INTERNATIONAL ASSOCIATION OF VOLCANOLOGY AND CHEMISTRY OF THE EARTH'S INTERIOR

IAVCEI
INTERNATIONAL SYMPOSIUM ON VOLCANOLOGY
ANDEAN AND ANTARCTIC VOLCANOLOGY PROBLEMS

9 - 14 September 1974
Santiago - CHILE

EASTER ISLAND
ISLA DE PASCUA

GUIDE BOOK - EXCURSION D-2

Prepared by

O. GONZALEZ-FERRAN* and P. E. BAKER**

SCIENTIFIC GUIDES: Peter Baker and O. González-Ferrán.

* DEPARTAMENTO DE GEOLOGIA UNIVERSIDAD DE CHILE

** DEPARTMENT OF EARTH SCIENCES UNIVERSITY OF LEEDS

NATIONAL SPONSORS

MINISTERIO DE RELACIONES EXTERIORES
COMISION NACIONAL DE INVESTIGACIONES CIENTIFICAS Y TECNOLOGICAS
INSTITUTO GEOGRAFICO MILITAR
UNIVERSIDAD DE CHILE
INSTITUTO DE INVESTIGACIONES GEOLOGICAS
INSTITUTO ANTARTICO CHILENO
ACADEMIA DE CIENCIAS - INSTITUTO DE CHILE

ORGANIZING COMMITTEE

JORGE LEON VILLARREAL
General de Brigada
President

Prof. OSCAR GONZALEZ-FERRAN
Executive Secretary

Prof. ALFREDO LAHSEN A.
Treasurer

Members: Ing. Iván Casanegra, Ing. José Castellá, Prof. José Corvalán, Sr. Germán Gaymer, Geól. Patricio Trujillo, Prof. Mario Vergara, Prof. Jean-Claude Vicente, Sr. Ulises Aburto, Sr. Angel Torre.

SANTIAGO - CHILE - 1974

A LA MEMORIA
DE NUESTRO COLEGA
RENE CARMONA
DESAPARECIDO EN LA ISLA
EL 30 DE SEPTIEMBRE DE 1967

POST-SYMPOSIUM EXCURSION

D-2 EASTER ISLAND (September 15 to 21)

Located 4.000 Kms from Santiago, in the middle of the Pacific Ocean (27° 08′ Lat. S., 109° 26′ W. Long.). The evolution, structure and petrographic characteristics of the volcanic centers Rano-Kau, Terevaka, Poike, Rano-Raraku, Anakena, Orito, will be studied together with several parasitic centers that make up the structure of this volcanic island.

SUNDAY 15. 13.15 hours. Departure from Pudahuel International Airport, Santiago. 15.50 hours (local time) arrival at Mataveri Airport, Easter Island. Lodging and dinner at the Hosteria.

GENERAL INTRODUCTION

Easter Island was discovered by Admiral Roggeven on Easter Day, 1722.

This island is wholly of volcanic origin and was formed on the East Pacific Rise. No continental or sedimentary rocks are found except for a negligible development of beach sand of shell and coral. The form of the island is roughly triangular due to the development of three principal volcanoes, one at each corner. The island measures about 22 x 11 Km in dimension, 117 Km^2 in area, and is about 506 m a.s.l. in maximum height (Maunga Terevaka).

Although many scientific works on this island have been published, most of them are on the archaeology, anthropology and linguistics, etc., because hundreds of great stone statues or "moais" and a large number of ceremonial centers or "ahus" have attracted the attention of scientists.

Geological studies, on the other hand, are rather few. Brief and fragmentary accounts on the petrography of the island were given by Tilley (1922), Rosenbusch and Ossan (1923), R. Speight (in Brown 1924, p. 66-67), Lacroix (1927), and others. The materials used in these studies were collected by earlier expedition parties. Chubb (1933) was the first geologist who visited the island (in 1925) and wrote on the geology and petrography. Then, Bandy (1937) spent eight days there in 1933 and studied the geology and petrology. The contribution provided by both geologists is valuable.

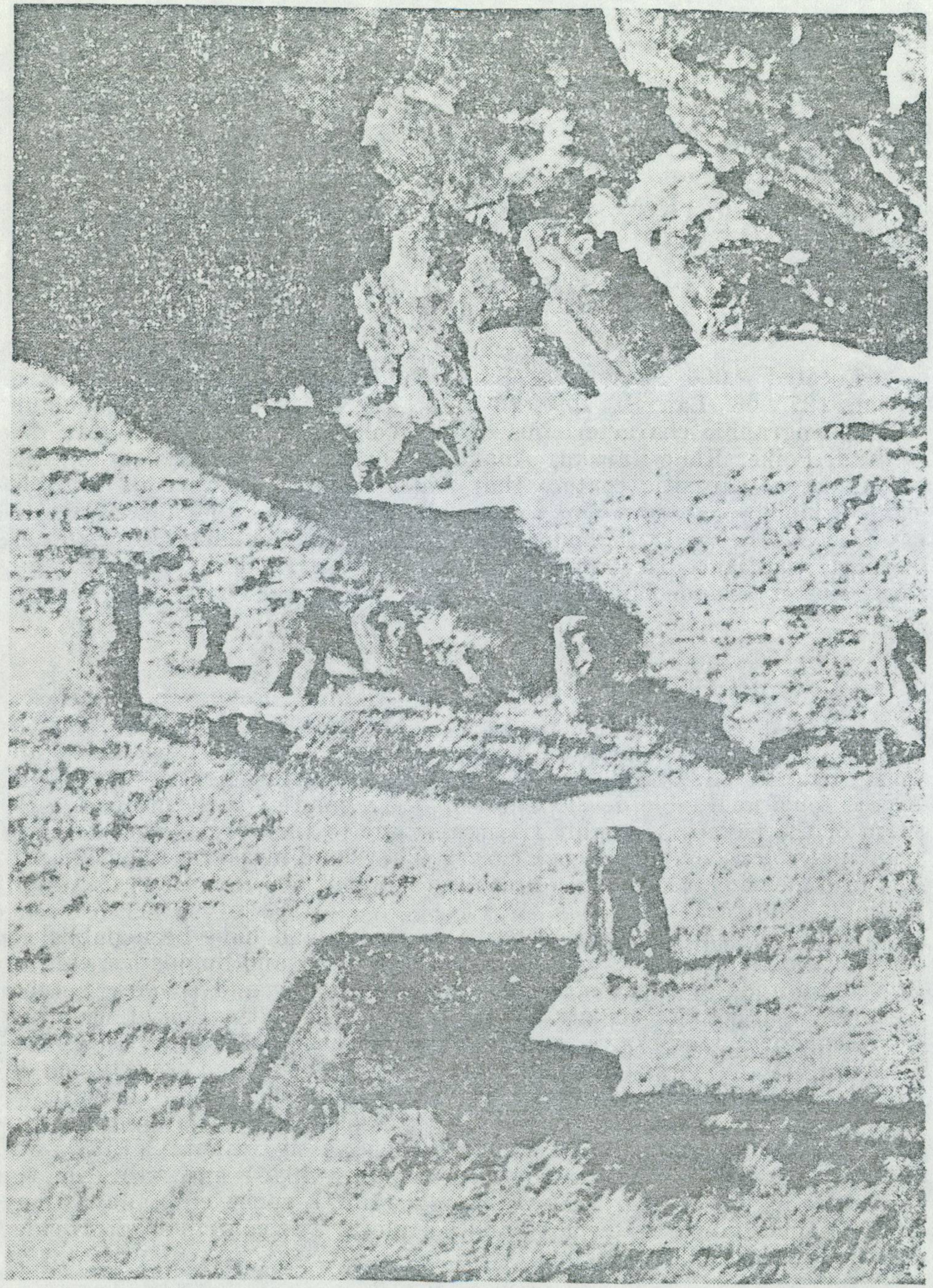


Fig. 1.—Rano Raraku volcano. Moais quarries.—Photo O. G. F.

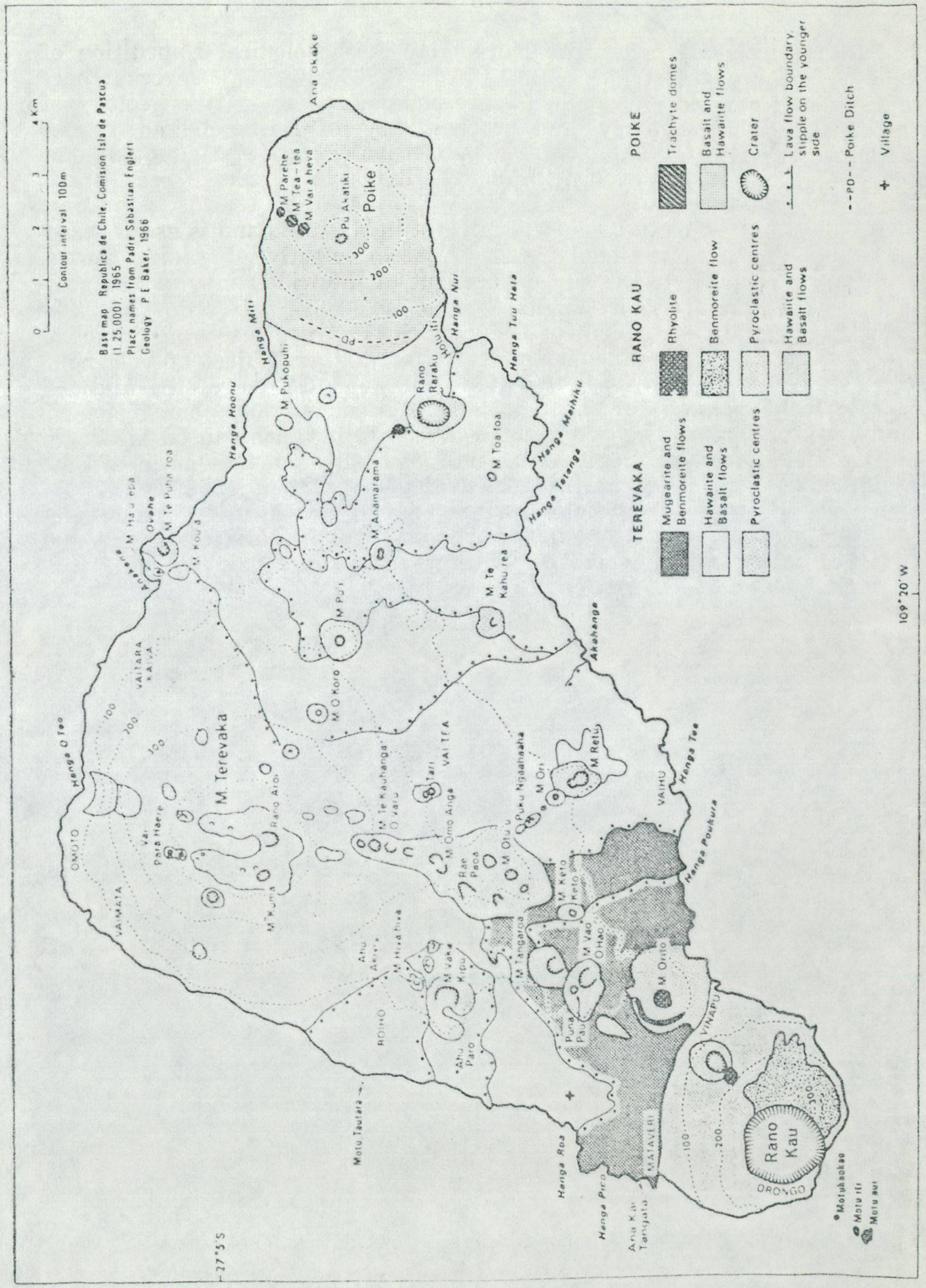


Fig. 2.—Geological Map of the Easter Island after Baker et al 1974

In recent years, after the Norwegian Archaeological Expedition of 1955-56 (Heyerdahl et al., 1961), Baker (1967) spent 3½ weeks there in 1966, and carried out a much more complete study on the geology of this island. The petrology and geochemistry of Easter Island is also described by Baker et al., 1974. The geochronology, Sr 87/Sr 86 relations and general geological evolution are described by González-Ferrán et al., in this Symposium.

Nowadays the main geological interest in Easter Island is as an example of a young volcanic island situated close to an active spreading centre.

It is especially interesting on account of the wide range of compositional types that are represented.

In 1967, the Department of Geology, the University of Chile, started the geological study of this island as a part of the project of volcanological study of Chilean territory. René Carmona R., one of the authors, of the Geological Map of the Island made a preliminary photogeological study. Unfortunately, he encountered an accident which caused his death during field work in September, 1967. In spite of this accident, the Department decided to continue the work. In October, 1968, O. G. F. and Y. K. F. carried out field work for a full month, under the special facilities kindly offered by "el Gobernador", "el Alcalde", "FACH" and many of islanders, to whom our hearty thanks are due.

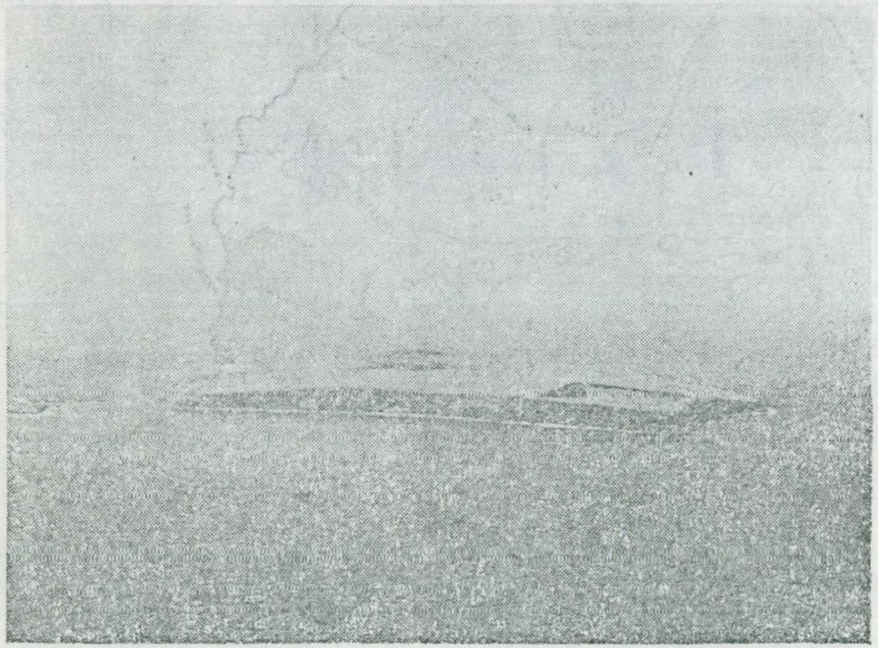


Fig. 3.—Poike Volcano, South East cliff.—Photo O. G. F.

STRUCTURAL SETTING

Easter Island is situated some 4.000 Km. west of the Chilean coast and is about 500 Km. east of the crest of the East Pacific Rise. It has been built about three main volcanic centers, Poike, Rano Kau and Terevaka, but much of the activity has clearly been fissure controlled. M. Terevaka is a complex fissure volcano with the major vents aligned in a NNE-SSW direction from Hanga Oteo to M. Orito. The parasitic centers of Rano Kau and Poike are aligned in a NE-SW direction. It is possible that the orientation of these vents is a reflection of the northerly or northeasterly trend of the East Pacific Rise. A second major directional control is clearly brought out by the line of cones running south-eastwards from the summit of Terevaka to Rano Raraku. This is precisely the trend of the Tuamotu and Nasca rigdes which intersect the East Pacific Rise to the south of Easter Island. The E-W trend of the Easter fracture zone wich runs to the north of Easter Island does not seem to find expression on the island itself.

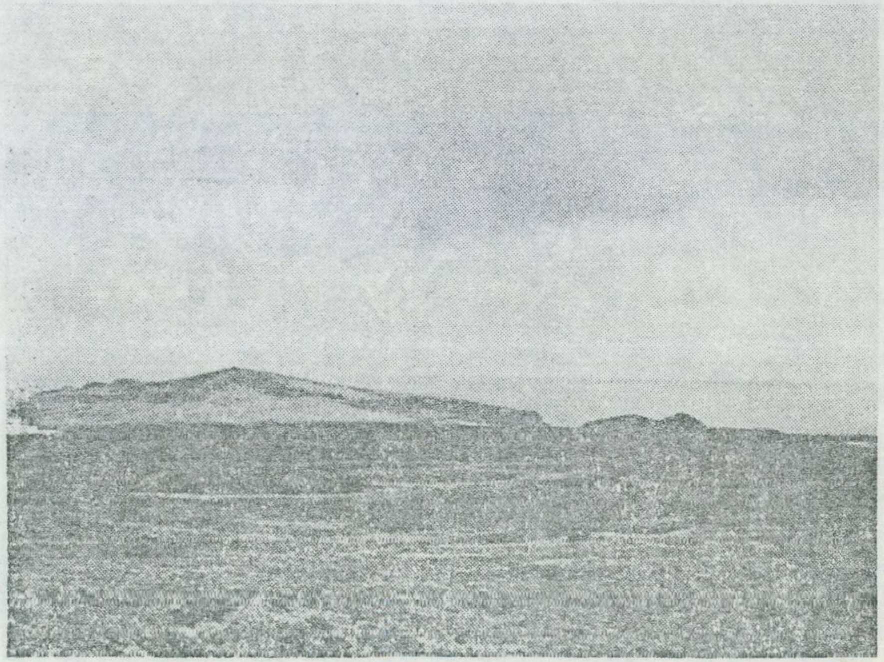


Fig. 4.—Poike Volcano and lava dome in the north. View from de west.—
Photo O. G. F.

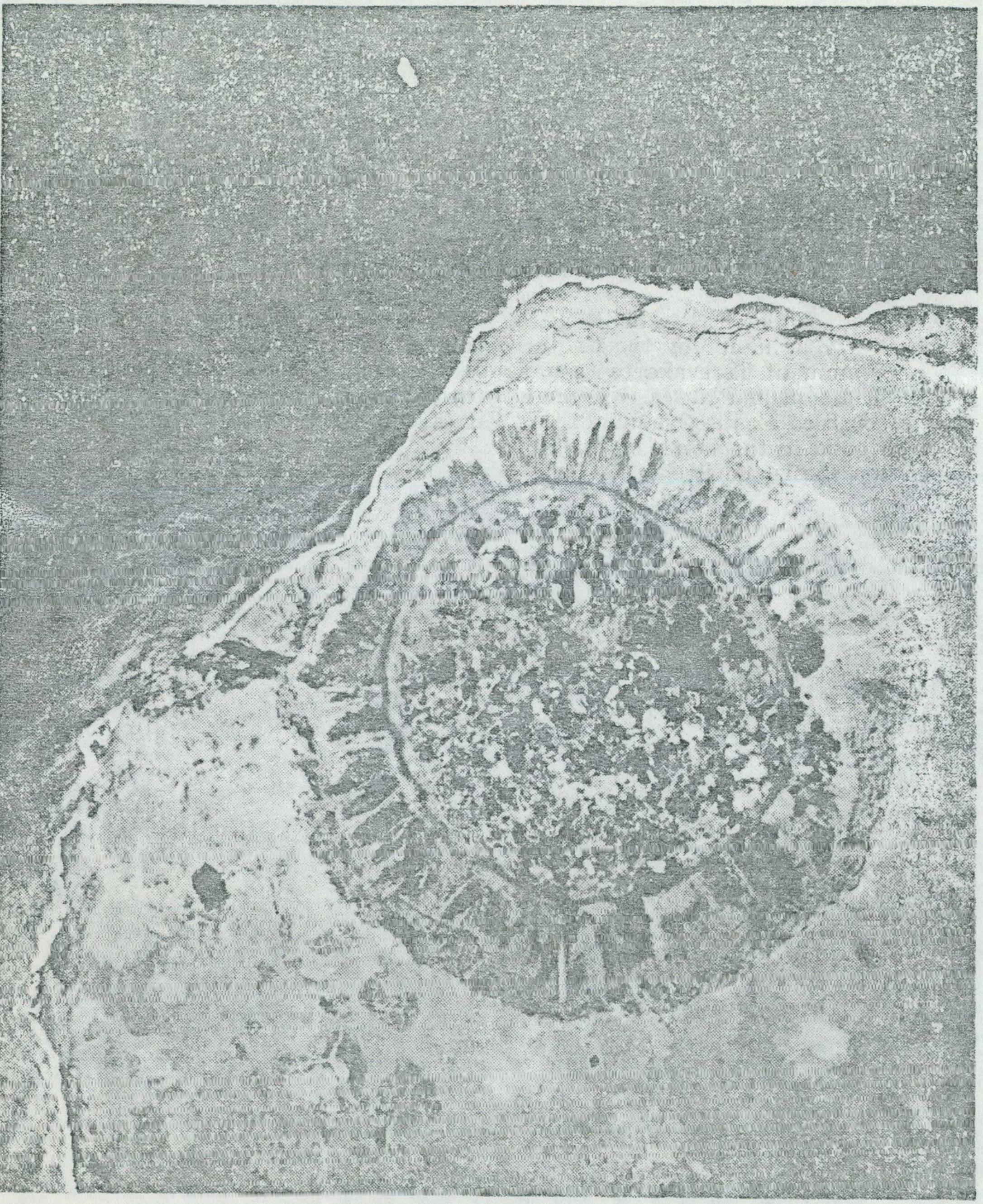


Fig. 5.—Rano Kau Volcano. Air view.—Photo FACH

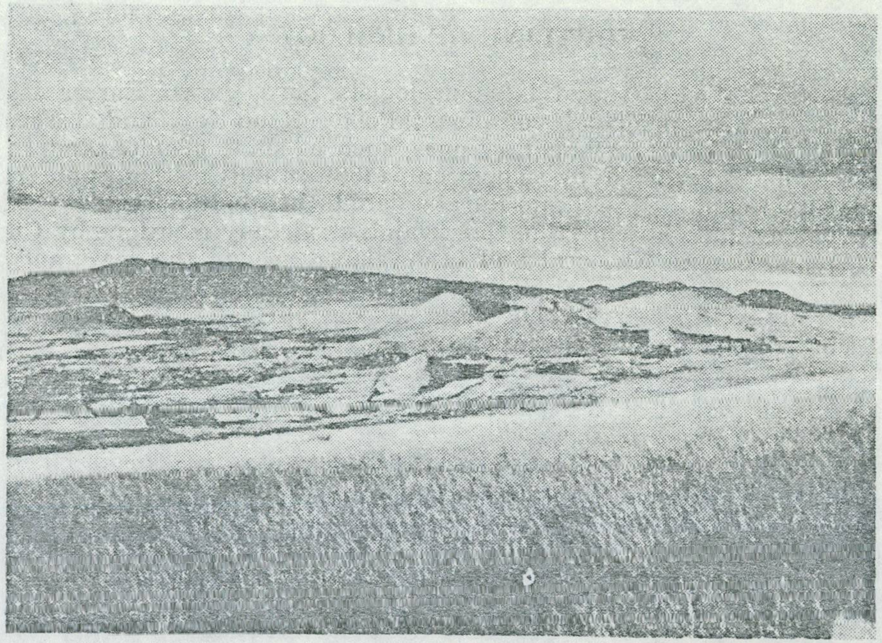


Fig. 6.—Terevaka and Otuu - Tangaroa Volcanoes.—Photo O. G. F.

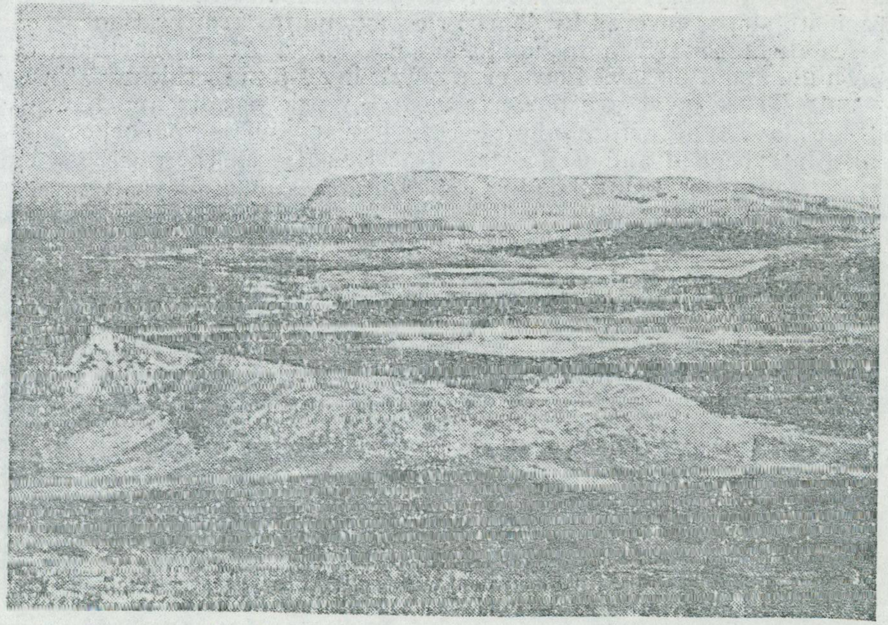


Fig. 7.—Rano - Raraku Volcano at the first plane and general view of the South coast.—Photo O. G. F.

OUTLINE OF GEOLOGY

As Chubb (1933) and later geologists have shown Easter Island consists of three principal volcanoes; Poike, Rano-Kau, and Terevaka. Continental rocks or sedimentary ones, such as slate, granite, and flinty beach pebbles reported by Thomson (1889), and metamorphic rock-fragments found in the Rano-Raraku lapilli-tuff by Routledge (1920), are probably quite absent from this island, as already mentione by Chubb (1933) and others. No coral reef is developed around the coast and the island is purely volcanic in origin. The volcanic topography of this island is generally well preserved. The great permeability of basaltic lava flows and cinders has an important bearing on the geomorphology of the island. As pointed out by Bandy (1973), there is practically no stream erosion. The formation of the island is supposed to range from Pliocene-Pleistocene to Holocene, according to the radiometric ages.

Poike Volcano

It shows a simple, nearly symmetric conical form, and is built up mostly of basaltic lava flows. At the center of the volcano there is a rather small summit crater named Pu-Akatiki, about 150 m in diameter and 10-15 m in depth, around which strongly porphyritic basaltic lava flows rich in large plagioclase phenocrysts widely extend, but pyroclastic materials are scarcely found. From the summit of the volcano, gentle and smooth slopes covered by short grass extend toward the flanks where high sea-cliffs, 25-175 m in height are developed. At the northern cliff, 175 m high, about 50 lava flows crop out, being 1-5 m in thickness in each flow unit. These lavas are porphyritic to aphyric basalts and hawaiites, mostly of "aa" type with clinkers on the surface, while "pahoehoe" lavas are also interbedded and well exposed at Rúa-Híe on the northern cliff, where a profile of "pahoehoe-toe" is typically shown. Lava tunnels are sometimes observed in the sea-cliff. The traditionally famous cave called Ana-o-Keke, where selected girls were kept to increase the whiteness of their skin, has an entrance near the top of north cliff through which a man can barely wriggle his way, although it leads to successive rooms continuing 380 m into the cliff (Heyerdahl, 1961).

As far as we observed in the sea-cliffs fragmental ejecta appear to be quite rare. In a northeast direction from the principal crater, three lava domes of aphyric trachyte are aligned. The northeast one of the three has been partly destroyed by the advancement of the sea-cliff. As metioned by Baker (1967) these are lava domes, although both Chubb (1933) and Bandy (1937) suggested they were cones.

At the western foot of Poike, a cliff obviously formed by marine erosion is also traceable inland, where porphyritic basaltic lavas from the parasitic cones of Terevaka abut against the western foot of Poike. It can be supposed that before the eruption of these Poike was most likely an isolated, volcanic island. Due to filling up with the new lavas further development of the sea-cliff was prevented. The age of linkage

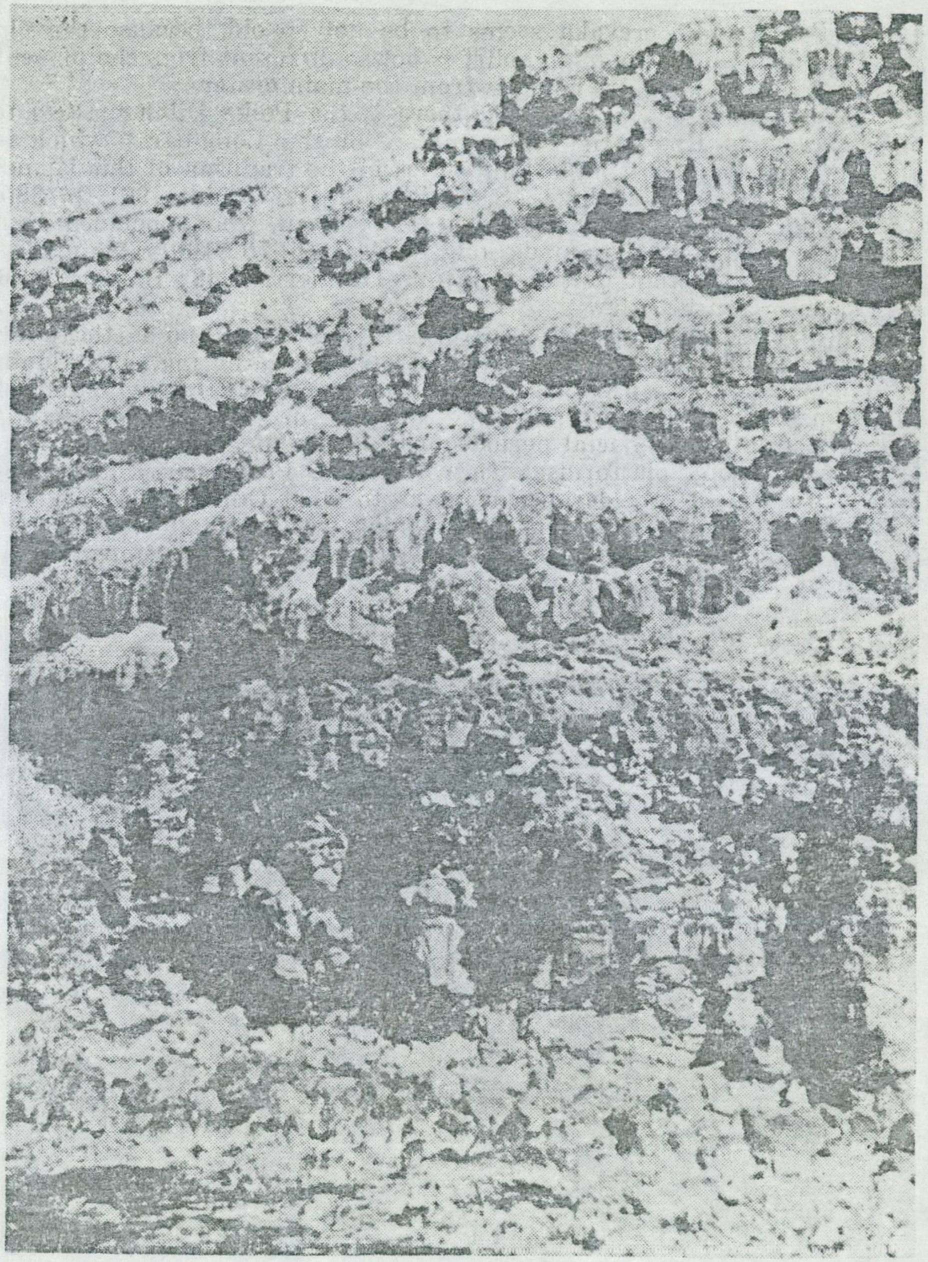


Fig. 8.—Northern cliff of the Poike Volcano. About 50 lava flows, being 1 to 5 m. in thickness each lava flows.—Photo O. G. F.

between Poike and Terevaka seems to be not so old, because the old coast line indicated by the inland cliff is not so different from the present coast line of other sides in distance from the main crater.

Above the western inland cliff, there is the Poike Ditch or "Ko te Umo o te Hanau Epe" (the cooking place of the Long-ears) which is known as one of the most important places in the tradition of this island. This ditch was excavated by C. S. Smith (in Heyerdahl, 1961, p. 385-391) of the Norwegian Achaeological Expedition who concluded that the ditch was entirely man-made, dug in A. D. 1676±100. This age almost concides with that of the tradition (Englert, 1948; Baker, 1967) subscribed to Smith's view.

One of the characterististic features of Poike volcano is the development of reddish soils indicative of tropical weathering. The flanks of Poike Volcano have been severely reduced by marine erosion. In this connection, Quiring (1957) suggests that the origin of the island is placed in the lats interglacial period, on the basis of a correlation of its two marine erosion platforms with world-wide Pleistocene chronology. However, we are in considerable doubt as to what Quiring has referred to. The marine erosion platforms in question was originally reported by Knoche (1925). According to him, the elevation of two platforms is 20 m and 5 or 10 m above the present sea-level, respectively.

One of the lava flows from the northern foot of Poike gave a K/Ar age of about 3 m.y. (Baker et al., 1974).

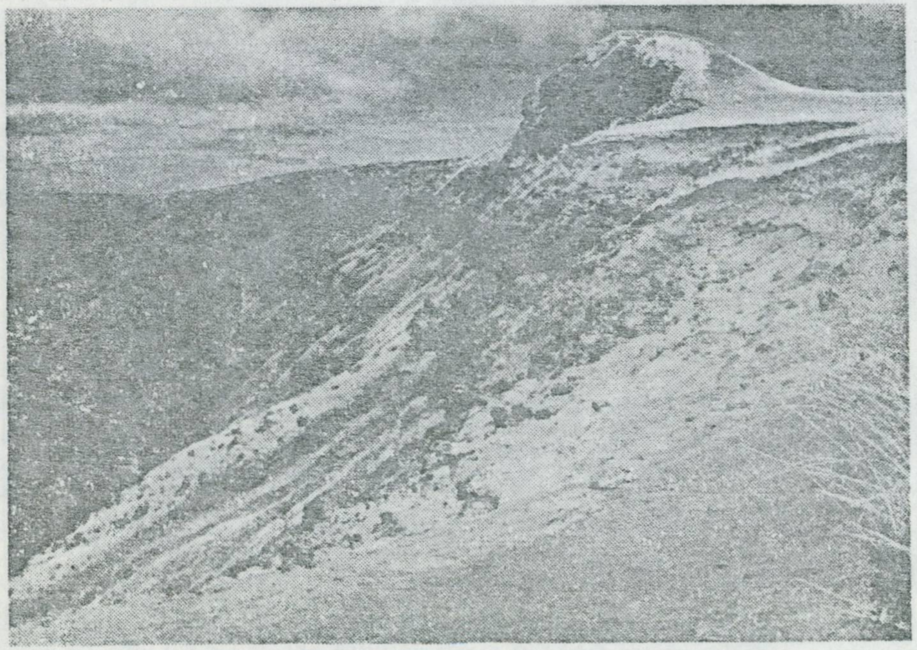


Fig. 9.—Poike Volcano. Maunga Papehe trachyte lava dome.—Photo O. G. F.

Fig. 10.—Pahoe-hoe-toe lava flows. Terevaka volcano.—Photo O. G. F.

Rano-Kau Volcano

At the summit of this volcano, there is a small caldera which measures 1.6 Km in diameter and 200-250 m in depth. Many lava flows are exposed in the upper part of the precipitous caldera wall, with steep slopes of heavy talus down to the bottom. Orongo, a traditional ceremonial center, is on the western part of the wall. The caldera floor is occupied by a shallow fresh-water lake covered by a thick floating bog of *Polygonum* and totora reed.

Marine erosion has curtailed most of the southwestern part of the volcanic body, where high sea-cliffs reaching 200-300 m are developed. At Kari-Kari, the sea-cliff is jointed with the caldera wall, and marine erosion is still reducing the wall. Almost 50 lava flows of aphyric and porphyritic basalts are exposed on these sea-cliffs. As with Poike, these are mostly "aa" type, and are interbedded with quite few pyroclastics. These are grouped as the lower somma lavas.

Near the caldera, especially on the eastern slope, thick lava flows of the upper somma benmoreite lava flow, form the rough irregular terrain; probably they were much more viscous at their eruption. These upper somma lavas are also well exposed in the upper part of the cal-

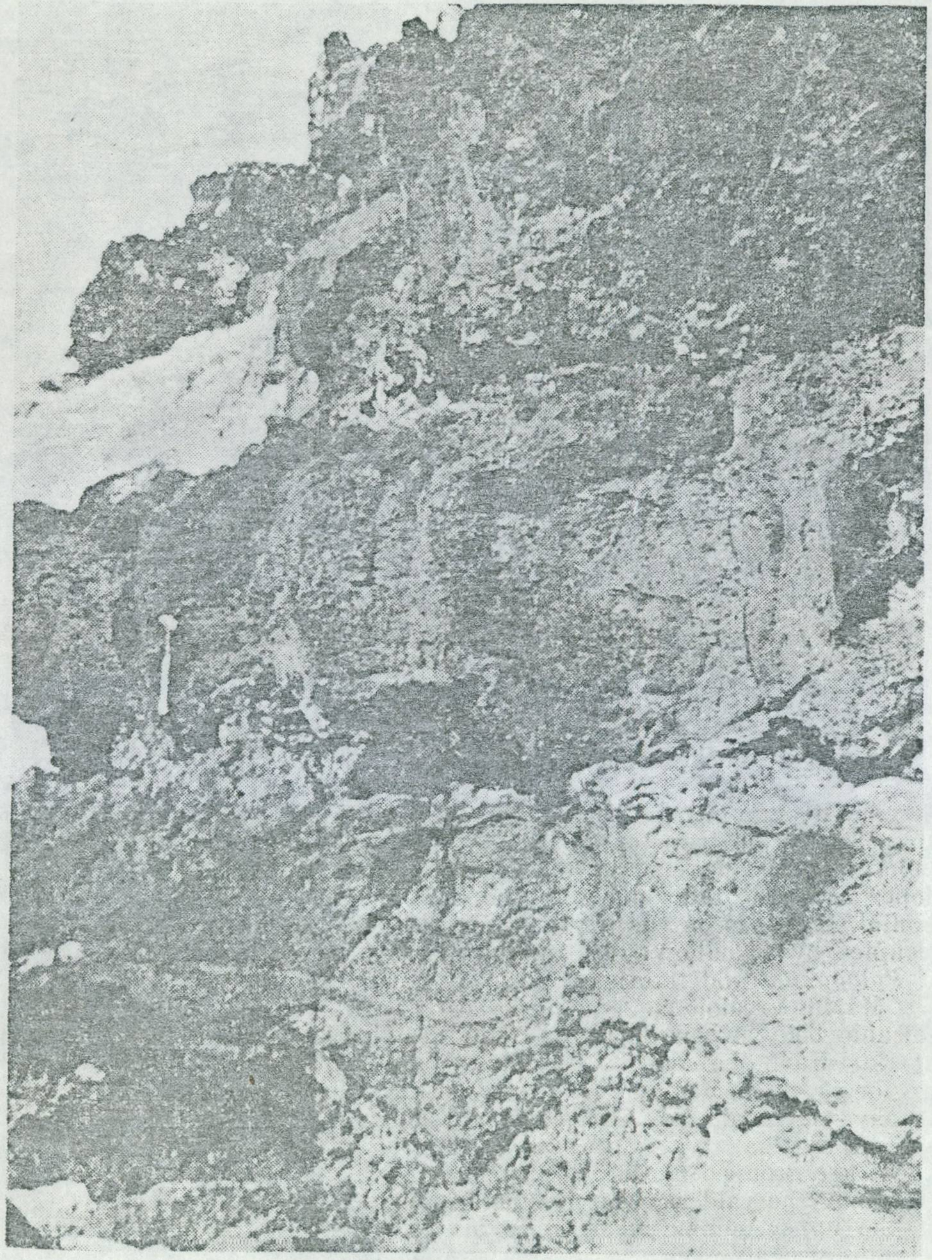


Fig. 11.—Rano Kau volcano. Lava flows at west cliff.—Photo O. G. F.

dera wall. Sometimes platy jointing is well developed. The "boat houses" at Orongo are constructed with these platy-fractured slabs.

The northeastern slope of Rano-Kau is generally gentle, and covered by a thick pumice deposit with obsidian and lithic fragments. This deposit reaches a maximum thickness of about 5 m at the northern rim of the caldera, where it covers the upper somma lava, showing a characteristic feature of pumice-fall deposit. It can be considered that this pumice was most likely erupted towards the final stage of Rano-Kau volcano, and that this activity resulted in depression of the caldera.

Before the culminating activity of pumice, however, some parasitic cones of intermediate to felsic products were formed in a NE to SW direction. On the northeastern slope, there is a low dome consisting of a light grey aphyric trachyte-rhyolite with obsidian on the surface. Northeast of Te-Mamavai, there is Maunga-Orito with a summit lava dome, about 200 m a.s.l., composed of rhyolite.

The area at the north on foot of Rano-Kau and Orito is covered by thick aphyric lava flows from Vai-o-ao, one of the parasitic cones of Terevaka. This relation can be well observed at Vinapu and Mataveri-o-Tai. It is noticed here that the younger lavas of Terevaka abut against the intensely weathered surface of Rano-Kau and Orito, in the same relationship as at the western foot of Poike.

Although we cannot say which volcano is older or younger, both Poike and Rano-Kau are, without doubt, older than Terevaka. Both volcanoes of the older stage of Easter island have been severely reduced by marine erosion and deeply weathered.

It may also be concluded that the greater part of both older volcanoes has been formed by repeated eruption of basaltic lavas in their youthful stage. But, toward the final stage, the magma became much more felsic; viscous lavas and lava-domes became were extruded along a NE-SW direction in both volcanoes. Subsequently, a vigorous eruption of pumice occurred at Rano-Kau, resulting in the formation of a caldera. However, as will be referred to later, Terevaka volcano appears to be still in its youthful stage. No felsic product has been erupted as yet from this volcano.

An intensely weathered surface of reddish color, especially on the eastern half of Orito, and the presence of a younger cinder cone at the north flank, might give an impression that most of the volcanic body of Orito is composed of pyroclastics as suggested by Baker. However, according to our observation (OGF, YGF) especially at the good outcrop of Vinapu coast, Orito is mostly built up of thick aphyric lavas of intermediate to felsic composition and a few pumice and ash deposits interbedded with them. They cover the basaltic older somma lavas of Rano-Kau. Then, subsequently, a highly viscous lava of trachyte-rhyolite was extruded, flowed down to the west and finally stopped the vent as a lava dome. Obsidian on the west flank represents the chilled surface of the lava.

Flow layers as shown in the old experiment by Reyer (1888) are typically developed in the dome lava. Recent engineering works on the small cinder cone on the north foot of Orito revealed its whole structure; it is an independent cinder cone composed of cow-dung bombs, scoria, and lapilli of aphyric basalt. It seems that subsequent to Orito this cone has erupted on the southern end of the major fissure system of Terevaka.

Off the southwest of Rano-Kau, three islets, (*) Motu Kao-Kao, Motu Iti, and Moto Nui, are arranged in the same direction of the parasitic eruption centers of Rano-Kau as mentioned by Baker (1967). Baker reported an occurrence of rhyolite and obsidian on these islets. Probably these islets were formed in the later stage of Rano-Kau, like the other parasitic eruption centers of Te-Mamavai and Orito.

Terevaka Volcano.

Terevaka volcano and its numerous minor parasitic cones form the major part of Easter Island. As already mentioned by Chubb (1933) and others, remarkable fissure systems from which eruptions took place, are well developed. Therefore, its volcanic shape does not represent a single conical form with a principal crater at summit, but it resembles a shield volcano.

Maunga Terevaka (506 m a.s.l.) and the northern part of the island, form the summit part of the Terevaka volcano. The summit area covers about 3 Km. in diameter and reaches, more than 400 m in elevation. Gentle slopes, mostly composed of basaltic and hawaiite lava flows, extend from the summit and join Terevaka with the two older volcanoes of Poike and Rano-Kau.

Sea-cliffs around Terevaka are generally low (5—25 m in height). However, exceptionally high cliffs, some up to almost 100 m in height, are developed on the northern coast of Terevaka. It is noticed here that the slopes of the hinterland are characteristically steep. As mentioned by Stearns (1966), waves are far more effective in cutting high cliffs in the same length of time on steep slopes, because the material off slopes can be transported into deep water more easily. Another exceptionally high cliff is found on the southeast side of Rano-Raraku, one of the parasitic cones of Terevaka. As suggested by Chubb (1933), this cliff has been cut by marine erosion prior to its enclosure by younger lavas from other cones. The development of this sea-cliff, however, is responsible for the rather soft lapilli-tuff which forms this cone.

About a hundred craters or eruption centers are distributed on the surface of Terevaka. Sixty per cent of them are aligned within a narrow belt 1 Km. in width and 12 Km. in length which runs from north to southwest through the summit, somewhat arcuately at the southwestern part. This may be called the major fissure system. This major fissure system consists of not a single but 4 or probably 5 fissure units.

Other craters are distributed on the east, south, and southwest slopes and flanks. Some of them also show remarkable linear arrangements, as

(*) "Motu" means islet.

Fig. 12.—Terevaka volcano. Lava tunnel.—Photo O. G. F.

manifested by 50-79 and M. Pu'i-Rano-Raraku; each arrangement comprises eight eruption centers. The three young, small cinder cones of M. Hiva-Hiva, M. Maea-Horu, and M. Omo-Anga clearly show a linear arrangement. More sporadically distributed parasitic cones are mostly seen on the eastern flanks of Terevaka where such a remarkable fissure system does not develop. Near the fissure systems independent cones are rather few as a rule. It may be considered that due to the development of the major and subordinate fissure systems, ascending magma has been concentrated in these systems.

As mentioned by Baker (1967) the bulk of Terevaka volcano, however, has been constructed by lavas and pyroclastics emitted from within the vicinity of the present summit.

The formation of the main volcano of Terevaka can be divided into the following three periods; the older, middle, and younger. The greater part of the main volcano of Terevaka is mostly built up of lavas and a few pyroclastic of aphyric basalt which have formed in its older period. The present outcrops of this older volcano are generally limited due to covering of subsequent lavas. On the northern flanks, for example, these older aphyric lavas are exposed in narrow ridges or slopes. On the southern flanks, however, their outcrops are much more extensive. Most of their emission centers are also concealed in the same way, but it is sure that they were in the vicinity of the present summit. An eroded cinder cone on the northern summit, 437 m in height, for example, represents one of them. This cone is composed of cow-dung bombs, scoria, and lapilli of aphyric basalt which are sometimes welded. Pyroclastic hills on the west of Rano-a-Roi are probably of this period: their craters are almost indistinct except for two explosion craters formed in a late phase of eruption. The above mentioned cinder cones in both regions represent the northern and southern extremities of the emission centers of this period.

On the western summit of Terevaka, a remarkable ridge composed of some 14 cinder cones extends a little over two kilometers from north to south. M. Terevaka, one of these cones, is the highest peak of the island, 506 m in elevation. However, each of these cones is itself less than 100 m in relief, and has a small crater, 50—100 m in diameter. In spite of such small cones they emited a great many lava flows of porphyritic basalt which widely covered the western half of the older main volcano. Extension of the lavas to the eastern side in uncertain due to covering of the lavas of late date. Probably they did not extend beyond the range of the older cinder cones.

Subsequent to the activity of the middle period, a large quantity of basaltic lava erupted from the eastern part of the summit, where several craters are aligned in a line running from north to south for a distance of about 1,2 Km. Rano-a-Roi, the largest crater, about 200 m in diameter, is at the southern end. Inside this crater, there is a shallow fresh-water lake in which totora reeds grow. A constant stream from the crater lake overflows for about 1 Km. before it sinks into the permeable lavas. Around the craters of the eastern summit, pyroclastic materials are scarcely developed, unlike those of the western summit. The central and

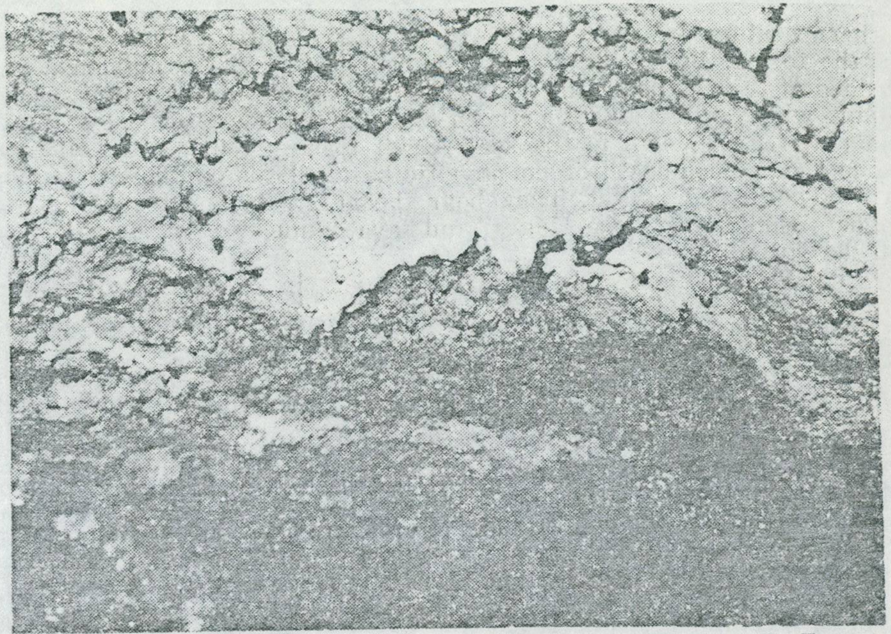


Fig. 13.—Lava tunnel. Hiva-Hiva lava flows.—Photo O. G. F.

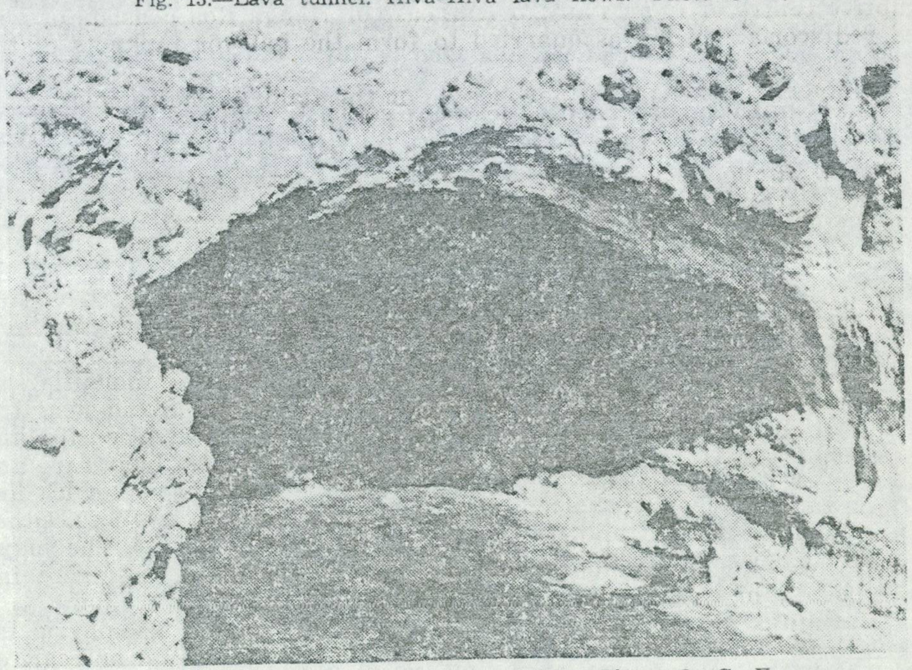


Fig. 14.—Lava tunnel. Orage Roa.—Photo O. G. F.

southern craters are larger than those of the northern part; it seems that the former have been enlarged by collapse when the magma column subsided at the final stage of activity. The lavas emitted from the eastern summit widely covered the northern and eastern slopes of the main volcano and flowed down to the sea. All of these younger lavas are very porous and are composed of porphyritic basalt. Soils on their urface are scarcely developed as yet. They bear the characteristic feature of "pahoehoe"; tumuli, pressure ridges, and lava tunnels of various sizes are well developed.

Rano-Raraku and M. Toa-Toa formed in the early period of Terevaka volcano; their flanks have been cut by marine erosion and buried beneath the younger lava as mentioned earlier.

Unlike most of the other cones of the island, both cones are built of lapilli tuff of basaltic composition. Consolidation of the lapilli and ash to tuff appears to have occurred mostly by the alteration of glassy materials (not by welding).

M. Toa-Toa is severely eroded and shows a pyramidal shape; but Rano-Raraku still preserves its original form except for the southeast part where a high cliff cut by marine erosion is developed. Rano-Raraku rises about 100 m above the surrounding younger lavas: in its crater which is 700 x 650 m in diameter, there is a fresh-water lake surrounded by a swamp of totora reeds and polygonum. All the great images or "Moais" were carved from the Rano-Raraku lapilli tuff. The small eruptive centre of Puna Pau 2.5 Km. east of Hanga Roa consists of welded red scoria which was quarried to form the hats or topknots of the moais.

Numerous other parasitic cones lie on the flank of the complex, most of them apparently lying along NW-SE trending fissures. The youngest of the lava flows is that emitted from M. Hiva-Hiva across the area known as Roiho. Another young flow occurs on the east of the island, emanating from the small centro of M. Anamarama.

PETROLOGY

Easter Island is composed of tholeiites or olivine tholeiites and their differentiates hawaiite, mugearite, benmoreite, trachyte and rhyolite. The suite is in many senses transitional between alkaline and tholeiitic suites (e.g. those of Hawaii) but is characteristic of those found near the crest of mid ocean rises and closely resembles the suites of Ascensión and Bouvet in the Atlantic. Basalts, in the strict sense are relatively rare and hawaiite is by far the dominant rock type. Tholeiitic basalts with low SiO_2 and K_2O and high total iron occur in the vicinity of Vai Tea. Other aphyric basalts are to be found on the south-west side of Poike. The young Roiho flow is on the boundary between basalt and hawaiite and contains an unusually high percentage of both modal and normative olivine.

Hawaiites are widespread and are generally plagioclase-phyric lavas with less conspicuous olivine and augite. They grade into mugearites and benmoreites, which are most abundant around Mataveri and Orito in

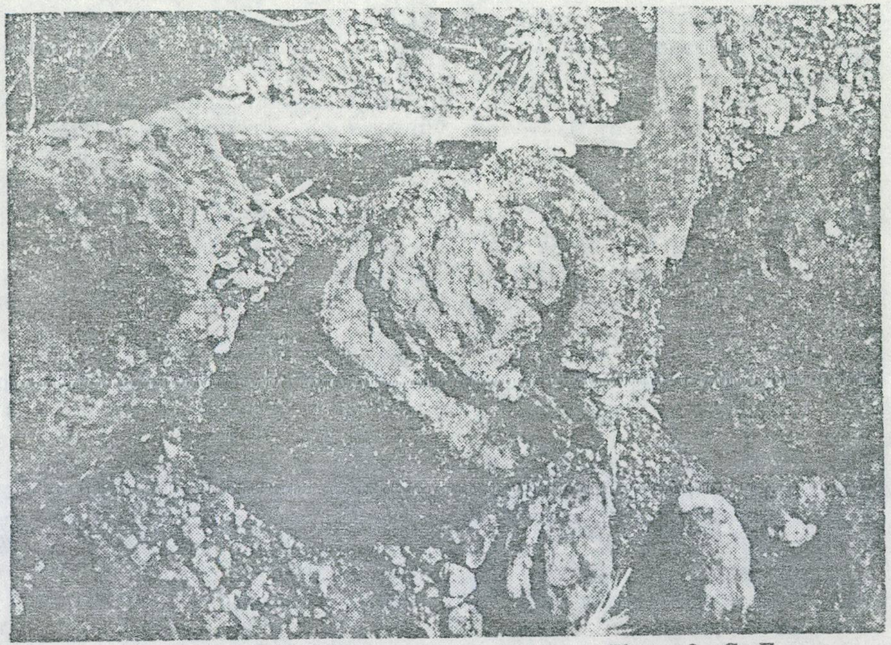


Fig. 15.—Cow-dang bomb. Otuu Volcano.—Photo O. G. F.

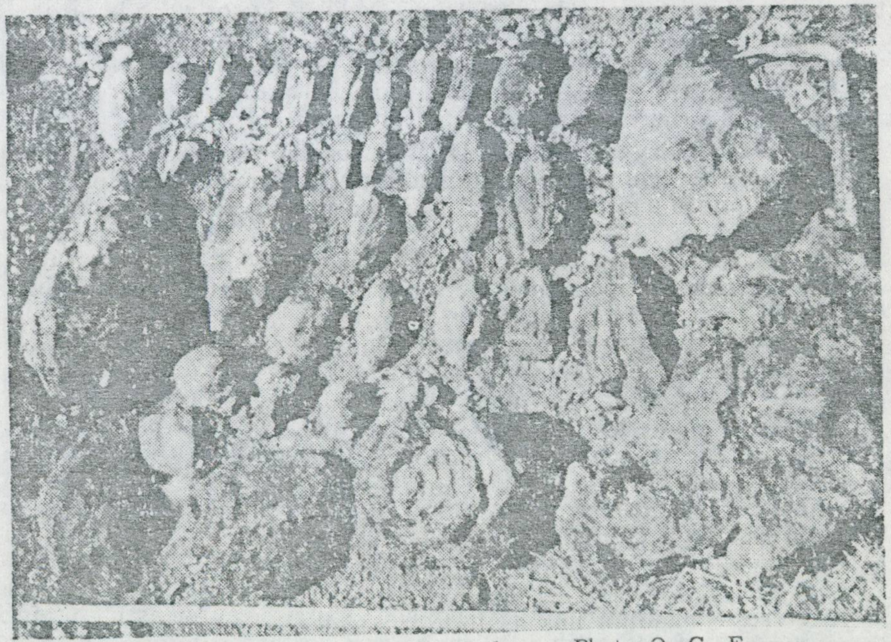


Fig. 16.—Bombs from Otuu volcano.—Photo O. G. F.

the south-west of Easter Island. These intermediate lavas tend to be aphyric or almost so. White fayalite-bearing trachytes form the parasitic domes on the north side of Poike and rhyolitic, slightly peralkaline (comenditic) obsidian are to be found in small outcrops on Rano Kao, the offlying islets and M. Orito.

Chemically the Easter island suite is distinguished by a combination of high total iron, low MgO and low K_2O. Na_2O is high throughout the suite and reaches over 6% in the Poike trachytes. There is a high concentration of Zr which reaches over 1.000 ppm in the acid rocks.

Although the compositional range represented at each of the three centers is somewhat different, the lavas generally conform to a uniform geochemical pattern. There are, however, some differences especially at the acid end of the suite where, for example, the Poike trachytes have relatively high concentrations of Zr, Rb, and Nb compared with their nearest equivalents from Rano Kao and Terevaka.

EASTER ISLAND — ITINERARY

MONDAY 16 SEPTEMBER p. m.—**Differentiated lavas of the southwest. Hanga-Pico — Ana-kai-tangata — Orito — Vinapu**

Basaltic or hawaiite lavas in the immediate vicinity of Hanga Roa are older flows that have been emitted from vents along the southern extension of the Maunga Terevaka scoria ridge. As we pass southwards along coast to Hanga-Pico we enter the Mataveri lava field, the island's principal area of intermediate lava flows which range in composition from hawaiites through mugearites to benmorites. These lavas have been erupted from a group of centres around M. Tangaroa and M. Vai O Hao which appear to be satellites of M. Terevaka, although compositionally they have more in common with Rano Kau. The benmoreites seem, on the whole, to belong to a slightly later phase of activity than the mugearites and hawaiites.

Almost all of these intermediate lavas are essentially aphyric, apart from the occasional appearance of plagioclase microphenocrysts. Seen in thin section they are composed mainly of plagioclase laths with interstitial clinopyroxene and opaques, though small elongate olivines may also occur. In hand specimen many of the benmoreites have a distinctly greenish or purplish tinge and some such as that forming Ana-kai-tangata (Cannibal's cave) weather to an orange-brown colour.

The intimate association of basic and acid products is particularly well displayed at M. Orito. This complex cone, which is again more probably related to Rano Kau than to Terevaka, is composed mainly of basaltic pyroclastics and includes at least one basic lava flow. However, the summit is formed by a plug of weathered rhyolite and a crescentic outcrop of rhyolitic obsidian occurs on the western flank of the cone. This very fresh obsidian has a slightly peralkaline composition (comenditic) and was the source of many of the artefacts to be found on Easter

Island. Obsidian is confined to the south-western part of the island, the only outcrops being M. Orito, Rano Kau and the offlying islets of Motu-iti and Motu nui.

From M. Orito we walk down to the well preserved ahu of Vinapu. In the cliffs below the ahu are a number of lava flows of hawaiite, mugearite and benmoreite composition, many of which weather to a slightly greenish colour. Some of these flows were erupted from Rano Kau itself but others appear to have been emitted from M. Orito or from other cones to the north.

TUESDAY 17 SEPTEMBER.—**The summit and central part of M. Terevaka. Vai Tea — Rano-a-roi — Hanga-o-teo — Anakena**

Maunga Terevaka, the youngest of Easter Island's three major volcanoes, is a complex fissure volcano lacking a single well-defined summit crater like those of Poike and Rano Kau.

In the vicinity of the farm at Vai Tea are several small outcrops of a pale grey basic lava. Although they are not distintive in the field or in thin section, chemically they are quite unlike any other lavas on Easter Island. They are basic, with low SiO_2 (42-43%), low K_2O (<0.3%) and unusually high total iron contents (ca. 16%). They have very low Rb contents and high K/Rb ratios (ca. 2.000).

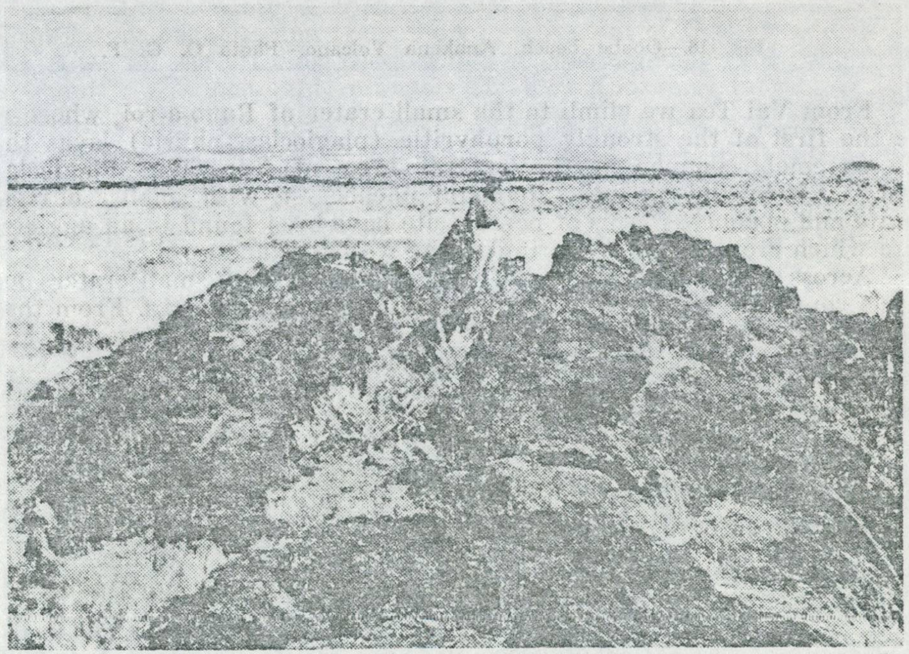


Fig. 17.—Lava tumulus, Terevaka volcano.—Photo O. G. F.

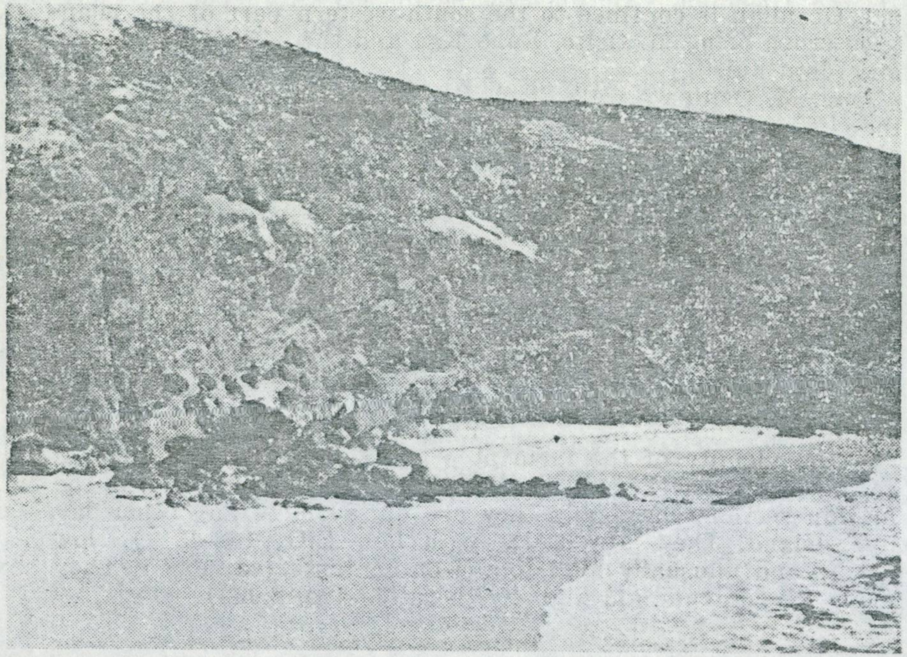


Fig. 18.—Obahe beach. Anakena Volcano.—Photo O. G. F.

From Vai Tea we climb to the small crater of Rano-a-roi, where we see the first of the strongly porphyritic (plagioclase-phyric) lavas that are extremely common in the central area of Terevaka. Plagioclase (An_{60-50}) is by far the most abundant phenocryst, with smaller olivines, augite and opaques. Blocks of benmoreite have been found in an agglomerate which crops out in a cutting to the west of Rano-a-roi.

Across the summit region of Terevaka numerous small craters and scoria cone have coalesced to form two NNE trending ridges. From these vents have come the plagioclase-phyric hawaiite lavas that flow eastwards towards Anakena and down the steeper slopes to the west coast. A K/Ar age of 0.3 m.y. has been obtained on a flow from the foot of the cliffs along the highest part of the west coast and this is likely to represent one of the oldest flows in the subaerial part of M. Terevaka.

Descending the northern slopes we pass over outcrops of yellow tuff and agglomerate above the large dissected crater of Hanga-o-teo. From here eastwards over the area known as Vaitara Kaiva are numerous plagioclase-phyric flows from Terevaka. Although they are mostly basic hawaiites a few of the less porphyritic flows are more differentiated, tending towards a mugearitic composition. The traverse ends at Anakena beach near to a cluster of small cinder cones and associated lava flows at Ovahe.

THURSDAY 19 SEPTEMBER a. m.—**Rano Kau Volcano**

From Hanga Roa we go to Mataveri and climb to the crater rim of Rano Kau. The truncated profile of Rano Kau and the abrupt beginning of the lava field on the eastern rim suggest that this was once a much higher strato-volcano. The name Rano Kau (large lake) refers to the 1:2 km. wide lake which has formed within what is probably a small caldera rather than simply a crater i. e. there has been some collapse.

The upper part of the crater wall is formed by a lava flow of benmoreite composition as is the young lava field at the surface extending from the eastern rim of the crater. The benmorites tend to be a brownish colour, often flecked by orange alteration products. This particular group of benmoreites from the summit region of Rano Kau is very distinctive. All of the specimens collected show strongly resorbed plagioclase phenocrysts (An_{34-27}) and contain doleritic xenoliths set in a pale brown, largely devitrified glassy matrix. The contrasting components and their obvious disequilibrium suggest a hybrid origin.

Beneath the uppermost benmoreite on the northern side of the crater rim is a tuff/agglomerate containing fragments of obsidian. Climbing back out of the crater we walk around the western rim of Rano Kau to Orongo where the flaggy benmoreites have been utilized in the construction of subterranean houses and earth drums. Orongo was the focal point of the bird-man cult. Bird-men petroglyphs are to be found on some of the larger boulders and from the vantage point of Orongo we can also look down on the offlying islets which played an important part in the ceremonial. The monolithic pinnacle of Motu Kaokao is formed of flow-banded rhyolite and the two lower islets are composed principally of obsidian and rhyolite flows.

Returning around the crater to the eastern rim we cross the younger benmoreite lava field before descending to the parasitic centre of Te Mamavai. This consists of a rather subdued crater with associated pyroclastic deposits. However, just above the crater is a small outcrop of crumbling white rhyolite and spherulitic obsidian. This outcrop falls directly on a NE trending line joining the M. Orito obsidian outcrop with that of Motu-iti.

p.m.—The Roiho lava field.

From Hanga Roa we drive northwards past the large parasitic cinder cone of Vaka Kipu. A little beyond here is M. Hiva-hiva, source of the youngest lava flow on Easter Island, which occupies the area known as Roiho. It is a pale grey almost aphyric lava, though some small olivine phenocrysts are just visible in the hand specimen. As seen from the thin section there is an abundance of olivine microphenocrysts and it is the only flow on the island where this is the dominant early-formed phase. Chemically it is an olivine tholeiite with pronounced alkaline tendencies which set it apart from the other lavas of the island.

The Roiho lava field possesses a network of lava tubes and tunnels, once used by the Easter Islanders seeking refuge from approaching raiders. The tunnels exhibit a number of interesting features such as lava stalactites, and terraces left as the level of the lava dropped. Close to Roiho is Ahu Akivi, a fully restored ahu with seven moais.

FRIDAY 20 SEPTEMBER.—**Rano Raraku and Poike.**

From Hanga Roa we drive to Rano Raraku on the eastern side of the island. This is a parasitic cone associated with one of the Terevaka fissures. Geologically it is distinctive as the only cone to be composed of palagonite tuff and archaeologically it is renowned as the site of the giant-statue or moai quarries. The cone appears to be a compound one that was formed about two craters, though one of them has now been eroded away. The high cliffs on the south-eastern side of Rano Raraku result from marine erosion but younger lava flows from M. Anamarama and nearby vents have since encircled the cone, protecting it from further destruction.

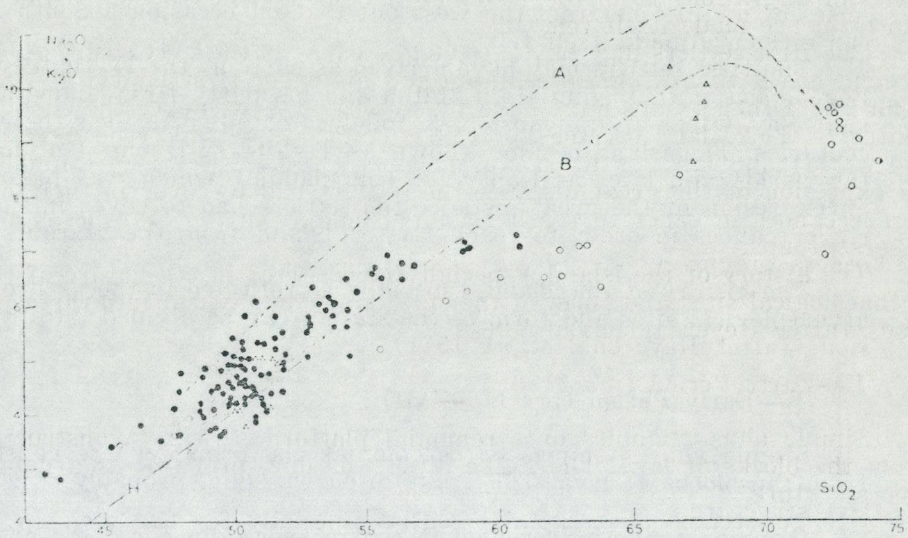
The Rano Raraku tuffs were probably formed in shallow water as both submarine and subaerial components are present. The pyroclasts also contain xenoliths of basaltic composition which were sometimes fashioned into artefacts by the statue carvers. The sudden appearance of a large xenolith during carving could put an end to that particular moai. Statues were cut along the bedding planes of the tuff and even today can be seen in all stages of development. Some are still attached to the rock, others await dispatch from the slopes of Rano Raraku, others were abandoned en route and the remainder reached their ahus only to be pulled down again in subsequent inter-tribal warfare.

The unparallelled development of statue sculpture on Easter Island may be ascribed in part at least to a geological factor, namely the occurrence of palagonite tuff which is incommon in Polynesia. The tuff is sufficiently amenable to carving and yet is at the same time strong enough to stand up to rough handling on the tortuous journey across the island and tolerably resistant to subsequent weathering.

The hawaiite lava on the west side of Rano Raraku comes from the small crater of M. Anamarama and is probably a very young flow. The lava to the east of Rano Raraku is a good example of a moderately porphyritic hawaiite, with plagioclase and olivine phenocrysts, lying somewhere in the middle of this compositional range.

From Rano Raraku there is a good view eastwards to Poike Volcano. Particularly well displayed from this viewpoint are the marine-eroded cliffs which now strike abruptly inland along the south-western side of Poike: the younger flows of Terevaka have linked the former island of Poike to the remainder of Easter Island.

Skirting around the western foot of Poike we go to the foot of the cliffs on the north side of the volcano to see a group of exceptionally porphyritic lavas, rich in plagioclase together with smaller olivines and



Total alkalies-silica (wt.-%) plot for volcanic rocks of Easter Island. △ Poike, ○ Rano Kau (including M. Orito), ● Terevaka. Line *H* is the boundary between Hawaiian tholeiitic and alkalic fields (Macdonald and Katsura, 1964; p. 87). *A* trend of Ascension Island lavas (Baker, 1973; and J. D. Bell, personal communication). *B* Bouvet suite (Baker, 1967)

Fig. 19.—After Baker et. al., 1974.

clinopyroxenes. A K/Ar date on one of these flows gave an age of ca. 3 m. y.: from geological considerations this is likely to be just about the oldest lava exposed on Easter Island. These strongly porphyritic lavas contrast with the almost aphyric flows which occur along the south-western side of Poike.

From the northern side we climb to the three parasitic domes of M. Parehe etc., which are composed of white fayalite-bearing trachyte, verging upon rhyolite in composition. We continue our ascent to the small summit crater of Pu Akatiki and return down the western slopes of Poike over the infamous Poike Ditch (the cooking-place of the Long Ears).

HISTORY AND ARCHAEOLOGY

Although medical and linguistic evidence point clearly to a Polynesian origin for the Easter Islanders, the structure of some of the primitive houses, the reed boats, the bird-man cult and the form of some of the statues are all suggestive of South American influences. It is probably fair to say that Easter Island was colonized principally by a series of migrations from the west but that on occasion a South American influence made itself felt.

The first settlers may have arrived as early as the IV century A. D. Legend has it that King Hotu Matua and his party first landed at Anakena Bay. Other groups must have followed at intervals over the ensuing centuries. The island became known as Te-Pito-Te-Huena (the navel of the world) and later as Rapa Nui (big paddle) which was presumably an expresion of the great distance the settlers had to cover in their out rigger canoes in order to reach Easter Island from the Marquesas and others groups.

The history of the island, especially as reflected in the nature of the archaeological sites and form of the statues can be divided into three periods (after Heyerdahl et. al. 1961).

1.—Early Period (pre-1100 AD).

Simple ahus (temples or ceremonial platforms) where constructed from the blocks of lava. The Poike ditch was dug, probably as a defensive structure.

Orongo became a ceremonial centre especially for the worship of Makemake god of the sun and fire. A number of small statues were carved; they had a more natural and individual form than the later ones.

2.—Middle period (1100-1680).

Many of the ahus, which had fallen into a state of disrepair were brought into use again and extensions were added in the form of wings and ramps. The latter were presumably for the purpose of raising the statues on the ahus, though they were also used as burial places. The moais were now produced on a large scale at Rano Raraku, probably by a group of professional carvers. They where cut by means of stone adzes known as toki.

As time went on the statues became larger and more stylized in the typical angular form. The average weight is about 20 ton but the largest weigh as much as 60 tons and are about 13 m. high.

From Rano Raraku they were moved along well worn routes to the ahus around the island. The red topknots from Puna pau were added and the circular eyes were shaped only when the moais were in their resting places on the ahus.

Meanwhile, at Orongo the bird-man cult gradually superceded that of Makemake. A script known as rongorongo has been found on a number of wooden boards but has not been thoroughly deciphered.

Late period (post 1680)

The ordered life of the island was irrevocably disrupted around 1680 when after a great deal of scheming and intrigue, the Long Ears

who were the statue carvers were eventually roasted by the Short Ears in the Poike Ditch. There followed a period of chaos when all of the statues were pushed off the ahus during local feuds and fighting. Cannibalism probably did not occur on the island until this stage: it persisted until the middle of the 19th century.

OTHER HISTORICAL DATES:

1722: First discovered by European-Dutch Admiral Roggeven.
1770: Claimed by Spanish who erected 3 crosses on the Poike domes.
1774: Visited by Capt. Cook.
1859: Peruvian raiders took 1.000 islanders to work on guano inlands.
1864: Arrival of the first missionaries.
1888: Annexed by Chile (Sept. 9 — Capitán de la Marina de Chile, Policarpo Toro) who rented it to a British company Williams and Balfour, as a sheep farm until 1954.

BIBLIOGRAPHY

BAKER P. E., F. BUCKLEY and J. G. HOLLAND, 1974.—Petrology and Geochemistry of Easter Island. Contr. Mineral, and Petrol. Vol. 44, 85-100.

BAKER, P. E. (1967).—Preliminary account of recent geological investigations on Easter Island. Geol. Mag., 104, 116-122.

BANDY, M. C. (1937).—Geology and petrology of Easter Island. Geol. Soc. Amer. Bull., 48, 1589-1610.

BROWN, J. M. (1924).—The riddle of the Pacific. London.

CHUBB, L. J. (1933).—Geology of Galápagos, Cocos, and Easter Islands, with petrology of Galapagos Islands by C. Richardson. Bernice P. Bishop Museum Bull., 110, 1-67, Honolulu.

DALY, R. A. (1916).—Petrography of the Pacific islands. Geol. Soc. Amer. Bull., 27, 325-344.

ENGEL, A. E. J. and Engel, C. G. (1964).—Igneous rocks of the East Pacific Rise. Science, 146, 477-485.

ENGLERT, S. (1948).—La Tierra de Hotu Matu'a.

FELSCH, J. (1913).—Las rocas de la isla de Pascua según su determinación macroscópica. Publicaciones, 4, 178-180, Santiago.

FUENTES, J. (1960).—Diccionario y gramática de la lengua de la Isla de Pascua. Editorial Andrés Bello, 1-1082, Santiago.

GONZALEZ-FERRAN O., V. CORDANI and M. HALPERN, (in this IAVCEI Symposium).

GORSHLOV, G. S. (1962).—Petrochemical features of volcanism in relation to the types of the earth's crust. Amer. Geoph. Union, Geoph. Monograph, 6, 110-115.

HEYERDAHL, T. et al. (1961).—Report of the Norwegian Archaeological Expediion to Easter Island and the East Pacific. Vol. 1. Archaeology of Easter Island. Monographs of the School of American Research and Museum of New Mexico, Nº 24, Part 1, 1-559, Santa Fe.

KNOCHE, W. (1925).—Die Osterinsel. Concepción.
LACROIX, A. (1927).—La constitución lithologique des iles volcaniques de la Polynésie australe. Acad. Sci. Paris, Mém., 59, 1-82.
LACROIX, A. (1936).—Composition mineralogique des roches volcaniques de l'Ile de Paques. Comp. Rend. Acad. Sci., 202, 527-530.
LACROIX, A. (1936).—Composition chimique de laves de I Ile de Paques. Comp. rend. Acad. Sci., 202, 601-6 05.
MACDONALD, G. A. (1949).—Hawaiian petrographic province. Geol. Soc. Amer. Bull., 60, 1541-1596.
MACDONALD, G. A. (1967).—Forms and structures of extrusive basaltic rocks of basaltic composition. Vol. 1, 1-61. New York.
McBIRNEY, A. R. (1967).—Genetic relations of volcanic rocks of the Pacific ocean. Geol. Rundschau, 57, 21-23.
OLIVER, J E., EWING, M. and PRESS, F. (1955).—Crustal structure and surface-wave dispersion, pt. 4, Atlantic and Pacific ocean basins. Geol. Soc. Amer. Bull., 66, 913-946.
QUIRING, H. (1957).—Alter der Osterinsel und ihrer Monolithe. Neues Jb. Geol. u. Paaont., Mh. H. 10, 449-464.
REYER, E. (1888).—Theoretische Geologie. Stuttgart, 88.
ROSENBUSCH, H. u OSSAN, A. (1923).—Elements der Gesteinslehre. Viert Ed. Stuttgart.
ROUTLEDGE, S. (1920).—The mystery of Easter Island. London.
SKOTTSBERG, C. (1920).—The natural history of Juan Fernández and Easter Island.
STEARNS, H. T. (1967).—Geology of the state of Hawaii. Pacific Books, 1-266-, Calif.
THOMSON, W. J. (1889).—Te Pito Te Huena, or Easter Island. Smithson. Inst. Rept., 447-552.
TILLEY, C. E. (1922).—Density, refractivity and composition relations of some natural glasses. Min. Mag., 19, 276-294.
VERLAIN, V. (1897).—Les roches volcaniques de l'Ile de Paques. Soc. Géol. France., Bull., 3 ser., 7, 410.

EDITED BY O. GONZALEZ-FERRAN

CHILEAN VOLCANOLOGY COMMITTEE
AND
VOLCANOLOGY SECCION
DEPARTMENT OF GEOLOGY OF THE
UNIVERSITY OF CHILE

NOTE: THE CONTEXT OF THIS VOLUMEN IS A REPRODUCTION OF THE ORIGINAL MANUSCRIPTS OF THE AUTHORS

COVER: Villarrica Volcano, 1964 eruption.