

SOME ASPECTS OF THE
IGNEOUS AND METAMORPHIC GEOLOGY
OF
CENTRAL SKYE

by

SHELAGH M. SMITH, B.Sc.

Thesis submitted to the University of Edinburgh for
the Degree of Doctor of Philosophy, 1958.



C O N T E N T S

| | |
|--|-----|
| ABSTRACT | i |
| INTRODUCTION ,... .. . | iii |
| BEINN NA CRO | |
| I. Introduction | 1 |
| II. Field Relations | |
| 1. Lavas | 2 |
| 2. Granulite and Gabbro | 2 |
| 3. Explosion Dykes | 4 |
| 4. Acidic Rocks associated with the Basic Rocks | 5 |
| 5. Granitic Rocks | 6 |
| III. Structure | 7 |
| IV. Petrography | |
| 1. Basic Rocks | |
| A. Basalt Lava | 9 |
| B. Fine-grained Granulite | 10 |
| C. Medium-grained Granulite | 11 |
| D. Coarse-grained Granulite | 12 |
| E. Mafic Granulite | 12 |
| F. Vein Gabbro | 13 |
| G. Coarse-grained Mafic Granulite | 14 |
| H. Gabbro | 16 |
| I. Explosion Dykes | 18 |
| 2. Hybrid and Acidic Rocks associated with the Basic Rocks | |
| A. The Contact of the Basalt with the main mass of the Beinn na Cro Granite | 22 |
| B. Net-veined Basalt | 27 |
| C. Net-veined Hypersthene Dolerite | 36 |
| D. Massive Hybrid Rocks | 39 |
| E. Tongue Rocks | 42 |
| 3. Granitic Rocks | |
| A. Beinn na Cro Granite | 46 |
| B. Quartz-porphyry | 49 |
| V. Modal Analyses | 51 |

BEINN NA CRO (Contd.)

| | |
|---|----|
| VI. Discussion | 53 |
| 1. Structure | |
| A. The Relationships between the Basalts and the Gabbros | 55 |
| B. The Relationships between the Basic and the Acidic Rocks | 56 |
| 2. Petrogenesis | 57 |
| A. Granulite and Gabbro | 58 |
| B. Explosion Dykes | 67 |
| C. Hybrid and Acidic Net-Veins | 71 |
| D. Massive Hybrid Rocks | 82 |
| E. Acidic Dykes and Tongues | 83 |
| F. Quartz-porphry | 90 |
| VII. Summary and Conclusions | 94 |

CREAGAN DUBH

| | |
|---|-----|
| I. Introduction | 96 |
| II. Field Relations | |
| 1. Lower Group | 97 |
| 2. Lavas | 105 |
| 3. Rhyolite and Bedded Agglomerate of Srath Beag | 106 |
| 4. Transgressive Agglomerate | 106 |
| 5. Acidic Rocks | 108 |
| III. Faults | 110 |
| IV. Petrography | |
| 1. Lower Group | |
| A. Agglomerate and Spotted Rock | 114 |
| B. Gneiss, Granite, Hornblende gneiss and Diorite, and Acidic Anorthosite | 118 |
| C. Gabbro, Dolerite and Basalt | 121 |
| 2. Lavas | |
| A. Lower Flows | 126 |
| B. Higher Flows | 129 |
| 3. Rhyolite and Bedded Agglomerate of Srath Bheag | |
| A. Rhyolite | 131 |
| B. Bedded Agglomerate | 132 |

CREAGAN DUBH (Contd.)

IV. Petrography (Contd.)

| | | | | | |
|--|-----|-----|-----|-----|-----|
| 4. Transgressive Agglomerate | ... | ... | ... | ... | 132 |
| 5. Acidic Rocks | | | | | |
| A. Quartz-porphyrity | ... | ... | ... | ... | 135 |
| B. Microgranite | ... | ... | ... | ... | 136 |
| C. Granite of Beinn Dearg Mhor | ... | ... | ... | ... | 138 |
| V. Discussion | ... | ... | ... | ... | 139 |
| 1. Structure | .. | ... | ... | ... | 141 |
| 2. Petrogenesis | | | | | |
| A. Lower Group (including the Gneiss) | ... | | | | 141 |
| B. Transgressive Agglomerate, quartz-porphyrity and Microgranite | ... | ... | ... | ... | 152 |
| C. Sequence of events which took place during the geological history of Creagan Dubh | ... | ... | ... | ... | 157 |

GLAS BHEINN BHEAG

| | | | | | | |
|--|------|-----|-----|-----|-----|-----|
| I. Introduction | ... | ... | ... | ... | ... | 158 |
| II. Field Relations | | | | | | |
| 1. Jurassic Sediments | ... | ... | ... | ... | ... | 159 |
| 2. Acidic Rocks | ... | ... | ... | ... | ... | 160 |
| A. Microgranite | ... | ... | ... | ... | ... | 161 |
| B. Granite | ... | ... | ... | ... | ... | 161 |
| C. Quartz-porphyrity | ... | ... | ... | ... | ... | 162 |
| III. Structure | ... | ... | ... | ... | ... | 163 |
| IV. Petrography | | | | | | |
| 1. Sediments | .. | ... | ... | ... | ... | 164 |
| A. Hornfelses and metamorphosed sandstones | | | | | | 165 |
| B. Feldspathic sandstones and quartzites | | | | | | 168 |
| C. Calcareous quartzites | | ... | ... | ... | ... | 169 |
| D. Mudstones | ... | ... | ... | ... | ... | 172 |
| 2. The Contact of the Sediments and the Microgranite | ... | ... | ... | ... | ... | 174 |
| 3. Acidic Rocks | | | | | | |
| A. Microgranite | ... | ... | ... | ... | ... | 178 |
| B. Granite | ... | ... | ... | ... | ... | 181 |
| C. Quartz-porphyrity | ... | ... | ... | ... | ... | 182 |

GLAS BHEINN BHEAG (Contd.)

| | |
|--|-----|
| V. Discussion | |
| 1. Structure | 186 |
| 2. Petrogenesis | |
| A. The Metamorphism of the Sediments ... | 188 |
| B. The Origin of the Microgranite .. | 191 |
| C. The Origin of the Quartz-porphyrines ... | 198 |
| D. The Dunan fault and the Dunan granite "contact" | 199 |
| VI. Summary and conclusions | 202 |
| SUMMARY and CONCLUSIONS .. | 203 |
| ACKNOWLEDGEMENTS | 206 |
| BIBLIOGRAPHY . | 207 |

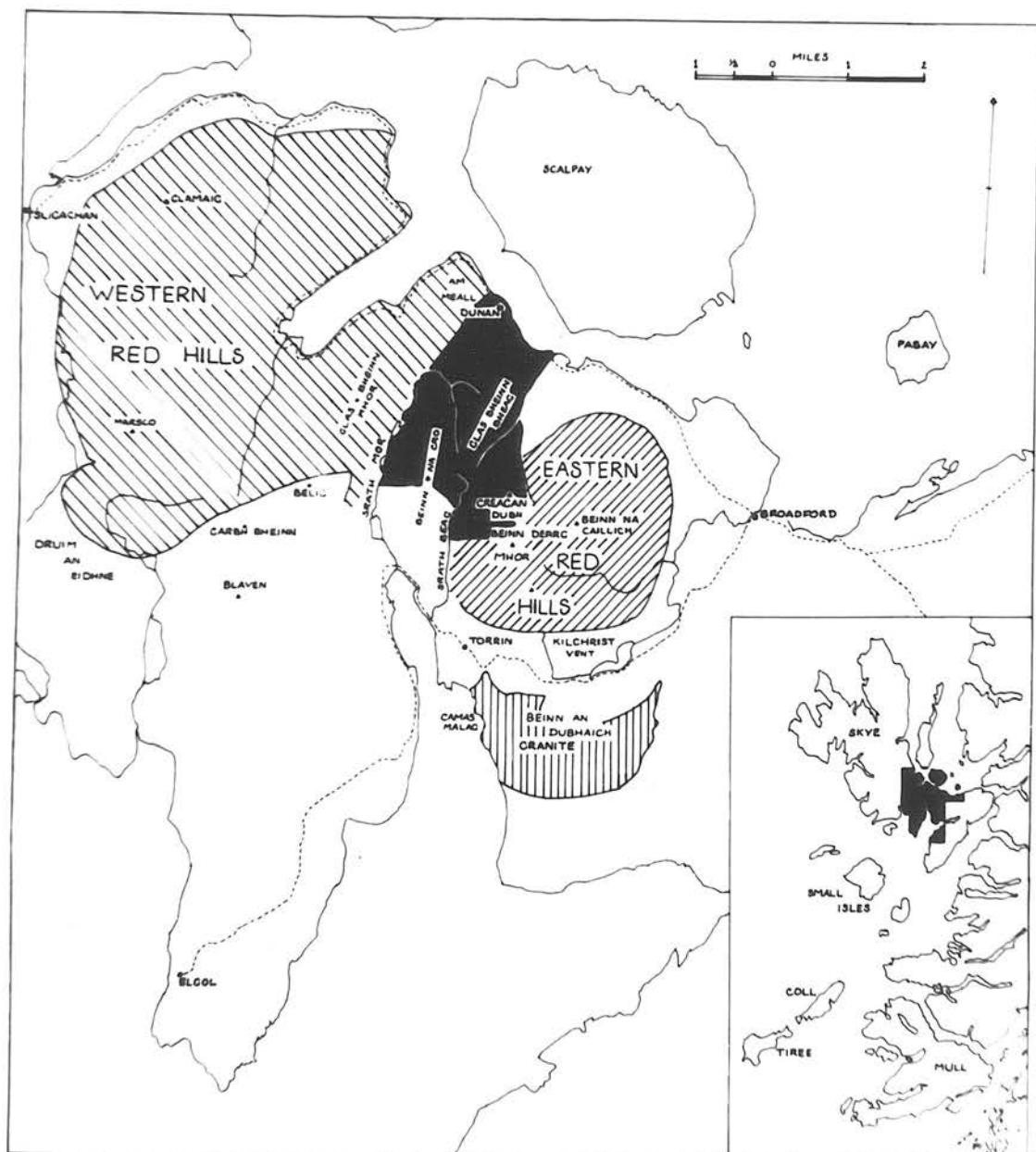


Figure 1. Locality map of Central Skye. Inset:
 Locality map of part of Western Scotland indicating
 Central Skye.

ABSTRACT

The part of Central Skye investigated and described in the present thesis consists of three adjacent areas: the geology of the three regions has not been correlated.

Beinn na Cro consists of a complex of Tertiary basic rocks which are cut by hybrid and acidic net-veins, dykes and great tongues, the latter extending into the basic rocks from the Beinn na Cro granite mass. The rocks comprise lavas which, it is postulated, have been metasomatised into granulite and gabbro and fluidised into dolerite as the result of the uprise of hot supercritical fluids along vertical concentric sub-arcuate fractures. The hybrid and acidic net-veins and dykes appear to have been emplaced partially by the metasomatic alteration of the country rock by acidic fluids and partially as fluidised acidic systems. Quartz-porphyry sheets of magmatic origin cut the other rocks.

Creagan Dubh is formed of a complex of Tertiary gneiss with pyroclastic and basic rocks overlain unconformably by lavas, the entire succession being cut by transgressive agglomerate and quartz-porphyry intrusions. It is suggested that the gneiss has formed as the result of the preferential alteration in situ of laminated and bedded tuff by ascending acidic /

acidic fluids without the operation of tectonic forces. The transgressive agglomerate and quartz-porphyry are of magmatic origin.

Glas Bheinn Bheag comprises Jurassic sediments in which a metamorphic aureole around a Tertiary microgranite has been detected. The introduction of heat, alkalies and bases into the sediments from the microgranite has resulted in the granulitisation and chemical alteration of the sediments. The microgranite is considered, at least at its margins, to be metasomatic in origin. Quartz-porphyry sills and dykes of magmatic origin cut the other rocks.

INTRODUCTION

The area of Central Skye, the geology of which forms the subject of this thesis, lies some six miles to the west of Broadford, and extends from the coast at Dunan, in the north, towards Loch Slapin, in the south (Fig. 1 and map, back pocket). The eastern boundary is the Eastern Red Hills which rise to over 2500 feet above sea level, while the western margin is the Blaven - Glas Bheinn Mhor range which attains a maximum height of over 3000 feet. The area is thus some two miles wide and about three miles from north to south. It is of moderate accessibility. Linking the main road through Dunan with the road from Broadford to Elgol are two footpaths, one leading through Srath Beag; the other lying in Srath Mor. The crofting township of Dunan is the only inhabited or cultivated part of the area.

The topography of the region is one of pronounced relief. Negative features are the U-shaped valleys of Srath Mor, to the west, and Srath Beag, which trend approximately north-south. Srath Mor is only a few feet above sea level, while Srath Beag can almost be described as a hanging valley, the major part of its floor being about 600 feet above sea level. Between the valleys rises the keel-shaped ridge of Beinn na Cro (1750 feet) its sides having an average slope of /

of about 40°. Glas Bheinn Bheag (1133 feet) lies to the north-east of Beinn na Cro and slopes gently towards the sea at Dunan. To the east of Srath Beag is the steep-sided Beinn Dearg Mhor (2323 feet), and Creagan Dubh (1750 feet) forms the northern end of this hill.

Srath Mhor is drained by the southwards flowing Abhuinn an t-Sratha Mhoir. The headwaters of this river are the Allt an t-Sithein which rises on Gualann nam Fiadh and flows northwards to its confluence with the Allt nam Fiadh draining westwards off Glas Bheinn Bheag. Numerous tributaries to the Abhuinn an t-Sratha Mhoir run more or less straight down the flanks of Belig and Glas Bheinn Mhor, to the west, and Beinn na Cro, to the east. The most important of the latter are the Allt na Caoraich and the Allt na Gobhar which have their sources near the summit of Beinn na Cro. In the eastern part of the area the drainage forms two systems. The Allt an t-Srath^a Bhig flows from Gualann nam Fiadh southwards down Srath Beag. Its only notable tributary, the Allt Beinn Dearg Mhor, rises on Beinn Dearg Mhor, to the east. An Slugan - Allt Strollamus rises in the boggy ground at the head of Srath Beag and flows northwards along the eastern foot of Glas Bheinn Bheag. It is joined from the north-east by the Allt na Teangaidh which rises in the coires to the east of Creagan Dubh.

The country is typical glacial terrain. The upper portions of the hills are smooth and the rocks are devoid of covering apart from extensive scree. Lateral moraines are well developed and extend up to 150 feet above the valley floors, while an esker about 25 feet high is present at the northern end of Srath Mor.

Beinn na Cro, Creagan dubh and Glas Bheimh Bheag have not been accorded prominent places in geological literature, although the Isle of Skye has attracted the attention of geologists since the beginning of the 19th century. Early geologists, notable amongst whom are Jamieson (1800), MacCulloch (1816, 1817, 1819), Boué (1820), von Oeynhausien and von Dechen (1829) and Zirkel (1871), devoted most of their attention to the more accessible sedimentary strata and the lavas of Trotternish at the northern end of Skye, largely neglecting the rugged Cuillins and the scree-covered domes of the Red Hills. It was not until 1856, when A. Geikie visited Strath, immediately to the south of the thesis area, that any one small part of Skye was mapped and described in detail. This work was published in 1858. Between 1856 and 1904, the year in which the Memoir "The Tertiary Igneous Rocks of Skye" was published, detailed work was carried out over much of Skye, by A. Geikie, Judd and Harker. Skye was the battle-ground /

battle-ground of Judd and Geikie, where they sought their field evidence. In Skye Judd (1874) saw the basal remains of one of his five great Tertiary volcanoes, whereas Geikie (1888) regarded the numerous basic dykes and the far-reaching plateau lavas as evidence for fissure eruptions, and considered each of the Red Hills as individual centres of volcanic emission. It was on Druim an Eighne (Fig. 1) that Judd (1893) found evidence in the form of acidic inclusions within the Cuillin gabbro, upon which he based his interpretation that the acidic rocks were older than the basic ones, and where Geikie (1894) observed acidic dykes extending from the Red Hills granite into the gabbro and thus inferred that the reverse was the case, a conclusion that was eventually forced upon Judd.

In 1888 Geikie published "The History of Volcanic Action during the Tertiary Period in the British Isles". In the section on Skye Geikie described the field relations of the gabbro, dolerite and basalt of Beinn na Cro and noted that at their southern end the basic rocks were truncated and veined by the Beinn na Cro granite. He also gave the petrography of the Beinn na Cro granite in some detail, and reported the occurrence of microgranite veins extending from the Beinn Dearg Mhor granite into the lavas of Creagan Dubh.

Geikie's /

Geikie's observations were confirmed and enlarged upon by Harker in "The Tertiary Igneous Rocks of Skye" (1904) (~~see pages~~ 7. More detailed reference to Harker's work is given in the discussions appropriate to the sections on Beim na Cro, Creagan Dubh and Glas Bheinn Bheag (see pages 53,57,61,139,186,194). His theories concerning the mode of intrusion of the Red Hills granites, which he considered to be laccolithic, were questioned by Thomas (1927) and Richey (1930) who concluded, largely from Harker's evidence, that the granites were ring-dykes (see pages 54 and 186).

More recent workers on Skye have, rather than theorising on the igneous rocks of Skye as a whole, described small, controversial, areas, none of which is included in the district discussed in this thesis. In 1946 and 1947 Richey, Stewart and Wager (1946 and 1947) on the one hand, and D.L. Reynolds and McIntyre (1947) on the other, dissented over the relative ages of the marscoite and granite at the northern end of the Western Red Hills, while in 1953 and 1954 B.C. King and Bailey disagreed on the mode of origin of the granite on Creag Strollamus, immediately to the east of Creagan Dubh. King (1953, 1954) considered that the granite represented metasomatised Torridonian sandstone, while Bailey (1954) maintained that it was magmatic in origin.

Although /

Although the three areas of Beinn na Cro, Creagan Dubh and Glas Bheinn Bheag are adjacent to one another, their geology cannot be directly correlated owing to faults and intervening deposits of drift and peat. The rocks of the two former areas exhibit a fair degree of similarity in that they both consist of volcanic rocks which have in part undergone high grade metamorphism and metasomatism, have been intruded by acidic material, and are associated with granite. The volcanic rocks of Beinn na Cro consist entirely of lavas, while those of Creagan Dubh comprise considerable quantities of bedded and intrusive pyroclastic rocks in addition to lavas. Metamorphic rocks in the former area are granulite, gabbro and hybrid rocks, while the notable metamorphic rock of the latter area is gneiss. The granite of Beinn na Cro clearly post-dates the lavas, while that of Beinn Dearg Mhor is separated by a fault from the rocks of Creagan Dubh and its age relative to the volcanics cannot be assessed. Glas Bheinn Bheag differs from the other two areas in that it is composed of Jurassic sediments which have been metamorphosed into hornfelses and quartzites at the time of the emplacement of the Tertiary microgranite which dips beneath the sediments.

The main problems discussed in this thesis concern the origin of the gabbro and the origin of the acidic net-veins /

met-veins of Beinn na Cro; the origin of the gneiss and the formation of the transgressive agglomerate of Creagan Dubh; and the metamorphism of the sediments and the origin of the microgranite of Glas Bheinn Bheag.

B E I N N N A C R OI. INTRODUCTION

Beinn na Cro is a narrow ridge some 1750 feet high and two miles long, striking south-south-westwards from Glas Bheinn Bheag and lying between the Western and the Eastern Red Hills of Skye (Fig. 1). The rocks under discussion occupy the northern part of Beinn na Cro. They consist of a complex of intimately associated Tertiary basic and acidic rocks, described by Harker (1904) and mentioned by Richey (1930). Much of the area is not readily accessible, as the steep western slopes of the hill are covered by loose and dangerous screes. However, it is possible to reach the exposures in and around the Allt na Gobhar and the Allt na Caoraich and the northernmost rocks which form a succession of low crags leading up to the summit ridge of Beinn na Cro. So great is the complexity of the geology of the area that mapping on the scale of six inches to one mile was found to be inadequate, except for the determination of the general distribution of the larger rock masses. The southern termination of the basic rocks of Beinn na Cro was therefore mapped on a very large scale, but the intricate contacts of the various basic units were found to be too intimate to be represented on a map.

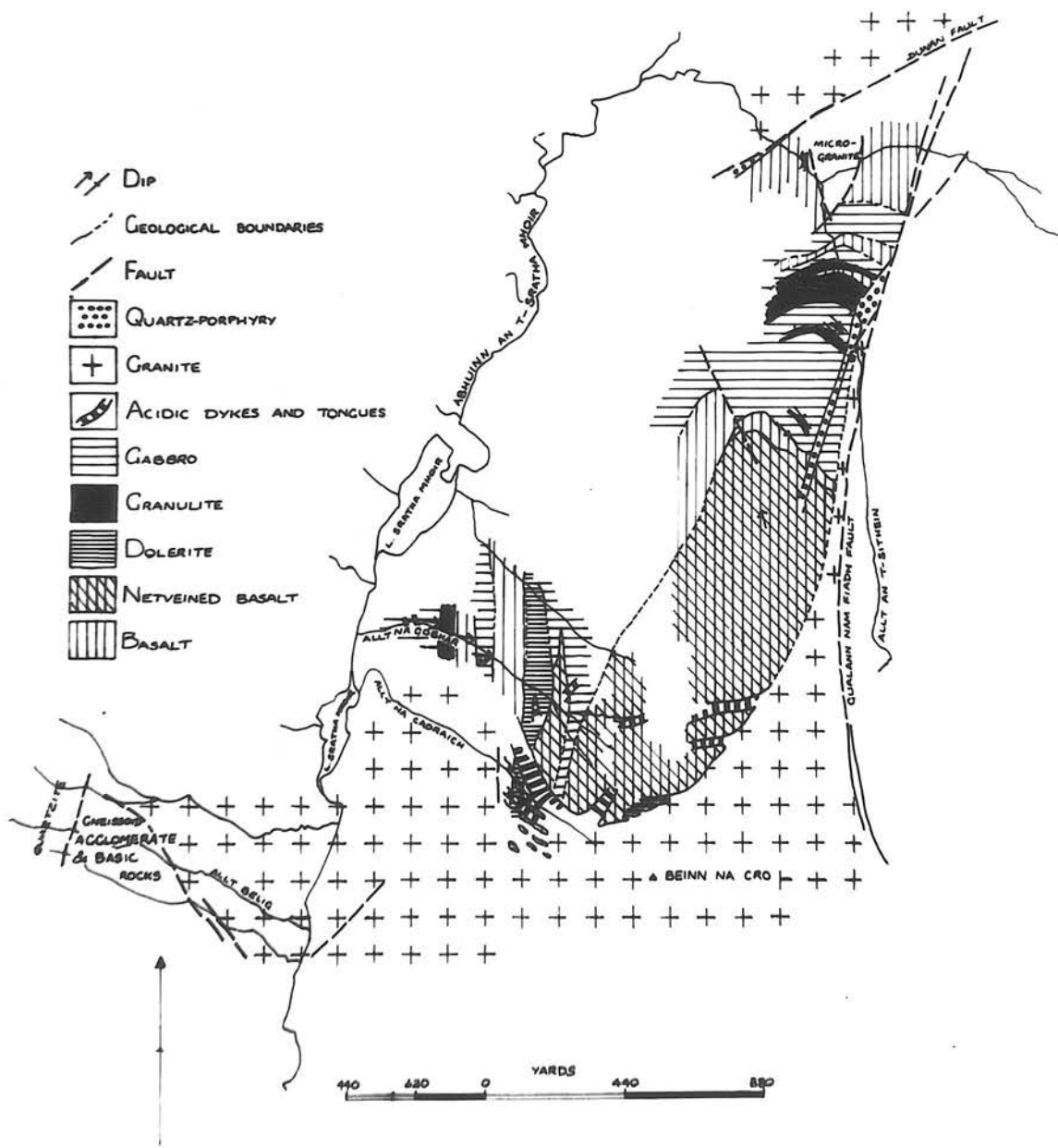


Figure 2. Geological map of Beinn na Cro.

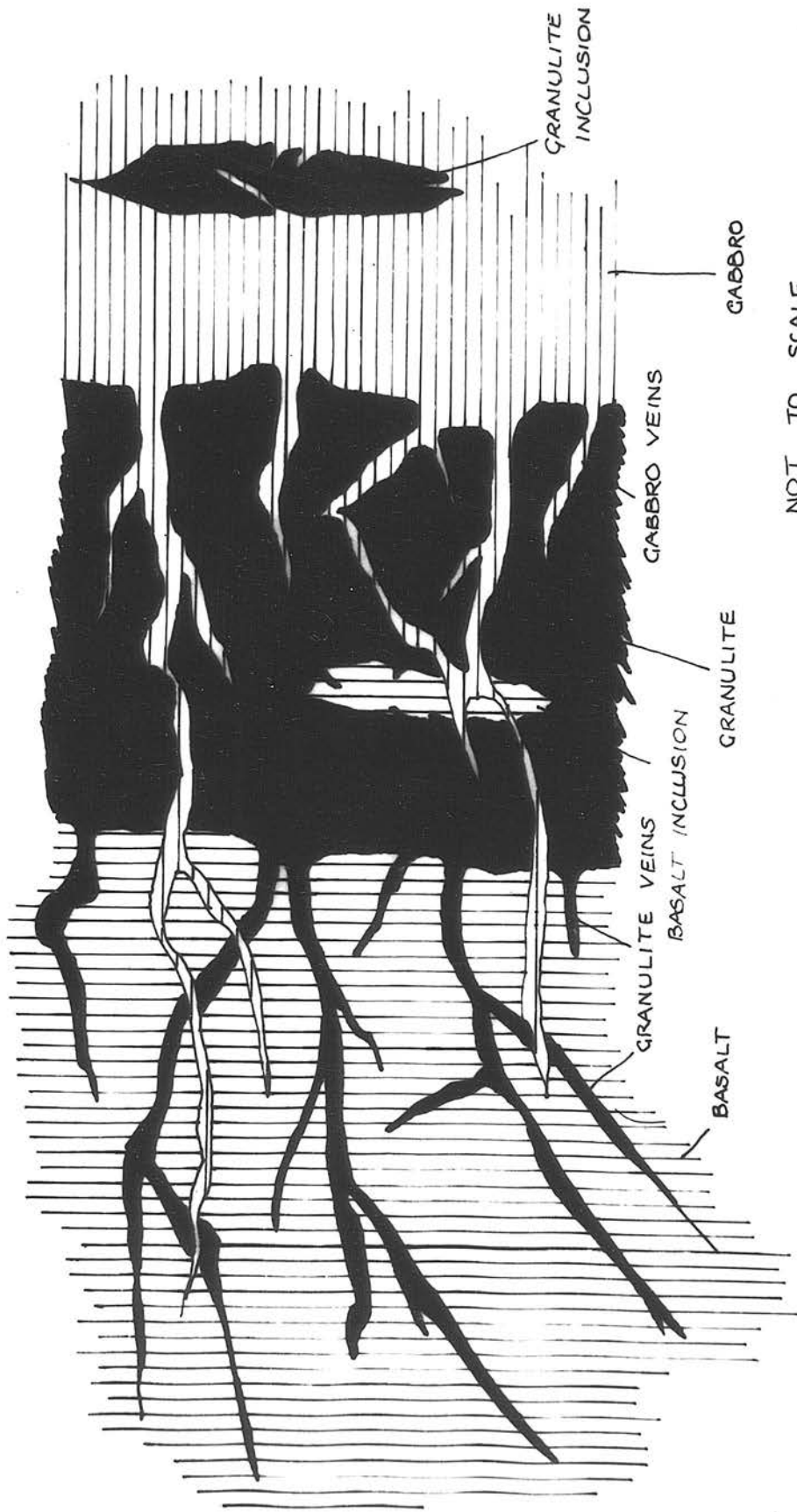
II. FIELD RELATIONS (Fig. 2)1. Lavas

Basic rocks occupy most of the region described.

Basalt and dolerite lavas, the oldest rocks found on this part of Beinn na Cro, dip at a low angle to the north-west or north. The bulk of the lavas contain numerous straight amphibolite veins which seldom exceed 1 cm in width (Plate Ia). The higher lavas, and those occurring in the south of the lava region, on the northern ridge, and on the western flank of Beinn na Cro, are riddled with hybrid and acidic net-veins which comprise up to 30% of the rock (Plates Ib, II and III). The majority of the net-veins are narrow and tortuous, but the larger and more acidic types are straight and parallel-sided.

2. Granulite and Gabbro

The lower part of the lava group, occupying the northern snout of Beinn na Cro and also occurring towards the base of its western flank, has been veined and intruded by granulite and gabbro and their derivatives. The contacts of granulite and gabbro with the lava are not conformable with the bedding of the lavas. In the north, gabbro, generally with granulitic marginal areas, occurs as vertical concentric parallel sheets, concave /

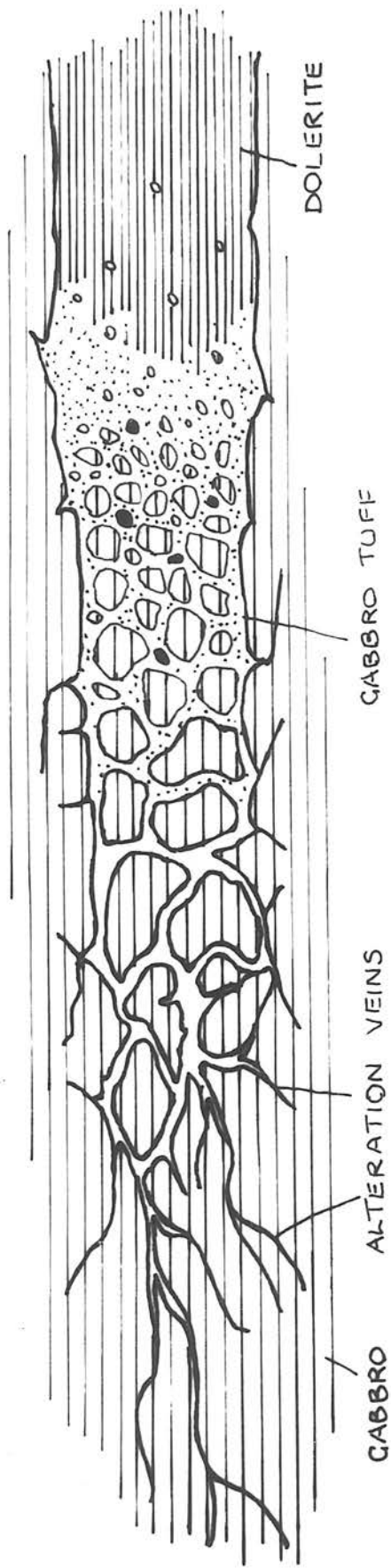


NOT TO SCALE

Figure 3. Diagrammatic sketch of the complex contacts of granulite with basalt and of gabbro with granulite and basalt on Beinn na Cro.

concave towards the south, the largest of which, the most southerly, is 500 yards thick. This gabbro encloses numerous small lenses of basalt and granulite which lie parallel to the gabbro margins. Other exposures of gabbro which dips westwards at 35° are found in the beds of the Allt na Gobhar and a small stream a short distance to the north, flowing parallel to it.

In detail the junction between the lavas and the granulite and gabbro is complex (Fig. 3). The contact zone is up to 10 yards wide, and consists chiefly of granulite. The association between lava, granulite and gabbro is intimate. Firstly, the lava has been veined by granulite, and more rarely, by mafic granulite. The former veins become more abundant when traced in the direction of the gabbro, so that the rock may eventually consist wholly of granulite. Secondly, the granulite is cut by veins of gabbro, and more rarely, by veins of coarse-grained mafic granulite. Again, when traced towards the gabbro, the veins of gabbro become more numerous and larger, so that a transition from granulite veined by gabbro, through granulite blocks enclosed in gabbro, to gabbro is present. This description, however, over-simplifies the situation. Although the gabbro and its veins are generally confined within the zone of the granulite and granulite veins, gabbro and gabbro veins also extend right across this zone into the lavas. The main mass of gabbro /



NOT TO SCALE

Figure 4. Diagrammatic sketch of an explosion dyke.

gabbro itself is in places in direct contact with the lavas. Further, patches of granulite, and of lava veined by granulite, and of unveined lava, occur within the gabbro proper. These masses are not necessarily confined to areas near the margins of the gabbro, but occur also in the interior of the gabbro. Moreover, veins from the gabbro extend into these patches. The basic inclusions may be up to several yards across and are usually somewhat elongate. As already mentioned, these lenses lie parallel to the main margins of the gabbro.

3. Explosion Dykes (Fig. 4)

The gabbro is cut by explosion dykes which are especially abundant towards the northern end of Beinn na Cro. The explosion dykes trend parallel to the general structure of the gabbro, are a few feet in width, and consist of systems of alteration veins in the gabbro which pass into breccia or gabbrotuff consisting of gabbro fragments with subordinate quantities of basalt, dolerite and granulite, in a fine-grained basic matrix. When traced along their length in the direction away from the areas of alteration veins, the breccias may pass into dolerite which commonly contains gabbro fragments. Other dykes are present which consist entirely of the dolerite, there being no traces of breccia or alteration veins.

4. Acidic Rocks associated with the Basic Rocks

No exposures are present at the foot of Beinn na Cro in Srath Mor, except in the bed of the Allt na Gobhar, where basic rocks have been found. On this side of the hill the basic rocks disappear below boulder clay and peat. To the north, the Dunan granophyre abuts against the lavas, separated from them by the Dunan fault. On the east, the Gualann nam Fiadh fault delimits the Glas Bheinn Bheag microgranite from the Beinn na Cro rocks. At the junction of the Allt an t-Sithein with its main tributary a small patch of faulted microgranite lies within the lavas. About a quarter of a mile to the south of this point, between the Gualann nam Fiadh fault and the basic rocks, granite is exposed in a narrow strip which stretches southwards, diagonally up the eastern side of Beinn na Cro, to join the main mass of the Beinn na Cro granite. At the base of the granitic crags and screes, near the summit of the hill, the contact of granite with basic rocks crosses the ridge. At this contact the granite shows a microgranitic facies and there is a transition from microgranite to granite over a distance of 200 yards. The boundary of the basic rocks may be traced southwards across the top of the Allt na Gobhar to the gully of the Allt na Caoraich where the junction is very complicated. Numerous net-veins, dykes and tongues of acidic rock, the latter up to 100 yards /

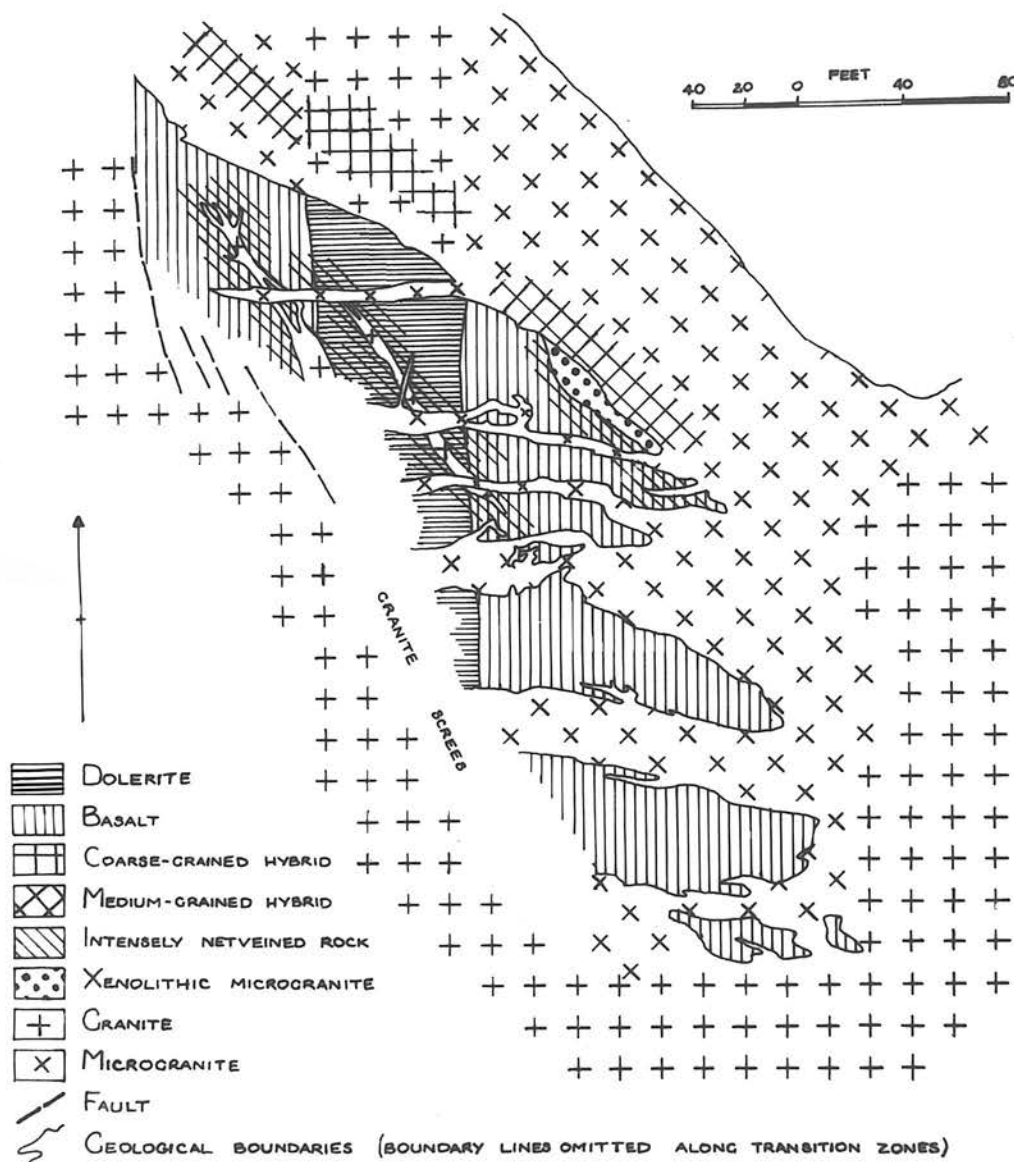


Figure 5. Geological map of the Southern Termination of the Basic Rocks of Beinn na Cro.

yards broad, extend into the basic rocks from the granite (Plate IV). The tongues cut north-west-trending dykes and strike westwards, north-westwards and north-eastwards and are composed of granite, microgranite and hybrid rocks. Some of the tongues end abruptly, some grade into the net-veins in the lavas, while some traverse the lavas and merge into the main granite mass. Along part of one margin of the largest tongue xenolithic microgranite is present. The xenolithic microgranite is a transition rock between net-veined basalt and massive tongue rock. Scree veils most of the outcrop to the south of the Allt na Caoraich but mapping indicates that the basic rocks terminate in the manner shown in Figure 5. Southwards there is a progressive increase in the amount of acidic rock which encloses areas of basic rock isolated from the main mass of lava.

5. Granitic Rocks

Granites, granophyres and microgranites occupy all but the northern end of Beinn na Cro. Acidic minor intrusions, quartz-porphyry and microgranite, cut both the granitic and the basic rocks of Beinn na Cro and occur in the region of the Allt an t-Sithein, the lower reaches of the Allt na Gobhar, and in the granite towards the southern end of Beinn na Cro.

III. STRUCTURE

As previously mentioned, the lavas of Beinn na Cro dip at low angles to the north and north-west. The lavas are cut by gabbro sheets, described on pages 2-4. The largest sheet may be traced around the northern end of the hill and south-westwards to a fault which displaces the outcrop of the gabbro in a dextral sense. On the southern side of the fault the gabbro dips at 35° to the west, while on the northern side of the fault it is vertical. Acidic tongues, in the main vertical, penetrate the basic rocks from the Beinn na Cro granite. The tongue form two groups; one, the minor, whose members are dyke-like, strikes north-westwards, and is cut by the major group, the tongues of which strike both north-eastwards, north-westwards and westwards. The Beinn na Cro granite is strongly jointed into rectangular blocks, the major joint planes dipping at 40° to 70° to the west (Plate V).

There are few faults in the area. The Dunan fault and the Gualann nam Fiadh fault delimit the Beinn na Cro area on the north and on the east respectively. The former is exposed out-with this region on the coast at Dunan where the shatter belt is over 40 feet wide. The Dunan granophyre lies to the north of the fault, and Jurassic rocks occur on the southern side. The fault /

fault may be traced west-south-westwards over the northern end of Glas Bheinn Bheag, and it is exposed further to the west in a small streambed and in the bed of the Allt an t-Sithein, where, although there is yet Dunan granophyre on the northern side of the fault, Beinn na Cro basalt occurs to the south. The outcrop of the Gualann nam Fiadh fault strikes north-westwards from Srath Beag, turning northwards over the shoulder of Gualann nam Fiadh, and for a distance of some 200 yards lies on the bed of the Allt an t-Sithein. Northwards the fault occurs in the low ground to the north-west of Glas Bheinn Bheag where the fault is truncated by the Dunan fault. Where exposed in the bed of the Allt an t-Sithein, the Gualann nam Fiadh fault is seen to have a hade of 10° to the west, and the dislocation separates Glas Bheinn Bheag microgranite on the eastern side from the Beinn na Cro granite (Plate VI). The faults surrounding the block of microgranite in the lower reaches of the Allt an t-Sithein are not well exposed. They appear to be slightly arcuate, that on the west curving round to meet that on the east which strikes south-westwards. Another fault occurs in the northern crags, and strikes north-westwards, displacing basalt and gabbro. Exposed in the bed of the Allt na Caoraich is a broad area of crushed granite which seems to indicate a north-westwards-striking fault separating the granite, on the south-west, from the basic rocks.

IV. PETROGRAPHY

It is convenient to discuss the petrography of the rocks of Beim na Cro in three sections, namely the basic rocks, the hybrid and acidic rocks associated with the basic rocks, and the acidic rocks.

1. Basic Rocks

A sequence can be traced from basalt through gabbroic rocks to rocks of doleritic character, along the series:- basalt, fine-grained granulite, medium-grained granulite, coarse-grained granulite, vein gabbro, gabbro, altered gabbro, gabbro-tuff and breccia, dolerite. Mafic granulite is associated with the granulites, and coarse-grained mafic granulite is associated with the vein gabbro and gabbro.

A. Basalt Lava. None of the basalt lava is entirely unaltered. In some places the lava is cut by acidic net-veins, elsewhere by basic veins, and locally it is granulitised, acidified, or basified. Only the basalt which has been veined by granulite or gabbro and comes within the basic sequence is described here. The description of the more acidic basalts is given on pages 23 and 28-32.

The least altered basalt lava is dark grey in colour and /

and fine to medium-grained. It consists of large crystals of plagioclase in a matrix of plagioclase and granular augite together with uralite, biotite and magnetite (Plate VIIa). The large plagioclase crystals (An_{40} to An_{50}) are up to 3 mm across, strongly zoned, and contain granules of dark minerals, chiefly augite and iron ore. The small plagioclase crystals, with a maximum length of 1 mm, and compositions in the range of An_{60} to An_{70} , are not zoned. Sparse granules of sodic plagioclase are also present in the matrix. Augite is more abundant than plagioclase in the matrix and occurs as granular, greenish-grey crystals which are partially altered to uralite and biotite. The uralite is pale green in colour, slightly pleochroic, and fibrous, while the biotite is greenish-brown in colour. Within the basalt at its contacts with veins of gabbro, the augite is extensively schillerised and uralitised, and magnetite, hornblende and biotite are more abundant than in the rest of the basalt. Common within the basalt are veins of a fibrous green amphibole in which the majority of the fibres lie normal to the walls of the veins.

B. Fine-grained Granulite. There is a transition from basalt to fine-grained granulite. The latter rock is black in colour, and the granular texture is just visible to the naked eye. /

eye. In thin section the rock consists of plagioclase, augite, uralite and magnetite with rare serpentine and olivine (Plate VIIb). The plagioclase occurs as large highly zoned crystals (An_{55}) with brownish interiors and fairly broad twin-bands. These crystals are, in the less granulitic parts of the rock, sensibly euhedral, but more commonly they are anhedral. Stubby lath-shaped crystals of plagioclase (An_{45}) and granules of more sodic plagioclase form prominent members of the matrix. The sodic plagioclases are associated both with the large plagioclases and with the small plagioclases. Augite occurs as grey granular crystals, smaller than the plagioclases, and is partially uralitised and marginally schillerised. Pale green fibrous amphibole occurs as uralite associated with augite and also in uralitic veinlets. Olivine, present in some specimens, has been largely altered to serpentine and magnetite.

C. Medium-grained Granulite. The medium-grained granulite is similar to the fine-grained granulite in many respects. It differs, however, in that the plagioclase is entirely granular, seldom zoned, and varies in composition within the range An_{30} to An_{65} , although the majority has a composition of An_{55} to An_{65} . Other differences are that some of the augite is subophitic and the magnetite occasionally occur as large vermicular blebs (Plate VIII).

D. Coarse-grained Granulite. The coarse-grained granulite represents a further stage in the transitional series from basalt to gabbro. The coarse-grained granulite is black and granular and consists of plagioclase, augite, magnetite, uralite and serpentine (Plate VIIb). Two types of plagioclase are present. The less common occurs as large zoned anhedral crystals (An_{75} to An_{85}) with embayments which contain plagioclase and dark minerals of the groundmass, and protrusions which extend into adjacent augite crystals. The zoning in these large crystals is invariably irregular and is not related to the present crystal boundaries. Inclusions within the plagioclase consist of small unzoned, equidimensional plagioclase crystals. The more common type of plagioclase occurs as clear, unzoned, subhedral or anhedral crystals which have a composition of An_{40} . Augite occurs as pale brown crystals which are subophitic towards the unzoned plagioclase. Alteration to uralite and serpentine and schillerisation are commonly encountered features. Magnetite is distributed throughout the rock as large irregularly shaped crystals.

E. Mafic Granulite. Mafic granulite has been found only as veins in the granulite and basalt. The veins are generally medium-grained with fine-grained, more feldspathic margins, and /

and seldom exceed 8 mm in width. The mafic granulite is very rich in augite but also contains plagioclase, uralite and magnetite. The augite occurs as rounded, greenish crystals which are schillerised and patchily altered to uralite. Schillerised crystals are most common near the edges of veins while uralitised ones are dominant in the interiors. Plagioclase is interstitial, in the form of stumpy or poikiloblastic crystals (An_{50} to An_{60}) which are twinned and occasionally zoned. Magnetite is chiefly found near the edges of veins as small granules.

F. Vein Gabbro. The transition stage succeeding that of the granulite is vein gabbro. This gabbro exhibits various textures; the crystals usually show no preferred orientation, but in some specimens the long axes of the plagioclase and augite crystals lie parallel to the walls of the veins, while in other specimens the long axes of the plagioclase crystals lie normal to the sides of the veins. The vein gabbro is coarse-grained and very dark coloured, and consists of plagioclase, alkali feldspar, augite, magnetite, uralite and chlorite. The plagioclase varies in composition from vein to vein from An_{45} to An_{80} . The more calcic crystals are not zoned but the more sodic types are strongly and irregularly /

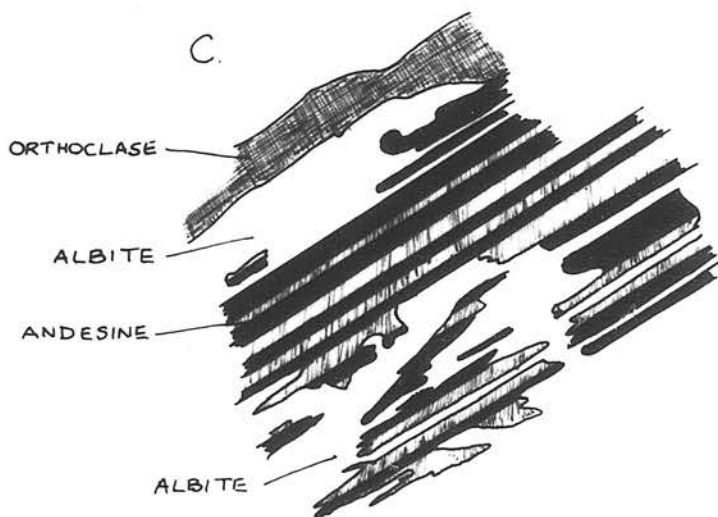
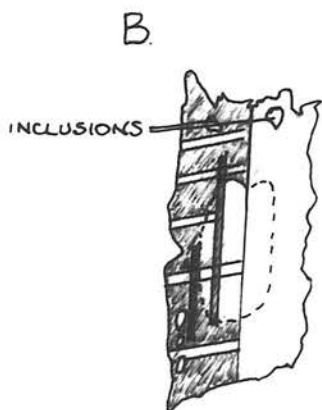
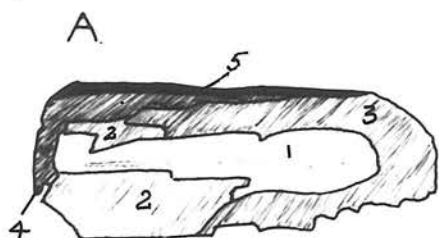
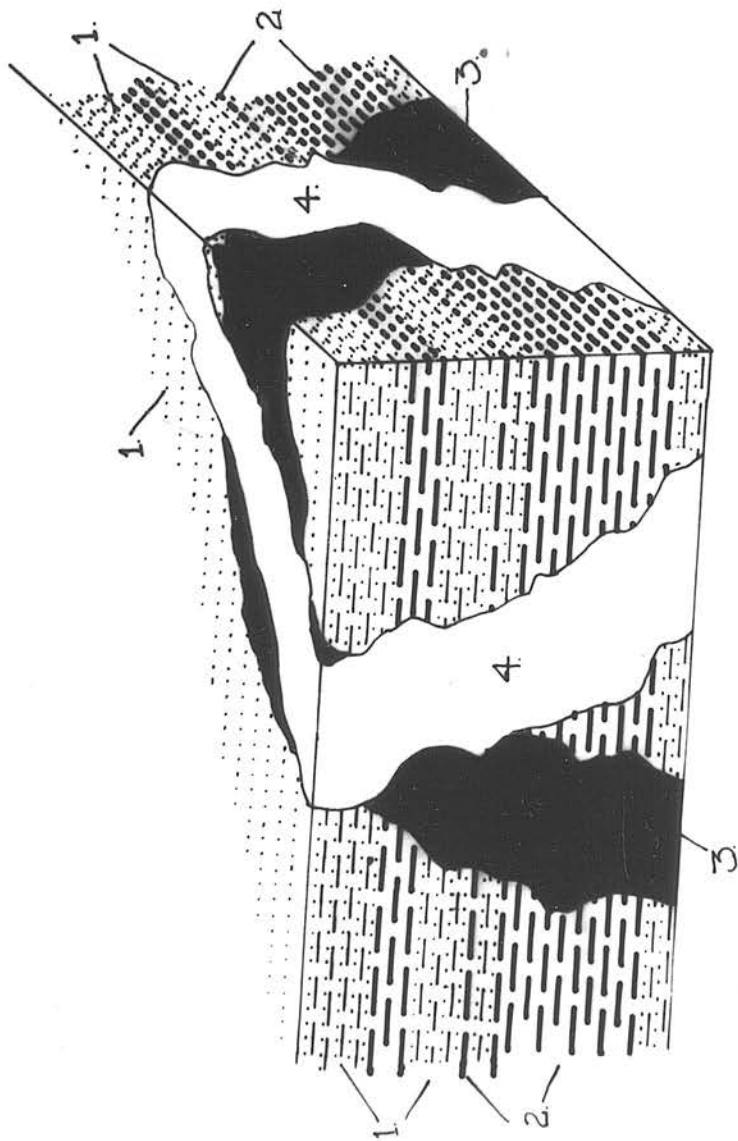


Figure 6. Petrographic features of basic rocks of Beinn na Cro.
 A. Zoned plagioclase crystal, zones numbered from the interior of the crystal outwards (vein gabbro).
 B. Zoned and poly-twinned plagioclase crystal (coarse-grained mafic granulite).

irregularly zoned, the zoning being most marked at the ends of the elongate crystals (Fig. 6A). The calcic plagioclases contain scattered minute angular inclusions of pyroxene and magnetite, while the more sodic crystals contain patches of albite and orthoclase lying along their twin-bands (Fig. 6C). All the plagioclase crystals are cut by veinlets of chlorite, albite and uralite which invariably intersect the twin-bands at high angles. Augite occurs as ophitic plates, is brownish-grey in colour, and partially schillerised and altered to pale green fibrous uralite. In rare instances the augite has been granulitised. Magnetite occurs in the form of large subhedral crystals associated with the uralite.

G. Coarse-grained Mafic Granulite. Coarse-grained mafic granulite occurs as veins cutting banded granulite in the bed of the Allt na Gobhar. Both the coarse-grained mafic granulite and the banded granulite are traversed by later veins of gabbro. Cut surfaces of hand specimens reveal that the banding in the granulite is not displaced by the veins (Fig. 7).

In thin section the banded granulite is seen to consist of alternate bands of fine and medium-grained granulite which differ from the granulite described on pages 10 and 11 (B and C), only in exhibiting a preferred orientation of plagioclase crystals /



- | | | |
|--|---|-------------------|
| 1. FINE-GRAINED FLUXION-GRANULITE | } | BANDIED GRANULITE |
| 2. MEDIUM-GRAINED FLUXION-GRANULITE | | |
| 3. COARSE-GRAINED MAFIC GRANULITE (VEIN) | | |
| 4. GABBRO (VEIN) | | |

Figure 7. Block diagram illustrating the cross-cutting relations of banded granulite, coarse-grained mafic granulite and gabbro on Beinn Na Cio.

crystals parallel to the bands, and in containing scattered anhedral crystals of grey hypersthene. The plagioclase is zoned, poly-twinned, and contains inclusions of ferromagnesian minerals (Fig. 6B).

The coarse-grained mafic granulite is a dark coloured granular rock, consisting of pyroxene, apatite, magnetite, biotite and plagioclase (Plate IXa). The pyroxene is of two varieties. Augite is dominant and occurs as rounded, grey schillerised crystals, 1 - 3 mm across. Hypersthene is less common but is present in large crystals, 2 - 5 mm across which are partially altered to uraltite and biotite. Magnetite is vermicular, up to 4 mm across, and is associated with augite, hypersthene and biotite. Apatite comprises from 15% to 30% of the rock and occurs as rounded crystals up to 1 mm in diameter. Much of the apatite is interstitial but crystals enclosed in augite are also common. Plagioclase (An₅₀) is present in accessory quantities only and forms irregular interstitial poikilitic crystals which enclose both augite and apatite.

The late veins of gabbro which cut the coarse-grained mafic granulite differ from the vein gabbro (F) described on pages 13-14 in several respects. The texture is not ophitic, and in addition to the minerals which characterise the vein gabbro /

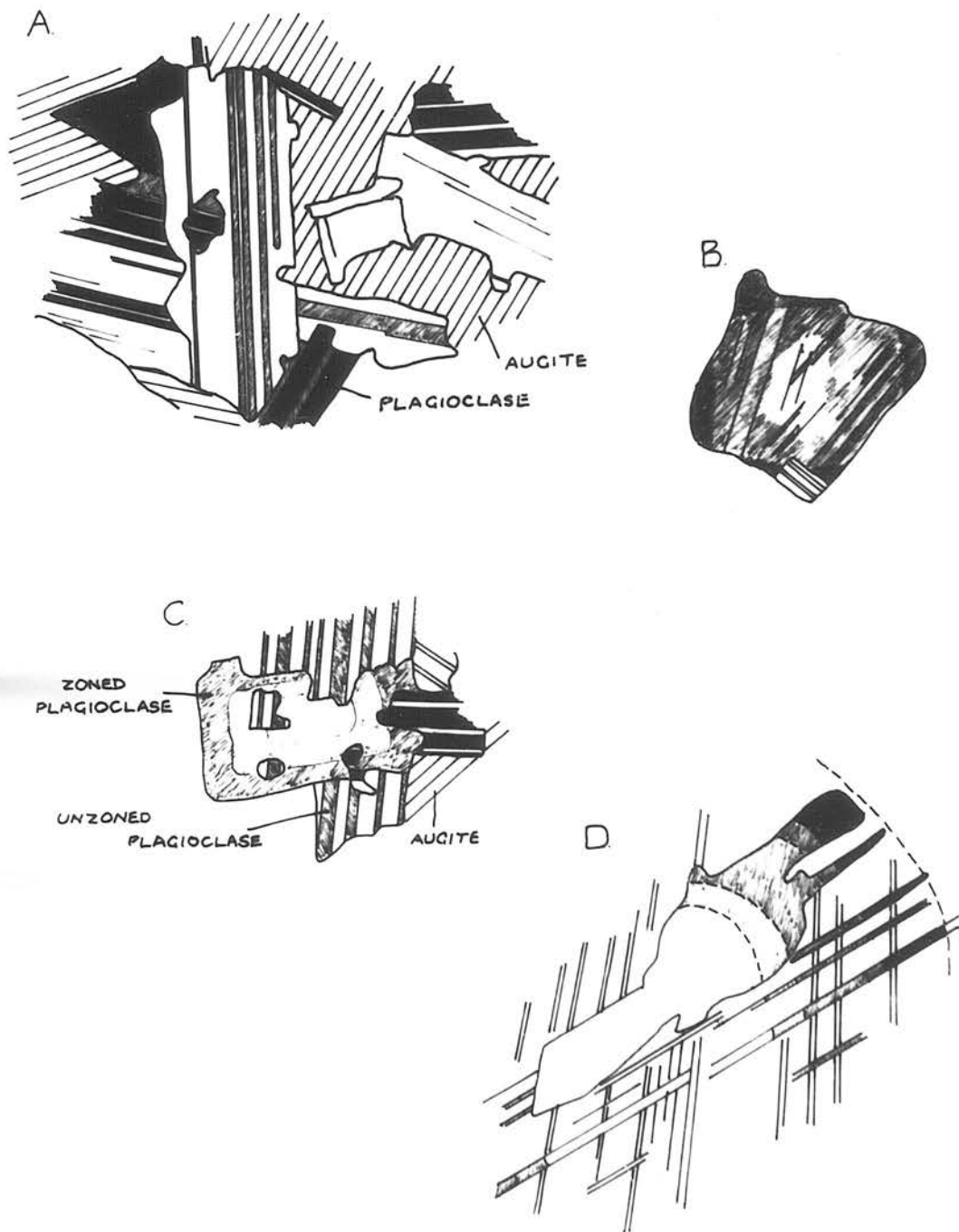


Figure 3.

Petrographic features of the gabbro of Beinn na Cro.
 A. Interlocking plagioclase crystals.
 B. Zoned and poly-twinned plagioclase crystal.
 C. Zoned and interlocking plagioclase crystals.
 D. Zoned and poly-twinned plagioclase crystal.

gabbro, apatite, biotite, hornblende and accessory haematite are also present.

H. Gabbro. The gabbros of the northern crags of Beinn na Cro and of the Allt na Gobhar region are very similar in their fundamental petrography. As much of the gabbro of the latter locality has been acidified, the following description is applicable only to the gabbro of the northern crags. In hand specimen the rock is black, massive, and exhibits a marked ophitic texture. Much of the rock is coarse-grained but finer-grained patches are also present, especially close to the contact with granulite.

The bulk of the gabbro consists of plagioclase, augite, magnetite, quartz, sparse highly altered olivine and alteration products and accessory minerals (Plate IXb).

Plagioclase. The plagioclase crystals in the gabbro vary in size from 0.5 cm. to 3 cm, and in composition from An₅₀ to An₉₀. Concentric zoning is common and ramifying veinlets of chlorite and albite are frequently encountered. In the finer-grained patches, adjacent plagioclase crystals tend to show interlocking and sutured margins (Fig. 8A and C). In the normal coarse-grained rock the texture of the plagioclase is more complex and many crystals exhibit a type of twinning which is here /

here referred to as poly-twinning. All stages may be observed from individual crystals (Plate X), through aggregates of interlocking crystals (Fig. 8A and C, and Plates XI and XII), to large poly-twinned crystals in which the outlines of the several component crystals are no longer visible (Fig. 8B and D, and Plate XIII). The true nature of these large plagioclase crystals is revealed by a study of their characteristic twinning. Several distinct sets of twin lamellae may be present and although their orientations were determined by use of the Universal Stage, it was found impossible to relate the suites to pericline twin systems which might be present in a single plagioclase crystal. The zoning of these poly-twinned crystals is of two types. By far the more common is that where the zones affect only one, nearly always the dominant, suite of twin lamellae (Fig. 8D). The other is where the zoning is independent of the twinning, and affects the whole crystal as if it were a simple one (Fig. 8B).

Augite. The augite is grey or greenish-brown in colour and occurs as large ophitic plates 1 - 5 cm. across. Uralitisation is more common than schillerisation.

Magnetite. Magnetite is present in very variable amounts and occurs as anhedral or vermicular plates and as a dusting of granules associated with serpentine.

Amphibole /

Amphibole. Much of the amphibole is secondary. The amphibole is pale green fibrous uralite where it is associated with augite as an alteration product, while where it is associated with sphene and interstitial quartz it is prismatic and bluish-green in colour.

Olivine. The olivine has been almost wholly altered to serpentine and magnetite. In some places the gabbro contains accessory amounts of cloudy alkali feldspar associated with quartz and apatite.

Veins of gabbro pegmatite up to six inches across cut the gabbro. The veins differ from the gabbro in grain size, degree of alteration, and in containing a larger amount of acidic material. Plagioclase crystals attain a length of 5 cm and are intensely albitised. Augite crystals may be a little larger and they are highly altered to uralite.

I. Explosion Dykes. The rocks comprising the explosion dykes may be divided into three groups, namely (i) Alteration Veins, (ii) Gabbro-tuff, (iii) Dolerite. All three types may occur in a single explosion dyke and they grade one into another along the strike of the dykes (Fig. 4).

(i) Alteration Veins

The alteration veins are locally encountered in narrow zone /

zone in the gabbro where they form vertical, parallel-sided net-vein systems. The veins vary in width from very narrow threads to 4 cm and are of two types. The more common differ only slightly from the gabbro. The plagioclase crystals are strongly zoned and cloudy, and are veined by chlorite and albite. The alteration of the augite is more intense in the alteration veins than in the gabbro, the augite in the former being almost entirely replaced by uralite. Quartz and alkali feldspar are interstitial and together comprise up to 10% of the rock. The second type of vein is characterised by a granulitic texture. These veins are usually less than 1 cm across and consist of granular plagioclase, augite and magnetite. The relative proportions of these minerals vary along the veins, plagioclase being more abundant where the veins cut plagioclase in the gabbro, and augite more abundant where augite is the gabbro mineral traversed.

(ii) Gabbro-tuff

The zones of alteration veins pass, along their strike, into dykes filled with gabbro-tuff. The gabbro-tuff is a dark coloured rock of variable composition and texture containing fragments of gabbro and gabbroic minerals, with subsidiary granulite and basalt fragments, in a fine-grained greyish-green matrix (Plate XIVa). The gabbro fragments are marginally altered in the same manner as gabbro has been altered to form alteration /

alteration veins of the first type. Individual plagioclase crystals are cut by numerous albite and chlorite veinlets and contain small quartz blebs. Although the majority of the augite crystals of gabbroic origin have been completely altered to uralite and magnetite, some of the augite fragments are merely schillerised and marginally uralitised. The plagioclase and augite at the margins of the basalt and granulite fragments have been respectively altered to albite and chlorite. The matrix of the gabbro-tuff is fine-grained and cloudy and consists of plagioclase, alkali feldspar, amphibole and magnetite. Plagioclase is dominant and consists of small altered fragments some of which exhibit rims of alkali feldspar which also enclose other minerals of the matrix. The amphibole of the matrix is green coloured, cloudy, and generally fibrous. Chlorite and magnetite occur throughout the matrix in irregular patches.

(iii) Dolerite

Within the explosion dykes there is a transition from gabbro-tuff to dolerite. Rocks intermediate between these two consist of coarse to medium-grained fragmentary crystals in a fine to medium-grained matrix consisting of smaller fragments and gabbro-tuff material and new-formed minerals. The new minerals are mainly large plagioclase crystals which enclose small /

small fragments of plagioclase and augite, and ophitic augite. Quartz and alkali feldspar are more abundant than in the gabbro-tuff.

The dolerite is a dark grey coloured rock consisting of a few large crystals of plagioclase and augite in a medium-grained matrix composed of plagioclase, augite, hypersthene and magnetite (Plate XIVb). The large plagioclase crystals (An₇₀ to An₈₀) are subhedral with broad twin lamellae, and on some cases exhibit poly-twinning. The crystals are zoned and have embayed margins and appear to be of gabbroic origin. Some of the larger plagioclase crystals are composite and consist of several smaller crystals aggregated together. Both types of large plagioclase have been cut by pyroxene or amphibole veins. Chloritic and albitic veins are numerous in the plagioclase and in some cases shattered plagioclase crystals have been rewelded with albite. The groundmass of the dolerite is medium-grained and sub-ophitic in texture. Plagioclase (An₄₅ to An₇₀) is the most abundant mineral and occurs as elongate lath-shaped crystals up to 1 mm in length which are zoned and rimmed by clear albite or cloudy alkali feldspar. The augite of the groundmass is sub-ophitic, partially schillerised and altered to uralite. Hypersthene is sparsely distributed throughout the rock as grey coloured sub-ophitic plates up to 2 mm /

2 mm across. Hornblende is not common and generally forms small anhedral green crystals. Magnetite is the only accessory mineral found.

2. Hybrid and Acidic Rocks associated with the Basic Rocks

A large number of the rock types on Beinn na Cro fall within this group. The most abundant types are the net-veins of medium and coarse-grained hybrid and acidic rocks which cut the basalt and dolerite lavas, and the hybrid and acidic rocks formed by alteration of the basic rocks. In general, the finer-grained rocks have been net-veined, whereas the coarser-grained ones have been altered. All these phenomena are confined to the more southerly part of the northern (Basic) end of Beinn na Cro, their greatest development being in that area where the basic rocks give way to granite.

A. The Contact of the Basalt with the main mass of the Beinn na Cro Granite. The contact of basaltic lava with the main mass of the Beinn na Cro granite is exposed over a distance of about ten feet on the western flank of the hill near the summit ridge and the head of the Allt na Gobhar. The junction at this locality is horizontal, the granite overlying the basalt. The basalt is somewhat variolitic in texture at the contact, which /

which is sharp, and the granite exhibits marginal modification. At the contact, micrographic and spherulitic microgranite are present, which, five inches from the contact, give way to spherulitic granophyre which in the field resembles microgranite and grades into normal Beinn na Cro granite over a distance of not less than ten feet.

In thin section the contact is seen to be more complex than it appears to be in hand specimen. Metamorphosed basalt gives way to 2 mm of coarsened acidified basalt which borders on a 5 mm broad zone of acidified basalt containing micrographic microgranite veins and micrographic microgranite containing diffuse patches of basic material. This zone grades into spherulitic microgranite which contains areas of micrographic microgranite and passes into spherulitic granophyre over a distance of a few inches.

(i) Basalt

The basalt is very fine-grained in this contact region and is both granulitic and variolitic in texture (Plate XV). The variolitic texture is developed only at the margin of the basalt and appears to be a metamorphic feature involving the rearrangement of augite granules into a variolitic pattern. The basalt farthest from the contact is granulitic and contains a very high percentage of brown augite, with subsidiary plagioclase /

plagioclase, foxy-red biotite and magnetite. Towards the contact there is an increase in grain size of all the minerals and a development of variolitic texture which is strongly expressed in the brush-like arrangement of the augite crystals. Quartz is present interstitially, and clear, slightly zoned plagioclase (An₅₀ to An₇₀) becomes more abundant. With further increase in grain size, there is an increase in the amount of quartz and the appearance of micropegmatite, while the plagioclase crystals have developed very distinct rims of albite. The brush-like clusters of augite have formed into larger needles of augite which are partially altered to form pale green acicular crystals of hornblende some of which are as much as 3 mm in length. These large hornblende crystals contain knots of brown augite and magnetite scattered along their length. The feldspar crystals in this zone are more equidimensional than those of the preceding zone (Plate XVI).

(ii) Micrographic Microgranite

By a significant increase in the amount of quartz and by the introduction of cloudy alkali feldspar which chiefly occurs in micropegmatite, and with a reciprocal reduction in the amount of ferromagnesian minerals and iron ore, there is a rapid transition into micrographic microgranite (Plate XVI). Individual plagioclase crystals occurring on the boundary between basic /

basic and acidic rock form integral parts of both rocks. The micrographic microgranite consists of large subhedral crystals of zoned plagioclase (An_{30} to An_{40}) containing blebs of quartz and micropegmatite which are rimmed by albite (Plate XVII). The plagioclase is also rimmed by albite and micropegmatite. Where these zoned and rimmed crystals lie across the boundary between basic and acidic rock, that part of the crystal which lies in the basic rock is generally smaller in size, due to omission of the more albitic zones which characterise that part of the same crystal which occurs in the acidic rock. That part of the crystal which occurs in the basalt contains no quartz or micropegmatite, and the two parts of the crystal are optically continuous with no visible break or junction. The micrographic microgranite also contains greenish-blue and brown varieties of hornblende which are strongly pleochroic, a little biotite, and blebs of magnetite, all of which lie in a matrix of micropegmatite. The basic patches within the micrographic microgranite consist of aggregates of crystals of bluish-green hornblende, foxy-red biotite, magnetite and accessory zircon. Although the micrographic microgranite veins in the basalt consist of quartz, alkali feldspar, plagioclase and hornblende in the same proportions as in the rest of the micrographic microgranite, the veins contain a lesser amount of micropegmatite and a greater amount of biotite.

(iii) Spherulitic Microgranite

The spherulitic microgranite is finer-grained than the micrographic microgranite. The former contains aggregates of alkali feldspar and interstitial quartz, which in texture strongly resemble the variolitic augite in the basalt. Also present are numerous angular crystals of plagioclase, many of which have been corroded along their twin planes. About 3 mm from the basic rock are developed true spherules consisting of plagioclase cores rimmed by fine pinnules of micropegmatite. There is a large amount of interstitial granular quartz and porphyroblastic alkali feldspar. Dark minerals are present in accessory quantity only.

(iv) Spherulitic Granophyre

Five inches from the contact there is a transition by increase in grain size from spherulitic microgranite to spherulitic granophyre. The latter rock in hand specimen is very light coloured, being white or pinkish, and medium to coarse-grained. In thin section it is seen to consist of large spherules with interstitial coarse-grained micropegmatite, quartz, plagioclase, microperthite¹, a few cloudy crystals of unidentified /

¹Throughout this thesis, the term "microperthite" includes all microscopic varieties of intergrowth of orthoclase with albite or oligoclase, irrespective of the proportions of the constituent minerals.

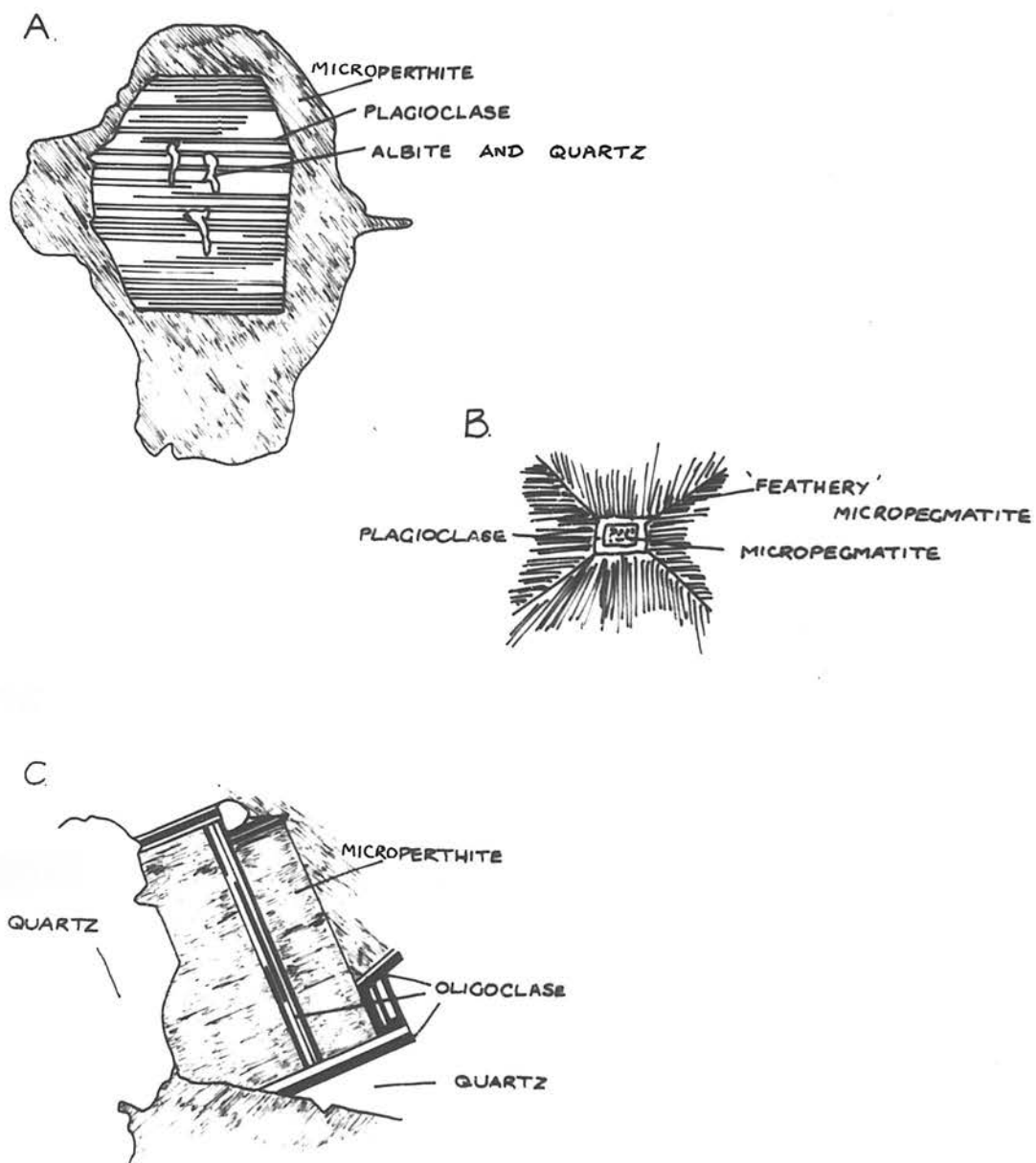


Figure 9. Petrographic features of acidic rocks of Beinn na C.
 A. Plagioclase rimmed by microperthite.
 B. Plagioclase altered to and rimmed by feathery microperthite.
 C. Microperthite rimmed by oligoclase.

unidentified ferromagnesian minerals, needles of hornblende and iron ore. The spherules consist of cores of anhedral plagioclase (An_{20} to An_{30}), highly corroded along twin planes and frequently containing central pseudomorphing masses of micropegmatite rimmed by albite. The plagioclase is rimmed by very fine-grained and feathery symmetrical cryptopegmatite and micropegmatite (Fig. 9B). The spherules never contain coarse-grained micropegmatite. Also present are large euhedral lamellar-twinned and zoned plagioclase crystals almost totally replaced by alkali feldspar so that the bulk of the crystal consists of microperthite. These crystals also have rims of micropegmatite. Other euhedral microperthite crystals present consist of a combination of cloudy alkali feldspar, microperthite and micropegmatite and contain scattered quartz blebs. Some parts of the rock are cut by veinlets similar to the spherulitic granophyre but differing in being granulitic and in containing a much higher percentage of iron ore.

The spherulitic granophyre passes into granophyre and granite typical of the Beinn na Cro granite described on pages 46-49.

B. Net-veined Basalt. A large proportion of the basalt of Beinn na Cro is intensely net-veined. Although the basalt is fairly homogeneous throughout the area, and the general /

general metamorphic effects on the basalt are almost uniform, the net-veins are variable in their field relations, their petrography, and in the nature of their contacts and contact effects upon the basalt. There are two petrological groups of net-veins: (i) Those which consist of entirely acidic material, having sharp contacts with the basalt, and are generally straight and parallel-sided (Plate XVIII); (ii) Those which consist of hybrid and acidic rock and grade into the basalt; these net-veins are generally tortuous and highly irregular in width (Plate XIXa).

(i) Entirely Acidic Net-veins

This group is far less common than the other and is confined to the large straight net-veins of the northern crags and to those rock masses where large tongues of microgranite abut directly against the basalt and where there is little small-scale net-veining. Such rocks are chiefly to be found in the region of the Allt na Gobhar and the Allt na Caoraich. In hand specimen the basalt is a dark grey rock which, close to the contact with the acidic rock, is almost black and very fine-grained. In thin section the basalt is seen to be fine to medium-grained and to consist of plagioclase, ophitic and granular augite, biotite and magnetite. The plagioclase crystals (An_{40}) are up to 0.5 mm in length and are zoned and lamellar- /

lamellar-twinning. A few strongly zoned oligoclase phenocrysts rimmed by albite are also present. Part of the albite seems to have replaced the oligoclase, but the fact that the albite appears to extend beyond the original boundaries of the oligoclase suggests that has not formed entirely in this way. The augite of the basalt is greyish in colour, more usually granular than ophitic, and partially altered to biotite. Biotite also occurs as large sieved crystals enclosing both plagioclase and augite. The biotite is strongly pleochroic with x = greenish-chestnut brown; y = dark foxy-red; z = very pale yellowish-brown. This pleochroic scheme is also typical of the biotite of the basalt net-veined by hybrid and tortuous acidic net-veins.

As the contact is approached, the basalt decreases in grain size and there is an increase in granularity of the plagioclase and the augite. At the actual contact of basalt with these entirely acidic net-veins there is a concentration of granular variolitic augite, generally uralitised, and iron ore, associated with large crystals of quartz and a very small amount of alkali feldspar. Narrow veinlets extend into the basalt from the acidic rock and consist of granular albite and pyroxene and a little quartz.

The net-vein material is medium to coarse-grained, and consists of orthoclase, microperthite, plagioclase, quartz, amphibole /

amphibole, pyroxene, biotite, magnetite and accessory zircon. The orthoclase is in the form of cloudy, anhedral discrete crystals, but is also present in micropegmatite and microperthite. Microperthite is cloudy and occurs as irregularly-shaped crystals, which, towards their margins, contain a high proportion of orthoclase. The microperthite crystals are sometimes partially rimmed by microperthite-quartz micropegmatite, the microperthite of which is in optical continuity with that of the main crystal. Two varieties of plagioclase are present. Oligoclase is dominant, and occurs as clear lath-shaped crystals exhibiting lamellar twinning and patchy zoning. Some of the crystals contain blebs of quartz rimmed by albite, or dark minerals, both of which occur chiefly along twin planes. In places the oligoclase has been partially replaced by albite or microperthite. In the latter case, the twinning remains distinct and unchanged in passing from the host oligoclase into the plagioclase member of the microperthite. Albite forms large clear anhedral lake-like crystals enclosing blebs of quartz rimmed by microperthite. Microperthite is also developed at the margins of albite crystals where these are in contact with quartz. Quartz occurs as small blebs in micropegmatite and as small discrete crystals. There are two types of amphibole. The first consists of pale green granules, whereas the /

the second type is in the form of large anhedral fibrous masses which are dark green in colour. The pyroxene is pale green, anhedral, and has uralitic margins. Magnetite and zircon generally occur in association, the former as irregular clots, the latter as stumpy prismatic crystals.

(ii) Hybrid Net-veins

This type of net-vein is more complex than the entirely acidic net-veins as well as being more widespread in occurrence. In some cases the basalt seems to have been net-veined more than once, the later net-veins tending to follow the same channels as the earlier ones (Plate II). Invariably the earlier net-veins are more basic than the later ones. The earliest net-veins consist of acidified gabbro, and the areas in which these net-veins are found are restricted to the lower part of the net-veined basalts, that is, that part which is nearest to the gabbro and gabbro veins. Later than the acidified gabbro net-veins are hybrid net-veins whose petrography is highly variable. The latest net-veins are microgranitic. The basalt in all cases is so similar to that previously described on pages 23-24 and 28-29 that, to avoid repetition, only the outstanding features of its petrography will be mentioned.

(a) Acidified Gabbro Net-veins - The basalt net-veined by acidified /

acidified gabbro is fine to medium-grained and consists of plagioclase crystals in a granular matrix of brown augite, magnetite, diffuse masses of chlorite, hornblende and brown biotite. Veinlets invading the basalt from the main acidified gabbro net-veins are coarser-grained than the basalt and consist of more sodic plagioclase and hornblende or biotite. The texture of these veinlets, however, resembles that of the basalt rather than that of the acidified gabbro. The sodic plagioclases of the veinlets are in many cases in optical and crystallographic continuity with the normal plagioclase of the basalt, individual crystals being at one end integral parts of the basalt and at the other end, where they are larger and more sodic, integral parts of the veinlets. Close to the main net-veins, the veinlets contain greenish-brown biotite rather than hornblende, and a little augite and cloudy alkali feldspar.

Although the veinlets which penetrate the basalt from the main net-veins of acidified gabbro exhibit gradational contacts with the basalt, the margins of the net-veins are fairly sharp. At the contact in this latter case there is a narrow zone consisting of large crystals of hornblende, hypersthene and magnetite, together with elongate crystals of plagioclase. Quartz, micropegmatite and chlorite are interstitial. The main part of the acidified gabbro net-veins has the texture of an ophitic /

ophitic gabbro in which the pyroxene has been replaced by hornblende and acidic material (Plate XIXb). Plagioclase is most abundant and occurs as large euhedral crystals which are commonly poly-twinned with each unit twinned on the Carlsbad/Albite law. These crystals are strongly zoned from cores of An_{30} to An_{40} to rims of alkali feldspar. Interstitial minerals are fibrous amphibole which is bluish-green in colour, quartz, brush-like aggregates of alkali feldspar and micropegmatite. Magnetite is present as scattered blebs which may be euhedral, rounded or vermicular.

(b) Hybrid Net-veins - Basalt which is net-veined by hybrid rock sometimes has a basic granulitic margin and the contact is sharp. In this case the contact features are similar to those which have been previously described on pages 28-30. In most cases, however, the contact between basalt and hybrid net-veins is of a somewhat diffuse nature. Where this is so, the basalt shows an increase in grain size towards the contact, and alkali feldspar has developed, rimming the plagioclase. The augite of the basalt has either reformed from granules into larger porphyroblastic crystals enclosing plagioclase or it has been uralitised, while porphyroblastic brownish-red biotite and quartz have also developed. Small veinlets invading the basalt from the hybrid net-veins consist of quartz, alkali feldspar, hornblende or biotite /

biotite, and plagioclase crystals which extend from the basalt into the veinlets (Plate XIXa).

The hybrid net-veinrock is less variable in composition than the large areas of massive hybrid tongue rock described on pages 43-46 . In most specimens the former is a medium or coarse-grained rock, granular or ^{micro}graphic in texture, composed of plagioclase, quartz, augite, hornblende and biotite together with accessory minerals (Plate XX and XXIa). Zoned plagioclase (An_{30} to An_{60}) is more abundant towards the margins of the net-veins than in their interiors, and crystals spanning the contact with the basalt are common. Microperthite and orthoclase on the other hand, are concentrated in the interiors of the net-veins where they occur as large subhedral crystals. Quartz is present in very variable amounts and occurs both in micropegmatite and as free subhedral grains. The principal dark mineral is augite which is frequently highly uralitised and altered to biotite. The hybrid rocks are notable for their variety and quantity of accessory minerals, amongst these being zircon, apatite, zoisite, epidote and orthite. Some of the hybrid net-veins consist of large poly-twinned plagioclase crystals which are highly zoned and contain blebs of quartz rimmed by albite, small quantities of schillerised augite, interstitial uralite, quartz, alkali feldspar and micropegmatite. These net-veins /

net-veins strongly resemble the acidified gabbro net-veins and appear to be more acidic varieties of the same.

(c) Microgranite Net-veins - The basalt associated with the microgranite net-veins is similar to that in contact with the acidified gabbro and hybrid net-veins and the contact phenomena are also of a similar nature. The microgranite net-veinrock is normal granular or micrographic microgranite. There are a few net-veins, however, which exhibit several unusual features. These net-veins contain numerous subhedral poly-twinned plagioclase crystals (An_{20} to An_{40}) which are highly altered and contain veins of quartz, albite blebs, and patches of alkali feldspar. At their margins the plagioclase crystals are rimmed by alkali feldspar and microperthite, which, when traced outwards from the crystals become more and more acidic until they grade into micropegmatite. The chief ferromagnesian mineral is green coloured hornblende which is scattered evenly throughout the rock. Also present in these net-veins are interstitial quartz, serpentine, brownish biotite, and a little brown augite and magnetite. This type of microgranite net-vein appears to be a more acidic type of acidified gabbro net-vein.

The salient features of the net-veined basalts may be summarised as follows:

1. /

1. Where the contact with the net-vein is sharp, the basalt has a fine-grained basic (augitic) margin.
2. Where the contact with the net-vein is not sharp, the basalt shows an increase in grain size towards the contact, and there is accompanying acidification of the basalt.
3. Individual plagioclase crystals which lie across the contact between basalt and net-vein are larger and more sodic in the net-vein than in the basalt.
4. The net-veins consist of either gabbro in various stages of acidification or of medium to coarse-grained granular or micrographic hybrid rock.

C. Net-veined Hypersthene Dolerite

Net-veined hypersthene dolerite has been found in the region of the Allt na Caoraich. This hypersthene dolerite appears to be a true dolerite of lava type rather than dolerite of explosion dyke type. The rock is dark grey in colour, medium-grained, and in thin section is seen to be ophitic in texture and to consist of feldspars, ferromagnesian minerals, magnetite, quartz and accessory minerals. The feldspars comprise large, highly zoned and albitised plagioclase crystals (An_{30} to An_{60}) which appear to be phenocrysts, lamellar-twinned and zoned plagioclase laths, some of which are brownish in colour and some clear albite. Cloudy orthoclase is also present, usually associated with quartz to form micropegmatite. Quartz is always interstitial, and comprises up to 5% of the rock.

The /

The chief ferromagnesian mineral is ophitic augite, which is brown, seldom schillerised, but frequently uralitised and sometimes granulitised. Greyish-green hypersthene occurs as fairly large crystals which are less altered than the augite.

Greenish brown needles of hornblende which show alteration to foxy-red biotite are also present. The accessory minerals are zircon and very long thin bent crystals of apatite.

At the contact with the net-veins there is a slight concentration of hornblende porphyroblasts within the dolerite.

The net-veinrock differs from the hybrid net-veinrock described on pages 34-35 in containing cloudy plagioclase and microperthite, hypersthene, augite and quartz.

Occurring in the region of the Allt na Caoraich are a few acidic dykes which strike north-westwards cutting the hypersthene dolerite. These dykes give rise to extensive net-vein systems along their margins. The dyke-rock, although of the same composition as the majority of the net-veins and acidic tongues of Beinn na Cro, is different in texture, containing as it does numerous rounded grains of quartz, some of which are strained. The net-vein part of these dykes is a light grey, medium-grained granular rock, consisting of plagioclase, alkali feldspar, quartz, hornblende and augite together with biotite and magnetite. The contact with the dolerite is fairly /

fairly sharp, with a slight patchy concentration of hornblende in the dolerite, while large lath-shaped plagioclase crystals span the junction.

The central portion of the net-veins consist of small, clear, unzoned granular plagioclase crystals (An_{30}) and large zoned plagioclase crystals (An_{20} to An_{35}) which have irregular alkali feldspar margins and contain quartz blebs rimmed by albite (Fig. 9A). Only traces of twinning remain in these large crystals which are highly altered. Most of the quartz in the net-veins is granular and rounded rather than interstitial. Anhedral crystals of hornblende, some of which exhibit schiller structure, are abundant, while anhedral augite is present only in very small quantity and the crystals are partially altered to urallite.

The main part of the acidic dykes shows a gradation from the rock of the net-veins to central, whitish, coarse-grained rock which is of a more acidic character (Plates XXIb and XXII). This rock consists of broken relic plagioclase crystals (An_{20}), largely altered to micropertthite which also occurs in the form of porphyroblasts enclosing numerous rounded grains of quartz. In some cases the proportion of included quartz in the porphyroblasts exceeds that of the host micropertthite. Skeletal brown hornblende is sparse, and has been largely /

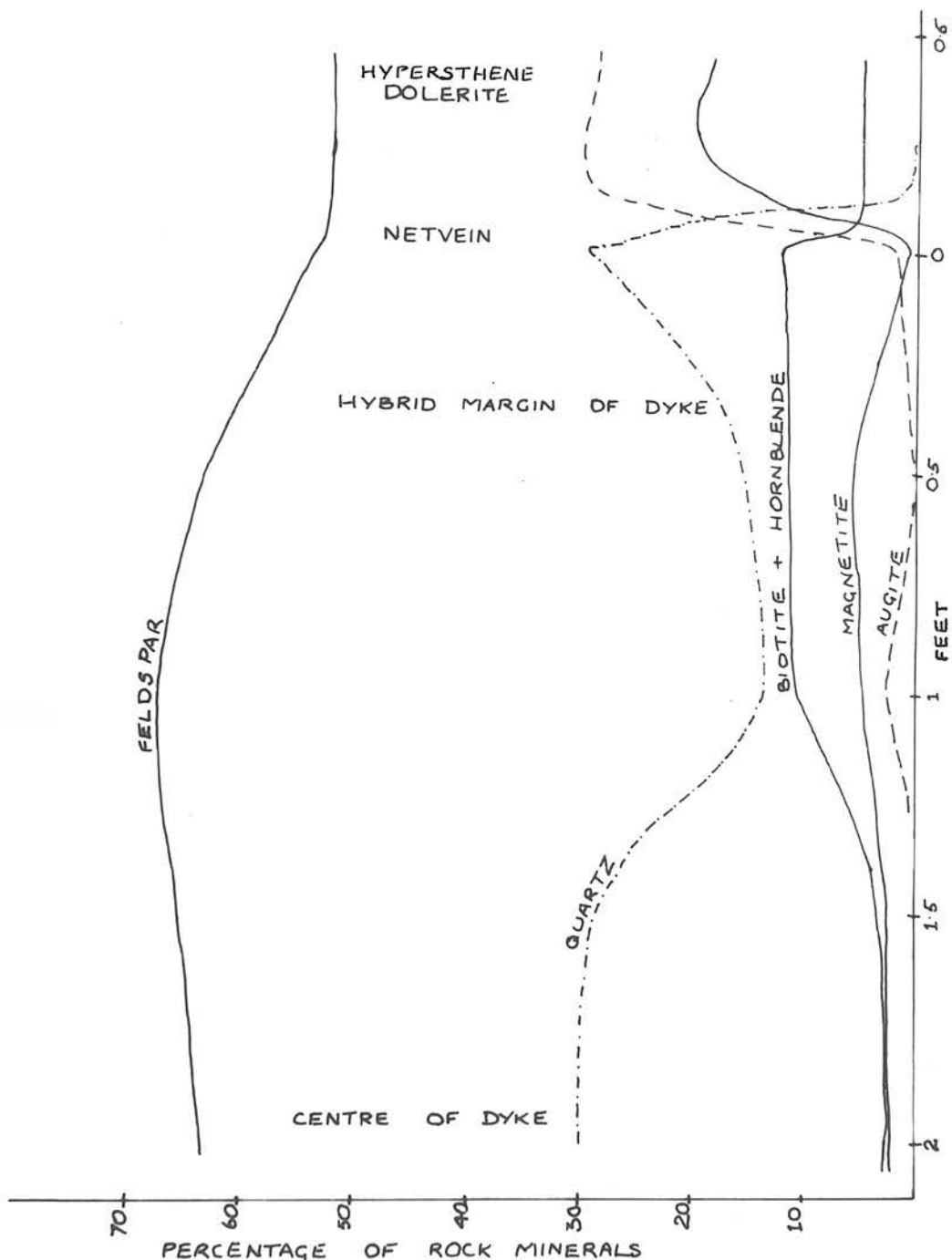


Figure 10. Variation diagram illustrating the variation in the proportion of essential minerals from the interior of an acidic dyke across its contact with hypersthene dolerite.

largely altered to porphyroblastic biotite. The progressive alteration of hornblende to biotite is well displayed in the gradational rocks near the margins of the dykes. Zircon occurs in measurable quantities and forms either large rounded crystals or small prisms. Euhedral magnetite is present associated with the biotite.

Modal analyses reveal that the most striking variation in mineral proportion is that of the quartz. While there is about 30% of quartz in the net-veins and in the interiors of the dykes, in the marginal regions of the dykes there is less than 15% (Fig. 10).

D. Massive Hybrid Rocks. In addition to the net-veined rocks, there are also massive hybrid rocks intermediate in composition between the basic and granitic rocks of Beinn na Cro. The mineral composition of these hybrid rocks is fairly constant, but the relative proportions of the constituent minerals is variable. The more basic hybrid rocks contain a high percentage of plagioclase and dark minerals, while the more acidic members contain a high percentage of alkali feldspar and quartz. The only mineral which occurs in the more acidic hybrid rocks and which is not present in the basic types is zircon.

Two varieties of hybrid rock occur in the Allt na Gobhar area. One, termed here acidified gabbro, is indistinguishable from the normal gabbro in hand specimen. In thin section, however, the former rock is very pale coloured, coarse-grained and consists of plagioclase, alkali feldspar, quartz, augite, uralitic amphibole, biotite, magnetite and hypersthene. Two types of plagioclase are present. The more common type occurs as large, clear, twinned and poly-twinned crystals with a composition of An_{30} to An_{40} . Alteration takes the form of oscillatory zoning and veins and patches of pale green chlorite. Smaller, zoned, granulitic plagioclase crystals (An_{30}) are less abundant and exhibit finer and more complex twinning. Both types of plagioclase contain inclusions of hypersthene. Cloudy alkali feldspar and quartz are interstitial. Augite is not common and occurs only as sparse relics within patches of pale green uralitic amphibole. Large plates of straw-coloured biotite have developed from the uralite.

The main difference between this acidified gabbro and the normal gabbro thus rests in the relative proportion of alkali feldspar and amphibole both of which are much higher in the former.

Similarly to the acidified gabbro, another type of massive hybrid rock occurs within gabbro sheets and is transitional /

transitional into gabbro. In the field this type of hybrid rock has the appearance of a dolerite containing patches of gabbro. In thin section, however, the rock is seen to be considerably more acidic. The "dolerite" is a basic microgranite, and the "gabbro" is a basic granophyre.

The basic microgranite is a medium-grained porphyritic rock. Plagioclase comprises the bulk of the rock and occurs both as large subhedral elongate crystals (Ab_{20}) which have been replaced marginally and along twin composition planes by albite, microperthite, orthoclase and quartz, and as smaller, zoned lath-like crystals rimmed by alkali feldspar which, together with quartz, brown hornblende, foxy-red biotite, augite and zircon form the matrix of the rock.

The coarse-grained part of the rock, the basic granophyre, consists of oligoclase with interstitial micropegmatite, granular quartz, hypersthene, magnetite and fibrous biotite. The oligoclase crystals are elongate, up to 4 mm in length, and resemble gabbro plagioclases in their poly-twinning. These oligoclase crystals have been replaced in the same manner as the large plagioclase crystals of the basic microgranite. Hypersthene occurs in rounded masses which appear to be pseudomorphs after olivine. Fibrous brown biotite aggregates almost completely replace pale green uralite. Occupying the interstices between /

between the feldspars, in the manner in which ophitic augite is interstitial to plagioclase in gabbro, are micropegmatite and quartz.

E. Tongue Rocks. Great tongue-like apophyses extend from the granite of Beinn na Cro into the basic rocks. Contacts between lavas do not appear to have been displaced across the tongues (Fig. 5). While the smaller tongues are uniformly composed of microgranite or felsite, the larger ones are complex.

(i) Microgranite Tongues

The contacts of the microgranite tongues with the basic rocks are extremely sharp. Towards the contact, the latter becomes finer in grain, richer in augite and iron ore and poorer in plagioclase and the augite exhibits a progressive change from ophitic through granular to subvariolitic texture.

The microgranite itself is medium-grained, granular, graphic or spherulitic and generally porphyritic. The constituent minerals are plagioclase, alkali feldspar, quartz, hornblende, biotite, augite and magnetite, together with accessory apatite and zircon (Plate XXIIIa).

Plagioclase. Plagioclase is present as large individual crystals and crystal aggregates up to 5 mm across. The individual crystals are in some cases poly-twinned, ^{but are} invariably zoned from /

from cores of An₄₀ to rims of alkali feldspar which contain blebs of quartz. In some specimens the large plagioclase crystals contain numerous inclusions of augite, hypersthene and magnetite. The aggregates of plagioclase are associated with granular augite and the plagioclase and augite are together rimmed by alkali feldspar. In some cases the plagioclase of the aggregates has been altered to microperthite and the augite to greenish hornblende.

Alkali feldspar. Cloudy alkali feldspar is the dominant mineral in the groundmass of the microgranite. The crystals are in some instances skeletal and bent and occur in aggregates up to 1 cm. in length. Individual crystals, rectangular in section, also occur throughout the groundmass.

Quartz and micropegmatite. Quartz is present interstitially and in micropegmatite. The feldspar of the micropegmatite may be cloudy microperthite or orthoclase.

Hornblende, biotite and augite. As in the granite, hornblende is the dominant ferromagnesian mineral. It is brown in colour, strongly pleochroic, and occurs in anhedral clusters and as curved needles up to 7 mm in length, carrying grains of magnetite. Biotite and augite are subsidiary and show the same characteristics as these minerals in the granite.

(ii) Complex tongues.

The large complex tongues exhibit somewhat transitional contacts /

contacts with the basic country rock. The latter shows an increase in grain size and albitisation of the plagioclase, with introduction of quartz and alkali feldspar. Net-vein systems occur extending from the tongues into the basalt. These net-veins grade into the basalt at their terminations. The net-veins differ from the net-veins associated with the acidic dykes described on pages 37-38 only in the complete absence of rounded quartz crystals, all the quartz being interstitial. Xenolithic microgranite may occur as a transition zone between the net-veined basalt and the tongues proper. The xenolithic microgranite consists of sub-rounded fragments of basalt in a hybrid or microgranitic matrix. Towards their margins the fragments are coarser in grain and acidified, while the adjacent matrix is considerably more basic than it is at a greater distance from the basalt. Plagioclase crystals extend from the basalt into the matrix. The matrix is somewhat more basic in composition than either the net-veins or the tongue-rock, and closely resembles the hybrid net-vein material described on page 36.

Occurring within the largest tongues is an elongate mass of hybrid rock. The variation of this mass in grain size and mineral composition is similar to that of the adjacent more acidic tongue-rock. A coarse-grained hypersthene-rich band extends across the tongue and the hybrid lens at a horizon corresponding /

corresponding to that of the hypersthene dolerite lava which occurs intercalated between basalt flows (Fig. 5). The finer-grained parts of the elongate mass of hybrid rock within the tongue consist of plagioclase, alkali feldspar, quartz, hornblende, magnetite and accessory minerals. The plagioclase occurs as lath-shaped crystals, somewhat zoned, lying in a matrix of cloudy alkali feldspar and quartz. Rounded or sub-hedral green hornblende crystals containing granules of magnetite along their margins cross-cut the other rock minerals.

The coarser-grained hybrid rock consists of alkali feldspar and plagioclase in almost equal amounts, quartz, hypersthene, hornblende, augite, biotite, magnetite and accessory apatite and zircon. The alkali feldspar is cloudy and occurs as large crystals partially replacing and rimming plagioclase. The plagioclase is highly zoned and may be poly-twinned. Irregular crystals of hypersthene are abundant and, rarely, are altered to foxy-red biotite. Hornblende, green in colour, occurs as irregular crystals and as an alteration product of the sparse augite. Large inclusions of hornblende within plagioclase are common. These inclusions are arranged ophitically with respect to sets of twin lamellae in poly-twinned crystals.

The /

The bulk of the tongue-rock is medium or coarse-grained, granular or micrographic in texture, and consists of plagioclase, alkali feldspar, quartz, hornblende, augite and zircon. Hypersthene is confined to the coarse-grained band opposite the hypersthene dolerite. Plagioclase (An_{30} to An_{45}) is most abundant. The crystals contain blebs of quartz and micropegmatite rimmed by albite and are themselves rimmed by alkali feldspar and microperthite. The bulk of the rock consists of lath-shaped crystals of oligoclase and alkali feldspar, quartz, which occurs with orthoclase as micropegmatite and in large lake-like areas, and highly altered hornblende. Where the hornblende is in contact with the large plagioclase crystals the latter have no marginal rims of alkali feldspar and the hornblende does not have its usual rim of magnetite and cloudy alteration products. Zircon is present as an accessory mineral.

3. Granitic Rocks

Under this heading are grouped the truly acidic rocks of Beinn na Cro; the main granite mass itself and the quartz-porphry minor intrusions.

A. The Beinn na Cro Granite. The main mass of the Beinn na Cro granite contains both granitic and granophyric rocks.

The /

The textural variation of these two types is entirely haphazard. Granophyre is probably in excess of granite but as it is impossible to determine the relative amounts of the two types, the name "granite" as employed by Harker has been retained. Different feldspars are dominant in different specimens, as are different textures, giving varieties such as microperthite granite, microperthite granophyre, orthoclase granite, orthoclase microperthite granite and orthoclase microperthite granophyre (Plates XXIIIb and XXIVa).

All the varieties of the Beinn na Cro granite are coarse-grained and consist of microperthite, orthoclase, oligoclase, albite, quartz, amphibole, biotite and augite, together with accessory magnetite, pyrite, haemetite and zircon.

Microperthite. Microperthite is the most abundant mineral in most varieties of the granite. It occurs as large euhedral crystals up to 4 mm across, or as cores to composite microperthite-micropegmatite crystals. Some of the euhedral crystals are rimmed by euhedral crystals of oligoclase (Fig. 9C). The component minerals of the microperthite are usually clear albite and cloudy orthoclase, although lamellar-twinned oligoclase may take the place of the former. Where the plagioclase component is albite, orthoclase is always in excess, while in those cases where the plagioclase is oligoclase the proportion of oligoclase may exceed that of orthoclase.

Orthoclase /

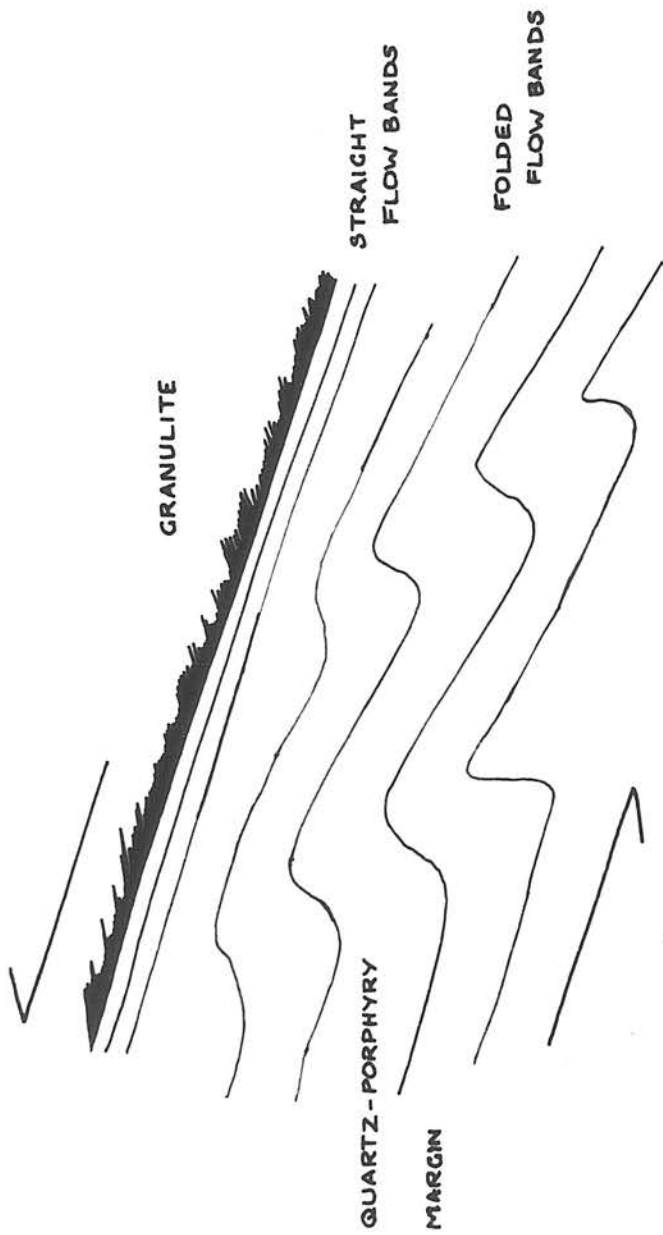
Orthoclase. Besides forming part of the microperthite, orthoclase also occurs as euhedral crystals and in micropegmatite. The euhedral crystals are smaller than the microperthite crystals and are always cloudy. Twinning is rarely seen.

Oligoclase. Oligoclase occurs as equidimensional, euhedral crystals up to 5 mm across and as elongate euhedral crystals up to 3 mm long rimming microperthite. The larger crystals are clear, zoned and rimmed by albite, orthoclase or microperthite. The smaller crystals are clear, unzoned, and show pronounced twinning in contrast to the larger in which the twinning is usually indistinct.

Albite. Albite occurs only in the microperthite and as rims around oligoclase.

Quartz. Quartz is present interstitially as anhedral crystals up to 8 mm in diameter, which are often strained, showing a cross-hatch extinction, and also in micropegmatite. The micropegmatite occurs in irregular patches up to 8 mm in diameter and is composed of quartz and microperthite or orthoclase. The relative proportions of the two constituents of the micropegmatite are extremely variable, quartz decreasing in amount towards the interiors of the crystals. The micropegmatite is more commonly myrmekitic than graphic.

Amphibole, Biotite and Augite. The total percentage of dark /



QUARTZ-PORPHYRY INTERIOR, CONTAINING FRAGMENTS

(ARROWS INDICATE SENSE OF MOVEMENT)

Figure 11. Diagrammatic sketch of the upper contact of a quartz-porphyrity sheet of Reinna na Dro.

dark minerals rarely exceeds eight in the Beinn na Cro granite. Hornblende is the most common and occurs as anhedral greenish-brown coloured crystals. Sparse amount of another amphibole, bluish-green in colour, are also present. Brown biotite, occasionally exhibiting pleochroic haloes, is associated with augite and accessory minerals. Small crystals of brownish-green augite, with rims of hornblende and biotite, are scattered throughout the rock.

B. Quartz-porphyry. Quartz-porphyry occurs as sheets and dykes intrusive into both the basic rocks and the granite of Beinn na Cro. Actual contacts of quartz-porphyry have only been observed with granulite and granite. At the former, there is no apparent alteration of the granulite, and at the latter the granite may be unaltered, granulitised, or shattered for a distance of up to two inches from the contact.

The quartz-porphyry intrusions have very fine-grained cryptographic or glassy margins which frequently are flow-banded. This banding consists of either straight or folded bands which are approximately parallel to the margins (Fig. 11). The rock is pale bluish-grey or yellow coloured in hand specimen and contains large crystals and crystal aggregates set in a very fine-grained matrix. The large crystals and crystal aggregates consist /

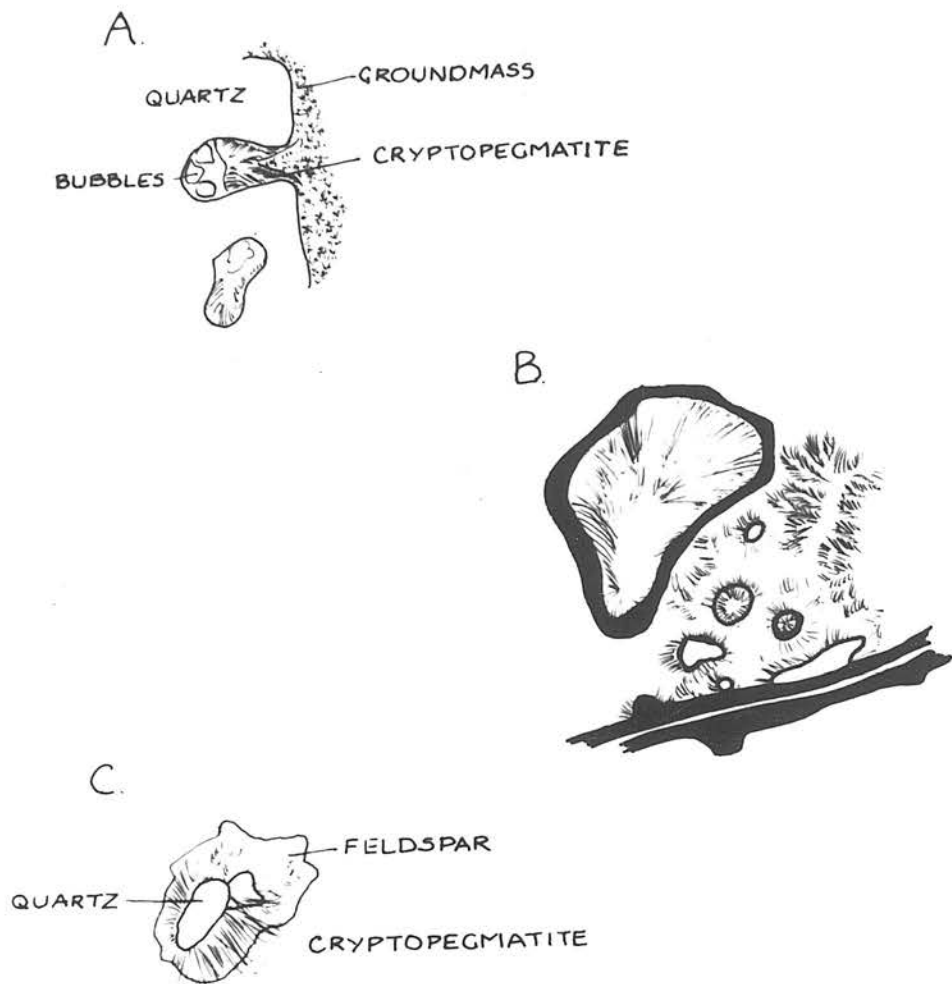


Figure 12. Petrographic features of the quartz-porphyry.
 A. Embayed and rimmed quartz.
 B. Angular bodies of glass and spherulitic material.
 C. Rimmed quartz.

consist of feldspars associated with quartz, as they are in the Beinn na Cro granite, discrete crystals of quartz, feldspars of the type found in the gabbro, and recognisable fragments of granite, gabbro and basalt. The majority of the crystals and fragments are shattered and some are highly altered and corroded with deep embayments (Fig. 12A and C). Many of the crystals and fragments have rims of constant width consisting of cryptopegmatite. This cryptopegmatite also extends into the embayments where it is associated with glass and bubbles. In some cases the groundmass of the quartz-porphyry is granular, consisting of quartz and orthoclase with sparse hornblende and magnetite. In the majority of cases, however, the matrix is cryptographic or spherulitic with fine-grained feathery patches, the larger of which are either contained within or surround spherical or sub-spherical parallel-sided balls and annular bodies of glass (Fig. 12B and Plates XXIVb and XXV). The fragments commonly occur towards the interiors of the intrusions, while the glass spherules, although ubiquitous, have their greatest development towards the margins where they indicate the flow-banding.

| | I | II | III | IV | V | VI | VII | VIII |
|-------------------------|-------------------|-------|-------|-------|-------|-------|-------|-------|
| Quartz | | | | | | 3.0 | 6.0 | 30.0 |
| Alkali feldspar | | 2.0 | | | | 9.0 | 24.0 | 30.0 |
| Plagioclase | 27.0 [#] | 34.0 | 44.0 | 57.0 | 67.0 | 32.0 | 27.0 | 21.0 |
| Pyroxene | 43.0 | 35.5 | 34.5 | 32.0 | 29.0 | 23.5 | 15.0 | 1.0 |
| Hornblende & biotite | 10.0 | 20.0 | 11.0 | 8.0 | 2.0 | 16.5 | 15.0 | 7.0 |
| Iron ore | 15.0 | 8.5 | 7.5 | 1.0 | 2.0 | 6.0 | 4.0 | 1.0 |
| Olivine | 1.0 | | 3.0 | 2.0 | | | | |
| | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |

[#]including apatite

Figure 13. Table of average modal analyses of rock groups of Beinn na Cro. I: Mafic granulite; II: Basalt; III: Granulite; IV: Vein gabbro; V: Gabbro; VI: Dolerite, including hypersthene dolerite lava; VII: Hybrid rocks; VIII: Microgranite and granite.

- 1 MAFIC GRANULITE
- 2 BASALT
- 2' OLIVINE-BASALT
- 3 GRANULITE
- 4 VEIN GABBRO
- 5 GABBRO
- 6 DOLERITE
- 7 HYBRIDS
- 7' NETVEINS AND ACIDIFIED GABBRO
- 8 MICROGRANITE
- 9 GRANITE

- Q QUARTZ +
ALKALI FELDSPAR
- P PLAGIOCLASE + APATITE
- F FERROMAGNESIAN MINERALS +
IRON ORE
- O OLIVINE

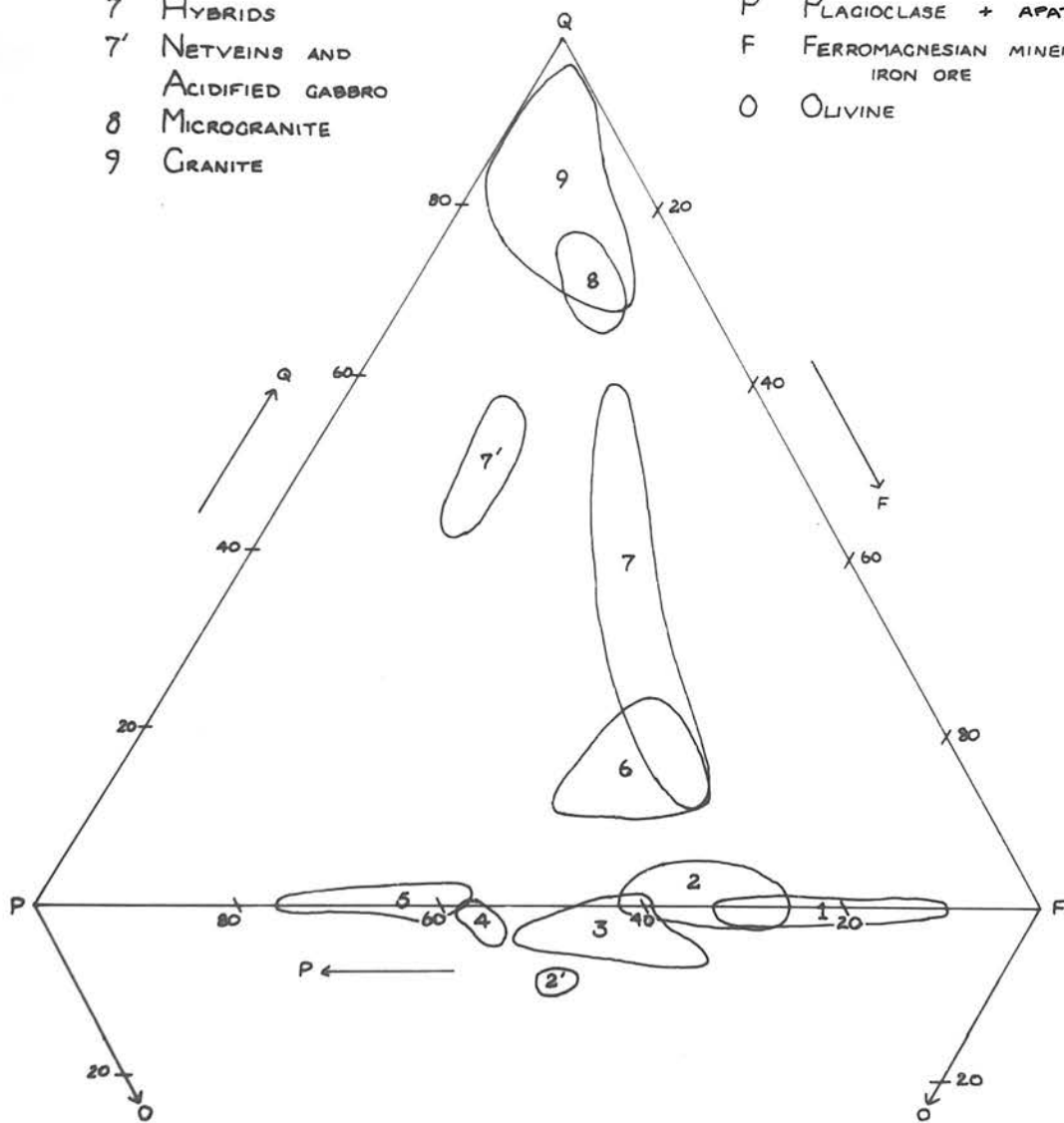


Figure 14. Plot of the modal analyses of the rocks of Beinn na Cro.

V. MODAL ANALYSES

A large number of modal analyses of the rocks of Beinn na Cro were made in order to test the validity of the petrographic subdivisions and to determine the variation in mineral proportions between the rock groups. These analyses were plotted on a double triangular diagram with co-ordinates: P - 100% plagioclase plus apatite; Q - 100% quartz plus alkali feldspar; F - 100% dark minerals; O - 100% olivine plus serpentine. Figure 13 is a table of the average modal analyses of each group, and figure 14 is the plot of all the analyses.

Each of the main groups of basic rock form well-defined fields lying on the P-F tie-line. The basalt lava area is overlapped by the area of mafic granulite (including coarse-grained mafic granulite) which extends towards the F apex, and by the area of granulite which extends towards the P apex. The latter group is succeeded along the P-F tie-line in the direction of the P apex by the fields of vein gabbro and gabbro respectively.

The most basic group lying above the P-F tie-line is that of dolerite lavas and explosion dykes which occupies a field close to that of the basalt lavas. This dolerite area is linked to acidic groups of microgranite and granite by an elongate /



elongate field representing the massive hybrid rocks and the tongue rocks, excluding microgranite. The analyses of acidified gabbro and hybrid and acidic net-veins in the basalt form an isolated field near the P-Q tie-line.

VI. /

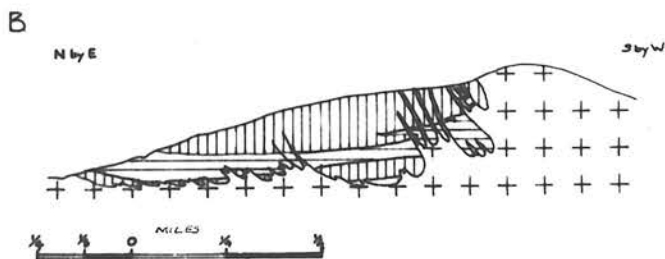
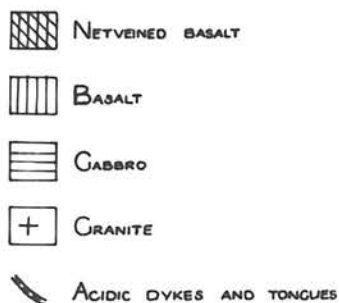
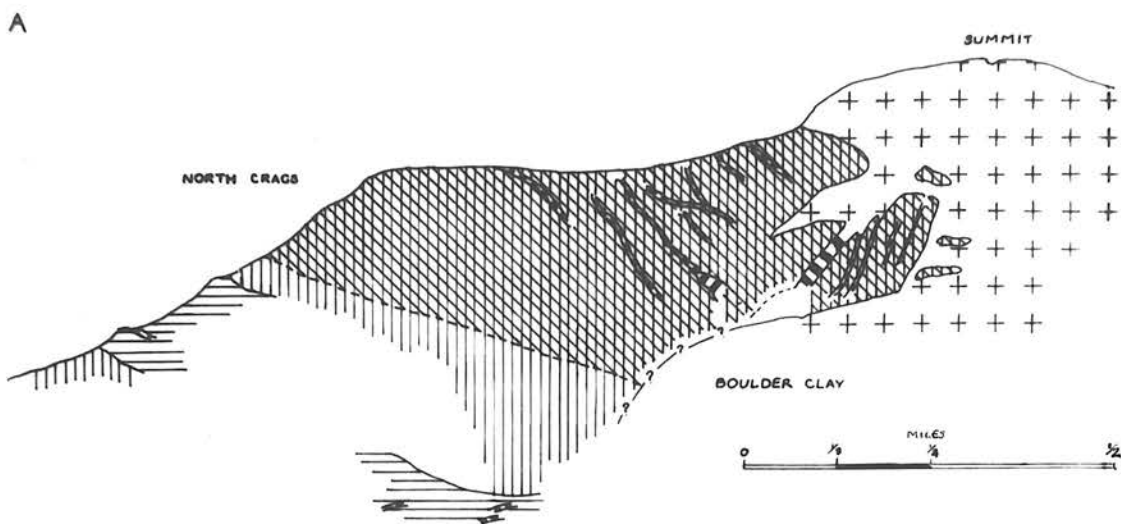


Figure 15.

- A. A sketch of Beinn na Cro from the west, illustrating the geology.
- B. Harker's interpretation of the relationship of the granite to the basic rocks of Beinn na Cro.

VI. DISCUSSION1. Structure

Harker (1904) considered that the lavas of Beinn na Cro, already invaded by gabbro, had been enveloped in the granite of the Red Hills, and that the granite had sent numerous offshoots, in the form of tongues and dykes, into the enclosed basic mass (Fig. 15B). On page 138 of the Skye Memoir, Harker shows the lavas to be underlain by granite, thus indicating either that the basic rocks are completely enclosed by granite or that they form part of the roof of the Red Hills "laccolith". Harker regarded a small outcrop of lavas resting on Jurassic strata at the southern end of Beinn na Cro as being a continuation of the Beinn na Cro lava at the northern end of the hill, and that the latter lavas, now occurring at a lower topographic level than the former, had been downfaulted prior to the intrusion of the granite.

While the present author has found no exposures towards the northern end of Srath Mor which would support or militate against Harker's description of granite underlying basalt (Fig. 15A), it has been discovered that the reported outcrop of lava at the southern end of Beinn na Cro does not exist. The so-called lavas are in fact hard black hornfelsed sediments, cut by /

by basic dykes and sheets which post-date the granite. There is thus no evidence for the presence of a pre-granite fault towards the northern end of Beinn na Cro as postulated by Harker.

Richey (1930) considered the Red Hills granite to have ring-dyke rather than laccolithic structure, and suggested that the Beinn na Cro basic rocks represent the outer wall of the outermost ring-dyke belonging to the Eastern Red Hills centre, this outermost ring-dyke being represented by the Beinn na Cro granite. The present mapping indicates that the approximate plane of contact between the lavas and the main granite dips at a high angle towards the north-west. This structure is that required by Richey's hypothesis that the contact is the margin of a ring-dyke. Richey obtained evidence for the prior age of this outermost ring-dyke, as required by the standard ring-dyke hypothesis, from exposures in the bed of the Allt an t-Sithein, and he stated that "Intensely brecciated granophyre [Beinn na Cro granite] and basic rock are exposed in a stream for 600 yards. Westwards, towards the Red Hills mass, the brecciation becomes less intense. Eastwards, an unbroken porphyritic granophyre, ^[Glas Bheinn Bheag microgranite] is chilled against the brecciated granophyre. It would seem likely that the Red Hills granophyre, together with basic rocks in continuation with the Beinn na Cro wall, was brecciated and then intruded by granophyre belonging to a Beinn na Caillich Eastern Red Hills centre" (1930, p. 77).

Investigation has revealed that the Beinn na Cro granite and the "porphyritic granophyre" are equally brecciated, this line of fracture forming part of the Gualann nam Fiadh fault, and therefore the age relations of the two granitic rock masses cannot be determined.

A factor not discussed by Richey and only briefly mentioned by Harker is the internal structure of the basic rocks of Beinn na Cro. The structure of these rocks can be divided into two fundamentally differing units; the structural relationships of the basalt to the gabbros, and the structural relationships of the basic rocks to the acidic net-veins, dykes and tongues.

A. The Relationships between the Basalts and the Gabbros. The gabbro occurs as sheets cutting the lavas. In the north the sheets are vertical, while towards the south-west across a fault (see pages 7 to 8) the sheets dip at 35° to the west. This difference in dip of the gabbro bands on either side of the fault can be correlated with change of dip in the lavas, and has probably resulted from a rotational movement in the fault plane, the original orientation of the gabbro sheets having been approximately vertical throughout. Thus it seems likely that the gabbros were arcuate in the north of the area, and /

and straight in the south-west, their structure approximating to that of an assymmetric ring-dyke.

B. The Relationships between the Basic and the Acidic Rocks. Acidic net-veins, dykes and tongues occur within the basic rocks and are concentrated towards the south-east and south. They are of two distinct structural types. Whereas the net-veins are sinuous and irregular and ramify the basalt in a broad strip a quarter of a mile wide adjacent to the contact with the main Beinn na Cro granite, the dykes and tongues are vertical and parallel-sided and show several directions of preferred orientation. The majority of the tongues are aligned south-west - north-east and north-west - south-east, a few striking westwards, and cut an earlier set of less numerous north - south dykes. The dykes and tongues are accompanied by their own minor systems of acidic net-veins which extend into the basic country rock. Stratum contouring of the arcuate south-eastern limit of the basic rocks clearly demonstrates that if this boundary is planar it dips at about 60° to the north-west. The symmetrical distribution of the dykes and tongues in relation to this plane is so pronounced that it appears to indicate some structural relationship between the orientation of the dykes and tongues and the disposition of the major junction between the basic rocks and the Beinn na Cro granite.

2. Petrogenesis

The petrogenetic relations of the different basic rocks and the association of the basic and acidic rocks of Beinn na Cro have not been greatly discussed by previous workers. While Richey made no mention of either subject, Harker's reference to the basic rocks is confined to a description of the veining of the basalt by the gabbro, and a mention of the uralitic alteration of the augite of the gabbro. He also noted the presence of olivine in one specimen of gabbro occurring in Srath Mor, but considered it to be a feature of no importance, the distribution of olivine throughout the Skye gabbros being so haphazard that no great significance could be attached to the presence or absence of this mineral. Harker's reference to the acidic net-veins and his conclusions regarding their origin are discussed on pages 71 to 72.

Despite the fact that previous workers have largely overlooked Beinn na Cro, the rocks of this area present several interesting petrogenetic problems, which may be enumerated as follows:- The origin of (A) The granulite and gabbro; (B) The explosion dykes; (C) The hybrid and acidic net-veins; (D) The massive hybrid rocks; (E) The acidic dykes and tongues with their associated net-veins and hybrid rocks; (F) The quartz-porphyrries. The origin of the Beinn na Cro granite presents another /

another problem which, however, will not be discussed as it encroaches upon a wider field of study, namely, the origin of the major Skye granites and granophyres.

A. Granulite and Gabbro. Granulite and gabbro are found only within the basaltic lavas. Granulite is present only at the contacts of gabbro and basalt. The field relations between basalt, granulite and gabbro are complex (see pages 2-4 and Fig. 3). Granulite veins extend into the basalt from the margins of the granulite; gabbro veins extend into the basalt and granulite from the margins of the gabbro and lenses of enclosed granulite and basalt occur within the gabbro. The granulite varies in grain size, the coarser-grained varieties veining the finer-grained varieties. It is thus readily established that the basaltic lava is the oldest rock, and the gabbro is the youngest. The granulite is intermediate in age, and the coarser-grained varieties are younger than the finer-grained ones. In addition, it may be observed that the coarser the grain size, the younger is the rock, excepting in the case of the finest-grained granulite which, although younger than the basalt, is of a similar grain size. The lack of off-set of the straight amphibolite veins in the basalt where they are cut by granulite veins, and of banded granulite where this is cut by gabbro /

gabbro veins (Fig. 7), suggests that both the granulite and the gabbro veins have been emplaced by a replacement rather than a dilational mechanism. The ramifying nature of the granulite and gabbro veins is so complex that any hypothesis that their non-dilational aspect has resulted from the removal of pre-existing rock in order to allow space for the incoming material cannot be entertained. The paradox therefore, that although no rock has been removed, new rock has been formed, can only be explained on the assumption that the granulite and gabbro vein rocks have originated in situ.

The mafic granulite occurs only as veins. The fine-grained mafic granulite veins the basalt, and although associated with the granulite, is cut by it. Similarly, the coarse-grained mafic granulite veins the granulite and is cut by gabbro veins and gabbro. Thus the fine-grained mafic granulite is intermediate in age between the basalt and the granulite, and the coarse-grained mafic granulite is intermediate in age between the granulite and the gabbro. All the veins of mafic granulite show similar relationships to the country rock as the granulite and gabbro veins, and there can be no doubt that the mechanism of emplacement is the same.

In the sequence which may be traced from basalt through granulite to gabbro, the most obvious modification is that of grain /

grain size. There is also an almost equally striking variation in texture and a significant change in mineral proportion. The plagioclases of the basalt occurs as elongate crystals, whereas those of the granulite, besides being larger in size, are somewhat stumpy. In the finer-grained gabbro the plagioclase crystals closely resemble those of the granulite, but towards the interior of the gabbro there is a transition from discrete plagioclase crystals, through interlocking crystals, to poly-twinned crystals typical of the coarse-grained gabbro. The transition from discrete to poly-twinned plagioclase crystals is in no way abrupt, discrete and interlocking crystals are commonly found in association, as are interlocking and poly-twinned crystals. The petrographic evidence suggests that the interlocking plagioclase crystals have developed by the intergrowth of several discrete crystals, and that with further adjustment, the crystal boundaries became progressively obscured until poly-twinned plagioclases were formed. It is evident that for crystals to have evenly and ubiquitously aggregated in this manner, without the development of isolated clots, and without the formation of very large simple crystals, there can have been little movement within the gabbro subsequent to the commencement of the formation of the complex plagioclase crystals.

The augite shows a parallel change in crystal habit.

While /

While in the least altered basalt the crystals are sub-ophitic, there is a transition to the most metamorphosed basalt in which the augite is distinctly granular and in no way different from that of the fine-grained granulite. In the fine-grained and medium-grained granulites the augite is somewhat rounded in habit, but with increase in grain size, however, there is a transition from granular to euhedral, and more rarely, sub-ophitic crystals in the coarse-grained granulite. The augite of the gabbro invariably occurs as large ophitic plates.

Basalt - granulite associations are not uncommon in Skye, and Harker has reported several occurrences. He considered (p. 115) the granulitic gabbro of Drium an Eidhne to represent metamorphosed basalt lava rather than a variety of gabbro, especially when this granulite was examined in the light of evidence from the western side of the Cuillins where he had discovered undoubted lava metamorphosed to granulite near the margins of the gabbro (pages 52 and 53). Harker's description of granulitic gabbro indicates that this rock does not differ in its petrography or field relations with gabbro from the granulites of Beinn na Cro, and it seems likely that the two rocks have similar modes of origin.

On Beinn na Cro it has been established that the basaltic lavas have been locally metamorphosed with increase in grade /

grade of metamorphism towards the granulite, and that the most metamorphosed basalt and the finest-grained granulite are virtually indistinguishable. Thus, it seems reasonable to suppose that the granulite could have been formed as the result of further metamorphism of the basalt. This hypothesis is supported not only by Harker's discoveries, but also by evidence from the granulite veins which cut the basalt. These veins are replacement veins, and it seems likely that they have developed from the basalt; as the veins are continuous with the massive granulite, it is extremely unlikely that the latter could have originated, in view of the evidence of metamorphism, by any process at variance with that which produced the veins. It was at first thought that the metamorphism of the basalt into granulite was a contact metamorphic effect caused by the emplacement of the gabbro. However, there are a number of factors which are not compatible with this interpretation. The sporadic distribution of the granulite, at places absent from the basalt - gabbro contact, the replacement nature of the granulite veins in the basalt and the lack of homogeneity in the massive granulite are difficult to explain on the hypothesis of simple contact metamorphism, and moreover, the close association of basalt and granulite in the inclusions in the gabbro would not be expected if the granulite had developed as the result of metamorphism /

metamorphism of the basalt by the gabbro. It appears that the granulite was formed prior to the emplacement of the gabbro.

In considering the origin of the gabbro a number of factors must be assessed. The intimate nature of the contact between the gabbro and the country rock is a significant and striking feature. There are not merely a few gabbro veins merging with the massive gabbro along a well-marked line of contact, but a complicated plexus of net-veins is present. These veins, when traced towards the gabbro, gradually increase in number and magnitude until the rock consists of gabbro with inclusions of country rock, and finally massive gabbro. It is impossible to determine where the vein system ceases and the gabbro proper begins. It has already been demonstrated that the gabbro veins are of replacement origin, and since the veins are continuous with the massive gabbro and do not differ from it petrographically, it seems that the margins of the massive gabbro at least may be of replacement origin. There is no evidence that the lens-shaped inclusions of granulite and basalt within the gabbro have been rotated as the result of the emplacement of the gabbro, and no evidence has been found contrary to the suggestion that the gabbro is of replacement origin. On the other hand, there is no evidence which refutes the possibility that the interior of the gabbro may have formed directly from a magma.

| | I | II | III | IV | V | IX | X |
|---|--------------|--------------|--------------|--------------|--------------|---------------------------|---------------------------|
| SiO ₂ | 39.5 | 42.5 | 44.0 | 48.0 | 49.0 | 46.61 | 50.78 |
| Al ₂ O ₃ | 10.5 | 14.0 | 15.0 | 19.0 | 22.0 | 15.22 | 17.16 |
| Fe ₂ O ₃ | 16.0 | 12.5 | 9.0 | 4.5 | 4.0 | 3.49 | 3.15 |
| FeO | 12.0 | 10.0 | 11.0 | 6.0 | 4.0 | 7.71 | 7.61 |
| MgO | 7.5 | 6.5 | 6.5 | 6.0 | 4.0 | 8.86 | 7.16 |
| CaO | 14.0 | 12.0 | 12.5 | 14.0 | 14.0 | 10.08 | 10.28 |
| Na ₂ O & K ₂ O | 0.5 | 2.5 | 2.0 | 2.5 | 3.0 | 3.10 | 2.61 |
| | <u>100.0</u> | <u>100.0</u> | <u>100.0</u> | <u>100.0</u> | <u>100.0</u> | <u>95.03</u> [†] | <u>98.73</u> [‡] |

[†]Other constituents omitted in this table.

Figure 16. Table of average chemical analyses, calculated from modal analyses. I: Mafic granulite; II: Basalt; III: Granulite; IV: Vein gabbro; V: Gabbro; IX: Olivine basalt lava, analysis given by Harker on page 31 of the Skye Memoir (1904); X: Gabbro, analysis given by Harker on page 103 of the Skye Memoir (1904). IX and X are given here for comparative purposes.

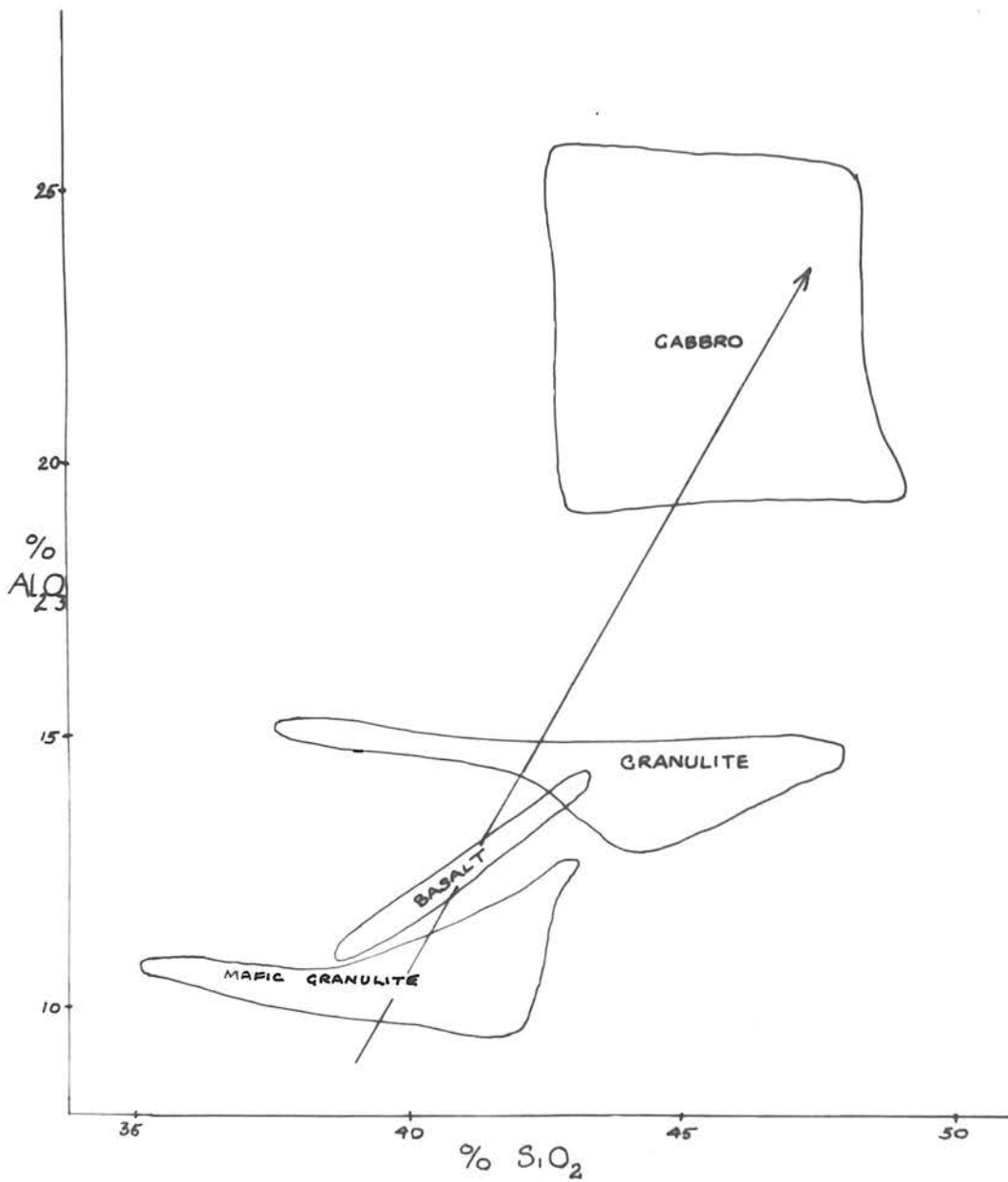


Figure 17. Variation diagram illustrating the variation in the $\text{Al}_2\text{O}_3/\text{SiO}_2$ ratio in the basic rocks of Beinn na Cro.

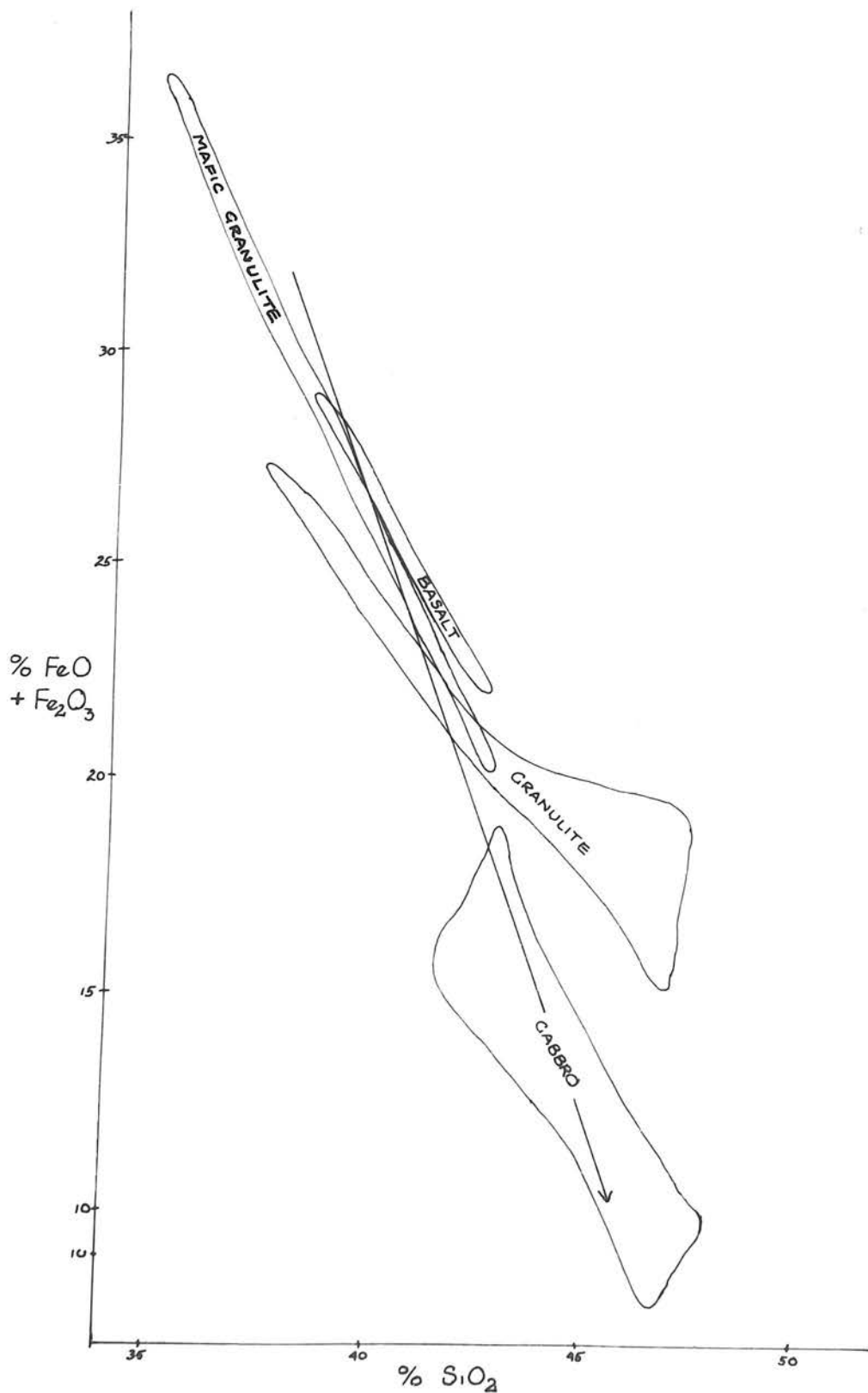


Figure 18. Variation diagram illustrating the variation in the $\text{FeO} + \text{Fe}_2\text{O}_3 / \text{SiO}_2$ ratio in the basic rocks of Beinn na Cro.

The variation in mineral proportion from basalt through granulite to gabbro is revealed by modal analyses (see pages 51-52 and Figs. 13 and ~~14~~¹⁴). The plot of these analyses shows that from basalt to granulite and from granulite to gabbro there is an increase in the percentage of plagioclase and a complementary decrease in the amount of mafic constituents. From basalt to mafic granulite, on the other hand, there is a decrease in the percentage of plagioclase and an increase in the amount of mafic constituents. The variations in mineral proportion are sufficiently large to indicate a variation in chemical composition. No actual chemical analyses were made of any of the rocks of Beinn na Cro. However, approximate chemical analyses were calculated from the modal analyses. The acidic groups contain such significant amounts of highly zoned plagioclase, microperthite and micropegmatite, that no attempt to calculate their chemical compositions could be made. Figure 16 shows the average calculated chemical compositions of the rocks of the basic groups, and Figures 17 and 18 are variation diagrams based upon individual analyses. The calculated amounts of SiO_2 , Al_2O_3 , FeO and Fe_2O_3 vary outside the limits of computational error and indicate that from basalt to gabbro there is, accompanying a slight increase in the silica percentage, an increase in alumina and a decrease in the iron oxides. From /

From basalt to mafic granulite, on the other hand, there is a decrease in silica and alumina and an increase in the iron oxides.

It has been established that the granulite has developed from the basalt as the result of metamorphism of this rock, and that the similarity of the gabbro to the granulite suggests that the gabbro may have been formed by a similar process. It was at first considered that the metamorphic agent was heat alone, the formation of the granulite and the increase in grain size indicating a significant rise in temperature. As there have been changes in chemical composition accompanying the changes in rock type, it is evident that a transfer of material must have taken place. The presence of the granulite and gabbro veins supports this premise, for had the metamorphism been caused by rise in temperature alone, it would be expected that the progressive changes in the basalt would mark isotherms which could be simply contoured. The veins have been shown to be of replacement origin and their very nature indicates that there can have been no increase in volume. Evidence that material may have been removed is afforded by the mafic granulite veins. These contain a higher percentage of mafic oxides, and are denser than either the rock which they cut or the associated granulite and gabbro veins. Further, the fine-grained mafic granulite veins are all /

all intermediate in age between the basalt and the granulite, while the coarse-grained mafic granulite veins are intermediate in age between the granulite and the gabbro. Thus it seems probable that the veins represent mafic material which has been expelled at the forefront of the metamorphic activity, the FeO and Fe₂O₃ being largely replaced by Al₂O₃ and SiO₂. The prevalence of sharp contacts and the complexity of the net-vein systems indicate that the metamorphism of the basalt could not have been the result of simple diffusional metasomatism. It is suggested therefore that the granulite veins were produced by the action of hot super-critical fluids upon the basalt, the presence of uralite in the basalt at the margins of the veins indicating that super-critical steam was an important constituent. Continued action upon the basalt resulted in the formation of the massive granulite. The internal variation and vein systems in the granulite, indicating sudden increases in grade of metamorphism, suggest that there were sudden increases in the metasomatic activity.

Although it is probable that the sudden change from granulite to gabbro was the result of a sudden change in conditions, such as a cessation followed by a renewal of activity, or perhaps even a change from metasomatic to magmatic conditions, though this is less likely, there is nothing to indicate the /

the true nature of this change. It is very likely, however, that the gabbro veins were formed in the same manner as the granulite veins, the greater grain size and larger amount of silica and alumina being the cumulative result of either more prolonged or more powerful activity.

The structure of the gabbro and the associated granulite, that of broad vertical arcuate sheets, suggests that the fluids which caused the formation of the granulite and some, if not all, of the gabbro ascended along major channels, possibly ring-fractures, thence percolating upwards and outwards along intergranular boundaries and other available passageways. There is no evidence for or against the chance that the gabbro was in part mobile and intruded along the main channels.

B. Explosion Dykes. The explosion dykes are confined to the gabbro and occur as narrow vertical dyke-shaped masses which strike parallel to the margins of the gabbro sheets. A transition may be traced along the dykes from a dyke-shaped system of alteration veins within the gabbro through gabbro-tuff to dolerite (Fig. 4). Although all three rock types generally occur within one dyke, several of the dykes are composed entirely of the dolerite. The majority of /

of the alteration veins are concentrated within narrow areas in which the gabbro, while remaining unbroken, has been intensely altered, with albitisation, uralitisation and the introduction of quartz and alkali feldspar. A subordinate number of alteration veins consist of granulite. That this granulite has been produced from the gabbro is evident from the presence of partially granulitised gabbro crystals at the margins of the granulite alteration veins. Moreover, although there is apparently no change in bulk composition from granulite to gabbro, the granulite is very variable in composition, and where narrow veins cut single crystals, it can be seen that where plagioclase is cut, plagioclase is dominant in the granulite, and where augite is cut, augite is dominant in the granulite.

Both types of alteration veins have manifestly been produced by alteration of the gabbro. In the more common type the effect is largely chemical, while the granulite veins suggest that heat has played a prominent part in their formation. In the normal alteration veins, however, the mineral assemblage suggests that the temperature has been somewhat lower, and their formation can be reasonably attributed to the result of action of hot aqueous solutions or gases containing silica and alkalies, percolating through the gabbro.

In /

In the transition from alteration veins to gabbro-tuff the veins increase in number and magnitude, causing blocks of gabbro to become isolated from the gabbro country rock. Simultaneously, the veins become increasingly shattered until they consist entirely of comminuted and altered gabbro. The gabbro-tuff consists largely of gabbro blocks, both angular and rounded, together with rare rounded basalt and granulite fragments, in a basic matrix of comminuted and altered small gabbroic fragments and crystals. The transition from the alteration veins to the gabbro-tuff is in no way abrupt and therefore indicates that the gabbro-tuff has been formed by a process related to that which produced the alteration veins.

Gabbro-tuff has been reported from other volcanic districts. In Arran, for instance, King (1953) discovered a rock of similar type to the Beinn na Cro gabbro-tuff. In discussing the origin of the Arran rock, King postulated that it had been formed as the result of the violent action of gas which had ascended along a line of weakness and shattered and comminuted the country rock. Fairbairn and Robson (1942) concluded that the breccias at Sudbury had been formed as a consequence of the permeation of fluids, possibly gases, under high pressure, along structural breaks. D.L. Reynolds (1954) has suggested that basic breccias of this type have been formed /

formed by fluidisation under sub-explosive conditions whereby gas (largely steam) has brecciated the country rock, there being little transport or change in chemical composition.

It has been concluded that the alteration veins formed as the result of the action of fluids upon the gabbro, and that the gabbro-tuff has been formed by a related process. The brecciated nature of the gabbro-tuff indicates that the gabbro was subjected to stress, and it is suggested that this stress was that of a fluid, the transition from alteration veins to gabbro-tuff revealing a gradual increase in pressure, mobility of the vein-fluid resulting in liberation of gabbro and other fragments at the initiation of the fluidisation process. The presence of rounded and alien fragments in the gabbro-tuff indicates that abrasion and transport of fragments took place.

The dolerite consists of scattered gabbroic fragments in a crystalline doleritic matrix. The transition from gabbro-tuff to dolerite indicates a progressive crystallisation of the dolerite from the gabbro-tuff. That the dolerite has not been comminuted to form tuff is evinced by the complete absence of dolerite fragments in the gabbro-tuff and of brecciation in the dolerite. Although the likelihood that the tuff was heated up sufficiently to produce a magma from which the dolerite crystallised cannot be ruled out, it seems /

seems more probable that continuation of abrasion and comminution within the tuff produced conditions of fluidisation (Reynolds, 1954), and that the dolerite was formed by crystallisation of the tuff when the bulk of the activity had ceased.

The presence of dykes consisting solely of this type of dolerite and so resembling normal hypabyssal dykes indicates that it is not improbable that the dyke-forming material was mobilised and intruded beyond the bounds of the gabbro-tuff.

It is concluded, therefore, that the explosion dykes were developed as the result of the action of fluids which initially formed the alteration veins. With increasing mobility of the liberated fragments the gabbro-tuff was produced, and it is suggested that actively-moving gases rather than permeating fluids were prominent at this stage. Finally, as the consequence of the fluidisation and recrystallisation of the gabbro-tuff, the dolerite evolved. The structure of the explosion dykes reveals that the location of the activity was predetermined by planes of weakness on the gabbro, these planes having the same structural origin as those which determined the structure of the gabbro.

C. Hybrid and Acidic Net-veins. Harker (1904) referred to the extensive systems of acidic net-veins within the /

the basic rocks of Beinn na Cro, and stated, page 139, "Veining on a minute scale is very characteristic of the basaltic lavas in the vicinity of the granite, and sometimes extends to very considerable distances from the contact, arguing a high degree of fluidity in the acidic magma. The phenomenon is well seen about Creag Strollamus, Beinn na Cro, Glamaig, Bellig, and elsewhere. It is very noteworthy that it affects the compact, not the amygdaloidal, varieties of the lavas, and it seems to have depended upon certain fissuring of these rocks prior to intrusion". Although Harker used only the term "acidic" it is probable that within it he included not only the true acidic net-veins but also the hybrid net-veins. It seems probable that such magmas are too viscous to permeate solid rock in the manner postulated by Harker, and therefore there must be doubt as to the validity of Harker's conclusions.

The hybrid and acidic net-veins occur in the lavas in a wide strip approximately parallel to the contact of the lavas with the Beinn na Cro granite. Although there are numerous net-veins associated with the great tongues and dykes, those at present under discussion, while of a similar type, are not clearly connected with the large acidic bodies, and are found through out the whole of the net-veined area of the lavas.

The net-veins are of two structural types. The less common variety occur as planar, subparallel-sided net-veins up to a foot across, which run straight for distances of up to 15 feet. Extending from, and cut by, these net-veins, are ubiquitous and more numerous net-veins which are tortuous and seldom exceed two inches in width. These net-veins generally exhibit swellings and constrictions.

The ease with which the contacts between lava flows can be traced across the net-veined area indicates that there has been little disturbance of the lavas despite ingress of large amounts of net-vein material. It is possible, but not probable, that the net-veins could have been emplaced as the result of adilational mechanism, some fracturing of the basalt allowing for slight displacement of loosened blocks without dislocation of the lines of contacts between flows. However, this process seems less likely, in view of the very large quantities of net-vein material and the lack of adequate disturbance of the lavas, than that of a replacement mechanism. The field evidence offers no satisfactory explanation of the type of replacement that could have taken place.

There are three petrological types of net-veins: acidified gabbro, hybrid, and acidic. The acidified gabbro net-veins occur furthest from the granite in the region of the gabbro. They are invariably tortuous and irregular and are /

are cut by hybrid and acidic net-veins which may follow the same channels as the acidified gabbro net-veins. Some of the hybrid net-veins are highly irregular but the majority, generally the broader ones, are somewhat planar. The hybrid net-veins are cut by the acidic net-veins which are the largest and the straightest net-veins. The acidified gabbro net-veins are thus the oldest, the hybrid net-veins are intermediate in age, and the acidic net-veins are the youngest.

While the contacts of the acidified gabbro net-veins and the hybrid net-veins with the basalt are invariably gradational, the larger, straighter acidic net-veins in some instances exhibit sharp contacts with the basalt. The basalt in the contact regions is markedly different in each case. At the gradational contacts the alteration of the basalt is manifested by increase in grain size, increase in the proportion of plagioclase, and decrease in the percentage of mafic minerals, while at the sharp contacts the basalt becomes finer in grain, granular, and more basic towards the contact. These differences, together with the contrasting field relations, suggest that the more basic net-veins were not formed by the same process as the most acidic net-veins.

(i) Acidified Gabbro Net-veins

The restriction of the acidified gabbro net-veins to the vicinity of the gabbro and gabbro veins at once distinguishes /

distinguishes these net-veins from the hybrid and acidic net-veins whose occurrence is more widespread. The acidified gabbro net-veinrock bears a remarkable resemblance to the normal gabbro, especially with regard to the plagioclase crystals, the only difference being that in the former rock the plagioclase is somewhat more sodic in composition and altered to albite and alkali feldspar. These factors indicate the likelihood that the acidified gabbro net-veins have been derived from normal gabbro. It is difficult to conceive how the large euhedral and interlocking plagioclase crystals could have been removed from the gabbro and transported intact and intruded along narrow tortuous veins. However, as a transition has been observed from massive normal gabbro to massive acidified gabbro, which suggests that the latter has been produced as the result of the acidification of the former (see page 82), it is likely that the acidified gabbro net-veins have developed in the same way by the alteration of gabbro veins. The presence of uralite, alkali feldspar and quartz in the acidified gabbro, in the place of augite, indicate that the alteration was conducted by aqueous fluids rich in silica and alkalies, the process operating for an insufficient time or at an insufficient temperature for complete alteration of the plagioclase. The pre-existing gabbro veins would have provided convenient channels along which the fluids could /

could percolate, and the local occurrence of very basic zones at the contacts of the basaltic country rock and the acidified gabbro composition of the net-veins suggests that excess mafic oxides derived largely from the augite were expelled into the basalt.

The veinlets which extend from the acidified gabbro net-veins into the basalt contain plagioclase crystals which span the contacts between the veinlets and the basalt, and, while the veinlets are coarser in grain than the basalt, and contain hornblende and biotite rather than augite, their texture resembles that of the adjacent basalt. These features suggest that the veinlets are replacement veins developed as the consequence of metasomatic alteration of the basalt. It is probable that the formation of the veinlets is due to the percolation of some of the acidic fluids from the acidified gabbro net-veins into the basalt.

(ii) Hybrid net-veins

Hybrid net-veins, which are both tortuous and straight, occur throughout the net-veined region of the basalt. A small number of net-veins of hybrid composition occur associated with the acidified gabbro net-veins, and as the texture of the former resembles that of the latter, the difference between the rocks lying only in the more acidic nature of the hybrid rock, it is more than likely that these hybrid net-veins were produced as the result of an extension of the process which formed the acidified gabbro net-veins.

The majority of the hybrid net-veins, however, are medium-grained and contain only scattered large plagioclase crystals. The basalt towards the contacts with the hybrid net-veins shows an increase in grain size and the appearance of quartz. The plagioclase crystals are rimmed by alkali feldspar, the augite has formed into large porphyroblastic crystals enclosing plagioclase, and uralite and biotite are present as alteration products of augite. This suggests that the basalt has been altered as the result of the introduction of potash and water and perhaps silica and iron oxides. The contacts of the hybrid net-veins and veinlets are similar; plagioclase crystals spanning the contacts with the basalt are ubiquitous, and the texture of the rock is not unlike that of the veinlets extending into the basalt from the acidified gabbro net-veins. This indicates that the veinlets and the margins of the hybrid net-veins could have developed by the alteration and metasomatic replacement of the basalt. In support of this conjecture is the presence, in the marginal regions of the net-veins, of augite containing inclusions similar to the augite porphyroblasts in the basalt. Although the margins of the hybrid net-veins are rich in plagioclase, there is a transition to the interiors of the net-veins where alkali feldspar is dominant. The textural relationship of the alkali feldspar to the plagioclase indicates that the former has been developed as the result of late stage /

stage deuteric action upon the latter. The balance of evidence suggests that the hybrid net-veins have developed largely by replacement of the basaltic country rock.

(iii) Acidic net-veins

There are two types of acidic net-veins. The less common net-veins are tortuous, and somewhat variable in texture and composition. The basaltic country rock has been acidified at its contacts with these net-veins, and veinlets extending from the net-veins grade into the basalt. Plagioclase crystals spanning the junctions between the basalt and the net-veins and veinlets are of frequent occurrence. There is nothing to suggest that this type of acidic net-veins was formed by any process other than that which formed the hybrid net-veins.

More abundant, however, are the straight parallel-sided acidic net-veins which have sharp contacts with the basalt. At a short distance from the contacts the basalt shows alteration in the form of albitisation of the plagioclase. Towards the contacts the basalt becomes finer in grain, granular and subvariolitic in texture and there is an increase in the percentage of augite and iron ore.

Fine-grained margins of basic rocks against acidic net-veins have been reported from Slieve Gullion by Reynolds (1954) who concluded that the dolerite had been melted by the acidic /

acidic material, and had subsequently solidified as a glass which has since devitrified. Although the fine-grained margins described on page from Beinn na Cro are similar in many respects to the phenomena observed by Reynolds, here no glass has been found, and evidence of melting is thus lacking. The granulitic nature of the basalt, however, does indicate that there has been considerable heating of this rock. The relationship of the granulitic margins of the basalt to the acidic net-veins cannot easily be explained by any hypothesis other than granulitisation as the result of heating by the acidic material. The higher proportion of mafic constituents in this region of the basalt suggests that the basalt has also been basified.

The veinlets which extend into the basalt from the acidic net-veins are tubular in shape and grade into the basalt at their extremities. These factors indicate that the veinlets have apparently formed by replacement of the basalt. The veinlets are granular and consist of albite, augite and a little quartz. Such an assemblage is consistent with the suggestion that the veinlets have evolved by metasomatic replacement of the basalt under the influence of acidic fluids.

The texture of the acidic net-veins themselves differs so markedly from that of the veinlets and the basalt that it /

it is extremely unlikely that the acidic net-veins have originated by direct transformation of the basalt. A striking feature of the acidic net-veins is the presence of rounded grains of quartz and orthoclase enclosed in alkali feldspar porphyroblasts. The included nature of the crystals reveals their earlier age, while their shape suggests that it is not impossible that they could have been transported. Also ubiquitous within the net-veins are highly altered oligoclase crystals rimmed by alkali feldspar. These resemble the orthoclase crystals in such a way that it is not improbable that they too have been transported. A transport medium that at once springs to mind is magma. The lack of disturbance of the lava is not easy to explain if magma has been injected into the basalt, and if the net-veins have been formed as the result of a replacement mechanism, it is equally difficult to explain why, and how, viscous acidic magma would follow immediately upon a gaseous and explosive phase necessary for the prior removal of the basalt. The presence of transported fragments, however, is inconsistent with metasomatic replacement of basalt, and some mechanism other than magma must be sought to explain the presence of the acidic net-veins within the lavas.

D.L.Reynolds (1954), confronted by a similar situation, demonstrated /

demonstrated that the transgressive granophyres of Slieve Gullion had been formed by fluidisation. The remarkable similarity of appearance of the net-veins of Beinn na Cro to those of Slieve Gullion suggests that the former could have been produced by a similar mechanism. The greater amount and variety of transported fragments in the Beinn na Cro net-veins would appear to be due to either a lower temperature or a shorter length of time of formation of the net-veins as compared with the conditions inferred for Slieve Gullion. A lower temperature is borne out by evidence from the basalt at the margins of the net-veins.

It seems probable therefore that the acidic net-veins of Beinn na Cro were formed by emplacement of fluidised systems. The systems appear to have consisted largely of particles of quartz, together with orthoclase and oligoclase, suspended in gas. As the material interstitial to these particles is chiefly alkali feldspar and quartz, it appears that the gas was rich in silica and alkalies. It seems likely that, following a reduction in the pressure and velocity of the gas the final stages of the process consisted of a settling of the fragments into a tuff-like deposit, and that gentle gas-fluxing through this incoherent debris resulted in its transformation into the solid rock of the acidic net-veins.

D. Massive Hybrid Rocks. In the field, the massive hybrid rocks are almost indistinguishable from the massive gabbro and the dolerite of explosion dyke type, and they occur with these two rocks within the gabbro sheets in the Allt na Gobhar area. A petrographic sequence can be traced between the basic rocks and the hybrid rocks, and, while the composition of the latter differs greatly from that of the former, there are three very striking textural similarities. The large plagioclase crystals of the coarse-grained hybrid rock exhibit poly-twinning, and occur as elongate crystals, thus giving the hybrid rock a gabbroid texture. The groundmass of the medium-grained hybrid rock resembles that of the dolerite, and the former contains large plagioclase crystals similar to those of the coarse-grained hybrid rock, while the latter contains large plagioclase crystals similar to those of the gabbro. Therefore it seems reasonable to suppose that the massive hybrid rocks are highly acidified gabbro and dolerite, and that the plagioclase has been partially albitised and altered to alkali feldspar and quartz, and the augite and iron ore almost totally replaced by uranalite, alkali feldspar and quartz. It is likely that this alteration was the result of thorough soaking of the gabbro and dolerite by emanations rich in silica and alkalies.

E. Acidic Dykes and Tongues. The narrow vertical acidic dykes which occur in the region of the Allt na Caoraich strike north-westwards, and are cut by more westerly trending tongues, thus establishing that the former are of an earlier age than the latter.

(i) Acidic Dykes

From the edges of the acidic dykes systems of tortuous net-veins extend into the dolerite (and basalt) lava country rock. The net-veins are generally acidic. They contain large plagioclase crystals similar to the plagioclase phenocrysts in the dolerite, from which they appear to have been derived. Elongate plagioclase crystals spanning the contacts of the net-veins with the dolerite suggest that the margins of the net-veins at least were formed by metasomatic replacement of the dolerite. However, granular quartz grains, which are not interstitial, but which seem to have been transported, are common, especially where the net-veins join the dykes. The marginal regions of the dykes are similar in texture to the rock of the net-veins but differ in containing a much lower percentage of quartz. There is a transition from the margins to the interiors of the dykes. The interiors are considerably more acidic and contain numerous broken relic plagioclase crystals which are extremely altered and rimmed by porphyroblastic microperthite. This microperthite also encloses /

encloses rounded quartz grains which are more abundant than at the margins of the dykes. These broken and rounded crystals are undoubtedly of early formation and they appear to have been transported. Two types of zircon, large round grains and small prisms are present. It seems unlikely that both were formed under the same conditions and it is suggested that the rounded crystals are the earlier and that they also have been transported. The progressive alteration of hornblende to biotite (the latter occurring towards the centres of the dykes) is another characteristic of the dykes, which, with the microperthite porphyroblasts, suggests that there has been formation of dyke minerals in the solid.

The transport of some minerals was at first thought to indicate that the dykes were magmatic in origin. However, the transition from the dykes to the net-veins which seem to have been formed by replacement of the dolerite, indicates that the margins of the dykes at least did not crystallise from magma. On the other hand, the margins of the dykes contain transported fragments. In the face of these apparently anomalous and contradictory factors, it is suggested, therefore, that the acidic dykes formed as the result of uprush of gases under pressure, transporting quartz, plagioclase and zircon. It is probable that erosion of the fissure walls played /

played a considerable part in the production of space for the dykes. While there is no indication of the stage at which the net-veins formed, it is suggested that quartz grains were expelled into crevices outwith the main gas stream, and that alteration of the dolerite into net-veins and subsequent out-growth of net-vein rock to include the quartz grains, were processes which operated throughout the history of the formation of the dykes. The presence of quartz, plagioclase fragments and zircon in the marginal as well as the interior portions of the dykes suggests that the more basic outer part of the dykes were formed, not by metasomatism of the dolerite, but rather as the result of mechanical mixing of basic attritus with the incoming fragments. It is reasonable to suppose that while in the interiors of the dykes the resultant movement of the gases was essentially linear, towards the margins friction caused turbulence with a consequent reduction of effective transportation. Accordingly, the interiors of the dykes, almost wholly composed of acidic material, would remain uncontaminated while eddying towards the margins would promote thorough mixing of basic and acidic material. That the temperature of formation of the acidic dykes was not very high is revealed by the lack of contact heating effects in the dolerite and the presence of very numerous transported fragments which show no signs of melting.

It /

It is probable that after a reduction in gas pressure there was settling of the material in the dykes to form a tuff-like aggregation of fragments, and that gentle gas fluxing caused the formation of interstitial minerals and porphyroblasts. It seems likely that the biotite was evolved at this stage as the result of greater activity in the interiors of the dykes. The presence of late microperthite and biotite, non-fragmentary hornblende and zircon, indicate that the gases consisted of steam containing K_2O and ZrO_2 . In view of the presence of fragments of quartz and plagioclase, and the high solubility of SiO_2 and Na_2O in steam (Morey, 1954), it is highly probable that these and other oxides were also in solution.

(ii) Great Tongues

The great tongues are straight vertical acidic or hybrid bodies which extend from the granite mass of Beinn na Cro and cut the basic rocks. Although the tongues differ from one another in their petrography and contacts with the basic rock, the gradation into the granite indicates not only that they have a common mode of origin but also that their genesis is intimately connected with that of the granite.

No evidence for the displacement of the country rock by either the tongues or the granite has been found. Further, small /

small blocks of basic rock which seem to be totally enveloped in the acidic rock are undisturbed, a feature which suggests that the tongues have developed by a mechanism other than that of simple dilation.

Some of the tongues are fine or medium-grained, and granular or felsitic in texture. The contacts of these tongues with the basic rocks are sharp, and at the contacts the basic rock is extremely fine-grained, granulitic or sub-variolitic in texture, and more basic than the bulk of the country rock. These characters are so similar to those found at the contacts of the acidic net-veins that the same inferences, namely heating of the basalt without melting, and basification, may be drawn.

Other tongues, usually the broader ones, are medium or coarse-grained and generally granitic in texture. The contacts with the basic rock are transitional, and the basic rock towards the contacts is coarser in grain and more acidic. In these cases there is no evidence of heating of the country rock. Net-veins extend from the tongues and are abundant. The contacts of these with the basalt or dolerite are transitional and exhibit the same features as the contacts of the hybrid net-veins described on pages 33-36, thus suggesting that they have developed by a similar process. The transition from /

from net-veined basalt through xenolithic microgranite to the tongue rock by reduction in amount of basic material, indicates that the process of formation of these three types is closely allied. Although dolerite occurs only a few feet from the xenolithic microgranite (Fig. 5), the blocks in the xenolithic microgranite are all basaltic, and this together with the transition from net-veined basalt to xenolithic microgranite suggests that there was little transport of the blocks of basalt. The microgranitic matrix of the xenolithic microgranite is more basic than both the net-veins and the tongue-rock and it seems likely that the microgranite has been basified by the incorporation of basaltic material.

The lenticular mass of basic hybrid rock occurring towards the south-western side of the largest tongue (Fig. 5), exhibits a significant variation in mineral composition and grain size. The tongue cuts a flow of hypersthene dolerite intercalated between basalt lavas. In that part of the hybrid lens corresponding in its disposition to the hypersthene dolerite, the hybrid rock is coarse-grained and rich in hypersthene. In that part of the lens corresponding to the basalt, the hybrid rock is medium-grained, consisting of elongate plagioclase crystals in an acidic matrix, and the texture of the rock is similar to that of the basalt. Hypersthene is notably /

notably absent. It seems likely that this lens of hybrid rock is a highly altered remnant of country rock, which may not be completely detached, and which most certainly has not been displaced. The tongue-rock associated with this lens exhibits a number of definitive features. Again, corresponding in position to the hypersthene dolerite, the tongue-rock, although more acidic than the lens-rock, is coarser in grain than usual and rich in hypersthene. These facts appear to indicate that the country rock has been metasomatised to form these regions of the tongue.

The tongues differ markedly from the acidic dykes in that they contain no evidence of transported fragments.

It was borne in mind that the tongues could have been formed as the result of magmatic intrusion, in the manner postulated by Harker, and that the transitional margins and the hybridisation might be metasomatic manifestations of contact metamorphism. However, it is difficult to envisage how the basic blocks enveloped in the acidic rock to the south of the tongue region could have remained in their original positions in the extremely less dense acidic magma.

On the other hand, the absence of large scale basic fronts does not favour the hypothesis that the tongues have developed by metasomatic replacement of basic country rock.

A fluidisation mechanism was also considered, but the coarse-grained hypersthene-rich area of the large tongue can only be consistent with this mechanism if conditions of perfect elutriation obtained (Cloos, 1941; Reynolds, 1954). However, the lack of corroborative evidence that such conditions occurred on Beinn na Cro renders pregnable the application in this case of such a special hypothesis.

It is suggested that detailed examination of the main Beinn na Cro granite is required before any conclusions as to the origin of the great tongues can be made. Such a survey was attempted by the author, but in the paucity of exposed contacts of granite with rocks other than the basic rocks occurring at the northern end of the mass, little additional information concerning the genesis of the granite and the tongues could be adduced.

F. Quartz-porphyry. The quartz-porphyry minor intrusions cut both the basic rocks and the granite of Beinn na Cro, and are thus the youngest of the Beinn na Cro rocks which are mentioned in this thesis. No effects have been observed in the granulite adjacent to the quartz-porphyry, however the granite in contact with the latter has been granulitised. This suggests that the quartz-porphyry was emplaced at a temperature high enough to metamorphose the granite but too /

too low to cause any changes in the granulite. The chilled edges of the quartz-porphyry indicate that there was a steep temperature gradient between the incoming material and the country rock. The inference drawn from the presence of spherulitic material and glass within the quartz-porphyry, is, that at the time of emplacement, the rock was in a melted condition, and that this, together with the fluxion structure at the margins of the quartz-porphyry, which appears to indicate flowage of viscous material, suggests that the quartz-porphyry was emplaced by means of magmatic intrusion.

The folds within the fluxioned margin of one of the quartz-porphyry sheets show that movement has taken place prior to final consolidation and that the sense of movement of the interior of the intrusion relative to the hanging wall was downhill (Fig. 11). The lack of exposures of the lower margin of this intrusion renders inconclusive any explanation of the origin of the folds. It is suggested therefore that either, subsequent to intrusion, the foot wall moved downhill relative to the hanging wall, dragging the quartz-porphyry with it; or, that the intrusion was emplaced from above; or, that at the close of the intrusive phase, ebbing of material already emplaced resulted in downwards dragging of the interior of the quartz-porphyry.

None /

None of the large crystals and crystal aggregates within the quartz-porphyry appear to be phenocrysts, they seem rather to be fragments. The assemblage of the fragments indicates that, while most of them may be matched with Beinn na Cro rocks, the presence of basic fragments at considerable distances from basic outcrops suggests that there has been a significant amount of transport of particles. The shattered nature of the fragments, especially quartz, indicates that they may have been removed from their place of origin by disruption rather than solution of their host rock. The majority of the fragments are corroded and embayed, subsequent to the shattering, and rimmed by glass and cryptopegmatite, thus indicating that they have been melted. The sharp boundaries between the rims and the groundmass of the quartz-porphyry is not easily explained if the rims represent similar material as the groundmass, that, with or without reaction, have crystallised around the fragments.

The relative distribution of the fragments, which occur towards the interiors of the quartz-porphyry, and the spherules, which are abundant towards the margins, reveals that in the interiors of the intrusions the rate of flow of the incoming magma was more rapid than at the margins, and it is suggested that this was not necessarily due only to the retarding /

retarding effect of friction against the walls, but that it could also have been due to the high viscosity of the rapidly chilling margins of the quartz-porphyry.

VII /

VII. SUMMARY and CONCLUSIONS

Basic rocks occur towards the northern end of Beinn na Cro. These consist of lavas, granulite, gabbro and dykes, which have been invaded by large quantities of acidic material which is manifested by net-veins, hybrid rocks, dykes and tongues. Later, quartz-porphyry minor intrusions were emplaced.

1. Basaltic lavas, the oldest rocks, have been locally metasomatised into granulite.
2. Subsequently, gabbro was emplaced by a process related to that which formed the granulite.
3. The granulite and gabbro occur together in sheets which at the time of emplacement were vertical and arcuate.
4. The metasomatism was achieved by means of addition of heat, silica and alumina and expulsion of iron oxides.
5. While the granulite and the margins of the gabbro can be shown to be of metasomatic origin, there is no evidence to indicate how the interior of the gabbro was emplaced.
6. Explosion dykes were emplaced along planes of weakness similar to those determining the location of the granulite and gabbro.
7. The explosion dykes were formed by explosive and fluidisational activity resulting in the ultimate formation of dolerite.
8. The basic rocks are involved with acidic rocks of younger age.
9. /

9. Several types of net-veins are present. The earliest of these were formed by acidification in the solid of gabbro veins by percolating aqueous fluids rich in silica and alkalies.
10. Subsequently, hybrid net-veins were formed by further acidification of basic rock by similar processes.
11. Later, entirely acidic net-veins were emplaced, probably by a fluidisation mechanism involving the transport of quartz and feldspars in acidic gas.
12. Massive hybrid rocks were formed as the result of soaking of basic rocks by aqueous fluids rich in silica and alkalies.
13. Acidic dykes were formed by a fluidisation mechanism which operated at a lower temperature than that which produced the acidic net-veins.
14. Quartz, plagioclase and zircon were brought in, and turbulence near the margins of the dykes resulted in mixing of basic country rock attritus with incoming material to form hybrid margins to the acidic dykes.
15. Of later age are great tongues which merge into the Beinn na Cro granite. No conclusion has been reached regarding the origin of the tongues or the granite.
16. Late-formed are the quartz-porphyry minor intrusions which were perhaps emplaced at a higher temperature than the other acidic rocks of Beinn na Cro and which appear to be magmatic in origin.
17. Thus, while all the basic intrusive rocks were probably formed by processes closely related in their origin, and while there seems to be a relationship between all the hybrid and acidic rocks, excepting perhaps the quartz-porphyry, no link has been found which would suggest relationship between the formation of the granulite, gabbro and explosion dykes and the formation of the net-veins and massive hybrid and acidic rocks.

C R E A G A N D U B HI. INTRODUCTION

Creagan Dubh forms the northern end of Beinn Dearg Mhor and is three-quarters of a mile to the east of Beinn na Cro. The main outcrop of the rocks of Creagan Dubh is a sloping crag between 750 and 1750 feet above sea level, and is a little over a mile long, measured from north-east to south-west, and half-a-mile wide. The region to be described extends a little beyond the crag itself, and is bounded on the north-east by the Allt na Teangaidh, on the north-west and north by An Teanga, on the south by the Allt Beinn Dearg Mhor, and on the south-east by the scree-covered shoulder of Beinn Dearg Mhor. Creagan Dubh was mapped on the scale of about 24 inches to one mile and consists of, at the base, a series of interbanded gneiss, tuff, agglomerate and basic igneous rocks, overlain unconformably by lavas which have been intruded by agglomerate, all of which are of Tertiary age (Plates XXVI, XXVII). The complex is cut by a late suite of basic dykes, belonging to the regional dyke swarm of Skye.

II. FIELD RELATIONS

(Map, back pocket)

Although Jurassic rocks are exposed immediately to the north of the area, their contact with the Creagan Dubh rocks is nowhere seen. The granite of Beinn Dearg Mhor is frequently exposed within a few feet of the volcanics, but its actual junction with them is visible only in the beds of the upper branches of the Allt na Teangaidh, where the contact is seen to be a fault, the Coire Garbh fault. The line of this fracture may be traced south-westwards up the side of Coire Garbh along the edge of the crags as far as the summit of Creagan Dubh. Along the line of the fault both the granite and the volcanic rocks are brecciated, the latter passing rapidly into massive rock, forming strong cliffs, away from the fault zone (Plate XXVIIIa). On the western side of the hill, no shatter belt is exposed. The volcanic rocks occur at a lower topographic level than the granite, with the result that the granite screes have completely hidden the contact. The western limit of the Creagan Dubh rocks is not seen in Srath Beag, owing to a deposit of boulder clay and peat.

1. Lower Group

This group contains the oldest rocks in the area and consists /

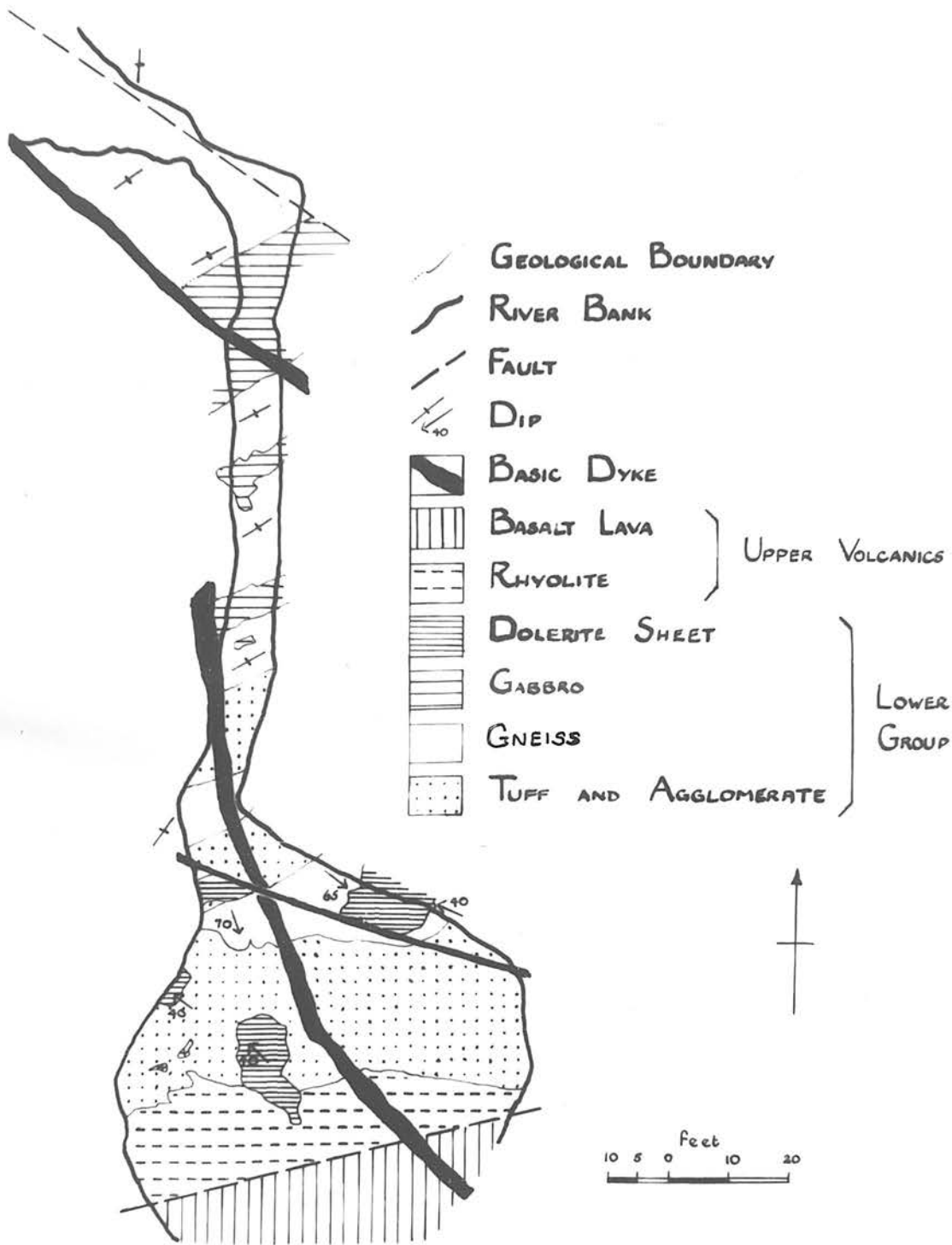


Figure 19. Geological map of the Allt na Teangaidh stream section.

consists of at least 750 feet of interbanded gneiss, tuffs and agglomerate, together with basic rocks. The base of the group is not seen and its upper surface is an unconformity. The rocks extend in a wide arc around the foot of Creagan Dubh, forming its northern and western extremities. A representative section across the strike of the gneisses occurs in the bed of the Allt na Teangaidh where over a distance of about 300 feet there is a continuous exposure of gneisses, agglomerates and basic rocks (Fig. 19). At the lower end of the exposure the stream is about ten feet wide; at the upper end it splits and rejoins and the total width of exposure is nearly sixty feet.

Starting at the downstream end, the rock on the right (eastern) bank is granitic in appearance. It is faintly foliated and grades upstream into gneiss which is strongly foliated; the foliation is vertical and strikes northwards. Some twelve feet upstream the rock contains basic bands and lenticles two inches wide, spaced at intervals of about two feet, and gives way over a few feet to a darker rock whose streaks and blebs of basic material show a rough parallelism to the somewhat irregular foliation. These rocks are cut off from the rest of those of the Allt na Teangaidh sections by a fault which strikes south-eastwards.

On /

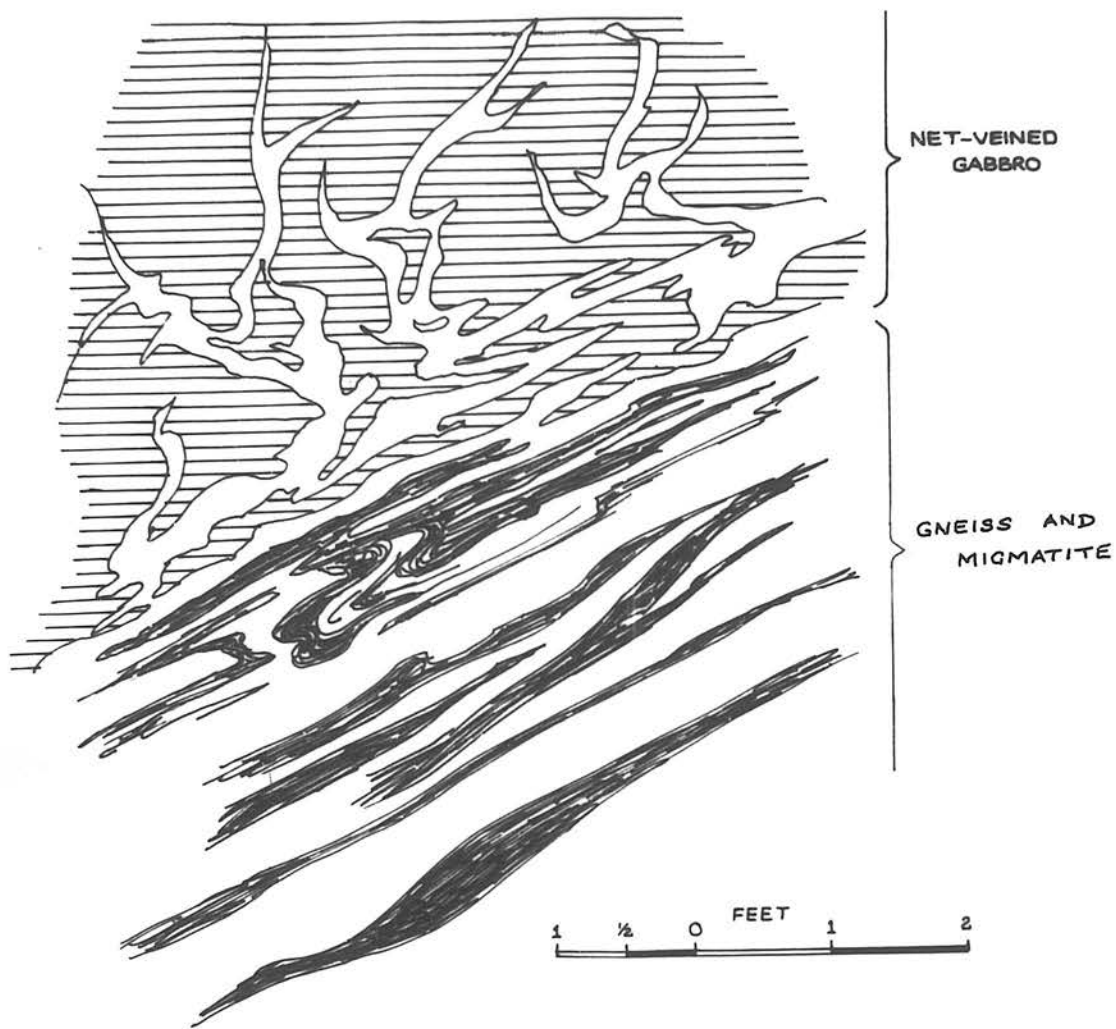


Figure 20. Diagrammatic sketch of a contact between gneiss and gabbro of Creagan Dubh.

On the opposite side of the stream, which has here deviated from its usual northerly flow to travel along the line of the fault, the gneiss is similar to that of the right bank. Although the foliation is vertical, the strike here is east-north-easterly. The foliation is well developed but is on a small scale, each lamina being only a few millimetres thick, or at most a few centimetres. A few feet further upstream this rock loses the regularity of its foliation, and grades over a distance of three feet into net-veined gabbro (Fig. 20). The net-veins are acidic and appear to be continuous with the leucocratic laminae of the transitional rock, while the gabbro appears to grade into the dark coloured parts. The junction between the gabbro and the gneiss is parallel to the foliation of the gneiss. The gabbro is 22 feet wide and its upstream contact is parallel to its downstream one and is of a similar nature. Continuing upstream, the foliation of the gneiss is somewhat irregular over a distance of 28 feet, and this rock contains another patch of gabbro which, although irregular in outline, lies approximately parallel to the foliation. The gabbro contains a few narrow acidic net-veins.

Above this locality the regular foliation is again seen, each lamina being about two cms. in thickness. Within the gneiss is a gabbro patch ten feet wide, lying parallel to the foliation. The gabbro differs from those downstream in /

in that its contacts are sharp. Four feet upstream, a boulder-like mass of gabbro about two feet wide and six feet long lies within the gneiss, the foliation of which is broken around the gabbro. Upstream the gneiss passes into twenty feet of pale-coloured slightly banded granitoid rock which in turn grades into agglomerate consisting of discrete aggregates of quartz and feldspar and basic fragments in a blotchy dark-coloured matrix. The rock is spotted in appearance, with an average fragment size of under two centimetres. The agglomerate is about forty feet thick and contains concordant lenses of gneiss.

In the wider part of the stream there is a slight change in the geology. The above-mentioned agglomerate sharply transgresses the foliation of the gneiss, which dips at 60° to the north-west (Plate XXVIIIb). In the bed of the easterly divergence of the Allt na Teangaidh this gneiss, 15 feet wide, is in sharp contact with 12 feet of sparsely net-veined basic igneous rock. The junction dips at the same angle as the gneiss, but irregularly transgresses it along the strike. The upstream contact is also parallel to the lamination of the gneiss which here dips at 40° to the south-west. A few feet beyond the dolerite the gneiss gives way to a large mass of agglomerate.

In the bed of the westerly divergence, the same rock types /

types are present but are slightly differently associated. The basic rock occurs some twenty feet to the west of its position in the other part of the stream, and the bulk of the gneiss occurs upstream of the basic rock, and extends for about 15 feet, grading rapidly through hornblende gneiss and diorite into agglomerate. The agglomerate is thirty feet thick and is overlain unconformably by rhyolite lava of the lava group. This flow dips at 30° to the north, and only a few inches of it are preserved, capping the agglomerate at the base of a ten-foot fault scarp, striking east-north-eastwards, where the fault has brought basalt lava down against the rhyolite.

Intermittent exposures of the Lower group occur in the knolls at the northern end of Creagan Dubh, and also in the steep grassy slope which forms the nose of the crag. Much of the outcrop is of a granular spotted rock which grades into gneiss. The latter is distributed in sheets and the foliation dips very irregularly at low angles to the south and south-east, and a structure resembling cross-bedding is well displayed and account for the apparent irregularity of dip. Towards the south-west, the low ground is largely occupied by scree, boulder clay and peat, and the rare exposures consist of agglomerate or pale-coloured spotted rock and /

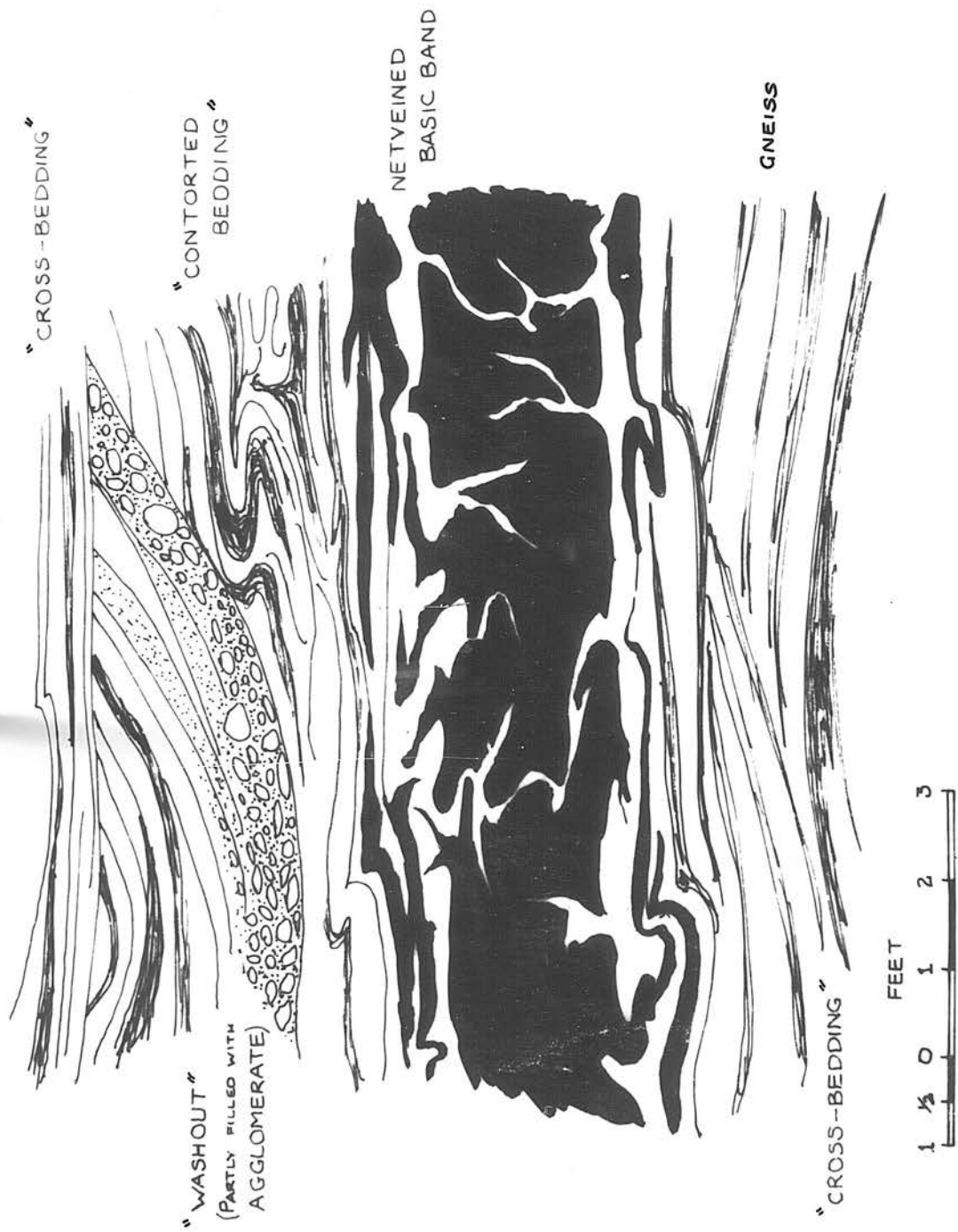


Figure 21. Diagrammatic sketch of typical relationships between gneiss, agglomerate and basic rock of Creagan Dubh.

and white pegmatite. The Lower Group is also found here at a higher topographic level, reaching more than half-way up the face of the crag. This new position is due to a fault, striking north-westwards, which has displaced the Lower Group in a sinistral sense. The majority of the exposures occur on glaciated surfaces. The rocks of this locality consist of layers of gneiss together with agglomerate, spotted rock, which together occur in almost equal proportion to the gneiss. The gneiss grades into the agglomerate and spotted rock, and the foliation is parallel to structures which appear to be bedding in the agglomerate (Fig. 21). The foliation of the gneiss is contorted, especially where there is a transition from gneiss to agglomerate and spotted rock, and at the contacts with basic rocks (see page 99). Irregularity of the foliation also takes the form of "cross-bedding". At one locality, the contact between the agglomerate and gneiss consists of a very fine-grained laminated rock which may well be mylonite.

Present within the Lower group are masses of granite, intermediate rocks and gabbro and basalt. The granite occurs as ill-defined areas which grade into both the gneiss and spotted rock and in some instances occurs as a transition zone between the two. Intermediate rock-types are represented somewhat sparsely. A hornblende-feldspar rock, in part foliated /

foliated and resembling hornblende gneiss, and in part massive and resembling diorite, occurs in the Allt na Teangaidh section (see page 101), and very small patches of diorite and acidic anorthosite are associated with the large patch of gabbro on the north-western side of Creagan Dubh (map, back pocket).

This gabbro lies within agglomerate and spotted rock of the Lower group. It forms an irregular area some 75 yards square and peters out in all observable directions excepting to the east where it is truncated by a north-westwards-trending fault. Associated with the gabbro are small patches of diorite, acidic anorthosite, granite and granite pegmatite, all lying haphazardly in the agglomerate. This agglomerate is formed of large blocks of various kinds of rock which, up to a foot across, are scattered throughout the matrix which is composed of coarse-grained spotted rock.

Occurring within the Lower group are numerous bands of basic rock which lie parallel to the foliation of the gneiss (Plate XXIX). Although the volumetric distribution of these appears to be fairly uniform through the area, those bands whose thickness is mappable occur chiefly towards the north, whereas a greater number of very narrow bands is to be found in the south. These bands within the gneiss are net-veined /

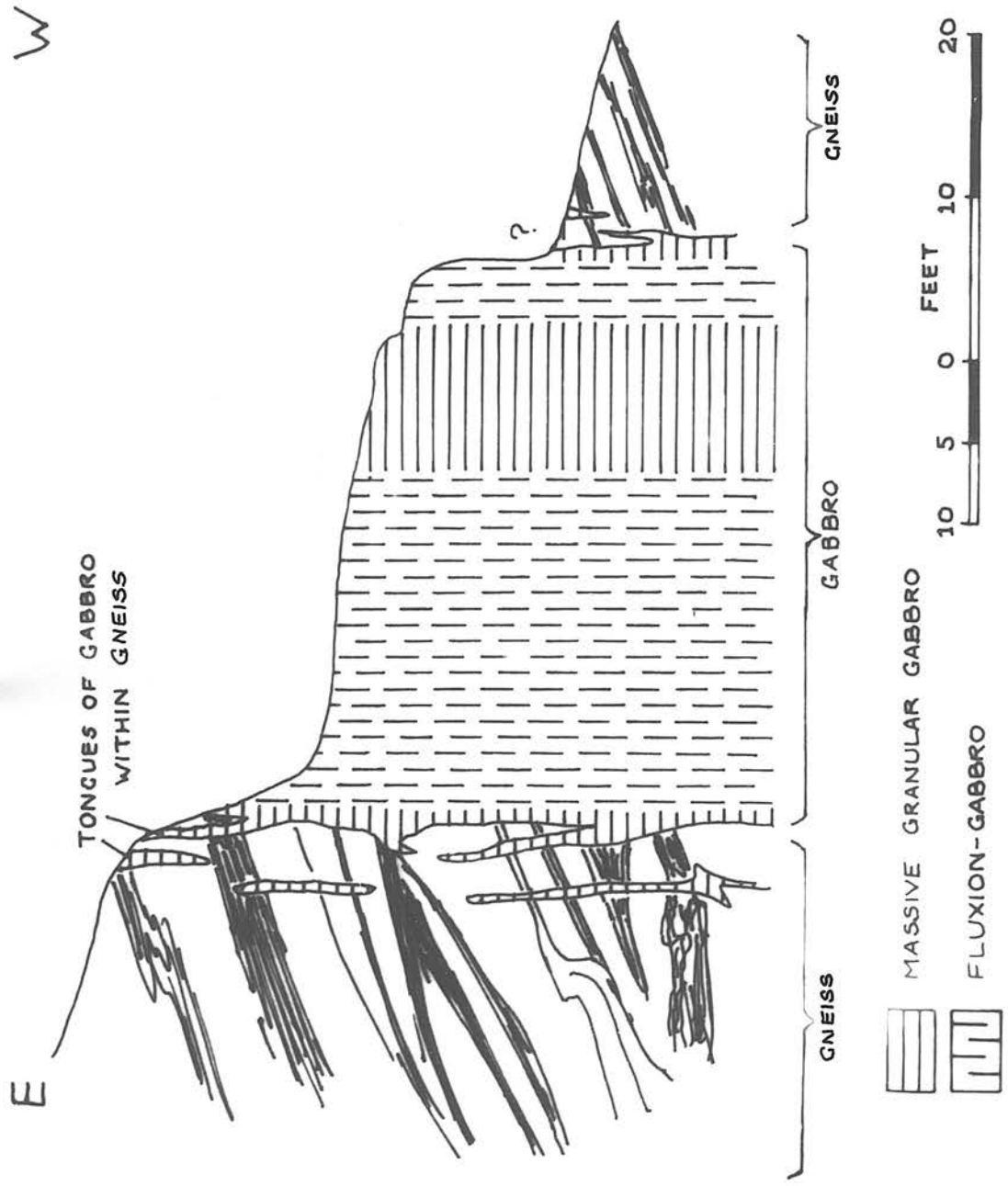


Figure 22. Diagrammatic cross section of the fluxion-gabbro dyke of Oregon Mts.

net-veined and are transitional into the gneiss. The knolls at the northern end of Creagan Dubh are composed of basalt, which forms layers, up to fifty feet thick, within the gneiss. Higher up the Group and higher up the slope are numerous streaks and lenses of gabbro lying parallel to the foliation. Above them are larger and longer sill-like masses of gabbro and a vertical gabbro dyke, part of which exhibits fluxion structure (Fig. 22). The fluxion-gabbro dyke lies within gneiss which dips at 10° to the south^{-east}. The dyke is 34 feet wide and strikes north-eastwards. It is cut off at its eastern end by a fault, and at its western end is overlain unconformably by lavas. The northern contact of the fluxion-gabbro dyke with gneiss is not seen although its position may be determined fairly accurately. Although the interior of the dyke is massive over an average width of ten feet, the gabbro towards both margins exhibits marked fluxion structure, the width of the fluxion zones being four feet on the northern side and twenty feet on the southern side. Narrow sub-vertical veins of massive gabbro extend from the southern margin of the dyke into the adjacent gneiss.

Two other basic bodies occur close to the extreme south of the Lower group. Both are basaltic and are almost vertical and strike east-north-eastwards somewhat across the foliation /

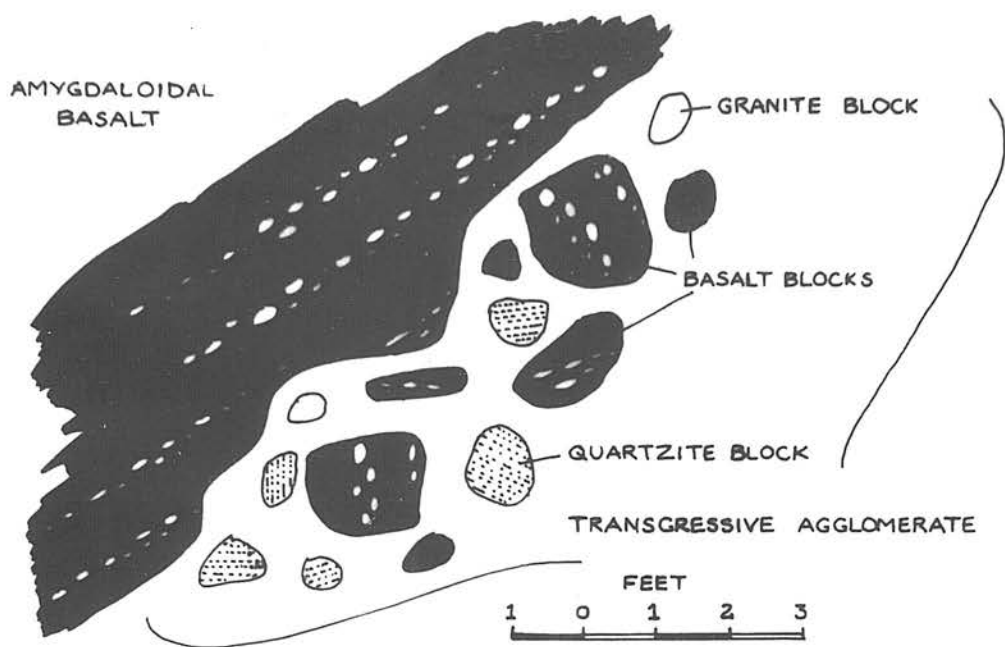
foliation of the gneiss. The northerly of these is about 90 feet wide and along part of its northern margin passes into gabbro. The southerly basalt is over 100 feet wide, and as its relationship to the Lower group is not clear, it may be lava belonging to the overlying Lavas.

2. Lavas

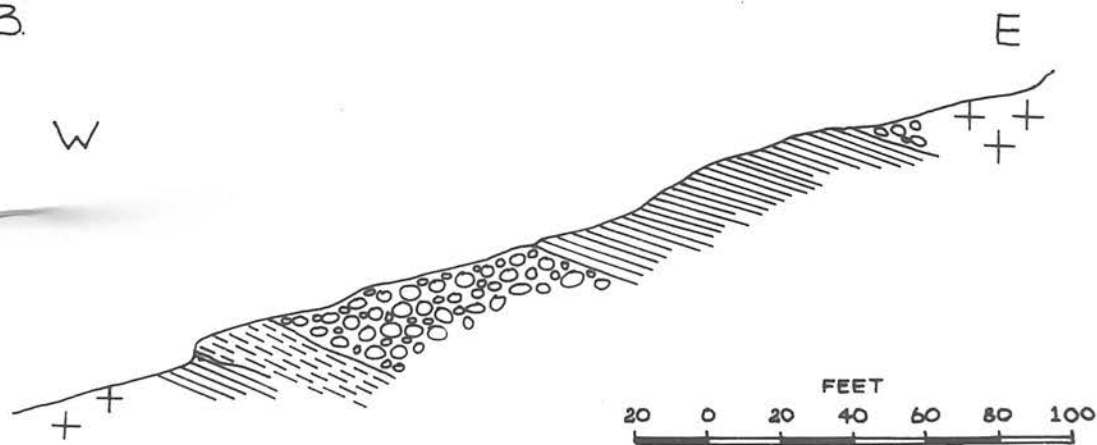
The lavas, resting unconformably on the Lower group are of the order of 1500 feet thick. They extend from far to the east of the Allt na Teangaidh, outside the Creagan Dubh area, to the southern part of Creagan Dubh, and form the most outstanding part of the crag. The lower flows are dark coloured, massive and somewhat indurated. Sparse amygdaloidal bands along with the poorly-visible contacts between flows indicate an average dip of 50° to the south-east. The higher flows, occurring towards the southern end of Creagan Dubh are pale in colour and associated with a large volume of transgressive agglomerate. Numerous bands of quartz-filled amygdales (Plate XXXIa) reveal that the lavas strike east-north-eastwards, and, although their dip may be as low as 30° , more usually the lavas are vertical or even slightly overturned towards the south-east.

Near the base of the lavas, exposed in the bed of the Allt na Teangaidh, are two beds of slightly hornfelsed mudstone /

A.



B.







-  GRANITE
-  AGGLOMERATE
-  AUTOBRECCIATED RHYOLITE
-  RHYOLITE

Figure 23.

- A. Diagrammatic sketch of a contact between lava and transgressive agglomerate of Creagan Dubh.
- B. Vertical section of the Allt Beinn Dearg Mhor stream section.

mudstone and a rhyolite flow. Intercalated within the higher flows are beds of fine-grained tuff, five to ten feet thick, exhibiting graded and cross-bedding, and a layer of bedded agglomerate which is about 100 feet thick. Associated with the higher lavas at the southern end of Creagan Dubh are concordant bands of gabbro. Between two of the faults on the north-western side of the crag there is a roughly rectangular patch of net-veined lavas in which the net-veins consist largely of calcite, chlorite and quartz and exhibit a fair degree of common orientation parallel to faults (Plate XXX).

The lavas are cut by numerous intrusions of transgressive agglomerate, and quartz-porphyry, and near the summit of Creagan Dubh are veined by microgranite.

3. Rhyolite and Bedded Agglomerate of Srath Beag

Two beds of rhyolite occur in the bed of the Allt Beinn Dearg Mhor. The lower one is 25 feet thick and its upper part is autobrecciated; the upper rhyolite is 75 feet thick. The rhyolites are interbedded with agglomerate, and the whole sequence dips at 35° to the south-east (Fig. 23B).

4. Transgressive Agglomerate

The transgressive agglomerate is coarse-grained, and the bulk of it occurs as broad vertical masses towards the /

the southern end of Creagan Dubh which, although more or less parallel to the lava flows in detail, may partially cross-cut them. The fragments in the agglomerate are largely angular and vary in size from one inch to one foot across (Plate XXXIb). The matrix is glassy and frequently exhibits a pronounced fluxion structure parallel to the boundaries of the agglomerate. Also parallel to this structure are lenticular areas within the agglomerate in which fragments are noticeably absent. In places the agglomerate is more clearly intrusive, transgressing, veining and brecciating the lavas (Fig. 23A). A good example of this intrusive phenomenon may also be seen in the basalts in the northern part of the crag where several small masses of transgressive agglomerate outcrop. The largest of these is sill-like and dips at 50° to the east, parallel to the bedding of the country lavas. The "sill" is up to 30 feet thick and along both sides brecciates and veins the lavas. Undoubted intrusive transgressive agglomerate also occurs at the north-eastern end of the crag as the infilling of a small vent, the Coire Garbh vent. The vent is almost circular in outline and the margins dip inwards at 75° to 80° . The vent is truncated on the south-eastern side by the Coire Garbh fault, and corresponding vent material has not been found to the south-east of the fault.

5. Acidic Rocks

The acidic rocks comprise quartz-porphyry, microgranite and granite. The quartz-porphyry is chiefly confined to Coire Garbh where it has intruded the lavas and the vent agglomerate adjoining the Coire Garbh fault. These intrusions are highly irregular in outline, and similar masses occur on the south-western side of Creagan Dubh also near the Coire Garbh fault. The largest single mass of quartz-porphyry forms a sheet, 20 feet thick and dipping at 60° to the north, cutting the lavas of the northern crag of Creagan Dubh (Plate XXXII). A petrographically similar quartz-porphyry cutting granite, presumably Beinn Dearg Mhor granite, in the bed of the Allt an t-Sratha Bhig forms a dyke, five feet wide, which strikes westwards.

Microgranite is present only in Coire Garbh near the summit of Creagan Dubh where it occurs as straight parallel-sided net-veins half-an-inch to several feet in width cutting the lavas. The offset of earlier net-veins across later net-veins is not proportional to the width of the later net-veins, and cannot have been produced as the result of the emplacement of the later net-veins by simple delational mechanism.

Massive granite of Beinn Dearg Mhor occurs to the east /

east and south of Creagan Dubh, beyond the Coire Garbh fault. Fragments of granite identical in appearance to this rock are found in the transgressive agglomerate of Creagan Dubh.

III. /

III. FAULTS

(Map, back pocket)

Creagan Dubh is a small area of rock isolated on the surface by surrounding drift and peat. Most of the component rocks lie at high angles or are vertical, with north-east or northerly strike, whereas the neighbouring bedded rocks (Jurassic strata) dip eastwards.

On the south-eastern side of Creagan Dubh the Coire Garbh fault can be traced from the Allt na Teangaidh over the summit of Creagan Dubh and into Srath Beag, where, although the fault itself is not seen its position can be inferred from the shattered nature of the bedded agglomerate in the bed of the Allt Beinn Dearg Mhor. Another fault, striking north-eastwards, occurs within the granite, some 200 feet upstream. Approximately parallel to the Coire Garbh fault, and some 500 feet to the west of it, is a strong line of dislocation, the Shoulder fault. This fault is exposed in the bed of the Allt na Teangaidh, where it has brought basalt, on the south-east, down against mudstone. It is also exposed near the summit of the crag, and is thought to lie in a grassy gully leading up to this point. South-westwards, the fault curves westwards down the shoulder of Creagan Dubh, where lavas and transgressive agglomerate, on the south-eastern side, lie against /

against the Lower group, to the north-west. To the north of the Shoulder fault and approximately parallel to it are two small faults within the lavas. At their south-western ends these small faults join a northerly-striking tear fault which has displaced both the Lower group and the lavas in a sinistral sense. The Shoulder fault cuts and displaces two sub-parallel north-west-trending faults which occur about 300 feet apart, and lie in gullies on the north-western flank of Creagan Dubh. On the south-eastern side of the Shoulder fault the north-west-trending faults occur further to the north-east and closer together.

Creagan Dubh is thus divided into five main structural units, separated by faults, and two minor units, delimited by lack of exposures. The latter are those of the Allt na Teangaidh, on the north, where the rocks are largely vertical and strike east-north-eastwards, and the Allt Beinn Dearg Mhor in the south, where the dip is 35° to the south-east. The main units are those of Coire Garbh; the Upper Allt na Teangaidh; North Crag; Western Area; Southern Area (Map, back pocket).

The Coire Garbh area lies between the Coire Garbh fault and the Shoulder fault and extends from the summit of Creagan Dubh to the Allt na Teangaidh. This block includes the /

the Coire Garbh vent together with massive lavas, quartz-porphyry and microgranite. The dip of the lavas is not known.

The Upper Allt na Teangaidh block lies adjacent to and north-west of the Coire Garbh block between the Shoulder fault and the fault lying immediately to the north of it. Lavas and mudstones trending north-south dip at 60° to the east on the crag, and curve round to strike at 80° in the bed of the Allt na Teangaidh.

The North Crag area lies to the west of the Allt na Teangaidh block and is terminated on the south-western side by the northerly of the two north-west-trending faults. This area consists of gneiss, spotted rock and agglomerate of the Lower group, the foliation of the gneiss dipping at low angles to the south or south-east. The Lower group is overlain unconformably by lavas which dip at 45° to the south-east.

The Western Area, comprising the remainder of the rocks to the north-west of the Shoulder fault, consists almost entirely of members of the Lower group. The foliation is very highly inclined or vertical, and strikes northwards in the north of the area and north-eastwards to the south of the area.

The rocks of the Southern Area lie between the Shoulder /

Shoulder fault and the Coire Garbh fault, on the Srath Beag side of Creagan Dubh. They consist of inclined, vertical and overturned lavas and transgressive agglomerate which strike eastwards.

IV. /

IV. PETROGRAPHY1. Lower Group

The rocks comprising the Lower group may be divided into three groups: A. Agglomerate and spotted rock; B. Gneiss, granite, hornblende gneiss and diorite, and acidic anorthosite; C. Gabbros, dolerite and basalt.

A. Agglomerate and spotted rock. Thin sections reveal that the gradation between agglomerate and spotted rock, as seen in the field, is one of grain size only, the texture and mineral composition of the spotted rock being similar to the matrix of the agglomerate; the former rock appears to be a tuff. Both the agglomerate and the spotted rock are slightly metamorphosed, the grade of metamorphism increasing markedly adjacent to the gneisses, thus forming transitional rock between the pyroclastics and the gneisses.

The agglomerate contains fragments of arenaceous and argillaceous sedimentary rocks, tuff, basalt, and gabbro in a groundmass consisting of smaller fragments. The dimensions of the fragments are most commonly one to ten centimetres, although some may be as much as several feet across. While retaining their original outlines, the fragments are uniformly metamorphosed, and exhibit no special metamorphic phenomena at their contacts with the groundmass. The sedimentary fragments /

fragments consist of granular mosaics of quartz with some feldspar and epidote, and contain shreds of foxy-red biotite which in the more argillaceous sediments form the bulk of the rock. The tuff fragments contain secondary green hornblende and foxy-red biotite, and are characterised by ubiquitous porphyroblastic alkali feldspar. The basalt fragments are largely granulitised or altered to albite, uralite and serpentine, while the gabbro fragments are also granulitised or partially altered to alkali feldspar, quartz, uralite, hornblende and biotite. The following description of the groundmass of the agglomerate also applies to the spotted rock or tuff.

The matrix of the agglomerate contains small rock fragments together with mineral fragments; quartz, calcium-bearing plagioclases, albite, orthoclase, and in addition a little microcline and microperthite, augite and aegerine-augite, hornblende and tremolite, chlorite, magnetite, ilmenite, pyrite, haematite and accessory zircon, apatite and sphene. Olivine is of sparse occurrence. Epidote and orthite are found in the more acidic varieties of the agglomerate and tuff. Micas are absent as primary minerals, but biotite is secondary (Plate XXXIIIa).

The most prominent metamorphic features in the matrix of the agglomerate and in the tuff are the alkalisation of /

of the plagioclase, the uralitisation of the pyroxenes, and the recrystallisation of the rounded grains of strained quartz to form rounded mosaic aggregates. Cryptopegmatite and micropegmatite have developed interstitially.

Plagioclase. Plagioclase occurs as rounded and broken fragments up to five millimetres across which are variable in composition and strongly zoned. The crystals have been partially replaced by albite and other alkali feldspars and contain irregular blebs of quartz rimmed by albite. Alkali feldspar rims the plagioclase. To a lesser extent the plagioclase has been granulitised. The interiors of the larger plagioclase crystals contain small fresh non-zoned euhedral plagioclase crystals which are haphazardly arranged both with respect to the host plagioclase and the acidic alteration products.

Alkali feldspars. Original crystals occur as rounded or angular grains which are subordinate in amount to the plagioclase. The new-formed alkali feldspar, which is cloudy and approaches orthoclase or microperthite in composition, has developed around, and in optical continuity with, detrital crystals of plagioclase and alkali feldspar.

Pyroxenes. The pyroxene crystals are rounded in outline and universal stage examination indicates a wide range of composition /

composition, the two most abundant varieties being brown augite and green aegerine-augite. Both have been partially altered to pale green fibrous amphibole, hornblende or chlorite.

Amphiboles and chlorite. These minerals occur as anhedral primary crystals and irregular patches in the matrix of the agglomerate and tuff. The hornblende is green or brown in colour while tremolite and chlorite are green. All are partially altered to green or foxy-red biotite.

Iron ores. Magnetite is present as anhedral or vermicular crystals. Haematite and pyrite are intergrown and together form crystals which are rectangular in outline. The ilmenite is partially altered to leucoxene.

Gabbro fragments. Small gabbro fragments, originally ophitic, are altered in an interesting manner. Although there has been no apparent change in chemical composition, excepting that of marginal alteration of the plagioclase (alkalisation) and conversion of augite to penninite, the texture is now myrmekitic rather than ophitic. Optically continuous blebs and tongues of fresh augite lie within the plagioclase (Plate XXXIIIb).

Rare granulite veins cut the agglomerate and the tuff. Within these veins the plagioclase and augite have been partially or totally recrystallised to form small stumpy crystals /

crystals of plagioclase and augite respectively. Veins consisting of alkali feldspar and quartz are also found.

B. Gneiss, granite, hornblende gneiss and diorite, and acidic anorthosite. Transitional rock-types occur between agglomerate and tuff (spotted rock) and the rocks of this group. Transitions within the group are equally abundant, there being gradations between gneiss and granite, gneiss and hornblende gneiss, granite and acidic anorthosite, diorite and acidic anorthosite.

(i) Gneiss

Gneiss is medium to coarse-grained and consists of feldspars, quartz, biotite, penninite, hornblende and magnetite together with accessory epidote, sphene zircon and apatite (Plate XXXIV). Augite is present in some specimens. The foliation of the gneiss takes the form of alternating dark and light coloured bands. The former contain the bulk of the dark minerals, and the latter are composed chiefly of quartz and feldspar. In some specimens these minerals are intermingled and the quartz is interstitial to the feldspar, but in others the quartz occurs as elongate aggregates, the dimensions of which are up to 3 mm. across and one to three centimetres in length, the long axes lying in the planes of the foliation. Plagioclase and alkali feldspars are both present /

present and either may be dominant. The plagioclase (An_{10} to An_{30}) occurs as subhedral crystals which are zoned, albitised and rimmed in a manner similar to the plagioclase of the agglomerate and tuff. The alkali feldspar occurs as large crystals up to five millimetres across, and generally encloses grains of quartz. Foxy-red biotite and pale green penninite are invariably closely associated with one another, and the latter appears to be an alteration product of the former. Both minerals are irregularly shaped and frequently curved, and their basal cleavages are commonly orientated parallel to the foliation. Hornblende is generally sparse and partially altered to biotite.

(ii) Granite.

The granite differs from the gneiss in containing only accessory amounts of dark minerals but contains micropegmatite which rims feldspars and quartz. The granite is also foliated to a lesser extent and is coarser in grain than the gneiss, and contains rounded inclusions, one to three millimetres across, of quartz and aggregates of dark minerals. The latter generally consist of minute flakes of foxy-red biotite or hornblende.

(iii) Hornblende gneiss and diorite

These rocks occur together in the field and differ only /

only in the arrangement of their constituent minerals. In the diorite there is no foliation. The hornblende gneiss is a very dark coloured rock with a distinct foliated texture. Crystals of brown hornblende, some 2 mm. in length, form bands two or three crystals deep, alternating with narrower bands composed of plagioclase (An_{40}) (Plate XXXVa). There is a little interstitial augite, and accessory amounts of alkali feldspar, quartz, magnetite, foxy-red biotite, apatite, green tourmaline and very rare olivine. The bulk of the dark accessory minerals are associated with the hornblende. The rock contains about 50% hornblende, 40% plagioclase and 6% augite. The hornblende is strongly zoned and sub-ophitic; is cut by numerous veinlets consisting of granules of pyroxene and tremolite, and also contains patches of blue-green amphibole which are especially abundant in the more acidic parts of the rock. Universal stage determinations of optical properties indicate that both the hornblende and the augite are slightly sodic. The augite in some places approaches aegerine-augite in composition and is somewhat uralitised. The plagioclase is generally cloudy and strongly zoned, with alkaline margins and internal blebs consisting of alkali feldspar and quartz. Some of the plagioclase crystals are clear and poly-twinned (see Beinn na Cro) and contain small euhedral plagioclase crystals.

(iv) Acidic anorthosite

This rock occurs associated with the large patch of gabbro on the western side of Creagan Dubh (see page 103) and is transitional into diorite, agglomerate and granite. While some parts of the acidic anorthosite appear to be blocks in the agglomerate, others appear to be interstitial to the blocks. The rock is almost white in colour and coarse-grained. It consists of feldspars with accessory quartz, dark green amphibole, magnetite, sphene and epidote. The feldspar comprise plagioclase (An_{10} to An_{30}) which are 1 - 5 mm. in length. They are poly-twinned and are largely altered to alkali feldspar.

C. Gabbro, dolerite and basalt(i) Granular gabbro

The granular gabbro within the Lower group generally occurs as elongate masses ten to twenty feet thick which lie within gneiss and parallel to the foliation of the gneiss. The margins of the gabbro appear to be transitional into the gneiss, and are invariably net-veined. The gabbro may be almost fresh in the interiors of the masses, but the marginal zones, and frequently the whole of the masses, are granulitized or highly altered, and consist of plagioclase and augite in approximately equal amounts together with magnetite, biotite /

biotite, quartz, epidote and alteration products (Plate XXXVb). Some specimens contain pseudomorphs after olivine.

Plagioclase. Plagioclase (An_{65}) occurs as elongate or equidimensional crystals which in some specimens partially enclose augite. Alteration has taken the form of either granulitisation resulting in the development of small equant grains of plagioclase which are frequently enclosed in large plagioclase crystals, or albitisation. In this latter case the plagioclase is cloudy and rimmed by porphyroblastic alkali feldspar which contains numerous inclusions of augite and hornblende.

Augite. Augite occurs as rounded crystals and is greyish, greenish or brownish in colour and in all cases is partially altered to uralite. In the more altered granular gabbros the augite has been either granulitised to form small equant grains which are invariably associated with magnetite, or has been almost totally altered to aggregates consisting of fibrous hornblende and/or biotite together with numerous specks of magnetite. The fibres of the alteration products lie parallel to the cleavage of the host augite.

The granular gabbro is invaded by two types of net-vein which extend into it from the adjoining migmatitic gneiss. At its contact with the more common type of net-veins the gabbro has been granulitised to form a fine-grained mass /

mass of granular plagioclase together with granular augite and magnetite. The net-vein margins are bordered by green amphibole granules and a small quantity of green biotite which appear to be alteration products of the ferromagnesian minerals of the gabbro. Extending from the net-veins into the gabbro are veinlets consisting of small granular crystals of quartz, biotite and alkali feldspar, including albite. Twin lamellae of albite at the contacts of the veinlets with the gabbro are continuous with those of the adjacent more calcic plagioclase crystals in the gabbro, the albite and the more calcic plagioclase together forming crystals spanning the contact. There is a transition from the veinlets into the net-veins by an increase in amount of alkali feldspar and micropegmatite and a decrease in the amount of biotite. The net-veins consist of large crystals of alkali feldspar and areas of micropegmatite with large "lakes" of quartz (Plate XXXVIa). The dark minerals are confined to the interiors of the net-veins, and consist of hornblende and magnetite with accessory epidote, orthite, zircon and sphene.

The less common type of net-vein in the granular gabbro consists of broken gabbro crystals separated from one another and from the rest of the granular gabbro by an acidic matrix containing large alkali feldspar porphyroblasts enclosing quartz and alkali feldspar.

(ii) Fluxion Gabbro

The fluxion gabbro is medium to coarse-grained, consisting of plagioclase, augite and magnetite together with accessory quantities of ilmenite and pyrite, interstitial quartz, cloudy apatite and green tourmaline (Plate XXXVIb). The plagioclase crystals show a fair degree of common orientation. They are strongly zoned, have a composition of An_{40} , and are poly-twinned (see Beinn na Cro). Some crystals are slightly cloudy while others contain cracks filled with chlorite and albite. The augite is less markedly orientated and is usually sub-ophitic, brownish-pink in colour, and may be schillerised. Ilmenite and fibrous green amphibole occur along the cleavage of the augite. The central massive portion of the fluxion gabbro dyke consists of coarse-grained gabbro. The plagioclase differs from that of the rest of the fluxion gabbro in that it is brownish in colour.

(iii) Ophitic gabbro

The large gabbro mass occurring on the western side of Creagan Dubh and the gabbros in tuff and agglomerate and those associated with the basalts are ophitic in texture and coarser in grain than the granular gabbros (Plate XXXVIIa). The ophitic gabbros differ from the Beinn na Cro gabbros only in their content of tourmaline and epidote. Principal minerals /

minerals are plagioclase, augite and magnetite, together with biotite. Chlorite, olivine and tourmaline are present in the large gabbro mass, while uralite, quartz and epidote distinguish the gabbros associated with the basalts. The plagioclase is very variable in composition between An_{40} and An_{85} , is generally poly-twinned, strongly zoned and cut by veins of albite. The smaller crystals of plagioclase appear to be totally enclosed within augite. The augite is ophitic, greyish in colour and schillerised and is cut by veins of uralite. Magnetite occurs as large vermicular crystals which are partially rimmed by foxy-red biotite, with which tourmaline may be associated. The olivine has been almost completely altered to serpentine and magnetite.

(iv) Dolerite

The dolerite is medium-grained and ophitic, consisting of a subordinate number of large strongly zoned poly-twinned plagioclase crystals set in a matrix of plagioclase, augite and magnetite. The plagioclase is generally slightly albitised. The augite is brownish, ophitic and partially uralitised and zoned, the crystals being paler in colour in the interiors and darker at the margins. The zones are related to the outer crystal boundaries rather than the contacts of the augite with enclosed plagioclase crystals. A larger amount of magnetite than is commonly found in the basic rocks of the Lower group is present.

(v) Basalt

The basalt is distinguished from all the other basic rocks of the Lower group in that it presents chilled or even tachylytic selvages to the country rock. Minute veins of black, iron-rich, tachylytic material containing crystals of plagioclase less than 0.1 mm in length extend from selvages composed of similar material into the country rock along intergranular boundaries and shatter cracks (Plate XXXVIIa). The bulk of the basalt is fine-grained and porphyritic and consists of plagioclase phenocrysts and many smaller elongate plagioclase crystals embedded in a matrix of ophitic augite and magnetite. Much of the plagioclase in the groundmass of the basalt has been granulitised while the plagioclase phenocrysts have been almost completely altered to chlorite and tremolite. The larger crystals of augite are brown and sub-ophitic and the smaller crystals are granular, forming brush-like aggregates associated with magnetite.

2. Lavas

A. Lower flows. The basalt which forms the bulk of the lower lava flows is black or bluish-grey in colour. It is indurated and is generally massive, but amygdaloidal patches /

patches are present, especially in the upper part of the group. A considerable amount of the basalt on the northern crags of Creagan Dubh is net-veined along shatter-cracks, and a little of it, in Coire Garbh, where the lava is intruded by numerous microgranite net-veins, is granulitic. The basalt is generally very fine-grained and the component minerals are not easily recognised as they have been altered to brownish-green chloritic material, in which are embedded numerous grains of magnetite and ilmenite. When distinguishable, as in the case of the coarser-grained basalts, the feldspar is seen to be a cloudy, zoned plagioclase, and the pyroxene is ophitic and brown or pinkish in colour and zoning is common, the enclosed plagioclase crystals cross-cutting the concentric zones (Plate XXXVIIb). Pseudomorphs of chloritic material after feldspar phenocrysts are abundant.

Amygdales, where present, are seldom more than 5 mm. long, and are rather irregular in shape. The majority consist of cloudy feathery aggregates of feldspar with some chlorite and epidote (Plate XXXVIIIa), while others are formed of chlorite or penninite, serpentine, apatite and epidote or calcite. Quartz is rare and where associated with calcite felted needles of wollastonite have formed.

The above description applies to 90% of the lower lava /

lava flows of Creagan Dubh, but the following rock-types are also present in small quantity.

(i) Olivine basalt

Olivine basalt occurs near the summit of Creagan Dubh. It is medium-grained and consists of plagioclase, augite, olivine and iron ore. The plagioclase (An_{55}) is cloudy and twinned. The augite is altered peripherally to amphibole, magnetite and limonite. The olivine is anhedral and has been largely altered to serpentine and bowlingite.

(ii) Xenolithic basalt

This rock is similar to the normal basalt except that it contains irregular patches of quartz with small, very pronounced, rims of granular augite or wider, more diffuse, rims of green hornblende; fragments of granulitised basalt and gabbro which consist of cloudy plagioclase and granular augite; and, most abundantly, fragments of quartzite which consist of quartz grains in a penninite matrix. The basalt at the margins of the quartzite fragments is rich in ferromagnesian minerals.

(iii) Veined basalt

The veined basalt occurring towards the northern end of the crag (see page 106) is similar to the normal basalt. The veins occur along shatter-cracks and are composed of calcite and chlorite or quartz and epidote.

(iv) /

(iv) Rhyolite

The rhyolite found in the bed of the Allt na Teangaidh is a banded and streaky pale greenish-grey rock, which is very brittle. Its lower surface is more or less planar, although in detail irregular due to partially enclosed fragments of the underlying agglomerate. The banding deviates around the fragments at the base of the rhyolite, but towards the interior of the flow displays a more regular pattern. In thin section the rock is seen to consist of a fine-grained mass of quartz crystals in an even finer-grained matrix.

(v) Mudstone

Two lenses of mudstone have been found between basalt lava flows in the bed of the Allt na Teangaidh. The rock is purplish in colour, faintly laminated, and very fine-grained and consists of quartz grains and a subordinate number of basalt fragments in a dark matrix.

B. Higher flows. The higher lavas are greyish-blue and generally rather lighter in colour than the lower flows. Amygdales are abundant, and occur in layers parallel to the flows. The vesicular material is more resistant to weathering than the groundmass, and shows up as smooth ellipsoidal pellets with their long axes parallel to the flows. The groundmass consists /

consists of very fine-grained or glassy material, containing microliths of feldspar and ferromagnesian minerals. The amygdales consist of quartz, with a little chlorite and epidote. The quartz crystals are regularly arranged in a marginal mosaic mass which surrounds the interior of the amygdale comprising a few large sutured crystals (Plate XXXVIIIb). Both the groundmass and the amygdales are cut by veinlets of quartz.

Occurring in association with the upper lava flows are three special rock types.

(i) Tuff

The tuffs are very hard, purple-coloured laminated rocks. The laminae show clearly on weathered surfaces due to differential erosion of the bands. The laminae, 0.5 to 2.5 mm wide, exhibit graded and cross-bedding, neither of which are disturbed by curious, hollow, iron-rich ovoid bodies which are about 5 cm. across. In thin section the lamination of the tuff is plainly visible. The grading is especially clear. Lighter coloured, coarser-grained bands grade upwards into denser coloured, finer-grained material (Plate XXXIXa). The rock is so fine-grained that no individual minerals may be distinguished.

(ii) Agglomerate

The agglomerate is bedded and consists of angular and /

and rounded pebbles up to several inches across in a granular matrix composed of smaller fragments. The pebbles consist chiefly of quartzite and basalt, together with granitic fragments.

(iii) Gabbro

The gabbro is a dark green coarse-grained rock, generally rather soft and weathered. It consists of about 45% plagioclase associated with augite, magnetite and accessory quartz and epidote. The plagioclase forms large sub-hedral crystals up to 8 mm. across, some of which are poly-twinned, zoned from An_{80} in their interiors to An_{65} near their margins. The augite is grey, subophitic, and uralitised in patches. The magnetite is vermicular. Epidote and quartz occur in association, the latter containing fibres of green amphibole.

3. Rhyolite and Bedded Agglomerate of Srath Beag

A. Rhyolite. The rhyolite occurring in the bed of the Allt Beinn Dearg Mhor is a pale blue, pink and yellow laminated rock containing crystals of quartz and alkali feldspar which are visible to the naked eye. These are approximately rectangular in outline and are orientated with their sides at about 45° to the lamination (Plate XXXIXb). In thin section the bands are seen to be from 0.2 to 2 mm. thick. They /

They consist chiefly of layers of cryptographic spherules alternating with subspherulitic cloudy feldspar and clear granular quartz. The upper part of the lower flow is auto-brecciated. The blocks are angular, 1 to 20 cm. in length, and haphazardly orientated. The groundmass between the blocks consist of similar rhyolitic material which has no lamination.

B. Bedded agglomerate. The bedded agglomerate is a coarse-grained mottled rock with a dark green groundmass in which are embedded numerous fragments. Most abundant of these are blocks of the associated rhyolite, but also common are sandy limestone, quartzite, trachyte and quartz-porphry. Fragments of mudstone, marble, calc-silicate rock, basalt, granite and felsite, and sparse coral fragments, schistose grit and pelitic schist are also present.

4. Transgressive agglomerate (Plates XL and XLI)

The transgressive agglomerate generally consists of sub-angular or angular fragments in an acidic matrix which is usually glassy but which may be spherulitic, cryptographic, micrographic or even granular. The larger the fragments, the more glassy the matrix. The fragments in the transgressive agglomerate are up to a foot across, although the average size is one to three inches, and the fragments are recognisable in the field. Different masses of transgressive agglomerate contain /

contain different proportions of the same types of fragments. The contacts of the large southern masses of transgressive agglomerate with the lavas and gabbro are vertical and sharp. In thin section the lavas and gabbro are seen to contain cracks and veins along which they have been granulitised. Large crystals have been shattered, broken up and granulitised. The plagioclases differ from those usually found in the gabbro in that they have developed at their margins very narrow twin lamellae and in their interiors they show shadowy extinction. The veinlets in the gabbro consist of brownish material which is a mixture of gabbro debris and acidic material. In this matrix are shattered and acidified crystals, some of which are markedly rounded. Where amygdaloidal bands in the lavas are in contact with transgressive agglomerate, blocks of the same amygdaloidal lava occur in the agglomerate. The trains of amygdales occur at high angles to those in the lava, showing that the blocks have been considerably rotated, while there has been little translational movement at the margins of the transgressive agglomerate (Fig. 23A). The fragments in this southerly mass of transgressive agglomerate are chiefly basalt and granite, there being an increase in the amount of granite towards the granite mass of Beinn Dearg Mhor. Also present are blocks of felsite, gabbro, trachyte, microgranite, spherulitic /

spherulitic microgranite, quartz-porphry, quartz amygdales, quartzite, hornfels, mudstone and calc-silicate rock. Thin sections reveal that the granite of the fragments is very like that of Beinn Dearg Mhor.

Much of this mass of the transgressive agglomerate exhibits vertical fluxion structure in the groundmass which forms swirls and eddies around the fragments. The matrix of the transgressive agglomerate is very hard, purple or black in hand specimen, greenish in thin section. In thin section the fluxion planes can be seen as lines consisting of spherulitic and frond-like aggregates of quartz and feldspar between the fragments. Some of the smaller fragments are orientated with their long axes parallel to the fluxion structure.

The Coire Garbh vent agglomerate at the northern end of Creagan Dubh consists chiefly of Jurassic mudstone and quartzite fragments, with some granite and microgranite, and sparse basalt, granulite and vein quartz. These lie in a glassy matrix which shows no fluxion structure. The contact of the vent agglomerate with the country rock is invariably sharp. The fingers of basalt within the vent on its northern side have fine-grained edges against the vent agglomerate, and the lavas appear to be unaltered by the vent agglomerate.

The agglomerate sill which lies within the lavas on the northern side of the crag is a very pale buff colour.

The /

The fragments are uniform in size, about two inches across, and consist chiefly of quartzite, together with some felsite, granite, basalt and granulite. The basalt country rock is a normal ophitic variety, containing large phenocrysts of plagioclase which are poly-twinned and strongly zoned and corroded at their margins. The contact of the transgressive agglomerate with the basalt is very irregular, and small veins extend from the agglomerate into the basalt. These veins contain broken pieces of the basalt and large angular brown and cloudy plagioclases and alkali feldspars (Plate XLa). The plagioclases are similar in their poly-twinning and zoning to those phenocrysts occurring in the basalt. The groundmass of the veins consists of cryptogranular quartz and feldspar.

5. Acidic rocks

A. Quartz-porphyry. The quartz-porphyry is a light coloured rock and is very similar to the Beinn na Cro quartz porphyries. The contacts between quartz-porphyry and country rock are sharp. In thin section the quartz-porphyry is seen to consist of a cryptographic, granular, or rarely, spherulitic matrix of quartz and cloudy brown feldspar in which lie fragments of feldspars, chiefly microperthite and plagioclase. Also present are fragments which include basalt containing /

containing tridymite pseudomorphs, trachyte, granite with mosaic quartz, mudstone with brown garnets, quartzite, hypersthene dolerite, quartz diorite, rhyolite and spherulitic microgranite. The quartz and feldspar are corroded and embayed and rimmed by cryptographic micropegmatite.

Cutting granite in the bed of the Allt an t-Sratha Bhig is a dyke of similar quartz-porphry about three feet wide. The rock is mostly greenish-grey in colour. In thin section it is seen to be microspherulitic or glassy. In the coarser-grained parts of the rock, rounded fragments of granite up to several millimetres across occur in a matrix of fronds of cloudy feldspar, granular quartz and plagioclase (Plate XLIIa).

B. Microgranite. The microgranite occurs as small irregular bodies in the transgressive agglomerate and as straight parallel-sided net-veins in the lavas. A few centimetres from the contacts with the microgranite net-veins the basalt lava consists of large sieved lath-shaped crystals of andesine, more sodic than the normal basalt plagioclase, containing dark minerals scattered evenly through them in almost the same density as the density of occurrence of those minerals in the unaltered basalt. Towards the contact granular greenish-yellow or foxy-red biotite becomes the most abundant ferromagnesian /

ferromagnesian mineral, but where quartz has developed pale green amphibole and a very little augite are also present. Magnetite granules are scattered evenly throughout the rock. Spanning the contact, which is otherwise sharp, are sparse porphyroblasts of plagioclase and alkali feldspar. Minute veinlets less than 0.8 mm. across, extending from the net-veins into the basalt consist of plagioclase, alkali feldspar, biotite and quartz. They exhibit marked margins of magnetite and augite. The plagioclase crystals (An_{35}), along with the dark brown biotite, are orientated with their long axes normal to the veinlet walls. This texture is also present in wider veinlets, 1 - 2 mm., which, however, consist of microperthite, strongly zoned plagioclase and very irregularly shaped plagioclase crystals rimmed by micropegmatite. Quartz, biotite and haematite are also present. The net-veins over 2 mm. across are marginally similar to the smaller veinlets, but towards their interiors micrographic texture gives way to granular texture (Plate XLIIb). The interiors of the net-veins contain plagioclase, alkali feldspar and quartz. The plagioclase (An_{25}) is clear, twinned and slightly zoned while the alkali feldspar is cloudy and porphyroblastic. The quartz may occur as large plates including feldspars.

C. Granite of Beinn Dearg Mhor. The name "granite" is used here indiscriminately to indicate both granite and granophyre as both are equally abundant. The granite is medium- to coarse-grained and consists of quartz, feldspars, dark minerals and accessories. The quartz is generally strained and forms rounded crystals and interstitial masses and is also a member of micropegmatite. Parts of the same crystal may be both free and intergrown. The feldspar may be cloudy, anhedral, subhedral or micropegmatitic, and has various compositions. Microperthite crystals (clear albite and cloudy orthoclase or lamellar-twinning oligoclase and cloudy orthoclase) up to 3 mm. across are very common. Free orthoclase and oligoclase are also present. The latter frequently is in the form of large crystals whose margins have been replaced by angular masses of fine-grained micropegmatite. Dark minerals are scarce, never amounting to more than 5% of the rock. They comprise green biotite with pleochroic haloes, chlorite, magnetite, ilmenite and haematite. Accessory zircon, sphene and fluorspar are also present. Although there are no ubiquitous diagnostic features distinguishing the Beinn Dearg Mhor granite from that of Beinn na Cro, fluorspar, of sparse occurrence in the former, has not been found in the latter.

V. DISCUSSION

The rocks of Creagan Dubh were described by Harker (1904) as lavas, below the base of which, on the western side, lay a strip of agglomerate which appeared to be associated with that of Kilchrist. He reported that the lavas, dipping to the south-east at moderate to high angles, had been faulted against the Beinn Dearg Mhor granite, and that the metamorphosed state of the lavas, and their penetration by tongues of granite indicated that the present boundary (the fault) was not far from the original junction of the lavas and the granite.

In the field, Harker considered the rocks of the Lower group, exposed in the knolls at the foot of Creagan Dubh, to be agglomerate, but he revised this opinion in the light of petrographic evidence and concluded that the rock was a syenitic modification of granite, its green and mottled appearance being due to brecciation. He considered the gneissoid rocks of the Allt na Teangaidh also to be brecciated granite. The great variation exhibited by the Lower group has rendered Harker's choice of specimens unfortunate, in that it misled him from his original more accurate surmise. He in no way explained how the granite and syenite came to be brecciated along a strip quarter of a mile broad between the Allt /

Allt na Teangaidh and the western part of Creagan Dubh, stating "its mode of occurrence is not displayed and it is in any case quite exceptional" (1904, p. 165).

F.H. Stewart (1948), on the other hand, thought that there had been no significant post-consolidation movement along the contact between the lavas and the granite, and considered that the granite veined the lavas and was also chilled against the latter.

In both the upper forks of the Allt na Teangaidh the contact of the lavas and the granite is exposed. At neither locality is the granite chilled; granite, as coarse-grained as the bulk of the granite, is clearly faulted against basalts, the alteration of which is slight and in no way resembles the intense metamorphism of the Beinn na Cro basalt in contact with the Beinn na Cro granite. In Coire Garbh the shattered nature of the microgranite and quartz-porphyry veins and tongues, and of the lavas, and granite, leaves little room for doubt that the contact between the lavas of Creagan Dubh and the granite of Beinn Dearg Mhor is a fault. Stewart also suggested that the gneissoid rocks of the Allt na Teangaidh might be Lewisian gneisses. The metamorphism of the Lower group and the development of the gneissoid texture, together with the probable age of these rocks, forms the main subject of the following discussion.

1. Structure

While the frequent occurrence of highly inclined strata on Creagan Dubh raises the interesting problem of the origin of this structure, this problem is considered to be insoluble with the data at present available. Creagan Dubh is a comparatively small area, and is completely isolated from surrounding rocks by the combination of the Coire Garbh fault and lack of exposures. Thus structural relations of Creagan Dubh to the encircling rocks is not displayed, and there is no evidence to suggest how the Creagan Dubh rocks reached their present remarkable attitudes.

2. Petrogenesis

A. Lower Group. The Lower group of Creagan Dubh presents two main problems, namely the age and origin of the gneiss, and the age of the basic rocks relative to that of the gneiss.

(i) The Gneiss

The gneiss of Creagan Dubh is interbanded with tuff and agglomerate, and gradational contacts between the gneiss and the pyroclastic rocks have been observed. The nature of these transitions clearly demonstrate that the contacts are not intrusive. The consistent orientation of the foliation of /

of the gneiss, the layering of the gneiss sheets, and the proximity of the sheets to one another do not favour a hypothesis which regards the gneiss as large blocks within the tuff and agglomerate. Further, if the gneiss does represent blocks it is remarkable that the subsequent metamorphic activity, required to produce the transitional zones between the gneiss and the pyroclastic material, has left the bulk of the incoherent rocks unaffected. On field evidence alone, therefore, it seems highly unlikely that the gneiss represents agglomeratic blocks.

The tuffs and agglomerates are so unlike the later transgressive agglomerates both in their field relations and petrography that it is highly improbable that they represent earlier manifestations of similar intrusive activity. The possibility that the pyroclastic rocks represent brecciated gneiss has been considered. The wide assortment of fragments, however, and the complete absence of fragments of gneiss, appear to invalidate such a hypothesis.

A Lewisian age for the gneiss has been proposed by F.H. Stewart (1948). Exposures of tuff and agglomerate apparently lying unconformably upon the gneiss would indicate an earlier age for the latter. If this were the case, it is difficult to understand how the pyroclastic rocks have become /

become interbanded with the gneiss unless they have been faulted or isoclinally folded together. Evidence for such pronounced tectonic activity is entirely wanting from the tuffs and agglomerates, and this, together with the general transitional contacts between the gneiss and the pyroclastic rocks, suggests not only that the interbanding is the result of the operation of some other process, but also that the gneiss is probably not older than the tuffs and agglomerates.

It is unlikely that the tuffs and agglomerates belong to an era of vulcanicity which is not elsewhere represented in Skye, and these rocks are therefore almost certainly of Tertiary age. As the Tertiary igneous activity marks the close of metamorphic activity in Skye, it is clear that the gneiss is most probably of Tertiary age also.

The metamorphic rather than intrusive contacts of the gneiss with the pyroclastic rocks and the foliation of the gneiss indicate that the gneiss is a metamorphic rock. Petrographic evidence such as the presence of pebble-like bodies within the gneiss, and of growth of porphyroblastic alkali feldspar around older feldspar crystals also favour a metamorphic origin for the gneiss.

As no trace of rock which might be the unmetamorphosed equivalent of the gneiss has been found, there is no direct /

direct evidence regarding the nature of the metamorphism. However, the margins of the gneiss exhibit features which may indicate the type of metamorphism which caused the gneiss to form.

As the pyroclastic rocks are traced towards the gneiss, chlorite and uralite become more common and alkali feldspar porphyroblasts and micropegmatite appear and become abundant. This suggests that the pyroclastic rocks of the narrow transition zones at the margins of the gneiss bands have been metamorphosed as the consequence of their invasion by aqueous solutions containing alkalies and silica from the direction of the gneiss. Although the transition between the gneiss and the pyroclastic rocks is continuous, there is insufficient evidence to indicate whether the alkalies, silica and water were also the agents of metamorphism of the gneiss, or whether they were expelled from the gneiss.

The gabbro sheets within the gneiss are net-veined, and at their margins grade into the gneiss. There is no reason to suppose that the gabbros may be of later date than the gneiss. If this were so, it is hard to visualise how the gabbros within the gneiss could have been altered by a second metamorphism, which would have to have operated along the same channels as the first, while the tuffs and agglomerates /

agglomerates, now being the weaker rocks, still remain unaltered. The net-veins reveal no evidence for either a replacement or dilational mechanism of emplacement. The granulitisation of the gabbro indicates that the temperature of formation of the net-veins was high, while the brecciation of the gabbro in the second type of net-veins, and the petrography of this type, suggest that these were emplaced as the result of powerful gas action. The gabbro at the margins of the more abundant type of net-veins is uralitised suggesting the metasomatic introduction of water, but the net-veins themselves offer no evidence as to their mode of formation. Both types of net-veins are acidic and this acidic material increases in abundance towards the gneiss and therefore appears to have originated from the gneiss. The disruption of the foliation of the gneiss in the transition zones suggests that some type of movement has taken place. This movement might have resulted from differential movement of the gabbro relative to the gneiss during the formation of the gneiss or from mobilisation of the gneiss as the result of advanced metamorphism. It is highly unlikely, however, that as the uralitic hornblende and biotite in the gabbro are haphazardly orientated, and as the gabbros have not been converted into amphibolite, movement has taken place, and the /

the likelihood that hot gases have played some part in the formation of the net-veins in the gabbro and haphazard occurrences of contorted foliation where no gabbro is present also favours the latter proposition. The apparent derivation of the acidic material from the gneiss suggests that this material became active during the metamorphism. There is at this stage insufficient evidence to suggest whether the acidic material was also responsible for the metamorphism of the gneiss or whether it was expelled from the gneiss as the result of the incoming of other metasomatic material.

A similar relationship of gabbro to metamorphic rocks has been noted from Messum by Korn and Martin (1954) who concluded that the tuffs and agglomerates within which are located the gabbro sheets, had been metasomatised pneumatolytically into granitic rocks, this process also resulting in the formation of acidic net-veins extending into the gabbro from the new-formed granitic rocks.

The relationship between the metamorphic gneiss and the almost unaltered pyroclastic rocks is so close that any satisfactory hypothesis concerning the origin of the gneiss must also explain the intimate association of the gneiss with the tuff and agglomerate. This interbanding immediately suggests that the metamorphic processes operated along, and were /

were confined to, particular horizons within the tuff and agglomerate, the distinctive petrography and structure of which rendered such horizons, unlike the pyroclastic rocks, highly susceptible to the metamorphic conditions which obtained. The matrix of the tuff and agglomerate of the transition zones is more highly altered than the fragments. This suggests that the rock from which the gneiss originated may have resembled the matrix of the pyroclastic rocks and may therefore have been a fine-grained sediment or tuff.

The pyroclastic rocks with which the gneiss is associated contain considerable quantities of dark minerals and argillaceous material. It seems probable that the sediments of Creagan Dubh, now represented by gneiss, were not highly siliceous but contained significant amounts of non-siliceous material of a similar nature to that in the pyroclastic rocks. If this is so, the discrepancy between such a composition and that of the gneiss suggests that the gneiss was formed as the result of metasomatism of the original rock by emanations rich in alkalies and silica. The unconformity between the gneiss and the overlying lavas, which clearly have not been metamorphosed at the time of the formation of the gneiss, is of great significance. It suggests that, as both the gneiss and the lavas are of Tertiary age and also belong /

belong to the same volcanic epoch, the Lower group was not buried beneath a vast thickness of rock at the time of the formation of the gneiss. This is also in favour of the hypothesis that the gneiss has formed as the result of high-level metasomatism rather than some deep-seated (regional) metamorphism.

It has been postulated that the gneiss has not formed as the result of regional metamorphism and it seems probable that the foliation of the gneiss formed as the result of metasomatism. Thus, it is likely that the foliation is based upon banding present in the original rock. It is therefore suggested that the main textural difference between the pyroclastic rocks and the rock from which the gneiss was formed, is, that whereas the former are massive and coarse-grained, the latter was banded and fine-grained.

The susceptibility of laminated rocks to metamorphism and metasomatism has been demonstrated by Sederholm in Finland where he described numerous occurrences of leptitic rocks, "which seem to have been originally sediments [or tuffs]. Their very distinct banding, which is caused by an alternation of lighter layers rich in feldspar and quartz and darker ones in which biotite and hornblende predominate is at least in part to be interpreted as bedding" (1926, p. 5). Sutton and Watson /

Watson (1950) have also demonstrated, from the Lewisian rocks of the Loch Torridon area, the intense alteration of argillaceous horizons and the comparative freshness of quartzite rocks.

The alteration of the massive gabbros of Creagan Dubh and the lack of alteration of the somewhat incoherent pyroclastic rocks appears paradoxical. However, so far as can be seen on the ground, the net-veined gabbros lie totally within the gneiss layers. The metamorphosing activity was clearly confined to these layers, and therefore the alteration of the gabbros appears to have been dependent upon their location. It seems likely that the high temperatures and the mobility of the material in the interior portions of the gneiss layers, where the most altered gabbros occur, were also contributory factors accounting for the alteration of the gabbros.

The pre-existence of fine-grained banded rocks within, and probably transitional into, pyroclastic rocks, indicates that the former were probably tuffaceous sediments. In support of this hypothesis is the presence of 'cross-bedding' structures in the gneiss. If the foliation is based upon bedding, it seems likely that the 'cross-bedding' in the foliation represents cross-bedding in the original rock.

Bedded /

Bedded tuffs alternating with massive tuffs and agglomerates have been described by Harker from Canna (1908), and it is postulated that the Lower group may have been a similar succession.

The position of the Lower group at the base of the succession on Creagan Dubh, and its maximum observed thickness of 750 feet, is comparable with other occurrences of Tertiary tuff and agglomerate in Skye and Canna. Harker has reported that the pyroclastic rocks of Belig lying beneath the lavas are some 1000 feet thick, while accumulations of tuff and agglomerates are also found near the base of the lavas on Creag Strollamus and around Glen Brittle. There is a thickness of about 200 feet of bedded tuffs and agglomerates near the base of the plateau lavas between Portree and Sligachan. The tuffs and agglomerates of Canna, some of which are bedded, are about 600 feet thick. Gneisses similar to those on Creagan Dubh also occur near Sligachan, and in a small faulted area on the western side of Belig (Fig. 2). The throw of the fault on the western side of this patch is of the order of 200 feet, and appropriate reversal of this movement would place the gneisses of Belig at a level approximating to that of the base of the lavas.

(ii) /

(ii) The Basic Rocks of the Lower Group

Present within the Lower group are numerous sheets of gabbro and basalt. While some of the basalt sheets clearly cross-cut the gneiss, tuff and agglomerate, and also present chilled selvedges to the country rock, thus clearly revealing their younger age and intrusive nature, there is no evidence of either age or mode of origin of those basalts occurring as thick sheets exposed in the knolls at the northern end of Creagan Dubh.

The modes of occurrence of the gabbro within the gneiss and those in the tuff and agglomerate are so similar as to suggest close affinity of the gabbros. If this is so, it seems likely that the bulk of the gabbros were formed at the same time, and, as indicated by the net-veined gabbros, at a time prior to the formation of the gneiss. There is no evidence to show whether the gabbros are interbanded with the pyroclastic rocks (including pre-gneiss-rock) in the manner of lava flows, or whether they represent intrusions. The net-veined gabbros and the fluxion-gabbro occur within the gneiss and are granular in texture and thus differ markedly from the gabbros occurring in the tuff and agglomerate which are ophitic. The invariability of this rule suggests that the distribution of the types of gabbro is not the result of coincidence, but rather that metamorphosing influences acting /

acting upon the gabbros within the gneiss resulted in the development of the granular from the ophitic texture.

The fluxion-gabbro differs considerably from the rest of the granular gabbros both in its fluxion structure and its dyke-like form. It clearly cross-cuts the foliation of the gneiss and is overlain by lavas. Such evidence at first sight suggests that the fluxion-gabbro is intermediate in age between the gneiss and the lavas and therefore occupies a unique place in the time sequence of the rocks of Creagan Dubh. However, as the granular (massive) gabbro of the dyke, especially that occurring in the gabbro tongues extending from the dyke into the gneiss, cannot readily be distinguished from the less altered granular gabbros occurring sporadically within the gneiss, it seems not impossible that the fluxion-gabbro dyke also ante-dates the gneiss.

B. Transgressive agglomerate, Quartz-porphyry and Microgranite

The transgressive agglomerate occurring in the Coire Garbh vent and within the lavas on the northern crags is clearly intrusive into the lavas (see p. 107). The agglomerate belonging to the large mass of agglomerate at the southern end of Creagan Dubh also exhibits detailed evidence of its intrusive character (see p. 133). The quartz-porphyry, on the other hand, cuts lavas, transgressive agglomerate and granite /

granite, and thus appears to be still later in age.

Both the transgressive agglomerate and the quartz-porphyry consist of fragments in a glassy or cryptographic matrix, and the only major difference between them is the larger size of the fragments in the agglomerate. This similarity suggests that the transgressive agglomerate and the quartz-porphyry have originated in a similar manner. Both are intrusive, and their glassy or cryptographic matrices are indicative of a high temperature of formation accompanied by rapid cooling. The lack of alteration of the fragments in the agglomerate, and the incomplete alteration of the fragments in the quartz-porphyry suggests that the formation, emplacement and cooling of these rocks took place rapidly. The fluxion structures in the matrices suggests that the material, molten at the time of emplacement, as indicated by the presence of glass, was extremely viscous. It is postulated, therefore, that the quartz-porphyries and transgressive agglomerates were emplaced as viscous magma, probably acidic in composition, carrying numerous fragments.

The majority of the fragments consist of basalt and sediments similar to the neighbouring Jurassic and Torridonian strata. Also present are quartz-porphyry and felsite fragments of the types found on Glas Bheinn Bheag, and of felsite /

felsite of other types. This appears to indicate that the fragments have been derived from below, and also that the quartz-porphyry found on Creagan Dubh is not the oldest quartz-porphyry in the area. No source for the numerous fragments of trachyte in the transgressive agglomerates has been adduced. The presence of trachyte lava in depth is not a pre-requisite, as the bedded agglomerates of Srath Beag also contains trachyte, and similar bedded agglomerates occurring to the south of this area near the Allt Slapin are cut by transgressive agglomerate. No fragments of gneiss or tuff and agglomerate of the Lower group have been found in the transgressive agglomerate despite the proximity of the latter to these rocks. The lavas overlie the Lower group, and the transgressive agglomerate cuts the lavas and, at one place appears to cut the Lower group although actual contacts have not been found. It seems, therefore, that the transgressive agglomerate is younger than the Lower group. On the northern crags of Creagan Dubh, gneiss is exposed dipping beneath lavas. Less than 30 feet away, transgressive agglomerate cuts the lavas at an angle steeper than that of the unconformity. Simple geometry indicates that the agglomerate should therefore cut the gneiss also. However, the fragments in the agglomerate are chiefly of Jurassic quartzite, and /

and no gneiss is present. The most simple explanation of such a situation appears to be that the gneiss fragments have been carried in the viscous agglomerate to a higher level, and that, as the result of little or no mixing, the level of quartzite fragments in the transgressive agglomerate is exposed at the present surface. Those smaller masses of transgressive agglomerate occurring scattered throughout the northern crags are confined to the lavas but are predominantly quartzite-rich, and thus it would appear that here also gneiss fragments have been removed to a higher level. The dyke-like mass of transgressive agglomerate which occurs alongside one of the minor faults at the extreme northern end of Creagan Dubh seems to cut the gneiss. However, the fragments within this agglomerate are quartz-porphyry and quartzite. Again the explanation put forward is that the gneiss and lava fragments have been removed to a higher level.

The assortment of fragments characteristic of the transgressive agglomerate towards the southern end of Creagan Dubh suggests that this explanation, which does not allow for mixing of fragments, does not here hold good. It seems more likely that in this area the great turbulent activity required to procure the space for large quantities of agglomerate resulted in some mixing of the fragments. If mixing /

mixing has taken place, the absence of fragments of gneiss at first appears to be anomalous. However, in this locality vertical transgressive agglomerate cuts vertical lava, and there is no structural evidence that the agglomerate cuts the gneiss.

The microgranite net-veins occurring in the basalt near the summit of Creagan Dubh reveal little evidence regarding their mode of origin. The veins are generally straight and parallel-sided, and in instances of cross-cutting of veins, the displacement of the earlier veins across the later is greater than or less than that expected if the later veins had been emplaced as the result of simple dilation. Thus, while it appears that there has been movement within the basalt during the phase of the formation of the microgranite net-veins, there is no evidence indicating whether the net-veins have been formed as the result of a dilational or replacement mechanism. The basalt at the sharp contacts with the net-veins has been granulitised and basified, indicating that the temperature of formation of the net-veins was high and that excess mafic material was expelled into the basalt. The presence of feldspar crystals spanning the junctions between the basalt and the acidic veinlets extending from the margins of the main net-veins suggests that the veinlets /

veinlets are of replacement origin and have resulted from the percolation of acidic fluids outwards from the net-veins. The net-veins themselves, apart from their lack of fragments and their micrographic margins, resemble the straight parallel-sided net-veins of Beinn na Cro (see pp.28-31), but there is nothing to indicate whether or not they have originated in a similar manner.

C. Sequence of events which took place during the geological history of Creagan Dubh

1. The Lower Group of tuffs, agglomerates and bedded sediments (probably tuffs) were deposited. Either intercalated with these, or subsequently intruded into them, were the basic igneous rocks of the Lower Group.
2. The bedded sediments and associated gabbros were metamorphosed: the former were converted into gneiss, and the latter were altered and net-veined.
3. The lavas, unconformable upon the Lower Group, were poured out.
4. The rocks of Creagan Dubh were tilted down to the south-east.
5. The upright nature of the Coire Garbh vent indicates that the transgressive agglomerate was intruded subsequent to the tilting.
6. The quartz-porphyrines were intruded.
7. The microgranite net-veins were emplaced.
8. The rocks of Creagan Dubh were faulted. The north-westwards-striking faults were formed firstly, and were cut by the Shoulder fault and the Coire Garbh fault.

GLAS BHEINN BHEAGI. INTRODUCTION

Glas Bheinn Bheag is 1,100 feet high, two miles long and one mile wide, and extends northwards from Gualann nam Fiadh to the north-east of Beinn na Cro (Fig. 1). The area to be described was mapped on the scale of six inches to one mile and is roughly triangular in outline. Its southern corner lies at the head of Srath Beag (Map, back pocket). The eastern boundary is the limit of the hill itself, namely the northwards-flowing stream called An Slugan, and its continuation the Allt Strollamus. To the south-west and west the margin of the area is the Gualann nam Fiadh fault, while the northern boundary is marked by a hillock, Am Meall, and by Loch Cairidh.

The summit and the eastern flank of Glas Bheinn Bheag are composed of Jurassic sediments - hornfelses, indurated feldspathic and calcareous sandstones and quartzites and mudstones - which dip at a moderate angle to the south-east. These rocks are metamorphosed and underlain by Tertiary microgranite which forms the western side of the hill.

II. FIELD RELATIONS

(Map, back pocket)

1. Jurassic Sediments

The Jurassic sediments occupying the summit and eastern flank of Glas Pheinn Bheag extend from Dunan as far southwards as the head of An Slugan. The strata dip south-eastwards and the angle of inclination, low to moderate in the north and west, increases eastwards and is about 50° where the rocks are exposed in the beds of An Slugan and the Allt Strollamus. The sediments are about 2000 feet thick and may be divided on lithological grounds into four stratigraphic units: Hornfelses and metamorphosed sandstones; Feldspathic sandstones and quartzites; Calcareous quartzites; Mudstones.

The lowest beds present are the Hornfelses and metamorphosed sandstones, and their maximum observed thickness is 700 feet. They occur in the north-western part of the area in the northern and western slopes of Glas Pheinn Bheag, but are cut out by the microgranite towards the south. Small bodies of hornfels occur in the microgranite below the main contact line of the microgranite with the sediments (see pages /

pages 175-177). Succeeding the hornfels group is a thickness of 350 feet of Feldspathic sandstones and quartzites. This group forms the summit and the upper part of the eastern side of the hill, and passes upwards into the Calcareous quartzites. This succession is 650 feet thick and consists of quartzites with calcareous lenses and doggers which become more abundant in the higher strata. The Calcareous quartzites are exposed near the head of An Slugan and on the lower part of the eastern side of Glas Bheinn Bheag (Plate XLIIIa). Mudstones follow upon the Calcareous quartzites. The former are found in the bed of the upper part of the Allt Strollamus (Plate XLIIIb).

Quartzite similar to quartzite in the Feldspathic sandstones and quartzites group also occurs in Srath Beag where the Gualann nam Fiadh fault bifurcates. The quartzite is exposed in the bed of the Allt an t-Sratha Bhig between the two divisions of the fault, and further occurrences are seen in the fault breccia on Gualann nam Fiadh.

2. Acidic Rocks

The acidic rocks of Glas Bheinn Bheag consist of microgranite, granite and quartz-porphry. The term 'acidic' is used here, as in the other sections of the thesis, solely to /

to denote igneous rocks. Thus the sediments of Glas Bheinn Bheag, although acidic in composition, are not referred to under this heading.

A. Microgranite. Microgranite occupies most of the western side of Glas Bheinn Bheag. Stream sections and intermittent exposures in the low ground to the west of the hill reveal that the microgranite, to the west, underlies the sediments to the east. The contact strikes approximately north-south along much of its length, nearly parallel to the strike of the sediments, but in the south the junction trends eastwards and crosses the ridge from west to east. The contact is not seen in the low ground at the source of An Slugan, due to a covering of boulder clay and peat. In the north, the contact has been displaced a quarter of a mile towards the west by an east-west fault. The western limit of the microgranite is the Gualann nam Fiadh fault.

B. Granite. Granite occurs at Dunan and on Am Meall in the northernmost part of the area. It is separated from the rocks of the rest of the area by the Dunan fault, which may be traced from the shore at Dunan west-south-westwards as far as the Allt an t-Sithein (see pages 7-8).

C. /

C. Quartz-Porphyry. Minor intrusions of quartz-porphyry are abundant in the sediments; most of them, however, are small and have not been recorded on the map. Two larger masses are exposed in the bed of the Allt Strollamus. One lies about 300 yards upstream of the old bridge, Drochaid Mhor Strollamus, and the other is a further 600 yards upstream. Each is exposed over a distance of about 100 yards, but their form and thickness cannot be determined.

Quartz-porphyry is less common in the microgranite. Several small masses have been found, and one large mass, exposed in the Allt nam Fiadh, about 100 feet downstream from the lowest hornfels (see page 177), is about 200 feet wide, measured along the surface of the ground. Marginal banding of the quartz-porphyry at its upstream contact with the microgranite is vertical, while that at the lower contact is horizontal.

| | <u>Distance southwards from previous fault</u> | <u>Strike</u> | <u>Downthrow side</u> | <u>Throw</u> (west) | <u>Throw</u> (east) |
|----|--|---------------|---------------------------|------------------------|------------------------|
| 1. | | E | North | 0 | 300 ft. |
| 2. | 300 yards | E | North | 200 ft. | |
| 3. | 250 yards | ESE | South | 100 ft. | |
| 4. | 200 yards | SE | North | 0 | 100 ft. |
| 5. | 200 yards | SE | South | 50 ft. | |
| 6. | 200 yards | SE | North | little | |

Figure 24. Table of the faults of Glas Bheinn Bheag, reading from 1, the most northerly fault, to 6, the most southerly, showing their relative positions, strike, downthrow side, and their throw. (west) and (east) refer to the amounts of throw, where different, on the west and east sides of Glas Bheinn Bheag respectively.

III. STRUCTURE

(Map, back pocket)

The structure of Glas Bheinn Bheag is relatively simple. The sediments dip eastwards in the extreme north of their outcrop at angles of up to 45° , but further to the south they dip south-eastwards at slightly higher angles.

The Gualann man Fiadh fault, marking the western limit of Glas Bheinn Bheag, and the Dunan fault are described on pages 7-8 . Fanning across the hill are several faults. The most northerly of these strikes almost due eastwards, and there is a gradual change in the direction of strike from fault to fault, so that the most southerly one strikes south-eastwards (Fig. 24). In addition to these major faults are three smaller faults: one occurs about half way along the western side of the hill and strikes west-south-westwards; the others are exposed in the bed of the Allt Strollamus on the eastern side of Glas Bheinn Bheag and have a more northerly strike.

IV. /

IV. PETROGRAPHY1. Sediments

The Jurassic sedimentary rocks of Glas Rheinn Rheag are metamorphosed and have been divided into six arbitrary metamorphic zones which range in thickness from a few feet to 200 feet (see map, back pocket), there being an increase in the grade of metamorphism towards the microgranite. Characteristic metamorphic features of the six zones, starting with the lowest grade of metamorphism, are as follows:

Zone 1. The sediments contain a large amount of groundmass, and less recrystallised material than original detrital material.

Zone 2. Compared with Zone 1, considerable recrystallisation and alteration of the feldspars has taken place so that the percentage of new-formed feldspar is greater than that of original feldspar.

Zone 3. In this zone much of the quartz and feldspar has recrystallised, while the amount of alkali feldspar has risen.

Zone 4. All the quartz and feldspar have recrystallised. The transition from Zone 3 to Zone 4 is extremely gradual.

Zone 5. The increase in the amount of biotite and iron ore over the amount occurring in the previous zone is marked.

Zone 6. This zone is characterised by the presence of feldspar porphyroblasts, a marked increase in the amount of feldspar and a proportional reduction in the percentage of quartz.

A marked feature of all the metamorphosed sediments of Glas Bheinn Bheag is that whereas the original quartz consists of subangular or rounded grains exhibiting shadow extinction, the new-formed quartz occurs in rounded mosaic aggregates or as discrete equidimensional crystals, the latter generally occurring where the percentage of quartz is low. The original feldspar also occurs as subangular or rounded grains which are generally clear, whereas the new-formed feldspar, in the lower grades of metamorphism, is cloudy, interstitial, diffuse marginally, and may rim original feldspar. In the higher grades, the new-formed feldspar exhibits a progressive decrease in cloudiness.

The detailed petrographic features of the metamorphic zones are described in relation to the lithological groups of the sediments.

A. Hornfelses and metamorphosed sandstones. These rocks are medium to fine-grained and generally dark in colour. Subangular grains of quartz with subordinate feldspar, chiefly orthoclase, microcline and the more sodic plagioclases, lie in a matrix of chloritic, feldspathic and sericitic material. Ilmenite and magnetite are present in variable quantity, and accessory mineral include apatite, zircon, sphene, brookite, tourmaline /

tourmaline and garnet. Zones 2, 3, 4, 5 and 6 are present.

Zone 2. The rock consists of subangular grains of strained quartz, sparse aggregates of mosaic quartz and a subordinate amount of rounded feldspars, in a groundmass composed of chlorite and sericite together with cloudy irregular masses of new-formed feldspar, some of which have diffuse margins. Accessory minerals are also present.

Zone 3. Only a small proportion of the quartz grains are unaltered: the bulk of the quartz consists of subangular aggregates of mosaic crystals set in a matrix of cloudy feldspar together with a little chlorite and accessory minerals.

Zone 4. The rock is distinctly banded. The quartz and feldspar are totally recrystallised, and the latter is less cloudy than in zone 3, and identified as alkali feldspar. The groundmass is chiefly composed of biotite, either foxy-red in colour where it rims magnetite, or more commonly greenish, with dark pleochroic haloes where it has apparently formed by the alteration of clots of green chlorite. Bands of heavy minerals, chiefly zircon and sphene, are the nuclei upon which biotite, chlorite, ilmenite and magnetite have grown.

Zone 5. The rock differs from that of zone 4 in that it contains a larger amount of feldspar, chlorite, biotite and /

| | <u>Zone 2</u> | <u>Zone 3</u> | <u>Zone 4</u> | <u>Zone 5</u> | <u>Zone 6</u> |
|----------------------------|---------------|---------------|---------------|---------------|---------------|
| Original quartz | 48.5 | 1.0 | | | |
| Recrystallised quartz | 11.5 | 38.5 | 50.0 | 41.5 | 11.0 |
| Original feldspar | 10.0 | 5.0 | | | |
| Recrystallised feldspar | 16.0 | 22.5 | 33.5 | 40.5 | 61.0 |
| Biotite and chlorite | 2.0 | 7.0 | 8.0 | 9.0 | 22.0 |
| Iron ore (and accessories) | 1.5 | 1.5 | 2.5 | 5.0 | 6.0 |
| Groundmass | <u>10.5</u> | <u>24.5</u> | <u>6.0</u> | <u>4.0</u> | <u> </u> |
| | <u>100.0</u> | <u>100.0</u> | <u>100.0</u> | <u>100.0</u> | <u>100.0</u> |

Figure 25. Table of average modal analyses of rocks of metamorphic zones 2, 3, 4, 5 and 6: Hornfelses and metamorphosed sandstones. The figures are regarded as being representative rather than strictly accurate.

and magnetite. Much of the feldspar is clear alkali feldspar.

Zone 6. The rock of zone 6 is very dark coloured, almost black, and granulitic in texture. It contains much feldspar, both interstitial cloudy sericitised feldspar and clear anhedral porphyroblasts of orthoclase, oligoclase and microperthite. A subordinate number of lake-like porphyroblasts of quartz are also present. These contain small inclusions of feldspar, quartz and ferromagnesian minerals. The matrix of the rock is granulitic and consists of bright green chlorite and tabular almost colourless biotite. Apatite containing inclusions is also present.

From the above description and the table (Fig. 25) it can be seen that in the group of Hornfelses and metamorphosed sandstones the most marked changes as the microgranite is approached are the increase in the amount of feldspar and dark minerals, and the corresponding decrease in the amount of quartz. There is also a reduction in the amount of groundmass and the development of porphyroblasts in the immediate neighbourhood of the microgranite. Although zone 6 is very narrow, within the zone there is a continuous change in the rock right up to the contact, where the greatest percentage of feldspar and ferromagnesian minerals is to be found.

B. Feldspathic sandstones and quartzites. The Feldspathic sandstones and quartzites are coarser in grain than the hornfelses. Most of the rocks are ~~are~~ evenly medium or coarse-grained, but gritty bands are also present. The rocks are generally white or pale bluish-grey in colour and consist of rounded and angular grains of quartz and feldspars set in a groundmass of sericite and chlorite. The feldspars are orthoclase, microcline, albite and more calcic plagioclase, together with a little microperthite. Ilmenite is the most abundant iron ore mineral, but magnetite is also ubiquitous. Accessory minerals are rare, and comprise muscovite, zircon and sphene. Zones 1, 2, 3, 4, 5 and 6 are present.

Zone 1. (Plate XLIVa) The rock consists of subangular and rounded grains of strained quartz, rounded grains of orthoclase, together with oligoclase, microcline and microperthite. Some of the oligoclase contains flakes of sericite. The groundmass consists of blebs of pale green chlorite and irregular clumps of ilmenite lying in a sericitic matrix.

Zone 2 (Plate XLIVb). The strained quartz grains are in some cases broken up into mosaic aggregates within the original grain boundaries. Much of the feldspar is cloudy, and the new-formed cloudy feldspar rims and partially replaces the original feldspar. The percentage of groundmass material is less than in the rocks of zone 1.

Zone /

Zone 3 (Plate XLVa). The rock shows an incipient development of granulitic texture. The feldspars are cloudy and granular, the original ones having partially lost their origin outlines. Most of the quartz is in the form of small mosaic grains, and sparse micropegmatite is present interstitially. Pale greenish-brown biotite is present in the form of needles and flakes, often with pleochroic haloes. The groundmass is sparse and consists of sericite and chlorite.

Zone 4 (Plate XLVb). The rock is finer in grain than that of zone 3, and is composed largely of mosaic quartz and granular feldspar. The iron ores occur as rims around the heavy minerals, and in laminae associated with biotite.

Zones 5 and 6 (Plates XLVI and XLVII). Compared with zone 4, these zones contain a greater amount of feldspar, much of which is porphyroblastic.

The changes in mineral composition of the Feldspathic sandstones and quartzites are not so marked as in the case of the Hornfelses and metamorphosed sandstones, and are essentially a gradual increase in the amount of feldspar and a sudden drop in the proportion of quartz in zone 6.

C. Calcareous quartzites. The calcareous rocks are generally coarse in grain and white in colour. They consist /

consist of subangular grains of quartz in a groundmass of calcareous material comprising a generally unstable assemblage of calcite and wollastonite, together with subordinate amounts of diopside, epidote and garnet. Ilmenite, pyrite and haematite are of sparse occurrence. The proportion and association of the metamorphic minerals is extremely variable. Criteria used in the determination of the zones of metamorphism in the other lithological groups are not generally applicable to the Calcareous quartzites and therefore the only character used is the degree of recrystallisation and granularity of the quartz. The accuracy of the determination of the zones of metamorphism based upon this one character alone is not great. Zones 2, 3, 4 and 5 are, however, considered to be present.

Zone 2. The rocks of this zone, unlike more typical Calcareous quartzites, contain feldspar as well as calcareous material and quartz. The rock is medium to coarse-grained, consisting of subangular grains of quartz, some of which show shadow extinction while others are broken up into mosaic aggregates; rounded grains of feldspar, chiefly cloudy orthoclase, together with clear microcline and oligoclase. The groundmass consists of greenish biotite, chlorite, ilmenite, calcite, sericite and wollastonite.

Zone /

Zone 3. More typically calcareous rocks occur in this zone. They consist of 60% to 80% quartz, which is largely in the form of mosaic aggregates, in a groundmass of calcite and a little argillaceous material, together with calc-silicate minerals. Wollastonite is the most abundant of these minerals, comprising up to 20% of the rock. It is present in the interiors of crystals of calcite, where it is granular and twinned on a lamellar law. It also is closely associated with quartz in the form of an inner rim of radial fibres within the quartz crystals and an outer rim of radial fibres at the margins of the quartz crystals (Plate XLVIIIa). The rock also contains green epidote, diopside and a colourless garnet. The diopside and garnet occur together as small idiomorphic crystals at the margins of, and included within, large crystals of calcite (Plate XLVIIIb).

Zone 4. In the more quartzose varieties of the Calcareous quartzites the rocks of this zone contain completely mosaic quartz; in those with a lesser amount of quartz the grains of this mineral, while totally recrystallised, are granular and separated from one another by a mass of fibrous wollastonite, diopside, epidote and a minute quantity of feldspathic material. The rimming of the quartz by the wollastonite is an extremely common feature of this rock.

Zone /

Zone 5. In this zone the quartz forms a bold mosaic. Little calcite, which may be secondary, is present. Wollastonite has not been found, the calc-silicate minerals being represented by diopside, epidote and garnet.

D. Mudstones. The usual colour of the mudstones is black or dark bluish grey, with streaks of red and orange. Some parts of the mudstones are massive, but most are finely laminated. Calcareous bands contain a shelly fauna. The extremely fine-grained nature of the rock, which in thin section exhibits no clearly marked features, has rendered work on the metamorphism of the mudstones impracticable.

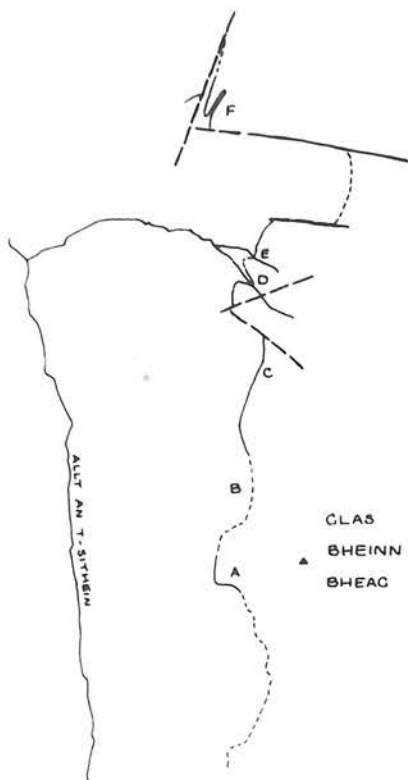
By use of the point counter, and by microscope analysis, the metamorphic zone of each sediment specimen, except those of the mudstones, has been determined. The localities of these specimens were plotted on a map of Glas Bheinn Bheag, and from these point-plots a map showing the approximate distribution of the metamorphic zones was compiled (Map, back pocket). The rational distribution of the arbitrarily determined metamorphic zones suggests that the characters upon which the determination was based are significant. Approximate thicknesses of the zones have been obtained by stratum contouring.

It /

It can be seen from the map that zone 1, which is of unknown thickness, occurs at the extreme north-eastern end of Glas Bheinn Bheag, and also in a small area on the eastern flank of the hill, about 500 yards south-west of Drochaid Mhor Strollamus. Zone 2 is about 100 feet thick and extends from the coast at Dunan southwards up the eastern side of the hill to some distance above the old road, but the larger tract of country occupied by this zone is an irregular area nearly half a mile long and of similar width, which occurs on the eastern side of the ridge about half a mile to the north-west of the summit. Zone 3, about 200 feet thick, is more widespread. It extends southwards from Dunan more or less along the crest of the ridge almost as far as the summit, and encircles zone 2, reappearing in an eastern strip in the Allt Ströllamus area. Zone 4 is of similar thickness to zone 3 and also occupies a large area. It occurs in the low ground to the north-west of Glas Bheinn Bheag, and extends in a fairly narrow strip southwards along the western side of the hill. It is found at the summit and on the whole of the south-eastern flank and in the bed of An Slugan. It also occurs to the north-east, around Drochaid Mhor Strollamus, and extends in a gully as far as a quarter of a mile to the west of the bridge. Zone 5 is rather narrow, perhaps

Figure 26.

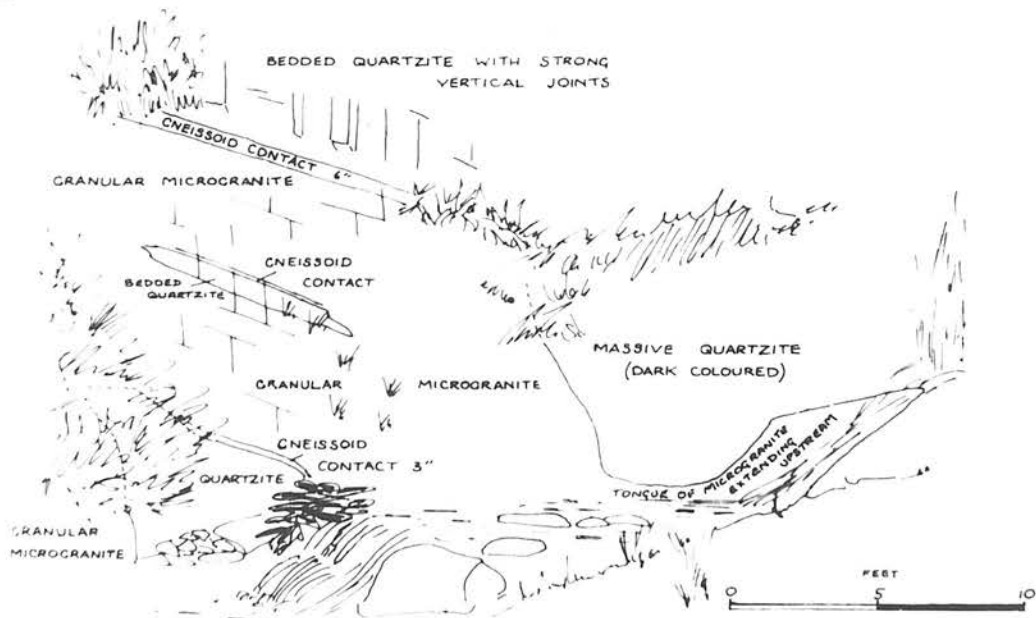
A.



A. A sketch map of the localities on Glas Bheinn Bheag at which the contact between the microgranite and the sediments is exposed.

B. A sketch of part of the contact complex exposed in the bed of the Allt nam Fiadh. For quartzite read hornfels.

B



50 feet thick, and zone 6 is only a few feet thick. These two zones occur together on the western side of Glas Bheinn Bheag along the contact with the microgranite. Zone 5 is also to be found at Dunan against the Dunan fault. Zones 4, 5 and 6 occur in Srath Beag, Zone 4 to the south, in the bed of the Allt an t-Sratha Bhig, and extending for a short distance up Gualann nam Fiadh. Zones 5 and 6 are present where the quartzite is narrow and cut out by the junction of the two branches of the Gualann nam Fiadh fault.

2. The Contact of the Sediments and the Microgranite

It can be seen from the map (back pocket) that the line of contact of the sediments with the microgranite strikes roughly southwards along the western side of Glas Bheinn Bheag. Stratum contouring of the metamorphic zones of the sediments indicates that the microgranite dips beneath the sediments in the manner indicated by Harker (1904), namely, roughly parallel to the dip of the bedding. The junction is exposed at four localities and can be determined to within a few feet at a fifth (Fig. 26A).

At the southernmost of these (A) the junction has an easterly strike and microgranite sharply transgresses feldspathic /

feldspathic quartzite of the Feldspathic sandstones and quartzites. The boundary is abrupt, yet there is no chilling or intense marginal baking. The quartzite is grey with narrow black laminae and two inches from the contact shows a very marked increase in feldspathic material, which occurs in association with the laminae. Nearer the contact the feldspathic content of the rock is even greater, and although the laminae are preserved the feldspar is more evenly distributed in the rock, which is now paler in colour. One centimeter from the microgranite the laminae die out and there is a transition through a granulitic rock with a high percentage of feldspar into granular microgranite. Within the microgranite, three centimeters from the contact large crystals of plagioclase and associated blebs of ferromagnesian minerals become apparent. The crystal aggregates are ubiquitous throughout the microgranite.

At (B) the contact of the sediments and the microgranite is not exposed, but here a mass of undisturbed hornfels about 15 feet thick is separated on the ground from the main mass of the sediments above by a similar thickness of microgranite. The hornfels is fine-grained, granulitic and highly feldspathic. The upper microgranite differs from the main mass below in that it bears some resemblance to granular /

granular quartz-porphry. The lower, main, microgranite is granular near the contact with the hornfels, and at a greater distance from the contact is micrographic.

At (C) the microgranite is in contact with laminated hornfels belonging to the Hornfelses and metamorphosed sandstones. The contact is parallel to the strike of the lamination in the hornfels. The change in the hornfels as the microgranite is approached can be seen in the field, and takes the form of an increase in the amount of dark minerals and feldspars. The microgranite is granular for a distance of seven feet below the contact, and grades rapidly into micrographic microgranite. About 100 feet below the contact granular microgranite again occurs. Its thickness is not known.

Localities (D), (E) and (F) are similar. Each is a stream in the bed of which strike sections of the contact are exposed. In each case the junction is multiple. That at (D) (Fig. 26B), the most complex, is described in detail.

The Allt nam Fiadh flows westwards off the slopes of Glas Bheinn Bheag and cuts a stepped gully through hornfels and microgranite. Several patches of hornfels occur in the microgranite below the main mass of the sediments. The hornfels layers and granular microgranite form the crests of /

Approximate thickness of layers

| | |
|-----------------------------------|-----------|
| 18. Main Sediment | |
| 17. Granular microgranite | |
| 16. Hornfels | 10 feet |
| 15. Granular microgranite | |
| 14. Hornfels | 10 feet |
| 13. Granular microgranite | 5 feet |
| 12. Hornfels | 5 feet |
| 11. Granular microgranite | 10 feet |
| 10. Micrographic microgranite | 20 feet |
| 9. Granular microgranite | 15 feet |
| 8. Micrographic microgranite | 12 feet |
| 7. Granular microgranite | 5 feet |
| 6. Hornfels | 20 feet |
| 5. Granular microgranite | 5 feet |
| 4. Micrographic microgranite | 20 feet |
| 3. Granular microgranite | 5 feet |
| 2. Hornfels | 10 feet |
| 1. Granular microgranite | v 10 feet |
| 0. Main micrographic microgranite | |

Figure 27. Table of the contact complex exposed in the bed of the Allt nam Fiadh, reading from top to bottom.

of the steps while micrographic microgranite lies in the hollows. The hornfels/microgranite^{complex} is layered, the bedding of the hornfels and the contacts of the hornfels with the microgranite dipping at 10° to the east. The uppermost contact is six inches wide and gneissoid in appearance; streaks of highly feldspathic white rock up to one inch wide alternate with bands of a dark coloured granular rock composed chiefly of dark minerals with a little quartz and feldspar. The feldspars are largely porphyroblastic while the quartz may be porphyroblastic or granular. Below this contact is a thickness of ten feet of granular microgranite which five feet from its top encloses a lens of hornfels one foot thick and five feet long (15, 16 and 17, Fig. 27). Beneath this granular microgranite is an irregularly shaped mass of hornfels whose upper contact is three inches wide and gneissoid. The ten-foot mass of granular microgranite above narrows very rapidly down dip, cutting the hornfels at a steep angle and dying out as a short tongue some three feet wide and ten feet long (Fig. 26B). The whole contact complex is represented in the table, Figure 27.

| | I | II | III | IV |
|-----------------|-------|-------|-------|-------|
| Quartz | 5.0 | 15.0 | 5.0 | 8.5 |
| Alkali feldspar | 4.5 | 11.0 | 3.0 | 17.5° |
| Plagioclase | 15.0 | 30.0 | 12.0 | 13.0 |
| Micropegmatite | 68.5 | 36.0 | 73.0 | 54.0 |
| Dark minerals | 7.0 | 8.0 | 7.0 | 8.0 |
| | ----- | ----- | ----- | ----- |
| | 100.0 | 100.0 | 100.0 | 100.0 |
| | ----- | ----- | ----- | ----- |

Figure 28. Table of average modal analyses of acidic rocks of Glas Bheinn Bheag. I. Micrographic microgranite; II. Granular microgranite; III. Spherulitic microgranite; IV. Dunan granite.

°This figure includes both microperthite and oligoclase-bearing microperthite.

3. Acidic Rocks

The relative proportions of the chief constituents of the Acidic rocks of Glas Bheinn Bheag are shown in the table, Figure 28.

A. Microgranite. Although the textural and mineralogical composition of the microgranite is variable, three main types may be distinguished, namely micrographic microgranite, granular microgranite and spherulitic microgranite. Micrographic microgranite is the most common type; granular microgranite is found only in the contact areas against the sediments where it is ubiquitous.

(i) Micrographic microgranite

The micrographic microgranite is a medium-grained pale coloured rock consisting of quartz, oligoclase, orthoclase, microperthite, albite, augite, hornblende, biotite, chlorite and magnetite, together with accessory haematite, ilmenite, zircon, sphene, epidote, orthite and apatite (Plate XLIX).

Quartz. Some of the quartz occurs as anhedral crystals up to one millimeter across which exhibit shadow extinction, but most of it is in the form of micropegmatite with various feldspars.

Oligoclase /

Oligoclase. Large crystals of oligoclase up to five millimeters across are of frequent occurrence, giving the micrographic microgranite a characteristic porphyritic aspect. These large oligoclase crystals exhibit the finely lamellar twinning typical of all the large crystals of oligoclase in the microgranites of Glas Bheinn Bheag. This twinning is indistinct towards the boundaries of the crystals, which are considerably more alkaline than their interiors. The crystals are embayed and rimmed by albite or orthoclase, which grades outwards into outer rims of micropegmatite consisting of quartz and orthoclase or microperthite or both, the orthoclase being in optical continuity with the orthoclase of the inner rim, while where albite forms the inner rim, it is in optical continuity with the albite of the microperthite. The oligoclase crystals are altered internally to chlorite and sericite or numerous blebs of quartz, alkali feldspar or micropegmatite rimmed by clear albite.

Alkali feldspars. The alkali feldspars rim the oligoclase and also occur in the groundmass of the microgranite, both in the micropegmatite and as discrete euhedral crystals. The micropegmatite rimming the oligoclase grade by a progressive increase in the proportion of quartz into free interstitial quartz.

Ferromagnesian /

Ferromagnesian minerals. The ferromagnesian minerals are generally anhedral and are associated with the large oligoclase crystals. Green augite is the most common, and may rim or be rimmed by brownish-green hornblende, biotite and chlorite. A bluish-green amphibole is of sporadic occurrence.

(ii) Granular microgranite

The granular microgranite differs from the micrographic microgranite in being granular rather than micrographic in texture: the former contains less micropegmatite but a higher percentage of quartz, fewer large crystals of oligoclase but a higher percentage of total oligoclase. The dominant ferromagnesian mineral of the granular microgranite is brownish-green hornblende rather than augite, and among the accessory minerals pyrite is present and orthite has not been found (Plate L).

(iii) Spherulitic microgranite

The difference between the spherulitic and the micrographic microgranites is one of textural variation. The micropegmatite of the spherulitic microgranite is much finer in grain and most of it has a feathery appearance. This is especially the case where it rims large oligoclase crystals /

crystals (Plate LI). The quartz and alkali feldspar units of the micropegmatite frequently lie almost normal to the oligoclase crystal faces. In the most spherulitic rocks the micropegmatite is cryptocrystalline and dendritic and is more abundant than in the less spherulitic rocks of this group. The dominant ferromagnesian mineral of the spherulitic microgranite is a reddish-green or pale green amphibole, the latter being an alteration product of augite.

B. Granite. The granite at Dunan and on Am Meall is medium to coarse-grained and very similar to that of Beinn na Cro (see pages 46 - 49). The constituent minerals are quartz, microperthite, orthoclase, oligoclase, albite, biotite, hornblende, magnetite, pyrite and haematite, together with accessory epidote, clinozoisite, orthite, tourmaline, sphene, apatite and zircon.

Quartz. Quartz occurs free, as anhedral crystals up to three millimeters across, which are generally laced with irregular stringers extending from adjacent microperthite or orthoclase, and also in micropegmatite. Euhedral crystals of quartz, seldom more than 0.3 millimeters in length, are associated with aggregates of epidote.

Feldspars /

Feldspars. Microperthite and oligoclase are the most abundant feldspars. The latter is in the form of euhedral crystals up to seven millimeters across, which are highly zoned with albitic margins and are rimmed by and contain angular embayments of microperthite and micropegmatite. Oligoclase crystals up to one millimeter long also rim microperthite. The microperthite occurs sparsely as euhedral crystals up to five millimeters across and is also present in micropegmatite. The microperthite consists of orthoclase with albite or oligoclase which occur in extremely variable proportions.

Dark minerals. The dark minerals are not abundant, and occur in clusters, the accessory minerals being associated with quartz and the ferromagnesian minerals and ores with the large oligoclase crystals.

C. Quartz-porphyry. Three distinct types of quartz-porphyry have been found. One has a granular matrix, another a micrographic matrix, and the third is spherulitic.

(i) Granular quartz-porphyry

The matrix of the granular quartz-porphyry is very fine-grained and consists of granular quartz, feldspar and chlorite. Set in the matrix are large crystals and crystal aggregates comprising quartz, orthoclase, oligoclase and micropegmatite /

micropegmatite; hornblende, augite, hypersthene and chlorite; magnetite, ilmenite and haematite; accessory sphene, zircon, epidote, orthite and apatite (Plate LIIIa).

Quartz. Quartz, apart from occurring in micropegmatite, has the form of discrete euhedral or subhedral crystals which are generally corroded.

Feldspars. Feldspars may also occur as discrete crystals, but aggregates are more common. The orthoclase is cloudy and is the usual feldspar component of the micropegmatite, while the oligoclase occurs as twinned, strongly zoned crystals rimmed by micropegmatite and containing blebs of quartz and micropegmatite rimmed by albite.

Micropegmatite. The micropegmatite is of two types. One is coarse-grained and occurs as isolated masses in the groundmass, in like manner to other crystals and crystal aggregates, while the other is feathery and rims the discrete oligoclase and the feldspar aggregates. Against the core crystals the micropegmatite is very fine-grained, but it increases in grain size outwards. There is, however, a distinct narrow rim of extremely fine-grained micropegmatite separating the inner rims from the groundmass.

Dark minerals. The dark minerals are in clots associated with the oligoclase. The augite and hypersthene are pale green /

green in colour and occur at the margins of reddish-brown biotite crystals. The hornblende, brownish-green in colour, occurs as acicular crystals along whose length are scattered small euhedral crystals of magnetite, and also as discrete irregular masses as an alteration of augite. The chlorite is most commonly found as an alteration product of hornblende.

This type of quartz-porphyry, while forming sills in the sediments, is more common as intrusive masses in the microgranite.

(ii) Micrographic quartz-porphyry

In hand specimen this rock is very similar to the granular quartz-porphyry, and only where the matrix is coarse-grained can it be easily distinguished. In thin section, however, the difference is readily apparent. The groundmass of the micrographic quartz-porphyry is spherulitic, micrographic or cryptographic and consists of quartz and alkali feldspar, together with a little chlorite, biotite and iron ore (Plate LIIf). Large crystals and crystal aggregates similar to those found in the granular quartz-porphyry are also present, and additional accessory minerals include rutile, clinozoisite, calcite, sericite, and a colourless garnet.

(iii) /

(iii) Spherulitic quartz-porphyry

Several of the minor intrusions of Glas Bheinn Bheag are composed of spherulitic quartz-porphyry. This is a fine-grained spherulitic rock with a granular matrix generally exhibiting fluxion structure. The spherules consist of feldspar, chiefly orthoclase and cryptoperthite, with or without micropegmatite. The groundmass is composed of quartz, together with a little alkali feldspar and chlorite.

V. DISCUSSION1. Structure

The sediments of Glas Bheinn Bheag and their relation to the microgranite are described in the Glenelg Memoir (Peach and Horne inter alia, 1910), but little detailed work has been published concerning the structure of the Glas Bheinn Bheag microgranite. Brief mention of Glas Bheinn Bheag was made by Harker (1904) who included the microgranite within the main Western Red Hills granite mass, and considered that the gently inclined contact of the microgranite with the sediments represented the upper surface of the Western Red Hills intrusion which he regarded as a laccolith.

Following the discovery of ring-dykes in Mull and Ardnamurchan, much of Harker's work was re-interpreted by two of the chief exponents of the ring-dyke hypothesis. Thomas (1927) regarded the low-dipping contact on Glas Bheinn Bheag as part of the dome-like roof of a ring-dyke belonging to a centre located in the Western Red Hills. Richey (1930), on the other hand, suggested that the Glas Bheinn Bheag microgranite belonged to an outer ring-dyke of granophyre focussed on Beinn na Caillich in the Eastern Red Hills, and that the microgranite was of younger age than the Beinn na Cro granite (see page 54).

It /

It is difficult to reconcile Richey's ring-dyke hypothesis as he applied it to the Glas Bheinn Bheag microgranite with the field evidence. The contact of the microgranite with the sediments, the inner contact of Richey's ring-dyke, departs from traditional ring-dyke structure in that it dips at a low to moderate angle to the east, that is inwards. Investigation of the outer contact of Richey's supposed ring-dyke reveals that the junction is a fault, post-dating both the granite mass of Beinn na Cro and the microgranite of Glas Bheinn Bheag (see pages 159-163).

Richey's hypothesis, based on singularly incongruous field evidence, is incompatible with that of Thomas, but further evaluation of their postulations cannot be accomplished without study of the other masses of granitic rocks of Skye, to which these eminent geologists referred. Such investigation lies beyond the scope of this thesis.

The field evidence recorded on pages reveals that the present form of the Glas Bheinn Bheag microgranite is relatively simple. On its eastern side the microgranite dips gently to the east below a roof of Jurassic sediments. On the western side its boundary is a fault, the Gualann nam Fiadh fault, which is post-microgranite in age. Towards its northern end the eastern margin of the microgranite is /

is cut by a number of east - west faults, the most northerly of which has displaced the contact rather less than a quarter of a mile to the west. The width of outcrop of the microgranite is thus considerably reduced, and to the north the mass narrows even further and terminates against the Gualann nam Fiadh fault. At its southern end the microgranite is obscured by peat and boulder clay, and thus the three-dimensional form of the body cannot be readily established.

The relationships of the Dunan fault and the Dunan granite to the sediments and the microgranite of Glas Bheinn Bheag are largely inferred from petrogenetic considerations, and are therefore discussed on pages 199 - 201 in the following section.

2. Petrogenesis

The main petrogenetic problems of Glas Bheinn Bheag concern - A. The metamorphism of the sediments; B. The origin of the microgranite; C. The origin of the quartz-porphyrines; and D. The Dunan fault and the Dunan granite "contact".

A. The Metamorphism of the Sediments. The induration and metamorphism of the sediments of Glas Bheinn Bheag were alluded to by Flett (1910), who described "a sliced specimen [of the Hornfelses and metamorphosed sandstones group] as /

as baked feldspathic sandstone, undoubtedly indurated and rendered more compact by thermal action but showing few mineral changes". p. 120. The alteration of the calcareous beds to "white sandy marble amongst altered sandstones" (p. 120) was also mentioned.

Field and petrographic evidence - in particular the cutting of the sediments by the microgranite and the increase in grade of metamorphism towards the microgranite - demonstrate that the sediments have been metamorphosed at the time of and in connection with the emplacement of the microgranite. The change in texture of the sediments from rocks composed largely of rounded detrital grains set in a fine-grained groundmass to granulitic rocks consisting of porphyroblasts of feldspar set in a matrix of equant grains of quartz, feldspar and ferromagnesian minerals, together with the absence of brecciation or other dynamic transformation, indicate that the operative metamorphic process was indeed one of thermal activity.

Accompanying the textural change, the sediments exhibit changes in mineral proportion (Fig. 29). The modal analyses of the sandstones and quartzites give at best only an indication of their chemical composition, but it seems probable that, as the changes in mineral proportion have been so /

so significant, these reflect chemical changes in the rock. Examination of the modal analyses (Fig. 25) indicates that chemical readjustment without metasomatism may have been responsible for the marked drop in the percentage of groundmass in the middle grades: the sharp increase in the amounts of feldspar and dark minerals in the high grades, however, is so great that these minerals cannot be regarded as having developed solely from the groundmass, and it appears that the sediments have undergone chemical change (metasomatism). The increase in the amount of feldspar from about 20% to about 70% is largely due to the development of alkali feldspar, and as over 20% of the increase has occurred in the highest grades, it seems likely that K_2O and Na_2O have been introduced. The increase in the amounts of biotite, chlorite and iron ore suggests that there may also have been some introduction of MgO , FeO , Fe_2O_3 and H_2O . As no chemical analyses of the sedimentary rocks of Glas Bheinn Bheag have been made (since the lithological variation renders the value of a small number of analyses equivocal), a more accurate assessment of the chemical changes undergone by the sediments is not yet possible.

The relationship of the metamorphosed sediments to the microgranite thus indicates that the alteration of the former /

former represents a metamorphic aureole contiguous to the latter, and it seems likely that, concomitant with the emplacement of the microgranite, hot aqueous fluids bearing K_2O , Na_2O , MgO , FeO , Fe_2O_3 permeated the sediments to a greater or lesser extent.

B. The Origin of the Microgranite. Good exposures of the contact between the microgranite and the sediments of Glas Bheinn Bheag reveal that the junction is complex. The alternating layers of hornfels and microgranite seen in the Allt nam Fiadh stream section (see pages 176-177) suggest two structural interpretations. The hornfels layers may be projections from the country rock into the microgranite, or they may be isolated rafts of hornfels in the microgranite. If the former is the case, the absence of evidence of melting of the hornfels and the lack of disturbance of the bedding of the hornfels indicate that if the microgranite, as a magma, invaded the sediments, space for the microgranite could not have been provided either by melting of the sediments or by disorientative disruption of the same. It is difficult to envisage how a magma could have stopped out sediment more or less horizontally without leaving traces of stopping activity such as partially disrupted country rock or disorientated stopped /

stoped blocks. The structure of the complex is, however, such that it is just possible that a magma could have entered the sediment along the bedding planes, prising apart the rock to form sill-like tongues of microgranite. However, the exposure reproduced in Figure 26E shows the termination of a tongue of microgranite and reveals that there is no disruption or displacement of the sediment concomitant with that to be expected at the termination of a sill. It is therefore suggested that if the structure is that of projections of hornfels into the microgranite, the lack of disturbance of the sedimentary rocks is more in accordance with the hypothesis that the microgranite has been emplaced by means of a replacement process of the sediments.

If the hornfels layers are rafts within the microgranite, it is most remarkable that they have remained undisorientated while floating in a microgranite magma, and the evidence is again more consistent with formation of the microgranite in situ from the sediments.

A third less likely but still possible structural interpretation of the contact complex is that the microgranite is in the form of pods within the sediments. If this is so, the microgranite pods must have developed as the result of replacement of the sediments in the solid.

The /

The alteration of the sediments by the microgranite has been discussed on pages 188-191, and it has been concluded that alkalies, mafic constituents and water were introduced during the emplacement of the microgranite to cause the zone of alkalisation and basification occurring at the contact. The granulitic nature of the highly metamorphosed sediments also suggests that heat played a considerable part in the metamorphic process.

Most of the contacts between the sediments and the microgranite are sharp, and from these little information regarding the mode of origin of the microgranite may be deduced. Some, however, are gneissoid, with a transition from the sediments into the gneissoid zone and thence into the microgranite. The banding of the gneissoid rock is parallel to the lamination of the sediments and there can be little doubt that the gneissoid rock has formed by the metasomatic alteration of the sediments. The lack of a sharp change between the gneissoid rock and the microgranite indicates that the microgranite adjacent to the gneissoid rock may also have formed by the same process.

The microgranite in the contact zone is invariably a granular variety, and granular microgranite has been found in no place inconsistent with the view that it is a contact phenomenon /

phenomenon and a marginal modification of the normal microgranite. Its chief difference from the interior microgranite is that of a more granular texture, and no significant difference in bulk mineral proportion has been detected, indicating that the granular and micrographic microgranites are of a similar chemical composition. The difference between the granular microgranite and the micrographic microgranite is therefore regarded as insufficient to warrant the two rock types separate consideration.

The most noticeable petrographic feature of the microgranite is the high percentage of micropegmatite. The formation of micropegmatite in the Skye granites was discussed by Harker (1904) who concluded that it had formed as the result of fractional crystallisation rather than under eutectic conditions. In all cases, while the shape of the components of the micropegmatite varies totally haphazardly, the proportion of quartz to feldspar varies significantly. The micropegmatite generally rims feldspar crystals which themselves are zoned from cores of oligoclase to margins of alkali feldspar, and the feldspar of the micropegmatite is in optical continuity with the outermost part of the feldspar crystal. The quartz of the micropegmatite increases in quantity /

quantity outwards so that the interstitial areas between the large micropegmatite units are largely composed of quartz. This variation in the composition of the micropegmatite clearly indicates that if the microgranite is of magmatic origin, the micropegmatite cannot have crystallised from a eutectic mixture as suggested by Cargill, Hawkes and Ledebøer (1928), who discussed Tertiary acidic rocks of Iceland similar in texture to the granites of Skye. Ramberg (1956) succinctly demonstrated the fallacy of the eutectic hypothesis, stating that, p. 203, "the occurrence in a single pegmatite of large graphic granite [micropegmatite] crystals with equally large crystals of quartz-free perthite and of pure quartz is hard to reconcile with the hypothesis that the graphic granite was the solidified eutecticum. Before the quartz-feldspar eutecticum is reached either feldspar or quartz will form depending on the original composition of the melt, but both cannot crystallise together. It is not legitimate to assume that quartz will crystallise after the quartz-feldspar eutecticum because the eutectic mixture is the last to solidify of any complex melt".

The hypothesis that the micropegmatite has formed as the result of fractional crystallisation of a magma, as put forward by Harker (1904), has also been asserted by Bowen (1928) /

(1928). If the microgranite of Glas Rheinn Rheag has formed from a magma such a hypothesis at first appears unassailable. The presence of clusters of haphazardly orientated grains of quartz, however, each surrounded by alkali feldspar ramifications extending from the margins of the micropegmatite units, indicates that these grains of quartz may antedate the alkali feldspar and therefore cannot represent a late stage siliceous residuum of an acidic melt. It is also difficult to understand how micropegmatite, present in the interiors of the large plagioclase crystals, could have formed by fractional crystallisation prior to the crystallisation of the plagioclases; or alternatively, how it could have been introduced, as a liquid, through the solid plagioclase crystals. It therefore seems unlikely that the process of fractional crystallisation from a magma resulted in the formation of the micrographic textures now seen in the microgranite. These less common features of the microgranite, together with the zoned nature of the micropegmatite units, indicates rather that the micropegmatite was formed as the result of replacement in the solid as suggested by Ramberg (1956). It is clear that a replacement process must have operated in order to produce the micropegmatitic alteration products present in the sediments and the micropegmatite of the gneissoid contact /

contact rocks. While it therefore seems reasonable to suppose that the micropegmatite of the microgranite has been formed by some process of metasomatic transformation, it is not clear whether the micropegmatite formed during a metasomatic formation of the microgranite, or whether it developed as the result of late stage action upon a pre-existing solid rock (Fenner, 1926).

It is suggested that while the marginal microgranite of Glas Bheinn Eheag may, possibly, be magmatic in origin, it is more probably metasomatic in origin. If the former be the case, the acidic magma invaded the sediments primarily along bedding planes, probably prising apart rather than stopping away the sediments in order to provide space for itself. Associated with the intrusion of the microgranite, heat and emanations invaded and metamorphosed the sediments, the most intense metamorphism resulting in the production of microgranitic rock at the contact zones. It would then seem likely that continued deuteric action within the microgranite caused the formation of the micropegmatite and also produced the final lack of distinction between the most highly altered sediments and the microgranite.

If the marginal microgranite be metasomatic in origin, it is suggested that that contact between the sediments and the /

the microgranite merely represents a diffusion limit (Reynolds, 1936), and that the granularity of the microgranite is the final remnant of the sedimentary texture.

The interior of the microgranite offers insufficient evidence concerning its origin and therefore no hypothesis encompassing the origin of the interior of the microgranite is put forward.

C. The Origin of the Quartz-porphyrries. The quartz-porphyrries cut and present chilled selvedges to both the sediments and the microgranite, and therefore appear to be the youngest rocks of Glas Bheinn Bheag discussed in this thesis. The quartz-porphyrries of Glas Bheinn Bheag are far less glassy than those of Beinn na Cro, but otherwise are very similar in appearance, and it seems likely that the former were emplaced in a similar manner to the latter, that is by magmatic intrusion.

Extremely fine-grained or glassy rims surrounding the quartz and feldspar fragments, as found in the Beinn na Cro quartz-porphyrries, are not present in the Glas Bheinn Bheag quartz-porphyrries; instead the rims consist of micropegmatite. Much of this micropegmatite is spherulitic or subspherulitic suggesting that it may have formed from glassy spherules with fragment nuclei as the result of devitrification.

If this is so, it seems likely that the cryptographic micropegmatite commonly encountered in the groundmass of the micrographic quartz-porphyry may also have been formed by devitrification.

The contrast between the matrices of the granular and micrographic quartz-porphyries indicates some fundamental difference between the two types of rock. Both occur in the microgranite and in the sediments, and there appears to be no correlation between the thickness of the intrusions and their petrography. It is suggested therefore that contributory factors causing the difference may have been the temperature at which intrusion took place, the rate of cooling, or possibly the percentage of volatile constituents in the quartz-porphyry magma and their rate of escape during crystallisation.

D. The Dunan fault and the Dunan granite "contact".

The contact of the Dunan granite with Jurassic sediments has formed the subject of papers by Day (1931) and Black (1955). The former author regarded the junction to be a normal intrusive one, but Black discovered that the granite and the sediments were separated by a fault (the Dunan fault), and that the cataclastic rocks of the fault zone had been altered, probably by gases containing Fe, Mg, Ti and OH.

The sediments of Glas Bheinn Bheag increase in metamorphic grade towards the Dunan fault. Stratum contouring of the sediments in this area indicates that they did not extend much further towards the north-west, and that the pre-fault contact of the sediment with acidic rock was not far to the north-west of the line now occupied by the Dunan fault. The metamorphic zones cut out by the fault are the highest zones which are rich in K_2O , Na_2O , MgO , FeO , Fe_2O_3 and H_2O (see pages 188-191). The cataclastic rocks of the Dunan Fault are, as shown by Black (p. 221) table I, considerably richer in K_2O and Na_2O than the adjacent sediments, and richer in MgO , FeO , Fe_2O_3 and H_2O than either the sediments or the granite. It seems likely that the sediments of the highest metamorphic zones may, at least in part, be represented in the fault breccia, and one wonders how much of the above oxides was introduced subsequent to the formation of the Dunan fault and how much was present in the original rocks.

The Dunan granite bears no close resemblance to the Glas Bheinn Bheag microgranite, and is considerably coarser in grain than the coarsest-grained microgranite. The microgranite increases in grain-size away from the sediments, and it was at first thought possible that the granite might /

might be the coarsest-grained, innermost member of the acidic rocks of Glas Bheinn Bheag. However, the Dunan granite, which is generally graphic in texture, is markedly granular in a zone up to 20 feet wide against and parallel to the Dunan fault. By analogy with the textures exhibited by the microgranite, this would appear to indicate that the original boundary of the granite lay near the Dunan fault. However, the lack of unfaulted boundaries of the Dunan granite and the presence of the Dunan fault make further discussion of the structure of the granite purely speculative.

VI. SUMMARY and CONCLUSIONS

1. Glas Bheinn Bheag consists of Jurassic sediments cut by Tertiary microgranite, both of which are cut by quartz-porphry minor intrusions.
2. The microgranite underlies the sediments, and layers of sediment (hornfels) alternating with layers of microgranite occur in a complex contact zone.
3. The sediments have been metamorphosed during the emplacement of the microgranite, the metamorphism taking the form of recrystallisation of constituent minerals and the formation of additional amount of feldspars and biotite, chlorite and iron ore, with probable introduction of alkalis, bases and water.
4. The sediments have thus been alkalisied and basified at the immediate contact with the microgranite.
5. The marginal microgranite may perhaps be magmatic in origin, but more probably it has been formed by metasomatism of the sediments.
6. The balance of evidence favours the conclusion that the contact between the microgranite and the sediments is a diffusion limit, and that the granular texture of the marginal microgranite is a relic sedimentary texture.
7. Textural relationships suggest that the micropegmatite has formed by replacement.
8. The quartz-porphyrines are the result of magmatic intrusion.
9. The Dunan fault lies near the original contact of the sediments with microgranite or granite, but the relationship of the fault to the original boundary of the Dunan granite is obscure.

S U M M A R Y a n d C O N C L U S I O N SBEINN NA CRO

1. The basic rocks of Beinn na Cro comprise lavas, which are cut by sub-arcuate vertical concentric sheets of granulite and gabbro and by basic (gabbro-tuff and dolerite) explosion dykes.
2. The nature of the veins extending from the granulite and gabbro into the country rock, together with the petrographic evidence, indicates that the granulite and at least the marginal areas of the gabbro sheets have been emplaced as the result of metasomatic alteration of the lavas.
3. The hot fluids responsible for this metasomatism entered along vertical planes resembling ring fractures.
4. More powerful manifestations of the same activity resulted in the formation, largely by means of fluidisation, of the explosion dykes.
5. At a later date the basic complex was cut by hybrid and acidic net-veins and dykes and by great hybrid and acidic tongues which are continuous with the Beinn na Cro granite.
6. The net-veins are of replacement origin and are of two types. While the earlier hybrid varieties are thought to have been formed as the result of metasomatic alteration of the basic country rock, the later most acidic set are thought to have been emplaced as fluidised systems.
7. The evidence suggests that the acidic dykes are also the result of fluidisation.
8. While it appears likely that the areas of massive hybrid rocks have been formed as the result of metasomatic alteration of gabbro and dolerite by aqueous solutions, the apparently conflicting nature of the evidence has resulted in no definite conclusions being reached regarding the origin of the great hybrid and acidic tongues.

CREAGAN DUBH

1. The lowest strata of Creagan Dubh have been found to consist of interbanded layers of gneiss, tuff and agglomerate, together with basic rocks. Much of the group is highly inclined.
2. The petrographic and field evidence demonstrate that the gneiss is not older than the associated pyroclastic and basic rocks, which are most likely of Tertiary age.
3. It is suggested that the gneiss has formed as the result of the preferential action of fluids containing silica and alkalies upon horizons of laminated bedded tuff intercalated with massive tuffs and agglomerates.
4. The granular texture and net-veined and metamorphosed condition of the gabbros lying within the gneiss, compared with the ophitic and unaltered nature of the gabbros lying within the tuffs and agglomerates, indicate that the gabbros were present prior to, and metamorphosed at the time of the formation of the gneiss, by the process which evolved the gneiss.
5. The probable Tertiary age of the gneiss, together with the unconformity separating it from the overlying lavas, indicates a high level of formation of the gneiss.
6. Basic lavas with minor quantities of associated rock unconformably overlie the lower group. The lavas are generally highly inclined.
7. The lavas are cut by transgressive agglomerates and quartz-porphyrines which appear to have been emplaced as the result of magmatic intrusion. The lack of fragments of gneiss and the abundance of blocks of sediments within the transgressive agglomerates and the quartz-porphyrines is regarded as being due to the gneiss fragments having been transported to a higher level than the present erosion surface.

GLAS BHEINN BHEAG

1. Metamorphosed Jurassic sediments overlie and are cut by Tertiary microgranite and both are cut by minor intrusions of quartz-porphyry.
2. The sediments have been divided into four lithological divisions and metamorphic phenomena have been recognised in all but the extremely fine-grained mudstones.
3. On the basis of petrographic evidence and modal analyses six arbitrary metamorphic zones forming an aureole around the microgranite have been erected.
4. Structural and petrographic evidence suggests that at least the margins of the microgranite may be of metasomatic origin.
5. The micropegmatite, ubiquitous in the microgranite and also occurring in the sediments, is regarded as being of replacement origin.
6. The quartz-porphyrines appear to be the result of magmatic intrusion.

ACKNOWLEDGEMENTS

The writer wishes to express deep appreciation of the constructive criticism of this thesis by Professor Arthur Holmes, Professor Frederick H. Stewart and Dr George P. Black under whose supervision this work was carried out.

The author warmly thanks her husband for his encouragement and advice.

A Post-graduate Studentship, awarded by the University of Edinburgh is gratefully acknowledged. The Swift Point-counter, provided by the Moray Endowment for the promotion of original research was used in the determination of the modal analyses.

BIBLIOGRAPHY

- BLACK, G.P. 1955. The Junction between Jurassic Sandstones and Tertiary Granophyre near Dunan, Isle of Skye: A Re-interpretation. Trans. Geol. Soc. Edin., XVI, pp. 217-222.
- BOUE, A. 1820? Essai Geologique sur l'Ecosse. Paris.
- CARGILL, H.K., HAWKES, L. and LEDEBOER, J.A. 1928. The Major Intrusions of Southeastern Iceland. Quart. J. Geol. Soc. Lond., 84, pp. 505-549.
- CLOOS, H. 1941. Bau und Tatigeid von Tuffschoten. Untersuchungen an dem Schwabischen vulkan. Geol. Rundschau, 32, pp. 709-800.
- DAY, T.C. 1931. An Intrusive Junction between Jurassic Sandstones and Tertiary Granite, south-east of Dunan, Isle of Skye. Trans. Geol. Soc. Edin., XIII, pp. 57-60.
- FAIRBAIRN, H.W. and ROBSON, G.M. 1942. Breccia at Sudbury, Ontario. J. Geol., 28, pp. 569-606.
- FENNER, C.N. 1926. The Katmai Magmatic Province. J. Geol. 34, pp. 673-722.
- FLETT, J. inter alia. 1910. The Geology of Glenelg, Lochalsh and Southeast Skye. Mem. Geol. Surv. Scotland
- GEIKIE, A. 1858. On the Geology of Strath, Skye. Quart. J. Geol. Soc. Lond., 24, pp. 1-23.
- _____ 1888. The History of Volcanic Action during the Tertiary Period in the British Isles. Trans. Roy. Soc. Edin., XXXV, pp. 60-179.
- _____ 1894. On the Relations of the Basic and Acid Rocks of the Tertiary Volcanic Series of the Inner Hebrides. Quart. J. Geol. Soc. London., 50, pp. 212-229.

- HARKER, A. 1904. The Tertiary Igneous Rocks of Skye. Mem. Geol. Surv. Scotland.
- _____ 1909. The Natural History of Igneous Rocks. London.
- JAMIESON, R. 1800. Mineralogy of the Scottish Isles. Edinburgh.
- JUDD, J.W. 1874. The Secondary Rocks of Scotland. (second paper) On the Ancient Volcanoes of the Highlands and the Relations of their products to the Mesozoic Strata. Quart. J. Geol. Soc. Lond., 30, pp. 220-301.
- _____ 1893. On inclusions of Tertiary Granite in the Gabbro of the Cuillin Hills, Skye: and on the Products resulting from the Partial Fusion of the Acid by the Basic Rock. Quart. J. Geol. Soc. Lond., 49, pp. 175-195.
- KING, B.C. 1953. Gabbro Tuff in the Central Volcanic Complex of Arran. Trans. Geol. Soc. Glasgow, XXI, pp. 440-446.
- _____ 1953. Structure and Igneous Activity in the Creag Strollamus Area of Skye. Trans. Roy. Soc. Edin., LXII, pp. 357-400.
- _____ 1954. The Strollamus Area of Skye. Geol. Mag., XCI, p. 255.
- KORN, H. and MARTIN, H. 1954. The Messum Igneous Complex in South-west Africa. Trans. Geol. Soc. South Africa, LVII, pp. 83-124.
- MacCULLOCH, J. 1816. A Sketch of the Mineralogy of Skye. Trans. Geol. Soc., III, pp. 1-111.
- _____ 1817. Corrections and Additions to the Sketch of the Mineralogy of Skye. Trans. Geol. Soc., IV, pp. 156-192.
- _____ 1819. A Description of the Western Isles of Scotland. London.

- MOREY, G.W. 1954. Vapour Transport. Carnegie Institute of Washington Year Book No. 53.
- OEYNHAUSEN, C. von and DECHEN, H. von. 1829. Die Insel Skye. Karsten's Archiv für Min. &c., I, pp. 56-104.
- PEACH, B.N. and HORNE, J. inter alia. 1910. The Geology of Glenelg, Lochalsh and Southeast Skye. Mem. Geol. Surv. Scotland.
- RAMBERG, H. 1956. Pegmatites in West Greenland. Bull. Geol. Soc. Amer., 67, pp. 185-213.
- REYNOLDS, D.L. 1936. Demonstrations in Petrogenesis from Kiloran Bay, Colonsay. Min. Mag., XXIV, pp. 367-407.
- _____ 1954. Fluidisation as a Geological Process and its Bearing on the Problem of Intrusive Granites. Amer. J. Sci., 252, pp. 557-614.
- REYNOLDS, D.L. and McINTYRE, D.B. 1947. Chilled and 'Baked' Edges as Criteria of Relative Age. Geol. Mag., LXXXIV, pp. 61-64.
- RICHEY, J.E. 1930. Tertiary Ring Structures in Britain. Trans. Geol. Soc. Glas., XIX, pp. 42-140.
- RICHEY, J.E., STEWART, F.H. and WAGER, L.R. 1946. Age Relations of Certain Granites and Marscoites in Skye. Geol. Mag., LXXXIII, p. 293.
- _____ 1947. Age Relations of Certain Granites in Skye. Geol. Mag., LXXXIV, p. 128.
- SEDERHOLM, J.J. 1926. On Migmatites and associated Pre-Cambrian rocks of Southwestern Finland. Part II. The Region around the Barosundsfjord w. of Helsingfors and neighbouring areas. Bull. Comm. Geol. Fin. No. 77.
- SUTTON, J. and WATSON, J. 1950. The Pre-Torridonian metamorphic history of the Loch Torridon and Scourie areas in the North-west Highlands and its bearing on the chronological classification of the Lewisian. Quart. J. Geol. Soc. Lond., 106, pp. 241-307.

- THOMAS, H.H. 1927. The Tertiary Plutonic Centres of Britain. Repr. Brit. Ass., pp. 43-57.
- WAGER, L.R., KENNEDY, W.Q. and STEWART, F.H. 1948. Skye and Morar. Guide to Excursion C.14, International Geol. Congress, 18th Session, Great Britain.
- ZIRKEL, F. 1871. Geologische Skisse von der Westkuste Schottlands. Zeits. Deuts. Geol. Ges., XXIII, pp. 1-124.

BEINN NA CRO

PLATE I

a) Basalt with early amphibolite veins
truncated by granulite; Allt an t-Sithein(p. 2).

b) Contact between lower amygdaloidal,
and upper massive, basalt lavas. Note
the net-veins(hybrid) present at the
contact; Northern crags of Beinn na Cro(p. 2).

PLATE I



PLATE II

a) Net-veined basalt. Later white acidic net-veins occupying the same channels as earlier grey hybrid net-veins; Northern crags of Beinn na Cro(p. 2).

b) Net-veined basalt and basic screens; west side of Beinn na Cro(p. 2).

PLATE II

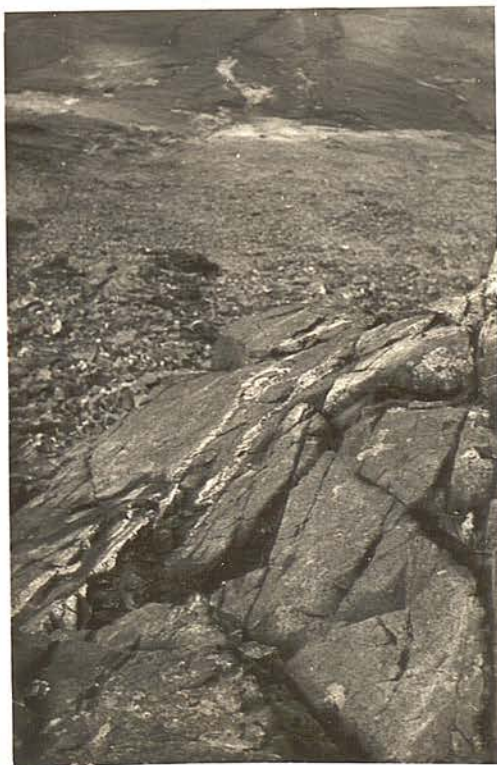
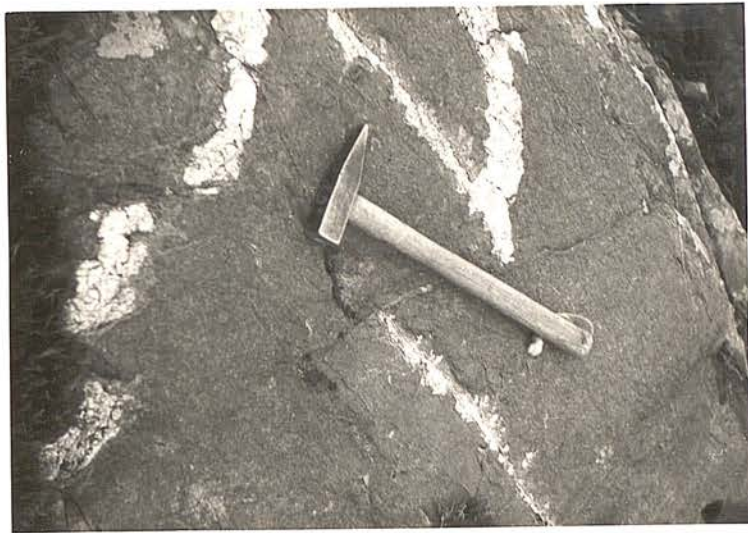


PLATE III

a) Profusely net-veined basalt; Allt na Gobhar(p. 2).

b) Net-veined basalt; Northern crags of Beinn na Cro(p. 2).

PLATE III



PLATE IV

a) Net-veins extending into basalt from
microgranitic tongue; Allt na Caoraich(p. 6).

b) Microgranitic tongue in sharp contact
with basalt; Allt na Caoraich(p. 6).

PLATE IV

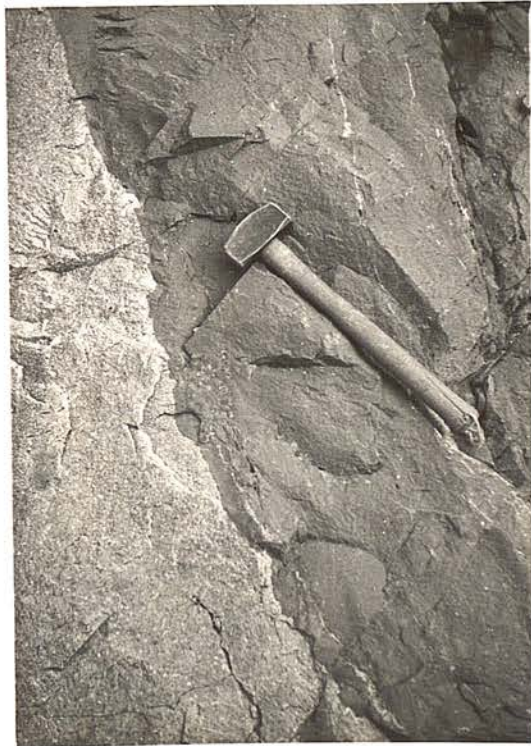


PLATE V

a) Granite weathered into slabs along major joint planes; west side of Beinn na Cro(p. 7).

b) Granite weathered into irregular blocks; east side of Beinn na Cro(p. 7).

PLATE V

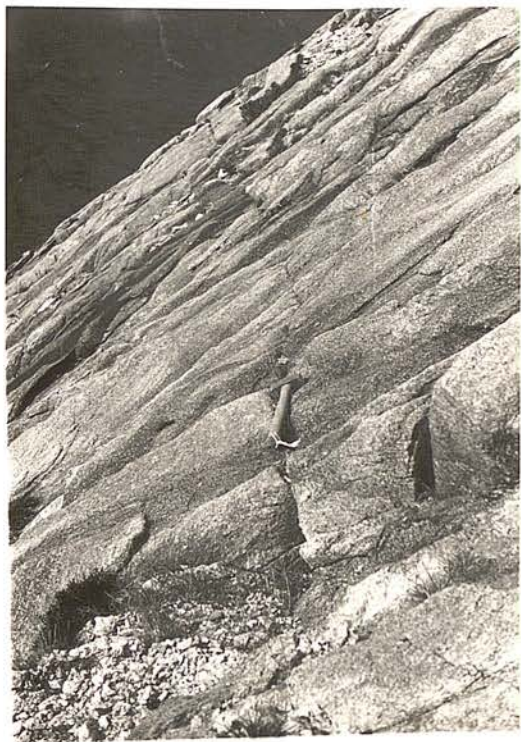


PLATE VI

a) The Gualann nam Fiadh fault exposed in the bed of the Allt an t-Sithein looking upstream(p. 8).

b) As above looking downstream.

PLATE VI

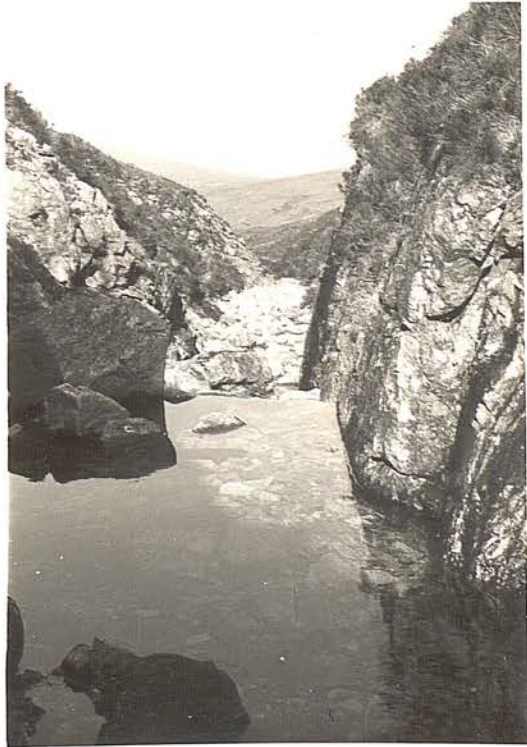


PLATE VII

a) Basalt; crossed nicols x 14. (p. 10).

b) Contact of fine-grained granulite with
coarse-grained granulite; crossed nicols x 14.
(p. 11).

PLATE VII



PLATE VIII

a) Medium-grained granulite; ordinary light x 14. (p. 11).

b) The same field as above under crossed nicols.

PLATE VIII

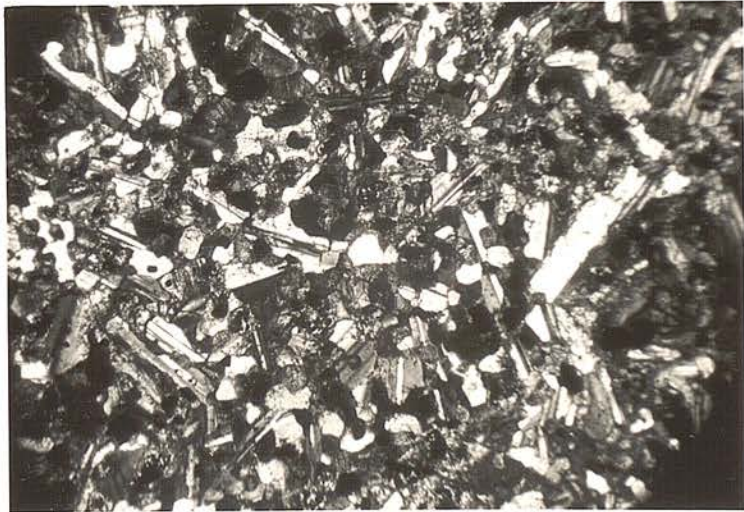
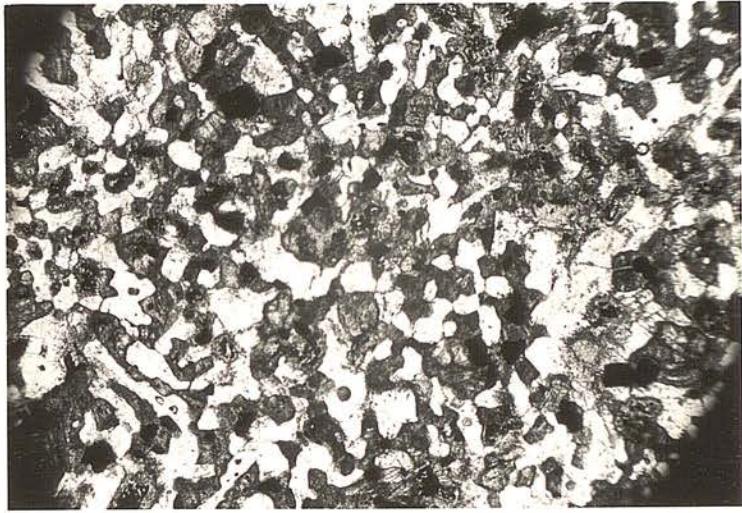


PLATE IX

a) Coarse-grained mafic granulite; ordinary light x 14. (p. 15).

Black mineral - magnetite.

Dark-grey mineral (equidimensional) - augite.

Pale-grey mineral with well developed cleavages - hypersthene.

Colourless mineral - apatite.

b) Gabbro; ordinary light x 14. (p. 16).

PLATE IX

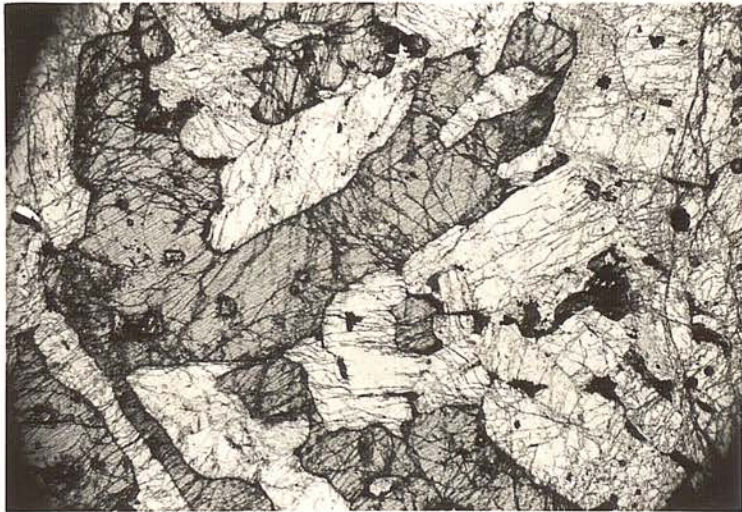
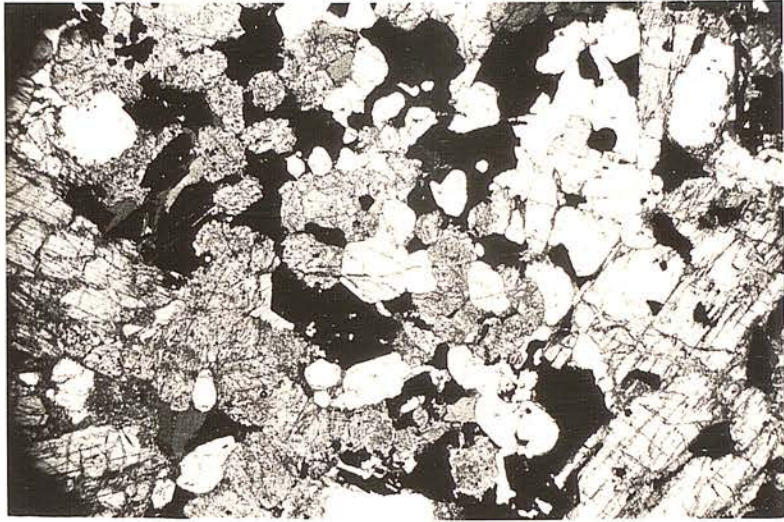


PLATE X

a) Gabbro; crossed nicols x 27. (p. 17).
Note the associated, but not interlocking
plagioclase crystals.

b) Gabbro; crossed nicols x 27. (p. 17).
Note the interlocking plagioclase crystals.

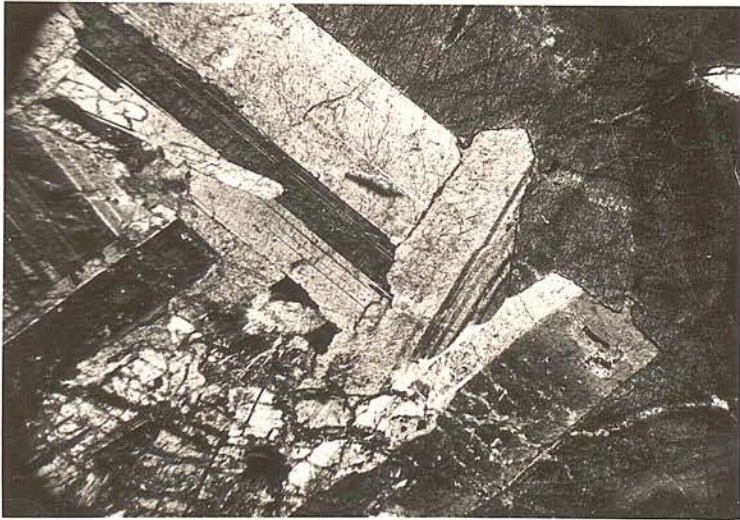
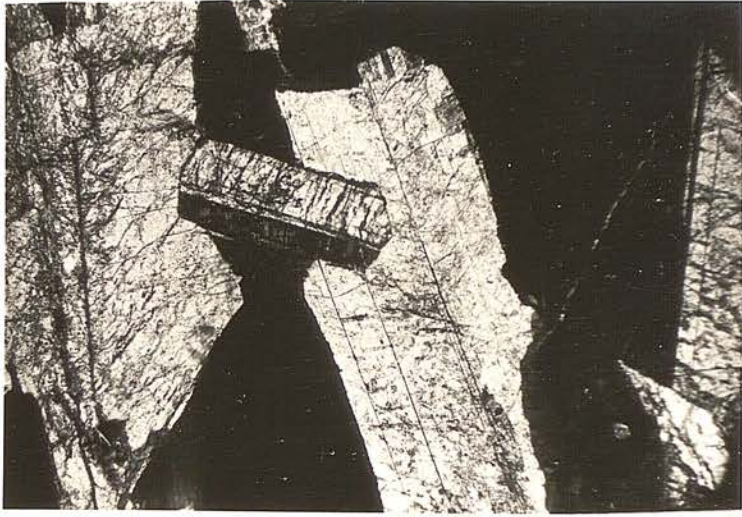


PLATE XI

a) Gabbro; crossed nicols x 14. (p. 17).
Note the interlocking plagioclase crystals.
The interior portion of the photograph is
represented in Figure 8A.

b) Gabbro; crossed nicols x 14. (p. 17).
Note the interlocking plagioclase crystals.

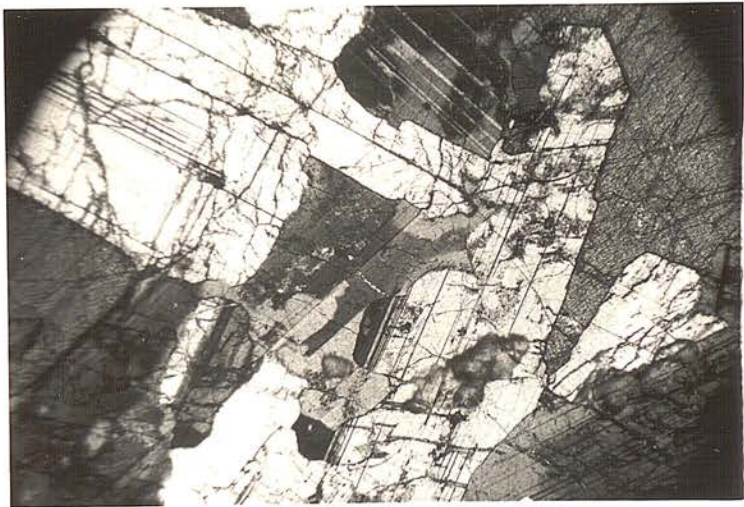
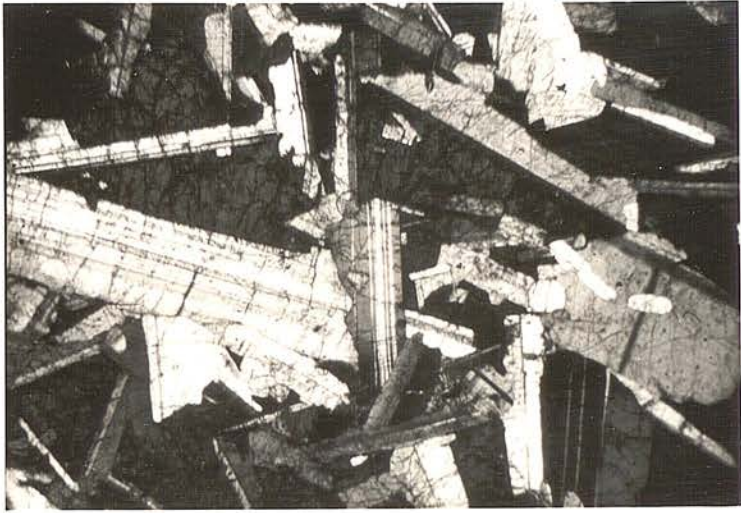


PLATE XII

a) Altered gabbro; crossed nicols x 27. (p. 17).
Note the interlocking plagioclase crystals.

b) Gabbro; crossed nicols x 27. (p. 17).
Note the poly-twinned plagioclase crystals.

PLATE XII



PLATE XIII

a) Gabbro; crossed nicols x 14. (p. 17).
Note the poly-twinned plagioclase crystals.

b) Gabbro; crossed nicols x 14. (p. 17).
Note the poly-twinned plagioclase crystals.

PLATE XIII

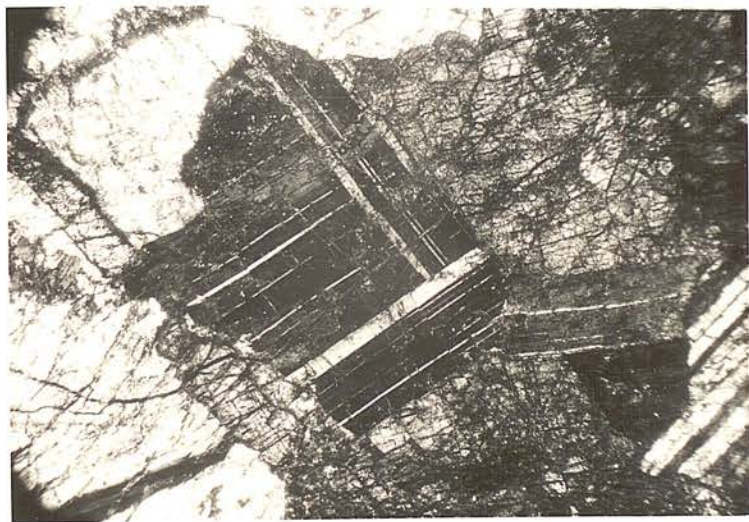


PLATE XIV

a) Gabbro-tuff; crossed nicols x 14. (p. 19).

b) Dolerite of the explosion dyke; crossed
nicols x 14. (p. 21).



Metamorphosed basalt one centimeter from the contact with the main mass of the Beinn na Cro Granite; ordinary light x 50. (p. 23).



PLATE XVI

a) Contact of basalt with the main mass of the Beinn na Cro Granite. On the right side of the photograph is coarsened and acidified basalt with a variolitic texture traced out by needles of hornblende and augite. On the left is microgranite which contains hornblende, feldspar and quartz; ordinary light x 50. (p. 24).

b) The same field as above under crossed nicols.

PLATE XVI



PLATE XVII

Microgranite one centimeter from the contact
of the main mass of the Beinn na Cro Granite
with basalt; crossed nicols x 14. (p. 25).

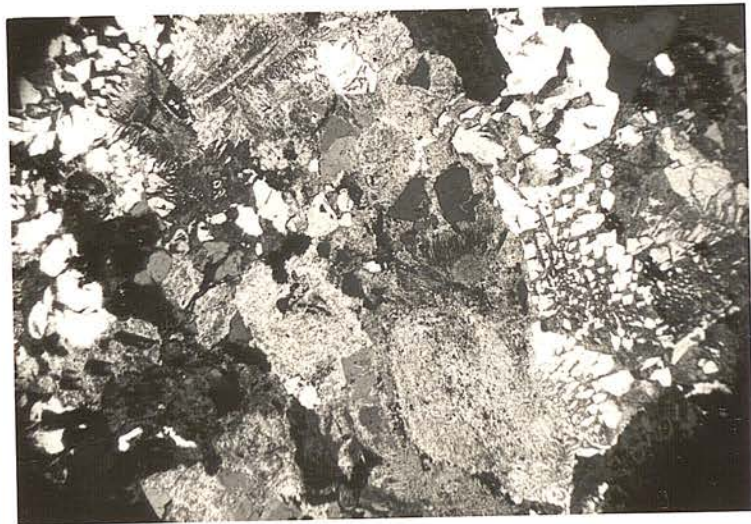


PLATE XVIII

a) Basalt in contact with microgranite net-
vein. The contact is sharp and the basalt
exhibits a variolitic texture; ordinary
light x 14. (p. 28).

b) The same field as above under crossed
nicols.

PLATE XVIII

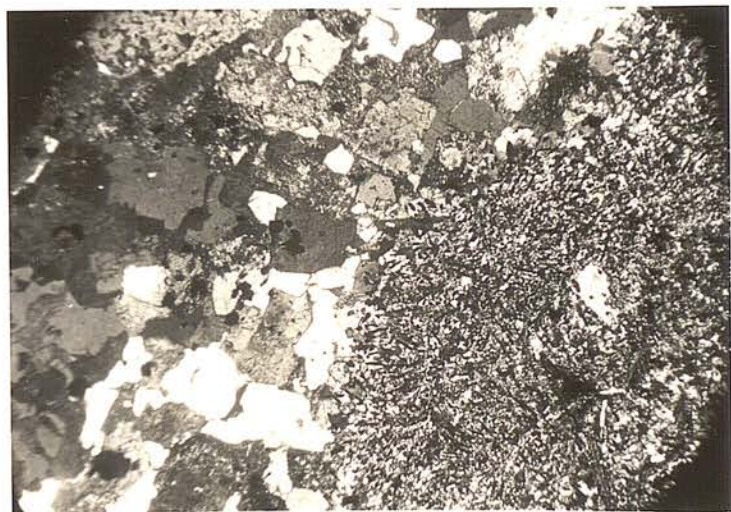
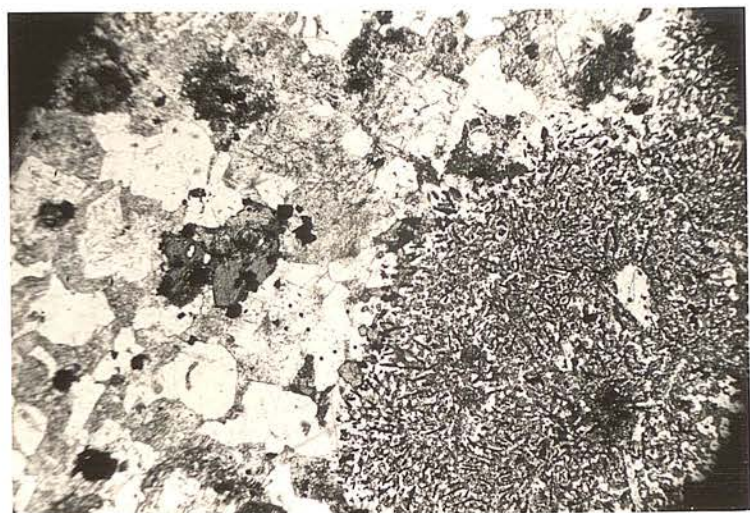


PLATE XIX

a) Basalt in contact with hybrid net-vein;
crossed nicols x 14. (p.28).
The left side of the large crystal of plagioclase
is integral to the basalt and encloses numerous
granules of augite, while most of the crystal
lies within the hybrid rock.

b) Acidified gabbro net-vein rock;
crossed nicols x 14. (p.33).
Interstitial to large albitised plagioclase
crystals are smaller plagioclase and alkali
feldspar crystals, quartz, micropegmatite
and sparse dark minerals.

PLATE XIX



PLATE XX

a) Hybrid net-vein rock; ordinary light x 14.
(p. 34).

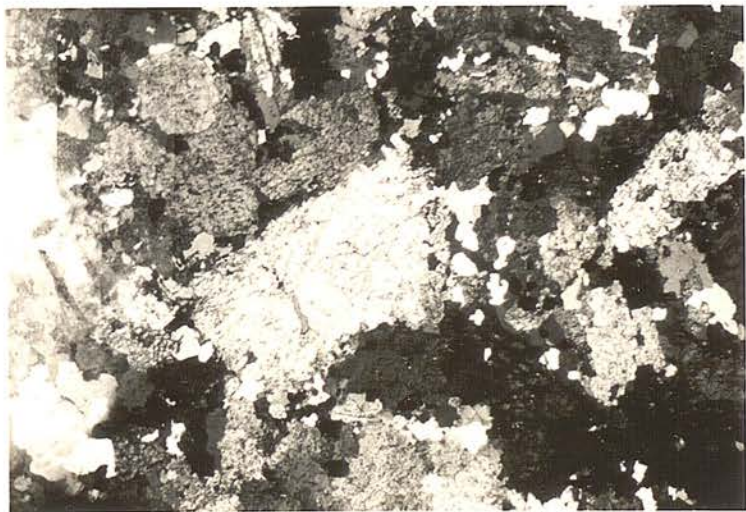
b) The same field as above under crossed
nicols.



PLATE XXI

a) Hybrid net-vein rock; crossed nicols x 14.
(p. 34).
The plagioclase crystals exhibit poly-twinning.

b) Hybrid rock six inches inwards from
the margin of acidic dyke; crossed nicols x 14.
(p. 38).



a) More acidic rock one foot inwards from the margin of acidic dyke; crossed nicols x 14. (p. 38).
Note the lighter area (quartz) in the interior of the large euhedral plagioclase.

b) Rock in the interior of the acidic dyke; crossed nicols x 14. (p. 38).
Note the rounded quartz crystals partially enclosed by the alkali feldspar rim of the large plagioclase crystal, and the higher proportion of quartz than in Plates XXIb and XXIIa.

PLATE XXII

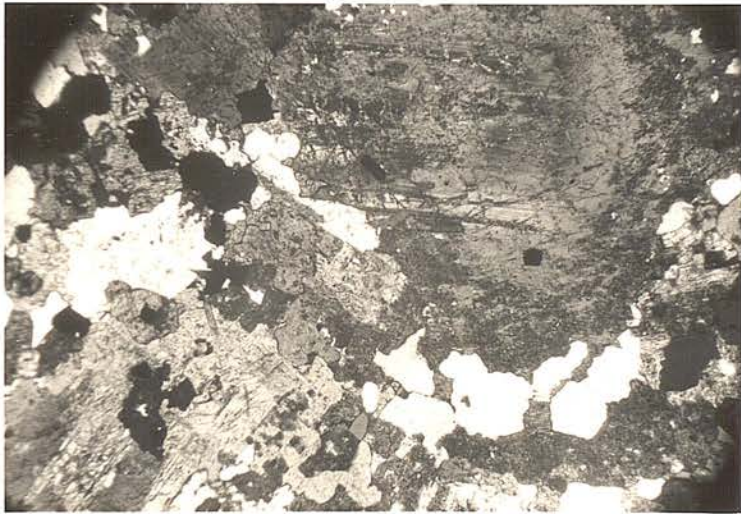
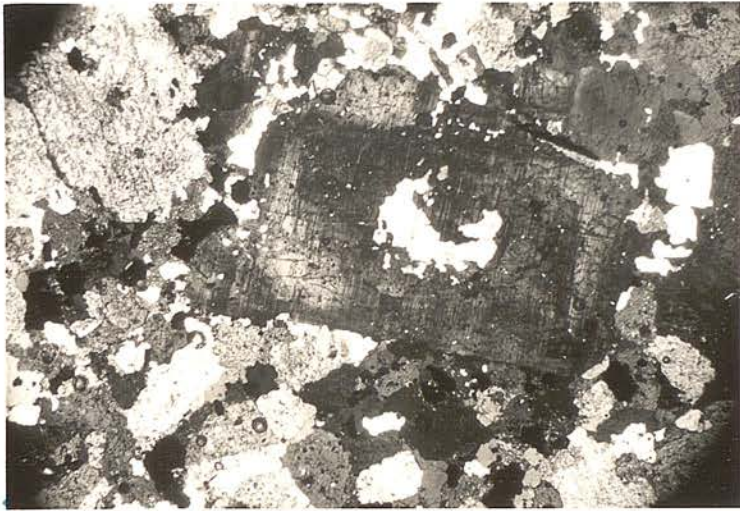


PLATE XXIII

a) Microgranitic tongue-rock; ordinary light x 14. (p. 42).
Note the acicular feldspar crystals and the curved needle of hornblende.

b) Microperthite Granite of Beinn na Cro; crossed nicols x 14. (p. 47).

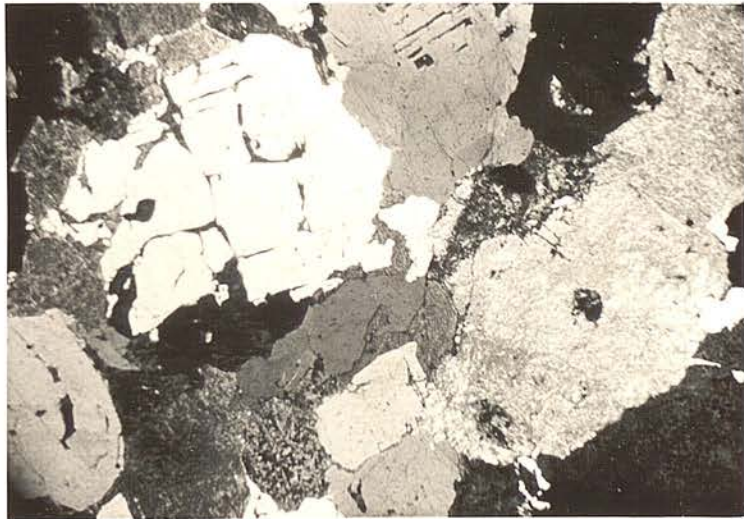


PLATE XXIV

a) Microperthite granophyre of Beinn na Cro; crossed nicols x 27. (p. 47).
Note the euhedral oligoclase rim to the microperthite.

b) Fragment of granite in quartz-porphyry; crossed nicols x 27. (p. 50).

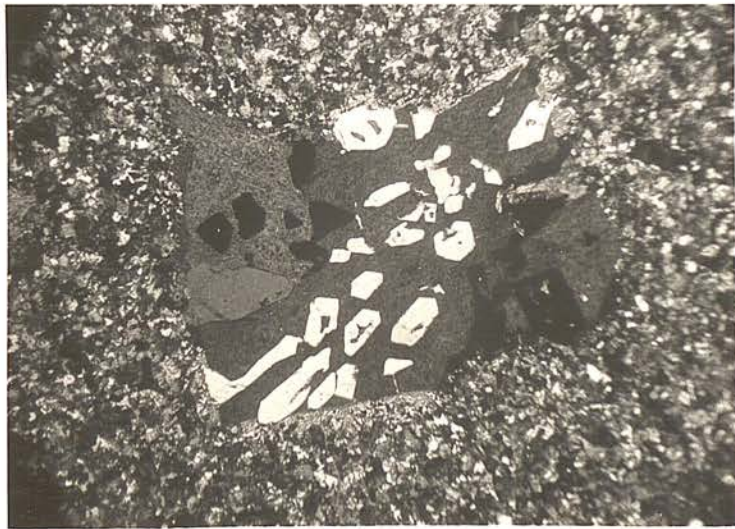
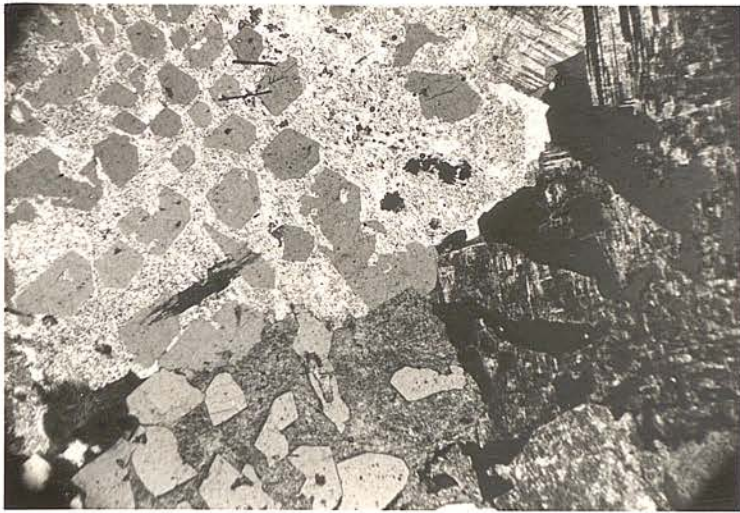


PLATE XXV

a) Quartz-porphyry; ordinary light x 50.
(p. 50).

Note the quartz rimmed by cryptopegmatite.
The matrix is sub-glassy - sub-spherulitic.

b) Quartz-porphyry; crossed nicols x 50.
(p. 50).

Note the shattered quartz crystal. This
crystal is rimmed by cryptopegmatite and
is also embayed.



PLATE XXVI

Creagan Dubh from the north-east. The sharp demarkation between the scree and the crags on the left of the photograph indicates the line of the Coire Garbh fault, while the gully (left centre) marks the line of the Shoulder fault. The pale coloured rock forming the lower part of the crag on the left is the Coire Garbh vent agglomerate. The overhanging crag (right centre) indicates the position of the unconformity.

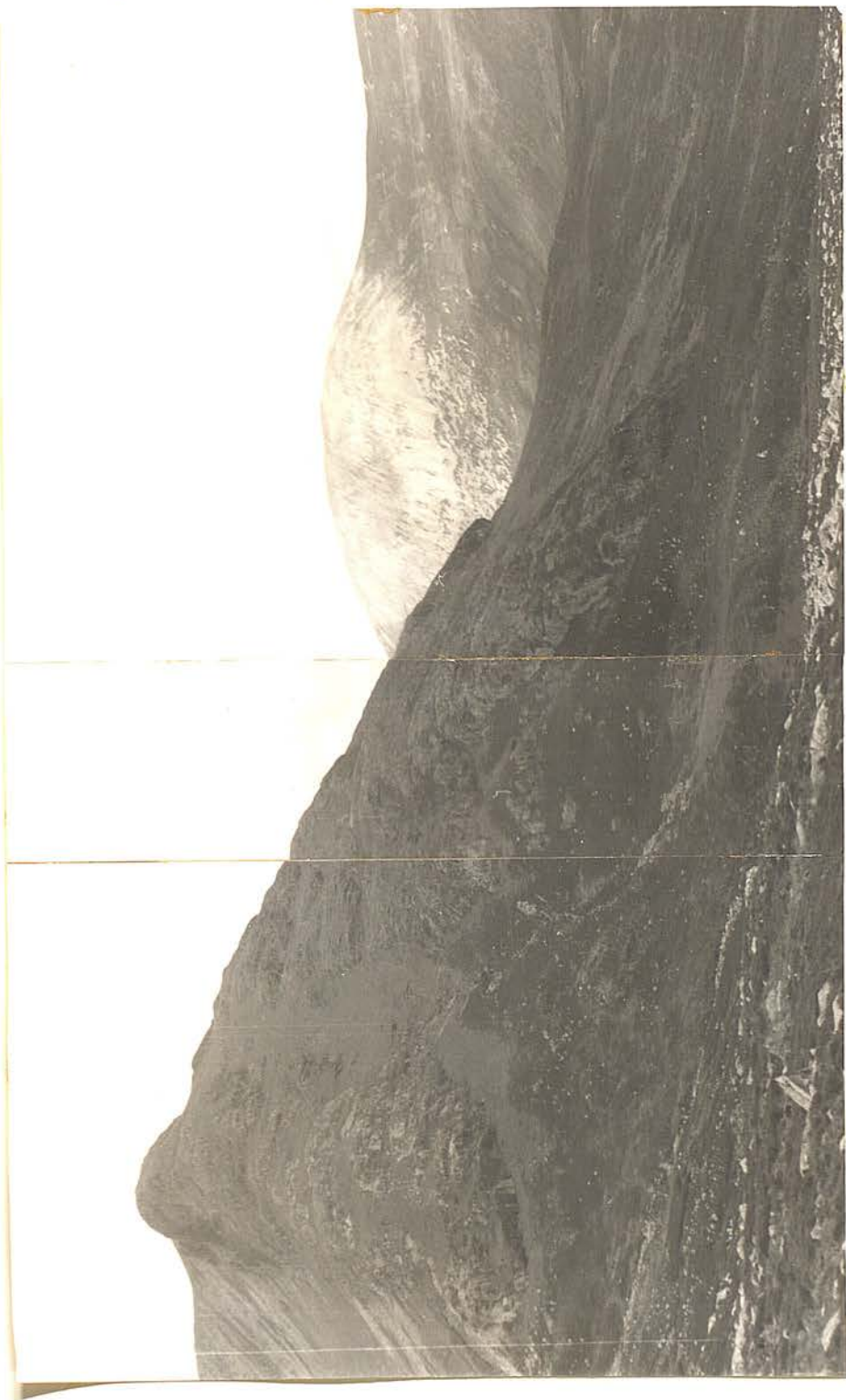


PLATE XXVII

a) Creagan Dubh from the west. The top of the crags marks the approximate line of the Coire Garbh fault. The base of the crags marks the unconformity between the Lower Group and the lavas.

b) Creagan Dubh from the south-west.



a) The north-eastern buttress and summit of Creagan Dubh. The massive crags are formed of basalt while the pale-coloured low crags on the right are formed of the Coire Garbh vent agglomerate. In the foreground are granite and granite screes of Beinn Dearg Mhor. The top of the white streak at the foot of the basalt crags marks a large vein of microgranite.

b) Gneiss; Allt na Teangaidh(p.100).

PLATE XXVIII

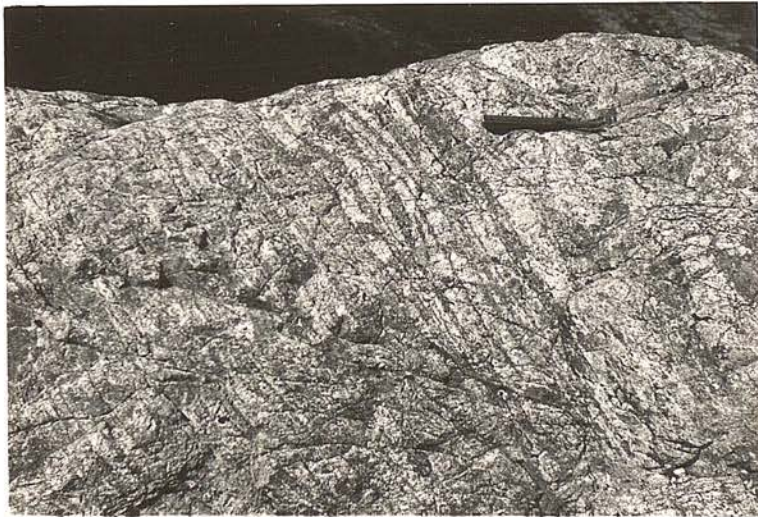


PLATE XXIX

a) Contact of gneiss with net-veined gabbro. The latter is at the top of the photograph; western side of Creagan Dubh(p. 103).

b) Gneiss in contact with net-veined gabbro. This is a section normal to the strike and shows the margin of the gabbro parallel to the foliation of the gneiss; western side of Creagan Dubh(p. 103).



PLATE XXX

Basalt lava net-veined along shatter-
cracks; northern crags of Creagan Dubh(p.106).
Compare with Plates II and III.



a) Amygdaloidal lava. The amygdales are composed of quartz; southern end of Creagan Dubh(p.105).

b) Transgressive agglomerate; southern end of Creagan Dubh(p.107).



Quartz-porphyry sheet in lavas; northern
crags (p. 108).



PLATE XXXIII

a) Basic tuff; Lower Group; crossed
nicols x 27. (p. 115).

b) Basic tuff; Lower Group; crossed
nicols x 27. (p. 117).
Note the fragment of plagioclase containing
myrmekitic augite.

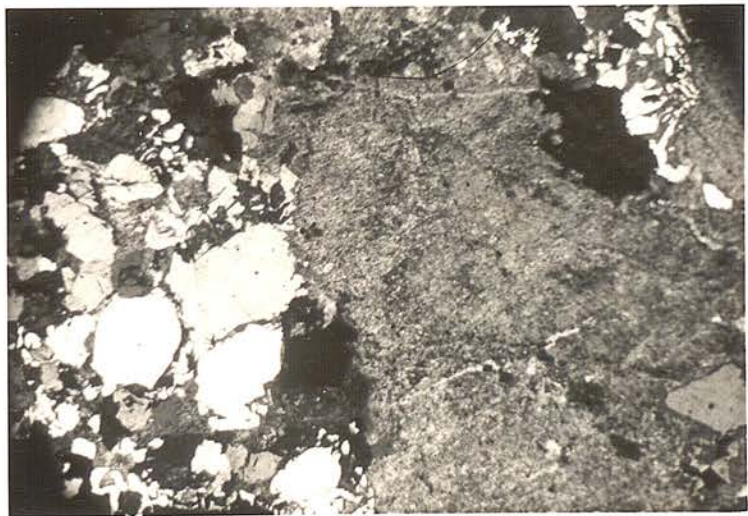


a) Gneiss; Lower Group; crossed nicols x 14.
(p. 118).

Note the large crystal of alkali feldspar,
the micropegmatite, and the granular quartz.

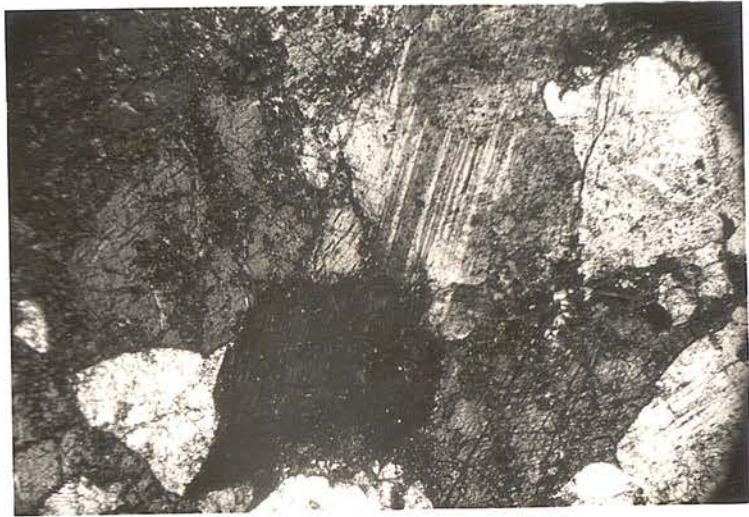
b) Gneiss; Lower Group; crossed nicols x 14.
(p. 118).

This rock in the field resembles pegmatite.



a) Hornblende gneiss, Lower Group;
crossed nicols x 14. (p.120).

b) Granulitised gabbro in contact with
granophyric net-vein, Lower Group;
ordinary light x 14. (p.122).



a) Granulitised gabbro, Lower Group;
ordinary light x 14. (p.123).

b) Fluxion-gabbro, Lower Group;
Crossed nicols x 14. (p.124).



PLATE XXXVII

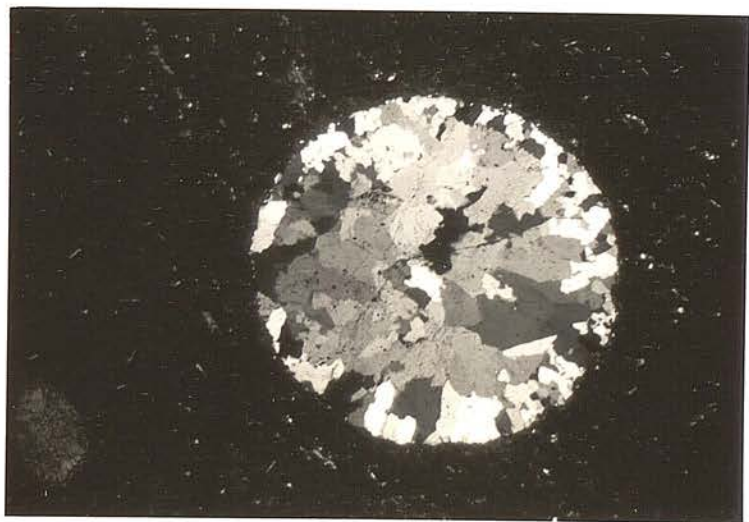
a) Gabbro cut by basalt and both cut by two late amphibolite veins; ordinary light x 14. (p. 124, 6).
Note the tachylitic selvage of the basalt.

b) Basalt lava; ordinary light x 27.
(p. 127, 7).



a) Feldspar filled amygdale in basalt lava;
crossed nicols x 14. (p.127).
Note the feathery habit of the feldspar.

b) Quartz filled amygdale in lava;
crossed nicols x 14. (p.130).
Note the symmetry of the vesicle and the
regular arrangement of small marginal
and large central quartz crystals.



a) Bedded tuff; ordinary light x 14. (p.130).
Note the graded bedding.

b) Banded rhyolite of Srath Beag;
crossed nicols x 27. (p.131).
Note the angle the phenocrysts make
with the banding.

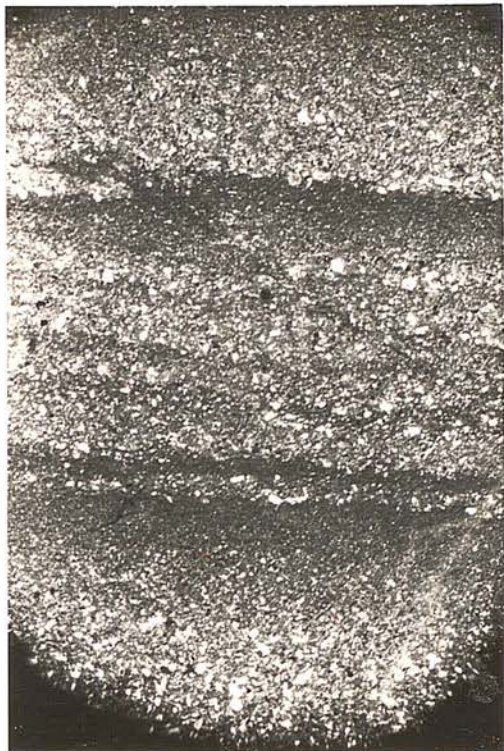
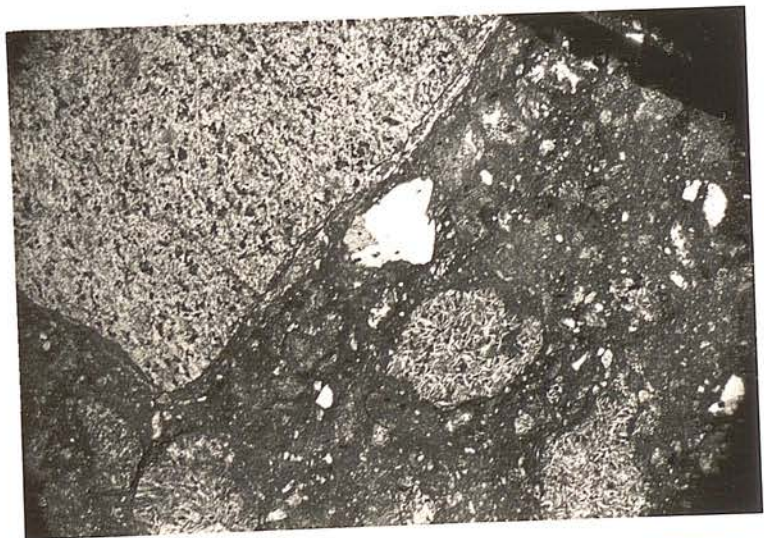
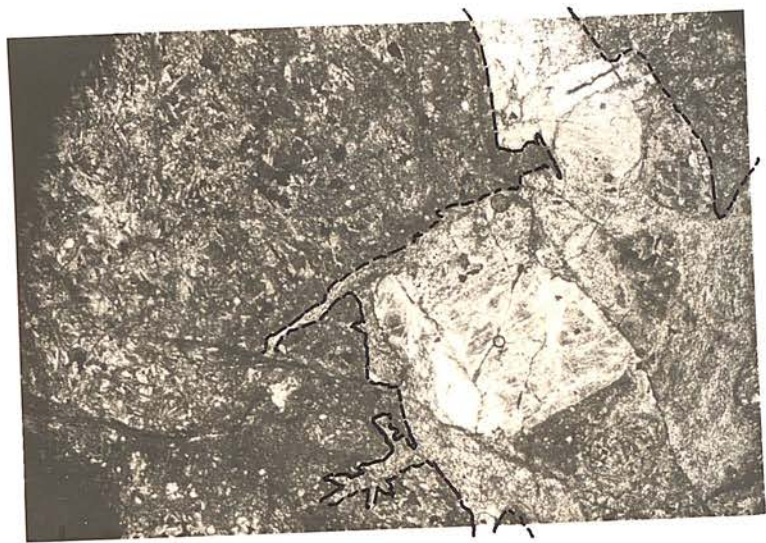


PLATE XL

a) Transgressive agglomerate in contact with basalt; ordinary light x 14. (p.132). Note the angular cloudy feldspar crystal within the paler coloured agglomerate.

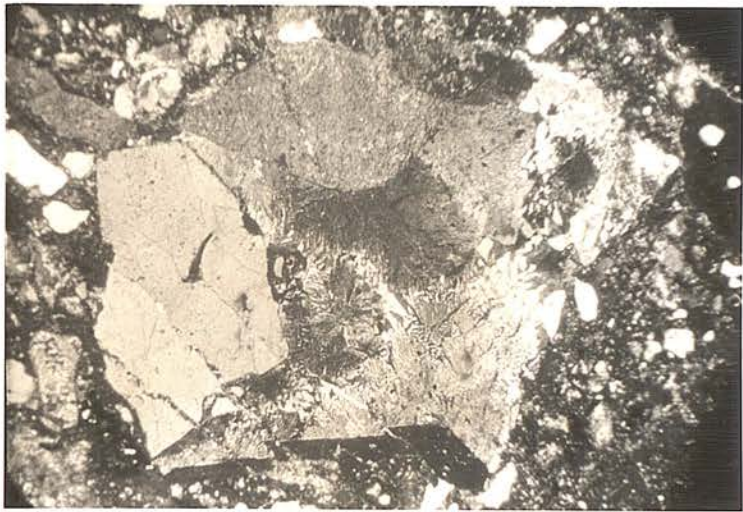
b) Transgressive agglomerate; ordinary light x 14. (p.132). Note the fragments of trachyte, basalt and quartz in the dark glassy matrix showing fluxion structure.

PLATE XL



a) Fragments of spherulitic microgranite
in trangressive agglomerate; crossed
nicols x 14. (p.132).

b) Fragments of granite in trangressive
agglomerate; crossed nicols. x 14. (p.132).

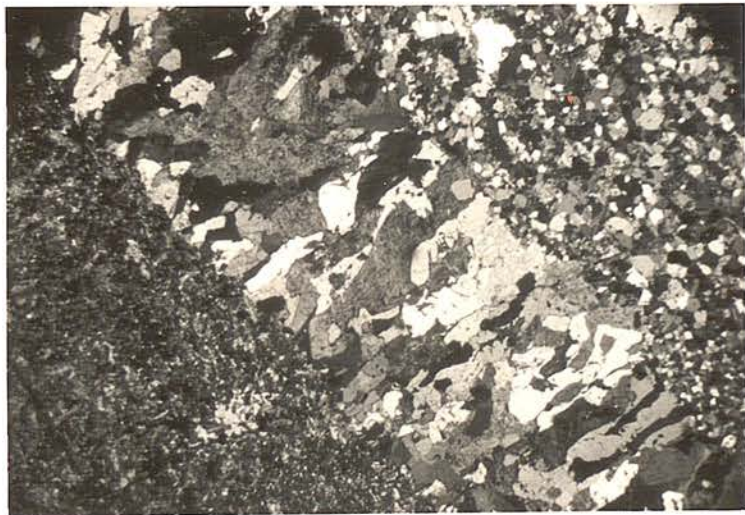
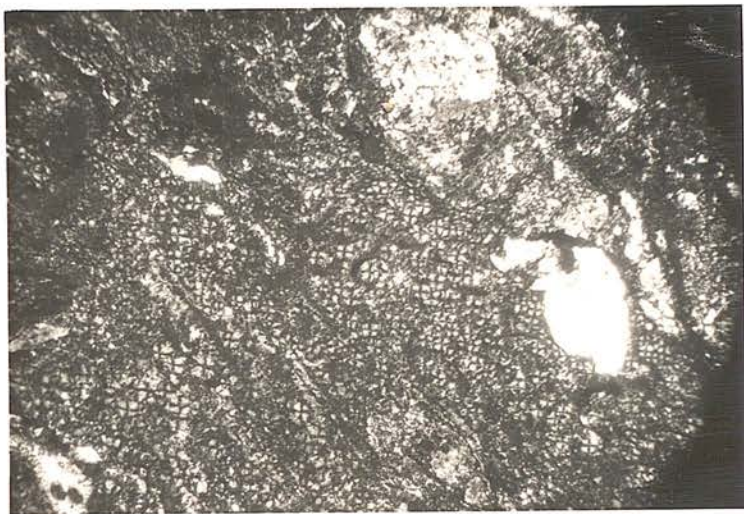


a) Quartz-porphyry; crossed nicols x 27.
(p. 136).

Note the quartz and feldspar fragments
embedded in the cryptospherulitic matrix.
The matrix is banded.

b) Microgranite net-vein cutting basalt;
crossed nicols x 14. (p. 137).
Note the micropegmatitic margin and the
granular interior of the vein.

PLATE XLII



GLAS BHEINN BHEAG

a) Calcareous sandstones, dipping eastwards;
Allt Strollamus (p. 160).

b) Mudstones dipping eastwards (centre),
and quartz-porphry sill (right);
Allt Strollamus (p. 160).

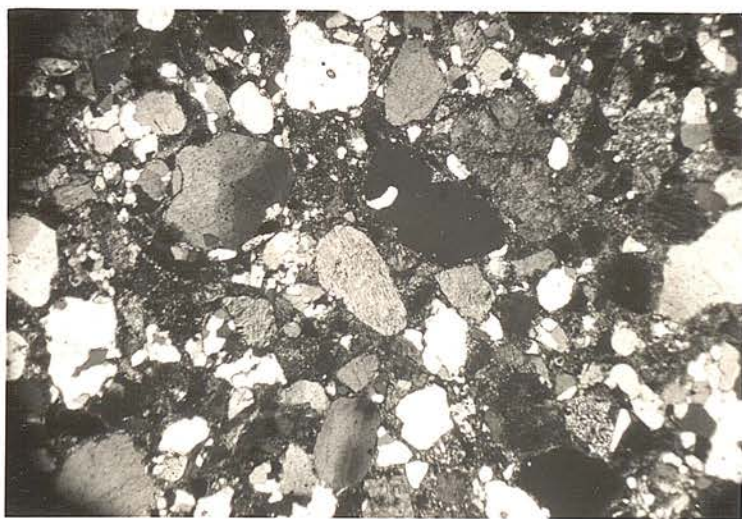
PLATE XLIII



a) Feldspathic sandstones and quartzites of Zone 1. Note the high percentage of groundmass and the strained quartz; crossed nicols x 27. (p.168).

b) Feldspathic sandstones and quartzites of Zone 2. crossed nicols x 27. (p.168).

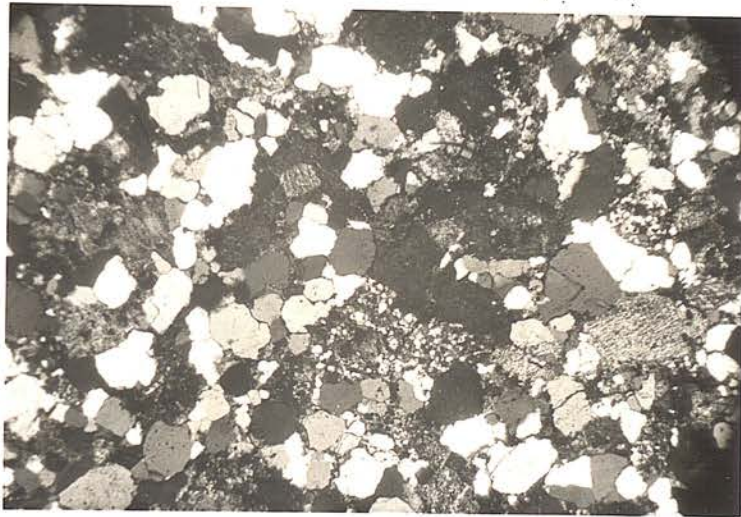
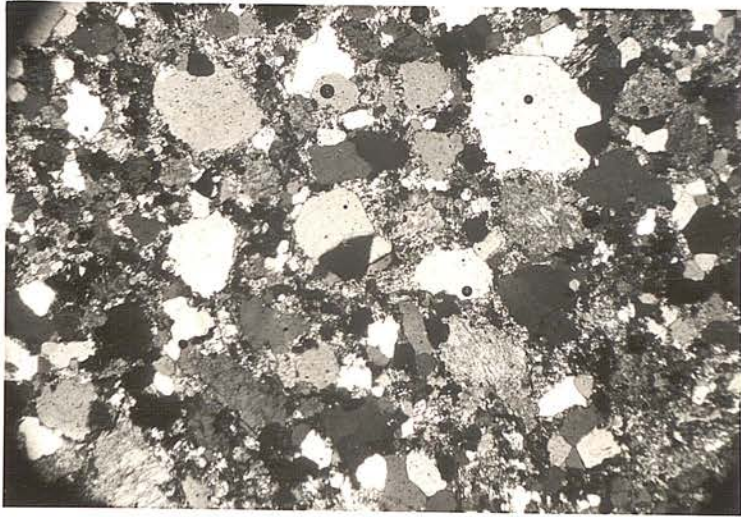
PLATE XLIV



a) Feldspathic sandstones and quartzites of Zone 3. Much of the interstitial material is alkali feldspar; crossed nicols x 27. (p.169).

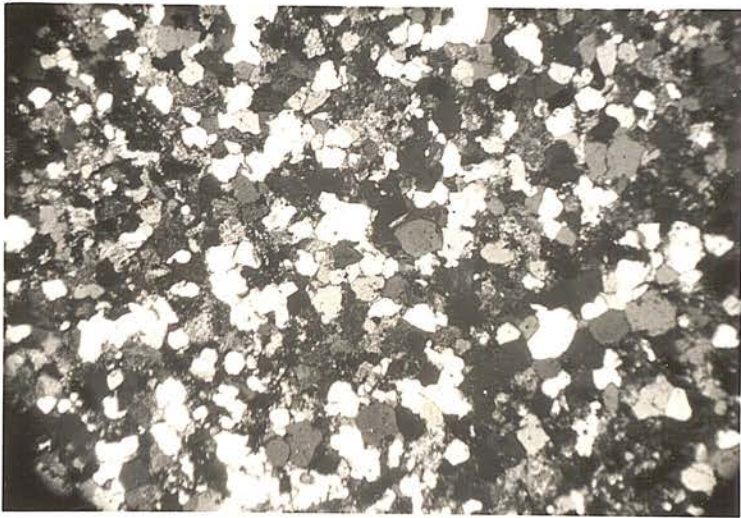
b) Feldspathic sandstones and quartzites of Zone 4. Note the granular quartz; crossed nicols x 27. (p.169).

PLATE XLV



Feldspathic sandstones and quartzites
of Zone 5. Note the granulitic
appearance of the rock; crossed nicols
x 27. (p.169).

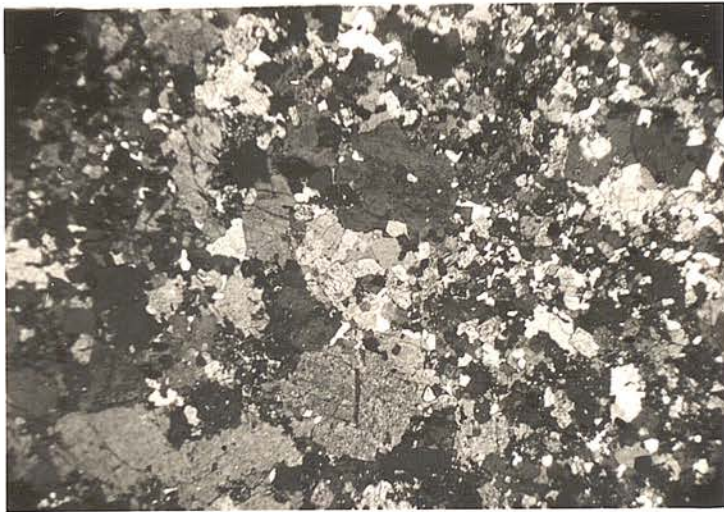
PLATE XLVI



a) Feldspathic sandstones and quartzites
of Zone 6. Note the feldspar porphyroblasts;
ordinary light x 27. (p.169).

b) The same field as above under
crossed nicols.

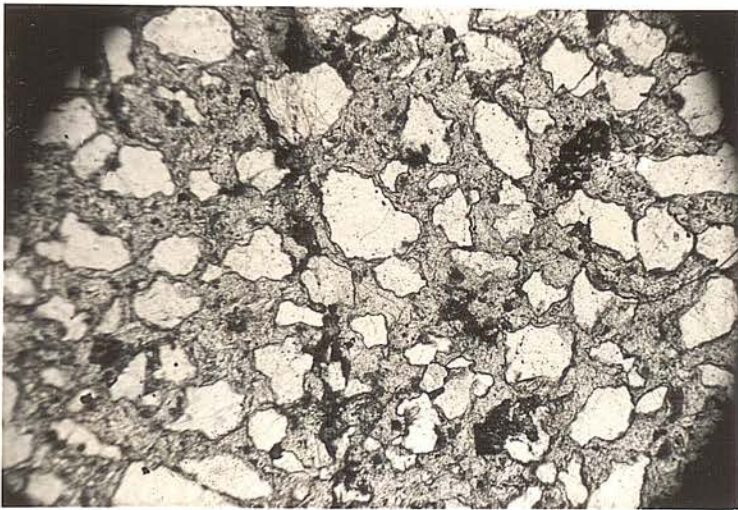
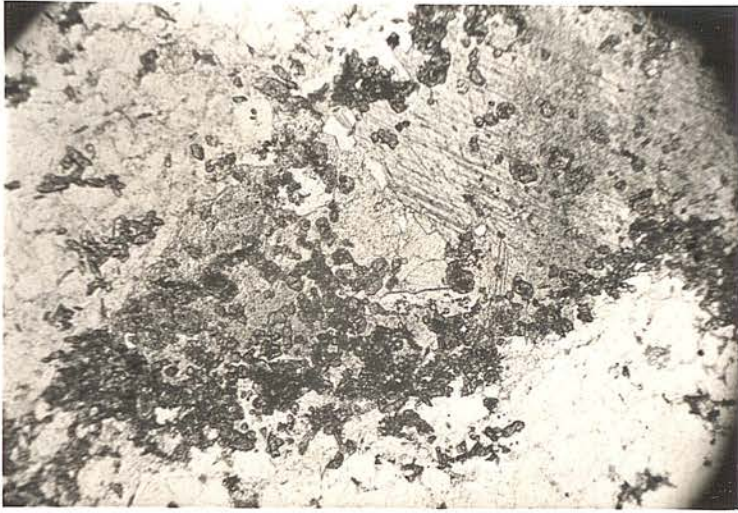
PLATE XLVII



a) Calcareous quartzites. Note the large crystal of calcite rimmed by diopside and garnet. The white areas are quartz; ordinary light x 27. (p. 171).

b) Calcareous quartzites. Quartz grains in a matrix of wallastonite; ordinary light x 27. (p. 171).

PLATE XLVIII



a) Micrographic microgranite; ordinary light x 14. (p. 178).

b) The same field as above under crossed nicols.

PLATE XLIX



PLATE L

a) Granular microgranite; crossed
nicols x 14. (p.180).

b) Spherulitic microgranite. Note
the large plagioclase crystal which
is strongly zoned, internally corroded,
and rimmed by feathery micropegmatite;
crossed nicols x 27. (p.180).

PLATE I



PLATE LI

a) Feathery micropegmatite in micrographic
microgranite; crossed nicols x 14. (p. 181).

b) Spherulitic quartz-porphyry; crossed
nicols x 27. (p. 181).

PLATE LI

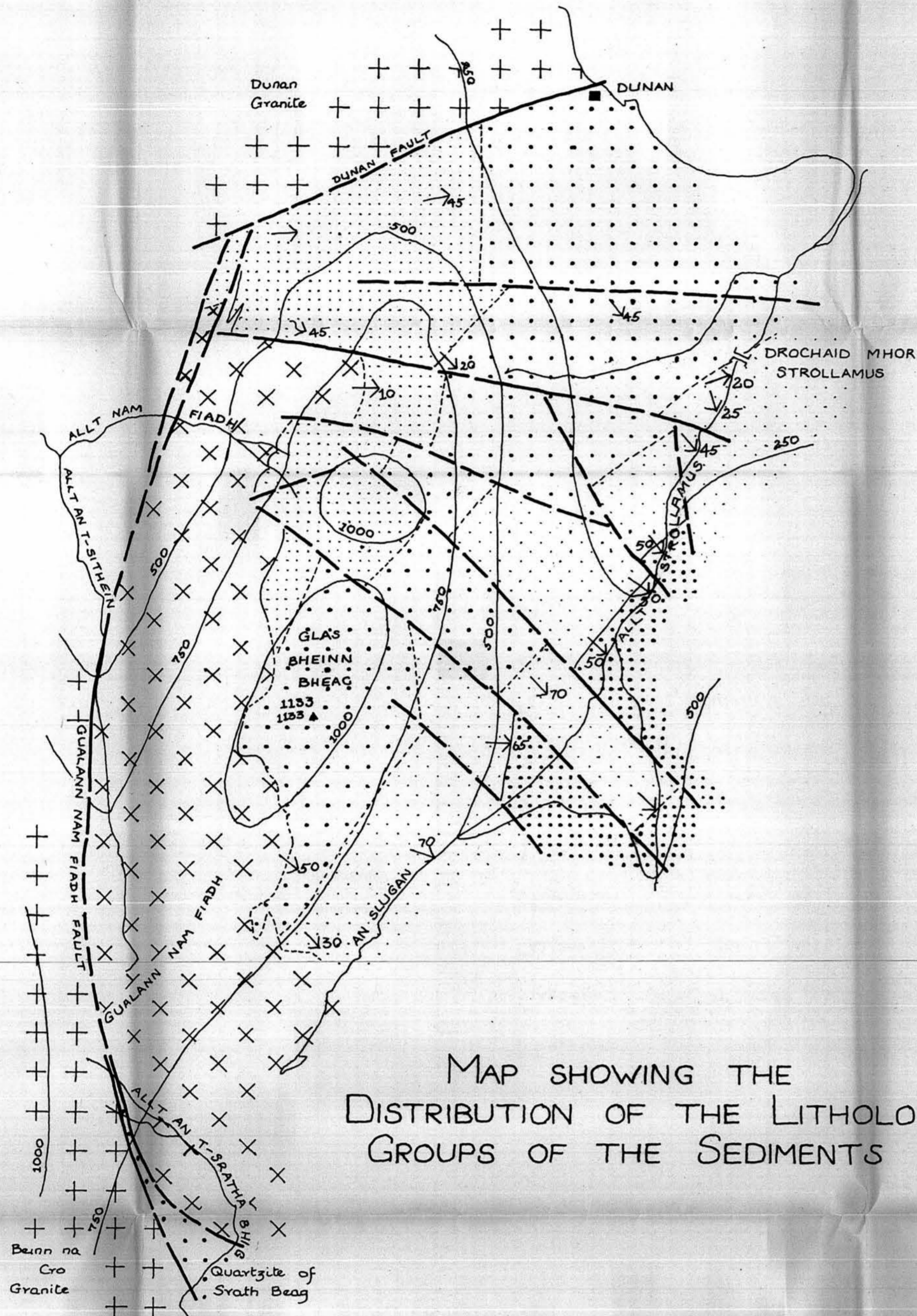


a) Granular quartz-porphyry. Note the large plagioclase crystals rimmed by feathery micropegmatite; crossed nicols x 14. (p.183).

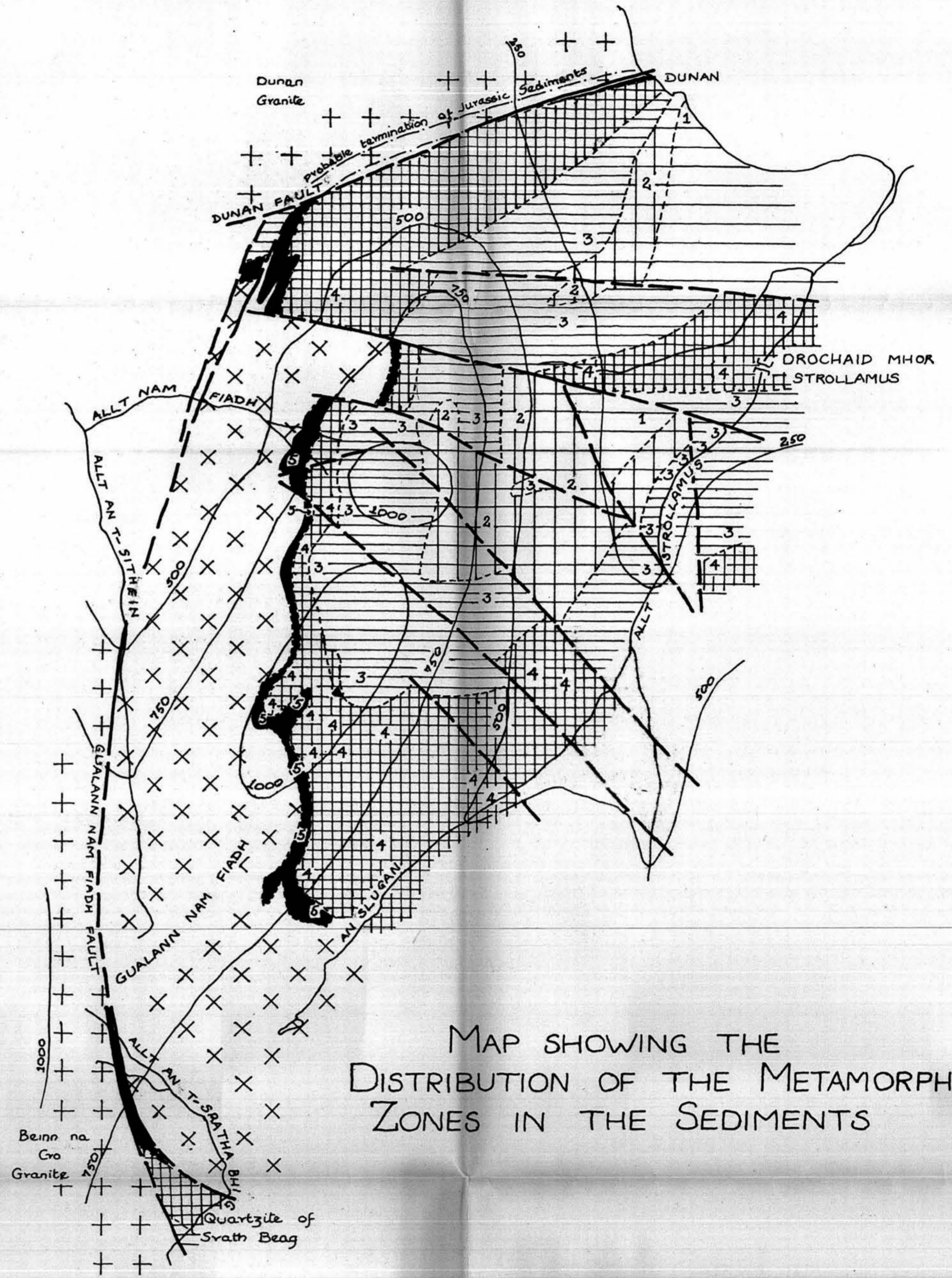
b) Micrographic quartz-porphyry; crossed nicols x 14. (p.184).



GEOLOGICAL MAPS OF GLAS BHEINN BHEAG



MAP SHOWING THE
DISTRIBUTION OF THE LITHOLOGICAL
GROUPS OF THE SEDIMENTS



MAP SHOWING THE
DISTRIBUTION OF THE METAMORPHIC
ZONES IN THE SEDIMENTS

| | |
|-----------|---|
| | MUDSTONES |
| | CALCAREOUS QUARTZITES |
| | FELDSPATHIC SANDSTONES AND QUARTZITES |
| | HORNFELSES AND METAMORPHOSED SANDSTONES |
| 1. | METAMORPHIC ZONES (THE NUMBERS ON THE MAP INDICATE POINT-PLOTS) |
| 2. | |
| 3. | |
| 4. | |
| 5. AND 6. | |
| | MICROGRANITE |
| | GRANITE |

JURASSIC SEDIMENTS

