Gariboldi Volcanic Complex, Ethiopia

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Abstract

The Garibaldi Complex is one of a chain of predominantly silicic volcanic cones along the centre of the Main Ethiopian Rift, which form part of the Pleistocene - Recent Aden Series (MOHR, 1962 *a*). The present form of the Complex is largely a result of silicic conebuilding episodes, between which ignimbrites were erupted and areas collapsed to form calderas, and to a lesser extent of recent basalt eruptions. Comparisons are made with other areas of caldera collapse and attention drawn to the possible relationship between caldera complexes and plutonic ring structures.

Introduction

The Gariboldi Complex (lat. 8°48′ N; long. 39° 42′ E) which covers an area of 250 km², lies at the northern end of the Ethiopian Rift (Fig. 1), near the junction with the Afar depression. It is about 160 km east of Addis Ababa and about 30 km southwest of Fantale volcano and a similar distance northwest of Boseti Guda volcano. These three volcanoes form part of a chain along the centre of the Rift associated with the Wonji Fault Belt (MOHR, 1960), a zone of intense Quaternary faulting in which the north-south faults are arranged in a series of en echelon zones oblique to the rift margin (Fig. 1).

Little detailed study has previously been made on the area, BUXTON (1949) noted the presence of a « crater » at Gariboldi Pass and the existence of fresh lava flows, and later, MOHR (1962*b*) briefly described the structure of the area and suggested it was worthy of

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further investigation. The present study is the result of two months fieldwork during the summer of 1967 and subsequent petrographic study at the University of Leeds. More detailed petrography and chemistry will be undertaken in the future by Dr. I. L. GIBSON in conjunction with his work on Fantale volcano.

Petrography

The rocks of the Complex were studied petrographically mainly to facilitate mapping and re-construction of the geological history. About 250 thin sections were examined but no detailed mineralogical or chemical investigation of the rocks were attempted. From this preliminary study the rocks were found to be divisible into five groups; trachytes and comenditic rhyolites; ignimbrites; pumices; syenite inclusions and basalts. The distinction between « trachyte » and « rhyolite » is based purely on the mineral content and later chemical analyses may necessitate a revision of terminology.

Trachytes and Comenditic Rhyolites

This group, which forms the greatest volume of rock in the Complex, can be subdivided on mafic phenocryst assemblage into:

Fayalite ferroaugite trachytes;
Fayalite sodic-ferrohedenbergite trachytes;
Sodic-ferrohedenbergite trachytes;
Sodic-ferrohedenbergite sodic-amphibole rhyolites.

Crystal content and texture vary considerably, but the earlier trachytes usually have a lower crystal content and have more euhedral phenocrysts than the later rocks. Most of the younger flows have an outer glassy margin, but in many of the older flows this has been eroded to expose hard grey or grey-brown rocks with a devitrified groundmass.

The trachytes all contain phenocrysts of anorthoclase and the rhyolites both anorthoclase and resorbed quartz. Most of the lavas also contain small crystals of an opaque mineral, probably ilmenite. Sodic amphibole (katophorite?) and cossyrite are present in small quantities in the groundmass of the sodic ferrohedenbergite trachyte,

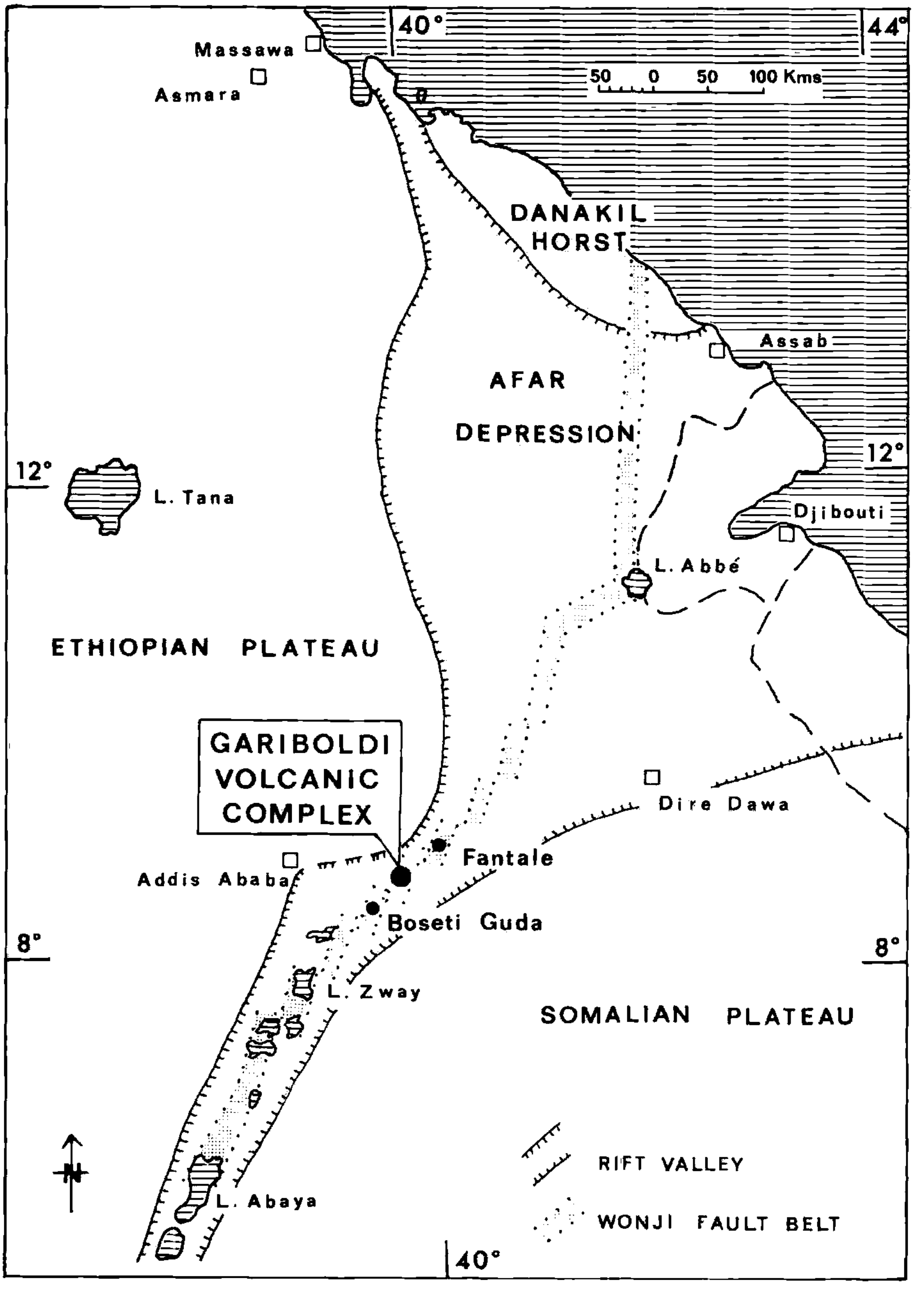

FIG. 1 - Map showing position of the Gariboldi Volcanic Complex in relation to the Main Ethiopian Rift and Wonji Fault Belt.

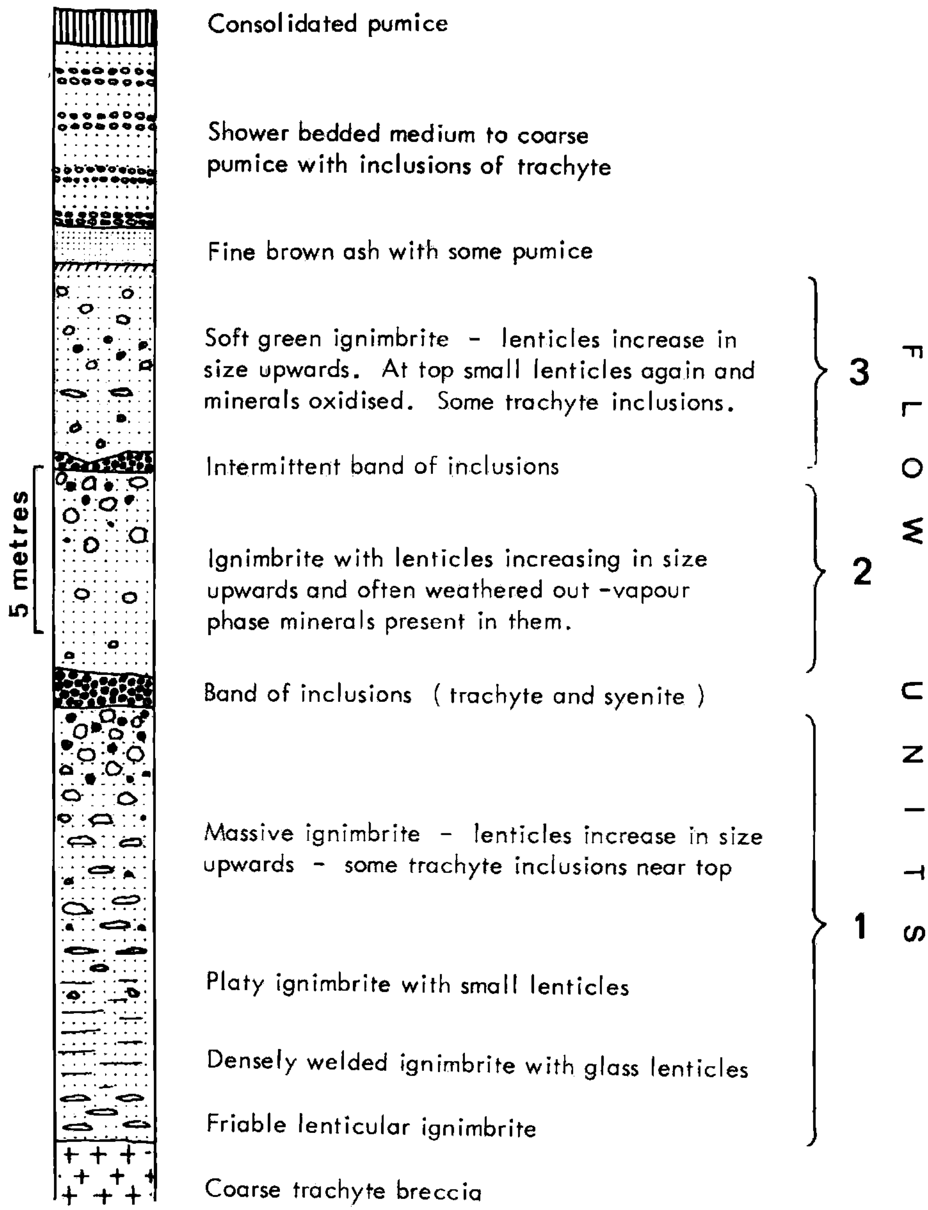

FIG. 2 - Section through the sodic-ferrohedenbergite cossyrite ignimbrite exposed in the Western Marginal Wall of caldera 8.

and are found both as phenocrysts and in the groundmass of the rhyolite where spongy aggregates of arfvedsonite and riebeckite are often found intergrown with a sodic-pyroxene (aegirine-augite or sodic-ferrohedenbergite).

Ignimbrites

The mineral content of the ignimbrites is similar to that of the lavas with which they are associated. They can however be distinguished from the lavas in the field by their green colour, eutaxitic texture and by the presence of weak colummar jointing in the more extensive units. The sheets vary in thickness from 15 centimetres to over 25 metres and usually show a gradation from a strongly welded base to a non-welded or poorly welded top. A typical sequence through one of the thicker ignimbrites is shown in Fig. 2. This example from the northern wall of caldera 8 (see Fig. 3) shows three flow units that must have been deposited within a short time interval for the whole sequence apparently cooled as one unit; this feature is common in ignimbrites elsewhere (Ross and Smith, 1960).

Most of the ignimbrites appear to have a well developed vapour phase zone suggesting they had a high gas content. This phase is represented in the sheets by a spongy area with numerous blocks of pumiceous material in the pores of which small euhedral crystals have formed. Near the base of the sheets, lenticles or « fiamme » of glass occur and these often appear to contain a higher percentage of phenocrysts than the surrounding matrix.

On top of some sheets is a fine loose ash which probably represents the unwelded top of the cooling unit. In a few cases this shows cross-bedding, probably resulting from transport and subsequent deposition by wind. Such a feature is common in non-welded ignimbrites studied by the author in the Tarawera Volcanic Complex, New Zealand.

Pumices

Pumice deposits are widespread in the Complex, and vary in thickness from 50 centimetres to over 20 metres. They usually show some shower bedding and are often interbedded with ignimbrite sheets. Most contain inclusions of trachyte, ignimbrite and syenite blocks which usually form 1-5%, and more rarely up to 25% of the deposit.

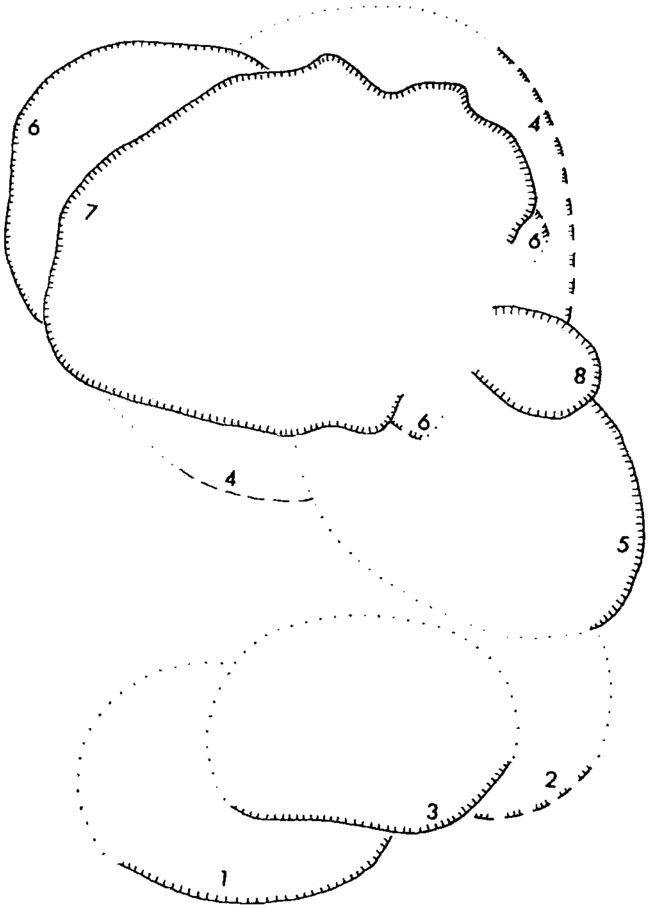

FIG. 3 - Probable positions of caldera margins at Gariboldi Volcanic Complex (Numbers are for convenience in discussion and may not represent sequence of collapse).

Syenite Inclusions

These blocks are of particular interest as they appear from superficial examination to be the plutonic equivalents of the lavas; further chemical work will be necessary to establish this link. Three types of syenite occur; the first contains augite, aegirine, ferrohastingsite, a zoned anorthoclase and some quartz; the second is apparently more silicic as it contains more free quartz, augite, aegirine and a sodic amphibole (either cossyrite or a brown ? katophorite); and the third type, which is thought to be the plutonic equivalent to the comenditic rhyolite, contains aegirine, arfvedsonite and a perthitic sanidine-oligoclase intergrowth which is itself often in myrmekitic intergrowth with quartz.

The texture of the syenite varies from a coarse almost pegmatitic rock with drusy cavities sometimes containing large crystals of amphibole or pyroxene, to a fine-grained rock usually with abundant quartz. One small block of a rock contained only aegirine and a small amount of sanidine and probably represents an accumulate formed at the base of the magma reservoir during the early stages of crystallization.

This association of extrusive lavas and plutonic inclusions is a common feature of calderas. It is found in New Zealand (EWART & COLE, 1967) and nearer to Gariboldi at Fantale (GIBSON, pers. comm.), and is considered to be of particular significance in studying the relationship between calderas and deeper seated ring structures.

Basalts

Three basic lava types are found in the Complex which can be distinguished on the amount and the type of phenocrysts in the rock. The first, an aphyric basalt, has a mesh of small crystals (< 0.25 mm) of plagioclase, iddingsite and magnetite usually surrounded by a basaltic glass. The second, an olivine basalt, has small phenocrysts of olivine and plagioclase (? labradorite) in a groundmass similar to the aphyric type, and the third variety has large phenocrysts of olivine, augite and plagioclase; the augite, which often shows « hourglass » zoning, is probably titan-augite.

Faulting

Two distinct sets of faults affect the Complex; (i) normal faults trending NNE form part of the Wonji, Fault Belt (MOHR, 1960), (ii) ring fractures along which caldera collapse has occurred. Both types have been active throughout the history of the Complex.

Normal Faults

The normal faults vary in downthrow from 2 metres to over 30 metres and, as the resultant offset has suffered little erosion, the faulting has a pronounced affect on topography. As MOHR (1962*b*) notes, the majority of the faults have a westerly downthrow but some are downthrown to the east and the two sets often result in small horsts and grabens. An example of the latter (Fig. 4) is well depicted in the walls of one of the younger calderas (No. 7 of Fig. 3).

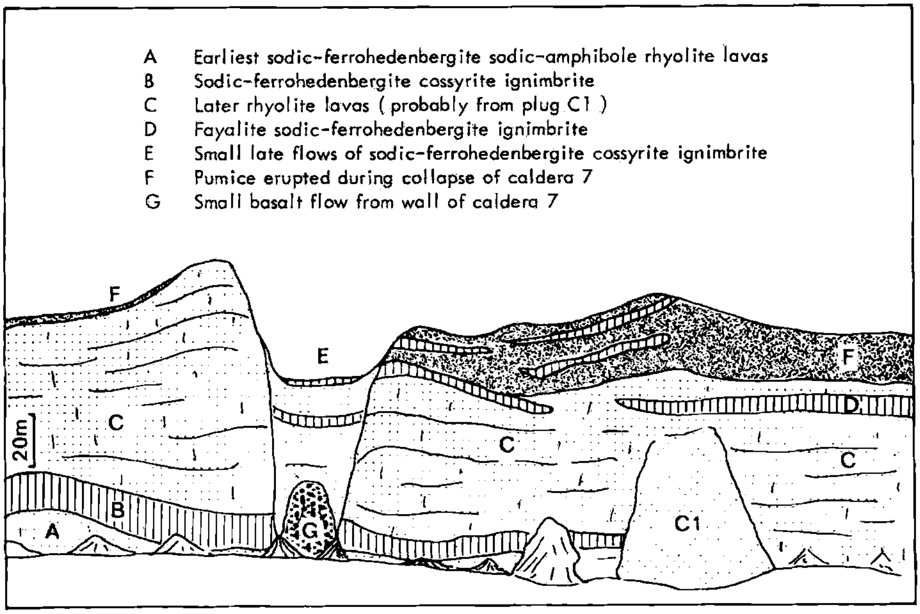

FIG. 4 - Part of the southern marginal wall of caldera 7, showing lavas of sodic ferrohedenbergite sodic-amphibole rhyolite with interbedded ignimbrite and final pumice deposit, downfaulted to form a graben which in turn is filled with later ignimbrite and basalt.

Caldera Structures

The earlier calderas are usually incomplete and represented only by an arcuate fault crossing the regional trend. In some cases they even lack topographic expression and can only be recognized by disruption of the ignimbrite sheets (Fig. 5). The pattern shown in Fig. 3 is thus partly conjectural and is largely based on the general structural relationships of the lava. Most of the calderas are elliptical in shape with the short axis approximately parallel to the north-south trend of the Wonji Fault Belt. The caldera of Fantale Volcano is also elongated in this direction (GIBSON, 1967).

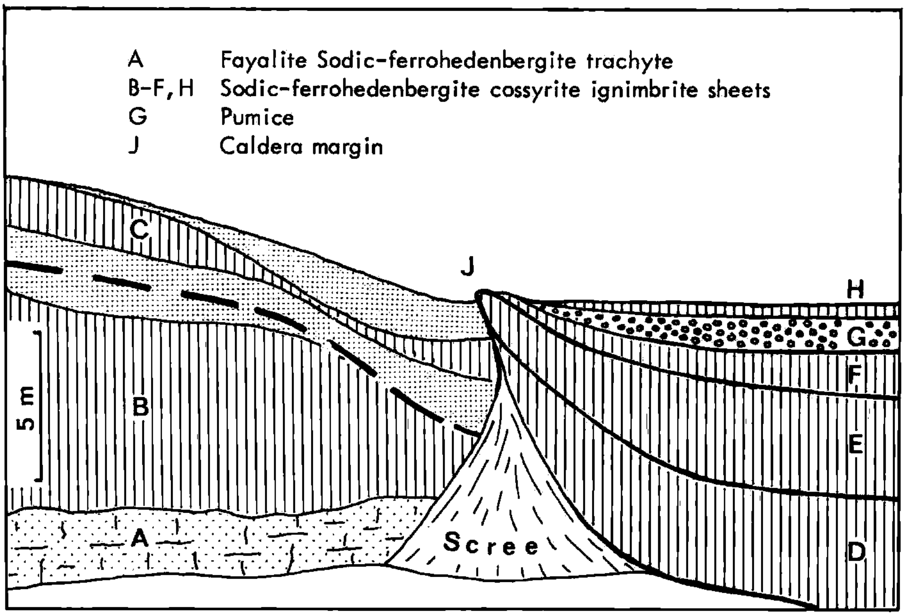

FIG. 5 - Sketch of the north eastern corner of caldera 7, showing ignimbrite sheets filling up the earlier caldera 6.

Not all the calderas are complete. The two most recent structures (7 and 8 of Fig. 3) share a common hinge-line and this is probably true of some of the earlier structures. Size varies from a maximum diameter of over 5 kilometres (caldera 6) to 1½ kilometres (caldera 8) and the height of the walls is as much as 200 metres, showing that considerable volumes of material must have been displaced during collapse.

Stratigraphy

As the area has undergone a complex history, the stratigraphic sequence is partly inferred. It is very probable that there were several distinct eruptive centres but the products of these overlap and hence it is now difficult to distinguish separate centres from parasite cones. However, three apparent silicic eruptive episodes may be recognized, followed by a basic phase.

The earliest eruptive phase probably formed the fayalite ferroaugite trachytes found in the south of the area; these are largely covered by ignimbrite sheets. The vent or vents for these lavas have not been identified, but it is assumed from their general attitude that the main vent was to the north of the present outcrops, and has now been obliterated by the collapse of a caldera after eruption ceased.

The next phase of activity was concentrated to the north of the earlier lavas to form the Main Cone of the Complex. Many flows of sodic trachyte were erupted but it is not known from this study whether there was any systematic variation in composition with time. It seems most likely that lava of only one mineral assemblage came from each vent but that during any one period of eruption two adjacent vents could have erupted lavas of different mineral assemblages.

These lavas, like the earlier flows, are commonly covered by ignimbrite sheets, but here the topographic expression of the lavas is better preserved. The ignimbrites, although thin (<3 metres) are equally distinct and in two examples in the east of the Complex may be traced to parasitic vents in the side of the main cone.

During and following the activity, several calderas collapsed; each was presumably associated with a centre of eruption but the sequence of collapse is debatable as subsequent activity has obliterated the evidence in some places. The collapse of two calderas (4 and 5 of Fig. 3) was accompanied by the eruption of pumice and this now rims the structure.

After the collapse of caldera 5, a sodic-ferrohedenbergite cossyrite ignimbrite was erupted from a vent within the caldera and the resultant deposit partly filled it. The ignimbrite flowed through a gap in the north western part of the caldera rim to partly fill caldera 4 and also through a graben in the walls of the northern side. Within the caldera, it is well exposed, as a later collapse structure (caldera 8) has produced a complete section both through the ignimbrite and the surrounding lava flows (Fig. 6). It is the top surface of this sheet that forms the flat floor of caldera 5 and it is possible that similar flat surfaces forming the floor of other calderas may have been produced in the same way.

The last silicic eruptive phase, represented by flows of sodic-ferrohedenbergite sodic-amphibole rhyolite, built up a cone within caldera 6. The full size of this cone is now unknown as the sequence of activity was similar to earlier phases and culminated in small ignimbrite eruptions and collapse to form calderas. This collapse

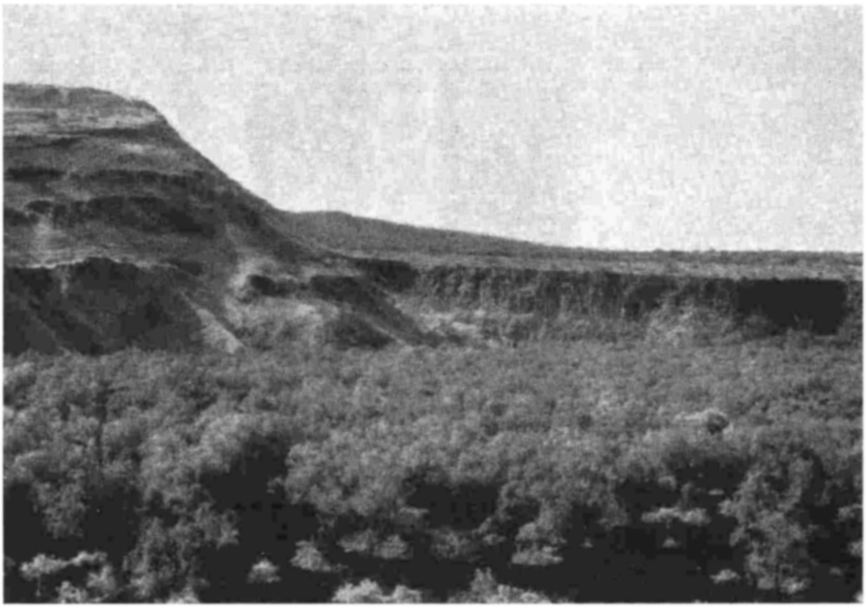

FIG. 6 - Eastern marginal wall of caldera 8, with trachyte lavas of Main Cone to left, and ignimbrite partly filling caldera 5 on right. The floor of caldera 8 (foreground) is covered with olivine-augite basalt.

has, however, resulted in good sections through the lava pile (Fig. 7 and 4). The pumice at the top of the section was probably erupted during the same eruption as the caldera collapse occurred, but the volume of it is much less than the volume removed during caldera collapse. The relationship is thus similar to that described by WILLIAMS (1942) at Crater Lake, Oregon.

Finally the type of activity changed, and eruptions of basalt took place. The first of these eruptions was small, producing stubby flows of aphyric basalts to the north and south of caldera 7 (Fig. 8). Small flows also veneer the inner walls of this caldera in places. These were succeeded by the formation of cinder cones along the hinge line between calderas 7 and 8 and from them *pahoehoe* flows of olivine basalt were extruded only to be partly covered by *aa* flows of olivine augite basalt. The most recent flows are traditionally dated at between 1810 and 1830 according to BUXTON (1949) and this recent date is consistent with their lack of weathering or thick cover of vegetation.

FIG. 7 - Northern marginal wall of caldera 7, showing two plugs of a parasitic cone of sodic-ferrohedenbergite trachyte. Later pumice fills the «crater» at the top.

Comparison with Other Areas

The rocks of the Gariboldi Volcanic Complex petrographically resemble those of the nearby volcano Fantale (GIBSON, 1967) and the comenditic volcanoes of the South Arabian Coast (GASS & MALLICK, 1968). In these examples however there are fewer calderas. At Fantale and Jebel Khariz there are single calderas, and Aden has two calderas (GASS, MALLICK, & COX, 1964). Multiple structures are much less common in calderas, but they do occur in ring structures. Examples occur in the Younger Granite Province of Northern Nigeria (JACOBSON *et al*, 1958) where the lava types are similar to those at Gariboldi. Furthermore, the common occurrence of syenite blocks at Gariboldi suggest that high level intrusions, petrographically similar to those found in Nigeria, underlie the volcanic superstructure. Thus, it seems possible that the Gariboldi Complex is the surface expression of ring structures similar to those found in Nigeria. It is also similar to Fantale, but as a greater volume of lava, ignimbrite and pumice have been erupted, greater compensation in the form of caldera collapse has taken place.

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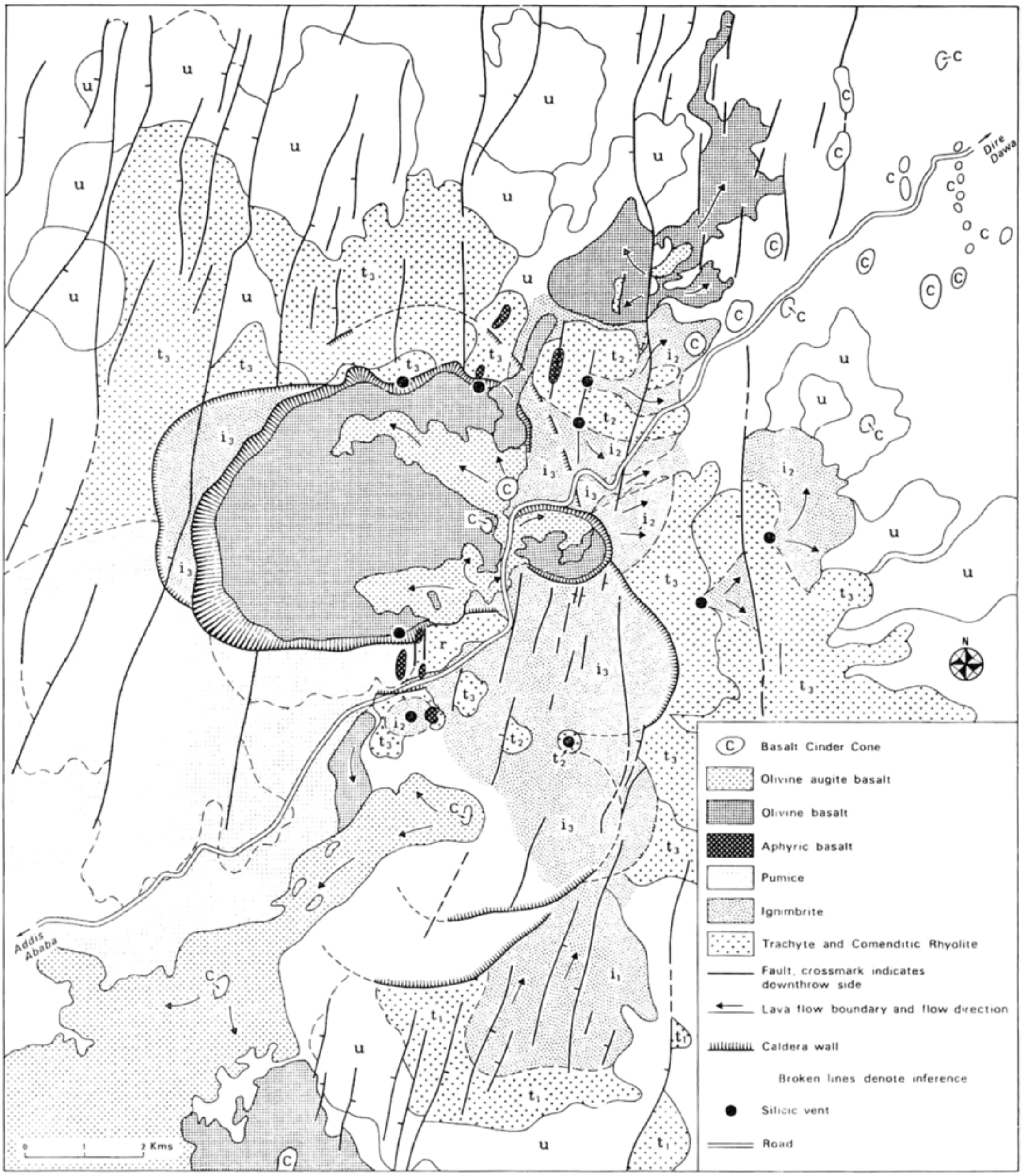

FIG. 8 - Geological Map of Gariboldi Volcanic Complex, Ethiopia. (t_1 - Fayalite ferroaugite trachyte; t_2 - Fayalite sodic-ferrohedenbergite trachyte; t_3 - Sodic-ferrohedenbergite trachyte; r - Sodic-ferrohedenbergite sodic amphibole rhyolite; i_1 - Fayalite ferroaugite ignimbrite; i_2 - Sodic-ferrohedenbergite ignimbrite; i_3 - Sodic-ferrohedenbergite cossyrite ignimbrite; u - undifferentiated lava flows).