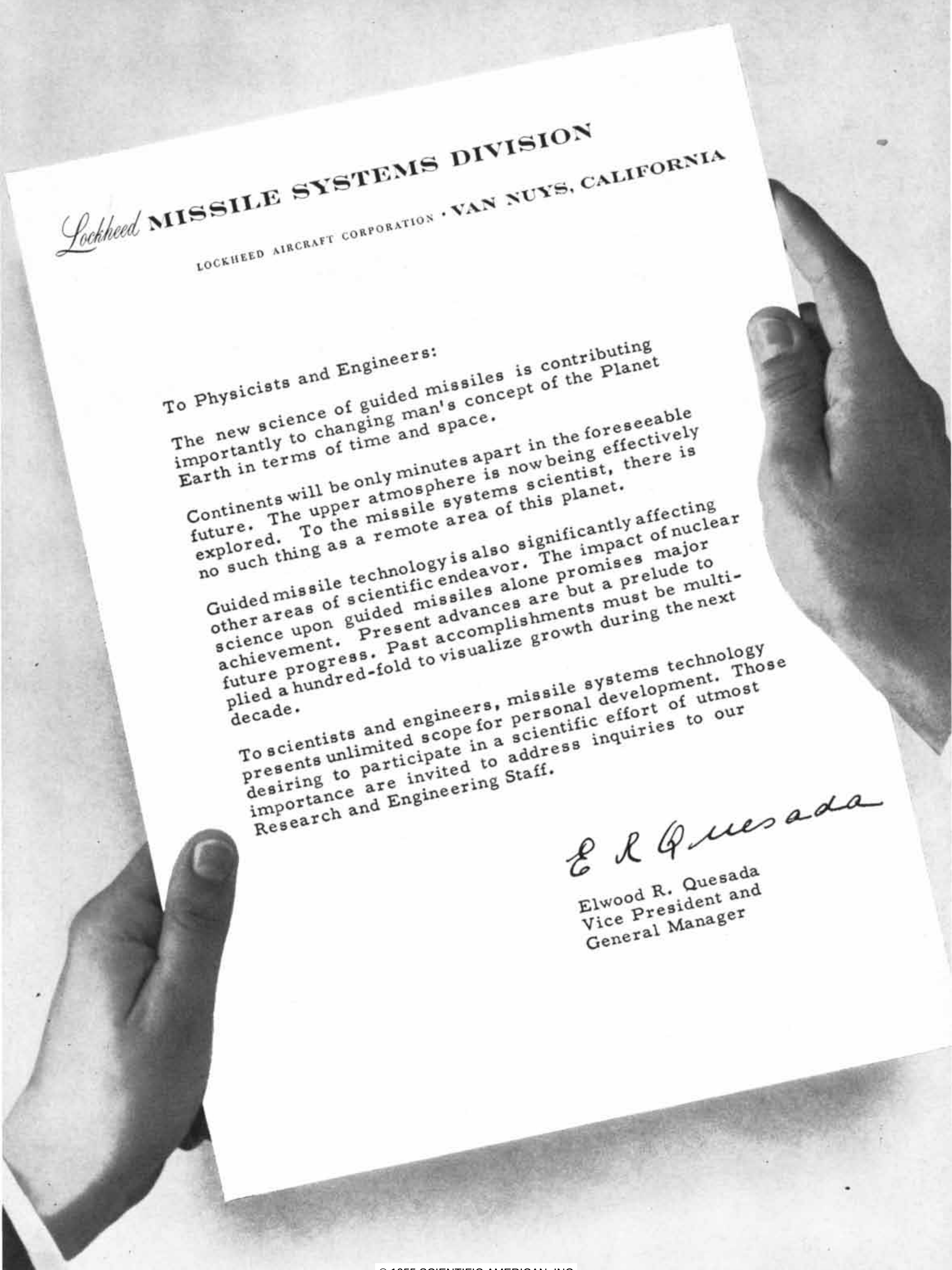


Lockheed MISSILE SYSTEMS DIVISION

LOCKHEED AIRCRAFT CORPORATION · VAN NUYS, CALIFORNIA

To Physicists and Engineers:

The new science of guided missiles is contributing importantly to changing man's concept of the Planet Earth in terms of time and space.

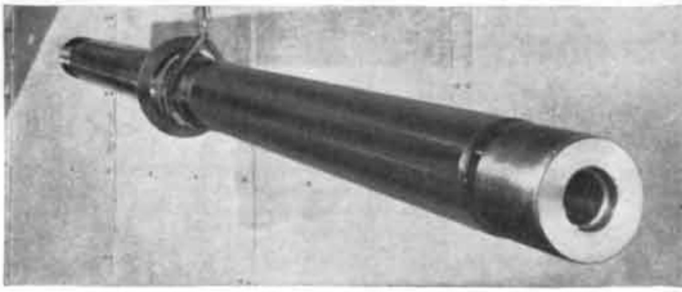
Continents will be only minutes apart in the foreseeable future. The upper atmosphere is now being effectively explored. To the missile systems scientist, there is no such thing as a remote area of this planet.

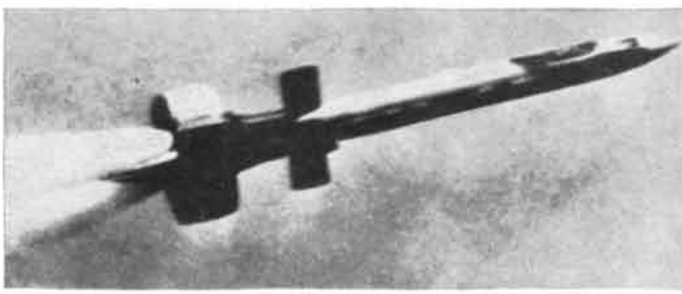
Guided missile technology is also significantly affecting other areas of scientific endeavor. The impact of nuclear science upon guided missiles alone promises major achievement. Present advances are but a prelude to future progress. Past accomplishments must be multiplied a hundred-fold to visualize growth during the next decade.

To scientists and engineers, missile systems technology presents unlimited scope for personal development. Those desiring to participate in a scientific effort of utmost importance are invited to address inquiries to our Research and Engineering Staff.

E R Quesada

Elwood R. Quesada
Vice President and
General Manager





"Our research department's big job is improving our own products and processes. This time, we've come up with something other businesses can use, too.

"We've developed a new process—a way to commercially apply a uniform coating of virtually non-porous nickel-phosphorus to many metallic and non-metallic materials—without the use of electricity. General American calls this the KANIGEN* process. Here are some of the things Kanigen can do for you.

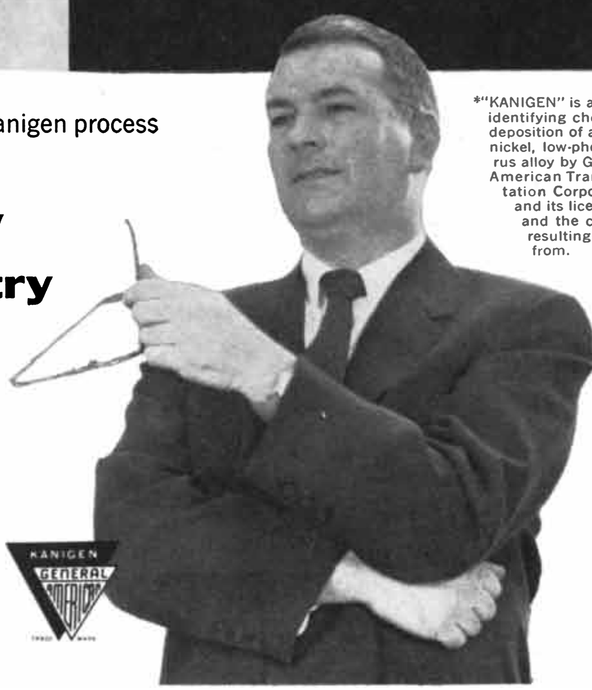
"You can coat aluminum directly for hardness, wear resistance, corrosion resistance and solderability. Light aluminum can replace heavy metal—important to electronics manufacturers and aircraft parts suppliers.

"Often, you can coat low-cost metals with a dense, corrosion-resistant material of nickel-phosphorus having a service life comparable with that offered by costly solid or clad materials.

"There is nothing like KANIGEN. Metallurgically unique—not just a substitute for electroplate—it has many unexplored uses. It is available only from General American and our licensees."

a General American engineer discusses the Kanigen process

"we found a brand-new material for industry in our search for corrosion resistance"



*"KANIGEN" is a mark identifying chemical deposition of a high-nickel, low-phosphorus alloy by General American Transportation Corporation and its licensees, and the coating resulting therefrom.

It pays to plan with General American

KANIGEN DIVISION

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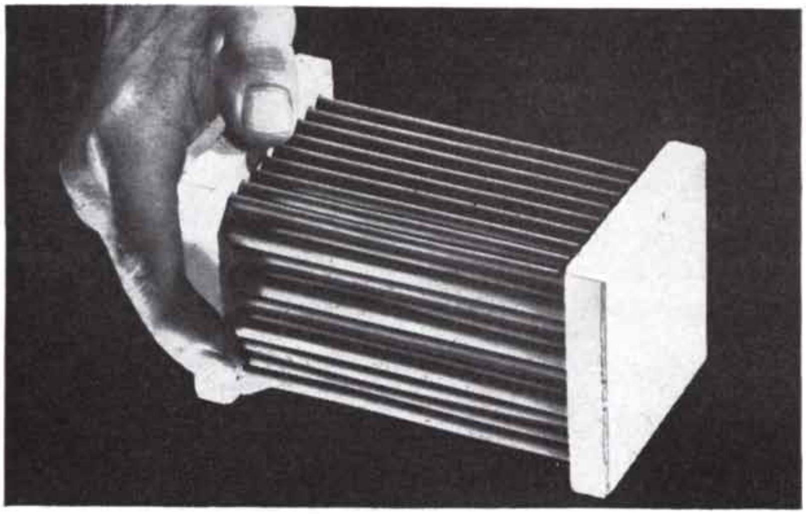
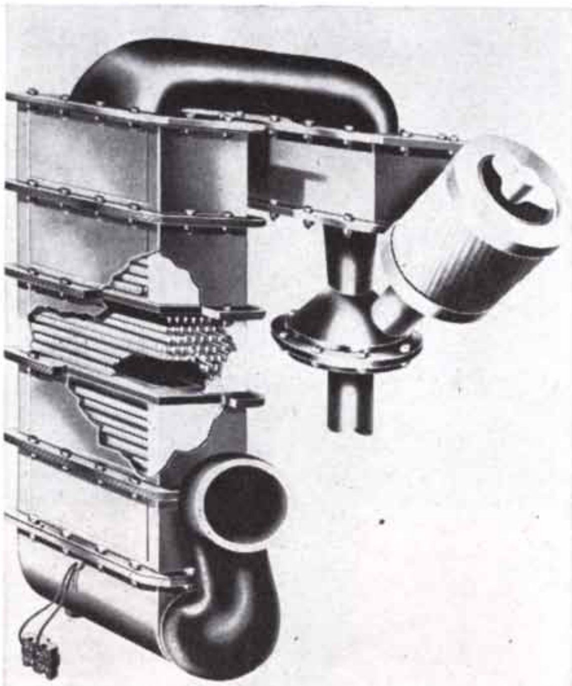
KANIGEN GENERAL AMERICAN



This new combustion catalyst, the oxycat, controls air pollution and creates energy and power by recovering waste heat. Porcelain rods (by Frenchtown Porcelain Company, Frenchtown, N.J.) are largely made of ALCOA Alumina to provide high resistance to thermal and mechanical shock. Rods are coated with a catalytic agent of ALCOA Activated Alumina and platinum.

In typical installations, oxycats are mounted in exhaust stacks of furnaces, drying ovens, incinerators, or any industrial processes where combustible gases are exhausted. Waste gases flow across rods. Combustion occurs at catalytic surface. Heat released by this exothermic reaction can be returned to the oven, converted to steam or used in other processes. Catalyst removes practically 100% of pollutants from gas streams.



Oxy-Catalyst catalytic exhaust, working on the same principle, ends dangerous exhaust fumes and odors from internal combustion engines. Made to take the place of standard mufflers, OCM is easily installed in gasoline, diesel or LPG-powered equipment.

Now ALCOA ALUMINA turns exhaust gases into energy instead of smog

Oxy-Catalyst, Inc. of Wayne, Pa., has put Alcoa Alumina to work eliminating air pollution and inefficient combustion, all in one operation.

In their new oxycat and OCM exhausts, Alcoa Alumina is part of the porcelain rods and catalytic coating. Used in the porcelain because it is highly inert and chemically stable, Alcoa Alumina does not interfere with the chemical reaction of the catalyst. In the coating, Alcoa® Activated Alumina provides extremely active oxidation maintained over a wide range of temperatures. It is very resistant to poisoning and highly efficient over a long period of time.

Alcoa Aluminas are remarkably versatile wherever they are used . . . with hundreds of applications in catalysis, desiccation, refractories and ceramics. Put Alcoa Aluminas to work *for you.* Write for samples of alumina to Aluminum Company of America, Chemicals Division, 706-J Alcoa Building, Mellon Square, Pittsburgh 19, Pennsylvania.

ALCOA CHEMICALS
ALUMINUM COMPANY OF AMERICA

A PRIMER ON GAS TURBINES

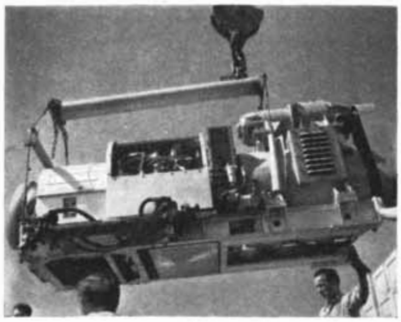
Facts about exciting new power plants for military and industrial applications

GAS TURBINE ENGINES today are writing one of the most significant chapters in the continuing history of prime movers. Alert leaders in industry, government and the professions are closely following gas turbine progress. Solar is proud of its proven accomplishments—and plans for the future—in this important field.

MAJOR ADVANTAGES are offered by small gas turbines. They are extremely light and compact. They permit smaller space envelopes and easy transportation, so important in such applications as portable fire pumps and airborne generator sets (photo below). Gas turbines are simple and rugged, with low maintenance cost. They need no cooling system and will operate on a variety of fuels. Low initial costs are anticipated, when gas turbines reach volume production.

SOLAR HAS PIONEERED in the small gas turbine field. Research began ten years ago and continuous design, development and production activities have been carried on.

Mars unit for C-121C Super Constellation



Jupiter shipboard generator

SOLAR ACHIEVEMENTS in the small gas turbine field are many. They include the world's first portable, hand-started gas turbine power plant, designed for use in a Navy shipboard fire pump. Solar built the first gas turbine unit installed on an American naval ship. Three major aircraft companies—Douglas, Lockheed, and Convair—have ordered Solar gas turbine airborne generator sets for important production aircraft.

TWO BASIC TURBINES are being built by Solar. One is the 50 hp "Mars®," shown in next column. The other is the 500 hp "Jupiter," pictured above in a Navy generator version.

THE MARS, smaller than a two-foot-cube, has a remarkable power-to-size ratio. The engine is sturdy and dependable. Its shaft turns at 40,000 rpm—about 20 times the speed of the average automobile engine.

THE JUPITER weighs less than 900 lb installed—less than one-fourth the weight of a comparable diesel engine! Both constant speed and variable speed Jupiters are manufactured by Solar. A recent Solar development is a Jupiter modified to furnish most of its output in the form of compressed air.

BOTH SOLAR TURBINES have been proven by extensive evaluation programs, as well as by many thousands of hours of actual service under demanding conditions. Both have shown trouble-free reliability; only routine maintenance is required between infrequent overhauls.

Solar turbines in production

Mars gas turbine weighs less than 100 lb

APPLICATIONS of Solar turbines include airborne and shipboard generator sets; ground power units; portable fire pumps; marine propulsion units; and a variety of other commercial and military uses.

POTENTIAL USES of gas turbines range over propulsion of land, water and air vehicles; many industrial applications, such as pumps, generators and compressors; and many additional military uses for Air Force, Navy and Army service.

CAN YOU USE small gas turbines? Booklets on Solar turbines and their applications are available on request. Write for them today!

SOLAR AIRCRAFT COMPANY
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DES MOINES

INFORMATION

For more information regarding any Solar product or service, write Solar Aircraft Company, Dept. B-56 San Diego 12, California

LETTERS

Sirs:

In "An Interview with Einstein," published in the July issue of your magazine, I. Bernard Cohen quotes remarks which Albert Einstein allegedly made about a recently published book and its author. Professor Cohen represents Einstein as having said that both the book and its author were "crazy," but not "bad."

As executor of Einstein's estate and as one who has the responsibility to protect his scientific and literary interests, I feel compelled to say that I deeply regret Professor Cohen's statements. The article was not submitted to me before publication. If it had been, I should have made every effort to prevent it from being published in its present form. Professor Cohen would certainly not have published it without Einstein's approval had he been alive. Similarly, after Einstein's death, it was Professor Cohen's duty to seek permission for publication.

The lack of discretion on the part of Professor Cohen has bewildered me the more since he himself, in the same article, quotes Einstein as having said in the same interview that "a man has the right to privacy, even after death" and that "even in correspondence there might be some personal things which should not be published." How much more that is true of remarks casually made in a private conversation! Professor Cohen can-

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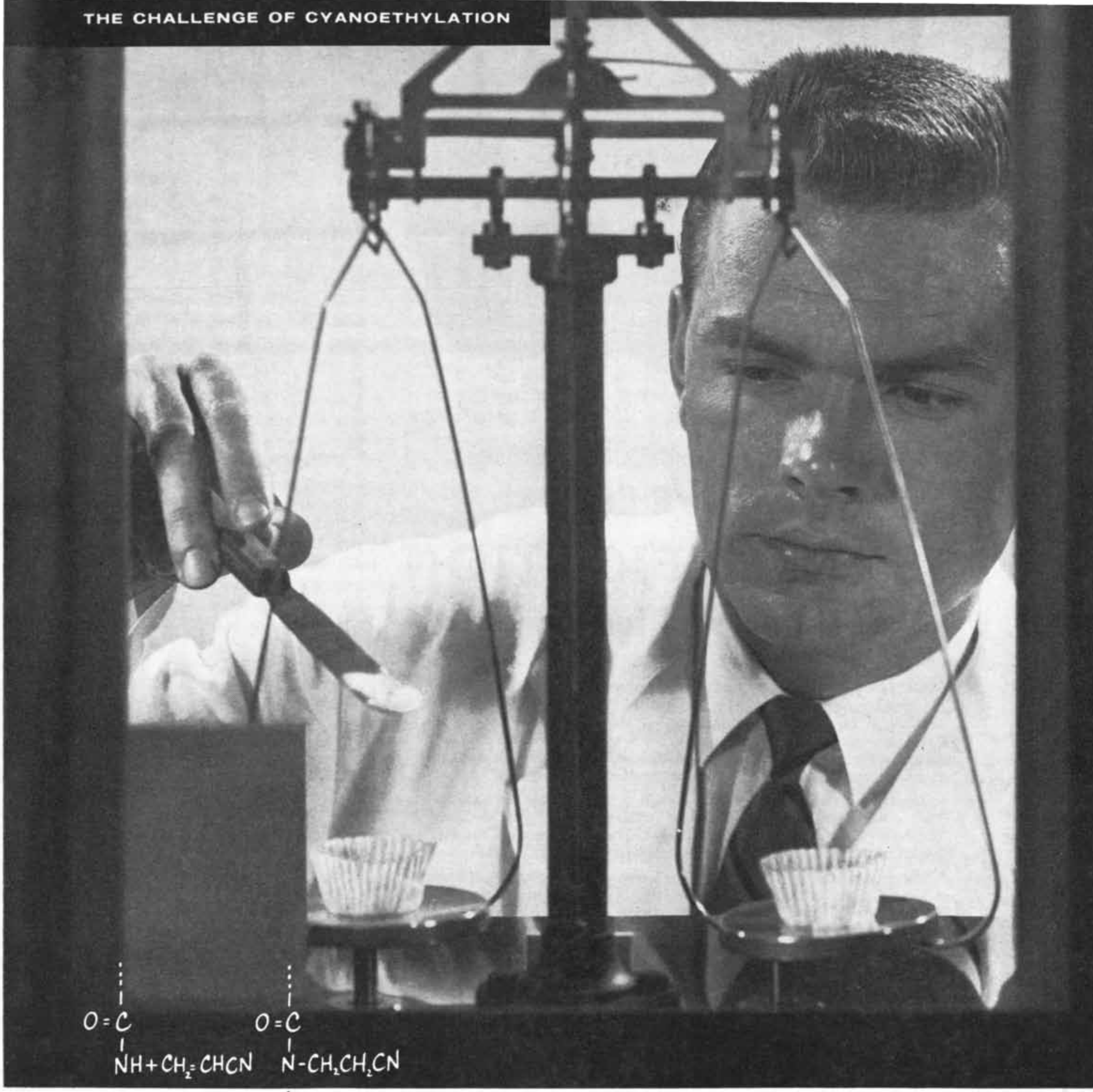
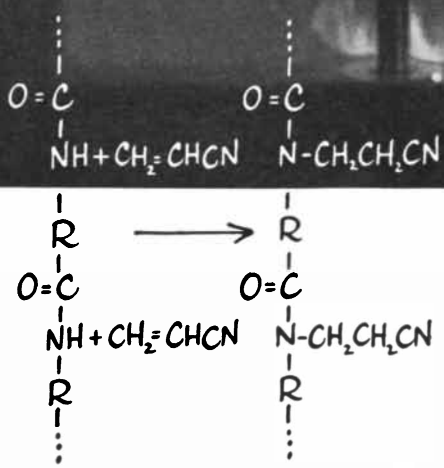
THE CHALLENGE OF CYANOETHYLATION





THIS FACT IS WELL-KNOWN:

Acrylonitrile will react with almost any organic or inorganic compound containing a labile hydrogen atom.

There are challenging possibilities on what might happen when acrylonitrile is reacted with proteinaceous polymers like silk, wool, fish scrap, dried blood, hoof and horn meal (all of which contain imide hydrogen).

Chemists have found that the imide hydrogen in the grouping -CONH- can be replaced with a cyanoethyl group. By such a reaction could wool be made mothproof? Could silk be made rotproof? Could fish scrap and dried blood be upgraded to fermentation resistant adhesives? Could adhesives be made less susceptible to moisture softening?

Answers to these questions by creative chemists may lead to exciting new industrial products.

If your company *would like to experiment with acrylonitrile, you are invited to write on your letterhead to Monsanto, the Monomer Headquarters of America, for laboratory samples. Address Monsanto Chemical Company, Plastics Division, Dept. SA9, Springfield 2, Massachusetts.*

MONSANTO

Nothing contained herein shall be construed as a recommendation to produce or use any product in conflict with existing patents.

not have had any doubt that Einstein's remarks about a book and its author, whatever they may have been, were not meant for publication.

OTTO NATHAN

New York, N. Y.

Sirs:

Dr. Nathan's letter raises two questions. The first is whether the opinions expressed by a great man who has died should be "authorized" by that person's executor before publication. The second question is closely related: To what extent does a man have a "right to privacy, even after death?"

When a man becomes a public figure because his ideas change the world—and especially when he enters the arena of political, social and economic discussion—then by his acts he removes himself from the category of the ordinary private citizen. Such a man then faces the sad dilemma of wishing to preserve his privacy while still hoping to change public opinion or counsel public action.

The historian's job is to present the true picture of such a man in all his aspects, so that we may hope to comprehend his deep creative powers and his influence on the world. This is a duty to society, and the historian hopes that the honest performance of his task may help society to understand itself, the better to secure the decent survival of man. Much as the historian may sympathize with any individual's desire for privacy after death, he cannot respect such a desire—save when it relates to information that on publication might result in needless unhappiness for any living person. If the writing of histories and biographies were restricted by conditions imposed by the subjects and their executors, then the historical record would lose that reality that makes it valuable for the understanding of man.

The immediate cause of Dr. Nathan's concern is my reporting of the remarks made in my presence by Professor Einstein about a book. The remarks were evidently intended to illustrate two main points: (1) that any acts toward suppressing a book which contains heretical or unorthodox ideas (even in science) is evil; (2) that there is no objective test of whether notions that contravene accepted scientific ideas and theories are the work of a crank or a genius, nor whether such ideas will forever seem crazy or perhaps become the orthodoxy

MISSILE TEST EQUIPMENT For over ten years Farnsworth has participated in the design, development, and production of guidance and control systems and special test equipment for such missile programs as Terrier, Talos, Sparrow, and others. Numerous "firsts" in this field have been accomplished as a result of contributions in the form of missile receivers, control systems, power supplies and complete system analyses.

IATRON A charge-controlled cathode ray "memory" tube permits operator-controllable image persistence from one millisecond up to several minutes duration. Unusually brilliant picture presentation at a brightness level of up to 10,000 footlamberts for projection purposes.

IMAGE CONVERTER TUBES Used in any application where it is necessary or desirable to "see in the dark." Convert an infrared image into a visible image. Applications: medical and biological research, hot-body observation, temperature distribution, crime detection, security, and photography.

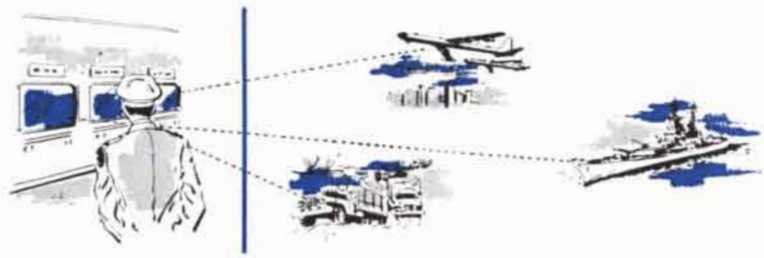
INFRARED VIEWER This unique, compact, easy to handle viewer is a valuable tool for crime detection, research and industrial application. Observation of objects or scenes in the dark is easily accomplished when they are illuminated by infrared radiation.

PHOTOMULTIPLIER TUBES Responsive in the near infrared spectrum featuring sensitivities as high as 50 amperes per lumen of incident radiation. Applications include photometric measurements for industrial and scientific uses.

IMAGE DISSECTOR A highly versatile TV camera tube particularly well adapted for use as a slide or facsimile scanner. This tube can be constructed in a variety of types to meet special requirements.

RADAR RANGE CALIBRATOR, AN/UPM-11A A precision instrument incorporating both "Radar" and "Beacon" functions. The equipment operates as a radar transponder in that pulsed r-f energy fed into the equipment results in a series of return echo pulses being fed back from the equipment to the radar under calibration. This simulates radar targets at accurately determined ranges.

PORTABLE CABLE TESTER Designed for testing all radio frequency cables that will accommodate, or can be adapted to, type "HN", "N", or "BNC" connectors. It will supply a d-c voltage up to 12,000 volts provided the current drain is negligible, and current surges of at least 3,000 amperes peak into a load of 0.05 ohm at room temperature.



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Guidance and Control Systems, Test Equipment.

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of the future. As an illustration there was a reference to Kepler and to a book which Professor Einstein had read and had found in part interesting. Professor Einstein did not mention the author's name because he was speaking in general terms about the above-mentioned issues and was using the book only as an example of work that was sufficiently unorthodox to appear "crazy" to a scientist. Thus on the basis of the few words said, and reported by me in full, there is no basis for concluding that Professor Einstein might not have had a friendly feeling for the author in question or that he might not have had some interest in his work. As is plain from my article, Professor Einstein sympathized with the author when he was attacked and disliked the methods used by some of his attackers.

I. BERNARD COHEN

Harvard University
Cambridge, Mass.

Sirs:

I am moved by your article entitled "An Interview with Einstein" to inquire whether it is not in the public interest to preserve Professor Einstein's house in Princeton for future generations. Consider, for example, how we should value the house and library of Isaac Newton. I think that the home of Professor Einstein is no less important, not only to physics but also in the larger sense as a testimonial that we welcome those out of "many kindreds and tongues" who flee from persecution anywhere.

JACK C. MILLER

Department of Physics
Pomona College
Claremont, Calif.

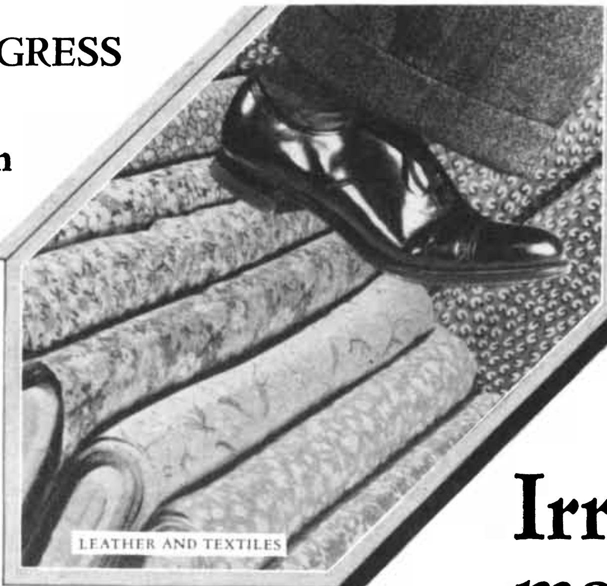
Sirs:

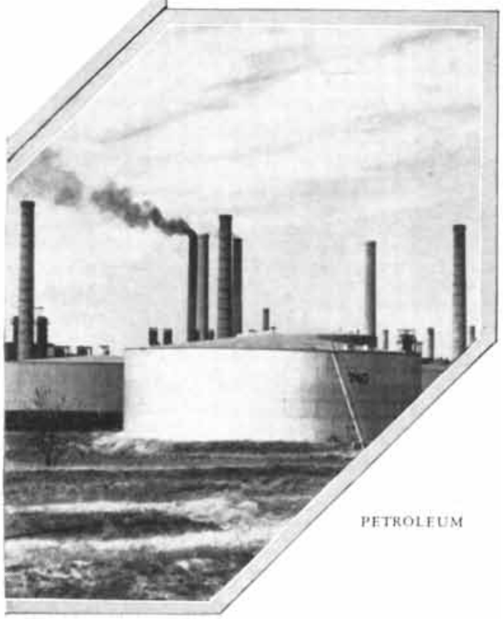
Frank B. Cuff, Jr., and L. McD. Schetky are to be congratulated for their interesting article "Dislocations in Metals," which appeared in the July issue of *Scientific American*. For the sake of completeness, however, one correction should be made.

The photograph on page 84, labeled "acid etch pits," is actually a photomicrograph of a thermally-etched surface of massive chromium. This configuration was produced during the course of an investigation on thermal etching which is being carried out in the metallurgy department of Rensselaer Poly-

G-E PROGRESS REPORT

on electron research





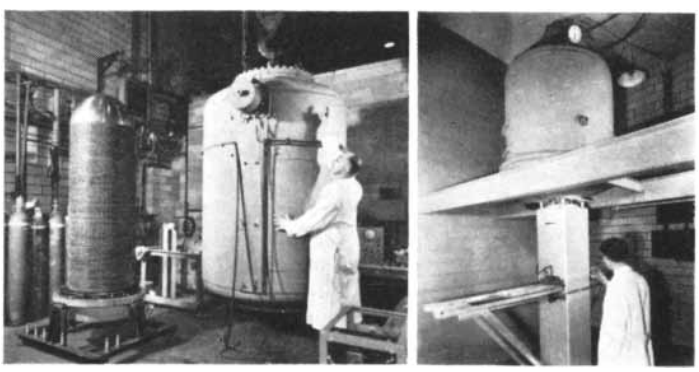
Irradiation moves into *new* fields

INVESTIGATION of high-energy irradiation for sterilization of foods is exciting great interest. It has been hailed as research that could result in the "ideal food preservation method."

From the start, G.E. has invited industry and others to participate in further study. Recent developments indicate the broadening range of this work.

For example, tests have indicated that shoes can be sterilized by high-energy irradiation without detrimental effects to the leather. Also, studies are being made to polymerize silicones in textiles. Gasoline is being tested with a view to polymerizing materials that produce "gum" in storage.

These are just a few of the research projects under way. General Electric offers you an easy plan for your own investigation. Preliminary tests will be conducted at the G-E Laboratory. Should these tests show promise, you can purchase equipment for use in your own plant, or you can rent it under the G-E MAXISERVICE® rental plan. For further details, call your G-E x-ray representative. Or write for technical literature to X-Ray Department, General Electric Company, Milwaukee 1, Wisconsin, Rm. TT94.



New G-E 2-mev electron beam generator (shown in assembly) joins the 1-mev generator (right) to broaden your research range.

Progress Is Our Most Important Product

GENERAL ELECTRIC

technic Institute. While the pits along the small-angle boundary represent dislocation sites, they do not owe their origin to acid etching. Acid etch pitting to show dislocation arrays has been employed by many workers, and many illustrations of this technique appear in the literature. As illustrated, thermal etching under the proper experimental conditions can give the same results as acid etching, but the mechanisms involved are different.

While the point raised is of minor consequence in the general theme of the article, nevertheless it is important to correctly indicate the processes leading to the delineation of dislocation arrays.

MALCOLM J. FRASER

Rensselaer Polytechnic Institute
Troy, N. Y.

Sirs:

May I congratulate James R. Newman on his article about James Clerk Maxwell [SCIENTIFIC AMERICAN, June]. The article is clearly written, well-balanced and most interesting. It is a tribute to both its subject and its author.

I have one minor criticism: Maxwell's equations are given in the modern form. My objection to this is that such a treatment tends to gloss over certain concepts and ideas which were important to Maxwell and embodied in his original equations—concepts which are still very important, though now omitted from his equations.

For example, Maxwell's equations originally contained the idea of magnetic vector potential, which he often designated as "electromagnetic momentum" (not to be confused with the modern concept of electromagnetic momentum). This idea is still of importance in electrodynamics.

I suppose that space limitations precluded mention of David E. Hughes in connection with Heinrich Hertz. There is strong evidence that Hughes (who invented the microphone) detected electric waves in space before Hertz did. Hertz, however, published his results first and gets the priority rating. Hughes was seven years ahead of Hertz, but was told by G. G. Stokes that he had given the wrong interpretation to his experiment. Hence he did not publish his results.

HERBERT KONDO

Champaign, Ill.

VARIAN KLYSTRONS are designed and built to deliver top performance under extreme conditions of shock and severe G-loads . . . such as occurred in the impact of the Viking rocket, falling from an altitude of 158 miles.

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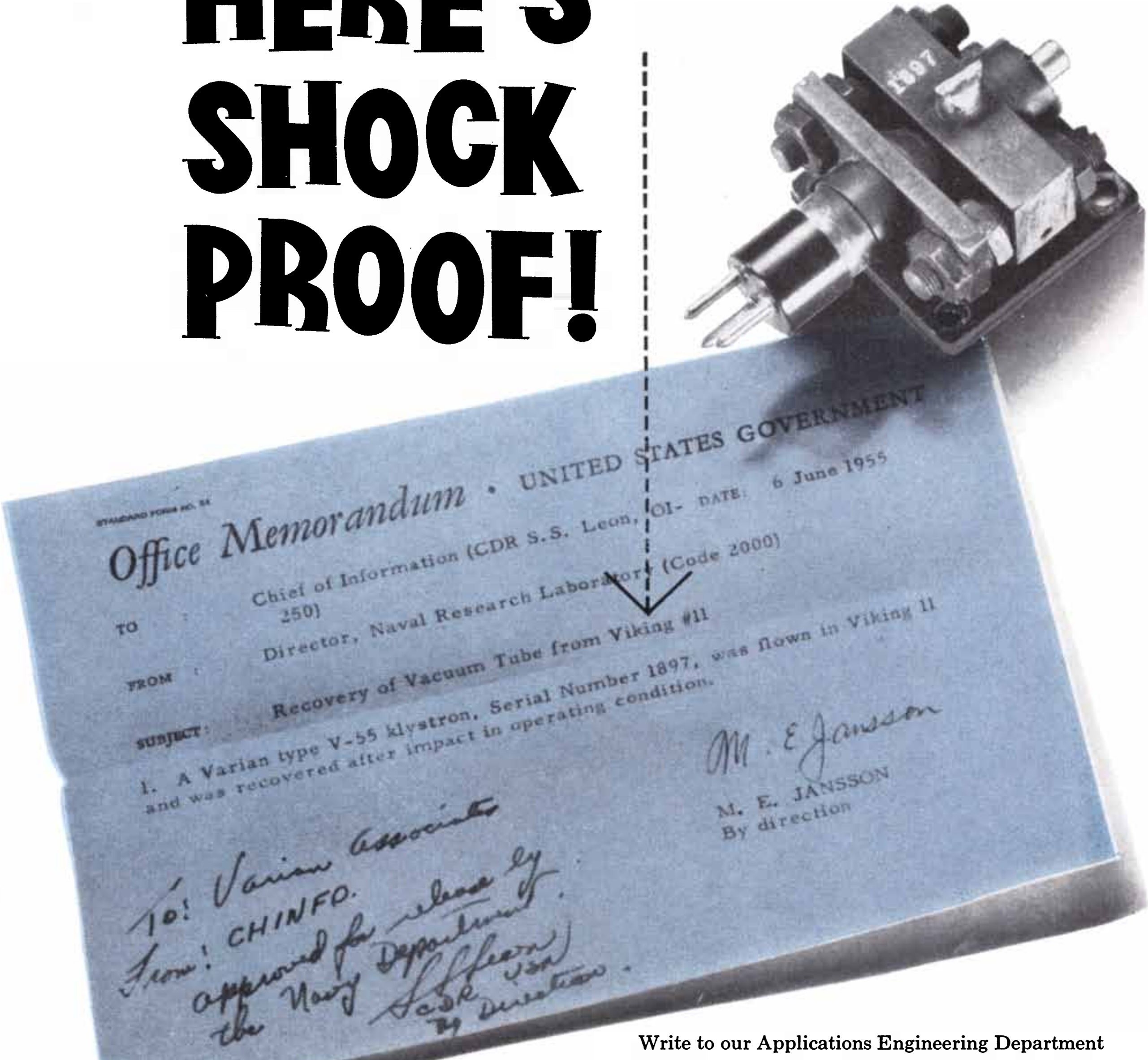

Write to our Applications Engineering Department for full information and specifications on Varian klystrons for airborne radar, missiles, beacons, relay systems, coherent transmitters, and high-power UHF-TV.

THE MARK OF LEADERSHIP

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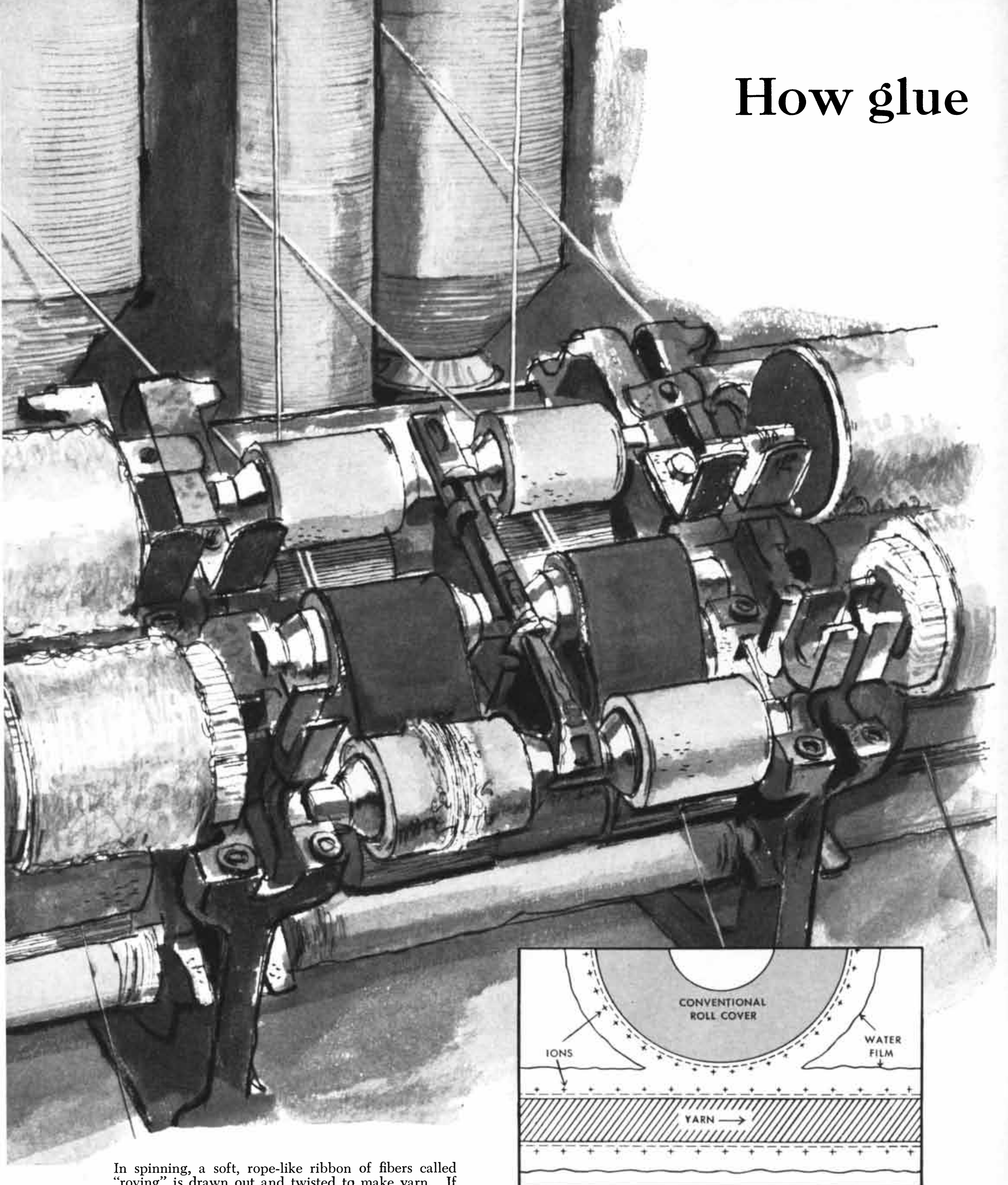
How glue



In spinning, a soft, rope-like ribbon of fibers called "roving" is drawn out and twisted to make yarn. If yarn breaks, adhesive force of invisible water films on both yarn and front spinning roll may cause yarn end to "lap up" or wrap around the roll, as shown in center above. Lapped yarn must then be cut away. If adhesive force is destroyed, however, broken yarn will fall away from roll, making it easier to "piece up" the end.

Two layers of ions (electrically charged particles) form in the microscopic films of water on both yarn and spinning roll cover. (Moisture film and yarn greatly enlarged in drawing.) This ion arrangement creates an adhesive force (electro-kinetic potential) that bonds water films tightly to surfaces of roll cover and yarn.

keeps water from becoming "sticky"

Unique electrolyte gets rid of surface attraction on yarn spinning rolls; may lead to improved drive and feed rolls for other industries

You can't see it, you can't feel it; but covering practically everything exposed to humid air is a microscopic film of water. Sometimes this film becomes "sticky" like an adhesive and bonds things together.

This stickiness, known technically as a form of surface attraction, has been the cause of serious problems in industry, particularly in spinning textile yarns. A few years ago, however, Armstrong textile research men found a way to prevent this water film from becoming sticky. Strangely enough, they did it with glue!

Armstrong chemists reasoned that a water film on a surface acts like an adhesive because it contains layers of electrically charged particles called ions. One layer of ions is positive, the other negative. This layer arrangement of ions creates an electrical potential that acts like an adhesive force. It actually bonds the moisture film tightly to the surface of the material it covers.

In the manufacture of yarn, the film of moisture on both spinning rolls and yarn frequently causes a phenomenon known as "lapping up." When the yarn breaks during spinning, the loose end sticks to the spinning roll and wraps tightly around it. Production is stopped until the lapped yarn can be removed from the roll.

Armstrong scientists prevent this "lapping up" by adding an electrolyte to the synthetic rubber used in making spinning roll covers. According to theory, this new roll covering material releases into the water film additional ions which cancel out, or neutralize, the bonding force created by the double-layer arrangement. The water film no longer holds the yarn to the roll.

Of all the electrolytes tested, one of the best at preventing water from becoming sticky is animal glue. (The details of this development are covered in Patents No. 2,450,409-410). Special studies are now going on at the Armstrong Research and Development Center to see if such electrolytic materials used in roll coverings can help solve surface attraction problems in other industries.

If you manufacture equipment using resilient rolls for handling web or film material, you may be troubled by a similar form of surface attraction. Specialists at the Armstrong Research and Development Center will be glad to determine whether or not an electrolytic rubber roll covering would improve the operation of your equipment. For details, call the nearest Armstrong Industrial Division Office or write on your letterhead to Armstrong Cork Company, Industrial Division, 8209 Inland Road, Lancaster, Pennsylvania.

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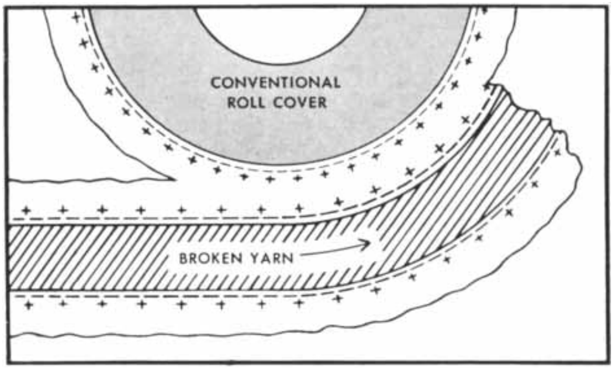
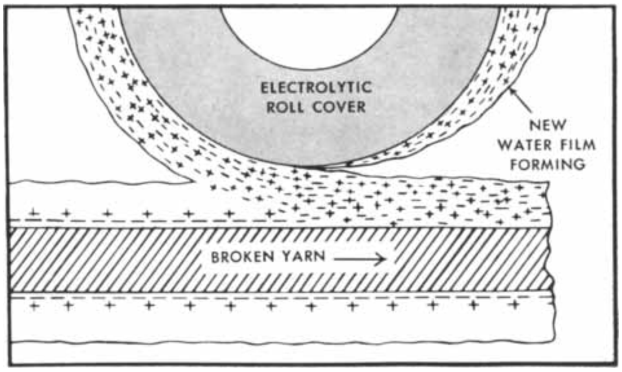
adhesives . . . cork compositions . . . cork-and-rubber . . . felt papers . . . friction materials



If yarn breaks after being drawn under roll, water films hold broken end to roll cover causing a "lap up." This is a result of two water films meeting under pressure of roll and merging into one. Internal forces in single film make it resist splitting . . . and ion arrangements bond it to surfaces of both yarn and roll.



Such "lap ups" are stopped by roll cover containing electrolyte which puts additional ions into water film. These break up ion arrangement, destroying adhesive force or electro-kinetic potential. Water film loses its stickiness . . . weight of yarn pulls it away from roll cover . . . and broken yarn end cannot "lap up."

50 AND 100 YEARS AGO

SCIENTIFIC AMERICAN

SEPTEMBER, 1905: "The Department of International Research in Terrestrial Magnetism of the Carnegie Institution of Washington is about to make a magnetic survey of the North Pacific Ocean. The brig *Galilee,* a wooden sailing vessel, has been fitted out at San Francisco for the expedition. The purpose of the expedition is to get exact data of the distribution of magnetic forces over the ocean, since the present magnetic charts used by navigators of the North Pacific depend chiefly upon observations made on islands and along the coasts. Observations of this kind are subject to disturbance by local conditions, so that the charts now in use are not trustworthy. It is thought that the work can be accomplished in three years and the sum of $20,000 has been allotted for the expenses of the first year. The *Galilee* will first cruise from San Francisco to San Diego, thence to Honolulu and back to San Francisco. Then a circuit will be made from the west coast of America to the Galapagos Islands, and thence to the Philippine Islands and Japan, returning by way of the Aleutian Islands and closing the circuit at San Francisco. The observations will be continued over a series of areas bounded by parallels of latitude and meridians of longitude each five degrees apart, lying next on the mid-ocean side of the circuit last made, proceeding gradually and by successive circuits into the central region of the North Pacific Ocean. The whole length of the course proposed is 70,000 knots. The work is directed by Dr. L. A. Bauer, who is in charge of the magnetic work of the U. S. Coast and Geodetic Survey. He will accompany the expedition to San Diego. The vessel will carry a sailing master and nine men as crew. The scientific head and commander is J. F. Pratt of the U. S. Coast and Geodetic Survey, who has had 30 years' experience in geodetic, astronomical, hydrographic and magnetic work."

"In order to prevent wireless messages interfering with one another, endeavors have been made to send electrical waves

After initial adjustments are made, as in photograph, "Mr. Meticulous" automatically performs critical operations in making junction tetrode transistors—tiny experimental devices which may find important uses in the telephone system.

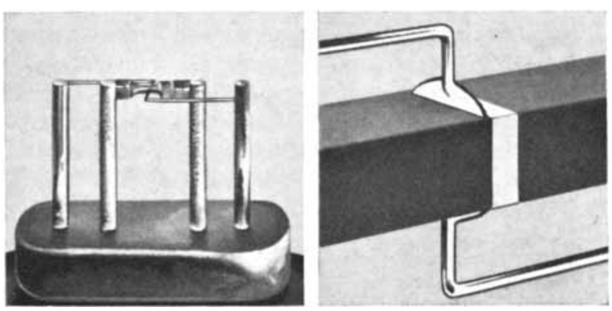
The machine we call "Mr. Meticulous"

Bell Laboratories scientists, who invented the junction transistor, have now created an automatic device which performs the intricate operations required for the laboratory production of experimental model transistors.

It takes a bar of germanium little thicker than a hair and tests its electrical characteristics. Then, in steps of 1/20,000 of an inch, it automatically moves a fine wire along the bar in search of an invisible layer of positive germanium to which the wire must be connected. This layer may be as thin as 1/10,000 of an inch!

When the machine finds the layer, it orders a surge of current which bonds the wire to the bar. Then it welds the wire's other end to a binding post. Afterward, it flips the bar over and does the same job with another wire on the opposite side!

Once only the most skilled technicians could do this work, and even their practiced hands became fatigued. This development demonstrates again how Bell Telephone Laboratories scientists work in every area of telephony to make service better.



Transistor made by new machine is shown in sketch at left above, magnified 6 times. At right is sketch of area where wires are bonded. The wires are 2/1000 inch in diameter, with ends crimped to reduce thickness.

BELL TELEPHONE
LABORATORIES

IMPROVING TELEPHONE SERVICE FOR AMERICA PROVIDES CAREERS FOR CREATIVE MEN IN MECHANICAL ENGINEERING only in one direction, as luminous signals are given off from a concave mirror. Prof. Braun has been engaged in experiments of this kind, and in a lecture held on July 11 before the Strassburg University Association of Electricians and Naturalists he announced that these experiments had come to successful conclusion. Prof. Braun's methods are based on the fact that three antennae arranged in the angles of a regular triangle are excited by waves of the same periodicity, but of different phases. The inventor states that one of the three antennae begins vibrating by 1/250,000 second earlier or later than the two others, this difference in time being kept up, according to experiments, with an accuracy of about one second in three years. This will result in different radiation according to the difference of the space, and by simply inverting a crank the direction of maximum effects can be shifted by 60 or 120 degrees."

"The great popularity of experiments in aerial navigation has again been proven by the interest evinced by the general public and the press of New York City in the recent successful airship flights of a young Westerner, A. Roy Knabenshue. So great was the curiosity of the New Yorkers to view the flights that almost all business and street traffic was at a standstill and throngs followed the course of the great dirigible balloon hovering over the city. The gas bag, 62 feet in length, which supports the framework carrying the motive power and the motive and steering apparatus, as well as the navigator, is cigar-shaped, the forward end being sharply pointed, while the rear extremity is rounded. The material used in the construction of the balloon is the finest Japanese silk, of great strength and exceedingly light weight, covered with a special varnish prepared by the aeronaut himself, which is said to be superior to anything of its kind hitherto used. The balloon of the *Toledo II* requires 7,000 cubic feet of hydrogen to inflate it. The two-bladed propeller, which is at the bow of the machine and pulls rather than pushes it, is 10 feet in diameter. The engine which drives the propeller is a four-cylinder air-cooled, gasoline motor. The entire weight of engine, shaft, clutch, batteries and tank is 92 pounds. Mr. Knabenshue can descend by pointing the nose of the balloon downward and using the screw, the power of which is sufficient for this purpose. As Mr. Knabenshue himself says, he has not solved the problem of aerial navigation, and has only demonstrated that, in the absence of heavy

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wind, it is possible by means of the usual screw and rudder to drive and guide a balloon. The practical airship of the future must be made to dispense with the huge gas-filled bag."

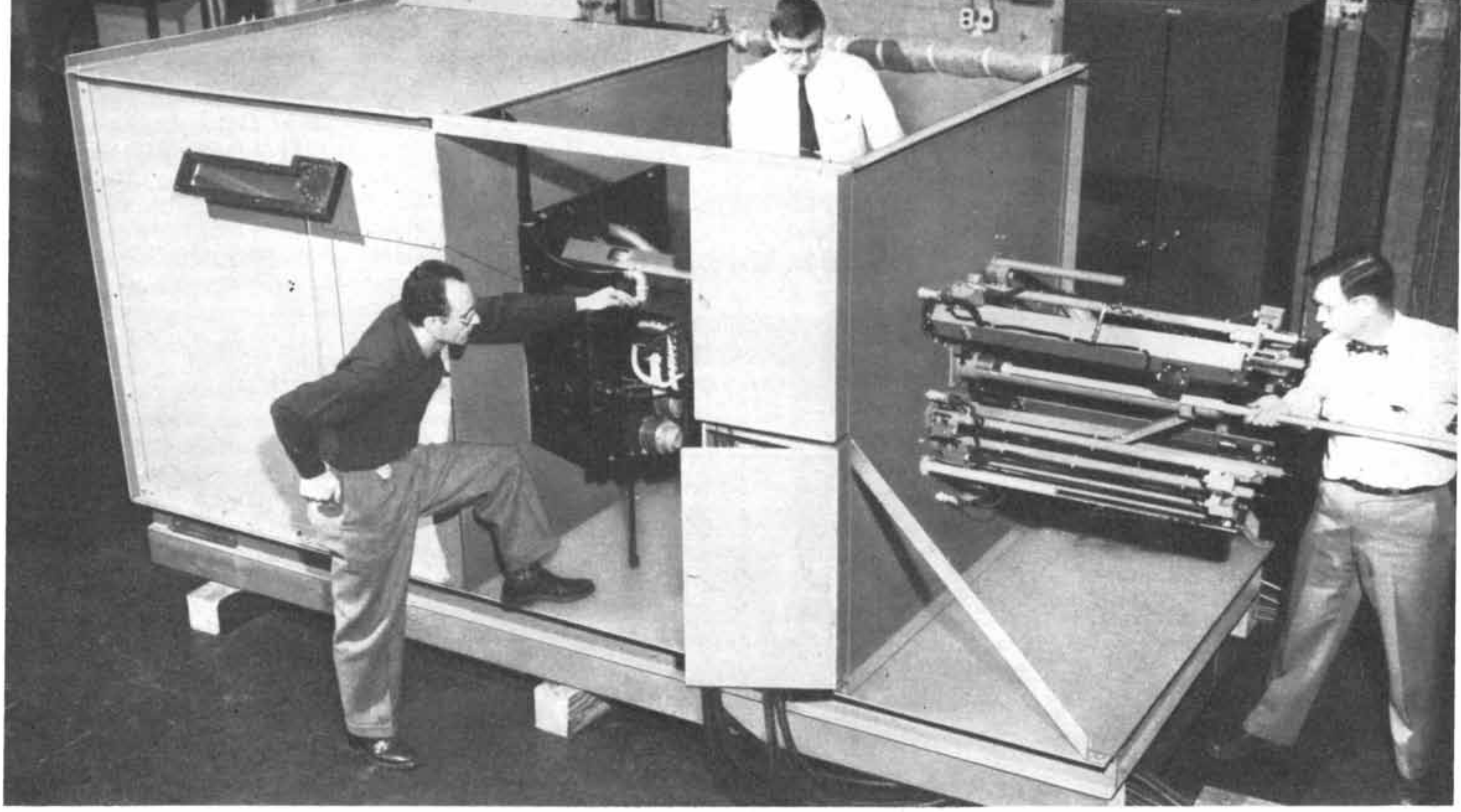
"Simon Lake, the submarine torpedo boat inventor, announces that he will settle permanently in Berlin, although he will still maintain an American office. The reason for his decision to leave the United States, he said, was because he is unable to get the recognition on this side of the water that is his in Europe. Mr. Lake said that in the tests made with his type of submarine on the other side of the Atlantic the boat had submerged 138 feet, the greatest depth ever reached by a submarine."

"During the first three months of this year, the British Post Office received 111 messages from the public for transmission to ships at sea *via* Marconi, in accordance with their agreement. Of this total, 21 messages failed to reach their destination. The incoming messages—from ships at sea for transmission to interior land-post offices—aggregated 1,655 for the same period. The revenue from this source of traffic averages about $12,000 per annum. There are, however, only six shore stations and 50 ships at present replete with the Marconi apparatus, and it is recognized that the number will have to be considerably increased before the scheme can become profitable."

SCIENTIFIC AMERICAN

SEPTEMBER, 1855: "At the Ninth Annual Meeting of the American Association for the Advancement of Science in Providence, R. I., Prof. S. Alexander of Princeton read a paper on the asteroids, characterized by much ingenuity but entirely speculative. He had arrived at the conclusion that between Mars and Jupiter there once revolved a planet with an equatorial diameter of 70,000 miles and a polar diameter of only 8 miles, thus being shaped like a wafer. Having a great velocity on its axis, it burst as some grindstones do, and its fragments formed the asteroids."

"Captain William Allan, of the British Navy, has published a book advocating the conversion of the Arabian desert into an ocean. The author believes that the great valley extending from the southern



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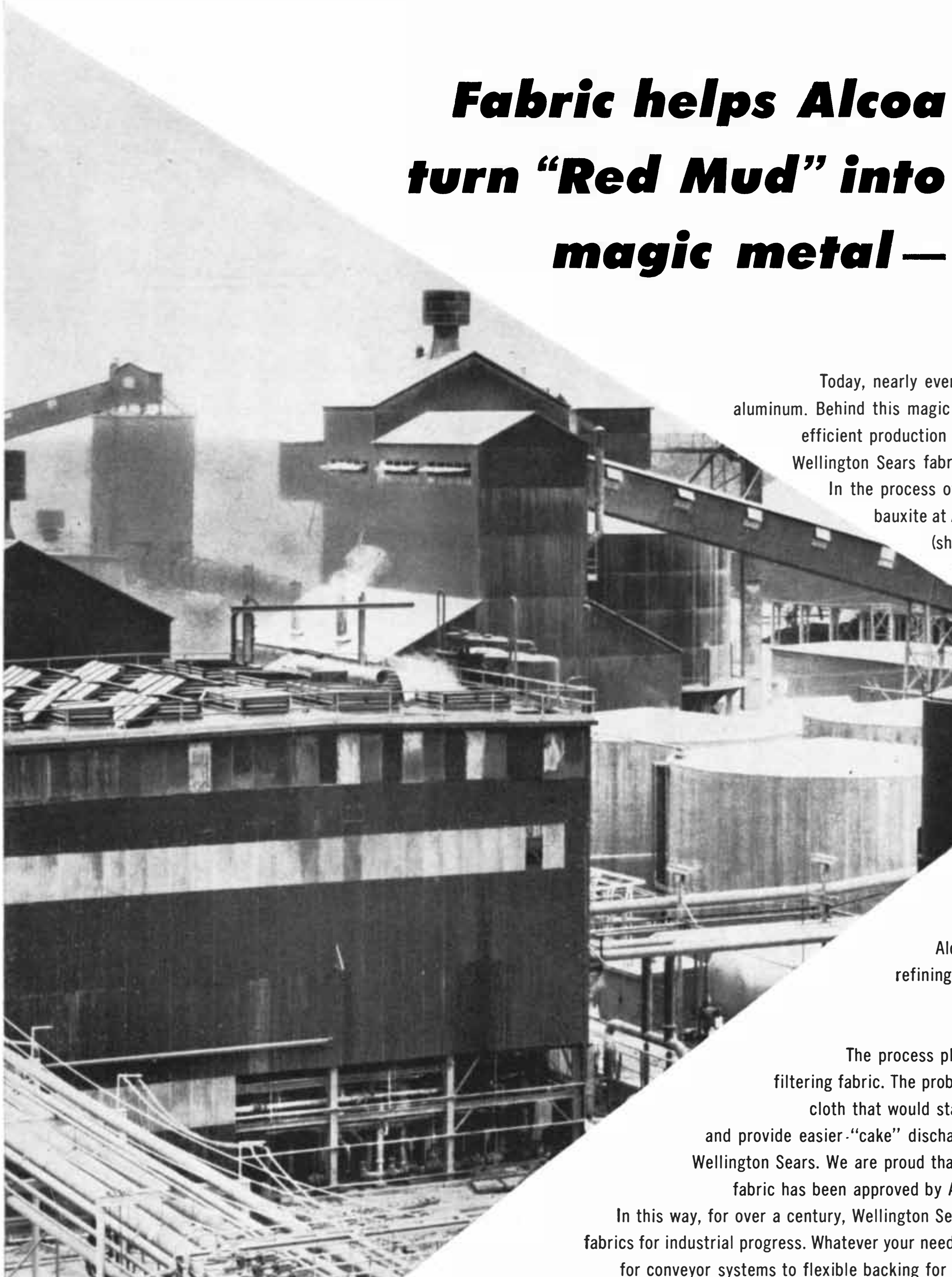
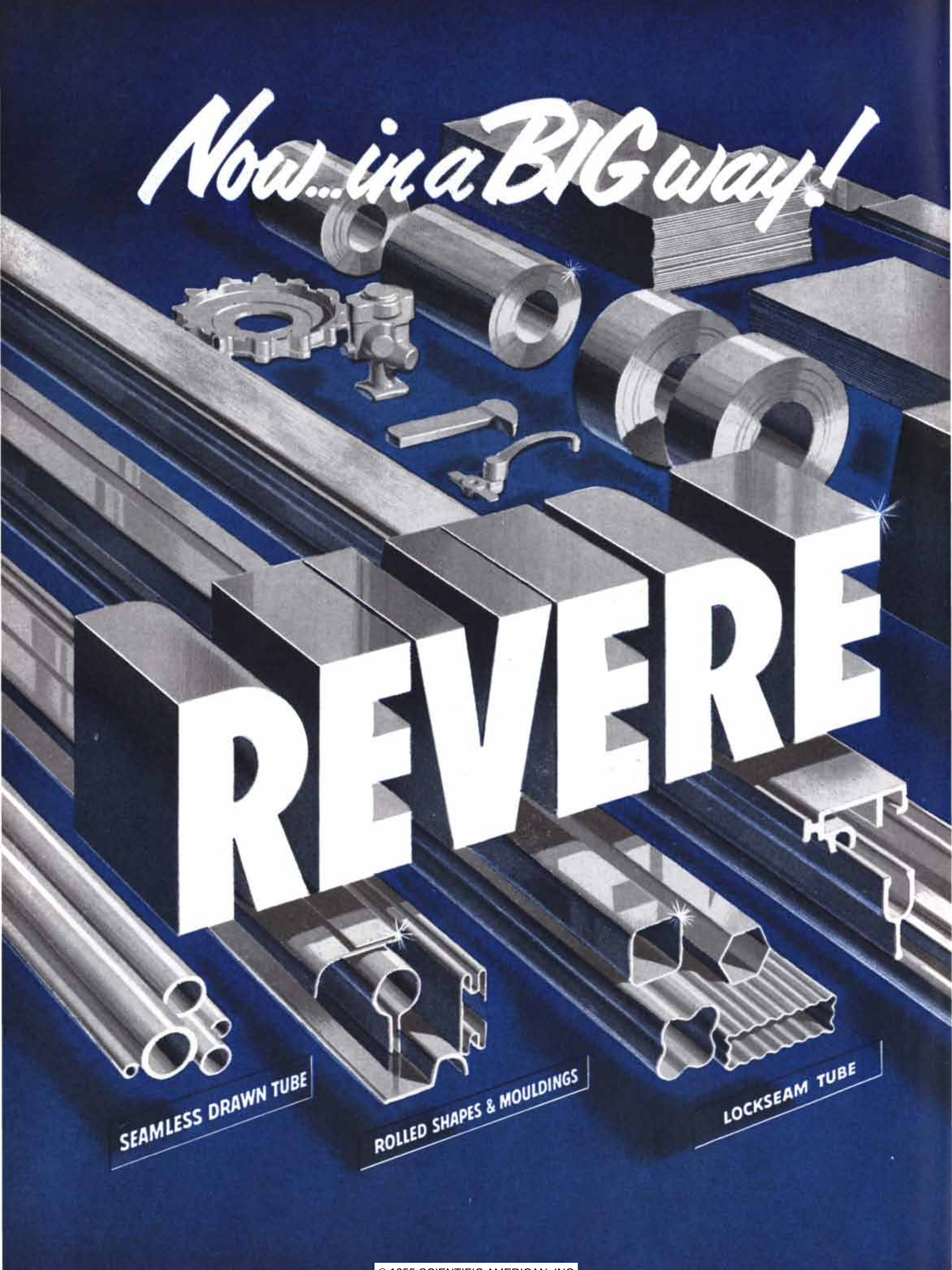
depression of the Lebanon range to the head of the Gulf of Akaba, the eastern branch of the head of the Red Sea, has once been an ocean. It is in many places 1,300 feet below the level of the Mediterranean, and in it are situated the Dead Sea and the Sea of Tiberias. He believes that this ocean, being cut off from the Red Sea by the rise of the land at the southern extremity, and being fed only by small streams, gradually became dried by solar evaporation. He proposes to cut a canal of adequate size from the head of the Gulf of Akaba to the Dead Sea, and another from the Mediterranean, near Mount Carmel, across the plain Esdraelon, to the fissure in the mountain range of Lebanon. By this means, the Mediterranean would rush in, with a fall of 1,300 feet, fill up the valley, and substitute an ocean of 2,000 square miles in extent for a barren, useless desert; thus making the navigation to India as short as the overland route, spreading fertility over a now arid country."

"The Emperor of Austria has conferred upon Professor Morse the large golden medal for arts and sciences, in consideration of the valuable services rendered by him to science by his system of telegraphs, which has been extensively applied in the Austrian dominions."

"At the Ninth Annual Meeting of the American Association for the Advancement of Science, held at Brown University, Providence, R. I., Prof. Joseph Henry detailed an experiment which was made at the Smithsonian Institution, in consequence of the granting of a patent for the separation of alcohol from whiskey, by placing a considerable quantity in a vertical tube. The patentee stated that by the use of a tube 100 feet in height, he had separated 100 gallons of alcohol in 12 hours. The experiment was made in one of the towers of the Smithsonian, with a gas pipe 260 feet long, into which stop-cocks were inserted at various lengths. A most careful examination of the whiskey at the various heights was made at the end of a few hours, and also at the expiration of some months, but no more variation could be discovered than in different samples of the same whiskey not subjected to the process. The patentee had, however, obtained his patent and sold several rights at a high price. A paper was read at the last meeting of the Association announcing this discovery. The gist of Dr. Henry's remarks was that the Patent Office, the Association and the country had been sublimely humbugged."

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THE AUTHORS

PAUL A. HUMPHREY ("The Voyage of the Atka") is a meteorologist in the Scientific Services Division of the U. S. Weather Bureau. On the *Atka* he represented the U. S. National Committee for the International Geophysical Year. He took part in organizing and carrying out the site surveys in the Antarctic and participated in the scientific programs of the expedition. A graduate of the University of Chicago, Humphrey participated in typhoon reconnaissance flights from the Philippines during World War II.

K. E. BULLEN ("The Interior of the Earth"), a seismologist, is professor of applied mathematics at the University of Sydney in Australia. Born in Auckland, New Zealand, he was appointed lecturer in mathematics at Auckland University College at the age of 21. It was not until a few years later, he writes, that a conjunction of two events aroused his interest in geophysics: "The first event was the Hawke's Bay earthquake in February, 1931, which was responsible for the greatest loss of life from an earthquake in the history of my home country. The second event was going to England in that same year and chancing to be at the same Cambridge college [St. John's] as Sir Harold Jeffreys, who introduced me to seismological research and inspired me with great enthusiasm for the study. His remarkable stimulation determined my subsequent career." After two and a half years at Cambridge, Bullen returned to his post at Auckland. He then taught at the University of Melbourne for several years, and in 1946 joined the University of Sydney.

MARSHALL KAY ("The Origin of Continents") is professor of geology at Columbia University. The son of a teacher of geology and mining at the University of Kansas, he took his first degrees at the University of Iowa, then came to Columbia as assistant curator of paleontology. He became assistant professor of geology at Columbia in 1937 and professor in 1944.

WILLIAM O. FIELD ("Glaciers") is head of the department of Exploration and Field Research of the American Geographical Society. His interest in the study of glaciers was aroused at Harvard University, where he majored in geology. The glaciers of Alaska were then report-

ed to be in a state of rapid change, and Field decided to study them "over a lifetime." As soon as he had graduated, in 1926, he made the first of his several trips to Alaska. In 1940 he joined the staff of the American Geographical Society and was assigned to the development of a comprehensive long-term glacier study program. During World War II he first made training films for the Signal Corps, then spent two years in a photographic company in India and Burma. Last year he was asked to draw up a glaciological program for the U. S. during the International Geophysical Year.

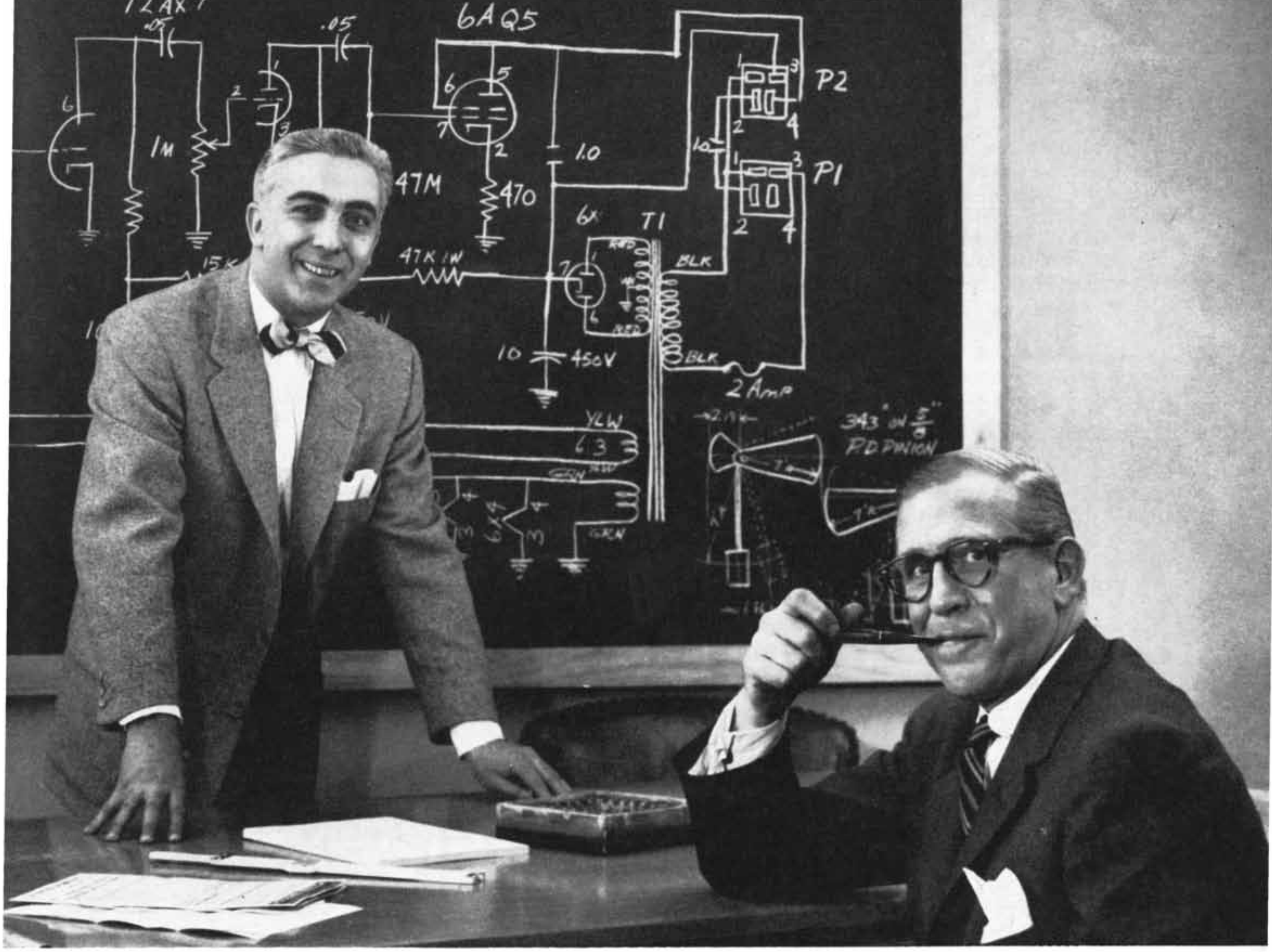
WALTER H. MUNK ("The Circulation of the Oceans") is professor of geophysics at the Scripps Institution of Oceanography in La Jolla, Calif. He was born in Austria—"a country which boasts of several oceanographers but of no oceans." He took an M.S. in geophysics at the California Institute of Technology and, in 1947, a Ph.D. in oceanography at the Scripps Institution. He writes: "Ever since I first took up science I have resented the need of having to specialize, of having to decide whether to push a pencil, to play with gadgets or to do field work. I have ended up in a field where I can do a bit of each."

HARRY WEXLER ("The Circulation of the Atmosphere") is chief of the Scientific Services Division of the U. S. Weather Bureau. An account of his career brings out several links with Jerome Namias, whose "Long-Range Weather Forecasting" appeared in last month's issue of SCIENTIFIC AMERICAN: "I became interested in meteorology while delivering a paper route through fair weather and foul. My interest was further stimulated by my physics teacher at the B.M.C. Durfee High School in Fall River, Mass., Leslie W. Orcutt (also our baseball coach). Another student in that class was Namias, a lifelong friend and now my brother-in-law (we married sisters whose artistic activities have tempered our scientific lives). It was he who persuaded me to study meteorology at the Massachusetts Institute of Technology after I had graduated from Harvard in 1932. At M.I.T. I had the good fortune of studying under Carl-Gustaf Rossby, a transplanted Swedish meteorologist who has the knack of stimulating his students and making major contributions to their understanding of atmospheric motions." Wexler took an Sc.D. in meteorology in 1939, while working for the Weather Bureau. He taught at the University of Chicago for a year,

then served in the Weather Service of the Army Air Force. He took up his present position with the Weather Bureau in 1946. He is Chief Scientist for the U. S. Antarctic Expedition of the International Geophysical Year.

T. N. GAUTIER ("The Ionosphere") is employed as chief of upper atmosphere research in the radio propagation physics division of the National Bureau of Standards. He was born in Miami, Fla., and has a B.S. and an M.S. in physics from the University of Florida. In 1942 he left the University of North Carolina, where he had been engaged in graduate work, to take a wartime job in the radio section of the Bureau of Standards. "I knew nothing," he writes, "of the ionosphere or of radio wave propagation except for some of the basic ideas of electromagnetic theory. The main reason for taking the job was to get into the Bureau of Standards, which had had a glamorous fascination for me since high-school days. A 'masterpiece' of science fiction—'The Skylark of Space'—had appeared in *Amazing Stories* in 1927. The hero worked at the Bureau of Standards."

C. T. ELVEY AND FRANKLIN E. ROACH ("Aurora and Airglow") are former colleagues at the McDonald Observatory in Texas, where they collaborated on a study of airglow in 1935-1936. Elvey is now Director of the Geophysical Institute at the University of Alaska. He was born in Phoenix, Ariz., and attended the University of Kansas, where he took a B.A. in 1921 and an M.A. in 1923. He took a Ph.D. in astrophysics at the University of Chicago in 1930, doing his graduate work under the supervision of Edwin B. Frost, the blind astronomer who was then director of the Yerkes Observatory. Elvey remained at Yerkes until 1935, when he transferred to the McDonald Observatory. During World War II he worked at the California Institute of Technology on rockets. He joined the Geophysical Institute in 1952. Roach is consultant to the radio propagation physics division of the National Bureau of Standards. An astrophysicist, he took his Ph.D. at the University of Chicago in 1934 and spent most of the following years at the Yerkes, Perkins and McDonald observatories. From 1936 to 1942 he taught physics and astronomy at the University of Arizona. During and after the war he worked at Cal Tech and at the Naval Ordnance Testing Station, to which he returned in 1952 after spending a year at the Institut d'Astrophysique in Paris on a Fulbright research fellow-



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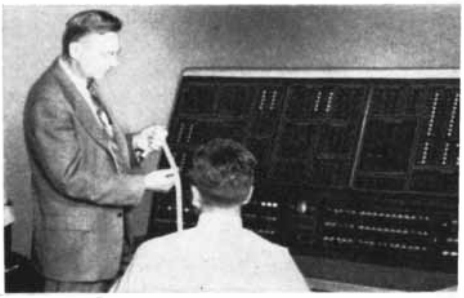

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SCALES • PUMPS • DIESEL LOCOMOTIVES AND ENGINES • ELECTRICAL MACHINERY • RAIL CARS • HOME WATER SERVICE EQUIPMENT • MOWERS • MAGNETOS ship. He joined the Bureau of Standards in 1954.

S. K. RUNCORN ("The Earth's Magnetism") is assistant director of research in the department of geodesy and geophysics at the University of Cambridge and a fellow of Gonville and Caius College. He was born in Southport, England, and educated at Cambridge and the University of Manchester. He first became interested in geomagnetism while working with P.M.S. Blackett at Manchester, where he acquired his Ph.D. He is now actively interested in the magnetization of rocks, and has for the past two summers collected specimens on the Colorado Plateau for his paleomagnetic work.

WEIKKO A. HEISKANEN ("The Earth's Gravity") is a Finnish geodesist who since 1951 has been director of the Institute of Geodesy, Photogrammetry and Cartography at Ohio State University. He was born in Kangaslampi, Finland, the ninth son of a farmer. "My first love—chronologically—was astronomy," he writes, "second my wife Kaarina (whom I married in 1922) and third geodesy." Starting out in astronomy, he took his B.S. and M.S. at the State University in Helsinki. In 1920 and 1921 he went to Germany, where he studied under David Hilbert, Max Planck and Albert Einstein. Noting at the time that there were only two astronomy professorships in all of Finland, it occurred to him that he might turn to geodesy. Heiskanen became assistant professor of geodesy at the Finnish Institute of Technology in 1926 and full professor in 1931. He has been the director of the International Isostatic Institute since 1936. From 1933 to 1936 he was a member of the Finnish parliament.

LLOYD V. BERKNER, who reviews Gerard P. Kuiper's *The Earth as a Planet* in this issue, is president of Associated Universities, Inc., an organization that sponsors various research projects and centers, notably Brookhaven National Laboratory. After graduating from the University of Minnesota in 1927 he worked for the U. S. Bureau of Lighthouses and the National Bureau of Standards, and went on the Byrd Antarctic Expedition of 1928-1930. From 1933 to 1941 he was a physicist with the Department of Terrestrial Magnetism of the Carnegie Institution of Washington. During World War II he was director of electronics materiel in the Bureau of Aeronautics of the Navy, and in 1946-47 was executive secretary of the Joint Research and Development Board.

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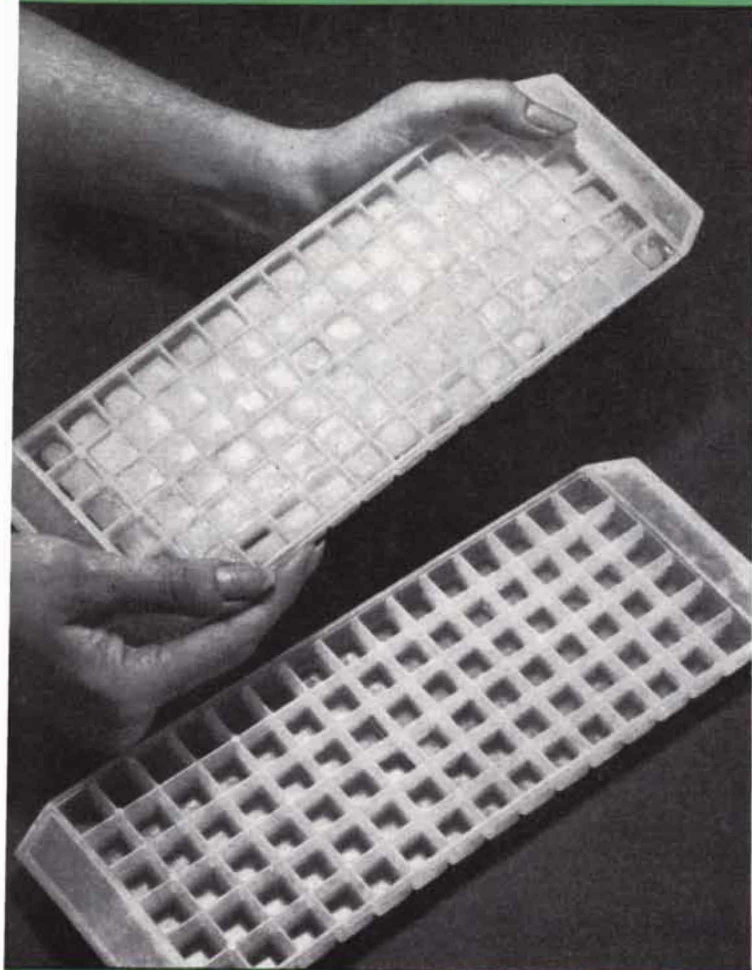

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Like Tenite Butyrate, available in an unlimited range of colors and a wide variety of formulations to satisfy different use requirements.

THE COVER

The color photograph on the cover shows parts of New Mexico and Arizona from a height of 78.3 miles. The photograph was made from a Navy Aerobee rocket launched from White Sands Proving Ground. In the foreground is the Rio Grande.

THE ILLUSTRATIONS

Cover by Applied Physics Laboratory, Johns Hopkins University

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CORNING GLASS BULLETIN

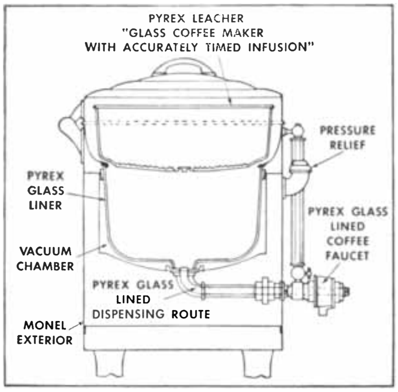
FOR PEOPLE WHO MAKE THINGS

"Urning" power

Coffee time these days is almost anytime.

And behind many a steaming cup there lies *glass*—a PYREX brand glass.

Take those big urns that gleam and glisten at your favorite snack shop. Outside, shining monel metal. But, on the inside, where the piping hot coffee is in the making, you'll find glass. As in this cross section of a coffee maker.



Glass liners of this type are made from that unusually versatile glass called PYREX brand No. 7740. And, for good reason.

This is a *balanced* glass. It has remarkable ability to take continuous heat, and still not crack when temperatures drop. It's mechanically strong, too, stands up under lots of physical abuse.

The clincher—glass neither *adds* to nor *detracts* from the taste. This glass will *not* contaminate by taking from or adding to what you make in it (or pipe through it)—coffee, milk, tomato juice, or something with even more zing, like fermented juice from plump grapes.

And any PYREX brand glass that handles foods and such is quickly and effectively cleaned with a minimum of effort.

Which suggests that the "urning" power of glass in some form might well be working for you.

As a start, take a look at "Properties of Selected Commercial Glasses"—Bulletin B-83; and/or Bulletin IZ-1, "Glass—its increasing importance in product design." Free.

Getting the mostest with the leastest

Taking to heart, with minor modifications, the advice about getting there "fustest with the mostest," we present Pattern No. 70 Low-Brightness Lens Panels.

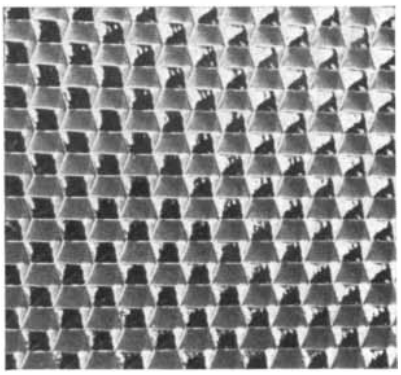
Said panels get there "mostest with the leastest"—*most* useful light, *least* glare.

Key to this light that's bright but not glaring is "a uniform configuration of six-sided glass pyramids"—otherwise known as prisms.

Prisms in light control are not new. But mass-produced, large panels, with prisms *built-in* represent quite an achievement in technology.

This we call to your attention not because you may have a problem of adequate lighting. We cite it, rather, as another indication of what lies behind the motto: "Corning means research in Glass."

Research activities have led us up a number of unusual glass paths. Case in point—glass that laughs at heat, that stands up to high temperatures (1200°C.) and chemical attack in the manner usually expected only of fused silica.



Other cases in point—glass that's optically perfect but capable of withstanding wind moving in closed wind tunnels at twice the speed of sound; glass that directs infrared and ultraviolet rays at will; glass that handles metal-eating acids with ease.

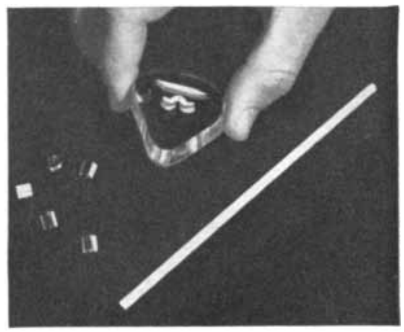
Among our 50,000-odd formulas for glass, there may be *one* with just the right balance of optical, thermal, chemical, mechanical and electrical properties, to solve one of your materials problems.

"Glass and You," a beautiful and informative booklet (if we do say so), will bring you up to date on how hundreds of our friends and customers are getting the "mostest" profits with the "leastest" trouble by making use of special glass researched into being by Corning. Write us for a copy—or check the coupon.

Reflections on some interesting bores

If the decision for precision falls to your lot, these bores may interest you.

These particular bores are the holes in thermometer tubing, a product we turn out by the mile. Practically invisible to the naked eye, these fine holes run to about ¼th the diameter of a human hair.



Yet, they are held to such exceptionally fine inside tolerances as ±.0003″.

As you might imagine, mercury pushed into such a small space is hard to see. So, around the bore we build some ingenious white reflectors of white glass. Then, when we form the tubing, we build a lens into it.

Thus, with the help of a white background and magnifying lens, those who must can readily and accurately tell how *hot* hot is and *cold* cold is.

The picture shows a cross section of one type of thermometer tubing. The largest piece in the picture, some 80 times normal size, shows you something of the intricate internal construction of thermometer tubing.

Without modesty we pinpoint this precision in glass to show you what can be done. Tubing, thermometer or just plain tubing, comes in many sizes and types. Write if you'd like to know more about it.

Corning means research in Glass

CORNING GLASS WORKS

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FLY THE SAFER, SMOOTHER COURSE WITH Bendix STORM-AVOIDANCE RADAR

Actual storm ahead as pilot sees it on radar scope. It indicates that, by changing course very slightly to the right, he will find a smooth, storm-free route.

This great safety device gives to executives who fly in

YOU heads of companies which own and operate their own airplanes for executive use should take a very serious look at the safety advantages of new Bendix storm-avoidance radar.

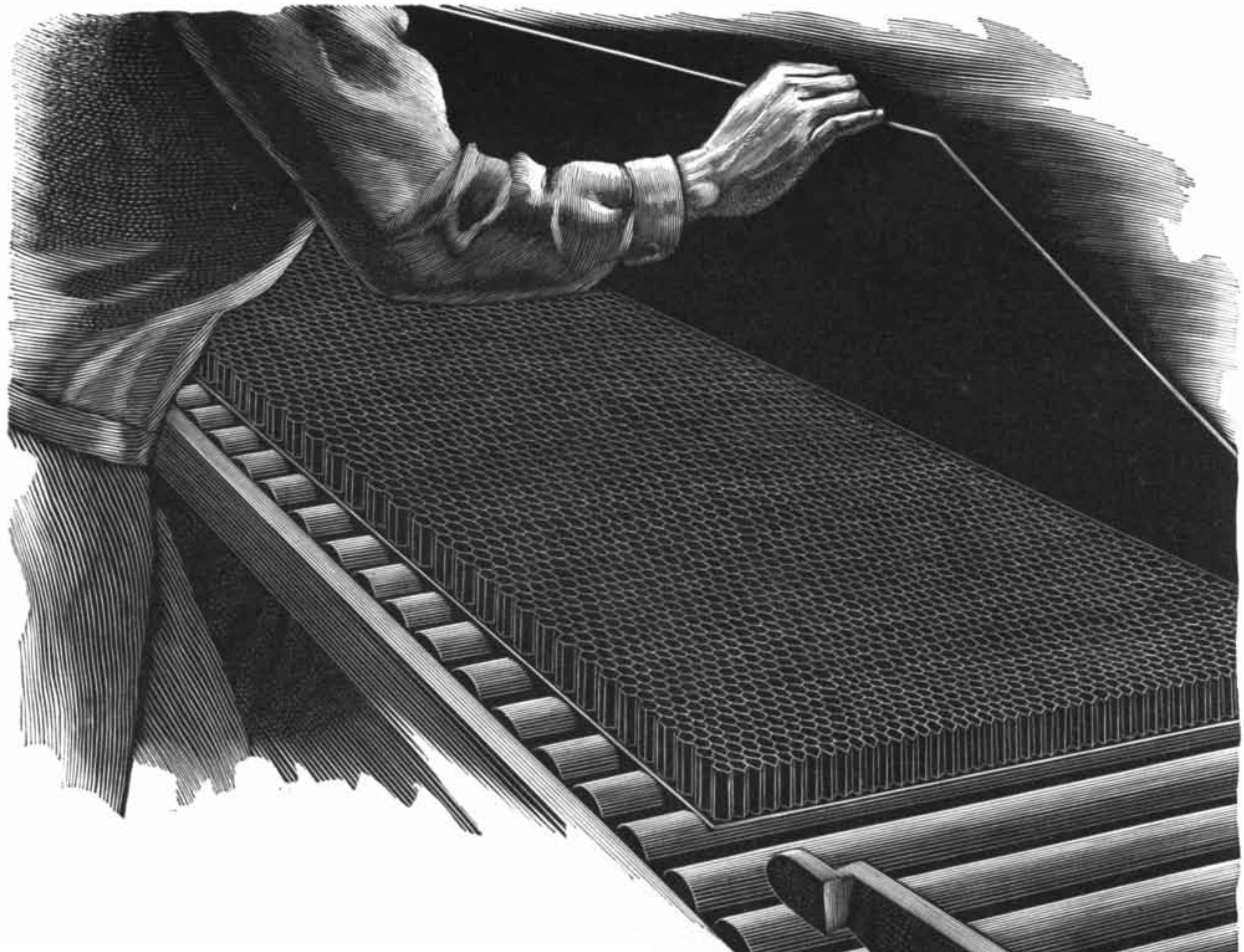
Over and beyond the obvious value of human life, the *business* value of a plane-load of top executives is almost impossible to reckon. So anything you do to increase the safety factor in your company plane is a very sound investment.

Equipping it with Bendix storm-avoidance radar is a definite safety measure. Airline pilots and military fliers who have flown millions of miles with Bendix radar say it's the greatest thing to come along in years!

What it does is see storms your pilot cannot see . . . night or day . . . as far as 150 miles ahead. It pictures these storms in detail on a radar screen in the cockpit so your pilot can confidently decide what to do—skirt the storm or fly through it if the radar shows a clear passageway.

Storms are not always turbulent from edge to edge. There are often safe, smooth corridors through them but, up to now, pilots have had to be guided by what they could see with their own eyes.

Bendix storm-avoidance radar also differentiates



New adhesive makes stronger, more heat-resistant sandwich panels

A remarkable new thermoplastic adhesive—Armstrong D-253N—holds dead loads twice as high as those held by conventional thermoplastic cements. And its unusual resistance to heat makes it useful at temperatures up to 180° F.

D-253N has high immediate strength, too. This makes it ideal for assembly-line applications. Spray it on core and skin sheets, force dry for one or two minutes, then assemble your sandwich. One run through a pinch roll—and the bond's made.

Using D-253N, you can bond honeycomb cores to many different skins, including plywood, stainless steel, aluminum, and plastic laminates. This versatility makes it easy to meet the constantly growing demand for sandwich panels in all their many forms.

Write today for data sheet on D-253N. For information on other Armstrong Adhesives, write for a copy of our 1955 Adhesives Manual, free to industrial users. Armstrong Cork Company, Industrial Div., 8009 Inland Rd., Lancaster, Pa. In Canada, 6911 Decarie Blvd., Montreal.

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SCIENTIFIC AMERICAN

Established 1845

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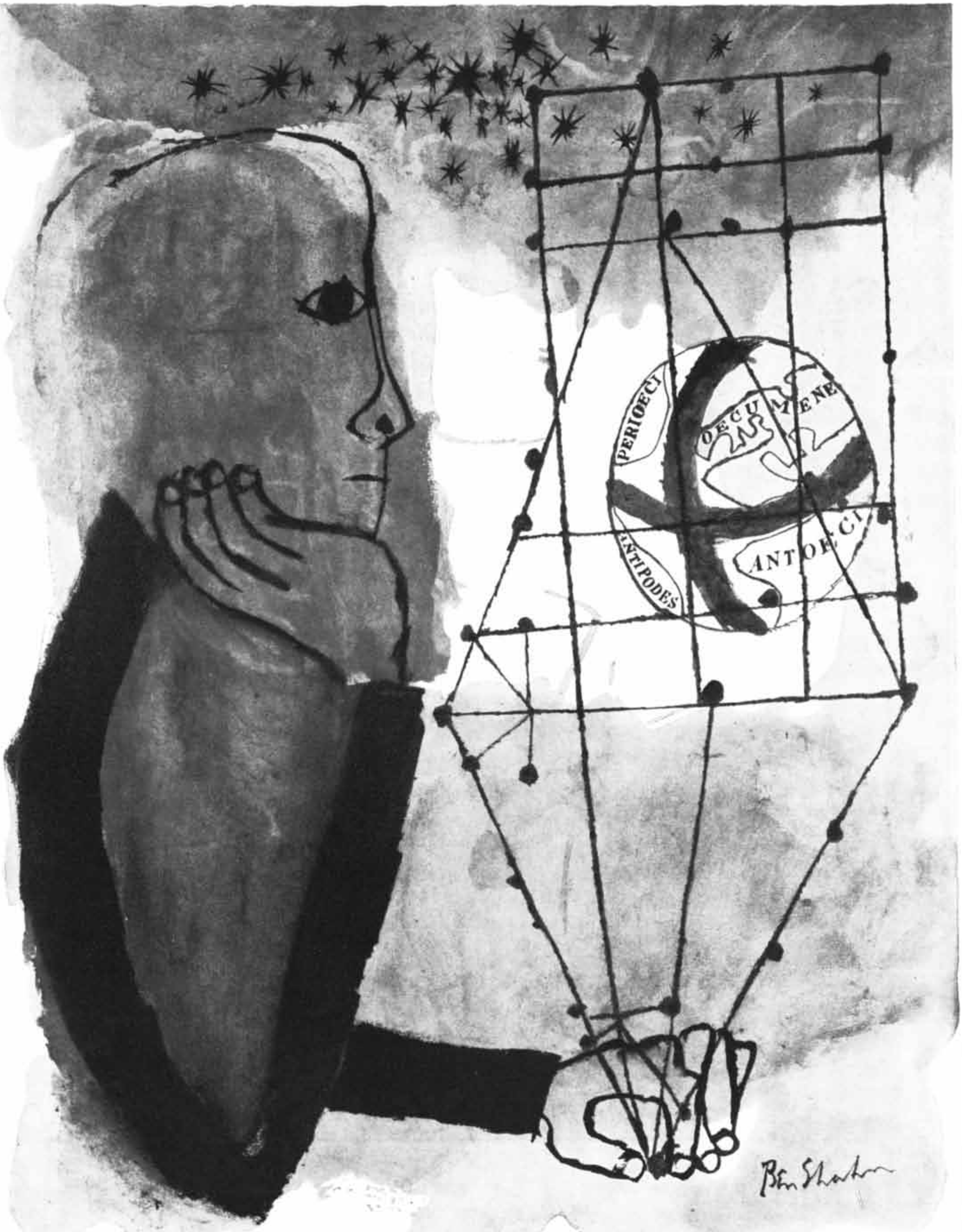
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Ben Shahn

SCIENTIFIC AMERICAN

SEPTEMBER, 1955 VOL. 193, NO. 3

THE PLANET EARTH

Presenting, on the eve of the International Geophysical Year, an issue solely devoted to geophysics: the study of the physical nature of man's terrestrial environment

Once a year this magazine devotes an entire issue to a single subject. This issue of SCIENTIFIC AMERICAN is concerned with the physical nature of the earth.

It is an appropriate time to reflect on our knowledge of the earth. The historic decision of U. S. scientists to attempt to launch an artificial moon within the next three years is a symbol of man's increasing ability to view the earth as a whole. This ability is also expressed in the plans for the International Geophysical Year, in which scientists of many nations will collaborate in a detailed examination of their planet. Although the Geophysical Year will not formally begin until July, 1957, for all practical purposes it is already under way. Led by the Comité Spécial de l'Année Géophysique Internationale, the nations are deep in preparation for the scientific work of the Year.

The Geophysical Year is by far the largest joint enterprise ever undertaken by scientists. There have been two cooperative studies of the earth in the past. The first International Polar Year was in 1882-83. The second Polar Year was 50 years later: 1932-33. Now, in keeping with the quickening pace of all the sciences, the third such undertaking comes after only 25 years.

During the Geophysical Year scientists of many disciplines will observe all the large-scale aspects of the earth: its interior, the oceans and glaciers, the lower and upper atmosphere, gravity and magnetism, and the extraterrestrial forces which profoundly influence these interacting features. From these observations will come a vast body of information which will take decades to analyze thoroughly. In the detailed program of the Geophysical Year, two main themes stand out. One is that the nations will join together to make the first extensive exploration and occupation, for purposes of geophysical observation, of the Antarctic continent. The other is that they will carry out synchronized observations from a network of points all over the world.

The Geophysical Year will achieve this integrated view of the earth in a number of ways. Each month there will be three regular World Days when certain phenomena will be observed in many places at the same time. Special World Days similarly will be designated. The world network for observations will include not only existing geophysical establishments and special expeditions but also three long chains of stations running from the Northern to the Southern Hemisphere. These stations will be along the meridians of 10 degrees east, 140 degrees east and 75 degrees west.

These concerted activities will inevitably increase knowledge of the unique physical environment which has resulted in the evolution of life and of man. They will also contribute to the easing of vexing conflicts of national and political interest. As Lloyd V. Berkner, vice chairman of the Comité Spécial, has written: "Tired of war and dissension, men of all nations have turned to [the earth] for a common effort on which all find it easy to agree."

FRONTISPIECE of this issue shows a man holding a Polynesian navigation map representing the region of Jaluit, Namork, Kili and Ebon in the Marshall Islands and Mankin in the Gilberts. Behind the map is a globe devised in about 145 B.C. by Crates of Mallus. Embodying the views of the Stoic school, the globe divides the earth into four quarters separated by oceans. It thus poetically anticipates the discovery of North and South America and Australia.

The Voyage of the Atka

Although the International Geophysical Year is in 1957-58, it has actually begun. An icebreaker has cruised to Antarctica not only to survey sites for the IGY but also to gather geophysical facts

by Paul A. Humphrey

The International Geophysical Year is nearly two years off, but already preparations for that great exploration are well under way all over the world. Research parties are being organized; special equipment is being built; sites are being reconnoitered for stations in remote corners of the earth. The voyage of the *Atka* was a reconnaissance of one of the most important areas that will be explored. A brief account of the voyage will illustrate the dimensions of the planned study of our planet and how the world's scientists will go about the investigation.

No region on the earth excites more curiosity among geophysicists than the Antarctic. It holds the world's greatest ice sheet and is a major hub of the earth's magnetic and meteorological activity. Its lands, atmosphere, climate and physical traits are still largely unknown; vast areas of the Antarctic continent have never even been seen by man. The Antarctic therefore will receive special attention during the IGY. At least 10 countries will man stations in the region: the U. S., the U.S.S.R., Great Britain, France, Norway, Australia, New Zealand, Argentina, Chile and Japan. Two international conferences have already been held—in Rome last year and in Paris this summer—to allocate sites and coordinate the plans. All told there will be some 31 stations. The U. S. will have six, of which three will be major bases—at Little America, in Marie Byrd Land and near the South Pole [*see map on pages 52 and 53*].

In the Southern Hemisphere summer of 1954-55 a party of U. S. scientists and Navy men voyaged to Antarctica in a Navy icebreaker, the U.S.S. *Atka*, to survey possible sites for stations on the coast and to make some preliminary scientific studies. The *Atka*, leaving Wellington, New Zealand, on January 7, approached the Antarctic continent on the Pacific side. When the ship arrived at the continental ice shelf, it soon became apparent that the coast had changed drastically since U. S. Navy icebreakers had last visited it in 1948. Discovery Inlet, a landmark used by previous expeditions, had disappeared, and at its location the ice edge of the continent had retreated some 10 miles; that is, part of the ice shelf extending from the continent had broken off and its edge was now 10 miles farther south.

The *Atka* turned and sailed along the coast toward the Bay of Whales, the location of Little America. The bay, an indentation in the Ross Ice Shelf, has been known in one form or another for more than a century; it was the shore base for five expeditions. In recent years the bay has been narrowing. Now the *Atka* found it gone altogether. At first sight it seemed that the Little America camps also had disappeared, but a careful scrutiny of the shore with binoculars disclosed several antenna poles still sticking above the snow.

The edge of the broken ice shelf was a steep cliff. With no bay ice to which to moor the ship, and no ramp for landing a small boat, the shelf was accessible only by helicopter. Helicopter landing parties discovered that the camps of Little America I (established in 1929), Little America II (1934) and Little America III (1940) were still there, though buried under snow; only a few feet of the 70-foot radio masts stood above snow level. But most of Little America IV, a camp established by a Navy expedition in 1947, had fallen into the sea. The break in the ice shelf had cut across its site. Gone were considerable amounts of stores and equipment, including six DC-3 airplanes, which scientists had hoped would be available for the IGY program.

A Quonset hut at Little America III proved to be buried under only a few feet of snow and was easily reached. The building inside was just as it had been left at the last visit in 1948, except that the floor appeared to have been arched upward a foot or two by the weight of snow. The temperature inside the hut was 11 degrees Fahrenheit—23 degrees colder than outside on the surface. Its stores and equipment were intact.

The position of the *Atka*, off the edge of the receding ice shelf at Little America, was determined to be at latitude 78 degrees 31.6 seconds south—the farthest point south ever reached by any ship except Roald Amundsen's *Fram*. The *Atka* stayed at Little America a few days for air mapping and studies of the snow and ice, but the work was limited by the fact that each helicopter could carry only the pilot, one passenger and about 100 pounds of equipment onto the ice shelf. During its stay in the area the ship sailed some 90 miles along the coast to map the ice front by radar. Then the *Atka* set off in search of a new location which might serve as the site of a main base.

About 40 miles northeast of the Little America camps the ship came upon a bay which looked promising. Called Kainan Bay, it has a flat ice surface roughly two miles square, with the suggestion of a ramp of snow leading to the top of the Ross Ice Shelf. The bay ice was attacked several times by the icebreaker, but it did not crack. This was a favorable sign that ships could moor and unload on it. Further surveys indicated that Kainan Bay was the only site suitable for a base in this vicinity.

It was on the ice shelf at Kainan Bay that one of the helicopter pilots was killed during a "white-out"—a cloudy sky condition which obliterates shadows and the horizon, making the ice indistinguishable from the sky. It appears that the pilot after take-off came out of a turn unaware that he was headed slightly downward, and the helicopter struck the ice surface at about 60 miles per hour.

After leaving Kainan Bay the *Atka* explored the shore around half the continent, from the Pacific to the Atlantic side. Attempts to break through heavy sea ice to Marie Byrd Land were unsuccessful. On the Atlantic side two promising bays were surveyed. The best location seemed to be a narrow bay about four miles deep at zero longitude.

The *Atka* then sailed for home through the Atlantic. Off the southern tip of South America it encountered many flat-topped icebergs (formerly part of the ice shelf). One was about 50 miles long, and its sides were pitted with deep blue grottoes as large as airplane hangars.

The scientific work conducted by the expedition ranged over much of the IGY program on a modest scale, embracing studies in meteorology, oceanography, glaciology, geomagnetism and cosmic ray and ionospheric physics.

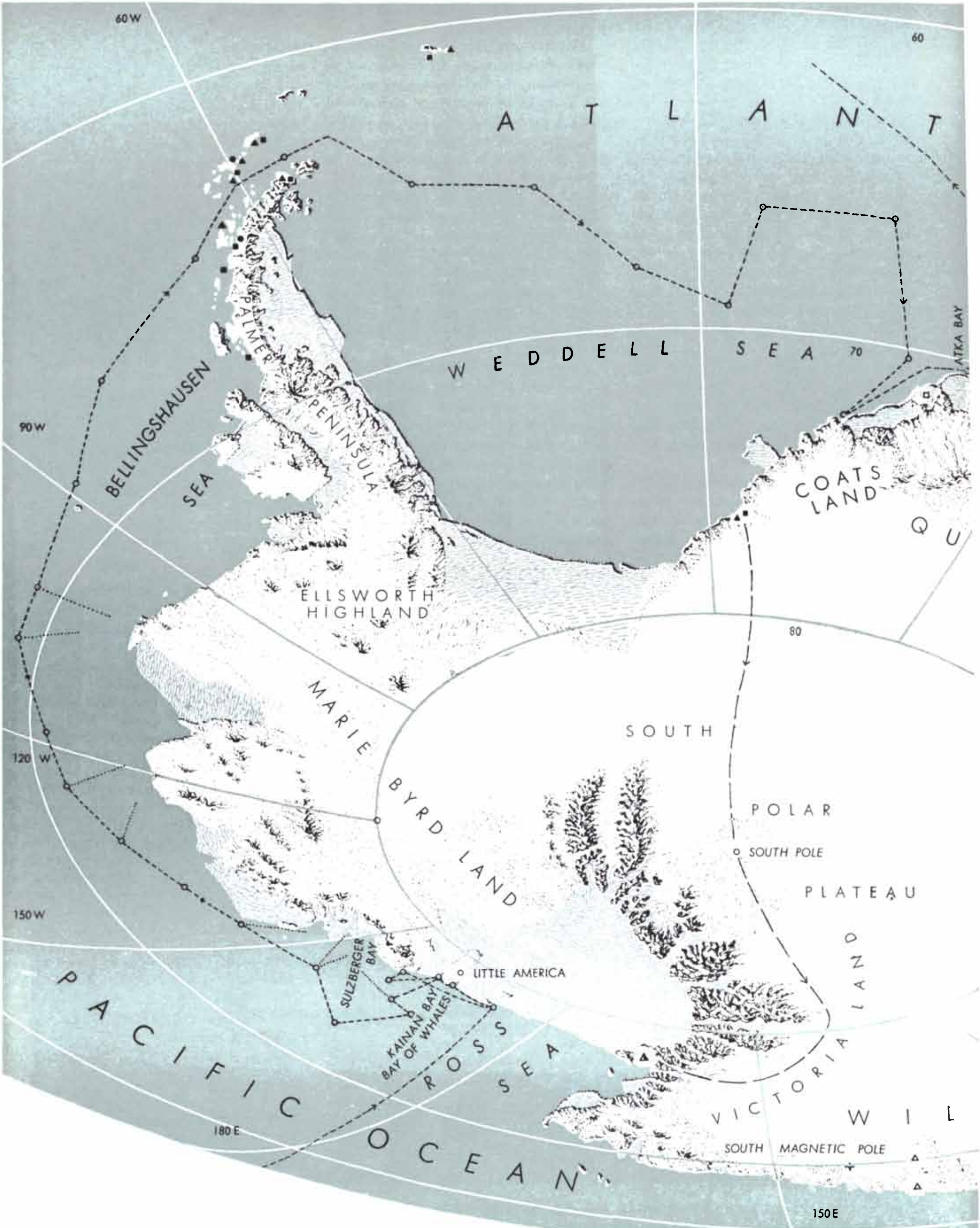
At Little America temperature measurements were made in the ice, cores were taken, the ice strata were studied and samples of snow were melted and bottled for analysis. Samples of the air also were collected, for measurement of its carbon dioxide content. Carbon dioxide in the air is believed to exert an important influence on climate, for it traps heat radiated from the earth like the glass in a greenhouse. The air was collected in high-pressure steel cylinders which originally carried helium for meteorological balloons; as the cylinders were emptied of helium, they were refilled with compressed air from the Antarctic atmosphere.

Twice each day balloons were sent to stratospheric heights for radiosonde recordings of temperature and humidity. The upper winds were estimated visually or by radar whenever there was an opportunity. At the surface hourly readings were taken of temperature and barometric pressure. Weather maps were made and analyzed to gain experience in Antarctic forecasting.

The *Atka* encountered no severe weather conditions in the Antarctic. The air temperature on the ship was usually in the neighborhood of 25 degrees F. (28 degrees F. is the freezing point of sea water). The lowest temperature observed on the ice shelf was about zero F. at Byrd Bay after sunset. No blizzards or snow storms worthy of mention occurred during the voyage. On the whole, conditions for scientific study were as good in the Antarctic as anywhere else on the voyage. The pack ice calmed the sea, and even while the *Atka* was plowing through the heaviest ice it was as steady as a railroad dining car. In the warmer latitudes the ship sometimes rolled badly, and temperatures in some parts of the vessel rose as high as 140 degrees F. near the equator.

The ship's meteorologists noted certain peculiar features of the Antarctic atmosphere which have been reported by previous expeditions: a persistent belt of deep low pressure systems surrounding the Antarctic continent; the low tropopause (boundary between the upper and lower atmosphere) characteristic of polar regions, and the fact that ap-

U. S. S. ATKA is photographed from the air alongside the Antarctic ice shelf. The *Atka* is a 5,000-ton vessel that is especially constructed to ride up over ice at the water level and break it with her weight. The ship will make another trip to the Antarctic this fall.

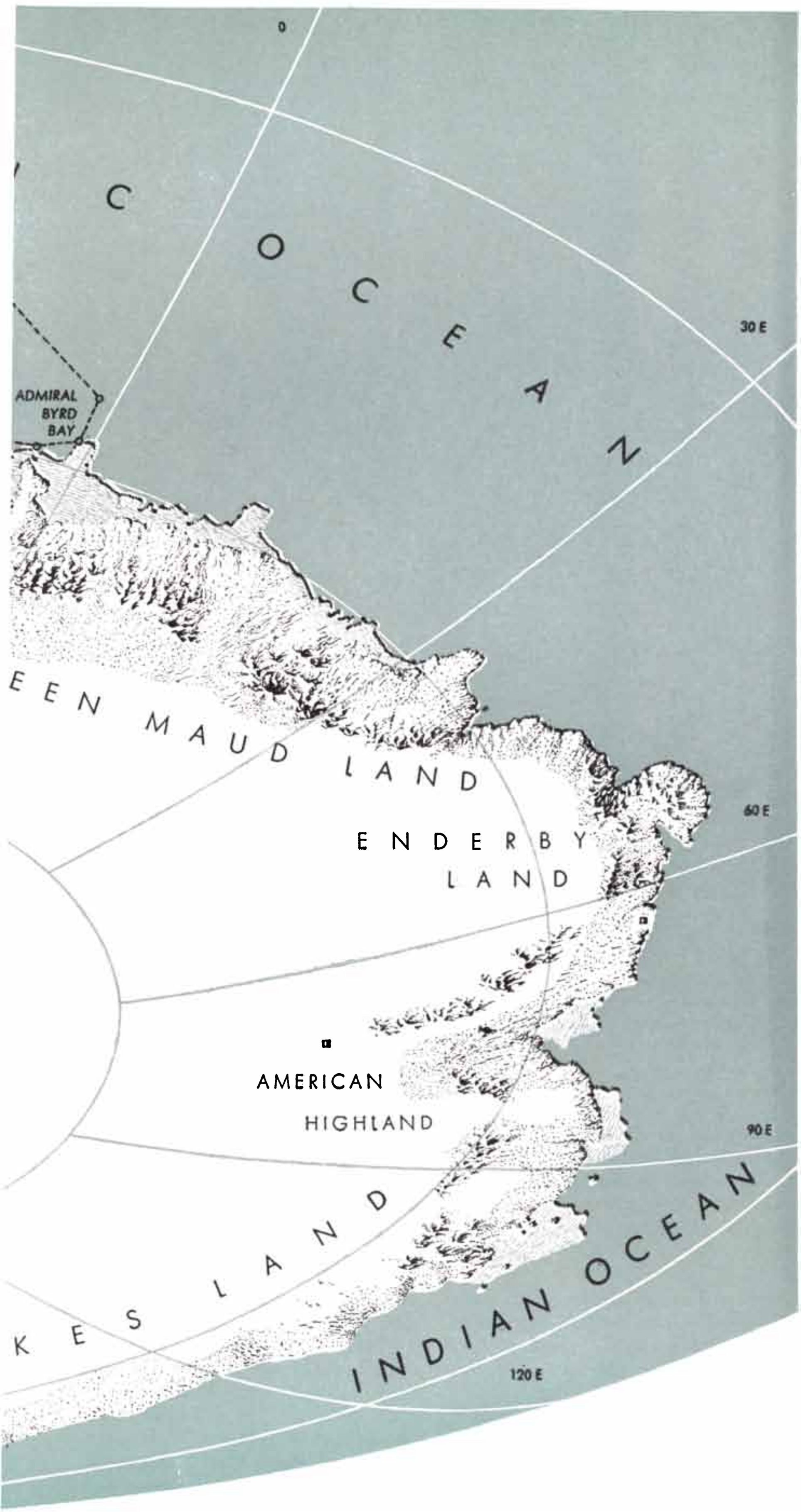

60 W
60
A T L A N T
WEDDELL SEA
70
ATKA BAY
BELLINGSHAUSEN SEA
PALMER PENINSULA
90 W
COATS LAND
QU
ELLSWORTH HIGHLAND
80
MARIE BYRD LAND
SOUTH POLAR PLATEAU
SOUTH POLE
120 W
150 W
SULZBERGER BAY
LITTLE AMERICA
KAINAN BAY
BAY OF WHALES
ROSS SEA
PACIFIC OCEAN
VICTORIA LAND
WIL
SOUTH MAGNETIC POLE
180 E
150 E

proaching fronts frequently failed to produce the high cirrus clouds that usually herald fronts in other latitudes. The expedition saw no aurora, as there was almost continuous daylight during its visit in the Antarctic zone.

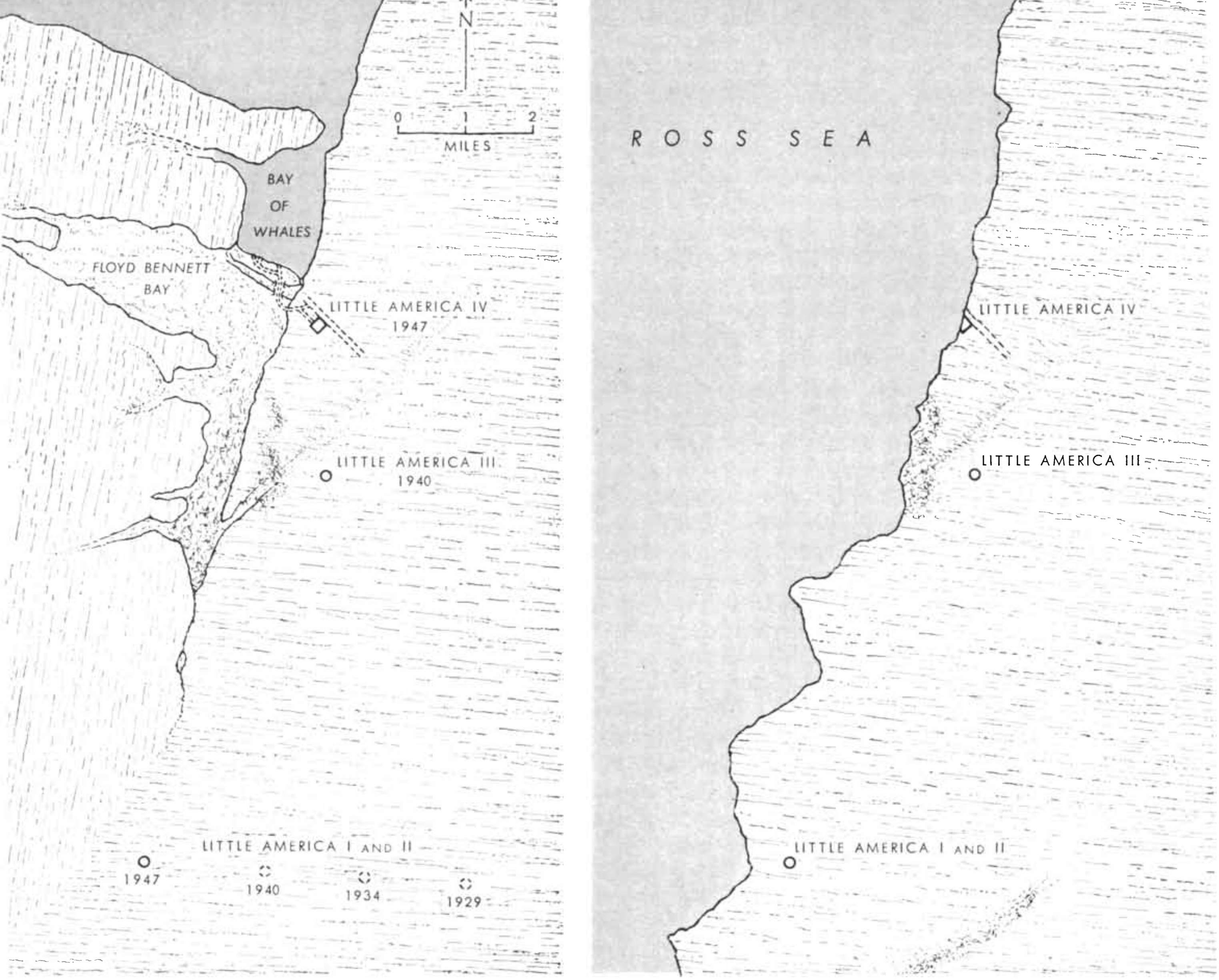
In the ocean hourly measurements were made of the water temperatures to depths of 900 feet by means of the bathythermograph; ice conditions were mapped; samples of the sea bottom were taken whenever the ship was in shallow water; the transparency and salinity of the water were measured; plankton was collected when possible. The *Atka* collected samples of surface water, rain water, snow and ice as part of a world-wide study of the distribution of deuterium oxide (heavy water).

The ship made continuous soundings of the depth of the ocean throughout the cruise. Much of its route was over areas where few soundings had been taken before. The *Atka* found some apparent errors in the charts of the Maria Theresa Reefs in the Pacific, and it made the first U. S. survey of the seldom visited St. Paul's Rocks in the mid-Atlantic near the equator.

On the Antarctic continent the expedition mapped some little-known areas and



ANTARCTICA is a continent of about five million square miles, or nearly twice as large as Australia. It lies almost wholly within the Antarctic Circle (latitude 66 degrees, 30 minutes). More than three million square miles of it remain unexplored. On this map the unknown region is suggested by the open areas. The mountain regions which have been surveyed to some extent are those closest to the coast. They include peaks up to 15,000 feet, some of which are active volcanoes. Only certain major areas are named on the map. Those bases, some old and others only projected, which various nations have already designated for the International Geophysical Year are marked on the map by symbols identified in the legend. The proposed British route across the continent is traced, as is the voyage of the *Atka*.



LITTLE AMERICA AREA on the Ross Shelf Ice is shown in these two maps. The map at the left indicates the general location of the camps and their relationship to the Ross Sea and Bay of Whales in 1947. The map at the right shows them as they were discovered by the men of the *Atka* this year. The northward-moving West Ross Shelf ice had sheared off from the westward-moving East Ross Shelf ice along the line of pressure ridges which divided them. Part of Little America IV, the most recently occupied camp, was lost.

prominent features by aerial photography and astronomical location of positions. Father Daniel Linehan, of the Weston Observatory of Boston College, measured the angles of the earth's magnetic field in the Antarctic, and also made some seismic soundings on the ice shelf to determine the thickness of the ice and major features of stratification.

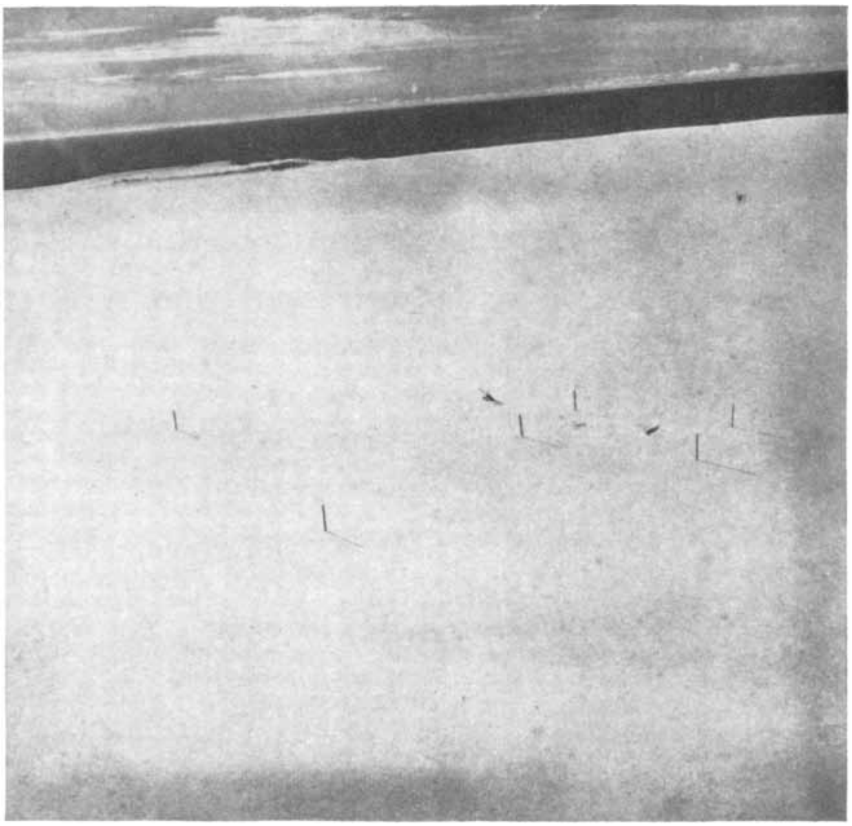
Probably the most important of the special scientific programs aboard the *Atka* were cosmic ray investigations conducted by the Australian Keith B. Fenton in a project jointly sponsored by the cosmic ray laboratories of the University of Chicago and the Canadian National Research Council. A special steel cabin was built on the *Atka* to protect the required electronic equipment and to serve as a laboratory. The cosmic ray measurements were carried on 24 hours a day from the moment the ship left Boston in the autumn of 1954 until it returned to Boston in April, 1955.

One of the chief purposes of these observations was to explore the earth's outer magnetic field. As cosmic ray particles come in from outer space, the magnetic field deflects them and tends to drive them toward the geomagnetic poles. John A. Simpson of the University of Chicago Institute of Nuclear Studies had discovered in 1948 that the concentration of neutrons, produced in the atmosphere by the cosmic rays, increases markedly from the equator to the poles. Consequently it should be possible to trace the magnetic equator by finding the circle of minimum neutron intensity around the earth. The *Atka* crossed this equator on opposite sides of the world—once in the Pacific and once in the Atlantic. The cosmic ray measurements have not yet been fully analyzed, but Simpson judges from his studies of them so far that the earth's outer magnetic field is distributed somewhat differently from what was supposed; that is, the plane of the magnetic equator is tilted from the geographic equator more than was thought. This of course would have a bearing on studies of the ionosphere.

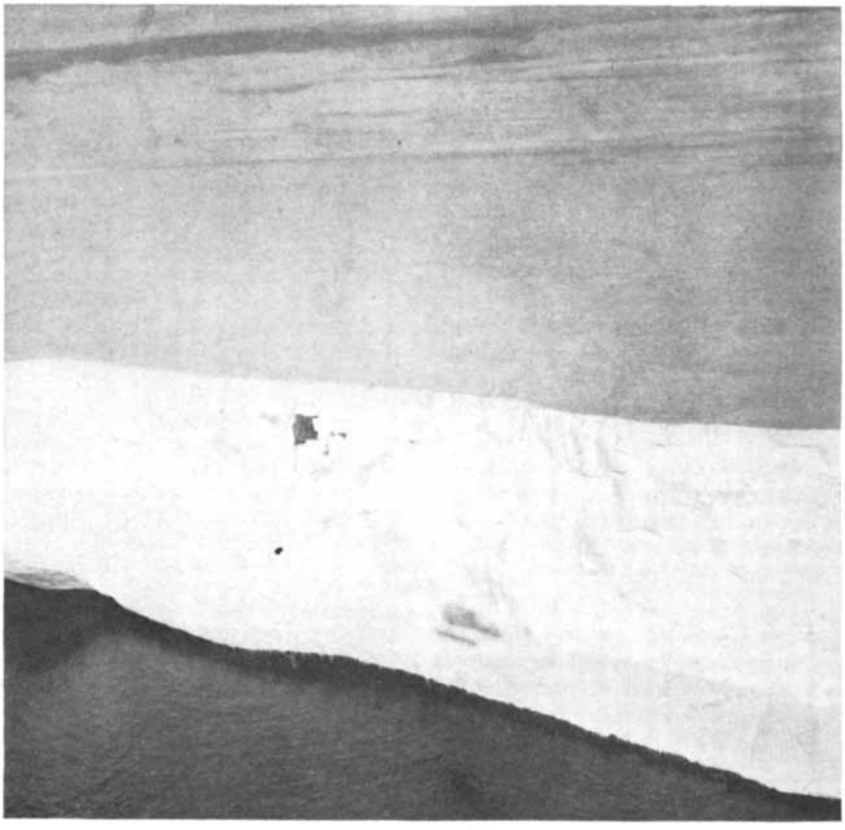
In the expedition's investigations of the ionosphere, a particularly interesting program had to do with a recently discovered phenomenon which may be used some day for long-distance radio communication. The discovery is that with suitable equipment one can sometimes hear certain peculiar whistles from the atmosphere. These whistles are believed to originate in lightning. L. R. O. Storey of England's Radar Research Establishment in Malvern suggests that some of the energy from a lightning flash follows the lines of the earth's magnetic field. Traveling along the magnetic meridian, it soars out of the atmosphere, reaches a height of 8,000 miles above the equator, and comes to earth again in the opposite hemisphere at the magnetic point corresponding to the one where it originated. In other words, if it starts at the north geomagnetic pole, it goes to the south magnetic pole; if it originates at 45 degrees north geomagnetic latitude, it comes down at about 45 degrees south magnetic latitude. After striking the earth the energy is deflected back to the point of origin along the same path.

Amory H. Waite of the U. S. Army Signal Corps, a veteran of three Antarctic expeditions, listened for such whistles on the *Atka* and recorded the noises he heard. At the same time observations were being made in two laboratories thousands of miles to the north—at the National Bureau of Standards radio laboratory in Boulder, Col., and at Stanford University in California. Waite kept a special vigil for whistles when the *Atka* was near the geomagnetic positions in the Southern Hemisphere corresponding to those of the two laboratories in the Northern Hemisphere. In the observations of whistles attention was given to their number, character and duration and to the effects of time of day and season.

The voyage of the *Atka* is significant for many reasons. Besides its scientific work, it represented the first major operational step of the U. S. in the launching of our portion of the IGY effort, and it prepared the way for setting up our bases in the Antarctic. A large Navy mission will go there this fall. Two icebreakers, two or three freighters and a fuel tanker will establish a station at or near Kainan Bay and land equipment and supplies for other bases. The station near the South Pole will have to be airlifted, and the Marie Byrd Land station will be established by tractor trains.



AIR VIEW of Little America III camp of 1940, made from a helicopter attached to the *Atka*, looks west over the site toward the open Ross Sea. In the middle are radio masts.



BROKEN SHELF of the East Ross ice was also photographed from a helicopter. A torn tent marks where the shelf sheared off. The helicopter's shadow is near bottom center.

THE INTERIOR OF THE EARTH

Perhaps more inaccessible than the nearest star, it is revealed by earthquakes. These indicate that matter in the earth's inner core is so highly compressed that it is twice as rigid as steel

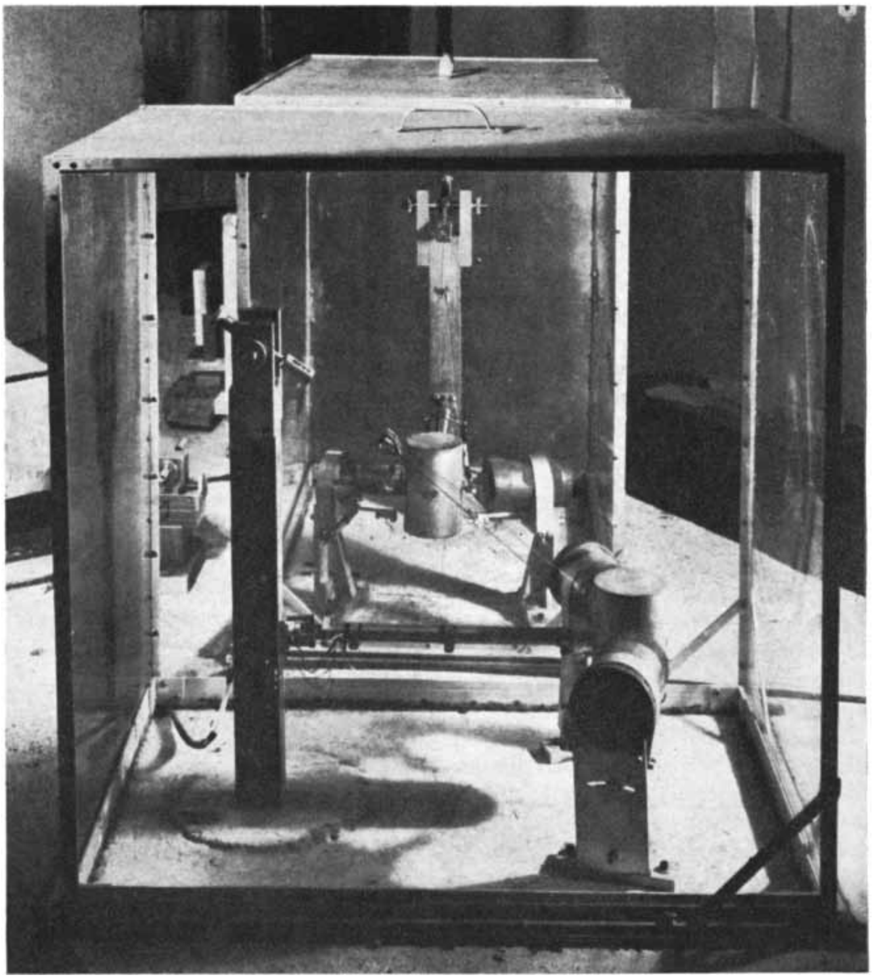
by K. E. Bullen

Each year 10 or more major earthquakes shake the earth. The smallest of them releases about a thousand times more energy than an atomic bomb; the Assam earthquake of August, 1950, had about 100,000 times that energy. The waves set up by these convulsions travel through the whole interior of the earth, including the core, and their paths are bent and shaped by the shells of the earth's internal structure. Thus the seismic waves bear clues of the regions they traverse, and from the story they tell when they are received at our seismological stations on the surface it is possible to infer a picture of the interior. In effect the seismologist X-rays the earth, even if at times he sees through a glass, darkly.

Seismology has lifted our notions about the interior of our planet from the realm of wild speculation to the stage of scientific measurement and well-reasoned inferences. Combined with geological information about surface rocks, laboratory experiments on rocks at high pressures and certain astronomical observations, it gives us a basis for learning something about the various conditions in the deep interior—its layered structure, the materials, their physical state, the pressures and so on.

The study of earthquakes is a fairly new science. In 1750 a writer on the subject in the *Philosophical Transactions* of the Royal Society of London apologized to "those who are apt to be offended at any attempts to give a natural account of earthquakes." But observations of earthquake effects accumulated, and late in the 19th century seismology began to emerge as a real quantitative science when the Englishman John Milne constructed in Japan a seismograph suitable for world-wide use. The seismograph was later developed further, notably by E. Wiechert in Germany, by Prince Galitzin in Russia and recently by Hugo Benioff of the California Institute of Technology.

The release of elastic strain energy at the source, or "focus," of an earthquake produces waves which begin to radiate in all directions from the focus. In 1897 R. D. Oldham of England identified on seismograms three main types of seismic waves: (1) primary (P) waves, which are compression-and-expansion waves like those of sound; (2) secondary (S) waves, which vibrate at right angles to the direction of travel, as



TWO SEISMOMETERS are photographed at the Lamont Geological Observatory of Columbia University. They consist essentially of three pendulums: one for each dimenlight waves do; (3) surface waves, which appear in the upper 20 miles or so near the earth's surface. The P waves travel through both solid and liquid parts of the earth; the S waves only through solid.

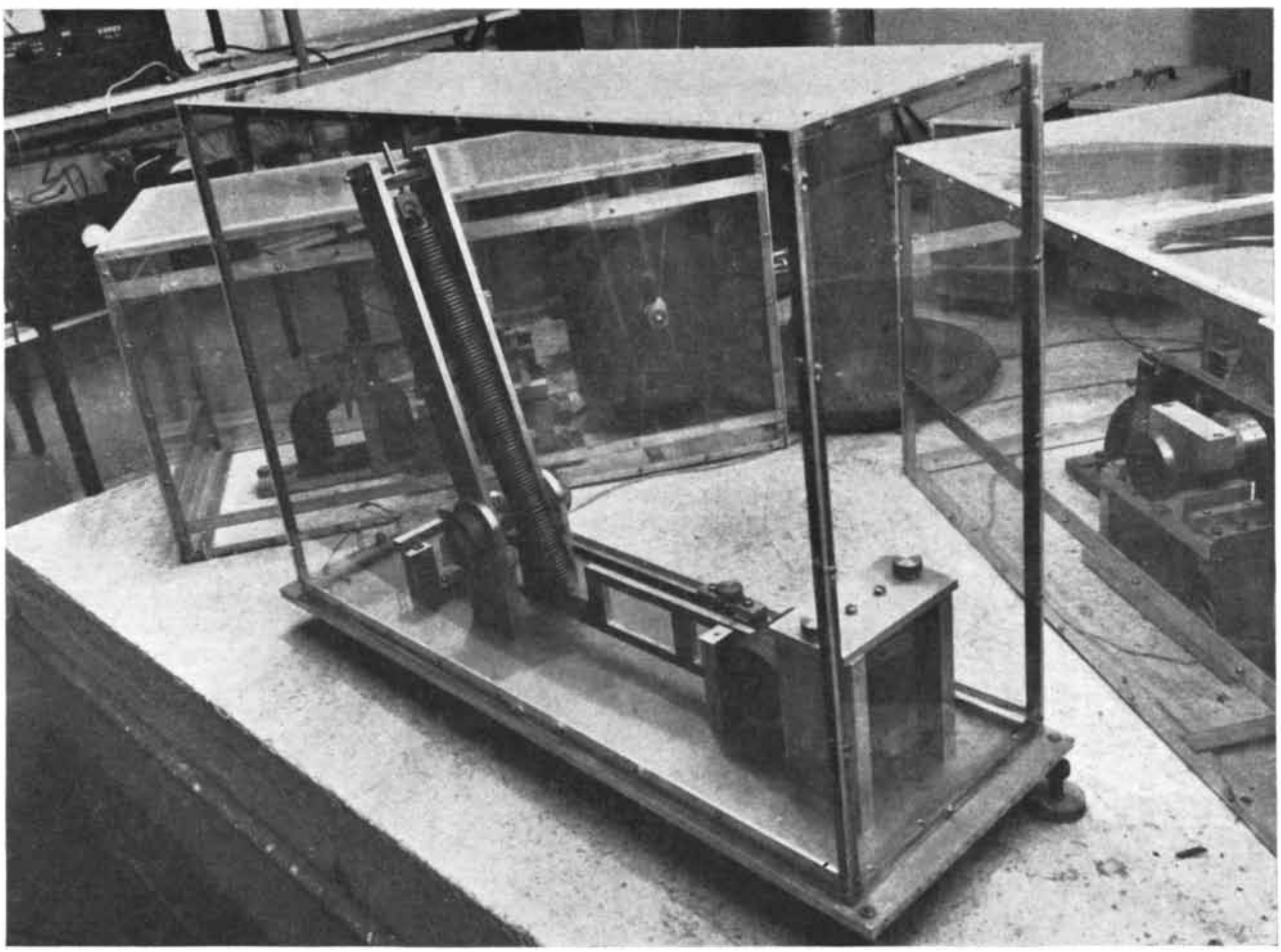
S waves travel at about two thirds of the speed of P waves. The speed of both varies with depth in the earth; for example, the P waves travel at 8½ miles per second, their maximum speed, at a depth of 1,800 miles and at about three miles per second in rocks near the earth's surface. Because of the change of speed, the path of the waves' travel usually curves upward. When they arrive at a boundary between layers they may be refracted or reflected, and on reaching the earth crust they are reflected downward again. At a boundary either a P or an S wave may give rise to both P and S waves. Thus any one seismogram from a particular earthquake may show many distinct phases, signifying the stages of the waves' routes and their changes of form. A typical seismogram illustrating several phases is shown on the next two pages.

With this kind of evidence Oldham proved in 1906 that the earth has a large central core, and in 1914 Beno Gutenberg, then in Germany, located the boundary of the core at 1,800 miles below the earth's surface. Since the radius of the whole earth is about 3,960 miles, the central core has a radius of some 2,160 miles.

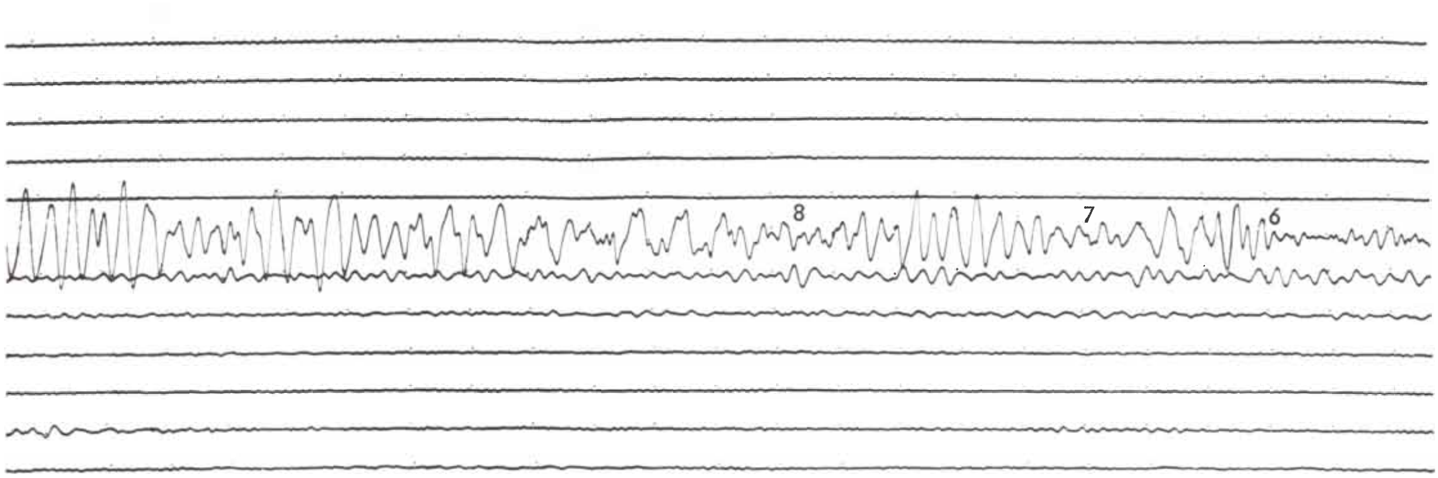
The discovery of the core came about from the observation of shadow zones where relatively few P waves were recorded. Consider P waves issuing from a major earthquake with its focus at the South Pole. These waves would be observed at the surface throughout the Southern Hemisphere and up to 15 degrees above the equator (*i.e.*, the latitude of Guatemala) in the Northern Hemisphere. But between the latitudes of Guatemala and Winnipeg little indication of P waves would be received. Then, from a latitude of 52 degrees north to the North Pole, the waves would come in again strongly. The whole of the U. S. would thus be part of a "shadow zone" for that earthquake. On examination, it was seen that the existence of such shadow zones required the presence of a central core which would bend sharply downwards the seismic rays striking it from above, somewhat after the manner in which light rays from a stick in water are bent by the water surface.

One of the great labors of seismologists during the first 40 years of this century was to evolve reliable tables for the times of travel of P and S waves along the various phases of their routes. In 1930 Sir Harold Jeffreys of the University of Cambridge, suspecting that the existing "travel-time tables" contained large errors, began a long series of studies to correct them. The author of this article was associated with Jeffreys in this work from 1931 to 1939.

The Jeffreys-Bullen tables of 1940 are now used internationally. They agree closely, in the main, with travel times derived about the same time by Gutenberg and Charles F. Richter at the California Institute of Technology. The travel-time tables are of cardinal importance for charting the structure of the earth's



sion. When the earth shakes, the pendulums tend to stand still. Their apparent motion is then recorded by a pen or a beam of light. One of the pendulums, suspended by a horizontal arm and two diagonal wires, is visible at right in the photograph at left.



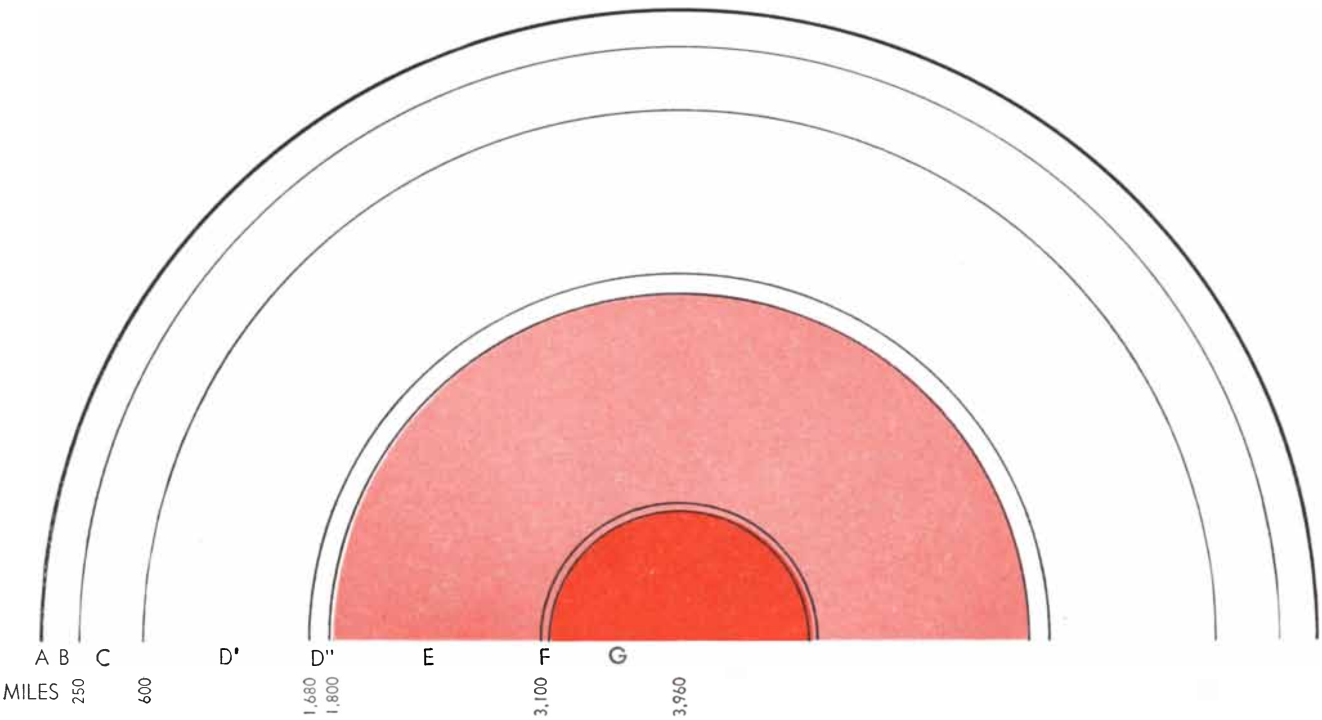
SEISMOGRAM of an earthquake on the Kamchatka Peninsula in Siberia was recorded at the Lamont Geological Observatory. The separate lines are actually part of a continuous spiral trace, going from right to left, on a circular drum. The interval between succes-

interior. It is possible to deduce from the tables the velocities of P waves and S waves in various parts of the interior. Studying the variations of velocity with depth, one can chart different layers and locate boundaries.

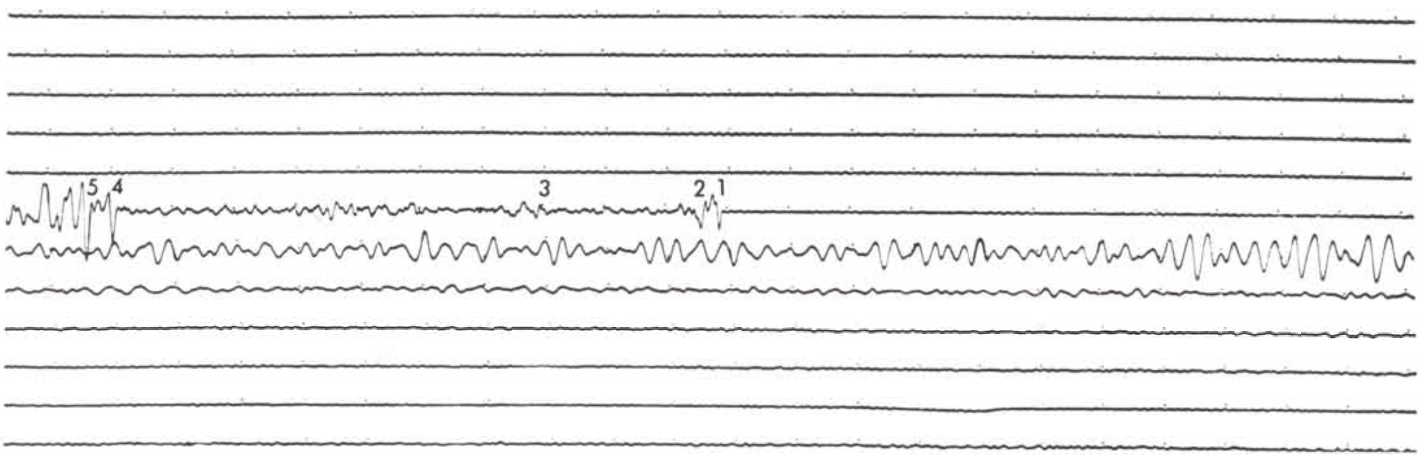
With the new tables Jeffreys calculated that Gutenberg's measurement, placing the boundary of the central core at 1,800 miles below the earth's surface, was correct within three or four miles. At least the outer part of the core is judged to be molten. S waves do not pass through it, and its fluid character is established by other evidence, including data on the tidal deformation of the solid earth and astronomical data on the movements of the earth's poles. H. Takeuchi of Japan has calculated that this region is at most one 300th as rigid as the next outward layer.

The use of the terms "solid" and "fluid" in connection with the huge pressures prevailing in the earth's interior is sometimes questioned. What a geophysicist means by the term "solid" in this context is simply that the elastic behavior of the material in question can be described by equations which match those applying to ordinary solids in normal laboratory conditions. These equations involve the use of two coefficients: "incompressibility," which is the measure of resistance to pressure, and "rigidity," signifying resistance to shearing stress. In the case of a fluid, the resistance to shear is much smaller than the resistance to compression. This is why a fluid does not transmit S waves.

All the earth outside the core is called the mantle. The whole of the mantle (apart from the oceans and pockets of magma in volcanic regions) is now known to be essentially solid: both S and P waves travel through every part of it.



EARTH'S CROSS SECTION is divided into distinct layers through which seismic waves travel at different speeds. The outer core is indicated by the lighter tone of color; the inner core, by the darker tone of color. Layer A is the thin crust of the earth.

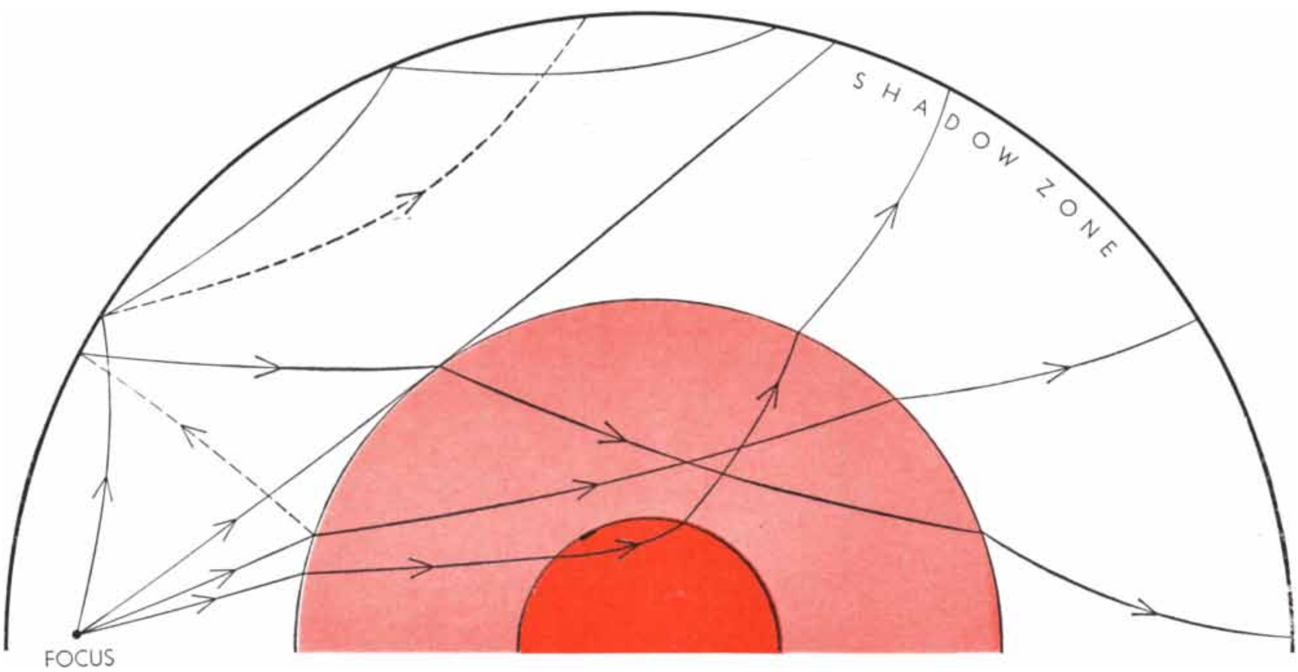


sive dots is one minute. The first disturbance recorded was the P wave designated by the number 1. Then followed the multiply reflected P waves 2 and 3. S waves begin at position 4, followed by multiply reflected waves at 5, 6 and 7. Surface waves start at 8.

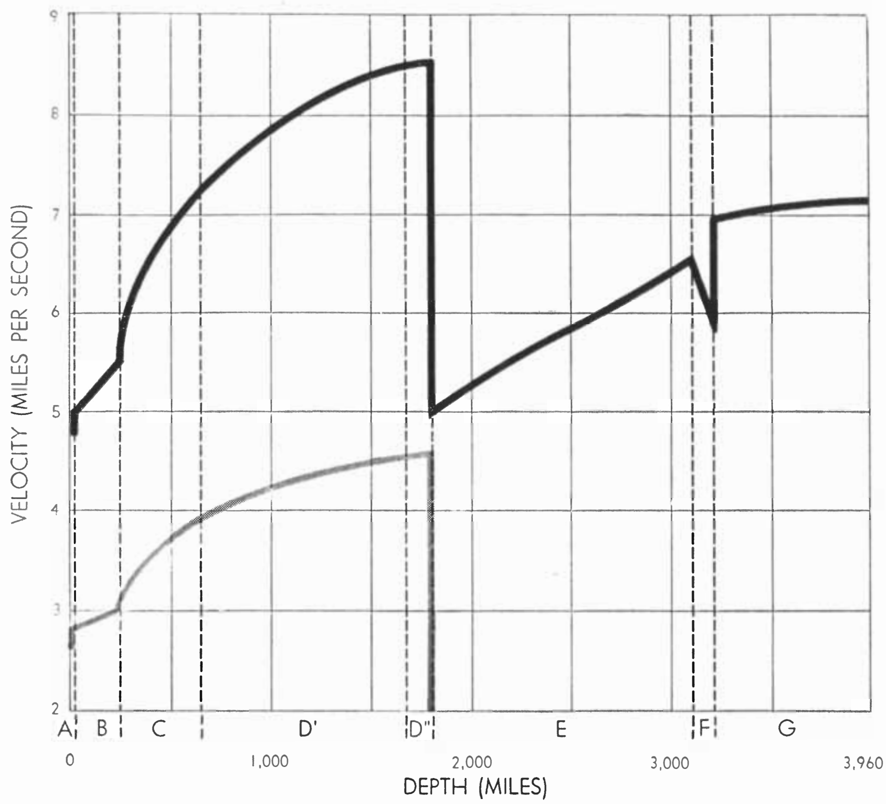
In 1909 the Croatian seismologist A. Mohorovicic, studying the seismograph of a Balkan earthquake, discovered an important discontinuity (boundary) now known to be some 20 miles below the earth's surface. The part of the earth above the Mohorovicic discontinuity has come to be called the crust. But nowadays the term "crust" has only a conventional meaning. According to seismic evidence the crust is not more rigid than the material just below it.

Seismologically speaking, the crust differs from the underlying part of the mantle in the fact that P and S waves travel in it more slowly and with more variable speed. This irregularity of travel velocity makes detailed charting of the crust difficult. The work is being pursued vigorously, however, by the study of surface waves, of P and S waves from near earthquakes (near the recording station), of waves from large man-made explosions (such as the one on Helgoland in 1947) and by seismic probings with dynamite, as in oil prospecting. One important discovery has been that the crust is much thinner under the continents than under the oceans.

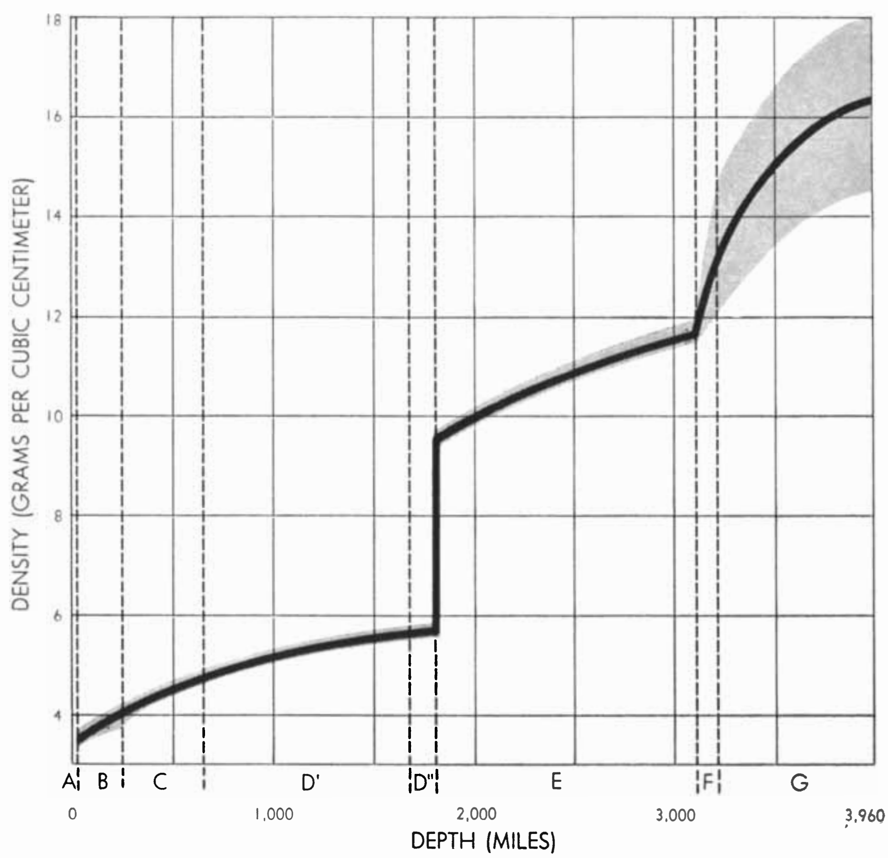
Seven distinct regions or shells have now been identified in the earth. In 1936 Miss I. Lehmann of Denmark discovered that the core was not uniform but seemed to consist of at least two different parts. Looking closely at the relatively minor P waves that emerge in the shadow zone on the surface, she concluded that these waves might come to the surface because they were bent sharply upward by an inner core where P waves traveled faster than in the outer core. Her proposal later received support from work by Gutenberg, Richter and Jeffreys. The inner core has a radius of some 800 miles, so the thickness of the



EARTHQUAKE WAVES are bent and reflected as they travel from their source. Solid lines represent P waves, dotted lines are S waves formed by reflection. The only P waves that can get into the shadow zone are those which enter the inner core and are sharply bent.



SEISMIC WAVE SPEEDS vary with depth. The black line gives velocities of P waves; the gray line, of S waves. Both change abruptly at core, or E layer, and the S wave disappears.



DENSITY of the earth's material increases with depth. The solid line shows the most probable value at each depth and the gray region outlines the probable range of uncertainty.

outer core would be about 1,300 miles.

On the basis of density variations the writer has divided the body of the earth into seven regions, called A, B, C, D, E, F and G [*see diagram on page 58*]. The A region is the crust. The rest of the mantle below is divided into B, C and D, with D subdivided into D′ and D″. These divisions are still tentative because of certain uncertainties in estimates of velocity gradients. The outer part of the core is called E, and the inner part, G. Between the inner and outer core Jeffreys finds a layer F, some 80 miles thick, where the velocity of P waves declines sharply. Gutenberg has not found this layer, but has said that his data do not exclude its existence.

How can we estimate the pressures and physical characteristics of matter at these various depths in the body of the earth? The velocities of P and S waves are determined by the density, compressibility and rigidity of the material through which they pass, but they do not provide enough information to solve exact equations for those values. There are, however, indirect clues which help us to arrive at estimates—information on the earth's mass and moment of inertia, field observations and laboratory experiments on rocks, mathematical theories of elasticity and gravitational attraction.

By such means the writer has estimated that the earth's density increases gradually from 3.3 grams per cubic centimeter just below the crust to 5½ grams per c.c. at the bottom of the mantle, then jumps suddenly to 9½ grams at the top of the core and thereafter increases steadily to 11½ grams at the bottom of the outer core.

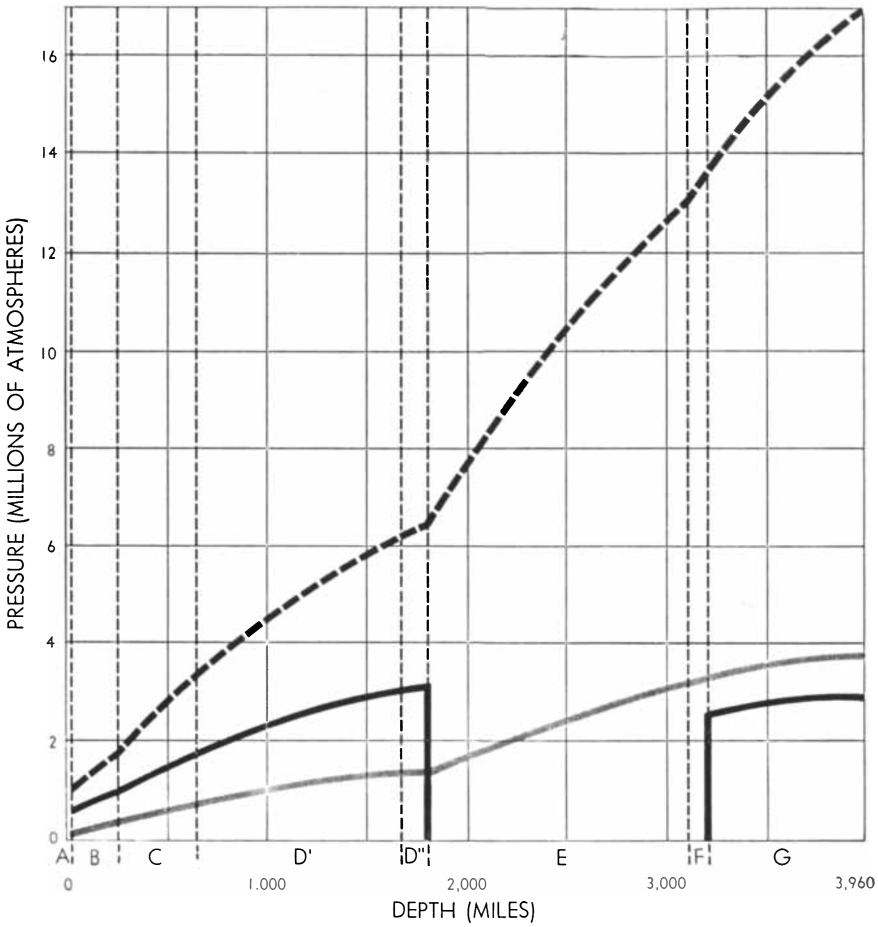
A related calculation gave the increase in pressure with depth in the earth. At the bottom of the Pacific Ocean the pressure is about 800 atmospheres. Only 200 miles down in the mantle the pressure is already 100,000 atmospheres—as great as the highest pressure Percy W. Bridgman of Harvard University has been able to produce in the laboratory. At the base of the mantle, 1,800 miles down, the pressure reaches the immense figure of 1⅓ million atmospheres, and at the center of the earth it is nearly four million atmospheres.

Next the calculations yielded the surprising finding that the rigidity of the material in the mantle increases with depth until, at the mantle's base, it is nearly four times that of steel in ordinary conditions. Below this, in the outer core, the seismic evidence shows that the rigidity sinks to practically zero, meaning that the material is essentially fluid.

Perhaps the most important fruits of this series of calculations have been the findings on compressibility. In spite of the sharp changes in density and in rigidity at the boundary between the mantle and the core, the compressibility of the material does not change substantially at the boundary, according to the calculations. This finding led the writer to examine the theoretical effect of pressures of a million atmospheres or more on materials likely to be present in the core. Taking into account a variety of evidence, the conclusion was that bounds could be set to the compressibilities of materials in the core.

Following this line of argument, it seems highly probable that the inner core, unlike the outer core, is solid in the sense defined. The idea that the inner core is solid, suggested by the writer in 1946 and since developed, would explain the speeding up of P waves when they penetrate into the inner core. Calculation indicates that the inner core is probably at least twice as rigid as steel at ordinary pressures.

On the same line of evidence we can also estimate, as we could not before, the density of the inner core. Apparently at the center of the earth the density is between 14½ and 18 grams per cubic centimeter. Yet another inference is that the increase of density with depth in the inner core (and at the base of the mantle) is greater than average, implying some variability in the composition of that region.



ELASTICITY of the earth's interior is shown graphically above. The gray line measures pressure. Incompressibility is indicated by dotted black line; rigidity, by solid black line.

What is the deep interior of the earth made of? For many years there have been good grounds for believing that much of the mantle below the crust consists of ultrabasic rock such as magnesium-iron silicate. The region B seems to be composed of a material like the known mineral olivine. C appears to be a transition region where the composition changes, perhaps only from one geometric form of olivine to another. The region D′ may contain several distinct phases, such as silica, magnesia and iron oxide. The bottom of the mantle, D″, is probably of variable composition, but there is as yet no widely accepted agreement on what materials would have gravitated to this depth.

The composition of the central core has lately become the subject of extremely interesting new conjectures. It had long been assumed that the core consists largely of iron or nickel-iron, and this view was supported by analysis of meteorites, believed to be pieces of an exploded planet resembling the earth. But in 1941 W. Kuhn and A. Rittmann of Germany put forward the radical idea that compressed hydrogen made up the core. This theory, while contradicted by weighty arguments, gave rise to new investigations based on the idea that under increasingly high pressures the material at the base of the earth's mantle might suddenly jump in density. Thus the outer core may consist not of uncombined iron or nickel but of a high-density modification of the rocky material in the mantle just above it. This theory is highly controversial. On balance of probability the present evidence appears to favor a compromise: namely, that the outer core contains both uncombined iron and some material of appreciably smaller atomic number.

An interesting aspect of the new theory is that it makes plausible the idea that the planets Mars, Venus, Mercury and Earth are all of the same primitive over-all composition. Jeffrey has shown that the earth cannot have the same elemental composition as the other planets if its core is completely different from the mantle in composition. According to calculations by W. H. Ramsey of England and the writer, the observed masses and diameters of Mars and Venus, and the oblateness of Mars, would be accounted for fairly well by the theory that they are composed of terrestrial materials modified by pressure at depth.

As regards the earth's inner core, it probably consists of nickel and iron with perhaps some denser materials as well.

Estimates of the temperatures in the interior of the earth are much less certain than estimates of pressure. In deep mines the temperature rises at the rate of about 30 degrees Centigrade per mile as one descends. If it rose at this rate all the way down to the core the temperature in the center of the earth would exceed 100,000 degrees. Actually it is practically certain that the rate of increase is very much less in the depths of the earth. Present estimates are that the temperature at the center is no more than 2,000 to 6,500 degrees. In any case, it is fairly clear that the increase of temperature in the earth's interior is dwarfed by the increase in pressure.

The Origin of Continents

The evidence of the rocks suggests that the great land masses grew by cycles in which chains of volcanoes rose from the sea and sediment washed into the deep troughs along their flanks

by Marshall Kay

The continents and the ocean basins are distinctly different aspects of the earth's crust. Not only do the continents stand higher, but they are made of different material. The difference can be summed up roughly in two chemical terms: sialic and simatic. The continents are composed chiefly of sialic (for silica-alumina) rock, which is especially rich in silica and comparatively light in weight and color; the ocean basins are mainly simatic (silica-magnesium) rock, which is denser and darker. Because granite is the chief sialic rock and basalt the chief simatic one, the continents are most commonly described as granitic and the ocean basins as basaltic.

For decades it has been realized that any attempt to explain the origin of the continents and the oceans must account for this fundamental difference in the respective portions of the earth crust. Many hypotheses have been erected on theories as to how the earth itself was formed. Those who supposed that the earth grew by the coming together of small, cold bodies (planetesimals) reasoned that the difference between the oceanic and continental parts of the crust was due to chemical evolution: the areas covered with water developed differently from those exposed to the atmosphere. The much larger school who believe that the earth was originally a molten mass have suggested a great variety of other explanations. Many have argued that the cooling earth was once crusted over its whole surface with a thin layer of granitic material, and that this layer was later parted in places to expose the basalt underneath—either by gradual drifts of the granitic material which piled it in continents, or by catastrophic events, such as a great oscillation that tore a chunk out of the earth and threw it into space as the moon, leaving the hole that is now the Pacific Ocean. Others have proposed that the entire earth was originally basaltic, and that the separation of ingredients to form the differentiated oceanic and continental areas was started by deformations of the earth's outer layers. Still others have suggested that the granitic rocks crystallized and floated to the top as the molten earth cooled.

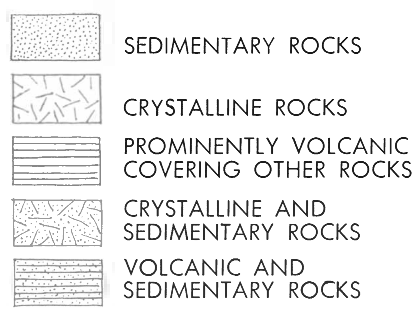
Many of these hypotheses have collapsed in the face of new information about the crust and the interior of the earth obtained during the past decade. The question as to how the continents and oceans were formed is approached by geologists from the opposite direction: instead of starting with speculations about the beginning of the earth and projecting hypotheses from those speculations, they start from the known facts about the present earth and work backward to reconstruct its unknown history. What we know about the continents and oceans gives us a number of clues for deducing their past.

Our firsthand information about the inside of the earth of course is still scanty: it is limited to studies of surface rocks, to soundings and samples of the ocean bottoms and to borings some four miles down into the earth's crust in mines and wells. But in recent years explorers of the interior have probed the earth deeply and intensively with revealing instruments. Foremost among them is the seismograph. Tracing the travel of waves from earthquakes and artificial explosions through the earth, timing their speed and plotting their paths, it has been possible to obtain a kind of X-ray picture of the earth's layered body. And this picture has been confirmed and filled in to some extent by gravity measurements which define areas and belts of differing density.

About three fourths of our planet is covered by ocean waters, but not all of that is actually oceanic basin, for the continents have broad shelves extending far out under a wash of shallow sea. The deep ocean basins—two miles or more below water level—account for about half of the earth's solid surface. These are the areas of the earth's crust that show a sharp contrast to the continents.

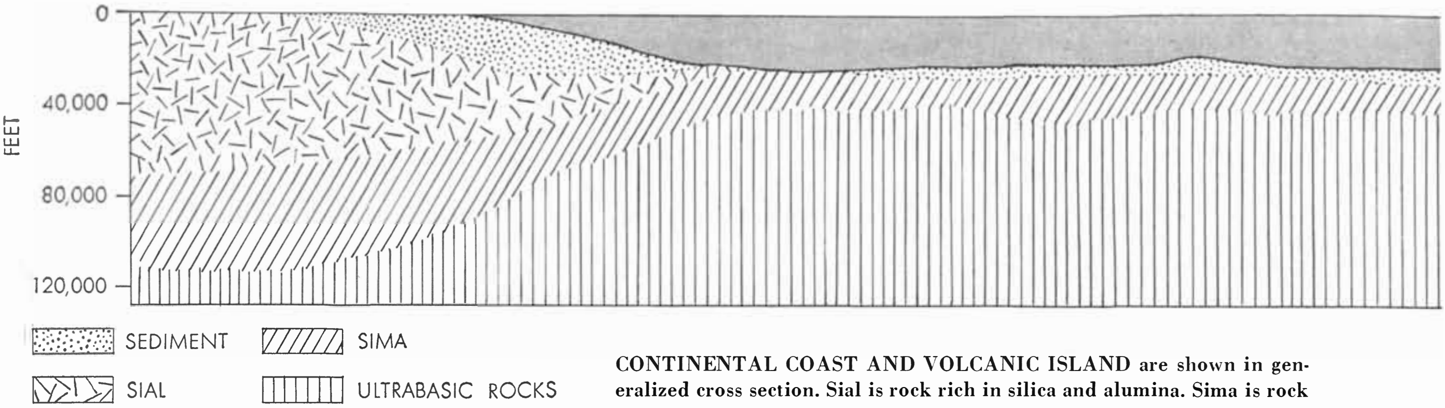
The conventional division between the crust and the "interior" of the earth is a boundary known as the Mohorovicic discontinuity—a transition zone between crystalline, basaltic rock and denser, noncrystalline rock beneath. This boundary is not level: it is lower under the continents than under the oceans. In other words, the continents not only stand higher but also plunge deeper into the dense sublayer. It is as if the crust of the earth consists of relatively light but thick continental blocks and thinner but denser oceanic blocks, both of which float on the substratum of the interior. As

SURFACE ROCKS of North America are classified on this map. The distribution of various types provides evidence for hypotheses on origin and growth of the continent.



measured by the seismic yardstick, the continental blocks are some 30 miles thick and the oceanic basins only about six or eight miles thick. The continental blocks are not granitic all the way down: at their base they have a layer of basalt, like the rock of the ocean basins.

Now to this general picture there are certain exceptions which look extremely significant. Some areas of the earth crust are neither strictly continental nor strictly oceanic—they seem to combine a little of both! These areas are the island archipelagoes: the islands of Japan; the chain consisting of the Philippines, the East Indies and New Guinea; nearer home, the West Indies. The principal islands in such chains have a dominantly continental character: their rock is chiefly granitic and the crust goes deeper than in the ocean basins. Yet each chain also includes parts which are dominantly oceanic; that is, they are underlain by a thin layer of basaltic rock (covered with sediments) and the crust is comparatively shallow. Gravity readings show long, sinuous bands of gravity deficiency, usually along the submarine troughs associated with the island chains. Seismic studies indicate that the island rock



CONTINENTAL COAST AND VOLCANIC ISLAND are shown in generalized cross section. Sial is rock rich in silica and alumina. Sima is rock

does not pass beneath the troughs. Apparently the gravity deficiency is due to the thinness of the crust under the trenches rather than to any downfold of granitic rock.

The island archipelagoes, then, are something intermediate between ocean basins and continents. Are they, perhaps, embryo continents in the process of growing up to become larger continents or additions to continents in the future? The question sends us back to examine the rocks of continents with a fresh eye and a hypothesis to investigate. Let us consider the North American continent. What light does the distribution of its various rocks throw on how the continent may have been formed?

The surface of a continent has two general classes of rocks (if we disregard the volcanic rocks, formed from lavas erupted onto the surface here and there). The first great class is the sedimentary rocks—the hardened remnants of sediments laid down by ancient rivers and seas. These are the sandstones, limestones, shales, marls and clays that cover much of our continent. In the central plains they lie in flat layers under the surface soil; in the mountain regions the layers may be tilted, warped, folded and broken, but the rock still has the same character and is unmistakably identified as sediment by the fossil remains of sea animals. These are the rocks that the prospector's drill probes in search of oil and gas. Along the Atlantic Coast the sedimentary rock is only a few thousand feet thick, but at the Gulf Coast in Texas and Louisiana it is piled to a depth of as much as eight to 10 miles.

If we peeled off the sedimentary layers, we would find below, mantling the whole continent, the second great class of rocks. This class includes two types: (1) the "plutonic" or "igneous" rocks, notably granite, and (2) the "metamorphic" rocks—schists, gneisses, quartzites, slates. The metamorphic rocks evidently are sedimentary rocks and lavas altered by heat and pressure. Just how the granites and other igneous rocks are formed is still a matter of debate; there is strong new evidence that they crystallize from molten magma deep in the crust [see "The Origin of Granite," by O. Frank Tuttle; Scientific American, April]. In any case, the metamorphic and igneous rocks are generally found together. And wherever we may go on the continents, if we drill deep enough we will find these rocks forming a "basement" beneath the sedimentary cover.

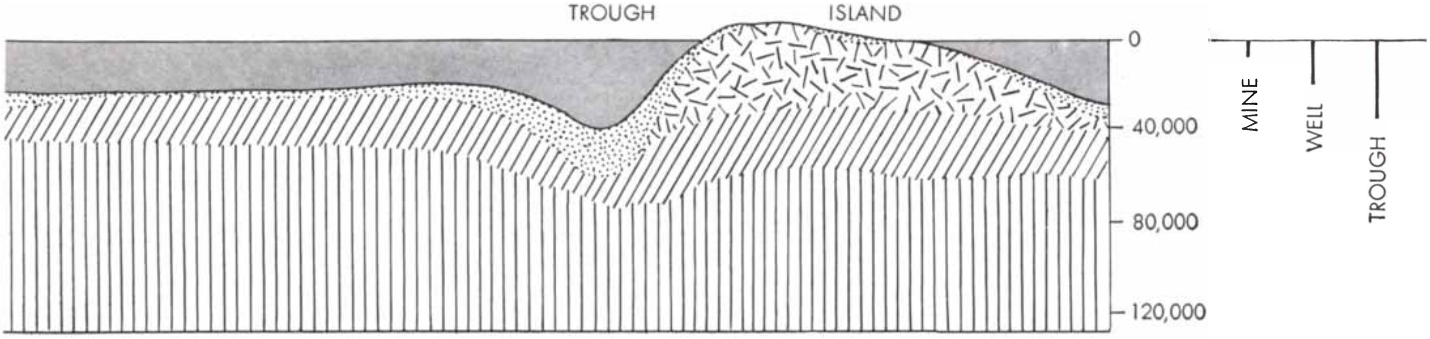
There are three large areas of North America where the granites and metamorphic rocks are not buried but form the surface of the continent. The first is a broad, circular region around Hudson Bay in Canada, extending east to the coast of Labrador and south into Minnesota, Wisconsin and New York where the granitic and metamorphic basement disappears under layers of sedimentary rock and slopes down gradually to its greatest depth at the Gulf Coast. The second belt lies along the Atlantic Coast from central Newfoundland to the Piedmont. The third is on the Pacific Coast from southern Alaska to the tip of Lower California.

This picture is somewhat simplified: parts of the Pacific Coast are covered by sedimentary rocks, and platforms of granite and metamorphic rocks appear in other, smaller, areas of the continent besides the three large ones mentioned. But if we concentrate our attention on these three great areas, we discover some significant relations which bear on the origin of continents.

In the belts along the Atlantic and Pacific Coasts, we can read in these rocks the record of a long series of mountain-building events, marked by the sinking of deep troughs in the crust and the rise of lands nearby. The troughs were deep enough to catch and pile up miles of sediments and volcanic rock, poured in from adjoining volcanoes. The sediments contain pebbles which must have been washed into them by streams eroding rather rugged lands. And they were invaded by granitic rocks and fluids which transformed them into metamorphic rocks. Moreover, some of the rocks along both the Pacific and Atlantic Coasts have intrusions of very basic rocks (unusually poor in silica) which must have come from considerable depth—peridotites and serpentines, including such rocks as the verd antique marble found in Vermont.

Several lines of evidence indicate that these belts of metamorphosed sediments and volcanic rocks with intrusions are the descendants of belts like the present island chains. (Indeed, the Pacific Coast belt still has an island arc—the Aleutians—extending from its northern end!) So we may deduce that the North American continent has grown on its western and eastern sides by the addition of what were once separate island archipelagoes. The period of upheaval and deformation that formed these additions to the continent seems to have ended, though there is still some unrest along the Pacific Coast. Dating events by the fossils and the radioactivity of rocks, it is judged that the time of principal activity along the Atlantic Coast ended about 200 million years ago, and along the Pacific Coast, perhaps 100 million years ago.

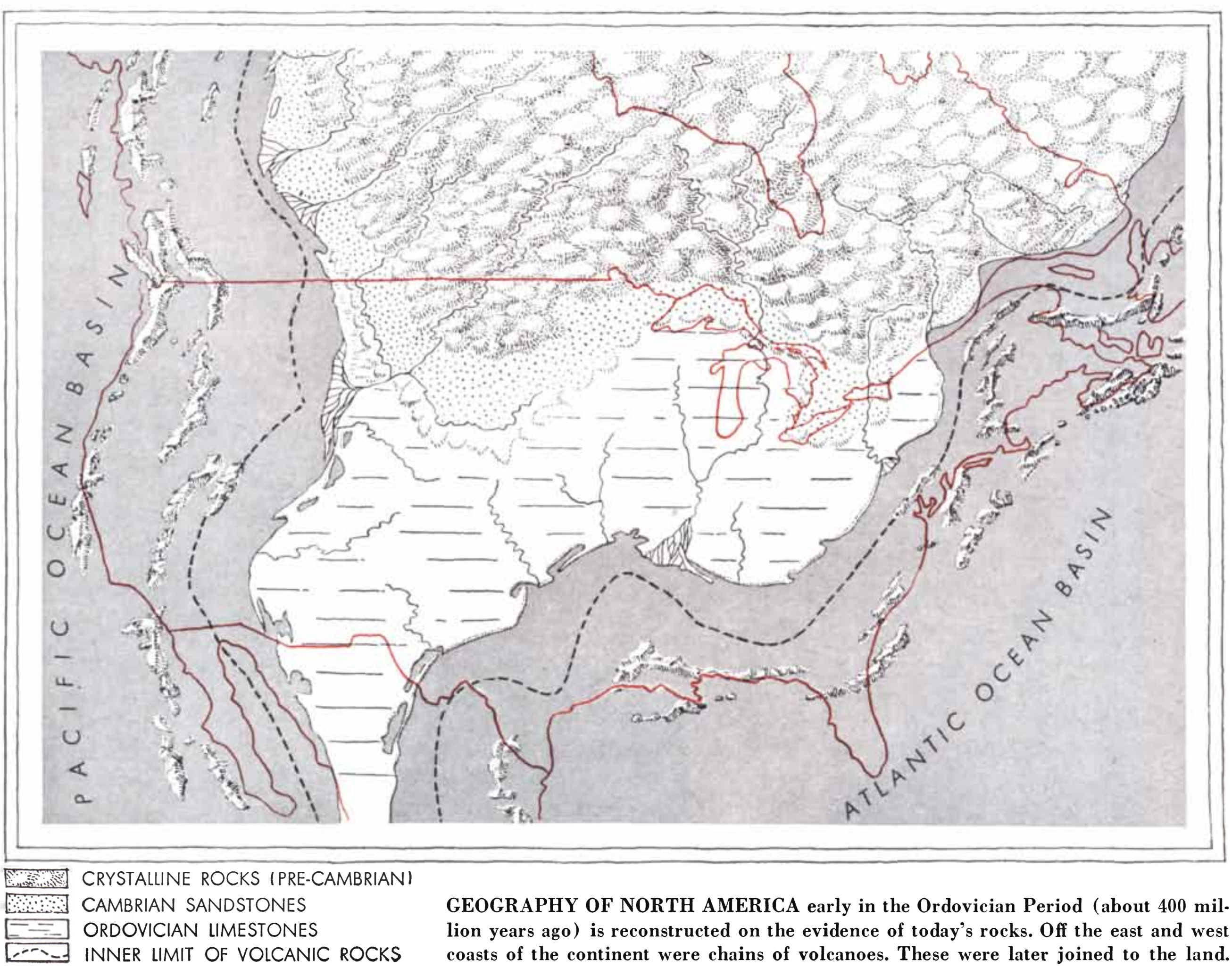
Let us return to the great shield of igneous and metamorphic rocks that covers central Canada. It, too, has granite and granitelike rocks which invaded and altered sediments and lavas. Hence, by analogy, it likewise should once have been an island belt margining the continent. But the rocks are now in the midst of the continent—in fact, as we have seen, the whole continent basement is made of such rocks. How, then, did the continent begin? Did it start as



rich in silica and magnesium. The boundary between sima and ultrabasic rock is called the Mohorovicic discontinuity. At the far right are the depths of the deepest mine (10,000 feet), the deepest well (about 22,000 feet) and the deepest oceanic trough (35,700 feet).

a single small island and grow by addition of island belts? We might be able to answer that question if we had dates for all the intrusive rocks of the continent, so that we could tell whether the central ones are oldest and surrounded by successively younger belts. There do seem to be belts of progressively younger intrusions around the central part of the Canadian shield. But on the other hand there are dated rocks that seem pretty old in far-flung parts of the continent—such as Colorado and Texas. So probably it is not as simple as one might like it to be. A working hypothesis is that the continent has grown from volcanic island belts which were formerly separated by subsiding, sediment-collecting troughs.

It seems that in the beginning all was ocean, from which the continents began to rise as small lands. Perhaps stresses upon the surface of the original whole-ocean earth caused it to buckle, producing troughs, ridges, folds and fissures. The more volatile or acidic or silicic constituents of the fluid rock beneath the surface may have concentrated in the original uplifts. Weathering by the oxygen-rich atmosphere may then have segregated the more acid material of these ridges in sediments. The silicic sediments, deposited along the edges of the



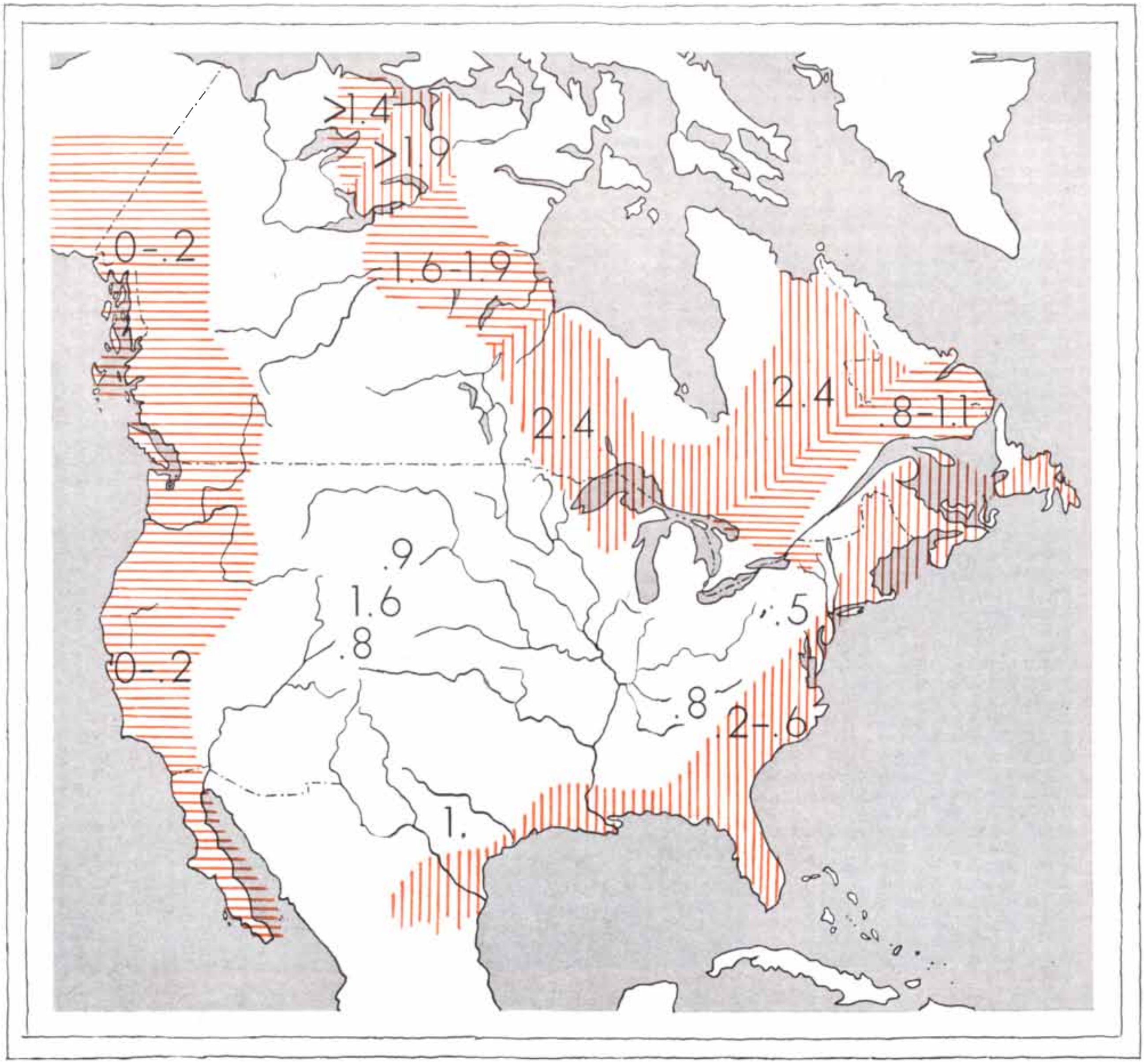
GEOGRAPHY OF NORTH AMERICA early in the Ordovician Period (about 400 million years ago) is reconstructed on the evidence of today's rocks. Off the east and west coasts of the continent were chains of volcanoes. These were later joined to the land.

raised lands, would have formed the first sialic areas on the earth.

The big question—how the continents became sialic—is full of difficulties and uncertainties. Seemingly the great long-term troughs in the crust of the earth, where thick deposits of sediments and volcanic rocks collect, are in some manner invaded by the underlying magma. Either the rising masses of fluid magma displace these rocks and themselves crystallize as granite, or their fluids and gases transform the existing deposits into granitelike rock. The popular hypothesis for the past decade has been that the furrows plunge so deeply into the substratum that the temperatures and pressures are sufficient to fuse the rocks and force fluids into them from below. Yet an invasion of this kind can hardly account directly for the production of sialic rock, since the substratum seems extremely dense and low in silica. Perhaps the process is roundabout: first sedimentary rocks, made more silicic than the original rocks by weathering, are laid in the troughs; then they are deeply buried, become fluid and eventually emerge as igneous magma which we no longer recognize as the original sedimentary and volcanic rock.

Any convincing hypothesis of the origin of the continents and oceans must be consistent with a reasonable theory concerning the origin of the earth itself. Geologists can be judges only of the end of this beginning—the time when the earth began to inscribe a permanent history in rock. The theories of the origin of the earth have been principally the inventions of astrophysicists, celestial mechanics and physical chemists, for the problems lie in those fields. The geologist is concerned only that the result be an earth which conforms to what can be deduced from the earliest known rocks.

Our knowledge of the earth has expanded tremendously in the past decade. Some old hypotheses have had to be abandoned; intriguing new ones are taking their place and will be tested in the next decade by geologists, geochemists and geophysicists all over the world.

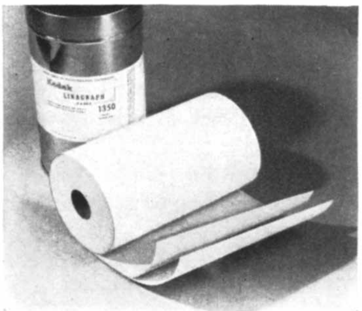


AGE of crystalline rocks in North America is given in billions of years. The oldest rocks are located around Hudson Bay. The younger rocks are along the present coasts. The symbols before the numbers at the top indicate that the rocks are older than these values.

Kodak reports to laboratories on:

dual wound recording paper . . . replacing protein in ruminant diets . . . an old technique for color photomicrography of colorless objects

Two at a time



Why not put up *Kodak Linagraph Paper* in a dual winding to give an extra copy of an important oscillograph record? Why not balance the two emulsions for equal density of the traces and make the top strip extra thin so that the bottom record comes out good and sharp?

No reason why not. No reason why you can't get it just that way from your Kodak Industrial Dealer. Just ask for the new Kodak Linagraph 1350 Paper.

Thirty wether lambs

They took thirty wether lambs of fine wool breeding at Ames, Iowa, and fed them various non-protein nitrogen compounds. They were exploring the biochemistry behind the current drive for replacing protein with urea, which is cheaper, in ruminant diets. It has been shown that all ten essential amino acids are synthesized in the rumen when urea supplies all the nitrogen. But no sheepman (or cattleman) dares supply all his nitrogen that way. What makes it dangerous? asked the men of Iowa State.

Simply that ammonia is released into the blood, they found. No harm is done—unless the urea feeding is overdone to a certain critical and fatal point. Likewise ammonium formate, ammonium acetate, and ammonium propionate can release lethal concentrations of NH_3 in the rumen. Not so the amides, for the rumen has little amidase; on propionamide, formamide, or biuret sheep may safely graze, as far as ammonia is concerned. The Iowans therefore looked further at these.

Formamide turned out to have some toxicity problems of its own, but propionamide was fine, gave the same weight gain as urea, and in one trial was equivalent to conventional protein at the replacement level of 30 percent. Propionamide appears to release ammonia at a rate just sufficient for adequate protein synthesis by rumen microorganisms, once they and the lambs get used to it.

One thing is sure. If *Propionamide* ever achieves practical importance for stock feeding it will have to come down in price many times below what it had to fetch as the highly purified Eastman 675 which we shipped to Ames for these experiments. Somebody other than we will doubtless be manufacturing it. If so, it won't be the first time that a compound becomes a big item of commerce from a lead it first gave as an Eastman Organic Chemical.

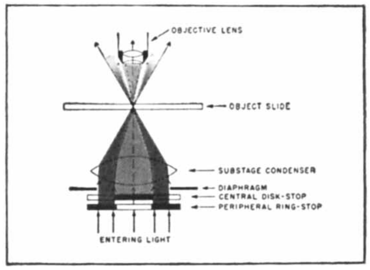
After all, there are a lot of them . . . some 3500 organic compounds sitting on our stock shelves and set down in our List No. 39. If you don't have the list, write to Distillation Products Industries, Eastman Organic Chemicals Department, Rochester 3, N. Y. (Division of Eastman Kodak Company).

Quekett, 1897

Dental chap came in with a live hamster for help in photographing its molars, and when that was done, he asked what's new in photomicrography. We told him about Julius Rheinberg's papers in the *Journal of the Quekett Microscopical Club* for April and November, 1897. He agreed the idea was clever, yet simple. When he later told the other chaps at his institution about Wratten-Rheinberg technique, they were impressed, too. Some beautiful Ektachrome photomicrographs of tooth structure have come out of this.

Wratten-Rheinberg is an adaptation of dark-field microscope illumination to introduce color differentiation in colorless objects by means of light rather than stains. It is accomplished by microscope substage filters obtainable at all of $3.75 each from a Kodak dealer, who can order in *Kodak Wratten Rheinberg Differential Color Filters* even though he hasn't heard of them before.

Seven of them are central disk-stops, which consist respectively of a blue (No. 49), green (No. 63), red (No. 70), purple (No. 35), greenish-blue (No. 45A), black (Neutral Density 4), or white matte (thin paper) 15-mm center in a thin 33-mm glass disk. Four of them are peripheral ring-stops with clear 15-mm centers surrounded by 9-mm-wide rings of red (No. 29), blue-green (No. 64), orange (No. 21), or blue (No. 38A). A central and a peripheral disk-stop are placed in tandem in the filter ring



of the regular substage condenser, which is focused on the object. If the adjustment is such that the central disk just fills the aperture of the objective while the peripheral zone provides light for the object to refract, then one sees things like a red paramecium swimming in a green pool, or vice versa as fancy and good seeing may dictate. Of course, this doesn't work with high-powered objectives that take all the available aperture of the condenser to fill them, in which case you had better look into phase microscopy after all.

There is one more string to the Wratten-Rheinberg bow, however —the luxury model *Sector Stop* for $9.50. It's a peripheral, with alternate 90° sectors of red and blue. Used with the black central disk-stop and lined up with a transversely striated object like a textile, it can make warp red and woof blue.

Slow though the Wratten-Rheinberg technique may be in gaining momentum, we look forward to the avalanche.

Questions about it should go to Eastman Kodak Company, Medical Division, Rochester 4, N. Y.

Prices quoted are subject to change without notice.

This is one of a series of reports on the many products and services with which the Eastman Kodak Company and its divisions are . . . *serving laboratories everywhere*

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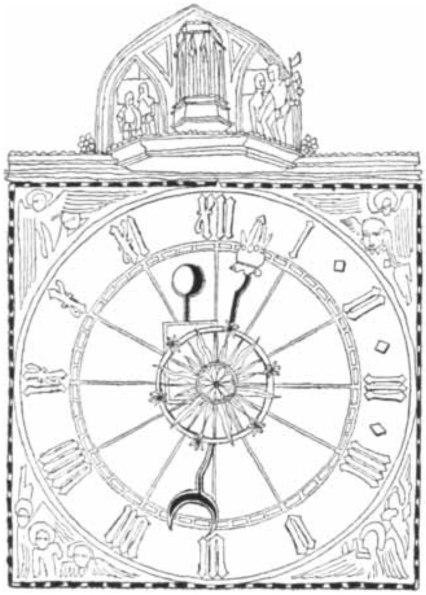

Geophysical Satellite

As this issue of Scientific American went to press, the National Academy of Sciences and the National Science Foundation announced that the U. S. plans to fire one or more small satellites high enough to orbit around the earth by 1957 or 1958 as a contribution to the International Geophysical Year. The decision was in response to a resolution by the Special Committee for the IGY, urging participating countries to make such an attempt. Noting the "advanced state of present rocket techniques," the Committee had recommended that "thought be given" to launching small satellite vehicles equipped with instruments which might record observations of the earth from outer space.

The nation's official scientific agencies wrote the Committee last month that the U. S. program "now includes definite plans for the launching of small satellites during the International Geophysical Year." In the public announcement they explained:

"The atmosphere of the earth acts as a huge shield against many of the types of radiation and objects that are found in outer space. It protects the earth from things which are known to be or might be harmful to human life, such as excessive ultraviolet radiation, cosmic rays, and those solid particles known as meteorites. At the same time, however, it deprives man of the opportunity to observe many of the things that could contribute to a better understanding of the universe. In order to acquire data that are presently unobtainable, it is most important that scientists be able to place instruments outside the earth's atmosphere in such a way that they can make continuing records of the various properties about which information is desired. In the past, vertical rocket flights to extreme altitudes have provided some of the desired information, but such flights are limited to very short periods of time. Only by the use of a satellite can sustained observations in both space and time be achieved. Such observations will also indicate the conditions that would have to be met and the difficulties that would have to be overcome, if the day comes when man goes beyond the earth's atmosphere in his travels.

"The satellite itself will orbit around the earth for a period of days, gradually circling back into the upper atmosphere where it will eventually disintegrate harmlessly."

The U. S. invited other countries to participate in the satellite project and offered to "provide full scientific information on the orbiting vehicle so that other nations may monitor the device."

A multi-stage rocket will carry the satellite up to about 200 to 300 miles and give it a horizontal velocity of about 18,000 miles per hour. The "bird" itself will be about the size of a basketball. The designers hope to pack it with instruments and a small battery to power them. To conserve power some of the instruments might be controlled by radio so they could be turned off except when the satellite was over an observing station.

The satellite will circle the earth every 90 minutes or so. Painted white, possibly with luminous paint, it should be a little brighter in the sky than the faintest star visible to the naked eye. It will move so quickly that it will probably have to be observed through binoculars aimed in advance at points where it is expected to appear. It will be easiest to see when it is over a station and illuminated by the slanting rays of the sun two to 15 degrees below the horizon.

Workers on the project are fully prepared for a number of failures before they achieve the first successful launching. The project is expected to cost $10 million or more.

Among the things geophysicists would hope to learn from a successful satellite operation are: the density of the high atmosphere, the precise shape of the earth, the density of hydrogen atoms in outer space, the density of microscopic particles in a meteor stream, information about electric currents in the ionosphere, about ultraviolet and X-ray radiation from the sun, about cosmic rays and about the streams of solar particles that produce auroras.

Long-Range Communication

Two "radically new and extremely important methods" for transmitting high-frequency radio signals for hundreds of miles have been made public by engineers at the Massachusetts Institute of Technology.

The methods make use of the discovery that ultra-high-frequency and very-high-frequency waves, which normally pass through the atmosphere into outer space, may be partly reflected by turbulences in the air. By making the signal strong enough and using suitable antennas, it is possible to bounce receivable UHF signals from the atmosphere about one mile up and VHF signals from the E layer of the ionosphere. The UHF waves travel 200 miles or more; the VHF, 1,000 miles. Enormous transmitting antennas are required. The VHF antennas are 120 feet high by 130 feet wide.

The methods were developed by the M.I.T. Lincoln Laboratory, working with the Bell Telephone Laboratories and the National Bureau of Standards.

A Real Radio Star?

In the old days of radio astronomy—six or seven years back—there was much talk about "radio stars." Improved telescopes soon demonstrated that none of the distant sources of celestial radio signals was small enough to be considered a star. Now astronomers at Ohio State University have found what may be a true radio star.

H. C. Ko and D. V. Stoutenberg discovered, near the constellation of Cancer, a spot which sends out a variable signal. The cycle of its fluctuations in strength is only two or three minutes long. The object also brightens and fades over a period of days. No such variable signal has ever been detected before. The fluctuations might arise in the earth's ionosphere, but the Ohio State observers believe that at least some of the variability resides in the object itself. In any case, the high rate of change suggests a very small source: an extended gaseous source of radiation could hardly twinkle so fast, nor could a large patch of ionosphere vary so rapidly.

John D. Kraus, director of the Ohio State radio observatory, suggests that the object may be a variable radio star, possibly too faint visually to be picked up with a light-gathering telescope.

Martian Intelligence

Last year, while Mars made one of its closer approaches to the earth, the red planet was subjected to the most intense scrutiny it has ever received. Seven widely spaced observatories maintained a continuous nightly "patrol" from May 1 to September 15. Another 10 stations cooperated with frequent observations. Some of the findings have just been summarized by William M. Sinton of the Harvard College Observatory in *Sky and Telescope.*

The haze in which Mars is normally cloaked was semitransparent for a couple of months last year, and during that time photographs through a blue filter showed for the first time a series of great cloud belts, roughly parallel to the Martian equator. One enormous W-shaped cloud persisted for a month, evaporating every morning and re-forming every afternoon.

Mars apparently has a maximum surface temperature of 77 degrees Fahrenheit at the equator about half an hour after local noon. At sunrise the same region is at 58 degrees below zero F. Observers also measured the temperature of a big yellow cloud which appeared one day. They hope that photographs from some of the patrol stations will show the shadow of this cloud on the surface, which would allow its height to be calculated. Then the rate at which temperature changes with altitude in the Martian atmosphere could be found.

In 1956 Mars will come even closer to the earth. A more elaborate observational program, planned on the basis of last year's experience, is scheduled for that time.

Payment for Plutonium

While uranium prospectors and miners get rich from atomic energy, some nuclear chemists and physicists also prosper. The Atomic Energy Commis-

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Thompson Products, Inc. of Cleveland, Ohio has installed the illustrated high-vacuum furnace to aid in its investigation of new and improved materials for the automotive and aircraft industries. Currently rated at 200-pound melt capacity, Thompson's furnace is capable of 1000-pound production with minor modification, an important advantage should full-scale vacuum metal production be initiated.

Stokes is the leading supplier of production vacuum furnaces for industry. Any of the basic furnace designs, ranging from laboratory units to 1000-pound capacity and higher, can be modified to meet your particular requirements. If your interest lies in high-purity metals, write for your free copy of Stokes Catalog 790, "High-Vacuum Furnaces."

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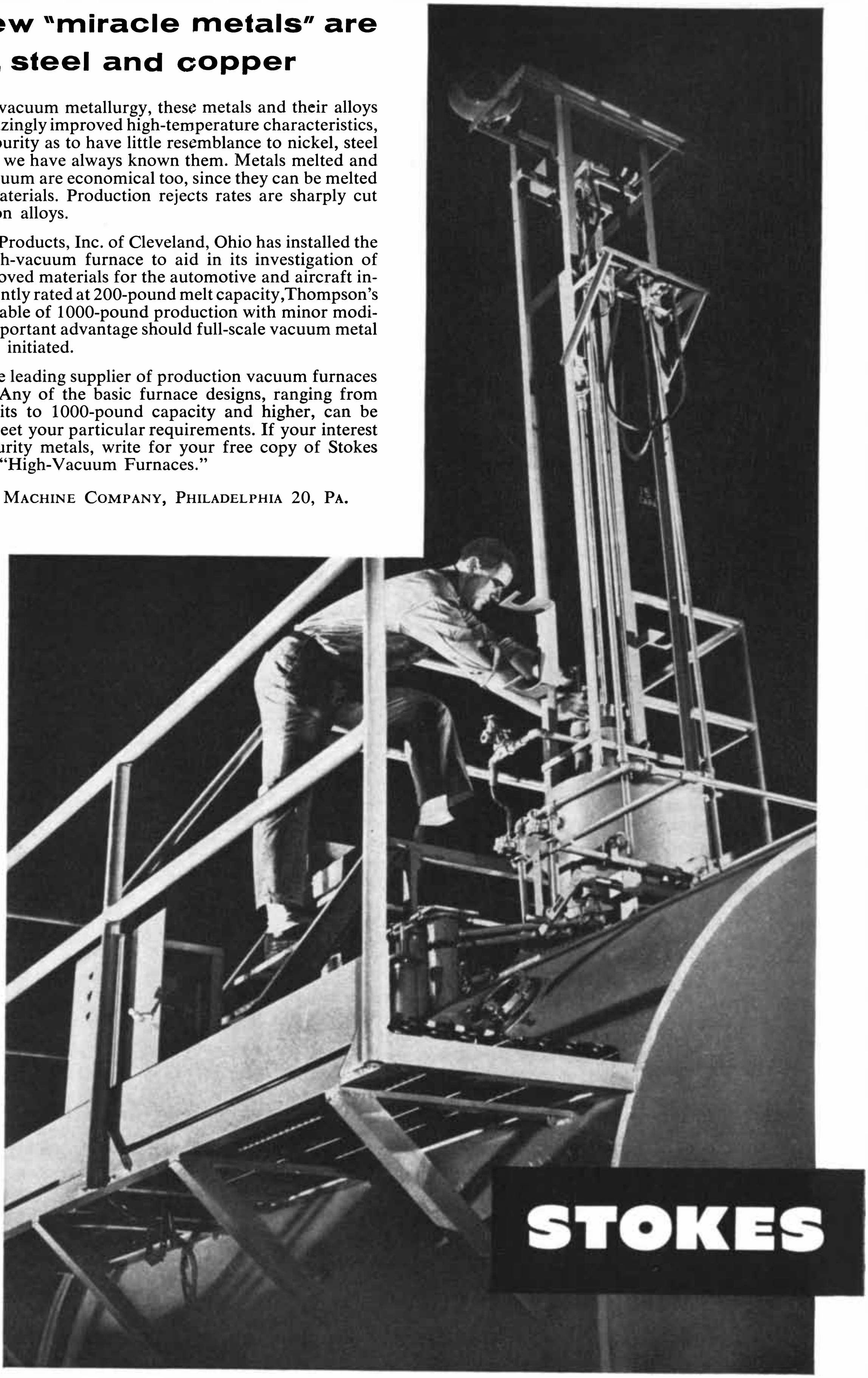


sion has paid $400,000 to four men for their early investigations of the chemical separation of plutonium.

The recipients are Glenn T. Seaborg and Emilio G. Segré of the University of California and Joseph W. Kennedy and Arthur C. Wahl of Washington University in St. Louis. They started working together on plutonium at the University of California late in 1940, before the Manhattan District project. The $400,000 pays for the patent rights on the work they did before being employed by the Government.

The four men filed classified patent applications between 1945 and 1947. Then, pursuant to the Atomic Energy Act, which vested the AEC with all nuclear patent rights but gave inventors rights to apply for awards, they filed an award application before the AEC's Patent Compensation Board in 1950.

Segré was also a member of the Italian group headed by the late Enrico Fermi which two years ago received $300,000 for its method of making radioactive isotopes by bombarding elements with neutrons slowed by a moderator.

The Right to Travel

The State Department last month issued a passport to Martin D. Kamen, radiobiologist at Washington University in St. Louis, after having refused to do so for eight years. The action followed a ruling by the U. S. Circuit Court of Appeals in the case of New York lawyer Max Shachtman that passports cannot be withheld arbitrarily without substantial cause and without due process of law.

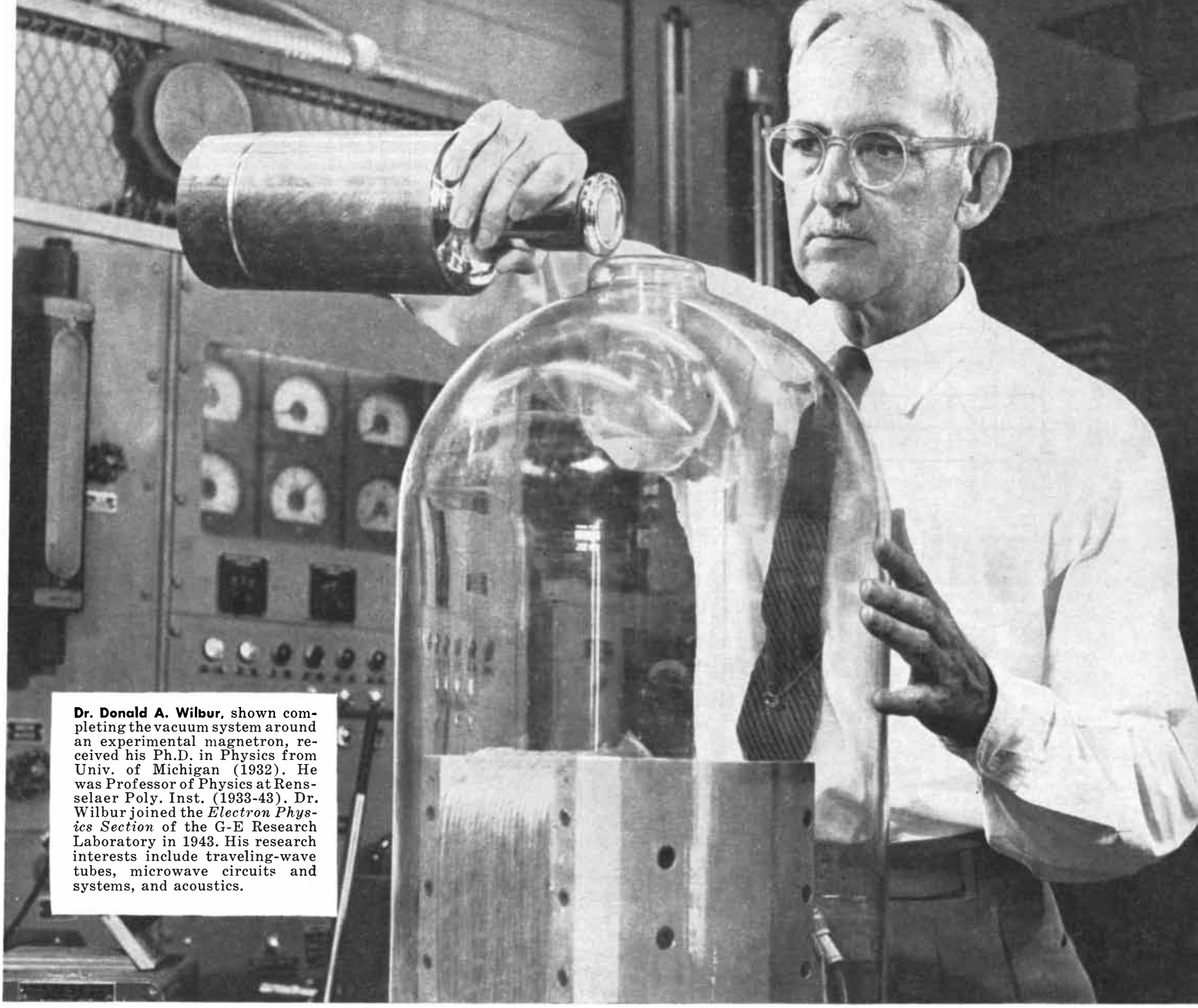
Kamen, accused of Communist-front associations which he denied, had filed suit against the Secretary of State in a test case supported by the Federation of American Scientists.

"It was apparent," said the F.A.S. after the State Department's capitulation, "that the State Department felt itself unable to prove the charge it had made against Kamen."

Missiles and Fizzles

The road to success in guided missiles, as in the history of rocketry generally, so far is littered with many wrecks. The available performance records were recently reviewed by R. P. Haviland, a guided missiles engineer with the General Electric Company, in *Jet Propulsion*, the journal of the American Rocket Society. Haviland reported the results of four U. S. missile-testing programs.

The first involved the V-2, which had been used in quantity by Germany to-



Dr. Donald A. Wilbur, shown completing the vacuum system around an experimental magnetron, received his Ph.D. in Physics from Univ. of Michigan (1932). He was Professor of Physics at Rensselaer Poly. Inst. (1933-43). Dr. Wilbur joined the *Electron Physics Section* of the G-E Research Laboratory in 1943. His research interests include traveling-wave tubes, microwave circuits and systems, and acoustics.

Rapid tuning for magnetrons

General Electric's Dr. D. A. Wilbur experiments with non-mechanical, electronic tuning methods

General Electric's interest in ultrahigh-frequency wave generators dates back to the pioneer work of Dr. Albert W. Hull, who invented the original magnetron in 1921. The subsequent role played by magnetrons in military radar is now familiar history. But until recently, tuning magnetrons over a broad range had to be accomplished mechanically; and this was a major problem, since space was limited within the vacuum envelope. Also, the required mechanical linkage made tuning a slow and cumbersome operation.

Dr. Donald A. Wilbur and his associates at the General Electric Research Laboratory have discovered how to tune magnetrons by varying the DC supply voltage. Because this method is electronic—rather than mechanical — the tuning can now be enormously speeded, permitting the use of magnetrons in many new automatic testing devices. As a result of this work by General Electric scientists, electronic tuning may soon be adapted to radar, television and radio broadcasting, and for testing the components of communications networks.

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ward the end of World War II. Of 68 captured rockets launched later in the U. S., only 32 worked well; 23 fizzled completely. The propulsion system was at fault in 40 per cent of the failures and the guidance system in 60 per cent.

The Viking, a U. S. modification of the V-2 design, in nine tests had three good flights, one acceptable flight and five total failures.

Bumper, a two-stage missile consisting of a small rocket mounted on a V-2, had two good, but not perfect, flights out of eight tries. The best flight, which set altitude and velocity records, gave only 80 per cent of the maximum design performance.

Hermes, a ground-to-air missile supposed to fly for 360 seconds, averaged only 20 seconds of flight in the first series of tests and 160 seconds in the second series.

Memory on Film

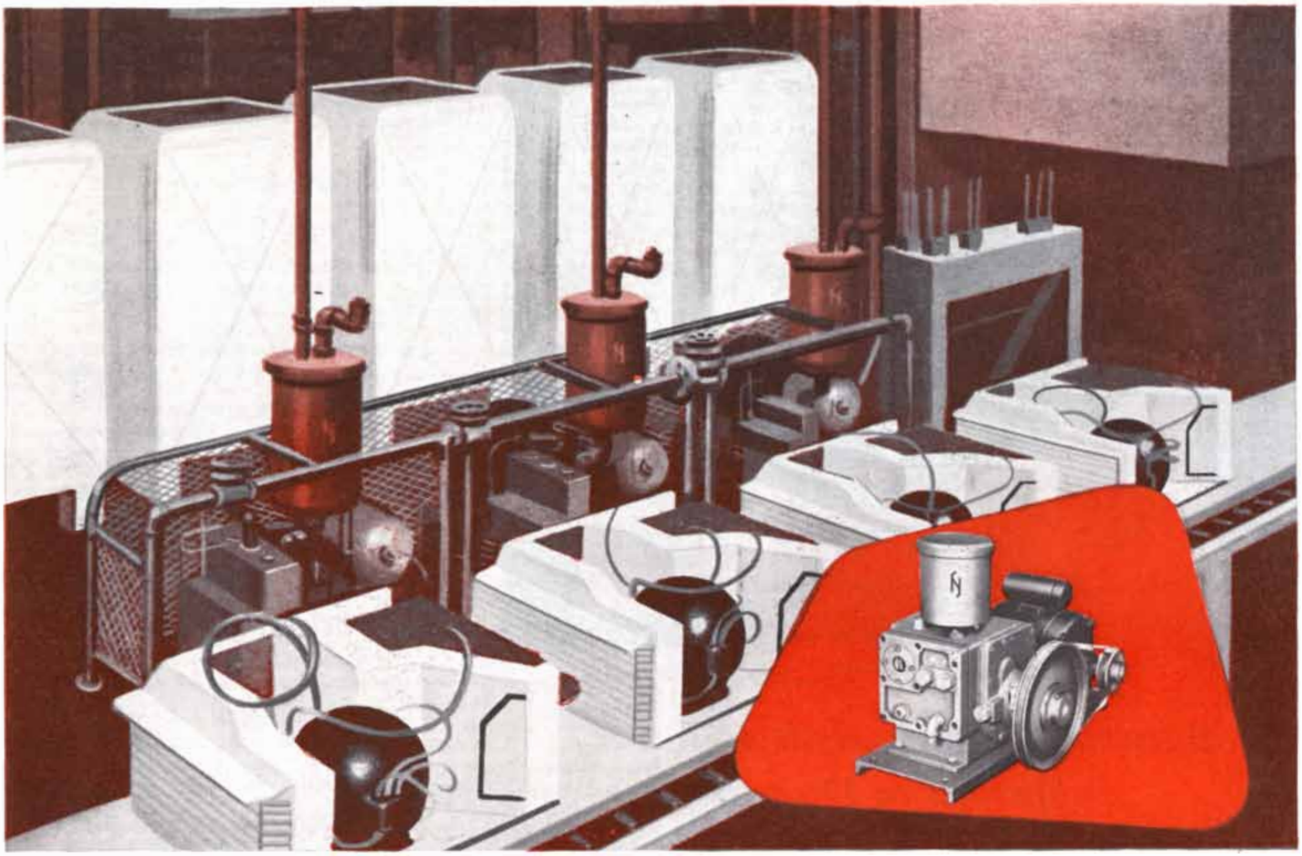
High-resolution photographic emulsions are receiving much current attention as possible memory-storage devices for computers and data-handling machines. On this new type of film the entire contents of the Library of Congress, if coded and reduced to the microscopic scale, could be stored in three or four shoeboxes.

Gilbert W. King, of the International Telemeter Corporation, described a film memory recently in *Control Engineering*. His film is inherently more compact and less expensive than magnetic tape, punched cards or any of the other conventional computer memories. In addition to holding a lot of information, King's system wastes little time in the search for specific items.

Information is reduced to the usual binary code, consisting in this case of black and white rectangles one thousandth of an inch wide by three thousandths of an inch long. Strips of these rectangles circle a disk in concentric tracks. To read the information, a sharp beam of light moves from track to track while the disk spins rapidly. The light beam is precisely oriented by alternating black or white guide circles which separate the strips of rectangles.

A single disk 16 inches in diameter, coded on only the outer four inches, can easily store 20 million "bits," the equivalent of four million printed characters, or several books. And the reading beam can locate and read off any item on the disk in less than 25 thousandths of a second.

The memory's one drawback is that its entries are hard to erase. But it is so speedy and compact that erroneous or



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out-of-date information might be left in the file, while fresh information superseded it.

A prototype of the machine is working successfully in International Telemeter's California laboratories.

Hormones and Vitamins

Two major achievements in biochemistry were announced at last month's International Congress of Pure and Applied Chemistry in Zurich.

Albert Wettstein of CIBA, Ltd., reported the total synthesis of aldosterone, one of the most important adrenal hormones. His paper was unscheduled—he and his collaborator, J. Schmidlin, had only finished their work a week before.

Aldosterone, a steroid manufactured by the adrenal cortex, was one of the last adrenal hormones to be isolated. Its structure was completely determined only two years ago by Tadeus Reichstein at the University of Basel.

Since its isolation, experiments with aldosterone have shown it to be one of the most potent and versatile of the body's chemical regulators. It plays a central role in governing the metabolism of sodium, potassium and calcium; it regulates the water balance of the body; it helps determine the use of carbohydrates and nitrogen. When given to dogs whose adrenal glands have been removed, it is 20 to 30 times more effective than the next most active hormone in keeping them alive.

The second announcement, by a group from the University of Cambridge, was the unraveling of the structure of vitamin B-12. This substance, first isolated five years ago, is the antianemia principle in liver. Consisting of 63 carbon atoms, 90 hydrogen atoms, 14 oxygen atoms, 14 nitrogen atoms and one each of phosphorus and cobalt, vitamin B-12 is the largest and most complicated known biological molecule next to the proteins. Working on the analysis were Sir Alexander Todd, Robert Bonnett, John R. Cannon, Alan W. Johnson and Ian Sutherland. The group has now begun to try to synthesize the molecule.

Polio Virus Culture

A new break-through in poliomyelitis research was announced by three University of California workers, Elsa M. Zitcer, Jorgen Fogh and Thelma H. Dunnebacke, last month. They have successfully grown the polio virus on human afterbirth tissue. Test-tube culture of the virus hitherto has required expensive monkey kidney tissue. Amniotic mem-

branes (afterbirths) could be provided at little cost by any hospital with maternity facilities. In addition use of this tissue would eliminate the fear that vaccines developed from virus grown on kidney tissue may sensitize some persons to kidney protein.

The California researchers have cultivated all three strains of polio virus with their new technique. They report that one amniotic membrane yields about as much virus as one monkey kidney.

The Future of Arid Lands

Man can effectively expand his world by making better use of arid lands. But how should he do it? Should he concentrate on bringing more water to dry earth or on adapting himself, his crops, and his animals to a parched environment? Both approaches were considered by the 71 delegates, representing 18 nations, who participated in the recent International Arid Lands Meeting and Conference in New Mexico.

The conclave was sponsored by the American Association for the Advancement of Science and financed by the National Science Foundation, Rockefeller Foundation and UNESCO. It started with public lectures and technical sessions in Albuquerque and wound up at the New Mexico Institute of Mining and Technology in Socorro. During the week delegates, some of whom had come from as far away as Australia, India and Pakistan, had a chance to tour the Rio Grande Valley to see how American farmers combat an encroaching desert.

Before disbanding, the scientists issued 31 recommendations, among them:

Some emphasis during the International Geophysical Year on studies of the arid belt between 30 degrees North Latitude and 30 degrees South.

A more vigorous study of all aspects of cloud seeding.

The fullest possible studies of the role of vegetation in the hydrology of dry lands and of plant species and communities as indicators of climates, past and present.

Studies of pharmaceutical and industrial uses of desert plants.

Insomniac Ruminants

Cows, sheep, giraffes, camels and other cud-chewing animals sleep "little if at all," according to a British dairy expert. C. C. Balch, of the National Institute for Research in Dairying, reports in *Nature* that he has found resting ruminants practically never relax completely when they lie down. They maintain a

characteristic fixed position with their heads up. This posture is necessary to keep their various stomachs in proper relative places so that food can travel from one to the other.

Balch admits that sleep is hard to define. He suggests that at a minimum it must involve "marked relaxation and loss of consciousness (especially of vision)." Although he has sat up many nights with many cows, he has never caught one in such a condition. Cattle keep their eyes open—and fully responsive to the surroundings—almost all the time.

The author has checked with other animal experts who confirm his findings. He has also questioned zoo keepers about nondomesticated ruminants. These animals have never been caught napping either.

Bird Talk

Bird language is more functional than human talk, according to P. Marler, a University of Cambridge ornithologist. From long observation he has learned that small birds, notably chaffinches, can lure a mate or safely warn of the approach of a hawk by a simple change of the sound pattern of their songs.

When singing to a prospective mate, the male chaffinch chirps a staccato soprano. Because the sound is so high and the waves so short, they do not pass readily around very small objects. Thus as the female cocks her head in different directions, she can locate the male by the pattern of sound "shadows" cast by her own head. The staccato quality also helps; she can sense the slight interval after a chirp reaches one ear and before it reaches the other.

When a hawk is near, the chaffinch is faced with an entirely different communication problem. He must warn his fellow chaffinches without revealing his hiding place to the predator. He does this by means of a gradually rising and falling note which Marler calls a "seeet." Because the note has no sharp beginning or end, the hawk cannot time it with its ears. Furthermore, the pitch is attuned to the hawk; the wavelength is about equal to the diameter of the hawk's head. Thus there is no sound "shadow" to help the bigger bird locate the source.

Commenting on Marler's analysis, the famous British biologist J. B. S. Haldane remarked: "If elephants ate chaffinches on a large scale, the alarm cry would presumably be a much lower note. . . . The human alarm cry, the shriek of fear, is somewhat lower than the chaffinch's and perhaps adapted to the larger heads of wolves, lions and bears."

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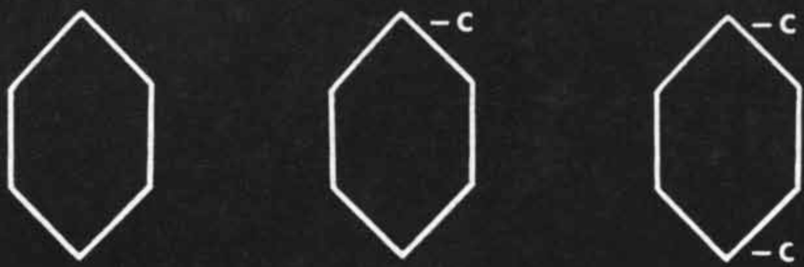

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Chemists and manufacturers are constantly searching for chemical raw materials that will bring higher yields . . . increased plant efficiency . . . better quality in finished products.

Sun Oil Company is satisfying this demand with their new petrochemical plants, which are among the largest and most modern in the country.

Today Sun's plants are producing petrochemicals unsurpassed in purity and quality. Typical are Sun Toluenes, which are guaranteed to contain less than 0.5% paraffins, well below the ASTM maximum of 1.5%.

Butylenes are eliminated from Sun Oil's propylene polymers. Sunaptic acids are saving thousands of dollars when used as a replacement for oleic acids, commercial naphthenic acids and synthetic acids in corrosion inhibitors for oil well casings and oil pipelines.

Other Sun Oil petrochemicals are just as outstanding. A rapidly growing list now includes benzene, toluene, mixed xylenes, propylene trimer and tetramer, high molecular weight naphthenic acids, water soluble sulfonates and polymerized drying oils. NH_3 and sulfur will soon be added to the list. More are in the planning stage.

If you are now using a petrochemical, or are developing new uses, see your Sun representative, or write for one of Sun's Technical Bulletins. Address SUN OIL COMPANY, Philadelphia 3, Pa., Dept. SA-9.

SOON AVAILABLE FROM SUN OIL'S NEW PETROCHEMICAL PLANTS

→ NH_3
SULFUR

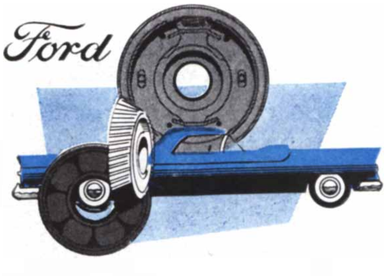
INDUSTRIAL PRODUCTS DEPARTMENT

SUN OIL COMPANY, Philadelphia 3, Pa.

IN CANADA: SUN OIL COMPANY, LTD., TORONTO AND MONTREAL

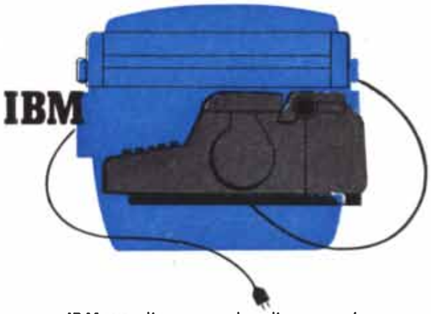
SUNOCO ®

Friden Calculating Machine Co., Inc. has many production as well as research uses for *-hp-* counters. These include matching relay closing times, checking electrical stability, determining electrical requirements of experimental circuits and testing pilot and production models.

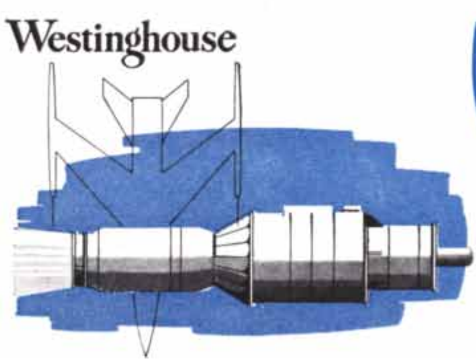


Ford's Engineering Research Laboratory at Dearborn finds *-hp-* counters a new, fast way to study automatic transmission performance, time braking action, measure engine cylinder volume and study valve train dynamics.

Douglas uses *-hp-* Counters for time interval work, (measuring time segments as small as 1/100th second) as well as for frequency measurement on AC inverters and generators and determining frequency characteristics of transformers.

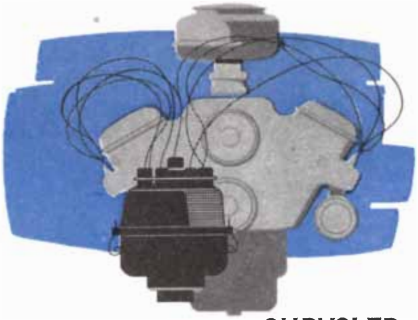


IBM quality control relies on *-hp-* Counters to check split-second operating times in electric typewriters and similar mechanisms. Counters help insure uniform type impressions.



At Westinghouse, the same versatile *-hp-* counters that measure turbo-jet rpm's also check adjustment of precision circuitry in new color television receivers and perform many other useful measuring jobs daily.

General Electric uses *-hp-* Counters in both development and production measurements. Typical uses include checking watthour-meter performance and checking crystal frequencies for keying G-E color and monochrome TV receivers.



CHRYSLER

Chrysler products must prove themselves before an impressive array of test devices. *-hp-* Counters measure revolutions and evaluate performance of moving parts with extreme accuracy —even timing actions occurring over intervals as small as 1/100,000 second.

Electronic Counters are one of many electronic test instruments ready to give you better engineering and manufacturing—*today!*

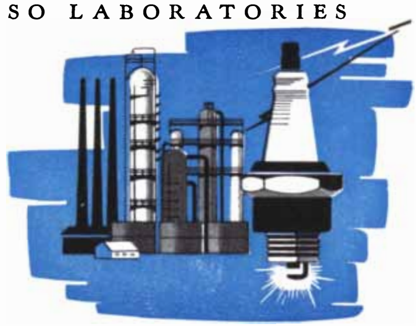
These Counters are not delicate, expensive prima donnas requiring a staff of PhD's to operate and maintain. About the size of a large table radio, they're rugged, dependable, job-proven, versatile, manufactured in quantity and priced from about $900. Anyone who can count can use them—they require no charts or complex calculation. Yet their performance is perfection itself—direct-reading, instantaneous, automatic; accurate within 1 part per 1,000,000.

Industry uses Electronic Counters to measure rpm and rps, weight, pressure, temperature, velocity, speed, acceleration, slippage, elapsed time or time intervals, frequency rates, production quantities. And, they have many other functions; Electronic Counters are only at the threshold of their usefulness to industry.

Electronic Counters

new way to better engineering

ESSO LABORATORIES



Standard Oil Development Company's Esso Research Center uses *-hp-* counters to reveal gasoline performance by quickly, easily measuring engine speed vs. torque, time lapse between "spark" and explosion, time required for maximum thrust after firing.

Hewlett-Packard is a world leader in Electronic Counters, as well as other major electronic measuring instruments. The *-hp-* line includes over 250 different equipments—providing almost complete coverage of measurements that can be made electronically.

Over 100 *-hp-* field engineers serve manufacturers throughout the United States and overseas. Their first job is to give you the right answers about applicability of electronic instruments to your operation. Their second is to recommend and help apply the correct equipment. If you'd like to explore this idea in more detail, please write us. The *-hp-* engineer in your city will reply promptly.

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3152

GLACIERS

Ice plays a critical role in the water economy of the earth. About 86 per cent of it is in the Antarctic, where it exerts a profound influence on the weather in all parts of the world

by William O. Field

Water is one of the few substances on earth existing in nature in all three physical states—liquid, solid and gaseous. Altogether our planet contains some 350 million cubic miles of water, most of it, of course, in the oceans. Of the earth's total water budget not much more than 1 per cent is in the solid form of ice or snow, and far less than that in the form of water vapor in the atmosphere. Yet these proportions make up a delicate balance which is immensely important to life on the earth. Any appreciable change in the ratios of water, ice and atmospheric moisture would have catastrophic consequences for man and his economy. The ice piled in glaciers on the lands, for instance, exercises a vital control over sea levels, climate and the continents' water supplies.

Glaciers now cover about 10 per cent (nearly six million square miles) of the world's land area. Our estimate of the total amount of water in them is only a rough guess, mainly because we have only a hazy notion of the thickness of the Antarctic ice sheet. This vast icecap accounts for about 86 per cent of the world's glacial area. The Greenland icecap makes up another 10 per cent. The remaining 4 per cent is not minor, as far as its effects go, for it includes tens of thousands of square miles of glaciers on mountains in the temperate zones, where they intimately influence man's climate and water supplies.

BERG GLACIER flows down Mount Robson, a 12,972-foot peak in British Columbia, into Berg Lake. Its whole length can be seen, including areas of accumulation and loss.

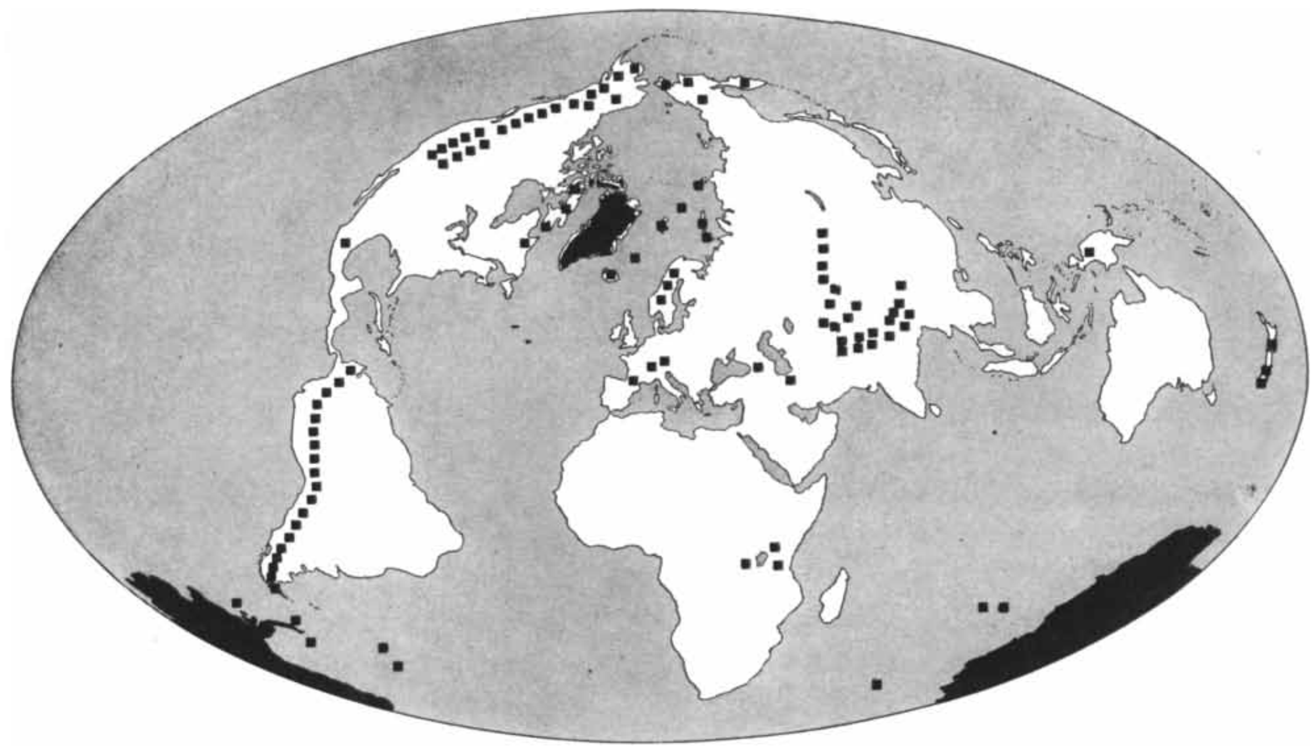
Estimates of the total volume of water in the world's glaciers range from about 2.4 million to more than six million cubic miles. If all this ice melted, the level of the world's oceans would rise by something like 65 to 200 feet!

Glaciers can grow only in areas where the snowfall is great enough year after year to exceed the annual rate of melting. Consequently the ice sheet is not necessarily thickest where the climate is coldest. In Alaska the greatest concentration of glaciers is along the southern coast, which is the warmest part of the Territory but has the heaviest winter snowfall. Parts of northern Greenland are barren of glaciers because there is not enough snowfall.

As snow accumulates, the pressure of the mounting layers compacts it into ice. Under its own weight the ice begins to flow to lower elevations. The rate of flow of glaciers varies tremendously: some move very slowly while others slide as much as 50 feet per day during the summer. At the lower elevations, the glacier melts or discharges icebergs into the sea. But under suitable conditions the glacier front may advance over the land year after year. It takes only a slight change in the combination of annual snowfall, melting-season temperatures

MORAINIC BANDS bound the confluence of Malaspina and Marvine glaciers in Alaska. From their juncture, at the base of the mountains to the right, a vast icefield spreads out to the left. The peak in the mountain chain in the background is Mount St. Elias.

RETREATING EDGE of Woodworth Glacier in the Tasnuna Valley of Alaska is at the upper right. Winding across the center is an esker, a narrow ridge of gravel left by a stream that ran through the glacier. The photographs on this page are by Bradford Washburn.

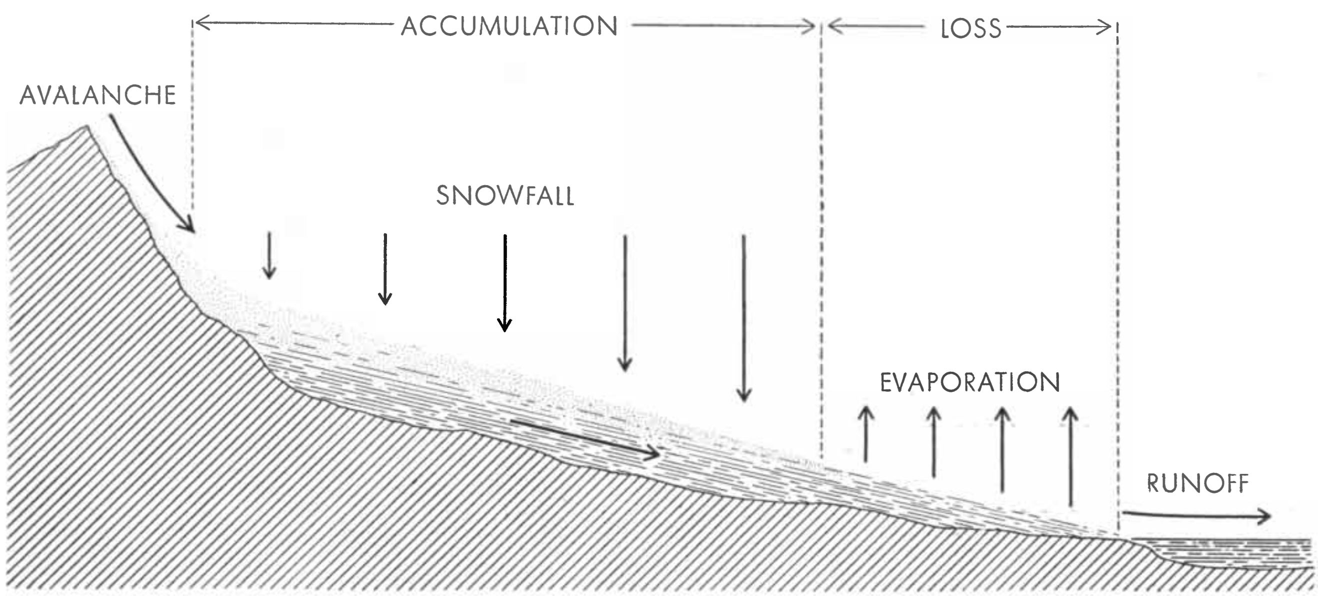


DISTRIBUTION OF GLACIERS over the earth's surface is indicated on this map by black squares and areas of black. Individual squares do not indicate equal areas of glacial ice. In this projection the Antarctic is divided into two areas (*bottom left and right*).

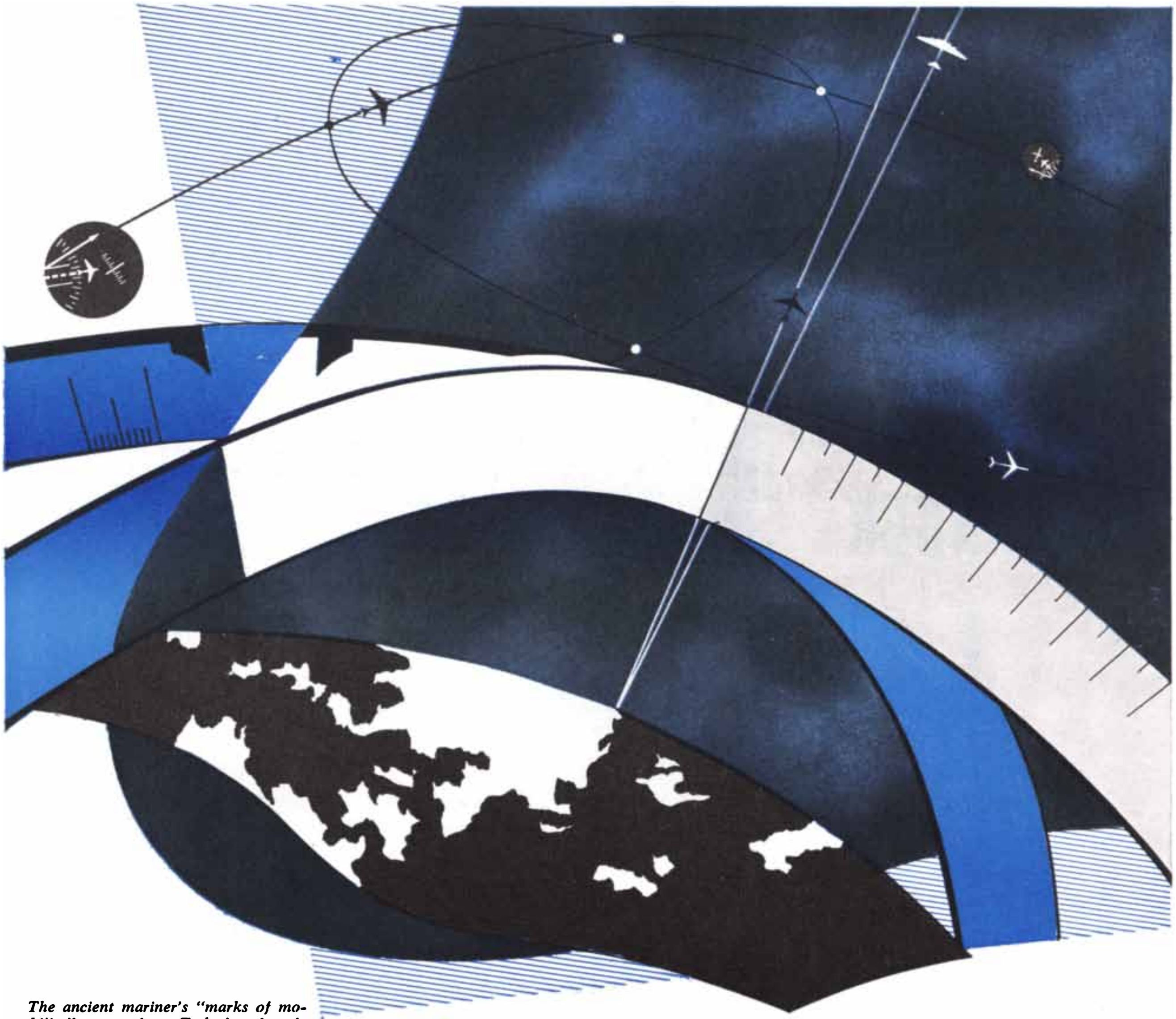
and other meteorological conditions to produce an advance or retreat of a glacier.

Probably during most of the earth's history it has been free of glaciers. We are in an exceptional era—neither glacial nor nonglacial. During the last million years there have been at least four great ice ages; at their maximum, ice covered about 32 per cent of the world's land surface. The ice ages were separated by long warm intervals during which the glaciers nearly disappeared. At present we seem to be in an in-between stage, somewhere between a glacial and an interglacial age. Some glaciers are growing; others are disappearing.

During the last Ice Age the sea level probably was more than 300 feet lower than now. Over the world the temperatures averaged 7 to 14 degrees colder. There were five continental ice sheets of more than one million square miles each. Three of these, in North America, Europe and Siberia, have disappeared, but the two in Greenland and Antarctica re-



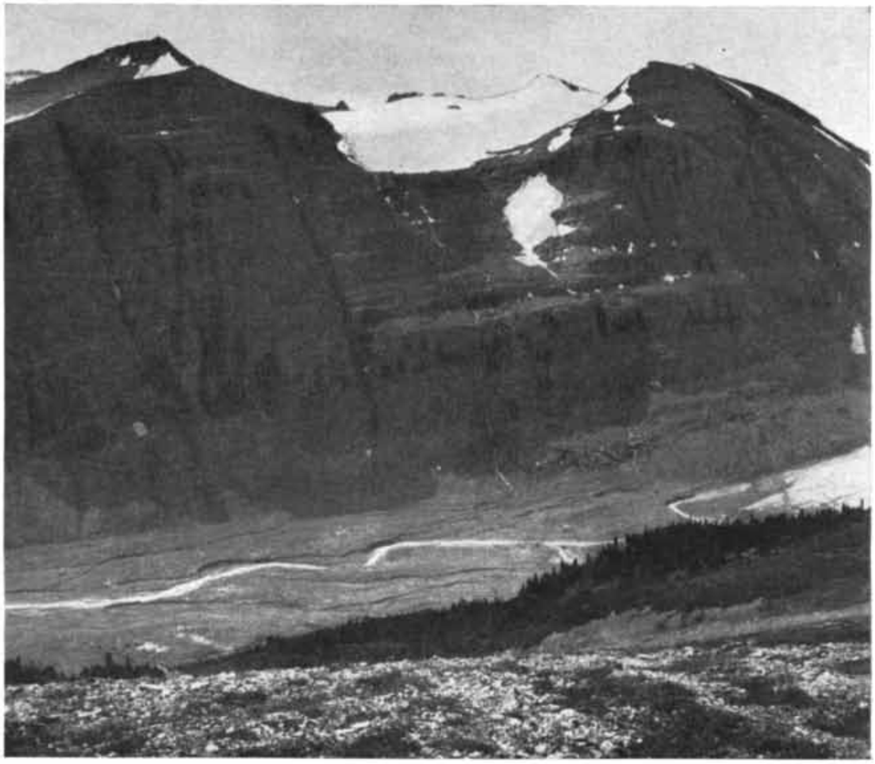
LIFE OF A GLACIER is depicted in this diagram of an ideal valley glacier. Falling snow carried by avalanche is compressed into ice, which begins to move by its own weight. The line dividing the areas of accumulation and loss is the firn line, where total accumulation equals total melting. Variations in snowfall, temperature and other conditions determine whether the glacier advances.



main. Mountain glaciers have all shrunk.

Human civilizations began to arise in Western Asia and North Africa just as the European and North American sheets were disappearing. About 3000 B.C. the climate in many, if not all, parts of the world was drier and warmer by two or three degrees than at present. The sea level was apparently five to six feet higher. The glacial region in the Alps was at least 1,000 feet higher than today. Ice in the Arctic Ocean probably melted completely each summer. Parts of the temperate regions where small mountain glaciers now furnish the summer water supply must have been arid.

Conditions began to change drastically about 1000 B.C. The climate became colder and more stormy in many parts of the world, and by about 500 B.C. glaciers began to grow again. Then, in the first millennium of the Christian era, came a period of glacier recession. After that glaciers advanced again to a maximum in the 17th to 19th centuries. This resurgence of glaciers was noted directly by observers in the Alps, Scandinavia and Iceland. Since the latter half of the



RETREATING TERMINUS of Saskatchewan Glacier in the province of Alberta is shown in these two photographs. The top photograph was made in 1922. The bottom photograph, made from the same point in 1948, indicates a recession of the terminus of about 2,600 feet.

PROGRESS THROUGH ANACONDA METALS

The new gleam in Brass costs less!

THE PROBLEM: When the manufacturer finishes up a handsome lamp like the one above, he must polish it to a gleaming fare-thee-well. The cost of this brass polishing comes high—is often more than the metal itself.

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The secret is in the way Anaconda rolls and anneals Formbrite. Special control exercised in these processes gives it a superfine grain structure. It also makes possible products that are more lustrous, more attractive, more scratch-resistant. On display shelves, Formbrite has eye-appeal that other metals don't have.

Though Formbrite often saves brass goods makers more than its own cost, *it doesn't cost one red cent more than ordinary brasses!*

THE FUTURE: The beauty of brass is eternal—in style and durability. More and more manufacturers are taking advantage of the unique qualities of this ever popular metal. At Anaconda they find the experience in both metals *and* metalworking that helps them make the best use of copper, brass and bronze—and the greatest possible saving. The Man from Anaconda can show you how. *Anaconda, 25 Broadway, New York 4, N. Y.*

*Formbrite registered U. S. Pat. Off. 55225

ANACONDA®

CAMP on Taku Glacier in southeastern Alaska was established by the Juneau Ice Field Research Project. The glacier at this point 16 miles above its terminus is four miles wide, has a maximum thickness of over 1,140 feet and a surface movement of two feet per day.

19th century glaciers throughout the world have tended to shrink once again. As a result the sea level has apparently been rising recently at the rate of approximately 2.5 inches per century. Some glaciers, however, have advanced, contrary to the general trend. In parts of the western U. S. there is a growth of glaciers at present which may indicate a changing climate.

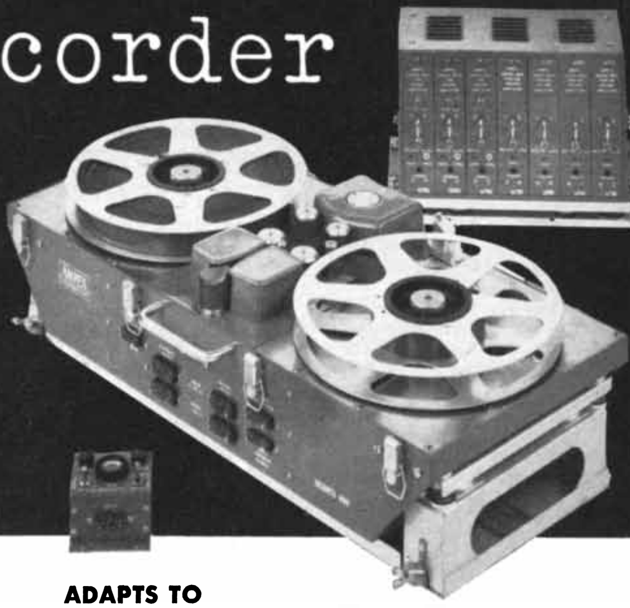
Glaciers have been studied seriously for a little more than 100 years. Beginning in 1919 Hans W:son Ahlmann of the University of Stockholm (now Sweden's Ambassador to Norway) introduced a new era in glaciology. He took a new look, in greater detail, at glaciers in Scandinavia, Iceland, Spitsbergen and northeast Greenland, and his examination led to new methods of measuring their nourishment and wastage. Observations of glaciers are now being made on a systematic basis in several parts of the world. During the last decade important studies have been carried out in Greenland, especially by Paul Victor's French Polar Expeditions, which determined the volume of the Greenland ice sheet and studied its regimen over a broad area.

The little-known Antarctic ice sheet is more than one and a third times the size of the U. S. and its territories. It covers practically the whole continent of Antarctica. Fully three million square miles of the continent have never been seen even from the air. The continent's icecap is known to rise as high as 10,000 feet, but the thickness of the ice has been measured in only a few places. Antarctica will be the scene of a major

DISTRIBUTION	
WATER IN THE OCEANS (CLOSE ESTIMATE)	329,000,000
WATER IN THE ATMOSPHERE (ROUGH ESTIMATE)	3,600
WATER IN GLACIERS (AVERAGE OF HIGH AND LOW ESTIMATES)	4,200,000
WATER IN LAKES AND RIVERS (ROUGH ESTIMATE)	55,000
GROUND WATER ABOVE 12,500 FEET (VERY ROUGH ESTIMATE)	1,080,000
GROUND WATER BELOW 12,500 FEET (VERY ROUGH ESTIMATE)	19,700,000

WATER BUDGET of the planet earth and its atmosphere is roughly tabulated here. The numbers are in cubic miles. Glaciers account for about 1 per cent of the total.

new versatile data tape recorder



THE MOBILE AMPEX 800

records the broadest combination of data ever obtained concurrently on one magnetic tape—performs with laboratory precision under severe field, airborne, shipboard and vehicular conditions—and furnishes data compatible with the most widely used playback equipment.

The Ampex 800 can provide from 1 to 28 data channels. By interchangeable amplifier units, each one can be adapted to any one of three basic magnetic recording techniques:

- **Direct recording**—300 to 35,000-cycle response for wide-band data or multiple recording of RDB subcarriers.
- **FM-carrier type recording**—D.C. to 5000 cycles and high instantaneous accuracy suitable for shock and vibration data.
- **Pulse-width modulation recording**—Up to 90 instrument readings commutated on to each tape track with frequency response 0 to 2 cycles/sec. With fewer instrument readings, frequency response is greater.

ADAPTS TO ANY DATA REQUIREMENT The Ampex 800's three available recording techniques can satisfy practically any test requirement by simple insertion of the proper plug-in amplifiers. Separate channels can be assigned to measurements requiring wide-band response or high transient accuracy. And by using pulse-width techniques, many relatively steady instrument readings can be commutated on to a single channel. All will have a common time base.

WITHSTANDS THE RIGORS OF AIRBORNE, SHIPBOARD, VEHICULAR AND GENERAL MOBILE USE The Ampex 800 will perform within specifications under vibrational forces as high as 10G—operates over a temperature range from −65°F. to 130°F.—is unaffected by altitudes to 50,000 feet—and withstands a relative humidity of 100% up to 122°F. The Ampex 800 is light in weight. It operates on 27.5 volts D.C. and 115 volts, 400 cycle, A.C. All operating functions can be remotely controlled.

RETAINS WIDELY ESTABLISHED RECORDER STANDARDS The majority of all magnetic recorders now in instrumentation use are Ampex machines. Their recording characteristics, tape speeds, track widths and other parameters have become standards. The Ampex 800 retains these while greatly extending the environmental and mechanical conditions under which accurate test data can be gathered.

Performance specifications, descriptions and explanations have necessarily been limited by the space on this page. A full description and detailed specifications on the Ampex 800 are available by writing Dept. 0-2328

AMPEX CORPORATION

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DISTRIBUTION	
NORTH AMERICA	30,890
CANADIAN ARCTIC ISLANDS	45,000
GREENLAND	666,300
SOUTH AMERICA	9,650
EUROPE	4,370
NORTHERN ATLANTIC AND EUROPEAN ARCTIC ISLANDS	45,400
ASIA	42,200
AFRICA	8
PACIFIC ISLANDS	392
SUB-ANTARCTIC ISLANDS	1,160
ANTARCTICA	5,019,000
WORLD TOTAL	5,864,370

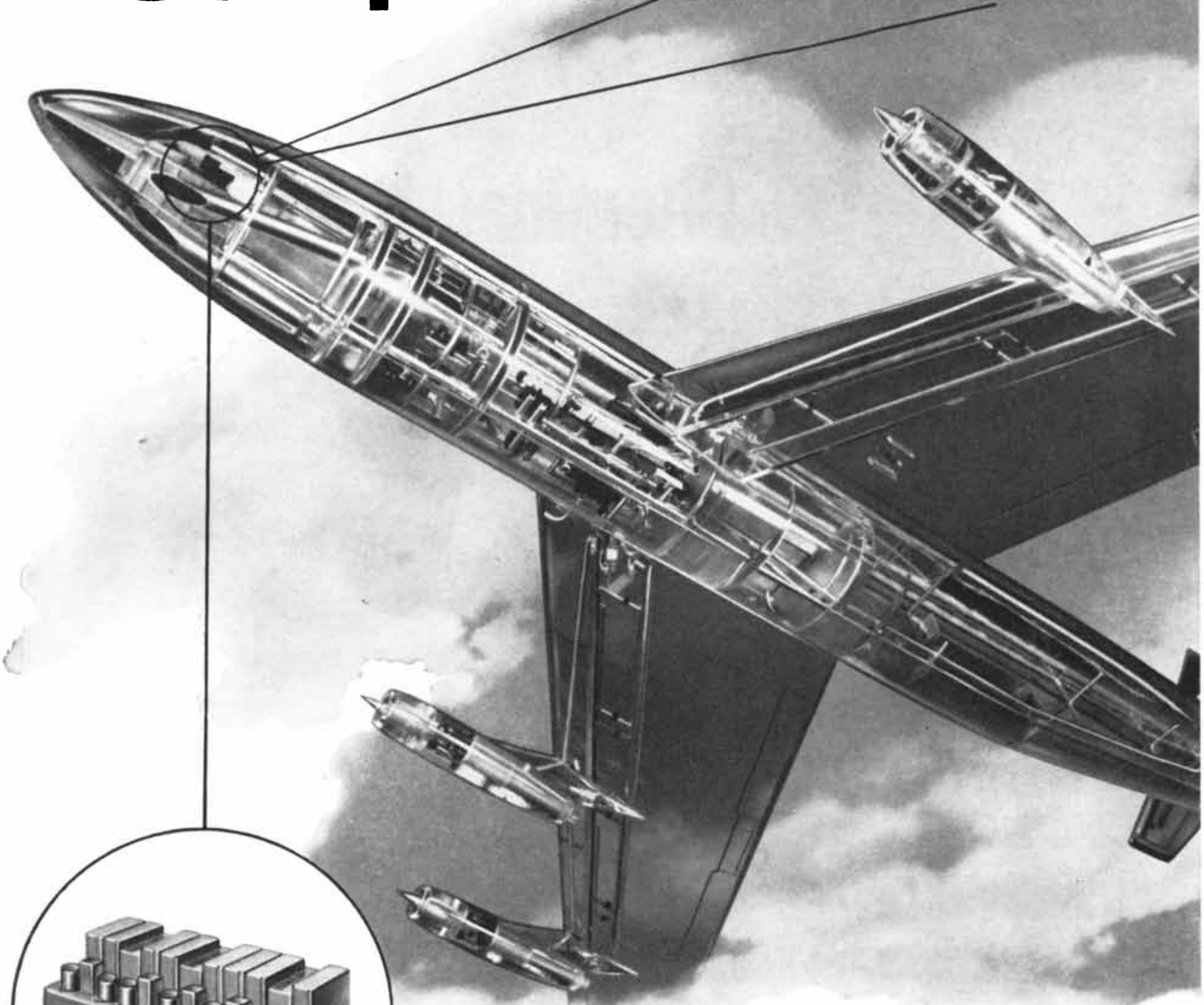
AREAS OF THE WORLD covered by ice are given in square miles by this table.

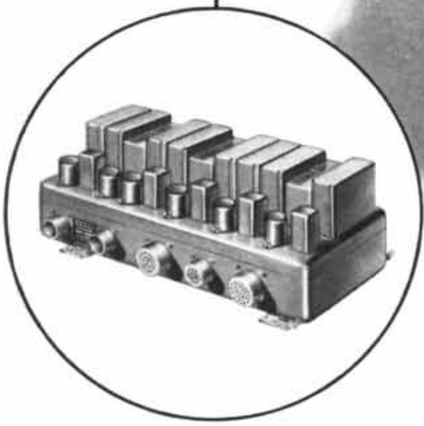
study by glaciologists (as well as other scientists) in connection with the International Geophysical Year. Parties of investigators will explore it for two years, at several bases and in snow vehicles and from the air. As much information as possible will be collected about the regimen, thickness, structure and variations of the ice sheet and the meteorology and morphology of the interior of the continent. One U. S. station will be set up near the South Pole at an elevation of about 9,500 feet, and other nations plan inland stations. It will be the first time men have ever wintered in the interior of the continent. No one knows exactly how cold it gets in winter near the South Pole, but temperatures of 100 degrees or more below zero Fahrenheit are to be expected.

In the Northern Hemisphere, the U. S. glaciological program will be directed primarily to a study of the nourishment, wastage and sizes of glaciers and their responses to varying meteorological conditions. There will be studies in the Pacific Northwest, in Alaska, in the Canadian Rocky Mountains (with Canadian cooperation) and on the Greenland icecap (with Danish cooperation). This program will be a continuation and expansion of studies carried on intermittently since the 1880s and more systematically during the past quarter century.

All these observations will be directed toward determining the present status of glaciers so that their behavior and the water balance in various parts of the world can be compared. They should tell us a great deal, not only about the earth's recent climatic history but also about possible developments in its water budget and climate in the future.

Complete air data





in one system

Here is a system that provides for the most efficient aircraft operation. It supplies all pertinent air data information to the flight engineer and pilot, or automatically makes in-flight adjustments. Similar systems are available for missiles. The air data computer system is one of many integrated systems completely engineered and manufactured by AiResearch. In the field of aircraft systems and integrated components, AiResearch has more development, manufacturing, operational and service experience than any other company.

CENTRAL AIR DATA COMPUTER BRAIN OF THE AIRESEARCH SYSTEM

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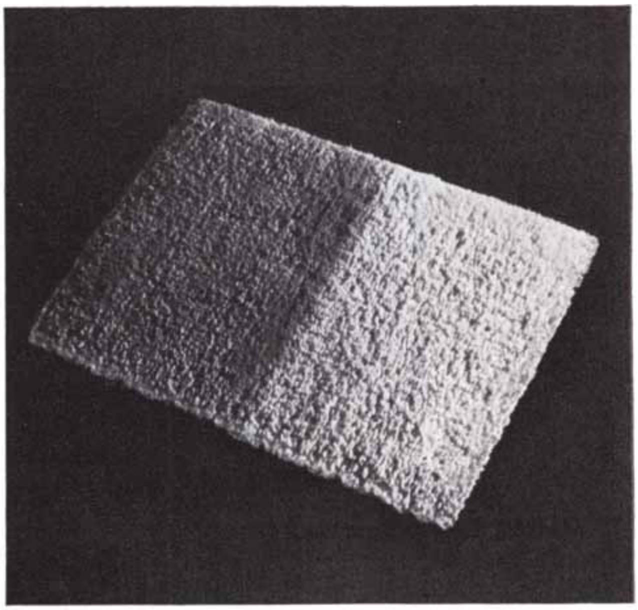
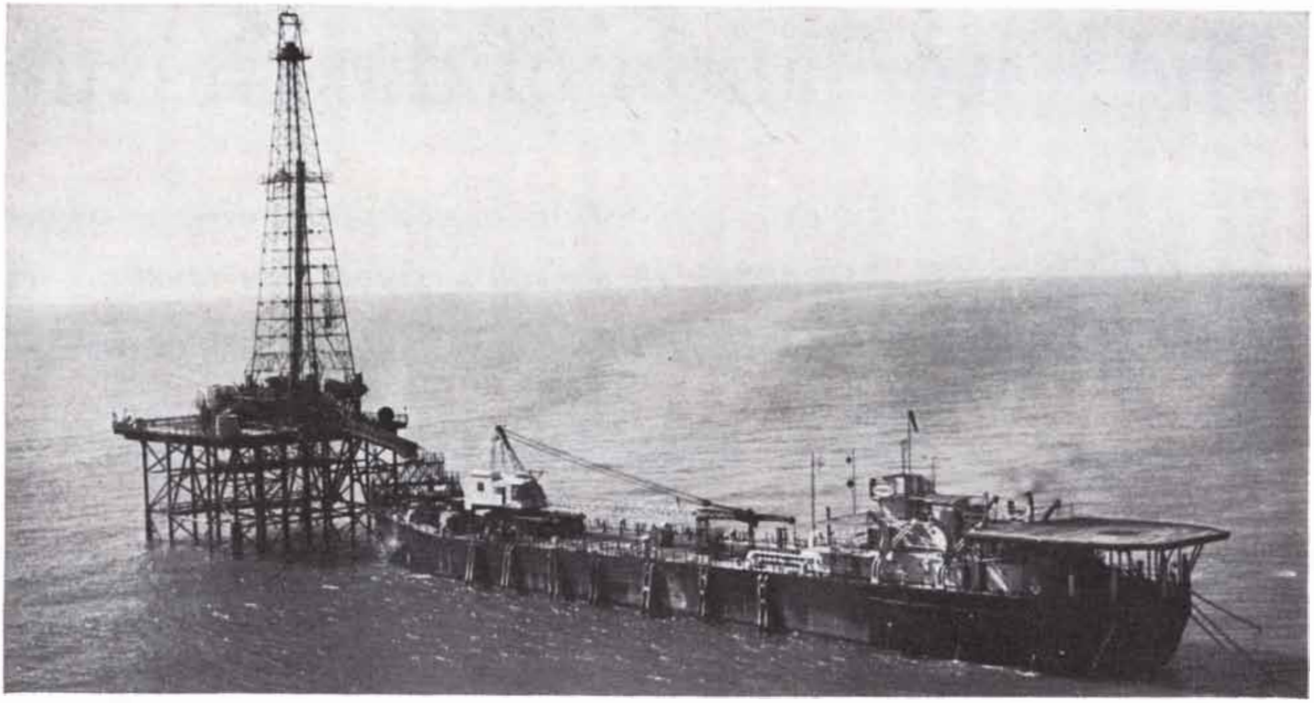
Life ...on the Chemical Newsfront

BLUETONGUE, A NEW DISEASE IN SHEEP first recognized in the U.S. a few years ago, now is spreading widely. Bluetongue may kill one out of five sheep infected, and severely set back the others. This virus disease has not been treated successfully but may be prevented with LEDERLE BLUETONGUE VACCINE developed by Cyanamid's Lederle Laboratories Division. Vaccination should be completed a full month before Bluetongue season arrives. Your veterinarian can give firsthand information. Our literature on Bluetongue disease and vaccine is available. **(Lederle Laboratories Division)**



RUGS COLLECT LESS DIRT, are cleaned more easily when treated with CYANA® Soil Retardant. Illustration shows striking contrast between treated and untreated sections of same rug exposed to identical soiling conditions. CYANA Soil Retardant acts by filling the roughnesses on the fibers with an almost invisible protective surface. This prevents soil from clinging and makes it easier to remove dirt. This new improved compound should be particularly valuable for treatment of non-wool rugs, which are increasing in popularity but tend to soil more readily than wool. **(Textile Resins Department)**

PUT PLANT REFUSE TO WORK. Corn stalks and roots were decomposed almost completely from Fall to Spring to form soil humus when plowed under with AERO® Cyanamid Granular (left photo) but remained firm and woody without this nitrogen- and lime-containing chemical (right photo). Illustrations also show improved condition of the soil due to humus formation with AERO Cyanamid. The high nitrogen content of AERO Cyanamid not only feeds the bacteria, which hastens decomposition, but also assures ample supply of this important plant nutrient for growing crops. AERO Cyanamid's lime content helps prevent soil acidity. For years AERO Cyanamid has improved soil and increased crop yields for farmers, and now is available as LAWN AND GARDEN Cyanamid to speed production of humus for home gardeners. **(Agricultural Chemicals Division)**



NEW ORGANIC WATER-LOSS CONTROL REAGENT, known as CYPAN* Drilling Mud Conditioner, is outstanding under high-temperature drilling conditions and where contamination is encountered (as with salt in off-shore drilling). Laboratory and field tests have demonstrated its effectiveness at temperatures as high as 350° F even in the presence of considerable amounts of contaminants. CYPAN Drilling Mud Conditioner is a high molecular weight, water-soluble acrylic polymer which does not require preservative treatment to prevent fermentation. **(Industrial Chemicals Division)**

**Trade-mark*

NEW VAPOR PHASE CHROMATOGRAPHY apparatus, developed in Cyanamid's Stamford Laboratories, automatically separates and identifies volatile organic liquids. Mixed vapors are separated in a partition column, and analysis is read directly on chart. Apparatus may be employed on stream or in research projects. Used at Stamford in research on new catalysts for petroleum refining, it permits rapid evaluation of catalyst efficiency. Cyanamid's extensive series of AEROCAT® Catalysts has reduced cost and increased efficiency in fluid catalytic cracking operations through development of catalysts with optimum particle shape, high pore volume, and extreme stability. **(Industrial Chemicals Div.)**

NEW WATER-SOLUBLE POLYMER, which forms water-insoluble films and coatings when air-dried or heat-cured, offers intriguing possibilities to paper, textile, adhesive and other manufacturers. The new polymer is methylolated polyacrylamide and may be made by treating aqueous solutions of polyacrylamide with formaldehyde using basic catalysts. Variation in properties may be obtained by changing processing conditions and by use of polyacrylamide of different molecular weights. Dried films of methylolated polyacrylamide are clear and hard, insoluble in boiling water, and may be softened somewhat by water immersion. Dilute solutions of the new polymer are stable for at least six months at pH 6-7. Samples of polyacrylamide and directions for methylolation are available on request. **(New Product Development Department)**

S.A.

Additional information may be obtained regarding these products by writing on your business letterhead to the Division of American Cyanamid Company, 30 Rockefeller Plaza, New York 20, N. Y., indicated after each product.

The Circulation of the Oceans

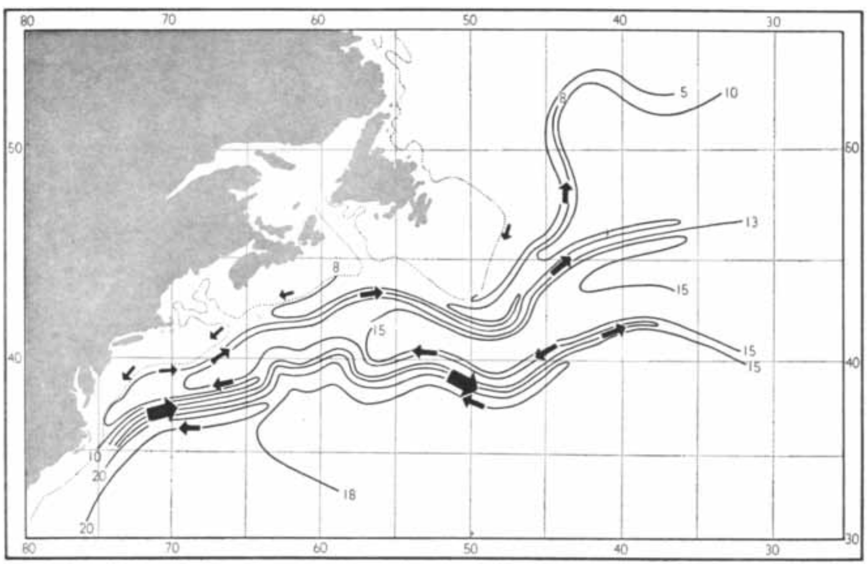
Driven by winds, the ocean waters flow in complex patterns whose broad outlines are beginning to be understood. Curiously, tiny ripples rather than large waves take up most of the winds' energy

by Walter Munk

Everybody knows the difference between climate and day-to-day weather. It is less known that a similar distinction applies also to the currents of the oceans. Until recently we were aware only of the broad, average features of the ocean movements—the "climatic" circulation. But modern studies have disclosed a fine structure which is superposed on this climate and which shifts from day to day in an unbelievably mercurial manner. If 10 vessels strategically placed in the Gulf Stream were to measure the currents and make a "weather map" of the Stream next Tuesday, the map would differ from the one for Friday. Not long ago we watched a freighter carefully holding a course which according to the climatic chart should have speeded it on its way to Europe by taking advantage of the Gulf Stream. Actually the ship was bucking a two-knot countercurrent; the Gulf Stream was 100 miles off its usual path!

The vagaries of the ocean currents were practically unknown until the last world war, when new techniques and more detailed mapping disclosed that currents in the Atlantic were not as steady or predictable as the earlier climatic maps had suggested. The upshot is that oceanographers have now become interested in two kinds of maps: the climatic map, which shows the average currents over a large area for a year, and the "synoptic" map, which is like a daily or weekly weather report, showing how the currents change from one week to the next. The currents look quite different in the two charts. In the synoptic picture they are narrow, winding and fast; in the climatic picture they are smooth, broad and slow.

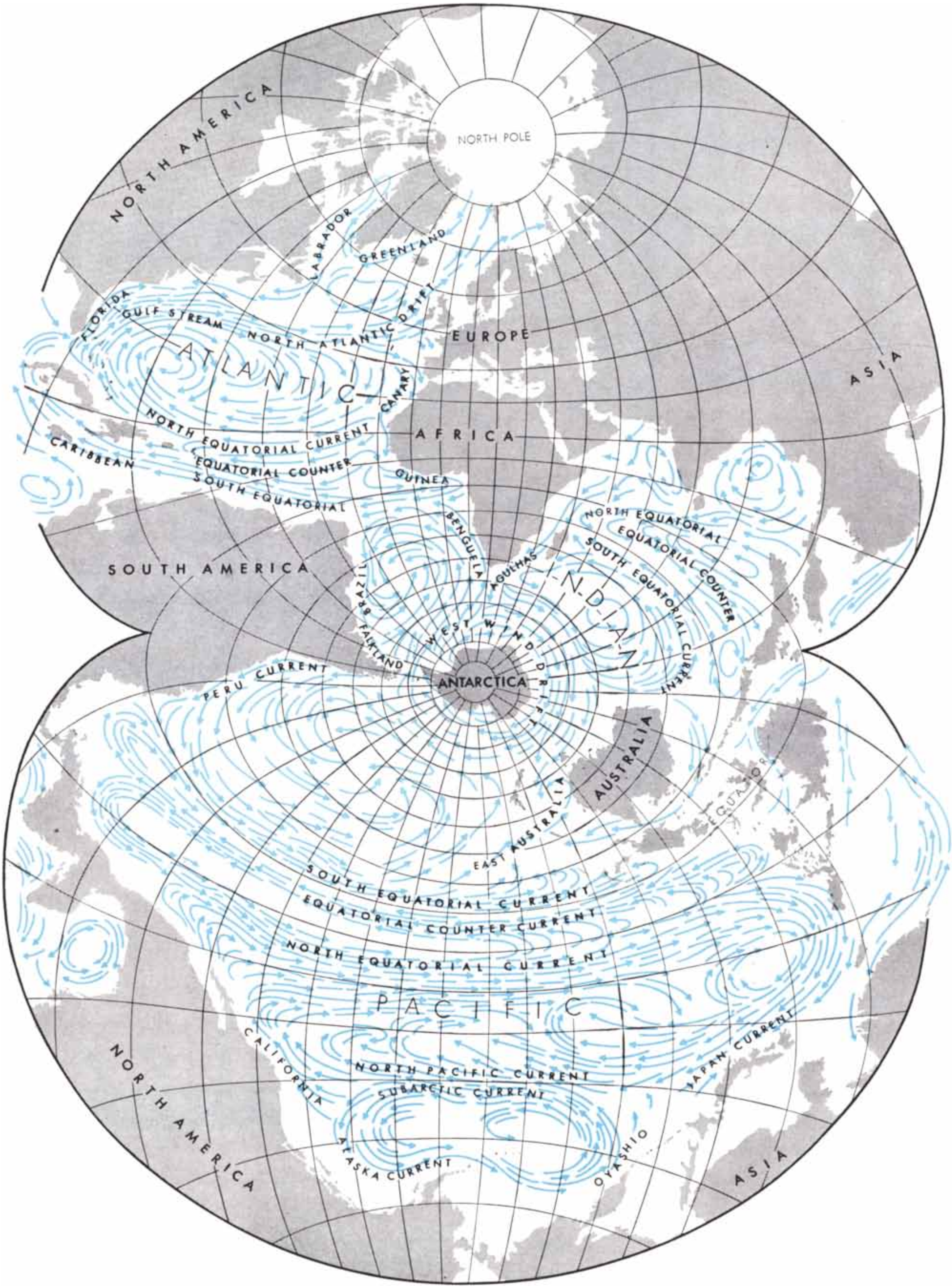
Both charts have their uses. If you want to study a long-term phenomenon such as the transport of sediments by currents off the coast of a continent, the climatic chart will be the one you need. On the other hand, if you are piloting a ship or submarine, you will find the synoptic chart much more useful.



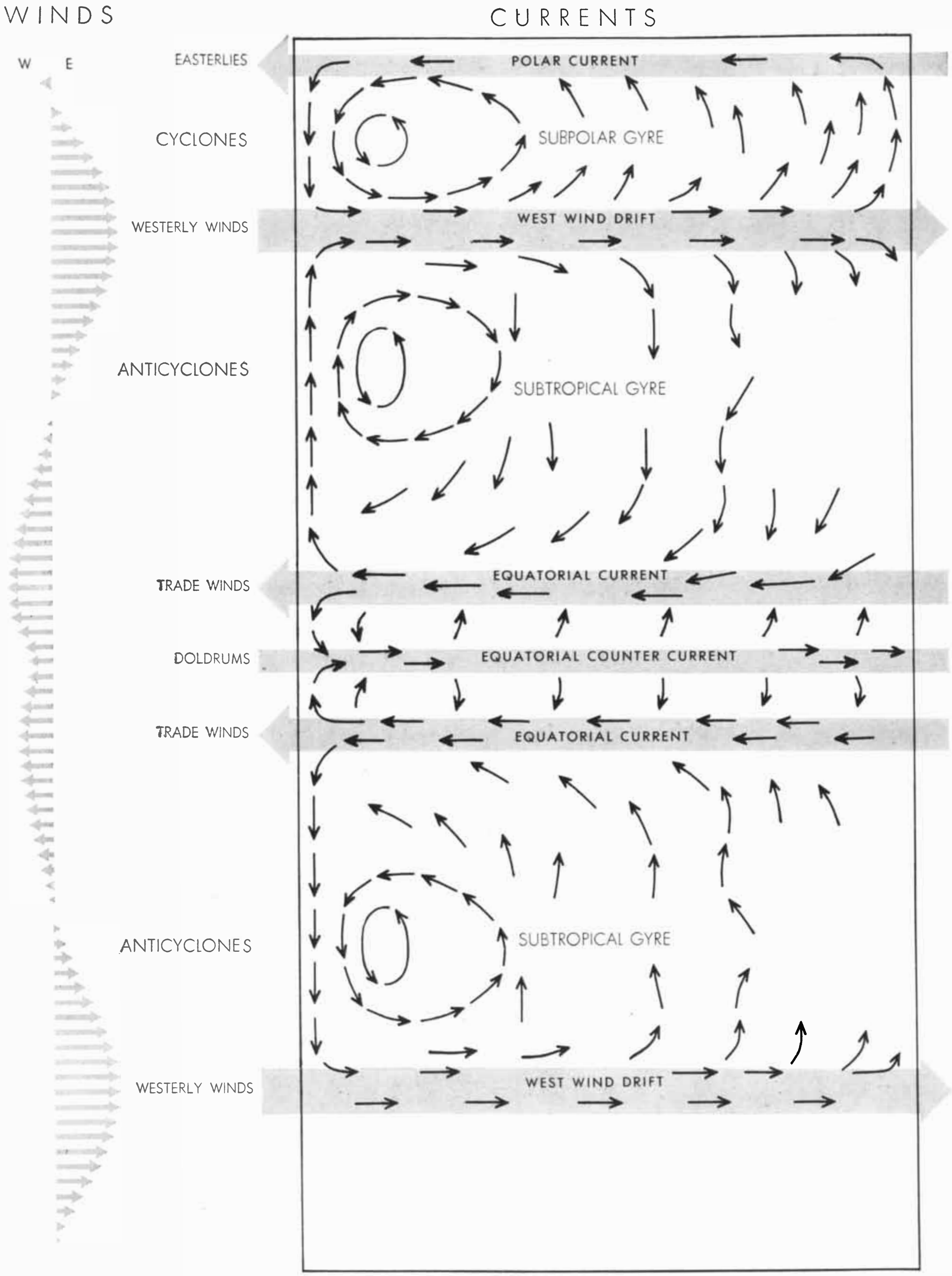
GULF STREAM, examined in detail, exhibits the narrow, fast-flowing filaments typical of all ocean currents. The solid lines mark regions of equal temperature, measured in degrees centigrade. The dotted line indicates the point at which the bottom is deeper than 100 fathoms.

Oceanographers have mapped the general circulation of all the world's oceans, relying mainly on a method which is like that for determining air currents in the atmosphere; that is, the currents are deduced from pressure fields in the sea, which in turn are indicated by measurements of water salinity and temperature [see "The Anatomy of the Atlantic," by Henry Stommel; SCIENTIFIC AMERICAN, January]. The map on the opposite page summarizes what we know about the climatic circulation of the oceans' surface (the top 1,000 feet).

Is there any system to this complex circulation pattern—any clue to how it may be produced? I think there is, and the chart on page 98 is an attempt to analyze the chief elements of the picture. Suppose we plot the currents that should appear in an idealized rectangular ocean responding to the known winds that blow over the world at the various latitudes. (To simplify things we take into account only the east-west components of the wind system, disregarding "details" such as the winds blowing around the Bermuda high.) The circulation in this schematic ocean then divides into several gyres (rings) corresponding to the wind belts—a counterclockwise gyre in the subpolar region, a clockwise circulation in the subtropical belt above the equator, a narrow gyre on each side of the equator and a counterclockwise gyre in the subtropical region below the equator. In each gyre there is a strong, persistent current on the western side



CLIMATIC CIRCULATION in the ocean basins is illustrated on this unusual projection. Colored arrows show the present picture of the average currents. Equatorial countercurrent, which is present in all the oceans, lies five degrees north of the geographic equator.



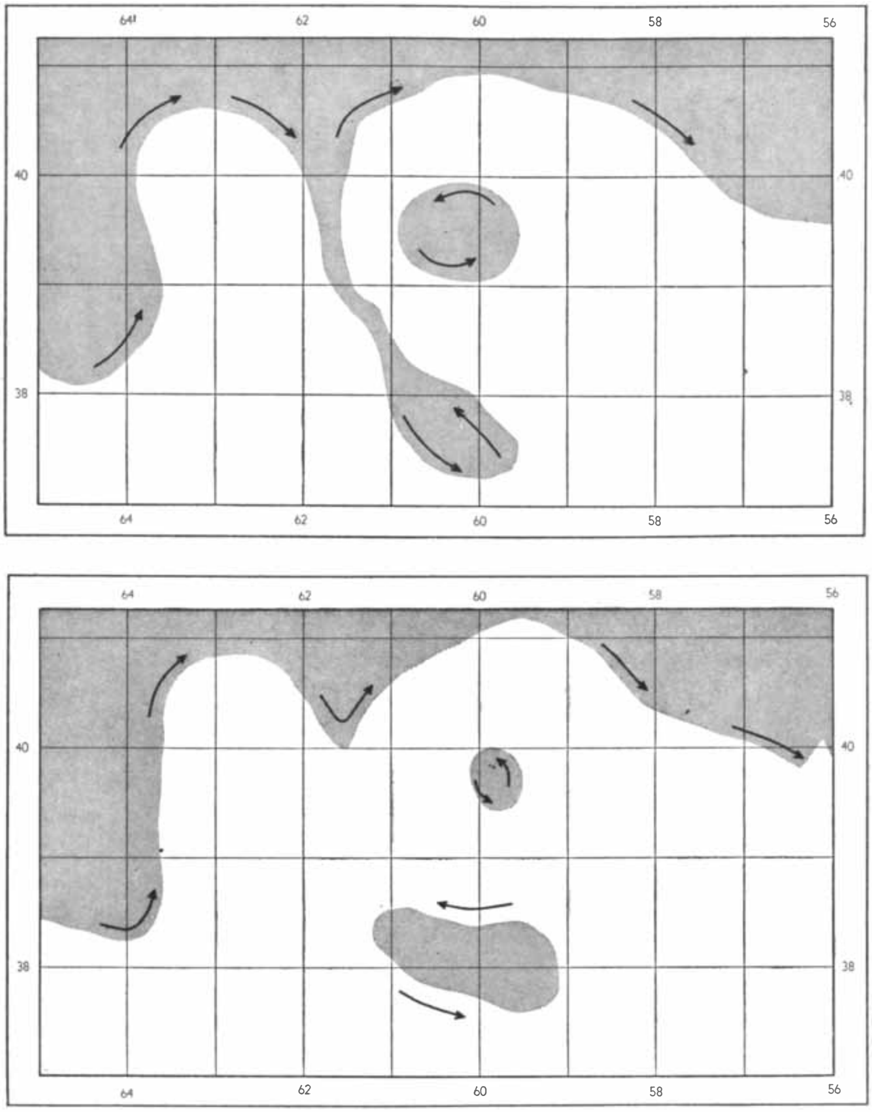
IDEALIZED OCEAN, rectangular in shape and subject only to the horizontal wind forces shown by the broad gray arrows, would have the circulation patterns traced by the black arrows. Approximate relative velocities of surface winds are indicated at left.

(due, as we shall see, to the rotation of the earth) and a compensating drift in the central and eastern portion.

With some imagination we can recognize this pattern in the three major ocean basins of the earth. The strong western current appears as the Gulf Stream in the North Atlantic, the Kuroshio in the North Pacific, the Brazil current in the South Atlantic, the Agulhas in the Indian Ocean, and possibly the East Australia current in the South Pacific. The current driven by the strong west winds in the "roaring forties" of the Southern Hemisphere flows not in a gyre but right around the globe, because no continent stands in its path; this is the mighty Antarctic circumpolar current.

The ocean-current gyres in our picture correspond closely not only to the wind systems but also to chemical and biological properties of the ocean regions. Each subtropical gyre, for example, encloses a sea which is relatively warm, salty, poor in phosphates, low in biological activity and blue in color (blue is the desert color of the sea). At the boundaries of the gyre these conditions change sharply. And the center of each gyre, near the western shore, is an unusually stable environment. The best known such region is the Sargasso Sea in the Atlantic, named after its sargassum, or gulfweed. Very possibly the six other similar regions in the world—the centers of the subtropical gyres in other oceans—will be found to have like populations of floating sea life with narrow environmental tolerances; that remains to be explored.

The precise mechanism whereby the winds produce the circulation gyres is complex and not clear. First of all, the action of wind upon water is itself a complicated matter. Wind can move water simply by frictional force as it slides over the surface, even when the surface is smooth. It must also accelerate the motion of water when it picks up spray and throws it down again, particularly during hurricanes, when so much water is pulled up into the air that the "boundary" between the sea and the air is lost. Another important means by which wind drives ocean water is its pressure on the waves as it sweeps over rough water—just as wind blowing over a field bends the blades of grass because pressure is higher on the windward sides than on the lee sides. It turns out that the important elements in the response of water to wind are not the large waves that rock boats and make people seasick, but the tiny bumps, the ripples. If we



GULF STREAM EDDY begins with the formation of a 250-mile loop in the current (*top*). Four days later, loop has been pinched off (*bottom*). Gray indicates cold subarctic water.

could cover the North Atlantic with oil and smooth these ripples, the Gulf Stream would lose an appreciable part of its strength. The importance of these tiny waves is surprising. Would any honest seafaring man care to admit that the tiny ripples, to which he paid so little attention, may have been partly responsible for setting him off his course?

How do the driving winds produce the great circulations (gyres) that we see in the oceans? During the last 10 years a theory has been developed. We start with a situation where no land barrier stands in the way of the wind-driven water. The currents will then flow in a great circle around the earth, as they do around the Antarctic Continent [*see page 102*]. Things get more complicated when we introduce land masses. Suppose we erect barriers and make an enclosed sea. Now if winds blow only from the west and have equal force at all latitudes in this sea, there can be no rotary circulation or currents; just as a paddle wheel subject to equal force from the same direction on its opposite blades will not turn. The wind will simply pile up water on the eastern side of the sea. But if the wind is stronger at some latitudes than at others, the stronger will overpower the weaker and the water will begin to circulate. The circulation will be even stronger, of course, if the winds at different latitudes blow in opposite directions. To this effect we must now add the effect of the earth's rotation. The turning of the earth toward the east exerts a torque on the ocean circulation, with the result that the center is displaced toward the west and the currents are intensified on the western side [*see lower drawing on page 104*].

In general the great wind-driven currents in the world's oceans do fit this model and the theory derived from it. The boundaries of the major currents are where they should be in relation to wind systems, and the strong western currents also appear where they should. Moreover, the theory has received some support from a laboratory model simulating ocean circulations. William von Arx, of the Woods Hole Oceanographic Institution, performed these experiments with a rotating basin shaped like a roulette wheel—essentially a hemisphere turned inside out. His "oceans" consist of a thin film of water clinging in an equilibrium distribution over the surface of the whirling basin, and winds are blown on the water from nozzles on vacuum cleaners. Von Arx projects the Northern Hemisphere into this basin, with the North Pole at the low point in the center. Potassium permanganate crystals are placed in the center, and when ink is introduced into the water, it reacts with the chemical to show the flow patterns in different colors. Von Arx's model faithfully reproduces the gyres of the North Atlantic and the North Pacific, including the intense western currents. The model is especially interesting because the topography and winds can be varied to show possible circulations of the oceans in the past, when conditions were different; for instance, one can investigate how the Gulf Stream might have behaved at a time when there was a separation between North and South America in the place of the present Isthmus of Panama.

It must not be supposed that the theory about how the ocean circulations are produced is fully confirmed by these observations and experiments. There are many inconsistencies; in particular, some of the circulation in the oceans of the Southern Hemisphere refuses to fit into the pattern pictured by the theory.

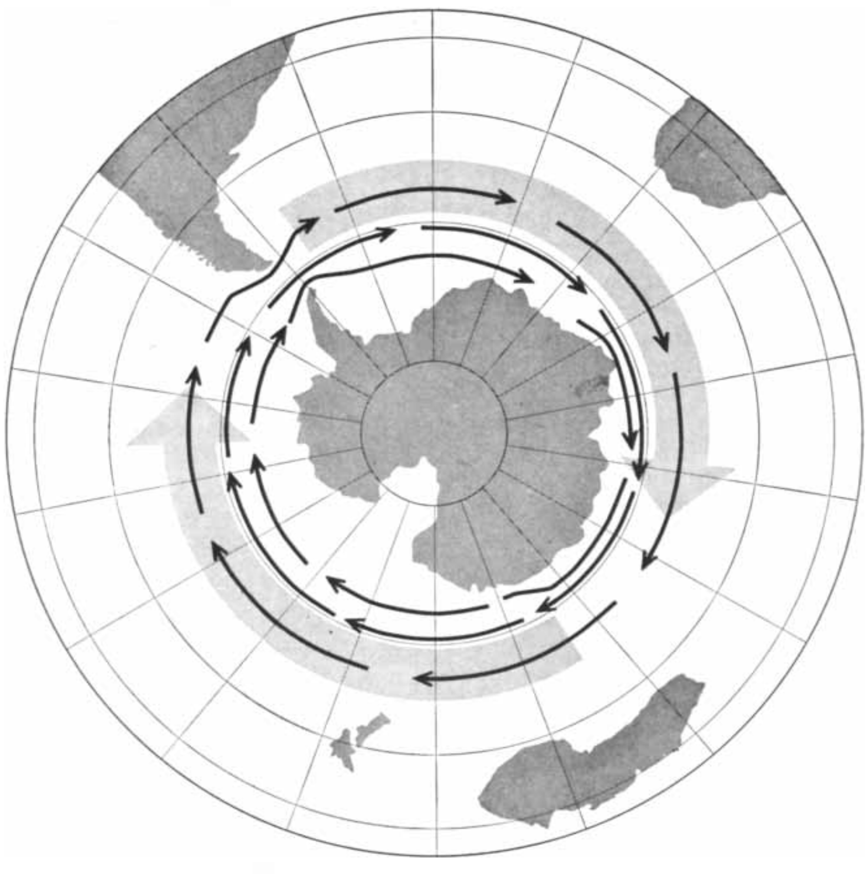
This is where we stand, then, on the climatic circulation. The era of measurement of the synoptic circulation, or day-to-day ocean weather, began with the recent invention of certain new techniques and instruments, notably (1) the radio location method called "loran," (2) the instrument for rapidly measuring temperatures at various depths which is called the "bathythermograph," and (3) an instrument, invented by von Arx and named the "geomagnetic electrokinetograph," which determines the motion of ocean water by measuring the electric potentials induced in it because of its movement through the earth's magnetic field.

Resurveying the Gulf Stream with these techniques, Columbus O'Donnell

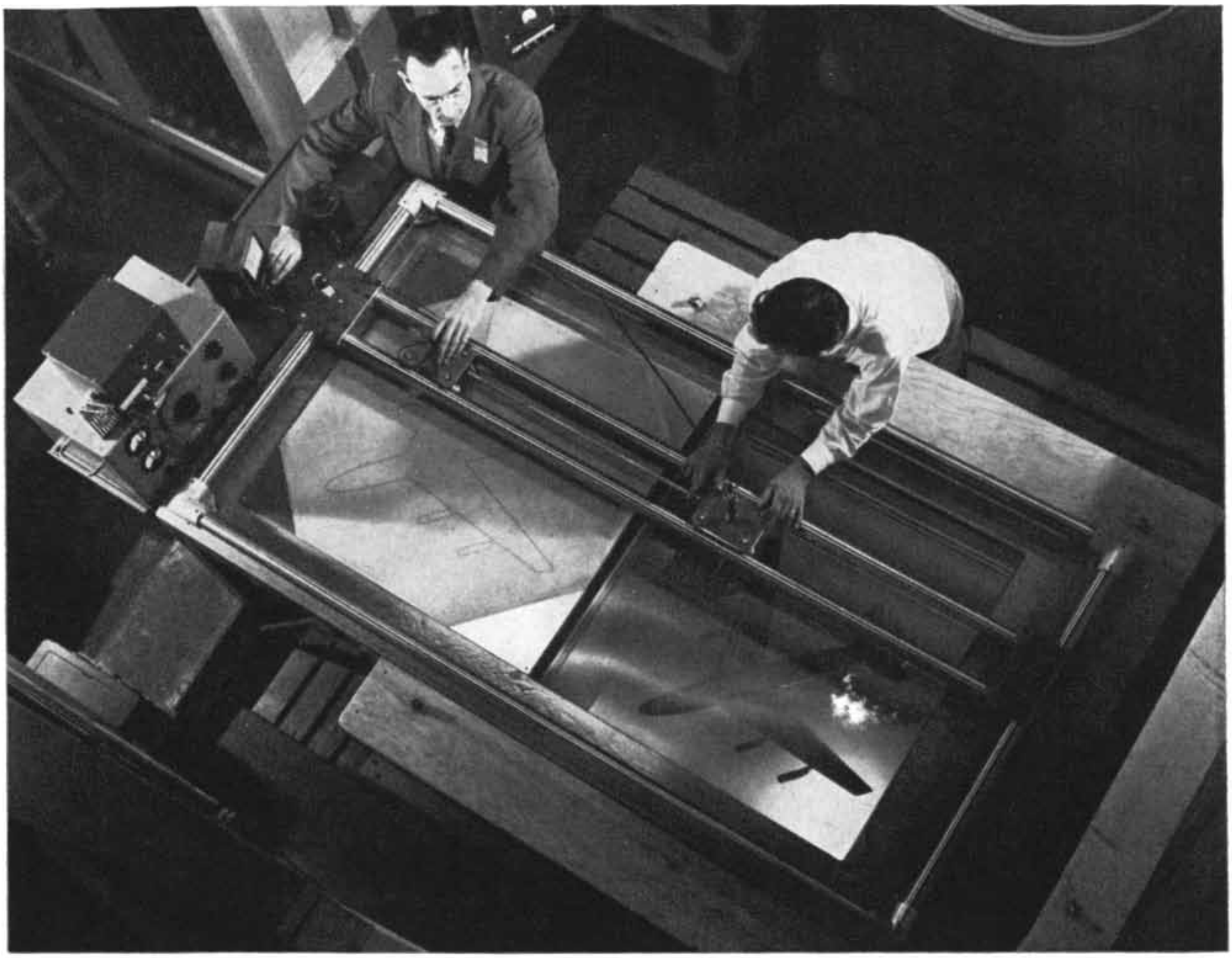
Iselin and his collaborators at Woods Hole discovered that the Stream was narrower and much faster than had been thought. As their instruments and techniques improved, the current became even narrower and faster. They also found that the position and direction of the current varied from one cruise to the next. A five-ship expedition called Operation Cabot was organized by the U. S. Navy Hydrographic Office in 1950 to study the Gulf Stream more closely. This cruise detected a most important and dramatic phenomenon: the Gulf Stream meandered off the usual course to form a loop 250 miles long! Within two days the loop broke off and separated as an independent eddy [*see charts on page 100*]. The eddy then gradually weakened.

It is estimated that this single eddy injected some 10 million million tons of subarctic water from the North Atlantic into the subtropical Atlantic. Obviously such an immense transport of water, with its content of living organisms, must be of considerable importance to the biology of the sea. Possibly similar eddies of water from the south break off toward the north, injecting subtropical water into the colder part of the ocean.

Frederick Fuglister of Woods Hole, an artist who has been in oceanographic work since the war, later discovered some other unsuspected characteristics of the Gulf Stream. Plotting currents by means of temperature gradients measured with the bathythermograph, he found a pattern which suggested that the Gulf Stream consists of a number of long, narrow, separate ribbons, or filaments. They are not continuous over thousands of miles; as a rule one will peter out and another will start somewhere else. In other words, it appears that the concept of a single, continuous Gulf Stream all the way from Florida to Europe must be abandoned. Rather one must visualize the Stream as composed of high-speed filaments of current separated by countercurrents [*see chart on page 96*]. L. V. Worthington of Woods Hole, using all the modern tools, has substantially confirmed this picture with detailed cross-section studies. In one 30-mile cross section he found three separate major filaments, each flowing at better than three miles per hour. Gunther Wertheim, also of Woods Hole, further demonstrated the complexity and variability of the Gulf Stream by discovering that the transport of water by the Florida current section



ANTARCTIC CIRCULATION is relatively simple because no land barriers prevent the waters from responding to the prevailing west winds. West-to-east current rings continent.



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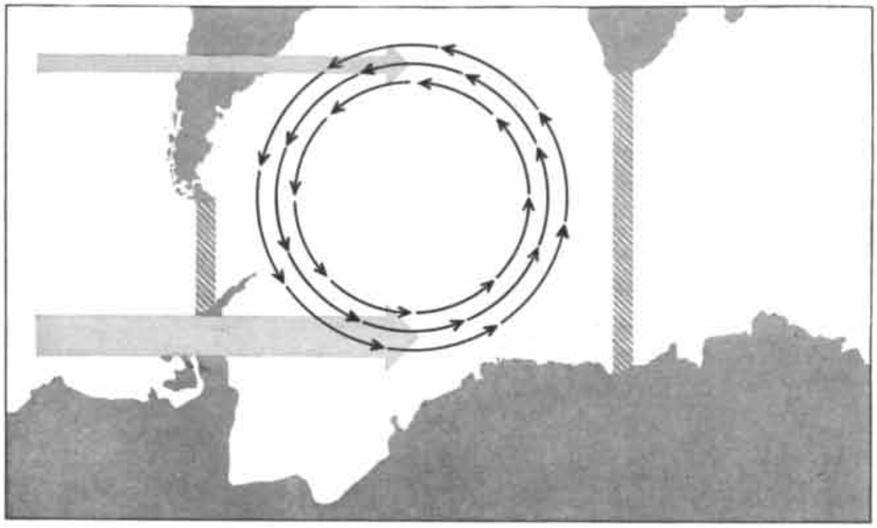

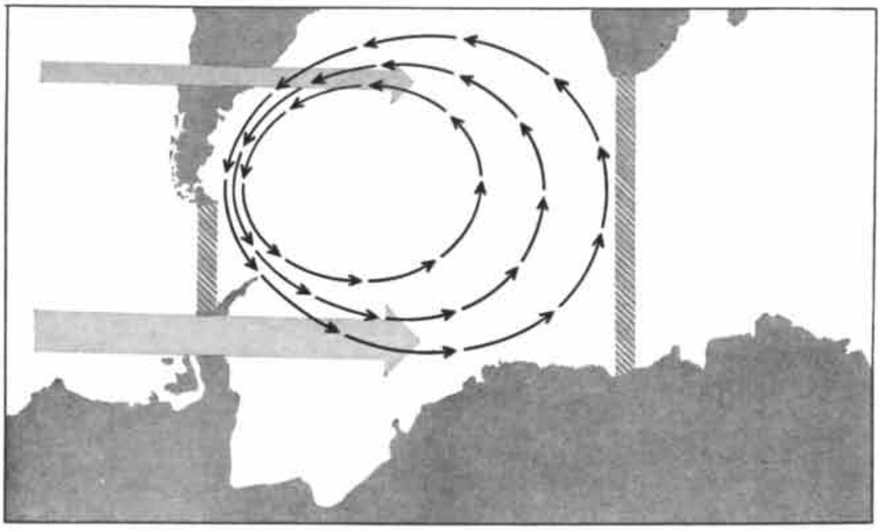

IMAGINARY SMALL OCEAN, made by enclosing part of the Antarctic waters with walls extending to South America and Africa, would circulate as shown at top if west winds in the south were stronger than those farther north. The effect of the earth's rotation would be to shift circulation pattern westward, as at bottom, compressing currents at the west wall.

of the Stream doubled from one month to the next! He computed the movement of water from measurements of electric potential between Havana and Key West, made by attaching electrodes to the Western Union telegraph cable between those points.

Fuglister has satisfied himself that the Japanese current also can be interpreted as consisting of filaments; in fact almost everywhere we look the ocean weather seems extremely fickle. Henry Stommel, monitoring radio drift buoys near Bermuda, found the currents highly changeable; every sudden waxing or waning of the winds set up rotary currents.

My interpretation of the new look with regard to the ocean weather is something like this. The motion of water in the open sea is highly irregular and variable. If we release a drift buoy, we can expect the current to carry it something like half a mile in an hour, but the velocity and the direction will be quite different from one day to the next. This unsteady motion—the "noise" of the ocean circulation—represents in some way the response of the sea to the multiplicity of shocks it receives from the wind blowing on its surface. The response is not simple, and the underlying laws have not yet been recognized. The transient ocean weather, unlike the slow climatic circulation, apparently has no blow-by-blow counterpart in the circulation of the atmosphere.

The fine structure of the ocean currents can be tied in with the climatic circulation only in a general way. It evidently results from the fact that the broad circulation cannot dissipate all the energy received by the ocean from the wind, but just why the fine structure takes the forms it does is a problem awaiting further exploration.

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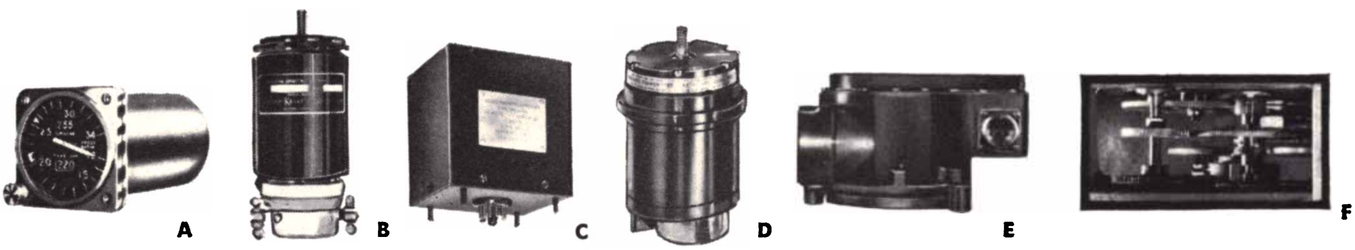
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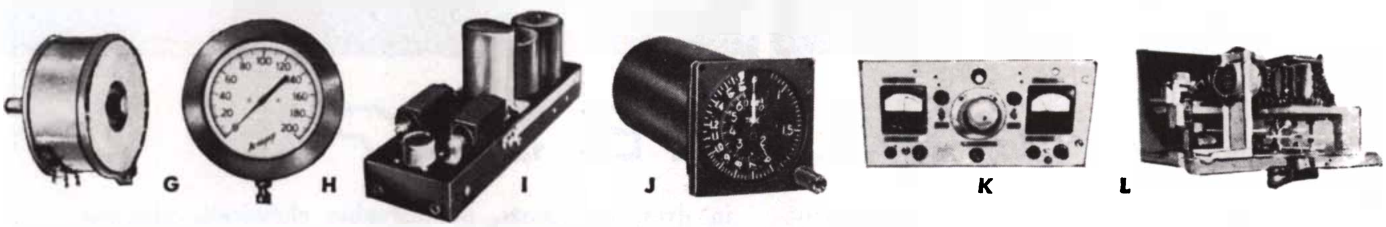

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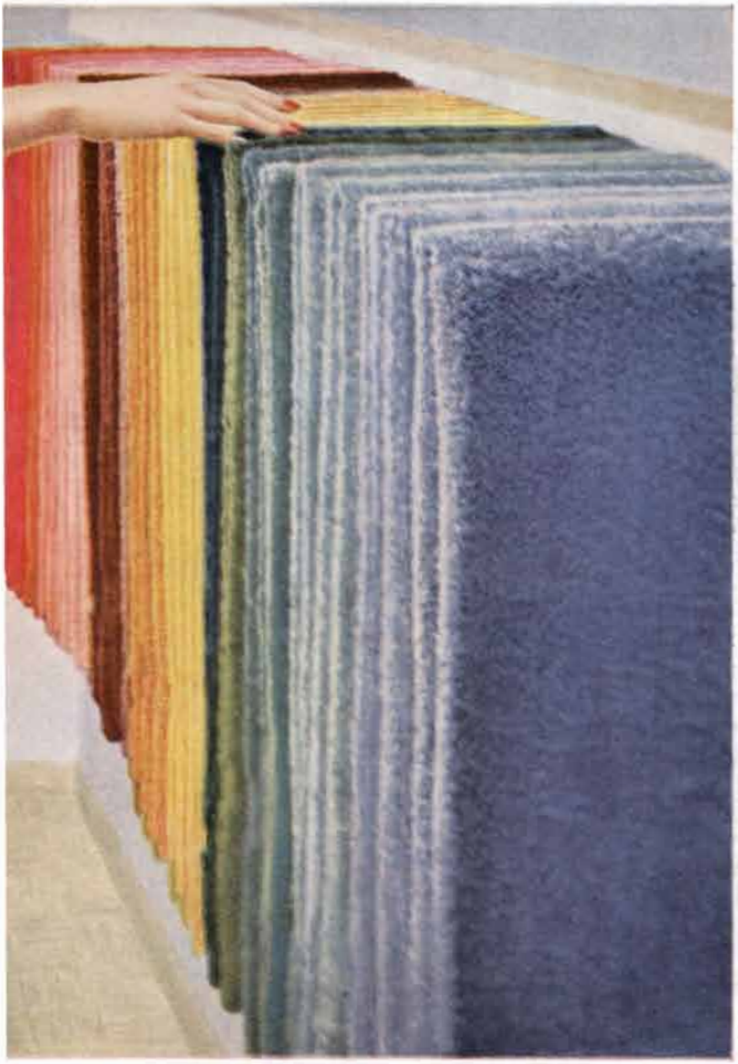

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The Earth from Space

The photograph on the next two pages is the most revealing yet made of the earth. It was exposed in a rocket at a height of 143.4 miles, which for all practical purposes is outside the earth's atmosphere

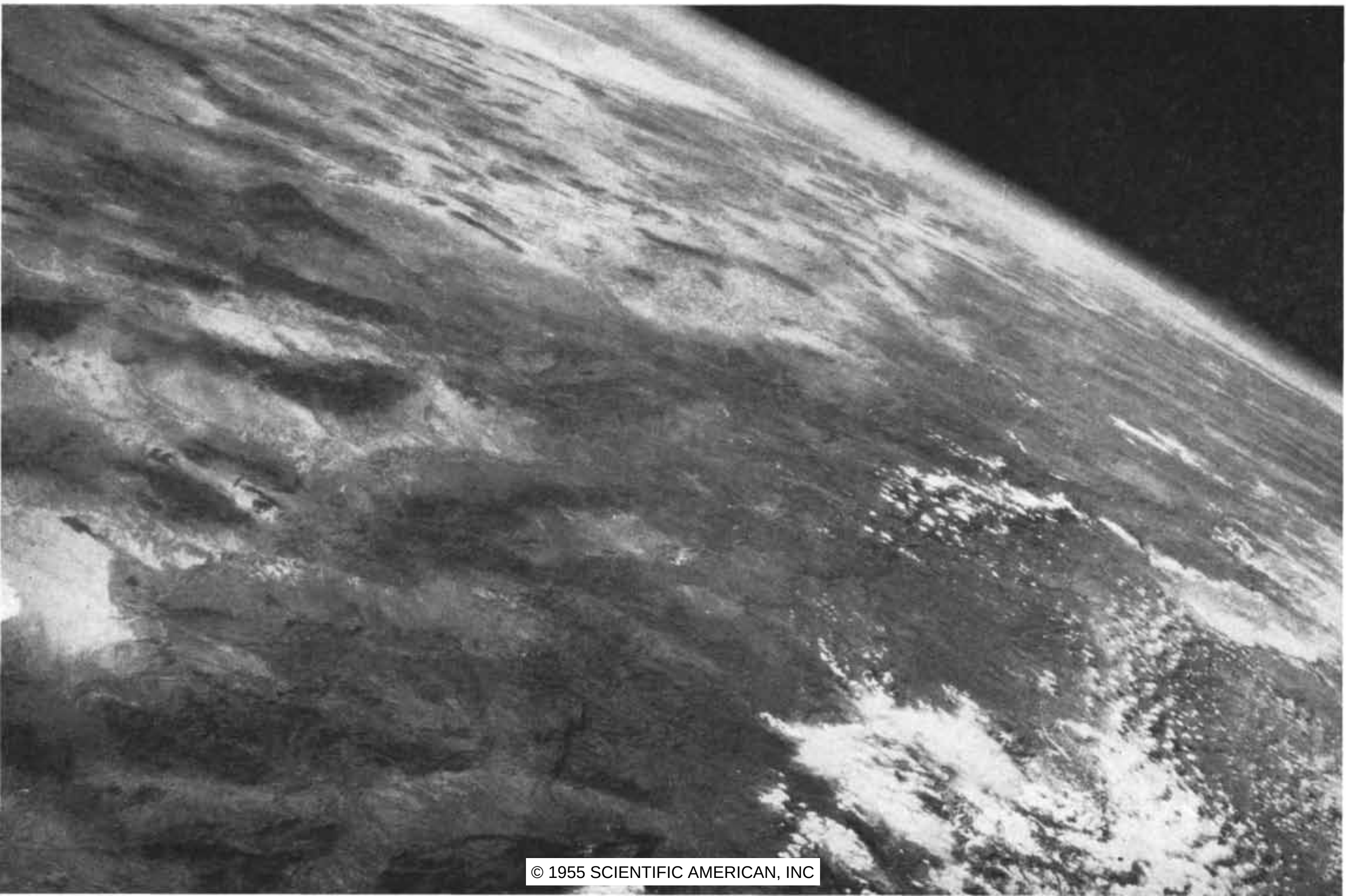
One of the many programs of the International Geophysical Year will be to fire large rockets high above the stratosphere of the earth. The U. S. will launch 45 rockets; the French, 12.

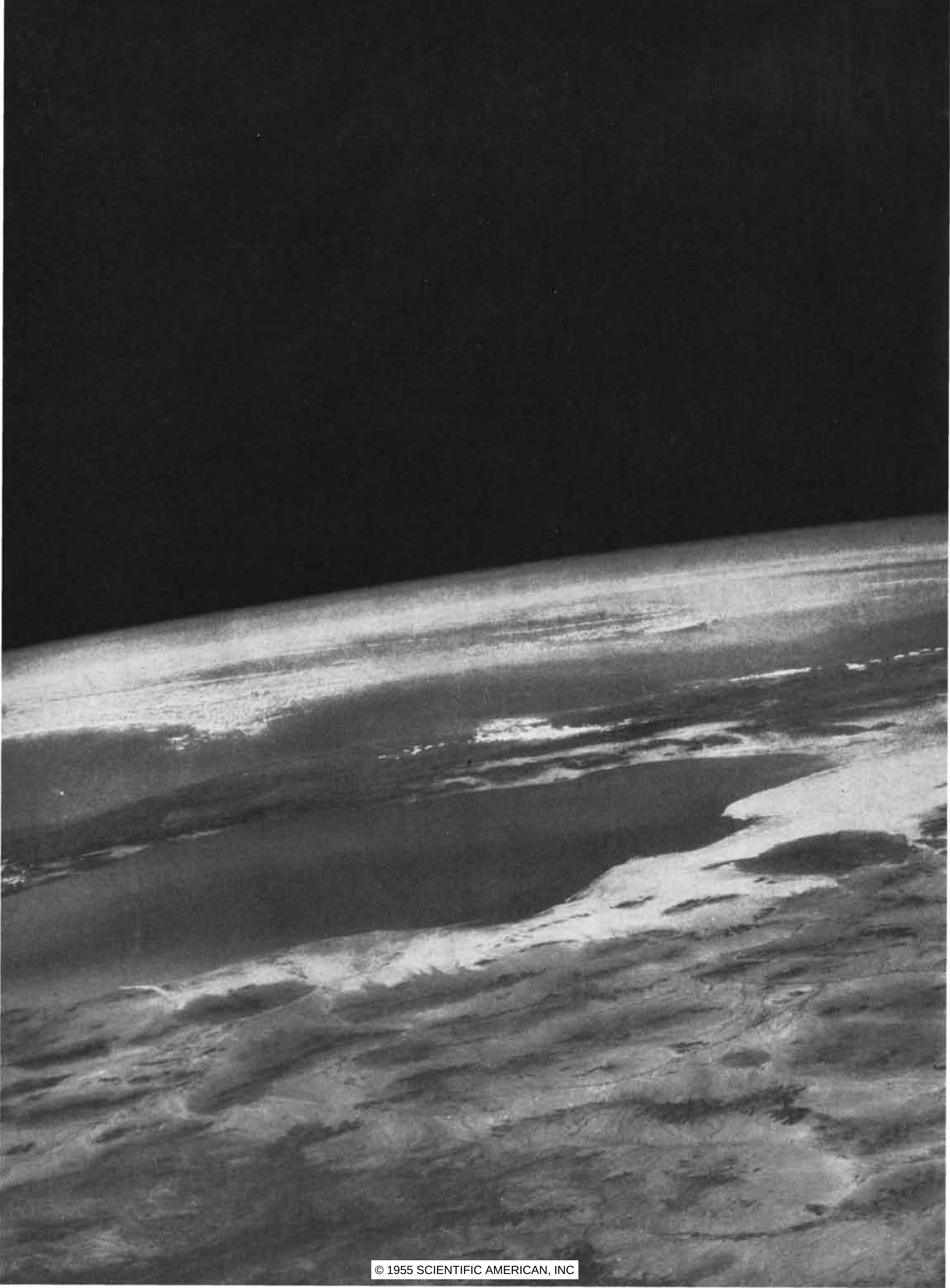
The art of photographing the earth from rockets has recently been developed to a high degree. The remarkable pictures on this and the next two pages were made from a Navy Viking rocket sent aloft from the White Sands Proving Ground in New Mexico on February 4. The rocket reached an altitude of 143.5 miles, a tenth of a mile below which the photograph on the next two pages was made. This is not the highest aerial photograph: an earlier Viking lifted a camera to a height of 158.4 miles. But advances in mounting the camera made the picture the clearest and most extensive of its kind.

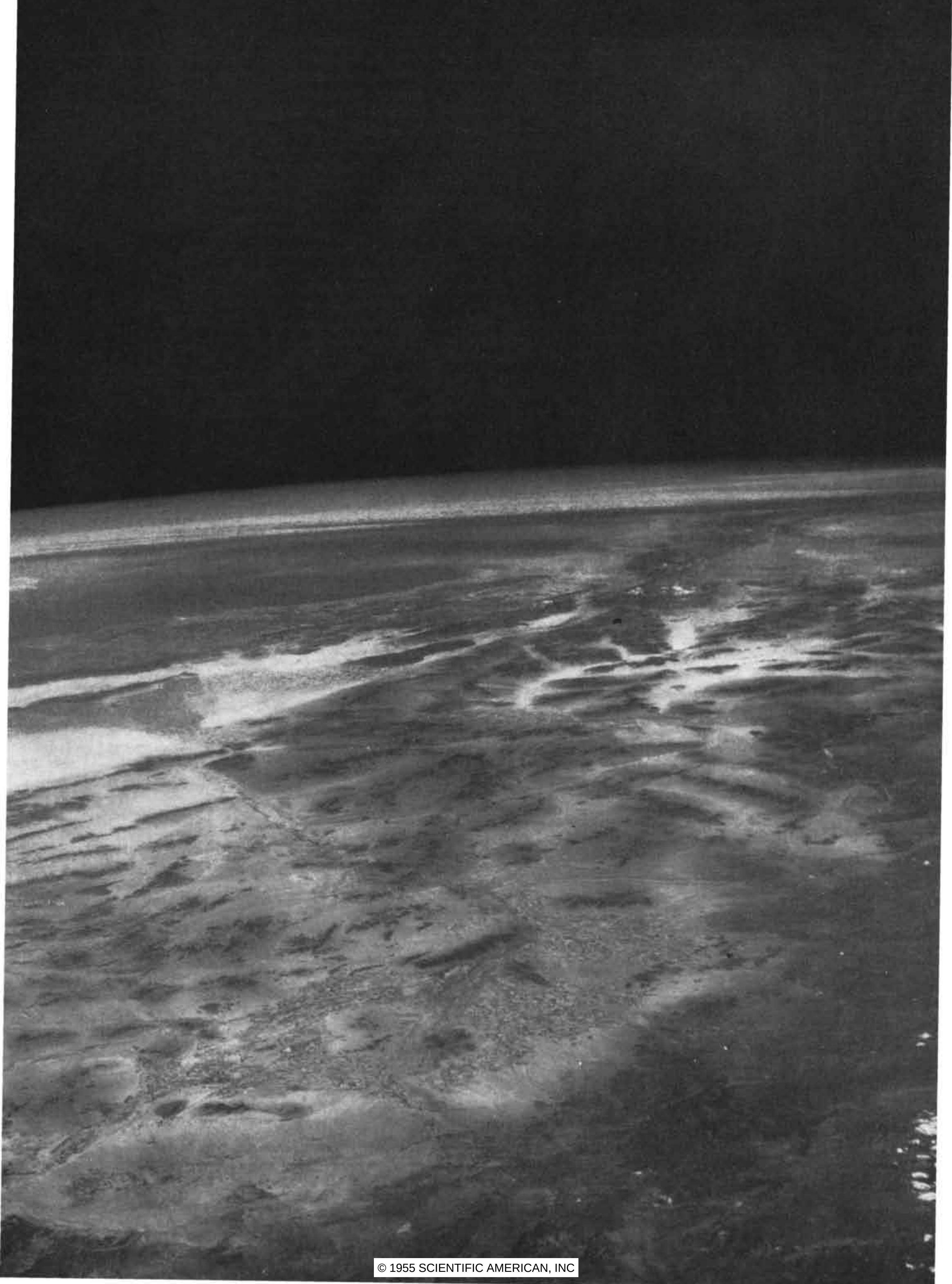
The photograph below was made from a height of 101 miles, while the rocket was on the way down. It shows about 300,000 square miles of New Mexico, Arizona, California and the Mexican province of Sonora. The photograph on the next two pages shows about 600,000 square miles. From left to right the photograph extends about 800 miles; the horizon is more than 1,000 miles away.

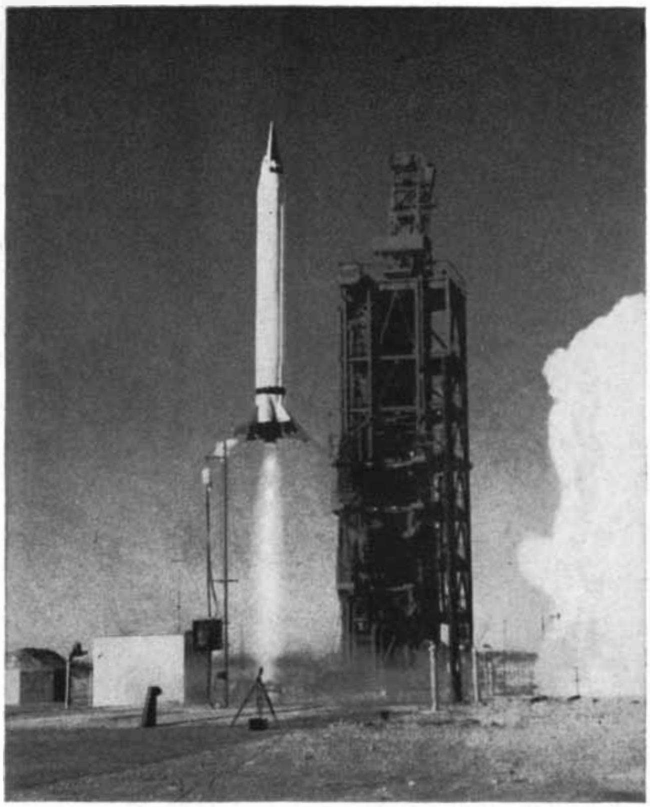
The photograph contains many clearly recognizable geographical features. The large body of water nearest the camera on the left-hand page is the Gulf of California. Beyond it is Lower California, and beyond that a broad expanse of the Pacific. The relatively small body of water near the center of the right-hand page is the Salton Sea. At its left end may be seen the cultivated area of the Imperial Valley. Above and to the right of the Salton Sea are snow-capped peaks in the Coast Ranges of California. Just above them is Los Angeles. The haze drifting out to sea from this area is presumably smog. Near the bottom of the right-hand page is the cultivated area around Phoenix, Ariz. The small body of water at the lower right is the artificial Lake Roosevelt in Arizona.

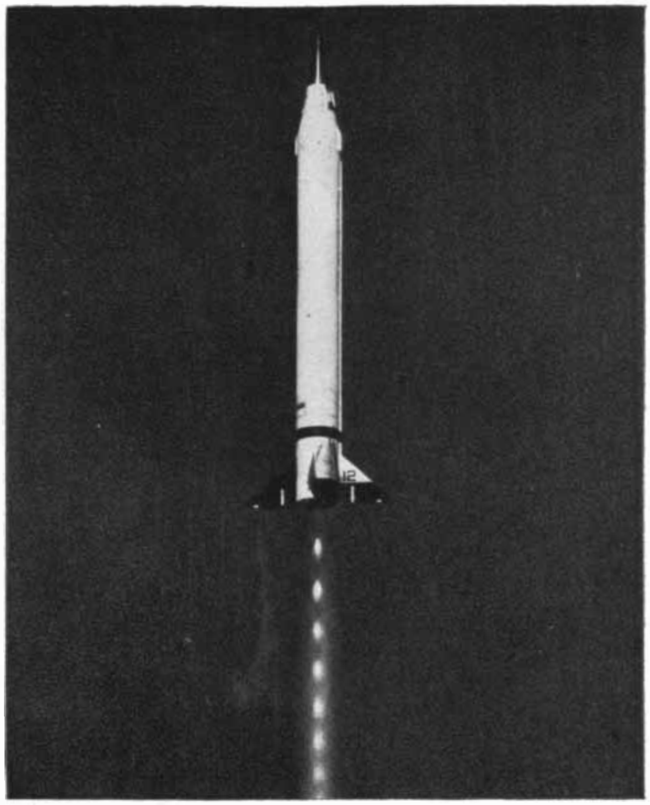
The horizon clearly delineates the curvature of the earth. The luminous band along the horizon shows the limit of that part of the atmosphere which contains an appreciable amount of water vapor. Beyond this is space.





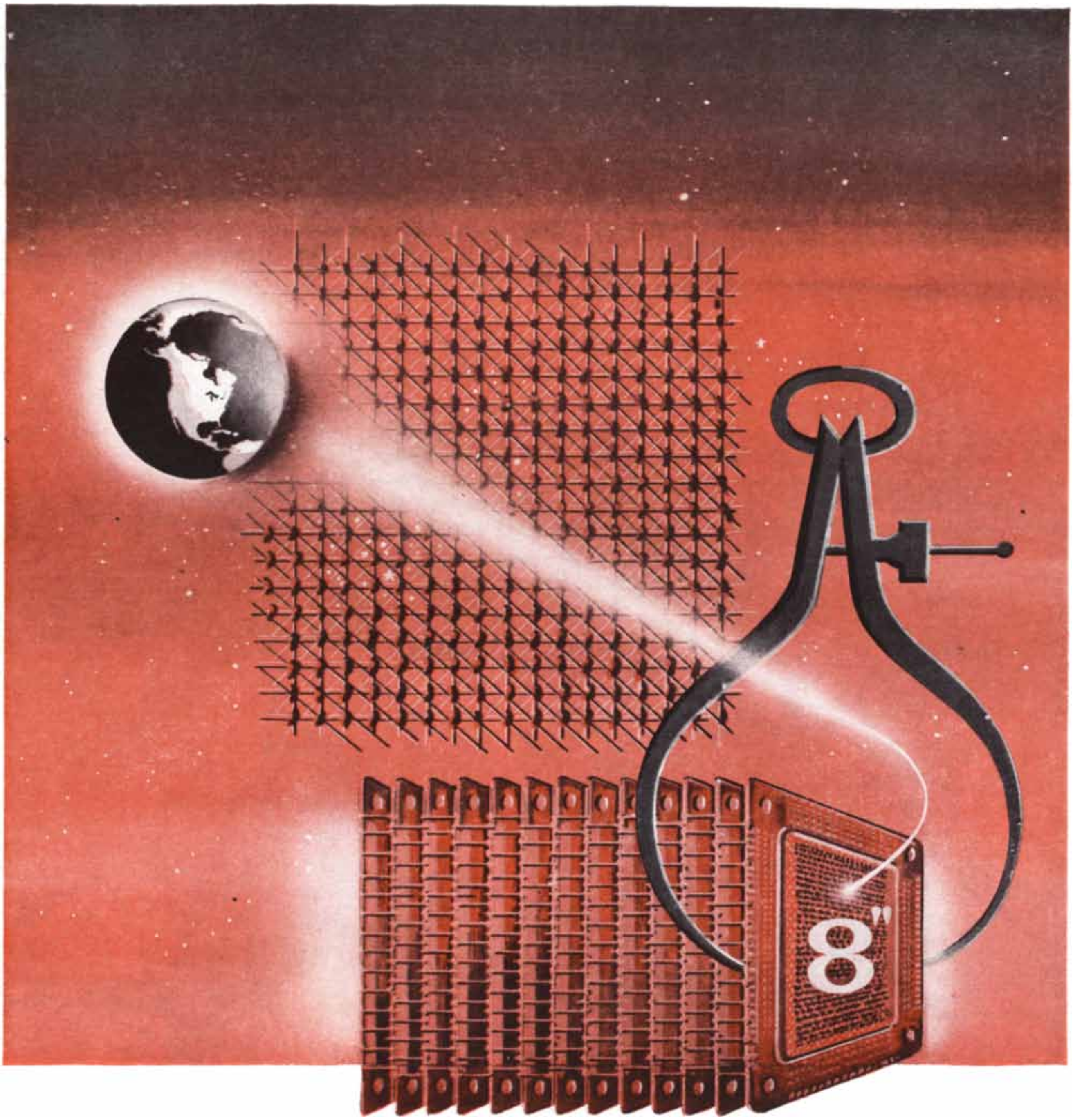






VIKING ROCKET from which the photographs on the preceding pages were made is launched at White Sands Proving Ground. This rocket is the Viking 12, the latest in a long series fired by the Naval Research Laboratory. It is 45 feet long and weighs 15,000 pounds.

ROCKET FELL 42 miles away from its launching site. The rocket fell in two sections. The section at left housed the camera, which was a modified K-25 aerial type using four-by-five-inch film. The film was wound in an armored case to prevent exposure on impact.



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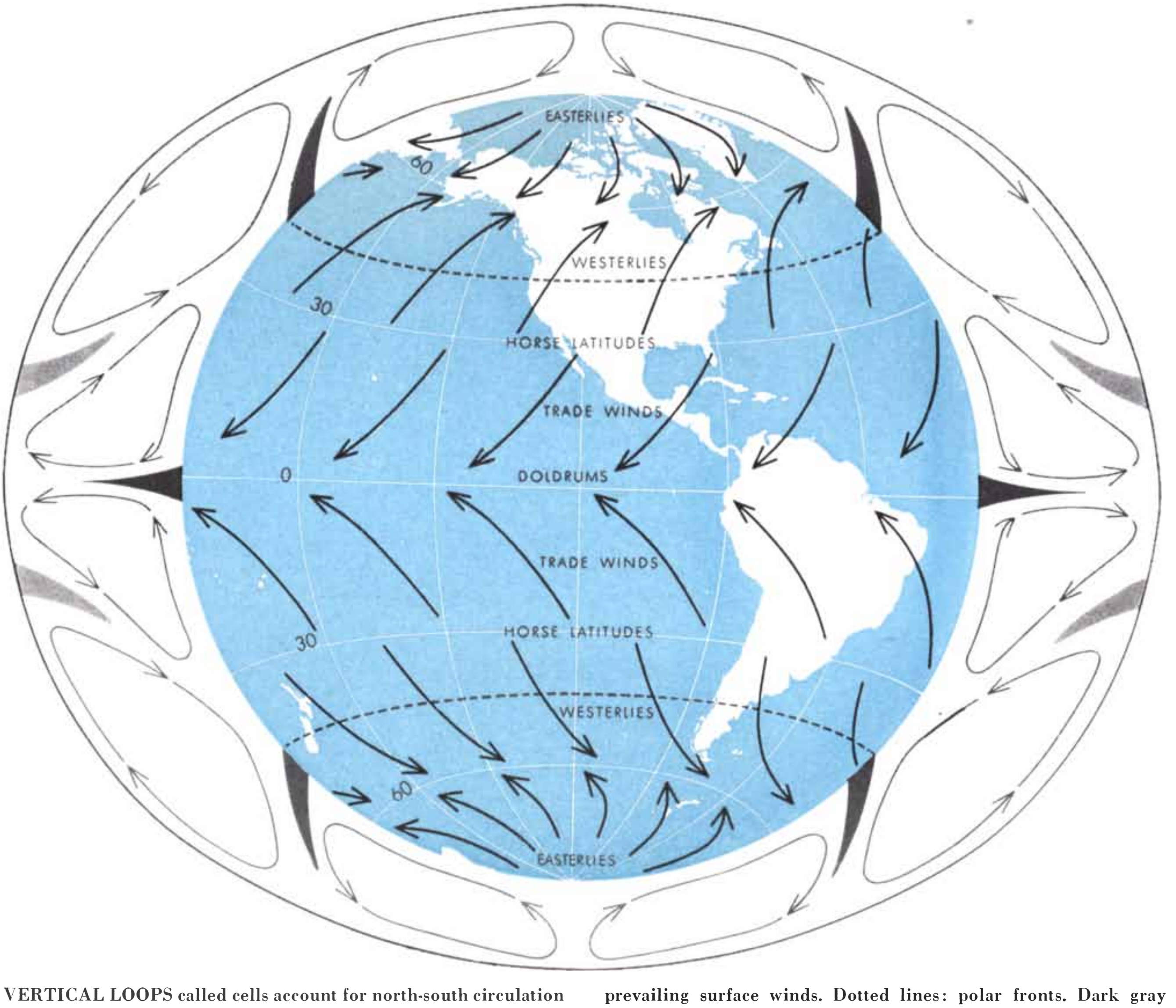
The Circulation of the Atmosphere

Powered by solar energy equivalent to nearly seven million atomic bombs, persistent winds weave vast three-dimensional patterns of which our daily weather charts show mere eddies

by Harry Wexler

We are indebted to the atmosphere for a number of things of which no one needs to be reminded: oxygen, moisture, insulation against deadly radiations from the sun. But most people are apt to overlook the too-obvious fact that among all the life-giving properties of the atmosphere, none is more important than its motion. Think what would happen if the atmosphere all over the earth were to fall into a dead calm. Winds distribute heat from the tropics to other regions, transport moisture from the oceans and drop rain on the continents, sweep the polluted air from cities and bring in clean air. In a windless world the tropics would become intolerably hot and the rest of the planet



VERTICAL LOOPS called cells account for north-south circulation of air and are supposedly responsible in part for differences in the prevailing surface winds. Dotted lines: polar fronts. Dark gray areas: low-pressure regions. Light gray areas: high-pressure regions.

unbearably cold; the parched continents would become dust; cities would suffocate.

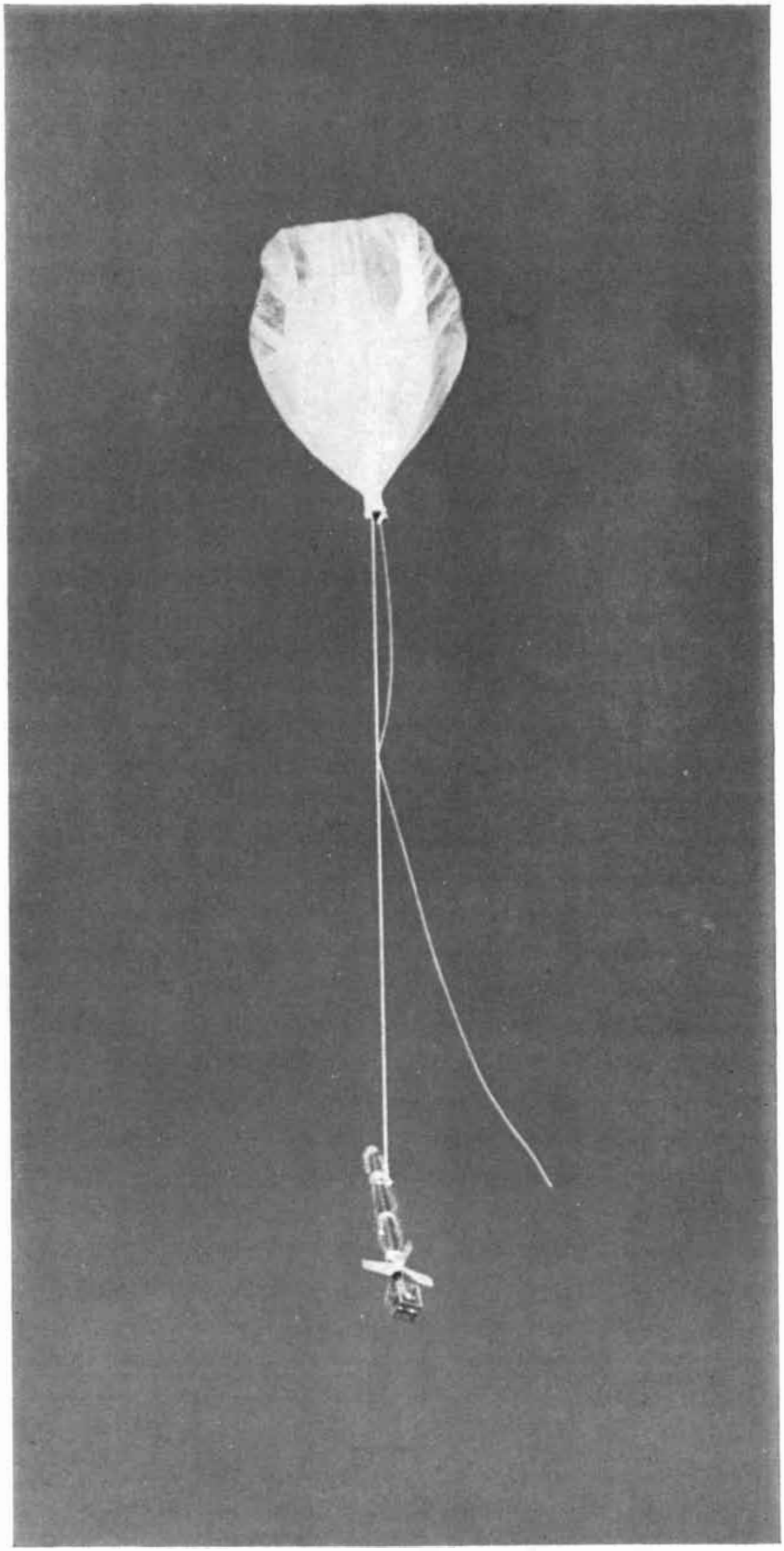
Fortunately the atmosphere has a general circulation which keeps the air moving rapidly over the globe day in and day out, year in and year out. The energy needed to drive this circulation is enormous: the winds of the earth have a total kinetic energy equal to nearly seven million atomic bombs, or to more electric power than all the power plants in the U. S. could produce in 100 years. The energy must be replenished constantly, because the loss by friction between the winds and the earth surface is so great that, if new energy were not supplied, all winds would disappear within nine to 12 days. The source of almost all the energy is, of course, the sun. By heating the air and by evaporating water it generates forms of energy which are converted into the air motions.

The world-wide circulation is derived from the fact that the tropical and subtropical regions of the earth (between the equator and 38 degrees latitude) absorb more solar radiation than they radiate away, while the rest of the world radiates more than it receives. As a consequence the air warmed in the tropics moves toward the poles. This fundamental movement launches a global circulation system in which the highs, lows and wind systems of our weather charts are mere eddies.

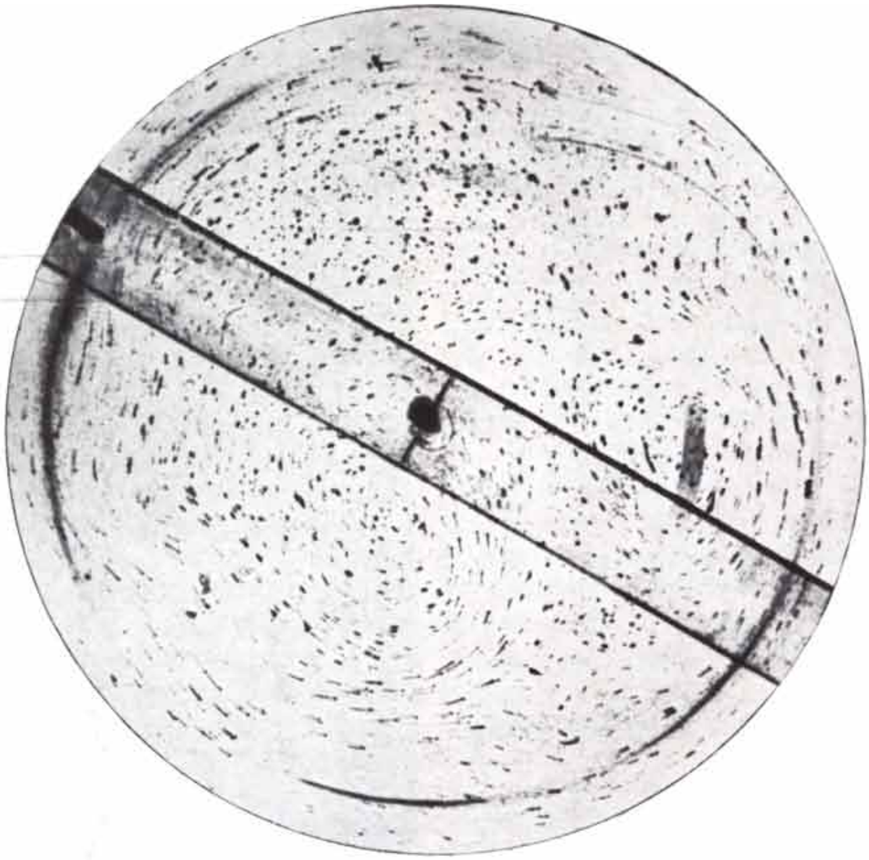
For more than 200 years meteorologists have been attempting to gain a picture of what the general circulation must be. Most of their work has had to be theoretical, because even today we have too little information about the upper atmosphere to chart the circulation from direct observation. The ocean of air in which we live is so vast that if it were divided up for observation among all the human beings on earth, each person would be responsible for watching approximately two million tons of air.

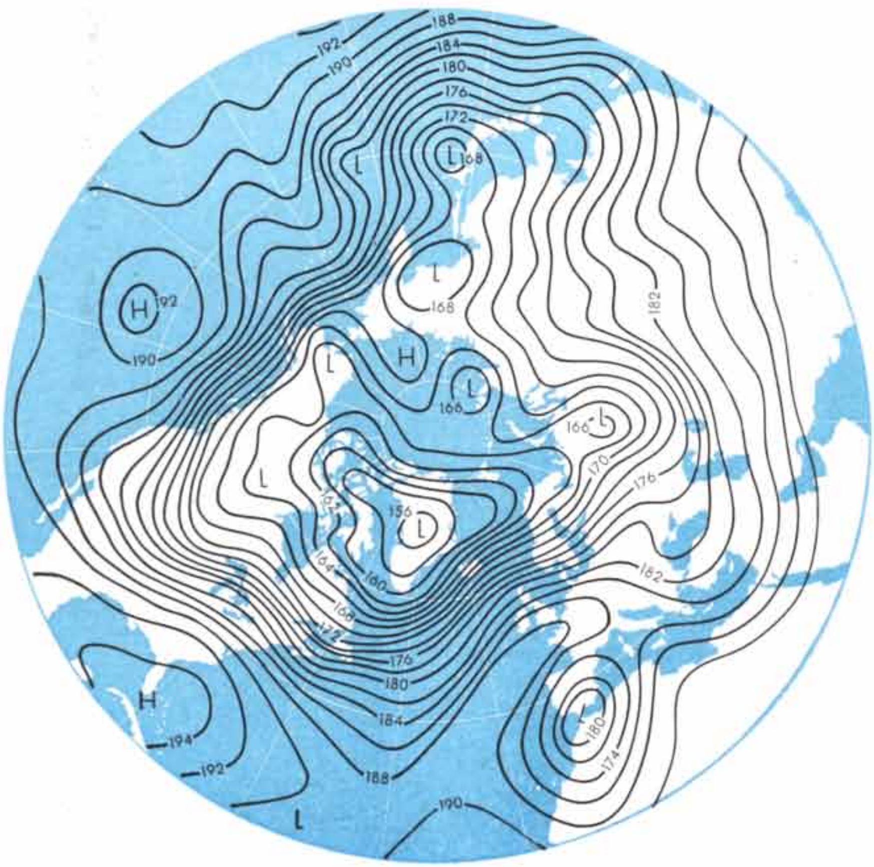
Let us look at the development of the classic, hypothetical picture of the general circulation. We begin with a simple scheme which takes only the heat factor into account. Air near the equator rises high in the atmosphere, flows toward the poles (north and south), is cooled, descends near the poles and flows back at a lower level to the equator again. The circulation in this first-stage model forms a great north-south vertical loop in the Northern Hemisphere and a similar loop in the Southern.

In the next stage we add the effect of the earth's rotation. The air now



BALLOONS will be launched in large numbers during the IGY to study cosmic rays and the circulation of the atmosphere. In the recent ascent shown here, a Navy balloon lifts a rocket for a cosmic-ray study. The rocket was fired at 77,000 feet and reached a height of 60 miles.





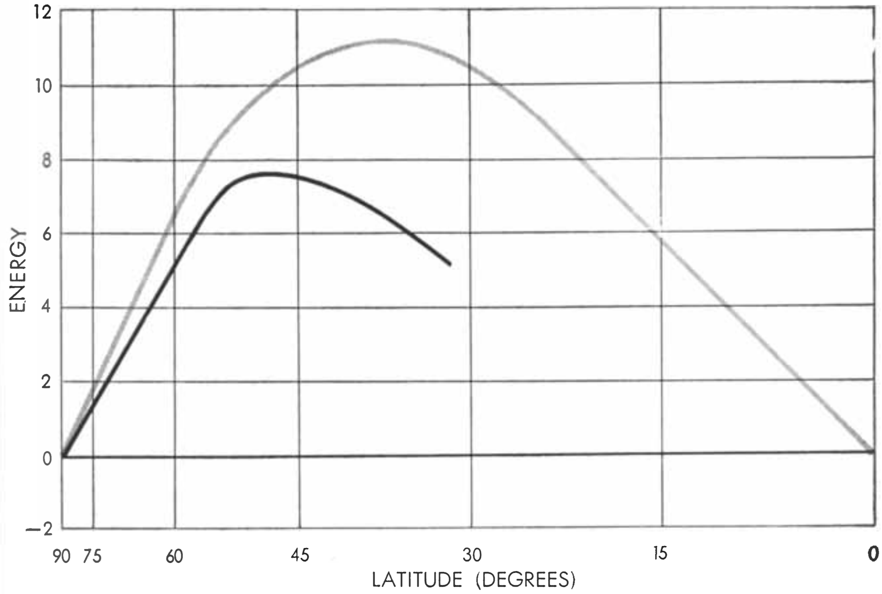
CIRCULATION PATTERN of particles floating in a rotating dishpan (*top*), set up by Dave Fultz at the University of Chicago, bears a striking resemblance to a pressure-contour map (*bottom*). The numbers are hundreds of feet at which a pressure of 500 millibars was observed.

moves not only poleward but also from west to east with the spinning earth. Over the equator it rotates at the earth's pace, but as it moves poleward it must rotate faster, being nearer the axis of rotation, in order to conserve the total angular momentum, just as a pirouetting dancer whirls faster when she pulls her arms in toward her body. Thus in the poleward-bound air aloft great westerly winds arise—air moving from west to east faster than the earth's surface. Conversely, the air below, returning toward the equator, loses rotational speed as it moves farther from the axis of rotation. There easterly winds develop, for the motion of air from west to east is not as fast as that of the earth's surface.

The westerly and easterly winds, it is calculated, would acquire speeds of hundreds or thousands of miles per hour. But a third factor must be introduced in the model—friction. When the circulating air makes contact with the ground, its wind speed (speed relative to the earth's rotation) is reduced by friction. The frictional stresses and retardation of winds again modify the original simple model: the north-south loop breaks down into two or three separate vertical cells in each hemisphere—one over the tropical region, one in middle latitudes and perhaps one in the polar region.

These cells in the classic model are supposed to be responsible for the tropical easterlies (trade winds), the middle-latitude westerlies and the polar easterlies. There is now fairly firm evidence for the tropical cell, which is called the "Hadley cell" because it was first proposed by George Hadley, an English meteorologist, more than 200 years ago. He suggested that such a cell would account for the trade winds and antitrade winds over tropical oceans. The existence of the middle cell, named for William Ferrel of the U. S., who suggested it a hundred years ago, also is supported by some evidence.

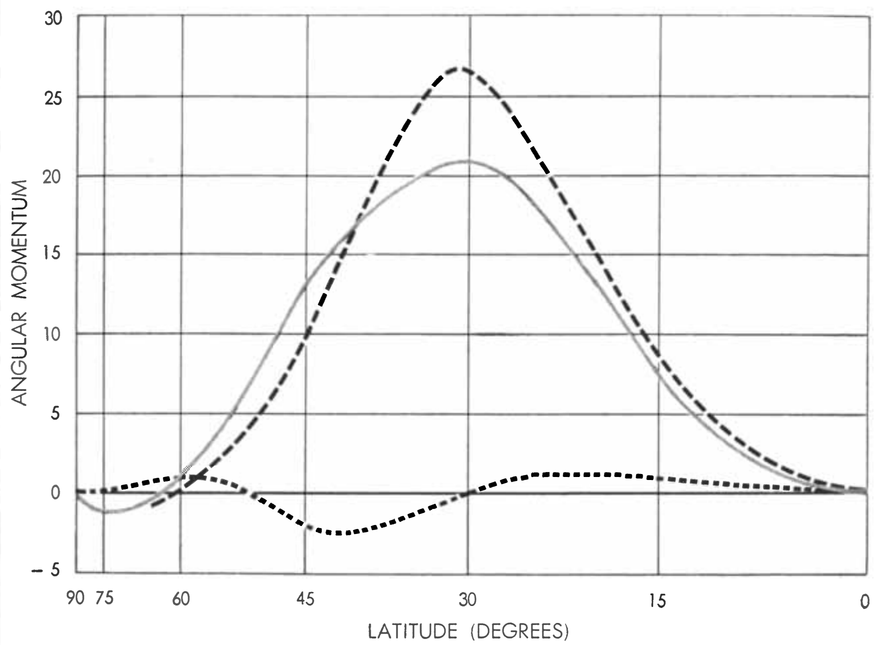
The cell model has recently been modernized by the Finnish meteorologist E. Palmén. He eliminates the polar cell, reasoning that in the polar regions the circulation is almost entirely horizontal in the form of eddies. But he retains the Hadley and Ferrel cells [*see diagram on page 120*]. According to our present picture, which is supported by laboratory experiments on spinning models, these vertical loops and the horizontal eddies both play important parts in the general circulation of the atmosphere, with the north-south cells taking a stronger hand in the lower latitudes. The horizontal eddies referred to here are circular wind systems about the size of the highs and



SURFACE WINDS account for only a fraction (*black curve*) of the energy carried poleward (*gray curve*). Circulation in vertical cells presumably makes up part of the difference.

lows on our weather maps. Very likely there are eddies of all sizes in the atmosphere, but we cannot detect the smaller ones because our stations usually are spaced too far apart.

We have, then, a reasonably believable model which outlines the traffic pattern of the atmosphere. Now let us look at the freight the circulation carries. One of the items of transport is momentum from the earth. Winds moving from the east, against the earth's rotation, pick up some of its westerly momentum through friction. Since it is unlikely that the atmosphere causes any net change in the earth's rotation rate, all of the momentum taken from the earth by the easterlies must be restored to it by the westerlies. This means that momentum picked up by the prevailing easterlies in the tropical and polar regions must be transported by the atmospheric circulation to the mid-latitudes, where westerlies prevail. The present evidence indicates that most of this transport is carried out by the horizontal eddies, rather than by the north-south vertical loops. The



ROTATIONAL MOMENTUM picked up from the earth is carried toward poles mainly by horizontal eddies (*dashed curve*). Vertical cells contribute little (*dotted*) to total (*gray*).

THE RARE EARTHS

a report by Lindsay, world's largest producer of cerium, rare earth and thorium chemicals

Let's look back billions of years. Far beyond the beginning of history, back to the very formation of the earth. Here the rare earths were created . . . conceived in the raging inferno of a newborn planet.

Down from the high country trickled the streams, joining into rivers, rolling on to the immense seas that covered much of the globe. On the deltas, the rivers deposited their loads of sand . . . some of it *monazite,* the glassy, brown globules that hold the rich treasures of thorium and that peculiar and wonderful chemical clan . . . the rare earths.

This was the beginning . . . this was the formation of the deposits of monazite that are found today in such widely separated locations as the Union of South Africa, India, Brazil and, domestically, certain southeastern and far western states.

* * *

The rare earths are metals, not earths — and they are by no means rare. Together they comprise approximately five thousandths of one per cent of the earth's surface. This group of 15 elements—atomic numbers 57 through 71—has evolved from a role of interesting chemical oddities to a position of exciting importance in scientific and industrial technology.

Until recently, the rare earths remained virtually untouched by commercial investigation. Many researchers believed them unavailable for large scale use because they were difficult to separate. This is no longer true. Lindsay is refining and separating these unique elements in large volume for commercial use. The rare earths offer a rich field for scientific study and hold significant possibilities for profitable application in a wide variety of industrial processes.

The use of rare earth-thorium ores was born with the invention of the incandescent gas mantle late in the 19th century. The key element in the manufacture of these mantles was thorium, which is found in conjunction with the rare earths in monazite ores. Interest in elements 57 through 71 was aroused and since then, they have become increasingly important in a wide variety of manufacturing processes.

Motion picture projectors, lighter flints, alloy steels, ceramic coloring, glass coloring, glass decolorizing, glass, mirror, television picture tube and granite polishing, photosensitive glass, paint driers, sunglasses, nausea preventatives, reagent chemicals . . . these are but a few of the many commercial applications of Lindsay rare earths.

With the invention of the electric light, the demand for gas mantles dropped sharply, and with it this need for thorium. In 1945, however, interest in thorium again shot upward, for this element holds great promise of becoming important in the development of atomic energy for peacetime use. You see, while thorium alone is not fissionable, it becomes so when combined with small amounts of uranium. Thus reactors, using relatively inexpensive amounts of thorium and uranium can equal the electricity-generating power of thousands of tons of coal. The nation's need for this material has prompted Lindsay to accelerate its search for domestic deposits of monazite ore which is now obtained from the Union of South Africa. As more thorium is extracted from this ore, more rare earths are available for industry.

Rare earth and thorium chemicals have attained new importance through the work of Lindsay scientists who, for 53 years, have pioneered the research and development of these chemical tools for industry. This, coupled with extensive raw material sources, has helped Lindsay develop the world's largest facilities for the production of rare earths. Salts of thorium and rare earths are available for prompt shipment—a gram or a carload.

We have noted a few of the industrial applications of rare earth chemicals. There are others and certainly many more as yet undiscovered. If you are curious about the possibility that rare earths may have useful applications in your industrial processes, or would like more information from us, we welcome your inquiry. Technical data is available and the facilities of our research staff may be helpful to you.

Please address your inquiry to:
Dr. Howard E. Kremers, *Director of Research.*

LINDSAY CHEMICAL COMPANY
FOUNDED 1902
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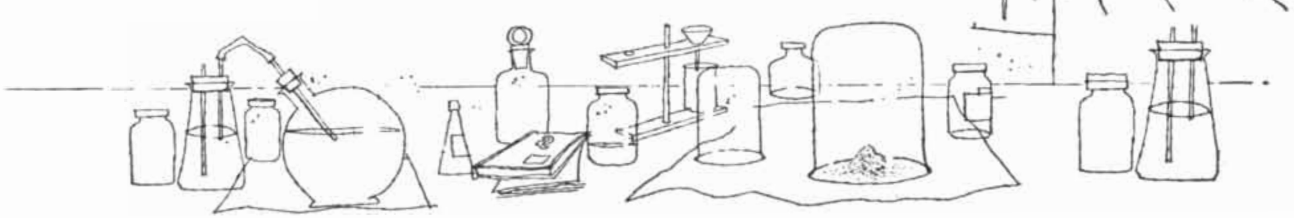
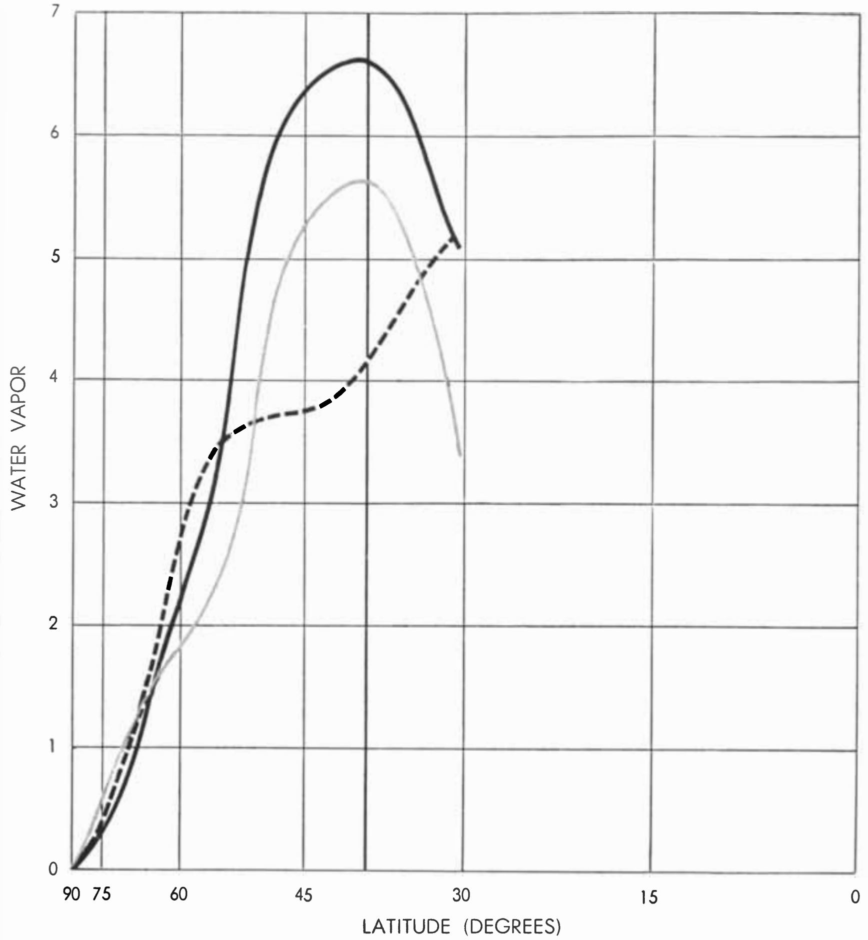
Latest addition to Lindsay monazite processing plant at West Chicago.

Part of 12,000,000 pound stock pile of monazite in Lindsay warehouse.

Small section of filtration floor in new plant addition.

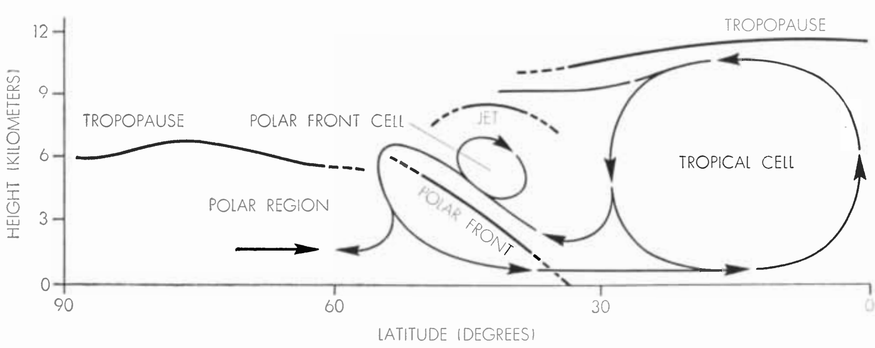




WATER VAPOR is transported poleward by horizontal eddies (*dashed curve*), except in middle latitudes. Solid curve shows total transport observed; gray curve, total calculated.

heaviest traffic in the transport of angular momentum occurs at 30 degrees latitude, "the horse latitudes." At this latitude there is little or no wind movement near sea level, but strong winds blow from the west just below the stratosphere at about 40,000 feet.

The second major item on the atmospheric cargo list is energy—some of it in the form of heat and some in the form of kinetic energy, or energy of motion. As we have seen, energy received from the sun must be transported from the tropical regions toward the poles. It is possible to calculate roughly the amount of energy that must be transported in any given year. Horizontal eddies, according to our observations, account for all the required poleward transport of energy above latitude 55 degrees, but not at lower latitudes; at latitude 30 degrees they apparently carry less than 50 per cent of the energy that must be moved. We cannot yet make an accounting of



PALMEN'S MODEL postulates how air is interchanged between troposphere and stratosphere through a supposedly sealed boundary. Note his exclusion of a defined polar cell.

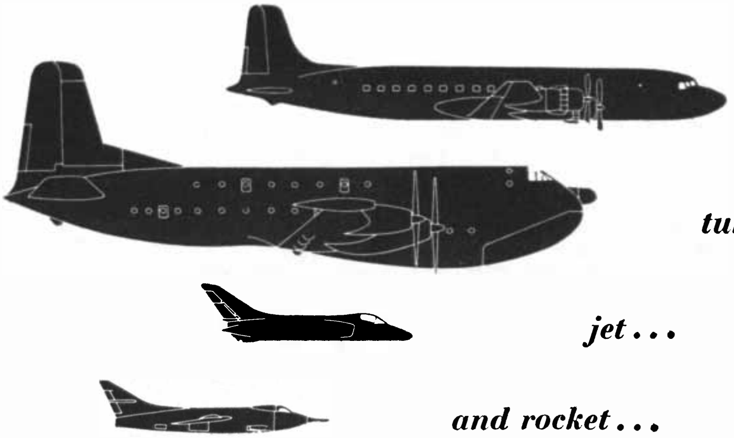
the difference. There may be some errors in the calculations, and it is also likely that the Hadley and Ferrel cells transport some of the energy and that the ocean currents carry more energy poleward than has been estimated.

The third item in the atmospheric cargo is water vapor. Actually this is a part of the energy transport, because it represents latent heat. When the amount of water vapor carried by the horizontal and vertical circulation systems is estimated, again it turns out that the horizontal eddies account for all the required transport at high latitudes but not at middle latitudes. This seems to confirm the deduction that the vertical Ferrel cell must play an important role in the poleward transport of energy. The observations also show that north of latitude 38 degrees the precipitation of water on the earth exceeds the evaporation from the surface, while the reverse is true south of 38 degrees, except in the equatorial rain belt.

The circulations we have been considering take place in the troposphere—the lower 30,000 to 50,000 feet of the atmosphere. Is there any circulation between the troposphere and the stratosphere above? Offhand this would seem unlikely, because the sharp temperature gradient at the boundary between the two regions has the effect of forming a ceiling over the troposphere which prevents air from rising. Yet there is much evidence that the air of the troposphere and the stratosphere does mix. We know, for instance, that air has about the same gaseous composition up to at least 40 miles above the surface; that extremely dry air from the stratosphere moves down close to ground level, and that moist air from the troposphere moves up into the stratosphere. The most decisive proof of vertical mixing is the fact that certain gases formed in the stratosphere or just beneath it—ozone, carbon 14, tritium, beryllium 7, argon 37—come down and are found in the air near the ground.

How does air get through the supposedly sealed boundary (tropopause) between the troposphere and the stratosphere? Palmén's model suggests the answer. On the poleward side of each vertical cell (Hadley's and Ferrel's) there is a gap in the tropopause [*diagram on page 120*]. Air passes from the troposphere to the stratosphere, and *vice versa*, through these gaps. High-speed westerly winds blow horizontally along each gap; one stream is called the polar front jet, the other, the subtropical jet.

So far we have been treating the cir-



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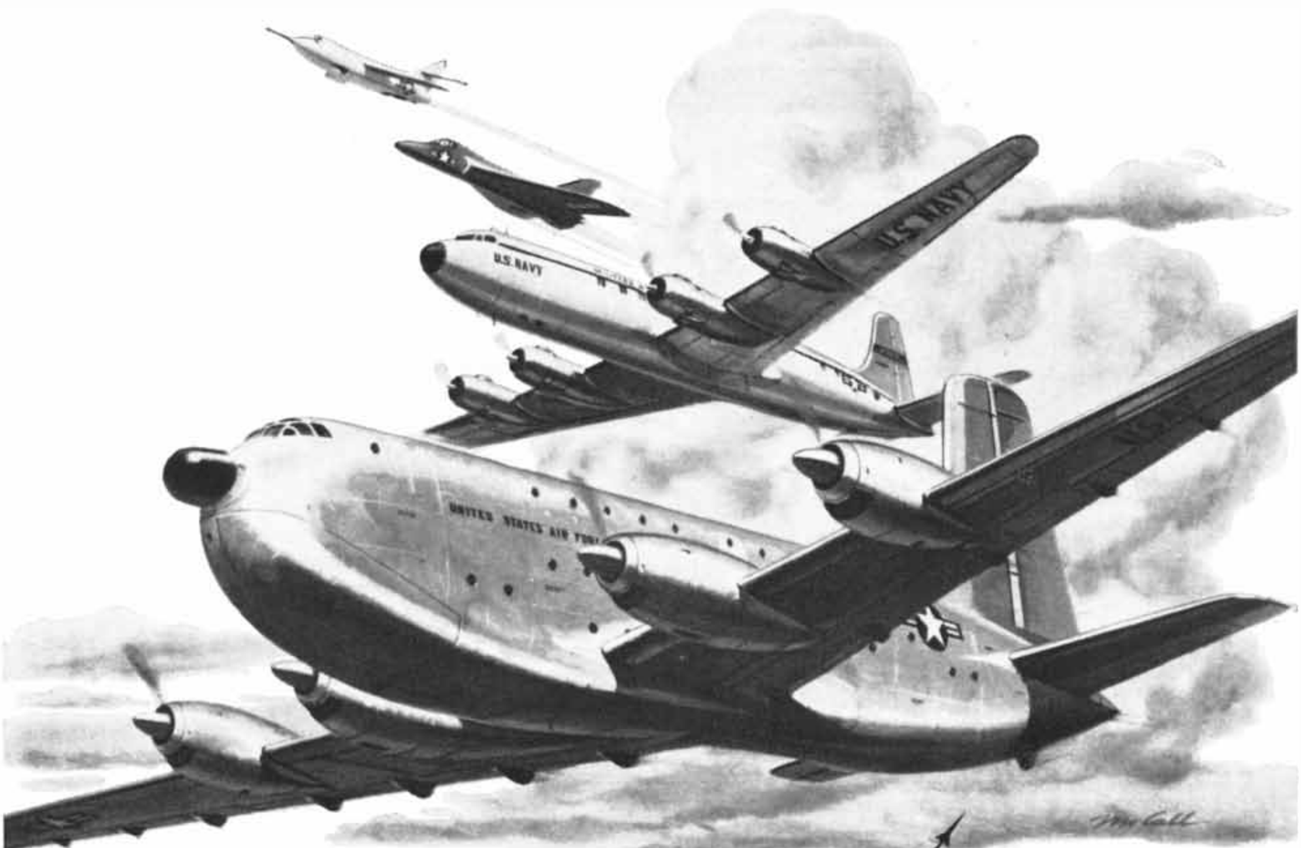
—only Douglas has used all four basic aircraft power plants

From *Cloudster*, first airplane to lift its weight in payload, to *Skyrocket*—first to fly twice as fast as sound—Douglas has now built and flown airframes for all basic power plant types.

Such experience leads to better integration of airframe and engine to tactical or logistic needs—more performance per pound of plane. The *jet-powered* F4D Skyray, capable of low-speed carrier landings, outraces sound in level flight. The piston-engine R6D-1 typifies the Douglas genius for economical and dependable air transports. The *turbo-prop* YC-124B points to a new race of larger, faster cargo planes. The *rocket-powered* D-558-2 hits 1327 m.p.h.!

Experience in use of *all* available engine types contributes to Douglas aviation leadership—and planes that fly *farther and faster with a bigger payload.*



Depend on *DOUGLAS* First in Aviation

culation of the earth's atmosphere as if it were divided into two completely separate systems, in the Northern and Southern Hemispheres. Actually there is some exchange of air between the two hemispheres. According to pressure readings, the total weight of air over the Northern Hemisphere is slightly less in summer than in winter. This must mean that some of the air flows into the Southern Hemisphere. The largest net flow out of the Northern Hemisphere occurs during the northern spring. At the end of the Southern Hemisphere winter there is a reverse flow from the Southern into the Northern Hemisphere.

During the International Geophysical Year meteorologists hope to obtain a fairly comprehensive picture of the atmosphere's circulation. They plan to establish several pole-to-pole chains of stations. One of these will probably be in the neighborhood of the 70th to 80th meridians west longitude—running from near the North Pole down through the eastern part of North America and along the west coast of South America to Antarctica. Other chains are planned along the meridians 10 degrees east longitude (Europe and Africa) and 140 degrees east longitude (Siberia, Japan and Australia). The stations may also be linked together in the east-west direction to form chains along several latitudes.

Each chain will obtain a daily picture of a cross section of the atmosphere, measuring the pressures, temperatures, humidity and winds at all levels up to about 100,000 feet. This will extend the observations well into the ozonosphere, where the sun's ultraviolet rays are absorbed. Variations in the ultraviolet radiation may help to explain spells of "unusual" weather on the earth.

Many other observations will be made: studies of the trend in intensity of radiation from the sun, measurements of carbon dioxide and its warming ("greenhouse") effect on the earth, daily aircraft reconnaissance to see whether the whiteness (albedo) of snow, ice and clouds over large areas is any index of large-scale weather variations, and so forth.

Not the least important of the meteorological studies will be the observations in Antarctica. Three stations to be established on the frozen continent will carry out the first general exploration of its atmosphere. Since the Antarctic has the coldest atmosphere and the most intense and most persistent lows on earth, its effects on the world's weather may be far greater than its remoteness or size might suggest.

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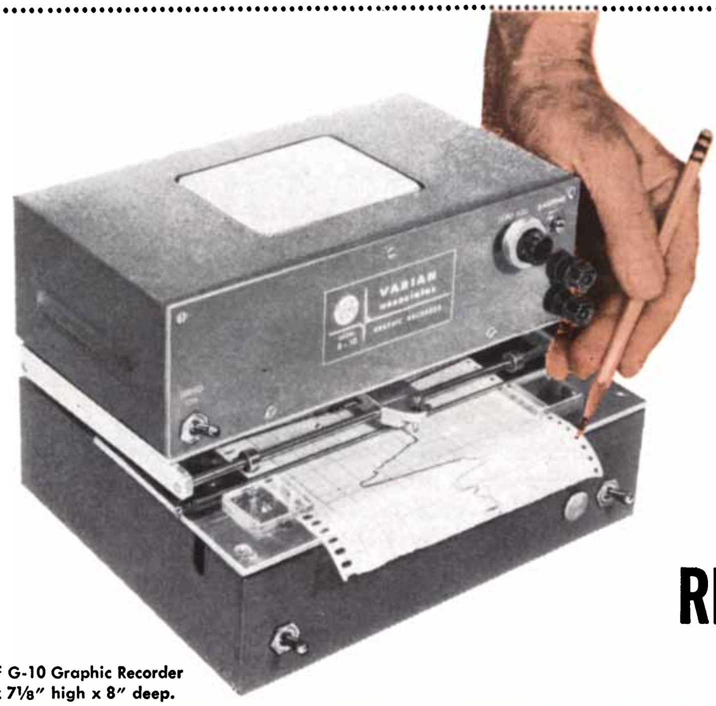

Actual size of G-10 Graphic Recorder is 10″ wide x 7⅛″ high x 8″ deep.

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Response time	2.5 sec. full-scale
Sensitivity	100 millivolts full-scale
Measurement accuracy	1%
Trace reproducibility	0.5% full-scale
Signal source resistance	0.5 megohm max.
Line requirements	105-125 volts a.c., 35 watts, 60 cps

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This new, portable Varian Graphic Recorder meets the growing need for a compact instrument to record phenomena capable of representation by d.c. millivolt signals. It's flexible — has widespread applications when used directly as a recording millivoltmeter and — with appropriate transducers — to record pressure, light intensity, temperature and many other physical quantities for which continuously recorded measurement is desired.

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Write for complete technical data and price information . . . on this remarkable new instrument and its full line of accessories, priced well within the limits of a modest equipment budget.

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THE IONOSPHERE

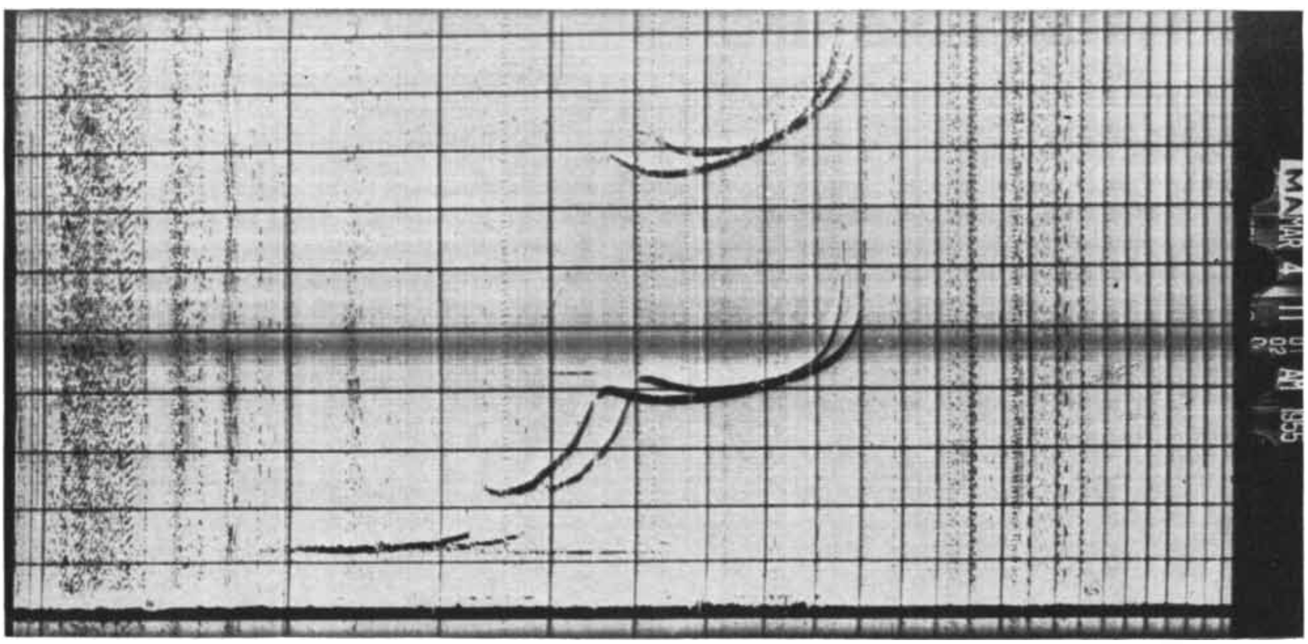
Above the stratosphere the sparse atoms and molecules of air are disrupted by the harsher radiations of the sun. A revealing and useful property of this mantle is its reflection of radio waves

by T. N. Gautier

Three quarters of a century ago the Scottish physicist and meteorologist Balfour Stewart, puzzling over the fact that the earth's magnetic field fluctuated from day to day, proposed what seemed at the time an unlikely idea. He suggested that somewhere in the upper atmosphere there might be a layer of air which conducted electricity; the motion of this air in the earth's magnetic field would generate electric currents, which in turn would produce small magnetic fields accounting for the daily variations in magnetic measurements.

Since the upper atmosphere was a wilderness unplumbed by any instrument man had yet invented, the significance of Stewart's brilliant suggestion was not widely appreciated. But when, in 1901, Guglielmo Marconi sent wireless signals across the Atlantic Ocean around the curvature of the earth, the upper atmosphere at once took on a new interest. Physicists had supposed that radio waves traveling beyond the horizon would continue in a straight line through the atmosphere and be lost into space. To account for Marconi's long-distance transmission around the earth, Arthur E. Kennelly in the U. S. and Oliver Heaviside in England independently revived the idea of an electrically conducting region high in the atmosphere, which would reflect radio waves back to the ground.

For nearly a quarter century afterward little more information was obtained about this region. Then toward the end of 1924 Edward V. Appleton and M. A. F. Barnett in England found important direct evidence for its existence when they performed measurements which indicated that radio waves from a distant station came down at an angle from the sky. A few months later the ionosphere was definitely identified and located. In the summer of 1925 the physicists Gregory Breit and Merle Tuve



IONOGRAM is a record of radio pulses reflected from the ionosphere. The black trace along the bottom was caused by the pulses as they left the transmitter. The curving traces just below the middle of the record were caused by echoes from the ionosphere. The curving traces near the top of the record were caused by pulses returning from a second round trip to the ionosphere. As the record moved from left to right, the frequency of each pulse was increased from one megacycle to 25 megacycles. Each of the thin vertical lines represents an increase in frequency of one megacycle. Each of the horizontal lines corresponds to a virtual height of 100 kilometers. Because the pulses are retarded in the ionosphere, the virtual heights indicated by echo traces are greater than the actual heights.

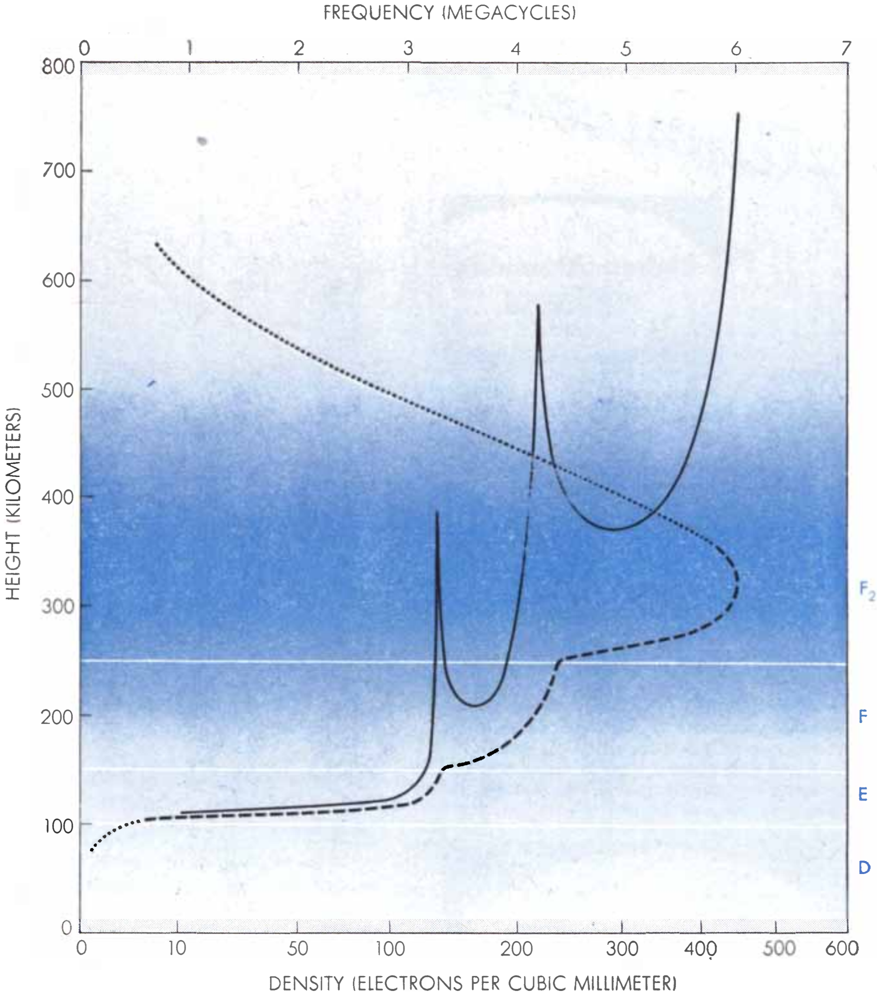
of the Department of Terrestrial Magnetism in the Carnegie Institution of Washington performed a historic experiment in cooperation with the Naval Research Laboratory on the Potomac. A radio transmitter at the NRL sent short pulses of radio waves straight up into the atmosphere. Breit and Tuve, eight miles away, caught echoes of these pulses with a receiver and recorded them on an oscillograph. (It was the first use of the principle of radar.) By timing the echoes they measured the height of the reflecting layer. There could no longer be any doubt that the upper atmosphere had an electrified region, or ionosphere. Breit and Tuve titled the paper on their experiment: "A Test for the Existence of the Conducting Layer."

The Restless Mantle

The ionosphere is a thick mantle of ionized air, now known to consist of at least four different layers, which occupies the region of the atmosphere from 45 miles to about 200 miles above the ground. Its electrical properties are due to free electrons and ionized atoms and molecules (some positively charged, some negatively). The chief cause of this ionization is ultraviolet radiation from the sun—radiation which is so strongly absorbed in the upper atmosphere that it is not detectable at the earth's surface.

Responding sensitively to streams of particles and radiation from the sun, to bombardment by meteors, even to the gravitational tug of the sun and the moon, which causes tides in the atmosphere, the ionosphere behaves like the restless sea. It changes from hour to hour, day to day and season to season. Occasionally it is seized by great electrical or magnetic storms. From the point of view of the workaday world the ionosphere has considerable technological and economic importance. Without it long-distance radio communication would be extremely difficult, but by the same token, disturbances and fluctuations of the ionosphere interfere freakishly with communications: sometimes they cause radio fade-outs over large areas; now and then they transmit television and FM broadcasts for startling distances around the globe.

It is the free electrons in the ionosphere that play the chief part in radio effects. As a radio wave enters the ionosphere, the electrons are swung back and forth by the electric field of the wave. Each electron set in motion becomes an oscillator, generating a radio wave at the

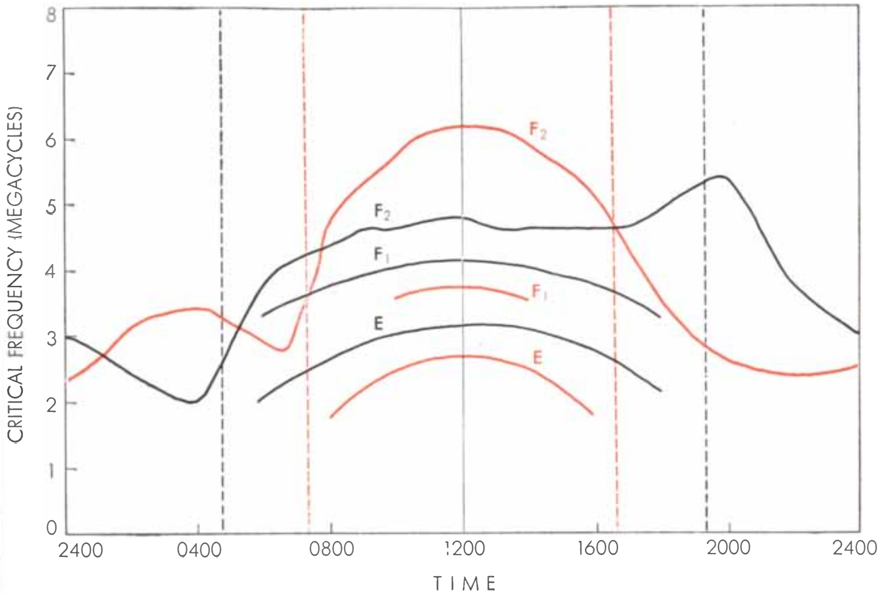


DENSITY OF ELECTRONS in the ionosphere is represented by the dashed curve in this chart. It is also suggested by the colored tone. The shorter dashes at both ends of the curve indicate the regions for which the evidence is inadequate. The virtual height at which radio waves of various frequencies are reflected is represented by the solid curve. The ionosphere layers related are indicated by the white lines and by the colored letters at the right.

same frequency as the incident wave. Part of this new radiation travels forward in the same direction as the incident wave; part is radiated back in the direction from which the wave came. As waves advance deeper into the ionosphere and encounter greater electron densities, the wave energy is retarded more and more, until it no longer can be propagated forward. Then all that remains is the backward radiation of the electrons: in other words, the wave is reflected. (Ionized atoms and molecules in the ionosphere contribute little to reflection because they are so heavy compared with electrons that they oscillate relatively little in response to radio waves.)

A radio-wave pulse traveling straight into a cloud of electrons is reflected when the density of electrons becomes such that the number of free electrons per cubic millimeter is equal to 12.4 times the square of the radio frequency in megacycles (million cycles) per second. A pulse with a frequency of five megacycles per second, for example, will be reflected when the density becomes 12.4 times 5 squared, *i.e.*, 310, electrons per cubic millimeter.

Thus by beaming radio pulses of various frequencies at the ionosphere, it is possible to determine the electron density as well as the height of each reflecting layer. Of course there are complicating factors which must enter into the calculations. One is the earth's magnetic field, which makes the ionosphere birefringent to radio waves, that is, splits the waves into two components. Another complication is the slowing of a radio pulse as it penetrates into a region of increasing electron density; this delay requires a correction factor to determine the height of the reflecting layer, since the basis for measuring the height is the



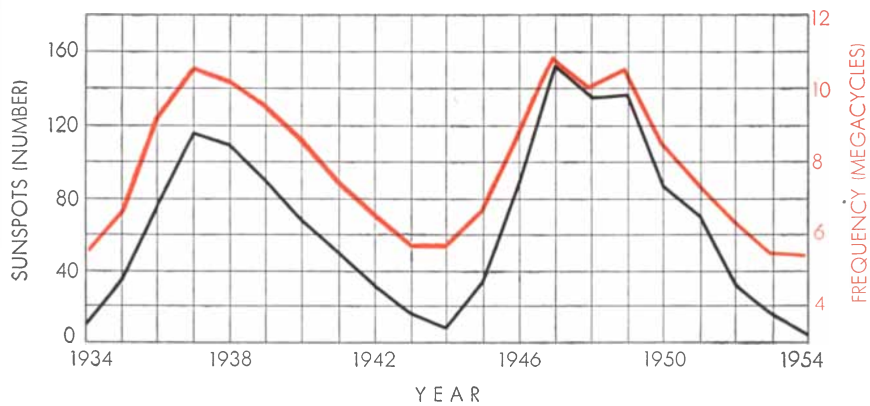
FREQUENCY OF REFLECTION changes with the season and the time of day. The black curves indicate the changes in the frequency reflected by the E, F_1 and F_2 layers over Washington, D. C., during the day in June, 1954. The colored curves indicate similar changes for a day in December, 1954. Dotted lines represent sunrise (*left*) and sunset (*right*).

travel time of the pulse, assumed to be moving at the speed of light.

The instrument used to explore the ionosphere is called an ionosonde. It consists of a radio pulse transmitter and a receiver, housed in the same cabinet, which receives the echoes. To make an ionosonde record (ionogram) the transmitter and receiver are tuned rapidly through a range of frequencies. The echoes received are displayed on a cathode ray oscilloscope and photographed. The distance from the base line, representing the time of transmission, to the trace showing the return of the echo is a measure of the pulse's travel time [*see illustration on page 126*].

The lowest stratum of the ionosphere is called the D layer. Its electron density has not been measured accurately but is known to be low, because the layer does not reflect radio waves of one megacycle per second or higher frequency.

Above the D layer are three other layers whose heights and electron densities are better known. They are the E layer (extending from about 60 to 90 miles above the earth's surface), the F_1 layer (about 90 to 150 miles) and the F_2 layer (above 150 miles). The density of electrons increases from layer to layer, but it varies considerably in each layer from day to night and from season to season. During daytime the densest region in the E layer typically has 120 electrons per cubic millimeter; in the F_1 layer, 220 electrons; in the F_2 layer, 450 electrons.



SOLAR ACTIVITY is correlated with the density of electrons in the ionosphere. The black curve represents the number of sunspots over a 20-year period; the colored curve, the yearly average in the noon value of the frequency reflected by the F_2 layer over Washington.

The radio frequencies reflected depend on electron density; the higher the density of a layer, the higher-frequency waves it will reflect. Thus the E layer will reflect waves of frequencies up to three megacycles per second (coming in vertically) when its maximum density is 120 electrons per cubic millimeter. In this case three megacycles is the "critical" frequency; higher frequencies will go through the layer and not be reflected.

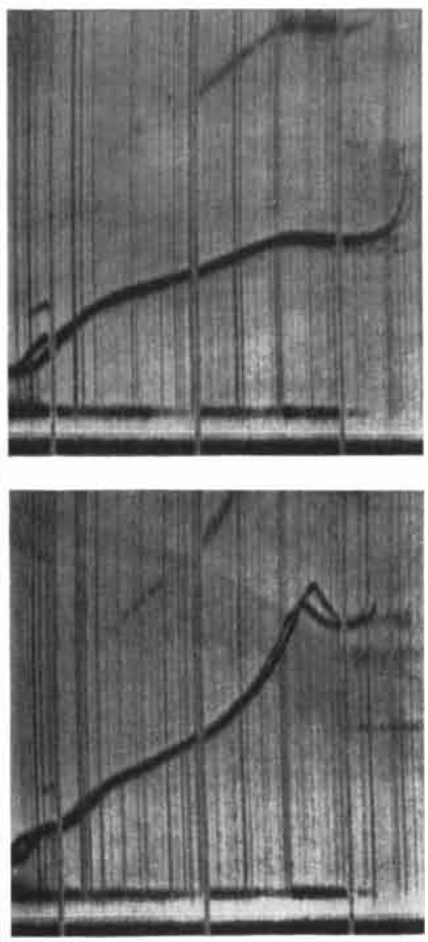
Changes in the ionosphere are detected primarily by shifts in the critical frequencies at which its regions reflect radio pulses. These shifts indicate increases or decreases of electron density. The density, *i.e.*, amount of ionization, is greater during the daytime than at night, but may be smaller in summer than in winter. It increases with increasing sunspot activity in the 11-year sunspot cycle. There are other regular variations associated with the geographic and magnetic latitudes, with the atmospheric tides caused by the sun and moon, and with strong winds which are known to exist in the ionosphere.

Besides the regular variations, there are many smaller ones of a seemingly random sort. The heights and densities of the layers change from minute to minute in an irregular fashion. Some of these irregularities may be due to turbulence in the high-altitude winds; others may be caused by fluctuations in ultraviolet radiation from the sun or in the streams of solar particles that produce auroras [*see article on page 140*]. Meteors, constantly bombarding the atmosphere, cause substantial irregularities in the E region: for a fraction of a second a meteor may increase the ionization along its path a thousandfold or more.

One of the outstanding mysteries of the ionosphere is a type of irregularity called "sporadic E." The E layer suddenly begins to reflect high-frequency radio waves which normally would pass right through the ionosphere. As a result television and FM signals, usually limited in range to the horizon, may be received hundreds of miles from the transmitter on these occasions.

The great disturbances of the earth's magnetic field known as "magnetic storms" invariably produce storms in the ionosphere—large, rapid fluctuations of electron density, especially in the F_2 layer, and partial disruption of the ionosphere's layer structure. These storms are believed to be the result of especially concentrated bursts of particles from the sun. Swinging into the earth's magnetic field, the concentrated streams of charged particles disturb the field and also produce strong electric currents, which cause further variations of the magnetic field. The electric and magnetic fields together disrupt the ionized layers and drive groups of ions about. All these rapid changes overwhelm the regular processes of electron production and recombination and of redistribution of electrons by diffusion and winds. The character of the ionosphere changes drastically.

The sudden outbursts of light from the sun called flares are responsible for an interesting and important change in the ionosphere. A flare apparently releases a burst of ultraviolet light or X-rays, for immediately there is a sudden increase in the ionization of the D region. Because the number of ionized molecules is multiplied, the D layer absorbs a great deal more of the energy of radio waves passing through it. Radio communications on the earth suddenly fade out. It may take anywhere from a few minutes to several hours for the D layer to recover its normal ionization, depending upon the severity of the disturbance.

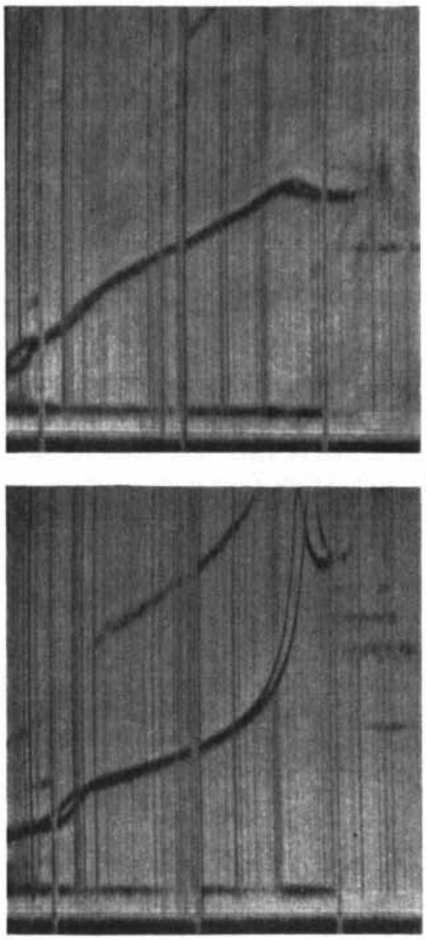


LUNAR TIDE in the ionosphere is demonstrated by these ionograms made in Peru. The vertical coordinate of each record is height; the horizontal coordinate, frequen-

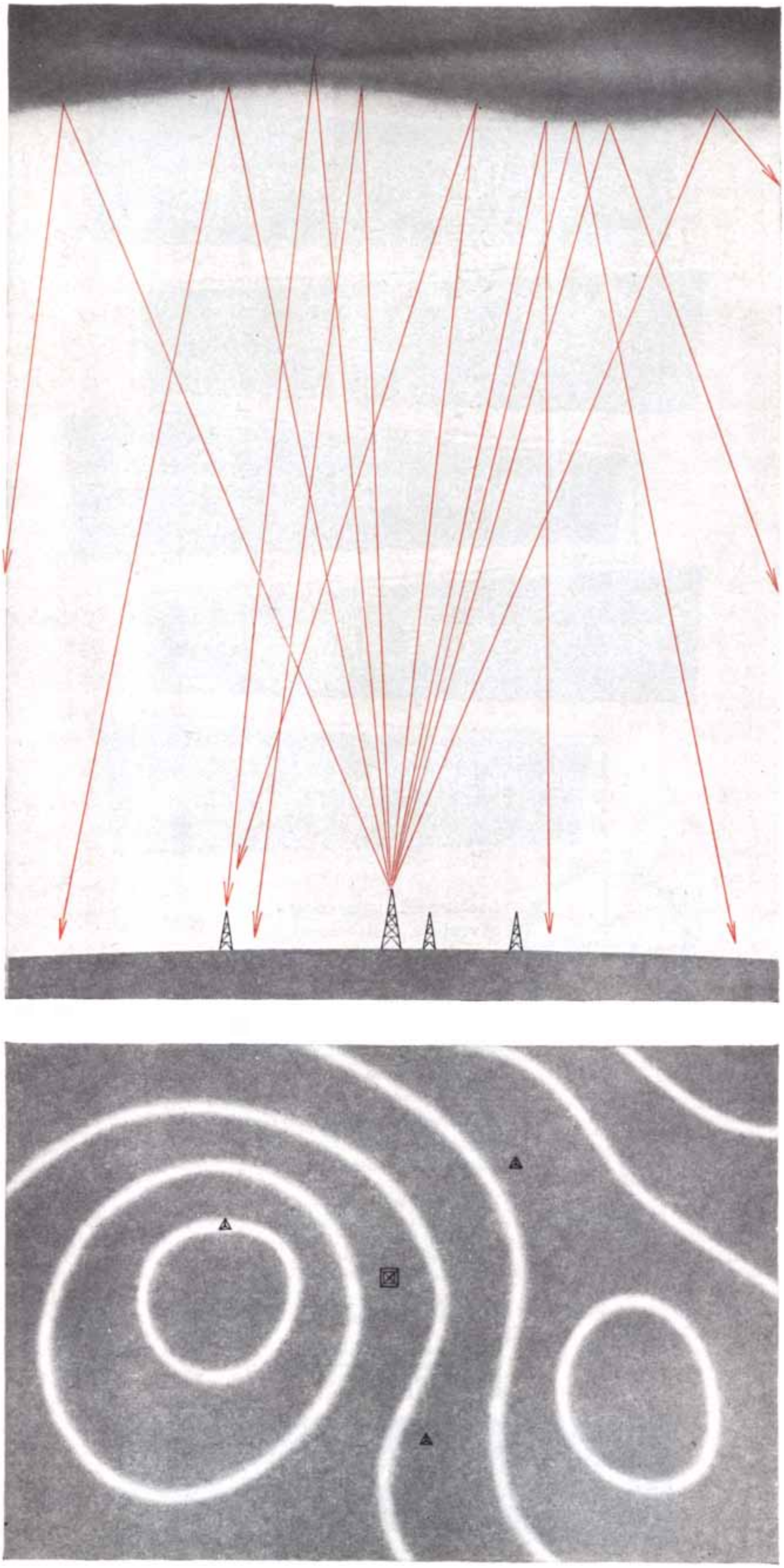
The electron density of the ionosphere increases and decreases regularly in close step with the 11-year sunspot cycle. In the F_2 layer, for instance, the density of electrons, as measured by the critical frequency for reflection of radio waves, may be twice as great at the peak of sunspot activity as at the sunspot minimum. Evidently during a sunspot maximum there is a considerable increase in the sun's radiation at ultraviolet or shorter wavelengths, though its radiation at visible wavelengths does not change markedly.

Motions in the Ionosphere

The movements of the high atmosphere, in which the ionosphere is embedded, have important effects on the distribution of ionization. The effects are complicated by the presence of the earth's magnetic field. Movements of the ionized air across the magnetic lines of force produce an electric field; this is called the "dynamo effect." The electric field may act in turn upon ionization else-



cy. The records were made at regular intervals between 1:15 p.m. and 3:30 p.m. The splitting of the main band in the later traces indicates separation of ionosphere layers.



IONOSPHERIC WINDS may be detected by variations in the strength of radio waves reflected from the ionosphere (*top*). Variations are depicted as contours on the ground.

where in the atmosphere. For example, a movement of air in the E layer might generate an electric field which would act upon ionization in the F_2 layer. Such complicated interactions between the ionosphere and the magnetic field make many aspects of the behavior of the ionosphere most difficult to understand.

Geophysicists have long been inclined to accept Balfour Stewart's idea that the dynamo effect of oscillations of the ionized atmosphere at high altitudes is responsible for the daily variations in the earth's magnetic field. But for many years it was difficult to see how the oscillations could be great enough, and in the proper phase, to account for the observed magnetic changes. The answer was found in a new resonance theory. It predicted that oscillations of the atmosphere due to the tidal effect of the sun should show a resonance effect, with a period of 12 hours. C. L. Pekeris in England showed that the oscillatory motion of the air above a height of about 20 miles should be in the direction opposite to that at ground level, and that the amplitude of the motion should increase with height so that in the lower part of the ionosphere it would be about 200 times the value at ground level. Thus the theory predicted an oscillation at ionospheric heights with the right phase and sufficient amplitude to produce currents strong enough to account for the daily variations of the earth's magnetic field.

In 1939 Appleton and K. Weeks in England found a 12½-hour oscillation of the E layer, which rose and fell about one mile in that period. This movement is attributable to the moon, whose tidal force has the same period. A striking effect of the moon has been found in ionosphere records at the Geophysical Institute of Peru. The lunar oscillation splits the F_2 layer into two strata, and the development of these layers, with the upper layer ascending, is disclosed by the echo record. The phenomenon occurs only during daylight hours. That the moon is responsible is shown by the fact that the periodicity of the separation coincides with that of the atmospheric oscillation caused by the moon.

One interpretation of the effect is as follows. The lunar oscillation of the atmosphere produces an unusually strong horizontal electric field, oriented in an east-west direction. This field, acting on the ionization in the F_2 layer at right angles to the earth's magnetic field, causes the ionization to drift upward. In the meantime, however, fresh ionization is still being formed at the usual height by the sun's ultraviolet rays. Thus as the

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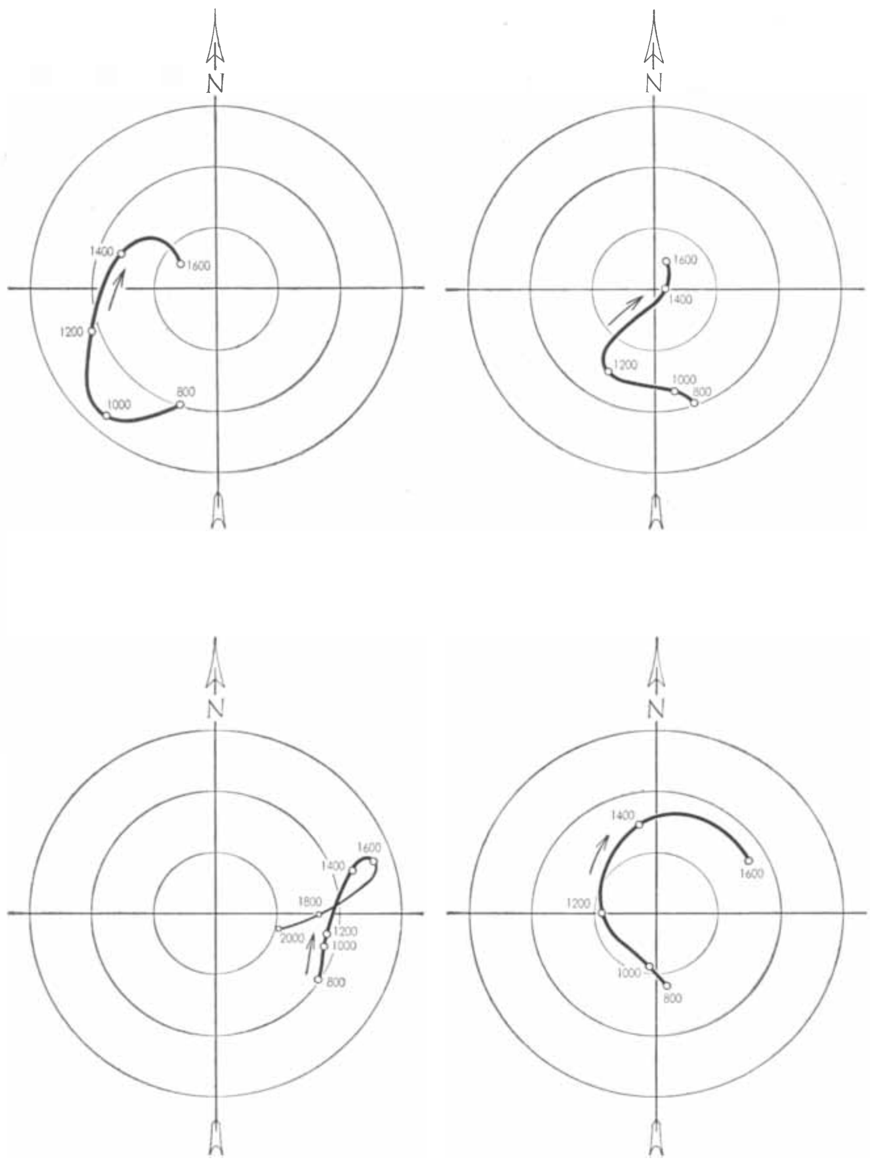
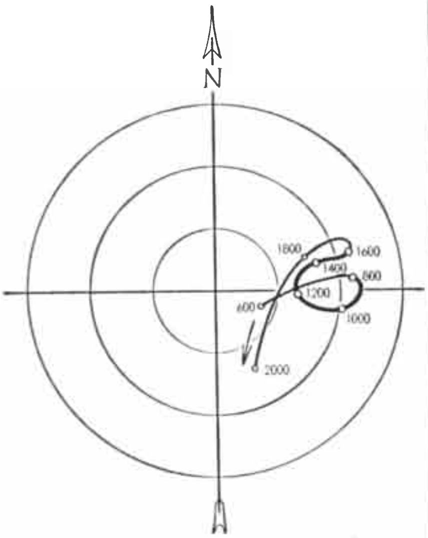
old layer ascends a new layer is formed underneath. When the ascent of the old layer is rapid enough, a separation between the old and new layers is detected.

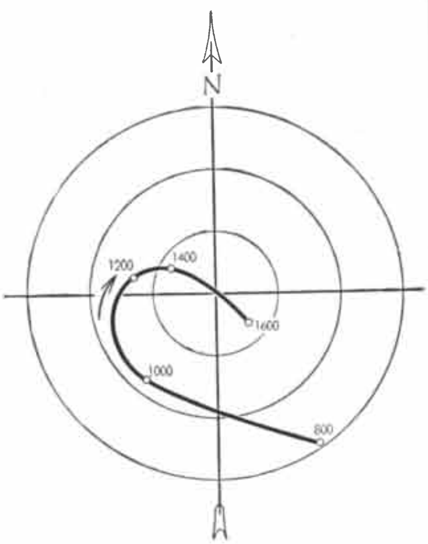
Several methods have been developed for tracking "winds" or drifts of ionized air in the ionosphere. Perhaps the simplest ionospheric "anemometer" is one which takes advantage of the fact that the reflecting surface of a layer in the ionosphere is usually a little rough, like the surface of the sea. A radio wave reflected from it to the ground is therefore somewhat irregular, varying in strength from place to place. In the method based on this fact, radio waves are beamed directly upward and the echoes are picked up by three different antennas placed about 100 yards apart at the corners of a triangle. If the ionized air overhead is moving horizontally, the pattern of irregularities in the reflected radio wave moves in the same direction, causing fading of the echoes received. The pattern of echo-fading received at one antenna will be repeated shortly afterward (*e.g.*, two seconds later) at a "downwind" antenna [*diagram on page 132*]. In this manner we can determine the speed and direction of the motion in



DIRECTION OF IONOSPHERIC WINDS over Washington during the day was averaged by the National Bureau of Standards for a period of three years. From upper left to lower right these six charts show the wind direction for January-February, March-April, May-June, July-August, September-October and November-December. The direction of the wind may be read by imagining an arrow extending from the intersection of the north-south and east-west lines to a point on the looping curve corresponding to the time of day. This is given in the ionosphere. There is no guarantee that the moving pattern actually indicates a wind; it may merely reflect a wavelike motion like the ripples on a pond. But the measured motions have many of the earmarks of winds, and the presumption is very strong that they are indeed for the most part true winds.

A variation of this method tracks the movement of a pattern of irregularities in the ionosphere by its effect on radio noise coming to the earth from space. The strength of the radio signals varies as ionized air in the ionosphere moves across their path from the distant source.





intervals from 0600 (6 a.m.) to 2000 (8 p.m.). The velocity of the wind is indicated by the distance of the curve from the intersection of the north-south and east-west lines. The maximum velocity represented here, in the last chart, is roughly 150 miles per hour.

Recordings at three different locations will show the speed and direction of the movement.

A more spectacular but considerably more difficult technique for measuring air movements in the ionosphere was developed by L. A. Manning, O. G. Villard, Jr., and A. M. Peterson at Stanford University. They detect the tracks of meteors in the E layer by radar. If the thin ionized track in the wake of a meteor is driven toward the radar receiver by a wind, the frequency of the reflected radio wave rises in proportion to the speed of the wind, because of a Doppler effect. If the track is being carried away from the receiver, the frequency of the reflected wave drops. Special sensitive equipment makes it possible to measure the amount of this Doppler shift even though the track may last only a fraction of a second. Measurements of ionospheric "winds" by this method agree well with those obtained by the fading method.

Frequencies for Radio

In the 50-odd years since Marconi's experiment, utilization of ionospheric reflection of radio waves for communication over long distances has increased by leaps and bounds. Today the band of frequencies which can be reflected by the ionosphere has become so crowded that many stations are interfering with one another. One of the functions of the research on the ionosphere at institutions such as the National Bureau of Standards is to provide basic information for the most efficient use of the available radio spectrum. It is important to know, of course, the upper limit of frequencies that can be reflected by the ionosphere, and ionograms showing the distribution of electron densities are necessary for that purpose. A network of about 75 stations over the world (not counting those in the U.S.S.R. sphere of influence) is now keeping track of variations of the ionosphere. The U. S. operates or helps support 19 of these stations. Each station makes an ionogram at least once an hour throughout the day. Pertinent information is scaled from each record and forwarded to data-processing centers, where the results are used to prepare predictions of maximum usable frequencies.

The National Bureau of Standards prepares such charts for each month. They show contours of maximum usable frequency plotted as a function of geographical latitude and local time of day. Each chart applies to transmission over a certain distance by reflection from a specific layer. The maximum usable fre-

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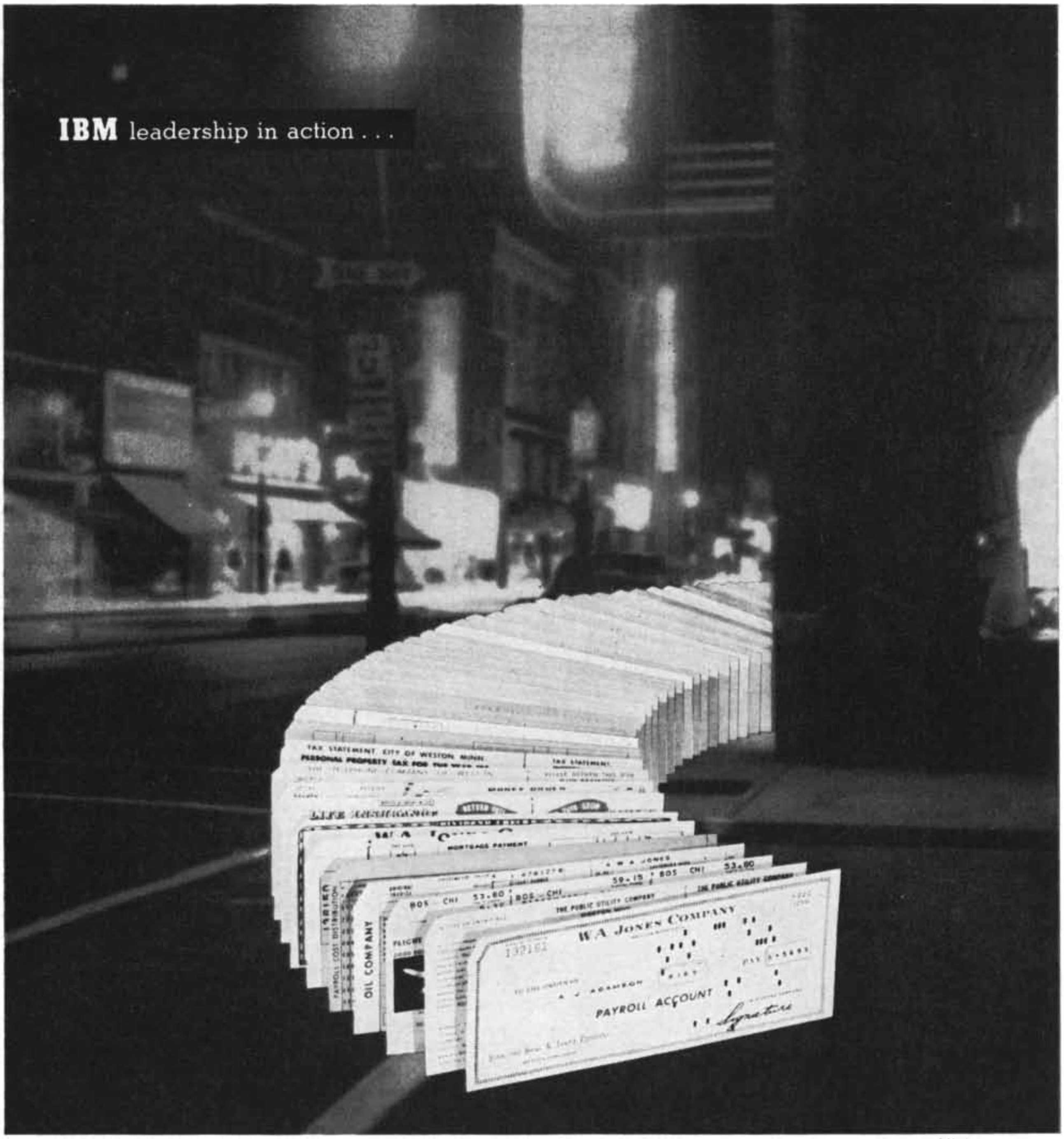
quencies for other distances can be derived from these values by means of a published formula.

During the International Geophysical Year, the main emphasis of the ionospheric program will be on obtaining systematic ionosonde records at as many qualified stations as possible. There will be three north-south chains of stations: along or near the meridians of 10 degrees east longitude (Western Europe-West Africa), 140 degrees east longitude (Japan-Australia) and 75 degrees west longitude (Greenland-South America). A special effort is to be made to establish stations near the geomagnetic equator, in order to study the F_2 layer in this region. There will also be an east-west chain of stations around the globe, somewhere near the equator; a group of stations in the zone of the northern aurora, and another group of stations on the Antarctic Continent. One station will be placed at the South Pole. There any changes in the ionosphere related to the rotation of the earth can be attributed to the asymmetry of the earth's magnetic field or to asymmetries in the atmospheric circulation, for the angle of the sun's rays does not change during the day. It will be interesting to find out how much of the polar ionosphere is preserved throughout the period of almost six months when no direct rays from the sun reach the ionosphere.

A high-priority project for the IGY will be measurements of the ionosphere's absorption of radio waves. Attempts to measure it have been much less successful than measurements of electron distribution. There are two principal methods for measuring absorption. One is to compare the strength of a radio pulse which has been reflected twice (two round trips between the earth and the ionosphere) with that of an echo reflected only once. The difference between the strengths of the once-reflected and the twice-reflected echoes is a measure of the absorption experienced by the twice-reflected echo on its second trip (if we make allowance for the losses of energy due to its reflection from the earth and its greater travel distance). The other method of measuring the absorption characteristics of the ionosphere is to measure the variations in strength of radio signals from outer space.

From a well-planned and well-executed program for investigation of the ionosphere we stand to gain much in the way of increased understanding of the world we live in, to say nothing of economic advantages which will accrue from increased effectiveness in exploiting the blanket of electrified air above us.



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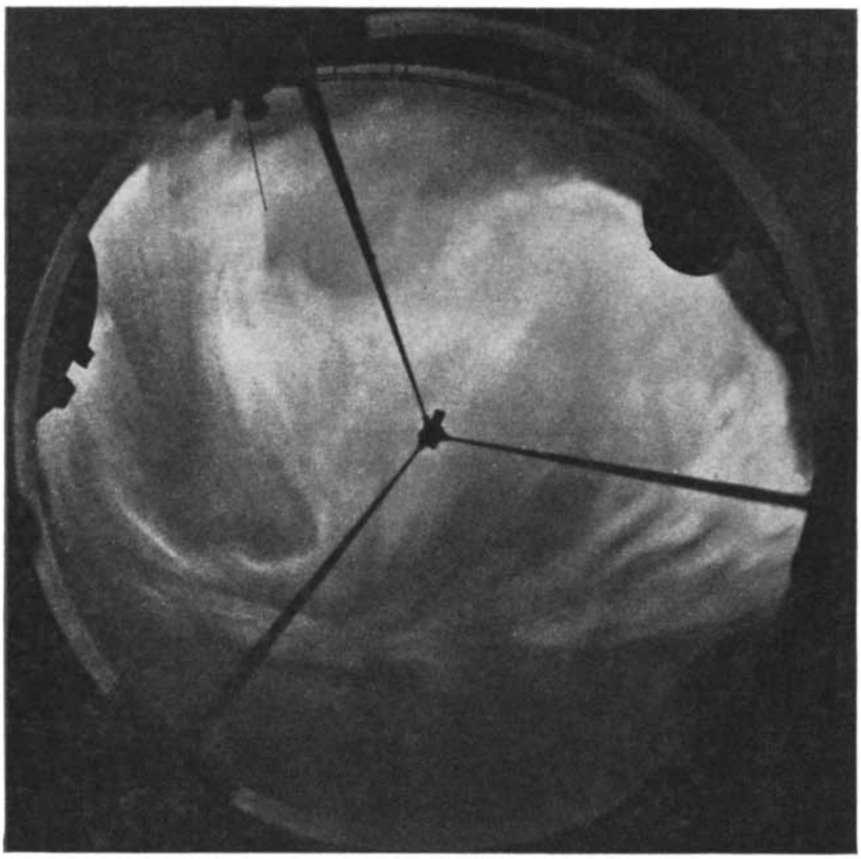
AURORA AND AIRGLOW

Under bombardment by solar corpuscles the atmosphere lights up like a neon tube in intermittent auroral displays. It also shines with a steady glow which is usually too dim to be seen

by C. T. Elvey and Franklin E. Roach

Across the darkening northern sky the horizon begins to glow with a faint greenish light. Soon the band of light brightens and mounts higher in the sky, arching from east to west. As it moves southward, more and more bands appear, and the night sky steadily grows more weirdly luminous. Then suddenly the ribbons begin to break up, filling the entire sky with rapidly moving rays and great draperies folding and unfolding. The colors are pastel greens, occasionally tinged with pink or purple. Watching the spectacle from the ground, you feel engulfed in a great, kaleidoscopic mass of light.

Of all natural phenomena, an aurora seems one of the most unreal and indescribable. What is it? What causes it? Can it be given a physical shape or form; can it be dissected, measured, located or bounded? The answer, of course, is that it can, and that some of the questions about the strange northern (or southern) lights which mankind has been asking for centuries can now be answered, though we still have much to learn about the phenomenon.



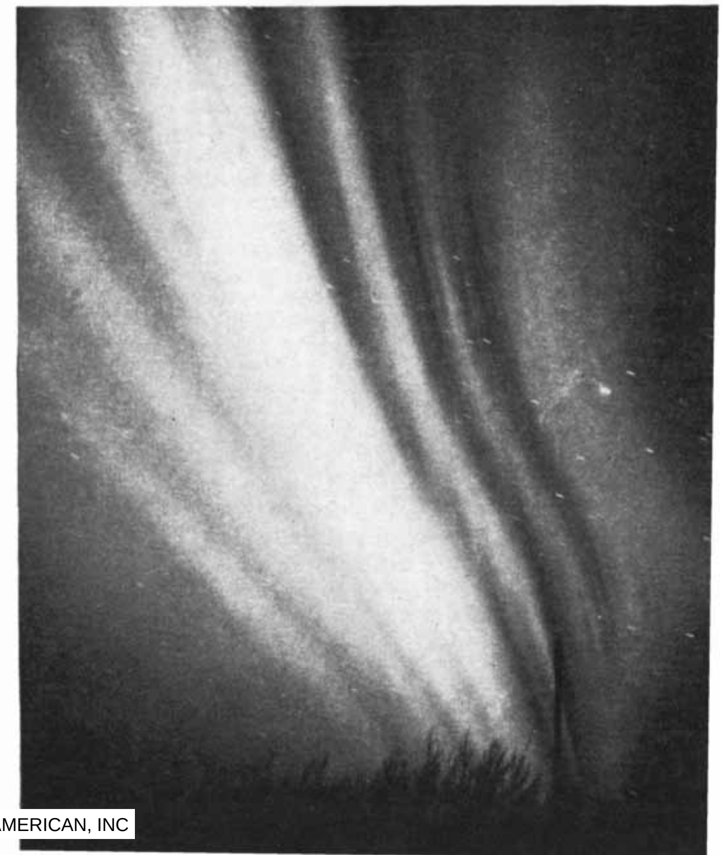
GREAT AURORA of August 19, 1950, is viewed through the all-sky camera. In this instrument a conventional camera photographs the image of the whole sky in a convex mirror.

Most astronomers and physicists believe the aurora is caused by streams of charged particles that come to the earth from the sun [see "Corpuscles from the Sun," by Walter Orr Roberts; SCIENTIFIC AMERICAN, February]. Captured by the earth's magnetic field, these particles are funneled toward the geomagnetic poles, which accounts for the fact that auroras are most frequent near the north and south poles. When they sweep into the earth's atmosphere, protons in the stream combine with electrons to form hydrogen atoms. This union radiates light. The fact that the radiation is hydrogen light shows that protons are bombarding the atmosphere during the initial phase of the auroral display. Later phases of the aurora, particularly its breakup into rays, apparently are excited by beams of electrons. Thus the mechanism responsible for producing an aurora—excitement of atoms and molecules in the atmosphere by bombarding particles—is much the same as that of a neon sign.

The aurora dips down toward the earth along the lines of magnetic force that channel the particle streams. It does not reach the ground, of course; photographs of the aurora taken from separated stations have shown that it ends about 60 miles above the earth's surface. The base of the aurora is visible for a distance of 600 miles from the point on the ground below it; beyond that it is hidden by the curvature of the earth.

As the result of nearly a century of observation, there are fairly comprehensive maps defining the areas of the world where auroras can be seen and where they occur most frequently. These maps are based on geomagnetic latitude. The

AURORAL DISPLAYS are shown in these photographs. Above is a drapery traversed by rays. At the left below is a rayed arc. At the right below is an array of arcs, some homogeneous and some rayed. The two arcs below extended past the horizon in both directions.



MAXIMUM FREQUENCY ZONE for auroras is indicated by the stippled circular belt. The dotted circle shows the southern boundary of the region where auroras are seen fairly often.

magnetic poles of the earth are not located at the geographic poles: the north geomagnetic pole is in northwest Greenland. The zone of greatest frequency of auroras is a belt about 23 degrees from the magnetic pole in each hemisphere. In the Northern Hemisphere it runs through Alaska between Point Barrow and Fairbanks, across Canada and the southern tip of Greenland, over the northern edge of Norway and off the northern coast of Russia and Siberia [*see map above*]. Between 60 degrees and 45 degrees geomagnetic latitude is a zone where auroras are seen fairly often. The southern boundary of this zone runs approximately through San Francisco, Oklahoma City, Memphis, Atlanta, the Azores, northern Italy, the southern part of the U.S.S.R. and the tip of the Kamchatka Peninsula [*see map*]. Below 45 degrees geomagnetic latitude auroras appear only during large magnetic storms, caused by exceptionally severe disturbances of the earth's magnetic field.

It is common knowledge that auroras are most likely to appear in March and September. Whether this is due to the seasonal instability of the earth's atmosphere or to the fact that the sun's north and south sunspot belts are tipped toward us at those times is a debated question. It is a fact that the frequency of auroras is correlated to some extent with cycles of sunspot activity.

An intensive study of the occurrence of auroras over Alaska is being made at the Geophysical Institute of the University of Alaska, in the town of College near Fairbanks. During the season 1953-54 (a time of near-minimum solar activity) there were occasional auroras over College even when the earth's magnetic field was almost completely quiet. On days of strong magnetic storms, auroras were active over the town for 52 per cent of the total observing time.

An aurora at the height of its activity is bewildering even to a veteran observer. Its motions, changing shapes and colors are so various that they almost defy description. It is worse than trying to watch a three-ring circus—the auroral display is all around and overhead.

While the rapidly moving rays and draperies of this stage are extremely spectacular, a scientist finds some of the aurora's quiet forms far more remarkable. Giant fluorescent ribbons span the sky, and they represent streams of protons focused in incredibly thin beams by the earth's magnetic field. The ribbon of auroral light sometimes is no more than

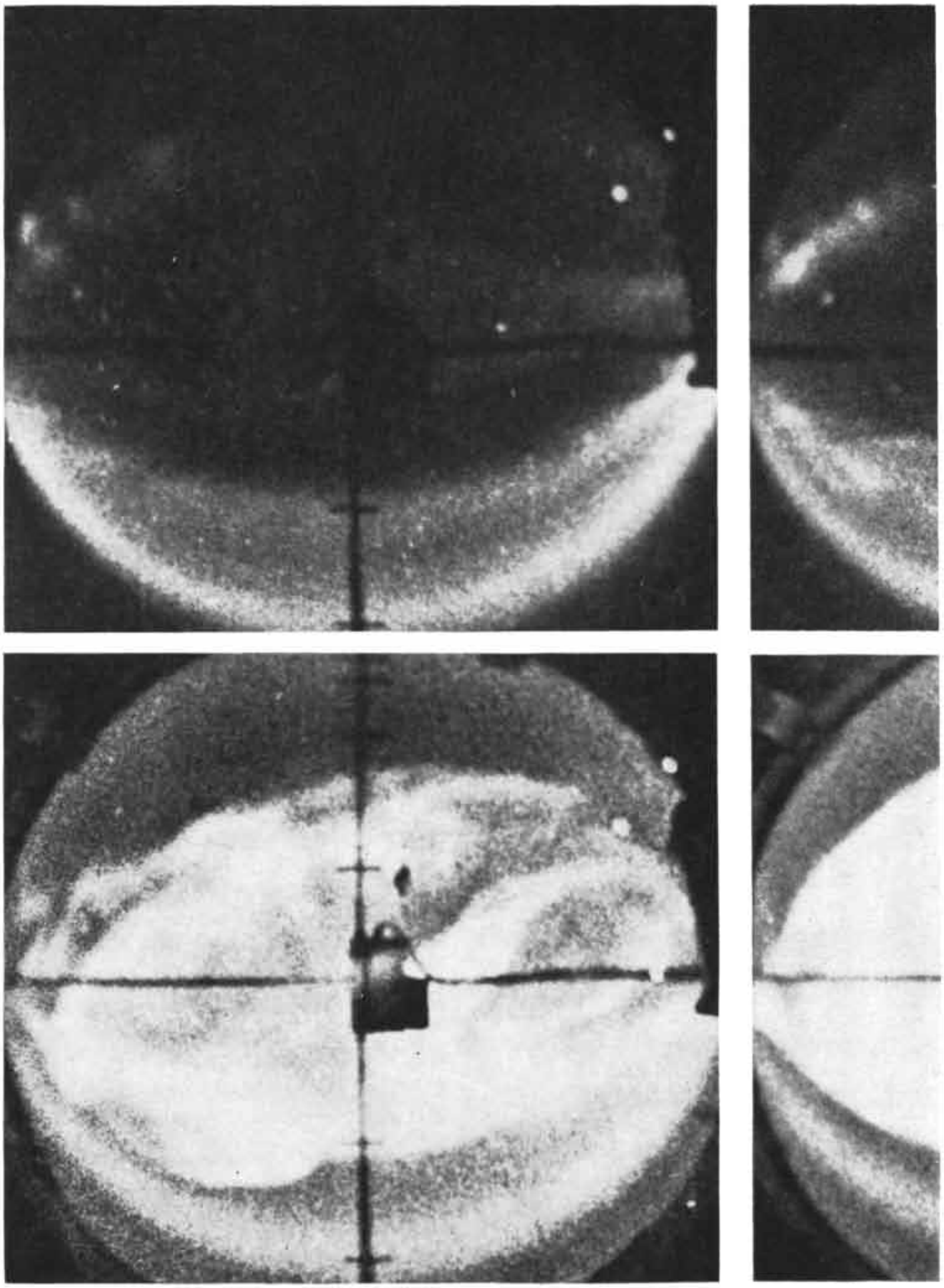
800 feet thick—the length of a city block. Yet this thin ribbon may reach as far as the eye can see from the east to the west horizon, 1,200 miles or more. How much farther the arcs extend, we do not know; one of the projects of the International Geophysical Year will be to find out how far the auroral bands go around the globe.

At College, which is near the middle of the most active belt in the Northern Hemisphere, we not only see the great auroras but are directly beneath a large majority of the minor ones. We have endeavored to gain a broader view of auroral displays by observing from five stations spread over Alaska. These stations are at College; at Northway, on the Alaskan Highway near the Canadian border; at Sheep Mountain, east of Anchorage; at Nome on the Seward Peninsula and at Point Barrow, the northernmost tip of Alaska.

To illustrate the development of an auroral display as seen in Alaska, let us take the aurora of March 26-27, 1954. All five stations reported throughout the night. At 8:40 p.m. a homogeneous ribbon of light appeared across the northeastern area of the Territory at approximately geomagnetic latitude 70 degrees. By 9:00 p.m. the arc had advanced south to 68 degrees latitude. Half an hour later there were four arcs between 67 and 70 degrees. The display gradually moved southward and added more arcs. The southernmost band was generally homogeneous, but the others were crossed by transverse rays. At 10:15 p.m. eight arcs were observed, the one farthest south at 62½ degrees. Not long afterward there occurred what we call a pseudo breakup—the disruption of one of the northerly arcs, with a temporary flareup of violent activity [*see photographs on next two pages*]. But the system quickly recovered its stable pattern. Then, shortly after midnight, the whole arc system broke up. The southernmost arc began to brighten and seemed to quiver throughout its length. In a matter of seconds the sky over all of Alaska north of 62 degrees was filled with draperies, rays and bands, all in violent motion. A few minutes later pulsating surfaces formed; at 1 a.m. they became diffuse, and by 3 a.m. the aurora had been reduced to a diffuse veil confined to the region between 66 and 68 degrees geomagnetic latitude. Thereafter the veil gradually faded until daybreak.

Several instruments have been valuable in investigating auroras. One is an "all-sky" camera developed for auroral work by C. W. Gartlein. It has a 16-

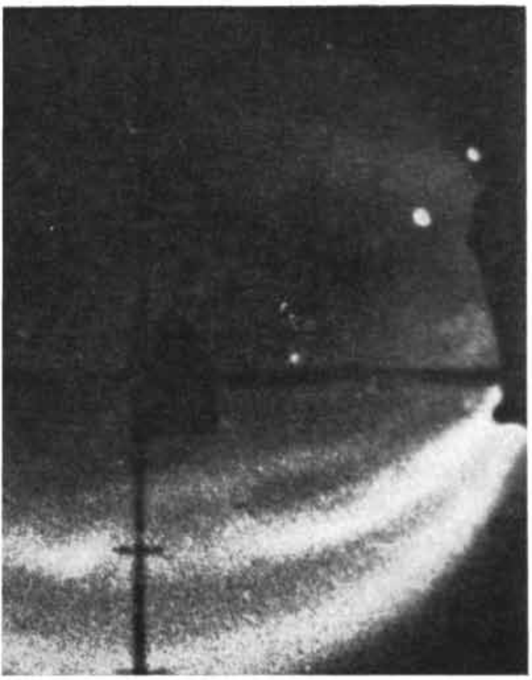
millimeter motion picture camera pointing downward to a convex mirror, which gives an image of the entire sky and makes it possible to maintain a continuous patrol of the heavens. Another invaluable aid is the spectrograph, which analyzes the light from an aurora and tells us the kinds of atoms and molecules present in the atmosphere, their temperatures, the amounts of energy radiated and something of the mode of excitation. The faintness of the aurora and the rapidity with which it changes make spectroscopy difficult, but development of the technique by Norwegian, Canadian and U. S. workers has produced beautiful spectrograms of auroras extending throughout the visible spectrum and into the near ultraviolet and the near infrared. A. B. Meinel and his colleagues at the Yerkes Observatory have found evidence, through spectroscopy and experimental bombardment of atmospheric gases at low pressures in the laboratory, that the aurora is excited by protons during its ribbon phase and by electrons after its breakup. Kenneth Bowles, at College, discovered another

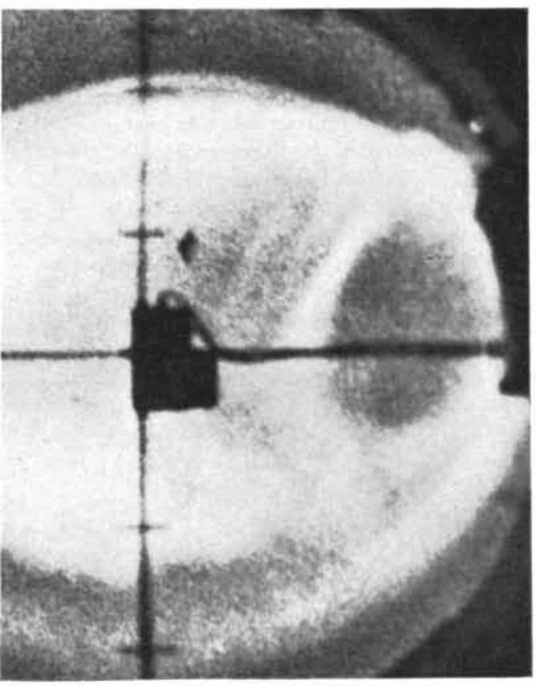


PSEUDO BREAKUP of a system of auroral arcs can be seen in this series of all-sky photographs taken a minute apart. The sequence begins at upper left and ends at lower right. In

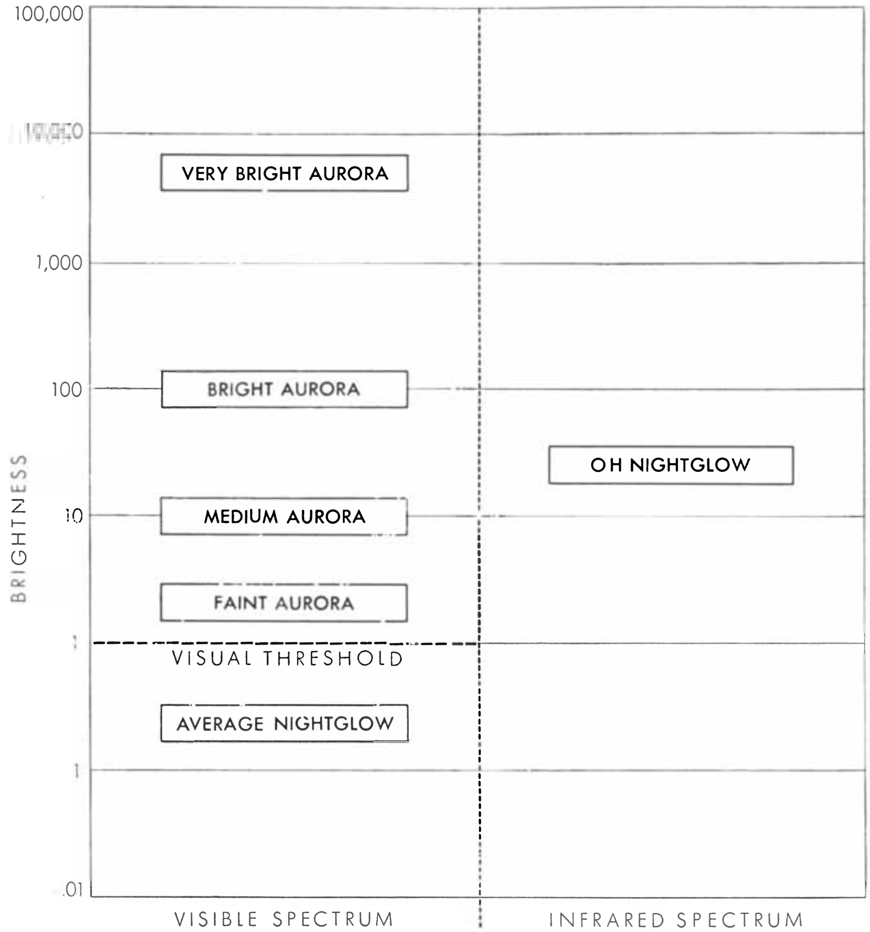
indication of this fundamental difference between the homogeneous and rayed forms of the aurora. Studying radio signals reflected from auroras, he found shifts in the frequency of the signal—a Doppler effect. When the echoes were from homogeneous ribbons, the shifts were in the direction indicating that the electrons were drifting downward; the echoes from rayed forms suggested electrons drifting upward.

Radio and radar have been very useful tools for the study of auroras. A radar set does not "see" exactly the same thing as





pseudo breakups only the northern bands are disrupted, and they quickly form again.

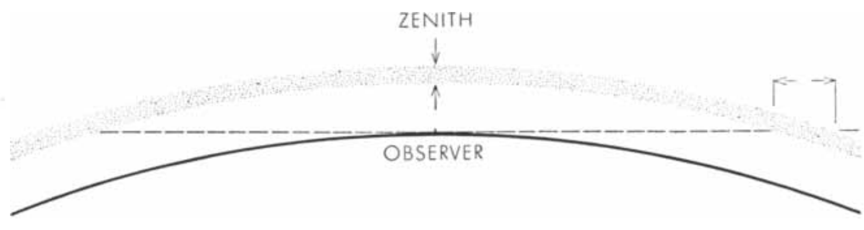


RELATIVE BRIGHTNESS of various atmospheric effects is indicated in this chart. Nightglow radiations in the visible portion of the spectrum are usually too dim to be seen.

the eye or the camera, but it has the great advantage that it can detect auroras through clouds or in daylight. Radio astronomy also has been helpful. Just as turbulence in the air of the atmosphere causes visible stars to twinkle, so an auroral disturbance of the electrical atmosphere makes radio stars twinkle. By careful experiments it is possible to determine the sizes and motions of the irregularities in the auroral zone. In addition, the auroral zone shows a measurable absorption of the general radio noise from space.

Various attempts have been made to measure the magnitude or intensity of auroras. The Geophysical Institute at College is now using a photoelectric photometer to measure the illumination of the sky during auroral displays. The measurement is made in a small portion of the visible spectrum which identifies the auroral light—say the green auroral line. These recordings indicate that an aurora increases the illumination of the night sky 10-fold on the average, and during bursts of intensity it may brighten the sky more than 100-fold.

The study of auroras during the International Geophysical Year will have several objectives—among them: to make simultaneous maps of the distribution of auroras over the globe; to correlate the auroral displays with activity in the sun



THICKNESS OF ATMOSPHERE along a line of sight determines the brightness of the airglow, proving that the light originates in the air. The glow is brightest near the horizon.

and with magnetic storms and other phenomena on the earth; to examine the physical processes and the size of the aurora itself. The frequency of auroras will be investigated intensively by counts of their occurrence over small, selected areas, say one square degree of the earth's surface (a square 69 miles on a side).

Enlisted in these investigations will be chains of stations equipped with the all-sky camera, radar stations, spectroscopic stations (including one flying laboratory in an airplane using a scanning spectrometer), radio telescopes and various other observatories and groups. The investigators will also seek reports from amateur observers of auroral displays, particularly in the zone where auroras are seldom seen; public alerts will be issued when an aurora is probable in this zone. The two U. S. centers for collecting and correlating all observations will be at Ithaca, N. Y., and College.

Closely connected with studies of the aurora will be a program for investigation of another important sky phenomenon, called the "airglow." The sky over the earth is suffused day and night with a faint glow which is not visible to the eye but has been detected by sensitive instruments. It is invisible mainly because it is so faint, but also partly because its strongest radiations are outside the visible band of the spectrum. If our eyes were sensitive to the infrared, the airglow would make the night sky as bright as mid-twilight.

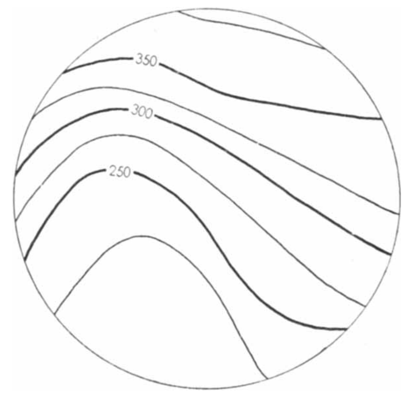
Like the aurora, the airglow is caused by excitation of atoms and molecules in the atmosphere. It seems also to originate at the same general altitude. The night and day glows apparently are produced by somewhat different processes. The nightglow is especially difficult to explain. Its ultimate source of energy is almost certainly the sun, but it is hard to imagine what sort of mechanism can account for the conversion into nightglow of a minute fraction of the solar energy continually bathing the earth. If we knew the answer, it might tell us something of great significance about the upper atmosphere.

The airglow was first detected several decades ago. In spectrograms of the sky astronomers found a persistent green radiation which could not be coming from stars or planets. Because the radiation evidently originated in the atmosphere and because it was the same green line that was seen in auroras, they named the glow the "permanent aurora." It was later renamed airglow.

At least four distinctive wavelengths

of the airglow have been identified. One is the green line at 5577 Angstrom units, emitted by excited atoms of oxygen; another is a red radiation at 6300 Angstroms, also emitted by oxygen atoms, at a different level of excitation; a third is a yellow radiation at 5893 Angstroms, produced by sodium; a fourth is a strong radiation in the infrared, at about 10,000 Angstroms, emitted by the hydroxyl (OH) molecule. The latter radiation would be as bright as an aurora if it were visible. The radiations in the visual part

1900



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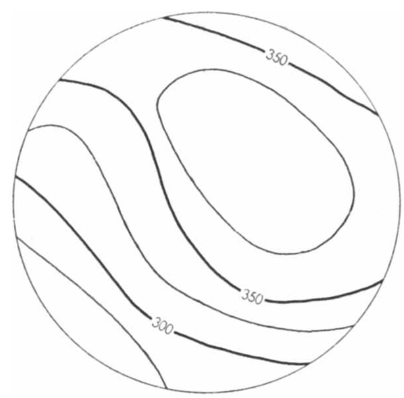
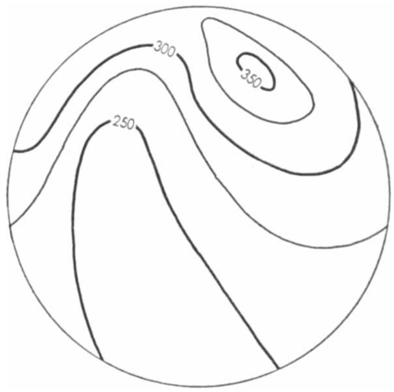


0300

NIGHTGLOW MAPS indicate light pattern of the sky at two-hour intervals by lines of

of the spectrum are usually far below the threshold of the eye's sensitivity, but on rare occasions they brighten sufficiently so that eyes adapted to the dark can barely make out some structural detail in the nightglow.

The airglow at night has received concentrated study during the past decade, and its characteristics can now be discussed in some detail. It is, of course, extremely hard to detect. Its spectral lines have been recorded by means of very long exposures (often for several



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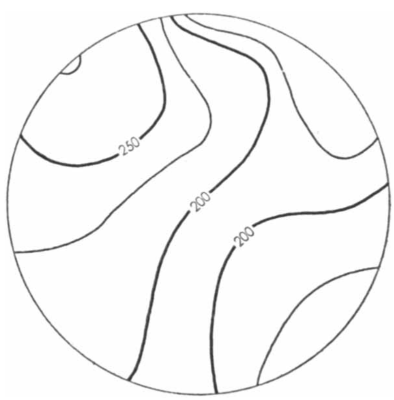


0500

equal intensity. The numbers denote millions of quanta per square centimeter per second.

nights) with highly efficient spectrographs. By the use of photoelectric photometers and filters which transmit very pure colors and exclude background radiation from space, it has been possible to study the varying strength of the nightglow, both in distribution over the sky and in time.

These studies show that the nightglow is faintest at the zenith overhead and grows in intensity down the sky until it reaches a maximum about 10 degrees above the horizon. This is to be expected, because from the zenith toward the horizon the camera looks through a progressively greater thickness of atmosphere; the fact that the airglow brightens correspondingly is a proof that it originates in the atmosphere. The height of the airglow above the earth surface can be estimated from the increase of intensity toward the horizon. The available indications place it between about 60 and 120 miles up.

The green light of the glow tends to grow in brightness during the evening hours and decline after midnight. On the other hand, the red radiation, which also comes from oxygen atoms, decreases in intensity during the evening hours and increases slightly just before dawn. This is very surprising, in view of what we know about the oxygen atom. When an oxygen atom emits the green (5577) radiation, it is left in a state in which it will readily emit the red (6300) radiation. It dawdles in that state for 110 seconds and then falls to the next lower state, emitting 6300. Evidently some physical intervention in the upper atmosphere must de-energize the oxygen atom during the 110 seconds before it can radiate 6300. Probably it is de-energized by collisions with other atoms. The situation is somewhat analogous to the fate of a baseball which has been fouled onto the roof of the grandstand. The ball rolls down the roof and falls into the grandstand. From there it might roll down the tiers of seats and fall back to the playing field. But every baseball fan knows that the chances of the ball's ever returning to the field are practically nil, as it suffers numerous collisions with various physical and human impedimenta and invariably ends up in a boy's pocket.

Sodium atoms release the energy producing their typical yellow radiation so readily that this radiation can be detected even where sodium is present only in minute amounts. Consequently, although in the upper atmosphere only about one atom in one million million is sodium, the yellow sodium radiation in the airglow is often as intense as the green and red emissions from oxygen. The most striking feature of the sodium nightglow is its fluctuation from season to season. In northern latitudes it is frequently brighter than the oxygen lines in late autumn, but in midsummer it is so weak that it is often undetectable. It has been suggested that a huge sodium cloud in the upper atmosphere may winter in mid-latitudes and summer in the tropics.

The discovery of OH radiations in the nightglow (first found in the near infrared and later, more faintly, in the visual part of the spectrum) has been very stimulating to studies of the origin of nightglow radiations. It is thought that the OH radiation may be due to collisions between hydrogen atoms and ozone molecules which produce O_2 and excited OH. A number of photochemical reactions which might produce other nightglow features have been proposed. One ingenious suggestion is that the nightglow is the result of large-scale electrical discharges in the upper atmosphere such as are commonly observed on a small scale near the earth's surface during an electrical storm.

The nightglow is only one form of the airglow. There is also a twilight glow, about 100 times as intense as the nightglow but not detectable by the eye because of the brighter sky. If the cause of the nightglow is a mystery, the reason for the twilight airglow is not. It is strongest when the sun is eight or 10 degrees below the horizon and the lowest sunrays cross the earth's atmosphere about 60 miles above the observer. The red 6300 line of oxygen and the sodium yellow radiation then flash out, but the green, 5577 line of oxygen is not strengthened. There can be little doubt that the twilight airglow is the result of the direct action of sunlight, raising the atoms of the upper atmosphere to the energy states necessary to produce the observed emissions.

Since the sun produces directly a twilight airglow, it must also create a day airglow. Naturally the latter cannot be detected in broad daylight. It might possibly be recorded by instuments carried in a rocket to high altitudes where the sky is essentially black because there are comparatively few particles to scatter sunlight. A few rocket launchings have been made, but no definite airglow emissions have yet been identified.

During the International Geophysical Year extensive observations of the airglow are planned, in close coordination with studies of the polar aurora, at chains of observing stations.

The Earth's Magnetism

The fact that the grains of ancient rocks are lined up like tiny compass needles has led to the astonishing conclusion that the earth's magnetic poles have wandered and reversed

by S. K. Runcorn

The magnetic field of the earth was the subject of one of the earliest treatises ever written on experimental science: *De Magnete*, published in 1600 by the English physician William Gilbert, who is sometimes called the father of electricity. By then it was known that a magnetized needle not only tended to point north but, if free to move vertically, would also dip in the Northern Hemisphere and point above the horizon in the Southern Hemisphere. Seeking to explain this behavior, Gilbert had made a sphere of loadstone and tracked its magnetic lines of force with dip needles. The needle's pointings and dips over this model followed approximately the scheme of its behavior in traveling over the surface of the earth. From which Gilbert concluded that the earth acted like a large magnet.

How was it magnetized? From century to century this became an ever more baffling riddle. Gilbert naturally inferred that the interior of the earth was made of a magnetic material. But scientists eventually realized that the core of the earth was much too hot to be permanently magnetized. And this problem was dwarfed by others far more subtle. In the first place, the axis of the magnetic field apparently was not the same as the axis on which the earth rotated: it was tipped so that the magnetic north pole was hundreds of miles away from the geographic North Pole. In the second place, systematic surveys over the earth showed that the compass deviated from true north in a most irregular fashion. Further, the pattern of the magnetic field was found to be changing over the centuries. There could be only one conclusion: the interior of the earth, where its magnetism was generated, was not rigid as had been thought. It must be in dynamic flux. As a famous geomagnetician of the early 19th century, Christopher Hansteen, truly said: "The earth speaks of its internal movements through the silent voice of the magnetic needle."

Let us see what the needle has to say. The strength of the earth's magnetic field, as measured by the force needed to deflect a compass needle from its preferred direction, is very small. At its strongest, near the poles, the field is several hundred times weaker than that between the poles of a toy horseshoe magnet. In general the needle tends to line up along north-south arcs around the earth, dipping down toward the ground near the north magnetic pole and pointing upward near the south pole [*see upper chart on opposite page*]. But there are very few places on earth where the needle actually points precisely to the true north. Its direction varies from region to region, so that the field seems to be full of irregular eddies. Over the long run the field is also changing in strength and direction. This secular change has been recorded at magnetic observatories for more than 400 years.

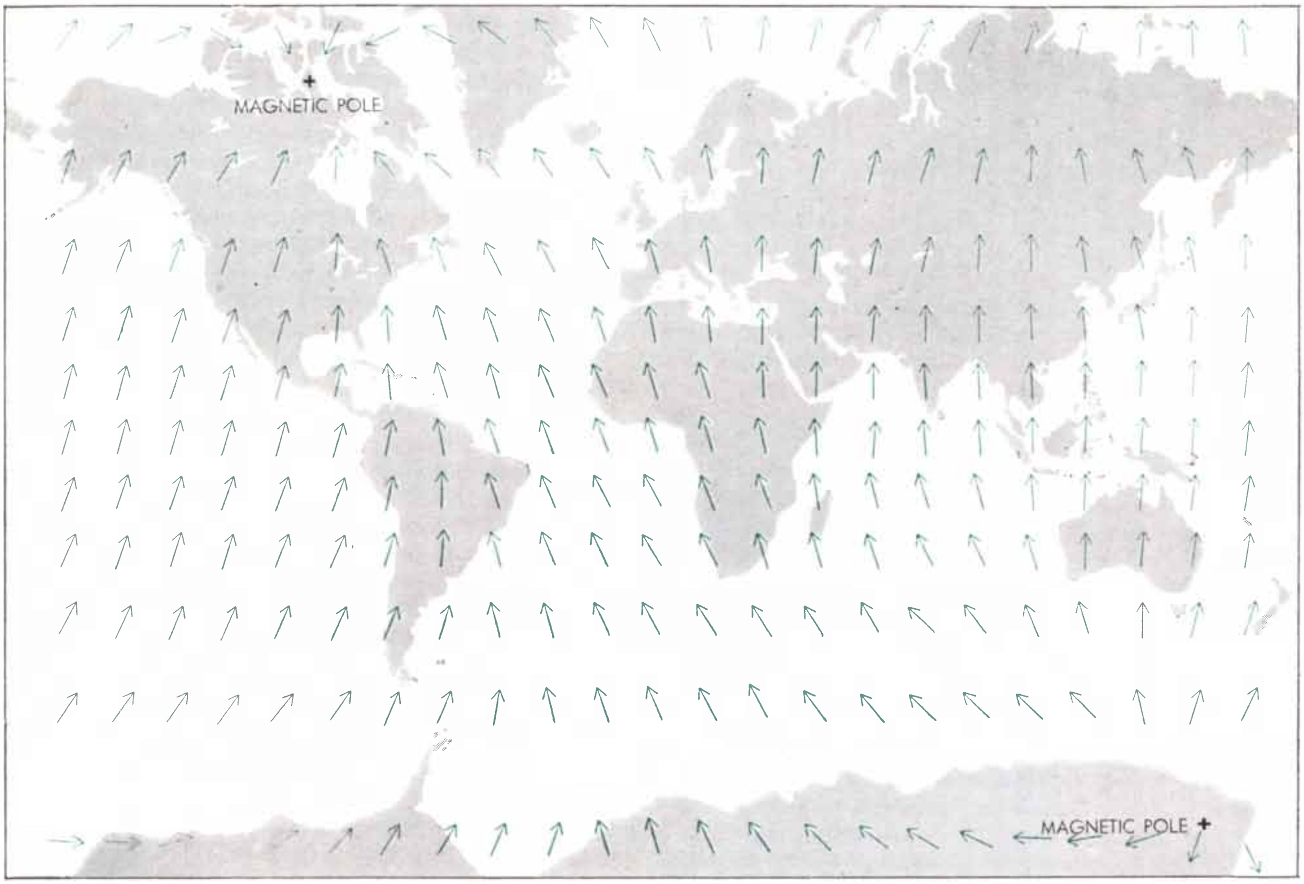
We now have many reasons to believe that the earth's field is made up of two components. First, there are constant lines of magnetic force which are always lined up with the earth's axis of rotation. Second, this main field is modified by other lines of force, produced by some different mechanism within the earth, which vary irregularly over the earth and change with time. We call the irregularities the "residual" field: it is measured by subtracting the main axial field from the actual field as traced by the compass. If we plot these differences over the earth—the amount of deviation from the main field in direction and strength at various places—we obtain a picture which represents the residual field [*lower chart on opposite page*].

Thus the compass readings suggest that the earth is magnetized in two different ways. It has a primary magnetism which is related directly to the earth's rotation. It also has shifting secondary magnetisms which are superposed on the primary force.

Observations made over the years tell us something about the nature of the changes in this secondary or "residual" magnetism. The residual field is slowly moving westward around the earth. And the pattern itself (the direction and intensity of the residual magnetism at various points) changes rapidly—within decades, years or even months. The residual field may be likened to a formation of moving clouds: it is continually changing in form and also drifting as a whole. The drift has been steadily westward throughout the centuries of observation. At the rate it has been moving, the residual field would travel full circle around the earth in about 1,600 years. For an effect connected with the "solid" earth, this is an astonishingly rapid evolution.

When we look farther into the earth's magnetic history, a still more remarkable story unfolds. In the past few years it

MAGNETIC FIELD of the earth is represented in the two charts on the opposite page. The top chart shows the total field, which has a regular component, as might be produced by a bar magnet in the earth's core, and an irregular component. The bottom chart shows the irregular component alone. This is obtained by subtracting a uniform north-south field from the total observed field. In the top chart the arrows indicate the direction in which a compass needle would point. In the bottom chart they indicate how it would point if there were no axial field.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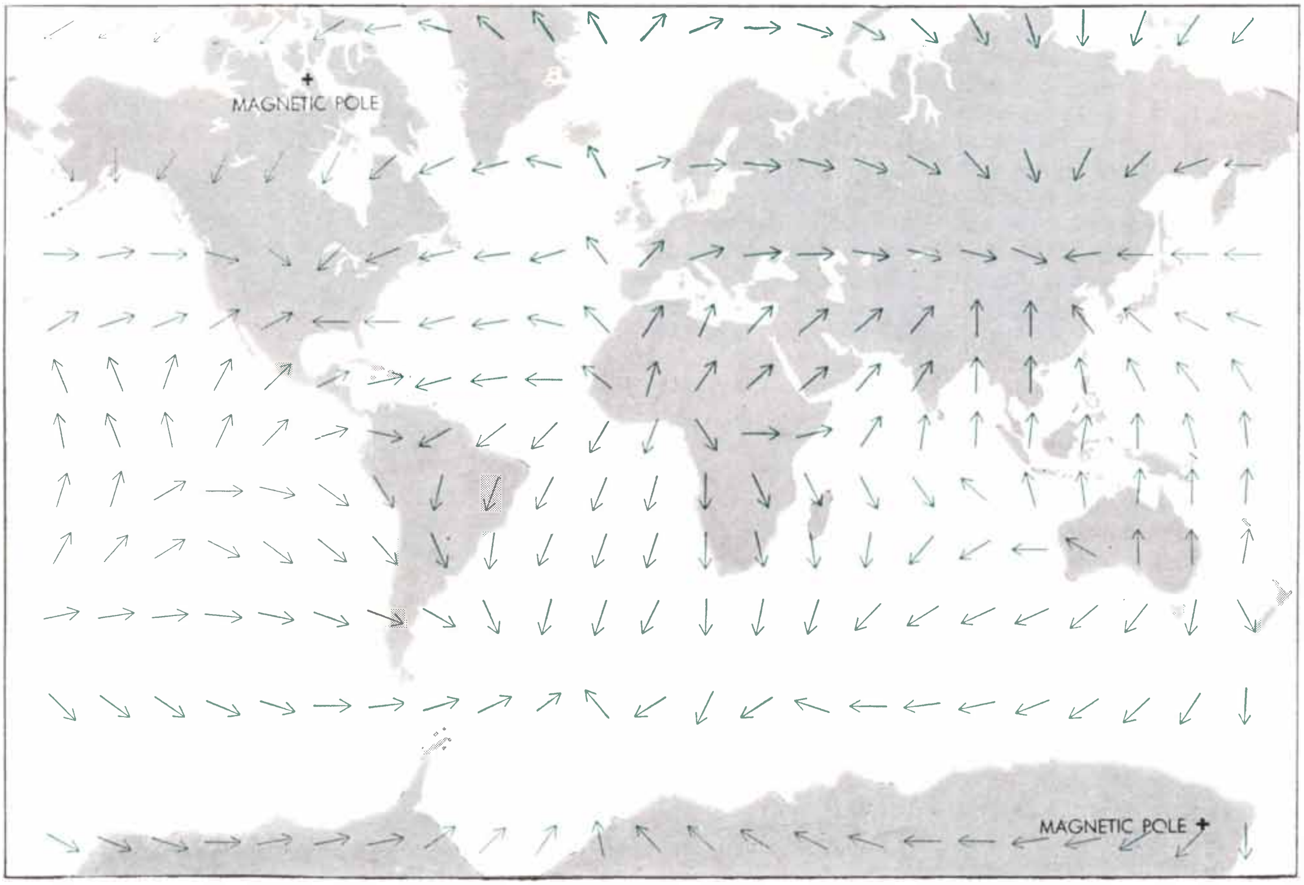
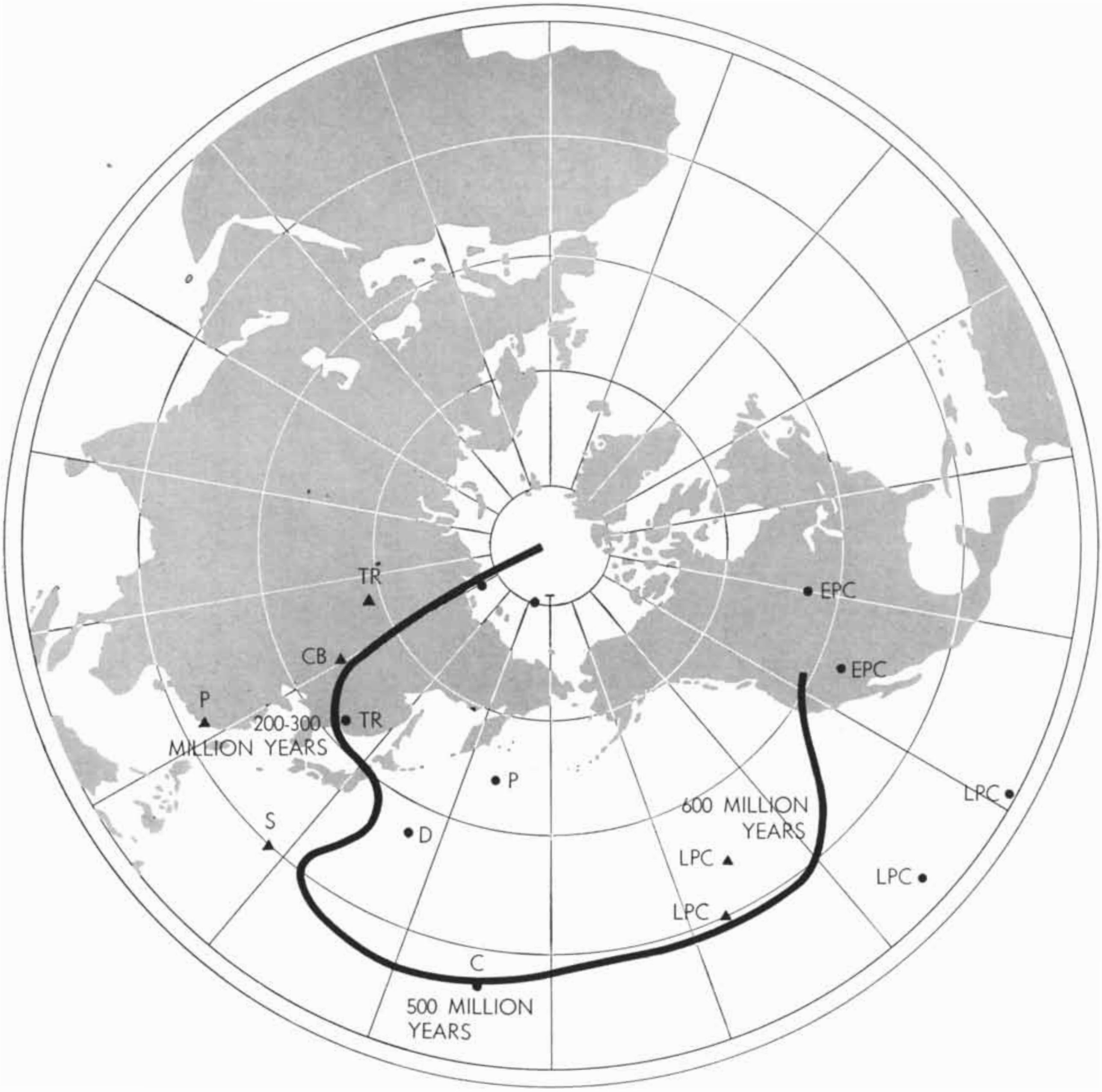
MAGNETIC POLE


MAGNETIC POLE
MAGNETIC POLE

has become possible to read the magnetic record for millions of years by means of certain natural compass needles which nature has frozen into the rocks. The needles are grains of magnetic iron oxide minerals, such as hematite (Fe_2O_3) and magnetite (Fe_3O_4). At high temperatures atoms of these minerals readily line up along a weak magnetic field. Thus when hot, molten lava first pours out on the surface from a volcano, its iron mineral grains become magnetized in the direction of the local geomagnetic field. After the grains cool, their magnetization can no longer be influenced appreciably by any change in the earth's field. Consequently the grains are magnetic fossils, recording the direction of the earth's field at the time the rock was formed. In certain parts of the world lava flows, piled upon one another in hundreds of layers, provide a veritable calendar of magnetic history. Iceland and the northwestern U. S. are rich in such deposits, some of them exposed in the walls of canyons.

Sedimentary rocks also may contain magnetic records. After magnetized particles were eroded from old volcanic rock, they would tend to line up along the earth's field when they settled in sediments. When the beds hardened into rock, the magnetic particles would be fixed in the direction of the field at the time.

Reading these magnets in rocks at various places around the world, we find evidence of astounding changes in the earth's main axial field. During the Tertiary period (between 60 million and one



APPARENT WANDERINGS of the North Pole are roughly traced by the heavy line on this map. The points on which the line is based are represented by dots and triangles. The dots refer to positions of the pole derived from the magnetization of rocks in the British Isles; the triangles, to positions derived from the magnetization of rocks in North America. The ages along the line indicate that the pole was near that position at that time. The letters refer to the positions of the pole in geologic periods: EPC, Early Pre-Cambrian; LPC, Late Pre-Cambrian; C, Cambrian; S, Silurian; D, Devonian; CB, Carboniferous; P, Permian; TR, Triassic; T, Tertiary.

Chemistry takes a new look at Mirrors

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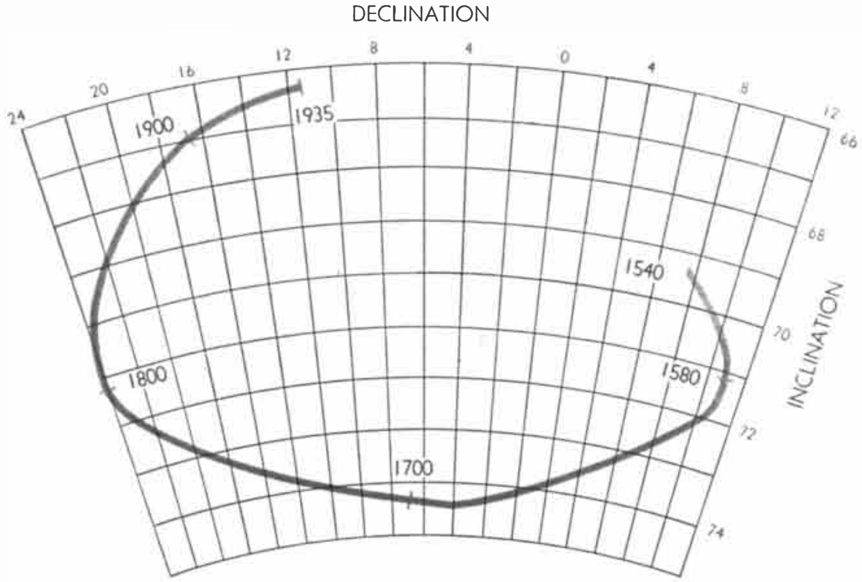


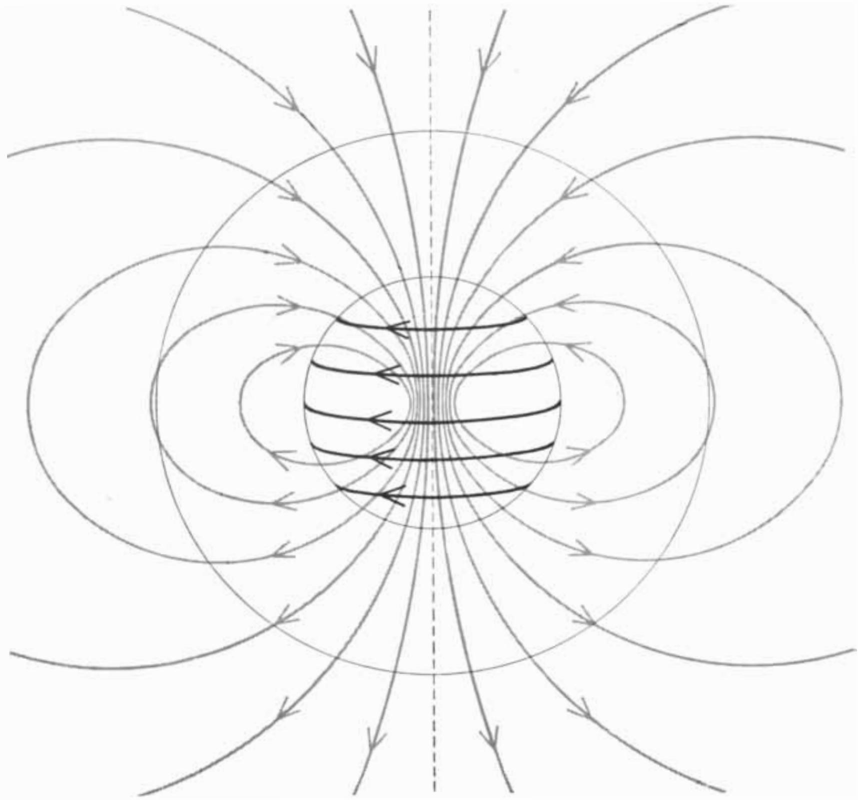
WESTWARD DRIFT of the irregular part of the earth's main magnetic field is clearly reflected by observations made in London. The north pole of a magnet, freely suspended to swing both horizontally and vertically, would have traced out the gray curve. Each date marks the point on the curve that gives the directions of the compass needle in that year.

million years ago) the north and south geomagnetic poles reversed places several times! It appears from the evidence of lava layers that after hundreds of thousands of years of stability the field would suddenly break up and reform with opposite polarity.

It should be said that not all students of geomagnetism accept this interpretation of the geologic records. Some prefer to believe that the iron oxide grains somehow reversed their magnetic directions independently of the earth's field. But the more rocks and locations we examine, the more the evidence accumulates that the earth did reverse its field many times.

So our attempts to explain how the earth's magnetism is generated must account for two types of fluctuation: the

LAYERS OF ROCK in Grand Canyon comprise a record of the local magnetic field at the time they were deposited as sediments. Their magnetic particles lined up with the field.

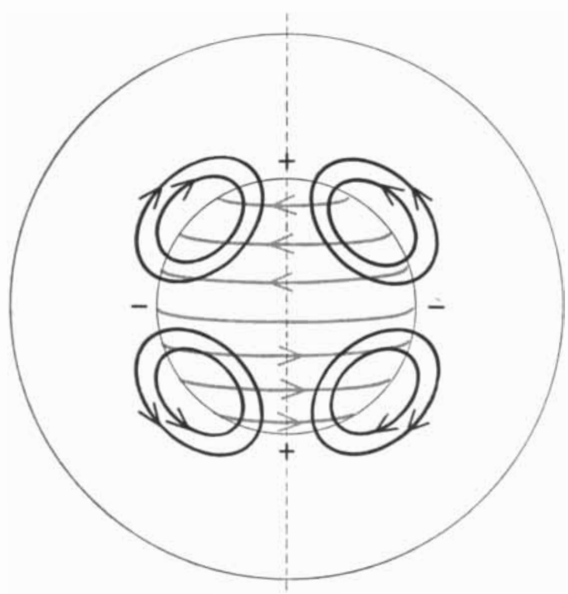


AXIAL DIPOLE FIELD of the earth is indicated by the gray lines. The electric current flow which could produce it is shown by the black lines following the surface of the core.

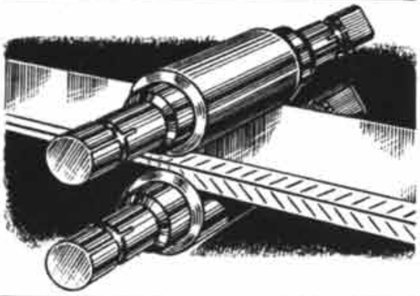
shifts of the main field and the secular variations of the residual field.

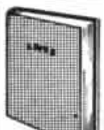
More than a century ago the great German mathematical physicist Karl Friedrich Gauss proved beyond question that the magnetic field must originate inside the earth. Today there can no longer be much doubt that it is generated by electric currents due to motions of material in the interior. The first suggestion as to how movements in a liquid core might explain the changing field came in 1939 from the physicist Walter M. Elsasser.

As a start, let us imagine that the earth's main magnetic field is produced by the system of electric currents in the conducting nickel-iron core pictured in the upper illustration on this page.



ELECTRIC MODE FIELD of magnetism is present within the earth's core, as shown by the gray lines. The lines of current necessary to support this field are indicated in black.





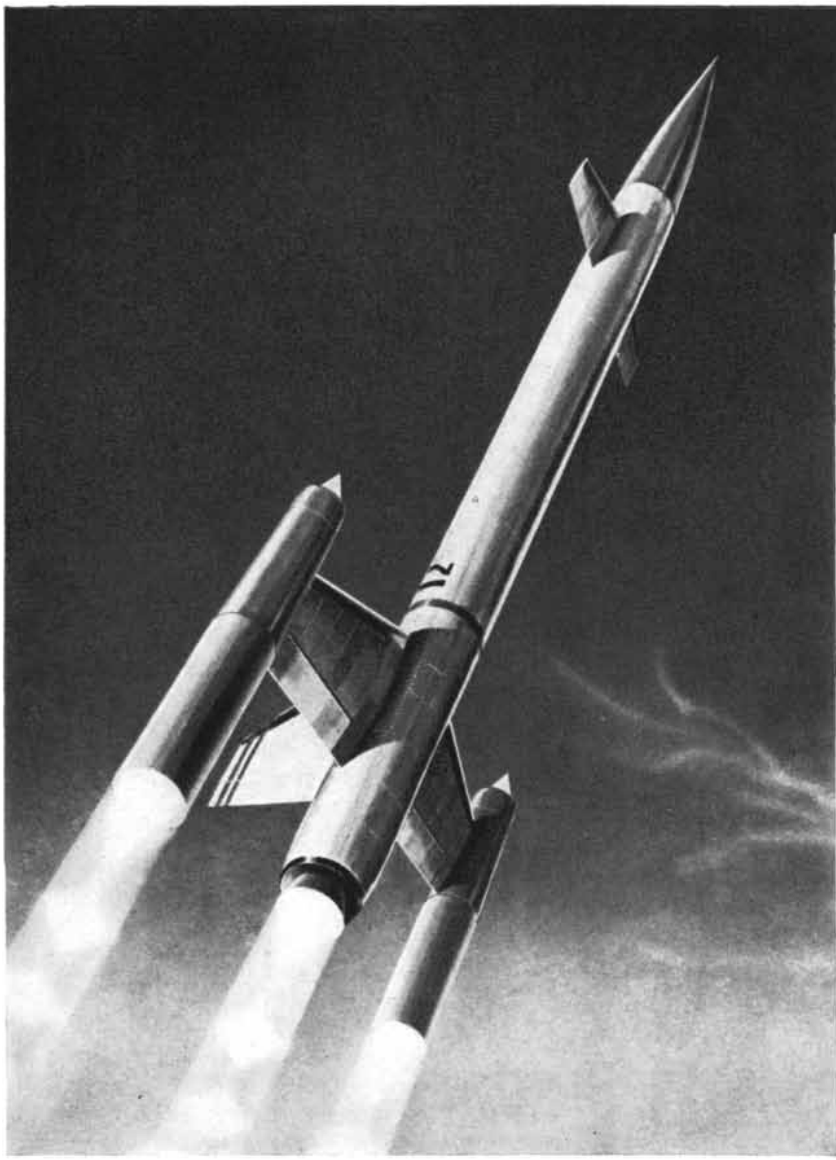
Convection motions within the fluid core might set up local eddies or whirlpools. Secondary electric currents generated in these areas would then generate a number of irregular magnetic fields, constituting the residual geomagnetic field. Changes in the unstable fields would be rather slow, because the extremely dense fluid of the core is much more sluggish than familiar liquids. Such a model would account for the geographical variations and the slowly changing pattern of the earth's residual field.

As for the westward drift, if our picture of the generating mechanism is correct we must suppose that the core of the earth is turning within the mantle around it. That is to say, the core is rotating from west to east more slowly than the mantle. There is good astronomical evidence for such a surmise. The speed of the earth's spin is not constant: very accurate measurements indicate that the time of its daily rotation varies continually by a minute amount. But the law of angular momentum says that if the rotational speed of the earth's surface changes, there must be an offsetting change of speed somewhere within. Thus if the mantle speeds up, the core must slow down, and *vice versa*.

The simplest way to account for these changes in speed is to suppose that the core and the mantle exert a force on each other which is produced by electric currents. (The effect would be analogous to that between the rotating armature and the field coils of an electric motor.) Any change in the currents of the core would alter the strength of the force between it and the mantle and affect their relative speeds of rotation. A large, abrupt change would cause a sudden and appreciable acceleration or deceleration of the rotation of the earth's surface. As a matter of fact, in 1897 its rotation suddenly speeded up by nearly three thousandths of a second per day, and in 1914 it decreased by about the same amount.

Now the simple model we have considered would leave unexplained some important aspects of the earth's magnetic field. To begin with, why should the currents flow around the axis of the core in one direction rather than the other, so that the magnetic field is oriented north-south? Secondly, there is the difficulty of the reversal of the magnetic poles. If this model were correct, we would have to suppose that from time to time in geologic history the currents died out and then started in the opposite direction.

The model had to be modified, and the basic ideas for a more satisfactory one were first suggested by Elsasser. He saw that another pattern, roughly the con-



ROCKETS

Reaction Motors rocket engines powered the Air Force's X-1A to piloted-aircraft speed record of 1600 mph-plus, and Navy's Viking to new altitude and speed records for single-stage rockets of 158 miles and 4300 mph.

RAMJETS

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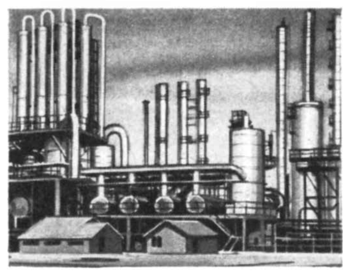

PROPELLANTS

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new team impetus for supersonic propulsion

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REACTION MOTORS

verse of the foregoing, was theoretically possible. In the first model, currents flow east-west around the core and set up a north-south field. The other possibility is that currents may flow north-south and set up a magnetic field which girdles the core in the east-west direction [*lower diagram on page 158*]. This magnetic field is called an "electric mode field." Confined to the surface of the core, the field cannot be observed on the earth's surface. The field we observe is a secondary effect: when liquid in the core moves across the electric mode field, it generates currents which produce the earth's north-south magnetic field.

Such a model solves the major difficulties of the simple scheme first suggested. The reversal of the poles can be explained by assuming certain plausible changes in the pattern of convective movement of liquid in the core. Moreover, the substantial changes in the speed of the earth's rotation become easier to explain: the earth's surface magnetism is not strong enough to account for the necessary force between the core and the mantle, but the electric mode field around the core, unobservable outside the earth, could be sufficiently strong.

We are still left with the problem of explaining how the primary currents responsible for the electric mode field arise in the first place. There are various possible speculations: the currents might originate from chemical action or temperature differences which produced a voltage difference between the poles and the equator of the core (one volt would be enough), or from some sort of self-exciting "dynamo" mechanism involving the core and the mantle.

Whatever the mechanism, there seems no doubt that the earth's field is tied up in some way with the rotation of the planet. And this leads to a remarkable finding about the earth's rotation itself. Aside from the complete reversals, or flip-flops, of the magnetic field, the magnetic poles have wandered gradually throughout the period of magnetic history readable in the rocks. We can only suppose from this that the earth's axis of rotation has changed also. In other words, the planet has rolled about, changing the location of its geographic poles [*see map on page 154*]. Either mountain building or convection currents in the mantle might account for this rolling. If the hypothesis of the wandering poles is verified, naturally it will be of great importance to geologists. It may explain, for example, the known fact that in the remote geological past there were glaciers near the present equator.

The Earth's Gravity

The attraction of the planet for objects on its surface varies with their geographic position. These differences indicate that the earth has curious bumps. They also cause discrepancies in athletic records

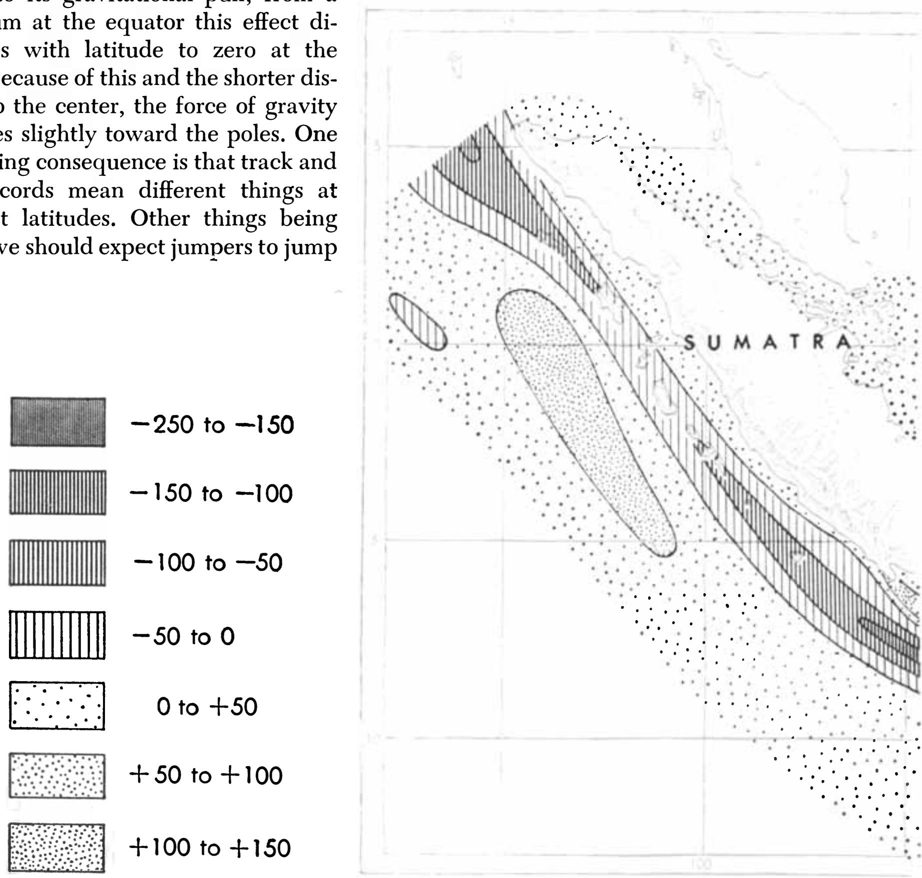
by Weikko A. Heiskanen

If the earth were a true sphere, life would be a great deal simpler, especially for mapmakers, geographers, navigators, geophysicists, oil prospectors and many other specialists. The fact that our planet bulges at the equator and is slightly flattened at the poles (because of its rotation) creates all sorts of practical difficulties for mankind and adds much complication to the science of geodesy—the measurement and mapping of the globe. What is worse, the earth is not even regular in its ellipsoid shape. Besides the irregularities of its surface (mountains, plains and seas), it is misshapen in a broader sense, like a battered orange.

Do not misunderstand: all these departures from true sphericity are comparatively small. The polar flattening, for instance, is so slight that the distance to the center of the earth is only about 13 miles less at the poles than at the equator—a difference of only one third of 1 per cent in the radius of 4,000-odd miles. But even these moderate irregularities make it inordinately difficult to map the earth's surface and define its shape. We have no calipers to encompass the great ball on which we live. The only way we can trace its girth and plot its distances accurately is to travel over its surface with a gravity meter, measuring the tiny differences in gravity from point to point as a guide to the ups and downs of the globe's undulating shape.

The principle underlying all this work is Isaac Newton's fundamental law of gravitation: two bodies attract each other with a force directly proportional to the product of their masses and inversely proportional to the square of the distance between them. In a ball the attracting mass can be considered to be concentrated at the center; thus gravity readings on the earth's surface furnish information from which, with other data, it is possible to calculate the density of the underlying earth mass and the variations in distance to the center at different points.

Certain other factors affect the force of gravity and must be allowed for. For instance, the centrifugal force of the earth's rotation exerts a small counteraction to its gravitational pull; from a maximum at the equator this effect diminishes with latitude to zero at the poles. Because of this and the shorter distance to the center, the force of gravity increases slightly toward the poles. One interesting consequence is that track and field records mean different things at different latitudes. Other things being equal, we should expect jumpers to jump higher and javelin throwers to hurl the javelin farther in the 1956 Olympic Games in Melbourne, Australia, than they did in the 1952 Games at Helsinki. Making corrections for the smaller force of gravity at Melbourne because of its closer approach to the equator, we calculate that the world record for the javelin throw is equivalent to 15.75 centimeters



LARGE GRAVITY ANOMALIES are found in the region of the Netherlands East Indies. Here the earth has failed by a wide margin to make an "isostatic" compensation for irreg-

(six inches) farther at Melbourne than at Helsinki; for the hammer throw, 12.54 centimeters (five inches) farther; for the broad jump, 3.63 centimeters (1½ inches) longer [*see table on page 170*].

The effect on sports records is but a trivial illustration. The gravity field of the earth has many real and important applications, ranging from the location of petroleum deposits to the purely scientific investigation of the earth's size, shape and composition. All over the world survey teams have been making gravity measurements, and the International Geophysical Year will accelerate this work.

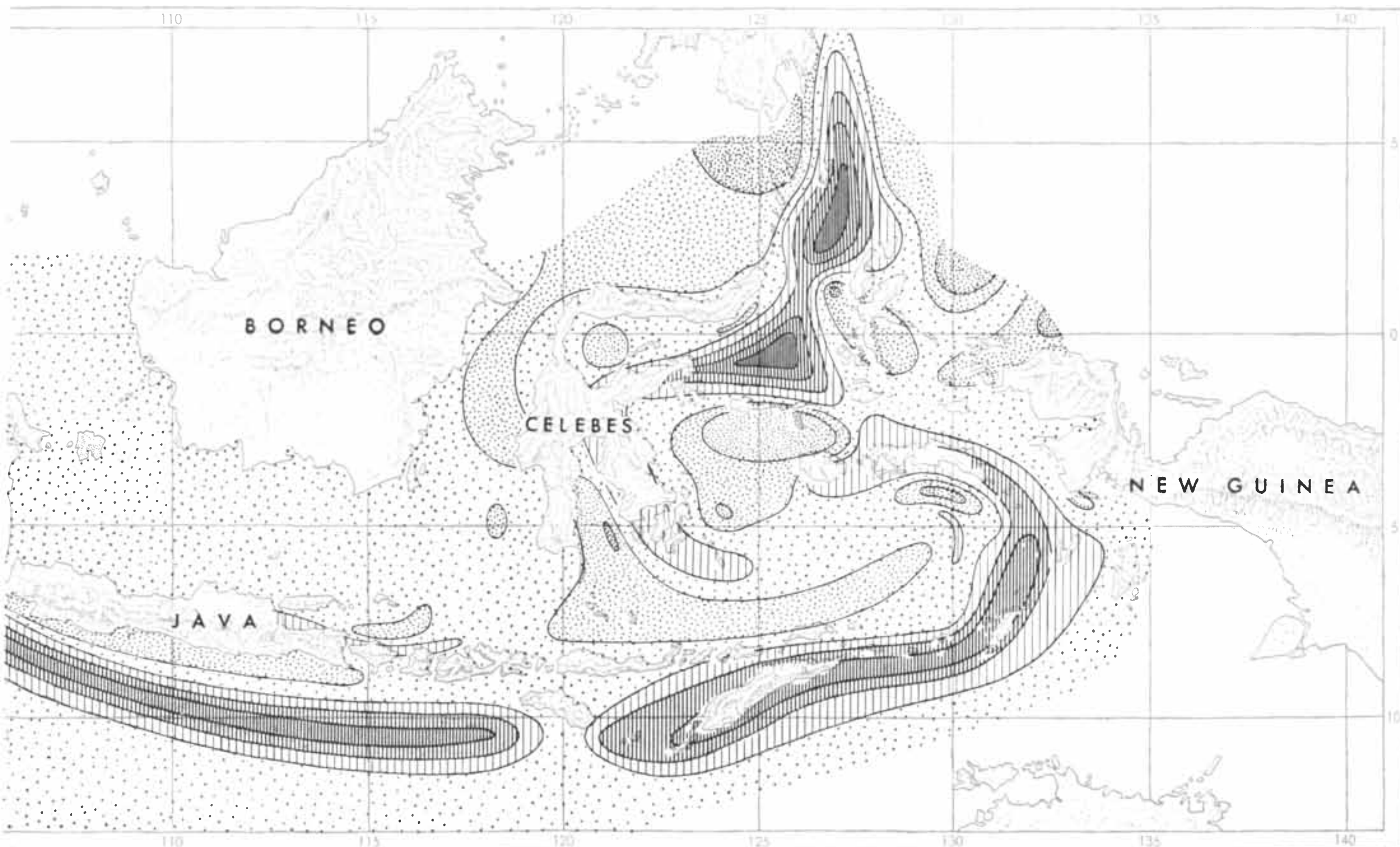
With modern instruments we can measure the strength of the earth's gravity to an accuracy as high as one part in 50 million. The traditional method employs a swinging pendulum: the period (time of one back-and-forth swing) of a pendulum of given length is a measure of the force of gravity, and very precise measurements of gravity can be obtained by timing several million swings. The pendulum is still the standard for absolute values of gravity, but nowadays the instrument most commonly used is the gravimeter, a supersensitive version of the ordinary spring scale. The earth's pull is measured by the amount of stretching of a thin wire of silica or invar (a nickel-steel alloy) on which a small weight hangs. The gravimeter, weighing only a few pounds, can be carried anywhere and gives a precise reading in three to five minutes. Its readings are only comparative from one point to another and have to be referred to a base station where the absolute value has been determined by other means.

In the deep ocean, gravity measurements are made in a submarine with an ingenious instrument, invented by the Dutch geophysicist F. A. Vening Meinesz, which uses three pendulums to cancel out the interference of water motion and give only the gravity. (Unfortunately it is not too easy to obtain the use of a submarine for purely scientific purposes.) In shallow water, gravity readings are made with a complex, encased gravimeter invented by the Gulf Oil Company. It is lowered to the bottom, and its measurements can be read in the boat on the surface.

The world standard station at which all gravity measurements are compared is the Helmert Tower in Potsdam, Germany. There painstaking pendulum measurements have established the value of gravity as 981.274 gal. This unit, named for Galileo, expresses the force of gravity in terms of the acceleration it will give to a freely falling body. Thus at Potsdam a falling body would increase in speed at the rate of 981.274 centimeters per second every second.

In practice most gravity measurements are calibrated not at Potsdam but at base stations which have been tied directly or indirectly to the Potsdam value. There are hundreds of base stations, and standard stations at Washington, Paris and Teddington.

The aim is to dot the entire earth eventually with stations tied to the Potsdam standard; the program of the International Geophysical Year will make an important contribution toward that goal. When we have comparable gravity



ularities under the surface. The anomalies are indicated in milligals by the shaded areas in accordance with the key at the left. One milligal is the amount of gravitational force that would speed up a falling body one thousandth of a centimeter per second each second.

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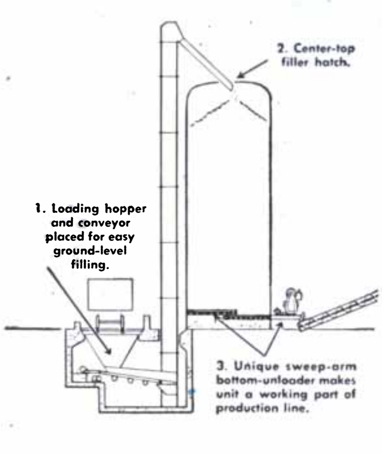

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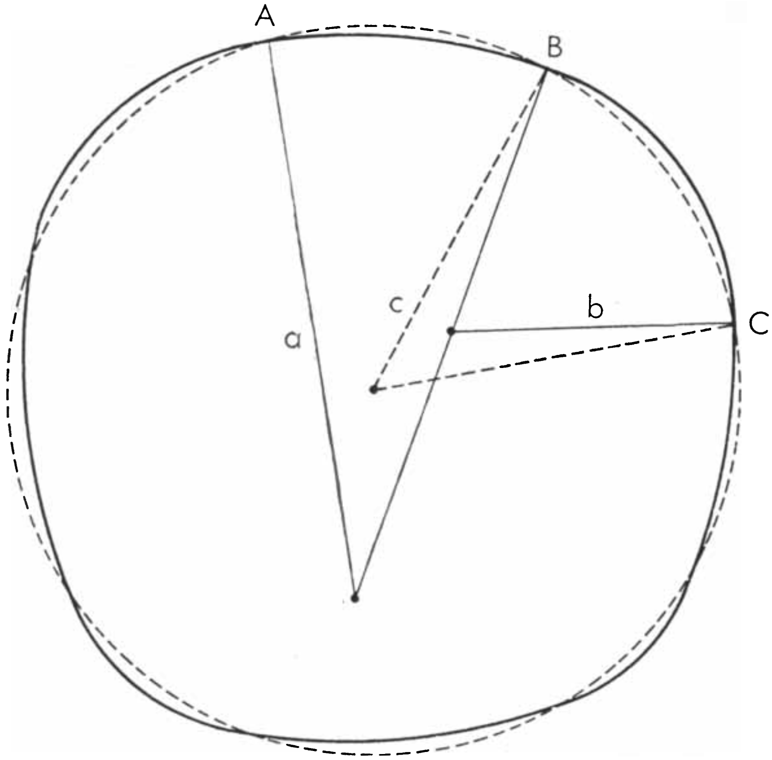


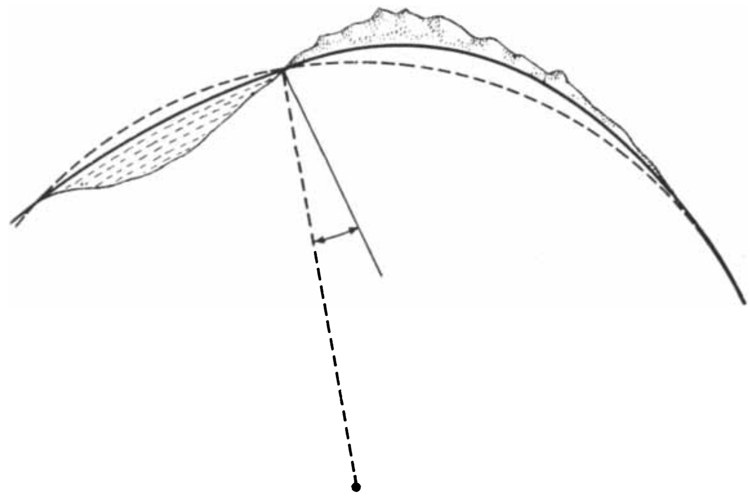
IRREGULAR SHAPE of the sea-level earth, or geoid, (*solid curve*) causes errors in measuring the radius of the planet's theoretical figure (*broken ellipse*). Where the geoid is flatter than the reference ellipse, as between *A* and *B*, verticals at the end points will meet at a point more distant than the true center, thus giving the radius *a*, which is too large. Where the geoid is more sharply curved than the reference figure, as between *B* and *C*, the verticals intersect before the center, thus giving radius *b*, which is not large enough.

measurements for all parts of the world, we shall be able to compute and outline the earth's actual shape.

A geodesist works with three different earths. First there is the geometer's "earth"—a perfectly regular ellipsoid which approximates the planet's average shape and is used as the reference figure. Then there is the sea-level earth, or "geoid," which departs from perfect smoothness because of variations in the mass of the earth. The geoid surface undulates around the world, and its undulations can be deduced from gravity readings. Finally there is the actual earth surface itself, with its mountains, valleys, plains and ocean basins.

The reference ellipsoid generally used is one computed by J. F. Hayford of the U. S. Coast and Geodetic Survey in 1910. Assuming a uniform earth of this regular shape, the Italian geophysicist G. Cassinis and the author in 1930 derived a general formula which gives the theoretical force of gravity at every latitude on the surface. This serves as a standard for judging the variations, or anomalies, of gravity. It is by interpreting these anomalies that we get a precise picture of the earth's crust and outline.

Let us say that we have taken a gravity reading at a certain point on an Alp in Switzerland. It is, of course, different from the theoretical or average value of gravity for that latitude. The first and most obvious reason is that, being on a mountain, we are farther than the average distance from the center of the earth. So we must correct the figure to a sea-level standard; the correction is about 9.5 thousandths of a gal per 100 feet of elevation. Next one would suppose we should make a correction for the extra attraction of the mountain mass beneath us. (In the ocean similarly we would correct for the relative lightness of weight of the water.) But oddly enough the mountain mass does not increase the gravity reading in the way one might expect. The reason is that the crust here is of lighter material and has a root which goes deeper than under lowlands; under the ocean basins the crust is still thinner [*see diagram on page 168*]. The roots of continents penetrate as far as 30 miles down into the crust, and at that depth the weight of the earth surface, whether under mountains, plains or oceans, is more or less equalized all over the earth—a condition called isostatic equilibrium. Gravity readings in connec-

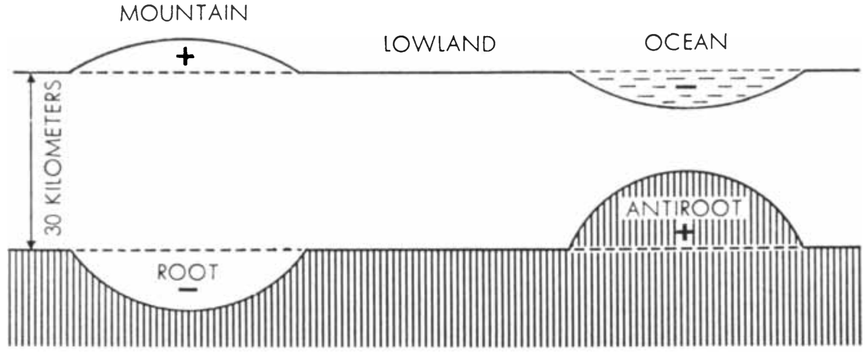


GEOID'S IRREGULARITIES are the result of uneven distribution of mass over the earth. Inequalities such as mountains (*right*) and ocean basins (*left*) pull the sea-level surface (*solid curve*) away from a regular ellipsoidal shape (*broken curve*). This means that at most points the direction of the plumb line, shown as a solid radial line perpendicular to the geoid, is deflected away from the true vertical or perpendicular to the ellipsoid.

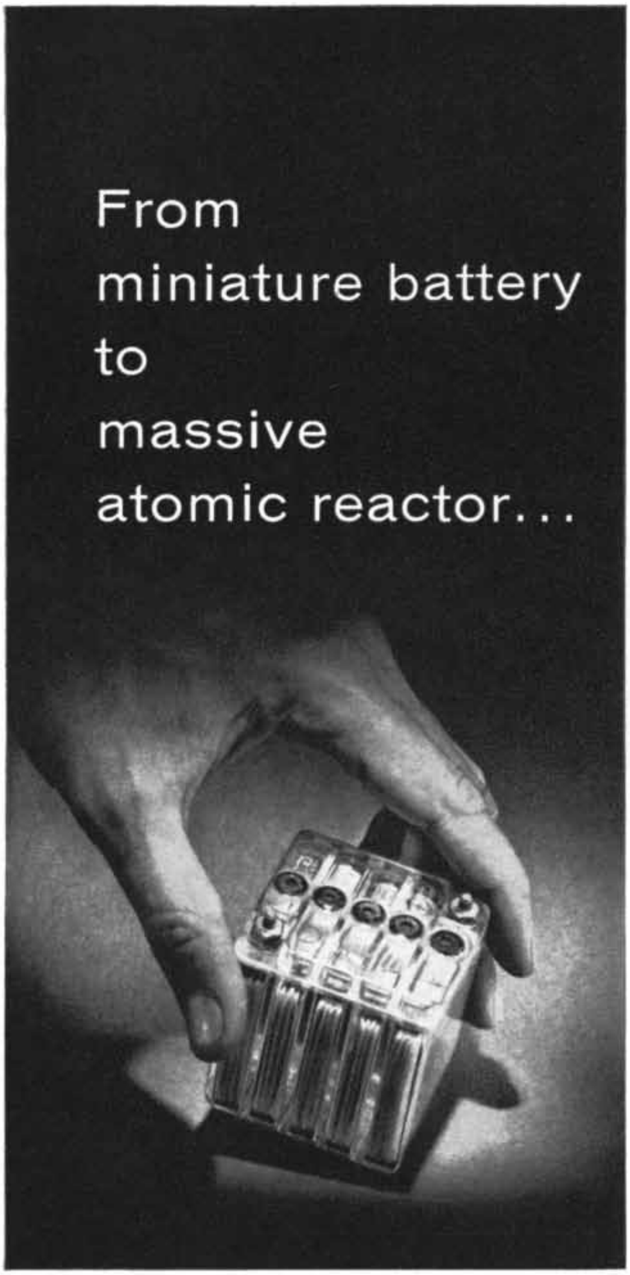
tion with the height of the surfaced elevation give us a measure of the thickness of the crust at any place, and my students and I have determined this thickness in a number of areas in Europe, Asia and Africa. Our values agree well with those obtained by seismologists, who measure the thickness of the crust by the travel time of earthquake waves.

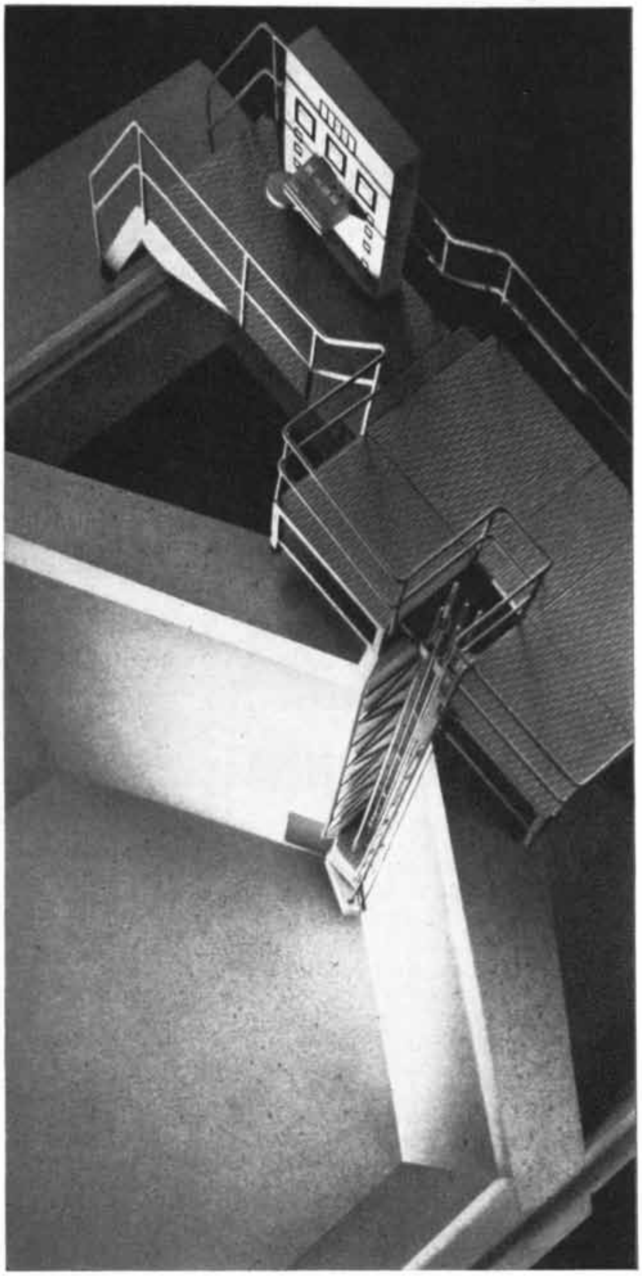
If we took gravity readings all over the earth and corrected them to sea level, we would have a gravity profile of the geoid. This profile undulates, as we have noted. It shows gravity anomalies due to local mass excesses and deficits. And because the geoid undulates, at almost any place on the earth's surface it is more or less tilted with respect to the surface of a perfect ellipsoid. If we drop a plumb line, it will hang perpendicular to the geoid at that point, but not perpendicular to the reference ellipsoid. The angle between the two perpendiculars measures the angle of the geoid's tilt from the theoretical ellipsoid surface [*see diagram above*]. We call the plumb line's deviation the deflection from the vertical.

As long ago as 1849 the English physicist Sir George Stokes suggested that the shape of the geoid could be calculated from world-wide gravity measurements, and Vening Meinesz in 1928 developed formulas for computing its tilt at any place. We still have too few gravity observations for an accurate picture of the geoid, but some of my students at the International Isostatic Institute in Finland have derived a rough approximation of it from the available measurements. The results of the



ISOSTATIC ADJUSTMENT of the earth's crust to mass differences on the surface reduces the anomalies that are found in the earth's gravitational force. Under regions of excess weight such as mountains there are deep roots of light crustal material. Conversely, under deficiency regions such as ocean basins there are antiroots of heavier subcrustal matter.





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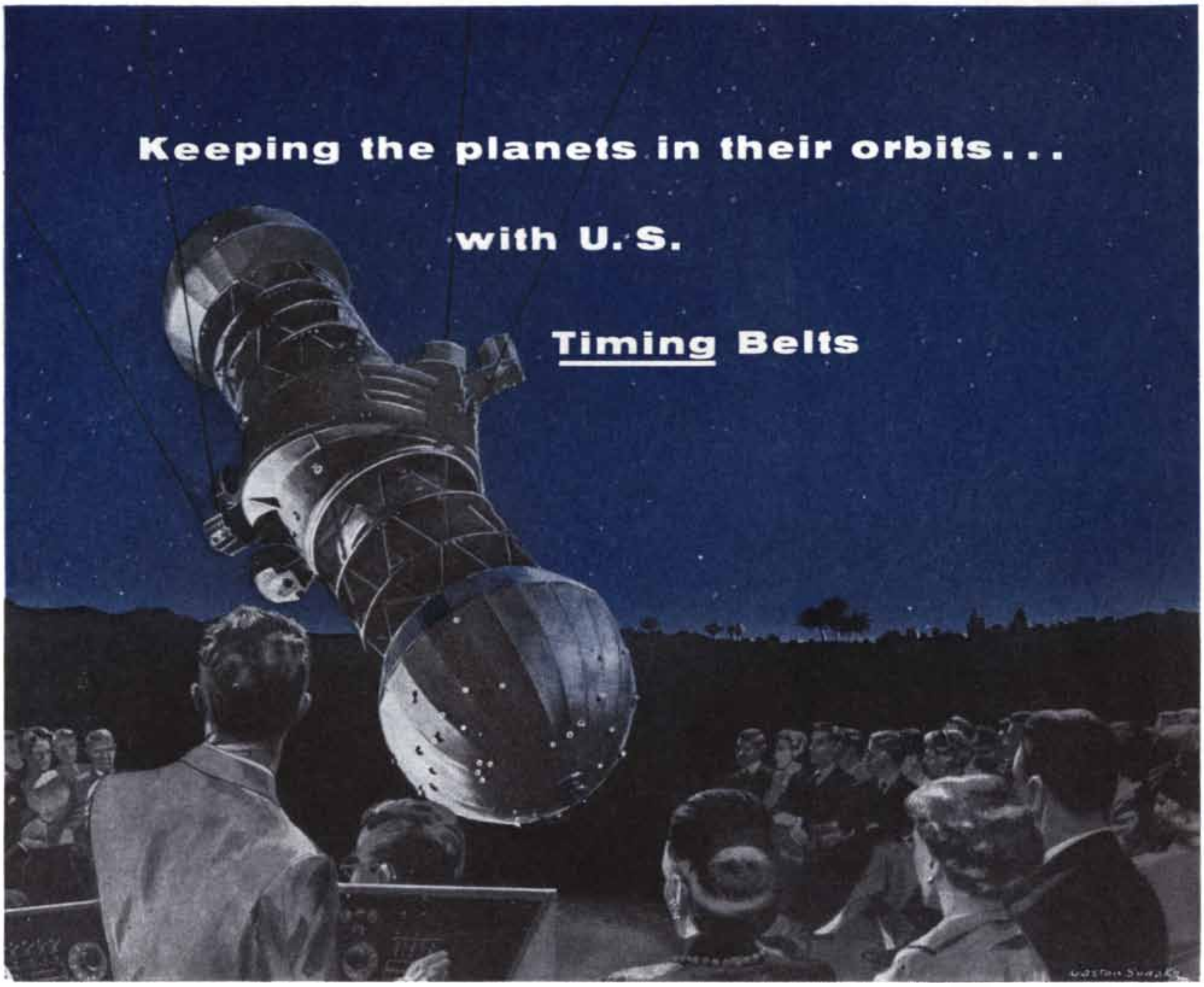
late L. Tanni, obtained in 1948, are accurate to within 30 feet or so at most of the computation points.

Only by knowing the tilt of the geoid at various places can we find the true verticals to the figure of the earth and thus measure the earth's radius and size [*diagram on page 167*]. We must also know the true vertical to locate points on the earth by sighting on stars. For example, in determining latitude the two reference points are the north star and our zenith—the point directly overhead. As indicated by a plumb line, the zenith will vary according to the slope of the geoid where the observer happens to be; if observations are to be comparable, the zenith must be determined from the true vertical (to a geometrically uniform surface) at every station on the earth.

The fundamental idea of the gravimetric method of mapping, and of the present world-wide gravity measuring program, is that the undulations of the geoid and its tilt at every place can be computed from the observed gravity

LATITUDE (DEGREES)	CORRECTION FACTOR	JAVELIN THROW 8,041 CENTIMETERS	HAMMER THROW 6,405 CENTIMETERS	BROAD JUMP 813 CENTIMETERS	SHOT PUT 1,854 CENTIMETERS
90 (POLE)	+.003043	+24.47	+19.49	+2.47	+5.64
70	.002463	19.80	15.78	2.00	4.57
65	.002117	17.02	13.56	1.72	3.92
60.2 (HELSINKI)	.001760	14.15	11.27	1.43	3.26
60	.001747	14.05	11.19	1.42	3.24
55	.001337	10.75	8.56	1.09	2.48
52.3 (BERLIN)	.001119	9.00	7.17	.91	2.07
50	.000901	7.24	5.77	.73	1.67
48.8 (PARIS)	.000796	6.40	5.10	.65	1.48
45	.000450	3.62	2.88	.37	.83
40 (COLUMBUS)	0	0	0	0	0
37.7 (MELBOURNE)	−.000199	−1.60	−1.27	− .16	− .37
35	.000436	3.51	2.79	.35	.81
34.1 (LOS ANGELES)	.000514	4.13	3.29	.42	.95
30	.000846	6.80	5.42	.62	1.57
25	.001216	9.78	7.79	.99	2.25
20	.001536	12.35	9.84	1.25	2.85
15	.001795	14.43	11.50	1.46	3.33
10	.001986	15.97	12.72	1.61	3.68
5	.002103	16.91	13.47	1.71	3.90
0 (EQUATOR)	.002143	17.23	13.73	1.74	3.97

ATHLETIC RECORDS should be corrected for differences in the force of gravity at the various points where the marks were established. The adjustments listed above will correct all figures to the gravity value at 40 degrees latitude. Each correction is obtained by multiplying the appropriate record, listed at the top of the last four columns, by the correction factor in the second column. Above 40 degrees latitude the corrections should be added to the actual performance figure; below this parallel the corrections should be subtracted.



Planetarium constructed by Spitz Laboratories, Inc., Elkton, Md., for the city of Montevideo, Uruguay, showing the heavens as seen looking southward from Montevideo.

The earth spins on its axis more than 10,756.265 times in the interval it takes Saturn to make one trip around the sun. Today there is a new planetarium so *accurate* that it shows the relative speeds of the sun, moon and the visible planets of the solar system moving in the same proportionate speed as they do in the real sky.

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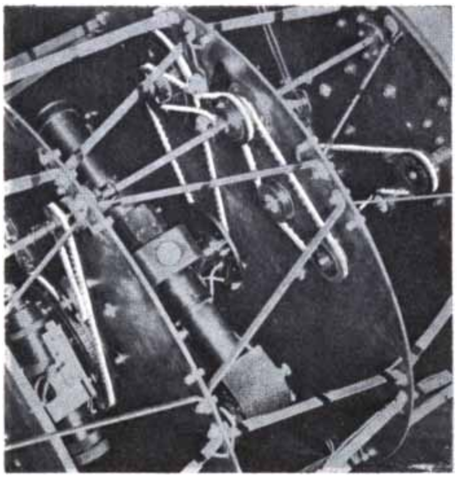

Close-up section of Spitz Planetarium showing some of the U. S. PowerGrip *Timing* Belts.

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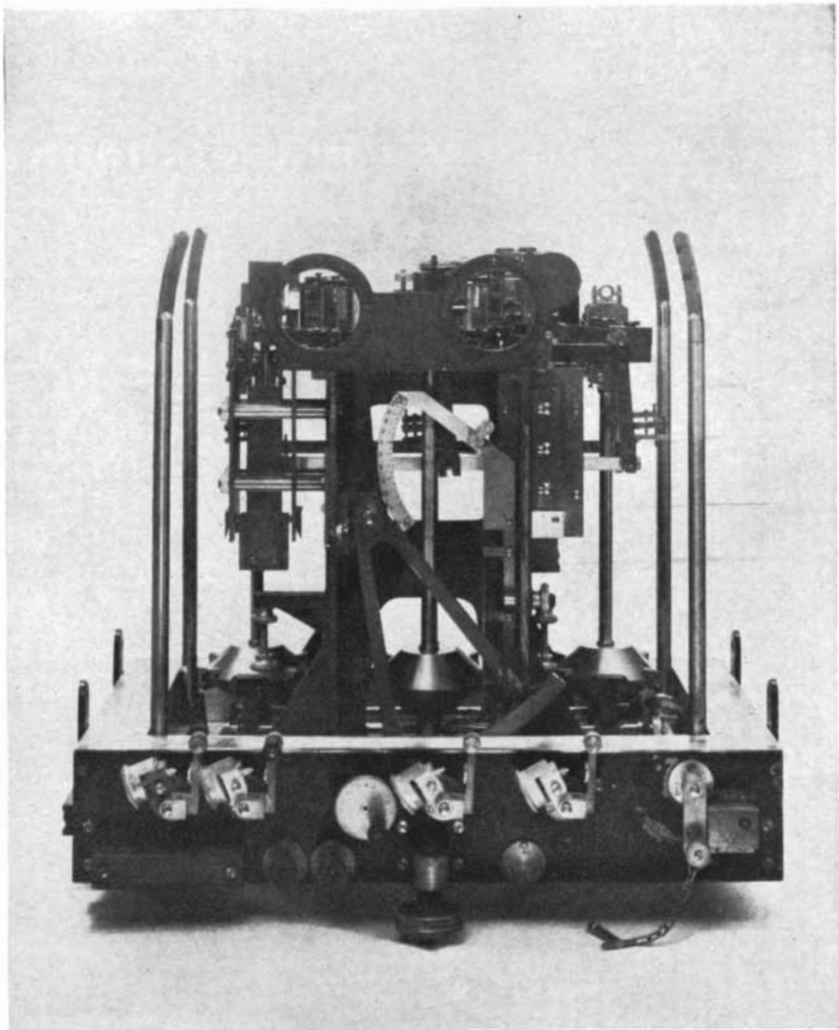

VENING MEINESZ APPARATUS **measures gravity over the oceans. It must be used in submarines, submerged to a depth where the disturbing effects of surface waves can no longer be felt. The device actually consists of three separate pendulum bobs, which hang directly over the base assembly in this photograph. The combined oscillations of the three average out the effects of the motions of the ship in which the measurement is being made.**

anomalies. Maps are usually made by selecting arbitrary control points and measuring the distances and directions of other points by triangulation. To do this we must make assumptions about the curvature of the reference surface and the true verticals at the reference points. Because maps of different regions are based on different reference figures, they do not connect accurately. When the two mapped regions are close together, the differences can be adjusted by direct connection between the two. But when the areas are very large or separated by oceans, where triangles and distances cannot be measured on the surface, this is difficult or impossible. In any case, the gravimetric method offers the fastest and most accurate way to link all maps to a common reference system.

As recently as 1948 the coordinates of the Swedish system differed by more than 300 feet from the Danish coordinates for the same control point, and the French differed from the English by about 600 feet. No one knows how great are the differences between the geodetic systems of different continents.

To establish a uniform world geodetic system, then, is one of the objects of the world-wide gravity program. This will be possible when enough values have been measured to allow accurate application of Stokes's and Vening Meinesz' formulas for the shape of the geoid. The data will also make it possible to map undeveloped areas where no triangulation systems have been set up. By locating a series of separate points astronomically and correcting for the deflection of the vertical, a reasonably accurate map can be made.

It is hoped that the world gravity survey will be carried out in the next few

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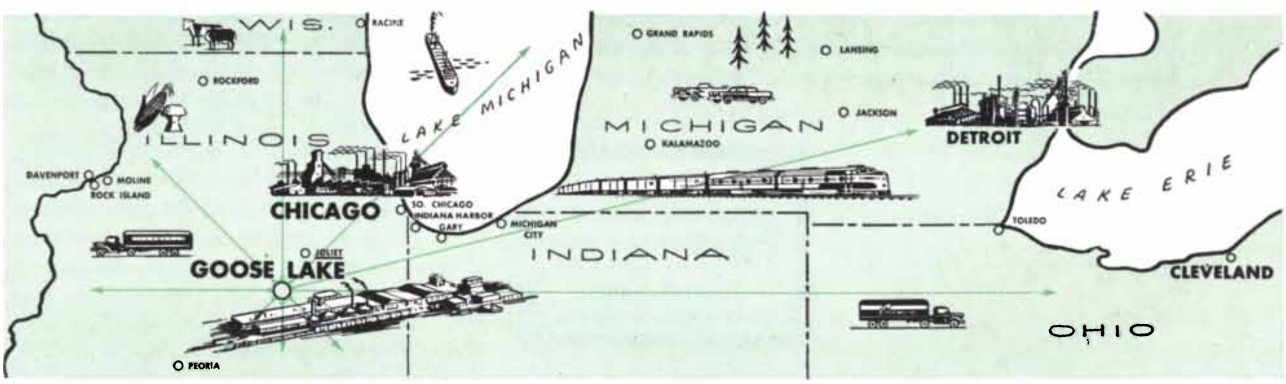

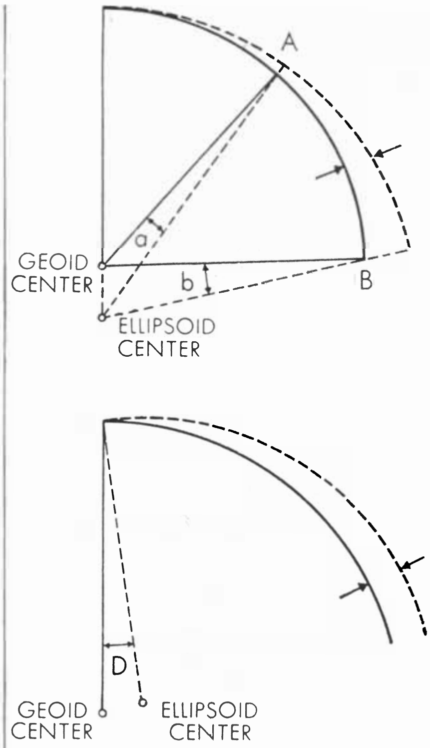

FALSE UNDULATIONS, or departures of the geoid's surface (*solid curve*) from that of the reference ellipsoid (*broken curve*), will result when the ellipsoid is incorrectly chosen. In the upper diagram the ellipsoid is too large and hence lies outside the geoid except at the origin of the particular reference system. The lower diagram shows an ellipsoid whose center does not coincide with that of the geoid and whose surface therefore also deviates incorrectly.

years. The program was set up by the author at the Mapping and Charting Research Laboratory of the Ohio State University under the sponsorship of the Cambridge Research Center of the U. S. Air Force. Thirty nations, most of the leading oil companies, and geodesists from all over the world are cooperating. As a start there are the hundreds of thousands of gravity readings which the oil companies have generously sent us, regional surveys in a number of countries and almost 4,000 points measured at sea, chiefly by Vening Meinesz and by Maurice Ewing and J. Lamar Worzel of Columbia University.

The chief purposes behind the program are to check the dimensions of the earth, to find the detailed shape of the geoid, to convert existing geodetic systems into an accurate common world system and to furnish control points for mapping in areas where there is no triangulation network. All this work will be facilitated by the gravimetric method.

Airborne magnetometer survey, Johannesburg area. AERO crews are at work on six continents.

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THE EARTH AS A PLANET, edited by Gerard P. Kuiper. The University of Chicago Press ($12.50).

"The history of the human race is a continual struggle from darkness toward light. It is, therefore, of no purpose to discuss the use of knowledge. Man wants to know and when he ceases to do so, he is no longer man." In these words, which will be chiseled on the frieze of the new library at Carleton College, the distinguished Norwegian scientist, explorer and statesman Fridtjof Nansen expressed the deep motivation that has inspired men to explore their earth. It is a motivation which excites the explorer, the scientist and the reader who learns their achievements.

The Earth as a Planet is essentially an account of the scientific exploration of the earth. It is concerned not with exploration in the geographical sense but with the earth's motions, interior, crust, oceans and atmosphere. Edited by the noted astronomer Gerard P. Kuiper, it examines the earth as we might study the planet Venus if we had the advantage of standing on its solid surface. It endeavors to view the earth as a whole, but in such detail as to stimulate the closer study of other planets.

In creating this picture Kuiper has produced a book of tremendous interest to the workers who study the earth without reference to other planets. The book presents 15 contributions from various disciplines, and in doing so has brought together knowledge heretofore scattered through the literature of all the sciences. Obviously the 700-odd pages of the book could not provide a compendium of everything we know about the earth. One misses, for example, a discussion of disturbances in the earth's magnetic field, of the structure and behavior of the ionosphere, of climate. To learn about such things the reader is referred to summaries elsewhere. One might say that *The Earth as a Planet* is addressed to the boundaries of our knowledge of the earth, rather than to all subjects that fall within these boundaries.

The systematic study of the earth was not pressed until the middle of the last century. Before that time there were not even reliable records of the weather. Until comparatively recent times men held magical theories as to the origin of such terrestrial phenomena as the aurora. It is only now that the essential unity of the earth's magnetism, the aurora and the ionosphere emerges in terms of light and atomic particles falling on the earth from the sun. The Swedish geographer Hans W:son Ahlmann remarked of glaciology that "even though snow, ice and glaciers have been noticed for centuries . . . they have been remarkably late in becoming the subject for systematic investigation." He might have said the same of most geophysics.

The age of indifference to our physical environment is passing. Within our generation, after the example of a few pioneering scientists and explorers of the last century, careful observations have permitted us to build theories of the properties of the earth. These theories have in turn directed our attention to experimental problems. Furious controversy as to the meaning of facts is encouraging new experiments and new theories. In such an atmosphere the scientist insists that descriptions of phenomena be so complete that no significant effects go unnoticed.

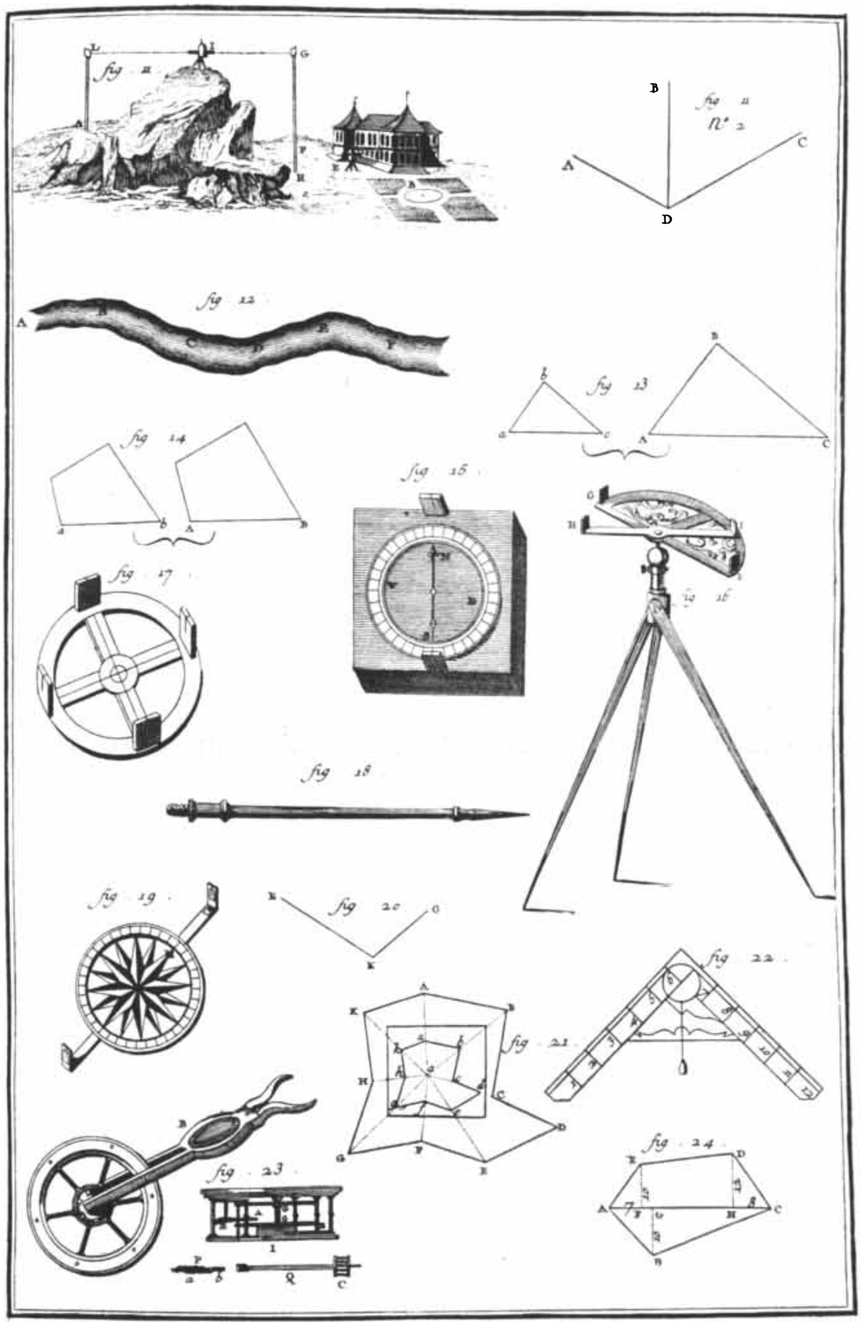
An illustration of our growing interest in the earth revolves around the Antarctic. It is hardly believable that in our period of rapid scientific and technological development there should be an area of six million square miles which is virtually unknown. The Antarctic has considerable geographic significance, but its importance to the understanding of the earth as a whole is enormously greater. An exact determination of the slight flattening of the earth depends on observations of gravity at stations distributed with reasonable uniformity over its surface. But gravity stations are woefully deficient at high latitudes—especially in the Antarctic. The simultaneity of southern and northern auroras remains to be observed systematically. The revolutionary idea that air masses are exchanged between the Northern and Southern Hemispheres by way of the stratosphere can be tested only by observations in the Antarctic. The Antarctic provides a current illustration of the extraordinary ice ages through which the earth has passed: its millions of cubic miles of ice provide large-scale evidence of our emergence from the last of these eras.

One could list a great many influences of the Antarctic on our terrestrial environment. The point is that exploration of the geophysical phenomena near the poles is essential not only to learn the facts of the polar regions, but also to provide knowledge basic to our understanding of the earth as a whole. The polar regions are unique in influencing terrestrial phenomena over the entire surface of the earth.

Our neglect of the polar regions is symbolic of our tardiness in pressing the systematic observation of our environment in more accessible regions of the earth. The material with which earth scientists must work to derive their conclusions is pitifully limited. Experiments and observations beg to be undertaken. It is these shortcomings that have led scientists and explorers to band together to establish the International Geophysical Year.

The Earth as a Planet is published at a significant time: two years before the opening of the International Geophysical Year. It bears a significant relationship to the Geophysical Year in that it emphasizes the key observations that are needed to unlock the doors to further comprehension of the earth.

The Geophysical Year is surely the most ambitious effort ever undertaken to extend our knowledge of the earth. Under the leadership of the International Council of Scientific Unions, and on behalf of the scientists of the International Unions of Geodesy and Geophysics, Astronomy, Geography, Scientific Radio, Pure and Applied Physics and Biology, together with the World Meteorological Organization, the scientific resources of more than 40 nations have been organized for cooperative and simultaneous observation of phenomena at stations in carefully designed networks over the earth's surface. Using every applicable tool of modern science and technology, scientific teams will fan out in every direction during 18 months of concentrated geophysical work beginning July 1, 1957. Ten or more nations will man more than 20 bases and numerous field stations in the Antarctic and sub-Antarctic regions. It is a hopeful augury that men are able to overlook their political problems to organize this single-minded cooperative effort to study their environment. The interest of scientists and statesmen in the Geophysical Year partakes of the vision of Benjamin Franklin, who during the War of Independence issued the following order to all armed ships acting by commission of the Congress: "Gentlemen, A ship was fitted out from England before the commencement of this war to make discoveries in unknown seas under the conduct of that most celebrated Navigator and Discoverer, Captain Cook. This is an undertaking truly laudable in itself, because the increase of geographical knowledge facilitates the communications between distant nations and the exchange of useful products and manufactures, extends the arts, and science of other kinds is increased to the benefit of mankind in general. This, then, is to recommend to you that should said ship fall into your hands, you would not consider her as an enemy, nor suffer any plunder to be made of the effects contained in her, nor obstruct her immediate return to England."



A collection of early geophysical instruments from Diderot's Encyclopaedia

What about the actual content of *The Earth as a Planet?* The book is technical, but not so technical that large parts of it cannot be read with profit by a general reader with a special interest in the subject of the earth. I should like to consider here only one aspect of its coverage: the solid earth. This will suffice to convey the flavor of the book, and will perhaps not repeat too much information contained elsewhere in this issue of SCIENTIFIC AMERICAN.

Let us begin with the shape and motions of the earth, discussed by Sir Harold Spencer Jones and Sir Harold Jeffreys in the book. Deductions about the shape of the earth and the nature of its interior are derived from two classes of information: (1) astronomical measurements of vagaries in the motions of the earth and the moon that may be influenced by the earth's shape, composition, distribution of mass, rigidity and so on; and (2) measurements on the surface of the earth, such as geodetic triangulation, the acceleration of gravity, the velocity and direction of seismic waves, volcanic activity, magnetism and the like. Lacking the advantages of most experimental sciences, geophysics and astronomy involve measurements beset by many disturbing influences. In these sciences simple experiments can seldom be devised; most observations include an assortment of natural variables. The "signal" is buried in a welter of "noise." The triumphs of geophysics arise from experimental or mathematical procedures which isolate the desired information unambiguously from the almost overwhelming contributions of these unwanted variables. This requires large numbers of measurements that average out the variables.

Nowhere is the need for precision in such measurements better demonstrated than in deductions concerning the earth made by astronomical means. Newton conjectured that the earth was an oblate spheroid, bulging at the equator as a consequence of centrifugal force acting on a homogeneous fluid mass in slow rotation. When the sun or the moon is above or below the equatorial plane of the earth each exerts a gravitational pull on the equatorial bulge of the earth, which tends to displace the earth's axis. Thus the axis precesses like a top pushed

a little to one side. Motions due to such forces are called nutations. The nutation of the earth's axis is complex, that due to the sun vanishing twice a year, and that due to the moon twice a month.

The observation of nutation shows that the phenomenon cannot wholly be described by the simple motion of a rigid earth. To account for a vibration of latitude with an amplitude of one tenth of a second of arc and a period of 14 months requires an elastic distortion of the earth. This indicates that the mean rigidity of the earth is equal to that of steel. Another vibration with a period of 12 months arises from the accumulation of air in seasonal "highs" of atmospheric pressure such as those over Central Asia that produce the Indian monsoons, and from the seasonal shift of ice (or perhaps transfer of water) from pole to pole. It may someday be possible to deduce the fluid nature of the earth's core from astronomical measurements of the 18.6-year nutation produced by the tilt of the moon's orbit with respect to that of the earth.

Astronomical observations made from ancient times are believed to show a systematic acceleration in the moon's motion which is not explained by astronomical theory; this suggests that the earth's rotation has slowly been retarded. There is some doubt as to the magnitude of the effect, but two billion horsepower seem necessary to explain it. It is apparently caused by oceanic tides. Since the tides of the open oceans involve a negligible expenditure of energy, it is now thought that the "missing" energy is supplied by the friction of tidal waters flowing in and out of narrow bodies of water all over the earth. It has been computed that the effect is due to the equivalent of 50 Irish Seas.

Imposed on such regular motions are random motions which must somehow be explained by changes in or on the earth. Thus the earth sometimes runs ahead of schedule, and sometimes behind, by a fraction of a second, and its tilt slightly exceeds predicted limits. In his contribution to *The Earth as a Planet* Jeffreys says: "It is difficult to see how any meteorological cause could account for [these effects] without having been noticed directly." These motions remain as a challenge to future investigators.

The mass of the earth is derived from one of the few laboratory measurements in geophysics, involving the celebrated "Cavendish experiment." This involves the detection of the displacement of one mass on a sensitive torsion balance by the gravitational attraction of another mass nearby. The result yields the constant of gravitation. From this the mass and density of the earth are readily derived.

In *The Earth as a Planet* the interior of the earth is taken up by Sir Edward Bullard. The seismic evidence for the nature of the interior is discussed by K. E. Bullen elsewhere in this issue. Sir Edward also goes into another significant feature of the interior: its heat. That the temperature of the earth increases as one goes downward through the crust was one of the earliest beliefs of man: it enters into his mythology and religion. Such ideas doubtless arose from the eruption of volcanoes. Observations in deep mines and wells indicate that temperature increases with depth at a rate ranging from 10 to 40 degrees centigrade per kilometer. The increase of temperature with depth implies that heat flows to the surface of the earth by conduction. This flow amounts to an average of 1.2 millionths of a calorie per square centimeter per second. It is surprising that only a few such measurements have been made, and these in limited areas of the earth's surface. Indeed, the now accepted value of heat flow may be seriously in error. The local variations in heat flow certainly have great meaning with respect to the structure of the crust and the interior of the earth. But it is not even possible to say whether the heat flow is consistently greater in one part of the world than in another, or whether there is a difference in heat flow between mountainous and low-lying regions.

The heat generated by the radioactive decay of uranium, thorium and potassium easily accounts for more than 80 per cent of the heat flowing to the surface of the earth. Lord Kelvin estimated that, if the earth had cooled from a molten state, it was now 30 million years old. This estimate was wrong because he did not take into account the effect of radioactivity. No more, and probably much less, than 20 per cent of the earth's heat can be attributed to the amount originally locked up in it.

Granite generates about two and a half times as much heat as basalt, and basalt about 30 times as much heat as ultrabasic rock. Since the crust of the earth is principally composed of granite and basalt, the rocks of the crust would appear to generate far more heat than the ultrabasic material on which they float. If we assume that the granite of a continent averages 25 kilometers in thickness, and its underlying basalt 10 kilometers, the heat flow at the surface would be 1.5 millionths of a calorie per square centimeter per second. This is a little too high for the observed value of 1.2. It implies that the basalt may be

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from 10 to 20 kilometers thick. It also indicates that the basalt under the continental granite may be thicker than that under the oceans.

The basalt under the oceans is estimated to be about five kilometers thick. Thus the heat flow through it should be much less than that through the surface of a continent. But recent measurements indicate that the heat flow in the Pacific is 1.2 millionths of a calorie, and that in the Atlantic 1.0. In other words, the flow of heat through the ocean basins does not differ significantly from the flow through the continents. This presents a serious dilemma whose resolution requires the rather strained assumption that radioactive material in the basaltic rocks underlying the oceans has migrated upward, raising their level of radioactivity far above that of the same rocks on the continents. Further studies of this problem are devoutly to be wished.

Depending on estimates of distribution of radioactivity in the crust, its thermal conductivity and the small heat flow into it from the slightly radioactive ultrabasic rocks of the underlying mantle, the temperature at the base of the crust can be estimated to be from 450 to 600 degrees C. higher than that at the surface. Since the radioactivity has diminished considerably over the life span of the earth, this indicates that the base of the crust would have been molten between three and four billion years ago. The result is consistent with the ages determined for the oldest rocks by other methods.

Since heat from depths greater than a few hundred kilometers has not had time to reach the surface during the life of the earth, observations of heat flow can give no indication of thermal conditions at great depths. There is some geomagnetic evidence that rock at a depth of 600 to 900 kilometers has a temperature of 1,000 to 1,500 degrees C. Beyond this, if we wish to investigate the distribution of temperature in the earth's interior, we are left to the fascinating game of exhausting the hypotheses of the earth's origin. Leading scientific minds have played this game by exploring various models of the primordial earth. One such model is that the earth was originally molten and cooled to its present state, as though it had been formed from the sun or a rapidly contracting cloud of dust. Another model is that the earth was first cold and solid, then melted and finally cooled to its present state, as though it had slowly been formed out of material high in radioactivity. A third model is that the earth was first cold and solid and then warmed to its present state, as though it had slowly been formed out of material low in radioactivity.

Another interesting contribution to *The Earth as a Planet* is Brian Mason's monograph on the chemistry of the earth. According to Mason's estimates the four most abundant chemical elements in the earth as a whole are iron (35 per cent by weight), oxygen (28 per cent), magnesium (17 per cent) and silicon (13 per cent). The constitution of the crust is quite different. Its four most abundant elements are oxygen (46.59 per cent), silicon (27.72 per cent), aluminum (8.13 per cent) and iron (5.01 per cent). The difference is explained by the separation of elements in molten magmas rising from the mantle.

If we compare the abundance of elements in the earth as a whole with the abundance of elements in the universe, we find that these differ even more markedly. It is useful to classify the elements of the universe into (1) inert gases and elements that enter into volatile compounds and (2) elements that enter into relatively stable compounds. The first category (mostly hydrogen, helium, neon, nitrogen and carbon) comprises 93 per cent of the mass of elements in the universe. The second (mostly oxygen, iron, silicon, magnesium and sulfur) comprises the remaining 7 per cent.

The elements of the first category do not appear *at all* among the 15 most abundant elements of the earth as a whole. The elements of the second, however, occur in the earth in much the same proportion that they do in the universe. It is true that the proportion of oxygen in the earth is substantially smaller than that in the universe, but we should remember that oxygen occurs not only in stable compounds but also in volatile compounds and as a gas. Thus part of the oxygen really belongs in the first category.

So the chemical difference between the earth and the cosmos lies in the fact that the earth is impoverished of volatile elements and inert gases. The earth is poor not only in helium and neon but also in the heavier inert gases krypton and xenon. Now even if the earth had been incandescent at the time of its origin, it would have retained these heavier inert gases. The fact lends weight to the hypothesis that the earth was made by the slow accretion of its characteristic substance.

It would appear that in the beginning the relative abundance of elements in the universe was determined by the stability of their nuclei. The elements with radioactive nuclei tend to die out; those with stable nuclei, to survive. The process by

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which the earth was formed separated these elements according to their volatility or their ability to form volatile compounds. Then the elements of the earth were further separated by their affinity for the metallic elements of the core or the silica of the mantle. With the solidification of the mantle and the formation of the crust a further fractionation occurred: fluids migrating through the crust took with them elements of certain chemical affinities. Yet another fractionation happens as a consequence of sedimentation in the surface waters of the earth. The grand theme is that the chemical structure of the earth is determined by the physical and chemical properties of the atoms of which it is composed.

These are some interesting features of the solid earth discussed in *The Earth as a Planet.* As I have indicated, the book is rich in other material: oceanography; the atmosphere up to 30 kilometers; the absorption spectrum of the atmosphere; density and other information about the atmosphere above 30 kilometers; the emission spectra of twilight, the night sky and the aurora; the physics of the upper atmosphere; dynamic effects in the high atmosphere; the earth as seen from outside the atmosphere; the reflectivity, color and polarization of the earth. Moreover, the book is only the second volume of a four-part series entitled "The Solar System." Scientists interested in the earth and the solar system eagerly await the next volume on comets and on planets in general.

Short Reviews

THE CRIME OF GALILEO, by Giorgio de Santillana. The University of Chicago Press ($5.75). Galileo's trial for heresy has had many reporters and commentators, but the account given in this volume, based upon a careful re-examination of the documents and a review of the glosses, is undoubtedly the best. His support of Copernican theories brought Galileo into two collisions with the Church. The first, in 1616, was a slight affair. Thanks to the support of Cardinal Bellarmino, Galileo got off with the gentlest of reproofs—so gentle, in fact, that he felt not merely free to continue his heretical teachings but positively encouraged to do so. The second encounter, provoked by the publication of the *Dialogue on the Great World Systems,* was a much graver matter and not only forced Galileo to his tragic confession and recantation but cost him his freedom for the rest of his life. De Santillana is ingenious in showing how the reproof of 1616 was cunningly interpreted as a flat prohibition and how Galileo fell victim to informers, connivers, power-corrupted men—some cynical, some fanatical, all aware that the advancement of knowledge and free speculation was a mortal enemy. Neither Galileo nor the Church were in all respects admirable. Galileo wanted to have it both ways: to preach Copernicanism but to maintain his standing as an orthodox, faithful Catholic; this made for a good deal of tight-rope walking, double talk and hypocrisy. The Church had plenty of political troubles of its own at the time, and had more important things to do than to concern itself over complex astronomical theories of a respected egghead. It would have let Galileo alone if he had been discreet or had propagated his learned heresies unobtrusively. However, he was a "troublemaker" who insisted on making great men look like jackasses. This was unforgivable. It is not a pretty story, but our age has not forborne its re-enactment. "We have come very close indeed," observes de Santillana, "to inquisitional conditions, without realizing it and without even the moral justification." This is an absorbing tale when the author sticks to his researches. His political, historical and philosophical reflections; his intricate, wordy conjectures and theological digressions are less rewarding. In fact they often becloud rather than clarify the issues. A shorter book would have been equally convincing and more readable.

THE SCIENTIFIC REVOLUTION, 1500-1800, by A. R. Hall. Longmans, Green & Co., Inc. ($3.75). SCIENCE IN HISTORY, by J. D. Bernal. C. A. Watts & Co., Ltd. (42 shillings). While it is not possible to do justice to either of these two excellent books in a short review, it may nevertheless be advantageous even in this brief space to consider both together. The study by Hall, who is lecturer in the history of science at the University of Cambridge, presents a detailed examination of the formation of the modern scientific attitude, especially in the physical and biological sciences. It re-examines and sifts the latest evidence very carefully and brings to light the subtle, complex weave of the growth of ideas, the interrelation between different strands of intellectual development, the continuing influence of the past on the ideas of today. One is made to see very clearly how much modern science owes to medieval science; the debt owed by Galileo, for example, to Oresme and Burden for their theory of impetus. Thus Hall refutes the false but still persistent notion that the Renaissance man of the

16th century turned sharply away from medieval thought and built almost without foundation an entirely new world of his own. Hall has given us a richly stocked, learned book, not always easy to read but invariably rewarding. Yet in one important respect it fails to satisfy, namely in relating scientific thought to other contemporary circumstances of history. In his concluding chapter, to be sure, the author raises the question of what made science move in Europe from the "intermediate to the modern stage," what social and economic factors attended and were in turn affected by the grand transition; but he argues that the answers cannot now be given because they require "psychological and philosophical insight, as well as a command of the historical facts, to which we have as yet scarcely attained." Bernal, on the other hand, is not so easily put off. In fact he undertakes to do precisely what Hall says cannot be done: to show at every stage the relations between the development of science and that of other aspects of human history. As we have come to expect from this brilliant Irish controversialist, social philosopher, historian of science and crystallographer, he has written a fascinating and in part fascinatingly perverse book. Bernal's interpretation is Marxist. This does not seriously get in the way of his examination of the history of science before the 20th century; indeed his interpretations of the interactions between science and technology, science and social organization, science and economic institutions are exceptionally successful. As a single illustration one may mention his discussion of the lags in the applications of electricity, whose fundamental uses were known to scientists for half a century yet were retarded because of the "enormous practical difficulties in introducing anything that required development before it would pay." But Bernal's treatment of the 20th century, occupying almost half of his 967-page book, is a broth of first-class science reporting, scrappy social-science commentary (for which, it must be said, he apologizes), political polemic and unreserved praise of the theory and practice of science in China and the U.S.S.R. This is the mixture we have come to expect from Bernal, yet it astonishes us every time it is served up. *Science in History* is nevertheless an invaluable study, a delight to read even when the author is most obviously preaching his orthodoxy. Perhaps the best advice on reading the weaker sections of Bernal is to enjoy his prejudices while not imitating them.

The Piltdown Forgery, by J. S. Weiner. Oxford University Press ($3.50). An engrossing account of what was once considered to be one of the century's most important scientific discoveries and now turns out to be the century's best scientific hoax. In December, 1911, Arthur Smith Woodward, an eminent British geologist, and Charles Dawson, a lawyer-antiquarian and fossil finder of high repute, announced to the world the discovery in gravel deposits at Piltdown, England, of parts of a human skull and an apelike jaw, remains of what the leading authorities proclaimed a specimen of *Eoanthropus* ("the dawn man") and the press vulgarly referred to as the "missing link." The fact that the skull and jawbone seemed obviously to belong to different species troubled many of the experts, but in due time their skepticism was overcome. The bones, it was alleged, had been found close together in hitherto undisturbed gravel; the gravel was said to be of appropriately ancient (early Pleistocene) origin; the jaw contained teeth which displayed in their wear "a marked regular flattening such as has never been observed among apes, though it is occasionally met with in lower types of men"; exceptionally primitive flint implements lay near the fossils. The clincher came with the discovery in 1915 of the remains of another Piltdown man in gravels two miles away from the first site. Though a few scientists clung stubbornly to their doubts, *Eoanthropus dawsoni* had secured its claim to a place in the evolutionary scheme. For 34 years it held its place; then the roof fell in. In 1949 Kenneth Oakley applied to the Piltdown bones the dating test based on the fact that fluorine present in the soil water steadily accumulates in the bones and teeth. The tests showed that the bones could not possibly be of a vast antiquity: at the most they were 50,000 years old, and perhaps much less. A team of British experts including Oakley, W. E. Le Gros Clark and the author of this book (reader in physical anthropology at Oxford) now brought to bear on the problem every modern scientific resource. Anatomical research showed that the skull had been improperly reconstructed; dental studies proved that the teeth, whose pattern of wear was such a decisive factor in reaching earlier conclusions, had been artificially filed down; chemical and spectrographic analysis demonstrated "that the jaw was a modern jaw which had been deliberately stained with iron and chromate salts to match the discoloration to be expected for fossils in the Piltdown graves"; the

dentine of the teeth, it was found, was a plastic material; the flint implements had been fraudulently stained; the gravels were not of the right period, besides which they were so acid that the bones could not have been preserved in them for the required length of time. Piltdown was a crude fake; the question remained, who was the faker? Skillfully weaving his web of circumstantial evidence, Weiner closes in on Dawson, who, despite his respectability and jolly Pickwickian appearance, turns out to have been a knave. An indefatigable antiquarian, he had been unable to achieve fame and had contrived the forgery to bring his name before the world. He died in 1916, so he enjoyed the fruits of his deception for only a short time. Still, there is something admirable about pulling the entire scientific world around by the nose with a homemade fossil; one is almost sorry to see the culprit caught. This is a first-class piece of ratiocination and scientific detection which makes the efforts of highly touted police and crime laboratories seem bush-league stuff.

THE UNDERWATER NATURALIST, by Pierre de Latil. Houghton Mifflin Company ($3.50). A literate, scholarly and engaging natural history of fish by a well-known French scientific writer. Born and raised in Nice, "underwater mecca of the Mediterranean," de Latil is of that queer but growing species known as skin divers (they also wear rubber suits) who, equipped with flippers, goggles, breathing mask, compressed air cylinders and harpoon, spend hours beneath the sea, sometimes at very great depths (100 to 300 feet) exploring grottoes, ambling in eelgrass meadows, watching and chasing fish, discovering wrecks, uncovering ancient remains and engaging in other submarine activities. The author is as gifted a writer as he is intrepid; his firsthand study of underwater life makes possible unusually vivid descriptions of the appearance and habits of fish in their native habitat. Among the most interesting parts of his book are the discussions of ancient stories and legends, for example, about the fish which the Romans raised for food, for pets and for disposing of unruly slaves and other disagreeable persons.

MACHINE TRANSLATION OF LANGUAGES, edited by William N. Locke and A. Donald Booth. John Wiley & Sons, Inc. ($6.00). The idea that mechanical translations from one language to another might be feasible seems to have arisen about 10 years ago in considering the applications of digital computers. It soon became apparent that not even the slickest machines could do the job until certain formidable problems of logical syntax and semantics were taken apart, problems which stood in the way of "predigestion" exercises. Much research along these lines has been done; there is now a fair prospect that a machine can make known to a reader the "essential content" of documents in foreign languages, even though there is no likelihood that the computer's product would inspire a Keats to go into raptures over a new translation of Homer. The present volume consists of 14 essays on such topics as translation, methods of mechanized translation, the design of an automatic Russian-English technical dictionary, problems of the "word," storage devices, the mechanical determination of meaning, model English, idioms and logical concepts for syntax. The book is written, one is relieved to discover, by live scholars, not digital computers.

THE BIOLOGIC EFFECTS OF TOBACCO, edited by Ernest L. Wynder. Little, Brown and Company ($4.50). There is a celebrated little jingle, two lines of which run:

> *Tobacco is a dirty weed.*
> *I like it.*

This book does not explain the second line but it amply substantiates the first. Six medical specialists and a biometrist make it abundantly clear that in its mildest form the tobacco habit is like chewing gum or playing the ocarina—which is to say that it is not unduly harmful. Far more often, however, it either causes, aggravates or paves the way for disease. The essays discuss the chemistry of tobacco smoke, the pharmacology of smoke and nicotine, the effects of smoke on the cardiovascular system (always bad but not necessarily permanent), lung cancer and tobacco, smoking and disorders of the gastrointestinal tract, tobacco allergy, the statistical evidence for cause and effect relations between tobacco and disease (overwhelming). A dispiriting book for smokers; an enlightening book for all.

AFRICAN INSECT LIFE, by S. H. Skaife. Longmans, Green & Co., Inc. ($11.00). This is an uncommonly clear and interesting survey of the principal species of the more than 100,000 different kinds of insects found in Africa south of the Sahara. Everything in Africa still seems a little queerer than almost anywhere else, and insect friends and foes are no exception. Skaife's book tells the farmer, gardener and householder what bugs to look out for, or to cherish and protect, and it will delight wealthy amateur naturalists, African or other. Illustrations, some in color.

VITAMINS IN THEORY AND PRACTICE, by Leslie J. Harris. Cambridge University Press ($6.50). The fourth edition, revised and substantially expanded, of a very good popular book on vitamins: how they were found, what they do, how they are synthesized. The information is up to date and authoritative (the author is director of the Dunn Nutritional Laboratory at the University of Cambridge), the exposition is clear but not oversimplified, the presentation is readable, the illustrations are excellent and the entire appearance of the volume is inviting.

PRINCIPIA ETHICA, by G. E. Moore. Cambridge University Press ($4.75). A reprint of what is perhaps the most influential book of British philosophy in the 20th century. Bertrand Russell and John Maynard Keynes are among those who were enormously affected by this great work when it appeared in 1903, and have paid eloquent tribute to it. Stuart Hampshire in a recent reassessment observed that not only has *Principia Ethica* "become a classic of the subject, alongside Hume and Mill, but it is alive and is continuously considered on its own terms."

MAN AND NUMBER, by Donald Smeltzer. A. and C. Black Ltd. (seven shillings sixpence). A simply written little book giving a brief account of the evolution of the use of number from the earliest times. The material has been well selected to exhibit the rich diversity of counting methods, signs and words, the various ways of recording numbers, early calculating devices, the development of the modern number system. An interesting example of an early system of number words believed to be of Celtic origin and still used by some of the shepherds of the Yorkshire dales runs as follows: yan (1), tyan (2), tethera (3), methera (4), pimp (5), sethera (6), lethera (7), hovera (8), dovera (9), dick (10). Instructive and enjoyable. Illustrated.

ION EXCHANGE AND ADSORPTION AGENTS IN MEDICINE, by Gustav J. Martin. Little, Brown and Company ($7.50). The author contends that an important factor in all chronic degenerative disease is the absorption from the intestine of small quantities of toxic chemicals—a theory not wholly dissimilar from that of the noted bacteriologist Elie Metchnikoff. (This opinion, he admits, is as yet unsubstantiated by clinical observations.) Research described in this volume has convinced him that by "conditioning" the gastrointestinal tract through the use of certain resinous substances effecting a differential or selective ion exchange the absorption of these toxic agents can be prevented while beneficial and nutrient materials are permitted to enter the system. A book for specialists to judge.

THE NEUROPHYSIOLOGICAL BASIS OF MIND, by J. C. Eccles. Oxford University Press ($6.50). This book, subtitled "The Principles of Neurophysiology," is based upon the 1952 Waynflete Lectures at Oxford and is essentially concerned with the nature and function of the machinery constituting the nervous system, and how far this model helps us understand the workings of the brain and the "liaison" between mind and brain. In part a technical and difficult account but full of fascinating material.

THERMODYNAMICS AND PHYSICS OF MATTER, edited by Frederick Rossini. Princeton University Press ($15.00). This cooperative volume in the series entitled "High Speed Aerodynamics and Jet Propulsion" deals with the basic principles of the thermodynamics and physics of matter from the standpoint of their application to problems of aerodynamics. Among the topics considered by various experts are thermodynamics, quantum mechanics, statistical mechanics and the kinetic theory of gases, transport properties of gases, theories of liquids and liquid solutions, solids and solid solutions.

Notes

MATHEMATICAL FOUNDATIONS OF QUANTUM MECHANICS, by John von Neumann. Princeton University Press ($6.00). An English translation by Robert T. Beyer of von Neumann's mathematically rigorous presentation of quantum mechanics.

GAS DYNAMICS OF COSMIC CLOUDS, edited by J. M. Burgers and H. C. van de Hulst. Interscience Publishers, Inc. ($5.75). A collection of papers given at a symposium held at Cambridge, England, in 1953.

WAVE MOTION AND SOUND, by R. W. B. Stephens and A. E. Bate. St. Martin's Press ($9.00). A sound, well-illustrated, moderately advanced survey in which the authors have endeavored not only to explain the theory of vibrations but to relate the subject to analogous problems in other branches of physics.

Dynamics of a System of Rigid Bodies, by Edward John Routh. Dover Publications, Inc. ($3.95). A reissue of the sixth, revised edition of the advanced part of a famous treatise on mechanics first issued in 1860.

The Dynamical Theory of Gases, by J. H. Jeans. Dover Publications, Inc. ($3.95). A reprint of the fourth edition of Sir James Jeans's noted mathematical work.

Radioisotopes in Biology and Agriculture, by C. L. Comar. McGraw-Hill Book Company, Inc. ($9.00). A useful, well-produced monograph on various applications of radioisotopes. For the student and the investigator.

Science and Its Background, by H. D. Anthony. St. Martin's Press, Inc. ($4.00). Second edition of a handy, simple history of science which attempts to give something of the story of science, together with the background of history in which that story is set. Illustrations.

The Philosophical Works of Descartes, rendered into English by Elizabeth S. Haldane and G. R. T. Ross. Dover Publications, Inc. ($7.95). A reissue of this standard translation of all the philosophical writings of Descartes, excluding his philosophical correspondence and his more specially physiological treatises. Another useful service to scholars by Dover.

The Nucleic Acids: Chemistry and Biology, edited by Erwin Chargaff and J. N. Davidson. Academic Press Inc. ($14.50). The second volume of this comprehensive survey, containing 28 monographs by various contributors.

Theory of Functions of a Real Variable, by I. P. Natanson. Frederick Ungar Publishing Co. ($6.50). English translation of a well-regarded Russian work which treats function theory from a "largely classical point of view."

The Micmac Indians of Eastern Canada, by Wilson D. Wallis and Ruth Sawtell Wallis. University of Minnesota Press ($7.50). A comprehensive anthropological monograph on an Indian tribe occupying for the last 300 years the Gaspé Peninsula, New Brunswick, Nova Scotia and Prince Edward Island. Besides describing the daily life and various aspects of the tribal culture, the authors present a collection of 144 Micmac folktales. Illustrated.

LEIBNIZ, by Ruth Lydia Saw. Penguin Books Inc. (65 cents). The head of the philosophy department of Birkbeck College in the University of London presents a brief memoir of the life of the great 17th-century thinker, a thumbnail sketch of his logic and a detailed description of his "bold and intricate" metaphysical system.

THE IDEA OF PROGRESS, by J. B. Bury. Dover Publications, Inc. ($3.95). A reissue of a thoughtful inquiry into the origin and growth of progress by a distinguished British historian. Introduction by Charles A. Beard.

CASIMIR FUNK, by Benjamin Harrow. Dodd, Mead & Company, Inc. ($4.00). A biography of a Polish-American biochemist, less well-known than he should be, who did important basic work in the study of vitamins and nutrition and is the inventor of the word vitamin.

BETA- AND GAMMA-RAY SPECTROSCOPY, edited by Kai Siegbahn. Interscience Publishers, Inc. ($20.00). An advanced monograph based on the "renaissance" in beta- and gamma-ray spectroscopy produced in the last decade by the evolution of instruments and methods, and, most important, by the introduction of the nuclear shell model.

STATISTICAL YEARBOOK, 1954. United Nations ($7.50). Sixth issue of this invaluable compendium presenting in 179 tables 20 years of international statistical data on subjects from food consumption to cultural instruction.

TOBATI: PARAGUAYAN TOWN, by Elman R. Service and Helen S. Service. The University of Chicago Press ($7.00). This is a careful study of community life in rural Paraguay, based upon analysis of documentary materials and field studies conducted in 1948-49. The book makes a solid contribution to ethnology and cultural anthropology. Illustrations.

THE ROGER ADAMS SYMPOSIUM. John Wiley & Sons, Inc. ($3.75). Six papers on various topics of chemistry presented in honor of a leader of American chemistry.

GENETICS AND METABOLISM, by Robert P. Wagner and Herschel K. Mitchell. John Wiley & Sons, Inc. ($7.50). A general picture of the biochemical basis of inheritance. For advanced students.

THE AMATEUR SCIENTIST

About the making of a coronagraph to view the prominences of the sun

Except for two obstacles you could raise your thumb to the sky on a clear day, line up the nail with the edge of the sun and see tongues of blood-red flame lashing thousands of miles into space. You are cheated out of this exciting spectacle by your heterochromatic eyes and the dense, dirty atmosphere of the earth. Glare refracted by dust, water vapor and the molecules of the air masks the relatively faint rays of these solar prominences. The problem of suppressing the glare and sorting the red rays from the white residue constitutes one of the most interesting challenges to the amateur astronomer.

Prominences show up clearly during a total eclipse of the sun, when the glare is masked by the moon. Why not equip a telescope with an artificial moon—an opaque disk just large enough to blot out the sun? Such a disk would be merely an elaboration of your thumbnail, and it would fail for the same reason that the thumbnail fails. The disk of the real moon is located in airless space: hence it casts a knife-sharp shadow. Your artificial moon would cut off the direct rays of the sun but could not stop the rays reflected from all angles by the dust-laden atmosphere. You must equip your telescope not only with an artificial moon but also with a filter which can distinguish between direct rays from the disk of the sun and those from the prominences. This requirement implies a difference between the two kinds of light, because you cannot sort things which are identical.

It turns out that prominences are largely composed of hydrogen, which emits a deep red light. The sun as a whole, on the other hand, is composed of all elements, each of which contributes one or more colors to the visible spectrum. White light is a mixture of all these colors. Thus the problem of seeing prominences comes down to dimming the white light as much as possible and filtering it out of the desired red of hydrogen.

A limited solution of the problem was devised in 1868. By attaching a spectroscope to a telescope, bringing the slit of the spectroscope tangent with the edge of the sun and moving the slit in a circle around the edge, prominences could be detected. Then the slit could be opened wide enough to see an entire small prominence or part of a large one. Even though this method distorts the image of a prominence, it is still used on special occasions.

In 1890 George Ellery Hale and Henri Deslandres independently invented the spectroheliosope. This instrument utilized the red light of hydrogen to produce an image of the entire disk of the sun. Thus prominences were visible not only at the edge of the sun but also on the face of it. For 40 years the spectrohelioscope was the major source of knowledge about solar prominences.

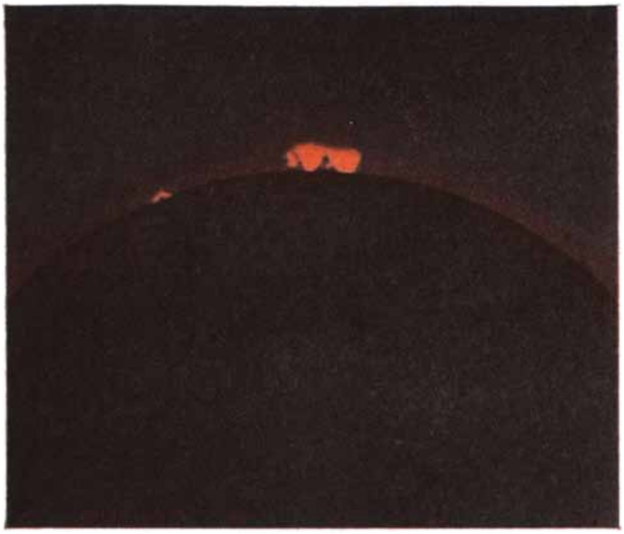
The sun is entirely gaseous. No solid surface lies beneath its outer layers. From the outside in, the outer layers are the corona, the chromosphere, the reversing layer and the photosphere (the layer we see when we look at the sun with the naked eye or a conventional telescope). An orderly mind instinctively seeks to arrange these layers in a diagram resembling the cross section of an onion. Illustrations of this sort do not appear in textbooks, largely because they would convey the misleading impression that the layers have sharp boundaries.

The corona, the pale yellow and pearly white outer aura seen during a total eclipse of the sun, is by far the thickest of the four layers. It extends beyond the visible disk of the sun for about one third of its diameter, and sometimes much farther. It is a diaphanous thing, fainter than moonlight. The scarlet clouds of hydrogen that comprise the prominences appear to shoot up from the chromosphere, which contributes only 12,000 miles to the 864,000-mile diameter of the visible solar disk.

Although the prominences take various flamelike forms, they are not flames in the ordinary sense because the sun does not burn. The astronomer Edison Pettit classified and named the prominences according to their behavior. There are three active types: "interactive," "coronal active" and "common eruptive." The latter are subdivided into "quasi-eruptive," "common eruptive," and "eruptive arch." Then there are the sunspot types: "cap," "common coronal sunspot," "looped coronal sunspot," "active sunspot," "surge," "ejection," "secondary" and "coronal cloud." The tornado types are "columnar" and "skeleton." Finally there are the "quiescent" and "coronal" types, which have no variants. Sometimes 20 prominences of these various types are simultaneously visible at the edge of the sun. Sometimes there is no prominence for days. Prominences erupt at velocities up to 451 miles per second; a common velocity is 100 miles per second. They often change from one type to another.

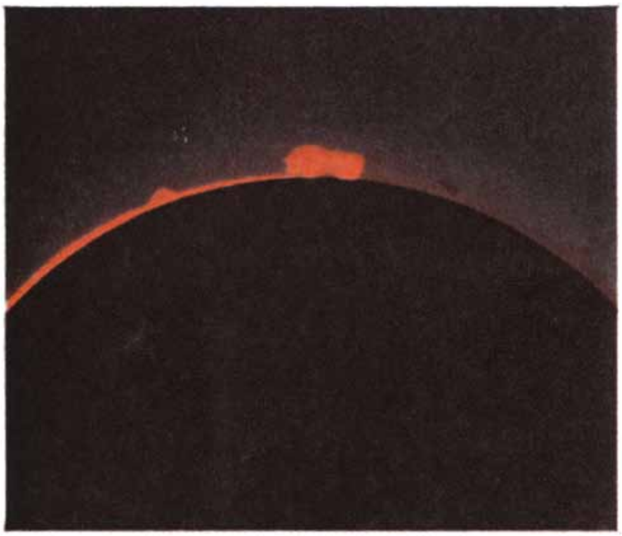
The natural fascination of watching things that move may largely explain the amateur astronomer's dream of owning an instrument that makes prominences visible. Because the prominences are so large by terrestrial standards, they appear to move lazily. But like the slow movement of the hour hand of a clock, their transformations can easily be perceived over a matter of minutes. When recorded by time-lapse photography, and then projected as a motion picture, prominences are an awesome spectacle of nature. Henry Paul of Norwich, N.Y., chemist and amateur astronomer, has written: "Spine-tingling excitement tinged with awe usually accompanies the first viewing of an eruptive prominence. These millions of tons of glowing gas often stream back in graceful arcs to the surface as if drawn by a huge magnet."

A good spectrohelioscope requires 17 optical surfaces and an original diffraction grating (a replica grating will not work). This doubtless explains why so few amateurs have built these instruments. This department knows of only



The coronagraph shows a prominence at 11:17 a.m.

The same prominence is photographed at 11:36



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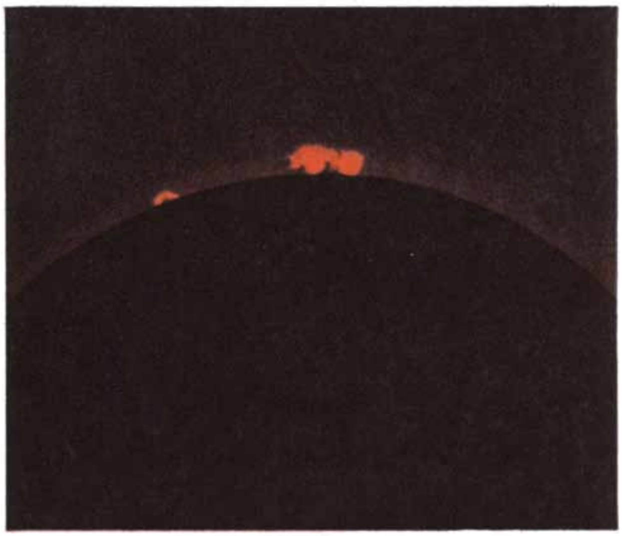

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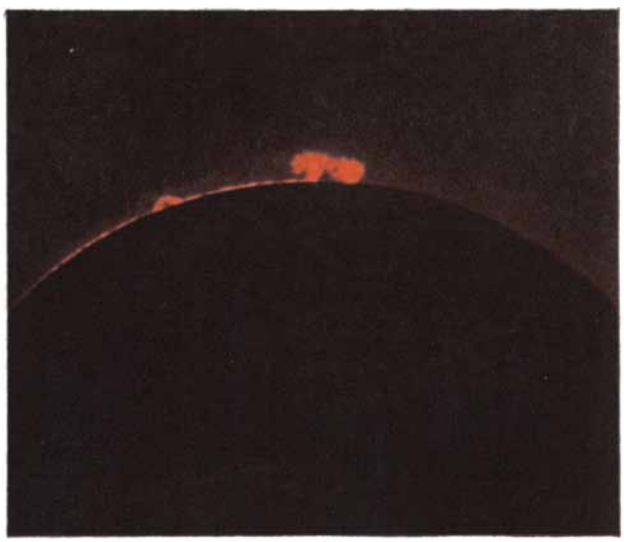

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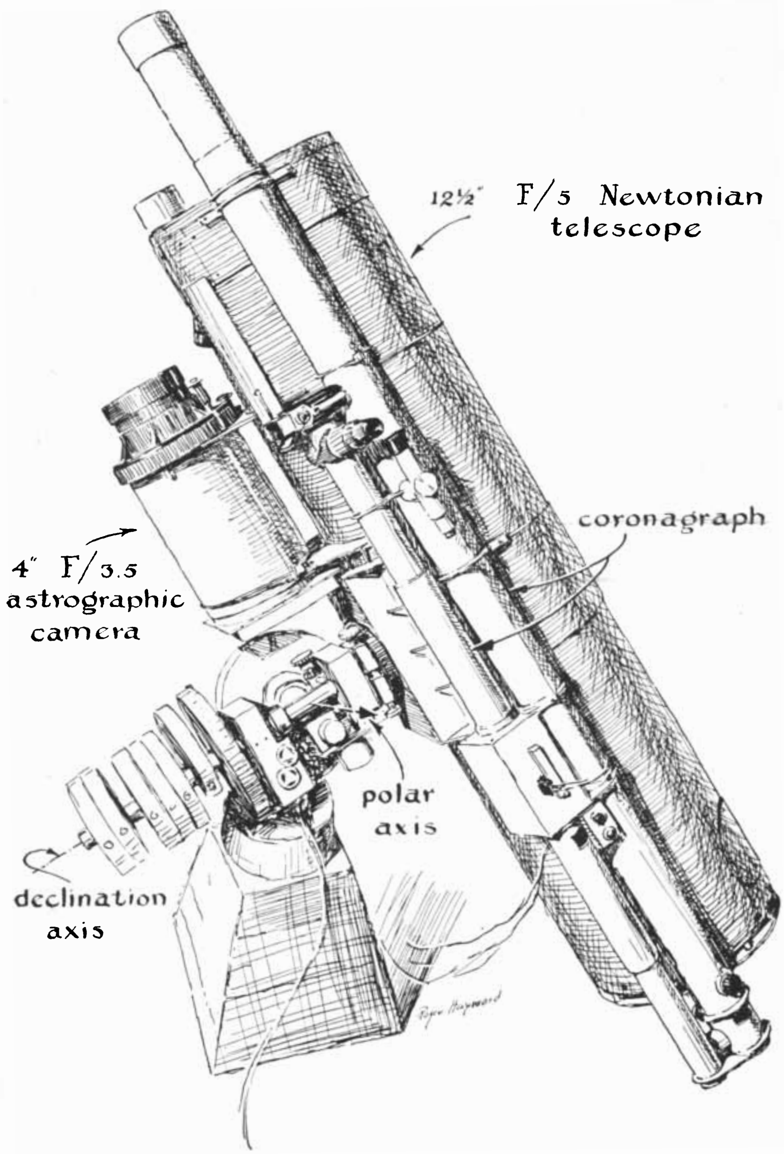


The coronagraph mounted with an astrographic camera and a reflecting telescope

five spectrohelioscopes made by amateurs—four in Great Britain and one in the U. S. The American instrument was destroyed in a fire.

Paul's exciting experience came not out of a spectrohelioscope but from a newer instrument called the coronagraph. Where the spectrohelioscope sorts out the red light of hydrogen by means of a diffraction grating, the coronagraph does so with a remarkably selective filter known as the quartz polarizing monochromator.

In general the coronagraph is the better instrument. One astronomer who began as an amateur telescope maker and has used both instruments says that the views with the coronagraph are enough to make a spectrohelioscope man feel that his life has been wasted. Another calls this an understatement. The older instrument does enjoy some advantages. It is superior, for example, in revealing details of the chromosphere, unless the design of the coronagraph is carried to the extreme limit of its capability—at greatly added cost. Moreover the spectrohelioscope may be adjusted to filter light of any color.

The coronagraph was independently invented by several astronomers: first the late Bernard Lyot of France and later Yngve Ohman of Sweden and John S. Evans of the U. S. (who began as an amateur telescope maker). Three amateurs are known to have built coronagraphs using the quartz polarizing monochromator: David Warshaw of Brooklyn, N.Y., who spent several years at the task and accomplished it in a kitchen without machine tools; Paul, who gained some insights in personal visits with Warshaw; and Walter J. Semerau of Kenmore, N.Y., who was aided by Paul's published instructions in *Amateur Telescope Making—Book Three* and directly by Paul.

After using his instrument for a year, Semerau writes: "My coronagraph performs beyond all my expectations. Building it was the most fascinating fun I have ever had." The prominence photographs on page 195 were made with this instrument.

Semerau mounted his coronagraph on the same telescope axes that support a 12½-inch astrographic camera he had made earlier. At the bottom of the coronagraph tube a pair of right-angle prisms jackknifes the light beam from the long-focus objective [*see drawing on the opposite page*]. Hence what appears to be two parallel tubes is in effect a very long single tube folded for the sake of convenience. In one part of the tube the light passes through a rectangular box containing the quartz polarizing monochromator. The monochromatic light emitted by the prominences is passed upward into the eyepiece by a reflex mirror. Light of other colors is absorbed by the filter and dissipated in the form of heat. The light can be directed into either of two cameras by moving a small lever attached to the mirror. The instrument can thus serve as either a coronascope or a coronagraph. The arrangement enables the observer to view prominences up to the instant when he wishes to make a photograph. The drawing shows a 35-millimeter camera in place. It may be replaced by a 16-millimeter time-lapse camera.

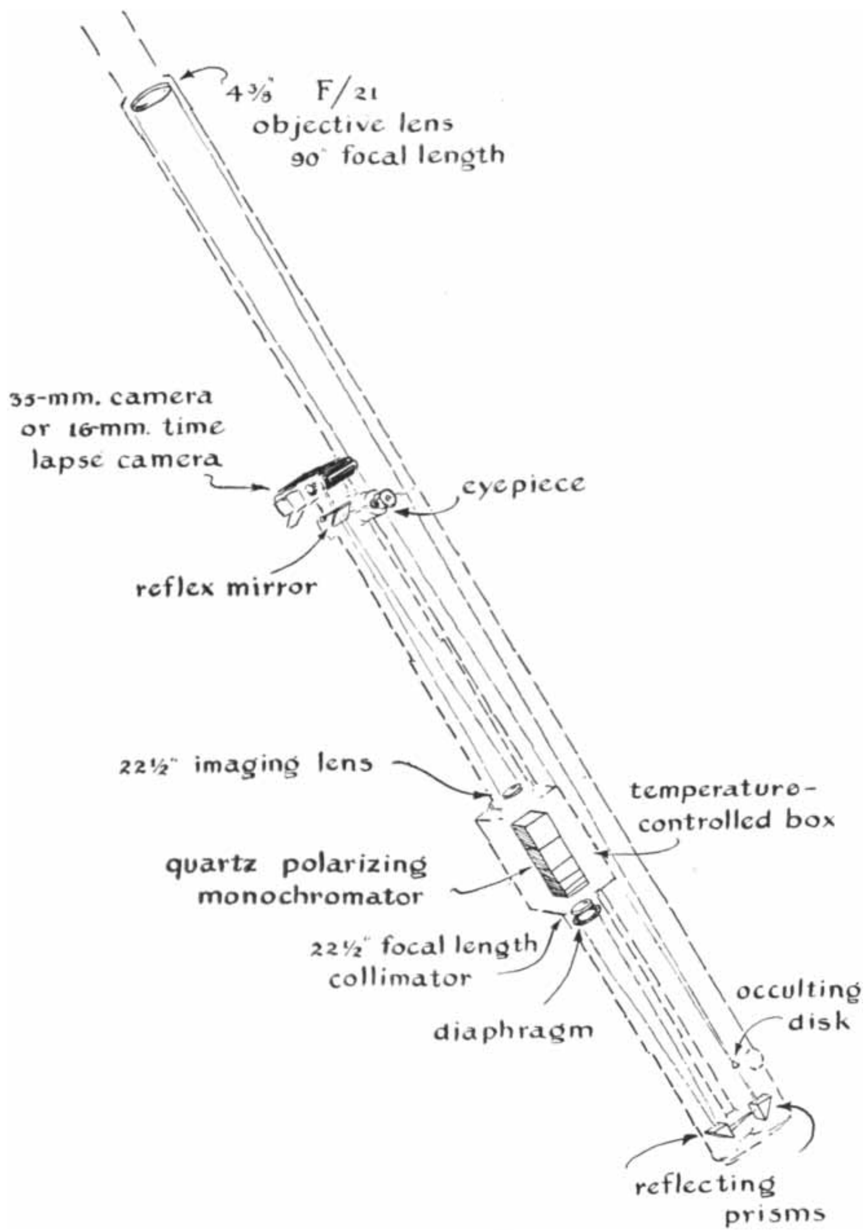
The business end of the coronagraph is the quartz polarizing monochromator. Though it is a filter, the term is misleading because it suggests simple glass or gelatin filters. Even the best of these would transmit a band of color much too broad. The filter must exclude all light waves which do not fall within a single hydrogen line—a band of about three to seven Angstrom units in the 3,750 Angstroms of the visible spectrum. To accomplish this the quartz polarizing monochromator sends the light through a stack of six or more quartz plates. At the top and bottom of the stack and between each pair of plates are sheets of Polaroid. In addition to this filter the coronagraph requires a cone of metal (the circular bottom of which eclipses the sun in the instrument), a field lens, a diaphragm, a lens to send the rays parallel through the quartz plates and another lens to focus the emerging rays.

Since the filtered light of a prominence is narrowly monochromatic, the objective lens of the coronagraph need not be corrected for color. In fact, a single-element lens works better than an achromat. The lens must be superlatively free of bubbles, striae, dirt, dust and even microscopic scratches which would diffract light. Single-element lenses may also be used beyond the eclipsing cone; these need not be so free from defects. A reflecting telescope cannot be used for a coronagraph because irregularities in the metal reflecting surface diffract light.

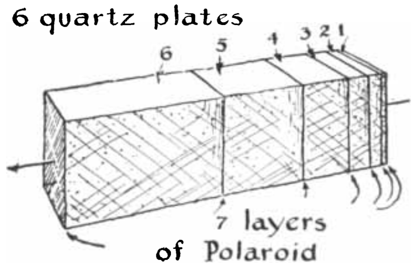
The quartz polarizing monochromator has other demands. It is an incurable thermometer watcher. It misbehaves unless the temperature is held constant within about one degree of a predetermined value, usually between 100 and 125 degrees Fahrenheit. This is usually done by heater bulbs, a fan and a thermoswitch.

The principle by which the quartz polarizing monochromator works has been explained many times but never so lucidly as by Evans in a leaflet issued by the semiprofessional Astronomical Society of the Pacific. The following is abstracted from this leaflet:

"The birefringent filter," Evans explains, "is a very simple and elegant device which, when attached to a small telescope, performs the same function as the spectroheliograph and spectrohelio-



The optical system of the coronagraph



The quartz polarizing monochromator

scope; better in some respects, and not so well in others.

"The basic function of these three instruments is to permit the formation of a well-defined image of an extended object like the sun in the light from a very narrow band in the spectrum. A radio set is a good analogy. Observation of the sun in white light is equivalent to trying to listen to a radio which receives all wavelengths simultaneously. All stations and static would come in together, and the result would be most unsatisfactory. To avoid this difficulty we use tuned radio filters, which receive only the narrow band of wavelengths put out by a particular station, excluding all other wavelengths. We then hear that station alone.

"The various kinds of atoms in the sun are like the radio stations. The hydrogen atoms broadcast only particular wavelengths of light which we can see as lines in the spectrum. If we can look at the sun through a filter which transmits only the wavelength of a hydrogen line, we can see the hydrogen on the sun to the exclusion of everything else, and its appearance is very different from the white-line picture.

"The elements 1 through 6 [*see drawing above*] are birefringent plates of crystal quartz. Each crystal is ground to a thickness one half that of the preceding element. Both surfaces are parallel to the crystal's optic axis.

"Each element receives plane-polarized light through a sheet of Polaroid film sandwiched between the quartz plates and splits it into two components of equal intensity which traverse the crystal at slightly different velocities. When the component rays emerge from the crystal, their combined polarization is altered in a manner depending on the wavelength. Certain wavelengths vibrate at right angles; intermediate wavelengths vibrate in ellipses. The next Polaroid transmits at each wavelength only that portion of the vibration parallel to the original direction, absorbing the rest. The resulting spectrum is represented graphically for the first plate [*top* *curve in drawing on page 202*]. Transmitted intensity [*vertical scale*] is plotted against wavelength [*horizontal scale*]. The other five elements of the filter yield similar curves. Curves for different elements differ only in the spacing between the peaks. The width of the spacing is inversely proportional to the thickness of the corresponding crystal. Since each crystal is one half as thick as its predecessor, successive curves have peaks twice as far apart.

"The transmission of any combination of elements is simply the product of their individual transmissions. Hence the alternate peaks emerging from the first plate which coincide with zeros of the second are absorbed, and the combination gives the solid transmission curve shown [*second curve from the top*]. Similarly, alternate peaks resulting from this combination coincide with zeros of the next pair of plates and are absorbed. The combination of the three elements, then, transmits a series of widely separated sharp bands. The separation of the bands can thus be increased to any desired amount by adding elements.

"A six-element filter, ideal for observing prominences, has a total thickness of about 4½ inches. It is best used on a refracting telescope, preferably with a simple lens objective, with an occulting disk covering the image of the sun in the focal plane. A small lens projects an image of the prominences around the occulting disk on an eyepiece or camera. Filters with band width greater than one Angstrom do not work well with reflecting telescopes because of the strong scattering of light by metallic reflecting surfaces."

The construction of the filter and optical system of a coronagraph is well within the capabilities of an experienced amateur telescope maker. The essential details of design and construction are given by R. B. Dunn in *Sky and Telescope* for April-October, 1951, and by Paul in *Amateur Telescope Making—Book Three*.

Writes Semerau: "The coronagraph can be built at a cost for materials of $150 to $200. Time of construction will be longer than for a telescope because it will take extra time to become acquainted with the special techniques of grinding, polishing, testing and orienting crystal quartz.

"If the close tolerances frighten the amateur who has made no telescope at all but has done fine mechanical work, the feeling is understandable, but Paul tells how the close work may be done with the aid of optical tests. With these aids the very close standards of optical

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"The Devil was having wife trouble"

"HERE I AM, twenty-four years old and what have I done?" he had once written. But he was 53, and his face, like his indomitable will, had become seared and toughened by years of Arctic struggle before he reached his ultimate goal.

On December 15, 1909, Robert E. Peary finally stood where no man had ever set foot:

North latitude 90°, longitude 0°. That day, he planted the American flag on the North Pole.

His return, afterward, to his base camp was so uneventful that one of his Eskimos explained it by saying the Devil must either have been asleep or having trouble with his wife.

Actually, good luck of that sort was a rarity to Peary. Enduring intense hardships, he had failed six times before to reach the Pole, but he never gave up. He lived all his life by his personal motto: *I shall find a way or make one.*

Peary's was a motto Americans find easy to understand. In fact, it typifies the practical "strike-out-for-yourself" spirit of the 160 million American citizens who stand behind U. S. Series E Savings Bonds. Perhaps that's why these Bonds are among the finest investments in the world today.

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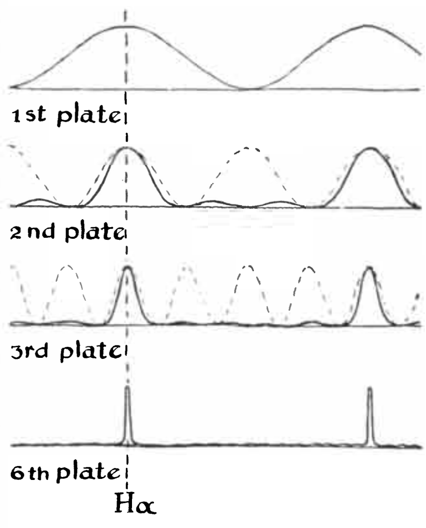
work are no more difficult than those of fine mechanical work. Nevertheless the apprenticeship in optical work gained by making a telescope is almost a 'must.'

"If the builder will accept the crystal quartz with chipped corners or other defects outside the clear round aperture of the instrument, which result in no actual harm, the cost for quartz will be greatly reduced. To make the least quartz go the farthest it is expedient to cut a potato to match the crystal in dimensions. Study the potato model very carefully and mark the direction of the optical axis as it would be found in the quartz. Cut the potato with as much care and love as if it were quartz. If then a mistake has been made, you may either change the dimensions of the plate or throw the potato away and start all over again.

"Just because some amateur telescope makers have no advanced degree in physics, they imagine they can't do the job and thereby miss a front seat at one of nature's best shows. A number of experts have commented favorably on the performance of my instrument. It certainly cannot be credited to my formal education. My schooling stopped with the ninth grade in 1925.

"I went to work in the coal mines, and continued until 1940. A part of that time was at the Alloy, W. Va., mine of the Electro Metallurgical Company, a division of the Union Carbide and Carbon Corporation. While working at this mine I built a stainless-steel press camera. This got me my first real break in life. My mine boss arranged with the management of the Electro Metallurgical plant to promote me to plant electrician. That got me out of the coal mine. After four years as an electrician I saw a men-



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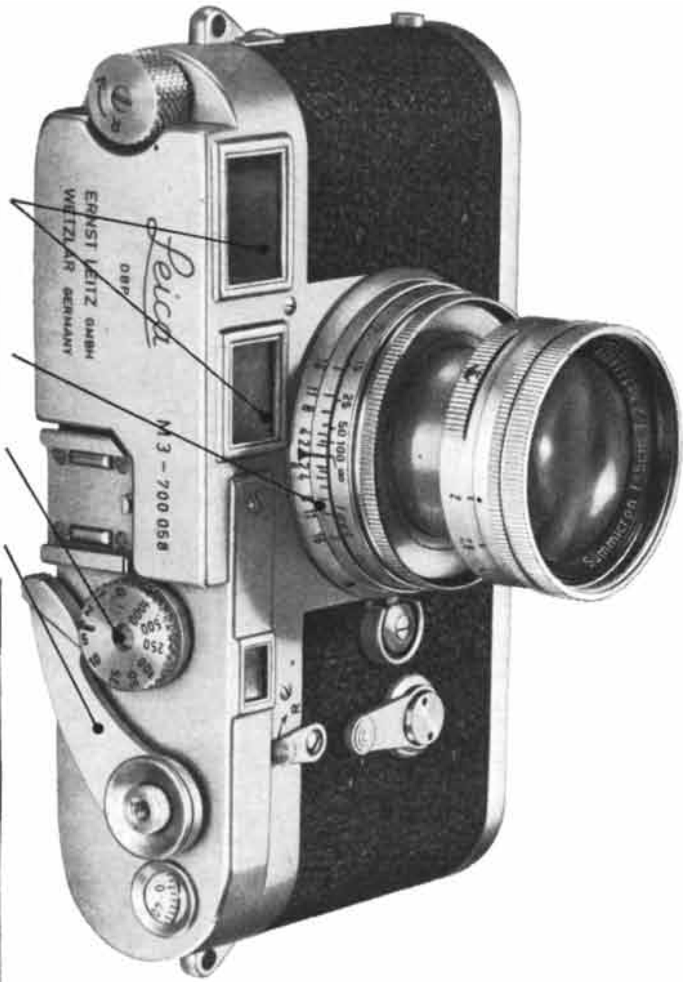

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tion of *Amateur Telescope Making* in SCIENTIFIC AMERICAN and built a six-inch telescope [see "The Amateur Astronomer"; SCIENTIFIC AMERICAN, May, 1948]. Meanwhile my press camera had been judged best in a fair at Electro Metallurgical, and company officials transferred me to another unit of Union Carbide, the Linde Air Products Company near Buffalo, N. Y., as instrument maker for their research laboratories. They had no instrument shop at the time, but they bought what I needed.

"In the seven years that I have worked as an instrument maker I have built three large spectrographs, a recording densitometer, many special types of cameras, a vibrating-reed electrometer, X-ray diffraction equipment, three schlieren apparatuses, a double-beam infrared spectrometer and many other pieces of equipment. I have accumulated one of the finest one-man instrument shops in the country. I am treated with as much respect as any Ph.D. on the property.

"I have no plans of my coronagraph or, for that matter, of anything I have ever built. Throughout the years I have trained myself to visualize how I want an object to be built. I make a few simple sketches—and I mean simple—to determine sizes and so on, and proceed to build. It usually turns out O.K. My employer likes it because it requires no engineering before an instrument is built. The drawings are made afterward.

"Since most solar observatories are perched on high mountains in clean air far from the smoky industries, many have the belief that very little can be done at a solar observatory at low altitude among industries. It is true that the higher the observatory and cleaner the air the better, but the amateur astronomer will be amazed at what he can see and learn of our sun from such a locality.

"A year of observing experience in the heavily industrialized area of Buffalo, N. Y., at an altitude of only 600 feet, has taught me the following facts about the coronagraph. A clear blue sky, preferably after a rain, with temperature not above 72 degrees, will give finest observing and photography. From mid-July to mid-September observing must be done before 10 a.m. while the earth is still cool. After mid-morning the heat from city streets and industry makes observing impossible. Observing is generally bad during December, January and February, when the sun is low and the light must pass through a thicker layer of smoke and haze. Prominences are just barely visible on a cool day if the sky is gray-blue or hazy."

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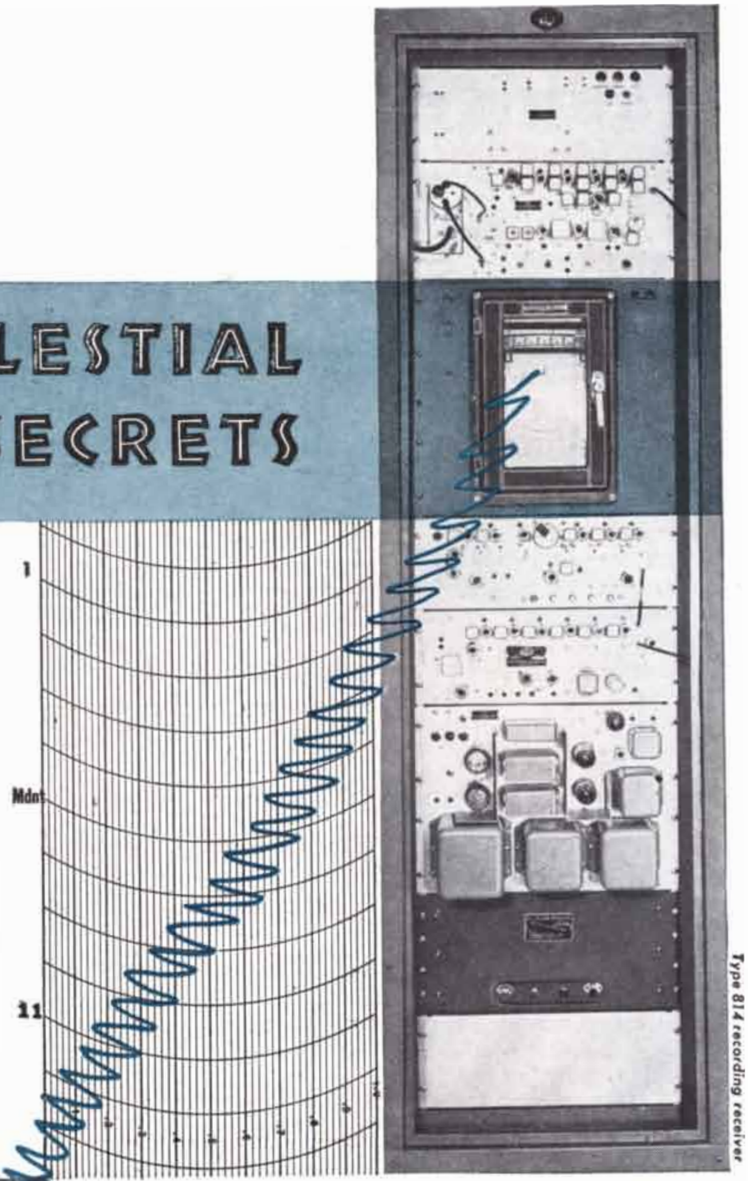

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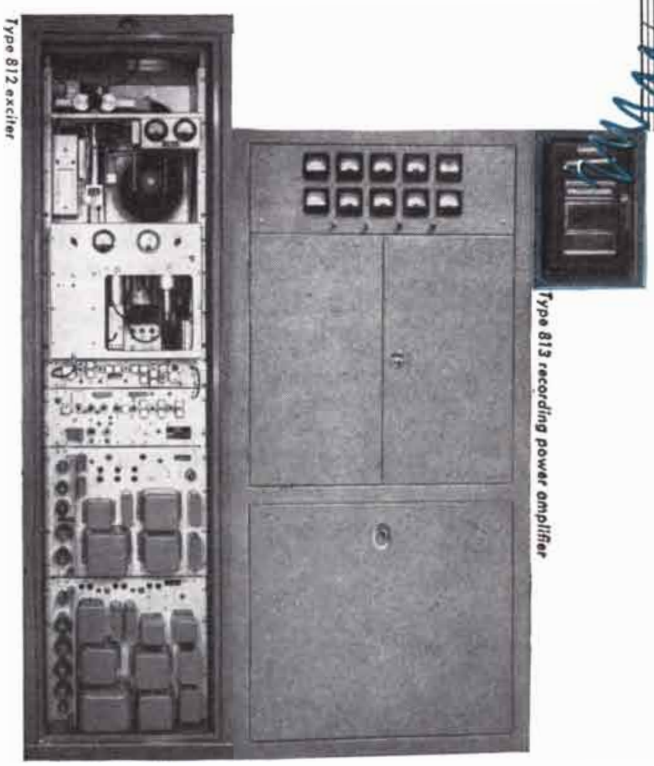

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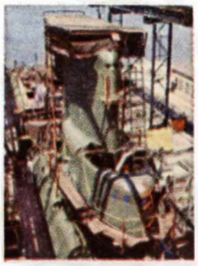

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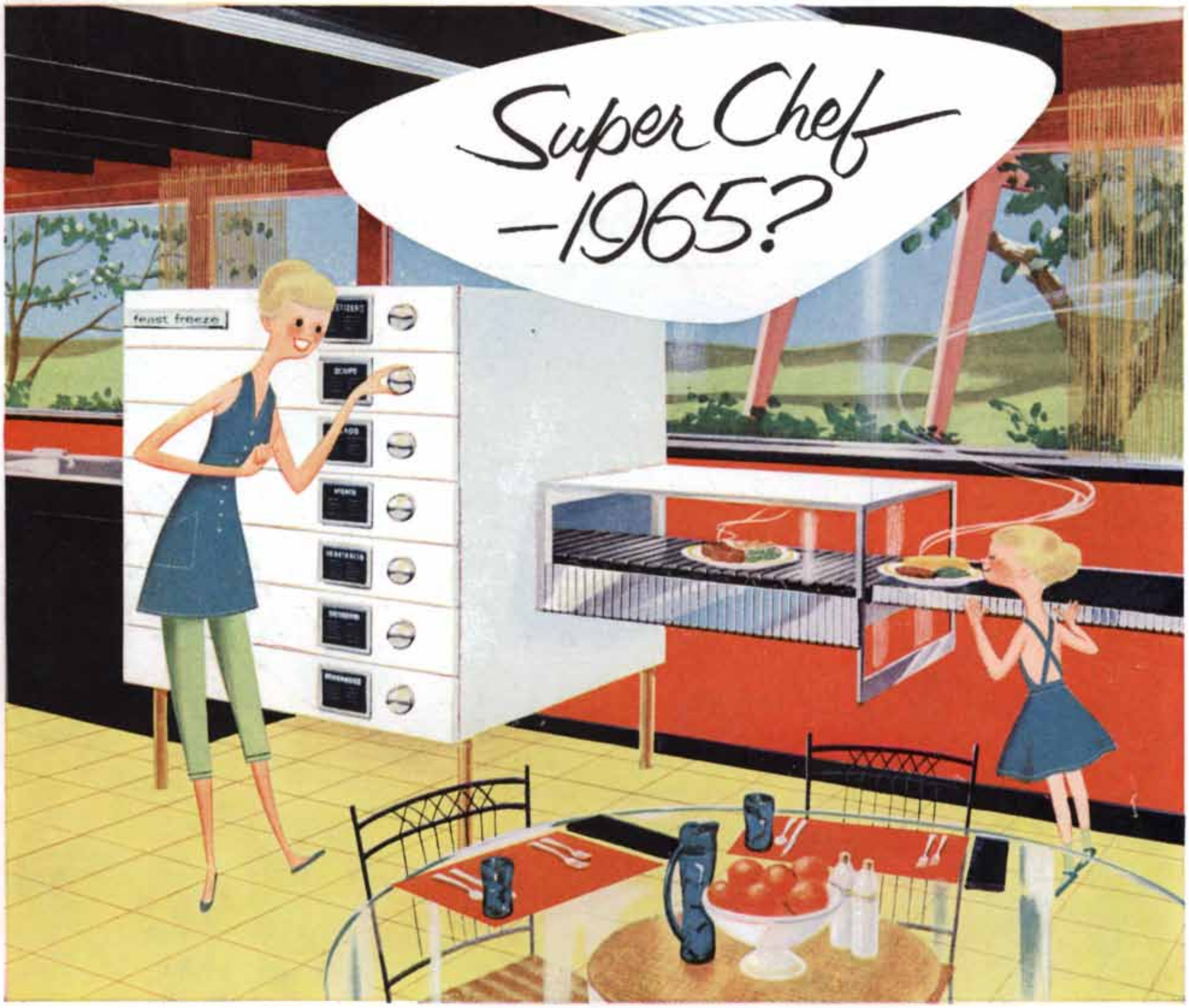

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