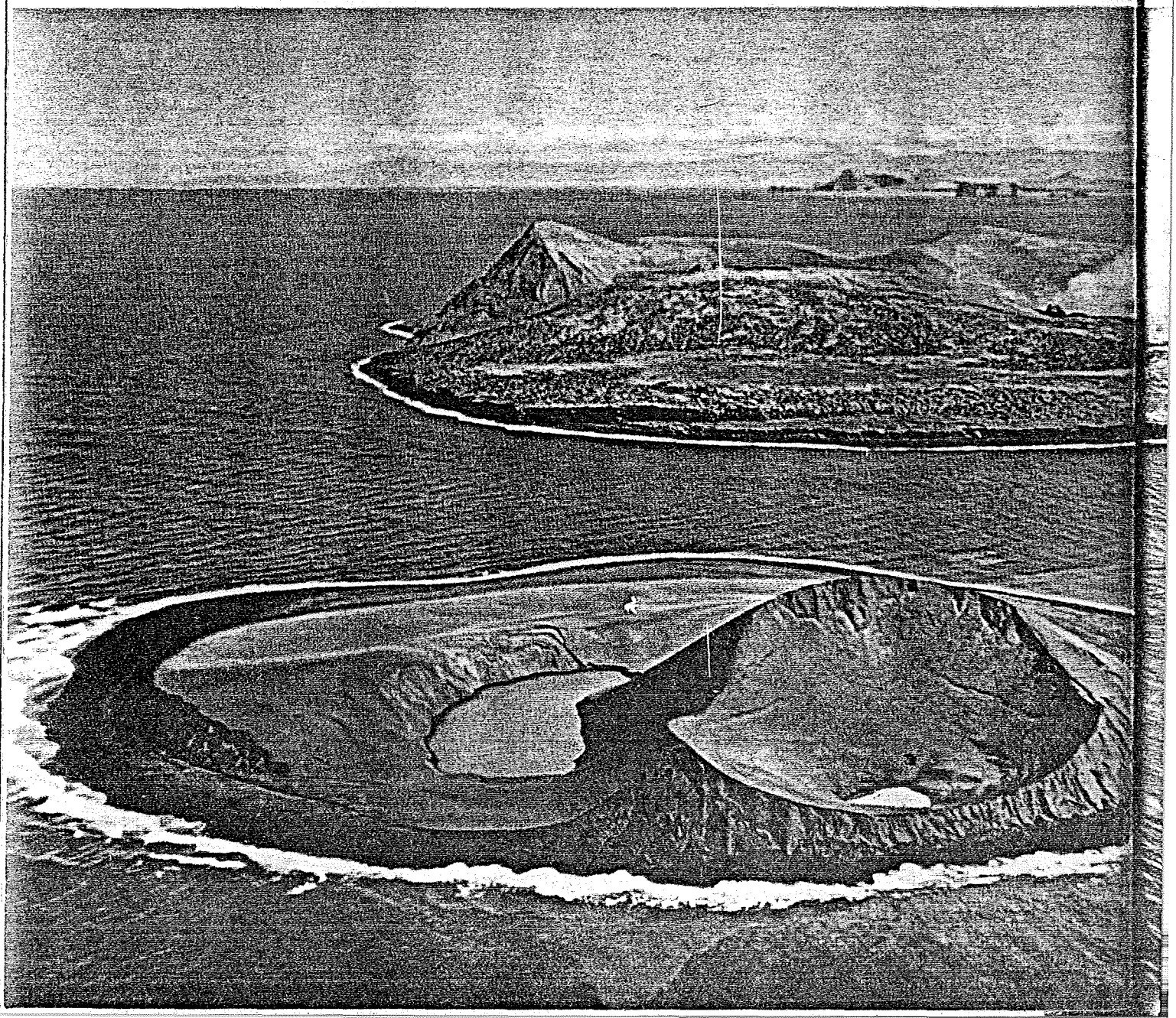
Iceland's Thermal G

An Icelandic saga tells of a tenth-century hero who stood on a coastal peak to guard an ancient settlement from raids by watching for the sails of Viking marauders. Today, this same peak is located near Hveragerdi, almost twenty miles inland; its location changed by intense deformational forces that raised the land and caused the shoreline to shift to the south. But this is not an unusual occurrence on this North Atlantic island, for Iceland is the scene of more active geologic forces than any comparably sized segment of the earth's surface.

Iceland, although smaller than New York State, is the largest land portion of the mid-Atlantic Ridge, a huge, largely submarine mountain chain, which stretches in a sinuous pink pattern for about 12,000 miles alon Atlan the ocean's center from the Arctic t olcan the Antarctic. Some of the mountain grou of this chain extend for as much a at t three miles above the ocean floo g th Other exposed segments of the ridg e oc include the Azores, St. Paul Rocks onti Ascension Island, St. Helena, an e ri Tristan da Cunha. Some geologist onve



al Geology

By Julian Kane

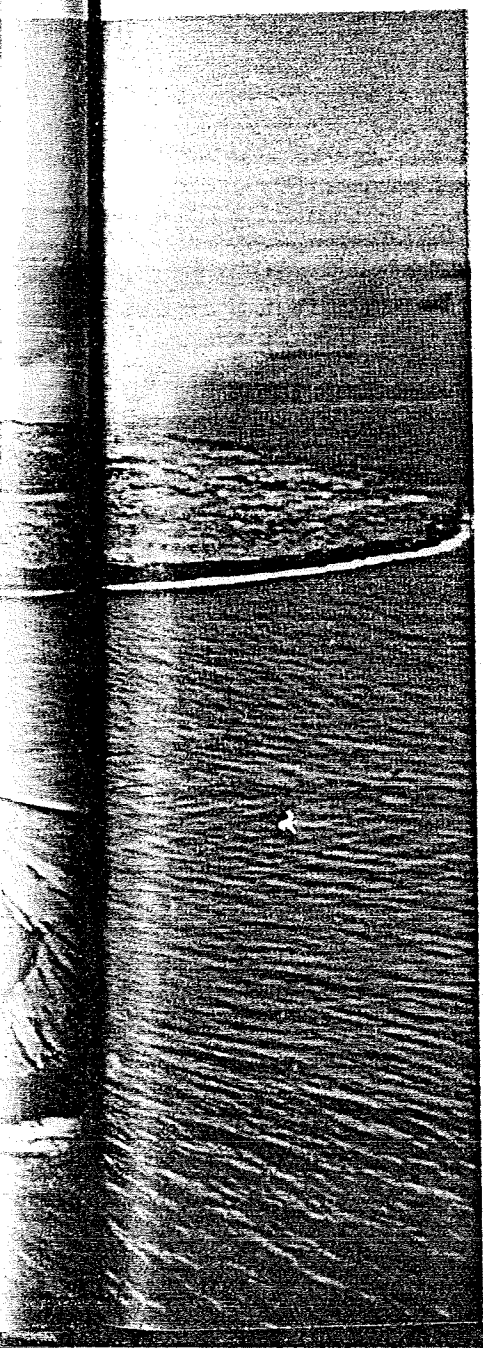
Photographs by William A. Keith

sinuou ink that the basaltic floor of the
les alon lantic continues to split as new
Arctic t canic material is forced up
ountain rough faults along the ridge, and
much a at the sea floor is widening, forc-
an floo g the continents on either side of
the ridg e ocean to move farther apart. The
il Rock ntinuing geologic activity along
ena, an e ridge may well be part of a huge
geologis nvection cycle, involving both the earth's crust and the hot mantle rock that extends for hundreds of miles into the earth. Large tension cracks (*gjas*), rift valleys (grabens), extensive earthquakes, and volcanic eruptions along the rift zone that bisects Iceland are surficial manifestations of the changes occurring far underground.

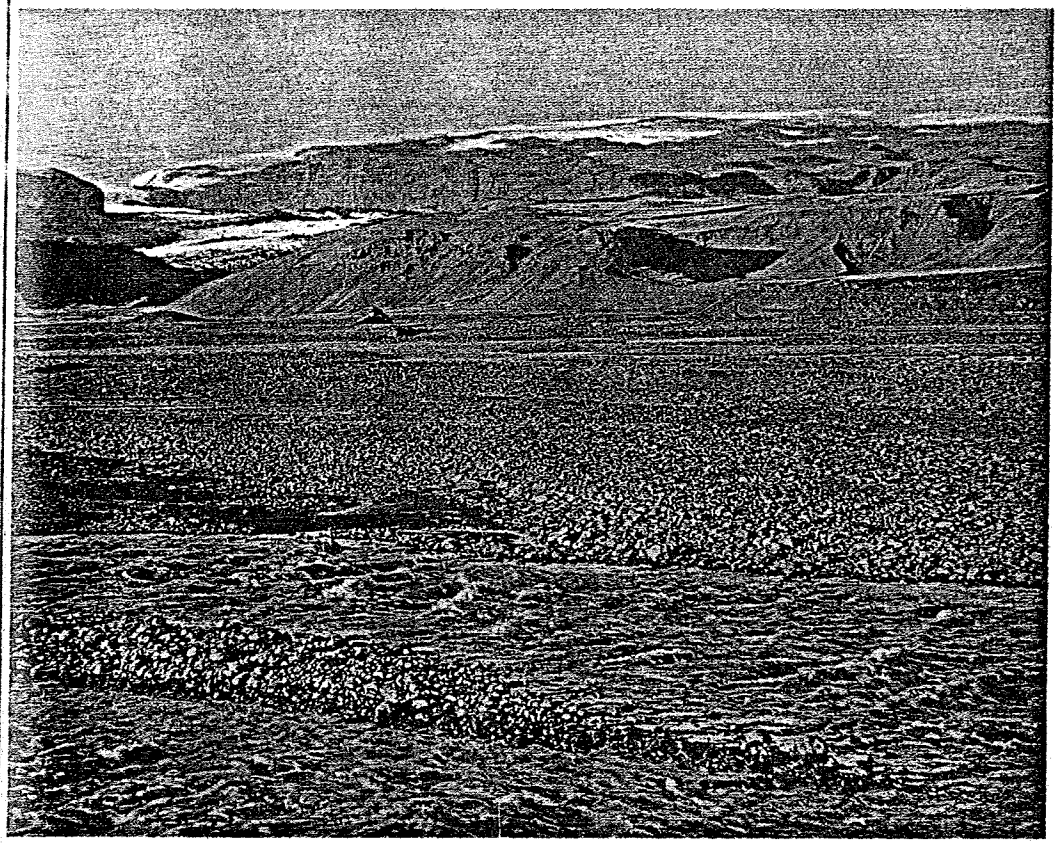
The bedrock of Iceland is mostly basaltic lava and ejected volcanic debris, the bulk of which was formed in early Cenozoic times (40-60 million years ago). Most of the recent igneous activity, however, has been confined to an irregularly linear area —approximately 50 by 250 miles in size—that runs roughly in a northeast direction through the central part of the island. Because of the igneous activity, fossils are rare and time dating is mostly limited to radioactive determinations.

In addition to containing a great number and variety of volcanic cones, Iceland is unique in having the only active fissure flows that form lava plains and lava plateaus. These are made up of successive outpourings of extremely fluid lavas, capable of covering many square miles prior to congealing in essentially horizontal layers. When magma pressures build up from below, the molten material readily finds its way up to the surface through the linear joints and cracks near the island's center, and fissure flows result. Careful measurements along the Almannagja, a major, five-mile fissure located thirty miles from Reykjavik, have shown it to be slowly widening over a period of years—a result of tensional forces related to the spreading of the sea floor. The steep eroded edges of hardened lava flows frequently exhibit faceted rock columns (columnar joints), formed when shrinkage cracks developed in the cooling lava.

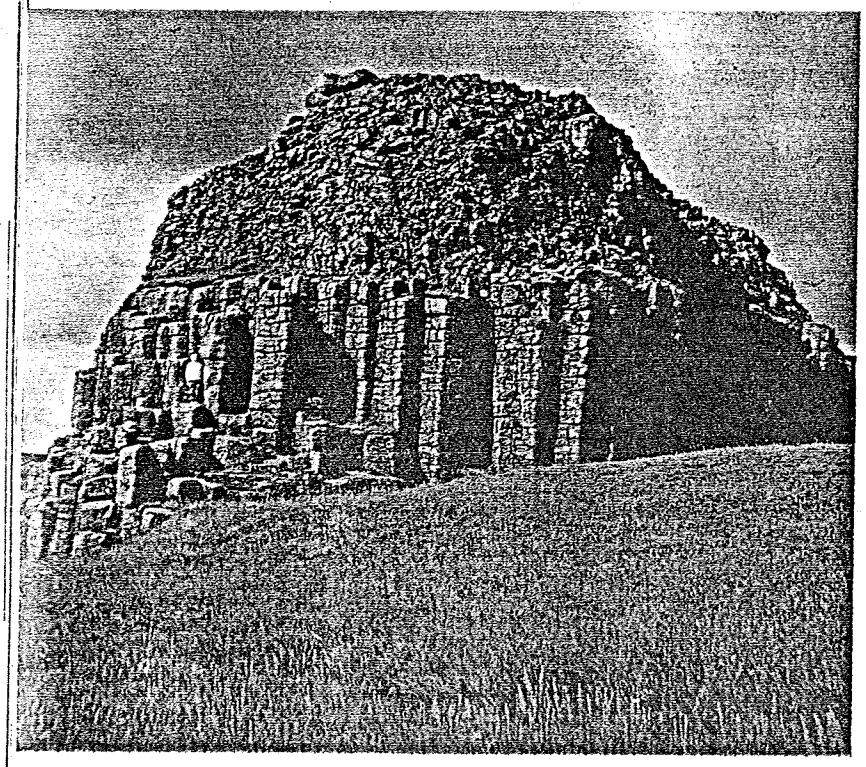
The Reykjanes Peninsula, on which the capital city of Reykjavik is located, has experienced many recent earthquakes. Their persistence, coupled with the birth of new

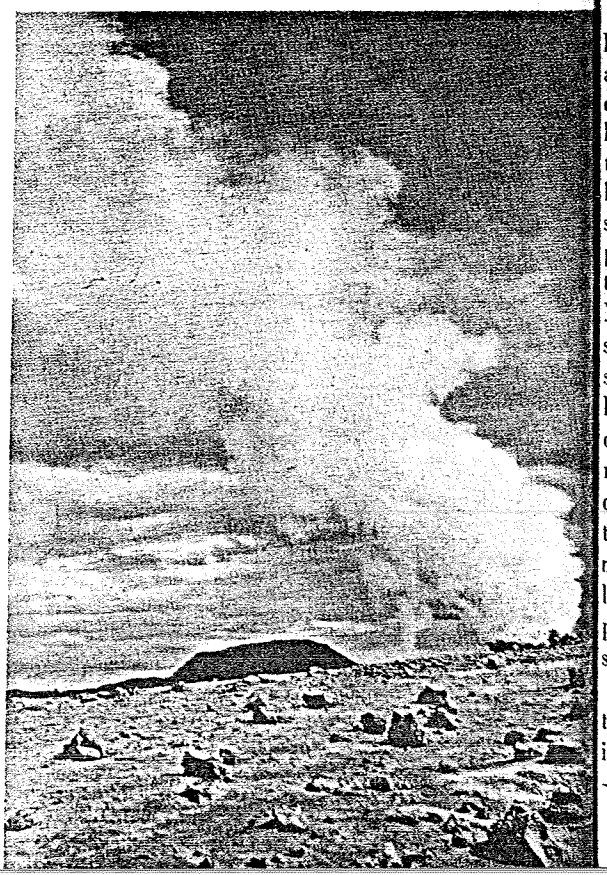


Islands south of Iceland lie along the Atlantic zone of volcanic activity. Eruptions between 1963 and 1966 formed those at left; one has since completely eroded. Older island, below, now contains a fishing village of 5,000 inhabitants.



Volcanic cobbles in a glacial stream, above, are gradually eroded into round, smooth shapes. Polygonal columns of basaltic rock, below left, form as lava cools and shrinks. Clouds of water vapor from a hot spring, below right, rise into the cold Icelandic air. Hot springs result from the heating of ground water by the volcanic rock beneath.





gjas and hot springs in the area, dicates that additional volcanic er tions may be expected in the ne future, and investigations are unc way to predict imminent volcanic tivity in order to avoid unnecessa loss of life and property. Infrar detectors capable of locating areas significant ground heat increases used on the surface, from airplan and from space satellites. Five gions have been identified in whi temperature increases indicate p tential eruption sites: Katla, Hek Odadahraun, Askja, and Surts The last area, a new volcano, h been erupting sporadically sin 1963 when it first appeared as island in the cold Atlantic waters the south coast of Iceland (NATUR HISTORY, March, 1967). Mou Hekla, Iceland's most celebrated vo cano, has experienced major eru tions of ejecta and lava appro mately twice per century since A 1100. From treeless lava plains miles east of Reykjavik, this elo gated composite cone, 4,900 fe high, stands starkly up against th gray, leaden skies.

Hekla's 1947 eruption began as tremendous ejecta discharge th reached to the stratosphere, darke ing the entire countryside and sen ing ash fragments as far as Scand

...avia, 1,000 miles east of Iceland. The lavas, which for more than a year poured out intermittently from many of the vents along the summit, had temperatures of approximately 2,000° F., and added 450 feet to the height of the cone. After the eruptions ceased in the spring of 1948, dense volcanic gases continued to seep down the flanks of the volcano, collecting in nearby depressions where grazing animals were occasionally suffocated by the fumes.

Periodically, portions of Iceland are devastated by great turbulent floods known as *jokulhlaups*. These are sudden outpourings of billions of cubic feet of melted glacial water and result from the subglacial eruptions of periodically active volcanoes, which melt out large pockets of water inside an icesheet. Huge volumes of ice are melted and retained under the glacier until a weakness is found along one side of the glacial terminus. The pent-up waters then burst through the rupture and surge across the countryside carrying huge ice fragments and boulders at velocities of about 60 miles per hour. Farmhouses, barns, people, and livestock in the flood's path are all swept up in a maelstrom from which virtually nothing escapes.

Two active subglacial volcanoes, Katla and Grimsvotn, whose flanks and tops are almost completely covered by broad continental ice sheets, have produced most of the country's recent large *jokulhlaups*. Katla, lying beneath the Myrdalsjokull glacier in southern Iceland, erupts about twice per century, unleashing a *jokulhlaup* that rushes pell-mell across the vast Myrdalsandur plains toward the south coast. Although its maximum surge lasted only two days, the 1918 Katla *jokulhlaup* exceeded the discharge rate of the world's largest river, the Amazon. Katla's most recent *jokulhlaup*, in 1955, was relatively small, but infrared measurements from the Nimbus weather satellite indicate that the volcano may be preparing to unleash its fury and destruction once again.

Iceland's coastal areas south of the Myrdalsjokull and Vatnajokull ice sheets contain wide, flat *sandurs*—broad plains made up of poorly sorted, irregularly layered sand, gravel, and erratic boulder deposits left by glacial meltwaters and successive *jokulhlaups*. Many glacier-fed streams meander southward across these plains toward the sea, while erosion and deposition along their banks cause the streams to shift their beds constantly, to the discomfort of cartographers and local farmers.

Many *sandur* streams in Iceland are unusual because of the rapid erosion of the inner banks along their curves. Normally, streams tend to accumulate deposits on their inner banks and to erode their outer ones since water usually slows down when going around the inner bank of a curve. In Iceland, however, oblique sand or gravel bars left by overloaded glacial meltwaters are often present in the curves at such an angle that the force of the flow may be deflected inward, causing erosion.

One of the world's three major geyser areas is located about 35 miles northwest of Mount Hekla (Yellowstone Park and the Taupo-Rotorua district in New Zealand are the other two). Grand Geysir, has largely ceased its activity during this century after having spouted frequently for hundreds of years. Its huge geyser cone of siliceous deposits—from the hot waters that evaporated after each eruption—is surrounded by about two dozen geysers of various sizes and periods of eruption.

The rarity of geysers throughout the world is determined by the unusual combination of factors essential to their existence. An extensive joint system must reach down into subsurface bedrock heated by adjacent magma. A high water-table (within a few yards of the surface) is also necessary. As ground water seeps into the joint system, the bottom waters are heated far above the normal surface boiling point due to the pressure of the overlying water. The heat spreads through the entire column of water, whose volume expands until its upper level reaches the surface of the ground. Some of the water then overflows out of the ground, sharply reducing pressure on the superheated waters at the bottom of the fissure. These are immediately transformed to gaseous vapors whose volume increases some 1,700-fold, forcing vapor, water, and steam to erupt from the vent until the pressure is spent. Then the system slowly refills with ground water as the cycle begins anew.

About 700 natural hot springs are scattered across Iceland. The hottest (more than 160° F.) are located in the central rift area of volcanism and geologic activity. In some cases, boiling temperatures cause hissing vapors to escape from vents under pressure and to condense as turbulent, misty jets. Whenever soil or clay covers these vents, noisy, bubbling mud pools are formed.

Many of the houses on the island are heated by these geothermal waters. Almost every building in Reykjavik, for instance, is heated by water tapped from 1,000- to 2,000-foot boreholes drilled into the earth. The water, with a temperature of about 220° F. at its underground source about ten miles from town, enters the homes at about 212° F., losing little heat in transit.

Hydrothermal energy is of vital importance to Iceland's economy, inasmuch as few trees grow on the island at present, and no significant coal or petroleum is found in the volcanic bedrock. Birch forests, which blanketed parts of the country centuries ago, never recovered from extensive cuttings by early settlers.

Hveragerdi is a small town located approximately 25 miles from Reykjavik. This little village, less than 200 miles from the Arctic Circle, is well known for its fruits, vegetables and flowers—even tropical varieties—the result of its hydrothermally heated hothouses. Many of the homes and work buildings are built right over the hot springs. Several years ago one family got more hydrothermal heat than it wanted when a crack opened in the kitchen floor and scalding water gushed through the house. Icelanders, however, are glad to deal with relatively small inconveniences in return for their inexpensive, pollution-free, and readily available heat source. With the benefit of centuries of experience, they have learned to cope with, use, and appreciate their country's unique, if sometimes troublesome, geologic resources.