COARSE-GRAINED ROCKS FROM ASCENSION ISLAND

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ABSTRACT

The lavas and pyroclastic rocks of Ascension Island contain a suite of coarse-grained igneous blocks which range in composition from dunite to granite paralleling, but extending beyond, the compositional range of the volcanics. The mineralogy, texture and chemistry of these blocks are discussed, together with their modes of occurrence. More specific features observed include partial melting seen in one suite which suggests that granitic liquids may be formed from blocks of intermediate composition; the occurrence of the rare minerals dalyite ($K_2Zr Si_6O_{15}$) and vlasovite ($Na_2ZrSi_4O_{11}$); and the crystallization *in situ* of a rock type considered to reproduce several of the features displayed by the blocks. The implications of this for the origin of the coarse-grained suite as a whole are considered.

INTRODUCTION

Ascension Island is situated at approximately 8°S 14°W in the South Atlantic. The island is some 92 km^2 in area and comprises the uppermost 800 m of a 3000 m single cone sited on magnetic anomaly 4 about 120 km west of the median valley of the Mid-Atlantic Ridge and 50 km south of the Ascension Fracture Zone. No explicit connection with either of these major structures has been identified (Van Andel and Heath, 1970).

Ascension Island has attracted the attention of numerous workers since before the visit of Darwin (Darwin 1876). Most prominent for general geology is the work of Daly (1925). A more recent briefer description has been given by Atkins *et al.* (1964). The rare minerals dalyite and vlasovite were identified in ejected granitic blocks by van Tassel (1952) and Cann (1967) respectively, and Roedder and Combes (1967) have carried out fluid inclusion studies on these same blocks.

Ascension Island has features of an oceanic volcano at an advanced stage of evolution. An eccentric main peak, Green Mountain, comprises a basaltic cinder cone built in a caldera-like structure consisting mainly of trachyte and comendite. The latter rock types also form numerous domes and lava and pyroclastic flows elsewhere on the island. Over ninety parasitic centres including lava cones, pyroclastic cones and explosion craters have been located. The lower slopes to the north-west and south are formed of more mafic lava flows ranging from hawaiite to benmoreite in composition. True basalt is relatively rare.

There have been no eruptions verified in historic times.

Bearing in mind that the exposed portion of this volcano is little more than 1 % of its total volume it is worth noting that salic volcanic rocks form a noticeably large proportion of this upper part, possibly as much as 50 %.

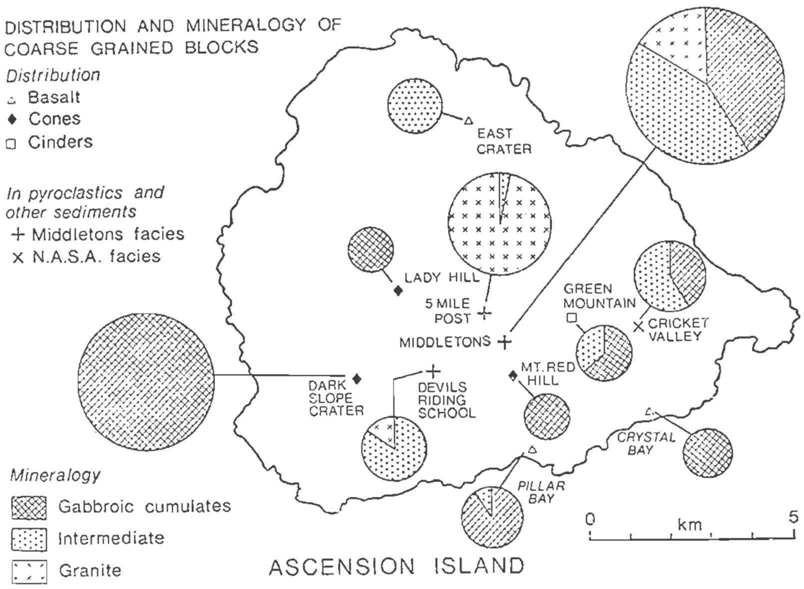

Fig. 1 — Distribution and mineralogy of coarse-grained blocks. The area of the circles is proportional to the number of blocks collected : the Dark Slope Crater circle = 100 blocks.

THE OCCURRENCE OF COARSE-GRAINED BLOCKS

Fig. 1 shows the distribution of blocks.

Coarse-grained rocks may be divided into four categories, (I), grouped phenocrysts, (II), cognate crystal clusters, (III), grouped xenocrysts, and (IV), xenoliths.

In this study, the blocks considered are mainly xenoliths and are found mostly in pyroclastic formations. In lavas the blocks are almost entirely restricted to basalt-intermediate types. A reason for this could be the difficulty of mixing when viscous salic magma passes through a coarse-grained rock body. Four «basaltic» cones have yielded blocks, though Dark Slope Crater is the only prolific source.

By far the most important sources of blocks are the pyroclastic formations and redistributed sediments. Three facies types account for nearly all of these.

(I) The Middleton's facies — white matrix-dominated sediments up to 70 m in thickness.

(II) The N.A.S.A. Road facies — poorly sorted red rubble, presumably mass flows.

(III) Fluvial sediments — mainly alluvial fans, the result of sporadic rainfall.

THE MORPHOLOGY, CHEMISTRY, MINERALOGY AND FABRIC OF BLOCKS FROM SPECIFIC LOCALITIES

Figs. 2 and 3 represent the analyses of individual phases from four important localities.

1) *Dark Slope Crater*

The blocks occur as small (few grains) to large (50 cm^3) samples, loose or in the wall of the crater. They are invariably coated with scoria and lava and many form the cores of bombs.

Fig. 4 shows the mineralogy in terms of the 3 main phases. Accessories are orthopyroxene, magnetite, ilmenite and chrome-spinel.

These blocks all show good cumulate textures. Preferred orientation of augite and plagioclase is very common and sometimes there is a marked linear alignment of augite crystals. Layering on the hand specimen scale is very rare (only 3 specimens) and is size and modal, rather than chemical pos-

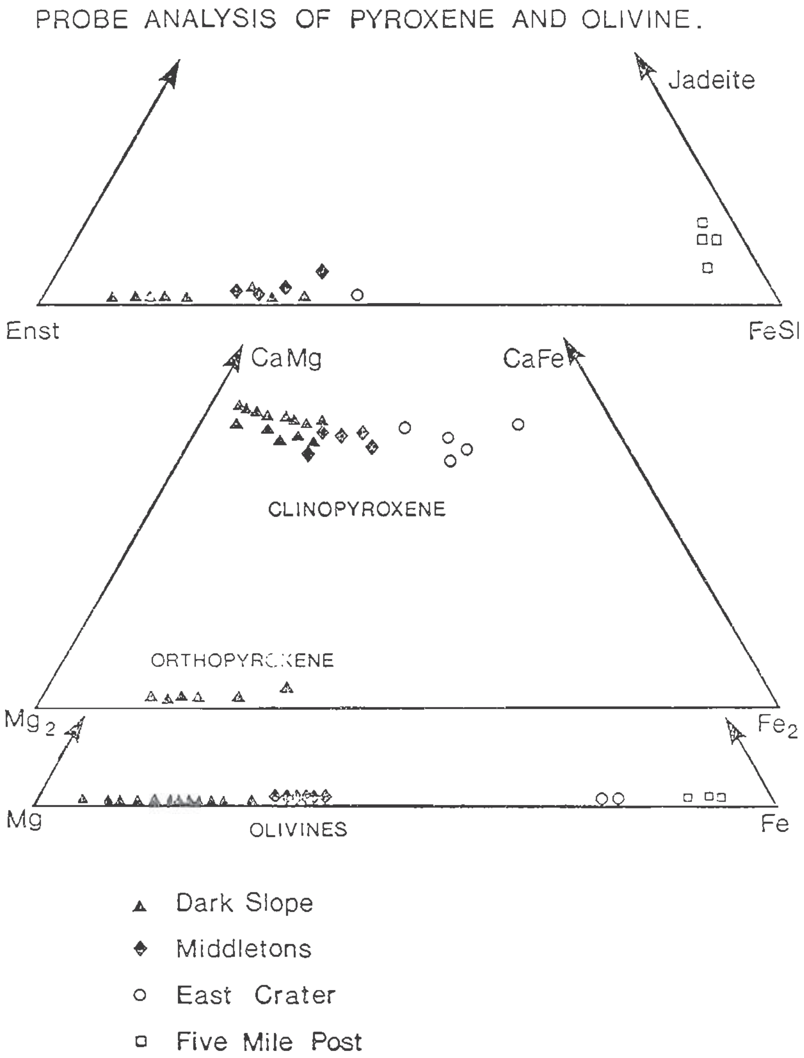

Fig. 2 — Probe analyses of pyroxene and olivine.

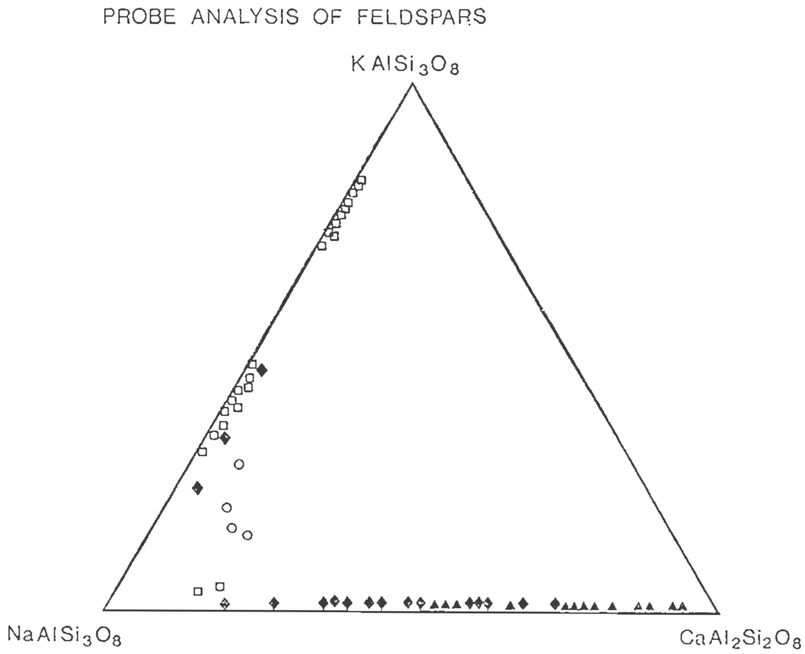

Fig. 3 — Probe analysis of feldspars.

sibly the result of very infrequent current action during otherwise undisturbed crystal settling. Grain size is quite variable but individual blocks are, in general, equigranular. An exception is the large clots (up to 5 cm) of augite sometimes seen in otherwise equigranular blocks (grain size 3-10 mm).

Orthopyroxene occurs as a cumulus phase in only one block, but is common along olivine-plagioclase boundaries in plagioclase-rich rocks (together with augite). Magnetite shows two types of occurrence: as a rare accessory in quite plagioclase-rich rocks and also as a major (up to 80 %) cumulus phase. The latter is seen in two specimens only, suggesting that magnetite crystallised in significant quantity during one or more brief intervals only.

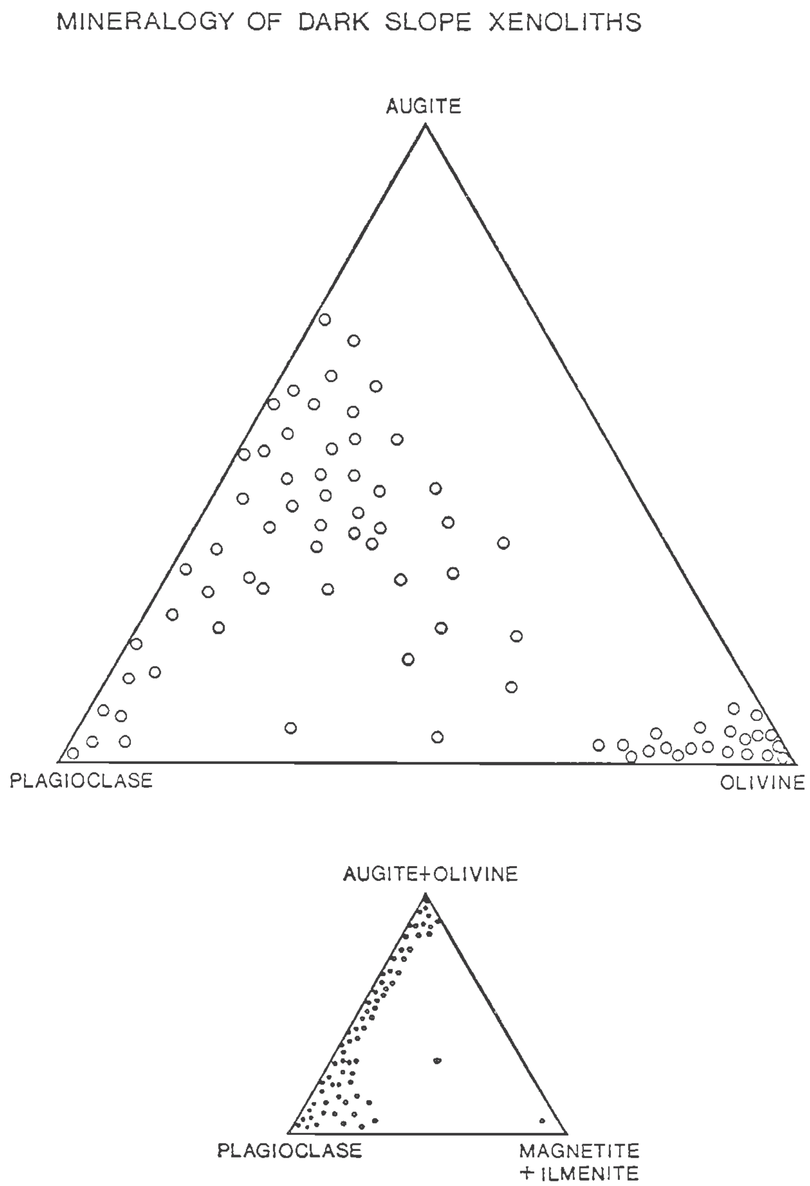

Fig. 4 — Mineralogy of Dark Slope xenoliths.

2) *Middleton's Ridge*

In places over 70 m of sediment of the Middleton's Facies are found. They contain the largest and most variable suite of coarse-grained blocks on Ascension. Of the three xenolith--rich horizons found, the lowest contains only granite, whereas the upper two contain both intermediate rocks and gabbros in approximately equal proportions.

The granites are very similar (if not identical) to the 5 Mile Post Granites described below. Vlasovite has been identified in one specimen. In the intermediate rock types, a typical assemblage is quartz (0-10 %), augite (5-20 %) and both sodic plagioclase and alkali feldspar. Many of the blocks are altered with the pyroxene replaced by amphibole and biotite, and the feldspar showing sieved rims.

The augite in some blocks contains up to 4 weight per-cent Na_2O.

In contrast to the Dark Slope gabbroic blocks, those on Middleton's Ridge are rather constant in mineralogy. Augite, olivine, and plagioclase are always present. Other differences in mineralogy include 1-10 % modal magnetite, more iron-rich ferromagnesian minerals and generally more sodic plagioclase. These suggest a slightly more evolved sequence.

The textures also differ conspicuously from those of the Dark Slope blocks. Preferred orientation is absent and nearly all specimens show a glassy mesostasis (up to 10 %), considered to represent interstitial liquid quenched during the sudden transfer of an incompletely crystallised rock mass to the surface (plate I).

3) *5 Mile Post (Green Mountain)*

The blocks here occur in a partially exposed horizon of poorly sorted sediment. The size of blocks ranges from 1 to 25 cm in diameter and most are rather friable and iron-stained.

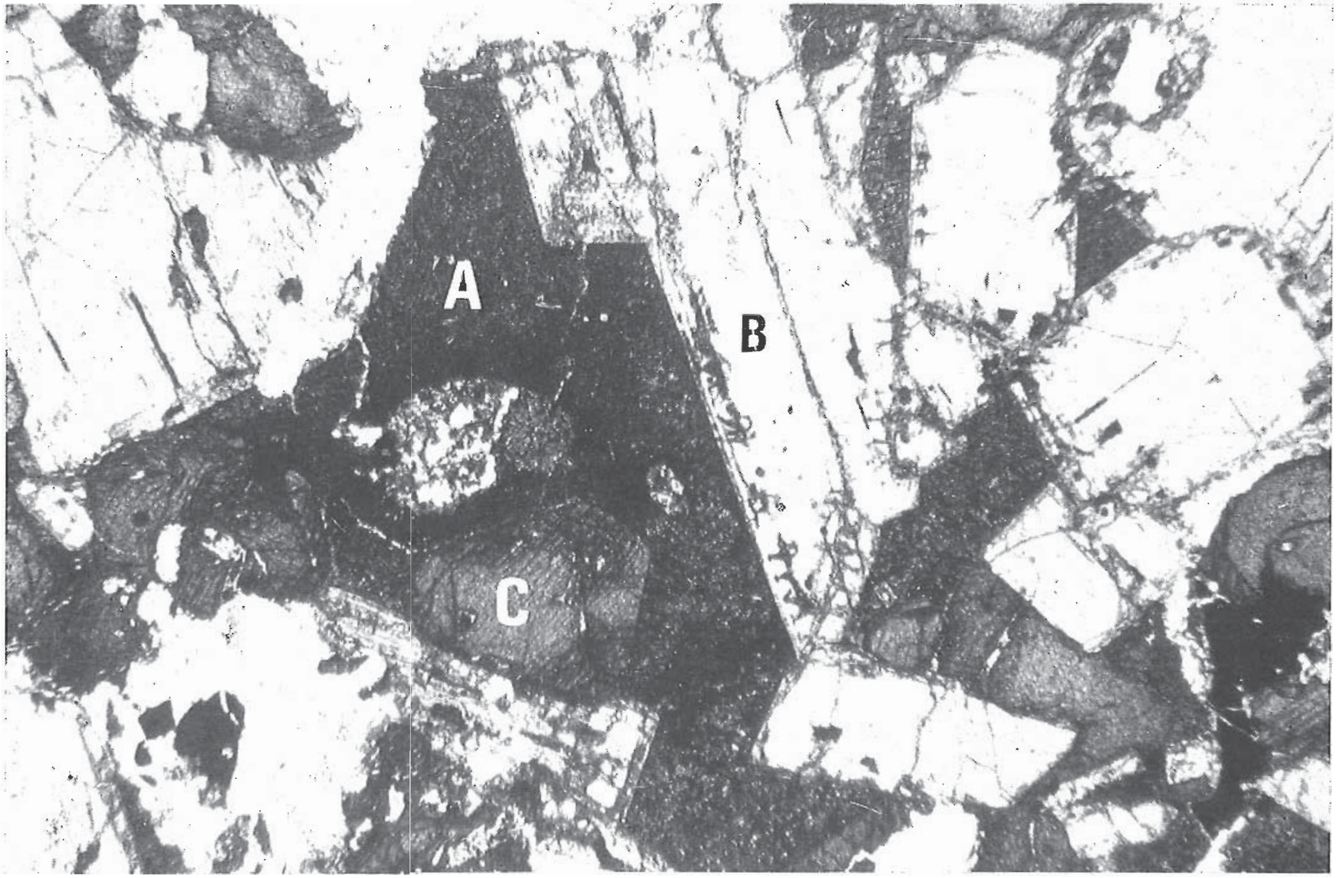

Plate I — Middleton's gabbro showing euhedral plagioclase (B) and augite (C) projecting into glassy mesostasis (A) (X15 PPL).

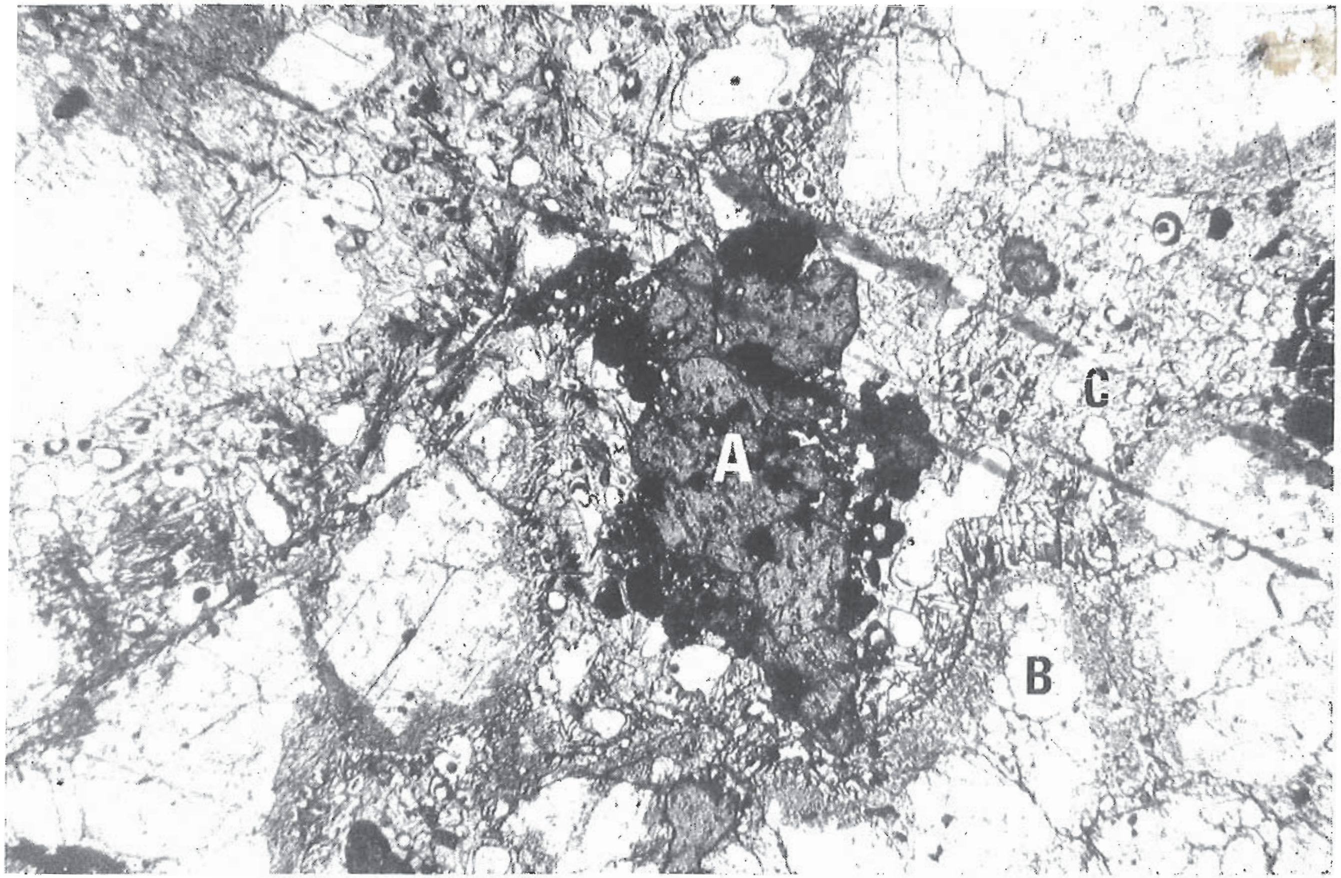

Plate II — Partially melted syenite from East Crater. A is augite containing small grains of an opaque mineral ; B is anorthoclase with sieved rims adjacent to glass (C) which contains small quench crystals of feldspar (X15 (PPL).

Three texturally similar types are evident (Roedder and Coombs, 1967) and appear to be intergradational. The rocks are all granites but with significant variations in mineralogy.

Hornblende-non-perthitic granites contain alkali feldspar which is rarely perthitic, accompanied by hornblende as the main mafic mineral together with some aegirine. This type is relatively rare.

Arfvedsonite/aegirine ± oligoclase granites contain alkali feldspar which is generally non-perthitic, and occasional small oligoclase grains. The mafic minerals occur in irregular clots, sometimes with a calcic pyroxene surrounded by arfvedsonite and aegirine. Biotite is present in some of the clots, possibly as an alteration product, and magnetite is a not uncommon accessory.

Arfvedsonite/aegirine perthite granites ± dalyite or vlasovite comprise about 70 % of the blocks collected at this locality. The feldspar and quartz often show a coarse granophyric texture. The «ferromagnesian» minerals are basically NaFe silicates and comprise 10-15 % of the rock. Rarer accessories are dalyite, vlasovite, aenigmatite, zircon and fayalite (in the cores of the mafic minerals). The blocks show prominent miarolitic cavities (distinguishing them from the other two types). Well-formed quartz and mafic minerals project into these cavities.

These blocks are remarkable for the presence of the zirconium silicates, dalyite and vlasovite, which are found in one and two other localities respectively (van Tassel, 1952 ; Cann, 1967 ; Fleet and Cann, 1967 ; Gittins et al., 1973 ; Tikhonenkova and Kazakova, 1961). Vlasovite ($Na_2ZrSi_4O_{11}$) may be interstitial or well formed and one good cleavage is visible in thin section. It is occasionally associated with zircon and sometimes rather altered. Dalyite ($K_2ZrSi_6O_{15}$) is unaltered, invariably interstitial and displays no cleavage, contrary to the description by van Tassel. It very closely resembles quartz in thin section. Vlasovite is much more common than dalyite but unaccountably was identified much later.

The two minerals have not, so far, been found in the same block. Dalyite blocks are slightly more miarolitic but otherwise they are identical. Differences between the whole rock chemistry of these two rock types are under investigation.

4) *East Crater*

At this locality, xenoliths occur in a trachyandesite emerging from a large cone ,and range in size up to 30 cm in diameter. Many show a cleavage and thus occur in flat tablet form. The mineralogy of these blocks is remarkably uniform. Unaltered specimens contain 0-5 % quartz, 5-15 % augite with the rest of the rock composed of variably perthitic anorthoclase with some orthoclase. Magnetite and zircon are accessories. In altered blocks biotite and amphibole rim or replace the augite.

The distinctive feature of this group of blocks is the textural evidence of partial melting invariably exhibited (Plate II) (Cox et al., 1979). The partially melted material, which ranges from 1-30 % modally has been preserved as quenched glass. This is light brown to colourless and is found in quantity only along boundaries between grains of two different phases. In simple terms this must be due to a mutual lowering of melting point. Considerably more glass is seen along quartz-feldspar boundaries than between augite and feldspar. The glass adjacent to magnetite and pyroxene is often stained dark brown, due to the presence of 1-2 weight percent of iron oxide.

In the four specimens analysed the colourless glass contains between 72-77 weight percent SiO_2 whereas the whole rock has about 65 weight percent SiO_2. Because quartz-feldspar contacts produce melts comparatively easily, partial melting of rocks such as these, with a small amount of modal quartz, produces liquids considerably richer in silica. Other features of partial melting include sieve textures in the rims of the feldspar and quench crystals which have formed along the grain boundaries of the feldspar on rapid cooling of the liquid.

OTHER LOCALITIES

These include other cones in which the blocks are all gabbroic but are smaller and finer grained than those of Dark Slope Crater ; the south coast lavas which contain small (rarely up to 10 cm) xenoliths in a «basalt» flow which is widespread along this coast. Most are gabbroic, some showing mesostasis or partial melting ; Green Mountain and Bears Back where the cinders contain small ($<$ 3 cm) gabbroic xenoliths remarkably similar in mineralogy and texture to Middleton's Ridge gabbros ; The N.A.S.A. Road facies in which the blocks are variable but rather altered ; Devil's Riding School, where intermediate types such as fayalite-syenite, and granite and granophyric types are found, the latter being similar in mineralogy to, but finer grained than, the granites at Five Mile Post.

The last rocks to be described occur within the Cricket Valley lavas. Two types of coarse-grained rock are found here : small gabbroic xenoliths of the type found in the south coast lavas and a curious outcrop of coarse-grained rock unique on Ascension.

This outcrop is an irregularly shaped, 3 m by 1.5 m, coarse-grained mass in a 30 m basalt cliff (on the N.W. side of Cricket Valley). The rock consists of alkali feldspar and plagioclase (both usually zoned), augite (sometimes intergrown with the feldspar), a small amount of interstitial quartz, long needles of apatite, and about 10 % magnetite.

The delicate textures seen in this rock are undisturbed at the boundary with the basalt, so it would seem that the rock has crystallized *in situ*. Since the boundaries are unchilled, it is not intrusive into solid, cold basalt. A possible explanation of this is that a pocket of liquid separated from the existing magma at depth. A higher iron content (14.16 weight % FeO compared to 11.04 weight % FeO in the enclosing lava) would confer a density greater than that of the remaining magma so that only small amounts of this liquid would be caught up in the subsequent eruption and transported to the surface. Once at the surface the higher iron content of the liquid would imply a lower solidus temperature for this material and crystallization would start essentially after the enclosing magma had solidified leading to the *in situ* formation of a coarse-grained facies ,as the surrounding lava might be expected to cool slowly once *in situ,* acting as insulation.

This rock provides one of the few direct insights into possible mechanisms of formation of coarse-grained rocks within, and possibly below, the Ascension structure.

CONCLUSIONS

1) The compositional range of the coarse-grained rocks is that which might be expected from coarse-grained equivalents of the observed volcanic rocks.

2) It seems that one or more magma chambers existed under Ascension in which slow crystallization occurred, allowing coarse-grained rocks to form. No evidence can yet be presented as to the depth, size and shape of these chambers but a small pocket of coarse-grained material appears to have crystallized at a depth of only 50 m.

3) From the evidence of the only *in situ* coarse-grained rock on Ascension, it is suggested that a more evolved, but denser liquid separated from the existing magma below Ascension. This may have remained at depth long enough to crystallize some of the coarse-grained blocks now found on the surface.

4) Granitic liquids can be produced, at least in small quantities, from less salic coarse-grained rocks by partial melting.

ACKNOWLEDGEMENTS

We thank S. Baker, N. Charnley, G. Collins, C. Fagg, R. Holland, P. Jackson, K. Parrish and E. Wearing for advice and technical assistance. C. Harris is grateful to the N.E.R.C. for supporting this work financially and to The Queen's College, Oxford, for a travel grant to attend the Azores symposium.

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