CHAPTER 13

Tristan da Cunha Group

General

The Tristan da Cunha group, lying in latitude 37° 05′ S, longitude 12° 17′ W, comprises the islands of Tristan da Cunha, Inaccessible, Nightingale, Stoltenhoff and Middle. The nearest land to the group is Gough Island, some 370 km to the SSE. Inaccessible is some 35 km WSW of Tristan da Cunha; Nightingale about 34 km to the SSW of the main island, these two smaller islands being some 20 km distant from each other. Stoltenhoff and Middle Islands lie off the N coast of Nightingale Island. It is usual to refer to the whole group by the simple name of 'Tristan'.

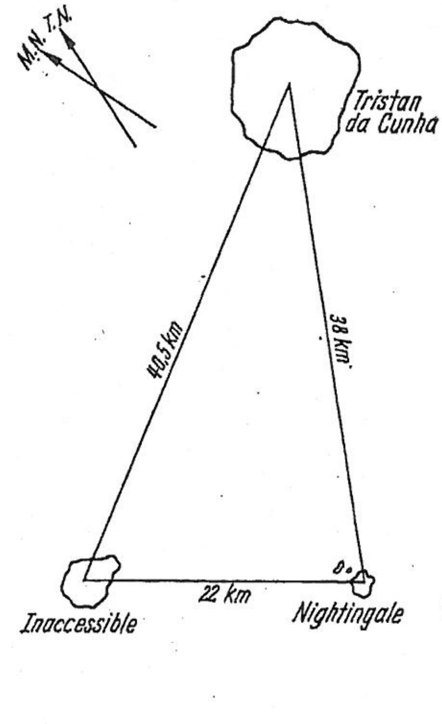


Fig. 80. The Tristan da Cunha Group. (Dunne, 1941)

The main island has an approximate area of 95 km^2, is roughly circular in shape, measuring some 11 km in length by 9.5 km in breadth. The highest summit, The Peak (Queen Mary's Peak) reaches 2062 m. Inaccessible has an area of some 10 km^2 and rises to 548 m. Nightingale covers an area of 2.6 km^2, highest point, 396 m. The islets are small indeed, Stoltenhoff with an area of some 25 000 m^2 rises to 105 m, Middle island with an area of 26 300 m^2 reaches an elevation of 65 m.

The island group, along with Ascension and Gough Islands, are dependencies of St. Helena, but all are administered by the British Colonial Office.

The flora and fauna are of great interest, chiefly because of the isolated position of the group and the loci of origin of many species – South America, Africa, Australasia, South Atlantic and Indian Ocean islands.

From a distance, the main island has a bleak and barren appearance. However there is an altitudinal zoning of the native vegetation, chiefly determined by climate but also by topography and soils. Soils and vegetation practically cease at an elevation of some 1350 m. The publication of N. M. WACE & M. W. HOLDGATE (1958) gives a detailed account of the botany of the main island, and U. HAFSTEN on the basis of pollen analyses of peat samples, concluded that no major vegetational changes had occurred during the last 5000 years, except during the last few hundred years when the island became inhabited. (The preliminary reports by M. W. HOLDGATE on the flora, and D. E. BAIRD on the fauna, as appendices in BAKER, GASS et al, indicate that the 1961 volcanic activity on Tristan da Cunha had only local effects on the plant and animal life, and overall, demage was not critical.)

The main crop is the potato, but a considerable number of apples and peaches are grown, all restricted to the main centre of habitation. Sheep, cattle, donkeys, geese and fowl are raised for domestic needs. Crayfishing is of some importance.

Tristan was discovered in 1506 by the Portuguese navigator Tristao d'Acunha. The Dutch took an early interest in the island, first landing there in 1643. The first settlement was made in 1810 by the British, and a British garrison arrived in 1816, probably aimed more at keeping an eye on American privateers than any attempted rescue of Napolean from St. Helena. The British left the following year, but Corporal Glass and his family decided to remain from which stems the real founding of the colony.

The Tristanians are of mixed origin. Male ancestors are chiefly of European and American descent, whereas the ancestors of the greater part of the females came from Europe, Africa and Malaya.

The population of Tristan da Cunha (the other islands are uninhabited) is about 300. The main centre is Edinburgh (often merely referred to as the 'Settlement'), near the NW coast, lying at an elevation of some 30 m. Only in this vicinity is there cultivated land, known as Potato Patches.

During the tremors and eruptions of late 1961, the entire population was first evacuated to Nightingale Island, then to South Africa, and eventually to Britain. But the people just could not adjust to the tempo of modern living and in such strange environments, and almost all returned back in 1963.

Physical Features

Tristan da Cunha

The main island rises out of the ocean like a steep cone, and, as DUNNE remarked, from a photograph or view from out at sea, presents a typical textbook example of a volcano.

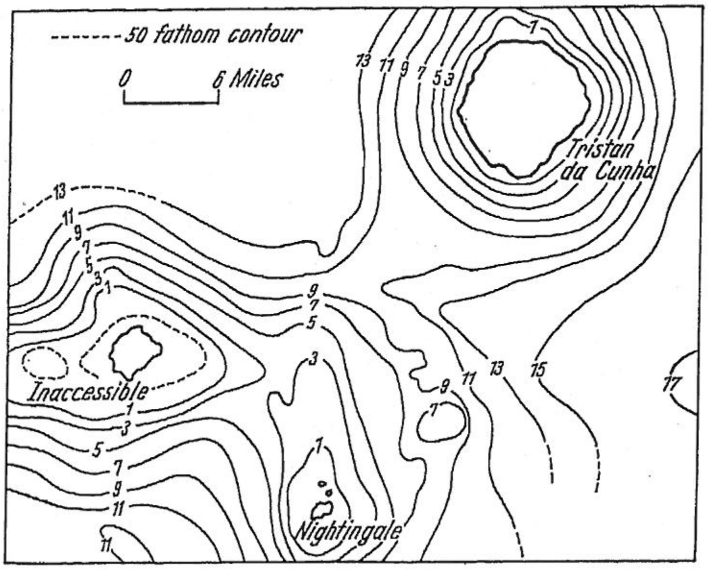


Fig. 81. Bathymetric contours at 200 fathom intervals. (BAKER, GASS, et al., 1964)

From most of the coastal area cliffs rise, often almost sheer, as high as 900 m above S. L. Fringing areas of flatter land, sloping seaward, are extremely scarce, and indeed only four are present. The largest one is where the settlement of Edinburgh is located in the NNW. Slopes here vary from 5° to 7° and occupy a region some 6 km in length and 1.5 km broad, bordered seawards by cliffs ranging from 5–15 m high. In the S are two smaller areas, around Cliff Pt. and Stony Hill, and at Sandy Pt. on the E coast is the smallest. In places sea caves 4 m above S. L. may be seen.

Whether or not faulting had anything to do with the formation of these restricted more level areas cannot be definitely ascertained. Alluvial wash and coalescing alluvial fans comprise the surface.

Between 600 m and 900 m, forming what is locally known as the Base, slopes are more gentle, forming an inclined plateau, with inclinations as low as 8°. From about 900 m, the land, known collectively as the Peak, rises more steeply at angles from 20° to 30° up to the central summit at 2062 m. The cinder cone begins at ca. 1740 m and continues to the top where there is a small crater lake with walls rising 20 m to 80 m above its surface.

It is to be noted, however, that on the E side of the island, this clear distinction between the slopes of the Base and the Peak is lacking, slopes here flattening-out much more gradually. On the W coast, where the distinction is marked, BAKER, GASS et al claimed that the steeper Peak slopes were determined by the angle of rest of the pyroclastics, the

Base slopes by fluid lavas, and they were not in agreement with DUNNE who invoked structure as the cause of slope differences. Nor would the above writers agree with DUNNE that the upper steeper slopes were comprised mostly of more viscous lavas.

The most impressive cliffs occur in the NW of the island – rising to 900 m – but on the E side, they have half this height, and in the SE, about one-fifth this height. Of interest is the fact that development and height of the cliffs bears no relation to present fringing coastal strips. Neither these latter nor the cliffs are the result of faulting; the former are due to flows from minor eruptive centres whereas the latter are the result of marine erosion.

The drainage is radial, their thalwegs reflecting the topographic slopes of the Peak, Base, cliff edges. When rains are copious and some of the streams are full, they plunge over cliff edges and thicker lava flows, some as high as 100 m as magnificent waterfalls. The greater part of the drainage is underground, and only for a few hours after rain do the gulches and gutters carry water. The larger gulches rise on the Peak, are narrow, V-shaped canyons, up to 60 m in depth, with step-like longitudinal sections, gravelly floors and vegetation. The gutters rise on the Base, are less long, less deep and have no gravelly beds but only vegetation. In times of heavy rainfalls, the bare Peak area allows of rapid runoff, quickly filling the channels and hence active fluvial erosion takes place. The gutters have gentler slopes, the terrain is carpeted in vegetation, scouring is less active, erosion greatly reduced. But as a considerable proportion of the surface water becomes lost to underground flow, fluvial erosion is actually a somewhat slow process.

Small alluvial fans develope below the cliffs, best observed on the small coastal strips, where they have been incised by the streams.

Springs are important, the chief ones occurring at the base of the cliffs, but they also are found high up on the slopes of the Peak. The Settlement derives its water supply from such a spring nearby at the foot of the cliffs.

Erosion is most active on the Peak and along the base of the sea cliffs. On the former, steep slopes, lack of vegetation, large amount of scoriaceous material allows of easy denudation. Marine erosion, with undercutting by the waves, with resultant landslides, is most active. BAKER, GASS et al refer to wave attack eating back some 10 m of the new lava field during a two month period in early 1962. By the same token, long-shore currents during the same period created a bar 150 m long, 10 m broad, cutting off the sea and forming a lagoon.

Between elevations of about 950 m to 1750 m, hogback ridges have been eroded out. The crest of these ridges are seldom broader than 6 m at the top, with slopes of 45° on either side. At ca. 1050 m elevation, the hogback crests begin to develope drainage systems which deepen into trenches, some 7 m deep, which continue for ca. 180 m gradually widening and splitting the hogbacks into divergent branches. Between 975 m and 950 m the ridges fan-out and form a continuous slope – the Base.

Many small secondary cones are scattered over the surface of the island. Seldom rising higher than 200 m, of almost perfect shape; they comprise explosion vents, scoria mounds, breached scoria cones with lava fields and effusive centres.

Between elevations of some 600 m and 900 m, in the NE part of the island, are three explosion craters containing miniature crater lakes. The largest measures 600 m from rim to rim, lake level 120 m below the rim, the water only a metre or two deep.

In no place does folding or faulting assume major proportions. Slumping, rock-falls, landslides do occur, small adjustment fractures, especially in tuffaceous beds, are present here and there. Dykes are radial in pattern and intrusive necks are common.

Inaccessible Island

The name given the island is appropriate, for almost everywhere near vertical cliffs rise to elevations varying between 150 m and 548 m, and landing has always been a difficult and hazardous matter.

Maximum elevations occur in the extreme W. Most of the interior shows rather level, undulating topography, sloping down gradually eastwards. Over the abrupt slopes forming the central interior region, streams tumble in cascades down to the shores. In the N and NW prominent landslide topography occurs. The NE central area has undergone greatest stream dissection, the principal drainage being in this direction down to the shore at the usual landing site. Along the southern coast are one or two abrupt conical masses, and the offshore islet of Pyramid Rock rises nearly vertical to over 75 m. A shallow water platform, depths less than 180 m, extends for as far as 9 km out from the island, leading Baker, Gass et al to postulate that Inaccessible is only a small emergent part of an original very much larger volcanic island.

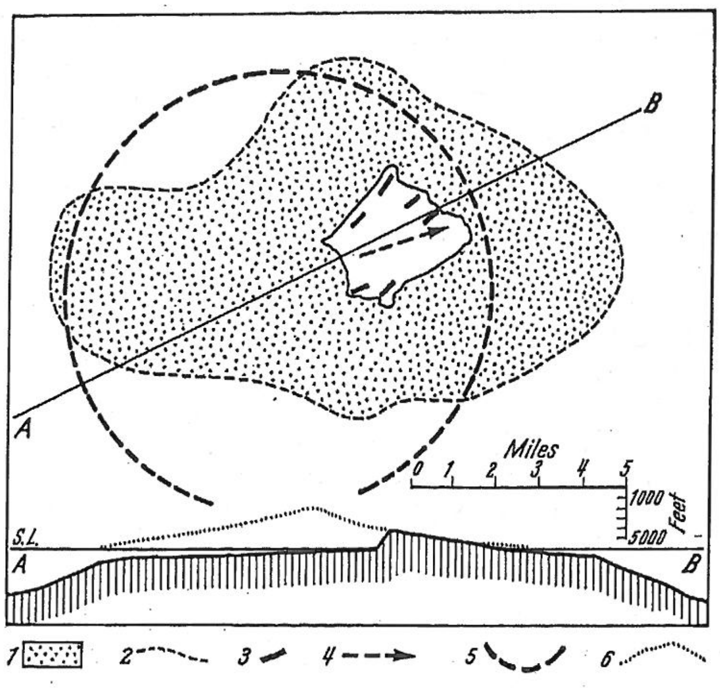


Fig. 82. Presumed position of Inaccessible Island with respect to original volcanic Island. 1. Submarine platform, 2. 100 Fathom contour, 3. Major dyke trend, 4. General dip of Main Sequence, 5. Postulated margin of original Island, 6. Postulated profile of original volcanic cone. (Baker, Gass, et al., 1964)

Nightingale Group

In Nightingale Island a prominent ridge runs N-S in the eastern extremity, culminating at 396 m, highest point on the island. This ridge is joined by a saddle to more subdued, irregular topography of the central and western areas, with depressions occupied by swampy ponds. S of the ponds, in the central area, is the second highest elevation, 289 m. There are no permanent streams. In the N, NE, E and SE, sea cliffs vary in height between 10 m and 46 m, but along the NW, W and SW coasts, cliffs rise sheer as high as 183 m.

Separated from Nightingale by a channel only some 300 m wide lies Middle Island, with many off-shore rocks. Near-vertical cliffs drop down to the shores throughout. The interior is somewhat flattopped in appearance, with minor depressions.

NW of Middle Island and separated by a 600 m deep water channel, lies Stoltenhoff Island. The major islet is rimmed by 100 m high vertical cliffs. The relatively flat interior slopes gradually to the NW. At the SW end of the islet are two smaller masses, separated by defiles weathered along major joints.

Climate

The climate is equable but wet, with violent gales common in winter, and most of the year strong winds from the NW and SW sectors are the rule. November to March are generally the best months.

The average summer temperature on Tristan da Cunha is 20° C, average winter temperature, 12° C. February is the warmest month, 18° C, August the coldest, 11° C.

High relative humidity, average 80 %, is characteristic throughout the year.

Rains are frequent, the average annual at the Settlement being 1650 mm, about 5200 mm on the Peak. During much of the year, skies are cloudy.

Some reports say frost is unknown, hail showers are rare and snow even more rare. On the other hand, it is reported that snow often lies above 900 m from June to October. Whether snow or not, opinions appear unanimous that the higher slopes are clouded in dense mist for much of the year.

On the basis of pollen analyses of peat samples from the main island, Hafsten believed there had been no distinct revertent climatic development during the past 5000 odd years.

Geology

For ease of treatment, the islands comprising the Tristan da Cunha group will be considered separately.

Tristan da Cunha

The island consists essentially of a composite volcanic cone, formed chiefly by a central vent from which alternate layers of basaltic flows and pyroclastics were erupted. Although there was a principal central conduit, smaller parasitic centres emitted scoria and some thick flow-banded trachybasalts.

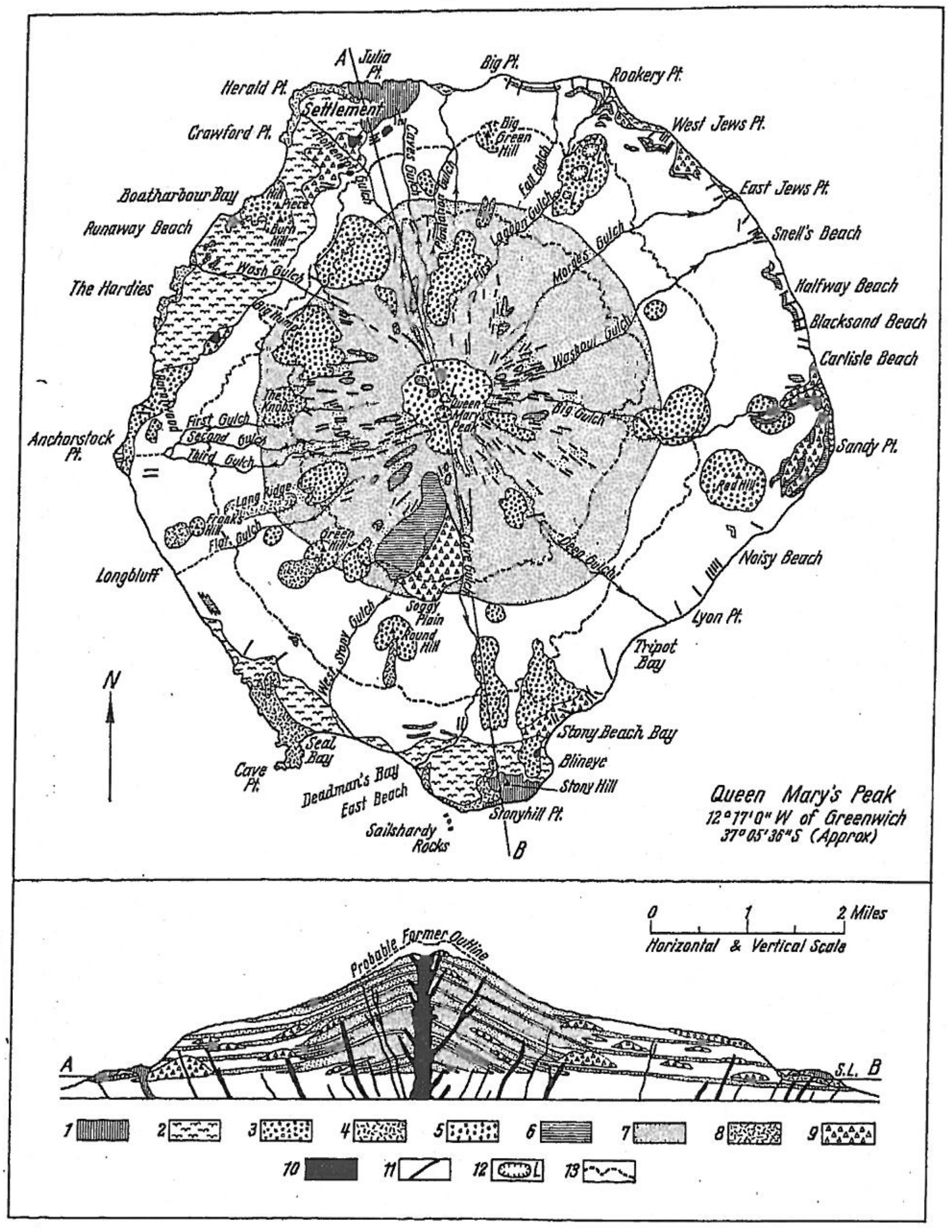


Fig. 83. Geologic Map & diagrammatic cross-section of Tristan da Cunha. 1. Recent Trachyandesite eruptions of Stony Hill & 1961, 2. Alluvium-mostly outwash deposits, 3. Surface cinder cones, 4. Lavas from surface cinder cones, 5. The Peak cinder cone, 6. Prominent lava flows, 7. Chiefly pyroclastics (Main volcanic Sequence), 8. Chiefly lavas (Main volcanic Sequence), 9. Pyroclastic centres (Main volcanic Sequence), 10. Intrusive masses, 11. Dykes, 12. Crater lakes, 13. Approx. position of 600 m & 900 m contours. (BAKER, GASS et al., 1964).

The inclination of the flows from the original central vent in the Base region varies from 5° to 10° and thus the topographic slopes here agree rather well with the dip of the flows. Higher up, in the Peak region, alternating flows and pyroclastics have a radial inclination up to about 25°, presumably due to the greater development of fragmental material as one approaches the central vent. (BAKER, GASS et al mention that here the proportion of lava to pyroclastics is much lower than further down on the Base, lava sometimes constituting only 25 % of the sequence.) The pyroclastics of the Peak consist mostly of reddish and blackish scoria, sometimes with bombs and intercalated lavas. S of the highest elevation is a earlier secondary vent in the form of noteworthy plug of trachyte and thus the upper steeper slopes of the island result from two centres of extrusion.

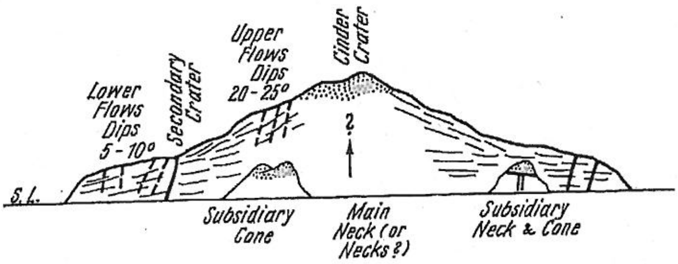


Fig. 84. Schematic section of Tristan da Cunha, showing types of volcanics units. (DUNNE, 1941)
– – – – Smaller dykes ——— Larger dykes

Because of dense vegetal covering, rock exposures on the Base are best observed in gulches and gutters, where basic lavas and pyroclastics dip radially outwards at approximately the same angle as the surface slopes. Outcroppings of the lavas across the stream channels result in waterfalls. Going upwards from the edge of the cliffs towards the steeper Peak area, the proportion of pyroclastics to lavas increases.

There are many secondary centres of eruption – over thirty have been mapped. BAKER, GASS et al have classified such into four main types:

a) Explosion centres, comprising a crater with little or no eruptive material in the vicinity, represented by three small radially-directed crater lakes in the NE part of the island. These ponds have been scalloped out of the seaward dipping lavas. There are three separate vents at depth, broadening out funnelwise nearer the surface so that their rims coalesce, forming V-shaped outlets.

b) Scoria mounds, with almost all material pyroclastic. Most comprise scoria and cinders, on occasion partly welded into agglomerates. The pyroclastics may be one or two hundred metres thick, and the mounds may measure several hundred metres across. Twelve such mounds are described in detail by the above authors.

c) Breached scoria cones, lava flows descending from breached crater. These are pronounced, well-preserved features. Invariably the breached part is on the downhill side, with the lava extending below as far as 800 m. The two best examples of such features are Hillpiece and Burnt Hill, lying between Potato Patches and the Settlement. It is surmised that effusive and pyroclastic action went on contemporaneously at these cones, the lavas being distinctly more basaltic than where effusive action only was taking place. Thirteen such cones are described by the above authors.

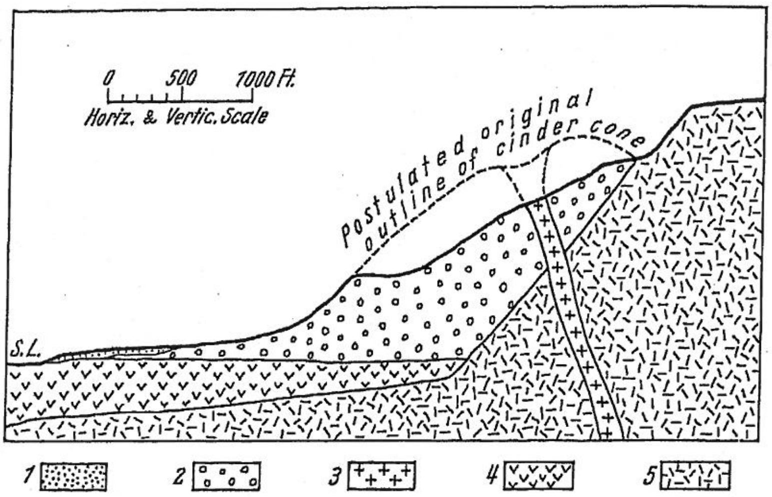


Fig. 85. Diagrammatic NW-SE section through the Burntwood parasitic centre. 1. Alluvium, 2. Pyroclastic debris (Burntwood centre), 3. Volcanic neck (Burntwood centre), 4. Leucitic Trachybasalts of Settlement coastal plain, 5. Interbedded lavas and fragmental horizons of the main sequence. (BAKER, GASS, et al., 1964)

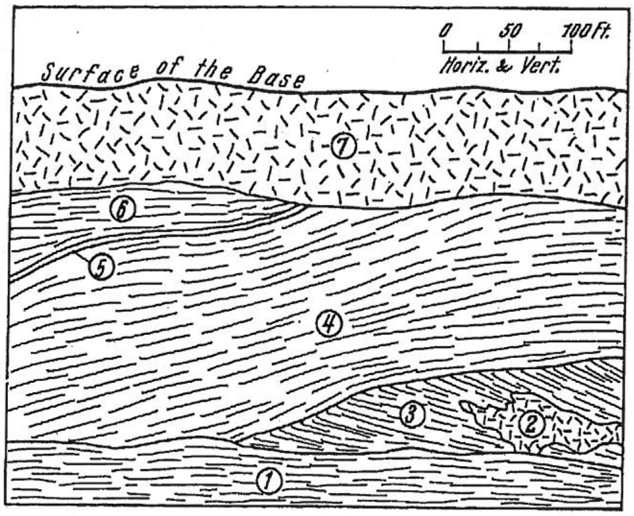


Fig. 86. Sandy Pt. parasitic centre. Sketch of S bank of Big Gulch. 1. Detritus in bed of Big Gulch, 2. Irregular intrusion of Trachybasalt, 3. Red ash and cinder with thin lava flows dipping SW at 10°, 4. Loosely cemented bright red ash and scoria dipping E at 15° to 20°, 5. Ft. layer of bright orange ash, 6. Dark red ash and cinder dipping S at 10°, 7. Thick flow of columnar pointed Trachybasalt. (BAKER, GASS, et al., 1964)

d) Loci of only effusive activity. These are represented by Stony Hill and the 1961 volcanic outburst, with thick flows of block lava. Stony Hill shows close similarity with the recent vulcanism, especially in the petrography of the rocks in question. The 1961 eruption will be mentioned later.

Baker, Gass et al, on the basis of radiocarbon datings of soil horizons under the Big Green Hill cinder cone, a scoria mound, suggest an age of 10 000 years for this Hill and several breached cones, whereas other breached cones and scoria mounds indicate a somewhat older age.

The great circle of cliffs which almost everywhere rise precipitously from the shore up to the seaward extent of the Base show a general horizontality of greyish lavas and red-brown pyroclastics, intersected by vertical dykes. As the island was formed from a central vent with many secondary centres of eruptivity material derived from both origins is decipherable in these immense cliffs, which, however present serious abstacles to the field geologist, due chiefly to their extreme steepness. Baker, Gass et al estimated that in every 600 m vertical of cliff there were some 60 individual lava flows with subordinate pyroclastic beds. The parasitic centres have contributed chiefly pyroclastics, but flows as thick as 100 m and up to 350 m broad are also encountered.

The above authors present views as to how the cliffing might have occurred: the island might once have been much larger, the upper slopes descending right to sea level and continuing in depth, in which case cliffing would be a subsequent phenomenon. On the other hand, perhaps the island was never much larger than at present but grew higher by the addition of further vulcanism at the same time as it was trimmed back by marine erosion. A marine abrasion platform offshore seems to be lacking, the water deepening regularly. If the cliffs are to be interpreted as a step, rather than a nick, in the profile, then this would suggest that the latter hypothesis is the more likely.

Dunne remarked that the only important fault on the island occurred "in the main cliffs S of Anchorstock Gulch. It is practically vertical with a throw of about 60 m and strikes 70° W of N". His map does not show the location of this Gulch, nor that of Baker, Gass et al, who in turn make no mention of any such fault.

The very small total area of relatively low flat land near the coasts comprise lava flows, pyroclastics and at the surface coalescing fans backed by the high cliffs and fronted by small sea cliffs thus actually constitute small piedmont alluvial plains. In some places, e. g. the Settlement plain, alluvium is seen to be some 100 m thick in places. Baker, Gass et al were quite certain that faulting had nothing to do with the formation of these small plains, but on the other hand, Dunne thought it unlikely that their presence could be accounted for other than by faulting, though he presents no concrete evidence of such. The small plain in the lee of the island at Sandy Point suggests that here subaerial erosion has been of greater importance than marine erosion, the Base area being embayed, allowing of deposition to form this small area of low ground.

Lava flows average between 2 m and 3 m in thickness, breadths of 1 km and lengths about the same can be observed. Flows are usually sandwiched between reddish-brownish rubble or pyroclastics. As seen in the major cliffs, pyroclastics appear to constitute between 15 % and 20 % of the rock sequence. The lower surface of the flows is uneven and brecciated, often showing chilled rims up to 5 cms. thick in non-porphyritic rock, up to 15 cms. thick in highly porphyritic rock. New flows spreading out over rubble and/or fragmental material have often picked up this and incorporated such as xenoliths in the basal half metre of the flow. The lower half of flows are usually compact and crystalline with well developed columnar jointing in thicker flows. The upper surface of flows have a decidedly scoriaceous appearance. In general, the degree of vesicularity increases upward in the flows, and indeed some even have the appearance of pumice. The upper metre or so of individual flows are of broken lava and fragmented parts of pahoehoe lava. On the other hand, highly porphyritic basic lavas have quite smooth upper surfaces with pronounced vesicularity.

On the Peak, basaltic flows occur but are not so prominent as those of trachy-andesite. In the main cliffs flows can be observed comprising trachybasalts, basalts, olivine-basalts, feldspar-phyric-basalts, porphyritic ankaramites, with trachybasalts as the commonest.

Black, brownish and reddish cinders are abundant everywhere and mantle the highest slopes of the island, as well as forming the principal material of the secondary vents and craters. Tuffs are not common, the largest and most important occurrence being behind the Settlement. Whilst flows maintain a close degree of thickness throughout their lengths, the pyroclastics vary rapidly in thickness. Usually finer-grained pyroclastics are well bedded, and display vertical grading. Where the grains are more even in size, stratification is lacking.

The radial pattern of the many dykes is striking. They are most prolific on the Peak, several can be seen on the major cliffs but as the Base is a constructional feature, they are very scarce here. Generally dykes are vertical, seldom broader than 2 m, and may protrude above the surrounding terrain as much as 20 m, and on the Peak, can be traced for several hundred metres. Chilled rims are invariably present. Baking of the host rock only occurs in the case of pyroclastics, affecting merely a few centimetres.

DUNNE remarked that all dykes were olivine-basalts, with one exception. BAKER, GASS et al, on the other hand, state that petrographically the dykes show the same range as the lavas of the main sequence.

DOUGLAS (1930) had mentioned tunnels in the lava into which streams disappear, to emerge lower down where a more impervious, resistant layer causes the water to become visible again.

BAKER & HARRIS have written of somewhat similar features, namely, lava channels or trenches. These may be as much as some 850 m in length, up to 25 m broad and as deep as 8 m. They can be well observed at Stony Hill, at Long Ridge and at the latest eruptive centre. Frequently the sides of the channels rise well above the surrounding terrain, forming parallel ridges or levees. These authors deem it necessary to distinguish lava levees from lava morains, the former term being taken to mean constructional features (of solid lava, not loose blocks) built up by the solidification of lava overflowing from a lava stream, whereas lava moraines apply rather to blocks and cinders falling and rolling down from ridges of the lava streams and forming block walls similar to lateral and terminal ice moraines.

BAKER & HARRIS envisaged the formation of the lava channels and levees as somewhat similar in development to a stream which rises in flood and pours over its banks – forming lava levees, and when the quantity of lava diminishes in the 'stream', the channel aspect is acquired. They did not believe the lava channels were collapsed tunnels, even although the origins are similar.

DUNNE remarked that in the southern part of the island (he did not specifiy more particularly), wind-blown sand dunes had been piled up to elevations as high as 200 m above S. L. and extending inland for as much as 1 km, with older, lower beds semiconsolidated. This may be so, but Baker, Gass et al make no mention of such, though their map shows considerable areas of outwash deposits behind Seal Bay and Stony Hill.

Inaccessible Island

Some 90 % of the island comprises interbedded pyroclastics and basaltic lava flows, all gently dipping eastwards. Baker, Gass et al presented a tentative table showing the age sequence as follows:

Surface pyroclastic centres
Trachybasalt lavas
Dykes
Parasitic pyroclastic centres } Approximately
Main basaltic sequence } contemporaneous
Trachytic domes and lavas }

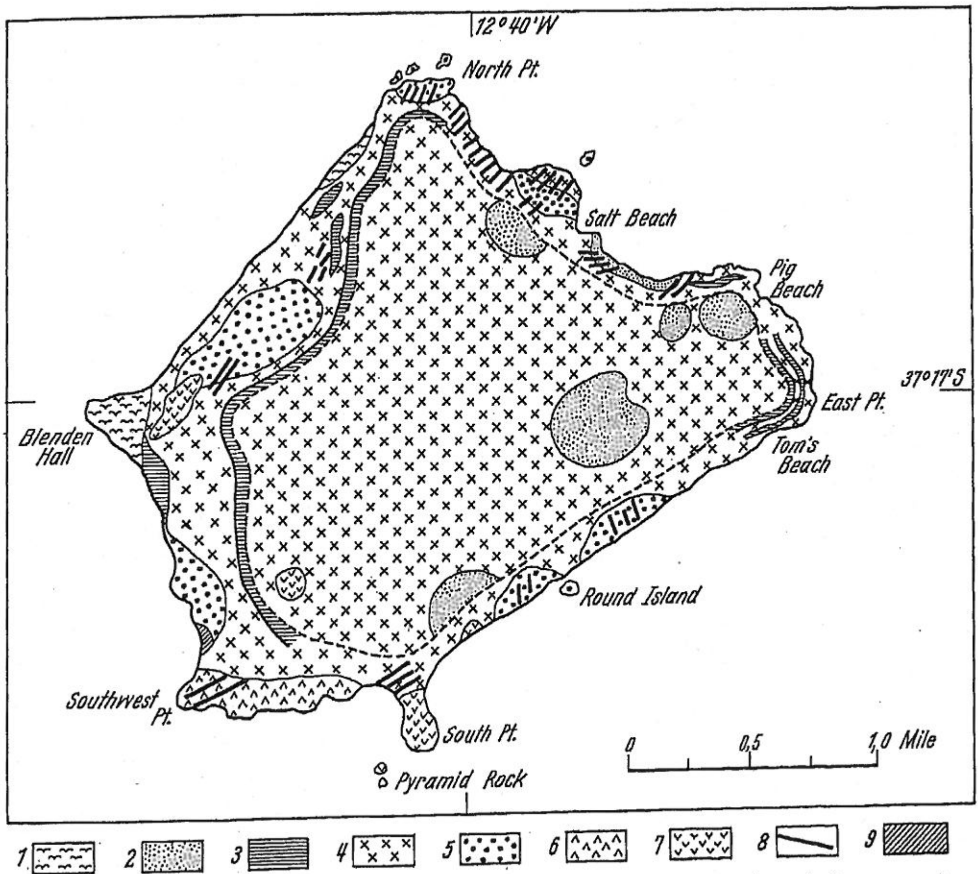


Fig. 87. Geologic Sketch Map of Inaccessible Island. 1. Detritus, 2. Surface cinder cones, 3. Thick Trachybasalt flows, 4. Main sequence – basaltic lavas and pyroclastics, 5. Pyroclastic centres with main sequence, 6. Trachyte lava, 7. Trachyte domes, 8. Dykes, 9. Landslide area. (Dunne, 1941, and Baker, Gass, et al., 1964)

Trachytic domes occur in the SW. As these represent the presumed oldest rocks, and, as previously remarked, present-day Inaccessible Island might possibly represent part of a once much larger volcanic cone, the eastern undissected part thereof, in which case these trachytic lavas may be representative of the more central parts of the original volcano, though all proof of such a contention is lacking as of now. On the other hand, DUNNE, the first to observe these trachytic domes, did not evidently regard them as the oldest rocks, for he speaks of a 'basal complex of the West', comprising a great number of dykes which have replaced, up to 75 %, the country rock which is a completely serpentinized olivine-basalt. (Admittedly rough seas prohibited DUNNE drastically in the executing of field work on this island, his observations being made chiefly from a boat at sea.) These domes are striking features, with smooth surfaces with outward curving columnar jointing, presenting rock faces 100 m in height.

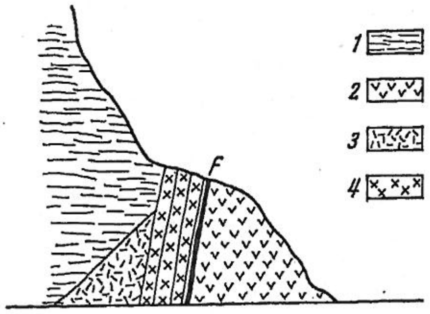


Fig. 88. Section of large dykes and trachyte dome, at Blenden Hall, Inaccessible Island. 1. Lava flows of main cliffs, 2. Trachyte dome, 3. Hornblende-bearing tuff neck, 4. Dykes, F = Possible fault plane. (DUNNE, 1941)

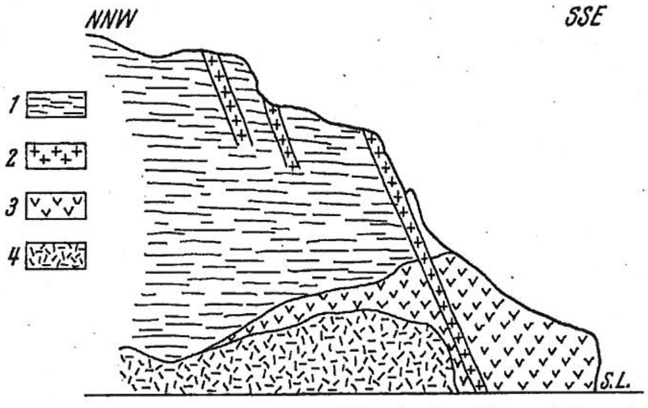


Fig. 89. Section at the bluff, SW Point, Inaccessible Island. 1. Flows of the main cliffs, 2. Trachy-Andesite dykes (?), 3. Trachyte intrusion, 4. Basal complex. (DUNNE, 1941)

Trachytic lavas form a tongue between the 'basal complex' and the main basaltic flows at SW Point. BAKER, GASS et al postulated that as these lavas are dipping eastward, their locus of origin must have been to the W of the present island.

The main basaltic sequence (olivine-basalts, as per DUNNE) comprise something like 130 individual flows, average less than 2 m in thickness, with interbedded tuffs and cinders comprising some 10 %. The dip varies between 3° and 5° to the E. These flows are similar petrographically to those on Tristan da Cunha, which, according to BAKER, GASS et al, range from basalts, through olivine-basalts to ankaramites.

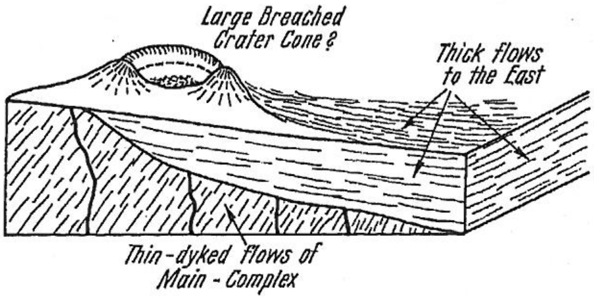
The above authors noted 10 parasitic pyroclastic centres, the cones varying between 400 m and 800 m in diameter, from 60 m to 245 m in height. Flows associated with these pyroclastics are thin and more steeply dipping – between 10° and 25°.

The dykes, of olivine-basalt or ankaramites in general, are well jointed, both horizontally, vertically and cross-columnar. Usually dykes are thin, tending to occur in swarms, but where not occurring as swarms, dykes are much thicker – up to 10 m in width. Dykes are relatively rare in the eastern end of the island. On the other hand, those of the western coastal region are not only numerous but well-defined and petrologically different from the others, for here they are mugearites, but mineralogically identical with mugearite dykes in the E.

Along the N coast, the dykes strike SW-NE; along the W coast the strike is WSW-ENE, whereas along the S coastal stretches it is presumed the dykes strike NW-SE.

Principally in the E, constituting what DUNNE called 'The Thick Flows', are a system of flows, average thickness 4 m, but attaining thicknesses of 45 m, of trachybasalt or olivine-trachyandesite composition (mugearites). Flows of such composition in the island appear to be associated with secondary pyroclastic centres, and DUNNE postulated that those of the E may have originated from a large breached crater cone ca. a kilometre to the W thereof. The geological sketch map of the island given by BAKER, GASS et al shows similar flows paralleling the NW and SW coasts and about 1 km inland.

Fig. 90. Section of eastern part, Inaccessible Island showing position of schematic crater. (DUNNE, 1941)



Several surface cinder cones are present, the largest being that above referred to by DUNNE. This one comprises red scoriaceous basalts intermixed with cinders, measures some 320 m across the rim and has its steepest slope facing W although it is breached on the E side. BAKER, GASS et al believed that these parasitic cones on Inaccessible were essentially the same in all respects to those of the Base in Tristan da Cunha, although it should be noted that these authors also made many of their observations of the island's geology from a boat.

It was the opinion of DUNNE, and appears to be echoed by the above authors, that Inaccessible Island is much more complicated structurally than either Tristan da Cunha or Nightingale, and the latter held the view that as regards the extent of erosion undergone, the island was intermediary between that of the other two islands.

Nightingale Group

Most of the island comprises trachytes and trachyandesites, mostly porphyritic, and volcanic ash and agglomerate. The 'basal agglomerate' of Dunne, or the 'older pyroclastic sequence' of Baker, Gass et al outcrops along the northern, eastern and southeastern sea cliffs. This comprises a basal agglomerate composed of fragments of trachyte, trachyandesite, trachybasalt, sometimes olivine-basalt, cemented together by brownish glass, ash and cinder. Lapilli have excellent banding striking S 70° E, frequently dipping at 40° to the N but sometimes at 35° to the NW. Dunne was uncertain whether such were primary dips or then the result of tilting . . . perhaps due to both.

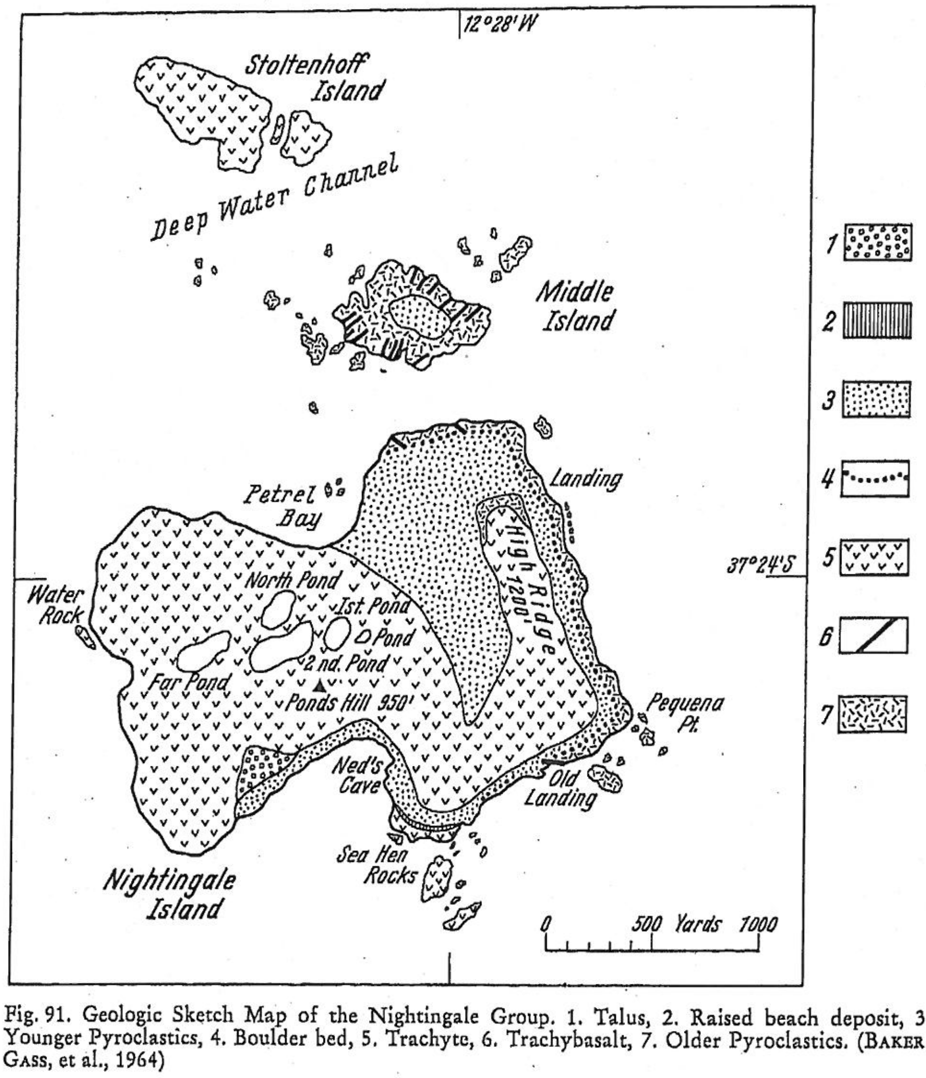


Fig. 91. Geologic Sketch Map of the Nightingale Group. 1. Talus, 2. Raised beach deposit, 3. Younger Pyroclastics, 4. Boulder bed, 5. Trachyte, 6. Trachybasalt, 7. Older Pyroclastics. (Baker, Gass, et al., 1964)

These agglomerates form the base of terraces lying 12 m above present S. L. (vd. below), which, according to DUNNE, represents an old eroded surface brought down to sea level before eustatic change took place.

Rocks of trachytic character constitute about three-quarters of the island. Though the mode of intrusion is presumed to have been of intrusive origin, this cannot be corroborated. Occasionally vertical columnar jointing is seen, especially in isolated outcrops. Lying within these trachytic exposures are circular depressions which DOUGLAS (1930) thought were explosion craters. In spite of the morphology of these lakes being indeed very similar to depressions of explosive origin, there are no indications of explosive products in the vicinity, and both DUNNE & BAKER, GASS et al agreed that these ponds were erosional features within an original irregular topography.

Lying between 5 m and 33 m above S. L. and varying in thickness between 0.3 m and 4.5 m is a boulder bed comprising pebbles and boulders of porphyritic trachyte. This bed, occurring in the cliffs along the eastern side of the island, lies unconformably on the volcanic ash and agglomerates, the upper surface having a slight dip seawards, and being overlain by younger pyroclastics. BAKER, GASS et al interpreted this boulder bed as representing a fossil beach deposit, indicative of a quieter period during the vulcanism of the island when earlier formed rocks were being eroded.

Tuffs and agglomerates occur lying unconformably upon all the older rocks. The lowest unit is a sandy tuff, slightly cross-bedded, and this fact, along with the excellent stratification, suggest it was deposited in shallow water, and plant remains may suggest a lagoonal environment. DUNNE thought that these tuffs, as seen for example at the Landing on the NE coast, were at least older than some trachytic flows, and if all the trachytes and trachyandesites were more or less contemporaneous and so younger than this sandy tuff layer, then the major portion of the island would represent a relatively late eruption. On the other hand, BAKER, GASS et al state that this tuff lies on coarse agglomerates of their 'older pyroclastic sequence', above which occur the trachyte masses. However they make no comment on the above statement of DUNNE, and hence the problem rests as is. (DUNNE included this sandy tuff in his 'basal agglomerate', equivalent to the 'older pyroclastic sequence' of BAKER, GASS et al.)

At the Sea Hen rocks off the S coast, a good sequence is exposed of these younger pyroclastics. The following is given by BAKER, GASS et al:

Sea Hen tuff	25 ft.
Trachytic lava	18 ft.
Fine tuff with abundant plant remains and numerous ash partings	10 ft.
Raised beach deposits	15 ft.
Weathered trachyte	30 ft.

Of interest here are the abundant carbonaceous plant remains, which, on the basis of radiocarbon dating, gave ages of 39.160 (+6090, −3410) years B. P. The topmost tuffs are similar to those at the Landing. On rocky islets offshore here a 3 m thick sandy tuff has so many plant remains it could be regarded, in part, as lignite.

The raised beach deposit will be mentioned below.

Baker, Gass et al presented the following table of events for Nightingale Island:

Raised beaches	Period of erosion
Younger pyroclastic sequence	Fine ash to coarse agglomerate, with local horizons rich in plant remains
Period of erosion	Formation of boulder bed, comprised chiefly of trachytic material
Intrusion and extrusion of trachyte masses	
Older pyroclastic sequence	Chiefly yellow agglomerates issuing from various centres and cut by numerous basic dykes

Middle Island is composed essentially of the same type of pyroclastics as form the basal beds in Nightingale Island, the geological sequence being the same as in the NE part of the latter. Along the N coast of Middle Island, the pyroclastics (older) have a dip to the N of between 20° and 30°, but in the S of the island, the dip is to the S at an angle of 60° maximum.

Sandy tuffs similar to those above described on Nightingale Island occur on the S coast of Middle Island, lying some 50 m above S. L. in unconformable relation to highly dipping older tuffs and agglomerates. These sandy tuffs also appear to be of lagoonal origin.

Innumerable trachybasalt dykes are seen along the northern and southern coasts, with a general NE-SW strike, and unconformably overlain by the above sandy tuffs.

Stoltenhoff Island is a monolithic structure of biotite-trachyte. The larger islet is completely surrounded by cliffs some 100 m high. The major joint pattern is orientated NNE-SSW, with a secondary pattern aligned almost E-W. Marine erosion along the major pattern has separated two smaller islets at the E end of Stoltenhoff. Baker, Gass et al thought that the island was a monolithic dome-like intrusion, similar to that forming the eastern N-S ridge in Nightingale Island and South Hill on Inaccessible Island.

Dunne devoted a section to the discussion of eustatic change in sea level of the Tristan group. Sloping rock benches, abandoned terraces and sea-caves are common around the coasts of Tristan da Cunha which all testify to a relative emergence of some 5 m. These are well expressed at Sandy Point and between Stony Beach and Seal Bay. Similar features can be seen along the W and SE coastal areas of Inaccessible Island. Benches, terraces and sea-caves are even more strikingly developed on Nightingale Island, but here and in neighbouring Middle Island, relative emergence amounts to some 12 m instead of 5 m. (The above section quoted from Baker, Gass et al at Sea Hen rocks, Nightingale Island, indicates a raised beach deposit lying above some 10 m of weathered trachyte, but unfortunately we do not know if the base of the trachyte was measured from sea level or higher up.) Dunne was in partial agreement with Daly's postulation of a 5 m post-glacial eustatic shift as deduced from many regions throughout the world, including oceanic volcanic islands. To account for the 12 m change in Nightingale Island, Dunne proposed that either this eustatic change was a separate and older one than the 5 m shift, or then Nightingale Island underwent a further 7 m change after the 5 m rise. He admitted it was difficult to decide, on the basis of evidence available, which hypothesis might be correct, but admitted it was somewhat difficult to account why and how Nightingale-Middle Islands should have risen a further 7 m when these islands in essence formed but a small part of an immense composite volcanic unit. (It should be noted that DOUGLAS (1930) claimed that Middle Island was once connected with Nightingale Island, but he doubted if Stoltenhoff Island was ever united with Nightingale, and DUNNE agreed with these views.)

Petrography

Early geological information on the Tristan group is mostly concerned with petrographic descriptions of specimens collected by various expeditions. RENARD (1885, 1887, 1889) described samples collected by the H. M. S. Challenger expedition; SCHWARZ (1905) described those of the H. M. S. Odin expedition; DOUGLAS (1930) described those of the 'Quest' expedition, as also did CAMPBELL SMITH (1930).

The first systematic study of the Tristan group was made by DUNNE (1941), whose publication is chiefly concerned with petrography. The Royal Society expedition (BAKER, GASS, HARRIS & LE MAITRE, 1964) members were dispatched in late 1961-early 1962 to study the recent alarming volcanic activity, and the report is not only the latest but also the most comprehensive dealing with all aspects of the geology of these islands.

In compilling the chapter on the Tristan da Cunha group, the author has relied chiefly on the publications of DUNNE and BAKER, GASS et al.

Nomenclature

DUNNE classified the rocks of the island group as follows:

Olivine-alkali-basalts
Hornblende-alkali-to-trachybasalts
Trachyandesite-basalts a) Mugearites
b) Trachy-andesite-basalts (tephritic)
Trachyandesites
Biotite-soda-trachytes
Feldspathoid-bearing trachytes
Essexitic Gabbros
Augitic-Hornblenditic-Biotitic-Anorthositic coarse-grained Xenoliths

BAKER, GASS et al thought that DUNNE's classification was somewhat cumbersome and so simplified this by classifying the rocks as

Alkali-basalts Trachyandesites
Trachybasalts Trachytes

along with appropriate prefixes, to cover the alkali-basalt – trachyte range of rocks occurring. They note that the rocks do indeed contain fair amounts of normative nepheline, but because this mineral never occurs in crystalline form (except specimen No. 30) the adoption of a terminology to indicate undersaturation was thought to be unnecessary. The divisions of the rocks are arbitrarily chosen, based upon their chemistry, with boundaries as shown in Fig. 92.

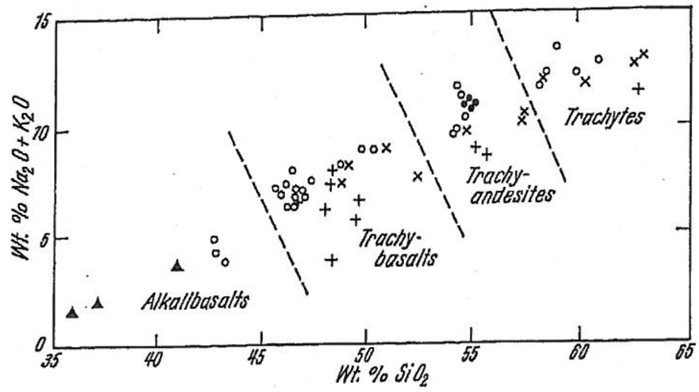


Fig. 92. Petrographic nomenclature: Total Alkali/Silica Diagram. (Baker, Gass, et. al., 1964)

▲ Tristan Xenoliths ○ Tristan lavas ● Tristan new lava

× Nightingale Group lavas + Inaccessible lavas

Seldom do these authors specify the types of pyroclastics present, but Dunne is more specific.

Rock Types

The rocks listed and described by Dunne (which includes collections studied by earlier workers) and Baker, Gass et al will be treated separately, the chemical analyses being shown in Tables 61 and 62 respectively.

Olivine-basalts and Olivine-alkali-basalts

These rocks vary in texture from strongly porphyritic to aphyric, they may be vesicular to dense if occurring as flows, or then anamesitic to doleritic if occurring as dykes. The melanocratic nature may vary from 40 % to 80 %.

Porphyritic types are the commonest, in which olivine and augite or plagioclase phenocrysts may be as large as 3 cms. In the more compact, black lavas, the phenocrysts may be either totally of ilmenite, magnetite, or then these two minerals. Most porphyritic types show phenocrysts of olivine, augite and plagioclase. The matrix is fine-grained, comprising pigeonitic augite, subordinate olivine, plagioclase laths with some interstitial alkali feldspar, 'anemousite and frequently some glass. The glassy nature becomes more pronounced in more scoriaceous parts of the rocks and may indeed comprise the entire groundmass. Iron oxides, serpentine, chlorite and saussurite occur as alteration products; apatite, ilmenite and magnetite occur as accessories.

As representative of these types of rocks occurring as flows, Table 61, No. 1 shows the chemical characteristics. Phenocrysts of augite, some olivine, plagioclase and ore comprise 42 % by volume of the rock, the groundmass being largely of plagioclase, alkali feldspar, 'anemousite', glass and augite. On a mineralogic basis, the rock resembles basalts found in volcanic oceanic islands, and chemically it is similar to many rocks analysed from Atlantic, Pacific and Indian oceanic island provinces. Specimen No. 1 can be termed a basic olivine-basalt tending towards alkalinity; a melanocratic increase would change the specimen into one of the ankaratrite group, and an increase in olivine, into an average olivine-basalt.

Olivine-basalts occurring as dykes comprise the same minerals as those present as flows, but are lighter coloured and of different texture. No. 2 is representative of the dyke rocks, showing plagioclase laths and interstitial orthoclase, anemousite and glass, these phenocrysts constituting some 60 % of the rock. Augite is prominent in the groundmass, and euhedral apatite and biotite flakes with ore comprise the accessories. No. 3 is an olivine-basalt from Inaccessible Island, whilst Nos. 4 and 5 are trachybasalts studied by CAMPBELL SMITH from the 'Quest' collection, which DUNNE preferred to call hornblende-alkali-basalts. Similarities between specimens 4 and 5 and a basalt from Madagascar and a trachydolerite from Kilimanjaro respectively were pointed out by CAMPBELL SMITH & DUNNE showed similarities chemically between the doleritic olivine-basalts as dykes in Tristan da Cunha with rocks from Kerguelen Island, Maui (Hawaii Islands), Mont Doré (Auvergne) and St. Helena, pointing out however that the chief difference between the Tristan rocks and the others referred to the ratio between the alkalis.

Hornblende-alkali to trachybasalts

Where the olivine-basalts show a smaller proportion of olivine – not exceeding 5 %, a greater abundance of leucratic minerals – usually more than 55 %, where the interstitial amount of alkali feldspar and nephelinitic material is greater – from 10 % to 20 %, and where titanium-rich basaltic hornblende occurs, then the rocks are named as above. Transitions occur between these rocks and the olivine-basalts on the one hand, trachybasalts on the other hand.

Most rocks have a greyish colour, are porphyritic, aphanitic to sub-fluidal matrix. Phenocrysts comprise: zoned augite, often showing hour-glass structure, brown basaltic hornblende showing all stages of resorption, plagioclase usually strongly zoned and commonly resorbed. Amongst the accessories, tiny phenocrysts of ore and apatite are most frequent, with occasional flakes of biotite. Transitional varieties to olivine-basalt show anhedra of olivine and magnetite. The groundmass comprises confused patches and laths of plagioclase, tabular pigeonitic augite, ore and a few scattered grains of olivine, usually altered. Alkali feldspar and anemousite occur interstitially, and a small proportion of brownish isotropic glass sometimes can be observed. Nos. 4 and 5 are representative of this class of rock. No. 4 was collected at the edge of the crater lake at an elevation of 1950 m, whereas No. 5 was got near sea level at Herald Point.

Trachy-Andesite-Basalts

These rocks are best developed on Inaccessible Island but also occur on other islands. Under this heading can be grouped rocks which by others have been named olivine-poor basalts, trachydolerites, andesine-andesites, andesine-basalts, trachybasalts and trachy-andesite. The greyish rocks occur either as flows or dykes, and have textures which may be either porphyritic, aphanitic, doleritic or fluidal. They may be considered as feldspathic rocks with a ratio of plagioclase to alkali feldspar of 5 : 1–2. Generally they show about 30 % melanocratic constituents, but as this may be as low as 5 %, then melanocratically some are trachyandesites, others trachybasalts.

DUNNE divided the group into two sub-divisions, the first of which was typified by the predominance of olivine over augite and the absence of an undersaturated leucocratic mineral. Such rocks were named mugearites by CAMPBELL SMITH, and indeed they are closely analagous to those from the type locality in Mull, Scotland. The other subdivision has very little olivine, perhaps none at all, along with interstitial undersaturated leucocratic constituents, and are here referred to as tepheritic trachy-andesite-basalts.

a) Mugearites. Many flows in the central and eastern parts of Tristan da Cunha and dykes in the western coastal area of Inaccessible Island comprise rocks of this type. These alkali-feldspar (oligoclase-andesine) rocks, 30–40 % melanocratic, may be well crystallized, of porphyro-doleritic appearance, ot then a fluidal arrangement of plagioclase laths with scattered phenocrysts may be evident. Specimen No. 6 is typical of the former, consisting of euhedral olivine, irregular augite, cubic ore and laths of andesine, with no interstitial material. Biotite flakes form the essential accessory. No. 7 is a fluidal-type mugearite, but as some pneumatolysis had occured in the specimen, it is scarcely typical. At Blenden Hall, Inaccessible Island, the fluidal variety is well represented, the rocks showing well-twinned laths of plagioclase enclosed in alkali feldspar, the whole displaying a marked fluidal arrangement when viewed microscopically. Phenocrysts of plagioclase and olivine, if present, are orientated parallel to the general flow direction. Biotite which frequently is the only phenocryst, occurs in some specimens. Apatite and basaltic hornblende occasionally are present as inclusion-filled phenocrystic euhedra. No. 8 is from a likely dyketype intrusion at South Point, Inaccessible Island. Phenocrysts comprise olivine and augite, and considerable less interstitial alkali feldspar is present. Ore is quite abundant, and some flakes of biotite. Under the microscope, the rock is very similar to some essexite boulders at Blenden Hall.

Rocks similar to the above are present in many places in the islands of the Pacific, Auvergne region, etc., though described under different names, and the trachydolerites of St. Helena and Madeira are chemically comparable. The mugearites of Mull, however, are slightly richer in alkalis and magnesia.

b) Tephritic Trachy-Andesite-Basalts. No. 9, collected at 1400 m on Tristan da Cunha, at First Lagoon Gulch, shows glomeroporphyritic clusters of plagioclase and some slightly resorbed hornblende, a few euhedra of olivine, magnetite and apatite, all in a strongly fluidal matrix of plagioclase laths, small pyroxene grains, elongated skeletal olivine, ore, and rare hornblende flakes. Interstitial matter comprises sodic plagioclase, alkali feldspar and glass. Nos. 10, 11 and 12 are from dykes on Middle Island, which can traced into Nightingale Island. The rocks here differ considerably from the Tristan da Cunha occurrences, although considered contemporaneous in age. Here the groundmass may approach that of the olivine-basalts and hornblende-alkali-basalts, or then to that of the trachy-andesite-basalts and trachyandesites. These Middle Islnd rocks are about 60 % melanocratic by volume, all are porphyritic, with the following commonest phenocryst associations: augite, augite-olivine, augite-olivine-hornblende, augite-hornblende. Subordinate to the above, or then absent perhaps, are strongly corroded plagioclase phenocrysts. The augites are strongly zoned, of titaniferous variety; olivine is partially altered to serpentine and the brown basaltic hornblende is unresorbed to an unusual extent.

Leucocratic varieties of these rocks may vary from aphyric to dopatic. Aphyric types have a groundmass similar to porphyritic types, but the amount of phenocrysts – chiefly hornblende – vary in abundance from dyke to dyke.

Nos. 11 and 12, studied by Campbell Smith, are representative of the aphanitic type of rocks and correspond most closely with the magma giving rise to these class of rocks. A few phenocrysts of plagioclase, partly resorbed hornblende, and magma cubes are present in a fluidal matrix of tabular and lath-shaped plagioclase, pyroxene, ore, serpentinized grains of olivine, tiny flakes of either biotite or hornblende. Interstitial material is partly orthoclase, but most is probably anemousite. (Note: Dunne believed that the chemical analysis of No. 12 by Campbell Smith was in error, for in thin-section this specimen showed no great difference from No. 11, and Dunne attributed the mistake to an over-estimate in the silica content.)

Trachyandesites

Dunne considered that almost the entire island of Nightingale was composed of rocks of this type, occurring also on Tristan da Cunha and Inaccessible Islands.

The Nightingale rocks were termed 'hybrid' trachyandesites, resulting from heterogeneous contamination of a trachytic, partly crystallized melt with 'foreign' phenocrysts of basaltic hornblende, plagioclase, augite, ore and apatite. According to the amount of xenocrysts which are admixed, a range of rocks from trachyandesites to biotite-trachytes outcrop. The degree of corrosion and solution of foreign material varies greatly, sometimes very slightly affected to complete disappearance. No. 13 is considered quite representative of the Nightingale rocks, which is greyish in colour, porphyritic, with phenocrysts of corroded basaltic hornblende, brownish biotite with magnetite rims, plagioclase often rimmed with a sodic border grading into orthoclase, colourless, zonal augite and greenish diopsidic augite. Accessories include sphene with resorption borders of ilmenite grains, apatite, and a few zircon grains. The matrix is a fluidal compound of alkali feldspar and plagioclase laths, grains and needles of colourless pyroxene, and grains of ore. Reddish varieties of this type of rock show a more trachytic groundmass, and biotite is the dominant dark phenocryst. Hornblende may have disappeared entirely, the olivine shows resorption, resulting in an augite rim around an iddingsite nucleus, the augites are of diopsidic and aegerine-augite varieties. The accessories are similar but sphene is not resorbed.

Interbedded with the lavas on Nightingale Island are thick layers of clastic material of similar mineralogical composition. In these brecciated tuffaceous layers, parts may be strongly vesicular, showing inclusions of large hornblende, plagioclase and ore. Field inspection shows that the hornblende was introduced during highly gaseous eruptive intervals, and spread through the lavas. Inclusion-filled apatites also occur in the hornblendes and masses of similar apatite and ore.

On Tristan da Cunha at an elevation of ca. 1300 m, on the NE side of the island, are somewhat vesicular flows, of uniform porphyritic appearance with well-developed flow structure. No. 14 shows phenocrysts of augite with features similar to those in the hornblende-alkali-basalts, partly resorbed hornblende and tabular plagioclase. Interstitially there is alkali feldspar, some anemousite and some grains and microlites of augite. Of accessories, there are anhedra of ore, very small phenocrysts of apatite and flakes of biotite.

On Inaccessible Island, at Blenden Hall, many remnant boulders and a few isolated outcrops of trachyandesites are found, and also as thick flows in the cliffs in the NW, W and SW of the island. These are closely associated and grade into mugearites, distinction being based on the more feldspathic groundmass and hornblende as the dominant dark phenocrysts in the trachyandesites. The rocks are light grey in colour, weathering to still lighter colours, are compact, with only a few phenocrysts of black hornblende and glomeroporphyritic plagioclase. Aphyric and vesicular types are also present. No. 15 is a dense, grey rock, with a few phenocrysts of basaltic hornblende slightly resorbed around the edges, glomeroporphyritic clusters of plagioclase in a fluidal, turbid matrix, diopsidic pyroxene and serpentinized skeletal olivine with interstitial alkali feldspar. Microphenocrysts of magnetite and apatite are accessories. No. 16, a dark grey, weathered porphyritic rock, shows phenocrysts of resorbed basaltic hornblende, some prismoids of augite, a flake or two or biotite and tabular plagioclase. The matrix is similar to the above specimen except that plagioclase occurs as tabular, zoned crystals. Calcite, serpentine and chlorite are present in small quantities.

High up in Cave Gulch, Tristan da Cunha, several flows are present which are presumed to have originated from the neck forming the second peak. These flows can also be termed trachyandesites, an analysis being given in No. 17. The light grey, compact, porphyritic rocks have evenly distributed phenocrysts of barkevitic hornblende, glomeroporphyritic clear zonal plagioclase, biotite flakes and zonal dioposidic augite. Accessories include small phenocrysts of magnetite, apatite, larger phenocrysts of sphene. The groundmass is a fluidal aggregate of plagioclase laths, alkali feldspar, grains and needles of diopsidic augite and abundant ore. Some boulders seen at West Point, Inaccessible Island, are very similar to these rocks and likely indicate a late phase of the trachyandesites.

Campbell Smith described a rock collected from the summit of Middle Island which he named a tephritic trachyte (No. 18). The rock forms a hard, compact matrix of breccia in a volcanic neck, and close by are rocks of chemical similarity to which Renard (1889) gave the name 'phonolitic tufa'. Few phenocrysts occur of plagioclase, augite, ore and resorbed hornblende, in a very fine-grained liquidous groundmass of plagioclase which is mostly enclosed in alkali feldspar, along with tabular augites, ore grains and often incipient mica. Chemically, these rocks are close associates of the trachyandesite-basalts dykes, trachyandesites and alkali-trachytes which also occur on Middle Island, as well as Nightingale Island.

Biotite-Trachytes

These rocks are represented as domes and monolithic masses on Inaccessible Island, as flows intermixed with 'hybrid' trachyandesites on Nightingale Island, as lapilli in the agglomerates of Middle Island and constitute the whole of Stoltenhoff Island. Those in the last-named locality are dense, greyish or reddish brown when weathered, somewhat porphyritic. No. 19, collected some 10 m above S. L. in the NW part of the islet, shows a few phenocrysts of plagioclase, biotite, diopsidic augite and rarely anorthoclase. The plagioclase is well twinned and of zonal character often tending towards a very sodic

For comparative purposes, the analysis of the Renard specimen is given below:

SiO_2	48.09
Al_2O_3	19.05
Fe_2O_3	3.44
FeO	5.59
MnO	0.00
MgO	3.50
CaO	9.42
Na_2O	5.06
K_2O	2.88
H_2O+	0.67
H_2O-	0.00
TiO_2	4.38
P_2O_5	0.00
Total	102.08

Specimen from NE Nightingale Island, opposite Middle Island.

rim bordered by alkali feldspar or then more frequently penetrated and replaced by the latter. Biotite is strongly pleochroic, but mostly is totally resorbed to yield a patchwork of iron oxides and other materials. Augites show good hour-glass structure and are often zoned. The matrix comprises alkali feldspar, diopsidic augite, magnetite cubes and biotite flakes, and, on occasion, sphene; magnetite and apatite are accessories. Seemingly no feldspathoids have been noted in these Stoltenhoff rocks but on Middle Island, rocks otherwise identical, do show some yellowish sodalites. The biotite-trachytes of Inaccessible Island are all quite similar and mineralogically analagous to the specimen described above. No. 20 is from the dome at Blenden Hall, Inaccessible Island. This reddish-white, porphyritic rock has phenocrysts of plagioclase, anorthoclase, biotite and barkevikitic basaltic hornblende, also inter-penetrating replacement growths of plagioclase and alkali feldspar. The matrix comprises laths of orthoclase, squares of strongly zoned plagioclase, short, tabular diopsidic augite, biotite flakes and ore. Cristobalite occurs in some vesicular interstices. Tiny euhedral phenocrysts of magnetite and apatite constitute the accessories. From SW Point, same island, trachytes similar to the above are found, but the phenocrysts of anorthoclase-plagioclase intergrowths are larger, the biotite is mostly resorbed, there are remnants of resorbed hornblende, and there are inclusion-filled, quite large phenocrysts of apatite. Specimens collected at S Point are identical to the above, but the plagioclase is somewhat fresher and is only partially replaced by alkali feldspar. The dome forming the summit of Inaccessible Island conprises deeply weathered trachyte, composed alkali feldspar, plagioclase and diopsidic augite.

Feldspathoid-bearing Trachytes

The most leucocratic rocks in the Tristan group are feldspathoid-bearing trachytes. Dunne was not sure whether or not nepheline was present in any of these rocks, but sodalite seemed more definite. Such rocks are exposed on Tristan da Cunha, Nightingale and Middle Island, and in each, the rocks are distinctive. Dunne classed them as of two types:

a) Sodalite-plagioclase-trachytes. No. 21, from the Peak crater, main island, is grey in colour when fresh, whitish when weathered, and has a rather drusy and somewhat porphyritic character. Small blue phenocrysts of sodalite and pyrite cubes are visible in hand specimen. Microscopically the rock is composed of glomeroporphyritic clusters of plagioclase, some being untwinned and strongly zoned and rimmed by alkali feldspar, whilst others do show twinning. There occur also resorbed biotite flakes, aegerine-augite, euhedra of sphene, some bluish sodalite grains. The groundmass is trachytic, comprising alkali feldspar and diopsidic augite, in which zircon, apatite and magnetite occurs as accessories. Chemically the rock is similar to the biotite-trachyte of Stoltenhoff Island.

b) Sodalite-trachytes. In eastern Nightingale Island, several large flows occur of compact, light greyish rocks with a pronounced flow structure. Where the rocks have been subjected to weathering, they acquire a strange mottled appearance, for which DUNNE could offer no explanation. Specimen No. 22, in thin-section, shows long prismoids of anorthoclase-orthoclase, aligned parallel in a fluidal aggregate of alkali feldspar, with cubes and hexagons of very small sodalites occurring interstitially. On a chemical basis, the specimen is analagous to many aegerine-augite trachytes and pulaskites.

On Middle Island some lapilli and the agglomerate at the Landing on Nightingale Island are essentially variations of the above in which anorthoclase, orthoclase phenocrysts are larger and perhaps include a lath or two of plagioclase. In the agglomerate of the flow E of the Landing, the trachytes have been contaminated with basaltic hornblende and plagioclase, but the matrix seems to have been little affected.

Specimen No. 23 is somewhat porphyritic and of brownish colour. Chief phenocrysts include irregular large sodalites, an occasional prismoid of anorthoclase, skeletal aegerine-augite and magnetite associations, some euhedra of sphene and zircon. The non-fluidal matrix comprises alkali feldspar, prisms of aegerine-augite, tiny magnetite cubes and minute, clear sodalites. Chemically this specimen is very similar to many phonolites and phonolitic trachytes, but the fm values of the latter are almost double those of the sodalite trachytes.

Essexitic Gabbros

On Inaccessible Island these rocks outcrop at Blenden Hall, and at W Point boulders of these rocks are found. No. 24, from the former locality, has a hypidiomorphic, granular texture, and consists of euhedral-subhedral olivine altered to serpentine, with iron oxides along cracks and cleavage planes, augite and some laths of plagioclase enclosed in a little alkali feldspar of anorthoclasic character in which are irregular intergrowths of sodic plagioclase. The accessories include grains and skeletal forms of ore, brown biotite and small apatites. The W Point boulders have the same minerals, but biotite is more plentiful and melanocratic minerals are less abundant.

These essexitic gabbros are chemically more rich in MgO than average rocks of this type, and indeed are more akin to some olivine-basalts, e. g. those from Juan Fernandez island group off the coast of Chile. (BAKER, GASS et al make no reference to essexitic gabbros in Inaccessible Island, doubtless regarding such occurrences as olivine-basalts.)

Table 61

Chemical Analyses of Rocks (CAMPBELL SMITH, 1930, DUNNE, 1941)

	Olivine-Basalts Ol.-Alk. Basalts			Horn.-Alkali to Trachy-Basalts		Trachy-Andesite-Basalts							Trachy-Andesites						Biotite-Trachytes		Feld. bear. Trachytes			Essex. Gabbro	Xenoliths		
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.	27.
SiO_2	42.51	46.24	47.76	47.44	46.31	49.30	48.10	49.30	50.02	48.76	50.64	52.13	54.40	54.43	55.51	54.94	54.35	57.10	59.91	62.36	58.20	62.23	58.71	48.11	35.70	36.76	40.76
Al_2O_3	12.82	15.75	15.68	17.17	17.36	18.85	19.39	16.36	19.58	15.10	21.75	20.48	17.34	18.23	18.20	17.69	19.97	21.05	18.44	18.99	19.10	18.43	20.03	14.29	10.45	16.18	19.19
Fe_2O_3	4.89	3.04	3.34	3.10	3.27	4.37	8.02	3.69	2.29	4.23	0.19	3.81	3.04	3.24	3.04	2.97	1.52	1.76	2.88	1.76	2.24	1.68	2.16	2.01	10.88	13.13	7.62
FeO	8.64	7.39	6.55	7.07	8.12	5.80	3.03	5.94	5.24	5.27	5.93	2.20	3.69	2.66	4.03	3.29	3.15	2.01	1.20	0.87	1.28	0.60	0.45	7.63	9.54	3.87	2.29
MnO	0.13	0.14	0.07	0.14	0.17	tr.	0.13	0.16	0.12	0.07	0.07	0.07	0.07	0.09	0.13	0.12	0.24	0.11	0.07	0.04	0.08	0.12	0.10	0.15	0.12	0.06	0.03
MgO	9.63	4.92	6.05	4.65	4.64	3.95	2.91	5.31	3.15	3.54	2.56	1.96	2.50	1.52	2.05	2.87	1.35	1.20	0.97	0.78	0.81	0.11	0.00	10.13	9.75	7.50	6.05
CaO	12.22	9.57	9.02	9.78	9.74	7.66	4.61	7.40	6.32	7.45	6.88	5.55	4.94	5.83	4.67	4.73	4.52	4.13	2.73	1.78	3.58	1.16	0.98	9.71	16.32	14.98	14.07
Na_2O	2.83	4.12	4.22	3.71	3.67	3.89	4.81	4.09	5.15	4.43	5.27	3.92	5.11	5.64	5.43	5.05	6.71	5.01	6.05	6.30	6.30	6.77	7.56	2.92	1.53	1.59	2.42
K_2O	1.40	2.60	1.94	2.95	2.79	2.65	2.56	1.71	3.71	3.96	3.73	3.75	4.73	4.71	3.15	3.76	4.53	5.33	5.83	5.01	5.94	6.28	6.03	0.98	0.14	0.33	1.36
H_2O+	0.41	0.29	1.87	0.28	0.21	0.45	1.87	1.67	0.21	3.11	0.44	2.21	1.11	1.55	0.56	1.03	0.38	0.97	0.30	0.63	0.90	1.60	3.19	0.46	0.61	0.83	0.70
H_2O-	0.05	0.05	0.00	0.11	0.08	0.30	2.08	0.49	0.00	0.43	0.31	1.96	0.00	0.00	0.25	0.47	0.04	0.43	0.16	0.24	0.13	0.06	0.22	0.09	0.00	0.00	0.00
TiO_2	4.29	4.48	3.05	4.02	3.64	2.02	2.60	3.18	3.39	2.93	2.50	2.00	2.38	1.82	2.12	2.18	2.18	1.11	1.21	0.72	1.33	0.65	0.39	3.27	5.13	4.88	3.56
P_2O_5	0.38	1.20	0.49	n.d.	n.d.	0.64	–	0.49	1.02	0.83	–	–	0.69	0.42	0.56	0.62	0.89	n.d.	0.22	0.21	0.21	0.07	0.06	0.31	0.05	0.02	1.99
Total	100.20	99.79	100.04	100.42	100.00	99.96	100.11	99.95	100.20	100.11	100.27	100.04	100.10	100.14	99.70	99.72	99.83	100.21	99.97	99.69	100.16	100.01	100.13	100.06	100.22	100.13	100.04
S. G.				2.85	2.83	2.68					2.72	2.41	a					2.61			b	c	d				

a) Includes ZrO_2 0.10. b) Includes Cl_2 0.06. c) Includes Cl_2 0.32. d) Includes Cl_2 0.32

1. Olivine-Basalt, Sandy Point, TdaC.
2. Doleritic Olivine-Basalt. Behind Settlement, TdaC.
3. Olivine-Basalt, West Pt., Inaccessible.
*4. Trachy-Basalt, TdaC.
*5. Trachy-Basalt, TdaC.
*6. Mugearite, Inaccessible Is.
*7. Mugearite, Inaccessible Is.
8. Mugearite, South Pt. Inaccessible Is.
9. Trachy-Basalt, First Lagoon Gulch, TdaC.
10. Trachy-Basalt, Middle Is.
*11. Trachy-Basalt, NE Peak, Middle Is.
*12. Trachy-Basalt, dyke, Middle Is.
13. Trachy-Andesite, Eastern section, Nightingale Is.
14. Trachy-Andesite, First Lagoon Gulch, TdaC.
15. Trachy-Andesite, Western section, Inaccessible Is.
16. Trachy-Andesite, Western section, Inaccessible Is.
17. Trachy-Andesite, Cave Gulch, TdaC.
*18. Tephritic Trachyte, Middle Is.
19. Biotite-Trachyte, Stoltenhoff Is.
20. Biotite-Trachyte, Inaccessible Is.
21. Sodalite-plagioclase-Trachyte, Crater Lake, TdaC.
22. Sodalite-Trachyte, E side, Nightingale.
23. Sodalite-Trachyte, Stony Beach, TdaC.
24. Essexitic Gabbro, Inaccessible Is.
25. Augititic endogenic inclusion in Basalt lava, Sandy Pt., TdaC.
26. Hornblenditic endogenic inclusion in Basalt, Sandy Pt., TdaC.
27. Biotite-bearing, plagioclase-rich endogenic inclusion in red cinder, Half Way Beach, TdaC.

(* = CAMPBELL SMITH specimen)

Beiträge zur Regionalen Geologie der Erde Band 10: MITCHELL-THOMÉ, S. Atlantic Islands
Gebrüder Borntraeger, Berlin · Stuttgart

ad p. 248

Table 61

	Olivine-Basalts Ol.-Alk. Basalts			Horn.-Alkali to Trachy-Basalts		Trachy-Andesite-Basalts							Trachy-Ande			
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	1
SiO_2	42.51	46.24	47.76	47.44	46.31	49.30	48.10	49.30	50.02	48.76	50.64	52.13	54.40	54.43	55.51	54
Al_2O_3	12.82	15.75	15.68	17.17	17.36	18.85	19.39	16.36	19.58	15.10	21.75	20.48	17.34	18.23	18.20	17
Fe_2O_3	4.89	3.04	3.34	3.10	3.27	4.37	8.02	3.69	2.29	4.23	0.19	3.81	3.04	3.24	3.04	2.
FeO	8.64	7.39	6.55	7.07	8.12	5.80	3.03	5.94	5.24	5.27	5.93	2.20	3.69	2.66	4.03	3.
MnO	0.13	0.14	0.07	0.14	0.17	tr.	0.13	0.16	0.12	0.07	0.07	0.07	0.07	0.09	0.13	0.
MgO	9.63	4.92	6.05	4.65	4.64	3.95	2.91	5.31	3.15	3.54	2.56	1.96	2.50	1.52	2.05	2.
CaO	12.22	9.57	9.02	9.78	9.74	7.66	4.61	7.40	6.32	7.45	6.88	5.55	4.94	5.83	4.67	4.
Na_2O	2.83	4.12	4.22	3.71	3.67	3.89	4.81	4.09	5.15	4.43	5.27	3.92	5.11	5.64	5.43	5.
K_2O	1.40	2.60	1.94	2.95	2.79	2.65	2.56	1.71	3.71	3.96	3.73	3.75	4.73	4.71	3.15	3.
H_2O+	0.41	0.29	1.87	0.28	0.21	0.45	1.87	1.67	0.21	3.11	0.44	2.21	1.11	1.55	0.56	1.
H_2O-	0.05	0.05	0.00	0.11	0.08	0.30	2.08	0.49	0.00	0.43	0.31	1.96	0.00	0.00	0.25	0.
TiO_2	4.29	4.48	3.05	4.02	3.64	2.02	2.60	3.18	3.39	2.93	2.50	2.00	2.38	1.82	2.12	2.
P_2O_5	0.38	1.20	0.49	n.d.	n.d.	0.64	–	0.49	1.02	0.83	–	–	0.69	0.42	0.56	0.
Total	100.20	99.79	100.04	100.42	100.00	99.96	100.11	99.95	100.20	100.11	100.27	100.04	100.10	100.14	99.70	99.
S. G.				2.85	2.83	2.68					2.72	2.41	a			

a) Includes ZrO_2 0.10. b) Includes Cl_2 0.06. c) Includes Cl_2 0.32. d) Includes Cl_2 0.32

1. Olivine-Basalt, Sandy Point, TdaC.
2. Doleritic Olivine-Basalt. Behind Settlement, TdaC.
3. Olivine-Basalt, West Pt., Inaccessible.
*4. Trachy-Basalt, TdaC.
*5. Trachy-Basalt, TdaC.
*6. Mugearite, Inaccessible Is.
*7. Mugearite, Inaccessible Is.
8. Mugearite, South Pt. Inaccessible Is.
9. Trachy-Basalt, First Lagoon Gulch, TdaC.
10. Trachy-Basalt, Middle Is.
*11. Trachy-Basalt, NE Peak, Middle Is.
*12. Trachy-Basalt, dyke, Middle Is.
13. Trachy-Andesite, Eastern section, Nightingale Is.
14. Trachy-Andesite, First Lagoon Gulch, TdaC.
15. Trachy-Andesite, Western section, Inaccessible Is.
16. Trachy-Andesite, Western section, Inaccessible Is.
17. Trachy-Andesite, Cave Gulch, TdaC.
*18. Tephritic Trachyte, Middle Is.
19. Biotite-Trachyte, Stoltenhoff Is.
20. Biotite-Trachyte, Inaccessible Is.
21. Sodalite-plagioclase-Trachyte, Crater Lake, TdaC.

Chemical Analyses of Rocks (CAMPBELL SMITH, 1930, DUNNE, 1941)

	Trachy-Andesites						Biotite-Trachytes		Feld. bear. Trachytes			Essex. Gabbro	Xenoliths		
12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.	27.
52.13	54.40	54.43	55.51	54.94	54.35	57.10	59.91	62.36	58.20	62.23	58.71	48.11	35.70	36.76	40.76
20.48	17.34	18.23	18.20	17.69	19.97	21.05	18.44	18.99	19.10	18.43	20.03	14.29	10.45	16.18	19.19
3.81	3.04	3.24	3.04	2.97	1.52	1.76	2.88	1.76	2.24	1.68	2.16	2.01	10.88	13.13	7.62
2.20	3.69	2.66	4.03	3.29	3.15	2.01	1.20	0.87	1.28	0.60	0.45	7.63	9.54	3.87	2.29
0.07	0.07	0.09	0.13	0.12	0.24	0.11	0.07	0.04	0.08	0.12	0.10	0.15	0.12	0.06	0.03
1.96	2.50	1.52	2.05	2.87	1.35	1.20	0.97	0.78	0.81	0.11	0.00	10.13	9.75	7.50	6.05
5.55	4.94	5.83	4.67	4.73	4.52	4.13	2.73	1.78	3.58	1.16	0.98	9.71	16.32	14.98	14.07
3.92	5.11	5.64	5.43	5.05	6.71	5.01	6.05	6.30	6.30	6.77	7.56	2.92	1.53	1.59	2.42
3.75	4.73	4.71	3.15	3.76	4.53	5.33	5.83	5.01	5.94	6.28	6.03	0.98	0.14	0.33	1.36
2.21	1.11	1.55	0.56	1.03	0.38	0.97	0.30	0.63	0.90	1.60	3.19	0.46	0.61	0.83	0.70
1.96	0.00	0.00	0.25	0.47	0.04	0.43	0.16	0.24	0.13	0.06	0.22	0.09	0.00	0.00	0.00
2.00	2.38	1.82	2.12	2.18	2.18	1.11	1.21	0.72	1.33	0.65	0.39	3.27	5.13	4.88	3.56
–	0.69	0.42	0.56	0.62	0.89	n.d.	0.22	0.21	0.21	0.07	0.06	0.31	0.05	0.02	1.99
100.04	100.10	100.14	99.70	99.72	99.83	100.21	99.97	99.69	100.16	100.01	100.13	100.06	100.22	100.13	100.04
2.41	a					2.61			b	c	d				

Trachy-Andesite, Western section, Inaccessible Is.
Trachy-Andesite, Western section, Inaccessible Is.
Trachy-Andesite, Cave Gulch, TdaC.
Tephritic Trachyte, Middle Is.
Biotite-Trachyte, Stoltenhoff Is.
Biotite-Trachyte, Inaccessible Is.
Sodalite-plagioclase-Trachyte, Crater Lake, TdaC.

22. Sodalite-Trachyte, E side, Nightingale.
23. Sodalite-Trachyte, Stony Beach, TdaC.
24. Essexitic Gabbro, Inaccessible Is.
25. Augititic endogenic inclusion in Basalt lava, Sandy Pt., TdaC.
26. Hornblenditic endogenic inclusion in Basalt, Sandy Pt., TdaC.
27. Biotite-bearing, plagioclase-rich endogenic inclusion in red cinder, Half Way Beach, TdaC.

(* = CAMPBELL SMITH specimen)

Beiträge zur Regionalen Geologie der Erde Band 10: MITCHELL-THOMÉ, S. Atlantic Islands
Gebrüder Borntraeger, Berlin · Stuttgart

ad p. 248

Augititic-Hornblenditic-Biotitic-Anorthositic Coarse-grained Xenoliths

CAMPBELL SMITH referred to hornblendic types of coasre-grained xenolithic inclusions and bombs, and DUNNE noted that they were associated with almost every secondary cinder cone of the main extrusive mass on Tristan da Cunha. They form approximately-rounded masses varying up to 30 cm in diameter and are 'cemented' along with basaltic blocks in the cinders or basaltic obsidian. They are to be interpreted generally as included cognate xenoliths rather than volcanic bombs. At Sandy Point, Tristan da Cunha, they occur scattered throughout the thick, fine-grained basaltic flow underlying the porphyritic olivine-basalt analysed in No. 1. At Stony Beach, a 20 m wide neck is filled with black, fragmented lava in which about 5 % by volume comprises xenoliths. A dyke on Nightingale Island, and basaltic flows on Inaccessible Island show much fewer similar inclusions.

Both as regards texture and mineral content, the xenoliths show great variation, which might suggest that they represent sporadic, heterogeneous, crystal agglomeration within a crystallizing magma rather than a 'truly' consolidated rock from such a magma. Textures are often hypidiomorphic to xenomorphic granular, and frequently coarse pegmatitic and fluidal schlieren-like varieties can be seen. On a volumetric basis, augite, hornblende and plagioclase are the dominant minerals; other minerals may include olivine, biotite, ore, titanite and apatite.

No. 25 is from a basaltic flow at Sandy Point, and is classed as an augititic endogenic xenolith, augite comprising 60.7 % by volume, plagioclase, 11.6 %, hornblende 7.9 %, titanite, apatite and interstitial matter, 19.8 %. These minerals seem to have crystallized almost simultaneously, the ore likely being slightly earlier. With an increase in the amount of hornblende, this type of rock passes over into a hornblenditic xenolith variety, and is here represented by No. 26. This specimen shows 32.4 % plagioclase by volume, 27.8 % hornblende, 27.6 % augite and 12.2 % ore. Here the crystallization order appears to have been plagioclase-ore-augite-hornblende. Specimen No. 27 is a friable rock showing recognizable fluidal character. Biotite in large flakes is present, the augite is non-zoned and the hornblende is often occurring parallel as thin blades, and frequently forms reaction rims around augite. The nature of the hornblende and large patches of biotite which have been changed to the so-called rubellanitic variety, indicate that the specimen underwent heating of different intensity. The mineral composition, on a volumatric percentage basis is: plagioclase 52.2, hornblende 24.6, biotite 14.0, augite 4.2, apatite 4.0, ore and titanite, 1 % each.

Xenoliths are indeed of great petrologic, genetic and volcanologic importance, but throughout the world not a great deal of rock analyses have been made of such endogenic inclusions, although of course many collections and descriptions have been given by various authors from many localities. The Tristan specimens appear to show a close analogy with those studied by LACROIX from Mont Doré, Auvergne, France, which he named mareugites, differing chiefly in that the former have no feldspathoids, although such are not always present in the LACROIX specimens. Chemically one can note some similarity between Nos. 25 and 26 and certain issites, avezacites and yamaskites, of the pyroxenite and hornblendite families, whilst No. 27 is akin to such types as berondites, melilite-fasanites, etc. It is also to be noted that chemically, the Tristan rocks are quite like many calcic basic volcanites such as basanites, melilite-ankaratrites, biotite-melilites, etc.

As already renarked, BAKER, GASS et al treated of a somewhat more simplified classification of the rocks. They pointed out the dominance of basalts, especially trachybasalts, and the more acidic character of the Peak material compared to that of the Base and the Main Cliffs.

Of distinct interest in the lavas is interstitial leucite (LEMAITRE & GASS, 1963) and the following points are noteworthy: it occurs only interstitially, it is a very rare mineral in oceanic islands, and apparently it has substituted for nepheline in an essentially silica-undersaturated magma series.

The following descriptions of rocks refer to Table 62.

Table 62 Chemical Analyses of Rocks (BAKER, GASS et al, 1964)

	28.	29.	30.	31.	32.	33.	34.	35.	36.	37.
SiO_2	42.93	42.43	45.5	45.70	46.48	46.00	46.01	46.07	45.96	46.36
TiO_2	3.73	4.11	3.3	3.65	3.10	2.83	2.19	3.08	3.44	3.54
Al_2O_3	12.05	14.15	18.3	16.70	16.68	17.03	16.84	17.06	17.84	16.19
Fe_2O_3	5.58	5.84	2.5	3.73	4.12	3.79	7.61	2.59	4.53	3.66
FeO	8.27	8.48	8.4	7.28	7.30	7.47	5.37	8.32	6.21	6.94
MnO	0.16	0.17	0.1	0.17	0.18	0.23	0.18	0.18	0.20	0.18
MgO	10.28	6.71	4.6	4.89	4.65	4.80	4.75	4.72	4.13	4.57
CaO	12.58	11.91	10.0	9.91	9.40	9.54	9.36	9.35	9.61	9.45
Na_2O	2.36	2.77	4.2	3.96	3.80	4.04	3.74	4.01	4.27	3.97
K_2O	1.47	2.04	3.0	3.10	3.07	3.11	2.72	3.16	3.16	3.15
H_2O+	0.15	0.34	0.1	0.09	0.57	0.09	0.01	0.12	0.17	0.29
H_2O-	0.11	0.44	0.2	0.12	0.07	0.02	0.08	0.06	0.05	0.19
P_2O_5	0.59	0.58	0.3	0.84	0.90	1.06	1.18	1.22	0.52	1.42
Total	100.26	99.97	100.5	100.14	100.32	100.01	100.04	99.94	100.09	99.91

	38.	39.	40.	41.	42.	43.	44.	45.	46.	47.
SiO_2	46.2	47.06	48.54	49.52	53.90	54.04	54.95	54.53	54.76	54.1
TiO_2	3.5	3.44	2.98	3.18	1.77	1.81	1.58	1.62	1.62	1.7
Al_2O_3	18.1	17.14	18.00	17.72	19.00	19.54	19.63	19.35	19.06	20.0
Fe_2O_3	3.1	3.29	3.78	2.55	3.37	2.60	1.62	4.85	3.15	2.0
FeO	6.7	6.65	5.18	5.66	3.05	3.35	3.31	1.20	2.95	3.3
MnO	0.2	0.18	0.18	0.18	0.18	0.19	0.18	0.18	0.18	0.2
MgO	4.6	4.35	3.32	3.42	1.68	1.66	1.42	1.50	1.51	1.8
CaO	9.4	9.00	8.49	7.58	6.25	6.22	5.73	5.76	5.60	5.2
Na_2O	4.7	4.08	4.74	4.94	5.04	5.26	5.89	5.84	5.87	6.1
K_2O	3.3	3.40	3.38	3.88	4.53	4.53	4.95	4.83	4.89	5.6
H_2O+	0.2	0.37	0.14	0.29	0.19	0.11	0.00	0.00	0.03	0.2
H_2O-	Tr.	0.27	0.03	0.15	0.28	0.19	0.01	0.02	0.03	0.3
P_2O_5	0.5	0.75	1.18	1.09	0.74	0.75	0.43	0.38	0.36	0.3
Total	100.5	99.98	99.94	100.16	99.98	100.25	99.96 a	100.22 b	100.17 c	100.8

a) Includes 0.27 Cl, 0.08 F. b) Includes 0.11 Cl, 0.12 F. c) Includes 0.13 Cl, 0.10 F.

Table 62 Chemical Analyses of Rocks (BAKER, GASS et al, 1964)

	48.	49.	50.	51.	52.	53.	54.	55.	56.
SiO_2	54.66	58.0	59.6	60.7	48.59	57.31	58.07	62.50	46.4
TiO_2	1.60	1.2	0.5	0.5	2.61	1.59	1.25	0.38	2.6
Al_2O_3	19.91	19.5	19.6	20.5	17.18	17.01	18.01	20.39	17.7
Fe_2O_3	3.07	1.7	2.4	2.3	2.64	6.47	2.92	0.31	3.3
FeO	2.73	2.2	0.1	0.4	5.12	0.28	2.30	0.84	7.2
MnO	0.18	0.1	0.2	0.2	0.17	0.12	0.13	0.09	0.2
MgO	1.10	1.0	0.4	0.2	3.53	2.05	1.15	0.02	5.8
CaO	5.56	3.3	1.3	1.4	8.08	3.71	3.15	1.28	9.3
Na_2O	5.85	6.5	5.7	6.2	4.13	5.38	6.00	5.93	3.9
K_2O	5.03	5.3	6.6	6.7	3.27	5.17	6.02	7.08	2.6
H_2O+	0.00	0.2	2.3	1.0	1.86	0.10	0.28	0.64	0.8
H_2O-	0.00	0.1	1.3	0.4	1.30	0.28	0.38	0.69	0.9
P_2O_5	0.29	0.2	0.05	0.03	0.87	0.52	0.43	0.10	0.2
Total	100.22 d	99.3	100.05	100.53	99.95	99.99	100.09	100.25	100.9

d) Includes 0.23 Cl, 0.10 F.

28. Base, Main Cliffs, E end, Sandy Pt.	Ankaramites
29. 300 yds. W of Caves Gulch. 100 ft. above SL.	Olivine-Basalt
30. East Molly Gulch. 4000 ft.	Trachybasalt
31. Hottentot Gulch. 5400 ft.	Trachybasalt
32. Small cinder cone, just N Big Sandy Gulch.	Trachybasalt
33. W headland, Boat Harbour Bay.	Trachybasalt
34. N end, Stony Beach. 1800 ft.	Trachybasalt
35. 'Pillow Lavas' foreshore, immediately W of 1961 lava.	Trachybasalt
36. Sandy Pt., 100 yds N of East End Gulch.	Trachybasalt (Flow-banded)
37. Pigbite Gulch. 60 ft.	Trachybasalt
38. Inside crater wall, Frank's Hill.	Trachybasalt
39. 100 yds. E of summit crater lake. 6550 ft.	Leucite-bearing Trachybasalt
40. Blineye parasitic cone.	Leucite-bearing Trachybasalt
41. Noisy Beach, 0.75 mile N Lyon Pt. 40 ft.	Leucite-bearing Trachybasalt
42. Stony Hill. SE lava.	Trachyandesite
43. Stony Hill. Prominent spine near summit.	Trachyandesite
44. 1961 eruption. Glassy bomb, 100 yds. W of tholoid.	Trachyandesite
45. 1961 eruption. W flank of tholoid, 40 yds. from summit.	Trachyandesite
46. 1961 eruption. Central flow.	Trachyandesite
47. W side of 'Ridge-where-the-goat-jumped-off'. 2500 ft.	Porphy. Trachyandesite
48. 1961 eruption. NE extremity of lava field.	Trachyandesite
49. SE flank of Peak.	Plagioclase Trachyte
50. 400 yds. W of Settlement Quarry, foot of Main Cliffs.	Phonolitic Alkali Feldspar Trachyte
51. 10 yds. E of Specimen 50.	Alk. Feldspar Trachyte
52. Cutting agglomerate N end of High Ridge, Nightingale Is.	Trachybasalt
53. 200 yds. NE of North Pond. Nightingale Is.	Trachyandesite
54. N end, High Ridge. Nightingale Is.	Plagioclase Trachyte
55. Hardies off Sea Hen Rocks, Nightingale Is.	Alk. Feldspar Trachyte
56. Headland, E of waterfall, Salt Beach, Inaccessible Is.	Trachybasalt

A. Picrite Basalts

Ankaramites. In hand specimen this rock (No. 28) is highly porphyritic with many phenocrysts of black pyroxene and less olivine, together constituting some 40 % to 50 % of the rock. The groundmass is aphanitic. Microscopically the phenocrysts are seen to be pyroxene, olivine, plagioclase and iron ore. The slightly zoned diopsidic-augite phenocrysts are usually euhedral and inclusions of iron ore are common. Colourless olivine is perfectly fresh, euhedral to subhedral and often has good cleavage. Plagioclase is progressively zoned from An_{85} in the centre to An_{45} at the borders, occurs as complex, twinned subhedral crystals, frequently as aggregates. More or less equidimensional iron ore is abundant. The matrix shows an intergranular texture, comprising essentially plagioclase, pyroxene and iron ore. The plagioclase is present as a felted mass of laths, with much granular iron ore and greenish grains of pyroxene, with olivine in minor quantity. Sometimes abundant needles of apatite are present.

B. Alkali Basalts

These are less common in Tristan than in many other oceanic islands. They are either equigranular or porphyritic, and with increase of olivine and augite phenocrysts, they pass into picrite basalts.

Alkali-Olivine-Basalt (No. 29). To the naked eye this is a greyish rock with a few small vesicles and a few phenocrysts of black pyroxene and red-brown olivine. In thin-section, the olivine phenocrysts are seen to be to euhedral to subhedral, often with good cleavage and no zoning. Iddingsitization is only slight, restricted to cracks and narrow border areas. The pyroxene phenocrysts are purple-brown titaniferous augite, with slight zoning, the rims sometimes packed with granular iron ore inclusions. The groundmass comprises pyroxene feldspar, iron ore, very small amount of amphibole and no olivine. The plagioclase has slight zoning, occurring as complexly twinned laths. In some interstices are areas of isotropic material, likely leucite, often containing apatite needles. Some flakes of brown amphibole and reddish biotite also occur in the matrix.

C. Trachybasalts

These are the predominant rocks of the islands and show considerable range in texture, occurring as flows, dykes, intrusive bodies and scoriaceous material in cinder cones. Many types contain interstitial leucite, and are here named leucite-bearing trachybasalts.

Trachybasalt. No. 30, a compact, greyish, aphanitic rock which, under the microscope is somewhat microporphyritic, having small phenocrysts of brownish titaniferous augite in a groundmass comprising plagioclase pyroxene, iron ore and some olivine. Plagioclase occurs as multiple-twinned laths, showing imperfect flow structure. The pyroxene is of same type as the small phenocrysts, occurring as rounded, prismatic grains, sometimes with iron ore inclusions. Iron ore is abundant as euhedral grains. Euhedral, fresh olivine very scarce, and some alkali feldspar occurs in some interstices. The specimen is taken from a dyke, but No. 31 is from a prominent flow. Megascopically this is a dense, somewhat porphyritic rock with pyroxene and plagioclase phenocrysts set in an aphanitic groundmass. In thin-section the euhedral to subhedral purple-brown pyroxene is likely a titaniferous augite, usually containing inclusions of iron ore. The plagioclase phenocrysts are slightly zoned with a tendency towards corroded outlines and may contain dust-like inclusions of iron ore. The matrix is a felted mass of ill-defined plagioclase laths and abundant granules of iron ore, along with pyroxene and olivine (?). The interstices are filled with alkali feldspar. No. 32, a highly vesicular trachybasalt, is a piece of a scoriaceous pyroclastic block so vesicular that in the centre it has a 'spongy' appearence. To the naked eye it is a dark grey, glassy rock with rare phenocrysts, and in thin-section is identical with the next specimen, No. 33. The latter is a vesicular trachybasalt, from the ropy surface of a lava at the base of the cliff section. The rock is dark grey in colour, aphyric, with many small elongated vesicles. Microscopically it comprises plagioclase, pyroxene, some olivine and iron ore set in interstitial glass. Plagioclase laths show some alignment and flow round the vesicles, being composed of albite, with Carlsbad twinning, the cores being approximately An_{65}. Pyroxene, euhedral to subhedral, shows some evidence of zoning, is unusually free of inclusions, as also is the perfectly fresh small olivine crystals. Iron ore occurs as clusters of somewhat equidimensional grains. Cloudy brown glass occurs interstitially. Specimens Nos. 32, 33 and 35, the last-named a trachybasalt from the 'pillow' lavas just N of the Settlement, are all identical in thin-section, and all came from parts of the Hillpiece parasitic centre. Trachybasalt from a columnar jointed lava hill (No. 34) is compact and aphanitic, with a few small phenocrysts of pyroxene and plagioclase. Microscopically there are seen a few phenocrysts of pyroxene, plagioclase and iron ore. Both pyroxene and plagioclase are anhedral. Resorbed basaltic hornblende crystals are probably xenocrystals. The matrix is intergranular, very fine-grained, comprising plagioclase, pyroxene, iron ore and amphibole. The plagioclase consists of minute laths, iron ore comprises small granules, the pyroxene is rounded and elongated. Pale-brown, pleochroic irregular flakes of amphibole also are present. The spotty appearance of the groundmass is due to the concentration of femic constituents along with a certain amount of isotropic material (leucite?). The flow-banded trachybasalt (No. 36) is an aphanitic rock with prominent 'flow' structures on weathered surfaces. In thin-section are seen a few microphenocrysts of iron ore. The matrix is intergranular, comprising plagioclase, iron ore, pyroxene and apatite. Viewed microscopically, the flow bands become vague. Plagioclase occurs as felted masses of laths, showing some zoning and multiple twinning. Interstitially occurs granular iron ore and pyroxene. Some flakes of slightly pleochroic amphibole can be detected. Hexagonal prisms of turbid apatite are fairly common. No. 37 is a greyish, compact rock with a fair number of small phenocrysts of black pyroxene and plagioclase. Microscopically the pyroxene is seen to be euhedral brownish titaniferous augite. Plagioclase also is euhedral and somewhat zoned. Equidimensional iron ore and small subhedral olivine crystals are also present. The matrix shows an intergranular texture, comprising plagioclase, pyroxene and iron ore. The plagioclase present as laths shows distinct parallel arrangement. Much granular iron ore occurs, also pyroxene between the feldspar laths. The interstices are filled with small amounts of alkali feldspar and leucite. No. 38 is a scoriaceous trachybasalt, a highly vesiculated dark-grey, aphanitic rock, forming part of a pyroclastic block. Under the microscope are seen a few small scattered phenocrysts of titaniferous augite. The matrix is partly crystalline, comprising slender laths of plagioclase, minute granules of iron ore and elongated grains of pyroxene, all set in a purplish-brown glass. Small grains of olivine (?) also occur in the groundmass. No. 39 is from a small plug at the summit crater lake, is massive, slightly porphyritic, with phenocrysts of black amphibole, black pyroxene and plagioclase laths in an aphanitic groundmass. Microscopically the phenocrysts comprise partly resorbed amphibole, pyroxene and plagioclase. The amphibole is similar to basaltic hornblende present in plutonic xenoliths (see below). It has a reaction rim consisting of granular iron ore, feldspar and pyroxene (?). The pyroxene is thought to be a slightly titaniferous augite, often showing simple twinning. The complexly twinned plagioclase is strongly zoned from An_{80} to An_{70}, is subhedral to euhedral and often packed with dust-like iron ore in the outer zones of the crystals. The matrix has an inter-granular texture, comprising plagioclase, pyroxene, iron ore, leucite and alkali feldspar. The plagioclase forms a felted mass of laths which often show simple twinning. Pyroxene and iron ore tend to be granular. In parts of the matrix the interstices are filled with alkali feldspar, often full of small apatite needles: in other areas, leucite fills the interstices, also often full apatite needles. No. 40 comes from a volcanic neck in the Blineye parasitic centre. It is a compact, greyish, aphanitic rock, some phenocrysts of plagioclase and amphibole visible megascopically. In thin-section the rock is slightly 'porphyritic', with 'phenocrysts' of plagioclase, resorbed amphibole, pyroxene, accessory iron ore and apatite. Very likely many of the 'phenocrysts' are actually xenocrysts derived from the plutonic xenoliths. Plagioclase occurs as euhedral crystals, complexly twinned and slightly zoned at margins. The amphibole is all but entirely resorbed and is now represented by iron ore, pyroxene and feldspathic material. It is deduced that the original amphibole was anhedral basaltic hornblende. The pyroxene is anhedral titanaugite, often with dust-like inclusion of iron ore. The matrix has a very fine-grained intergranular texture, consisting of plagioclase, iron ore, pyroxene, leucite and sodalite. Minute flakes of biotite (?) also present in small quantities. The 'spotty' appearance of the groundmass is due to concentrations of femic constituents and leucite. The latter occurs interstitially and also fills small cavities. Sodalite was only positively identified in X-ray powder-photographs. No. 41 is a greyish, aphanitic rock with a few small irregular vesicles. Pale-grey leucite-rich spots cover ca. 10 % of the surface, the spots often being arranged in roughly parallel lines, thus giving a flow-banded appearance. In thin-section there occur some micro-phenocrysts of faintly zoned plagioclase and rare pyroxene. The groundmass has a fine-grained, intergranular texture, comprising plagioclase, pyroxene, iron ore, some olivine and leucite, as also a few minute flakes of amphibole and biotite. Pale-grey spots on the weathered surfaces are seen as rounded areas in the matrix where the interstices are entirely filled with leucite. If these areas become larger, they are often crowded with acicular needles of apatite.

D. Trachyandesites

In the secondary centres these are the chief rock types, also occurring as flows in the main sequence, probably also as dykes. No. 42 is a greyish, finely porphyritic rock with some phenocrysts of feldspar and elongate hornblende. In thin-section shows hyalopilitic and somewhat trachytic texture, with subparallel phenocrysts of plagioclase, pyroxene and amphibole in a microcrystalline to glassy matrix. Phenocrysts of plagioclase display large unzoned cores of labradorite and finely-zoned borders ranging to andesine. Most plagioclase is free of inclusions and alternation products. Pyroxenes have a prismatic habit, show well-defined zoning. It is possible that the core represents soda-augite, the wide rim, titaniferous soda-augite and the thin outermost border, titaniferous aegerine. Amphibole phenocrysts always show some degree of resorption, and is at times completely replaced by ore. Two varieties, both likely basaltic hornblende, were recognized. The hyalopilitic matrix comprises a network of small plagioclase laths, aegirine microlites and ore in a turbid aggregate of alkali feldspar and abundant glass. The tholoid from the same locality, very similar to the above specimen, is analysed in No. 43.

Nos. 44, 45, 46 and 48 are taken from the region of the 1961 eruption. The material of the initial tholoid (No. 45), the central flow (46) and the dome show a uniformity, being greyish, finely-vesicular rocks with occasional stumpy prismatic plagioclase crystals and elongate amphibole in an aphanitic base. In thin-section, the rocks show fluidal texture, with here and there large phenocrysts of plagioclase, clinopyroxene and basaltic hornblende, along with microphenocrysts of plagioclase and pyroxene in a microcrystalline to glassy matrix. The large phenocrysts of plagioclase have basic labradorite cores surrounded by a zone ranging to sodic andesine. Microphenocrysts of plagioclase show similar cores with borders ranging outwards to An_{40}. Large phenocrysts of clinopyroxene sometimes occur, and frequently enclose poikilitically small plagioclase laths and ore granules. The core of these phenocrysts is evidently aegerine-augite, with borders probably of a titanaugite. Strongly coloured amphibole phenocrysts may be basaltic hornblende, but because of titanium present in analyses, also sphene and ilmenite, may be these amphiboles are akin to kaersutite in composition. The abundant ore is predominantly ilmenite. A most interesting constituent, occurring as scattered, discrete grains, is the mineral haüyne. Nos. 47 and 48 are from lava fields. No. 47 is a porphyritic rock with many phenocrysts of white plagioclase, black, elongated amphiboles and black plates of biotite, all set in a greyish aphanitic groundmass. Microscopically the phenocrysts comprise plagioclase, amphibole, biotite, iron ore, some pyroxene and apatite. The plagioclase shows normal zoning, often bordered by a thin layer of alkali feldspar, and frequently occurs as glomerocrysts. The amphibole may be barkevitic hornblende, is euhedral to subhedral, very fresh and almost unzoned. The biotite is strongly pleochroic and shows very slight indication of resorption. Apatite and pyroxene also occur. The matrix comprises a felted mass of alkali feldspar laths. Minute needles of colourless pyroxene and euhedral grains of iron ore are abundant in the matrix. (Note that No. 47 is NOT related to the 1961 eruption.) No. 44 is a volcanic bomb associated with the 1961 tholoid. The bombs in general have highly vesicular, scoriaceous crusts. A microscopic study of one of these (not the above specimen) showed phenocrysts of plagioclase, clinopyroxene and basaltic hornblende in a predominantly glassy matrix. The few large plagioclase crystals show a network of glassy material in the core. Plagioclase microphenocrysts are somewhat zoned. The basaltic hornblende shows no resorbed rim or corona of iron ore. Amphibole seems rather more abundant in bombs than in specimens from the initial tholoid, lava field and dome. Sometimes phenocrysts of aegerine-augite are present. The pyroxene microphenocrysts have a prismatic habit. Ilmenite crystals are common, but no haüyne has been detected. The matrix comprises plagioclase and pyroxene microlites.

E. Trachytes

Usually these rocks occur as intrusives, more rarely as lava flows, Mineralogically they can be divided into two groups: plagioclase trachytes and alkali-feldspar trachytes. In some there is a tendency towards phonolite.

Plagioclase Trachyte. No. 49 is from a volcanic plug. The specimen is compact, porphyritic, having lath-like phenocrysts of plagioclase and black, elongated pyroxenes and amphiboles, set in an aphanitic matrix. Foliation is very clear in the phenocrysts. Microscopically the phenocrysts are seen to incorporate plagioclase, amphibole, pyroxene, iron one and sphene. Plagioclase occurs as complexly twinned laths, with some oscillatory zoning and often a thin border of alkali-feldspar. Basaltic hornblende is euhedral to subhedral, always partly resorbed to an aggregate of granular iron ore, often with apatite inclusions. Aegerine-augite is euhedral to subhedral showing slight zoning and inclusions of iron ore and apatite needles. Euhedral sphene and prismatic apatite also occur. The groundmass comprises blocky laths of alkali-feldspar, pyroxene needles and euhedral grains of iron ore. Foliation can also be observed in the matrix.

Phonolitic Alkali-Feldspar Trachyte. To the naked eye, No. 50 shows many small phenocrysts of nepheline, with one or two phenocrysts of alkali-feldspar. In thin-section the phenocrysts are nepheline, alkali-feldspar and minor sphene. Nepheline is present as euhedral, hexagonal prisms with a yellow alteration product border, having many inclusions of pyroxene. The alkali-feldspar occurs as subhedral laths and there are also some exsolution blebs of a more sodic phase. The matrix is very cloudy, comprising ill-defined alkali-feldspar laths, elongated grains of aegerine-augite and iron ore.

Alkali-Feldspar Trachyte. Megascopically No. 51 is a compact rock of somewhat speckled appearance. In thin-section, phenocrysts are alkali-feldspar, iron ore and sphene. The alkali-feldspar is euhedral to subhedral, occurring as laths and often clusters, showing signs of exsolution to a more sodic phase. Sphene occurs euhedrally. The groundmass has a very fine trachytic texture, consisting of alkali-feldspar, aegerine-augite and iron ore. The pyroxene is oxidized and is present as very ragged crystals frequently poikilitic. Iron ore is scattered throughout the matrix abundantly. A colourless isotropic mineral (sodalite?) often occurs as a coating to the alkali-feldspar laths and also as discrete crystals where sometimes it is associated with small nepheline crystals.

F. Plutonic Xenoliths

Baker, Gass et al examined some 250 specimens of these rocks from Tristan da Cunha and in general confirmed the observations of Campbell Smith & Dunne regarding these rocks. Mineralogically they are relatively simple, comprising essentially plagioclase, clinopyroxene, amphibole and iron ore, in all proportions. As accessories there are apatite, biotite and sphene. Olivine is very rare, hypersthene entirely absent, thus quite unlike the gabbroic xenoliths of Gough and Ascension Island. Plagioclase is usually quite fresh, has a composition in the labradorite-bytownite range, and sometimes is slightly zoned. Clinopyroxene appears similar to titanaugites in the lavas. Often it shows irregular alteration to a brown amphibole. Iron ore sometimes occurs as exsolved rods and blebs. The amphibole is similar in appearance to that seen in many trachybasalts and trachyandesites. Dunne has named the amphibole kaersutite, which commonly occurs as discrete blade-shaped crystals. In xenoliths found in effusives, the amphibole is usually altered to a granular mixture of ilmenite, pyroxene (referred to by Dunne as rhoenite) and plagioclase. Frequently such alteration is complete and at such a stage the xenolith is ready to split-up into xenocrysts. Iron ore occurs usually as large irregular masses, more rarely as discrete grains. Apatite might be abundant. Biotite is present as a secondary mineral, with a tendency to be present in xenoliths derived from tuffs and cinder cones.

Specimens 52–55 are from Nightingale Island, and No. 56 is from Inaccessible Island.

Trachybasalt. No. 52 is from a thin basic dyke intruding volcanic agglomerates on High Ridge. The rock is dark-grey, aphanitic, with occasional phenocrysts of pyroxene. Microscopically the rock is fine-grained with flow texture. Plagioclase laths often show only simple twins. Pyroxene is present interstitially as tiny granules, also as rare crystals. Iron ore granules occur in the interstices also, some unidentifiable ferromagnesian material and some residual patches of leucite. Rare xenocrysts of resorbed basaltic hornblende and occasional fragments of trachyte also are present. No. 56, a dyke rock from Inaccessible Island, is classed in the table by BAKER, GASS et al as a trachybasalt from the Salt Bay area. They give general petrographic descriptions of ankaramites, olivine-basalt and basalt dykes in this region, but none referring to this actual specimen.

Trachyandesites. No. 53 has a porphyritic appearance, with phenocrysts of white plagioclase, dark-brown amphibole and pyroxene, in a greyish aphanitic groundmass. In thin-section, the phenocrysts are seen to include plagioclase, pyroxene, highly resorbed basaltic hornblende and apatite. The subhedral plagioclase is complexly twinned, slightly zoned and at times has a rim of alkali-feldspar. Pyroxene is zoned from purplish titaniferous augite to greenish aegerine-augite. Basaltic hornblende is frequently completely resorbed. The matrix consists of felted material of ill-defined alkali-feldspar laths, granules of aegerine-augite and deep-red hematite (?).

Trachytes. No. 54 is a compact, porphyritic rock with phenocrysts of black amphibole and pyroxene, and plagioclase, the matrix being bluish and aphanitic. Microscopically the phenocrysts were identified as plagioclase, pyroxene, resorbed basaltic hornblende and apatite. Plagioclase is slightly zoned, is complexly twinned, euhedral to subhedral in form. The euhedral pyroxene is aegerine-augite, a second generation of elongated pyroxene crystals also being present. Basaltic hornblende is usually completely resorbed. Elongated, turbid apatite is present but not common. The groundmass comprises blocky crystals of zoned alkali-feldspar, small grains of euhedral iron ore and minute, rod-like crystals of another pyroxene. No. 55 was from a columnar jointed lava underlying tuff horizons. To the naked eye the rock is coarse-grained, but actually is porphyritic, with many phenocrysts of white feldspar and some black elongated pyroxenes, set in a greyish, crystalline groundmass. In thin-section the phenocrysts comprise alkali-feldspar, aegerine-augite, iron ore, sphene and zircon. The alkali-feldspar is present as tabular crystals, twinning is not common, and there are blebs of an exsolved sodic feldspar present. Iron ore, sphene and zircon occur as accessory phenocrystal minerals. The matrix comprises a mass of blocky and felted lath-like crystals of alkali-feldspar, with granules of aegerine-augite and iron ore.

Norms and Modal Composition

Tables 63 to 67 refer to statistics provided by DUNNE. In Table 63 it is seen that in the olivine- and hornblende-alkali-basalts, the normative molecular quantities of potash feldspar vary between 8.5 and 17.3, nepheline between 5.3 and 10.7. The normative nepheline is not ascribed to the presence of large quantities of augite by DUNNE but rather to the fact that it is chiefly suppressed in the matrix, mostly in the form of anemousite, lesser so in the form of glass. The ratio of normative amounts of An to Ab varies between 1.4 and 0.6.

Table 63

Norms (Dunne, 1941)

Sample Number	Q	Or	Ab	An	Sod	Ne	Wo	En	Hy	Fo	Fa	Mt	Hm	Ru	Ap
1.	–	8.5	12.0	18.3	–	8.2	16.1	–	–	20.1	7.7	5.2	–	3.1	0.8
2.	–	15.8	22.5	16.8	–	8.8	9.9	–	–	10.3	7.3	3.2	–	3.2	2.2
3.	–	11.8	29.5	18.3	–	5.3	9.6	–	–	12.7	6.0	3.6	–	3.2	1.0
4.	–	17.3	15.8	21.5	–	10.7	12.2	–	–	9.7	6.8	3.2	–	2.8	n.d.
5.	–	16.8	16.1	22.7	–	10.2	10.4	–	–	9.7	8.0	3.5	–	2.6	n.d.
6.	–	15.8	34.0	26.5	–	0.9	2.3	–	–	8.3	4.5	4.6	–	1.4	1.7
7.	8	15.7	41.8	23.8	–	1.8	0.4	–	–	6.3	–	7.4	0.9	1.9	n.d.
8.	–	10.3	37.7	21.6	–	–	4.8	5.6	–	7.1	5.4	3.9	–	2.3	1.3
9.	–	21.5	28.3	19.3	–	10.5	2.5	–	–	6.5	4.9	2.3	–	2.3	1.9
10.	–	24.2	29.0	9.8	–	7.6	9.3	–	–	7.6	4.0	4.7	–	2.1	1.7
11.	–	22.0	20.2	24.2	–	15.8	3.9	–	–	5.2	6.8	0.2	–	1.7	n.d.
12.	–	23.2	36.5	28.3	–	–	0.1	5.7	–	–	0.6	4.2	–	1.4	n.d.
13.	–	27.8	39.5	10.3	–	4.1	4.0	–	–	5.2	2.8	3.2	–	1.7	1.4
14.	–	27.8	36.5	10.5	–	8.4	6.4	–	–	3.2	1.6	3.2	–	1.5	0.8
15.	–	18.5	49.2	16.0	–	–	1.6	5.6	–	0.1	3.3	3.2	–	1.4	1.1
16.	–	22.5	45.5	14.8	–	–	2.0	3.6	–	3.3	2.4	3.2	–	1.5	1.2
17.	–	26.2	35.5	11.0	1.0	13.0	2.5	–	–	2.7	3.1	1.6	–	1.8	1.6
18.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
19.	–	33.8	48.8	5.8	–	2.9	2.5	–	–	2.0	–	3.0	–	0.8	0.4
20.	1.2	29.2	56.2	8.5	–	–	0.1	2.2	0.3	–	–	1.8	–	0.5	–
21.	–	34.5	40.5	6.3	1.0	8.0	4.0	–	–	1.7	0.4	2.3	–	0.9	0.4
22.	1.4	37.0	50.2	2.7	5.0	–	1.1	0.3	–	–	–	1.6	0.1	0.5	0.1
23.	–	35.5	45.5	4.2	5.0	7.4	0.1	–	–	–	–	1.4	0.5	0.3	0.1
24.	–	5.8	26.2	23.0	–	–	9.3	7.5	–	15.3	7.9	2.2	–	2.3	–
25.	–	0.8	2.1	22.0	–	7.4	25.1	–	–	22.1	5.9	11.9	–	3.7	–
26.	–	2.0	7.8	37.5	–	4.4	16.0	–	–	16.2	–	9.2	3.4	3.5	–
27.	–	8.2	13.5	38.2	–	5.2	8.4	–	–	12.7	–	5.6	1.7	2.5	4.0

Table 64

NIGGLI Values of Tristan Samples (DUNNE, 1941)

Sample Number	si	al	fm	c	alk	k	mg	c/fm	t	p	Magma Type
1.	85	15	51	26.5	7.5	0.25	0.56	0.50	6.5	0.3	Ankaratritic-Alk-Issitic
2.	113	22	39	25	14	0.30	0.46	0.65	8	1	Normal Theralite-Gabbroic
3.	116	22.5	41	23.5	13	0.24	0.53	0.57	5.5	0.5	Ditto
4.	115	25	37	25	13	0.34	0.45	0.68	7	–	Ditto
5.	110	24	38.5	25	12.5	0.34	0.42	0.64	6.5	–	Ditto
6.	127	29	36	21	14	0.31	0.42	0.58	4	0.7	Normal Dioritic to Mugearitic
7.	135	32	36	14	18	0.26	0.33	0.38	5.5	–	Ditto
8.	129	25	41	21	13	0.21	0.50	0.50	6	0.6	Ditto
9.	137	31	31	18	20	0.32	0.43	0.58	7	1.2	Normal Essexitic
10.	133	24	35	32	19	0.37	0.41	0.62	6	1	Mugearitic
11.	138	35	24.5	20	20.5	0.32	0.42	0.81	5	–	Rouvillitic
12.	164	38	24	19	19	0.39	0.38	0.79	5	–	Essexitic-Akeritic (?)
13.	167	31.5	28	16	24.5	0.38	0.41	0.57	5.5	1.0	Kassaitic to Nosykombitic
14.	168	33	22	19	26	0.35	0.33	0.90	5	0.5	Kassaitic
15.	175	33	28	16	23	0.27	0.35	0.56	5	0.8	Kassaitic to Nosykombitic
16.	171	32.5	29	16	22.5	0.33	0.45	0.54	5	0.8	Ditto
17.	170	37	19	15	29	0.31	0.33	0.81	6	1.0	Larvikitic-Essexitic-Foyaitic
18.	190	41	16	15	28	0.41	0.37	0.94	3	n.d.	Larvikitic-Leuco-Syenitic
19.	213	39	16.5	10.5	34	0.39	0.31	0.63	3	0.3	Pulaskitic
20.	243	43.5	13	7.5	36	0.34	0.36	0.58	2	0.4	Nordmakitic
21.	200	39	14	13	34	0.38	0.30	0.93	3	0.3	Pulaskitic
22.	252	44	8	5	43	0.38	0.09	0.58	2	0.1	Bostonitic
23.	225	45	8	4	43	0.34	0.00	0.50	1	0.1	Alkali-Syenite-Aplitic
24.	106	18.5	51	23	7.5	0.18	0.65	0.45	5.5	0.3	Normal Gabbroic to Essexite-Gabbroic
25.	64	11	55	31	3	0.06	0.47	0.57	7	0.04	Issitic
26.	71	18.5	47	31	3.5	0.12	0.46	0.66	7	0.01	Ditto
27.	89	24	36	33	7	0.27	0.54	0.90	6	2	Berondritic

Table 65 Average NIGGLI Values of the Main Groups of Rocks (DUNNE, 1941)

Rock Group	si	al	fm	c	alk	k	mg	Magma Type
Pyroxenitic and Hornblenditic Xenoliths	67	15	51	31	3	0.09	0.47	Issitic
Olivine Alkali Basalts	85	15	51	26.5	7.5	0.25	0.56	Ankaratritic
Olivine-hornblende Alkali Basalts	113	23.5	39	24.5	13.0	0.31	0.47	Normal-Theralite-Gabbroic
Trachy-andesite-Basalts, including Mugearites	133	29	34	19.5	17.5	0.30	0.42	Normal Essexitic
Trachy-Andesites	170	33.5	25	16.5	25	0.33	0.37	Kassaitic
Plagioclase-rich Trachytes	206	39	15	12	34	0.38	0.30	Pulaskitic
Trachytes	240	44	10	5	41	0.35	0.15	Nordmarkitic

Table 66 Modal Composition, measured and estimated, in Volume Percentages (DUNNE 1941)

	1.	2.	3.	4.	5.	6.	8.	9.
Plagioclase	2P 23G	16P 30G	35	45	45	53	50	5P 40G
Alk. Feldspar	15^1	17	15	10^2	15^3	20	16	20
Anemousite								
Anorthoclase								
Sodalite								
Glass			10					10
Augite	28P 10G	3P 20G	21	30	30	8	11	6
Diop. Augite								
Aeg. Augite								
Hornblende				5				2
Olivine	8P 2G	5P 2G	9	p	p	12	13	10
Biotite			2			2	1	
Apatite	p	1		p	p	1	1	1
Titanite								
Zircon								
Ore	4P 8G	6	8	10	10	4	5	6
Serp. Calcite Chlorite.							3	

In the trachybasalts and trachyandesites of Inaccessible Island (Nos. 6, 7, 8, 15 and 16), olivine is more abundant than augite. Compared to the olivine-alkali-basalts and the other trachyandesite-basalts and trachyandesites, these rocks show much greater saturation and indicate a somewhat special group, with affinities to specific Pacific rocks rather than the pronounced Atlantic character of the others. The normative amount of potash feldspar varies between one-fifth and one-third of the total alkali-feldspar. Normative anorthite constitutes ca. 30 % of the total feldspar in the mugearites, and 20 % in

Table 66 Modal Composition, measured and estimated, in Volume Percentages (Dunne 1941)

	10.	13.	14.	15.	16.	17.	19.	20.
Plagioclase	2.6P 10G	9.3P 18G	10.5P 20G	4P 75G	2P 75G	8P 40G[8]	6P	8P 10G
Alk. Feldspar	50[4]	50	40				84	70
Anemousite								
Anorthoclase								4P
Sodalite								
Glass			10			35		
Augite	25	0.4P 11G	3.5P 9G	5[6]	10[7]	1P 6G		
Diop. Augite							4	0.5P 3G
Aeg. Augite								
Hornblende	5.4	5.8	2.5	5	2	3.5	3[10]	3[11]
Olivine	2							
Biotite		0.5						
Apatite			2[5]	1	1	2[9]		
Titanite								
Zircon								
Ore	5	1P 2G	1.5P 3G	5	5	0.5P 3.5G	3	1.5
Serp. Calcite Chlorite.				5				

	21.	22.	23.	24.	25.	26.	27.
Plagioclase	10P			45	11.6	32.4	51.2
Alk. Feldspar	75	90	86				
Anemousite							
Anorthoclase				15			
Sodalite	3	5	10				
Glass							
Augite				14	60.7	27.6	4.2
Diop. Augite	1P 5G						
Aeg. Augite		3	2.5				
Hornblende					7.9	27.8	24.6
Olivine				23			
Biotite	1			3[13]			14.0
Apatite							4.0
Titanite							1.0
Zircon	1						
Ore	4	2[12]	1.5		19.8	12.2	1.0
Serp. Calcite Chlorite.							

P = Phenocrysts G = Groundmass p = Present

[1] Includes Anemousite and Glass.
[2] Includes Glass.
[3] Includes Glass.
[4] Includes Glass, etc.
[5] Includes Sphene and Zircon
[6] Includes Olivine.
[7] Includes Olivine.
[8] Includes Alk. Feldspar.
[9] Includes Sphene and Zircon.
[10] Includes Biotite.
[11] Includes Biotite.
[12] Includes Titanite.
[13] Includes Apatite and Ore.

Table 67

Molecular Base (Dunne, 1941)

Sample Number	Rock Name	Si	L			
			Kp	Ne	Hl	Cal
25.	Pyroxenitic Xenolith	64	0.5	8.7	–	13.2
26.	Pyr.-Horn.-Plag. Xenolith	71	1.2	9.1	–	22.5
1.	Alk. Olivine-Basalt	85	5.1	15.4	–	11.0
27.	Horn.-Biot.-Plag. Xenolith	89	4.9	13.3	–	22.9
24.	Essexitic Gabbro	106	3.5	15.7	–	13.8
5.	Alkali Basalt	110	10.1	19.9	–	13.6
2.	Doleritic Alk. Ol.-Basalt	113	9.5	22.3	–	10.1
4.	Horn. Alk. Basalt	115	10.4	20.2	–	12.9
3.	Alk. Ol.-Basalt	116	7,1	23.0	–	11.0
6.	Mugearite	127	9.5	21.3	–	15.9
8.	Mugearite	129	6.2	22.6	–	13.0
10.	Trachy-Andesite-Basalt	133	14.5	25.0	–	5.9
7.	Mugearite	135	9.4	27.0	–	14.7
9.	Trachy-Andesite-Basalt	137	12.9	27.5	–	11.6
11.	Trachy-Andesite-Basalt	138	13.2	28.0	–	14.5
12.	Trachy-Andesite-Basalt	164	13.9	21.9	–	17.0
13.	Trachy-Andesite	167	16.7	27.8	–	6.2
14.	Trachy-Andesite	168	16.7	30.3	–	6.3
17.	Trachy-Andesite (Latite)	170	15.7	35.2	0.1	6.6
16.	Trachy-Andesite	171	13.5	27.3	–	8.9
15.	Trachy-Andesite	175	11.1	29.5	–	9.6
18.	Tephritic Trachyte	190	18.7	26.9	–	11.4
21.	Sodalite-Plag.-Trachyte	200	20.7	33.2	0.1	3.8
19.	Biotite-Trachyte	213	20.3	32.2	–	3.5
23.	Sodalite-Trachyte	225	21.3	39.2	0.5	2.5
20.	Biotite-Trachyte	243	17.5	33.7	–	5.1
22.	Sodalite-Trachyte	252	22.2	34.6	0.5	1.6

the trachyandesites. Compared to other basalts, these rocks have a much smaller quantity of Wo in proportion to other melanocratic molecules.

In the remaining trachyandesite-basalts (Nos. 9–12), the Or content is greater than in the alkali-basalts and mugearites, about the same as in the saturated trachyandesites, but less than in the other trachyandesites. The An content (except No. 10) is much higher than occurs in the trachyandesites, and is more comparable with that found in the alkali-basalts and mugearites. (As remarked earlier, Dunne believed that the analyses given by Campbell Smith for Nos. 11 and 12 were unreliable, with too high an Ne value for No. 11, and that the SiO_2 and Al_2O_3 content was over-estimated in No. 12.) The above trachyandesite-basalts lie between trachybasalts and trachyandesites, having the more basic plagioclase of the former and the total dark component percentage of the latter, or vice-versa. The norms, however, justify the classification as trachyandesite-basalts.

As distinct from the above rocks, three of the trachyandesites Nos. 13, 14 and 17, are under-saturated, with a normative amount of nepheline and feldspathoid varying between 4.1 and 13.0. Compared to the trachyandesite-basalt, they have more Or and Ab but

M					Q		k	mg	π	λ
Cs	Fs	Fa	Fo	Cp	Ru	Q				
18.8	11.9	11.8	21.1	–	3.7	10.3	0,06	0.47	0.59	0.30
12.0	14.3	4.3	16.2	–	3.5	16.4	0.12	0.46	0.69	0.25
12.1	5.2	10.3	20.1	0.8	3.1	16.9	0.25	0.56	0.35	0.25
6.3	8.2	2.8	12.7	4.0	2.5	22.4	0.27	0.54	0.56	0.19
7.0	2.2	9.0	20.9	0.5	2.3	25.1	0.18	0.65	0.42	0.18
7.8	3.5	9.7	9.7	–	2.6	23.1	0.34	0.42	0.31	0.25
7.4	3.2	8.9	10.3	2.2	3.2	22.9	0.30	0.46	0.24	0.23
8.1	3.2	8.4	9.7	–	2.8	24.3	0.34	0.45	0.30	0.28
7.2	3.6	7.8	12.7	1.0	2.2	24.4	0.24	0.53	0.27	0.22
1.7	4.6	6.8	8.3	1.7	1.4	28.8	0.31	0.42	0.34	0.08
3.6	3.9	7.3	11.3	1.3	2.3	28.5	0.21	0.50	0.31	0.13
7.0	3.7	6.4	7.6	1.7	2.1	25.1	0.37	0.41	0.13	0.26
–	8.7	3.8	6.3	–	1.9	28.2	0.26	0.33	0.28	–
1.9	2.3	6.2	6.5	1.9	2.3	26.9	0.32	0.43	0.22	0.10
2.9	0.1	6.9	5.2	–	1.7	27.5	0.32	0.42	0.26	0.19
0.1	4.2	2.7	4.3	–	1.4	34.5	0.39	0.38	0.32	0.01
3.0	3.2	4.4	5.2	1.4	1.7	30.4	0.38	0.41	0.12	0.17
4.8	3.3	3.2	3.2	0.8	1.5	29.9	0.35	0.33	0.12	0.31
1.9	1.6	3.9	2.7	1.6	1.8	28.9	0.31	0.33	0.12	0.33
1.5	3.2	4.0	6.0	1.2	1.5	32.9	0.33	0.45	0.18	0.10
1.2	3.2	4.9	4.3	1.1	1.4	33.7	0.27	0.35	0.19	0.08
0.5	1.8	2.5	2.5	–	0.8	34.9	0.41	0.37	0.20	0.07
3.0	2.3	1.6	1.7	0.4	0.9	32.3	0.38	0.30	0.06	0.34
1.9	3.0	1.5	2.0	0.4	0.8	34.4	0.39	0.31	0.06	0.23
0.1	2.2	0.7	0.0	0.1	0.3	33.1	0.34	0.00	0.04	0.03
0.1	1.8	1.1	1.6	–	0.5	38.6	0.34	0.36	0.09	0.02
0.8	1.8	0.8	0.1	0.1	0.5	36.9	0.38	0.09	0.03	0.22

much less An and melanocratic molecules. The Or, Ab and An values in these three specimens are about equal, and only the Ne of the leucocratic molecules undergoes change.

Compared to the trachyandesites, the trachytes (Nos. 19–23) show more Or and Ab but less An and melanocratic normative molecules. These rocks are more leucocratic, having less plagioclase but more alkali-feldspar. They consist chiefly of alkali-feldspar (70–85 %) of which the normative potash feldspar content varies between 40 % and 50 %. Nos. 19, 20 and 22 are almost saturated, whereas Nos. 21 and 23 are distinctly under-saturated. Melanocratic molecules vary between 2.5 % and 8.5 %, but it must be added that quite a proportion of the leucocratic normative minerals are present in the dark components, e. g. the Or in biotite, the Na_2O of Ab in aegerine, etc. The Wo content must of course be treated with due caution in such rocks which contain large percentages of alkali and lime alumino-silicates. Specimen No. 20 contains 1.2 normative quartz, shown microscopically as small quantities of cristobalite. No. 22 yields 1.4 quartz, if the total possible sodalite is built, but it is evident that if the Cl_2 was incorrectly determined, then most of the 5 % sodalite should be converted to Ab. This Q excess may be due either to an error in analysis or then the sodalite, and perhaps the feldspar molecules too, are more silicified than the theoretical ones.

The essexitic-gabbro (No. 24) is much more saturated than any of the basalts, with no normative Ne, and as much as 7.5 En. As regards saturation, it is like the trachyandesite-basalts of Inaccessible Island. Its *mg* content of 0.65 (Table 64) is higher than any other rock discussed here from the Tristan group. Its *k* content of 0.18 is less than any others, with the exception of the coarse-grained inclusions.

Of the three analyses of xenoliths (Nos. 25–27), all show a small percent of normative nepheline, all of which occurs in the dark components, especially hornblende, and the Or, Ab and An also is attributed to melanocratic material. Hornblenditization is evidenced in the state of oxidation, for the Fe of the hornblende is almost entirely in the ferric state. Nos. 26 and 27 therefore only show Mt and Hm and no Fa in the norms.

Table 68

Norms (Baker, Gass et al, 1964)

Sample Number	Q	Or	Ab	An	Ne	Di	Ol	Wo	Mt
28	–	8.68	6.73	17.95	7.17	32.18	10.76	–	8.09
29	–	12.06	6.95	20.16	8.93	28.01	5.48	–	8.47
30	–	17.73	6.03	22.23	15.99	20.80	6.84	–	3.63
31	–	18.32	11.58	18.64	11.88	20.12	5.11	–	5.41
32	–	18.15	16.16	19.39	8.66	17.25	6.12	–	5.97
33	–	18.38	13.27	19.15	11.33	17.24	7.21	–	5.49
34	–	16.08	21.63	21.13	5.43	13.73	4.03	–	11.03
35	–	18.68	13.63	19.22	10.99	15.71	9.09	–	3.76
36	–	18.68	11.88	20.18	13.13	19.16	2.53	–	6.57
37	–	18.62	17.92	17.06	8.49	16.51	5.51	–	5.31
38	–	19.51	8.70	18.55	16.83	19.95	4.47	–	4.49
39	–	20.10	15.45	18.42	10.33	17.15	4.85	–	4.77
40	–	19.98	22.80	17.86	9.37	13.15	2.73	–	5.48
41	–	22.93	22.48	14.72	10.46	12.68	4.17	–	3.70
42	–	26.78	33.37	15.85	5.02	8.09	0.45	–	4.89
43	–	26.78	32.25	16.33	6.64	7.71	1.30	–	3.77
44	–	29.27	29.99	13.57	9.66	9.60	0.94	–	2.34
45	–	28.55	31.61	12.68	9.26	8.03	–	0.88	–
46	–	28.88	31.67	11.74	9.23	8.96	–	0.77	4.56
47	–	33.10	22.20	10.66	15.94	10.64	0.96	–	2.90
48	–	29.72	31.14	14.10	9.03	6.22	–	1.29	4.45
49	–	31.33	40.12	8.38	8.06	5.36	0.55	–	2.46
50[1]	–	39.01	44.39	6.12	2.08	–	0.70	–	–
51[2]	–	39.60	43.57	6.75	4.82	–	0.35	–	0.49
52	–	19.33	24.79	20.32	5.50	11.31	4.74	–	3.83
53[3]	–	30.55	45.52	7.00	–	3.13	2.56	–	–
54	–	35.58	39.17	4.44	6.28	6.18	–	0.19	4.21
55[4]	–	41.85	46.34	5.70	2.08	–	0.67	–	0.44
56	–	15.37	13.19	23.12	10.73	17.54	9.07	–	4.78

Table 68 Norms (BAKER, GASS et al, 1964)

Sample Number	Il	Hm	Ap	Fr	Hl	H_2O+	H_2O-	Pf	X
28	7.08	–	1.39	–	–	0.13	0.11	–	12.3
29	7.81	–	1.37	–	–	0.32	0.44	–	16.3
30	6.27	–	0.71	–	–	0.09	0.20	–	35.0
31	6.93	–	1.98	–	–	0.05	0.12	–	22.2
32	5.89	–	2.12	–	–	0.53	0.07	–	25.5
33	5.37	–	2.50	–	–	0.05	0.02	–	28.8
34	4.16	–	2.78	–	–	0.04	0.08	–	1.8
35	5.85	–	2.88	–	–	0.07	0.06	–	35.2
36	6.53	–	1.23	–	–	0.15	0.05	–	14.8
37	6.72	–	3.35	–	–	0.23	0.19	–	22.0
38	6.65	–	1.18	–	–	0.18	–	–	22.4
39	6.53	–	1.77	–	–	0.34	0.27	–	22.6
40	5.65	–	2.78	–	–	0.09	0.03	–	14.2
41	6.04	–	2.51	–	–	0.24	0.15	–	23.1
42	3.36	–	1.75	–	–	0.16	0.28	–	4.0
43	3.44	–	1.77	–	–	0.08	0.19	–	20.1
44	3.00	–	1.01	0.09	0.45	0.02	–	–	34.7
45	2.91	4.85	0.91	0.17	0.18	0.02	0.02	0.12	0
46	3.08	–	0.84	0.14	0.21	0.03	0.03	–	8.8
47	3.23	–	0.71	–	–	0.19	0.30	–	25.1
48	3.03	–	0.67	0.16	0.37	0.00	0.00	–	4.5
49	2.28	–	0.47	–	–	0.19	0.10	–	20.4
50[1]	0.64	2.40	0.12	–	–	2.30	1.30	–	0
51[2]	0.95	1.96	0.07	–	–	1.00	0.40	–	0
52	4.96	–	2.05	–	–	1.82	1.30	–	21.8
53[3]	0.85	6.47	1.23	–	–	0.08	1.28	1.11	0
54	2.37	0.01	1.01	–	–	0.26	0.38	–	0
55[4]	0.72	–	0.24	–	–	0.64	0.69	–	92.7
56	4.94	–	0.47	–	–	0.79	0.90	–	25.7

[1] Includes 0.84 C., 0.16 Ru.

[2] Includes 0.58 C.

[3] Includes 1.21 Tu.

[4] Includes 0.89 C.

Column "X" = $\frac{FeO}{MgO + FeO}$ % in Di, Ol, Hy.

Table 68 shows the norms of the rocks studied by BAKER, GASS et al.

Table 69 (p. 266–269) gives spectrographic analyses of trace element content in parts per million, after BAKER, GASS et al. In the plotting of diagrams given by the above authors of the element concentrations, the implication was made that their samples formed part of a differentiation sequence – see later.

Additional Comments

BAKER, GASS et al considered the presence of leucite and the significance of the plutonic xenoliths worthy of further remarks, and the following are their generalizations.

Table 69 Spectrographic Analyses of Trace Element content in parts per million (BAKER, GASS et al, 1964)

	28	29	30	31	32	33	34	35
Si	201	198	213	214	217	215	215	215
Ti	22	25	20	22	19	17	13	17
Al	64	75	97	88	88	90	89	90
Fe^{3+}	39	41	17	26	29	26	53	18
Fe^{2+}	64	66	65	57	57	58	42	65
Mn	1	–	–	–	–	–	–	–
Mg	62	40	28	29	28	29	29	28
Ca	90	85	71	71	67	68	67	67
Na	18	21	31	29	28	30	28	30
K	12	17	25	26	25	26	23	26
Fe (total)	103	107	82	83	86	84	95	83
Differentiation Index	22.6	27.9	39.7	41.8	43.0	43.0	43.1	43.3
Nb	20	35	100	110	120	130	95	130
Mo	<3	3	4	5	6	6	5	7
Zr	100	200	300	300	350	350	300	350
Ga	25	27	27	28	28	28	27	35
Cr	250	65	–	–	30	45	18	30
V	400	400	200	400	190	180	200	200
Y	10	15	50	40	60	55	40	60
La	<100	110	190	200	200	200	180	250
Be	–	–	–	–	–	–	–	–
Ni	150	50	–	–	–	10	–	10
Co	50	40	18	25	20	20	20	25
Mn	550	1100	1600	1600	1800	1800	1600	1700
Sr	700	1000	1200	1600	800	1100	1100	900
Pb	<10	10	18	11	12	18	18	21
Ba	700	750	1000	1200	800	1000	950	850
Li	<4	4	10	7	4	4	<4	6
Rb	90	110	300	170	180	170	110	170

a) Significance of leucite

No previous investigators of the Tristan rocks had observed leucite, although SCHWARZ (1905) no doubt was near the mark when he described greyish rocks with lighter rounded spots, but thought this was clear, residual glass.

Leucite usually forms early as euhedral phenocrysts or then a euhedral matrix, but in Tristan it is present interstitially as a late-stage product most frequently. Almost never is leucite present interstitially in rocks throughout the world.

Leucite occurs in rocks from the Cape Verde Islands and also from Kerguelan Island. However in the former there is a structural relation with Africa, whereas in the latter, geological evidence suggests an affinitiy with the Antarctic continent.

The Tristan leucite-bearing rocks show no other outstanding differences from suites in other oceanic islands. Continental leucite-bearing rocks show much more K_2O than Na_2O, but the converse is the case in Tristan. Nepheline is almost absent in these rocks,

Table 69

Spectrographic Analyses of Trace Element content in parts per million
(Baker, Gass et al, 1964)

	36	37	38	39	40	41	42	43
Si	215	217	216	220	227	231	252	253
Ti	21	22	21	21	18	19	11	11
Al	94	85	96	92	95	94	101	103
Fe^{3+}	32	26	22	21	26	18	24	18
Fe^{2+}	48	54	52	52	40	44	24	26
Mn	–	–	–	–	–	–	–	–
Mg	25	28	28	26	20	21	10	10
Ca	69	68	67	64	61	54	45	44
Na	32	29	35	30	35	37	37	39
K	26	26	27	28	28	32	38	38
Fe (total)	80	80	74	73	66	62	48	44
Differentiation Index	43.7	45.0	45.0	45.9	52.2	55.9	65.2	65.7
Nb	85	110	100	80	160	120	160	160
Mo	5	6	4	4	9	5	5	4
Zr	300	300	300	300	400	350	350	400
Ga	27	27	28	27	29	28	27	28
Cr	–	–	–	–	–	17	–	12
V	200	300	170	280	250	200	130	130
Y	30	40	45	25	50	40	45	50
La	170	200	170	160	250	180	250	250
Be	–	–	–	–	–	–	–	–
Ni	–	–	10	–	–	–	–	–
Co	14	20	18	15	14	10	–	–
Mn	1500	1500	1500	1300	1800	1400	1700	1700
Sr	1100	1400	1100	1100	1100	1500	1200	1300
Pb	15	8	35	10	16	10	17	15
Ba	950	1000	950	1000	950	1200	1100	1100
Li	10	7	6	6	< 4	10	12	11
Rb	110	160	180	110	220	190	200	200

an interesting point, for in the majority of under-saturated oceanic lavas, either nepheline or analcime are the first under-saturated minerals to be produced.

The above authors speculate on two possible causes for the presence of leucite in these Tristan rocks: the desilicating effect of the resorption of the under-saturated basaltic amphibole, and the high volatile content of the lavas which might have aided to suppress leucite during early stages of crystallization.

b) Plutonic Xenoliths

These may be of accidental origin, they might be parts of the source rock from which the containing magma was derived or then they may have crystallized under plutonic conditions from the same magma as the extrusives in which they occur.

It is thought that amphibole, pyroxene, plagioclase and ore formed the stable mineral association at depth. Such xenoliths in lavas display amphibole converted to pyroxene,

Table 69 Spectrographic Analyses of Trace Element content in parts per million (BAKER, GASS et al, 1964)

	44	45	46	47	48	49	50	51
Si	257	255	256	253	256	271	279	284
Ti	9	10	10	10	10	7	3	3
Al	104	102	101	106	105	103	104	108
Fe^{3+}	11	34	22	14	21	12	17	16
Fe^{2+}	26	9	23	26	21	17	16	3
Mn	–	–	–	–	–	–	–	–
Mg	9	9	9	11	7	6	2	1
Ca	41	41	40	37	40	24	9	10
Na	44	45	45	45	45	48	42	46
K	42	41	41	46	43	44	55	56
Fe (total)	37	43	45	40	42	29	33	19
Differentiation Index	70.1	70.4	70.7	71.2	71.5	79.5	85.5	88.0
Nb	140	170	150	130	140	130	160	230
Mo	6	6	6	7	6	7	< 3	4
Zr	350	350	350	300	350	350	500	500
Ga	29	27	28	27	26	27	29	26
Cr	–	–	–	–	–	–	–	–
V	95	100	120	75	110	50	16	20
Y	40	55	45	45	45	35	20	40
La	200	250	200	200	200	190	120	250
Be	–	–	–	–	–	–	8	13
Ni	–	–	–	–	–	–	–	–
Co	–	–	–	–	–	–	–	–
Mn	1500	1800	1500	1300	1600	1200	1500	1900
Sr	1300	1400	1500	1000	1400	650	40	55
Pb	14	16	17	22	14	28	24	25
Ba	1200	1300	1400	1100	1300	1000	20	25
Li	10	12	13	12	13	15	15	20
Rb	230	220	210	270	260	350	400	280

whilst those from pyroclastic centres, sometimes the converse can be seen. It is possible for amphibole and pyroxene to co-exist at depth provided there is lack of water to provide all the hydroxyl, as also to provide necessary pressure conditions for the stability of amphibole. The change-over from pyroxene to amphibole as a magma slowly rises with constant water pressure can be favoured by any of three factors: 1. where there is equal water pressure at all levels, the content of water will be greatest at the summit, and so if the equilibrium or equipotential factors are maintained, water content will increase in the rising column, decrease in the reservoir beneath, and such an increase in water content would allow of further conversion of pyroxene to amphibole. 2. where the water pressure remains constant but there is a decrease of total pressure, then the magma could migrate from an area of pyroxene stability to amphibole stability. 3. heat loss by conduction could cause the magma to migrate into an amphibole stable area.

Table 69

Spectrographic Analyses of Trace Element content in parts per million
(Baker, Gass et al, 1964)

	52	53	54	55	56
Si	227	268	271	291	217
Ti	16	10	7	2	16
Al	94	90	95	108	94
Fe^{3+}	18	45	20	2	23
Fe^{2+}	40	2	18	7	56
Mn	–	–	–	–	–
Mg	21	12	7	0	35
Ca	58	27	23	9	66
Na	31	40	45	44	29
K	27	43	50	59	22
Fe (total)	58	47	38	9	79
Differentiation Index	49.6	76.1	81.0	90.3	39.3
Nb	130	140	140	130	110
Mo	5	6	10	3	5
Zr	350	500	550	550	300
Ga	29	35	35	30	24
Cr	–	17	16	–	20
V	200	75	75	10	200
Y	40	35	15	10	50
La	200	180	< 100	100	180
Be	–	–	–	–	–
Ni	–	45	–	–	80
Co	12	10	–	–	–
Mn	1500	1200	1000	650	1600
Sr	1000	650	750	180	800
Pb	16	14	17	18	32
Ba	950	700	700	160	850
Li	8	8	15	9	8
Rb	150	220	270	250	170

Where the magma is less hydrous but displaying effusive features, the amphibole would be less inclined to convert into pyroxene. If such a fluid lava erupts it might be that the amphiboles in the xenoliths are partically converted into pyroxene – a stable phase under surface conditions where the water pressure is negligible.

Magma Differentiation and Genesis

Dunne believed that the Tristan rocks were good examples of magmatic differentiation by means of fractional crystallization, which was controlled by the settling of crystals under gravitational influence.

Studies of the majority of the volcanics of Atlantic association show only basaltic rocks – ca. 99 % of the total bulk – which, though showing great variation in themselves, are yet quite different chemically from lesser volcanic masses composed of trachytic and phonolitic rocks. The usual absence of true intermediate rock types or, if such are present, their specific grouping, does not find a ready explanation. DUNNE suggested that the answer lay in the speed of crystallization, which conceivably could vary at different stages of the process, and may indeed even be rhythmetical in nature.

The rocks of the Tristan group were all named alkaline by DUNNE, even those basalts of distinctly femic character. These volcanics showed no evidence of a primary 'normal olivine-basalt' such as interpreted by DALY, which latter may be taken as representative of the solid phase of the 'primary magma'. It was concluded therefore that the trachytic and intermediate lavas were differentiates of an alkaline basalt which itself of course could very well be a product of differentiation. DUNNE was of the opinion that many of the so-called plagioclase trachytes, trachyandesites, etc. were not 'true and direct' differentiation products, but that they represented rocks of auto-assimilation or auto-hybridization during the magmatic evolution. Thus they are are to be considered rather as trachytic melts into which have been introduced phenocrysts which crystallized directly from a basaltic magma. This trachytic magma must have been of high viscosity, witnessed by the tendency to form domes and flows of only small length, and was extruded during the last magmatic phase.

DUNNE summarizes the process and mechanism of differentiation with regard to the Tristan rocks as follows: 1. Differentiation occurred principally upon the withdrawal of augite, plagioclase and, to a lesser degree, of hornblende and olivine. The role of olivine in the process is of small significance, picritic lavas or peridotitic inclusions being absent. 2. In the development of the trachytic melts, diffusion on a large scale was important, being due to the dissolved volatiles. 3. The principal differentiation products were basalts and trachytes, but rocks intermediate between these groups also are present. 4. Many so-called intermediate rocks are really assimilation products of the basaltic phenocrysts by the trachytic melt. 5. The general sequence of eruptions was as follows:

Olivine-alkali-basalt
Hornblende-alkali-basalt
Trachybasalt
Mugearite
Trachyandesite-basalt
Trachyandesite
Biotite-trachyte
Sodalite-trachyte

6. This order is the same as that of the trend of differentiation.

Table 70, from BAKER, GASS et al gives the chemical composition of four average rock types and their norms, reference only to rocks from Tristan da Cunha. It is seen therein that SiO_2, Al_2O_3, Na_2O and K_2O increase through the series, whereas the other oxides decrease, a variation reflected in the norm minerals. Here there is an increase in Or, Ab and Ab + Ne from the basic to the acid end, whilst An shows decreases overall. Di and Ol decrease rapidly, the latter being absent in the average trachyandesite and trachyte. Il and Mt decrease steadily. All such changes are also found in many other suites of volcanics.

If it is assumed that xenoliths are obtained directly from crystallization in a differentiating magma, such low silica material crystallizing and separating at depth would inhibit further under-saturation in silica within the residual liquid and might be the reason why final members are trachytic instead of phonolitic. Had the magma been less hydrous one would look for greater under-saturation in the end members. It could also

Table 70 Composition of Average Rock Types (Baker, Gass et al, 1964)

Weight %	1.	2.	3.	4.
SiO_2	43.1	46.7	54.9	60.0
TiO_2	4.1	3.6	1.8	0.9
Al_2O_3	13.1	17.3	19.6	20.2
Fe_2O_3	5.5	3.8	2.8	2.1
FeO	8.5	7.1	2.9	1.1
MgO	9.0	4.7	1.5	0.5
CaO	12.4	9.7	5.7	2.3
Na_2O	2.7	4.1	5.9	6.8
K_2O	1.6	3.0	4.9	6.1
Norm				
Or	9.5	17.7	29.0	36.0
Ab	4.6	11.2	29.8	41.1
Ne	9.9	12.7	10.9	8.9
An	18.9	20.0	12.5	6.6
Di	33.8	22.6	8.1	2.7
Ol	7.6	3.5	–	–
Wo	–	–	2.2	0.6
Il	7.8	6.8	3.4	1.7
Mt	8.0	5.5	4.1	0.9
Hm	–	–	–	1.4
$\frac{FeO \times 100}{FeO + MgO}$ (In femics)	12.7	20.4	0.7	0
Differentiation Index	24.0	41.6	59.7	76.0

1. Average Alkali Basalt (3 analyses)
2. Average Trachybasalt (10 analyses)
3. Average Trachyandesite (9 analyses)
4. Average Trachyte (4 analyses)

be argued that if the xenoliths came from pre-existing material, then their assimilation into a 'normal magma' would give rise to an under-saturated magma such as that of Tristan.

Trachytes and trachyandesites are repeated at various times in the eruptive history of Tristan. If the former are differentiation end-products, then this process has been repeated with new mother-material being added periodically. Baker, Gass et al believed that such repetition in the volcanic sequence implied new material being introduced into the magmatic cycle on each occasion.

The rocks of Tristan da Cunha show higher normative nepheline than those from the other islands. The average content is as shown:

	% Normative Nepheline		
	Tristan	Nightingale	Inaccessible
Trachybasalt	10.0	6.6	5.7
Trachyandesite	10.4	2.1	0
Trachyte	6.7	3.4	0

The Tristan rocks display distinct differences in degree of saturation from those of the other two islands. As Tristan is younger than the other two, the composition difference amongst the islands is due, no doubt, to the time factor. But whether such differences occur in the original parent magmas or then due to differentiation processes, cannot be stated. We would note, however, that some Nightingale and Inaccessible basalts are quite as under-saturated as are Tristan basalts, and this fact, along with the identity in trace element compositions of the three islands presume it likely that the parental material has been equally under-saturated and very similar. The difference lies in the contention that the process of differentiation giving rise to the Nightingale and Inaccessible rocks was different from the later differentiation processes in Tristan in that more saturated derivatives were produced.

Gass (1965) remarked that although the rocks of the Tristan group belonged to the alkali-basalt type of magma, there was a difference from most other oceanic islands in the relatively large content of potassium, rubidium, strontium, barium and niobium. He believed that high-level magma chambers were present, now or earlier, beneath the three principal islands of the group, that fractionation of a parental trachybasaltic magma in these chambers gave rise to ankaramites, olivine-basalts, trachyandesites and trachytes. This trachybasaltic magma was thought to have had its source in the upper mantle. The means whereby the highly potassic rock assemblages were produced included: 1. partial fusion of abnormal mantle material, 2. primary differentiation of the magma in the mantle in an intermediate pressure environment, 3. enrichment of the magma within the mantle of those elements typical of residual liquids by means of a mechanism similar to zone-refining, and 4. very slight melting of mantle material. The absence of a known sialic crust prohibits assimilation of crustal rocks as providing the potassium and trace elements. Baker, Gass et al conclude by saying: "No matter how the parental magma has acquired its unusual characteristics, it is considered to have been tapped-off at intervals and admitted to the region of normal differentiation, in which trachyandesites and trachyte have formed". The rocks of the Tristan group therefore would appear to indicate a two-stage process: firstly, the basalt becomes highly concentrated in residual elements typical of the island group, and secondly, trachyandesites and trachytes form as the result of normal differentiation processes.

Provincial Relationship

Physiography

Gough and Ascension Islands are single volcanic peaks, St. Helena has the volcanic pile of the island itself and an accompanying submarine peak some 100 km to the W thereof, and Tristan has three volcanic peaks. Other comparative matters are shown in Table 71.

Vulcanology

There is no evidence of volcanic activity in historical times in Gough, St. Helena or Ascension, although the first-mentioned erupted some 2300 years ago (U. Hafsten, 1960). It should also be noted that Daly (1925, vd. Ascension references) remarked upon the young appearance of volcanic features on that island.

Table 71 Physiographic Relationships (Based on Baker, Gass et al, 1964)

	Gough	Tristan	St. Helena	Ascension
No. of islands in group	1	3	1 (+1)	1
Approx. area (km²)	65	108	118	98
Max. height. (m)	907	2062	823	859
Height above sea-floor (m)	3960	6095	5180	2740
Distance from supposed Mid-Atlantic Rift (km)	560 E.	480 E.	768 E.	112 W.
Distance from axis of Mid-Atlantic Ridge (km)	336 E.	368 E.	800 E.	144 W.

However, characteristic of the four islands referred to here, is the periodic eruption of trachytic lavas within basaltic eruptions. Gough and Tristan have abundant dykes, with a marked radial pattern; Ascension has very few dykes. Parasitic cinder cones are common features.

Table 72 Comparative Vulcanology (Baker, Gass et al, 1964)

	Gough	Tristan*	St. Helena	Ascension
Recorded historical volcanic activity	None	Recent	None	None
Eruptive sequence	(T), B, B, B, T, B	No apparent rhythmic sequence	B, T	B, T, B
Volcanic form	Complex mass	Single cone with parasitic centres	Complex mass possibly a doublet: fissure eruptions?	Irregular shallow cone with parasitic cemtres
Erosional state	Deeply dissected	Very little erosion except for sea cliffs	Deeply dissected	Very little erosion
Dyke characteristics	Radial dyke patteren; swarms in lower horizons	Marked radial dyke pattern	Multiple linear dyke swarms; especially in pyroclastic compleyes	Very few

* Not including Nightingale and Inaccessible. B = Basalt phases. T = Trachytic phase.

Petrography

Table 73 shows petrographic relations between Tristan, Gough, St. Helena and Ascension. The rocks of these island belong to the Atlantic or soda-alkaline suite.

All types of rocks, from basalt to trachyte, are well represented in these islands, and from those of the latter composition, late differentiates tend towards either phonolites or then rhyolites. Basaltic rocks are more abundant than trachytic, with the exceptions of Gough and Nightingale Islands.

All except St. Helena have xenolithic material, the commonest types being gabbroic and peridotitic; dioritic, syenitic and granitic types are restricted to Ascension. In both

Table 73 Comparative Petrography (Baker, Gass et al, 1964)

	Gough		Tristan			St. Helena			Ascension		
Volcanic Rocks											
Ankaramites, etc.	X	↑	X	↑		X	↑		–		
Alkali Basalts	X	│	X	O		X	│		X	↑	
Trachybasalts	X	O	X	↓	↑	X	O		X	O	
Trachyandesites	X	│	X		A	x	│		X	↓	
Trachytes	X	│	X		↓	X	│	↑A	X		↑
Phonolites	x	↓	X			X	↓	↓	–		│
Rhyolites	–		–			–			X		A
Obsidians	–		–			–			X		↓
Approx. % of basaltic rocks	45		95 Tr 5 Ni 90 In			98			88		
Xenoliths											
Peridotitic	x		–			–			X		
Gabbroic	X		X			–			X		
Dioritic	–		–			–			X		
Syenitic	–		–			–			X		
Granitic	–		–			–			X		
Charakteristic Minerals of Gabbroic Types											
Olivine	X		x			–			X		
Hypersthene	X		–			–			X		
Amphibole	–		X			–			X		

X = Occurrence of rock type or mineral. x = Rare occurrence of rock type or mineral.
O = Crystallization range of Olivine. A = Crystallization range of Amphibole.
Tr = Tristan. Ni = Nightingale. In = Inaccessible.

Gough and Ascension, gabbroic types feature hypersthene, a mineral which does not crystallize from alkali magmas normally, but can do so if at depth and under pressure.

The Tristan rocks show close similarity to most other soda-alkaline provinces, and such minor differences as occur are due to such factors as likely slight differences in the primary magmas, and the method which differentiation pursued. It results that some minerals and rock types may be more or less prolific, perhaps even absent, in the various provinces. But, as Dunne remarked: "... the really remarkable similarities met with in the soda-alkaline volcanic rock associations are probably the best proof that they must all have been derived from a similar primary source by one and the same uniform process, which can only be that of magmatic differentiation controlled mainly by fractional crystallization".

Chemistry

Chemical comparisons between the above four islands are shown in Table 74 (p. 276) and Fig. 93, both of which are based upon averages of respective analyses.

A study of the CIPW norms brings out the chemical differences. Regarding the two Tristan averages, for a given SiO_2 content, the high alkalies are reflected in the large amounts of nepheline in the normatives, these two analyses lying well within the alkali-

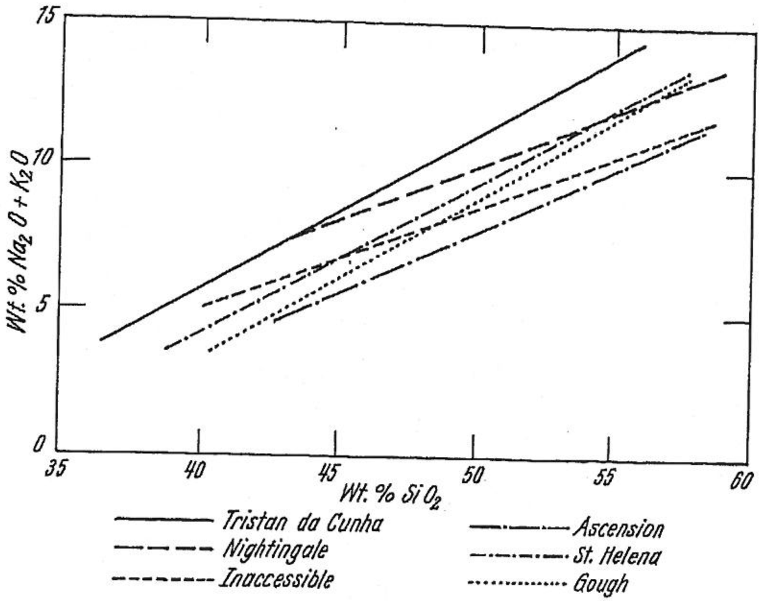


Fig. 93. Comparative chemistry of some Mid-Atlantic Ridge Islands. (Baker, Gass, et al, 1964)

basalt field. Gough and St. Helena have small quantities of nepheline in their norms, being close to the critical plane of silica under-saturation. But Ascension has normative hypersthene, and thus would lie in the olivine-tholeite field. Baker, Gass et al simplified the norm into various summations and compositional ratios for comparative purposes. Thus, comparing the Tristan trachy-basalt with the basalts of St. Helena and Ascension, a close similarity developes between the three ratios (FPO), the Fe percentage and the differentiation index. But the similarity cannot be pushed further, for the OrAbAn ratios for the Tristan trachybasalt (24/49/27) are quite different from those of St. Helena and Ascension (approx. 11/51/38), which but again reflects the high K_2O values for Tristan. It should also be noted that the FPO, Fe% and differentiation index ratios for Tristan and Gough show no similarity.

Baker, Gass et al summarize their comparative studies as follows.

The Tristan rocks are higher in alkalies and relatively under-saturated with respect to silica compared to other islands on the Mid-Atlantic Ridge. There is some indication that island location with respect to the Ridge has some bearing on the compositional variation. Ascension, with its strongly rhyolitic late differentiates, lies close to the centre of the Ridge; Gough and Tristan, further removed from the Ridge, show trachytic late differentiates with slight phonolitic tendencies: St. Helena, furthest removed, has definite phonolitic late differentiates. One may surmise, therefore, that increased distance from the Ridge results in increased silica under-saturation. Carrying this concept well beyond the confines of the Ridge, the same would appear to hold true, for in Fernando do Noronha, Trindad and Martin Vaz, closer to the South American continent (as also the Canary Islands and the Cape Verde Islands, closer to the African continent), the rocks are all strongly phonolitic and alkaline in character.

Table 74 Chemical Relationships (Baker, Gass et al, 1964)

		Gough 'basalt'	Tristan		St. Helena 'basalt'	Ascension 'basalt'
			basalt	trachy-basalt		
SiO_2		47.7	43.1	46.7	47.9	50.1
TiO_2		3.2	4.1	3.6	3.6	2.8
Al_2O_3		15.2	13.1	17.3	16.4	16.3
Fe_2O_3		2.3	5.5	3.8	3.9	4.1
FeO		8.7	8.5	7.1	8.2	7.5
MgO		9.7	9.0	4.7	6.4	5.4
CaO		8.9	12.4	9.7	8.7	8.8
Na_2O		2.7	2.7	4.1	3.8	3.7
K_2O		1.6	1.6	3.0	1.1	1.3
Q	F	–	–	–	–	–
Or		9.46	9.46	17.73	6.50	7.68
Ab		22.13	4.55	11.17	29.65	31.31
Ne		0.39	9.91	12.74	1.36	–
An		24.63	18.90	19.95	24.45	24.03
Di	P	15.67	33.79	22.59	15.03	15.82
Hy		–	–	–	–	5.50
Ol		18.30	7.63	3.48	10.52	4.39
Il	O	6.08	7.79	6.84	6.84	5.32
Mt		3.34	7.97	5.51	5.65	5.95
Total F		57	43	62	62	63
Total P		34	41	26	26	26
Total O		9	16	12	12	11
Mol. % Fe in P		22	13	20	22	25
Or		16	18	24	10	12
Ab (+Ne)		42	46	49	52	51
An		42	36	27	38	37
Diff. Index (Q + Or + Ab + Ne)		32	24	42	38	39

Economic Geology

Guano deposits occur in the Tristan group but are considered of no economic value. Douglas (1930) gave chemical analyses of those on the N side of Nightingale Island and in a cave in Middle Island:

	Nightingale	Middle
Moisture	72.12	17.00
Organic matter, ammonia salts	24.70	15.15
Phosphoric acid	nil	3.85
Lime	nil	5.10
Magnesia, alkalis, etc.	1.60	10.20
Siliceous matter	1.58	48.70
Total	100.00	100.00

Geochronology of the Tristan Group

Other than outwash alluvial material, no sediments, no fossils occur in the islands.

Dunne, writing before radiometric dating techniques were available, attempted utilizing indirect means for assessing the age of the group.

Obviously the islands are older than the eustatic changes in sea level. Even the late secondary vents on Tristan da Cunha must ante-date this event, for sea caves here and there are carved out of lava flows originating from such vents.

Dunne, adopting Daly's approach for St. Helena (q. v.), was of the opinion that in Tristan da Cunha and Inaccessible Islands, the age of such was "several millions of years". (Vd. the radiometric datings for St. Helena indicating an age of more than 14 m. y.)

The great heights of the cliffs in Tristan da Cunha and Inaccessible Island led Dunne to postulate an age of one or two million years for the islands, whereas the less dissected landscape of Nightingale-Stoltenhoff-Middle Islands suggested a considerably younger age.

Miller (1964) carried out radiometric datings on samples collected by the Royal Society Expedition, herewith presented in Table 75 (p. 278). Basalt samples were studied, using the potassium-argon method, as also samples 17, 18, 19 and 20 which were collected by the Challennger Expedition in 1885 and housed in the British Museum. Sample 20 gave a much older dating than the other Tristan da Cunha values, and this, along with the fact that the precise locality from where it was taken is not known, caused Miller to disregard the dating. On geomorphological grounds, the degree of dissection of the landscapes increase from Tristan da Cunha to Inaccessible to Nightingale, the last-mentioned being all that remains of a deeply eroded volcanic mass. Radiometric datings would confirm these age relationships, where the averages of the samples tested give values of 1 m. y., 6 m. y. and 15 m. y. respectively for the above three islands. (There seems little doubt that Dunne was in error in believing that Nightingale had been subjected to less erosional wasting than the other two.)

Gass (1967) has an interesting publication dealing with the question of the ages of the Tristan group, and gives some added radiometric information.

Regarding Tristan da Cunha, he mentions a private communication from Baker, Dodson & Rex informing him that a specimen taken from the N cliff of the island, at an elevation of some 180 m above S. L., gave a probable age value between 30 000 and 70 000 years.

Two Carbon-14 determinations were made of a carbonaceous, brown, organic silt containing diatoms occurring in a freshwater pool on the sides of the main cone, formed after eruptivity had ceased here, which yielded ages of 10,770 ± 156 years B. P. and 11,310 ± 168 years B. P. These silts were later overlain by scoria and cinders erupting from the Big Green Hill parasitic cone. As this Hill represents but one of some 30 odd secondary centres formed on the constructional surface of the primary cone, some estimate can be made as to the age of the other centres by comparing their erosional state with that of Big Green Hill, realizing of course that such an estimate has no quantitative value. It is thus surmized that eruption via the central vent ended some 15 000 years ago and that during the past 10 000 years, vulcanism has occurred in some 11–15 parasitic centres. It is further deduced that subaerial eruptions forming the island took place over

Table 75 Radiometric Datings of Tristan Samples (MILLER, 1964)

$\lambda_e = 0.584 \times 10^{-10}$ yr^{-1} $\lambda_\beta = 4.72 \times 10^{-10}$ yr^{-1}		K_2O (%)	Atmosph. contam. (%)	Age + est. error. (m. y.)	Island
Sample					
D 1	Flow or large sill halfway between Big Pt. and Rookery Pt. 10 ft. above S. L.	2.54	–	Recent	Tristan da Cunha
D 2		2.30	–	Recent	
D 3		2.73	12.2	3 ± 3	
*E 1	Flow halfway between Big Pt. and Rookery Pt. immediately beneath D 1, D 2, D 3	2.78	–	Recent	
E 2		2.79	–	Recent	
E 3		2.81	94.8	0.5 ± 1	
G 1	Sea-edge of flow 100 yds. extreme W of flow 10 ft. above S. L.	4.66	79.8	0.6 ± 1	
G 2		4.66	31.3	0.8 ± 1	
I 1	Flow forming 3rd. waterfall above largest waterfall, Hottentot Gulch. 1500 ft. above S. L.	2.65	–	Recent	
I 2		2.55	85.9	1 ± 1	
I 3		2.51	–	Recent	
H 3	Flow on seashore between Settlement and E of Herald Pt. O ft. above S. L.	3.14	–	Recent	
H 2		3.21	–	Recent	
H 1		3.18	–	Recent	
J 1	Flow approx. 100 yds. W of pinnacle, Hottentot Gulch. 900 ft. above S. L.	2.38	–	Recent	
J 2		2.51	–	Recent	
906	Basalt	1.64	–	Recent	
BM	Settlement Plain 1927 1252 (22)	2.79	54.1	3 ± 1.5	
BM	Basalt from edge of lake. 1927 1252 (2)	3.3	37.5	3 ± 1	
BM 64747	Basalt	2.9	77.5	9 ± 2	
BM 64775	Basalt from dyke intruding rear of Blomby's Cove.	4.8	95.5	2 ± 1	Nightingale Is.
BM 64760	Basalt	1.9	43.2	6 ± 1.5	Inaccessible Is.
BM 1927	Basalt. 1252 41.	3.73	97.8	12 ± 4	Middle Island
BM 1927	Basalt. 1252 41.	3.73	96.6	18 ± 4	

* Using an omegatron type mass spectrometer, this sample gave ages of 0.80 ± 0.10 and 1.10 ± 0.15 m.y, in agreement with the above determination. A figure of 0.95 m.y. is got from the mean of the two values.

a period of some 150 000 ± 37 000 years. Assuming a constant rate of eruption, then the total volcanic mass of which Tristan da Cunha represents merely the uppermost 5 %, was formed throughout a period of some 3 m. y.

Specimen No. 22 in Table 75, Inaccessible Island, likewise was collected by the Challenger Expedition, its locality not being precisely given. Another specimen collected by the Royal Society Expedition from one of the lowest lavas seen in the cliffs behind Salt

Bay gave a age value of 2.9 ± 0.3 m. y., and MILLER has suggested that this value, rather than that of the Challenger specimen (6.0 ± 1.5 m. y.) should have preference. As the Royal Society specimen came from the basal volcanic sequence, one might therefore postulate that during the past three million years, the island was constructed to a maximum diameter of some 16 km – the maximal extent of the shallow-water platform surrounding the island – and to a maximum height of some 2290 m. If these postulates are accepted, then between 90 and 95 % by volume of this original island has been destroyed by marine erosion during the past 3 m. y.

The three determinations given in Table 75 for the Nightingale group are Challenger specimens. Basalts from dykes in Middle Island gave radiometric datings of 18 ± 4 m. y. and 12 ± 4 m. y. From Nightingale Island, a dyke of similar composition yielded an age of 2 ± 1 m. y. As previously mentioned, organic material in the raised beaches on Nightingale Island gave ages of 39 160 (+6090–3410) years and more than 36 900 years B. P. in near-by localities – say 40 000 years B. P. The above basaltic dykes cut the Older Pyroclastics and thus the latter are older than 18 ± m. y. (The 2 ± m. y. age for the Nightingale dyke is thought to be in error.) It could be postulated therefore that the first subaerial volcanic activity of Nightingale is far older than that on either Tristan da Cunha or Inaccessible. The 40 000 year age for the raised beach deposit would suggest that volcanic activity recurred on Nightingale after a long period of both quiescence and erosion, a period perhaps of the order of 10 m. y.

GASS (op. cit.) thought that the Tristan group of islands showed a two-phase cycle: 1. an eruptive phase, when they were volcanically formed and during which agents of erosion were of minor importance; 2. a phase of lessened or ceased volcanic activity – but perhaps spasmodic outbursts – with erosion now dominant. He believed that Tristan da Cunha was likely near the end of the first phase, for eruptions over the past 15 000 years have been restricted to parasitic cones, during which time marine erosion has made few changes. This constructional phase was of very short duration, perhaps some 150 000 years. Inaccessible and Nightingale Islands represent second phase islands, the former having experienced erosional attack for some 3 m. y., the latter for some 18 m. y. By analogy with Tristan da Cunha, it can be presumed that both had a relatively short constructional phase, lasting probably not more than one million years and later erosion operative for some 20–25 m. y. which also likely represents the life-span of these two islands.

Lastly it should be noted that in general oceanic islands show high positive gravity anomalies and are thus isostatically unstable, hence a tendency to sink. Islands constructed of lighter material, e. g. phonolitic, trachytic, may quite possibly have a somewhat longer life than the 20–25 m. y. years postulated for basaltic oceanic islands.

Geological Evolution

The geological history of Tristan da Cunha began when a volcanic complex was formed, chiefly through a central locus or loci of central type, from which olivine-basaltic flows in the main were extruded. Intercalated with these flows were a few eruptions of pyroclastics forming tuffaceous beds. Smaller vents of somewhat later date erupted ash, glass and thinner olivine-basaltic flows. These less powerful and more transitory eruptions were subsequently smothered by extrusions still continuing from the main central vent area. Such later eruptions from the central locus involved thinner, more viscous hornblende-alkali-basalt flows, building-up the Peak region. During this phase, explosive activity was more frequent, resulting in larger and thicker beds of pyroclastics. The next phase was the emission of a vast quantity of black and red ash which today forms the uppermost 200 m of the Peak. Pene-contemporaneous with this event, another vent slightly S of the main one went into action, so constructing the second peak, and thus in present-day Tristan da Cunha the Peak area is actually formed of eruptive products from these two focal localities. Within the cinders forming the Peak crater occur outcrops of hornblende-alkali-basalts similar to those mentioned above, as well as sodalite-trachytes and trachyandesites, present high up in Cave Gulch. We can thus presume that trachytic eruptions succeeded the basaltic outpourings but were formed prior to the formation of the black and red ash forming the central summit.

A relatively long period of quiescence followed the construction of the main cone and hence the main portion of the island. Erosion had probably not wrought much more change than is seen today, but then a relatively sudden onset of vulcanicity occurred which was characterized by the formation of small cinder cones and explosion craters aligned along definite trends. The cinder cones comprise tuffaceous ash and a few thin flows of hornblende-alkali-basalts; the explosion craters are built of ash, except in one instance when trachytes were emitted after the crater formation.

Inaccessible Island, structurally the most complex, began by the emission of olivine-basaltic flows which were rudely deformed by the intrusion of a great number of olivine-basalt, trachybasalt, trachyandesite and trachyte dykes. Following this phase, essexitic gabbros were formed but consolidated under a considerably thick mantle of rock now no longer evident. It is presumed that the flows issued from several vents but quite likely a main locus of activity. As the rate of eruptivity was not the same at these centres, various of them became inundated by either later or then more voluminous outpourings from other vents.

The eastern part of the island is formed of thick flows of trachybasalts and olivine-trachyandesites lying unconformably upon thinner olivine-basalts. Many dykes cut the latter but do not penetrate the former, indicating an age for the dykes between that of the thick and the thin flows. One important centre of eruption of the later flows is the breached crater in the SE part of the island, from which mugearites were outpoured, and in the vicinity are one or two smaller trachyte cones. Dunne believed that the trachytic eruptions on Inaccessible were more or less contemporaneous with the main phase of vulcanicity in Tristan da Cunha, whereas Gass (1967) believed all essential construction had ended long ago on Inaccessible by the time Tristan da Cunha was building up.

The Nightingale group form a unit which can be treated together. Basal rocks exposed on Nightingale comprise volcanic agglomerates, consisting of fragments of various types of lava cemented by brown glass, ash and lapilli. It is significant that within this agglomerate occur pieces of all the lava types, e. g. sodalite-trachyte, alkali-trachyte, trachyandesite, trachybasalt, olivine-basalt, which were formed on the island subsequent to the formation of said agglomerate. Basic dykes which do not cut the later rocks are numerous in the agglomerate. Most of Nightingale is composed of biotite-soda-trachytes and hornblende-trachyandesites. The former occurs as lapilli in the basal agglomerate, as boulders on the abandoned shoreline on the S coast, and within the N-S ridge in the E. The trachyandesites are considered to be xenolithic admixtures of basaltic phenocrysts in a trachytic melt. It was the opinion of DUNNE that the trachytes and trachyandesites represented one large, composite, monolithic intrusion, with associated dome construction and lava flow formation. Preceding the extrusion of these trachytic magmas, much pyroclastic material was expelled, seen in the basal agglomerates, and much brecciation took place. Lying in unconformable relation upon the agglomerates is a 2 m thick sandy tuff. It is older than the trachytic flows, but it cannot be said with certainty that it is older than all the trachytic and trachyandesitic eruptions. To postulate here an age sequence basal agglomerates(oldest)-sandy tuff-trachytic masses would imply that the bulk of the island is of relatively late origin.

Such a scheme as outlined above for the evolution of the Tristan group is not in entire agreement with the radiometric datings. DUNNE believed that the main building of Inaccessible Island was more or less contemporaneous with that of Tristan da Cunha, whereas GASS, adopting radiometric datings, would claim that Inaccessible underwent construction a long time previously, that during the period of construction of Tristan da Cunha, Inaccessible was undergoing drastic erosion. DUNNE would claim that the Nightingale group are of relatively recent origin, whereas GASS considered the group to be the oldest, perhaps some 20 m. y. old.

Table 75 lists 24 radiometric datings. Of these, three are stated by MILLER-GASS to be of questionable value – the 9 m. y. basalt sample from Tristan da Cunha, the 2 m. y. sample from Nightingale Island and the 6 m. y. sample from Inaccessible Island, in other words, 12–$^1/_2$ % of the age determinations are not trust-worthy, by admission of those intimately concerned with said datings. We must further note the large role which supposition plays in the geochronological scheme of things as presented by GASS, quite as outstanding as the indirect deductions made by DUNNE. One cannot help but note that the 2 m. y. age for the Nightingale basalt dyke specimen, though thought to be erroneous by MILLER-GASS, would accord well with DUNNE's contention that the island is of relatively late origin. The older radiometric dates for the Nightingale group come not from Nightingale itself but from Middle Island. Agreed, the basalt dykes from which the specimens were studied in Nightingale and Middle Islands are said to show similar composition, but in spite of this, in spite of acknowledged propinquity, this does not argue, *ipso facto*, for similarity in age for the Nightingale group as a whole.

Considerable work dealing with the assessing of radiometric age determinations has led the writer to view with most cautious reserve all such findings. At this time, we must frankly confess that techniques involved are in need of much improvement.

The 1961 Eruption

The primary objective of the Royal Society Expedition was to make a geological survey of the Tristan group, study the new eruption and the effects on the vegetation and fauna.

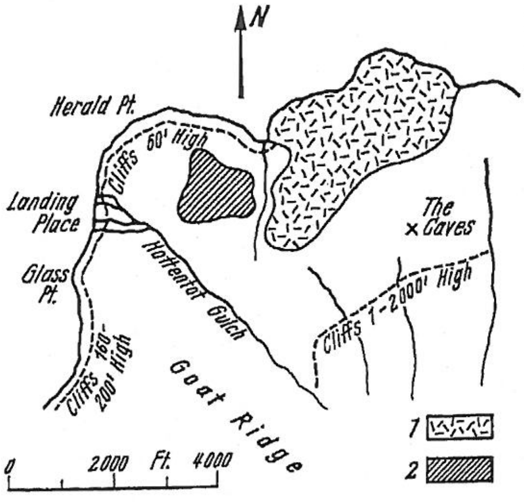


Fig. 94. Sketch Map of area of volcanic activity, Dec. 16–17, 1961, Tristan da Cunha. 1. Extent of lava flows, 2. Edinburgh. (Harris & LeMaitre, 1962)

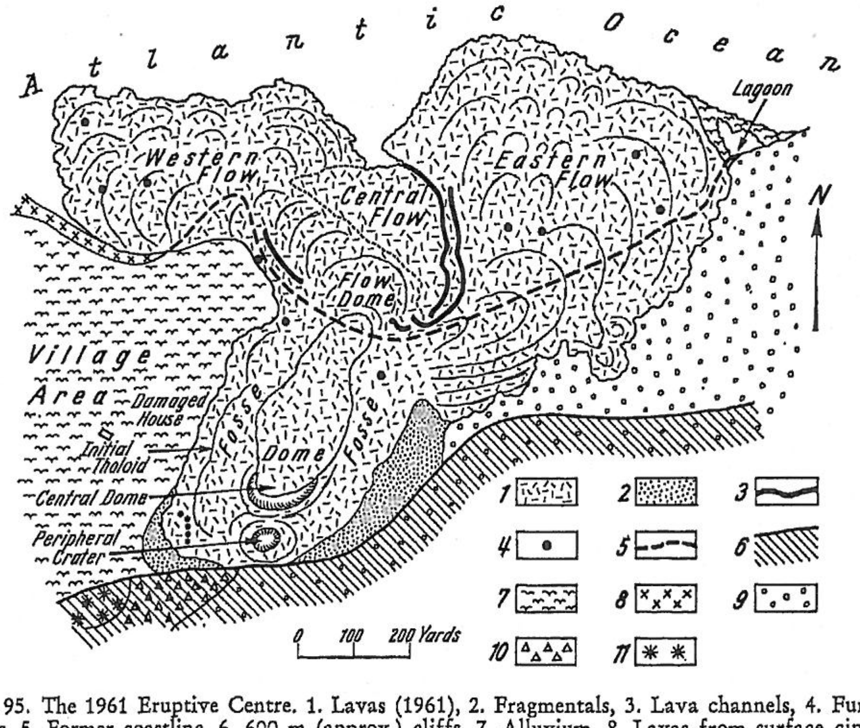


Fig. 95. The 1961 Eruptive Centre. 1. Lavas (1961), 2. Fragmentals, 3. Lava channels, 4. Fumaroles, 5. Former coastline, 6. 600 m (approx.) cliffs, 7. Alluvium, 8. Lavas from surface cinder cones, 9. Lavas, main volcanic sequence, 10. Pyroclastic centre, main volcanic sequence, 11. Intrusives. (Baker, Gass et al, 1964)

Tremor Phase

Though a volcanic island, Tristan da Cunha had shown no indications of vulcanism since the Stony Hill parasitic cone was in action probably some 200–300 years ago. Earthquakes had never been known. But beginning in the first week of August, 1961, slight shocks were felt near the Settlement and at Sandy Point. During the next three weeks, these increased in intensity, and then there was a lull. Tremors began again in early September, now more frequent and more violent, thought to have grades, as per the Modified Mercalli Scale of: A = 3, B = 4, C 5, D 6. It was believed that the hypocentre lay at a depth of about 1.6 km, with a magnitude of 3 and energy release of perhaps 10^{10} ergs. Along with the heaviest tremors, many rock-falls occurred behind the Settlement and to the NE of the village.

These Tristan tremors were comparable to seismic disturbances commonly heralding vulcanicity. The shallow-focus and hence rapid horizontal decrease in intensity of such tremors was well exemplified here, for at distances of 6–7 km away from Settlement area, shocks were mild, and at a distance of 11 km, not noticed at all. Increasing intensity of the shocks as October approached was likely due to approach of the ascending magma towards the surface. The tremor phase reached a climax on October 9th., when great cracks, 200 m in length and 2 m broad, were formed parallel to the coastline. On the seaward side, land was upraised 9 m and from the cliffs behind, blocks were detached and rolled downward, such landslides being most evident just behind the Settlement.

Eruption Phase

Tremors ceased as soon as the eruptive phase began, which latter began by a reddish glow emanating from a mound in the early hours of the morning of October 10th. In but a few hours this had developed into a dome or tholoid measuring ca. 20 m in height and 50 m in diameter. During the day this continued to grow, and also a further disturbance took place some 200 m W of the tholoid. After four days the tholoid had grown to a height of some 75 m, covering an area of 12 500 m^2. Soon afterwards lava began pouring out and flowing down northwards, and by the 27th., the canning factory, NE of the Settlement had been overwhelmed. Data are lacking as to events in November, but on December 6 the volcano was erupting violently, the red glow of the lava being visible more than 30 km away at sea. On the 16th two geologists of the Expedition, Harris & LeMaitre arrived by ship, and although unable to land, could observe events. Now the original plug had been breached on the seaward side and a stream of block lava coursed seawards. They estimated that the volcano had now reached a height of some 145 m above S. L., the lava field pushing beyond the original coastline for some 400 m and about 1000 m wide at the seaward margin. By January 5, 1962, the first crater was still active, emitting brownish lava, steam and smoke, and the lava front was now some 1300 m wide. The Expedition arrived on January 27th., by which time activity was very much less. The embryonic dome was now an elevated ridge which attained a maximum elevation of 147 m above S. L., thus showing a very slow rate of growth, compared say to Mont Pelé. (This maximum elevation was attained on March 19th.) Fumarole activity lessened during February and March. The Expedition left Tristan on March 20th., by which time relative quiet reigned.

Morphology

The land surface upon which volcanic products were formed had an inclination seawards of some 10°, and this inclination no doubt determined the form of the volcano and the lava field were directly influenced by this surface. The lava field achieved a maximum width of 1200 m with a maximum longitudinal extent of 1000 m approximately. The volcanic products cover a total area of some 585 280 m², two-thirds of which lies beyond the former coastline.

Fig. 95 shows the morphological features of the eruptive area. The source region plus the lava field constitute the two chief units of the eruptive centre. The source region is rimmed by a U-shaped ridge open seawards to the lava field. The ridge is the external vestage of the initial tholoid. In the central part of this marked subsidence occurred when the first lava poured out. In this area of subsidence rises the central cone to a height of some 137 m above S. L. The dome breaches the northern wall of the cone and extends downwards and seawards. Separating the central cone and the dome from the outermost ridge is an arcuate fosse. A smaller peripheral crater occurs at the southern extremity of this ridge where the latter meets the base of the main cliffs.

Petrography

All specimens analysed by the Expedition have a trachyandesite composition. The table below shows modal analyses of samples from various units of the parasitic volcano, which demonstrates their restricted mineral variation:

	Initial tholoid	Lava flows	Dome
Plagioclase	29.0	28.2	28.8
Pyroxene	4.7	7.6	6.4
Amphibole	2.3	2.1	1.5
Ore	2.6	4.0	4.1
Groundmass	61.4	58.1	59.2
No. points counted	3319	4597	5271

Hand specimens show the rocks to be finely vesicular, with now and then short prismatic crystals of plagioclase and elongate amphibole in an aphanitic base. Large plagioclase phenocrysts have a basic labradorite core, surrounded by a narrow zoned rim ranging in composition to sodic andesine. These plagioclases have strongly corroded cores which contain brownish glass and ore and pyroxene inclusions. Large clinopyroxene phenocrysts are much rarer, occurring poikilitically enclosing plagioclase laths and ore granules. The core of these crystals is aegerine-augite, and the wide rim likely a titanaugite. Strongly coloured amphibole phenocrysts show some degree of resorption. The amphibole is thought to be basaltic hornblende, but it may approach kaersutite in composition. The ore seems to be chiefly ilmenite. A most interesting constituent of some specimens, occurring as scattered, discrete grains, is haüyne. Leucite is sparingly present, and, unlike all other occurrences in the Tristan rocks, here it does not appear interstitially.

Occasional small plutonic xenoliths are present in the dome and lava field. Four were examined, from which the following modal analyses were made:

Sample No.	No. 645	No. 510	No. 519	No. 509	Average
Plagioclase	62	60	46	45	56
Olivine	1	0	0	0	–
Pyroxene	25	16	6	3	14
Hornblende	7	0	1	4	5
Biotite	0	16	33	33	15
Ore	4	6	9	10	7
Apatite	1	2	5	5	3

As plagioclase decreases, so also does pyroxene, whilst ore and apatite increase. Olivine only occurs in the rock with highest pyroxene content. Under the naked eye, these plutonic xenoliths have a gabbroic appearance and granular texture. In thin-section, some unzoned plagioclase occurs with a composition of ca. An_{75} whilst the strongly zoned ones have cores of about An_{65}. The clinopyroxenes are strongly coloured, ore inclusions are common. Subhedral, platy crystals of amphibole show no resorption, and appear to be chiefly basaltic hornblende. Some biotites are strongly oxidized. The granules of ore are thought to be mostly ilmenite. Apatite is abundant, present poikilitically in plagioclase, pyroxene and amphibole crystals.

On a mineralogical basis, these coarse-grained xenoliths show close resemblance to those found elsewhere in Tristan da Cunha.

Fumarolic minerals are plentiful in and around the small peripheral crater at the southern margin. Colours of these are grey, white, yellow and orange. They may occur as clear crystalline masses or then amorphous masses. Such minerals are present on blocks of lava which are bleached white. The following minerals were identified:

Sulphates: Gypsum, anhydrite, bassanite, alum, mirabilite(?), louderbackite, metavoltine, jarosite.

Fluorides: Fluorite(?), cryolite(?), ralstonite, thomsenolite(?), hieratite, cryptohalite.

Chlorides: Halite, erythrosiderite.

Carbonates: Natron.

Borates: Tincalconite(?).

Elements: Sulphur.