Towing the airborne magnetometer, an Aero Service Corp. airplane flies over Bethlehem Steel's new Grace Mine, near Morgantown, Pennsylvania. Bethlehem geologists spotted the big ore deposit four years ago when they analyzed an aeromagnetic survey made by Aero Service. The deposit had eluded earth-bound geologists.

Technology

Airborne Surveyors

Aircraft, camera, and electronics survey the earth—topside and below the surface—at high speed and low cost. Whether you're planning a factory, looking for minerals, or measuring a coal pile, the airborne surveyor can help.

One of the most fruitful technical alliances of the last twenty-five years has been that between the airplane and the aerial camera. One of the most promising new alliances is that between the airplane and a new family of airborne electronic instruments. In less than six years of commercial use, one of these instruments—the airborne magnetometer—has supplied oil and mining companies with geophysical data that might have taken a century or more to compile by traditional ground-based methods. Guided by a tiny part of this aeromagnetic information, Bethlehem Steel Co. has already staked out two substantial ore bodies, one in Pennsylvania, one in Canada.

The broad function of aerial surveying, photographic or electronic, is to expedite man's engineering activities. Photomosaics and topographic maps compiled from aerial photographs are widely used for hydroelectric, irrigation, and flood-control projects, for highway, railroad, and pipeline routing, for community and industrial planning—and even for inventorying coal, ore, and wood piles (see page 122). Aerial photographs may also be used for making forestry inventories and for studying large-scale geological formations. One set of aerial photographs—perhaps the most valuable over taken—recently led U.S. Steel to Cerro Bolívar, Venezuela's multi-billion-dollar mountain of iron. (See photomosaic, facing page.)

While accurate aerial photography and aero-mapping techniques have been available for some thirty years, government and industry have used them extensively only in the last fifteen, and many potential uses are still unexploited. It would seem desirable, for example, to launch all Point Four programs with a complete photo survey of the region to be developed. From the survey Point Four engineers could quickly estimate surface resources (forests, arable land, water) and suggest basic river-valley development projects and the like. But this is practically never done.

To be comprehensive, a Point Four survey might also include mapping with one or more of the new airborne instruments, listed here in approximate order of state of development:

▶ *The airborne magnetometer.* Conceived by Gulf Research & Development Corp. during the Thirties, the magnetometer was improved by Gulf, Bell Laboratories, and others during World War II, when the instrument was called the "magnetic airborne detector" (MAD, for short) and used for submarine locating. Since the war, the magnetometer, further improved by Gulf, has been used for mapping magnetic irregularities in the earth's crust that might indicate iron or, indirectly, oil and various non-magnetic minerals. (To find out what the magnetometer discloses, see diagram, page 123.) While Bethlehem's two ore deposits are the magnetometer's only major discoveries announced to date, it is no secret that the instrument has greatly aided other companies in their search for titanium, asbestos, and chrome. The magnetometer's role in finding oil is more complex. Oil prospectors are fond of saying that nothing finds oil except a drill. What the magnetometer does, briefly, is indicate *potential* oil sites faster than any other method yet devised. "The magnetometer can only find the haystack," explains one oil geophysicist. "You still have to hunt for the needle."

▶ *The airborne scintillation counter.* Generally known by the tradename Scintillometer, this instrument was developed a few years ago by Canadian atomic scientists. The scintillation counter contains one or more synthetic crystals that scintillate when struck by nuclear radiations. Flown 200 to 500 feet above the ground, it will signal when the aircraft passes over radioactive elements. While these elements must lie in the top few inches of the earth's surface to be detected, it is not unusual for deeply buried bodies of uranium or thorium to produce the necessary surface radioactivity. This may occur in two ways: surface rocks may be close enough to the primary ore body to become "hot" from long exposure to radiation, or ground water may carry radioactive salts to the surface. Recently one Canadian geophysicist, Hans Lundberg, made the startling suggestion that the scintillation counter may be useful in finding oil. When he has flown the instrument over known oil deposits, he has noted two curious signs: a "halo" of radioactivity around the edge of the deposit, and a comparative absence of radioactivity directly above the oil. Lundberg's intriguing—but highly controversial—oil-finding method is diagramed on page 123.

▶ *The airborne electromagnetic surveyor.* Another Canadian development, this device is so new it doesn't yet have an accepted name. Its great significance is that it can theoretically point out *any* ore deposit—not only magnetic or radioactive ones. Whereas magnetometer and Scintillometer depend on a field or signal emanating from the earth, the electromagnetic instrument inspires its own signal, in the manner of Army mine detectors. The airborne instrument consists of a low-frequency transmitter in the aircraft (which must be of wood), and one or more receivers, either in the aircraft or at the end of a towline. One system using receivers aboard the plane (see diagram page 123) has been developed by Hans Lundberg and his associates in Toronto. A system employing a receiver on a towline was devised by Stanley Davidson of Sudbury, Ontario, and has been developed further by International Nickel Corp. Inco hopes that the instrument will ferret out a variety of non-magnetic ores. Lundberg claims that his instrument will also point out geological formations that might contain oil.

Surveying's Big Three

More than half of all the world's commercial aerial photo mapping and magnetic surveying is done by three organizations: Aero Service Corp., Philadelphia; Fairchild Aerial Surveys, Inc., Los Angeles; and the Hunting Air Survey Group with home offices in London. Although exact figures are not disclosed, it appears that the biggest of the three is Aero Service, which claims it is doing a $6-million-a-year business, if revenues of its affiliates are included. (Something over $500,000 comes from non-flying sidelines.) Fairchild Aerial, a subsidiary of Fairchild Camera & Instrument Corp., expects to gross over $2 million this year. The Hunting Group, offshoot of a shipping firm, began aerial photography in 1921. It operates about forty aircraft and would appear to gross perhaps $4 million directly from aerial surveying. Roughly half of Hunting's aerial work is done by its Canadian affiliate, Photographic Surveys, Ltd. Photographic Surveys, in turn, has an affiliate, partly U.S.-owned, called Aeromagnetic Surveys, Ltd.

In the U.S., Aero Service and Fairchild compete with perhaps a score of other photo-surveying companies, of which the two largest are Jack Ammon Photogrammetric Engineers, San Antonio, and Lockwood, Kessler & Bartlett, New York. Prior to World War II Fairchild Aerial did, by its own estimate, more than 90 per cent of all commercial photogrammetric mapping in the U.S. The rapid postwar rise of Aero Service and others in this field has been due in large part to the development of a low-cost ($5,000) map-plotting instrument invented by Harry Kelsh, a photogrammetrist with the U.S. Geological Survey. (The Kelsh plotter appears on page 122.)

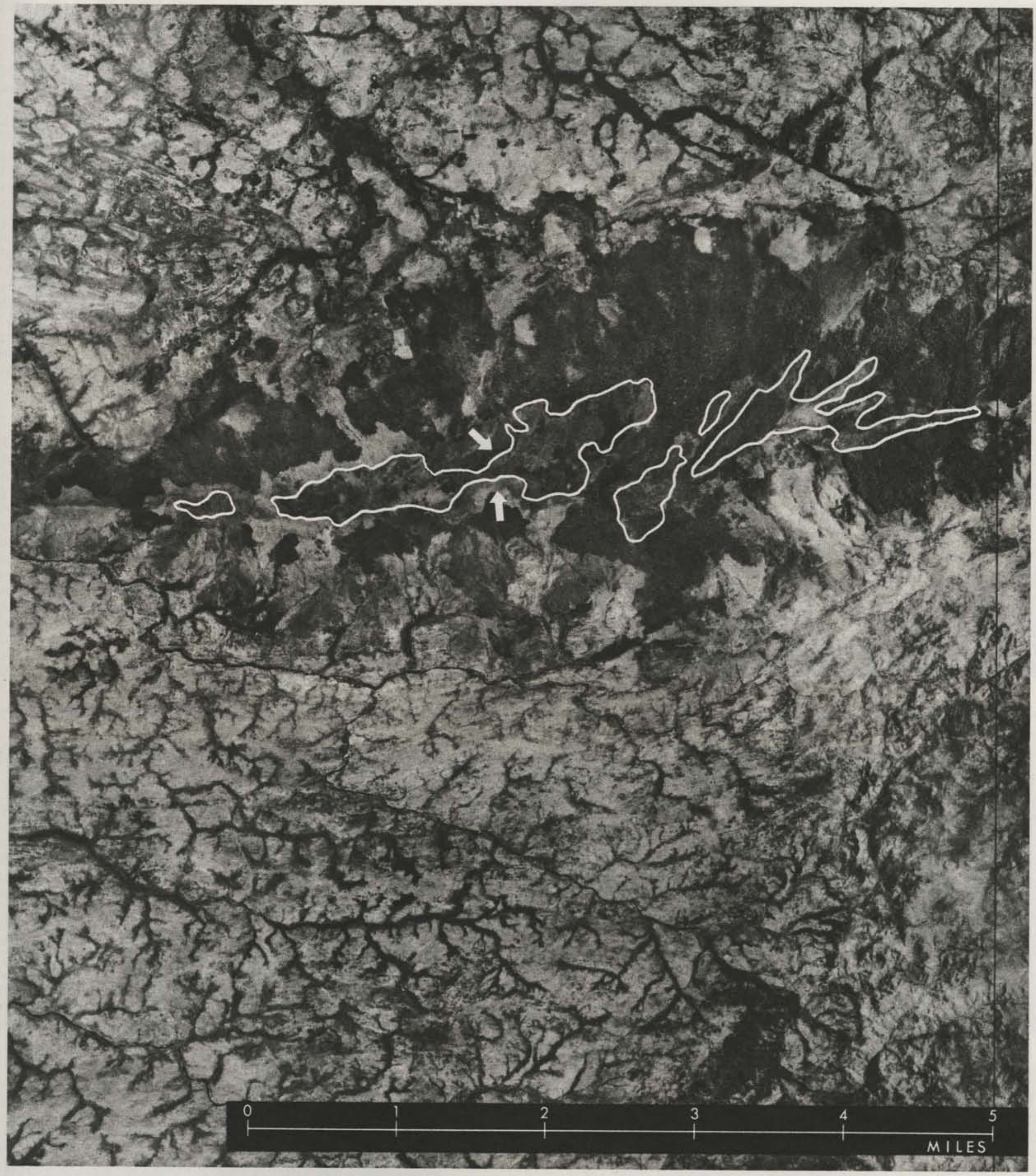
The biggest photo map-making organization in the U.S. is the Army Map Service of the Corps of Engineers, an organization charged with providing accurate maps of every land area in the world where U.S. forces might have to fight. Next biggest is the U.S. Geological Survey. Neither does any picture taking. The U.S.G.S. buys its aerial photos from Aero Service, Fairchild, and other commercial outfits. Army Map gets the bulk of its pictures from the Air Force, but contracts with commercial flyers on occasion. The U.S.G.S., which is charged with supplying up-to-date topographical maps of the U.S., began routine use of aerial photos in the late 1930's and today keeps a staff of 3,000 busy turning photos into maps. Last year the U.S.G.S. mapped 90,000 square miles of the U.S. and Alaska, using approximately 30,000 separate aerial pictures. Recently it has begun to contract out a growing portion of map compilation to commercial firms. (An aerial photograph of virtually any part of the U.S. can be purchased from the U.S.G.S. for 50 cents and up.)

While the U.S.G.S. has never cared to fly its own aerial cameras, it did obtain legal permission to fly one aircraft to carry the magnetometer, and recently the Scintillometer as well. The U.S.G.S., which is not primarily interested in locating oil or new ore deposits, uses data from the two instruments to improve its knowledge of geological structures. (Incidentally, however, it has found evidence of substantial iron in New York's Adirondacks.)

New shutter, new business

Major credit for promoting commercial aerial photography in the U.S. must be given to Sherman Fairchild, a wide-ranging entrepreneur whose name has now been associated with such things as flying boxcars, magnetic-tape recorders, and a photoelectric engraver. In 1919, at twenty-three, Sherman Fairchild invented the first practical between-the-lens shutter for aerial cameras. By replacing the focal-plane shutter, which produced distorted aerial pictures, Fairchild's shutter finally

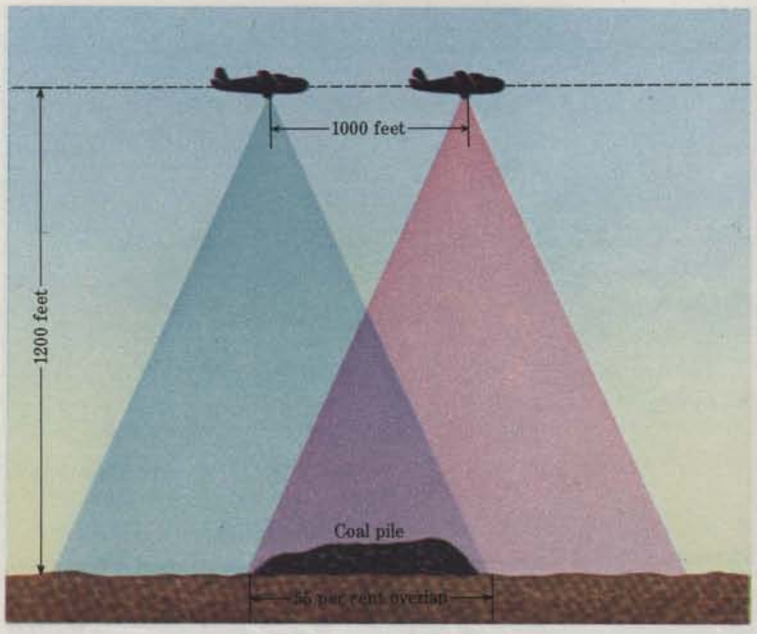
Text continued on page 144.
Overleaf: how to map the earth, inside and out, from the air.

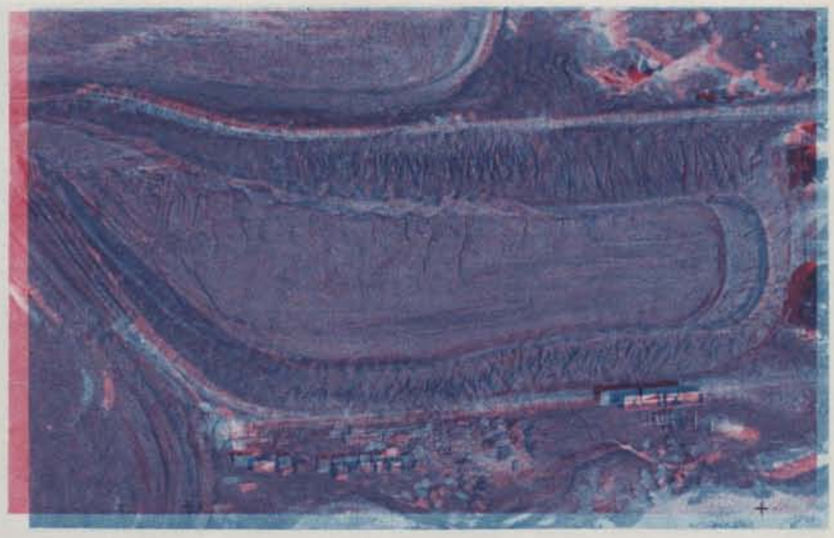


How much is this picture worth?

Fairchild Aerial Surveys, which made this photomosaic, would not claim it is the most breath-taking aerial view ever made. Yet it may be the most momentous. In public print for the first time, it represents about fifty square miles of Venezuela, photographed in January, 1947, for a U.S. Steel exploration team headed by Mack Lake. The engineer who requested the pictures and studied them was F. H. Kihlstedt. When he spotted the landslides (arrows) he suspected they might be caused by silica's having washed away from ferruginous quartzite, a non-magnetic iron-bearing rock. The rest is history. Kihlstedt had found Cerro Bolívar, hailed as "the richest and greatest iron deposit in the history of the world." U.S. Steel, more modest, admits proved reserves of only 500 million tons, worth at least $4 billion. (Ore bodies are outlined in white, their exact dimensions revealed here for the first time.)

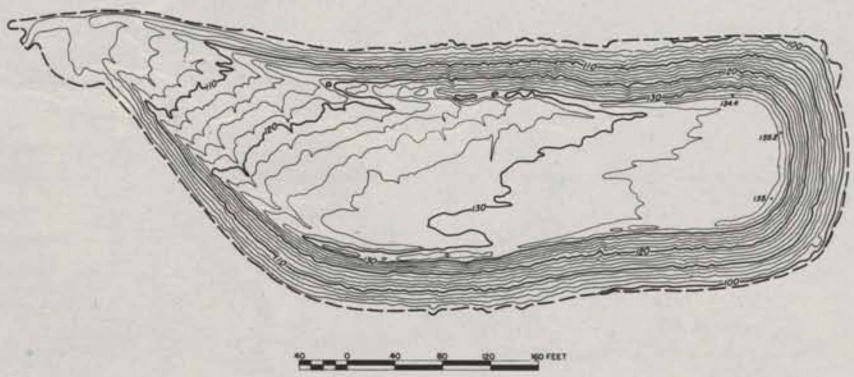
Photography maps the earth's exterior

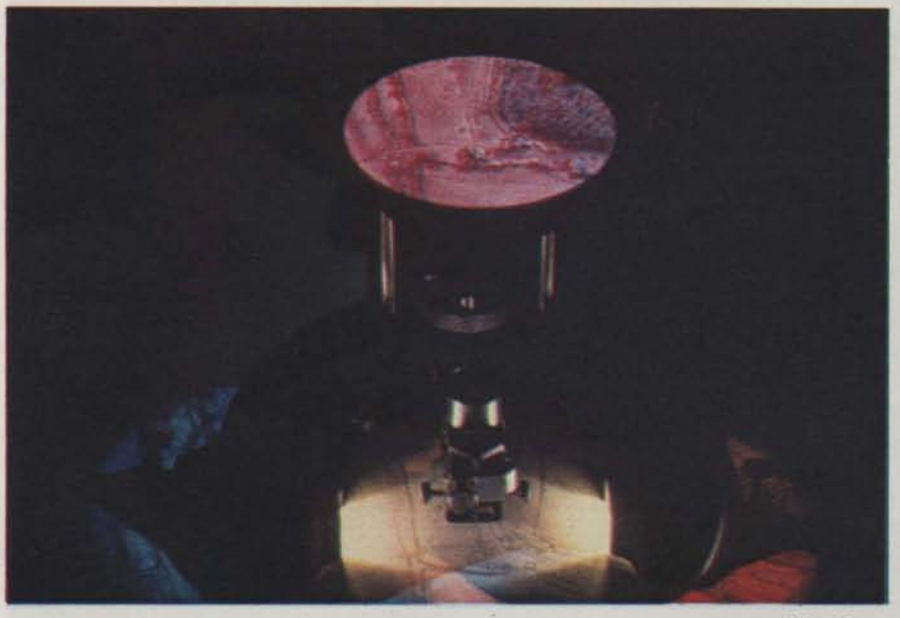




This is an anaglyph. Images in blue and red represent aerial photographs taken 1,000 feet apart, as shown at left.

A contour map of a coal pile, right, provides a simple example of what can be done with airplane and camera. The coal pile is one of thirty-nine that Aero Service Corp. regularly photographs for Philadelphia Electric Co. Purpose: inventorying. Formerly the job was done by ground surveyors, cost a third more than by air, and was probably less accurate. In the aerial method a plane takes a pair of overlapping pictures (above), which can be translated into a contour map with the help of an instrument like the Kelsh plotter, discussed below. The plotter creates a bicolor image, simulated at upper right, which appears three-dimensional to an operator wearing bicolor glasses. (If the reader can find a set of red and blue filters he should be able to see the same stereoscopic effect.)

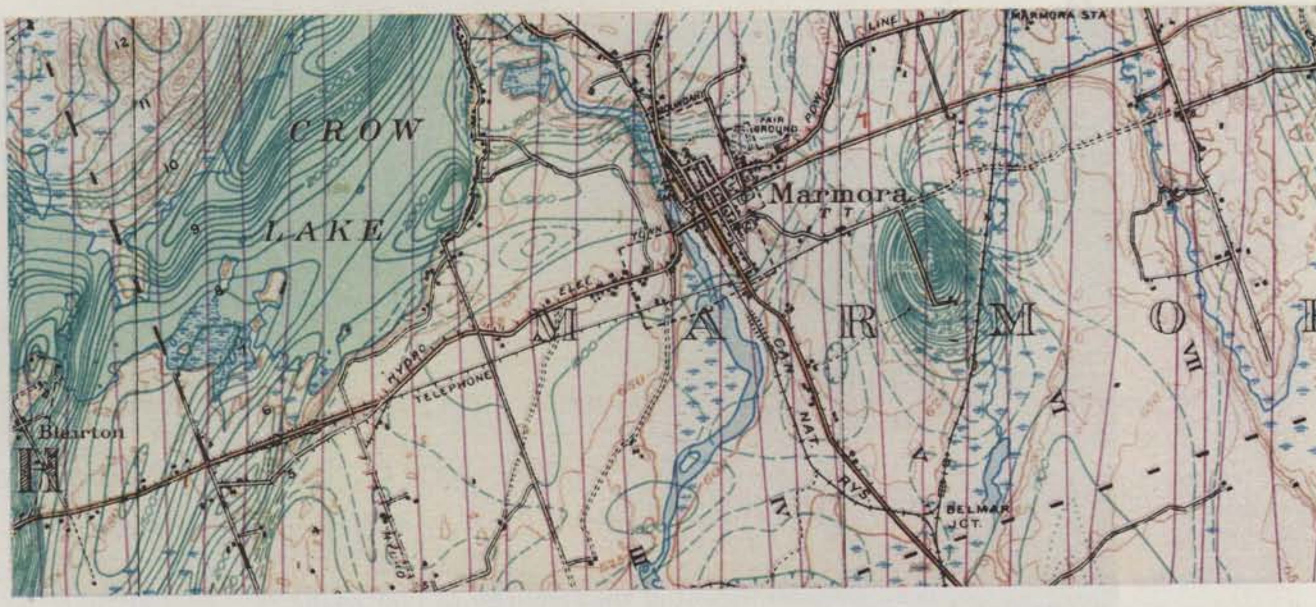




Nelson Morris

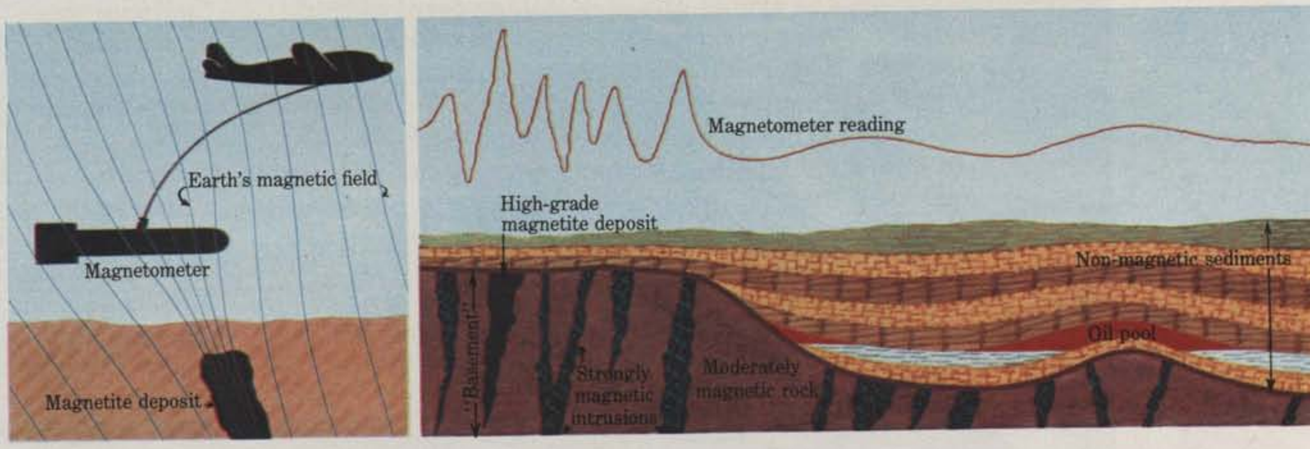
The Kelsh plotter, right, invented by Harry Kelsh of the U.S. Geological Survey, is perhaps the simplest instrument yet devised for translating a pair of aerial stereophotographs into an accurate contour map. The device, which costs about $5,000, projects one photo in blue light, the other in red, onto a round white plate (close-up above). With the aid of bicolor glasses, the operator sees things in three dimensions. He also sees a "floating" dot of light, which he can raise or lower. As he makes the dot touch points of equal elevation by moving the white plate, a pencil beneath the plate traces contour lines on a map. A $45,000 Swiss plotting device appears on page 146.

Iron on a 25-cent map



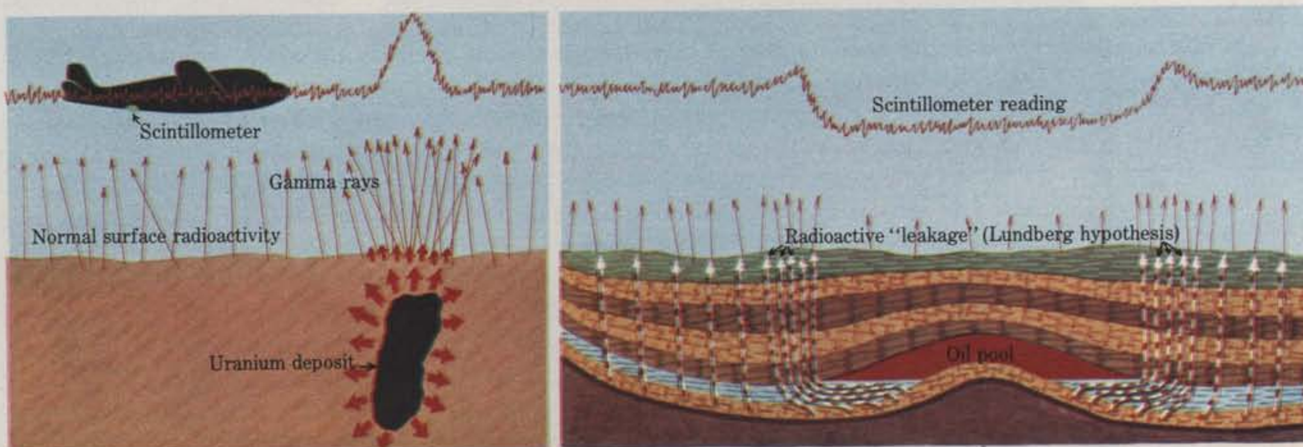
Not long ago, the Department of Mines and Technical Surveys of Canada put on sale, for 25 cents, a map of Ontario described simply as an "Aeromagnetic Survey, January, 1949." Sharp-eyed geologists working for Bethlehem Steel Co. immediately spotted an intense magnetic "high" near the town of Marmora (see map), 100 miles north of Lake Erie. This "high" resembled the one in Pennsylvania under which Bethlehem had just found a deposit of magnetite. To the chagrin of other steel companies—which had also paid 25 cents for the map—Bethlehem moved in fast and staked out the Marmora deposit. It was the second major ore discovery turned up by the airborne magnetometer, described below.

The airborne magnetometer, invented by Gulf Research & Development Corp., has been in commercial use for five years. As depicted at right, the magnetometer responds to distortions in the earth's magnetic field. A rich deposit of magnetite (as at Marmora) produces a strong signal. Oil geologists use the instrument to determine the depth of the so-called "basement." The deeper, the more likely the occurrence of oil above it. As the basement drops, the magnetometer reading smooths out. A slight rise in signal could indicate a hump in the basement underlying an oil pool.



Canadian razzle-dazzle

The airborne scintillation counter, or Scintillometer, counts the number of gamma rays leaving the earth's surface. All earth is more or less radioactive, but that overlying a deposit of uranium or thorium is apt to be especially "hot." There also seems to be an exciting correlation between radioactivity and oil—a discovery made by Hans Lundberg, a Toronto geophysicist. Flying over oil, he usually obtains the high-low-high Scintillometer pattern shown at far right. Lundberg says such patterns have actually helped him to find oil.



The airborne electromagnetic surveyor, newest electronic prospecting tool, can—in theory—locate nearly any ore deposit, plus certain geological structures. One form of the instrument devised by Hans Lundberg and associates is illustrated at right. The transmitter consists of loops of copper cable hooked up to an alternating-current generator. Operating transformer fashion, the transmitter sets up a secondary current in buried electric conductors (e.g., ore bodies). These, in turn, generate a magnetic field (shown in blue), which is picked up by sensitive receivers. The instrument has to be flown in a wooden plane at low altitude.