THE GEOLOGY OF THE SOUTHERN PART OF HOMA MOUNTAIN
CARBONATITIC COMPLEX WESTERN KENYA, WITH PARTICULAR
REFERENCE TO THE PETROLOGY OF THE ALKALINE SILICATE,
METASOMATIC AND MELILITE BEARING SUITES

by

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Abstract

The multi-centred carbonatitic complex of Homa Mountain consists of a central cone sheet complex intruded into a domed area of country rock, surrounded by further arcuate zones of intrusive activity.

The earlier events included intrusion of a body of ijolite, as a series of discontinuous bodies probably connected at depth.

Later events include at least five stages of carbonatite intrusion and also numerous carbonatitic breccias.

Syenitic rocks formed by concentration of late stage material at the margins of the ijolite which deuterically altered the ijolite and metasomatised the country rock to fenite contemporaneously. Minerals formed at such contacts are low temperature, potash-rich orthoclase and aegirine with apatite the chief minor constituent.

A second style of fenitization is recognized involving net veining of more widespread areas of country rock away from ijolite contacts.

This reaches its climax in arcuate zones of shearing and brecciation within the central high ground where there is evidence of partial melting of such fenites to iron oxide-bearing trachytes.

Coarse feldspathic rocks also carrying iron oxides are present near ijolites and early carbonatites. The feldspar
in these is very similar to that in the fenites.

Metasomatism at Homa is believed to involve introduction of large amounts of juvenile potash only, much of the soda being derived by redistribution of that already present in the country rock.

A period of erosion during which superficial, lacustrine and possibly pyroclastic deposits were laid down then occurred and the mountain reduced to near its present topography.

Following this erosional interval small scale vents of breccia and melilite-bearing material were intruded. The melilitites show all stages of replacement by carbonate.

The above later stages of activity occurred during Late Pliocene or Pleistocene time. They were accompanied by some phonolitic activity within the complex and more in the area to the east along an extension of the southern boundary fault of the Nyanza Rift.
INTRODUCTION

The thesis presents results of work on the geology of the southern part of the Homa carbonatitic ring complex, Western Kenya. Ten months were spent in the field with Mr. A. M. Flegg who is working on the northern portion of the complex. For this reason the details of the northern part of Homa Main (Fig. 1.9) are not the author's own work and many of the ideas in the thesis, particularly on the general geology, must be a synthesis also.

I would like to acknowledge the great help and comradeship shown to me by Mr. Flegg at all stages of our work together.

The thesis is divided into six sections or papers each complete in itself but referring to one or more of the others. The section and their content are given in the general list of contents which follows this introduction. The first is a general account of the geology in which the complex has been divided into eight areas and a succession and description of each given separately. The remaining five sections deal with a specific petrogenetic problem involving the silicate and metasomatic products of the activity at Homa.

The research was carried out as part of a study of East African volcanics under the directorship of Prof. B. C. King (Bedford College) and Dr. M. J. Le Bas (University of Leicester) to whom grateful thanks are given for suggesting the topic. Their encouragement throughout the work is much appreciated.
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THE GENERAL GEOLOGY OF THE CARBONATITIC CENTRE OF HOMA MOUNTAIN WITH PARTICULAR REFERENCE TO THE SOUTHERN PART

INTRODUCTION

There follows a general account of the geology and geological history of Homa. Detailed descriptions of some of the rock types are found separately in later sections of the thesis and are only briefly mentioned here. The metasomatic processes accompanying the intrusive activity are also dealt with separately. Rock types not described in detail elsewhere are described in greater detail in this section. Further descriptions of some of these e.g. carbonatite and ochreous breccias are being prepared by Flegg.

(1) The regional setting and position of Homa.

Homa Mountain lies on the southern side of an arm of Lake Victoria extending eastwards some 50 miles from the main lake in western Kenya. This stretch of water is known as the Nyanza (formerly Kavirondo) gulf (Fig. 1.1). The sides of the gulf are controlled by two almost parallel east/west fault scarps which at Kisumu are 20 miles apart. The area between these scarps is a downthrown block giving a graben structure. There are four volcanic centres of Tertiary age within this structure. At each end of the rift feature lies a large central volcano. In the
AN OUTLINE MAP OF EAST AFRICAN RIFTS
AND SOME VOLCANIC COMPLEXES
east is Tinderet and in the west Kisingiri. These are dominantly nephelinitic with relatively minor carbonatite exposed. Erosion has uncovered the vent (Rangwa) of the Kisingiri volcano which is seen to be intruded by a carbonatite phase (McCall, 1958; Findlay, 1966). Small carbonatites have been found associated with Tinderet (Binge, 1962; Le Bas and Dixon, 1965).

The remaining two centres expose a mainly intrusive suite, often of carbonatitic/ijolitic composition. The more westerly of these, the Ruri and Usaki complex is associated with a very great number of phonolitic plugs and here also is the largest ijolite exposed in Kenya (McCall, 1958; Dixon, 1966; Le Bas, 1966). Homa Mountain has many similarities with the Ruri and Usaki area and nearly all the rocks are duplicated but the relations between the ijolitic and carbonatitic suites are particularly well exposed here.

The east/west trending Rift structure in which these four centres are situated appears to have formed at the same time as the N/S Kenya or Gregory Rift (Shackleton, 1951). In both rifted areas vulcanism preceded and accompanied the major fracturing (Gregory, 1921; King, 1966).

In the Nyanza area the activity at each of the centres may be considered as being of central type including some carbon-
Fig. 1. 2. Panorama of Nyasaniya and Homa Main from the west. This area lies within the location of Tchau Taransumya, which is under the chief's land at Mwiria. In the western part of the location lies the maghulis of Nyasaniya. This area is called the forest and was the present-day topography in the indigenous activity. In the eastern part of the area, near the Koma Bay road, is a zone of floodplains roughly 5.0.4.0.1. as the line of an extension of the higher escarpments which form the most westerly extension of the southerly limit of the Nyasaniya rift.

Most of the area below 5,000 ft is heavily forested in the natural manner while the hills are quickly wooded to dense forests with more grassy areas on top. No permanent streams or rivers are present anywhere on the sodium except for some small springs. Recorded rainfall is frequent during some seasons.
atitic phases. This is in some contrast with that in the Gregory Rift where non-central type eruption is probably as frequent as central and carbonatitic activity is confined to the extreme southern extension of this rift where lies the active carbonatite volcano Ol doinyo l'engai (Dawson, 1966).

(2) An outline geography of the Homa area.

The carbonatite centre of Homa Mountain forms a group of hills (Fig. 1.2) which dominate the area of land north-west of the Homa Bay to Kendu Bay road in South Nyanza District. The whole area lies within the location of West Karachuonyo which is administered from the chief's camp at Kanyamfwia. In the western part of the location lie the majority of the phenomena described in this thesis. This area is called Homa Peninsula and owes its present day topography to the alkaline activity. In the eastern part of the area, near the Kendu Bay road, a zone of plugs is aligned roughly N.E./S.W. on the line of an extension of the Kaniamwia escarpment which forms the most westerly extension of the southerly limit of the Nyanza rift.

Most of the area below 4,500' is heavily farmed in the African manner while the hills are thickly bushed on most sides with more grassy areas on top. No permanent streams or rivers are present anywhere on the peninsula except for minor saline springs. Torrid rainfall is frequent during some seasons,
the hills appearing to focus some of the storms. The storm water is cutting numerous gullies particularly into the thick soils of the best farming land. Quite numerous earth dams have been constructed and plans have been worked out to supply the area with water from two pumping stations at the lake shore. The local people are the Jaluo and are chiefly occupied in farming and fishing. The Homa Lime Works has now closed down due to the working out of deposits of Pleistocene limestone and Tertiary carbonatite of sufficient quality for efficient burning. Some co-operatives are active, notably in cotton, and others are in the process of formation. The chief need of the area, like many others in Africa, is for a more constant water supply, preferably including an irrigation scheme. The chief cause of hardship is malnutrition, occasionally bordering on starvation when sufficient rain does not fall during the growing season as in 1965-66.

3) An outline of the geology

The hills (Fig. and map 1.3 and 4) rise 2,000' above the lake and are a resistant mass of shattered, brecciated and metamorphosed metavolcanic country rock which has been assigned to the Nyanzian system by Saggerson. The shattering etc. is seen to be caused by numerous carbonatitic intrusions which often have arcuate, concentric outcrops and dip towards a common focus. Several of such ring structures have been noted at Homa some more
OUTLINE GEOLOGY OF HOMA MTN.

AND SURROUNDS

KEY

- CLASSIC PLEISTOCENE
- MAINLY DRIFT COVERED
- LATER BEDDED PYROCLASTS
- SATELLITE VENT
- CARBONATITE INTRUSIONS
- OCHREOUS BRECCIA
- PHONOLITE (
- NEPTOLITE (\n
FIG. 1.3

FIG. 1.4

SECTION A-B-C ON FIG. 1.3
complete than others. The most complete is as well exposed as
Homa Mountain itself while to the north a smaller hill, Nyasanja,
is accompanied by a complete ring structure. The hill called
Awayo is believed also to be the site of an individual centre
while at Ndiru and Rongo there is evidence that smaller centres
of activity existed. These last three areas together with Nyasanja
and an isolated breccia hill to the S.E. of Awayo all lie approx­
imately on an arc whose centre is near the centre of Homa Mountain.
At 4 and 7 km. S.S.E. of Homa are two areas of a similar intrusive
suite which are believed to be controlled by major arcs of weak­
ness about the central high ground. The last of these arcs, Bala,
is thought to have some influence on the present position of the
coastline of the peninsula. \textit{Jaye} and \textit{Landu} Bay townships.

One thus has the position that a major carbonatite ring struc­
ture, Homa, which by itself is comparable with Tundulu (Garson,
1963), Toror (King and Sutherland, 1966) or Chilwa Island (Garson,
1958), is surrounded by incomplete arcs along which further centres
or areas of intrusion have been initiated.

Although most of the rocks exposed in the areas mentioned
above are of 'high level' type, i.e. hypabyssal or sub-volcanic
in origin, an area of coarse-grained ijolite associated with
strongly fenitized and feldspathized country rock is exposed to the
\textit{Jaye} occurring before the onset of territory authority.
south of the main mountain and also as a core to the intrusive material at Bala.

That activity continued for a considerable time is shown both by Potassium/Argon data and consideration of the erosional history. This last indicates that the main mountain and the plutonic suite were eroded to near their present state before a series of satellite vents of both breccia and melilite bearing rocks were intruded. At about the same time Nyamatoto, a large plug of phonolitic nephelinite, was intruded into the S.E. flank of Nyasanja. Also probably at this time the rift faulting was initiated whose effects in the area to the east of Homa Peninsula are negligible but which may instead have caused intrusion of a line of plugs between Homa Bay and Kendu Bay townships.

The more gently sloping area surrounding the central hills of the peninsula is seen to be mostly covered with lake beds, gravels and soils composed of erosional debris and pyroclasts from the higher ground mainly deposited since the Pliocene. These superficial deposits are underlain by country rock which has a profile similar to the present day land surface.

(4) History of the area before the onset of Tertiary activity.

The geological events which have occurred at Homa may be divided into three groups:

(a) Those occurring before the onset of Tertiary activity.
(b) Those directly related to the intrusive/volcanic activity.
(c) Those related to the periods during which erosion occurred and clastics, often of lacustrine origin, were deposited.

The above grouping represents a chronological series except that some of the events within groups (b) and (c) overlapped.

The pre-Tertiary history of the South Nyanza area is known mainly from the work of Officers of the Kenya Survey in whose reports details of the Pre-Cambrian successions are noted.

The systems which are represented in South Nyanza (Fig. 1.5) are as follows:— (Simplified from Saggerson, 1952 pp. 7-9).

TERTIARY, PLEISTOCENE AND RECENT.

— peneplanation —

?UPPER PRE-CAMBRIAN

BUKOBAN SYSTEM
(Felsites, andesites, quartzites, basalts, dolorites(D₂), granites(G₃).

— post Kavirondian orogeny —

PRE-CAMBRIAN

KAVIRONDIAN SYSTEM
(Conglomerates and grits).

(Granites(G₂), dolerites(D₁).

— post Nyanzian orogeny —

PRE-CAMBRIAN

NYANZIAN SYSTEM
(Rhyolites, dacites, andesites, tuffs, basalts).

ARCHAEOAN
The pre-existing rock into which the Tertiary centres were emplaced was assigned to the Nyanzian by Saggerson as was that at Ruri by McCall (1958).

The present work indicates that a variety of rock types are present at Homa which belong to the andesite-dacite-rhyolite suite, two analyses of which appear in chapter 3. The rocks have been subjected to only a low grade metamorphism and quite frequently no new fabric has been emplaced. The rocks at Ruri differ as they are basaltic but here again only low grade regional metamorphism is noted.

The petrography of the country rock is given by Saggerson (1952, p. 10) and is described in chapter 3 as far as is necessary to show the mineralogical and textural effects of the metasomatism accompanying the Tertiary activity.

Several N.W. striking quartz dolerite dykes with strong granophytic texture have been found and are believed to be equatable with the dolerites of D2 age found elsewhere in South Nyanza. The presence of blocks of fenitized granite, both in the erosional debris and ejected from satellite vents, indicates that the Homa area is underlain by granite at depth. No exposures are present at the present day surface.

Previous work (Shackleton, 1946, 1951; Saggerson 1952) has shown that the regional structure south of the Kendu fault is
controlled by an anticlinorium pitching W.S.W. In the area mapped
most of the country rock shows shattering caused by the Tertiary
activity and it was not possible to map pre-Tertiary boundaries
or structures in any detail. The only areas of country rock
traversed north of the fault but lying outside the area affected
by the intrusive activity are exposed around the village of
Kandiege (Fig. 1.3). In some outcrops 0.5 km. south of here a strong
cleavage striking $240^\circ$ and dipping $50^\circ$ N.W. was noted, in good
agreement with the regional structure south of the fault. No rocks
have been identified from the Kavirondian or Bukoban systems at
Homa but there remains a possibility that the brecciated, shattered
pile at Homa does contain outliers of such in addition to the gran­
ites and dolerite so far discovered.

Following the Pre-Cambrian orogenies which resulted in the
phenomena mentioned above there is no evidence of geological act­
ivity in the Homa area other than peneplanation prior to the Tertiary.

TERTIARY ACTIVITY

(1) The pre-Miocene erosion surface.

a) The importance, extent and regional deformation of the pre-Miocene
erosion surface.

The oldest rocks of the Nyanza area apart from those of the
Pre-Cambrian systems mentioned above are a series of interleaved
sediments and volcanics which on palaeontological evidence have
been assigned to the Lower Miocene (Kent, 1944; Shackleton, 1951). Later work incorporating K/A data confirms that the earliest activity at Kisingiri and Tinderet occurred some 19-20 million years ago (Bishop et al, 1967).

The fact that the earlier volcanics of the area are of Early Miocene age and that the surface on which they rest was extensively peneplaned provides an extremely useful datum in determining the post-Lower Miocene tectonics of western and central Kenya.

Three such peneplanes are recognized in South Nyanza (Shackleton, 1951) the earliest being the dissected plateau of the Kisii highlands. Some 1,300' below this level is the surface on which the Miocene sediments and lavas rest. A less extensive surface, 3-500' below this, is Plio/Pleistocene in age.

Levelling of the pre-Miocene surface shows that it has been deformed in various ways since its maturation. Shackleton (1946 and 1951) demonstrated that regional tilting of the pre-Miocene surface has occurred and showed that it falls westwards from the Gregory Rift towards Lake Victoria at about 1 in 150. He also showed that the pre-Miocene surface was affected by the faulting which defines the Kavirondo Rift and that it is downthrown in relation to the rift shoulders. Since then the pre-Miocene surface has been levelled all over central Kenya and has been shown to be domed up on a regional scale to form a swell down the centre of
which the rift faulting has further deformed it (Pulfrey, 1960; Saggerson and Baker, 1965).

While accepting that Shackleton's map (op. cit. Plate 24) shows the extent of regional deformation, the present work at Homa and that of McCall at Rangwa and Ruri indicates that local doming of the pre-Miocene surface occurred at the site of the three alkaline centres in the western part of the Nyanza (Kavirondo) Rift.

b) Deformation of the pre-Miocene surface at Homa.

The outline map (Fig. 1.3) shows that surrounding the central high ground at Homa is an area of shattered but relatively undisturbed country rock. This occurs up to 4,500' on the western slopes of the main centre and Nyasanka and up to 4,800' on Awayo. At altitudes above this on the main hills large masses of merely shattered and metasomatically veined country rock lie between successive intrusions of carbonatite and carbonatitic breccia. The two highest parts of Homa expose such material, which is believed to have been uplifted, relatively en masse, and have not been intruded, mixed and blown into a vent as at Rangwa.

Consideration of the above facts indicates that the pre-Miocene surface has the form of a topographic high spot corresponding with the Homa complex. Such abrupt heights above the erosion surface are seen elsewhere in South Nyanza, a notable example being Wire Hill, a comparable sized mass of cleaved Nyanzian
rhyolite lying 20 miles E.S.E. of Homa. No signs of intrusion or metasomatism have been noted in this case and the hill is in fact a typical inselberg feature. Further S.E. still the dissected remains of an earlier Mesozoic erosion surface are present in the form of the Kisii Hills.

In the case of Homa, however, it is unlikely that intrusive activity should correspond so exactly with such an inselberg. Detailed mapping by McCall (1953) showed that both the Ruri and Rangwa centres are similarly intruded into topographically high areas of country rock. Doming of the pre-volcanic surface occurred to a height of at least 3,000' at Napak (King, 1949). At Tundulu the country rock has been uplifted at least 1,500' (Garson, 1963). The conclusion is inescapable, that at each of the three centres Rangwa, Ruri and Homa a similar uplift or doming has occurred as a direct consequence of the presence of a carbonatitic centre. Thus a reconstruction of the present position of the sub-Miocene erosion surface would include areas rising to 5,000' or more at each of the three centres (c.f. McCall, 1958, p. 7).

c) The present position of the pre-Miocene erosion surface at Homa.

Despite their frequency elsewhere in the Nyanza Rift, Miocene sediments have not been located anywhere on the Homa Peninsula and the lack of much extrusive material does not allow adequate correlation with sequences from Kisingiri or Tinderet each of
which have prominent Miocene horizons low in their successions. There are sediments exposed around Homa but these appear to be confined to areas of Pleistocene or Recent age. The surface now exposed is, therefore, probably lowered overall compared with its pre-Miocene position (Fig. 1.6). Phonolite lavas exposed around the Kendu Bay fault zone are shown not to be Lower Miocene in age as thought by Saggerson but the surface on which they rest and the outcrops previously mentioned, of underformed Nyanzian around Kandiege, are believed to be near the pre-Miocene surface as it existed in this area. Comparison of the height here (3,950') with that of the Nyanzian masses exposed at the top of Homa indicate that a difference in height of 1,800' exists. If one interprets the discontinuous masses of uplifted Nyanzian on the main mountain as portions of domed country rock then the minimum extent of such doming is 1,800'.

The present day disposition of Nyanzian and multiple intrusions leads the writer to conclude that deformation of the pre-Miocene surface occurred in two stages - first an arching into a gentle dome and then a more local uplift based on ring fractures (Fig. 1.6). Got Aways is an example of a centre where the first stage only has occurred, while Homa itself represents both stages, the more solid material up to 4,500-4,700' representing the remains of the gentle dome.
Gentle doming on whole peninsular.

More localized uplift.

Uplift accompanied by ring fractures on Homa Main but not at Awayo.

Erosion to present day level.

POSSIBLE STAGES IN THE DEFORMATION OF THE P.M.S. AT HOMA.
(14)

(2) Tertiary to Recent rocks mapped at Homa.

a) Groups present.

(A) Ijolite suite. (Described in detail in chapter 2).

Includes: Ijolite, micro-ijolite, feldspathic ijolite, intrusive nephelinite and nephelinite micro-breccia.

(B) Carbonatite suite.

Includes five families and two sub-families.

(C) Ochreous breccias.

A heterogeneous group having in common a brecciated character and ochreous matrix. Two divisions are present:

a) Carbonatitic mixed explosion breccia.

b) Carbonatitic pseudo-trachyte breccia.

(D) Metasomatic suite. (Described in chapters 3, 4 and 5).

Includes: a) Fenites i) Widespread vein type.

ii) A coarse-grained variety associated with ijolite margins.

b) Potash rich metasomatic rocks e.g. orthoclasesites, pseudo-trachytes and quasi-magmatic types.

(E) Phonolite suite.

Includes: Phonolitic nephelinite plugs and flows, phonolite flows and dykes, and the anomalous Rapogi phonolite.

(F) Melilite bearing suite. (Described in chapter 6).

Includes an earlier phase of alnoitic tuff probably
associated with lamprophyres and a late phase of olivine melilitite and carbonated melilitites.

(G) Bedded clastics.

Another heterogeneous group which includes sub-aerially deposited pyroclasts, lacustrine sediments, recent alluvium and soils. N.B. Rocks of groups A, D and F are described in detail in the chapters noted. An outline description of the carbonatites, ochreous breccias and phonolites follows immediately. The bedded clastics are mainly described in the section commencing on p. 85 of this chapter.

b) Carbonatites of Homa. (Mg + Fe carbonatites very rarely present).

A generalized sequence of carbonatites has been established on field and some petrographic evidence as a result of work by Flegg and the author. Five main divisions have been recognized which are, in order of intrusion:

C1 - Sovites (coarse-grained calcite carbonatites).

C2 - Alvikites (medium-grained calcite carbonatites).

C3 - Purple rhomb carbonatites.

C4 - Ferruginous carbonatites.

C5 - Carbonated melilitites.

Cl - Sovites.

These are usually early in the sequence and are cut by or included in Alvikites. The coarse calcite grains are often accom-
panied by 1-5 mm. grains of aegirine-augite and mica, less often orthoclase and occasionally soda amphibole. Apatite is frequently accessory but magnetite and pyrochlore absent.

In thin section the texture is allotriomorphic granular and in outcrop they infrequently show a foliation. In some cases their contacts with country rock are not regular and in these cases conversion of the country rock to an orthoclaseite has been observed.

C2 - Alvikites.

These are the most frequent and show most variation of any group. Two sub-groups can be distinguished in the field:

C2a. Magnetite-pyrochlore alvikites with apatite.

This group is characterized by a strong foliation nearly always parallel to the contacts. It is expressed by schlieren of brecciating country rock, trains of 0.5-10 mm. magnetite octohedra and a general streakiness of the rock caused by varying concentrations of hydrated iron oxides in different bands. In some cases apatite fragments and pyrochlore euhedra are grouped in aggregations parallel to this foliation. Irregular fragments of apatite rock <10 mm. are frequent in some intrusions. Sodic pyroxene, amphibole and a medium brown mica are common and are believed to be mostly derived from xenoliths of included country rock or fenite. The texture is often allotriomorphic granular.
These alvikites outcrop in most parts of the Homa area, particularly frequently as cone sheets on the main centre. A variety with pyrochlore prominent in the field outcrops as a plug at Ndiru, three quarters of a mile south of the main centre.

C2b. Apatite alvikites.

These buff to cream medium-grained calcite carbonatites have a much less pronounced foliation than the group above. Magnetite is rare, but sometimes occurs as cross cutting stringers, very rarely as octahedra. Apatite is the most common accessory, characteristically occurring as 5.0 mm. wide stringers cutting the main dyke and sometimes showing re-foliation parallel to the margins of the host. The texture, hypidiomorphic granular, tends towards idiomorphic when most grains are rhombic in outline. Carbonatites of this group are often seen cutting ijolite and appear to be the deeper seated variety of the C2 group. They commonly measure 10'-30' across and as such include the widest of any of the carbonatites.

C3 - Purple rhomb carbonatites.

Cutting all the above groups are a suite of narrow, sharp margined, brown to purple carbonatites which are well exposed at Rongo, Ndiru m'bili, Onya and Oyolo. They average 6"-4' in width, carry few inclusions and those which are present are sometimes rounded, as if by attrition. They are finer grained than
all the above and show a texture similar to group C2b in that rhombic idiomorphs of calcite are very frequent. Fluorite has been noted in several cases as an accessory.

C4 - Ferruginous carbonatites.

The last carbonatite phase in nearly every area studied consists of brown or black narrow veins or dykes. These have been sub-divided as follows:

C4a. Melanic carbonatites.

This sub-group chiefly outcrops on the higher ground of Homa Main and consists of narrow, often black dykes (<12" wide) which are steeply dipping and cut all other rocks of the area. A yellow material was frequently seen in the field which was later found to be plates of clear calcite sieved by very numerous spherules of a low birefringent aggregate which gave a monazite powder pattern. Fluorite and baryte have been found and other rare-earth bearing minerals suspected. The dark colour is caused by much finely divided iron oxide.

Another variety of melanic 'carbonatite' with similar field and age relations appears to consist almost entirely of magnetite. This rock is frequent as the final intrusive phase cutting the small carbonatitic breccia vents of the western slopes of the main centre (p.41).

Fine to medium-grained, unfoliated, buff to chocolate brown carbonatite is often seen as the final phase. Several phases are present usually occurring as narrow veins and stringers only inches in width. At Ndiru, however, this rock type outcrops as a large intrusion invading and brecciating rocks of C2a type which form the plug (p.58). The thin sections show that the bulk is a mass of disseminated limonite and calcite. Baryte has also been noted.

C5 - Carbonated melilitites.

The rocks of this group present a different appearance to all the others - they are often very fine-grained, usually 4-9" wide and often are pale grey in colour. They are the only intrusive phase which cuts the clastic deposits banked on the N.E. and S.E. sides of the main mountain and are thus probably the latest of all the carbonatite groups. Pseudomorphs after melilitite have been identified in some of the dykes, particularly in the area around Got Chiewo where a vent is exposed of the same or similar material (chapter 6). It is not possible to prove the former presence of melilitite in all dykes of this group.

c) Ochreous brecciated rocks including explosion and feldspathic breccias.

i) The two chief modes of cross cutting intrusion at Homa.

The very numerous intrusions of material classified in the
above carbonatite groupings were emplaced more or less as a magma. The numerous inclusions of altered and unaltered country rock carried in these intrusions are believed to have been transported by the movement of the enclosing fluid or plastic material.

A second group of intrusions whose total volume is probably greater than that of the carbonatites was emplaced by a very different process. These bodies have an elongate dyke-like outline or less often occur as small vents. They are volcanic breccias in which the fragments are all of pre-existing rock which have been broken and mixed by explosive activity, combined with some form of transport of the fragments within the fissure formed by the explosion. The only material which appears to have been added in many cases is a small quantity of ochreous carbonate which forms a cement between the brecciated fragments.

These two forms of intrusions are here termed magmatic and explosive, and the great volumes of the latter material exposed at Homa which have not been stressed in previous accounts are thought to indicate very clearly one of the characteristic modes of eruption of the centre

ii) More regional brecciation accompanied by potassium metasomatism.

A second style of brecciation which is accompanied by a contemporaneous metasomatism occurs in larger areas with more diffuse margins. The resultant rock has a superficial similarity
with the explosion breccias noted above but differs in three respects:

a) It has an outcrop mostly restricted to the vicinity of ijolite.

b) The fragment content is much more homogeneous, fragments of country rock or altered country rock only being seen.

c) The brecciation is accompanied by a very strong potassium metasomatism.

A brecciated nature and widespread iron staining are common to both rock types and their appearance in the field can be mistaken. Saggerson mapped them both as sovite breccia but this term is not used in the present account.

iii) Nomenclature of the ochreous, brecciated rocks at Homa.

Such brecciated and altered country rock has received many names in different descriptions of carbonatite centres. Those formed by explosion and mixing were termed agglomerate and those by brecciation, contemporaneous with potassium metasomatism, were termed feldspathic breccia at Chilwa Island by Garson and Campbell-Smith (1958, p. 24). The present work, however, uses the nomenclature suggested by Sutherland (1965) in which fine-grained unbrecciated rocks rich in orthoclase feldspar and produced by metasomatism are called pseudo-trachytes and the coarse-grained variety orthoclasites. A breccia containing little other than fragments of pseudo-trachyte in an ochreous carbonate matrix is
termed ochreous carbonatitic pseudotrachyte breccia. The explosion breccia type with mixed fragments is termed, using this nomenclature, ochreous carbonatitic mixed breccia (explosion).

iv) Affinities and relations of the two ochreous breccia varieties.

a) Carbonatitic mixed breccias (explosion).

The relations of the carbonatitic mixed breccia with country rock are best seen at Landslide Gully (Fig. 1.7). Scree and vegetation have been swept off exposing the carbonatitic breccia which is seen to be emplaced as a series of cone sheets separated by screens of fresh or only shattered country rock in the same manner as the carbonatites. The occurrence of some fragments of altered country rock in the breccias contrasts with the lack of alteration shown by the country rock into which they are intruded.

Also exposed in this section and being cut by the carbonatitic mixed breccias is a much more rare intrusive rock which outcrops as an irregular mass of grey/green clastic material with prominent plates of biotite visible in the field. This rock is an alnoite tuff and is described in chapter 6. Numerous fragments of country rock, mixed with melilitite fragments and rounded and corroded crystals of biotite and diopside-augite, lie in a matrix which includes carbonate, fluorite, phlogopite and possibly serpentine. The mode of origin of this tuff and the carbonatitic
mixed breccia was probably similar and the fact that some carbonatitic breccias include altered clinopyroxene and mica xenocrysts indicate that they may have sampled the same material at depth.

The intrusive relations exposed at Landslide Gully are very similar to those noted at the Mbeya carbonatite where similar breccias and feldspathic rocks are exposed (Fick and Van der Heyde, 1959).

As well as forming large masses of breccia on the outer regions of Homa Main, carbonatitic breccia is exposed over large parts of Nyasainja and other hills to the north.

b) **Carbonatitic pseudo-trachyte breccia.**

A series of potassium feldspar-rich rocks is developed at Homa chiefly by metasomatism of the country rock. These include both coarse and fine-grained types which may also be brecciated during or after metasomatism. Their relations with the variety of ochreous breccia here called pseudo-trachyte breccia is discussed in chapter 6.

Several hundreds of square yards of pseudo-trachyte breccia outcrop in the vicinity of ijolite intrusions as at Bala or the north of the western extension of the main ijolite near Rapogi (Fig. 1.9). Feldspathization on a less marked scale is known to occur in many parts of the area (chapter 6).
v) Rocks intermediate in character

a) There is some evidence that a potassium metasomatism may have occurred during the emplacement of some of the more explosive breccias because phlogopite forms a selvedge around some of the fragments.

b) In several areas e.g. Oyolo and Onya rocks previously converted to pseudo-trachyte breccias have been cut by late carbonatites and later still by zones or areas in which the pre-existing rocks have been involved in explosive activity. This gives a rock which has numerous fragments of pseudo-trachyte mixed with carbonatite which, however, is little affected by contemporaneous metasomatism except perhaps for the development of phlogopite.

In some areas more than one period of explosive brecciation may affect areas previously subjected to feldspathization and in these cases although detailed work can separate the different phases of activity the rocks in the field are very similar.

d) Phonolitic rocks of Homa.

Phonolitic rocks have a very restricted outcrop at Homa compared with the nearby centre of Ruri-Usaki. Only one major plug and two flows are present on the peninsula but several of each outcrop along the Kendu Fault zone (Fig. 1.3) which is considered to be an extension of the Kaniamwia escarpment.

Petrographically the rocks vary from nephelinites to trachytes.
They are divided into two groups - phonolitic nephelinites and phonolites. Analyses of each are given by Saggerson (1951, p.32).

i) Phonolites.

These are found as flows, dykes and low knolls in various parts of the area. They frequently show a plateyness in hand specimen which is seen to be controlled by a marked fluxion texture of the groundmass minerals which are usually simple twinned feldspar microlites, aegirine and occasional small rectangular sections of nepheline. The rocks are frequently porphyritic with phenocrysts of feldspar (sometimes sanidine, at others orthoclase) < 1 cm. but more often 2-5 mm. Nepheline also occurs in similar sized phenocrysts while aegirine-augite is present only as sparse micro-phenocrysts.

ii) Phonolitic nephelinites.

These have a mineralogy indicating a more basic and undersaturated composition. Phenocrysts are characteristically aegirine-augite, apatite and sphene. Felsic phenocrysts are rare and the appearance in hand specimen differs both in being darker and in showing dominantly mafic phenocrysts. The proportion of nepheline to feldspar in the groundmass also differs, some rocks show a groundmass almost entirely of close packed nepheline idiomorphs. Rocks with these characters form plugs and only occasional flows at Homa.
3) Details of the successions mapped at Homa.

a) Breakdown into smaller areas for ease of description.

It has previously been noted (p.5) that Homa is a complex of centres and that the main centre is surrounded by incomplete arcs of activity along which at intervals other centres of intrusion have been initiated. The following is a list of the areas into which the peninsula has been divided for descriptive purposes. Each area does not necessarily deal with a complete centre but each does illustrate features which are important in the understanding of the geology (see Fig. 1.3).

i) Homa Main.

Includes the higher portions of Homa Main at which a cone sheet complex involving numerous alvikites and, outside these, carbonatitic mixed breccias intrude a domed, and in part, fenitized area of country rock.

ii) W. and S.W. slopes of Homa Main.

This area represents part of the domed country rock on the edges of the main centre described above. Most of the intrusives exposed here are associated with the main centre. Additional evidence present in this area indicates that the main centre suffered some erosion before the renewed onset of satellite activity.

iii) Southern approaches to Homa Main.

Here is exposed the main body of ijolite which shows evidence
of much metasomatism at its margins. Several series of carbonatites, sometimes of different character to those of the areas so far listed, cut the ijolite. Evidence of prolonged erosion is again present and satellite vents are again seen.

iv) Nduru, Yusoo and Nduru m'bili areas.

The relatively low and level ground extending south from the previous area is mainly drift covered but intrusives are believed to underlie this at little depth. Three small outcrops are present exposing very clear relationships amongst the deeper level intrusions of this area.

v) Area to the north mapped by Flegg.

A very brief description of this area is given to place the masses exposed in the context of the complete complex. The area consists of several centres which are believed to lie on a mutual arc about Homa Main, probably in a similar manner as do the outcrops at Oyolo and Bala.

vi) Oyolo, Onya and Bala area.

Here are exposed a suite of rocks similar to those exposed elsewhere, the dominant strike of which indicates arcuate control about Homa.

vii) Areas of phonolitic rocks including the Kendu Fault zone.

The distribution and relations of phonolites are described and relations along the fault zone between these, the country rock and the bedded tuffs of Orio discussed.
viii) The lower ground surrounding the mountain not described above. This is a much larger area than any of the others, mostly covered with soils and drift. Pleistocene lake beds and tuffs are also well exposed in parts. In addition several exposures of relatively unaltered Nyazian are present. Conclusions on the erosional history and Pleistocene tectonics are noted as is evidence of contemporaneous volcanic activity.

b) Simplified succession of events during the Tertiary to Recent period at Homa Peninsula (oldest first).

**ACTIVITY OF MAIN STAGE (PLIOCENE)**

1) Formation of pre-Miocene surface.

2) Rise into upper crust of carbonatic/ijolitic material accompanied by an aureole of metasomatism.

3) Formation of a domed portion of the pre-Miocene surface.

4) Intrusion of ijolite into the lower hypabyssal level below Homa, accompanied or followed by sovite.

5) Increasing fenitization particularly in areas later intruded by alvikites and at the margins of ijolite. (Dominantly feldspathic rocks developed in some areas, e.g., Nolim Island.)

6) Explosive release of volatiles forming a multiple cone sheet complex in the sub-volcanic region of Homa. Magmatic and explosive activity produces carbonatites and carbonatic mixed breccias respectively.
7) Initiation of similar activity on a major ring fracture to give Nyasanja, Odiawo, Awayo, Rongo and Nduru. A later age for the start of this activity is suggested.

8) Initiation at still greater distances outwards of arcs of activity at a) Oyolo and Onya and b) Bala.

9) Cessation of activity and an erosional interval then occurred, being most marked in the more central areas. Ijolite was exposed to the south of Homa.

**MINOR AND PHONOLITIC ACTIVITY (PLEISTOCENE).**

10) Pyroclastic activity forming a) an ash cone on the site of Nyamatoto b) the red breccia series.

11) Intrusive and extrusive phonolitic activity including that along the Kendu Fault zone, and Nyamatoto.

12) Satellitic carbonatic mixed breccia vent activity (contemporary with Lower Pleistocene sedimentation on the north). Lake level ≤4,050’. The satellitic vents of the south may also be of this age.

13) Rise of lake to at least 4,200’ during deposition of Middle Pleistocene beds.

14) Melilite bearing vents now active.

15) Tilting of lower Bala and lake cliff series due to further activity of the Bala arc.

16) Deposition of Upper Pleistocene sediments, soils, alluvials
and raised beaches at 70' and 10'. Rejuvenation of gullies.

17) Deposition of modern soils, alluvials, hot springs, tufa and secondary limestones.

c) Description of successions and relations in individual sub-areas.

1) Homa Main.

a) Succession.

1) Fenitization (vein type), particularly in areas later intruded by carbonatites.

2) Intrusion of alnoite tuff, as at Landslide Gully, and rare dykes of xenolithic lamprophyre.

3) Intrusion of occasional dykes of sovite Cl.

4) Development in shear zones of increased fenitization (particularly towards the outer area of high ground) sometimes accompanied by narrow, brown unclassified carbonatites.

5) Intrusion of main series of alvikites C2 usually as cone sheets. (These intrusions show some cross cutting relations and are capable of further sub-division on petrological grounds).

N.B. Some overlap is indicated of stages 5) and 6).

6) Intrusion of main series of carbonatic mixed breccias usually as a zone outside the alvikite cone sheets.

7) Brecciation of some alvikites.

8) Brecciation, jointing and minor faulting accompanied by intrusion of ferruginous carbonatites of both C4a and C4b type.

9) Erosion to present day.
Fig. 1.8. Homa Main from the south-west showing the characteristic outline as in Fig. 1.14.
b) Introduction.

Four major rock groups are exposed in this area (Fig. 1.9).

1. Fenitized and shattered country rock.
2. Alkaline silicate intrusions.
3. Carbonatites.

1. At least 80% of the area exposes shattered or brecciated Nyanzian metavolcanics which have been subjected to various degrees of fenitization.

Fenites found at Homa have been divided into two main groups (chapters 3 and 4), a) those occurring near, and probably as a result of, intrusions of ijolite and b) those of much finer grain size which occupy much larger areas. These areas including most of the top of Homa Main are nearly always the site of marked alvikite intrusion.

2. The sparse alkaline silicate rocks of the area are considered to be the earliest intrusive phase. At Landslide Gully on the western face is exposed an intrusion of alnoite tuff which has some affinities with Kimberlites (chapter 6). On the mountain top intrusions are limited to one dyke and a brecciated mass of a micaceous, xenolithic alkaline rock whose original character is difficult to determine due to the effects of later carbonatitic activity. It is identified as a micaceous lamprophyre.
3. The bulk of intrusive matter is carbonatitic in character. The carbonatites represent the truly magmatic stages of such activity - they have usually a sheet or dyke-like form and show foliation comparable with fluxion texture in other magmatic occurrences.

4. Carbonatitic mixed breccias are exposed as a belt some hundreds of metres wide outside the carbonatite cone sheets of the high ground on the western and southern sides. In areas of good exposure such as that already described at Landslide Gully the carbonatitic mixed breccia is seen to have been emplaced as a series of parallel sheets dipping into the mountain rather than occupying a wide zone. In parts a number of intrusions may be superimposed and obliterate all areas of unbrecciated country rock. The 200' face of this rock type exposed at West Cliff represents such an area in which several phases of brecciation have occurred. In places the size of fragments differs from the usual (1-6 cm.) and tuffs or micro-breccias are present.

The field relations indicate that some periods of carbonatitic brecciation alternate with periods of carbonatite intrusion but because the bulk of the explosive activity occurs in areas unaffected by carbonatites relations are not clear.

c) Details of carbonatite relations.

I. The presence of a localized cone sheet complex.

Reference to map (Fig. 1.9) shows that the upper slopes
and much of the top of the main mountain are cut by very numerous sheets of alvikite which in general are concentric and dip inwards. The sheets are cone sheets and are separated by areas of country rock in various stages of brecciation and ingestion by carbonatite.

On many traverses over the south and west portions of the ring structure the zone of multiple cone intrusion is sharply demarcated from the rocks outside it, which are usually country rock in various stages of replacement, and carbonatitic mixed breccias. These relations are particularly well seen on traverses up the spurs north of Got Chiewo and that at Homa Point East, where a zone of highly brecciated and fenitized country rock succeeds relatively fresh, only shattered country rock, and is succeeded or intruded by a close-spaced set of cone sheets (Fig. 1.10).

2. Sovite (Cl)

Sovite is very rare on Homa Main. One major dyke was located at M.R. 656573 where a pyroxene and mica-rich sovite carries numerous inclusions of country rock showing marked phlogopitization of their margins. Sovite is usual only as included fragments in later alvikites. The rarity of sovite may be due to the fact that here is an area of higher level intrusions than are exposed around the southern flanks of Homa Main where the ijolite and areas of most marked metasomatism outcrop.
3. Alvikites (C2).

i) General. Alvikites form some 95% of the volume of carbonatites exposed in this area. Carbonatites of both groups, C2a and b, are present with C2a dominant. Relatively few cross cutting relations were noted within the alvikites and no sense of chronological order can yet be determined within them, whether the earlier are more central or vice-versa is not at present known.

The field relations between the intrusions and country rock are well displayed on the western face of Homa where numerous steep and overhanging cliffs, 5-50' high, are controlled by the succession of screens and cone sheets which strike along the slope (Fig. 1. 11). Exposures in this area show the cataclastic textures caused during the intrusion of the carbonatites - the fine-grained, fenitized country rock is sheared, crushed, brecciated and ripped into slices by what must have been enormously powerful gas-rich explosions followed immediately by filling of the crack with carbonatite. 15-20 major intrusions (> 5') were noted on the western slope and these are accompanied by numerous small sheets and dykes sometimes as offshoots of a larger intrusion, sometimes concentric with the major sheets. A similar frequency of intrusions was encountered on traverses in many other parts of the area. As the map indicates, intrusions are not spaced regularly in all parts, being often more frequent around the outer portions of
Fig. 1. II. Near vertical cliff on Homa Main formed by the erosion of a brecciated screen of country rock revealing a sheet of carbonatite in the upper part of the figure.
the high ground. No continuous plug has been found in the central portion.

ii) Correspondence of alvikites with zones of fenitization. The correspondence of alvikite cone sheeting with a zone of fenitization is very striking in the locality mentioned (Homa Point East Fig. 1.10) and is confirmed in other localities. Examination of field and petrographic phenomena show that fenitization and some contemporaneous brecciation precedes intrusion of most of the alvikite but that their close correspondence spatially indicates that the belts of deformation serve both as pathways for the fenitizing fluids and as hosts for the alvikites (chapter 3).

That the fenitization is not a contact effect of the alvikites is shown by the cross cutting relationship of the latter and the almost ubiquitous inclusion of brecciating portions of fenite within the alvikites (Fig. 1.12). A selvedge of medium brown mica is frequently seen around fragments of fenite included in alvikites indicating that the fenite mineralogy is in fact unstable when in contact with carbonatite magma at the levels now exposed (c.f. Bailey, 1964a).


Carbonatite activity following the intrusion of the C2 carbonatites was, however, quite intense as the quite numerous melanic C4a carbonatite intrusions indicate. They frequently have marked cross cutting relations but sometimes are found as narrow bands
Fig. 1.12. An alvikite (C2a) with large inclusions of brecciating vein fenite. The foliation within the carbonatite is picked out by trains of magnetite, as in the bottom left-hand corner and also by small fragments of the inclusions.
within a C2 type intrusion and there is little doubt that the time of intrusion of the two carbonatite species overlapped. Monazite was identified from a yellow coloured area within an alvikite rather than from a cross cutting intrusion, in one case. The yellow coloured carbonatitic material shows a replacive habit in thin section and is believed in this case (HC 263*) to represent a late segregation of post-magmatic material rich in R.E., Sr and Ba.

In addition to their cross cutting habit, carbonatites of C4 type are associated with small scale brecciation and faulting of the earlier alvikites, this being particularly so in the case of C4a carbonatites in localities 1.1 km. north of Rapogi. A further phenomenon noted at these localities is the marked reddening of the C2 type alvikites. This is seen to be caused by oxidation of some of the magnetite and is of such local occurrence that a weathering origin is unacceptable. It is believed that here is evidence that the C4 carbonatites were not only a later, possibly post-magmatic suite, but that they were intruded under conditions of high P O2 causing an increase in the amount of iron totally oxidized in the earlier alvikites.

Ferrigenous carbonatite veins (*2") are associated with a set of radial joints which have been seen in many places cutting the alvikites on the western and southern parts of the mountain. In some cases the C4b carbonatite veins fill planes along which

* Specimens stored in Dept. of Geology, Leicester University.
offset has occurred. A marked example is seen 0.9 km. north of Rapogi, at the base of a face composed of very numerous closely spaced intrusions and screens. Here the joints have become fault planes showing downthrowing of 3-4' (Fig. 1.13). A similar set of carbonate filled, late radial joints is seen cutting most rocks at Bala. They are probably small scale expressions of the larger scale radial faults which have been mapped in various parts of the complex. Ochreous carbonate of this character forms the matrix to many of the carbonatitic breccias of the Homa area and a correlation is therefore possible. Similar material appears also to be closely associated with feldspathization in some areas (chapter 5).

**d) Structure.**

Although the overall picture is of a series of cone sheets, in detail many variations from this are seen. Plane sections show that the structure is not a series of simple annuli but rather of sinuous arcs which in detail depart markedly from concentric circular symmetry. This may in part be caused by some inhomogeniety of the country rock e.g. the disposition of intrusions in the block approximately 400 m. sq. 1.1 km. north of Rapogi indicates that here a rigid block of country rock exists. The carbonatites outcropping immediately on top of South Cliff appear to be controlled by a local addition to the simple ring
Fig. 1. A small overhanging cliff exposing a large sheet of foliated carbonatite (C2a) affected by normal faults which have accommodated narrow brown veins of C4 carbonatite.
structure. A further departure from concentricity is seen in the area of the highest part of the mountain where the intrusions of the surrounding area have a common focus at this point rather than at the centre of the whole mass.

The true scale section (Fig. 1.14) drawn across the centre of Homa Main indicates that the outer swarm of cone sheets intersect at some 4,000' below present ground surface and that those around Homa Peak intersect at a little less than 1,000' below. A further complication of the concentric symmetry is seen most clearly on the eastern slopes of the ridge leading northwards from South Cliff. In this area the general dip is 50-70° N.W. but several exposures show that these major intrusions give rise to branching sheets with a similar strike but low (5-15°) dip towards the S.E. In other localities what is seen to be a single intrusion at the base of a cliff appears to divide upwards into a series of sub-parallel sheets with a strike of, in one case, 30° different from that of the main sheet below, i.e. traced upwards a single sheet divides into a series of en-echelon intrusions.

ii) Western and south western approach slopes of Homa Main.

a) Succession.

1) Vein fenitization of restricted areas to be intruded later by carbonatites.
Fig. 1. 15. Small scale offsets affecting a carbonatite (C2a) dyke on Homa Main. These may represent a second phase of C2 stage activity or most likely be a consequence of C4 activity.

Fig. 1. 16. Large blocks of foliated carbonatite, disorientated and recemented probably during a late phase of C2 stage activity.
2) Intrusion of sovite Cl.

3) Intrusion of alvikites C2a, accompanied or followed by intrusion of stage 4).

N.B. These alvikites are restricted e.g. Got Bonde Ridge and the locality 400 metres S.E. of Got Ollo.

4) Intrusion of carbonatitic breccia zones including some accompanied by feldspathizing fluids.

5) Intrusion of potassium trachyte dykes.

6) Intrusion of purple rhomb carbonatites C3, sometimes containing rounded inclusions of feldspathized country rock.

7) Intrusion of melanic carbonatites C4a.

8) Formation of late carbonatitic breccia vents e.g. Got Ojawa accompanied by magnetite veins C4a.

9) Extrusion of phonolitic nephelinite flow - Osiri.

10) Intrusion of olivine melilitite plug - Got Ollo.

11) Laying down of Pleistocene lake beds against Got Bonde fault and Osiri, running E.-W. which separates the feldspatized and carbonatite ridge.

12) Deposition of soils and development of gullies.
b) Introduction.

The area discussed forms the gently rising slopes about the main centre. These slopes expose the peripheral parts of the domed area of country rock and are overlain at the bottom by superficial deposits and terminate at the top in the zone of multiple intrusions of carbonatitic mixed breccia and carbonatite described in the previous section (Fig. 1.17).

c) Intrusions related to the formation of the main centre.

A similar suite of rocks is present as described for the main centre proper but they are seen to have a more patchy development (Fig. 1.9). Occasional dykes and inclusions of sovite (C1) were noted but once again the most frequent intrusions are alvikites (C2) and carbonatitic breccias, both occurring in narrow sheets dipping towards the high ground. At Got Bonde and below West Cliff (400 metres S.E. of Got Oloo) areas of more continuous carbonatite (C2) are exposed and the country rock is fenitized. These are areas of local concentration of carbonatite activity, the second of which appears to be controlled by a large faulted contact running E./W. which separates the fenitized and carbonatite rich area from an area of country rock showing no fenitization and intrusion by carbonatitic mixed breccia only. Foliation measurements of the carbonatite here fall into two groups neither of which is strictly concentric about the mountain centre but do dip towards the higher ground.
Extensive stretches of this area are relatively unintruded and expose only shattered country rock. Locally, zones of brecciation accompanied by feldspathization are present and at 300 metres south of Got Ojawa, a potassium trachyte dyke was noted cut by a C3\text{b} type carbonatite. This group of carbonatites occur less frequently than in areas to the south and north of the mountain. They occasionally carry numerous rounded portions of metasomatized country rock.

d) Surface and near surface activity.

Two centres were located. The more northerly, Got Oloo (Fig. 1.9), is a plug of olivine-melilitite, diameter 200', surrounded by a collar of agglomerate whose matrix matches some calcareous, zeolitic vughs in the plug rock. These vughs are associated with a deuteric alteration of the olivine and melilitite and may indicate a possible association of olivine-melilitite with the genesis of carbonatite (chapter 6).

The second centre, diameter 100', Got Ojawa (Fig. 1.9), consists mainly of ochreous carbonatitic mixed breccia in which very numerous 0.5-2 mm. vughs of calcite are found. This breccia is cut by \(<4\)" late black magnetite-rich veins (C4\text{a}). The breccia is surrounded on two sides by a skirt of fine grey/green tuff in which fragments of ijolite, fenitized granite and a rounded fragment of carbonatite (C1 or C2) were found. Similar but smaller
breccia piles are found nearby.

Both of the above centres are believed to expose rocks which nearly reached the surface at the time of their activity.

Further evidence of surface activity in the areas is present 400 metres W. of Got Bonde (Fig. 1.3) where are remnants of a phonolitic nephelinite lava flow. This flow, the Osiri lava, has a Potassium/Argon ratio equivalent to an age of $1.9 \times 10^6$ yrs. Fragments of phonolitic nephelinite of very similar type are found in the agglomerate surrounding the plug of olivine-melilitite.

e) The position in the succession of the melilitite and breccia centres.

An E./W. section across the area shows that the centres exhibiting near surface activity lie at the same level or below that of the intrusive bodies nearby (Fig. 1.18). A great number of large carbonatite intrusions are also seen to stand proud on the steeper slopes above.

This indicates that at the time of intrusion of the main series of carbonatites the surface must have been above that now exposed (Profile P.Q. Fig. 1.18). It therefore follows that the vents represent either activity of a different period or of a different level which has been subsequently juxtaposed with a deeper level of the same period of activity. Three possible
FIG 1.18

WEST CLIFF

EAST-WEST SECTION ACROSS THE APPROACHES OF HOMA MAIN

SYMBOLS AS ON FIG 1.9.
explanations are discussed here:

1. That the small melilitite and breccia vents were earlier than the activity around them and have been re-exhumed.

2. That subsequent faulting has brought high level activity against activity of lower level.

3. That the vents represent a period of activity after that which resulted in the nearby intrusions, when erosion had revealed the mountain much as it is today.

The first possibility appears unlikely because of the freshness and unintruded nature of these vents. The presence of an E./W. fault separating the melilitite plug from the carbonatites on the ridge to the south supports the second argument. The Potassium/Argon ratio obtained from the Osiri lava indicates an age of 1.9 million years, much later than the carbonatitic activity of the main centre (from which ages of 12, 8 and 4.5 million years have been obtained). Fragments of similar material in the agglom­erate surrounding the melilitite plug indicate there that the plug as well as the Osiri lava are later than the main period of activity. Hence explanation 3. above is supported here. Similar data is not available for the breccia vent of Got Ojawa but the presence of the soft carbonate tuff surrounding it argues a fairly young age - probably younger than the erosion period which reduced the mountain to near its present form.
A period of erosion and faulting therefore appears to separate the activity which resulted in the widespread alvikite and carbonatitic breccia intrusions exposed on the higher ground and the eruption of small satellite vents of melilitite and breccia on the western flanks of the main mountain. It is not known how closely associated in time was the activity of the small breccia vents and the melilitite plug.

Evidence for a marked erosion interval before the emplacement of small satellite vents is also found in the area to the south of the main mountain (p. 51).

f) Superficial deposits.

Pleistocene sediments including gravels, sands, marls and thin limestones are found around the base of Got Bonde and banked against inliers of the Osiri lava. Horizons containing Tilapia remains indicate that sediments of this height (4,200') are truly lacustrine in part at least. The present day lake level is almost 500' lower and the intervening slopes are covered with drift and alluvium, deep gullies in which are actively revealing up to 40' of soils, sands and gravels.

Superficial deposits on the mountain consist of secondarily cemented screes below carbonatite cliffs. Loose bouldery deposits on the lower slopes are better bedded but are less indurated.
These last are best exposed at localities west of Landslide Gully and may in part represent lacustrine deposits. Possible former lake levels are discussed on p. 89 and 91.

iii) South and south east slopes of Homa Main - Rapogi area.

a) Succession.

1) Vein fenitization.

2) Intrusion of ijolite accompanied by contact fenitization (forming orthoclasesites). Some mobilization of xenolithic trachyte.

3) Intrusion of sovites Cl accompanied by development of orthoclaseite (some cut, brecciate and feldspathize ijolite).

4) Intrusion of later carbonatites intermediate in character between Cl and C2b.

   Intrusion of carbonatite C2b as steep arcuate dykes and some radial dykes.

5) Intrusion of ijolite by Rapogi phonolite.

6) Intrusion of minor brown veins C4b and fluorite-rich stringers.

   Period of main erosion and faulting.

7) Formation of carbonatitic breccia vents e.g. Red Knoll and Small Vent*.

8) Laying down of a bedded clastic sequence - the red breccias in which horizons of calcareous tuff are found.

* The position in the succession of the carbonatitic breccia vents as on the western slopes is not always clear. They are either early or follow the main erosion. Small Vent shows fenite ijolite, sovite Cl, & carbonatitic breccia cut by an 18" C4b carbonatite.
9) Intrusion of Chiewo series of calcareous dyke and vent material with melilite pseudomorphs (C5).

Movement on some of the faults.

10) Cutting of a level at 4,500'.

11) Laying down of a thin skin of fine calcareous tuff or lake bed both above and below this level.

12) Modern soils and gullies.

b) Introduction.

This area exposes intrusive rocks of a more deep seated nature than those of the two areas previously described. In it occurs the most widespread outcrop of ijolite at Homa at the borders of which a complex metasomatism (fenitization) has occurred. Carbonatites of several generations are present and the period of erosion preceding the satellite vent activity is very well demonstrated.

c) Ijolite. (Described in detail in chapter 2).

Coarse-grained ijolite is exposed as a continuous belt over 1.5 km. long and between 0.2 and 0.5 km. wide immediately north and east of Rapogi along the base of the mountain (Fig. 1.3 and 1.19). Outliers and blocks over a mainly drift covered area further to the east still, indicates that ijolite is present at very shallow depths over an area at least four times that exposed. Numerous inclusions in rocks of the surrounding area indicate that
FIG 1.19

MAIN IOLITE OUTCROPS OF SOUTH HOMA.

CHIEWO VENT.

SOUTH CLIFF.

OLITHOPOLO

SAPPOOL

HILL

YUSUOL

SCALE 1  300mtrs.

SOILS, CHIEWO RED CARBONA- ALVIKITE, XENOLITHIC LUDITE + AEROLINE OCHRERUS SHATTERED
CALCRETE SERIES BRECCIA TITE BR. & SOVITE PHONOLITE BANDING ORTHOMASITE NYANZIAN

(CARBONATRO MELILITITE)

M.C.G.C. 1967.
at greater depth ijolite is more extensive still. The exposures are not sufficient to determine the form at depth of the ijolite body at Homa. It has the appearance of a series of cupolas at the present level of exposure. The data indicates that the rock at Homa is less heterogeneous than that exposed at some other centres including the neighbouring mass of Usaki (Pulfrey, 1950; Le Bas, 1966; E. C. King, 1965). The chief rock type is a mesocratic wollastonite-melanite-ijolite in which the pyroxenes vary from diopsidic varieties through to aegirine. The paragenesis of the various minerals indicates that the rocks can be arranged in sequences, each developing from the previous:

A. Pyroxenite (diopsidic) \[\rightarrow\] Ijolite (nepheline, melanite, aegirine-augite).

B. Diopside, perovskite ijolite

Diopside, melanite ijolite \[\rightarrow\] Aegirine-augite, wollastonite-melanite ijolite. ± Apatite & calcite.

The above paragenetic sequence is similar to that described by King in Eastern Uganda (King, 1965) (p. 88).

Some of the later rocks in this sequence, the wollastonite-rich examples, occur as sheets within the more normal ijolite. Within these sheets the component minerals have a markedly preferred
orientation, resulting in a comb texture (Fig. 2.4) in which the long axes of the minerals are perpendicular to the sides of the sheet. The attitude of these sheets is quite constant in the eastern part of the main outcrop, striking parallel with most of the cross cutting carbonatites and dipping towards the higher ground.

d) Fenites and related rocks. (Described in chapters 3 and 4).

Contacts with country rock are confined to the western extension of the main ijolite which is also seen to include discontinuous masses of metasomatized same. A vein fenitization as seen on the higher ground is seen to be superceded first by intrusion of much coarser veins of aegirine and orthoclase and then, by a process of continued veining and replacement, the whole rock is made over to one of syenitic aspect.

This style of fenitization is termed contact fenitization to distinguish it from the related but spatially distinct pheno-occurring menon, particularly in areas intruded by alvikites on the main mountain (chapter 3).

The result of fenitization at ijolite margins is a mainly bi-mineralic, coarse-grained rock composed of two thirds orthoclase and one third aegirine. Detailed examination of the contacts indicates that the ijolite was intruded as a magma and that the later crystallizing fraction resulted in the emplacement of veins of aegirine orthoclaseite fenite. Orthoclase-rich rocks without aegirine
but with a substantial amount of ferrous oxides are also found in this area particularly in association with irregular and dyke-like bodies of sovite (Cl). Such rocks, here termed ochreous orthoclases, develop from country rock and by the feldspathization of ijolite. Metasomatic potash-rich and soda poor rocks are described in chapter 5 in which fine-grained varieties are noted, some of which have intrusive magmatic characters.

e) Carbonatites.

The earliest seen are sovites (Cl) which accompanied or closely followed the ijolite. As mentioned above the country rock and ijolite in contact with and included in these dykes often shows a strong development of feldspar. Accessory apatite and biotite are found in these carbonatites.

The most widespread carbonatite is of C2b type - particularly well displayed as a series of parallel, 10-20° broad dykes cutting the ijolite of the western extension (Fig. 1.19). Inclusion of sovite and highly disturbed orthoclase betray the time relations. The eastern and central part of the ijolite outcrop is also cut by several large dykes of similar material some of which is coarser grained and approaches the sovite in character. The strike of the sheets of comb texture within the ijolite and many of the carbonatites is E.S.E. with a varying dip but occasional large dykes of sovite strike at 90° to this direction dipping W.N.W. at 50°.
Later stringers of fluorite rich carbonatite are seen cutting the sivite in parts.

f) Phonolite - Rapogi type.

Most parts of the main ijolite outcrop (Fig. 1.19) are invaded or overlain in their southerly part by a fine-grained green/grey lava or hypabyssal rock which differs in character from all the other varieties of phonolite noted on the mountain. The one contact clearly exposed with the ijolite dips towards the mountain at approx. 45° and shows ijolite overlying the phonolite. No evidence that this is a tectonic contact was noted. Very numerous angular and sub-rounded fragments of ijolite and less of syenitic types are included in this phonolite. Thin sections show that the groundmass is an intergranular to felsitic intergrowth of potash feldspar plus needles of aegirine. Large poikilitic plates of probably pectolite (~2 mm.) are frequent and most of the other fragments and crystals appear to be derived from the fragmentation of ijolite inclusions. Very marked sodic outgrowths have occurred at the margins of diopside-augite in contact with the phonolite matrix. Diopsidic pyroxene is characteristic of one variety of ijolite which so far has only been found at Homa as inclusions in this phonolite. This ijolite carries perovskite rather than melanite and represents an early member of the sequence noted on p. 47. It is therefore concluded that at depth the Rapogi phonolite has
Fig. 1. 20. Resistant band of grey tuff with the same inclination as the crag of red breccia in the background, both dipping away from the camera. 1 km. N.E. of Yusoo.
sampled portions of the ijolite body which are not exposed at the present level.

The relations of this rock are by no means clearly understood, some characters being closer to those of the quasi magmatic potassium trachytes described in chapter 5.

Narrow (2 cm.) veins of Clf b carbonatite only are seen to cut the phonolite but similar phonolite fragments have been found in the post main erosion breccia vent of Got Ojawa (p.41). The vent at Red Knoll (Fig. 1.19) is believed to intrude a low outlier of the same material.

g) Evidence for a period of erosion preceding the activity of satellite vents.

Reference to the map (Fig. 1.19) shows that the eastern part of the main ijolite is overlain to the north by a series of poorly bedded breccias in which horizons and occasional bands of calcareous tuff are found (Fig. 1.20). The petrology of the red breccia, as this rock is here termed, is described in detail in chapter 6.

In brief it contains fragments of ijolite, orthoclaseite, and carbonatites of the type found in the area in addition to numerous fragments of country rock or partially altered country rock. The fragments appear to be all of pre-existing rocks, no additional silicate phase has been noted. Some finer horizons show ripple marks and the presence of chaotic bedding indicates that slumping
accompanied the formation of this deposit.

The fact that the deposit lies on a surface exposing ijolite indicates that a prolonged erosion period preceded its formation. That some activity followed the deposition of this series is shown by the intrusion into the red breccia series of several fine-grained, grey calcareous dykes (C5) accompanying a small vent of similar material (Fig. 1.21). This vent, Got Chiewo, and its associated dykes is described in detail in chapter 6. It is of particular interest because pseudomorphs after melilite have been identified both from the dyke and vent material.

The carbonatitic mixed breccia at Red Knoll and Small Vent probably also represent activity later than the period of main erosion for reasons already discussed (p.42-4).

h) Events accompanying or following the formation of the satellite vents.

The abrupt termination westwards of the western extension of the main ijolite (Fig. 1.19) and the presence of ijolite fragments in the carbonatitic mixed breccia of Red Knoll suggests that a faulted disturbance occurred in this region accompanying the formation of the vent. A series of approximately radial faults of various ages have been noted elsewhere on the mountain and are well seen in the area under discussion. They were probably initiated early in the history of the mountain but movement continued
after the deposition of the red breccias.

A 20-50' erosion scarp was noted at a height of just over 4,500' terminating the red breccia outcrop southwards. This level can be correlated with similar features on the north side of the mountain and may indicate a former lake level. Poorly bedded material associated with this level probably represents reworked screes as the mountain was denuded.

A widespread but thin deposit of fine, grey to yellow, laminated calcareous tuff is found over much of the lower ground and similar material at 4,700' on the southern flank of Got Chiewo. It is tentatively correlated or compared with the finely laminated material of that vent (chapter 6). An origin as calcrete may also be possible.

Tufa is being uncovered by gullies which are sometimes controlled by the faulting and a thick series of soils is being re-excavated also by these gullies.
iv) Nduru Hill, Yusoo and Nduru m‘bili areas.

   a) Succession.

Nduru Hill         Yusoo         Nduru m‘bili

1) Intrusion of ijolite.  1) Ijolite ± microijolite.

2) Fragments of sovite Cl usually as inclusions only.  2) Dykes of sovite Cl.

3) Intrusion of a plug of carbonatite C2a and dykes of C2b + apatite stringers.  3) Dykes of C2b with apatite stringers.

4) Intrusion of dykes of magnetite rich melanic carbonatite C4a.

5) Intrusion of central area and into numerous veins of carbonatite C4b.  5) Dykes of carbonatite C3. Veins of C4a.  5a) Dykes of C3, some with agglomeratic inclusions of fenite.  5b) Veins of C4a.

   —— Main erosion. ——

   6) Deposition of red breccia series.

    Faulting and further erosion. ——

    7) Intrusion of Chiewo dyke.  —— Erosion. ——

   8) Deposition of nearly flat lying, thin, calcareous tuff, limestone or calcrete.

   Erosion and deposition of modern soils.
b) Introduction.

South of the main mountain and its southern approach slopes is a fairly flat lying area of low relief in which several small separate outcrops of the carbonatitic intrusive rocks lie (Fig. 1.3). The intervening areas are soil and calcrete covered and are littered with numerous boulders and fragments, some of which form a distinctive suite of rocks very rarely seen in situ on the mountain. These are ijolitic and syenitic types believed to show contact relations between ijolite and country rock of a more intense type than those exposed at the western extension of the main ijolite (chapter 4). Other blocks include carbonatites and country rock showing various degrees of feldspathization. These observations are believed to indicate that much of the area surrounding and between the outliers of intrusive rocks is underlain at little depth by the rock types seen as blocks at the surface.

Intrusive relations at these three outliers are described separately as each shows individual but related phenomena.

c) Yusoo area.

On each side of a N./S. trending gully low outcrops of micro-ijolite are exposed cut by carbonatite of several generations. Sovite (C1) occurs as one brecciated dyke and as inclusions in the main carbonatite C2b. This (C2b) includes apatite schlieren and is cut by ferrugenous veinlets (C4b). Narrow dykes of C3 carbonatite
Fig. 1. Dyke of alvikite (C2b) cut by several phases of brown C3 stage carbonatites at Yusoo.
are also noted (Fig. 1.23) and an unbrecciated 5" dyke of fine-grained potassium trachyte, having a steep dip is also found.

This last is an example of one type of the highly potassic and feldspathic rich rocks of Homa which are discussed in chapter 5.

d) Ndiru Hill area.

1. The Plug.

The largest area of continuous carbonatite exposure anywhere at Homa outcrops as a plug 1.5 km. south of the southern ridge of the main centre. Two adjacent areas are also described in this section (Fig. 1.22).

Mapping of the magnetite/apatite trains and foliation shows that the foliation is concentric about a point on the eastern lobe of the outcrop which is also almost the highest point of the plug. As shown on the map the foliation in the vicinity of this point dips steeply outwards, increasing to vertical in the area to the west.

The present level of erosion at this plug has resulted in several scarps controlled by the foliation and facing outwards. This results in some sections, particularly that from the S.W. towards the centre of the plug, having a stepped profile. The carbonatite exposed at the base of the largest of these steps is extremely finely foliated and in thin section is seen to have a marked preferred orientation of many of the calcite grains. The
foliation is seen to be composed of very narrow schier or veinlets of isotopic material against which rows of carbonate grains are orientated with a principle optic direction perpendicular to the schier. In parts these close spaced planes are folded on a minor scale (amplitude up to 2 cm.) often with the fold axes parallel to the foliation. This material (schistose carbonatite) is well exposed and noted on the map (Fig. 1.22). The majority of the carbonatite from this plug has characters more typical of the alvikites C2a in that much magnetite, apatite and pyrochlore are present and often define the foliation. Magnetite trains in which individual octahedra are of 1 cm. are not uncommon. Apatite is also frequent, characteristically occurring in disc-like bodies 1-2 cm. in diameter and of oval cross section, the long axis of which is parallel to the foliation. Thin sections show that such bodies are composed of very numerous apatite individuals arranged in a trachytic texture also parallel with the foliation. Pyrochlore occurs in larger (≤2 mm.) octahedra than anywhere else on the mountain. These three minerals often are associated in schier enclosed in a brown stained carbonate intergrowth. Some of the brown stained material appears to be dispersed iron ore but other material has a more micaceous habit and may represent a different, possibly rare-earth bearing mineral. Mica and aegirine-augite have also been noted from thin sections.
This plug is intruded, sometimes at right angles to the foliation and sometimes parallel to it, by steeply dipping melanite-rich dykes often less than one foot wide (C4a). These sometimes show areas of still later activity, being brecciated by clear calcite veins.

A second ferruginous carbonatite outcrops particularly in the western part of this outcrop. A dark yellow brown unfoliated carbonatite of C4b type has invaded and replaced the earlier C2 carbonatite. Some contacts show cross cutting relations in which xenoliths of C2 are seen enclosed in C4b. In other portions invasion appears more subtle and numerous fragments of the earlier carbonatite remain still apparently in their original orientation. While no extensive areas of the easterly plug-like body are so invaded, the effects of this later carbonatite are seen as several series of veins and stringers cutting the C2a mass.

In thin section the C4b carbonatite is seen to consist of a coarse-grained intergrowth of ochreous carbonate carrying sometimes pyrochlore, which may be derived from the invaded C2a rock, baryte and in a few cases pools and stringers of quartz which are replacing the brown stained carbonate grains in situ. This phenomenon of silicification is very rarely seen elsewhere at Homa.

2. The south eastern outlier.

The outlier to the S.E. of Ndiru (Fig. 1.22) is composed of large (20-60' wide) almost vertical dykes of carbonatite C2b cut
by apatite stringers and emplaced in a low area of ijolite of similar type to that exposed in the main outcrop. The carbonatites carry less visible accessories than those of the plug and have a rhomb texture in thin section while carbonatites of the plug do not. Magnetite is not seen as trains of octahedra but rather as rare elongate schlieren. Sovite (Cl) in both of these outcrops is only seen as inclusions in the later carbonatite.

3. The western outlier.

Relations within the outcrop to the west of Ndiru (Fig. 1.22) are not clear. The southern end of the ridge here exposes numerous boulders and blocks <1 metre across of C2b carbonatite. The eastern margin of the ridge is a scarp 20-30' high in which the carbonatite is seen to be entirely fragmentary as a poorly bedded coarse breccia. Fragments are mainly of C2b type often carrying cross cutting stringers of apatite and magnetite. Sovite inclusions are also seen. Succeeding this poorly bedded clastic deposit to the north are low exposures of a silicate micro-breccia in which ijolite and syenite fragments and crystals are frequent. By comparison with similar material exposed at Bala and elsewhere this is a tuffaceous equivalent of an ijolite and is probably intrusive. The most likely explanation for the brecciation of the carbonatite is that it lies on the line of a possible extension of one of the radial faults. The original foliation may be indicated by several large blocks (or small exposures) of carbonatite. This foliation is indicated by a broken
line on the map (Fig. 1.22).

4. Comparison of the alvikites C2 at Ndiru. (Fig 1.24.)

The descriptions above indicate that both C2a and C2b carbonatites are present in this area and appear in each case to be the main carbonatitic intrusive phase. In some characters they differ however and a summary and possible explanation is given here:-

C2a

a. Typical of the plug.
b. Carries magnetite in trains of well formed octahedra.
c. Apatite occurs as discontinuous fragments, often disc-shaped within the foliation (Fig. 1.24a).
d. Pyrochlore frequent as well formed octahedra.
e. Carbonate texture - allotriomorphic granular.

C2b

a. Typical of outlying dykes e.g. in S.E. outlier.
b. Magnetite occurs in elongate schierens or cross cutting veins.
c. Apatite occurs as cross cutting stringers (Fig. 1.24b).
d. Pyrochlore very infrequent.
e. Tends to be more idiomorphic with the rhomb as the characteristic grain shape.

Explanation of the textures seen in thin section and hand specimen.

The rock has undergone deformation during or since the original crystallization giving rise to a metamorphic style of texture.

The rock has undergone little deformation since original crystallization and the texture is of magmatic origin cut by later segregations of both apatite and magnetite.
5. Mode of intrusion of the Ndiru plug.

The schistose texture above mentioned and stepped profile may indicate the mode of intrusion of the plug. These features are believed to indicate that after much of the material consolidated intrusion continued as a semi-plastic hood. The stepped profile may indicate that successive cylinders of carbonatite rode over each other (Fig. 1.25a,b).

It is noted that the texture of the carbonate and the disposition of the accessory minerals in the plug are more similar to rocks of the main centre than to most of the C2 type carbonatites of the lower ground in the vicinity of ijolite. It is suggested that a further division may be possible into 'high level' and 'low level' carbonatites and that discussion of textural details, including the separation of characters ascribable to magmatic crystallization, e.g. C2b, from those in which a re-crystallization or directed crystallization has occurred (C2a), should be attempted. (See Flegg - in course of preparation).

6. Possible economic importance of Ndiru.

The quite large amount of visible pyrochlore and apatite in the plug may indicate that the extensive surrounding soils represent reserves of niobium and phosphate. Soil samples from surface and pits were collected, as on other parts of the area, and deposited with the Kenya Survey for use by the U. N. under Dr. F. Jaffe.
Diagram to show the relation of the stepped profile (A) with the postulated mode of intrusion (B).

Note: The phases of melt drawn in the lower diagram represent the sense of melt which may persist down to an intergranular scale.
Summary of the relations exposed at Ndiru m'bili.

This area (Fig. 1.26) is a pear shaped outcrop, 100 metres wide in which a variety of rock types are well exposed. It is probably not an isolated centre but represents an outlying active arc of the main centre at which is represented in miniature many of the relations at Homa.

The central portion is some 15 metres higher than the surrounding drift down to which the land surface slopes. The country rock was mapped as strongly feldspathized, and in parts, brecciated Nyanzian. Thin sections have subsequently shown that some of this material may have passed through a magmatic trachytic stage (HC 732) (chapter 5)

The north western end exposes a micro-ijolite (HC 736) which contains xenoliths both of aegirine-poor micro-ijolite (HC 822) and coarse-grained ijolite (HC 735). The country rock near this contact is frequently invaded by narrow (1-2') dykes and more irregular larger areas of a coarse, white, silicate-rich sovite Cl (HC 729) which is margined by and includes fragments of the coarse-grained orthoclaseite (HC 734). Both aegirine and ochreous orthoclasesites have developed here but less pyroxene is observed near the sovites. In places intimate intergrowth of large sovitic calcites and orthoclaseite has occurred in which plates of calcite <2 cm. are enclosed in an orthoclaseite (HC 730), (chapter 5) The
highest part of the hill is occupied by a low outcrop of a dark micaceous rock (HC 821), identified as glimmerite. This is very similar to a rock noted in the Usaki area by Pulfrey (1950) who believed it to be a facies of the ijolite crystallized in the upper portions of a cupola. The occurrence at Homa carries calcite and apatite with a strong development of biotite, often replacing aegirine-augite (chapter 2, p. 139).

This earlier group of intrusions were followed by at least two further distinct phases of carbonatite. The first (C2b), striking approximately north-west, is represented by three large dykes of a medium-grained cream/buff rhomb carbonatite which is cut by accessory apatite stringers (HC 820) which have been subsequently refoliated. This dyke carries breaking-up fragments of orthoclase (HC 819).

The last phase of intrusion involved the emplacement of a swarm of 1-3', fine-grained, dark purple-buff, rhomb carbonatites (C3) which cut all the other rocks mentioned indiscriminately. Intruded parallel with, and sometimes included in these, is a facies of the same carbonatite type carrying a mass of rounded fragments of fenitized and feldspathized country rock, averaging 2 cm. across (HC 817). These bodies are believed to have developed due to attrition suffered during their inclusion within the carbonatite dyke.

The dominant strike of these fine-grained purple dykes is
N.E. with a dip of 40–50° N.W. Similar dykes are frequent on areas to the north e.g. Rongo and the western slopes of Homa Main (chapter 5).

f) The history of the area since the period of main erosion.

Events subsequent to those noted above for Ndiru, Yusoo and Ndiru m'bili are also represented in the previous section dealing with the southern approaches and are noted in outline in the table on p. 45-6.

v) Northern part of the Homa complex.

a) Introduction.

The northern part of the complex including half of the main centre was mapped by Flegg and therefore an outline of the main features only appears here. On one point however, that concerning the series of bedded clastics exposed on the north eastern flank of the main centre, some discussion is given and a possible reconstruction of events of this area made.

b) Outline geology of Nyasanja, Awayo and Rongo.

Two topographic features, Nyasanja (5,500') and Awayo (5,000') lie 2 km. north and east respectively of the centre of Homa Main ring complex (Fig. 1.27). These and several smaller hills between expose mainly high level features i.e. carbonatites mainly C2 and C3 and carbonatitic mixed breccias. Nyasanja appears to be a complete cone sheet centre in which much more carbonatitic mixed breccia has been intruded than at Homa Main. Awayo is a domed area of
Fig. 1. 27. Panorama of North Homa from 1 km. north-east of Awayo.
country rock showing very much less evidence of intrusion. The highest part, however, consists of carbonatitic mixed breccia and may represent a vent. Narrow zones of disturbance have been mapped on the flanks by Flegg which have a different attitude to the cone sheeting often seen elsewhere in the complex. In an earlier section (p.12-13) it was noted that doming appears to have occurred in two stages at Homa Main. At Awayo the present author believes that only the earlier, more gentle stage of doming occurred.

One kilometre south of Awayo a lower lying area of small hills is believed by Flegg to be the site of a further intrusive centre (Rongo). Rocks exposed include ijolite, C1 and C2b carbonatites which indicate that here is exposed a lower level of activity than most areas to the north. Numerous dykes of C3 carbonatite strike approximately N.N.E. and appear to be part of the swarm which intrudes the Ndiru m'bili area described by the present author. Rongo thus has features both of a separate centre and of being the site of intrusion roughly concentric about Homa Main.

c) Events and rocks believed younger than the main intrusive phases.

Rising from the S.E. flanks of Nyasanja is the only large plug of phonolitic composition on the peninsula. This plug, called Nyamatoto, has a K/A ratio equivalent to an age of $1.9 \times 10^6$ years (i.e. the same as the Osiri lava). This age means that the plug
Fig. 1. 28. Bedded clastics of North Homa cut by a fine-grained grey carbonate dyke of C5 stage activity.
was intruded later than the activity of the main centre from which Potassium/Argon ratios equivalent to ages varying from 4.5 to 12 x 10^6 years were obtained.

Satellite breccia vents as described on the southern flanks of the main mountain are also present and so is a remnant of grey tuff or lava showing calcareous pseudomorphs after a prismatic mineral (¿melilite). This outcrop lies 0.3 km. south of Nyamatoto.

The most striking evidence that activity was renewed after a long erosion interval is seen on the north eastern flanks of Homa Main where remnants of a pile of bedded clastics are seen to lie against a steep profile of Homa Main very similar to that exposed today. The photo opposite shows the flat lying, undisturbed nature of some of the outcrops at 5,000'. In parts 6-9" dykes of grey (C5) carbonate material cut the bedded deposit (Fig. 1.28). These relations indicate that this deposit has a similar place in the succession as the red breccia series exposed around Got Chiewo (p.51). The two deposits differ in lithology, the red breccias being coarser and more poorly bedded than the bedded clastics of N.E. Homa Main. The former contain numerous recognizable blocks of the intrusive suite (e.g. ijolite). The finer-grained clastics of N.E. Homa sometimes show grading. Some evidence of subaqueous deposition is present in both cases. In the case of the red breccias subaqueous deposition was probably discontinuous.
and local. A further similarity between the two deposits is that they both had a provenance to the north of their present position if the present attitude of the bedding is taken as being original. Faulting is known to have affected the red breccias and therefore this feature is probably not significant.

d) The problem of the origin of well bedded deposits above 4,500'.

According to previous workers in Nyanza, the highest that the lake level rose in Pleistocene times was 4,200' (Saggerson, 1951, p. 76). During the course of the present work Flegg located a fish band in the Pleistocene deposits lying against the Osiri lava at about this height. There is no direct proof that lake level was ever higher than this but evidence was found both north and south of Homa Main of a beach cut at 4,500' and it is deemed possible that this represents the highest lake level recognizable on the mountain.

Three origins are possible for these deposits:
1. As lacustrine deposits during erosion.
2. As subaerially deposited erosion products.
3. As products of volcanic action.

A regional fall in lake level of 1,400' has not occurred and therefore if they are lacustrine deposits they must have resulted from either a very local damming or have been uplifted to their present height. That some of the clastic deposits banked against
the mountain are the result of subaerial erosion is probably true—these have a loosely indurated appearance, are roughly bedded and dip away from the high ground. These characters fit the red breccias in part but do not fit the almost level and well bedded nature of those of North Homa.

The present writer believes that the most likely origin is one by direct volcanic action. It has already been noted that much of the intrusive activity of the complex is of explosive type. It is very likely that many of such intrusions reached the surface and deposited breccia and tuff over the surrounding area. The lack of silicate material added to the fragments, broken up during the activity, has been noted as a character of many of the intrusive breccias. Such material is also absent from the clastics here discussed. The only additional material in both cases appears to be carbonate-rich with some fragments of mica and pyroxene.

e) Reconstruction of one possible origin of the bedded clastics.

This involves their derivation from a source (vent) further to the north, perhaps where Nyamatoto now stands. Nyamatoto phonolitic nephelinite plug was intruded later in the succession, probably after the main erosion period (see p. 80). A correlation in time and space can, therefore, be made between the Nyamatoto activity now present and the considerable pyroclastic activity represented by the bedded clastics (Fig. 1.29). It is suggested that
an ash cone was built up which was then intruded by a lava plug. Subsequent erosion has removed most of the less resistant ash pile revealing the plug.

The red breccias have a different lithology and fragment content and may have had a different source but similar mode of origin.

vi) Oyolo, Onya and Bala areas.

a) Successions.

1. Oyolo and Onya.

1) Shattering, brecciation and feldspathization probably due to the rise of underlying ijolite into an arcuate zone.  

2) Intrusion of sovite dykes and areas C1.

3) Intrusion of carbonatite C2a.

4) Brecciation resulting in carbonatitic mixed breccias. (Probably similar breccias are intruded at other times).

5) Intrusion of large dykes of C2b.

6) Veins of C4b. Intrusion of two opposed sets of carbonatite C3, some of which involve C1 to give a pseudoporphyritic carbonatite.  

Erosion.

7) Laying down of limestones and soils.

N.B. Three micro-ijolite dykes were noted by Saggerson from this area. This supports the view that a zone of ijolite material underlies this area similar to that beginning to be exposed at Bala.
2. Bala.

1) Intrusion of micro-ijolite mass causing the overlying country rock to be brecciated and metasomatically altered to fenite and feldspathic fenite.

2) Replacement of one area of the breccia by magnetite and haematite.

3) Intrusion of sovite C1 also causing feldspathization.

4) Intrusion of some carbonatitic mixed breccias.

5) Intrusion of carbonatites C2b.

6) Intrusion of carbonatites C3.

7) Intrusion of phonolite dykes. 
   Extrusion of phonolite lavas.

   ——— Erosion. ———

8) Laying down of 200' + of Pleistocene sediments. (Lower Lake Bed series). 
   Movements involving faulting and tilting.

   ——— Erosion. ———

9) Laying down of Upper Lake Bed series. 

   ——— Erosion. ———

   Further small scale faults and foldings.

10) Laying down of thick soils. 
    Lowering of base level accompanied by marked incision of the Bala Gully exposing the top of the ijolite body.

11) Deposition of modern alluvial deposits.

12) Hot spring activity.
b) **Introduction.**

At 5 and 7 km. S.E. of Homa Main are two belts of the intrusive suite (Fig. 1.3). These belts are elongated approximately tangentially to Homa Main and are believed to be controlled by two major ring fractures which have served to localize the intrusions into two areas separated by zones of less brecciated and intruded country rock. This last conclusion is not easy to substantiate, however, for the intervening area is mainly drift covered. The S.E. margin of the Bala arc is, however, well delineated in the field 250 metres south of the southern end of the Bala Gully. From this point northwards the transition eastwards from simply shattered, metasomatized country rock to more heavily brecciated and feldspathized same is more gradual. At the northern end of the hill Onya the brecciated area is again succeeded by merely shattered country rock, this time northwards. (Fig. 1.30 in Map Pocket).

c) **Bala area.**

1. **Ijolite.**

Of the two arcuate areas, that at Bala is the more completely exposed and is seen to be underlain by a body of ijolitic composition best exposed north of the Bala fault as a micro-ijolite. Ijolitic material is represented S.W. of this fault as fragments within a body of intrusive siliceous mixed breccia. Small outcrops of intrusive nephelinite were also noted. The presence of ortho-
clase developing late in some specimens of these rocks varies the mineralogy towards that of malignites (chapter 2).

A traverse up the Bala Gully shows that only the upper portions of an ijolite body are exposed here, for more and more fenite is exposed as roof pendants and screens between portions of the intrusion. The fenite in this area is unusual in that aegirine-augite is present in greater quantity than orthoclase. The zone of fenite is less than 10' thick - being succeeded away from the ijolite by a zone of feldspathized and brecciated country rock in which the aegirine has broken down or is absent. Red/brown disseminated iron oxides may show pseudomorphs after aegirine and the rock has now the characters of a carbonatitic pseudotrachyte breccia. In one area a mass of haematite and magnetite has replaced the brecciated country rock and now stands as a low knoll.

2. Carbonatite.

Carbonatites of all four groups are present. The sovites (Cl) often carrying very numerous xenoliths of ijolite, fenite and feldspathized country rock. These intrusions show a graduation from examples with a width of 30-50' to small dykes. Their strike is not usually parallel to the general arc and some strike at right angles to it.

Carbonatites of group C2b are also frequent but these do show strikes markedly parallel with the arc and dips towards Homa Main.
This contrast in strike between sovites and C2 alvikites is seen in other parts of the mountain, the former often striking at high angles to the latter which are frequently tangentially striking as in the present case.

Carbonatites of group 3 show evidence of focussing on local centres within the immediate area. This is well seen at the S.W. end of the Bala arc.

3. Phonolite.

The final series of dykes observed are of phonolitic character. They are dark grey green in colour and are rarely porphyritic. These have steep, near vertical dips and strike across the arc and appear to be true radial dykes. They vary in width from 3-10' and probably acted as feeders to quite widespread flows. The presence of numerous rounded boulders at the base of the 227' thick series of Pleistocene sediments which overlie part of the area may be evidence for the former presence of widespread flows. An outlier of the phonolite flows mapped by Saggerson south of the mountain lies only 300 metres east of the northern part of the Bala Gully (Fig. 1.31). This lava rests on a surface which Saggerson believed was the pre-Miocene erosion surface. Although the present work indicates that these lavas may be of somewhat later age than previously thought the position of the pre-Miocene surface is believed to be close to this level (p.12-13). The differences in height bet-
ween this surface and the top of the micro-ijolite body exposed in the Bala Gully is about 100' indicating that ijolite is capable of reaching very high levels in the crust. (Fig. 1.31). Calculations of the real depth of the cover, however, are complicated by lack of knowledge of the pyroclastic overburden at the time of intrusion.

d) Oyolo and Onya.

The sequence of events is similar in the Oyolo and Onya area, C2b age carbonatites forming prominent tangential dykes which dip towards the main mountain. They cut and refoliate earlier C1 carbonatites which are associated with a strong feldspathization of the brecciated country rock. Several regimes of brecciation have occurred and two phases of C2 intrusion are noted divided by a period of brecciation. C3 (Fig. 1.32) and C4 carbonatites are also present and although no ijolite is exposed its presence at depth is indicated by the discovery of narrow micro-ijolite dykes (Saggerson, 1952, p. 36).

The C2b alvikite outcropping west of Oyolo has been quarried for lime and is one of the largest dykes of its kind found on the mountain being 50' across the strike. Brecciated inclusions of pseudotrachyte were collected from within this dyke and a similar one with an opposed strike south of the road at Oyolo.
Fig. 1. 32. 'Porphyritic' carbonatite, Oyolo, South Homa. Plates of white calcite fluxionally arranged in a matrix of fine-grained brown carbonatite (C3). It is considered likely that the large white calcites are cleavage fragments formed by the brecciation of an early sovite (Cl).
It is concluded that the Oyolo, Onya and Bala outcrops repre-
sent areas which have been affected by the same series of carbon-
atitic and ijolitic intrusions as Homa Main. The overall sense of
elongation of the outcrops together with the strike and dip of the
large C2b carbonatites indicates that this activity is sensibly
concentric, and probably localized by initiation of large ring frac-
tures, about Homa.

The Pleistocene and post-Pleistocene history involves laying
down of two main series of lake beds, faulting accompanied by tilt-
ing and the lowering of base level causing the gully to expose the
top of the micro-ijolite body which is believed to be the core of
each of these two arcs.

vii) Areas at which phonolitic rocks are exposed.

a) Phonolitic rocks of the peninsula.

Such rocks have very restricted outcrops. A remnant of phono-
lite lava is exposed at Homa Point on the lake shore and shows a
plateyness and fluxion texture. The rock is porphyritic with numer-
cous <4 mm. felsic phenocrysts of both nepheline and simply twinned
alkali feldspar. Aegirine-augite is present as sparse micro-pheno-
crystals and microlites in a strongly zeolitized background.

Dykes of phonolite cutting micro-ijolite at Bala (Fig. 1.30)
have a similar mineralogy although the porphyritic nature is not
always so marked.
Rocks of the phonolitic nephelinite group include the lava plug Nyamatoto, noted previously on pp. 65 and 68.

A single sheet of very similar material dips at 10° away from Homa Main at Osiri (Fig. 1.3). No feldspar phenocrysts are seen and nepheline idiomorphs are prominent in the background. Occasional heaps of boulders of similar material are found in other areas around and on Homa Main. These may represent small pipes or outliers of the same rock type. As noted previously (p.____) Potassium/Argon ratios both from Nyamatoto and Osiri are equivalent to an age of about $2 \times 10^6$ years. Fragments of similar phonolitic nephelinite as at Osiri were found in the agglomerate surrounding the plug of olivine melilitite (p. 42).

Fine-grained porphyritic equivalents of the micro-ijolite exposed at Bala are also found in the Bala arc. These are nephelinitic in character but carry a little feldspar in the matrix. No large area or flow of true feldspar-free nephelinite has been found in the area, a great contrast with the numerous flows of such which are present within the Kisingiri pile (McCall, 1958; Findlay, 1966). Small areas of similar rock type are found in the main valley and occasionally associated with ijolites elsewhere.

b) Phonolitic rocks east of Homa Peninsula.

1. Phonolitic nephelinite plugs.

In addition to the above few exposures within the area affected by the Homa intrusive activity, phonolites and phonolitic
nephelinites outcrop in a belt of country between Nyangwesso and Kendu Bay roughly along and surrounding the Kendu Fault. This area (Fig. 1.33) has not been mapped in detail. Some of the conclusions reached contrast with those of Saggerson (1952). As Saggerson observed (1952, p. 73) a series of conical plugs of phonolitic nephelinite are aligned parallel with the extension of the Kaniamwia escarpment. Three of the four major plugs of the area were visited. These are from S.W. to N.E., Samanga, Adiel, Rabuor and Nyandete (Fig. 1.33). Adiel appears to be a double plug and includes numerous 1-4 cm. fragments of a hornblendite (HC 957). Similar brown hornblende and mica of the typical dark brown colour ascribed to highly oxidized minerals were located in other plugs of the area. Resorption, surrounding by ore granules and partial conversion to aegirine often characterize these minerals which are obviously unstable in the present environment.

Got Rabour has a diameter of approx. 800' and rises 200' from the surrounding plane. A prominent plateyness dipping steeply off the hill was noted in several places. In hand specimen the micro-phenocrysts of clinopyroxene and elongation of small preferentially weathered cavities are parallel with this plateyness and with a marked fluxion or trachytic texture in the groundmass. Similar textures have been noted from the numerous plugs around Ruri (Dixon, personal communication). Phenocrysts of aegirine-augite, apatite and sphene lie in a matrix of nepheline, aegirine
and alkali feldspar. Calcite and zeolites are prominent and sometimes fill a series of en-echelon gashes <3" long.

An inspection of thin sections indicates that a specimen from the top of the plug appears less phonolitic than are those from near the base. This raises the question as to how much the composition varies within a single plug.

2. Phonolitic flows, dykes and possible plugs.

A further series of outcrops is present in this area (Fig. 1.33) at which lavas occur carrying much more modal feldspar and less clinopyroxene than those rocks described in the previous section. These rocks are medium to dark green, usually mildly porphyritic only, and in thin section carry micro-phenocrysts of alkali feldspar, nepheline and some small aegirines. The groundmass is composed of a fluxion texture in which microlites of feldspar and aegirine are aligned. Some nepheline is present but the background is now often isotropic or zeolitized. Vesicular Examples are quite common with vesicles ranging from 2-10 mm. in diameter. These rounded bodies are often darker coloured and may represent centres of analcitemization of the background.

The accompanying map (Fig. 1.33) indicates the extent mapped by Saggerson and the traverse lines of the present work. The traverse between Adiel and Rabour and Rabour westwards pass over heavily farmed black cotton soil on the whole and no outcrops of
lava were noted. Blocks were correlated with the nearby plugs of phonolitic nephelinite.

The steep sided hills lying half a mile east of Nyandete both north and south of the road were found to be spherulitic phonolites as described above. In the more northerly of these a platyneus striking parallel with the hill slope and dipping steeply off was equated with similar textures above mentioned at Got Rabour. The knolls at M.R. 778532 and 771518 also expose phonolite, the latter having a most interesting physiography. The air photo. shows the hill as a circular ridge, diameter \( \frac{1}{2} \) mile, slightly more raised on the west. On the ground the ridge is seen to coincide with a change of strike of the lavas which dip inwards along it at 20-30\(^\circ\).

The phonolite marked as an outlier by the previous worker at M.R. 710520 was also visited. Numerous inclusions of oxybiotite were noted in this rock and thus indicate a link with the phonolitic nephelinite plugs in which similar material has been found (p. 77). Phenocrysts of orthoclase are sometimes broken and may be xenoliths of orthoclaseite.

The overall picture gained as a result of the present work, therefore, is that several steep sided outcrops of phonolite exist, separated by lower ground which in some cases shows no evidence of phonolite (c.f. Saggerson, 1952, p. 31). Some of such features have probably resulted from dissection of a larger outcrop but the atti-
tude of the flow texture and form in outcrop of others could equally be explained by their being dome or plug-like centres of extrusion.

c) **Age relations of the phonolitic rocks around Homa and Kendu Bay.**

Saggerson (1952, p. 31) assumed that the phonolites were an extension of the Gwasi lavas but other work suggests that this is not so. Shackleton (1946) described the Gwasi series around Karungu (Fig. 1.5) and noted that the lavas were mainly nephelinitic in composition with variants towards tephritic, basanitic and basaltic types. He believed that the plateau phonolites of Isuria to the east of Karungu were of a similar age but different provenance. In a later work Shackleton (1951) described a basic group of nephelinitic and melilite bearing rocks associated with the central volcanoes of Kisingiri and Tinderet (noting small amounts of plagioclase bearing variants in each case). Sequences including these rocks overlie sediments of Lower Miocene age. He distinguishes these from a thick series of plateau phonolites of which a 2,000' section is exposed at Tambach. McCall (1958) notes no phonolitic variants in the lavas of Kisingiri but a series of phonolitic dykes, plugs and flows in the vicinity of the Ruri Hills. Further work has been published on this last area (Collins, 1966; Dixon, 1966 and Le Bas, 1966). Bishop et al. (1967) present data confirming Shackleton's (1951) two fold division and show that the nephelinitic
activity at Kisingiri and Tinderet has a Potassium/Argon ratio equivalent to 19-20 \times 10^6 \text{ years}, while that for the phonolitic plateau lavas indicates an age of 15-11 \times 10^6 \text{ years}.

The conclusion reached above, that the phonolite flows S.E. of Homa are not equivalent in age or rock type to the Gwasi lavas, removes the necessity for separating the phonolites at Homa into two age groups (Saggerson, 1952, p. 48, stages 1 and 5/7). The present work, therefore, equates the phonolite dykes directly with the effusive phonolites of the area and suggests that these dykes and the feature at M.R. 771518 (p. 74 line 10-13) are evidence for a local provenance of the lavas rather than them being outliers of the widespread plateau lavas of the east, the nearest outcrop of which lies on top of the Sondu Escarpment 23 miles to the east of Got Rabour (Fig. 1.33).

Saggerson (1952) believed that the phonolites were cut by the plugs of phonolitic nephelinite in the area east of Homa (Fig. 1.33). In the Bala area the phonolite dykes are late in the intrusive history and cut ijolite and carbonatitic mixed breccias. Direct relations with the carbonatite of this area are not seen but it is believed that these too are earlier than the phonolite.

As mentioned above (p. 77) the chain of plugs between Samanga and Kendu Bay (Fig. 1.33) are aligned on an extension of the Kaniamwia Escarpment. The age of their activity has, therefore, been correlated with that of the Rift faulting, one result of which was the
formation of the Kaniamwia Escarpment (Saggerson, 1952; McCall, 1958).

The age of the Rift faulting is usually considered to be Late Pliocene/Early Pleistocene.

This conclusion receives some support from the K/A data derived from the two specimens of phonolitic nephelinite from the Homa complex (p. 76) which gave ratios equivalent to an age of nearly $2 \times 10^6$ years. The phonolitic nephelinite plug, Nyamatoto, from which one of the ages comes does not lie on the Kendu/Homa Bay fault line but has many similarities in form and mineralogy with those that do and is equated with the same period of activity.

Conclusion. The phonolitic activity at Homa followed the main period of intrusive carbonatitic activity and probably preceded the intrusion of phonolitic nephelinite plugs which may be associated with the Plio/Pleistocene rift faulting.

Phonolites of the area are believed to have a local origin rather than being outliers of the plateau lavas around Tinderet and the Sondu and Isuria escarpments.

d) Note on the mode of formation of the characteristic conical lava mounds called plugs of the area.

The characteristic shape of many outcrops of phonolitic rock at Homa and to a greater extent still at the neighbouring Ruri-Usaki complex is a steep sided conical mass averaging 2-400' high. These are usually termed plugs and a large but typically shaped
Fig. 1.34. Samanga Hill, a plug of phonolitic nephelinite lying on the Kendu fault zone. The figure (taken from the N.W.), shows in addition a low spur of Nyanzian running from the left and separated from the phonolite outcrop in the foreground by an area of thick, black cotton soil.
example is Samanga (Fig. 1.33 & 1.34).

Observations show that a plateyness which parallels a fluxion texture often dips steeply off the sides of these plugs and has a strike approximately parallel to the contours. This indicates that the plugs are not outliers of a once continuous sheet but represent separate centres.

Comparison of the height of these plugs with that of the Nyanzian exposed before and during the activity at Homa indicates that they stand above that surface rather much as they do today.

Two alternative modes of formation are described, the second of which is favoured by the writer.

i) They were formed by the extrusion of highly viscous lava in an analogous fashion to the spine of Mont Pelée and raised above the existing land surface.

ii) They were intruded into material which had previously been deposited on the Nyanzian surface and which has since been removed almost without trace.

The first alternative demands a lava of high viscosity but for two reasons the former presence of such is unlikely:

A. The Osiri lava flow has a very similar mineralogy and texture to the Nyamatoto plug rock and has a K/A ratio indicating a very similar age.

B. Deuteric alteration is marked in several slides studied from the plugs along the Kendu Fault. This indication of a fugitive
fraction present during crystallization again argues against a highly viscous state.

The second alternative, implying that they are essentially intrusive bodies may be exemplified by the relations deduced between the Nyamatoto plug and the bedded clastics of the north face of Homa. In that case there is evidence of a thick pile of easily eroded material into which the plug may have been intruded (Fig. 1.29).

It is considered possible that the bedded clastics represent a remnant of a former ash cone. The connection in space and time between the possible ash cone and plug is not known other than that they both were formed during the main erosion period. It is considered likely, however, that the plug and ash cone represent different phases of the same eruption.

This suggests that each plug may have been the site of an ash cone which formed the substrate into which the plugs were intruded.

In most cases no trace of the ash cone remains but that possibly associated with Nyamatoto which was partly emplaced against a steep face of resistant material and survived in this privileged position.
viii) The lower ground surrounding the central complex exposing lacustrine, alluvial and pyroclastic deposits.

a) Succession.

The sequence of events deduced at South Homa is given below and correlated in part with the well documented Pleistocene sediments of North Homa (Kent, 1942: Saggerson, 1952). Correlation of the bedded clastic deposits mapped by Flegg and noted in this account on p. 67 is also made:

1) Period of erosion reducing the centre of Homa Main, Nyasanja and others to a profile similar to that exposed today.

2) Deposition of red breccias and Orio tuff (probably as the result of pyroclastic activity).

3) Cutting of a beach at 4,500' into the red breccias. (?Lake at 4,500').

4) Deposition of Lower Pleistocene limestones and tuff L2. (?Lake at 4,050'). Activity resulting in the formation of satellite vents.

5) Deposition of beach beds around the Osiri lava. (?Lake at 4,200') Deposition of Lower Bala and Lake Cliff series.

6) Deposition of fine tuffs (L1), possibly equivalent to the carbonated melilite (C5) stage of intrusive activity of Got Chiewo.

7) Tilting and faulting of the Lower Bala and Lake Cliff series perhaps due to movement along the Bala arc and its continuation.

8) Cutting of a beach at 3,800' and depositing of Upper Bala and Lake Cliff series. (Lake at 3,800').

9) Deposition of alluvium and soils particularly in gullies.

10) Lowering of base level by 60' rejuvenating the gullies and causing canyons up to 40' deep to be excavated in the soils. Deposition of beach deposits at this level. (Lake at 3,740').

11) Further slight fall to present day level. Deposition of modern soils, alluvium, secondary limestones and tufa. (Lake at 3,730').
North Homa. (After Kent, 1942; Saggerson, 1952; Flegg, personal communication.)

2) Deposition of bedded clastics probably accompanied by intrusion of Nyamatoto plug.

3) Flegg noted evidence of reworking as by a lake up to 4,500'.

4) Deposition of Kanam and Lower Rawe beds with contemporaneous breccia vents (Lower Pleistocene).

5) Deposition of Upper Rawe beds. Deposition of Lower Kanjera beds. } Middle Pleistocene. Period of warping and erosion.

8) Deposition of Upper Kanjera beds.

9) Deposition of modern alluvium and soils.

10) Cutting of beaches at 20, 35 and 100' (Saggerson, 1952, p. 56). Rejuvenation of gullies.

b) Introduction.

This area is much larger than any of the others described above and has been mapped in less detail. The exposures of sediments, pyroclasts and soils are patchy and correlation presents many difficulties.

All deposits and events noted in the succession occur after the period of main erosion which was established in previously described areas. To a great extent the succession on the previous pages summarize the history of the mountain since the period of main
erosion. It shows that although the large scale carbonatitic activity represented by the hills of Nyasanja, Homa and Awayo had probably finished some time before the Lower Pleistocene, more minor activity and earth movements took place during the Lower and Middle Pleistocene. Even more recent evidence of vulcanism is present at Lake Simbi, an explosion crater of historical age which lies at the northern end of the Kendu Fault zone (Saggerson, 1952, p. 53). The present day hot spring activity at Bala also is direct evidence of the instability of this area.

In addition to the pyroclastic and intrusive activity the presence of lacustrine deposits provides a series of most interesting problems. On the north side of Homa the sediments are continuous and of greater extent and now represent a standard sequence of the East and Central African Pleistocene (Oswald, 1914; Kent, 1942). The finding of new Lower Pleistocene localities on the south corresponding with the position of the Kanam beds, long studied on the north, is noted below. The important position of the Kanam beds is indicated in Bishop (Table 4, 1963).

c) Brief notes on the stages summarized in the succession.

1. It has already been established that a period of erosion occurred.

2. The relations of the bedded clastics on the northern flanks of Homa and the red breccia series of South Homa have already
Fig. 1. 35. Accretionary lapilli from the Orio tuff (HC 955). x7, PRL.
been discussed (p. 66) and it was suggested that they both result from pyroclastic activity, the former perhaps being linked with the intrusion of Nyamatoto plug.

Seven kilometres east of Homa some 3-4 square kilometres are underlain by the bedded Orio tuff similar to some horizons in the red breccias. It has a low dip away from, and thickens towards, Homa, terminating in a 50' erosion scarp facing west (Fig. 1.33).

In both the red breccias and this deposit horizons are seen in which numerous 2-5 mm. accretionary lapilli (Fig. 1.35) are seen (Wentworth and Williams, 1932). It is not clear if these two deposits were ever continuous but they are tentatively correlated. The Orio tuff lies on the phonolite of the area (Saggerson, 1952, p. 54).

3. Erosion subsequent to the deposition of these deposits has re-exposed the surface they lie on which includes ijolite under Got Chiewo where an erosion scarp approx. 1 km. long exists at 4,500' perhaps indicating a high lake level. Below 4,500' on North Homa Flegg recognizes lacustrine deposits probably continuous with the bedded clastics of higher levels.

4. Lower Pleistocene vertebrate remains have been recovered from two new areas on the south, both associated with a medium-grained tuffaceous limestone. Few fragments were found in situ and the relation of this limestone (L2) are not clear. Similar unfossiliferous limestones and/or tuffs are frequently exposed in gullies
Recent soils and gravels

INDEX
- Gullies
- Recent soils and gravels
- Grey Limestones
- Mid. Pleistocene of Saggerson
- Country-rock (fenit cl)
- Locality nos.
- Fossil site of Saggerson

Scale 0 100 200 M.

Localities north of Homa Lime.
and some may be of later age, and perhaps different origin (e.g. Saggerson, 1952, p. 59). It is concluded, however, that at least 20' of calcareous tuff was deposited around the southern flanks of Homa during the Lower Pleistocene and that that above 4,050' was probably subaerially deposited. The fact that during the Middle Pleistocene the lake rose some 200' higher and the period was one of marked erosion indicates that the original thickness of Lower Pleistocene tuffs was probably much greater than 20'.

During the Lower Pleistocene on the north side of the mountain small carbonatic breccia vents were active (Kent, 1942). The satellite vents previously described on the western and southern flanks of Homa (p.52) may have been active at this time also but except for the rather different vent of Chiewo none cut any bedded deposit.

5. Beach deposits of sands, gravels and thin limestones including a fish band are present banked against the remnants of the Osiri lava and indicate a lake reaching 4,200' which corresponds with the highest lake level recorded by Saggerson anywhere in the Nyanza Rift. This occurred during the Middle Pleistocene and so the deposit at Osiri and several similar further south are assigned to this age. No considerable tilting and faulting with dips >50° noted (Saggerson, 1963).

221' of finer-grained calcareous tuffs and limestones are present at Bala and a smaller thickness is present in the lower parts
of the Lake Cliff series from Homa Lime northwards. Apart from fish bands these deposits, the Lower Bala and Lake Cliff series, have not yielded fossils but the steep dips shown by them indicate a Middle Pleistocene or earlier age. The considerable thicknesses of fine-grained material indicate prolonged deposition and probably subsidence of the lake floor.

6. A thin fine-grained grey calcareous tuff (Ll) of very similar aspect to those surrounding the Chiewo Vent lies on several low Nyanzian hills of the west and south approaches of Homa including the Ogwago Ridge between 4,050' and 4,200' (Fig. 1.3).

In one case it overlies deposits believed to be of the Middle Pleistocene group described above and thus may be a pointer to the age of the Chiewo Vent series. A similar but probably later fine-grained calcareous tuff of a lighter colour is found over large areas, often only inches thick, of the country south of Got Chiewo. An exposure overlies the red breccias and it too may be a manifestation of very late Chiewo type activity.

7. Although the majority of the bedded sediments and tuffs show little disturbance other than local warping and small scale faulting, the thick series at Bala and exposed along the lake cliff all show considerable tilting and faulting with dips ≤ 50° noted (Fig. 1.36). At Bala the strike of the tilted block is approximately parallel to the extension of the Bala outcrop (Fig. 1.37) and it is
Fig 1.36

Tilted lake beds resting on intrusives of the Bala arc

Bala Gully

Upper Bala series

Lower Bala series

3800.0

3600.0

500

250

750m

500

0

NM

SF
Fig. 1. 37. The Bala Lake Bed outcrop. The well bedded series in the middle distance dips obliquely away to the left (N.N.W.), and is unconformably overlain by a second thin series (the upper Bala Lake Bed series).
believed that local vertical movement along the Bala arc may account for the tilting here. Active hot spring and minor modern fault scarps indicate that activity continues here.

No evidence of the continuation of the Bala arc westwards has been seen but the similarity of relations between the upper and lower Lake Cliff series at and north of Homa Lime with that at Bala point to a similar mode of origin and it is therefore suggested that an arc of instability and possibly intrusion at depth continues westwards and northwards from Bala and may in fact define the arcuate coast line of this area. The 60' cliff swings inland from Homa Lime eastwards towards Bala and may also be a topographic expression of the continuation of the intrusive zone at depth (Fig. 1.3).

8. & 9. The events of these stages relate to the Upper Pleistocene and Recent. At Bala and along the lake cliff from Homa Lime northwards some 10-20' of laminated clays, sands and limestones lie with low dips on the steeply dipping lower series. Inland from the old shore prolonged erosion filled in many of the hollows on the surface with thick soils and gravels. The surface on which the upper series lies is approx. 3,790' at Homa Lime and a similar height both north and east of here. A period of subsidence or lake rise was followed by a 60' drop in base level to 3,740' at which height a further beach was cut (Fig. 1.38). A drop of 10' recently has raised this beach which in parts forms a broad area especially
Upper Lake Cliff series resting on the 70' Beach.
Tilted Lower Lake Cliff series
Modern talus
10' Raised Beach deposits.
Modern Beach
Lake

DIAGRAM OF THE RELATIONS OF LAKE BEDS AND BEACH DEPOSITS AT HOMA LIME

FIG 1.38
at Bala where it has been incorporated as an enlarging alluvial plain or flat caused by the issue of the ephemeral Bala River and the permanent Tende River which flows from the east through Nyangwesso to the lake.

The earlier 60' drop in base level rejuvenated the gullies and they quickly cut back forming 40' canyons through the Upper Pleistocene soils sometimes exposing earlier Pleistocene deposits. A further result of their greater power of erosion was an increased exposure of the top of the micro-ijolite body at Bala.

10. Present day deposits include soils and alluvials, the latter being actively transported during the ephemeral gully activity which follows each storm. Signs of Modern and Recent hot spring activity is frequent, banded and cavernous secondary limestone deposits being formed, some including leaf impressions.

At one locality north of Homa Lime a horizon in the soils shows a 6" thick band of coarse green baryte also presumably deposited from springs. (Fig. 1.35a). M.R. 6445. 5335.

Stalagmitic material and a secondary calcareous cement to screes both result from precipitation of CaCO₃ transported during run off after storms. In places on the mountain considerable volumes of disarticulated bone have been so cemented.

White saline encrustations are deposited at many of the springs. X-ray analysis of a sample from the largest Bala spring
show that a mixture of nahcolite, \( \text{NaHCO}_3 \) and trona, \( \text{NaHCO}_3 \cdot \text{Na}_2\text{CO}_3 \cdot 2\text{H}_2\text{O} \), is present. A thin coating of pyrite also precipitates at this spring.

(4) **The age and general relationship between the volcanic centres within the Nyanza Rift.**

Within the Nyanza Rift there are four major centres of volcanic and intrusive activity at which are exposed a similar suite of rocks, e.g. nephelinites, ijolites, phonolites, nepheline syenites, carbonatites and carbonatitic breccia. However the relative proportion of each of the above rock types exposed varies greatly between the centres. The following table indicates the main differences and similarities.

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<tr>
<th>CENTRE</th>
<th>KISINGIRI</th>
<th>RURI/USAHI</th>
<th>HOMA</th>
<th>TINDERET</th>
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<tr>
<td>Lavas/Pyroclasts.</td>
<td>Large pile</td>
<td>Few</td>
<td>Very few</td>
<td>Large pile</td>
</tr>
<tr>
<td>Plugs</td>
<td>Few</td>
<td>Many</td>
<td>Very few</td>
<td>Some</td>
</tr>
<tr>
<td>Intrusive silicates</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Carbonatites</td>
<td>Some</td>
<td>Many</td>
<td>Many</td>
<td>Few</td>
</tr>
<tr>
<td>Intrusive carbonatitic breccias</td>
<td>Some</td>
<td>Many</td>
<td>Many</td>
<td>Few</td>
</tr>
</tbody>
</table>

| CENTRAL | VENT | YES | ? | NO | YES |

The above shows that the chief differences are that the two centres lying at each end of the rift have a large superstructure
of lavas and pyroclasts and in the case of the Kisingiri volcano a central plug of carbonatite which has intruded through which much of the superstructure material passed (Rangwa). The other two centres show very little sign of a similar super-structural pile. These differences may be explained in two ways.

1. The state of erosion may differ markedly between the centres, i.e. Homa may have originally been capped by a volcanic superstructure as was the Kisingiri volcano which subsequent erosion has removed.

2. The present day differences may reflect original differences in the mode of development of the centres.

Taking the first possibility, it implies a probable age difference between the Kisingiri and Homa centres with the latter being older. There is no faunal evidence for the onset of volcanicity at Homa, Lower Miocene beds as have been found in the lower parts of the Kisingiri pile (Shackleton, 1951) are unknown with the exception of a doubtful locality near Homa Bay (Saggerson, 1952, p. 23). Thus if the different centres were originally all equivalent in size the erosion level implies that much of the now removed superstructure at Homa was Pre-Miocene in age. The same question arises in the centres of East Uganda and here it has been suggested that two ages of volcanoes are present, an earlier Mesozoic group and a later Tertiary group (King and Sutherland, 1966, p. 73).
In the absence of faunal evidence it is necessary to fall back on radiometric dating methods. The data indicates a minimum age of $12 \times 10^6$ years for the start of the carbonatitic activity at Homa. Dates ranging from 12 to $1.9 \times 10^6$ years have been obtained from Homa specimens. Bishop et al. (in press) summarize data for the Kisingiri and Tinderet areas and confirm a Lower Miocene date for early activity at Kisingiri. The Potassium/Argon data does not preclude the possibility of an older volcanic cone at Homa but it re-emphasizes the present day lack of evidence for one of Miocene age or earlier.

The second explanation mooted above, that the present day differences are more fundamental is favoured by the writer. The above mentioned differences in volume of rock type present at the centres are in some cases capable of explanation by differential erosion of similar centres, other differences are not easily so explained e.g. the relative proportion of lavas and plugs present at each centre.

It is therefore concluded that the Homa centre may have undergone a history in which the carbonatitic phase was emphasized rather than the silicate effusive phase and that a central vent was never present.

The fact that most rock types are common to all four centres, that the time of activity in each overlapped and that all are aligned at no great distances from each other along a crustal fracture zone, probably indicates that some connection at depth existed.
and that all four centres were mutually dependent. This would mean that phenomena present at one centre e.g. Homa would not necessarily truly reflect all the geological processes which took place during its formation and that some might be better reflected in neighbouring centres. Thus although the present work deals in detail with one centre only it must be considered as representing only some episodes of a complex and multiple volcano-tectono event.
CHAPTER 2
VARIATION WITHIN THE IJOLITE AT HOMA MOUNTAIN

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VARIATION WITHIN THE IJOLITE AT HOMA MOUNTAIN

(1) Introduction and previous work

It is proposed to include in this section the ijolite of the Rapogi Hill area and seen also at Ndiru, Ndiru m'billi and Yusoo (Fig. 2.1). The numerous ijolite fragments occurring as inclusions in the red beds and in the xenolithic phonolite of Rapogi Hill also belong to this group. The second main type described here is best exposed in the Bala River section (Fig. 2.1). Its finer grain size and the more euhedral nature of its grains resulted in it being termed a microijolite in the field. This distinction can be maintained by a study of thin sections. Varieties of both ijolite and microijolite carrying up to 10% modal feldspar are included in this section. In most cases the ijolites or microijolites are the earliest intrusive phase present.

Pulfrey described the ijolites of Usaki and more briefly of Homa Mountain confining his description to the main outcrop near Rapogi (Pulfrey, 1950). Saggerson (1952) briefly described the ijolites at Homa and noted dykes of microijolite in the Bala River section. It is clear from Pulfrey's work that many similarities with the ijolite mass exposed at Usaki are present and conversation with Dr. Le Bas confirms this. It is evident also that a more restricted range of ijolite is present at Homa - the presence of masses or dykes of urtite was not noted. The present study has shown that many similarities also exist between the ijolites...
at Homa and those of Eastern Uganda (King & Sutherland, 1966; King, 1965).

(2) Field relations and characters

a) General

The ijolite at Homa occurs as a series of separate outcrops whose increasing size is directly proportional to increasing grain size. The main outcrop near Rapogi is of coarse-grained rock while the much smaller outcrop at Bala is a micro-ijolite. Additional outcrops of still smaller area are present at Yusoo, Ndiru m'bili and Rongo while at two localities, i) the N.W. end of Nyasanja Valley and ii) the S.W. extension of the Bala arc, bodies of intrusive nephelinite are present. In both micro-ijolite and nephelinite numerous inclusions of coarser-grained rocks of the same suite occur in addition to xenoliths of metasomatized country rock.

It is deduced that the ijolite at Homa is exposed as a series of small cupolas at some of which finer-grained rock is present. At depth these separate exposures are probably more continuous. Evidence for this in part is the widespread inclusion of xenoliths of coarse-grained ijolite in finer-grained rocks of the same suite.

b) Ijolite

The most extensive outcrop occurs at the south foot of the cliffs of the main ring complex at Homa (Fig. 2.2). The westward extension of the outcrop is terminated by a zone of disturbance
or faulting and the eastward extension is overlain by both rocks of the red breccia series and by thin, calcareous beds of later sediments or tuffs. The ijolite is invaded by a fine-grained alkaline hypabyssal rock (hereafter termed the Rapogi phonolite) which takes the form of a low plug at Rapogi Hill (chapter 1, p. 50). This rock contains very numerous rounded and angular fragments of ijolite.

The southern boundary is overlain by soils and only along the northern boundary west of South Valley are there indications of the character of the contacts with the country rock. Even here continuous exposure across the contact is rarely seen, but indicates that the marginal country rocks are brecciated and crossed and re-crossed by several phases of feldspar/pyroxene veins up to 2" across (chapter 4). The contact appears to be sharp and in parts the ijolite near the contact is finer-grained than normal and frequently shows patches of clear feldspar. The area of ijolite immediately south of these outcrops is intruded by several east-west carbonatite (C2b) dykes. Towards the southern part of this part of the outcrop lenses of country rock, often metasomatized to feldspar and feldspar/pyroxene rock are seen surrounded by ijolite. These are often associated with coarse-grained carbonatite without sharp cross cutting margins with the altered country rock. In these cases the alteration of the country rock to feldspar appears to be very marked.
The ijolite outcropping east of South Valley is also cut by Cl and C2 carbonatite dykes. These sometimes include large masses of feldspar rock, some of which appear to be developing new feldspar penetrating the calcite rock. Evidence that feldspar was developing during the emplacement of these dykes is given in another section (chapter 5).

The average rock has a grain size in the region 2.5-10 mm. but variation is frequent, grain size and proportion of light to dark minerals varying quickly in parts of the outcrop. The three major minerals, nepheline, clino-pyroxene and melanite, are usually visible and the grains are mostly anhedral although cubic forms sometimes are visible in the garnet.

The ijolite forms a mainly subdued topography apart from Manera Hill (Fig. 2.2). Sparse low crags are separated by surfaces covered with numerous rounded fragments of ijolite 1-6 cm. in diameter. In addition to the more normal heterogeneous appearance in outcrop two marked textures are seen at intervals: -

i) Brecciated texture.

Some outcrops show angular, subangular and subrounded areas of darker ijolite in a distinctly leucocratic matrix which is often more coarse-grained than the included material. The angular nature of some of the included fragments imply at least two phases of intrusion (Fig. 2.3a). It is not clear whether this was originally a magmatic effect for evidence of replacement of grains by others.
Fig. 2. 3a,b. Melanocratic ijolite fragments included in more leucocratic material; Manera Hill.
is almost ubiquitous in slides studied of the Homa ijolite. Dr. Le Bas (personal communication) notes that in the neighbouring Usaki area of ijolite there is evidence of veins and dykes of urtite invading more melanocratic ijolites. The evidence from Homa is less clear but may indicate later phases of more leucocratic (i.e. urtitic) composition (Fig. 2.3).

ii) Comb texture.

The most marked and widespread directional feature seen in the ijolites is a preferred orientation and elongation of most of the minerals in one part of an outcrop. Pyroxene, wollastonite and apatite show this most clearly. Such elongation is controlled by planes at right angles (foliation), thus giving a sheet or banded appearance to much of the outcrop (Fig. 2.4). The strike of this foliation is reasonably constant and appears also to be parallel to the strike of most carbonatites cutting the ijolite (Fig. 2.5). The dip of the banding in the ijolite is approximately north-east but the nearby carbonatites show much less agreement of dip than of strike with the ijolite. However, on two occasions small (12 in.) coarse-grained intrusions of carbonatite can be shown to have the same inclination as the sheets of comb texture in the nearby enclosing ijolites. The majority of the carbonatites, however, have dips which are opposed to that of the banding, i.e. they dip south-south-west.

In addition to the area of ijolite outcrop marked on the
Fig. 2.4a,b. Coarse and comb textured ijolite; main outcrop. Note in the lower figure that bands of comb texture are not separated.
FIG 2.5 IJOLITE AND CARBONATITE TRENDS IN THE AREA NORTH OF RAPOGI HILL
map (Fig. 2.2), several times this area is believed to be underlain by ijolite at very little depth (Fig. 2.1). Fragments of ijolite, ijolite carrying a considerable growth of late potassium feldspar and rocks derived by metasomatism in the vicinity of an ijolite intrusion are present (chapter 4).

Inclusions of ijolite in the very numerous carbonatitic mixed breccias (chapter 1, p. 41) of the Homa complex are very frequent on the southern slopes of Homa Main but the presence of occasional examples on other parts may indicate that at greater depth even more of the Homa complex is underlain by ijolite.

c) Micro-ijolite.

i) Exposures in the Bala Gully

Micro-ijolite is an important member of the rocks of the Bala arc (chapter 1, p. 71). The greatest exposure is present in the banks of the gully running southwards to the Bala hot springs (Fig. 2.1). Saggerson (1952) reported that three micro-ijolite dykes outcrop in the Bala River and his map indicates the same plus two others of which one has a width of 200 metres across the strike.

During the present work at least five separate bodies of a fine-grained ijolitic rock were encountered while traversing the Bala Gully (fig. 2.6). They are all approximately 50-100 metres wide and are separated by narrow zones of fine-grained metasomatized country rock. The contacts are not always clearly exposed but where
RHOMB PORPHYRY

CBT BLOCKS

CBT VEINS

FIG 2.6
BALA RIVER SECTION

Paleogene sediment
Pronolite dike
Medium grained Buff Sowite
Coarse grained White Sowite
Micro-Ijolite
Country rock altered to Pyroxene + Feldspar
Breciatedjochreous
Feldspathized country rock
Breciated country rock replaced by Iron Oxides
Foliation within altered country rock
Joints, often filled with Carbonatite

Observed contact
Inferred boundary

100
200
Saggerson was not able to trace these extensive bodies along their strike away from the gully and indicates on his map that the area west of the gully is of 'sovite breccia' i.e. brecciated, iron stained and carbonated country rock. This rock is termed here (chapter 1, p.19) ochreous breccia. He notes no exposure to the east and probably did not traverse the area. The present mapping confirms Saggerson's observation and shows also that ijolite is not exposed on the ground which rises gently up to a broad ridge running parallel with the gully to the east. This area has good exposure of brecciated, iron stained and altered country rock cut by occasional dykes of coarse-grained sovite near and at the contact with which the brecciated country rock is feldspathized (chapter 5). Further to the east still the country rock is seen to be less altered.

Thus in an east/west section there are two zones of topographically higher ground occupied by altered, brecciated country rock separated by lower ground down which the Bala Gully runs and in which ijolitic and strongly fenitized rocks occur. It has been noted already that the N.W. trending contacts between the fenite and the ijolite bodies are steep while the lateral extension in outcrop of these bodies appears to be little more than the width of the gully. These observations, together with those in the more northerly part of the gully where the ijolite is seen to
be discontinuous and to include masses of altered, fenitized and iron stained breccia and at loc. 1316 where a low outcrop of ijolite is succeeded westwards by fenite, lead the writer to conclude that here is exposed the very top of a composite body of ijolite whose immediate contacts show great alteration to feldspar/pyroxene rocks (fenites).

This structure may be explained by analogy with a shallow anticline with a slight northward plunge. The $S_1$ surfaces of the anticline are represented by surfaces separating ijolite and fenite, and fenite and ochreous breccia. The core of the anticline has been dissected to a lesser degree in the north than in the south. This has resulted in less ijolite and more fenite being exposed in the north.

The structure as deduced above is shown in diagrammatic form in the sketch sections (Fig. 2.7).

(Ornamentation as on the map of the Bala section, Fig. 2.6.)

ii) Micro-ijolite and xenolithic micro-ijolite elsewhere

The above is the largest area of micro-ijolite at Homa. Significant features are present at smaller outcrops elsewhere within the complex. Small inliers at Yusoo, Ndiru m'bili and Rongo (chapter 1, pp. 54 and 64) show the earliest intrusive phase to be micro-ijolite which outcrops as areas of low relief. Relations are most clear at Ndiru m'bili where metasomatised country rock is in contact with xenolithic micro-ijolite. At this locality also
BLOCK DIAGRAM OF THE BALA GULLY

SECTION DOWN THE BALA GULLY SHOWING THE PRESENT DAY SURFACE 'a-b' AND A RECONSTRUCTION OF THE IJOLITE CONTACT

FIG 2.7 (ornamentation as fig.2.6)
the microijolite appears associated with an intrusion of glimmerite, a black melanocratic rock rich in biotite (p. 139).

d) **Nephelinite**

Small bodies of highly xenolithic intrusive nephelinite are present. This was mapped as microijolite but thin sections revealed a proportion of fine-grained groundmass in which the typical ijolite minerals are porphyritic (Fig. 2. 7a). M1005.

The outcrop in the western part of the Bala arc has had little effect on the country rock, rounded fragments of which are included. At the N.W. end of the Nyasanja Valley (Fig. 2. 1) similar material outcrops. A high proportion of xenoliths including ijolite, microijolite, feldspathic ijolite and fenite are present.

A rock with a similar range of fragments and components but with a micro-breccia texture is seen west of Ndiru Hill (chapter 1, p. 59) and as small outcrops in other parts of the area. It is termed a nephelinitic mixed micro-breccia and an origin by explosive activity is suggested. It is unclear whether this rock is intrusive.

e) **Pyroxenite**

Pyroxenite has a very limited occurrence at Homa but the rock type is considered important enough to mention here. Diopsidic pyroxenite is found at only one outcrop, immediately south of Red Knoll, an ochreous carbonatitic mixed breccia vent (Fig. 2. 2).
Fig. 2. 7a. Intrusive nephelinite from Bala. The fine-grained matrix includes some orthoclase. HC 1005. X 9. P.P.L.
This outcrop is low and relations with the nearby ijolite are unclear. Nowhere is a contact between the pyroxenite and any other rock type exposed, but bands of more ijolitic composition do cross the pyroxenite. It is considered probable that the pyroxenite represents a large mass brought up from depth. Melanlite rich bands are also seen. A single fragment of Jacupirangite was located as a fragment in the lower Lake Cliff series of Homa Lime (chapter 1, p. 85).

More aegirine rich pyroxenite is occasionally seen in thin section but usually in bodies only 1-3 mm. in diameter and in this case appears to be a multiphenocryst.

(3) Evidence for differentiation within the ijolites of Homa

a) Introduction - Assemblages recognized within the ijolites

As a result of detailed study of the ijolites it is possible to divide them into a number of assemblages each of which appears to have a genetic connection with one or more of the others. It must be emphasized that all these assemblages do not represent a series of rock types or individual intrusions but may be more profitably considered as facies of the heterogeneous body of ijolite at Homa.

Seven assemblages are listed here in approximate order of development, from early magmatic to deuteric hydrothermal, and their spatial relationships indicated on the diagram (Fig. 2.8 ).
COMPOSITE SKETCH SECTION TO SHOW THE CHIEF OUTCROPS OF IJOLITE GROUPS

FIG 2.8

- Associated Country Rock
- Fenite
- Ijolite
- Comb. Ijolite
- Apogi Phenolite
## Ijolite Assemblages (Facies) Recognized at Homa Bay

<table>
<thead>
<tr>
<th>ASSEMBLAGE</th>
<th>NAME OF ROCK</th>
<th>OCCURRENCE</th>
<th>DEDUCED MODE OF ORIGIN</th>
<th>CRYSTALLIZATION TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Diopside</td>
<td>PYROXENITE (INCLUDES JAC-</td>
<td>Irregular masses vein by ijolite.</td>
<td>An accumulation of early crystallizing pyroxene.</td>
<td>ACCUMULATE</td>
</tr>
<tr>
<td>B. i) Diopside, perovskite, melanite, nepheline.</td>
<td>DIOPSIDE</td>
<td>Inclusions in</td>
<td>By co-precipitation of nepheline and diopside. An earlier assemblage than most exposed at present surface. Probably more characteristic of the ijolite at depth.</td>
<td>ORTHOMAGMATIC</td>
</tr>
<tr>
<td>ii) Diopside, melanite, nepheline.</td>
<td>IJOLITE</td>
<td>Inclusions in ijolite at Nduru m'bili, also in other parts.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. Diopside partially altered and/or zoned to aegirine-augite, melanite, nepheline. <em>Calcite, apatite, sphene.</em></td>
<td>AEGIRINE-AUGITE, IJOLITE (TYPICAL IJOLITE)</td>
<td>Frequently over most areas of the main outcrop. Often variable in grain size.</td>
<td>Intruded as a magma. Shows evidence of a late volatile/alkali fraction.</td>
<td>ORTHOMAGMATIC AND DEUTERIC STAGE</td>
</tr>
<tr>
<td>D. As C but with late often interstitial wollastonite.</td>
<td>WOLLASTONITE, IJOLITE</td>
<td>A variety of C not distinguishable in the field.</td>
<td>Variety of above in which calcium is concentrated to excess in later fractions</td>
<td>ORTHOMAGMATIC AND DEUTERIC STAGE</td>
</tr>
<tr>
<td>E. Aegirine-augite, nepheline, wollastonite, <em>melanite. (Minerals with marked preferred orientation.)</em></td>
<td>COMB TEXTURED IJOLITE</td>
<td>As bands of comb texture with a strike and rarely dip, similar to some of the nearby carbonatites.</td>
<td>A late assemblage, developed within the main ijolite as a result of syntectonic recrystallization during the emplacement of carbonatites.</td>
<td>METAGMOMATIC RECRYSTALLIZATION</td>
</tr>
<tr>
<td>F. As C or D but with up to 10% interstitial feldspar as well as calcite. The clinopyroxene is often aegirine-augite with aegirine margins. (Minerals are generally of more euhedral habit and rock of often finer-grained nature than the above).</td>
<td>FELDSPATIC IJOLITES AND MICROIJOLITES</td>
<td>Best seen at margins of main ijolite body e.g. N.W. of Rapogi. Also exposed in the Bala Gully which has been deduced as being the upper portions of an ijolite body.</td>
<td>Normal ijolite with a late stage sometimes post-magmatic crystallization of orthoclase, calcite and sodic pyroxene. Feldspar forms either as &lt;2 cm. 'pools' or microscopic euhedra in the groundmass.</td>
<td>ORTHOMAGMATIC HYDROTHERMAL</td>
</tr>
<tr>
<td>G. 70% biotite, <em>Calcite, aegirine-augite and apatite.</em></td>
<td>Glimmerite</td>
<td>A low mass surrounded on all sides by country rock at Nduru m'bili.</td>
<td>Crystallization in the upper portions of a magmatic chamber in which volatiles could not escape.</td>
<td>HYDROTHERMAL</td>
</tr>
</tbody>
</table>
b) List of the groups of data described

1. Evidence from a study of the mineralogy and crystallography of individual mineral species.

2. Evidence from microprobe analysis of individual mineral species.

3. Evidence from chemical and modal analysis.

4. Evidence from mafic olitic cavities.

5. Evidence from varying and transitional assemblages.

6. Evidence from a study of contact relations.

c) Evidence from a study of the mineralogy and crystallography of individual mineral species

1) Introduction

All ijolites studied from Homa contain nepheline, clinopyroxene and a titanium mineral, usually melanite. These minerals are joined on some occasions by one or more of the following: wollastonite, biotite and feldspar. Accessory minerals are usually restricted to apatite.

Replacement and alteration phenomena are frequently seen although difficulty was found in establishing criteria for distinguishing which of two adjoining minerals replaced part or all or any of the other. Replacement of pyroxene by garnet is clearly seen, however, and a sequence amongst the titanium minerals from perovskite→dark melanite→light melanite→sphene was clearly established also.

Alteration of pyroxene to flecks of brown mica, and nepheline to cancrinite, natrolite, analcite and sericite is seen often
and has been assigned to two differing origins: 1. as a result of a deuteric process, 2. as a result of intrusion by carbonatite dykes.

ii) Simplified paragenetic sequence of minerals

a) Ijolite

<table>
<thead>
<tr>
<th>Early magmatic stage</th>
<th>Later magmatic stage</th>
<th>Post magmatic</th>
<th>Deuteretic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pyroxene (diopside)</td>
<td>Aegirine-augite</td>
<td>Calcite</td>
<td>Phlogopite</td>
</tr>
<tr>
<td>Nepheline</td>
<td>Nepheline</td>
<td>Apatite 2</td>
<td>Cancrinite</td>
</tr>
<tr>
<td>Perovskite</td>
<td>Melanite/Sphene</td>
<td>Feldspar</td>
<td>Sericite</td>
</tr>
<tr>
<td>Apatite 1</td>
<td>Wollastonite</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Apatite 2</td>
<td></td>
</tr>
</tbody>
</table>

b) Microijolite

<table>
<thead>
<tr>
<th>Magmatic stages</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st</td>
</tr>
<tr>
<td>Diopside</td>
</tr>
<tr>
<td>Nepheline 1</td>
</tr>
<tr>
<td>Apatite 1</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>2nd</td>
</tr>
<tr>
<td>Aegirine-augite rich in Na.</td>
</tr>
<tr>
<td>Nepheline 2</td>
</tr>
<tr>
<td>Apatite 2</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>3rd</td>
</tr>
<tr>
<td>Cancrinite</td>
</tr>
<tr>
<td>Phlogopite</td>
</tr>
<tr>
<td>Pectolite</td>
</tr>
</tbody>
</table>

iii) Clinopyroxene

a) Measurement of variation within pyroxene

Optical and chemical variation within pyroxenes of ijolites is known to be very great (King, 1962). Measurement of extinction
angles shows that optical orientation varies greatly not only between different grains but between different portions of the same grain. Analyses of over sixty pyroxenes from the alkaline suite of Eastern Uganda can be expressed in terms of the diopside, hedenbirgite and acmite molecules (Tyler and King, 1967). Measurement of the angle between the nearest optic axis and the c crystallographic axis shows that there is a systematic increase in this angle ($A_{\perp}^c$) from more diopsidic to more acmitic pyroxenes. In view of the great similarity of rock type and mode of development between the rocks of Eastern Uganda (King, 1965) and Homa (chapter 1), it is proposed to use the data of King and Tyler as a method of estimating the variation in chemical composition of the pyroxenes from the ijolitic suite at Homa. This has been achieved by interpreting the data (King and Tyler, Fig. 6) as a result of which estimates of pyroxene composition corresponding with five values of $A_{\perp}^c$ have been made:

<table>
<thead>
<tr>
<th>$A_{\perp}^c$</th>
<th>%Di</th>
<th>%Hd</th>
<th>%Ac</th>
</tr>
</thead>
<tbody>
<tr>
<td>16°</td>
<td>66</td>
<td>19</td>
<td>15</td>
</tr>
<tr>
<td>20°</td>
<td>49</td>
<td>30</td>
<td>21</td>
</tr>
<tr>
<td>22°</td>
<td>31</td>
<td>36</td>
<td>33</td>
</tr>
<tr>
<td>24°</td>
<td>19</td>
<td>31</td>
<td>50</td>
</tr>
<tr>
<td>30°</td>
<td>10</td>
<td>21</td>
<td>72</td>
</tr>
</tbody>
</table>

These correlations are approximate only but enable a quick estimate
to be made of the proportions present of the three different end members. In some cases measurement of the extinction angle $X^c$ has also been made. These two angles define $2V$.

b) Clinopyroxene in the pyroxenite

This mono-mineralic rock has an allotiomorphic granular texture and is composed of diopside/augite with the following optical properties:

The grains have pale brown to almost colourless cores, usually margined by colourless borders with lower R.I. The strongest absorption colours were seen in HC 988*: $X =$ pale grey brown, $Y =$ pale brown green, $Z =$ orange brown. $Z > X$ or $Y$.

Measurement of optical orientation gave:

\[
A_1^c = 13.5^\circ
\]
\[
X^c = 48
\]
\[
Bxa = Z \\
\text{Dispersion almost nil.}
\]
\[
2V = 57^\circ
\]

In addition to the \{110\} cleavages a parting on \{100\} is prominent. This feature was also noted from the pyroxenes of ijolites included in the Rapogi phonolite (p. 114). The pyroxenite is being converted in parts to a more ijolitic assemblage and part of this change occurs when the paler original grains are replaced progressively by darker green granules of new pyroxene in which $A_1^c = 20$, i.e. replacement by aegirine-augite is occurring (p. 138).

*HC numbers refer to specimens lodged in the Dept. of Geology, University of Leicester.
c) Clinopyroxene in jacupirangite.

A specimen of coarse-grained melanocratic rock found in the lower Lake Cliff series at Homa Lime was found to have the following mode:

Mode of jacupirangite, HC 44:- (Fig. 2.7). 1230 points - one slide.

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clinopyroxene (mainly titan-augite)</td>
<td>71%</td>
</tr>
<tr>
<td>Magnetite</td>
<td>20%</td>
</tr>
<tr>
<td>Biotite</td>
<td>1%</td>
</tr>
<tr>
<td>Calcite and apatite</td>
<td>5%</td>
</tr>
<tr>
<td>Zeolites</td>
<td>3%</td>
</tr>
</tbody>
</table>

The pyroxene, magnetite and mica are considered original, while the zeolites and fine-grained carbonate are believed to be secondary alteration products. Coarser grained carbonate containing some apatite is considered to have crystallized after the pyroxenite and before inclusion in the lake sediment (Photo.).

No comparable rock has been found elsewhere in the area but because several authors have noted an association in the field between rocks of this nature and those of the ijolite suite, (Barth and Ramberg, 1966; Melcher, 1966), a brief description is given here.

As noted in the mode, most of the pyroxene is considered titaniferous; this was assumed because of the characteristic purple tints of the absorption colours. Such tints are sometimes absent in the cores which show pale yellows. The presence of ≥4% titanium
Fig. 2. 9. Jacupirangite. Mainly zoned titan augite and magnetite. HC 44. X 9. P.P.L.
oxide was confirmed during a microprobe study of a series of pyroxenes from the Homa silicate rocks. These results are tabulated on p. 131.

A sharp boundary exists between the cores and margins across which the refractive index increases to the purple mineral. Study by means of the universal stage shows that the two phases are crystallographically continuous and show no change in the optic plane. The orientation of the X and Y axes changes sharply however:

**CORES**

Pale yellow - colourless

\[ A_1^c = 12^\circ \]
\[ 2V = 58^\circ \]
\[ X^c = 49^\circ \text{ calc.} \]
\[ \text{Bxa} = Z \]

Dispersion - very weak

Pleochroism - weak,

X = pale yellow green

Y = pale green

Z = very pale yellow green

R.I. < Margin

\[ \delta < \text{Margin} \]

**MARGINS**

Purple - brown

\[ A_1^c = 24^\circ \pm 2^\circ \]
\[ 2V = 57^\circ \pm 2^\circ \]
\[ X^c = 35^\circ \]
\[ \text{Bxa} = Z \]

*Dispersion - strong R>V

Pleochroism - medium,

X = pale grey purple

Y = medium purple

Z = pale brown

\[ \delta \text{ rises with purple colour.} \]

Orientation OAP // 010.

The optical data above indicates that the pyroxenes are of the series diopside-augite.

It is of interest that the angle \( A_1^c \) appears to vary in this
pyroxene. It is greatest for those areas richer in titanium. In this case, soda is not increasing so care must be taken in interpreting the angle $A_1^c$ as a guide to substitution within the diopside-hedenbergite-acmite series (Tyler and King, 1967; this chapter p. 110).

d) Clinopyroxene in ijolite and microijolite

1. Diopside

The earliest forming pyroxene noted in the ijolites shows nil or faint pleochroism. It is best displayed in the perovskite bearing ijolites which are only found as xenoliths in the Rapogi Hill phonolite. This paragenesis of diopside, perovskite and nepheline is believed to represent a facies of the ijolite not exposed at the present level. The fact that most of the ijolites seen in situ carry pyroxenes marginally altered to more sodic rims and carry melanite rather than perovskite indicates that they developed from such diopside and perovskite bearing rocks. Measurement of the optical directions of the pyroxene from an example of the Rapogi Hill xenoliths (HC 28B) gave the following:

$$\begin{align*}
X^c &= 50^\circ, 52^\circ, 52^\circ, (51^\circ) \\
A_1^c &= 12^\circ, 12^\circ, 15^\circ, 13^\circ, (13^\circ) \\
\therefore \ 2V &= 52^\circ
\end{align*}$$

Pleochroism nil
Optical sign positive
Parting* // 100

* The occurrence of a prominent parting // 100 in these pyroxenes is unusual in the ijolites at Homa. The fact that a brown oxidation product appears to favour this direction may indicate that it is acting as a plane of incipient alteration. No difference in relief or orientation was detected so an origin by exsolution is
Rocks from elsewhere in the complex sometimes show colourless pyroxenes with similar properties. A rock in which nepheline with triple point junctions is frequent (HC 596; Fig. 2.10) carries interstitial pale pyroxene. Inclusions of ijolite with wholly diopsidic pyroxene are seen in the microijolite of Ndiru m'bili, e.g. in specimen Hc 823 measurement of $X^c = 50^\circ$. Such xenoliths show a gradational border in which these non-sodic pyroxenes are replaced by the more sodic material typical of the microijolite.

Ragged and corroded diopsides are not infrequent in some of the ochreous carbonatitic mixed breccias of the area. Both in these and in the alnoitic tuff of Landslide Gully they are accompanied by biotite (chapter 1, p.22).

There is thus great similarity in optical properties between the pyroxenes characteristic of the pyroxenite inclusions, the earlier pyroxenes of the jacupirangite and those of ijolites earlier or of deeper level than most found at the present surface.

These are believed to represent earlier crystallizing assemblages of the melt which gave rise to the ijolite suite at Homa.

2. Diopside zoned or altered to more sodic portions

Most pyroxenes within the ijolite show a trend towards more sodic compositions during later stages of formation. This is shown in thin section by a deepening of the body colour in greens. The first indications are often irregular patches and areas of green
Concentrating the significance of 'triple point' relations.

Such triple point relations with 3 grain boundaries involving angles of 120° are thought to indicate attainment of stability when seen in annealed metals or metamorphic rocks.

More general knowledge is seen in the microstructure of felsic rocks, where such examples are known, as in metamorphic rocks, if present in a development of local strain in a three-dimensional system, the mechanics of which may be approximated by the following equation:

\[
\sigma_{ij} \equiv \sigma_i \delta_{ij} + \sigma_j \delta_{ij} + \sigma_k \delta_{ik} + \sigma_l \delta_{il} + \sigma_m \delta_{jm} + \sigma_n \delta_{ln}.
\]

This equation is in great contrast with the comparatively simple strain in most of the grains in these rocks. This probably indicates that the strain in the rock in this case and the significance of such a strain is unknown also, but it is held that there might be a profitable line of thought toward the development of metamorphic rocks.

These examples illustrate the characteristics of the particular crystallographic plane or of the highest plane of cleavage of the triple point.


Local strain balance of 3 equal interfacial strains.

In the metamorphic rocks, the tension is in great contrast with the comparatively simple strain in most of the grains in these rocks. This probably indicates that the strain in the rock in this case and the significance of such a strain is unknown also, but it is held that there might be a profitable line of thought toward the development of metamorphic rocks.

These examples illustrate the characteristics of the particular crystallographic plane or of the highest plane of cleavage of the triple point.

FIG 2.10

Triple point junctions of nepheline

HC596
**FIG 2.11**

Soda rich bands traversing pyroxene.

**FIG 2.12**

Calcite filled cavity.

HC 749

HC 865

darker green cpx.

cancrinite

Calcite filled cavity.
both within and at the margins of the grains. Specimen HC 315 shows such features surrounding included apatites and at pyroxene/calcite interfaces. The original pale pyroxene is sometimes seen to be crossed by narrow belts or veins of deeper green material which appears in one case to be associated with a replacing nepheline (HC 749, Fig. 2.11).

In several sections in which carbonate is present the pyroxene in contact shows margins strongly zoned to darker green, margins (Fig. 2.12). In the case illustrated nepheline in contact with the carbonate shows alteration to cancrinite. In other cases no such zoning or alteration may occur.

The margin of ijolite xenoliths included in the Rapogi phonolite show very strong replacement and outgrowth by sodic pyroxene (Fig. 2.12a) on diopside. This growth of sodic pyroxene in contact with the groundmass of a phonolite indicates that this groundmass contains much free soda. There is evidence, therefore, that soda is concentrated in the final stages of the phonolite. It is possible that the later crystallizing stages of the ijolite also concentrate soda which is dispersed in part as metasomatic veinlets (c.f.HC 749) and more often by means of the perhaps fluid or volatile later fractions, e.g. carbonate (c.f.HC 865).

3. Diopside aegirine-augites

Pyroxenes showing a greater area of green body colour and more marked pleochroism are characteristic of many parts of the
Fig. 2. 12a. Diopside perovskite ijolite xenolith included in the Rapogi Hill phonolite. Outgrowths of aegirine augite and finally aegirine occur at the margins of the fragment. The perovskite is rimmed by melanite and both appear opaque in the photograph. HC 28B. X 9. P.P.L.
ijolite. Like most sodic pyroxenes they are distinctly unhomo-
geneous but in general show a deepening colour from the core to
margin. Such pyroxenes are characteristic of much of the micro-
ijolite at Ndiru m'bili and Bala and also the more marginal por-
tions of the main ijolite outcrop N.W. of Rapogi. They are more
idiomorphic and are sometimes accompanied by development of feld-
spar.

Determinations of optical directions:-

i. Normal ijolite with
aegirine-augite (HC 574).

\[ A_1^c = 26^\circ, 19^\circ \text{ and } 23^\circ \text{ in different grains.} \]

ii. Ijolite with zoned
pyroxene (HC 866)

\[ X^c = 47^\circ \text{(core) to } 31^\circ \text{(margin).} \]

iii. Microijolite from
Bala (HC 930)

Showed occasional pale cores
\((X^c = 47^\circ)\) but more often more
homogeneous green colouration
\((X^c = 35^\circ \rightarrow 27^\circ)\). Also \((A_1^c = 23^\circ,
24^\circ, 25^\circ, 23^\circ \text{ in different grains})\).
Pleochroic scheme of these last:

\[ X = \text{deep green}, Y = \text{yellow green}, Z = \text{yellow green}. \]

iv. Ijolite carrying feldspar
from the marginal facies
of the main outcrop (HC 934)

N.B. Pyroxene of deepest
colour and highest \(A_1^c\)
value is in contact
with feldspar.

\[ X^c = 36^\circ, 14^\circ \rightarrow 8^\circ \]

\[ A_1^c = 23^\circ, 23^\circ \rightarrow 12^\circ \]

\[ \text{five single grains} \]

Pleochroic scheme of margins:

\[ X = \text{dark green}, Y = \text{pale green}, \]
\[ Z = \text{yellow-brown green}. \]
v. Intrusive nephelinite from the S.W. extension of the Bala arc (HC 1005).

The mid-green pyroxene is euhedral and prismatic and measurements on different grains gave:

\[ X^\circ = 34^\circ, 30^\circ, 30^\circ, 28^\circ. \]
\[ A^\circ c = 24^\circ, 24^\circ; \quad Bxa = 2 \]

In addition to the variation indicated by these measurements most grains have a narrow border of deep green, aegirine-rich material.

4. Mossy outgrowths of aegirine

In the microijolite and more often the intrusive nephelinite of Bala the last pyroxene to crystallize did so as ragged, very deep green outgrowths on previously idiomorphic grains. This feature is more commonly seen in the lavas of phonolite composition of the area and may indicate a link between the finer-grained ijolitic types (which often carry feldspar, see p. 127) and phonolites.

e) Trends shown by clinopyroxene compositions determined optically

The above data indicates that a very marked increase in acmite content occurs in the later stages of crystallization of pyroxene at Homa. The highest acmite content (>75%) is present in the margin of pyroxene at pyroxene/feldspar interfaces. This assemblage is discussed later (p. 127). The optical data indicates that while diopside is characteristic of pyroxenite and much of the coarse-grained ijolite, the microijolites characteristically carry aegirine-augite.
There is thus a variation towards soda rich compositions in the later crystallizing portions and more marginal and roofing facies of the ijolites.

iv) Nepheline

The characteristic felsic mineral of the ijolites is nepheline which most often occurs in irregular intergrowth with the other minerals (HC 940, Fig. 2.13). Triple point junctions are occasionally well developed (HC 596, Fig. 2.10) and elongation parallel to the c axis is seen in the comb textured ijolite (p.141).

As well as pyroxene, nepheline and melanite tend to be more euhedral when in contact with later crystallizing feldspar and/or calcite. It is believed that such a textural relationship is developed in an analogous fashion to that of drusy cavities in other rocks. The earlier crystallizing minerals grow into a cavity or segregation of material which eventually crystallized as feldspar and/or calcite. An alternative explanation is considered by Dr. Sutherland (personal communication) who believes that the feldspar may have grown by replacement of the nepheline and has replaced it along crystallographic directions preferentially.

Apparent replacement of pyroxene by nepheline is often seen (fig.2.14, HC 736). In this case nepheline encroaches on and embays the pyroxene, sometimes isolating (in the plane of the slide at least) two portions of an optically continuous crystal. In specimen
FIG 2.13

Ijolite with allotriomorphic texture.

HC 940

FIG 2.14

Nepheline replacing (?) pyroxene.

HC 736
FIG 2.15

HC 84a

Optically continuous fragments of pyroxene in nepheline.
HC 84a (Fig. 2.15) a texture is present which might be interpreted as a more advanced case of the phenomenon shown in the previous figure. At every interface the nepheline embays the pyroxene, all five disconnected portions of which are in optical continuity. The writer prefers to believe that this is evidence of replacement of pyroxene by nepheline but accepts that the texture may result from ophitic growth of pyroxene.

Nepheline and pyroxene are often seen to be earlier in the crystallization history than melanite which may send out projections along the interfaces of adjacent nepheline (HC 940, Fig. 2.13). Relations with wollastonite (p.123) are not clear but some contemporaneous crystallization has taken place. Small apatite sections of the first generation are enclosed.

More idiomorphic nepheline of two generations is characteristic of the microijolite outcrops at Homa. The numerous square and hexagonal cross sections of the earlier are seen to include orientated rods and grains of aegirine in their outer zones. The second generation nepheline is confined to the groundmass and accompanies aegirine and feldspar.

Two styles of nepheline alteration have been noted, a) that resulting in the development of cancrinite at nepheline/calcite borders (Fig. 2.12), b) that which develops as a series of very small micaceous flakes, often along the nepheline cleavages. These patches may increase in area until the complete nepheline is
replaced. Powder photos. of such material show the presence of sericite and analcite. Nepheline altered in this way is often associated with late crystallizing segregations of calcite and/or feldspar, often filling the vughs previously mentioned (p. 119).

v) Titanium bearing minerals

A paragenetic sequence of titanium minerals is clearly demonstrated in the rocks from Homa. Perovskite is characteristic only of rare assemblages found as inclusions in the cross cutting Rapogi phonolite. Melanite is typical of the majority of ijolites while sphene accompanies and more often follows the development of melanite.

Perovskite has a dark brown colour, high relief, anomalous interference colours and shows multiple polysynthetic twinning. In section HC 27 it forms the majority of the titanium mineral present. It is sometimes rimmed by and altering to melanite. The melanite directly in contact shows a deep almost opaque brown colour (Fig 2.16).

Melanite is the most common mineral of this group, occurring in every specimen studied. Its habit is variable from irregular masses to euhedra. Frequent colour zoning is seen, the outer zones being usually a less deep colour. Rhythmic colour zoning is sometimes seen. Preliminary counts with the microprobe show that variations in titanium oxide content are marked. Values from 5 to 12% were recorded (see p. 135).
Fig. 2. 16. Perovskite habit in ijolite. Polysynthetic twinned perovskite granules sometimes included and replaced by melanite. HC 28B. X 180. X.N.

**FIG 2.17**

Skeletal melanite in calcite.
The most euhedral melanite is found in the microijolites and nephelinites. The relations of melanite with calcite are of interest. Euhedral melanite is frequently best developed in the presence of calcite. In some cases optically continuous plates of carbonate include discontinuous or skeletal melanite (HCR 17, Fig. 2.17). In this case some solution or replacement of the melanite is seen because the colou...
HCR17
Melanite of two shades replacing pyroxene

HC 321a
Sphene replacing melanite
A brown, high relief mineral with high birefringence and a cloudy leucoxene-like alteration product is identified as rutile in one section (HC 574). It is altering to a sphene-garnet intergrowth.

vi) Other minerals within the ijolite

a) Wollastonite

This mineral is present in one quarter of the thin sections studied and in the wollastonite ijolites attains the status of an essential mineral. It is a prominent member of later crystallizing assemblages, being associated sometimes with second generation apatite (HC 736, Fig. 2.20) and the period of crystallization resulting in the formation of feldspar and calcite. It is also prominent in some bands of comb textured ijolite in which it assumes a marked prismatic habit being often visible as satiny prisms ≤ 2-3 cm. long. Wollastonite also fills interstitial areas very much as do feldspar and carbonate.

A further example of an assemblage containing stable wollastonite occurs at the margin of a very coarse diopside bearing ijolite fragment included in a fine-grained lava similar to the Rapogi phonolite (chapter 1, p. 50). In this case, wollastonite (2V, -ve, = 37°), sphene and feldspar (2V, -ve, = 36°) euhedra are all enclosed in large poikilitic plates of calcite and appear equally stable (HC 743, Fig. 2.21).

Occasional embayment of wollastonite by nepheline may indicate
Fig. 2.20. Wollastonite-rich portion of ijolite. Opaque melanite, dark aegirine augite and high relief apatite are also present. HC 736. X 9. P.P.L.

Marginal zone of an ijolite fragment in syenite.
that the periods of crystallization overlapped. In the same specimen (HC 964) alteration of nepheline and wollastonite occurs adjacent to interstitial carbonate. Nepheline is replaced by cancrinite and wollastonite by pectolite (Fig. 2.22).

b) Apatite

Accessory apatite is present in nearly all slides studied in two separate generations. The earlier occurs as chadacrysts within nepheline and no alteration surrounds them. The much more prominent second generation apatite characterises assemblages believed for other reasons to be later. In this case the apatite is coarser-grained, often markedly prismatic and sometimes occurs in clusters or tightly packed areas (HC 962, Fig. 2.23). In the example shown apatite surrounds euhedra of pyroxene zoned to acmite rich margins, i.e. the apatite has the same relation to the pyroxene as does calcite and feldspar in other cases. Similar apatite accompanies wollastonite in HC 736 (Fig. 2.20).

A more direct association of apatite with carbonate is often seen. A two inch carbonatite vein within ijolite shows clusters of apatite of second generation type towards the contact (HC 330, Fig. 2.24).

c) Calcite

Calcite is present in most of the sections of ijolite studied. It is often accompanied by alteration of adjacent minerals, e.g. development of cancrinite against nepheline, orange-brown biotite
HC 964
Alteration of wollastonite and nepheline near calcite.

Fig. 2.23. Aegirine augite euhedra zoned to aegirine borders and enclosed in high relief apatite. Sparse nepheline is present in the upper part of the figure. HC 962. X 9. P.P.L.
Fig. 2. 24. 4 cm. sovite vein intruding wollastonite ijolite. Several aegirine augite grains have become isolated and partially replaced by carbonate. Coarse apatite of the second generation occurs in clusters at the contact and within the nearby carbonatite. A very fine-grained ferruginous carbonatite vein cuts and brecciates the sovite in the upper part of the figure. Stringers of fluorite and carbonate rich material cut all other phases. HC 330, X 9. P.P.L.
in clinopyroxene, sodic rims and areas within clinopyroxene, and pectolite in wollastonite. Examples of such relations appear under the individual mineral descriptions.

In most of these cases calcite occurs either as narrow cross cutting stringers (HC 596, Fig. 2.25) or as late infillings between the other minerals. When present as large plates or pools, it allows the adjacent minerals to develop euhedral faces (c.f. feldspar, apatite), particularly melanite. In some rocks melanite appears to develop rather like a scarn mineral by reaction of pre-existing rocks with incursions of material of which calcite is a major phase, e.g. HC 938a, 365 (p.138). In other cases (HC 330, Fig. 2.24) when calcite is present as large plates, prisms of the second apatite generation are included. Apatite of the same habit is seen both within the ijolite and the carbonatite. In this case little reaction with the ijolite minerals is seen. The chief feature of an irregular intergrowing contact is marked replacement of pyroxene by carbonate.

Specimen HC 482 shows a 2 cm. vein of fine-grained carbonate cutting a block of highly altered ijolite. Stringers of coarser-grained carbonate cut this vein and feldspar is developing at their margins and along the margins of the earlier vein. The nepheline of the ijolite is altered to a very fine-grained micaceous mineral and the clinopyroxene to mica and iron oxides in areas crossed by carbonate veins. The new feldspar occurs towards the centres of
FIG 2.25

HC 596

Dilationary calcite vein.
these veins. Calcite and apatite are strongly represented in the
glimmerite of Ndiru m'bili.

Any explanation of the part played by carbonate during the
development of the ijolites must take into account the fact that
every outcrop of ijolite is intruded or accompanied by numerous
carbonatite dykes. From the above observations it can be seen that
carbonate occurs in two contrasting relationships:-

A. As interstitial plates and vughs between the other minerals.
In these cases reaction is less between the silicate minerals
and the carbonate.

B. As cross cutting, dilating stringers or veins. Reaction is
often more marked in these cases, particularly involving
the formation of the potassium phases - biotite and ortho-
clase.

In view of the large number of cross cutting carbonatites,
it appears likely that some at least of the carbonate in the ijolites
is introduced during the emplacement of the large carbonatite dykes.
The carbonate within the vughs, however, is assigned as a late crys-
tallizing, primary phase of the ijolite. Feldspar with the same
textural relations is similarly assigned.

d) Feldspar

The presence of up to 10% modal, low temperature, soda-poor
orthoclase was noted in several ijolites, particularly those from
near the contact N.W. of Rapogi, the microijolite of Bala and more
rarely elsewhere. Mineralogically these rocks are near malignites (Johannson, 1939) but are here termed feldspathic ijolites because of their genetic connection with ijolites.

Another group of rocks with some ijolitic characters but carrying more than 10% feldspar and accompanying rocks of syenitic aspect are described in chapter 4.

In each case the feldspar bearing rocks have characters indicating that they are facies of the ijolite near or at the contact with country rock e.g. the Bala microijolite is believed to represent the very top of a composite intrusion and thus represents a marginal facies.

In the ijolite N.W. of Rapogi large (1-3 cm.) grey feldspar crystals are seen within the otherwise normal ijolite. Thin sections show large pools of clear, rarely twinned feldspar into which the essential ijolite minerals mostly project as euhedral forms (HC 934, Fig. 2.26). This phenomenon has already been discussed on p. and two explanations noted. The writer believes that the feldspar crystallized very late in the sequence of minerals from a fluid into which idiomorphs of the earlier ijolite minerals were able to develop freely, i.e. the feldspar was a post magmatic stage crystallization. Mention has already been made (p. 116) of the marked enrichment in soda of the last clinopyroxene crystallizing at clinopyroxene/feldspar interfaces (HC 865, Fig. 2.27). More rarely the feldspar exhibits a replacive habit towards the nepheline and pyroxene
Fig. 2. 26. Feldspar (orthoclase) filling a vugh into which project euhedral nepheline and aegirine augite. HC 934. X 6. P.P.L.

Fig. 2. 27. Euhedral, zoned clinopyroxene included in late crystallizing orthoclase. HC 865. X 160. X.N.
Fig. 2. 28. Later crystallizing feldspar replacing aegirine augite. HC 865. X 160. X.N.
The similarity between the relations of calcite, feldspar and wollastonite in that they all crystalize late in the sequence is also seen in an assemblage at the margin of a fragment of diopside ijolite included in Rapogi phonolite (see p. 123). Here all three of the above minerals, together with sphene, are present, the feldspar and calcite being the latest to crystallize.

The relations of feldspar within the microijolite at Bala are a little different, the mineral appearing mainly as small laths accompanying nepheline between the main coarse-grained mineral species. Occasionally larger plates are seen poikilitically including numerous aegirine needles. Late vughs as described from the main ijolite are not seen but once again the feldspar is late in the paragenetic sequence. It follows the main period of pyroxene, nepheline and garnet crystallization and accompanied the formation of the most soda rich pyroxenes.

X-ray diffraction studies show that the albite content is very low in these feldspars. Measurement of 2V gives values of 35-40°(-ve) with the O.A.P. orientated parallel \( \{010\} \). Dispersion \((r>v)\) is medium and the plates are mostly optically homogeneous. This data confirms the low temperature and soda-poor nature of the characteristic feldspar crystallizing late and accompanying acmite pyroxene in the ijolites.

Feldspar accompanying cross cutting carbonate veins and string-
ers is seen in many parts of the ijolite and is considered in chapter 5.

e) **Biotite**

Large poikilitic plates of mica ($X = \text{pale buff}, \ Y = \text{grey green}$) are sometimes seen in the perovskite bearing ijolite ($\text{Mg}/\text{Fe ratio}^{\text{distribution}}$ by microprobe; HC 28b, Fig. 2.12a). Biotite ($X = \text{pale buff}, \ Y = \text{dark brown}$) with similar habit was seen in the jacupirangite (HC 44, p. 112). In these cases the mica is believed to be a late primary phase in the rocks.

Biotite ($X = \text{pale yellow-brown}, \ Y = \text{orange-brown}$) rich rocks called glimmerite are found at Ndiru m'bili (chapter 1, p. 63) and are believed to result from the deuteric alteration of ijolite (p. 139).

Irregular growth of orange-brown biotite flakes by alteration of ferro-magnesium minerals are common in many sections studied. This patchy alteration is believed to be a late stage or transgressive metasomatic effect probably accompanying the crystallization of carbonate. Small euhedra of similar material is occasionally seen associated with calcite, sphene and melanite (HC 321a, Fig. 2.19)

f) **Pectolite**

Pectolite occurs as ragged plates after wollastonite in the main ijolite (p. 123) but in the microijolite at Bala it has a poikilitic habit enclosing second generation nepheline and is
believed to result from a primary crystallization in the rather different conditions expected near the upper contacts of ijolite bodies.

d) Evidence from microprobe analyses of individual mineral phases

i) Variation of the chemical composition of pyroxenes

The section above in which the texture and habit of the pyroxene in various rocks of the ijolite suite was described included optical data which indicated that a great range of pyroxene composition is present in the ijolitic suite at Homa.

The optical data also indicates that variation in composition exists within a single grain.

Although much analytical data has already appeared on the pyroxenes from the very similar rocks of Eastern Uganda (Tyler and King, 1967), it was decided that a microprobe study of some pyroxenes from Homa would be very useful, particularly in the case of optically inhomogeneous grains. The fact that the microprobe can be used to analyse small areas within individual grains was thought to outweigh in usefulness the standard deviations involved. The deviations applied to the results are much greater than in classical analysis being of the order ± 10% of the total present for each oxide except Na₂O (± 50%). Nevertheless, inspection of the results shows that such deviations do not invalidate the trends shown by the mean:-
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<td>3.00</td>
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</table>

**Notes:**
- The table represents data collected at various time intervals.
- Analysis of the data reveals significant changes at certain points.
- Further investigation is recommended for a comprehensive understanding.

**Conclusion:**
- The observed patterns indicate potential issues that require immediate attention.
- Further tests and experiments are warranted to confirm the findings.
Owing to the inability of the method to distinguish between the different oxidation states of a single element all iron is expressed as Fe$_{2}O_{3}$ in these analyses. Fifteen differing grains or portions of grains were analysed, including two pairs of like grains from each of the pyroxenites HC 44 and HC 988a as a test of homogeneity. The results have been placed in order of increasing Fe$_{2}O_{3}$ content as this was seen to show the widest variation. This results in the analyses of differing portions of the same pyroxene being separated from each other in each case where optical inhomogeneity was noted. An analysis of pyroxene from a fenite is also given (No. 15).

The progressive compositional changes predicted from the optical data are seen and indicate that increasing proportions of aegirine characterise the later crystallizing portions of the ijolite body and also the fenite.

The fragment of jacupirangite carries pyroxenes with cores of diopside mantled with a pyroxene of very different composition, namely an augite rich in titanium and particularly so in alumina. Study of this analysis (No. 5), indicates that the alumina is substituting for silica. This pyroxene is, therefore, crystallizing from a melt rich in TiO$_2$ and alumina and poor in silica. The mode of the parent rock (p. 112.) shows the presence of biotite, magnetite, $K_2O$, calcite and apatite. This indicates that Fe$^{++}$, $H_2O$, CO$_2$ and $P_2O_5$ were also available in the melt. It is, therefore, concluded that
the jacupirangitic titan augite results from the crystallization of a melt which would precipitate nepheline and more acmitic pyroxene but for the absence of Na₂O.

ii) Preliminary microprobe analysis of four nephelines for alkalies

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<th>Sample</th>
<th>K₂O</th>
<th>Na₂O</th>
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<tbody>
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<td>HC 28B (diopside ijolite)</td>
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<td>18.5</td>
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<tr>
<td>HC 934 (feldspatic ijolite)</td>
<td>7.9</td>
<td>17.5</td>
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<tr>
<td>HC 1005 (feldspatic nephelinite - phenocryst)</td>
<td>7.5</td>
<td>19.5</td>
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<td>HC 1005 (feldspatic nephelinite - groundmass)</td>
<td>7.0</td>
<td>19.0</td>
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Conclusion. The results do not show a significant trend but suggest that later crystallizing nephelines may be richer in Na₂O.

iii) Preliminary microprobe analysis of three melanites for titanium dioxide

<table>
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<th>Sample</th>
<th>% TiO₂</th>
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</thead>
<tbody>
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<td>5.5</td>
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<tr>
<td>HC 464 (main ijolite)</td>
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<td>HC 1005 (feldspatic nephelinite)</td>
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</tbody>
</table>

Conclusion. The TiO₂ percentage in melanite does not vary systematically with known trends, on this evidence.

e) Evidence from modal and chemical analysis

Five new chemical and seven new modal analyses are available from rocks of the ijolite suite at Homa. Also plotted is one (41/1000) previously published (Saggerson, 1952, p. 35).
The analyses are arranged in order of decreasing grain size of the rocks:

HC 309 - Heterogeneous normal ijolite of coarse-grained type.
HC 356 - Normal ijolite.
41/1000 - Ijolite from Homa.
HC 936 - Feldspathic ijolite from the marginal facies N.W. of Rapogi
HC 929 - Microijolite from Bala.
HC 912 - Feldspathic microijolite from Bala.
HF 89A - Intrusive feldspathic nephelinite from North Homa.
HC 1005 - Intrusive nephelinite from Bala.

Modal analyses of further ijolite samples from Homa are given by Saggerson (1952, p. 34).
### Modal Analyses

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<th>HC356 41/1000</th>
<th>HC936</th>
<th>HC929</th>
<th>HC912</th>
<th>HF89A</th>
<th>HC1005</th>
</tr>
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<tbody>
<tr>
<td>Clinopyroxene</td>
<td>28(19-32)</td>
<td>19.0</td>
<td>32.0</td>
<td>26.0</td>
<td>32.0</td>
<td>50.0</td>
<td></td>
</tr>
<tr>
<td>Nepheline</td>
<td>47(37-53)</td>
<td>53.0</td>
<td>26.9</td>
<td>34.0</td>
<td>41.0</td>
<td>23.0</td>
<td></td>
</tr>
<tr>
<td>Melanite</td>
<td>16(8-25)</td>
<td>23.0</td>
<td>8.0</td>
<td>18.0</td>
<td>9.0</td>
<td>4.5</td>
<td></td>
</tr>
<tr>
<td>Apatite</td>
<td>1.0</td>
<td>2.0</td>
<td>2.5</td>
<td>3.0</td>
<td>2.0</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td>Calcite</td>
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<td>0.5</td>
<td>4.5</td>
<td>1.0</td>
<td>0.5</td>
<td>0.5</td>
<td></td>
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<tr>
<td>Sphene</td>
<td>0.5</td>
<td>0.5</td>
<td>-</td>
<td>-</td>
<td>1.5</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>Biotite</td>
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<td>4.0</td>
<td>1.0</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Cancrinite</td>
<td>5(4-8)</td>
<td>1.5</td>
<td>-</td>
<td>} 8.0</td>
<td>} 3.0</td>
<td>} 11.0</td>
<td></td>
</tr>
<tr>
<td>Zeolite</td>
<td>-</td>
<td>-</td>
<td>21.3</td>
<td></td>
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<tr>
<td>Feldspar</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>5-10%</td>
<td>-</td>
<td>10.0</td>
<td>some</td>
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<tr>
<td>Wollastonite + pectolite</td>
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<td>0.5</td>
<td>-</td>
<td>10.0</td>
<td>1.0</td>
<td>2.0</td>
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<td>CHEMICAL ANALYSES</td>
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<tr>
<td>------------------</td>
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</tr>
<tr>
<td></td>
<td>HC309</td>
<td>HC356</td>
<td>41/1000</td>
<td>HC936</td>
<td>HC929</td>
<td>HC912</td>
<td>HF89A</td>
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<tr>
<td>SiO₂</td>
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<td>38.35</td>
<td>40.27</td>
<td>41.42</td>
<td>42.89</td>
<td>45.64</td>
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<tr>
<td>Al₂O₃</td>
<td>14.99</td>
<td>14.38</td>
<td>18.02</td>
<td>14.35</td>
<td>14.91</td>
<td>15.44</td>
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</tr>
<tr>
<td>FeO</td>
<td>2.73</td>
<td>2.63</td>
<td>3.18</td>
<td>2.44</td>
<td>2.16</td>
<td>2.73</td>
<td></td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>6.08</td>
<td>7.52</td>
<td>4.78</td>
<td>7.53</td>
<td>5.22</td>
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<tr>
<td>TiO₂</td>
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<td>3.16</td>
<td>2.48</td>
<td>2.74</td>
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<td>1.50</td>
<td></td>
</tr>
<tr>
<td>MnO</td>
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<td>0.20</td>
<td>0.12</td>
<td>0.22</td>
<td>0.38</td>
<td>0.23</td>
<td></td>
</tr>
<tr>
<td>CaO</td>
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<td>17.53</td>
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<td>14.90</td>
<td>15.10</td>
<td>9.81</td>
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<tr>
<td>MgO</td>
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<td>2.70</td>
<td>3.38</td>
<td>2.00</td>
<td>1.90</td>
<td>1.85</td>
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<tr>
<td>K₂O</td>
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<td>2.99</td>
<td>2.14</td>
<td>2.93</td>
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<td>Na₂O</td>
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<td>6.57</td>
<td>6.26</td>
<td>5.19</td>
<td>9.11</td>
<td>6.30</td>
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<tr>
<td>H₂O⁻</td>
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<td></td>
<td>0.56</td>
<td>0.30</td>
<td>0.32</td>
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<tr>
<td>H₂O⁺</td>
<td>0.88</td>
<td>0.47</td>
<td>1.60</td>
<td>2.11</td>
<td>1.61</td>
<td>4.15</td>
<td></td>
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<tr>
<td>CO₂</td>
<td>0.93</td>
<td>1.09</td>
<td>1.39</td>
<td>1.26</td>
<td>1.59</td>
<td>3.74</td>
<td></td>
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<tr>
<td>P₂O₅</td>
<td>0.61</td>
<td>0.83</td>
<td>0.28</td>
<td>0.71</td>
<td>1.05</td>
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<td></td>
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<tr>
<td>Total</td>
<td>98.29</td>
<td>98.87</td>
<td>99.223</td>
<td>98.42</td>
<td>99.47</td>
<td>100.00</td>
<td></td>
</tr>
</tbody>
</table>


*Total includes 0.02 Cl and 0.003 S.
f) Evidence from the presence of microlitic cavities

Rarely within rocks of otherwise normal facies type prominent sub-spherical bodies are seen, usually 2-8 cm. in diameter. These are margined by subordinate nepheline and prominent dark green pyroxene showing idiomorphs projecting into the more leucocratic central portion. In thin section these microlitic cavities (Fig. 2.29) are seen to be filled mainly with rhombs of calcite and plates of natrolite. The natrolite appears primary and is not pseudomorphing or replacing a previous mineral. Apatite and sphene are also seen in the centre of these bodies.

As deduced for the smaller series of cavities in which late feldspar crystallizes (p. 127) it is believed that the idiomorphic pyroxene projecting into the cavity is evidence that its contents represent crystallization of post magmatic material. This material is deduced to have been rich in CO₂, H₂O and alkalies from the minerals now present.

g) Evidence of one assemblage being made over to another

The above data on the properties and relations of individual mineral species indicates also the general sequence of assemblages. In addition three cases were noted where one rock shows evidence of two different assemblages.

A. In which a diopсидic pyroxenite is being converted to an ijolitic assemblage.

In an earlier description of the field relations of the pyroxenite bodies west of Rapogi it was mentioned that at intervals
Fig. 2. 29. Microlitic cavity in normal ijolite. Cavity is filled with rhombic outlined calcite and plates of natrolite. Idiomorphic aegirine-augite surrounds the cavity and high relief sphene is present showing an irregular system of cracks. HC 321A. X 9. P.P.L.
they are crossed by veins and stringers < 4 cm. wide of both ijolitic and melanite-rich mineral assemblages.

A thin section study of these rocks shows that replacement of the pyroxenite appears to have occurred rather than intrusion. In specimen HC 988a a 2 cm. zone of mesocratic ijolite is bordered by melanocratic diopside rock (Fig. 2.30). The lack of sharp borders can be seen and at higher powers (Fig. 2.31), evidence of mode of development. The original pyroxenes are surrounded and replaced by granules of a darker green more sodic variety (p.111). Melanite develops around these and large plates of nepheline between areas of pyroxene and melanite. Alteration to cancrinite is seen at the borders of some nepheline grains. The crystallization of new silicates was accompanied by that of calcite and apatite.

Another example is seen, HC 989a (Fig. 2.31), of a 2 mm. vein along the margins of which garnet has replaced the pyroxene and projects well formed faces out into the vein. The vein is filled with nepheline, calcite and apatite and in this case there is no evidence of reaction between the nepheline and carbonate (Fig. 2.33). Occasional nepheline is developed throughout the matrix. Sphene and orange-brown mica are often accessory in the more ijolitic portions of these rocks.

Some idea of the chemical differences involved may be seen by comparing the analyses of typical ijolites (p.136) with that of the pyroxene from the pyroxenite (p.131). This indicates that
Fig. 2. 30. Narrow zone of ijolite traversing pyroxenite.

HC 988. X 6. P.P.L.
Fig. 2. 31. Aegirine augite granules surrounding and replacing original paler coloured pyroxene. Nepheline plates have also developed and are altering to cancrinite where in contact with calcite. Dark melanite surrounds some of the new mafic mineral. HC 933. X 40. P.P.L.
Fig. 2. 32. Calcite-nepheline vein crossing pyroxenite. The coarser, pale diopsidic pyroxene is seen replaced by darker (more sodic) pyroxene towards the vein. Melanite (opaque) has developed at the margins of the vein. HC 989A. X 9. P.P.L.

Fig. 2. 33. As Fig. 2.32. Detail of the vein. No cancrinite has developed at the calcite/nepheline interface. HC 989A. X 40. X.N.
The oxides chiefly increased in the leucocratic assemblage are those of the alkalies, alumina, carbon and phosphorus. The writer believes that transformation to an ijolitic mineralogy took place along zones which look superficially like veins but are seen to have gradational contacts and concludes that the production of an ijolitic assemblage is at least in part due to metasomatic transformation brought about by the passage of carbonatic alkali-rich volatiles along zones of weakness within the pyroxenite. Conditions might occur at the top or margins of a magmatic body, such as described by Pullenoy (1958) to explain the ijolite association in the Bushveld complex. He concluded that this suite of minerals was produced by reaction of alkali carbonatitic volatiles with a rock containing the minerals aegirine-augite and pyroxene. The ijolite contains no aegirine-augite, but both phenocrysts and groundmass are present. The pyroxene is altered to iron oxides in part. Carbonate and apatite of a form similar to that of the second generation seen in ijolites (p. 124) make up the remainder of the rock, nepheline is not seen. These relations indicate that an earlier suite of minerals of which only aegirine-augite relics remain was included in material rich in K<sub>2</sub>O, CO<sub>2</sub>, P<sub>2</sub>O<sub>5</sub> and H<sub>2</sub>O. The Na<sub>2</sub>O released during the breakdown of the pyroxene was not fixed in this rock and is presumed to have been transferred elsewhere, possibly as a metasomatic front.
The writer believes that the above features have similarities with those already noted as occurring in the later stages of the crystallization of ijolite in which carbonate and apatite are late in the sequence (p. 125), and small patches of biotite develop by replacement of pyroxene (p. 124). It appears, therefore, that the glimmerite may develop under conditions existing late in the crystallization history of normal ijolite but in which the late stage and deuteric effects are greatly enhanced.

Such conditions might occur at the top or margins of a magmatic body at which volatile concentration was great. An explanation similar to this was proposed by Pulfrey (1950) to explain the presence of glimmerite at Usaki which contains over 80% biotite. He concluded that biotite-rich facies are characteristic of cupolas over ijolite bodies. The term glimmerite was also used to describe a rock containing 98% biotite believed to have developed under hydrothermal conditions at the margins of a pyroxenite mass (Larsen and Purdee, 1929).

In the present case the evidence not only illuminates phenomena connected with the development of ijolites but also those concerned with the origin of carbonatites for the mineralogy of the glimmerite is similar to that of many carbonatites except for the relative proportion of minerals present.
Fig. 2. 34. Band of comb-textured wollastonite ijolite crossing more melanocratic granular ijolite rich in melanite. HC 649. X 1. P.P.L.
Evidence of variation from a study of comb textured ijolite.

Note has already been made of the occurrence and preferred strike of the linear belts or sheets within the ijolite which show a preferred elongation of minerals at right angles to the strike of the belts. Photographs of exposures of such texture (Fig. 2.44) show that several comb textured bands may adjoin without recognisable 'screens' between them. It is concluded that their distribution is controlled by some imposed stress pattern. This stress pattern also appears to have controlled in part at least the orientation of the cross cutting carbonatites of the main outcrop (Fig. 2.5). The sheets of comb textured ijolite resemble dilations which have been filled but the margins in thin section are seen not to be sharp. They are similar to the ijolite pegmatites described from E. Uganda (King, 1965).

One of the characteristic minerals of ijolite showing such comb texture is wollastonite, a mineral which readily assumes a prismatic habit. Examination of some specimens shows that wollastonite and melanite have an antipathetic relationship in granular and comb textured ijolite. The following are modes of two areas within a single hand specimen (HC 649; Fig. 2.34):

<table>
<thead>
<tr>
<th></th>
<th>% Granular ijolite</th>
<th>% Comb textured ijolite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clinopyroxene</td>
<td>19</td>
<td>29</td>
</tr>
<tr>
<td>Nepheline</td>
<td>25</td>
<td>41</td>
</tr>
<tr>
<td>Melanite</td>
<td>45</td>
<td>0</td>
</tr>
</tbody>
</table>
Two alternative explanations of this difference are discussed below.

a. That the difference is caused by the imposition of a stress pattern within the ijolites which caused recrystallization of minerals in preferred orientation. Pyroxene, apatite, nepheline and wollastonite all adopt a prismatic habit within bands of comb texture while the cubic melanite is much reduced or absent (as in the case above). This suggests that the crystallization of the cubic mineral may be suppressed in such conditions. The additional calcium and iron may be taken up by the increased amount of pyroxene and the wollastonite. This explanation contrasts with the known behaviour of garnets in metamorphic rocks e.g. schists. (NB. MJD states that this comparison is not valid.)

b. The second explanation involves an origin as separate intrusions or segregations into or within the ijolite body. Minerals present within them are characteristically later crystallizing phases (wollastonite and aegirine-augite) and the increased grain size and comb texture indicate affinities with pegmatites of intrusive bodies elsewhere in the world. The writer favours the second

<table>
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<tr>
<th></th>
<th>Granular ijolite</th>
<th>Comb textured ijolite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wollastonite</td>
<td>0</td>
<td>21</td>
</tr>
<tr>
<td>Calcite</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Apatite</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Sphene</td>
<td>2</td>
<td>0.6</td>
</tr>
<tr>
<td>Zeolite</td>
<td>2%</td>
<td>0.3%</td>
</tr>
</tbody>
</table>
explanation and believes that the similarity in strike of the sheets of comb texture and that of carbonatites cutting the ijolite (Fig. 2.5 p. 101) indicates that some structural control common to both existed and that as both may fill dilations within a large ijolite body, a genetic control may also be indicated.

It is recognised that the problem of the sheeted, comb textured ijolites is not adequately covered in this account and it is believed that the problem should form the basis of a more detailed study of such phenomena, including those of the much larger expense of ijolite exposed at Usaki (Le Bas, 1966).

h) Evidence from a study of contact relations.

A detailed description and discussion of the phenomena present at the contacts of ijolite with country rock is given in chapter 4. The commonest feature present at such contacts is evidence of the conversion of country rock near the contact to a rock rich in orthoclase and aegirine (aegirine orthoclase fenite).

That the mineralogy of these fenites is very similar to that of some of the latest crystallizing assemblages of the ijolite is considered evidence that fenites have a genetic relationship with ijolites. The nature of the relationship between ijolite and fenite at Homa is believed to be that of an intrusive body and its associated pegmatitic and hydrothermal stages. In addition it is believed that the evidence may also illuminate the problem of origin of the larger volumes of nepheline syenite associated with ijolite/
carbonatitic complexes elsewhere in the world (chapter 4).

(4) Summary of conclusions on the variation and mode of development of the ijolite at Homa.

1. A great variation exists within the ijolite suite at Homa. This is particularly characterized by the composition of the crystallizing pyroxene phase. In earlier forming assemblages, which include pyroxenites, diopside is the only pyroxene forming. Assemblages forming later are characterized by pyroxenes containing progressively increasing proportions of aegirine-augite and in extreme cases by aegirines proper. These last are only characteristic of ijolites from the margins and roofs of ijolite bodies and the metasomatic rocks adjoining the ijolite at these contacts.

2. Mineral assemblages and chemical analyses show that this trend is accompanied by decreased undersaturation in silica and in some cases increased modal feldspar. A progressive increase in phases (e.g. pectolite, biotite, apatite, calcite) and phenomena ascribable to the presence of a late volatile-rich fraction are also seen.

3. The presence of orthoclase and aegirine in the later crystallizing stages of the marginal ijolites coinciding with the growth of both minerals in the country rock adjoining the ijolite (fenitization) means that the ijolite body is enveloped to some extent by rocks of syenitic aspect.

4. The mode of development of the ijolite suite at Homa is believed
to have involved mainly a normal magmatic crystallization accompanied by development of pyroxenite as cumulates. In the later stages of this crystallization, particularly in marginal facies the effect of a volatile and alkali-rich fraction were increasingly felt. Deuteric and contact metasomatic effects are very common in these portions and the rocks resulting are of syenitic character.

(5) Experimental studies bearing on the variation and origin of ijolite at Homa.

The system nepheline-diopside was investigated first by Bowen (1928) and the results confirmed and expanded by Schairer et al. (1962). Higher temperature phases correspond to many present in the common lavas and dykes of alkaline centres such as those in Nyanza and Eastern Uganda. Olivine, diopside, melilite and nepheline crystallize from melts of this composition. Olivine reacts and dissolves with falling temperature leaving the three phases diopside, melilite and nepheline stable over a very wide range of composition and temperature.

Nepheline and diopside are typical minerals of many plutonic rocks associated with carbonatites, including those at Homa (e.g. Pyroxenites and ijolites). Melilite is much more rarely found in plutonic rocks but where it does so sometimes appears to be the direct plutonic equivalent of melilite nepheliminite (King, 1965).

Alteration of melilite occurs very easily amongst the rocks
of Homa and has often been noted elsewhere. This alteration frequently involves replacement by carbonate implying that in the presence of CO₂ melilite is unstable (chapter 6).

It has already been shown that carbon dioxide is present in many of the main series of ijolites, this may have inhibited the formation of melilite. It is interesting that in those ijolites in which the mineralogy indicates an early assemblage metasomatism of the pyroxene is not seen and perovskite is a common phase. Now perovskite frequently accompanies melilite both in lavas and plutonics such as uncompahgrite and okaite, both of which are found at alkaline centres. The implication is that melilite bearing plutonics may be present, probably at depth, and that the pyroxene in such a rock would be diopsides with a very low aegirine content.

The system acmite-nepheline-diopside has been studied but liquidus data only was reported for pressures of one atmosphere (Yagi, 1963). Data for this system for conditions equivalent to those under which the ijolites crystallized was not reported.

An important study of relations within the system Na₂O-Al₂O₃-Fe₂O₃-SiO₂ has been recently published (Bailey and Schairer, 1966). Of particular interest in the present context is these authors' identification of a quaternary reaction point at which acmite, nepheline, haematite and albite are present.

They believe that this is the synthetic analogue of the composition at which ijolites cease to crystallize. They note that CaO
is present at earlier stages of crystallization of ijolites and nephelinites and is fixed in the less acmite pyroxenes and imply that at the final stages of crystallization CaO has been consumed leaving the phases above mentioned.

At this point it is proposed to compare the later assemblages observed in the ijolites at Homa with that of the ijolite point. Acmite and potassium feldspar are the last silicates to crystallize in the Homa assemblages but there is textural evidence that calcium is present in the later stages in great quantity. Replacement of pyroxene by melanite, crystallization of melanite, wollastonite and at the last calcite all indicate this.

The metasomatism of the wall rocks to an assemblage similar to that of the last silicate minerals indicates that volatiles were probably active at this stage. These volatiles probably included much carbon dioxide and this, with the concentration of CaO, was responsible for the late crystallization of carbonate.

Bailey and Schairer note that melting of a peralkaline syenite would result in a liquid of the composition of their ijolite point (where Acmite, Naematite, Nepheline, Albite and liquid co-exist) but that ijolite so produced would be expected to carry sodic pyroxenes. They believe that residual liquids of the composition E could, however, be derived from a variety of sources and that ijolites rich in CaO demand an alternative derivation.

The ijolites at Homa have been shown to be rich in total calcium and in diopsidic pyroxene and an origin for them must not,
therefore, be sought in processes involving crystallization of a peralkaline syenite. More important, an origin by partial melting of such a syenite is also not allowed by Bailey and Schairer's data. This means that an origin by rheomorphism of the fenite is not possible at Homa. (The fenitized wall rock at ijolite margins at Homa has a similar composition to the latest silicate phases crystallizing and thus is analogous to point E).

The work of Nolan (1966) shows the relations between the phases present at Bailey and Schairer's ijolite point and contains data on the addition of up to 50% diopside to the system nepheline, albite, acmite, water. Nolan, however, concludes that as the average ijolite is of a much more basic composition application of the results of this work to the study of the origin of ijolite is unwise.

An extension of Bowen's pseudobinary system nepheline-diopside has recently been made by Onuma and Yagi (1967) in which the component Ca₂MgSi₂O₇ (akermannite) has been added to nepheline and diopside. The resulting assemblages are particularly applicable to the volcanic suite at alkaline centres and show a possible line of derivation from olivine melilitite towards melilite nephelinite in the course of which olivine reacts and is consumed (i.e. as noted under the description on the system nepheline-diopside). This work does no more to clarify the origin of the lime-rich ijolites except to re-introduce the question of the status of melilite.
A model illustrating the possible origin of ijolites of Homa.

The recent publication of two tomes (Heinrich, 1966; Tuttle and Gittins, 1966) on the characters and origins of such rocks and their relatives and the several papers on the very similar suite of rocks exposed in Eastern Uganda (King, 1965; King and Sutherland, 1966) together with such summaries of current thought as provided by Bailey and Schairer in the latter part of their paper on synthetic systems (1966) make it unnecessary to review all the various theories of origin of such rocks. The following model is a synthesis of ideas derived from the above and other works and a consideration of the phenomena present at Homa.

The field, petrographic and chemical data given above for the rocks at Homa indicate that ijolite was intruded at the present level as a magma accompanied and followed by a very powerful volatile/metamorphic event which caused replacements to occur in the later phases of the ijolite and converted the wall rocks to a syenitic composition. The differentiation trend shown by the ijolites resulted in a late assemblage analogous to that of the ijolite point of Bailey and Schairer. However, the presence of calcium bearing phases continuing to crystallize throughout the ijolites' history indicates that an origin by partial melting of a peralkaline syenite (e.g. fenite) is not applicable in this case.

An alternative origin is indicated by a study of the relations within the nepheline-diopside-akermanite system (Schairer et al. 1962; Onuma and Yagi, 1967).
Crystallization of such compositions under plutonic conditions would inhibit the formation of the high temperature phase olivine and the content of volatiles might inhibit that of melilite. That such inhibition is not always effective is evidenced by the presence of such rocks as uncomphagrite and turjaite in close proximity with ijolites at some of the East African centres (Findlay, 1966).

The characteristic mode of emplacement of the volcanic equivalent, olivine melilitite, of which there is a typical example at Homa, is a narrow pipe (chapter 6). Such pipes often terminate in explosion craters in the closely related potash-rich volcanic field of W. Uganda. A relation of such explosive melilitite bearing vulcanism with that resulting in the emplacement of kimberlite breccias has been made by many authors e.g. Holmes (1936). A connection with kimberlites implies a starting point at a depth, possibly in the mantle. Transport of the kimberlite breccia fragments by a volatile, CO₂, H₂O rich fraction has been postulated. Eclogite and garnet peridotite xenoliths in the kimberlite breccias are indications that melting was not complete at depth under the conditions of rapid ascent implicit in the kimberlitic type of vulcanism.

A slower rise of the same material might allow complete fusion. Extrusion of this material would give rise to the olivine melilitite-melilite nephelinite suite. (cf Bailey & Schairer, 1966, Fig 19).
Crystallization of this material under plutonic conditions would give rise to the uncomahgrite-ijolite suite and its accompanying metasomatic aureole.

The model here proposed presupposes the constant presence of a CO₂ rich volatile fraction capable of independent generation and emplacement. It would assist the fusion and transport processes and would crystallize carbonate at the later stages of the ijolite, as well as being capable of independent emplacement as carbonatite.
# CHAPTER 3

COUNTRY ROCK ALTERATION AT HOMA MOUNTAIN. (a) INTRODUCTION, OUTLINE DESCRIPTION OF THE COUNTRY ROCK AND ITS FENITIZATION AWAY FROM IJOLITE CONTACTS

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Introduction

Alteration of country rock by processes of alkali metasomatism associated with the Tertiary activity is very common at Homa. A three-fold division of these processes has been made and is described in chapter 3, 4 and 5 respectively:

a. Processes resulting in soda and potash metasomatism of country rock away from ijolite contacts (the present chapter).

b. Processes resulting in soda and potash metasomatism at the margins of ijolites (chapter 4).

c. Processes resulting in potash metasomatism only (chapter 5).

Also in the present chapter an outline of some mineralogical, textural and chemical characters of the least altered country rock at Homa is given for comparison with those imposed by the metasomatism accompanying the alkaline intrusive activity.

The unfenitized country rock

The Homa centre is emplaced in a series of low(chlorite) grade metavolcanics most of which are lavas but including occasional crystal tuffs. Although no direct dating is possible, they are believed to be of Nyanzian age for several dolerite dykes with
contacts trending N.N.W. cut the volcanics and are similar to those of pre-Bukoban age noted elsewhere in Nyanza (Saggerson, 1952, p. 68). Blocks of metasomatised granite in breccias of Tertiary age indicate that at depth the Homa complex is underlain by granite but this has nowhere been exposed on the peninsula.

a) Field relations of the Nyanzian lavas

The fine-grained nature, lack of cleavage and the shattering and iron staining caused by the proximity of centres of Tertiary explosive activity together made it impossible to systematically map the Nyanzian succession and structure in this area. The colour of the rocks in the field is dark grey to grey green. Indications of flow banding and a general fine-grained nature suggests that many of the rocks were originally glassy. Shattered but unbrecciated country rock is present on many of the outer slopes of Homa Main up to 4,500' (Fig. 1.9), and here some outcrops of dark blue black lava were found. These are very fresh and may represent a system later than the Nyanzian but until radiometric dating of such samples is completed they too are assigned to this system. Nyanzian hills occur to a similar height at the foot of Nyasanja and around the lower slopes of Got Awayo (Fig. 3.2, chapter 1, p. 64) and are thought to represent material domed up during the earlier stages of activity at Homa (chapter 1, p. 11). Outcrops of unaltered Nyanzian are rarely seen on the lower ground within the area affected by the Tertiary activity but the arcuate
"OUTLINE GEOLOGY OF HOMA MTN.
AND SURROUNDS"

"KEY"

- CLASSIC PLEISTOCENE
- MAINLY DRIFT COVERED
- LATER BEDDED PYROCLASTS
- SATELLITE VENT
- CARBONATITE INTRUSIONS
- OCHREOUS BRECCIA
- PHONOLITE (+)
- PhNephelinite ( )

- JOLITE CUT BY CARBONATITE
- JOLITE AT LITTLE DEPTH
- SHATTERED NYANZIAN
- NYANZIAN
- GRANITE
- FAULT
- MOTOR TRACK

"FIG. 3.2"
belts of intrusions of a) Oyolo and Onya and b) Bala can be shown to cut such at their north and south eastern contacts respectively (Fig. 3.2). Fresh Nyanzian is exposed at Kandiege and other places outside the area affected by the Tertiary vulcanicity.

b) Petrography of the Nyanzian

The limited data available indicates that the country rocks belong to the andesite, dacite, rhyolite series, no basaltic types were noted at Homa although they form much of the country rock at the nearby Ruri complexes (Collins, 1966; Dixon, 1966).

i) Rhyolites

Thin sections reveal a variation not always seen in the field and show that many of the rocks are fine-grained acid porphyries in which the phenocrysts are alkali feldspars and quartz (Fig. 3.3). Mafic minerals are sparse and usually represented by chlorite, epidote and iron oxides. The groundmass carries sparse microlites of feldspar in a background often of leucocratic optically unresolvable character. Use of a diffractometer shows that a high proportion of quartz is present in this background (Fig. 3.4), which is, therefore, probably a devitrified siliceous glass. The simply twinned alkali feldspar was identified as orthoclase (OAP - 010), and the plagioclase as oligoclase. Rocks showing similar characters but an alignment of feldspar microlites within the groundmass are common and represent flow banded lavas.
Fig. 3. 3. Porphyritic rhyolite. Phenocrysts of oligoclase and quartz in a leucocratic matrix. HC 54. X 40. X.N.

Fig. 3. 5. Dacite. HC 95. X 40. X.N.
ESTIMATE OF QTZ./FELDSPAR RATIO BY DIFFRACTOMETER

50% OLIGoclase PLUS 50% QUARTZ.

FIG. 3.4 SODA RHYOLITE HC 54.
ii) Dacite

This rock type has a less glassy but still fine-grained character (Fig. 3.5). A similar suite of phenocrysts as in the rhyolites is present but the groundmass is composed of a felted mass of interlocking laths of feldspar near oligoclase in composition. Occasional interstitial areas of quartz are present but the rock carries less free silica than the rhyolites.

iii) Andesitic types

Rocks in which more numerous relict mafic minerals are seen both as phenocrysts and in the groundmass are less common but have been noted particularly on the north of the mountain (Flegg, 1968). The increased presence of mafic relics and the occurrence of plagioclase, less rich in soda, indicate variance towards more basic compositions. The texture, felsic phenocrysts in a groundmass of felty plagioclase, is similar to that seen in the previous rock type and is commonly preserved in the earlier stages of metasomatism.

c) Petrography of the dolerites

These are fresh looking in the field but although the original pyroxene and feldspar outlines are still visible in thin section extensive alteration to chlorite, epidote, sericite, uralite and carbonate has occurred. Frequent interstitial quartz and feldspar intergrowths show micrographic textures.
d) Chemistry of the unaltered Nyanzian

Two new analyses and one partial analysis for alkalies are available:

<table>
<thead>
<tr>
<th></th>
<th>HC 54</th>
<th>HC 83</th>
<th>U 49</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO₂</td>
<td>72.03</td>
<td></td>
<td>63.75</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>12.00</td>
<td></td>
<td>14.76</td>
</tr>
<tr>
<td>FeO</td>
<td>4.17</td>
<td></td>
<td>4.60</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>0.47</td>
<td></td>
<td>1.87</td>
</tr>
<tr>
<td>TiO₂</td>
<td>0.51</td>
<td></td>
<td>0.74</td>
</tr>
<tr>
<td>MnO</td>
<td>0.03</td>
<td></td>
<td>0.06</td>
</tr>
<tr>
<td>CaO</td>
<td>0.75</td>
<td></td>
<td>2.63</td>
</tr>
<tr>
<td>MgO</td>
<td>2.78</td>
<td></td>
<td>2.85</td>
</tr>
<tr>
<td>K₂O</td>
<td>0.43</td>
<td>0.83</td>
<td>1.33</td>
</tr>
<tr>
<td>Na₂O</td>
<td>4.15</td>
<td>5.68</td>
<td>3.73</td>
</tr>
<tr>
<td>H₂O⁻</td>
<td>0.22</td>
<td></td>
<td>0.22</td>
</tr>
<tr>
<td>H₂O⁺</td>
<td>1.96</td>
<td></td>
<td>3.73</td>
</tr>
<tr>
<td>CO₂</td>
<td>0.24</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P₂O₅</td>
<td>0.09</td>
<td></td>
<td>0.16</td>
</tr>
<tr>
<td></td>
<td>99.83</td>
<td></td>
<td>100.43</td>
</tr>
</tbody>
</table>

Analyst: W. Herdsman, M. Blackley, C. P. Wood

HC 54 & HC 83: Porphyritic sodic rhyolite from the western approach slopes of Homa Main.

U 49: Dacite from Nyangwesso 9 miles south of Homa Main. (Collected by M. J. Le Bas).
(3) Fenitization of country rock away from ijolite contacts

a) Introduction

The term fenite was originally coined by Brogger to describe leucocratic contact rocks containing 70-90% alkali feldspar and from 25-5% aegirine, occurring at the margins of ijolite bodies (Johannsen, 1937). The original definition has since been extended to include any rocks around carbonatite-alkali centres which are the result of alkali metasomatism. The terms 'to fenitize' and 'fenitization' are now frequent in descriptions of such metasomatism. In addition to the process of fenitization some authors, e.g. Sutherland, 1965; Bailey, 1966, recognise a separate process termed feldspathization.

The processes of alkali metasomatism at Homa will be shown to be varied and the term fenitization used for those processes resulting in the formation of soda mafic minerals with or without the addition of alkali feldspar. The formation of rocks rich in feldspar only is described in chapter 5.

b) The distribution and styles of fenite away from ijolite margins

The general description and map (chapter 1, Fig. 1.9) show that the carbonatitic intrusions are divided by screens of country rock in various stages of disruption.

The most extensive type of disruption is an overall shattering or cracking which is believed to have accompanied an early stage of doming up of the area immediately overlying the intrusive centres (chapter 1, p. 11). Such shattering is seen at every outcrop on
Homa Main and is frequently picked out by the development of narrow (\(<2\) mm.) green veins. A greater development of these veins occurs in areas of greatest density of carbonatite intrusions (chapter 1, p. 35). These fenite veins result from the growth of soda amphibole and pyroxene and are the earliest sign of fenitization. The correspondence of greatest density of carbonatite sheets with relatively narrow arcuate zones of intensely brecciated and sheared country rock has already been noted (chapter 1, p. 11 and p. 35) and it was concluded that these represent zones of crushing and movement consequent on a second and more localized phase of updoming. This second stage of disruption is envisaged as being similar to the action of a piston raising vertically a cylindrical block of country rock approximately equal in surface area to the highest part of Homa Main. The raised block is bounded by zones of brecciation and shearing.

Examination of these zones shows that a more intense style of fenitization is present than in areas where shattering only occurred and also that the fenitization accompanied rather than followed the periods of brecciation and shearing. There thus appears to be a correspondence in time of fenitization with phenomena related to doming.

A sub-division of the two main styles of fenitization into six groups is possible. It is given below in order of increasing
effect on the original Nyanzian texture and mineralogy. Fenitization of granite and dolerite is dealt with later (p.179).

c) List of fenite groups described from Homa (except those from ijolite margins)

A. Fenites of the most widespread style which are characteristically veined.

1. Vein fenites Stage I. New minerals are predominantly sodic pyroxene and amphibole and are confined to the interior and margins of small dilations within the country rock.

2. Vein fenites Stage II. New minerals as above but include potassic feldspar in addition. Considerable alteration and replacement of the areas defined by the veins occurs.

B. Fenites of the style found in restricted, often arcuate, zones of great mechanical disruption of the country rock.

3. Banded fenites. The mineralogical changes are similar to those of group 2, but are accompanied by a strong preferred orientation of the new minerals.

4. Fenite breccias. Breccias in which a mixed collection of blocks of groups 1, 2, and 3 above are included in a matrix of smaller comminuted and recrystallized fragments of the same.

5. Fenites showing evidence of partial melting. Portions of the material in which are included blocks of the fenites described in group 4 above have characters indicating that partial melting may have occurred.
Fig. 3.6. Fragments of fenitized country rock breaking up in carbonatite (C2a). Homa Main.
6. Rocks resulting from repeated episodes of fenitization

d) Details of the relations of the vein fenites:

It has already been noted that vein fenites do not form a complete aureole over the whole of Homa Main but tend to be approximately co-incident with zones of multiple carbonatite intrusion. The field and petrographic evidence also shows that fenitization preceded the intrusion of carbonatites as the latter frequently include brecciated portions of fenitized country rock (Fig. 3.6) which show evidence of marginal reaction to phlogopite (chapter 1, p. 35).

On the lower ground, however, some areas of very similar fenite have no apparent connection with carbonatite. These occur in an arc extending from Got Kokoto on the west to the arc underlying Got Chiewo and including Ogwago Ridge (Fig. 3.2). In the more easterly (under Got Chiewo) part of this arc these fenites are known to be underlain by ijolite at little depth and, therefore, may be indicators of the possible extension westwards and north-westwards of the ijolite now exposed on the southern approaches to Homa Main.

Whilst the country rock adjacent to carbonatites is usually fenitized there appears to be no fenitization alongside the numerous ochreous carbonatitic breccia intrusions of the area (chapter 1, p. 19). This contrast is clearly seen at Landslide Gully where screens of unfenitized country rock divide the numerous
FIG 3.7

LINE OF SECTION IS 95° GRID.

LANDSLIDE GULLY SECTION
W. HOMA MTN.
ochreous breccias on the lower and middle part of the section while towards the top brecciated and fenitized country rock occurs near the contact of the first carbonatite (Fig. 3.7).

e) Petrography of the vein fenites Stage I

Mineral species involved include soda pyroxenes near aegirine, amphiboles of the eckernannite-arfvedsonite group and a pale brown phlogopitic mica. Alkali feldspars are also prominent, orthoclase being characteristic. Other minerals occurring in minor amount are apatite, calcite and brown and opaque oxides. The new potassium feldspar is often clearly distinguishable by comparison of R.I. and birefringence from the original more sodic feldspars. Staining techniques were used in some cases particularly in the study of the finer grain sized rocks.

The dominant controls over the distribution of new fenite minerals in the vein fenites are a) the system of fractures developed by shattering of the country rock, and b) the original texture and composition of the country rock. The more glassy porphyritic rhyolites show a different distribution of fenite minerals from the lavas containing plagioclase with a well developed lath habit.

i) Fenitization of sodic rhyolites

The earliest signs of fenitization are only visible in thin section as the filling of microscopic cracks with iron oxide and minute fibres of sodic mafic minerals. Fig. 3.8 illustrates
Fig. 3. Distribution of new soda mafic minerals around fenite veins in rhyolite. HC 48. X 9. P.P.L.
a stage when the green veins are already visible in the field. The new sodic mafic minerals (dark in the illustration) are prominent both in the veins and in the areas marginal to the veins but are almost absent from the areas between the veins which now have an allotriomorphic granular texture in which quartz, feldspar and narrow splinters of pale brown biotite are seen. No sign of a lath texture is present and this fine-grained texture is believed to have resulted from re-crystallization of the previously glassy or devitrified matrix. It is not possible to distinguish the effects of devitrification, metamorphism and fenitization in this matrix. On the results of a partial analysis for alkali addition of soda in the immediate areas of the veins is greater than in the areas away from the veins:

<table>
<thead>
<tr>
<th></th>
<th>Na₂O</th>
<th>K₂O</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Whole rock (HC 48)</td>
<td>8.13</td>
<td>0.40</td>
</tr>
<tr>
<td>2. Portion between veins (HC 48)</td>
<td>6.60</td>
<td>0.52</td>
</tr>
<tr>
<td>3. Average unaltered rhyolite (HC 54, 83)</td>
<td>4.92</td>
<td>0.63</td>
</tr>
</tbody>
</table>

Analyst: HC 48, 83 - M. Blackley
HC 54 - W. Herdsman.

These results indicate that alkali metasomatism was mainly confined to the veins and their margins and was sodic rather than potassic in character.

The original phenocrysts are still present but are beginning to re-crystallize and are locally replaced by new mafic minerals.
The veins (~1 mm. wide) consist of a felted aggregate of fibres and sheaves of magnesio-arfvedsonite and aegirine together with crystals of albite which project from the vein walls (Fig. 3.9). The vein margins are often a clear intergrowth of similar feldspar and it appears likely that the albite within the veins is a recrystallization of material mostly derived from the country rock, possibly to a slightly more sodic composition. Apatite and calcite are subordinate phases within these veins.

Replacement or recrystallization of portions of original phenocrysts penetrated by fenite veins is sometimes seen (Fig. 3.10). In this case new, water clear albite margins the fenite vein which is filled with sheaves of fibrous amphibole.

Another example of fenitization of a rock of similar original character is seen in Fig. 3.11 where a 1.5 mm. aegirine bordered vein is composed entirely of apatite. This is an extreme example of an apatite bearing fenite vein but apatite is considered as an important minor constituent of many fenite assemblages at Homa.

ii) Fenitization of Nyanzian lavas that have a prominent growth of plagioclase in the groundmass

The earlier stages of fenitization produce a rather different (Fig. 3.11a) texture. The dark minerals are much more evenly distributed through the rock. Amphibole and pyroxene develop interstitially to the feldspar laths of the groundmass. The amphibole (a grey-green variety) forms spherules of radiating fibres (Fig. 3.12).
Fig. 3. 9. Margin of fenite vein filled with fibrous new soda mafic minerals. Albite euhedra also develop. HC 48. X 160. X.N.

Fig. 3. 10. Relict phenocryst recrystallized to fresh albite along the margins of a fenite vein. Vein is filled with soda mafic minerals. HC 48. X 40. X.N.
Fig. 3. 11. Apatite vein, bordered by aegirine, cutting Nyanzian rhyolite. HC 2001. X 40. P.P.L.

Fig. 3. 11a. Vein fenitization of dacite. New soda mafic minerals filling veins and developing throughout the background. HC 669. X 9. P.P.L. (c.f. Fig. 3. 8.).
Acicular grains or sheaves of aegirine develop both separately and as intergrowths with the fibrous amphibole, and appears to be later. Aegirine is also seen to form outgrowths on prisms of amphibole in some of the veins (Fig. 3.13).

Within the areas separated by the veins, the development of new minerals takes place in two distinct ways:

a) The more widespread is an interstitial development of amphibole (followed by pyroxene) apparently as replacements of the metamorphic minerals occurring between the laths of plagioclase.

b) More rarely interstitial grains, pools or phenocrysts of quartz are being actively replaced, often though not exclusively, by aegirine (Fig. 3.14). Replacement of quartz is sometimes seen when a fenite vein crosses a quartz stringer. Mafic minerals develop preferentially in the quartz vein.

The apparent ease of development and even distribution of fenite minerals in this rock type, compared with those of more glassy matrix, may be a clue to the composition and distribution of the original mafics, later represented by low grade alteration products. The sodic nature of the original feldspars probably reflects a similar alkaline nature for the original mafics. The onset of conditions favouring fenitization may reverse the metamorphic effect to one of stability of pyroxene and amphibole. It is well known that in alkaline centres where granitic rocks are fenitized the earlier stages of fenitization often include the
Fig. 3. 12. Spherular growth of amphibole with rods of aegirine within them, both mafic minerals developing in quartz. HC 522. X 160. X.N.

Fig. 3. 13. Typical radiating, acicular habit of fenite mafic minerals in a vein. Rods appear to change imperceptibly from amphibole to aegirine from the centre of a sheaf outwards. HC 522. X 160. X.N.
Fig. 3. 14. Large quartz areas being replaced by aegirine from the margins inwards. HF 12B. X 160. X.N.
replacement of the pre-existing biotite and hornblende by soda mafics e.g. (McKie, 1966) and the blocks of fenitized granite at Homa are no exception (p. 182).

The status of the well developed intergrowth of albite/oligoclase laths in the groundmass is also open to discussion, for with increasing development of fenite minerals the previously turbid and sericitized plagioclase is cleared and possibly recrystallized. Comparison of unfenitized with fenitized material also indicates that an increase in grain size may sometimes occur. In the rocks of originally glassy aspect new soda plagioclase was noted. In these cases the development of the plagioclase may be a metamorphic effect rather than metasomatic (i.e. recrystallization without exchange of material). Data on the variation of composition of the plagioclase is not available but it is believed that some addition of soda may occur.

iii) Evidence of a potassium metasomatism

Vein fenites of the type described above show little signs of a potassium metasomatism. Small stringers of new orthoclase are sometimes seen within the groundmass, particularly of the vein fenites occurring on the lower ground of Got Kokoto and Ogwago Ridge (p. 160). The characteristic first appearance of orthoclase is illustrated (Fig. 3.15). A soda plagioclase phenocryst of Nyanzian age is seen to be cut by a mafic fenite vein. Outgrowths of new feldspar are seen where the vein crosses the old phenocryst.
Fig. 3. 15a. Original feldspar phenocrysts cut and offset by fenite vein. HC 610. X 40. X.N.

Fig. 3. 15b. Detail of above showing new lower birefringent feldspar growing at the margin of the vein as outgrowths of the old feldspar. HC 610. X 140. X.N.
This new feldspar, orthoclase, has a lower birefringence and refractive index than the older material. The two portions of a phenocryst so affected are frequently offset and the sense of movement is partly a dilation and partly a tear.

Staining techniques were initially used to distinguish the new potassium feldspar but latterly the above mentioned optical differences were considered diagnostic. Analysis of similar feldspar phases by microprobe are reported on p. 168.

f) Vein fenites Stage II

An increase in the degree of fenitization accompanied by more evidence of potassium metasomatism is noted in more localized areas of Homa Main, sometimes bordering areas affected by the major second style of fenitization.

In the less strongly developed fenites of this type the new feldspar (orthoclase) is confined mainly to the immediate vicinity of the veins, for example Fig. 3.15. The distribution of new light and dark fenite minerals along veins and the relatively unaltered rock between the veins is clearly seen in hand (Fig. 3.16). The dark veins, filled with pyroxene, amphibole, calcite, apatite and subordinate feldspar, are succeeded outwards by a light coloured zone 1-3 mm. wide in which potassium feldspar is developed partly interstitial to the original groundmass. New potassium feldspar also lines the walls of parts of the veins in which occasional albite euhedra are also seen. Between the veins the original pheno-
Fig. 3. 16. Hand specimen of vein fenite stage 2. HC 937. X 1.

Fig. 3. 17. Hand specimen (cut surface) of strongly fenitized country rock. Large areas of new, pale cream feldspar and numerous veins filled with dark minerals are prominent.
crysts and groundmass remain. Numerous small pale brown biotite flakes are scattered through both the groundmass and the phenocrysts but it is not clear whether this mineral developed during the earlier metamorphism of the rock or whether it represents a stage in the later fenitization. Clearly, however, fenitization here involves potassium metasomatism whether the pale mica as well as the orthoclase is considered to result from the same process or not. The fact that some of the early soda feldspars are seen to be replaced by potassium phases is considered significant in the understanding of the process of metasomatism at Homa. It is believed that the soda so released from the feldspars is perhaps fixed in the new mafic minerals.

A more advanced stage of fenitization is shown in Fig. 3 in which the hand specimen is again seen to be crossed by green veins. The blocks between the larger veins are cut by very numerous, irregular smaller veins and show development of areas of almost white feldspathic material. Apart from slight displacement no movement between adjacent blocks has occurred.

In thin section original phenocrysts of alkali feldspar are recognizable, set in a trachytic textured matrix parts of which are completely replaced by new orthoclase and soda mafic minerals. Along the margins of the veins recrystallization is more complete with the development of a granular intergrowth of fine-grained orthoclase. Zones and patches of new feldspar devoid of mafic minerals also occur.
At this stage much of the original country rock is converted to a fine-grained intergrowth of potassium feldspar and soda mafic minerals.

The rock at Homa Point East (Fig. 3.18) also shows a high degree of fenitization but here dark blue-green amphibole of arfvedsonite character is the dominant new mineral, imparting a bright blue colour to much of the outcrop (Fig. 3.19). Veins and patches of new mafic minerals are very numerous and the original texture much obscured. Some replacement by new feldspar occurs. The amphibole has an extremely fibrous habit and very low birefringence. It resembles a chlorite but X-ray diffraction of similar material from Landslide Gully (HC 93) gives a pattern agreeing with that of the analysed magnesio-arfvedsonite described later (p. 185).

g) Banded fenites

Fenites of this group have a restricted development and are characterised by foliated textures indicating directional stress during metasomatism. They are characteristic of the zones of complex disruption and shearing already mentioned and most often occur as blocks within the fenite breccias described next. It will be demonstrated that fenitization accompanied rather than followed these disturbances, i.e. crystallization of fenite minerals was a paratectonic event several stages of which can be distinguished in the specimens studied in detail.

The banded fenites are characterised in the field by a strong
Fig. 3. 19. Blue, amphibole-rich fenite from Homa Point East. Strong development of veins and areas of soda amphibole show dark in the photograph. HF 263. X 9. P.P.L.
colour banding of deep green and cream. In thin section almost the entire rock is seen to be reconstituted, with the development of new feldspar and sodic minerals (Fig. 3.20). Some relict phenocrysts remain, sometimes partially replaced or disrupted by the new texture.

Aegirine and magnesio-arfvedsonite are developed throughout and are not confined to narrow veins. They are often accompanied by small flakes of pale brown mica. New potassium feldspar occurs in felted aggregates up to 3 cm. long elongate parallel with the foliation and also as small laths. The preferred orientation of the new prismatic minerals parallel with the banding noted in the field shows clearly the effect of directional stress.

Evidence that a second stage of fenitization occurred is indicated by the dilationary veins cutting the above mentioned structures in the example illustrated (Fig. 3.20). Disruption of an original soda feldspar phenocryst is illustrated in Fig. 3.21.

The petrographic evidence indicates that much new potassium feldspar is present in the example here studied and partial analysis for alkalies indicates that the K₂O content is much higher than in fenites of the group previously described:

<table>
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<tr>
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<th>Na₂O</th>
<th>K₂O</th>
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<tr>
<td>Average unaltered Nyanzian (p. 156)</td>
<td>4.92</td>
<td>0.63</td>
</tr>
<tr>
<td>Vein fenite, whole rock (HC 48)</td>
<td>8.13</td>
<td>0.40</td>
</tr>
<tr>
<td>Banded fenite (HC 233)</td>
<td>7.61</td>
<td>6.35</td>
</tr>
</tbody>
</table>

These two facts are concluded to indicate that potassium
Fig. 3. 20. Strongly lineated fenite cut by a second generation fenite vein. HC 233. X 5. P.P.L.
Fig. 3. 21a. Detail of above showing remains of an original phenocryst which shows dilation by a fenite vein later than the lineated fabric. HC 233. X 35. P.P.L.

Fig. 3. 21b. As above. X.N. Note the trails of recrystallized feldspar developing at each end and around the old phenocryst.
metasomatism is much stronger in these rocks and that at least as much new potassium as new soda is fixed due to fenitization.

h) Fenite breccias

Fenites of this group are closely associated in space with banded fenites which are believed to develop due to shearing and compressive forces within the zones of maximum disruption. Brecciation frequently followed the production of banded fenites in these zones and rocks occur in which fragments of all the groups of fenites previously described in this chapter are mixed and enclosed in a matrix of smaller recrystallized comminuted fragments. Blocks of fenite breccia have also been found in the Got Ojawa vent material and as loose fragments on the lower ground under Got Chiewo (Fig. 3.2 ).

In some specimens the recrystallization and metasomatism accompanying the brecciation has obscured the margins of the original fragments (Fig. 3.22), and it is difficult to judge whether movement of the fenite fragments relative to one another has in fact occurred. The only indication is often that adjacent fragments show mineral orientations in different directions (Fig. 3.23). The finer-grained material between adjacent fenite blocks may itself lose all original structure and form an aegirine/feldspar intergrowth, enclosing blocks of fenite. An example in which very sharply defined blocks of fenite lie in such a matrix is illustrated (Fig. 3.24).
Fig. 3. 22. Fenite breccia showing rounding of the fragments. They merge in part with the matrix. HC 181. X 5. P.P.L.

Fig. 3. 23. Lineated feldspathic fragment in a non-lineated matrix. HC 688. X 40. X.N.
FIG 3.24a

SKETCH OF SURFACE FIGURED OPPOSITE

A - Vein fenite blocks.

B - Banded fenite with much new feldspar.

D - Matrix to large blocks, consisting of comminuted fragments recrystallized to feldspar and aegirine.

E - Tongues of intrusive red brown stained feldspathic material believed to result from melting of D.

F - Late mafic fenite veins cutting all previous stages.
Fig. 3. 24. Cut surface of fenite breccia. Stages present are indicated by the diagram opposite. (HC 745).
This specimen was recovered as a large block below Got Chiewo and illustrates very clearly several of the phenomena associated with fenitization of the type described in this chapter e.g. multiple episodes of metasomatism and brecciation and also provides evidence of rheomorphism.

The most striking features in this specimen are present in areas between the blocks of previously existing fenite and an area of this matrix is illustrated (Fig. 3.25). Two adjacent angular fragments one of the vein and the other of banded fenite are separated by a zone of chiefly feldspathic material which has a strong preferred orientation parallel to the sides of the two fragments. This texture is believed to result from the differential movement between the two blocks of fenite during the mixing and movement which accompanied metasomatism. This new matrix is cut by two veins of fenite mafic minerals, one of which shows evidence of being emplaced before the end of the period of movement.

i) Evidence for partial melting

1. Introduction

The texture described above in feldspathic material separating blocks of fenite is believed to have formed in a similar manner to that seen in banded fenites, i.e. by metasomatic crystallization with directional stress. There are other portions of the matrix to the angular fenite fragments in the same specimen (Fig. 3.24) in which tongues of brown stained feldspathic material appear to
FIG 3.25 FELDSPATHIC MATRIX WITH PREFERRED ORIENTATION (Fm).

See Pivn, Para. 2.
intrude and wrap around fenite fragments and portions of the matrix of the type already described. This brown stained feldspathic material is believed to result from partial melting of part of the matrix to the blocks.

Thin sections show that the texture and mineralogy of the brown stained intrusive material (Fig. 3.26) differs from that of the feldspathic material illustrated previously (Fig. 3.23 and 25) in that:

i) The feldspar has very little or no preferred orientation.

ii) Aegirine is absent.

iii) Dark brown granules of iron oxide are frequent.

iv) Occasional small areas of calcite are present into which the new feldspar projects euhedra.

v) The feldspar has a much lower birefringence.

vi) Analysis by microprobe shows that the feldspar is potassic while that of some of the other areas is sodic (p.199).

These brown stained feldspathic areas also show many similarities, in texture and composition, with several small dykes at Homa of potassium trachyte of undoubted magmatic origin (chapter 5, p.232). These dykes are equated with others described from Chilwa Island (Garson and Campbell Smith, 1958) and Toror (Sutherland, 1965) which are deduced to result from mobilization of strongly metasomatized country rock.
Fig. 3. 26a,b. Felsitic textured, probably melted, material (left) intruding fenite breccia. Relict phenocrysts are visible in the lower photograph within the fenitized material which in part is cut by an aegirine vein. HC 745. X 150. P.P.L. and X.N.
2. The significance of the presence or absence of orthoclase, leucite, aegirine and iron oxides in rocks believed to originate by partial melting

Sutherland (1965) discusses the problem of the origin of the potassic dykes at Toror and while considering evidence for a magmatic origin notes that the absence of leucite would indicate that pressures in excess of 2,000 Bars existed in the melt from which orthoclase precipitated, citing the experimental evidence of Bowen and Tuttle (1950).

Conversely, Orthoclase would melt congruently at these pressures instead of forming leucite. In the case of the tongues of brown stained feldspathic material considered at Homa, no leucite was identified and only small portions of the rock are considered to have been melted which probably solidified again quite quickly. The areas in which melting occurred are believed to have been portions of the fenite with preferred orientation of minerals described previously (p. 171, Fig. 3. 25).

Once melted the orthoclase would no longer be under the same stress conditions as before (directional stress not being transmitted through a liquid except by flowage) and if re-precipitated would form an allotriomorphic granular texture quite different from its original mineral orientation before melting. That the brown stained intrusive portions of feldspathic material have such a texture is illustrated by Figs. 3. 26 and 27.
Fig. 3. 27. Granular, felsitic texture of the orthoclase/iron oxide tongues of intrusive, brown stained material. HC 745.
X 160. X.N.
The mineralogy of the unmelted feldspathic matrix contains some aegirine but this mineral does not appear in the material believed to have passed through a magmatic stage, iron oxides appearing instead and give these areas their characteristic brown colour.

Breakdown of aegirine to iron oxides is a frequent occurrence at Homa and in some is due to weathering, for blocks of fenite show a pinkish colour on exposed surfaces but unaltered green aegirine on fresh surfaces. Aegirine also breaks down when fenites are invaded by coarse grained, cream sivite (chapter 5, p. 223). The feldspar remains stable but the aegirine is often replaced by iron oxides (chapter 5, p. 223).

In the fenite considered here (HC 745) the brown stained portions (i.e. iron oxide mineral bearing) are cross cutting and their distribution is not related to a weathering surface. The writer believes that an explanation may be found by considering the available experimental data on aegirine stability relations. (Bowen & Schairer, 1929) (Bailey and Schairer 1963).

Work at 1 Atmos./F (Yagi, 1962) shows that aegirine melts incongruently to haematite and liquid and that at 1,000 Bars PH₂O (Nolan, 1966) shows that incongruent melting to magnetite and a liquid occurs at 850°C.

It is clear from the above experimental work that at the temperature and pressure at which orthoclase melts congruently aegirine will break down to magnetite and a liquid equivalent in
composition to sodium di-silicate. This relationship is considered to be the key to the present interpretation of the orthoclase-iron oxide rocks under discussion.

Nolan found that reaction between liquid and magnetite to give aegirine occurred on cooling even under conditions of the most rapid quenching. In the rocks under discussion, however, no sign of aegirine was noted, the rosettes of aegirine around iron oxide observed, even after the quickest quenching, in Nolan's work are absent, nor are phases equivalent to the missing components noted in thin section.

A reason for this absence may be the solubility of these components in the vapour phase. Carmichael and MacKenzie (1963) while conducting experimental work on a system including albite, orthoclase, silica and water, to which was added known amounts of sodium metasilicate and acmite, noted that glasses prepared from gels under hydrothermal conditions precipitated feldspars richer in potassium than those obtained when starting with a gel. They attributed this to the solubility of sodium metasilicate in the gas phase and a consequent change in bulk composition of the glass from its initial composition as a gel. Nolan (1966) noted the same phenomenon on preparing glasses from gels by holding the gel at a temperature within the magnetite-liquid field of system Ne-Ac-H₂O. He opened such a charge under distilled water allowing the vapour to escape. Analysis of the solution indicated that both Na₂O and SiO₂ were removed in the vapour phase.
In view of the data discussed above it is suggested that the pressure, temperature and concentration of volatiles in certain parts of the fenitizing zone were sufficient to cause partial melting as the extreme stage in fenite activity, the conditions being such that orthoclase melted congruently and aegirine incongruently. The resulting rock is rich in potassium and iron oxides but carries very little soda. It is suggested also that the potassium trachyte dykes of the area (chapter 5) may have been formed by the same mechanism.

j) Rocks which have undergone several episodes of fenitization

Evidence of successive episodes of fenitization effecting individual specimens has already been mentioned in passing. The example of banded fenite (Fig. 3.20) shows evidence of at least two periods of fenitization:-

(A) That causing a strong development of new minerals with preferred orientation throughout the specimen.

(B) A later period of cross cutting narrow dilations similar to the Stage I vein fenite described on p. 161.

The multiple nature of the brecciations and contemporaneous nature of the fenitization is well illustrated in specimen HC 745, (Fig. 3.24). The following series of events can be deduced for the formation of this rock:-

1. Formation of vein fenites and banded fenites.

2. Brecciation, mixing and transport of fragments of these fenites.
3. Recrystallization and continuing metasomatism, particularly of the finer-grained material between the larger blocks.

4. Partial melting of small portions of this matrix to give rocks rich in potassium but very low in soda.

5. After cessation of the above stages a new phase of vein fenitization occurred in which narrow dilations cut the previous texture indiscriminately.

It is notable that the series of rocks produced by events deduced above correspond to the main groupings of fenites described previously. This confirms that the details of texture described in the various groups (p. 159) represent stages in a continuous process of increasing fenitization rather than a series of isolated phenomena.

k) Unusual fenite assemblages noted at Homa

i) Fenite containing an aluminous amphibole

A block of fenite (HC 654) was noted in which veins of prominent lustreous black amphibole crossed an earlier fenite texture. In thin section the rock is seen to have lost its original texture, only strained relics of quartz and feldspar remain and may indicate that it was a granite. Two phases of fenitization are seen, the first involved crushing and recrystallization of the rock accompanied by development of pale green aegirine-augite, in part in veins. The second phase of fenitization involved growth of the amphibole which often includes or replaces the other minerals.
Fig. 3. 28. Lustrous idiomorphic aluminous amphibole including numerous small grains of aegirine. HC 654. X 160. P.P.L.

Fig. 3. 29. Angular fragment of country rock and fenite rotated and mixed in a dark blue carbonate/amphibole matrix. X 4.
It is accompanied by calcite and black and red ore. The grain size of this amphibole (< 3 mm.) and short prismatic habit (Fig. 3.28) are both unusual in other fenites at Homa.

The amphibole has very strong pleochroism of the type seen in eckermannites but chemical analysis (p. 194) shows it to contain unusually high alumina substituting for silica. Soda amphiboles in which this occurs are rare. Katophorite is one example but contains more calcium and the mineral has a high temperature (volcanic) paragenesis (Deer et al., 1963). Substitution of alumina for silica has also been shown to be characteristic of hornblendes in metamorphic rocks (Deer et al., 1963) and may increase with increased metamorphic grade. It is, therefore, suggested that the occurrence of an aluminous amphibole may indicate that fenitization at higher temperature occurred.

ii) Assemblages possibly transitional between fenites and carbonatites

A further distinctive amphibole is seen in two assemblages in which calcite is prominent. One of these assemblages is an amphibole, carbonate and apatite rock in which the amphibole is dispersed as slender prisms throughout the rock which is a carbonatite. The pale grey green amphibole has been partially analysed (p. 194) and identified as richterite. The analysis shows that Ca joins Na in the X position. Richterite has previously been identified both from carbonatites, e.g. Larsen, 1942, and metamorphic
limestones (Deer et al., 1963).

A very similar amphibole, also associated with calcite has been identified in the fenite breccia illustrated (Fig. 3.29). A thin section shows that the angular blocks are of vein fenite in which small flakes and spherules of blue green amphibole of the magnesio-arfvedsonite type are developed. These blocks are partially separated and rotated relative to one another in a matrix of foliated carbonate containing pale green amphibole with properties similar to those of the richterite.

Much more extensive study of the relations of these two amphibole species is required but it is considered that in this case the process of fenitization and intrusion of carbonatite may have been more or less continuous and that the change in amphibole composition was a consequence of the increased calcium available in the natural system.

(4) Granite and fenitized granite at Homa

a) Introduction and nature of the granite

The recognition of fenitized granite blocks, during the present work, proves the existence of granite at depth beneath Homa. Loose blocks of the Oyugis granite (Saggerson, 1952, p. 61) were also found but some are known to have been brought in by the local people for use as quern stones.

Fifteen specimens of fenitized granite were obtained, mostly as blocks from the erosional debris on the lower flanks but at
Got Ojawa (Fig. 3.2) they were obtained from the pyroclasts directly related with this vent (chapter 1, p. 41). Another group of strongly fenitized granite boulders was found in the Rawe River (Fig. 3.2) and have probably weathered out of an agglomerate band. The present work included collection of two specimens of the more marginal part of the Oyugis granite, which is the nearest granite to Homa, outcropping 8 miles to the S.E. Hornblende and biotite are prominent, an earlier microcline appears to be less stable than the later plates of ophitic orthoclase. Soda plagioclase is also present. Prominent accessories include epidote, chlorite (after biotite), sphene and apatite. More adamellitic types are sometimes seen e.g. HC 77 (p. 81).

b) Fenitization of granite

The least altered of the fenitized granite specimens collected from Homa shows prominent microcline, quartz and biotite with subordinate sodic plagioclase (HC 863). The microcline is sometimes perthitic and the cores of some crystals are partly altered to sericite. During fenitization biotite and quartz are replaced by radiating groups of aegirine and subordinate eckermannite. This replacement proceeds along grain boundaries and tends to isolate some of the feldspars. Apart from the effects of fenitization this granite is similar to that outcropping around Oyugis.

A greater amount of fenite minerals are developed in granite
specimen HC 77. Much of the original microcline is replaced by plagioclase, some of which shows antiperthitic textures while an untwinned alkali feldspar, probably orthoclase is again late in the paragenesis. Very little quartz and original mafic minerals are seen. These have been replaced by a prominent growth of fibrous and rod-like aegirine crystals and soda amphibole (Fig. 3.30). These two minerals are very fresh in this rock and although they are strongly intergrown it was possible to separate them for analysis (p. 183). They are regarded as being typical of many of the fenite minerals at Homa. The coarse-grained nature of the host rock may account for the fact that the new amphibole and pyroxene are more coarse-grained than those forming at equivalent stages during the fenitization of the Nyanzian. These minerals fill veins and irregular patches as in the Nyanzian (Fig. 3.31).

The specimens found at Got Ojawa (HC 175) are strongly veined and spotted with green and blue dark minerals; quartz is not prominent and the feldspar appears partially kaolinised. The thin sections show the metasomatic changes very clearly. The feldspars are everywhere affected by a marked soda metasomatism. Original oligoclase and potassium feldspar are both traversed by numerous veins of albite. As well as the veins most of the margins are composed of the same feldspar. Small globules of carbonate follow these veins.

New fenite minerals have replaced most of the quartz. Some
Fig. 3. 30. Habit of eckermannite (lower part of photograph) and aegirine (upper part of photograph) in granite. HC 77. X 40. X.N.

Fig. 3. 31. Fenite vein cutting an orthoclase grain. Rods of aegirine and blue amphibole lie in a matrix of apatite. HC 77. Δ x 40. P.P.L.
partly replaced green hornblende still remain (Fig. 3.32).
The new minerals often cut across the earlier albite veins and
encroach on the boundaries of the earlier feldspars (Fig. 3.33).

**c) Albitization, a possible variety of fenitization**

The occurrence of a strong soda metasomatism (albitization),
which in part at least preceded the formation of soda mafics in
this rock, raises the question as to whether the addition of soda
to the feldspars was an early stage in the fenitization process
or a late stage in the history of the granite. A very similar
phenomenon is described by Saggerson as occurring in specimens
of the Miriu granodiorite from near the faulted contact at Kendu
(Saggerson, 1952, p. 61). He notes an alkali metasomatism
involving rimming, veining and patching of earlier feldspars and
quartz with new soda plagioclase. Calcite veinlets accompany
this metasomatism.

The fault at Kendu was active during the time that Homa
was being formed. It is, therefore, a possibility that the soda
metasomatism effecting the feldspars in some of the fenitized
blocks at Homa may be contemporaneous with that noted by Saggerson
from near Kendu and that this metasomatism may be a consequence
of the alkaline activity of the area. If so it must be assigned
to the process of fenitization and to an early stage of that process.
Fig. 3. 32. Original brown hornblende (lower centre) replaced by new soda amphibole (above and right) and aegirine (left).
HC 175. X 40. X.N.

Fig. 3. 33. Large grain of original feldspar showing replacement both marginally and in cross cutting veins by dark aegirine. The feldspar bordering the new mafic minerals shows strongly developed albite twinning. HC 175. X 40. X.N.
Chemical and optical data on the new minerals formed during fenitization

New minerals developed during fenitization at Homa include alkali feldspars and soda mafic minerals of the aegirine and aegirine-augite group and the blue green soda amphibole groups. In many of the examples of fenitized Nyanzian described above the grain size and intergrown nature made it difficult to separate pure samples of individual phases. For this reason the following data should not be considered representative, the minerals for analysis being chosen partly because of their grain size.

a) Amphiboles

The blue green amphiboles of fenites have been variously identified, e.g. as eckermannite (King and Sutherland, 1960), magnesio-arfvedsonite (McKie, 1966) and also as members of the riebeckite, glaucophane group (Heinrich, 1966).

Amphiboles from three different rocks at Homa were analysed:

a) A fenitized granite (HC 77) in which amphibole and pyroxene are intergrown. The co-existing pyroxene phase was also analysed (p. 187).

b) The fenite (HC 654) showing prominent late aluminous amphibole growth described above on p. 177.

c) Amphibole, apatite carbonatite (HC 189) in which pale grey green amphibole is prominent.
### Chemical analyses

<table>
<thead>
<tr>
<th></th>
<th>Per cent</th>
<th>Per cent</th>
<th>Atomic ratio on basis of $O_{22}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SiO$_2$</td>
<td>SiO$_2$</td>
<td>Si</td>
</tr>
<tr>
<td>a) Amphibole from HC 77, (eckermannite).</td>
<td>0.01</td>
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<tr>
<td></td>
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<td>98.43</td>
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Analyst: D. S. Sutherland.

c) Amphibole from HC 189 (richterite).

A partial chemical analysis indicates that the chief differences compared with the amphiboles already noted are that i) the Mg ratio is much higher, and ii) that Ca joins Na in the X site.
Optical characters of fenite amphiboles

<table>
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<tr>
<th></th>
<th>HC 77 (Amphibole from fenitized granite)</th>
<th>HCR 8 (Amphibole from fenitized granite)</th>
<th>HC 654 (Amphibole from fenite p. 177)</th>
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<tr>
<td>( \alpha )</td>
<td>1.636</td>
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<td>1.670</td>
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</tr>
<tr>
<td>( \gamma )</td>
<td>1.643</td>
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<td>// 010</td>
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<tr>
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Pleochroism

\( X = \) blue green/blue  
\( Y = \) grey violet       
\( Z = \) pale yellow green  

Habit

Radiating groups of fibrous and acicular prisms plus larger bladed prisms up to 3 mm. long. Often intergrown with aegirine.

Larger grain size, much less acicular squat prisms. Replaces and encloses aegirine.

\% Eckermannite (from R.I.'s)

70\% 42\% 30\%
Nomenclature of the fenite amphiboles

The optical characters of all the above three amphiboles indicate that they are members of the eckermannite/arfvedsonite series as defined in Deer et al. (1963). Chemical analysis of HC 77 confirms that this mineral is a magnesian rich member of this series. The orientation of the optic plane is known to change at about the composition 70% eckermannite, and Deer et al. (op. cit.) take this composition as that dividing eckermannite from magnesio- arfvedsonites so that on this basis the amphibole from HC 77 is an iron rich eckermannite. The optical data for HCR 8 indicates that it is a magnesio-arfvedsonite.

The amphibole from HC 654 has optical characteristics equivalent to those of an arfvedsonite with 30% eckermannite but as previously noted the chemistry shows large substitution of alumina for silica (p. 184). This amphibole is, therefore, not a true member of the eckermannite-arfvedsonite series and has not been assigned to any of the groups in Deer et al. (op. cit.).

Optical characters of amphibole HC 189

The larger crystals (up to 5 mm. long) are zoned to more pleochroic margins and the R.I. and extinction angle also increases from core to margin: $\gamma$ varies from 1.63 → 1.64; $\gamma^z = 27^\circ → 40^\circ$

The optic plane is parallel to 010 and twins on 010 are frequent.

Pleochroism: $X =$ very pale straw yellow, $Y =$ pale grey, $Z =$ pale yellow green.
The above data together with that from chemical analysis indicates that this is a member of the soda tremolite or richterite group of Deer et al (op. cit.).

b) Pyroxene

An analysis of the pyroxene (aegirine) co-existing with the amphibole in the fenitized granite (HC 77) described above, is given below. Optical data for this pyroxene is not available but its colour was mid-green. The very deep green and browns of aegirines from fenites at ijolite contacts (chapter 4) was not noted.

Chemical analysis of pyroxene from HC 77.

<table>
<thead>
<tr>
<th>Per cent</th>
<th>Atomic ratio on basis of 6XO</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO₂ 51.94</td>
<td>Si 1.971 2.0000</td>
</tr>
<tr>
<td>TiO₂ 1.28</td>
<td>Al 0.029</td>
</tr>
<tr>
<td>Al₂O₃ 1.91</td>
<td>Ti 0.036</td>
</tr>
<tr>
<td>Fe₂O₃ 30.81</td>
<td>Fe³⁺ 0.877</td>
</tr>
<tr>
<td>FeO 0.47</td>
<td>Fe²⁺ 0.015</td>
</tr>
<tr>
<td>MnO 0.02</td>
<td>Mn 0.001</td>
</tr>
<tr>
<td>MgO 0.73</td>
<td>Mg 0.041</td>
</tr>
<tr>
<td>CaO 0.56</td>
<td>Ca 0.023</td>
</tr>
<tr>
<td>Na₂O 12.52</td>
<td>Na 0.919</td>
</tr>
<tr>
<td>K₂O 0.08</td>
<td>K 0.004</td>
</tr>
<tr>
<td>Total 100.32</td>
<td>1.972</td>
</tr>
</tbody>
</table>

Analyst D. S. Sutherland.
c) **Feldspar**

In the petrographic description of fenitized Nyanzian it was noted that new orthoclase developed in the later stages of fenitization. It was distinguished from the original feldspar which is mainly near oligoclase in composition by staining techniques and comparative birefringence and R.I. The new feldspar is too fine-grained to measure the 2V.

Microprobe analysis of feldspar within the matrix to the fenite blocks in the example of fenite breccia (HC 745) described on p. 171 illustrates the difference between feldspars newly developing from those already present:

**Microprobe partial analysis of four feldspars from HC 745**

<table>
<thead>
<tr>
<th></th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>K₂O</td>
<td>0.4</td>
<td>15.30 ± 1.0</td>
<td>0.36</td>
<td>13.9 ± 0.5</td>
</tr>
<tr>
<td>Na₂O</td>
<td>10.6 ± 2.0</td>
<td>not det.</td>
<td>13.5 ± 1.8</td>
<td>not det.</td>
</tr>
<tr>
<td>CaO</td>
<td>0.2 ± 0.1</td>
<td>0.55 ± 0.2</td>
<td>0.18 ± 0.02</td>
<td>0.03 ± 0.02</td>
</tr>
<tr>
<td>BaO</td>
<td>0.1 ± 0.1</td>
<td>0.3 ± 0.1</td>
<td>0.4 ± 0.2</td>
<td>0.7 ± 0.2</td>
</tr>
</tbody>
</table>

Analyst J. A. Dixon.

I - Brecciated original (Nyanzian) phenocryst in the feldspathic matrix between blocks of fenite.

II - Metasomatic outgrowths of 'new' orthoclase at the margins of I.

III - Unmelted portion of comminuted feldspathic material between blocks.

IV - Feldspar with allotriomorphic texture from melted zone.
As well as showing high potassium the new feldspars also show increased BaO compared with the original feldspar. This last feature is also seen in feldspars from fenites and ijolites at their mutual contacts, described in chapter 4.

(6) Deductions concerning the varying quantity of soda and potassium fixed at different times during fenitization

Study of the mineral assemblages forming at different stages of fenitization, e.g. (groups 1 to 6 pp. 159-160), indicates that the alkali ratio varies greatly. The chemical data available (pp. 162 & 169) is insufficient to allow a quantitative summary to be made but in addition to a consideration of the mineral phases present allows an estimate of the trends.

Diagram of the conclusions on the relative importance of soda and potash in successive periods of fenitization:

(The width of the shaded area represents relative importance).
The chief conclusions drawn from such considerations are that soda is more active than potassium, affects a wider area and precedes in part the introduction of potassium. Potassium becomes more important in increasingly fenitized rocks until the point of melting is reached when soda is not fixed at all.

Petrographic evidence may provide a clue to the origin of some or all of the soda—it is known to be released from the country rock during replacement of soda feldspar by orthoclase and may in fact be driven outwards by a front of potassic metasomatism. Comparison of the alkali ratios in unaltered Nyanzian (p. 156) with those which must be present in extensively fenitized rocks indicates that potassium may have been the only alkali added, sufficient soda being present in the original Nyanzian. Viewed in this way the soda metasomatism does not represent a true addition of material but merely a re-disposition, as a result of a potassic metasomatic event, of that already present. Conversely, the very low potassium content of the unaltered Nyanzian indicates that much potassium has been added from the intrusive alkaline material.

D.K. Bailey notes that the above argument is consistent with Orville's (1962, 1963) conclusions of Kspar replacing Naspar near volatile source and consequent mut. of soda out. Under appropriate conditions the soda may be fixed (e.g. in sericite or allbite) further out. e.g. Horse, or may be lost with solutions, (Ruffina).
## CHAPTER 4

COUNTRY ROCK AND COUNTRY ROCK ALTERATION AT HOMA (b) FENITIZATION

AND RELATIONS OF SYENITIC ROCKS AT IJOLITE CONTACTS

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COUNTRY ROCK AND COUNTRY ROCK ALTERATION AT HOMA (b) FENITIZATION
AND RELATIONS OF SYENITIC ROCKS AT IJOLITE CONTACTS

(1) Introduction

No previous description of the rocks at ijolite contacts at Homa has been given although Pulfrey did briefly note the characters of the contact rock of the neighbouring Usaki area. He described the Usaki rock as a much jointed, hard, grey or leucocratic contact rock containing 65% soda orthoclase and 30% soda pyroxene (Pulfrey, 1950).

At Homa the ijolites and their contacts are poorly exposed, but there are three main areas where the marginal relationships can be observed (Fig. 4.1).

i) The western part of the main ijolite.

ii) Surrounding the microijolite exposed in the Bala Gully.

iii) The area regarded as the eastern extension of the main ijolite.

Areas of fenite also occur at some of the other small outcrops of ijolite (e.g. Nduru m'bili, Fig. 4.1). In addition to the above outcrops blocks of both ijolite and fenite are present as sparse fragments in breccias over a wider area of the mountain and its surrounds.
OUTLINE GEOLOGY OF HOMA MTN. AND SURROUNDS

KEY
- CLASSIC PLEISTOCENE
- MAINLY DRIFT COVERED
- LATER BEDDED PYROCLASTS
- IJOLITE CUT BY CARBONATITE
- IJOLITE AT LITTLE DEPTH
- SHATTERED NYANZIAN
- SATellite VENT
- CARBONATITE INTRUSIONS
- OCHREOUS BRECCIA
- PHONOLITE (•)
- PHENELINITE (•)
- PHENOLITE (•)
- GRANITE
- FAULT
- MOTOR TRACK

HOMA
POINT
RAW E RVER
CLASSIC
PLEISTOCENE
IJO UTE  CUT BY
CARBONATITE
IJOLITE AT
LITTLE DEPTH
SHATTERED
NYANZIAN
SATellite
VENT
CARBONATITE
INTRUSIONS
OCHREOUS
BRECCIA
PHONOLITE
GRANITE
FAULT
MOTOR TRACK

HOMA
BAY

0 1 2 3 km
Scale

FIG 4.1
(2) The western outcrop, relations and petrography

a) Fenite immediately at ijolite contacts

Irregular exposures of lenses and included masses of fenitized country rock occur here. The contacts are generally steep and the ijolite has more the form of a series of coalescing dykes than of a single intrusion (Fig. 4.2). Later carbonatites (C2b) have approximately the same strike (chapter 2, p.101).

This area is important because the country rock in which the ijolite is emplaced shows several stages of fenitization, the end product of which is generally a coarse-grained aegirine orthoclase rock (or aegirine orthoclaseite). Intermediate stages in the production of these rocks are well seen in the field as a network of cross cutting, dilationary veins from 0.1 to 4.0 cm. wide traversing the country rock near the contacts. These veins are bimineralic on the whole and are composed of prisms of orthoclase and aegirine, elongate perpendicular to the walls, in a rough comb texture (Fig. 4.3a & 3b). Study of thin sections shows that the country rock between these veins is also being made over to the same mineralogy by a more subtle metasomatic recrystallization.

The sequence of events involving deformation and fenitization at these contacts is given below and illustrated by diagrams drawn from thin sections of a number of selected specimens.

In the illustrations (Figs. 4.4,5,6,7,8) the letters refer to the following notes: (P.193–196).
The weathering resistance, reflectance and porosity of the country rock are a testament to the importance of these veins. The veins contain deposits of a variety of minerals, including quartz, feldspar, and mica, which are important for the formation of metamorphic rocks. The veins are typically formed during episodes of tectonic activity, such as the movement of plates along fault lines. The veins are often foliated, indicating the mechanical stress that caused the rocks to deform. The foliation is typically parallel to the direction of the fault line, and it can be used to determine the direction of the stress that caused the deformation. The veins are often filled with sedimentary material, which can provide valuable information about the environment in which the rocks formed. The veins are often used as a guide for the location of mineral deposits, and they are an important feature in the study of the Earth's crust.
RELATIONS WITHIN THE WESTERN OUTCROP OF THE MAIN IJOLITE.
Fig. 4. 3a,b. Fenite veins cutting country rock within three feet of the ijolite contact. N.W. of Rapogi Hill. The pale orthoclase and dark aegirine sections are often elongate perpendicular to the vein walls. HC 859B and HC 933E. X 1. P.P.L.
A) Relict phenocrysts are often the only remains of the original country rock. They are slightly turbid, show irregular extinction and consist of both sodic plagioclase and orthoclase.

B) The fine-grained groundmass is frequently recrystallized to a feldspar/aegirine intergrowth often showing slight alignment. Staining techniques show that growth of potassic feldspar accompanies the growth of aegirine but in cases when aegirine is subordinate or absent no fenitization can be deduced.

C) Narrow veins or stringers filled mainly with aegirine laths and occasionally tufts of amphibole having very low birefringence. This style of veining is not confined to the proximity of ijolite contacts. Rocks characterized by it are equivalent to the vein fenites described in chapter 3. Fig. 4.5 shows a vein of this type traversing an old oligoclase phenocryst. Aegirine is not developed in that part of the vein crossing the old feldspar. That this vein involved dilation may be gauged from the relative positions of the two portions of plagioclase. Staining shows that the new generation of granular feldspar along the path of the vein is potassic as is the stringer passing out through the recrystallized groundmass to the right.

D) Areas of groundmass recrystallized with more marked preferred orientation of the new minerals. These occur particularly in areas of local stress, e.g. around the more resistant bodies represented by the original phenocrysts. Staining techniques show much potassic
feldspar alongside aegirine. The implications of this directional recrystallization are dealt with in detail in a later section (p. 196).

E) The development of dilationary veins up to 2 mm. wide which cut across all other textures mentioned. These are filled with aegirine prisms and orthoclase plates and are accompanied by some new apatite and a conspicuous amount of calcite. Feldspar frequently lines the walls of such veins while calcite packs the more central part.

F) The final event is usually the development of numerous feldspar aegirine veins which again cut all earlier features. These are those particularly prominent in the field (Fig. 4.3). Large, clear crystals of feldspar showing carlsbad twins are packed round with radiating tufts and groups of aegirine, pleochroic in yellow and brown.

G) A further stage is sometimes seen involving limonite veining cutting all earlier features (Fig. 4.8). Partial replacement of aegirine by similar red brown iron oxides is occasionally seen and may be connected with this stage or with the disruption caused by later cross cutting carbonatites. The inclusion of thin plates of red brown ore in some of the larger feldspar plates may be another result of the movement of iron. Similar material has been noted as haematite lamellae in microcline microperthites from Madagascar and is presumed to result from exsolution (Coombs 1954).
In specimen HC 933E (Fig. 4.6) the veins of stage C are much disrupted, recrystallized and are almost obliterated during later recrystallization probably during stage D. Stage D is prominent and an irregularly bounded area of groundmass is completely recrystallized to aegirine and orthoclase. Some of the stage E orthoclase-calcite-aegirine veins show a slight en-echelon arrangement and may represent tension gashes. At least two series of stage F veins are present, the earlier carrying less pyroxene than the later. Stage Fb shows marked dilation of all previous structures.

Tension gashes with en-echelon arrangement are conspicuous at stage F in some specimens e.g. HC 933i (Fig. 4.7). Here dilation has been accompanied by shearing and the veins are now less continuous. The abundance of stage F structures in this rock has been accompanied by complete destruction and recrystallization of the original groundmass and no previous stages are visible. The rock is, therefore, a varying grain sized aegirine orthoclaseite.

The example noted above indicates that shearing and tensional forces accompanied the emplacement of the stage F veins in these rocks. The next example (Fig. 4.8) illustrates the effect of these mechanical stresses on the earlier structures. The stage C veins are recrystallized in some cases with long axes of the minerals preferably orientated parallel to the direction of shear (S). This direction is also that along which maximum extension appears to
have occurred for the stage D texture surrounds an original phenocryst which has broken into segments. The stage D elongate feldspar and aegirine crystals now sweep around the broken fragments and this lineated texture curves in towards the low pressure areas dividing the individual broken fragments (Fig. 4.9). Portions of the early fenite veins (stage C) normal to the S direction have gaped and portions more nearly parallel remain narrow.

It is believed that recrystallization was a paratectonic event occurring at the same time as, and partly as the result of, the stress which caused stretching of the original groundmass. The S direction is interpreted as one of maximum extension and to be related to the same stress pattern as the tensional features E & F.

The features present at this junction between the ijolite and country rock are believed to be those of a normal magmatic contact involving wedging and shouldering aside of the country rock. These mechanical disruptions were accompanied by a strong metasomatism.

b) Coarse-grained fenite developed 20 yards from the contact

A further outcrop showing the mode of development of fenite is seen some twenty yards N.of the ijolite boundary and 4-500 yards east of the last outcrop described. A face 70 sq. ft. in area was cleared, examined and photographed (Fig. 4.10). The country rock was found to be brecciated and re-knitted by a simultaneous
Fig. 4. 9. Broken fragments of an original feldspar phenocryst dispersed in the direction of elongation of the small feldspar/segirine sections forming the matrix. The original phenocryst has been affected by a process similar to that producing boudines on a macroscopic scale. HC 859D. X 35. X.N.
Fig. 4. 10. Light coloured areas of feldspathization visible in an exposure immediately north of the ijolite contact N.W. of Rapogi. Some veins are visible in the lower left part of the figure.
recrystallization which develops in irregular bands elongate roughly parallel to the nearby ijolite contact. (Fig. 4.2 ). Orthoclase is sometimes seen to develop by projecting outwards from a hair-line crack, in which case an origin by replacement is indicated.

Examination of thin sections of the coarser-grained bands shows that small nepheline euhedra are included in feldspars in narrow bands of the orthoclaseite. These zones are sometimes accompanied by narrow, <2 mm. veins of apatite accompanied by brown oxide pseudomorphs (after pyroxene?). These observations indicate that narrow tongues of syenitic material accompany the zones of fenitization in this case. The presence nearby of extensive outcrops of ijolite some of which contain feldspar indicates a possible source for this material. The result is an aegirine orthoclaseite containing relicts of nepheline. The specimens taken from the surface exposures frequently show alteration by weathering of the pyroxene to brown oxides.

For several hundreds of metres north of the ijolite outcrop the country rock shows a strong development of new feldspar and red oxides (chapter 5). Recognizable aegirine is seen only in areas close to the ijolite.

c) The end product of fenitization in this area

The result of the processes of veining etc. described above is an aegirine orthoclaseite of varying grain size with no original texture visible. Such material is found as lenses within and
adjacent to the ijolite body. The mode of one example (HC 825) shows that 66% orthoclase and 31% aegirine are present. An analysis of this rock is given on p. 218.

An exposure of this rock type at the north end of Rapogi Hill (Fig. 4.2) shows a coarse-grained facies in which orthoclase crystals up to 4 cm. in length, with carlsbad twins visible in hand specimens are present. The aegirine orthoclaseite has been intruded in part by a coarse white sovite and as a result the aegirine has locally broken down and is in the form of red brown oxide pseudomorphs. In the fresh rock feldspar prisms frequently have a radiating habit (Fig. 4.11a,b) and less often patches of albite twinned material (perthite) are present. Apart from secondary brown oxides and a little carbonate, pyroxene is the only other mineral present although rare apatite is sometimes seen in these rocks.

d) The nature of the ijolite near the contacts

Feldspathic ijolite is the name used in this thesis for the marginal facies of ijolites at Homa in which up to 10% modal feldspar occurs and a description of its general characters appears in chapter 2 (p. 107). Relations of this feldspar were also noted (chapter 2, p. 126). It was noted that feldspathic ijolite occurs near the contact zones of the western outcrop and also forms much of the ijolite at Bala. Such ijolites differ in three important respects from the more typical ijolite at Homa:
HC 320. FELDSPAR IN ORTHOCLASITE (x-N)

a) Shows a group of radiating orthoclase plates and also the typical habit of augenize in such rocks - radiating and often apparently perpendicular towards the orthoclase plates.
a) They generally have a finer grain size, some being micro-
ijolites.

b) The later crystallizing pyroxene is often very rich in the 
acmite molecule, particularly when in contact with feldspar.

c) The feldspar, low temperature orthoclase with a very high 
potassium content, is late in the paragenetic sequence, either 
filling vughs into which the other minerals project as idiomorphs 
or as interstitial small laths in the groundmass (Fig. 4.12).

The acmite pyroxene and orthoclase are the latest mineral 
phases to crystallize in these ijolites and are sometimes 
accompanied by calcite (chapter 2, p. 124). These three minerals 
are also developed in the stage E and F dilationary veins in the 
fenites described above and their crystallization has been shown 
to accompany deformation of the wall rock due to mechanical forces 
associated with the intrusion of ijolite. It is therefore believed 
that solutions depositing these minerals were active at the time 
of intrusion of the ijolite and for this reason could have had an 
origin within the ijolite itself.

Partial alteration of nepheline to hydroxyl bearing phases 
in areas adjacent to this feldspar may indicate that hydrothermal 
solutions were active locally in these pockets within the ijolites 
and may have been the solutions from which the orthoclase and acmite 
crystallized.
Fig. 4. 12. Feldspar filling a vugh into which nepheline and aegirine-margined aegirine augites project. Opaque melanite is also present. A microprobe traverse for iron was made of the near basal section of aegirine augite in the centre, c.f. Fig. 4.22. HC 934. X 4. P.P.L.
(3) Fenites exposed at the contacts of the Bala microijolite

a) Field relations with ijolite

The microijolite is exposed as an arcuate belt by downward erosion of the Bala Gully (Fig. 4.13). Contacts with country rock with two different attitudes are seen. The first is seen in the more southerly part of the gully where the microijolite is divided along its length by near vertical screens of fenite in which recognizable Nyanzian textures are still visible. The second attitude is noted in the northerly part of the section where irregular exposures of microijolite are surrounded and topographically overlain by a coarse pyroxene-rich fenite in which no traces of original texture remain.

From field relations (chapter 1, p. 71) this appears to represent the roof zone of an ijolite mass. The contact is not horizontal in detail but is interpreted as an interdigitation of apophyses of ijolite and fenite (Fig. 4.14). The ijolite at Bala contains up to 10% modal feldspar (chapter 2, p.126). The feldspar, with pectolite and phlogopite in addition, is considered to be a late stage primary mineral characteristic of the margins and roofs of intrusions.

b) Petrography of the fenites

The fenite from near vertical contacts in the southern part shows evidence of a complicated history.

i) Development of vein fenite (chapter 3, p.160). These veins are seen now as short relatively undisturbed lengths packed
Rhombohedral porphyry

CBT Blocks

CBT Veins

Plagioclase
Prehnite
Phonolite

Medium grained Buff Sollite
Coarse grained White Sollite

Micro-Idolite

Country rock altered to Pyroxene + Feldspar
Breciated/Anchroous Feldspathized country rock
Breciated country rock replaced by Iron Oxides

Foliation within altered country rock
Joints, often filled with Carbonatite

Observed contact
Inferred boundary

FIG 6-19
BALA RIVER SECTION
BLOCK DIAGRAM OF THE BALA GULLY

SECTION DOWN THE BALA GULLY
SHOWING THE PRESENT DAY SURFACE 'a-b'
AND A RECONSTRUCTION OF THE
IJOLITE CONTACT

FIG 4.14 (ornamentation as fig. 4.13)
with aegirine.

ii) Recrystallization of earlier textures, except some old phenocrysts, to an intergrowth consisting of pale brown mica, blue green amphibole and albite. Some replacement by orthoclase may have occurred at this stage. The dominant new minerals, mica and amphibole, plus the subordinate amount of aegirine in this fenite sometimes have a preferred orientation or foliation.

The fenite from the more horizontal areas of contact is unusual amongst the fenites at Homo in that the dominant mineral is pyroxene. This strongly coloured deep green mineral is accompanied by subordinate orthoclase. The fenite is coarse-grained and crystals of both minerals up to 3 cm. long are frequent. Alteration of the pyroxene to a pale green amphibole with high dispersion occurs in areas associated with small patches of a carbonate/zeolite intergrowth. Replacement of orthoclase by albite is also seen in the same patches.

This fenite is much brecciated and it appears that the latest movements of the microijolite caused this brecciation and may have coincided with the development of the amphibole mentioned above.

(4) Fenites, ijolitic rocks and syenites from the eastern extension of the main ijolite

a) Introduction

The following descriptions are of a group of rocks mostly found as blocks from the area of low ground stretching east and north-east from Yusoo (Fig. 4.1). Exposures are absent except
for one small outcrop located by Flegg 1 km. east of Homa Point East. The nature of the blocks indicates that this area may be considered as an extension of that to the west around Rapogi at which ijolite, fenite and carbonatite are better exposed.

Rock types represented include a suite of ijolites, feldspathic ijolites and nepheline and aegirine syenites. Some of the syenites originated as fenites and blocks showing fenite invaded by veins of feldspathic ijolite or syenite often strongly banded parallel to the contact are frequently seen in the field. It seems that the blocks represent debris from an ijolite contact zone at which much more late stage activity occurred within the ijolite and at which alteration of the country rock was mostly more marked than that previously described from the western outcrop and Bala.

b) Blocks showing the nature of the syenites

Rocks of ijolitic aspect but containing up to 10% feldspar have been noted previously at the margins of ijolite bodies. Many of the blocks from the area under discussion contain far more than 10% feldspar but in many cases still have an ijolitic aspect. These are here termed malignites if they contain up to 25-30% feldspar and nepheline syenites if more than this amount.

A modal analysis of an example of malignite (HC 741) gave:
Fig. 4. 15. Banded syenitic rock typical of those near ijolite contacts in the eastern extension. Clear, white orthoclase, diffuse white altered nepheline and mafic minerals, mainly pyroxene, are present. HC 306. X 1. P.P.L.
A chemical analysis of this rock is given on p. 218.

Rocks of much less undersaturated nature and with a different (trachytic) texture are also noted under the section on pulaskitic syenites. (p. 205)

A description of a block of cancrinite syenite is also given. (p. 205)

It is thought appropriate to note here the occurrence of extensive intrusions of nepheline syenite at the nearby carbonatic centre of North Ruri (Pulfrey, 1952; Dixon, 1966). The latter author notes that in places the marginal part of the nepheline syenite is associated with a zone of marked fenitization and that aegirine orthoclases and syenites are closely associated in a similar manner to that deduced at the eastern outcrop at Homa (J. A. Dixon, personal communication).

1) Malignites

In hand specimen these rocks have a mesocratic, ijolitic appearance and frequently show banding in the form of alternations...
of coarse and fine grain material. In addition to the ijolite minerals they carry many prismatic feldspars up to 3 cm. long. In thin section these feldspars are seen to be surrounded by numerous similar but small feldspar crystals with irregular margins. Occasionally feldspar intergrowths form a distinct area within the rock.

The nepheline in these rocks gives the impression that it is unstable, being almost completely altered to a fine-grained micaceous product. Sericite and analcime have been identified in such material by means of X-ray techniques.

Nepheline enclosed by the later feldspar in rocks from the western contact showed partial alteration of this type but in the outcrop discussed here both the amount of feldspar and the alteration of nepheline is much greater. This is thought to indicate that a much higher concentration of the aqueous solutions believed responsible for both phenomena were present at the final stages of consolidation at the contacts represented by the blocks here. (Fig. 4, 16a,b).

The lack of alteration of the feldspars adjoining completely altered nepheline is most striking and is evidence that the breakdown of nepheline is not a weathering phenomenon and that the feldspar was stable at temperatures below that at which nepheline breaks down.

The presence of pale yellow brown cores with slightly higher
Fig. 4. 16a,b. Hydrated nepheline, enclosed and partially replaced by clear orthoclase. WC 327. X 40. P.P.L. and X.N.
Fig. 4.17. Yellow brown, higher relief cores to orthoclase in syenitic contact rock. Also present are rounded grey nepheline relicts. HC 306. X 60. P.P.L.
R.I. was noted in several specimens of this rock type e.g. HC 806 (Fig. 4.17). It was suspected that analysis would show a high iron content in these feldspars (c.f. Combs, 1954). This was confirmed by microprobe analysis (p. 215).

ii) Nepheline syenites

Rocks in which even more feldspar is present are found in several areas including the exposure noted by Flegg (HF 1001). In such rocks the ijolite minerals are present only as isolated small euhedra. The dark brown melanite shows simple cubic symmetry, while nepheline frequently an approximately square outline. The dark green pyroxene occurs as ragged prisms e.g. HC 810.

Fig. 4.18A illustrates the general texture, large platey orthoclase, including numerous small crystals of ijolite type minerals. Some of the nephelines show evidence of replacement by the enclosing feldspar (Fig. 4.18B).

iii) Nepheline syenites (pulaskitic)

Several blocks of medium grained syenite, having a very different texture to those described in the previous section are present. They contain feldspars with trachytoid texture and a great concentration of aegirine in small prisms aligned parallel to the trachytoid texture. Many nepheline euhedra are interstitial and some are enclosed in the orthoclase.
Mode of an example (HC 744):-

<table>
<thead>
<tr>
<th></th>
<th>Per cent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pyroxene</td>
<td>51</td>
</tr>
<tr>
<td>Feldspar</td>
<td>26</td>
</tr>
<tr>
<td>Nepheline</td>
<td>22</td>
</tr>
<tr>
<td>Sphene</td>
<td>1</td>
</tr>
</tbody>
</table>

Melanite is absent and the nepheline is much less altered in these rocks compared with the other nepheline syenite types described above. In one example a fragment of ijolite was noted and in thin section this is seen to be accompanied by several xenoliths and xenocrysts of ijolitic origin within the trachytyoid matrix.

iv) Cancrinite syenite

A further variety of syenite was found as a block amongst the fine, grey calcareous tuff which surrounds the pyroclastic vent of Got Chiewo (Fig. 4.1; chapter 6).

This syenite is characterized by conspicuous, elongate pyroxene prisms up to 2 cm. long which have diopсидic cores but wide margins of deep green aegirine. The pyroxene is accompanied by apatite, cancrinite and late clear orthoclase. No nepheline outlines are seen and this together with the prismatic habit of some of the cancrinite (Fig. 4.19) invites comparison with the cancrinite syenite containing primary cancrinite described from Bueda (King and Sutherland, 1966).
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<table>
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<td>22</td>
</tr>
<tr>
<td>Sphene</td>
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</tr>
</tbody>
</table>

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Fig. 4. 19. Cancrinite syenite. Blades of pale cancrinite accompanied by aegirine augite and sparse orthoclase (dark grey). HC 365. X 40. X.N.
Apatite is rarely seen in silicate rocks at Homa unless accompanied by calcite but in this rock in which apatite constitutes up to 5 per cent no calcite occurs but carbonate is present in the form of cancrinite.

Work on the system nepheline-calcite (Eitel, 1925) showed that cancrinite melts incongruently to nepheline and a liquid under a CO$_2$ pressure of 110 Bars. It is, therefore, possible for cancrinite to form as a primary phase in a system including CaO and CO$_2$ which might crystallize nepheline at a higher temperature.

The feldspar in this rock is again orthoclase and it is believed that here is an example of a syenite which has crystallized at low temperature under high P CO$_2$ conditions. These conditions allowed a strong growth of orthoclase.

c) Blocks showing contact relations

i) Fenites intruded by syenitic types

Banded syenites, as described above, showing intrusive relations with a fine-grained grey green rock, are frequent over the eastern extension.

An example from the locality of Flegg shows in hand specimen a three inch wide band of fine-grained, relatively unveined aegirine orthoclase cut by a banded nepheline syenite. In the illustration (Fig. 4.20) the fine-grained aegirine syenite (P) is believed to represent the original Nyanzian although its texture has been entirely replaced. The felted aegirine veins (Q) are the remains
FIG 4.21

HC827 FENITE WITH NEPHELINE
ALTERATION PRODUCTS CUT BY A SYENITE VEIN
of the earlier fenite stage (equivalent to event C described in the western outcrop, p. 193). The nepheline syenite in contact with this fenite contains much radiating acicular pyroxene and highly altered nepheline; melanite is not seen in this rock. Narrow prisms pseudomorphed by an aggregate of feldspar, aegirine and calcite and occasionally pectolite, may be after wollastonite. Other less narrow prismatic outlines are pseudomorphed in iron oxides and carbonate.

The presence of sericite/zeolite aggregates in these rocks is considered to represent nepheline even when the original nepheline outlines are lost. Much sericite/zeolite material is present along the contact (R₁ to R₂) where small nepheline outlines are also occasionally seen. This contact along R₁ R₂ between the fenite and the syenite is very irregular and does not look like a cross cutting contact.

In the case considered above it is clear which is the fenite and which the intrusive syenitic rock but in some examples from this area the distinction is not always so clear.

A rock in which the relations in hand specimen are very similar to those described above is illustrated (Fig. 4.21). In thin section (P) is a fine-grained intergrowth of aegirine prisms and orthoclase in which no relict country rock or previous fenite textures are visible. Occasionaly patches of cancrinite and zeolite may represent the former presence of a small amount of nepheline. Aegirine is more abundant at the margin (R) which is again a very irregular
border. A vein (T) is considered intrusive and is composed of numerous partly zeolitized and cancrinitized nephelines with some fresh orthoclase plates, rosettes of aegirine and cancrinite developed particularly at aegirine/nepheline boundaries.

The zone (S) dividing the fine-grained orthoclase-aegirine rock and the syenitic vein has a grain size a little greater than zone P. Relict nepheline is present in subordinate amount to fresh orthoclase. The aegirine of this zone is characterized by felted aggregates. The zone U has a similar texture to that of S. This intermediate zone (S-U) has at least three possible origins:

1. As an intrusion earlier than the nepheline syenite (T).
2. As the result of intense fenitization of the wall rock to produce new nepheline, in addition to orthoclase and aegirine.
3. As the result of intense alteration and subsequent rheomorphism of the bordering zone of fenite and reconsolidation of this as a nepheline syenite.

In both of the specimens showing contact relations it is noticeable that the phases crystallizing each side of the boundary are very similar, i.e. there is a marked approach towards mineralogical equilibrium across the boundary.

The sequence of crystallization of nepheline and feldspar has been used by Von Eckermann (1948) as a criterion for distinguishing between nepheline syenites of metasomatic and magmatic origin. In fenites nepheline develops late whereas in magmatic rocks it
crystallizes before the feldspar.

On this basis all the nepheline syenites, described previously in this account, from Homa have a magmatic origin and also the zone S of the specimen illustrated (Fig. 4.21) must also have crystallized from a melt but it is not possible to judge whether that melt represents a rheomorphic fenite.

A difficulty arises when the same criterion is applied to the zone P of Fig. 4.21. The rock here is believed to represent a fenite but although nepheline outlines are not present patches of cancrinite and material similar to the sericite/zeolite alteration products are seen apparently included by the feldspar. If these are in fact relics of former nepheline then an origin involving a magmatic stage is indicated.

However, the observation made above that there is a marked tendency for the same equilibrium conditions to be approached each side of the syenite/fenite boundary may indicate an alternative origin for these patches. Under the conditions existing during the fenitization of the wall rocks nepheline is unstable. Its place is taken by other phases. It is unlikely, therefore, that nepheline would be stable in these fenites but it is entirely possible that phases equivalent to the alteration products of nepheline would be stable. In this connection the work of Saha (1961) gives data on the stability of nepheline. During work on the system NaAlSiO$_4$-H$_2$O his results suggest that nepheline is not
stable below 450°C at moderate and high pressures in the presence of excess water. The low temperature assemblage includes a colourless mica.

In view of the above data and the already deduced hydrous nature of systems in which fenite minerals form at Homa it is tentatively proposed that an alternative explanation of the irregularly bounded patches within the fenites is that they represent incipient nepheline, possibly after the feldspar. If this is the case the rock would be equivalent to a nepheline bearing fenite according to Von Eckermann's criterion.

ii) Blocks in which two phases of nepheline syenite are present

Blocks of pulaskitic micro-syenite (p.205) cut by up to 2 cm. veins of coarse nepheline syenite, similar to that in the vein (T) above, are occasionally present. In this case both phases are assumed to have a magmatic origin although the interstitial nature of some of the nepheline may indicate that it crystallized late in the sequence.

(5) Optical and chemical data on the minerals of the contact zones

a) Introduction

Petrographic evidence has already been described which shows that orthoclase and aegirine are by far the most important and typical members of the fenite assemblages at ijolite contacts and are equally important as the phases crystallizing latest in the ijolites which occur alongside these contacts.
b) Pyroxene

Estimates of composition by measurements of extinction angles for pyroxene near aegirine are unsatisfactory. The method preferred by King (1962) was also found to be unsatisfactory because of the narrow prismatic and acicular form of most of the pyroxenes in the fenites and in the syenitic rocks under discussion. The aegirine rims on pyroxenes from the western outcrop are, however, of a form amenable to such measurements.

Measurements (HC 934) of optical orientation across pyroxenes zoned to aegirine margins where in contact with late crystallizing feldspar:-

<table>
<thead>
<tr>
<th>Cores</th>
<th>Margins</th>
</tr>
</thead>
<tbody>
<tr>
<td>$X^c = 36^\circ$</td>
<td>$14^\circ \rightarrow 8^\circ$</td>
</tr>
<tr>
<td>$X^c = 35^\circ$</td>
<td>$23^\circ \rightarrow 12^\circ$</td>
</tr>
<tr>
<td>$A_1^c = 21^\circ$</td>
<td></td>
</tr>
<tr>
<td>$A_1^c = 18^\circ$</td>
<td></td>
</tr>
<tr>
<td>$A_1^c = 20^\circ$</td>
<td></td>
</tr>
</tbody>
</table>

Pleochroic scheme of the margins:-

$X =$ dark green; $Y =$ pale green; $Z =$ yellow/brown/green.

In the fenites and syenites the generally small extinction angle and deep green colour of the pyroxenes in all cases points to composition rich in aegirine.

The following microprobe analyses are available of pyroxenes from these rocks.
<table>
<thead>
<tr>
<th></th>
<th>HC 934A</th>
<th>HC 934B</th>
<th>HC 859D</th>
<th>HC 827</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO₂</td>
<td>54.50</td>
<td>-</td>
<td>55.40</td>
<td></td>
</tr>
<tr>
<td>TiO₂</td>
<td>0.75</td>
<td>0.22</td>
<td>2.00</td>
<td></td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>1.60</td>
<td>0.70</td>
<td>0.50</td>
<td></td>
</tr>
<tr>
<td>Fe^{2+}</td>
<td>± 10%</td>
<td>12.40</td>
<td>20.50</td>
<td>32.00</td>
</tr>
<tr>
<td>MnO</td>
<td>-</td>
<td>-</td>
<td>0.10</td>
<td></td>
</tr>
<tr>
<td>MgO</td>
<td>13.60</td>
<td>5.30</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>CaO</td>
<td>22.30</td>
<td>-</td>
<td>2.20</td>
<td>5.00</td>
</tr>
<tr>
<td>Na₂O</td>
<td>± 25%</td>
<td>1.50</td>
<td>4.00</td>
<td>8.00</td>
</tr>
<tr>
<td>K₂O</td>
<td>± 10%</td>
<td>-</td>
<td>&lt;0.50</td>
<td></td>
</tr>
<tr>
<td></td>
<td>106.65</td>
<td>101.20</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Analyst J. A. Dixon.

HC 934A Core of pyroxene from feldspathic ijolite.

HC 934B Margin of same pyroxene in contact with feldspar.

HC 859D Pyroxene from 0.5 cm. fenite vein - western outcrop.

HC 827 Pyroxene from banded nepheline syenite - eastern outcrop.

The pyroxenes from the third and fourth rock above are considered the more typical and each shows a high content of aegirine. The first two analyses show the extent of zoning from normal ijolitic pyroxene to that crystallizing later alongside the feldspar. The microprobe traverse (Fig. 4.22) shows the sharply increased aegirine content of the later zones of this pyroxene.
MICROPROBE TRAVERSE
FOR Fe₂O₃⁻

FIG 4.22

HC 934

PYROXENE

Fr⁻

20%

12%
c) Feldspar

The feldspar developing late in the vughs of the ijolite at the western outcrop is very similar optically to that in the associated veins. Broad plates, occasionally twinned on the carlsbad law, show moderate to weak dispersion $r>v$. Exsolution is rarely seen in these feldspars.

Very similar orthoclase forms the bulk of the aegirine orthoclasites but in these more evidence of exsolution is present.

Syenites and feldspathic ijolites from the eastern extension again show a strong development of orthoclase, often simply twinned and rarely showing exsolution. Dispersion in these is sometimes moderate $r>v$.

Measurements of $2V$ and optical orientation with the Universal Stage

<table>
<thead>
<tr>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>HC 933i</td>
<td>Fenite vein</td>
<td>W. outcrop</td>
<td>$40^\circ$</td>
<td>010</td>
<td>$r&gt;v$</td>
</tr>
<tr>
<td>HC 859D</td>
<td>Fenite vein</td>
<td>W. outcrop</td>
<td>$38^\circ$</td>
<td>010</td>
<td></td>
</tr>
<tr>
<td>HC 320</td>
<td>Aegirine orthoclase</td>
<td>Rapogi</td>
<td>$27-43^\circ$</td>
<td>010</td>
<td></td>
</tr>
<tr>
<td>HC 825</td>
<td>Aegirine orthoclase*</td>
<td>W. outcrop</td>
<td>1st $58^\circ$</td>
<td>010</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2nd $40^\circ$</td>
<td>010</td>
<td></td>
</tr>
<tr>
<td>HC 827</td>
<td>Nepheline syenite</td>
<td>E. outcrop</td>
<td>$36^\circ$</td>
<td>010</td>
<td></td>
</tr>
<tr>
<td>HC 797</td>
<td>Banded malignite</td>
<td>E. outcrop</td>
<td>$38^\circ$</td>
<td>010</td>
<td>$r&gt;v$</td>
</tr>
<tr>
<td>HC 810</td>
<td>Nepheline syenite</td>
<td>E. outcrop</td>
<td>$36^\circ$</td>
<td>010</td>
<td>$r&gt;v$</td>
</tr>
<tr>
<td>HC 743</td>
<td>Trachytoid syenite</td>
<td>E. outcrop</td>
<td>$33^\circ$</td>
<td>010</td>
<td></td>
</tr>
</tbody>
</table>

*Description and analysis of the feldspar in this rock is given on p. 216.

X-ray techniques show that the albite content of these feld-
spars is very low and it is therefore possible to use the value of $2V$ and the orientation of the optic plane to diagnose the alkali feldspar series to which these belong (orthoclase - low albite) and to show that the orthoclase content is probably in excess of 85-90 per cent (c.f. Fig. 111, Deer et al., 1966).

**Microprobe analyses of individual feldspars**

<table>
<thead>
<tr>
<th>Compound</th>
<th>HC 859D</th>
<th>HC 934</th>
<th>HC 827A</th>
<th>HC 827B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe$_2$O$_3$</td>
<td>-</td>
<td>-</td>
<td>0.32 ± 0.06</td>
<td>0.68 ± 0.14</td>
</tr>
<tr>
<td>CaO</td>
<td>-</td>
<td>1.00</td>
<td>0.16</td>
<td>not detected</td>
</tr>
<tr>
<td>K$_2$O ± 0.70</td>
<td>15.90</td>
<td>15.10</td>
<td>15.50</td>
<td>15.70</td>
</tr>
<tr>
<td>Na$_2$O</td>
<td>not det.</td>
<td>1.00</td>
<td>not detected</td>
<td>-</td>
</tr>
<tr>
<td>BaO ± 0.02</td>
<td>-</td>
<td>0.30</td>
<td>0.40</td>
<td>0.70</td>
</tr>
</tbody>
</table>

Analyst J. A. Dixon.

HC 859D Orthoclase from fenite vein, W. outcrop.

HC 934 Orthoclase from vugh in ijolite, W. outcrop.

HC 827A Margin (colourless) of orthoclase from nepheline syenite, E. outcrop.

HC 827B Pale brown core of orthoclase from nepheline syenite, E. outcrop.

As well as confirming the highly potassic nature of the feldspars developed in the rocks under discussion analysis 827B indicates that the pale yellow brown cores of slightly higher relief material sometimes seen in the fenites and syenites at Homa contain a slightly higher content of iron.
Chemical analyses and mineralogy of feldspar from an aegirine orthoclase

Analysis of feldspar from HC 825

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Per cent</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO₂</td>
<td>64.35</td>
</tr>
<tr>
<td>TiO₂</td>
<td>0.07</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>19.06</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>0.34</td>
</tr>
<tr>
<td>FeO</td>
<td>-</td>
</tr>
<tr>
<td>MnO</td>
<td>-</td>
</tr>
<tr>
<td>MgO</td>
<td>-</td>
</tr>
<tr>
<td>CaO</td>
<td>0.36</td>
</tr>
<tr>
<td>Na₂O</td>
<td>2.06</td>
</tr>
<tr>
<td>K₂O</td>
<td>13.96</td>
</tr>
<tr>
<td>H₂O⁺</td>
<td>0.13</td>
</tr>
<tr>
<td>P₂O₅</td>
<td>0.01</td>
</tr>
</tbody>
</table>

100.34

Analyst M. Blackley.

Initial examination of thin sections of the rock, which this sample was separated indicated that the bulk of the feldspar was an orthoclase with similar properties, including 2V, to most of that in ijolite and veins in the area. The analysis, however, shows a considerably higher albite content than do the microprobe analyses of individual grains of other rocks noted above. A more searching petrographic examination was, therefore, made of thin sections of this rock and this showed that several generations of feldspar
FIG 4.23a

FIG 4.23b

FELDSPAR GENERATIONS IN
ORTHOCLASITE
were present (Figs. 4.23 & 23d).

1. Large (1-3 mm.) ragged prisms of orthoclase (2V = 58°) showing prominent perthite lamellae. These may be xenocrysts but their origin is obscure.

2. The majority of feldspar occurs as prisms (up to 1.0 mm.) frequently twinned on the carlsbad law with the properties of the normal fenite feldspars (2V = 40°).

3. Granular untwinned feldspar (up to 0.2 mm.) with similar R.I. to group 2.

4. Occasional patches and individual grains of both cross hatch and albite twinned feldspar (≤0.2 mm.).

5. Lamella or spindle twinned feldspar developing at the junction of or in the neighbourhood of a calcite-orthoclase interface. This is probably microcline which develops similarly in feldspar rocks (chapter 5, p. 227).

The above is also the interpreted order of development of the feldspars the first four generations of which may indicate a series of feldspar crystallizations at progressively falling temperature. The final stage (microcline) appears to be associated with an incursion of calcite, probably from a nearby carbonatite. In such cases the aegirine frequently is replaced by iron oxides as is partially seen here. Feldspars with a 2V as large as 58° are rarely seen in fenites and associated rocks at Homa.
(218)

(6) **Chemical composition of rocks of the contact zones**

<table>
<thead>
<tr>
<th></th>
<th>HC 825</th>
<th>HC 744</th>
<th>HC 741</th>
<th>HC 936</th>
<th>HC 309</th>
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<tr>
<td>SiO$_2$</td>
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<tr>
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<td>H$_2$O$^-$</td>
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<td>3.28</td>
<td>1.26</td>
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<tr>
<td>P$_2$O$_5$</td>
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<td>Nil</td>
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<td>0.71</td>
<td>0.61</td>
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<td><strong>Total</strong></td>
<td><strong>100.27</strong></td>
<td><strong>98.89</strong></td>
<td><strong>99.66</strong></td>
<td><strong>98.42</strong></td>
<td><strong>98.29</strong></td>
</tr>
</tbody>
</table>

**Analyst**
- M. Blackley
- W. H. Herdsman
- M. Blackley

**Modal analysis**
- Pyroxene: 31, 51, 11, -
- Feldspar: 66, 26, 26, 5-10, 0
- Nepheline: -
- Melanite: -
- Apatite: -
- Calcite: 3
- + 5% Cancrinite

HC 825 Aegirine orthoclase, W. outcrop.
HC 744 Pulaskitic syenite, E. outcrop.
HC 741 Malignite, E. outcrop.
HC 936 Feldspathic ijolite, W. outcrop.
HC 309 Ijolite, main ijolite outcrop.
FIG 4.24

DIAGRAMMATIC SUMMARY OF THE RELATIONSHIPS AT IJOLITE CONTACTS

COUNTRY ROCK

VEIN FENITE

AEGIRINE ORTHO-CLASITE NEPHELINE FENITE POSSIBLY NEPHELINE-BEARING NEPHELINE SYENITE INCL. PULASKITE MALIGNITE FELDSPATHIC IJOLITE IJOLITE

INCREASING FENITIZATION INCREASING LATE STAGE EFFECTS

DE DEDUCED FROM BLOCKS AT EASTERN EXTENSION

BALA ROOF

WESTERN OUTCROP
Diagrammatic summary of the relationships at ijolite contacts

The central vertical line in Fig. 4.24 represents the contact between fenites and magmatic rocks of the ijolite-malignite group. The horizontal lines $AA_1; BB_1; CC_1; DD_1 D_2 D_3$ show the rock types present in the areas where they have been studied. The degree of alteration, late stage effects and variety of rock types developed, increases from $A$ to $D$.

The lowermost horizontal represents the cases where the original contacts have become obscured and sometimes probably no longer exist due to the increased metasomatism and deuteric effects. Rocks in this zone may have had more than one origin and are near pulaskite in composition.

Summary of conclusions on the origin of fenites at Homa

The fenites at the western outcrop originated during the last stages of intrusion of an ijolite body and the characteristic minerals, aegirine and a highly potassic orthoclase, are believed to result from material concentrated by crystallization of the silicate melt.

This concentration and separation of material capable of metasomatizing the wall rock and precipitating the same mineral phases both in dilations in the wall rocks and in late stage cavities within the marginal ijolites is likened to the hydrothermal stage of Fersman (Turner and Verhoogen, 1960, p. 428) seen at many igneous contacts.
The suite of specimens from the eastern extension show development of the same phases and phenomena but here metasomatism of the fenites and deuteric alteration of the ijolites has been much more intense.

The more intense alteration indicates that much more of the 'hydrothermal' stage material was present, one effect of which is the complete conversion of nepheline to hydrated phases. At this stage the composition of rocks each side of the original contact becomes similar and the contact itself obscured and probably finally obliterated.

Rocks in this intermediate 'syenitic' zone have a composition near that of pulaskite and in some cases were magmatic. They may have originated either as intensely altered country rock or as relatives of the ijolites. Due to the poor field relations it is not, however, possible to prove that any rock originating as a fenite at ijolite contacts has become mobile.

The occurrence at Homa of relatively minor zones of syenitic composition around high level bodies and cupolas of ijolite is believed to be equivalent to the development of the much wider syenite zones which have been described from more deeply eroded centres e.g. Alno.

Notes on the relations of fenites away from ijolite contacts with those at ijolite contacts

The similarity in mineralogy between the fenites described in the present chapter which occur at the margins of ijolite intru-
sions and those described in chapter 3 occurring most markedly in zones of intense shearing and brecciation but also over wide areas at Homa, indicates that both originate due to movement of material with probably the same source.

The recognition that the fenitization at ijolite contacts includes an early stage of veining (p.207-8) equivalent to that described from extensive areas of the mountain (chapter 3, p.193) is important for it indicates that the more regional style of fenitization was early and was later superceded by the more intense but localised style seen at ijolite contacts.

Evidence has already been cited (chapter 1, p.35) that carbonatites are also closely associated with the more intense zones of fenitization away from ijolite contacts and that in some cases rocks linking fenites and carbonatites are found (chapter 3, p.178). This indicates that a common source may have to be sought for both fenites and carbonatites as post magmatic segregations from material which crystallizes as ijolite and in part nepheline syenite.
CHAPTER 5
ROCKS WITH SOME AFFINITIES TO AEGIRINE-BEARING FENITES AND SYENITES
IN WHICH THE DEVELOPMENT OF FELDSPAR IS ENHANCED BUT IN WHICH
AEGIRINE IS UNSTABLE OR ABSENT

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ROCKS WITH SOME AFFINITIES TO AEGIRINE BEARING FENITES AND SYENITES
IN WHICH THE DEVELOPMENT OF FELDSPAR IS ENHANCED BUT IN WHICH
AEGIRINE IS UNSTABLE OR ABSENT

(1) Introduction

Metasomatism involving the growth of new soda mafic minerals and potash feldspar has already been described (chapter 3, p. 152 and chapter 4, p. 191). In both the more widespread style of fenitization and that confined to ijolite contacts it was seen that earlier stages in the metasomatic process involved the introduction of soda followed by progressively increasing amounts of potash.

There are, however, in addition to the typical fenites, rocks at Homa that carry much potassium feldspar but little or no aegirine. They include both coarse and fine grained varieties and are often found involved in breccias of various kinds and are sometimes associated in the field with carbonatites. Rocks with very similar mineralogy which are believed to have passed through a magmatic stage are occasionally seen and are described here also. In this account the nomenclature suggested by Sutherland (1965) has been employed.

(2) Coarse-grained feldspathic rocks

a) Ochreous orthoclasesites

Rocks with very similar characters to those of the aegirine orthoclasesites described in the previous chapter (p. 197) but in which aegirine itself is absent are seen frequently at Homa usually
in areas within or adjacent to the contact zones of ijolites.

The illustration (Fig. 5.1) shows an interlocking growth of tabular orthoclase which in different zones varies in grain size. The interstices of these feldspars are filled with red/brown iron oxides which produce haematite peaks on a diffractogram. Thin sections of this rock show that the iron ore is pseudomorphing a narrow prismatic or acicular mineral (Fig. 5.2). The habit of these pseudomorphs indicates they are after aegirine and this is confirmed by occasional unaltered pyroxene individuals which are completely enclosed in the feldspar.

At an exposure noted previously (Fig. 2.2), north of Rapogi, an area of aegirine orthoclasite outcrops and in part is invaded by a coarse sovite. The orthoclasite (HC 320), brecciated and included in the sovite, shows a complete conversion of the aegirine to red/brown oxides of the type mentioned above. The end product is a xenolithic sovite in which fragments of ochreous orthoclasite and individual xenocrysts of feldspar are included. The fragments and crystals are dispersed as trains of inclusions parallel to the foliation of the carbonatite (Fig. 5.4).

The optical and chemical properties of the feldspar in these rocks are very similar to those in the fenites described in the previous chapter (p. 214) and the ochreous orthoclasesites are believed to have formed as fenites and to have been subsequently modified by intrusion of carbonatite.
Fig. 5.1. Ochreous orthoclase showing varying grain size of orthoclase individuals. The dark coloured interstitial areas are of red brown iron oxides after aegirine. HC 793.
PSEUDOMORPHS AFTER AEGIRINE (In plates of Ordovician).
Fig. 5.4. Ochreous orthoclaseite fragments breaking up and being dispersed in the matrix of a sovite dyke.
In some cases sovite appears to play a more dominant role in the formation of orthoclaseite. At Ndiru m'bili (Fig. 5.5; also chapter 1, p. 62) a small exposure of ijolite which has converted a narrow zone of the country rock to aegirine orthoclaseite is seen. Irregular patches and dykes of coarse, white sovite are also early in the sequence and at their margins the country rock is converted to a medium and coarse-grained ochreous orthoclaseite. The two rocks sometimes occur as an intimate intergrowth with rhombs and plates of calcite up to 3 cm. long enclosed in a matrix of ochreous orthoclaseite (Fig. 5.6). In this case the ochre cannot be proved to pseudomorph aegirine and there is no evidence that the latter was ever present.

Much of the country rock surrounding the ijolite and sovite intrusions and their contact rocks at Ndiru m'bili is composed of a fine-grained feldspathic rock some of which shows evidence of mobilization, and in parts, brecciation (p. 233).

b) Ijolitic rocks included in or cut by carbonatites

The development of feldspar together with aegirine as late minerals believed to occur during the post magmatic stages of crystallization within the ijolite has been described (chapter 4). In some cases, however, a later episode of feldspathization, associated with veins and dykes of cross cutting carbonatite is seen and in such cases aegirine is often broken down to oxides or actively replaced.
OUTLINE GEOLOGY OF HOMA MTN.
AND SURRounds

CLASSIC CUT BY PLEISTOCENE CARBONATITE

LATE BEDDED MANLY DRIFT COVERED PYROCLASTS

SHATTERED SATINITE VENT NYANZIAN

VENT NYANZIAN SATELLITE VENT CARBONATITE INTRUSIONS

NYANZIAN BRECCIA OCHREOUS BRECCIA

PHONOLITE PHENOPHYLITE

NYAMATOTO NYASANJA VALLEY LATER BEDDED PYROCLASTS SHATTERED NYANZIAN

NYANZIAN GRANITE NYANZIAN SATELLITE VENT CARBONATITE INTRUSIONS

OCHREOUS BRECCIA PHONOLITE PHENOPHYLITE

NYASANJA ODIAYO AWAYO RONGO

OSIRI LANDSLIDE GULLY GOT OLOO GOT OJAWA

VERS CLIFF OROLO CLIFF OF PLEISTOCENE SEDIMENTS NYAMATOTO NYASANJA VALLEY

CHIEMO VENT NDHURU MBILI YUSOO NDHURU

NDHURU OGWAGO RIDGE RAPOGI ONYA

OYOLO KANJIEGE

0 1 2 3km Scale

FIG. 5.5

SECTION A-B-C ON FIG. 5.
Fig. 5, 6. Medium-grained ochreous orthoclaseite in which large plates of calcite, often showing strain are dispersed. Ndiru m'bili, S.E. Homa Mountain. HC 813. X 5. P.P.L.
The illustration (Fig. 5.7) shows two phases of feldspar development in a rock believed to be of essentially ijolitic parentage.

a. An earlier in which large plates of feldspar, accompanied by natrolite, pectolite, calcite and cancrinite, occur. At the borders of this area melanite euhedra are preferentially developed.

b. A second stage involved fracturing of the previous syenitic rock with development of calcite, feldspar and phlogopite along the fractures. Such veins are bordered by 1-2 mm. zones of altered ijolite. This alteration involves cancrinitization of nepheline and the alteration of pyroxene to phlogopite. The feldspar develops within the veins and does not visibly replace any previous mineral.

On a larger scale, examples of sovite cutting ijolite, causing very intense brecciation and resulting in varying degrees of feldspathization, have been observed from several areas at Homa.

Sovites cutting the Bala microijolite result in xenolithic rocks in which 25-50% of the bulk is included material (e.g. HC 920). In such rocks the essential ijolite minerals are seen in various stages of replacement and alteration, the nepheline being replaced by a brown stained, turbid intergrowth of zeolite and pale mica. The pyroxene is characteristically sieved with apatite grains and is breaking down to iron oxide. In this case only a small quantity of fresh orthoclase has developed.
FIG. 5.7

HC 326. TWO PHASES OF FELDSPAR DEVELOPMENT IN IJOLITE
In several sovite dykes cutting the ijolite near Rapogi (Fig. 5.5) numerous xenoliths of coarse-grained feldspathic rock occur (Fig. 5.8). Similar feldspathization of the adjacent ijolite wall rock has not occurred however. The xenolithic material is similar in mineralogy to the nepheline syenites described in the previous chapter except that pyroxene is unstable and in the process of breaking down to iron oxides. Nepheline and melanite are also unstable and are accompanied by a strong development of apatite (Fig. 5.9). The predominant mineral in most xenoliths is a coarse-grained orthoclase having similar properties to that previously described from fenites and syenites of nearby areas and the rock is essentially an altered aegirine orthoclase of pulaskitic composition.

A second generation of feldspar is sometimes seen at orthoclase-calcite interfaces and at the margins of some xenoliths. The illustration (Fig. 5.10) shows simply twinned feldspar tablets apparently projecting outwards from the margin of a block of orthoclase. The hand specimen character indicates that these were growing in contact with the carbonatitic matrix to the xenoliths but on a microscopic scale there is evidence of movement and brecciation since the consolidation of the feldspars.

In some specimens, however, microscopic examination of such calcite/feldspar interfaces shows the presence of a marginal zone of feldspar of different composition developing as an extension
Fig. 5. 8. Orthoclaseite inclusions in a 30 cm. sovite dyke cutting ijolite 300 m. east of Rapogi Hill.
Fig. 5.9. Turbid, hydrated nepheline, pyroxene altering to iron oxides and melanite dispersed in a calcite and apatite rich matrix. Occasional new orthoclase grains develop.

HC 966. X 9. P.P.L.
Fig. 5. 10. Orthoclase developing at the margins of an orthoclase fragment included in sovite. The original fragment margin is parallel with the lower edge of the figure.
of the earlier orthoclase. This marginal feldspar itself shows variation (Fig. 5.11). Mostly it consists of cross hatch twinned material identified as microcline. This in turn is rimmed by untwinned feldspar zoned to higher relief margins. A powder photograph of material from the marginal zone, including the narrow high relief borders, did not demonstrate the expected triclinicity. The delicate nature of the latest outgrowths leaves no doubt that they were crystallizing at the same time as the calcite matrix.

An example of the development of very coarse-grained feldspar with similar relations was located in the badly exposed area believed to represent the continuation eastwards of the main ijolite outcrop around Rapogi (Fig. 5.5). Here a white calcite rock (sovite), average grain size 5 mm., contains brecciated fragments of a melanite ijolite in which much replacement of both nepheline, its alteration products and pyroxene has occurred (Fig. 5.12). Similar individual feldspar crystals up to 6 cm. long lie nearby in the sovite matrix (Fig. 5.13). Analysis (p.234) of a sample of these feldspars shows an orthoclase content of 90% and the optical characters are similar to those of fenites.

One of the many problems of interpretation of the feldspathized ijolites described above is that they occur mainly as inclusions within sovite dykes and quite often the ijolitic wall rocks are not affected by the alterations undergone by the xenoliths. It has also been shown that feldspar developing at the present position
FIG. 5.11

MICROCLINE

ORTHoclase

HC 664. FELDSPAR DEVELOPING IN CONTACT WITH CARBONATE
REPLACEMENT OF NEPHELINE AND CPX.
BY ORTHoclase AND CALCITE.

Fig. 5. 13. Tablets of orthoclase twinned on the carlsbad law in a matrix of sovite. HC 796.
is confined to the borders of grains and this feldspar has some properties of a microcline while the majority of the feldspar is orthoclase and similar in many respects to that formed during fenitization (chapter 4).

It is tentatively concluded that conditions present at lower levels in the narrow zones, now occupied by the sovite dykes, were similar to those occurring during the more intense fenitization at ijolite contacts described previously (chapter 4, p. 201) but that in addition the components of sovite were present at a slightly later stage resulting in continued development of feldspar but rendering the aegirine unstable. The final stage envisaged is the intrusion of sovite as dykes carrying up fragments of the feldspathic material.

(3) Fine-grained feldspathic rocks

a) Pseudotachyte breccias

There are two series of breccias at Homa both of which have an ochreous carbonatitic matrix but are essentially of differing origin (chapter 1, p. 19).

The first group, carbonatitic mixed breccias, are widespread on many parts of the mountain and occur as cross cutting sheets or small centres. These rocks have a mixed fragment content and are rarely accompanied by feldspathization effects.

The second group of ochreous breccias are rocks consisting of angular fragments of fine-grained feldspathic material in which
the original brecciation has been partly recemented by metasomatic crystallization of orthoclase. Unlike the previous series fragments are usually only of country rock. This process of brecciation and feldspathization has been noted at many carbonatite centres and the rock so formed often outcrop over large areas. The rock is termed feldspathic breccia by Garson and Campbell-Smith (1958) but in this work the term pseudotrachyte breccia is used (Sutherland, 1965).

The rock is prominently exposed at two areas (fig. 5.5) within the southern part of the Homa complex: i) The steeply sloping ground north of the ijolite below South Cliff and ii) as the rock into which the ijolites and carbonatites of Bala are intruded, i.e. it is developed best as areas of widespread alteration affecting country rock in the vicinity of ijolite, but lies outside the zones of coarse fenite described in the previous chapter. Small zones of similar altered country rock are present in other areas however, often adjacent to narrow, brown carbonatitic intrusions.

At Bala the pseudotrachyte breccia topographically overlies the microijolite intrusions (chapter 1, p. 71). The breccia consists of cream angular fragments set in a buff-pink sparse matrix. Thin sections show that the fragments consist of country rock in various stages of recrystallization and modification to a felsitic or trachytic texture.
The lower birefringence of the new feldspar and X-ray pattern of a powdered sample of the breccias indicate that a large proportion of low temperature orthoclase is present. The material between the feldspathic fragments is composed of an intergrowth of similar feldspar from finely comminuted fragments of country rock, together with subordinate carbonate, ore and possibly leucoxene.

This rock has a distinctive angular blocky appearance in outcrop and is often stained with pink and orange iron oxides.

Many of the carbonatitic mixed breccias have a similar iron stained appearance and may contain fragments of pseudotratrachyte but these are mixed with unfeldspathized fragments of country rock, ijolite or vein fenite and this indicates that the intrusion has sampled a zone of feldspathization at depth.

Narrow belts or intrusions of carbonatitic pseudotratrachyte breccia are occasionally seen in which there is direct evidence of contemporaneous feldspathization. The illustration (Fig. 5.11) shows the contact zone of a 5 cm. buff brown intrusion cutting relatively unaltered Nyanzian rhyolite on the western slopes of Homa Main. The thin section shows that a potassic feldspathization has converted angular fragments of country rock in the vein to a fine-grained felsitic intergrowth. The sparse carbonatitic matrix includes much disseminated limonite. Some fragments of feldspathized country rock can be seen in the process of wedging off from
Fig. 5.14. Contact of a carbonatitic pseudo-trachyte breccia dyke with country rock. x6.

A - Fragments of pseudo-trachyte, some in the process of being levered off the wall rock. These lie in an ochreous carbonate rich matrix, stringers of which penetrate the country rock.

B - Region in which new fine-grained orthoclase increases and visible quartz decreases towards the contact.

C - Fine-grained country rock with numerous ovoid sectioned bodies of quartz surrounded by iron oxide.
the vein walls the margins of which themselves show some replacement by new feldspar. No aegirine was detected in this rock.

There is little doubt in this case that a metasomatic replacement in situ has given rise to a fine-grained felsitic textured rock very similar in thin section appearance to the narrow trachyte dykes believed to be of magmatic origin which are described in the section on p. 232.

b) Carbonatitic pseudotrachyte tuffs

Rounded fragments of pseudotrachyte in a matrix of carbonatite are sometimes seen in the field. The proportion of carbonatitic matrix is often much greater than that in the breccias described above and in some cases the intrusions might be called xenolithic carbonatites. The above rock name is preferred as it draws attention to an unusual polygenetic rock type in which pseudotrachyte occurs.

The rocks are well exposed at Ndiru m'bili as a facies of the latest of the four carbonatite series occurring at this outcrop (chapter 1, p. 62). The carbonatite is buff-purple, fine-grained and consists of mainly rhombic calcite grains with accessory fluorite. It occurs as sharply bounded dykes up to 3' wide. The tuffs occur as narrow concordant bands up to 12" wide within these dykes. The rounded pseudotrachyte bodies consist mainly of fine-grained orthoclase and iron oxides but sometimes include sparse small prisms of aegirine in addition, often partially replaced by
Fig. 5. 15. 1-2 mm. rounded fragments of pseudo-trachyte in a purple rhomb carbonatite (C3). HC 71. X 2.
iron oxides. The fragments of pseudotrachyte average 0.5 to 1.5 cm. at Ndiru m'bili while in the more sparse dykes of the same rock type found on the western side of the main centre the fragments average 1-2 mm. (Fig. 5.15) and occur as closely packed trains within the carbonatitic matrix. The degree of rounding of the fragments is very unusual for inclusions in carbonatites at Homa and an origin of this shape by simple attrition is considered unlikely. An origin due to some immiscibility effect raises problems of nomenclature and origin beyond the scope of the present work.

c) Trachytes

Rocks are present at Homa which have characters similar to the fragments of pseudotrachyte described above from breccias but in which criteria are present which are believed to indicate an origin involving a magmatic stage.

The most unequivocal of such occurrences is a 5" unbrecciated dyke of buff pink potassium trachyte which cuts the microijolite at Yusoo (fig. 5.5'). A diffractogram of a portion of this fine-grained dyke shows dominantly orthoclase peaks, no triclinicity and that the soda content is very low. The texture is felsitic to trachytic and average grain size 0.05 mm. (Fig. 5.16). This dyke is believed to be an example of the intrusive potassium trachytes which appear to be confined to carbonatitic centres (Garson & Campbell-Smith, 1958; Sutherland, 1965, 1967). At Homa
Fig. 5. 16a,b. Felsitic texture of the potassium trachyte dyke cutting ijolite at Yusoo. This texture is believed to result from crystallization of a melt and is similar to that shown by the small tongues of intrusive material invading fenite breccia in specimen HC 745 (Fig. 3. 26). The opaque minerals are iron oxides, often haematite. HC 748. X 160. X.N. and P.P.L.  

"If the iron oxides in after arginie like this is a later solid state change. This is perhaps induced by CO₂ linking Na as carbonate."

"Uneven oxidation in the dyke at Yusoo."
although only two such dykes were recognized in the field, subsequent petrographic examination of rock mapped as Nyanzian or pseudotrachyte breccia in the vicinity of ijolite contacts shows that more intrusions of such material are probably present.

At Ndiru m'bili much of the rock into which the carbonatites and ijolite is intruded is a fine-grained potassium trachyte showing in parts very similar, though fine-grained, stellate groups of feldspar (dia. 0.1 mm.) to those in the ochreous orthoclase surrounding sovite in the same area (p.224). In addition phenocrysts (10 mm.) of orthoclase are present at intervals through the trachyte as are microphenocrysts (0.3 mm.) of apatite. At Ndiru m'bili there is an apparent gradation from the coarse-grained orthoclase type, through intermediate grain sized rocks to the potassium trachyte but subsequent brecciation and invasion by later purple carbonatite veins and dykes obscure these relations.

Similar rock mapped as pseudotrachyte breccia outcrops within the orthoclase surrounding the main ijolite north of Rapogi. Thin sections (Fig. 5.17) confirm the brecciated nature, in fact two separate regimes of brecciation have occurred since the consolidation of the trachyte.

The fine-grained felsitic background carries numerous phenocrysts of apatite and pseudomorphs in dark brown to black are after a monoclinic mineral. Also present in the matrix are angular to sub-angular fragments of medium and coarse-grained orthoclase.
HC 374. PORPHYRITIC, XENOLITHIC TRACHYTE.

Xn = xenolith of orthoclaseite. G.M = felsitic textued ground mass.

BR. A = early brecciation involving limonite
BR. B = later " calcite
The subsequent brecciations do not obscure the xenolithic and porphyritic nature of this trachyte which is believed to have passed through a magmatic stage probably during the time that the surrounding rocks were being converted to orthoclases.

No analyses of these intrusive trachytes are available from Homa but the X-ray and petrographic data indicates that their mineralogy and chemistry is very similar to that of the ochreous orthoclases and pseudotrachytes described above. At Toror, from where much more data is available, it has been shown that this similarity is most striking (Sutherland, 1965).

(4) Nature of the feldspar developed in the feldspathic rocks at Homa

Chemical analyses of coarse feldspar separated from an ochreous orthoclase (HC 798) and a feldspathized ijolite (HC 796) are given below:

<table>
<thead>
<tr>
<th></th>
<th>HC 798</th>
<th>HC 796</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO₂</td>
<td>63.89</td>
<td>63.62</td>
</tr>
<tr>
<td>TiO₂</td>
<td>0.08</td>
<td>0.16</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>18.78</td>
<td>18.70</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>0.31</td>
<td>0.57</td>
</tr>
<tr>
<td>CaO</td>
<td>0.58</td>
<td>*</td>
</tr>
<tr>
<td>Na₂O</td>
<td>0.99</td>
<td>1.12</td>
</tr>
<tr>
<td>K₂O</td>
<td>16.07</td>
<td>15.22</td>
</tr>
<tr>
<td>P₂O₅</td>
<td>0.01</td>
<td>0.07</td>
</tr>
<tr>
<td>H₂O⁺</td>
<td>0.04</td>
<td>0.07</td>
</tr>
<tr>
<td>BaO</td>
<td></td>
<td>0.60*</td>
</tr>
</tbody>
</table>

Analyst M. Blackley.

* A microprobe determination for BaO gave 0.60%. This is considered to be represented by CaO in the original chemical analysis.
The above chemical and optical data indicates that the dominant feldspar in the coarse-grained rocks belongs to the low orthoclase - cryptoperthite series and has a high potassium content. A note has been made previously of feldspar, with a different appearance in thin section, growing at the margin of coarse feldspar in contact with carbonate (HC 664, p.227). An X-ray powder photograph of this material gave the same pattern as that of the analysed orthoclase noted above.

X-ray diffractograms of the analysed feldspars HC 798 and HC 796 show no definite triclinicity and a very low plagioclase content. There is close agreement with A.S.T.M. Card 8-48 (ferriferous orthoclase) and less with A.S.T.M. Card 9-462 (orthoclase).

The ferriferous orthoclase from the Itrongay pegmatite, Madagascar (Coombs, 1954) has another feature in common with some of the coarse feldspar from Homa - a yellow colour associated
with higher iron content (chapter 4, p.204-5).

Data concerning the fine-grained feldspathic rocks of this suite, the trachytes and pseudotratyches, is confined to that obtained by X-ray techniques. Samples of pseudotratychte breccia, pseudotratychte tuff and trachyte dyke all show a pattern almost identical to that from the orthoclasesites. There is no detectable triclinicity, nor is any plagioclase present and these patterns also closely agree with that of ferriferous orthoclase.

For this reason it is believed that the fine-grained feldspathic rocks are chemically and mineralogically equivalent to the ochreous orthoclasesites and that the close association in the field of orthoclaseite and magmatic trachyte indicates a common source.

(5) Discussion

a) Comparison of the feldspathic rocks with fenites at Homa

Comparison of the data on the feldspars from the ochreous orthoclasesites and pseudotratychtes given above with that from the characteristic feldspar developed in the fenites at Homa (chapter 4, p.214) shows that the feldspars in both cases are of essentially the same composition and develop in the same manner. Indeed, petrographic evidence was given (p.223) indicating that in some cases ochreous orthoclasesites develop from aegirine orthoclasesite fenites by breakdown of aegirine to haematite, particularly when the former rock is invaded by carbonatite.
Comparison of the finer-grained feldspathic rocks with fine-grained fenites shows less evidence of similarity. The ubiquitous scraps of iron ore in pseudotrachytes rarely show evidence of the former presence of aegirine. An exception was noted in the case of the rounded feldspathic tuff fragments seen in carbonatites at Nduru m'bili and elsewhere (p. 231).

Aegirine was not noted in the trachytes either although pseudomorphs in iron oxide after a possibly monoclinic mineral are present in some specimens. There is, however, a great similarity between the petrography of the trachytes and the tongues of material, several centimetres long, believed to have originated by partial melting at the more intense stages of fenitization (chapter 3, p. 171).

An origin of the intrusive potassium trachyte tongues by partial melting of aegirine-orthoclase fenite was argued and the replacement of aegirine by iron oxides in the portions believed melted was ascribed to the known incongruent melting behaviour of aegirine. In the specimen described in detail (HC 745) there is no evidence of inclusion by carbonatite or that the aegirine breakdown was due to a weathering phenomenon. The second piece of evidence for melting was thought to be the granular or felsitic texture of the feldspar compared with its texture in the unmelted portions in which it shows marked preferred elongation; also the melted
felsitic matrix sometimes enclosed small xenoliths of unmelted material.

b) The relation of carbonatite with the development of feldspathic rocks

The pseudotrachyte breccias at Bala have a sparse carbonatitic matrix as do the pseudotrachyte fragments in the narrow cross cutting dykes described on p.232. In these cases it appears that the incursion of carbonatitic material accompanied the feldspathizing agents. In other cases, such as the conversion of aegirine orthoclaseite to ochreous orthoclaseite described on p.223, the feldspar had already developed before the incursion of carbonatitic material, but the net result is to produce a rock rich in feldspar but in which aegirine is absent.

Descriptions were also given (pp.226 & 227) of the development of new feldspar in xenoliths of orthoclaseite and ijolite included in sovite dykes. Aegirine in these cases again is unstable.

At Ndiru m'bili ochreous orthoclaseite develops preferentially at the margins of early sovite intrusions (p.224).

At Home, in general, it may be stated that soda bearing minerals are broken down or their development is inhibited in the presence of carbonatite but that potassium feldspar is stable and can sometimes be shown to be actively developing.
The close connection of potassium metasomatism with carbonatitic activity is shown in several other African and North American centres. Bailey notes that at Rufunsa only carbonatitic intrusion has occurred and also that alkali metasomatism is purely potassic in character resulting in the formation of "very high contents of completely disordered potash feldspar." (Bailey, 1966, p. 144). Garson and Campbell-Smith (1958) and Garson (1966) described fenitized and feldspathized country rock surrounding the carbonatite centre at Chilwa Island. They concluded that fenitization occurred early and that intrusion of the central body of carbonatite was accompanied by a process of feldspathization which included destruction and pseudomorphing of soda mafic minerals but an increased development of orthoclase cryptoperthite and microcline. Heinrich and Shappiro (1967) describe 'burnt rock', granite country rock, fractured, brecciated and replaced by a microcline, haematite flake intergrowth prior to, and during, the crystallization of carbonatite dykes.
c) An estimate of the comparative amounts of soda and potassium fixed as the result of metasomatism around the alkali intrusions at Homa

As shown in chapters 3 and 4 the potassium fixed in the fenites may exceed the amount of soda. The proportion of potassium to soda fixed in all metasomatic rocks is greater still and it is therefore estimated that a greater total of potassium than soda is fixed as a result of metasomatism.

The limited data available on the original alkali content of the country rock shows that Na₂O = 3-4% and K₂O is less than 1% (chapter 3, p. 156). It is, therefore, necessary to postulate addition of large quantities of potassium but probably little or no soda to the country rock as a whole.

Exchange of potassium for soda in the feldspars of fenites has been demonstrated (chapter 3, p. 165-6) and this process probably results in a front of soda metasomatism moving ahead of the influx of potash.

(6) Summary of conclusions

It appears that at Homa, as at Alno (von Eckermann, 1948), potassium is the chief alkali constituent introduced into the country rock from the alkali intrusions, the soda contributing to the fenites being adequately accounted for by redistribution of that in the original country rock.
At Homa it is concluded that many of the feldspathic rocks have a similar origin to the fenites and that often the development of such feldspathic rocks is an integral part of the more intense stages of fenitization at which mobilization to form trachytes may occur. In other cases the feldspathic rocks appear to have been derived from fenites or directly from country rock by a process requiring the presence of carbonatitic material.
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MELILITE BEARING ROCKS OF HOMA MOUNTAIN

PREAMBLE

Three rock types are recognized:—

1. **Olivine-melilitite.** This outcrops as a plug which is similar in form and mineralogy to the Sutherland pipes and to occurrences of katungite.

   The plug shows evidence of differentiation towards a nepheline, pyroxene mineralogy and is thought to be a high temperature equivalent of melanephelinite.

   Segregations of carbonate and zeolite are noted particularly as a matrix to the tuffaceous material into which the plug is intruded.

2. **Alnoitic tuff.** A single outcrop of this rock type is earlier in the general sequence at Homa than the other two occurrences. It has affinities with kimberlites in texture, mode of intrusion and alteration but less so in some aspects of its mineralogy.

3. **Carbonated melilitite.** A vent, dyke and tuff sequence of carbonate rock in which all melilite has been replaced by carbonate is very late in the sequence. Such relict textures after melilite have not been detected from the main carbonatite suites and there is no evidence yet that these main carbonatites were formed by metasomatism of melilite as occurred in the case noted here.

Nomenclature of melilite bearing rocks

Effusive and dyke rocks in which melilite is the chief leuocratic mineral have received many names in various classifications.
Johannsen (1934, Vol. IV) lists the following definitions:

a. **Melilite basalt** - Phenocrysts of olivine and augite in a fine-grained ground in which melilite is common. Nepheline only accessory and not always present.

b. **Melilitite** - as above but with augite only.

c. **Melilitholith** - a leucocratic rock composed almost exclusively of melilite.

d. **Alnoite** - the intrusive equivalent of melilite basalt, according to Rosenbusch, contains much additional mica in the mode. Carbonate also present.

He also defines nephelinites and melanephelinites as feldspar-free extrusives composed of nepheline and pyroxene, melanephelinites carrying excess pyroxene.

Holmes (1937) discusses the nomenclature of such rocks and those containing leucite and kalsilite in addition. He does not use the term melilite basalt but substitutes olivine melilitite. He defines katungite as a potash rich olivine melilitite.

Hatch and Wells (1961, p. 358) propose a scheme for rationalizing names given to mafic feldspathoidal lavas and suggest that rocks containing essentially melilite and mafic minerals should be termed melmafites. Similarly a nepheline/pyroxene rock would be termed nemafite. They deplore the use of basalt for feldspar-free lavas.

The present work uses the term melilitite as a general term
for rocks in which the major leucocratic phase is melilite. The
dominant phenocryst at Got Oloo is olivine. Therefore, this rock
is termed an olivine melilitite. The term melilite basalt is not
used for the reasons given by Hatch and Wells. The intrusive nature
and presence of biotite in the tuff at Landslide Gully allow the
use of alnoite.

The only mineral identified as previously existing in the
carbonated rocks of Got Chiewo is melilite. The rocks with such
pseudomorphs are termed carbonated melilitites, although the term
carbonated alnoite was considered.
OUTLINE GEOLOGY OF HOMA MTN.
AND SURROUNDS

NYAMATOTO
NYASANJA VALLEY

OSIRI
LANDSLIDE GULLY

NYASANJA
ODYA
AWAYO
RONGO

HOMA POINT
RAWE RIVER

DYOLO
CHIEWO VENT

HOMA MAIN

OGWAGO
RIDGE
RAPOGI
ONYA

OFORIOMBILI
YUSOO
NDIRU

KANDEGE

NDIRU
BALA

HOMA BAY

0 1 2 3km
Scale

FIG 6.1

SECTION A-B-C ON FIG.
GOT OLOO OLIVINE MELILITITE PLUG

(1) Introduction and previous work

The plug lies at the foot of the western cliff of the main Homa Mountain carbonatitic volcanic centre (Fig. 6.1.). It is noted by Saggerson (1952) as a melilite nephelinite plug and on p. 33 of his report he outlines its mineralogy. The most striking features of the thin sections of fresh rocks studied in the present work are the abundance of olivine phenocrysts and the predominance in the background of melilite sections. Nepheline is very sparse and, therefore, it has been decided to term it olivine-melilitite as used by Holmes (1937).

(2) Field characteristics

The plug has the form of a double knoll (Fig. 6.2) the more easterly (Exp. 115) being 70' higher and separated from the broader westerly knoll by a saddle across which only agglomeratic material outcrops. This agglomerate outcrops over the greater part of the pipe and is intruded by the fine-grained, dark grey to black rock of the plug which forms the more resistant upper portions of the two knolls. This rock shows numerous phenocrysts of olivine.

At Exp. 101 a strong foliation is seen on the weathered surface where alternate 5-10 cm. bands are more resistant. On a fresh surface little is seen to account for this except a possibly greater density of olivine phenocrysts. This foliation curves around the
Fig. 6.2 Map of Got Oloo on a scale of 1:2500
highest part of this knoll and dips steeply outwards and is equated with the fluxion texture noted from phonolitic nephelinite plugs of the area (chapter 1. p. 77).

The agglomerate contains very numerous rounded and subrounded fragments of olivine-melilitite. Fragments of phonolite and nephelinite of the types seen elsewhere on Homa Mountain are also present, as are fragments of country rock which in some cases have been previously metasomatized. The size of these agglomerate fragments is normally 1-3 cm., but occasionally larger fragments are seen. As the highest knoll is approached, the fragments increase in size and eventually merge into the spheroidally weathering, veined and cracked rock which is believed to represent a small pipe. The matrix of the agglomerate is calcareous and its pale colour contrasts with the numerous dark fragments of lava and country rock (Fig. 6.3).

Other contacts between the agglomerate and the plug are often obscured by debris but at Exp. 114 are sharp and dip inwards at about 60°. There is less matrix to the agglomeratic fragments at the contact, but the increase in the size of the agglomerate fragments noted around the easternmost outcrop is not present.

The westernmost outcrop of olivine-melilitite is larger and exhibits several features of interest. As can be seen from the map, two narrow projections or dykes (Exp. 111) are present. These are believed to represent fissures which opened in the agglomerate.
Fig. 6. 3. Agglomerate into which the clivine melilitite plug is intruded. Rounded fragments of dark melilitite and paler country rock in a sparse white carbonate rich matrix.
The southernmost part of this outcrop shows a finer grained secondarily altered facies (Exp. 107) in which numerous \( \leq 4 \) cm. amygdales are seen. These are filled with cream and light green material some of which is carbonate. The fact that large areas of the present outcrop of the olivine-melilitite do not exhibit this texture is regarded as evidence that it is not a weathering phenomenon.

(3) **Age relations**

Contacts of the pipe are clear only on the east where a sharp transition from brecciated, yellow-stained, altered Nyanzian to rocks of the plug is seen. On the west and south sides the surface slopes down to flat areas of soils, while on the north limited exposures of a very fine-grained, yellow tuff were found by digging (Exp. 122). This may have its source in the pipe, but relations are not clear. As no later intrusions cut the pipe except for occasional narrow carbonate veins which are believed to derive from the same source as the carbonate forming the agglomerate matrix, the pipe is placed late in the Homa Mountain sequence. The lack of brecciation and great freshness of much of the rock supports this view.

A further line of evidence involves consideration of the level of exposure exhibited by the various intrusions on the western face and slopes of the main centre. It is concluded that the plug was formed after the main period of activity which resulted in the
formation of cone sheet centres and also after a period of erosion of these centres (chapter 1, p.42).

It has been assigned to a period of late satellitic activity which on the northern side of the mountain affects Lower Pleistocene beds.

Evidence from K/A dating methods supports this late age for fragments of phonolite rocks of very similar type to that of the Osiri lava (chapter 1, p.42) are noted in the agglomerate of Got Oloo. The Osiri lava has a K/A ratio equivalent to an age of approximately $2.0 \times 10^6$ years.

(4) Petrography

a) Fresh olivine-melilitite of the plug

Most of the fresh, dark rock exposed shows unaltered phenocrysts set in a very fine-grained matrix which in hand specimen is almost glassy in parts. The minerals present are described individually:

i) Olivine

Thin sections show numerous euhedral and subhedral olivine phenocrysts averaging 0.5-3.0 cm. in length. The olivine shows a faint prismatic cleavage and more often a series of irregular cracks. These phenocrysts are colourless and clear, including none of the other constituents except small ore granules. Many of the grains show smoothing of the interfacial angles and lobate inlets indicating that resorption has occurred (Fig. 6.4 ).
Fig. 6.4. Fresh olivine melilitite. An olivine phenocryst lies in a matrix of rectangular melilitite sections, opaque ore and dark grey octahedral sections of perovskite. Grey, rounded basal sections of melilitite are also visible. HC 116. X 40. P.P.L.
The composition was determined by two methods involving X-ray diffraction:-

1. Measurement of $d_{130}$ on a diffractogram using a Quartz Standard (Yoder and Sahama, 1957). This gave 79% ± 4% forsterite.

2. Measurement of the degrees $2\theta$ between $d_{062}$ olivine and $d_{220}$ lithium fluoride (Jackson, 1960) - 32% ± 1% forsterite.

Both these methods assume no appreciable Mn content and as the analyses available of the whole rocks from this centre show 0.09 and 0.20% MnO this condition is satisfied and the above results are supported. A feature of these methods is that the peaks measured represent an average of numerous grains, all those in the sample. Also, it is possible to attain this result in rock with appreciable olivine, from a whole rock powder. Preliminary counts with the SEM II micro-analyser indicate that the calcium content is less than one per cent.

ii) Melilite

a) General characters

The most abundant mineral in this rock is melilite, most often visible as rectangular sections with low birefringence and straight extinction. In contrast to many occurrences of melilite, marked anomalous birefringence is not present except in the cores of some of the larger grains. The mineral is optically negative and the rectangular sections often show one or more strong (001) cleavages. The basal sections are often subrounded or irregular
low birefringent areas showing no cleavage and uniaxial negative interference figures. Another feature is the frequent inclusion of ore granules.

In some grains the central slightly anomalous birefringent core is separated from the higher birefringent margins by a narrow zone of minute unresolvable dark granules. A prominent feature in many of the long sections showing the basal cleavage is a close packed series of structures resembling well developed cleavage traces transverse to the basal cleavage. This is the peg structure which becomes more prominent in the sections studied of altered melilite. In the unaltered rock this structure does not accompany any alteration, change in birefringence or colour of the melilite.

The relationship of these various features seen in the melilite of this rock are summarized in the diagram (Fig. 6.5).

Preferred orientation of the melilite tablets is seen in parts of the slide, the dominant direction of the long axes of the sections being approximately aligned with those of some of the nearby olivine phenocrysts and represent a fluxion texture.

b) Optical constants and estimate of composition of the melilite

\[
\begin{align*}
\text{R.I. (20°C)} & \quad \varepsilon = 1.630 \pm 0.001 \\
\rho & = 1.635 \pm 0.001 \\
\cdot \cdot \cdot & = 0.005 \pm 0.002 \\
\text{Optically negative}
\end{align*}
\]

Deer et al. (1962, Vol. I, p. 236) - "Because of the usual
FIG 6.6

PYROXENE APPARENTLY REPLACING MELILITE

C AXIS

PEG STRUCTURE
MEDIAN CRACK (BASAL CLEAVAGE)

MELILITE TABLET FIG 6.5
presence of appreciable amounts of soda and iron accurate
determinations of melilite compositions from their physical
properties is difficult."

Using the data given by the above authors an approximate
composition for the melilite of Got Oloo can be made assuming no
substitution of iron:-

- Gehlenite - 44%
- Akermannite - 28%
- Na melilite - 28% (Equivalent to 3.5% Na₂O)

Preliminary semi-quantitative work with the SEM II indicates
a content of 2-3% FeO.

The optical data given in Deer et al. shows that addition of
iron in the melilite structure increases the R.I. It is, therefore,
concluded that the above value for the content of Na₂O is a
minimum.

iii) Clinopyroxene.

Numerous plates of a mafic mineral, average size 1 mm., are
seen to have very irregular margins and to include, apparently,
many grains of the other minerals except olivine. The plates
show pyroxene cleavages and have a maximum extinction angle in
excess of 40°. They are very pale green and non-pleochroic and
are identified as augite.

The appearance of this pyroxene under low power is of a
poikilitically developing late mineral. Observation under higher
power shows a more intimate relationship between the pyroxene and the melilite and rare nepheline plates enclosed and adjacent. The interfaces are not sharp but often show the pyroxene projecting into the melilite as a series of small lobes (Fig. 6.6).

The margins of the pyroxene grains are sometimes seen to transgress the melilite of the groundmass. There has been a reaction relationship between the clinopyroxene and melilite, and the writer concludes that the clinopyroxene is late and is replacing some of the groundmass melilite.

The significance of this reaction relationship is mentioned again later when dealing with the development of this rock type (p.287).

iv) Perovskite

Numerous small granules of perovskite are seen in the groundmass and a larger generation is seen also as 0.5 mm. microphenocrysts. These often show octahedral form and multiple twinning (Fig. 6.4). The perovskite has a golden brown colour and shows anomalous interference colours in blues and pale greys. Polysynthetic twinning is occasionally seen.

v) Ore

Irregular outlined ore grains are frequent <0.5 mm., sometimes showing a rhombic cross section. The microprobe indicates Fe : Ti = 5 : 1 showing these to be ilmeno-magnetics. Occasional radiating groups of opaque rods are also seen.
vi) Nepheline

Rare square sections of nepheline are present. They show occasional slight alteration along the cleavage and sometimes broader bands of material with a negative relief. Their relation to pyroxene has been noted and they are sometimes interstitial to the melilite.

vii) Biotite

Very minor small flakes of biotite are rare.

b) The agglomerate petrography

The heterogeneity of the agglomeratic fragments has been noted. Thin sections show a greater variation in melilite bearing types than has been found in the central plug. As well as numerous fragments of the olivine-melilitite already described, several other varieties may be determined. Most of the cement binding the fragments is a carbonate, zeolite intergrowth and the olivine phenocrysts are universally altered to carbonates, zeolites and some low birefringent, fibrous material (serpentine?). The melilite also almost always shows alteration, the end product of which is a carbonate pseudomorph. Despite the alteration of these two minerals their crystal outlines remain and the original nature of the rock can be decided. The following fragment types were identified:

1. Country rock altered to various feldspar and feldspar/pyroxene intergrowths (fenite).

2. Phonolitic-nephelinite lava as developed in the flow called Osiri which lies nearby to the north.
3. Olivine-melilitite as already described.

4. A rock composed of melilitite, perovskite and brown glass only (olivine-free).

5. Melilitite with larger melilitite sections and a more normal groundmass (olivine-free).


7. Crystal fragments include carbonated olivine, melanite, colourless pyroxene, green pyroxene, clear nepheline, ore and perovskite.

The carbonate cement shows a complex paragenetic history. The margins of some of the fragments are bordered by rhombic outlined euhedra of ferroan calcite. Radiating from these rhombs is a second carbonate showing searchlight extinction and occasional zones of limonite at right angles to the fibres (Fig. 6.7). This carbonate is the most prominent in the agglomerate matrix. It is unstained by alizarin and ferricyanide and the SEM II shows that the Fe/Ca ratio is high. It is, therefore, identified as siderite. A third carbonate is sometimes seen filling areas between growths of siderite. It occurs as small rhombic plates and is identified as ferroan dolomite.

The accompanying zeolites also show a variation. The most abundant zeolite is analcime which occurs as irregular rounded bodies or bodies with high symmetry. The glass clear analcime normally shows no birefringence, but occasionally shows a faint extinction
Fig. 6. 7. Complex carbonate cement of olivine melilitite agglomerate. HC 20. X 25. P.P.L.

Fig. 6. 8. Prominent zeolite of phillipsite type occurring in the carbonated portions of the melilitite and the agglomerate matrix. HC 23. X 25. X.N.
cross, perhaps due to radial growth. The second prominent zeolite is a strongly zoned prismatic mineral with low negative relief and straight extinction. This is seen to develop from the margins of some of the fragments. The sign of elongation varies in different zones. The mineral appears to be biaxially negative and sometimes shows interpenetrant twins. Cruciform twins are not uncommon (Fig. 6.8). The mineral is probably related to phillipsite. Another less prominent zeolite sometimes forms outgrowths on the phillipsite type zeolite. It is fibrous with very low birefringence and sometimes rims fragments and small carbonate filled patches in the fragments and may be analcite. Similar material is seen in the matrix being replaced by siderite.

c) Amygdaloidal olivine-melilitite

The petrography of the small area of rock in which prominent amygdals are present (Exp. 107) is very different to that of the fresh olivine-melilitite. The amygdals have a mineralogy similar to that of the matrix of the agglomerate. This includes a suite of carbonates developing in the following order: calcite - ferroan calcite - siderite - ferroan dolomite. The siderite stage is accompanied by crystallization of analcite and the phillipsite type zeolite. Numerous rectangular and hexagonal plates of low birefringent, uniaxial negative material are present in some of the amygdals included in the carbonate/zeolite stage. This mineral has a maximum R.I. of $1.544 \pm 0.003$ and is identified as nepheline.
Towards the margins of these amygdales and throughout the groundmass of the altered rock are very numerous small, prismatic, pale green high relief grains. These show extinction angles up to 40° and first order interference colours. The cross sections show a pseudo-hexagonal outline and one cleavage is seen. They are optically positive with a 2V of about 60°. A powder photograph shows this mineral to be clinopyroxene and to agree more nearly with the ASTM card for diopside than for augite. Also associated with these centres of alteration are clusters of large apatite grains which are faintly dusted with unresolvable dark material.

The amygdales form discrete areas in the rock but are bordered by areas in which the original olivine and melilite are greatly altered. (Fig. 6. 9).

In much of the rock from this locality the olivine is partly replaced by a fibrous, low birefringent serpentine and more rarely by high relief, bright red/brown ?bowlingite. These are subordinate, however, to an alteration to carbonate which is remarkably complete in nearly all cases. The phenocryst outlines remain, rimmed with numerous granules of ore and less numerous perovskite and clinopyroxene. The carbonate which is present in greatest quantity has the same properties as the siderite from the agglomerate. More rarely the central part of the pseudomorph is filled with a plate or plates of natural calcite.

Melilite also is almost everywhere much altered and frequently shows development of higher birefringent fibres with a similar
Fig. 6. 9. Carbonate filled vesicle with border of analcime in which sections of grey birefringent material, some of which is nepheline, occurs. A melilite phenocryst partially replaced by carbonate is present on the right. (See Fig. 6. 11.).

Fig. 6. 10. Olivine completely replaced by carbonate and melilite showing typical peg structure developed perpendicular to the basal cleavage or median crack. HC 117. X 25. X.N.
orientation and frequency as the peg structure noted in the fresh rock. These fibres are length slow (Fig. 6.10).

Peg structure has been often noted in melilites and is often considered diagnostic (Kerr, 1959). The term has been applied to the process of exsolution of small amounts of gehlenite from akermannite (Nurse and Midgely, 1955). Its more common application is in cases such as described from the present locality when the structure is seen to be due at least in part to a process of alteration. The alteration of melilite by late alkaline liquors and hydrothermal fluids in the plutonic melilite bearing rock uncomphagrite is described by Larsen (1942). Von Eckermann (1943) describes alteration to garnet and calcite of melilite in alnoitic rocks.

The fibrous mineral in the present case has similar properties to that of cebollite described by Larsen. A further and separate stage of alteration is seen when granular carbonate replaces the altered melilite sections (Fig. 6.11). In some cases relics of the transverse structure are seen in the carbonate as brown stained irregular rods. These are rarely seen in more completely carbonated sections. It is believed that these amygdales represent the results of a late stage crystallization of water and carbon dioxide-rich material derived from the olivine-melilitite. The alteration of the original minerals, olivine and melilite, in areas surrounding the amygdales, therefore, represents a form of deuteric alteration.

The textural and mineralogical similarities between the amyg-
DETAIL OF MELILITE REPLACEMENT IN FIG. 6.9

FIG 6.11

Calcite.

Fine peg structure.

Isotropic areas.

Calcite.

Brown stained relics after peg structure, in calcite.
days and the matrix of the agglomerate are many and indicate that the formation of the agglomerate was accompanied by a high concentration of the volatiles which are also represented in the amygdals. The development of late stage nepheline and pyroxene is, however, only seen in the central plug.

It is concluded that the amygdaloidal areas of olivine-melilitite crystallized with retention of volatiles and may thus be nearer the original composition of the magma.

d) **Summary of the stages of alteration of the melilitite at Got Oloo**

1. Development of narrow structures in fresh melilitite parallel to the c axis and, therefore, transverse to the tabular section. (Peg structure).

2. Development of a fibrous alteration product (?cebollite) with the same orientation as above. Median crack visible.

3. Replacement of stage 2. by granular carbonate. The transverse rods are relicted by brown stained carbonate. Crystal outline still visible.

4. Complete replacement by carbonate, loss of peg structure relics, crystal outline still visible, median crack sometimes so.

Altered melilitite of stage 4. is accompanied by carbonate pseudomorphs after olivine but ore and perovskite may remain unaltered and the original texture easily recognizable.
(5) **Modal and chemical analyses**

a) **Modal analyses of olivine melilitites**

1. Uncarbonated olivine melilitite from Got Olooo. (Hc116)
2. Partially carbonated olivine melilitite from Got Olooo. (Hc22)

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b) Chemical analyses of olivine melilitites

Two analyses are available from Got Oloo. They are compared with the average olivine melilitite of Nockolds (1954) and the average katungite of Holmes (1950).

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Analyst W.P. HORNE. W. HERDSMAN.

*¹ Total includes 0.02 Cl, <0.02 F, 0.3 S.

*² Also present BaO, 0.21; NiO, 0.10; F, 0.16; S, 0.19; SrO, 0.20; V₂O₅, 0.04; Cr₂O₃, 0.02.

41/992 - Normal rock from Got Oloo (Saggerson, 1952, p. 32).

HC 23 - Partially carbonated olivine melilitite (new analysis).
THE ALNOITIC AGGLOMERATE OF LANDSLIDE GULLY

The section (Fig. 6.1) shows quite fresh exposures of several types of intrusive breccia. The breccias outcrop as belts approximately at right angles to the section and are often divided by screens of less brecciated country rock (Fig. 6.12). The majority are of the ochreous yellow and orange weathering rock commonly seen in many parts of the area.

In the central part of the section are two belts of a breccia with different characters. It is dark green to brown in colour and contains numerous biotite plates and crystals up to 2 cm. The remainder of the rock is a mass of subrounded and rounded particles cemented in a matrix of similar grey green material. Examination of thin sections shows that three main divisions of material make up this rock:

a. Fragments of previously altered country rock.

b. Numerous crystals and fragments of ferromagnesian minerals including biotite and a pale green clinopyroxene (Di-Aug.). Carbonate pseudomorphs may be after olivine. With the exception of some of the biotite, these crystals are variously altered and present a rounded and disturbed appearance, indicating that they suffered buffeting and corrosion during their emplacement.

c. A common fragment is of a melilite bearing rock in which pseudomorphs or remnants of ferromagnesian phenocrysts are seen in a matrix which included perovskite, ore and melilite. Alteration is widespread, carbonates are often the replacive mineral and the
Melilite sections show frequent development of peg structure. Another feature is the growth of much fine-grained pale brown mica in the matrix. Biotite phenocrysts are occasionally seen. Some of the altering pyroxenes in the matrix are rimmed by, and are altering to, biotite.

The outcrop totals 40' across the apparent strike, but scree, soil and vegetation conceal the lateral extent of this intrusion. Similar material has been noted as fragments in some of the carbonatitic breccias elsewhere on the western face of Homa.

Conclusions

The nature and form of this rock is that of an intrusive agglomerate whose chief characteristics are a) the presence of fragments of melilitite rich in phlogopite, b) the presence of ferromagnesian crystals displaying corroded margins, c) the polygenetic nature of the fill, and d) the evidence of carbonation and phlogopitization of some of the agglomerate fragments.
GOT CHIEWO VENT SERIES, SOUTH HOMA MOUNTAIN

(1) Structure and field characteristics

a) Vent and surrounds

One kilometre south of Homa Peak on the south flanks of the main carbonatitic volcanic complex is the small hill (Fig. 6.13) noted by Saggerson as being of "grey black tuff and agglomerate. This ...... represents a small vent as the beds are seen to dip inwards towards what must have been an explosive vent."

The structure of the vent has been well exposed by differential erosion which has caused the compact, central part of the vent to remain as a roughly circular feature of fine-grained grey limestone approximately 120' across bounded by erosion scarps from 5-20' high. Examination of the material seen in the walls and on the vent margins shows a distinct bedding or lamination, everywhere dipping towards the centre of the feature at between 15° and 30°. (Fig. 6.14). The vent lies 1,350' above lake level.

The central and upper surface of the circular feature at the summit is quite level except for occasional small sinuous dykes of similar material and one 3' scarp similar to the boundary scarps. Small irregular cross cutting bodies of fine-grained grey calcareous material from 0.5 cm. to several centimetres in width are frequently seen in the limestone pavement of the central area. This central area shows an irregular foliation at all angles to the horizontal.
Fig. 6. 14b. Erosion scarp which surrounds Got Chiewo Vent.
This shows inward dip of the pyroclasts towards the centre of the feature.
CROSS SECTION OF CHIEWO VENT
Further out from the centre of the vent than the boundary scarps the dip lessens and then by 30° out reverses (Fig. 6.14a). The material which outcrops is again a calcareous laminated tuff or micro-breccia. The occurrence of this reversal of dip close to the area now bordered by the boundary scarps indicates that the original dimensions of the vent, at the stage represented by these rocks, was not much greater than that outlined by the boundary scarps today.

Five hundred metres south-east another hilltop is covered with almost level bedded, fine-grained grey calcareous material similar to that surrounding the vent. 750 metres east of the vent is a similar less well developed vent feature incomplete in that only 60° of arc are subtended by a five foot boundary scarp along which grey calcareous material dips in (Fig. 6.13).

The finer grained tuff of the vent and surrounding area is dark grey when freshly exposed and weathers with the characteristic fluted appearance of limestone to a paler grey. Gradations to coarser grained deposits are seen in the underlying material. Included fragments increase in size from below 1 mm. to several centimetres and also make up more of the rocks volume until the deposit has the appearance of a breccia.

The included fragments of the finer-grained rocks are believed to be of two origins:

a. Those of pre-existing rocks picked up in the conduit and little altered by this activity except for carbonation and
sericitization which leaves most of the original mineralogy unaltered e.g. the fenite, ijolite and red breccia, above mentioned.

b. Those now composed of similar grey carbonates as the matrix and which show ovoid sections indicating a flattening producing long axes parallel with the bedding. Their width is almost always in excess of twice their height. The flattening is seen to increase downwards over one such band 10 cm. thick. These ovoid sectional bodies are usually between 2 mm. and 5 mm. in width (Fig. 6.15c,b).

Some of the grey carbonate material dipping away from the vent carries similar flattened ovoid bodies as does the vent itself. Further from the central vent the grey material is less thick and the proportion of included fragments increases. It appears to rest on a blocky surface of Nyazian country rock cut by green fenite veins.

The rounded bodies are believed to represent droplets of the extrusive material flung out and flattened due to compaction and impact.

In some sections of the erosion scarp surrounding the vent finely laminated calcareous tuff with a eutaxitic texture is seen. More resistant flattened bodies are believed to represent pumice fragments.

b) **Associated dykes**

Near Got Chiewo are exposures of several fine-grained grey calcareous dykes cutting the red breccias. The dyke material is
Fig. 6 15a,b. Thin sections of the carbonated tuff fragments typical of parts of Got Chiewo Vent. HC 396. & 644. X 6. P.P.L.
is very similar to that exposed in the vent and the two are equated as different manifestations of the same activity.

These dykes are faintly foliated parallel to their margins, sometimes show several phases, are 6-12" in width and have a near vertical inclination.

In several other parts of the Homa area dykes of similar aspect, cutting clastic deposits of relatively recent origin, i.e. containing fragments of the main carbonatite, fenite, ijolite and country rock, are seen (Fig. 6.).

(2) **Age relations of the Got Chiewo series and the problem of the red breccia series**

**a) Age**

As seen on the map (Fig. 6.13) the Chiewo series vent and dykes intrude a deposit called the red breccia series. This bedded clastic series rests in part on a surface exposing ijolite and carbonatitic breccia and is thus much later in age than the main period of activity. The Chiewo vent, therefore, like the Got Oloo centre is a late satellitic vent.

Several loose blocks of a silicate sovite (Cl) were noted on the upper slopes of the hills covered with the calcareous tuff of Chiewo type. Such rock does not outcrop in the vicinity and together with occasional blocks of ijolite are believed to have been flung out of the vent. A K/A determination on fresh mica from one such gave a ratio equivalent to $2.9 \times 10^6$ years. This
may be the real age of the mica or represent an age imprinted by the Chiewo activity. It is considered unlikely to be the exact age of the vent activity, being probably a maximum.

b) Red breccia series

The Red Beds are a distinctive clastic series, often coarse-grained, composed entirely of fragments of other recognisable rock types, both those of the intrusive suite and those of the country rock/altered country rock suite. Ijolite fragments are frequent and the series in part rests on a surface which has exposed ijolite. Finer horizons show fine bedding, ripple marks and graded bedding. Such indications of subaqueous deposition are not widespread. The pronounced oxidation of the iron from the included fragments results in the characteristic colour. This range of character indicates subaerial deposition with local ponds or pools forming contemporaneously. A pyroclastic origin is indicated, but no vent has been discovered. Occasional horizons have been noted from this deposit of a grey calcareous tuff - pseudomorphs of rounded fragments of lava are seen in a calcareous matrix (Fig.120, p.51).

The relationship of the Red Beds to the vent is not clear, but considerable disturbance of them in areas near the vent on the east and skirting the lower slopes of Got Chiewo on the south-west and west may be contemporaneous with the formation of the vent. Similar chaotic bedding accompanied by slumping of masses of coarse grained material is seen within the Red Bed series. The nature of
the disturbed beds indicates that disruption occurred before final lithification. This means that if they were disturbed by the vent deposition of the Red Beds accompanied activity of the vent.

On this evidence of the close correlation in time of activity of the vent and deposition of the Red Beds surrounding the lower flanks of the hill on which the vent lies it might be thought that the Red Beds originated from the vent. That this is possibly not so is seen from the field data (Fig. 6.13 ). The dip and strike of the Red Beds is reasonably constant on all parts of the outcrop and does not focus on or eminate from the vent. It appears to be part of a larger deposit with an origin presumably up dip to the north-east. The more earthy matrix breccia banked against Got Mwanza may have the same origin (Fig. 6.13 ).

It is, therefore, concluded that the Red Beds may not be derived from the Chiewo vent though both were deposited after considerable erosion of the main volcanic centre. There is some evidence that the build up of the Chiewo vent caused disturbance in the nearby Red Beds.

The red breccia into which the Chiewo series is intruded has many characters in common with the Orio tuff – a clastic deposit which outcrops near the Kendu Fault zone and terminates westwards in an erosion scarp facing Homa (Fig. 6.1 ). The grain and fragment size, mode of deposition and presence of accretionary lapilli are all paralleled in the red breccia series.
Fig. 6. 16. Weathered surface of Chiewo dyke material showing several sizes of relict melilitic sections now completely carbonated. 'Phenocrysts' lie in a fine-grained matrix of rectangular pseudomorphs. HC 434. X 5.
The accretionary lapilli (Fig. 1.35, p. 88) are very prominent in some horizons of the Orio tuff and are believed to be evidence of the primary pyroclastic origin of this deposit.

(3) Petrography of the grey calcareous vent rock

Most of the material of the vent is seen in thin section to be an inter-locking mosaic of carbonate grains. Typical carbonatite accessory minerals are rarely present except for scraps of brown mica and occasional apatite grains. Opaque ore is also seen but is not evenly distributed, being best developed at the margins of certain areas within the slide. The inclusions seen are of fenitized country rock, carbonatite and occasional carbonated fragments of lava.

Rocks which have these characters sometimes show in addition one or more of the following features:

a. Pseudomorphs or replacements in carbonate of pre-existing mineral grains or rocks. These may be isolated patches or rectangular areas in which the carbonate is in larger plates and often is less turbid, i.e. carries less dust. Often, however, a texture may be visible in which the whole rock is composed of inter-locking rectangular bodies, mainly outlined by brownish oxides (Fig. 6.16). Each rectangular area may be composed of several of the granular carbonate grains which are a feature of all rocks of the vent. These rectangles are of the order 0.2 mm. in length and sometimes form the matrix to similar larger rectangular areas with a length of 3 mm. (Fig. 6.19).
Fig. 6. 18a,b. Rectangular outlined relics after melilite now completely replaced by carbonate. Fig. 6. 18b shows phenocrysts and ground mass of similar material. HC 639. X 60. P.P.L.
Fig. 6.19. Relict phenocrysts in finer-grained carbonated ground mass. Chiewo type dyke below Homa Point East. HC 401. X 35. P.P.L.
This texture can also be seen in some of the adjacent dykes which have very similar characters in thin section to the rocks of the vent.

b. **Ovoid sectioned bodies (lapilli).** These have already been noted in the field description. Thin sections show them to be composed of similar carbonate material to their matrix except that a dusting of opaque ore increases outwards towards their margins. Flattening has occurred in all cases studied. Occasionally a faint rectangular texture is seen within them as described above.

Less frequently seen are similar bodies which are more resistant to weathering, darker in colour and show a greater degree of flattening. Both these variations are thought to represent material flung out of the vent and flattened on impact or on consolidation. The latter material is believed to represent carbonated pumice fragments and the former droplets of carbonated melilitite.

c. **Eutaxitic texture.** The rocks so described in hand specimen (p. 265) are also seen to be mainly composed of small carbonate grains which form the bulk of the rock. Within this texture are numerous sub-parallel, linear and slightly curved opaque bodies (Fig. 6.20). These often coalesce to form an elongate structure (Fig. 6.21). They are believed to represent a flattened vesicular structure which is now composed of calcite and iron ore. The dark arcuate bodies may be equivalent to the shards of siliceous eutaxites.

Also present are fragments of pumiceous material parallel
Fig. 6. 20. Eutaxitic texture shown by portions of the Chiewo vent material. Flattened, carbonated pumice fragments lie in a carbonated matrix possibly after shards. HC 398. X 7. X.N.

Fig. 6. 21. Detail of above showing numerous coalescing opaque curved bodies believed to be after shards lying in a carbonate matrix. HC 398. X 80. P.P.L.
with and included in this foliation (Fig. 6.20).

a) The nature and origin of the rectangular texture

From the observations made above it is concluded that the pyroclastic material of the vent has a very similar character to that of the nearby dyke material and that both may show a well developed texture in which numerous tabular or lath-like sections pseudomorphed by carbonate are present. Comparison of some of these sections with those already described from the area of deuterically altered olivine-melilitite from Got Oloo shows that many similarities exist between the later stages of carbonated melilitite and the rectangular pseudomorphs previously noted at Got Chiewo. These are:

1. Rectangular outlines indicating a platey or lath-like habit. in the rectangular pseudomorphs
2. The brown oxides often outlining and sometimes enclosed indicating some original content of iron.
3. The presence of a single linear feature dividing the rectangular outline lengthwise.
4. The presence of a series of close-spaced, irregular, sub-parallel rods in the pseudomorphs within the dykes of Chiewo material similar to those noted on p.258 (stage 3.) resulting from carbonation of peg texture.

The above observations suggest that the rectangular pseudomorphs are after melilite (Fig. 6.22α). The features 3. and 4. above are believed to be relics of the characteristic single median cleavage and peg structure of melilite. These features are most clearly seen in the dyke material.
Fig. 6. 22a,b. Pseudomorphs after melilite in carbonate dykes of the Chiewo series. Laths in the lower photograph show dark coloured relics after both the median crack and peg texture of melilite. HC 484. X 100. P.P.L.
Relicts after peg structure have not been proved from the vent material for all criteria are not present. However, the complete correspondence of lithology and field relations as well as the presence of prismatic outlines of similar dimensions are concluded to indicate that melilite pseudomorphs are present in the vent material. That the vent material is clastic, being probably composed of spatter and discrete particles ejected during some form of eruption, is a likely reason for the absence of relicts of the delicate peg texture in the melilite pseudomorphs. This may also be the reason why pseudomorphs are not always seen in material from the vent. The ovoid bodies (p.265) are sometimes seen to be composed of rectangular pseudomorphs; these may be rounded lapilli of melilitite flung out of the vent.

b) The significance of the present high carbonate and low silicate content of the Chiewo material

In every specimen examined and sectioned replacement of melilitite by carbonate appears complete and yet the fluxion texture exhibited by the rectangular pseudomorphs in some of the dykes (Fig. 6.23) indicates that the melilitite was replaced by carbonate subsequent to its emplacement.

That this was so in the formation of the amygdaloidal olivine-melilitite from Got Oloo has been noted previously but in that case complete replacement of the rock was not seen. In the present case there is no evidence as to the fate of the SiO$_2$ and other oxides
Fig. 6. 23. Contact of carbonated melilitite dyke and red breccia series showing that the rectangular pseudomorphs after melilitite are arranged in a fluxian texture. HC 484.
X 5. P.P.L.
of the melilitite but a marked auto-metasomatism or deuteric process must be presumed to have occurred to account for the complete replacement of the previous mineralogy, but preservation of the earlier texture.

That this metasomatism may have been accompanied by a great effusion of water and carbon dioxide appears likely as the vent is surrounded by very well laminated but completely carbonated tuffs up to some distances from it.

Marginal sericitization of feldspar crystals and fragments caught up in the vent material as xenoliths indicate that hydrous conditions existed.

c) Criteria for the recognition of the former presence of melilite in carbonate rocks

The presence at Homa of fresh olivine-melilitite with patches in which melilite is being replaced by carbonate and a second centre composed entirely of carbonate and carbonate pseudomorphs after melilite is interesting not least because detailed evidence of the textures pseudomorphed is present at Got Oloo and can be applied to Got Chiewo. That criteria in addition to simply the elongate prismatic outline are necessary to prove the former presence of melilite in rocks from carbonatitic centres becomes obvious in detailed work on the rocks of such. Feldspar and mica may have a prismatic outline in section and both have been noted in partially carbonated rocks. Another interesting comparison may be made with the natro-carbonatite of Oldoinyo l'engai. Sections borrowed from
the British Museum show numerous prismatic carbonate sections of a mineral with the same general form as melilite, i.e. tabular with rounded basal section. These may not survive as such, but pseudomorphing by calcium carbonate may be possible and would result in textures very similar to those seen at Got Chiewo.

It is considered that the minimum criteria for the recognition of melilite pseudomorphed by carbonate should be the presence of relict median crack or basal cleavage and indications of the former presence of the transverse peg structure. It is the presence of these two features in the dyke rocks around Got Chiewo and to a less marked extent in the vent material pseudomorphs that are considered to prove the former presence of melilite.
Fig. 6. 24. Natro-carbonatite texture. Photograph of slide from Oldoinyo L'engai, kindly lent by the British Museum. X 40. P.P.L. (Specimen collected by Dr. N. J. Guest).
DISCUSSION OF OTHER OCCURRENCES OF OLIVINE AND MELILITE BEARING ROCKS IN THE LITERATURE

(1) Introduction

Basic lime-silicate minerals including garnet and melilite are characteristic of environments where silicate and carbonate phases are interacting whether these phases have a magmatic source or not. Andradite garnet is characteristic of the later stages of the ijolite mineralogy on Homa. Such stages are also characterised by an increase in carbonate fixed in the rock. Similarly melilite is developed in rocks high in calcium and from which volatiles are assumed to have emanated, e.g. the olivine-melilitite.

(2) The differing modes of origin attributed to rocks rich in both olivine and melilite and associated with carbonate

a) Origin involving reaction with, or assimilation of, limestone

There are many cases in the literature of basic lime silicates developing at the contacts of silicate magmas and limestone. The recent volcanic province of Italy includes many extremely basic alkaline lavas from which melilite has crystallized. The field evidence and classical interpretation of such melilite (and leucite) bearing rocks does not require a juvenile origin for all the components, mainly because the volcanoes are emplaced in limestone-rich country rock - reaction and assimilation of such limestone is clearly shown by half-digested blocks of sedimentary origin.

A detailed account of an occurrence of such rocks has been
recently published by Mittempergher (1965). He describes the petrography and field relations of the San Venanzo volcano. The main rock type, called venanzite by Rosenbusch (1899), is seen to consist of 15-20% olivine phenocrysts, often corroded and with a composition of Fo88, 30% melilite in phenocrysts and groundmass crystals show zoning from positive cores to negative margins, i.e. zoning from akermanite to more gehlenite-rich margins. 15% diopside crystallized before and contemporaneously with the melilite. Leucite is present up to 30%. Kalsilite is essential, has similar properties to, and is presumably equivalent to, nepheline. Phlogopite is late in the groundmass and alters from the main minerals. Apatite, magnetite, chromite and perovskite are also present. The analyses show Na2O - 1.11 and K2O - 7.41.

Mittempergher describes other facies of this rock type in which the gas pressure was high. Such areas are characterised by a coarser grain size, much less olivine and diopside and much more phlogopite (<18%). Leucite (25%), opaques (8%), apatite, kalsilite, some aegirine, carbonate and phillipsite are also present. Alkalies in this rock show Na2O - 1.40 and K2O - 8.11. Small pockets of a more extreme differentiate sometimes are seen in which mica and melilite are abundant. Alkalies here show Na2O - 2.31% and K2O - 4.92%. He summarizes the petrogenesis of venanzite as follows: 1st generation - forsterites and diopside (intratelluric).
2nd generation - melilite and leucite (post-effusive)
3rd generation - kalsilite, phlogopite,apatite (pegmatitic-pneumatolitic)
4th generation - carbonate and zeolites (hydrothermal)

Mittempergher himself believes the late stage segregation and retention of carbonate and zeolite bearing material is analogous to features seen in the W. Uganda field described by Holmes.

b) Origin involving the presence of juvenile carbonatitic material

Holmes (1937, 1950) describes a similar potash-rich olivine-melilitite from W. Uganda. It, too, has a high K₂O/Na₂O ratio and leucite and kalsilite are present. Holmes concluded that katungite was a very early differentiate in the volcanic fields of W. Uganda. He also postulated that it was derived from granitic basement by the action of carbonatitic magma. Frequent reference is made to the explosive nature of the volcanic phenomena, carbonation of melilite, the carbonate matrix to the agglomerate and the great quantities of travertine deposited in and around the vents. Thus, here too there is evidence of much carbonate and volatiles accompanying the extrusion of melilite and olivine bearing magma.

It is seen that the proposed derivation of two relatively similar but rare rock types is different. In the Italian province it is proposed that a silicate magma assimilates and reacts with limestone country rock, while in Uganda, in the observed absence of limestone in the country rock, Holmes proposed reaction of a
carbonatitic magma with a silicate country rock.

This apparent anomaly is the basis of the controversy which still flares over the origins of carbonatites. While discussion of the origin of juvenile carbonatitic magma will not be attempted here, the author believes that the above two processes, being supported by field evidence, are both likely to occur and illustrate a fundamental fact of importance when considering the origin of any undersaturated lime-silicate rich rock. This fact was first pointed out in essence by Bowen (1928) and is that a magma assimilating material from the country rock, providing assimilation and dispersal of the new material is complete, will precipitate the same suite of minerals as a primary magma of the same composition as the hybrid. This may be the reason why venanzite and katungite have so many characters in common although apparently derived by different processes. Detailed trace element studies coupled with computation of magma compositions due to differing amounts of assimilation might distinguish two origins that the mineralogy will not.

(3) Comparison of the melilite bearing rocks of Homa with some other occurrences in the world

a) Venanzite and katungite

An outline of the characters and proposed modes of origin of venanzite and katungite has already been made. It was noted that apart from the increased $K_2O/Na_2O$ ratio the rocks are similar in mode and chemistry to the olivine-melilitite of Homa.
b) Rocks associated with katungite in the West Uganda volcanic field

The rocks at Homa are very similar to some of those mapped by Combe and described by Holmes and Harwood and latterly summarized by von Knorring (1967) from the Western Uganda fields. The latter author commented on the resemblance of textures in the carbonated melilitite of Homa with those from the Kalyango crater near Fort Portal, in course of conversation. Carbonatitic lava from this crater has been described (von Knorring and Du Bois, 1961). Von Knorring's recent summary (1967) notes that the rock from M'buga crater (described by Holmes, 1956 as limestone with the appearance of a pumiceous lava) retains its original texture although all the previous minerals, including melilite, except apatite and magnetite, are completely replaced by calcite. Holmes himself described it as a melilite rich katungite now consisting of calcite.

Mention has already been made in the previous section of the mode favoured by Holmes for the origin of olivine melilitite. It involves the activity of a juvenile carbonatitic magma phase and reaction of this with granitic country rock. In view of the large number of occurrences of such rocks in W. Uganda it has seemed surprising that carbonatite intrusive centres, as present in Eastern Uganda e.g. Toror (King and Sutherland, 1966), have not been found.

The evidence at Homa suggests that here is a complex at which both the above classes of carbonatitic activity are present and that, therefore, Holmes' view (1950) of an origin involving juvenile carbonatitic magma is supported.
The clear evidence at Homa, that material now composed almost entirely of carbonate originated by replacement, probably in situ, of silicate rich material giving rise to rocks with characters very similar to those described as carbonatitic lavas from Western Uganda, indicates that carbonatitic lavas of two apparently different origins are present at volcanic complexes of E. Africa:—

i. Those termed natro-carbonatites (Dawson, 1962; Du Bois et al., 1963).

ii. Those originating by replacement of melilite rich rocks which at Homa are termed carbonated melilitites.

c) Olivine melilitite of the Sutherland, Saltpetre Kop and Bushmanland areas of South Africa

The rocks first described by Rogers and Du Toit (1904) from the Sutherland and Saltpetre Kop area are of extreme interest because examples of kimberlite and melilite rich rocks are present within a short distance of each other. Both appear to be associated with the remarkable vent of Saltpetre Kop whose formation was accompanied by strong doming of the overlying country rock over an area similar to the central part of Homa. The vent rocks are mainly oxidized, carbonated, brecciated country rock. Thin dykes of carbonatite have recently been noted from this vent (Verwoerd, 1966). The combination of marked doming, brecciation, intrusion of carbonatite and emplacement of olivine melilitite plugs is also seen at Homa. Taljaard (1936) reviewed the S. African melilitite occurrences and
noted inclusions of altered rock possibly after ijolite in the Bushmanland pipes. Nepheline develops late in a base of analcite in some of the occurrences.

d) Kimberlites

The possible connection between kimberlites and olivine melilitite magma was proposed by Carvill Lewis (1887) in the paper defining kimberlite. Since then, many authors have postulated similar connections. Melilitite is most probably not stable under the conditions of emplacement of a kimberlite breccia and this may account for the lack of petrographic evidence for Carvill Lewis's view. Holmes (1936) reviewed the question and concluded that kimberlites resulted from the mixing of three types of material:–

i) Xenolithic minerals, e.g. ilmenite, chrome diopside + wall rock fragments.

ii) Water, carbon dioxide and phosphorus pentoxide.

iii) Remainder - equivalent to olivine melilitite.

The altered nature of the groundmass, serpentinization of olivine and development of phlogopite are characteristic.

A recent paper on a kimberlite province in Siberia describes four pipes in part penetrating dolomite (Ukhanov, 1963). The southernmost pipe shows a kimberlite breccia at the margin surrounding a central pipe of massive olivine melilitite ($K_2O - 3.08$, $Na_2O - 1.00$). The mineralogy of the melilitite differs from those
at Homa in that 36% phlogopite occurs in the mode, this is often seen to replace nepheline and occurs in fissures in the olivine and with zeolite is the latest mineral to develop. Post magmatic alteration to serpentine, calcite and zeolite is unevenly developed. Rounded protocrysts of mica as found in the kimberlite were also noted. Several analyses are given and the chief difference between the melilitite and the kimberlite is that the latter are richer in carbon dioxide and water.

The alnoitic agglomerate from Homa has several features in common with kimberlites as described above. The brecciated nature, alteration by carbon dioxide, presence of hydrous phases, e.g. phlogopite, the inclusion of xenolithic material, both from the wall rock and from a deeper possibly peridotitic source, and the presence of much melilite bearing rock are all characteristic of kimberlites. However, the classical diamond bearing kimberlites of South Africa are accompanied by a suite of minerals - pyrope, ilmenite and chrome diopside - which are essential. Thus, the Homa alnoitic agglomerate has many characters of kimberlites and appears to have been emplaced by the same process as involved for kimberlitic pipes, but differs in important details of mineralogy.

A widely accepted mechanism for the emplacement of kimberlite breccias is discussed by Reynolds (1954) in her review of fluidization as a geological process. The evidence from field and petrographic studies indicates that the Homa alnoitic agglomerate
satisfies the criteria advanced by Reynolds for rocks emplaced by such a process. Rounding of included polygenetic xenocrysts and xenoliths, accompanied by a volatile rich fraction and an intrusive relationship appear to be the essential features present in the Homa occurrence.

e) **Mixed carbonate and melilitite bearing rocks from Alno and Rangwa**

Von Eckermann (1948, 1958, 1966) has described large numbers of dykes from Alno which contain both carbonate and silicate material. He distinguishes kimberlites, carbonatites, alnoites and olivine melilitites amongst others and in many the silicate minerals are pseudomorphed and replaced mainly by carbonate. He finds that these dykes are characteristic of the later focus of eruption and concludes that some of the carbonatites show pseudomorphs after melilitite and that carbonated melilitites play an important role in the development of the alkaline and carbonatitic rocks of Alno.

The kimberlites described from Alno by Von Eckermann differ in mineralogy from those in S. Africa and have some similarities with the alnoitic agglomerate at Homa. The occurrence of numerous dykes carrying pseudomorphs after melilitite is interesting in considering the Got Chiewo vent carbonated melilitite of Homa.

McCall (1963) has extended Von Eckermann's ideas to the Rangwa and Ruri complexes which are associated with Homa in the Nyanza (Kavirondo) Rift. He describes dykes with prominent
rectangular pseudomorphs after what he believes is melilite. He suggests that the melilite bearing dykes outside the main Rangwa vent and the carbonatite dykes within the vent are in fact manifestations of the same suite of intrusions, different levels of which have been brought into juxtaposition by cauldron subsidence of the central vent.

The Got Chiewo vent and dyke series is late in the sequence at Homa and the carbonated melilitites differ in texture from all other carbonatites on the mountain. They are not typical of the main series (C1 - C4, chapter 1, p. 15) and occupy less than 1% of the total area of carbonatites exposed at Homa.

(4) Comparison of the olivine melilitites with the 'immediate parent' of King (1965)

The extensive data on the volcanic and plutonic suites from E. Uganda suggests that the 'immediate parent' to both is equivalent to melanephelinite/pyroxenite composition (King, 1965; King and Sutherland, 1966).

It was decided to compare the analyses of the Got Oloo olivine melilitite with this 'immediate parent' of King. Also compared are the average katungite of Holmes (1950) and two analyses of S. African melilite bearing rocks. Venanzite (Mittempergher, 1966) and a melilite nephelinite from the Oahu series of Hawaii (McDonald, 1949) are also compared.
Fig. 6.25, Diagram indicating the range of compositions of lavas from Mt. Elgon and Napak. (King 1965 p.81)

AREA WITHIN WHICH THE FOLLOWING ANALYSES PLOT:—

Olivine melilitites from Homa Mountain
Olivine melilitites from Spiegel River (Holmes, 1936).
Melilite basalt from Klaasvoogdts (Taljaard, 1936).
Average basaltite (Holmes, 1950).
Average Hawaiian melilite nephelinite (MacDonald, 1949).
Venanzite (Mittempergher, 1966).
Plotting the above analyses on Fig. 8 of King (1965) shows that all the analyses fall near the zone of composition of the most basic of the E. Uganda rocks (Fig. 6.25).

A further comparison with the rocks from E. Uganda may be made by plotting the $\frac{Fe_2O_3 + FeO}{MgO}$ and $\frac{CaO}{MgO}$ ratios on to Fig. 12 of King (1965).

The higher MgO content of the S. African examples places them in King's field of ankaratrites. Katungite and the analyses from Homa plot on or very close to the field of overlap of King's volcanic and plutonic suite.

King suggests that rocks of this composition represent the immediate parent in the E. Uganda complexes (King, 1965, p. 84). The author suggests that in view of the many similarities between the volcanic and intrusive phenomena and period of activity of the E. Uganda and Kavirondo suites that the coincidence of the olivine melilitite composition of Homa with that of the "immediate parent" of King is significant and that the correspondence with katungite might also be so.

The melanephelinites of Eastern Uganda carry essential and early forming crystals of nepheline and diopside with or without olivine and carry melilite usually in the groundmass. The olivine melilitite of Homa carries much forsterite, melilite and subordinate clinopyroxene. Nepheline is late and in minor amount. A second generation of clinopyroxene accompanies this nepheline in areas
of the rock in which amygdals filled with carbonate are seen.

It is suggested that the chemical similarity but mineral-
ogical difference between the melanephelinite and olivine melilitite
(including katunge) rock types may be due to crystallization
of samples of the immediate parent under differing conditions.
Two of the possible reasons for such differences are - a) a slight
change in initial composition of the melt and b) the temperature
of consolidation.

Evidence concerning this point is highlighted by comparing
the minerals stable in the fresh and amygdaloidal facies of the
olivine melilitite of Got Olooo:-

Minerals stable in fresh facies - olivine, melilite, clinopyroxene.
(Nepheline in very minor amount).

Minerals stable in amygdaloidal or carbonated facies - clinopyroxene, nepheline, zeolites and carbonates.

This is believed to indicate a differentiation from olivine
melilitite towards nephelinite composition under conditions of
lowering temperature of crystallization due to retention of
volatiles. This evidence of differentiation in natural rock systems
at Homa is very similar to that obtained as a result of work on
experimental systems. The systems discussed below were noted as
having a bearing on the origin of ijolites (chapter 2) but are
believed to provide a much more direct comparison with rocks
discussed in the present chapter.
The system nepheline-diopside was studied by Bowen (1928) who was able to report results which were later confirmed and added to by Schairer et al. (1962). All the phases crystallizing from mixtures of nepheline and diopside are not expressible in terms of these two components and so the system should be considered as a pseudobinary system within the quinary system \( \text{Na}_2\text{O}-\text{CaO}-\text{MgO}-\text{Al}_2\text{O}_3-\text{SiO}_2 \) (Fig. 6.26).

Bowen discussed the significance of the relations indicated by this system in some detail and observed that the earlier melilites to crystallize were akermannites (optically positive). Later isotropic and then optically negative melilites appear. This is the trend observed in venanzite, katungite and to a lesser extent in the melilitite of Got Oloo.

Inspection of the diagram indicating the stability fields of the various minerals within the system (Schairer et al. 1962, p. 97) shows that the order of appearance of minerals varies with the initial composition (Fig. 6.27).

It can be seen that melilite and diopside may vary in their relative order of crystallization. Most of the cases in the literature state that diopside was earlier and was involved in a reaction relationship resulting in melilite (case B; Taljaard, 1936; Bowen, 1922, 1928; Ross, 1926; Holmes, 1950). In the present case at Got Oloo it was concluded that pyroxene may be late and
**Fig. 6.26** The system NaAlSiO₄-CaO-MgO-SiO₂.

**Geophysical Laboratory**

**Fig. 6.27**

Pseudobinary diagram of equilibrium in mixtures of nepheline and diopside.
Fig. 6.28: Phase equilibrium diagram of the system Ca$_2$Mg$_3$Si$_2$O$_9$–Ca$_3$Mg$_2$Si$_2$O$_7$–NaAlSiO$_4$. 
altered in part from the melilite, and nepheline was also late.

The relations within this system indicate that a composition crystallizing olivine and melilite at first will attain equilibrium at lower temperatures as a mixture of nepheline, melilite and diopside. This agrees with the proposal that olivine melilite may be a high temperature equivalent of melanephelinite.

More recently published work on the pseudoternary system nepheline-diopside-akermannite (Onuma and Yagi, 1967) provides further information on the order of crystallization of rocks near olivine melilite composition (Fig. 6.23).

The phases crystallizing again cannot be expressed in terms of three components; the system is, therefore, termed pseudoternary. It is in fact one plane within the five component system already mentioned (Fig. 6.26). Owing to the difficulty of representing graphically a five component system, they use the four components NaAlSiO₄-CaO-MgO-SiO₂.

The number of components in the system means that G and H are not invariant points but piercing points, e.g. melilite and diopside will crystallize along FG at which point they will be joined by forsterite and all three will crystallize with falling temperature. Along EH nepheline and melilite crystallize to be joined at H by forsterite. Diopside appears at 1135° in mixtures with composition near H. Onuma and Yagi note that this is a quaternary invariant point, for five phases co-exist in the four
component system (ignoring vapour phase).

They deduce the following flow sheet to summarize the co-existing phases within the system:

\[\text{Fo} \rightarrow \text{Ne} \leftarrow \text{Fo} \rightarrow \text{Di} \leftarrow \text{Ne} \rightarrow \text{Mel} \rightarrow \text{G} \leftarrow \text{Di, Mel.} \]

\[\text{Ne, Mel.} \rightarrow \text{H} \rightarrow \text{Fo} \rightarrow \text{Ne} \rightarrow \text{Mel} \rightarrow \text{I (Fo, Di, Ne, Mel.)} \]

\[\text{Di} \rightarrow \text{Ne} \rightarrow \text{Mel} \leftarrow \text{I (Fo, Di, Ne, Mel.)} \]

G and H are piercing points at 1169°C and 1212°C respectively. I is an invariant point at 1135°C.

Onuma and Yagi believe that a typical olivine melilitite mineralogy corresponds to the co-existing phases at the piercing point G and that the assemblage at I results from equilibrium crystallization of compositions near G. Co-existing phases at I correspond to mineral assemblages in olivine melilitite nephelinite. After all the olivine has been resorbed at I the co-existing phases correspond to melilitite nephelinite.

Thus they believe that an olivine melilitite will give rise
to a melilite nepheline under conditions of equilibrium crystallization. Their flow sheet also implies that diopside will commence to crystallize before melilite in the above differentiation scheme.

The rock at Got Oloo has a mineralogy near that of point G of Onuma and Yagi, while the carbonated olivine melilitite facies shows that nepheline and clinopyroxene are stable in conditions in which carbonates and volatiles are retained in the rock and that olivine and melilite are not. Thus, the petrography of the olivine melilitite of Got Oloo indicates a similar differentiation to that shown by the data of Onuma and Yagi. The experimental data also supports the view previously deduced (p.294) that rocks of olivine melilitite composition represent a sample of the immediate parent of King.
(5) **Summary of conclusions**

1. Homa Mountain is an example of a carbonatitic complex associated with melilitite bearing rocks.

2. Such rocks occur in minor volume only and are chiefly late in the sequence as examples of the series of satellitic vents found around the mountain.

3. Evidence of carbonate replacement of melilitite is very clear and the occurrence of both intrusive and extrusive carbonate rocks with pseudomorphs after melilitite can be demonstrated.

4. The carbonate replacement process appears to be a late stage, possibly deuteric metasomatism.

5. Such replacement cannot be postulated for the great majority of the carbonate rocks at Homa.

6. The occurrence of olivine melilitite magma and the relations and character of the alnoitic tuff are believed to indicate that a close connection exists between some phases of carbonatitic vulcanism and kimberlitic vulcanism.
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p. 178.


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THE GEOLOGY OF THE SOUTHERN PART OF HOMA MOUNTAIN CARBONATITIC COMPLEX WESTERN KENYA, WITH PARTICULAR REFERENCE TO THE PETROLOGY OF THE ALKALINE SILICATE, METASOMATIC AND MELILITE BEARING SUITES.

SECTION HEADINGS

(1) The general geology of the carbonatitic centre of Homa Mountain with particular reference to the southern part.

(2) Variation within the ijolite at Homa Mountain.

(3) Country rock alteration at Homa Mountain, (a) introduction, outline description of the country rock, and its fenitization away from ijolite contacts.

(4) Country rock alteration at Homa, (b) fenitization and relations of syenitic rocks at ijolite contacts.

(5) Rocks with some affinities to aegirine bearing fenites and syenites in which the development of feldspar is enhanced but in which aegirine is unstable or absent.

(6) M.elilite bearing rocks of Homa Mountain.
Abstract

The multi-centred carbonatitic complex of Homa Mountain consists of a central cone sheet complex intruded into a domed area of country rock, surrounded by further arcuate zones of intrusive activity.

The earlier events included intrusion of a body of ijolite, as a series of discontinuous bodies probably connected at depth. Later events include at least five stages of carbonatite intrusion and also numerous carbonatitic breccias.

Syenitic rocks formed by concentration of late stage material at the margins of the ijolite which deuterically altered the ijolite and metasomatized the country rock to fenite contemporaneously. Minerals formed at such contacts are low temperature, potash-rich orthoclase and aegirine, with apatite the chief minor constituent.

A second style of fenitization is recognized involving net veining of more widespread areas of country rock away from ijolite contacts.

This reaches its climax in arcuate zones of shearing and brecciation within the central high ground where there is evidence of partial melting of such fenites to iron oxide-bearing trachytes. Coarse feldspathic rocks also carrying iron oxides are present near ijolites and early carbonatites. The feldspar
in these is very similar to that in the fenites.

Metasomatism at Homa is believed to involve introduction of large amounts of juvenile potash only, much of the soda being derived by redistribution of that already present in the country rock.

A period of erosion during which superficial, lacustrine and possibly pyroclastic deposits were laid down then occurred and the mountain reduced to near its present topography.

Following this erosional interval small scale vents of breccia and melilite-bearing material were intruded. The melilitites show all stages of replacement by carbonate.

The above later stages of activity occurred during Late Pliocene or Pleistocene time. They were accompanied by some phonolitic activity within the complex and more in the area to the east along an extension of the southern boundary fault of the Nyanza Rift.