Nature and origin of meladiorite layers in northern Guernsey, Channel Islands

A. C. BISHOP

Department of Mineralogy, British Museum (Natural History), London SW7 5BD

AND

W. J. FRENCH

Department of Geological Sciences, Queen Mary College, London E1 4NS

ABSTRACT. The Cadomian igneous complex of N. Guernsey includes gabbro, diorite, granodiorite, and adamellite. The gabbro is layered, shows variations in colour index and texture, contains abundant amphibole, and is cut by the diorites. The diorites show little variation in mineral compositions despite considerable variation in modal proportions. They contain numerous thin and roughly parallel veins of leucodiorite and granodiorite, and layers of meladiorite occur in several places within the veined diorites. These meladiorites, previously interpreted as separate intrusions, form individual layers from a few centimetres to several metres thick which can be traced for some tens of metres along strike. The upper surfaces of the meladiorites are planar but the lower tend to be indented and irregular. The layers thin out laterally and usually pass into the host diorite by way of a zone containing dark spots and both the spots and the meladiorite layers are composed of actinolitic hornblende and Mg-biotite.

Chemical and petrographic data are presented for most of the rocks and minerals especially for the meladiorites and their host, the veined diorites. The rock chemistry and particularly the compositions of the amphiboles and micas of the meladiorites and the mafic spots, taken together with the presence of unmixing lamellae in the amphibole and the details of the field relationships, indicate that the rocks tended to equilibrium under subsolidus conditions and are most probably of metasomatic origin.

Acid pipes and pegmatites occur within and are restricted to the meladiorites. The forms of the pipes were previously taken to indicate that they were magmatic at the same time as the meladiorites. The metasomatic origin for the meladiorites proposed here calls into question this magmatic interpretation and it is suggested that the pipe formation is connected with the metasomatic process. It is envisaged that the alteration of the veined diorites took place under conditions in which high gas pressures allowed acidic melt to be produced at temperatures only a little above the solidus of the diorites. The thermal impulse for this recrystallization may have resulted from the polyphase intrusive history of the complex as a whole.

THIS paper concerns unusual melanocratic layers which occur in the Cadomian igneous complex of N. Guernsey (fig. 1). The layers are up to several metres thick and dip gently west. They are strictly parallel but are discontinuous laterally and consist of what Elwell et al. (1960) have called meladiorite. Their dominant minerals are actinolite and Mg-biotite with minor magnesio-hornblende and plagioclase. The meladiorites occur within more normal diorites which contain thin leucocratic veins and are conveniently called veined diorites. These diorites and their veins are mainly composed of magnesio-hornblende and zoned altered plagioclase. The meladiorites contain thin pipes and sheets of granitic composition and have been interpreted (Elwell et al., 1960) as igneous sheets. The new data presented here suggest an alternative origin for them involving subsolidus recrystallization and metasomatism perhaps accompanied by partial melting.

The igneous complex as a whole is made of four main units, all of which appear to have been emplaced some 550 Ma ago (Adams, 1976). The oldest intrusion, the St. Peter Port gabbro, is emplaced in Pentevrian gneisses (c. 2500 Ma) and is cut by structurally complex diorites and granodiorites which were formed in several stages. These rocks are referred to as the Bordeaux diorites and Chouet granodiorites and are cut by the Cobo adamellite and the l'Ancresse granodiorite.

The meladiorite layers are confined to the outcrop of the Bordeaux diorites and the best exposures occur on the foreshore to the north of Bordeaux Harbour (fig. 1). Particularly good exposures occur in the cliffs near the marina at Beaucette and we have concentrated chemical and mineralogical work on these rocks.

General relationships of the igneous complex

The field relationships of the igneous complex have been outlined by Roach (1967) and details were given by Drysdall (1957) in an unpublished thesis. Chemical data for the Bordeaux diorites and Chouet granodiorites have been presented by Brown *et al.* (1980).

The St. Peter Port gabbro. Synoptic chemical data for the gabbros and related rocks are given in Table I: their most striking properties are high contents of Al_2O_3 and low amounts of MgO and SiO_2. Analyses of constituent amphiboles and a clinopyroxene are given in Table II. The gabbros are composed mainly of clinopyroxene and plagioclase with poikilitic brown amphibole. Orthopyroxene and olivine occur rarely. Variation in the proportion of plagioclase and mafic minerals gives rise to layers up to several metres thick, which dip gently west, and have melanocratic bases and leucocratic tops. Less commonly there are layers with bytownite and abundant brown amphibole— the bojites of Drysdall (1957)—in which the amphiboles are elongate and arranged with their long axes in the plane of the layering. The textures of all the layered rocks, and of some more homogeneous gabbros which occur to the south, suggest that considerable subsolidus recrystallization has taken place. Some rocks show amphibole and clinopyroxene intimately intergrown and enclosing rounded remnant grains of plagioclase, and the amphiboles of the bojites have corroded scalloped margins and consist of several separate granular parts.

Numerous small basic dykes cut the gabbro and while some of these are dolerite, others comprise more than 80% granoblastic hornblende. The gabbro into which these dykes are intruded also contains substantial amounts of the granular amphibole and in general, late, black, lustrous amphibole occurs dispersed throughout the gabbros, as ductless masses of hornblendite up to a metre across, and as encrustations on joint surfaces. Another form of alteration results in the formation of coarse-grained rocks of appinitic aspect in which hollow-shell amphiboles reach up to 50 by 4 cm. Sometimes these rocks make pools up to several metres across in the gabbros but in other exposures they occur as parallel layers normal to the gabbroic layering and with the large amphiboles arranged with their long axes perpendicular to the secondary layering.

The gabbros are also cut by at least three ages of composite dykes which consist of a central, dominant, mass of fine-grained diorite and outer selvages, a centimetre or two thick, of coarse-grained plagioclasite or leucodiorite. These marginal rocks are usually appinitic and form sharply defined reticulate veins in the host gabbro. The central parts of the dykes may also be cut by the marginal rocks but in many intrusions the central darker diorite takes the form of rounded blocks in a matrix of sparse leucodiorite. The globular masses are very closely packed and each becomes progressively finer-grained towards its margin. Some of the composite dykes are extremely irregular and may be up to several metres thick. The thicker dykes have both globular and angular blocks of the diorite but also contain blocks of darker, doleritic rock and large masses of extremely altered layered gabbro. The structural relationships of these dykes suggest that the dark central diorites slightly preceded the coarser, more leucocratic rocks; the emplacement of these composite dykes may relate to the pervasive recrystallization of the gabbro as a whole since they are themselves unaltered but may be accompanied by the formation in the gabbro of abundant secondary amphibole. The gabbro also contains leucocratic veins and dykes which are not part of the composite dyke system. These include two suites of plagioclasite veins (andesine and albite) and veins of leucodiorite and granodiorite. The last two are associated with the larger appinitic patches in the gabbro and tend to be abundant round them.

The Bordeaux diorite–Chouet granodiorite complex. Diorite makes up the bulk of this complex, but quartz diorite and granodiorite also occur, sometimes as xenolithic sheets and veins, sometimes as larger masses feeding the vein systems, and sometimes as rafts. Typical compositions for some of these rocks are given in Table IV and representative mineral analyses are given in Tables II and III. Through this rock series, passing from basic to more acidic rocks, the amphiboles show only a slight enrichment in Fe, Si, and Mn at the expense of Na, K, Ti, and Mg; the micas also show some Fe enrichment; and feldspars become more sodic, though most are within the andesine range. The similarities of mineral compositions through the rock series are much more striking than the differences so that the rocks essentially represent differing proportions of hornblende, biotite, andesine, and quartz.

The diorites in the eastern part of the complex contain veins of leucocratic quartz diorite forming 5 to 10% of the rock mass and arranged broadly parallel to one another so that they define a layering dipping west at up to 50°. The margins of these veins are rarely parallel but have upward or downward prolongations into the host diorite. Cross connections are common and the vein thickness varies markedly. Generally, the coarser the grain-size of the diorites, the coarser are the
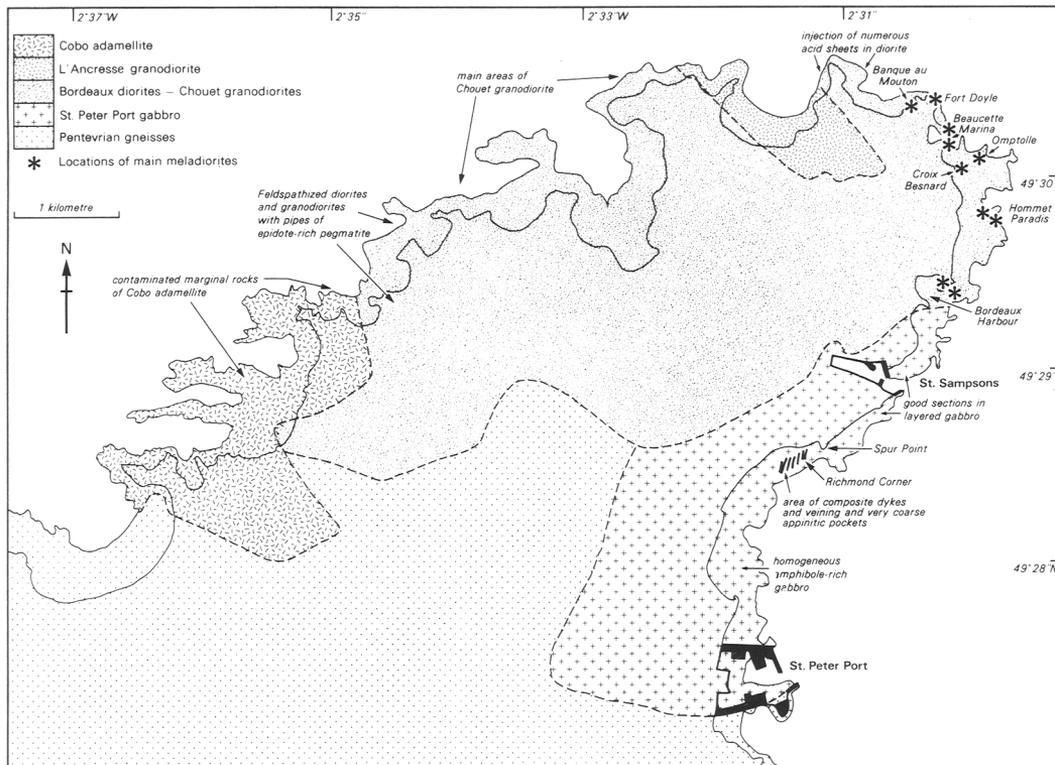
FIG. 1. Geological sketch map of N. Guernsey.

leucocratic veins and the thicker and further apart they become. The veins are typically about 10 to 15 cm thick and about a metre or two apart, but in places they reach 80 cm thick and may be several metres apart. In these larger structures the diorite between the veins tends to become more leucocratic and appinitic upwards. These leucocratic upper rocks penetrate as veins into overlying dark diorite to form a structure identical with that at its own base (cf. Bishop, 1963). The dip of the sheeted structure decreases westwards and both veins and diorite become finer-grained and the veins more closely spaced. In many instances the diorites become progressively finer-grained towards the veins and the further apart the veins, the greater the distance, up to 15 to 20 cm or more, over which the grain-size reduction occurs. There is sometimes a narrow, dark, and much finer-grained zone in the diorite at the junction with a vein.

It is these various veined diorites which contain the meladiorites described in detail here. The diorites also contain widespread aggregates, a few millimetres in diameter, of the same actinolitic amphibole and mica as the meladiorites. These mafic clots are sometimes orientated in north to south trending planes, indicating that the diorites recrystallized in a stress field.

The l'Ancresse granodiorite. This is a homogeneous granodiorite which cuts the Bordeaux diorites and Chouet granodiorites described above and may be later than the event which produced the orientated mafic clots. It has a weak, north-east trending foliation and its margin is partly sheeted with irregular thick sheets of granodiorite cutting the older granodiorites and diorites.

The Cobo adamellite. This body has a marginal, early, contaminated facies which is cut sharply by the main adamellite. The alkali feldspar is rather sporadically distributed and in places the rock is megacrystic while elsewhere it is aphyric. North of the adamellite the older Chouet granodiorites and Bordeaux diorites are feldspathized and contain large masses of orthoclase, and smaller metasomatic pipes and veins of orthoclase, epidote, and quartz, often of pegmatitic grain-size. Feldspathization is widespread in the older diorites and granodiorites and even affects the l'Ancresse granodiorite, but large amounts of the new feldspar are developed only locally near the adamellite. Some of the lesser occurrences of alkali feldspar
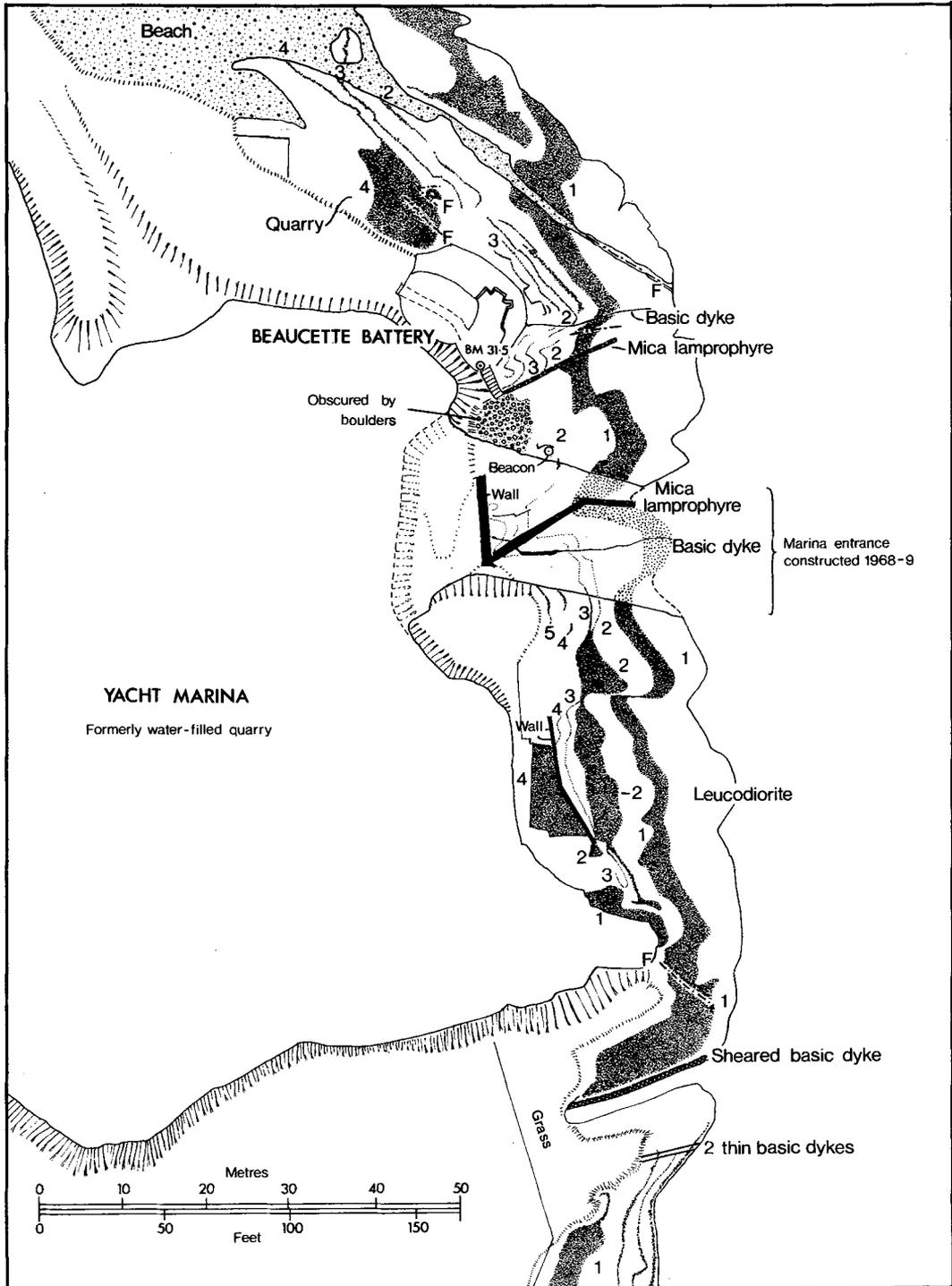
FIG. 2. Geological map of the area around Beaucette Quarry, NE Guernsey showing the distribution of meladiorite layers (stippled) in veined diorite. The layers are numbered from the lowest upwards.
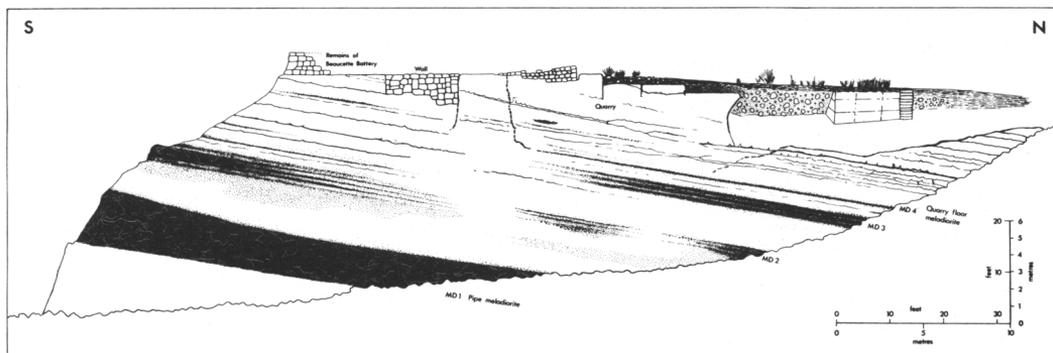
FIG. 3. Section of the layered diorites north of the marina entrance, Beaucette, NE Guernsey MD1, MD2, etc. are the meladiorite layers numbered 1, 2, etc. on fig. 2.

may have grown during the formation of the diorites and granodiorites rather than in association with the emplacement of the Cobo adamellite.

Field relationships of the meladiorites

Beaucette. When this work was started the cliffs at Beaucette separated a large water-filled quarry from the sea. Access has since been made from the sea into the quarry, which is now used as a marina. Part of the remaining cliff has been obscured by white paint marking the entrance to the marina. Fig. 2 shows the geology of this area before the construction of the marina. The meladiorites occur in veined diorite in which the veins are some 50 cm apart, and both the veins and the meladiorites dip west at about 15°. Of the 35 m thickness of this section, a total of about 6 m is meladiorite (fig. 3).

The meladiorite layers vary from a few centimetres to a few metres in thickness and are generally lenticular in form, passing both laterally and vertically into veined diorites containing layers of dark spots (fig. 4). These spots are the same as those mentioned previously which occur throughout the diorite and which in places are elongated and mark a weak, vertical, planar structure trending roughly north to south.

The most persistent meladiorite layer at Beaucette is about 2.5 m thick. It is almost continuously exposed from south of the marina northwards to the pebble beach between Beaucette and Fort Doyle (fig. 2), and is distinctive because it contains numerous pipes of granitic material. South of the marina entrance there are four meladiorite layers above this thick meladiorite, while north of the entrance there are five such dark layers. Each of these upper layers passes laterally into veined diorite containing the dark spots only to reappear at the

same level a few metres away (see figs. 2 and 3). The upper and lower surfaces of the layers pass into veined diorite by a reduction in the number of spots, often over a distance of only a few centimetres. The spots are most abundant near the meladiorites and tend to lie in layers, typically 2 or 3 cm thick, parallel to the meladiorites and which weather out as parallel ribs. Locally there are multiple layers rich in the amphibole and mica spots, each layer being about a centimetre thick. These may be incipient meladiorites or the terminations of meladiorites not now exposed. Both the host diorite and its veins are crossed by the layers of spots.

Pegmatite veins and granite pipes occur in, and are restricted to, the meladiorite layers and both the veins and the pipes vary in size in sympathy with the thickness of the layers. The pegmatites in the largest meladiorites are up to 30 cm thick and are dilational; they do not cut the surrounding veined diorites but merge into the leucocratic vein
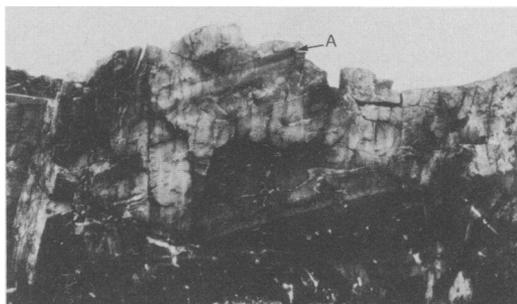

FIG. 4. Meladiorite sheets in veined diorite, Beaucette, NE Guernsey. The meladiorite sheet at the bottom of the photograph contains granitic pipes. A thin upper sheet (A) dies out to the left.

system with less evidence of dilation. They are made of quartz, K-feldspar, and smaller amounts of biotite. At the base of the section, to the south, there is a spheroidally weathered meladiorite containing a few small acid pegmatite veins which terminate at the surface of the layer. This layer has a planar top but is gradational over a few centi-metres into veined diorite with reduction in the number of dark spots. Some 20 m to the east there is a further exposure of meladiorite and here the veins of the veined diorite pass into substantial pegmatitic veins in the meladiorite. Another meladiorite which occurs only 10 m to the east contains acid pegmatite veins which connect upwards with the leucocratic veins of the veined diorite while, further south, yet another meladiorite is cut by an acid pegmatite sheet which passes into granodiorite in the host veined diorite. A particu-larly instructive pegmatite occurs in an old quarry north of the marina entrance. Here the marginal zone of the pegmatite contains biotite crystals which are orientated in the same plane as the dark spots. The pegmatite thins towards the surface of the meladiorite and again merges with the vein system of the veined diorites. The origin of these pegmatites therefore seems to be directly connected with that of the meladiorites and may have some relationship with the formation of the veins in the diorite.

The granitic pipes in the meladiorites are straight and mostly circular or elliptical in cross-section though some of the smaller bodies in the small meladiorites are more nearly rectangular. In the main meladiorite sheet they are typically 10 cm in diameter and their long axes are not perpendicular to the surfaces of the meladiorite but plunge southeast at about 30°. The pipes are composed of quartz, K-feldspar, and biotite which also form upstanding rings on the weathered surface of the immediately surrounding meladiorite. The pipes become notably more pegmatitic and acidic upwards along their length. In exposures at the southern end of the section they can be seen to arise directly from leucodiorite beneath the mela-diorite and one has been found to extend for several centimetres into the overlying veined diorite. Apart from these occurrences, however, the pipes are confined to the meladiorites.

Bordeaux Harbour. To the north of Bordeaux Harbour the veined diorite contains veins a few centimetres thick and a metre apart, which dip northwest at about 30°. This diorite contains clots of secondary amphibole like those described from Beaucette, together with two masses of meladiorite. One of these is about 5 m across and mostly fault-bounded and the other is a sheet up to 2.2 m thick which dips northwest at 40° and can

be followed for about 40 m. This latter sheet has a planar top, gradational over some 10 cm from meladiorite, through a zone of abundant amphi-bole and mica spots, into veined diorite with few spots. The rocks along the upper surface are leucodiorite to coarse-grained diorite and, occasionally, acid pegmatite appears in the leucodio-rite veins close to the upper surface of the meladio-rite. The attitude of the base and the thickness of the sheet both vary considerably and erratically, and at its northeast extremity the body thins to less than 1 m before the exposure ends. Where the veins of the underlying veined diorite approach the meladiorite they become suffused with acid pegmatite and protuberances arise from them into the meladiorite in the form of planar sheets up to 10 cm thick which connect with thicker and less regular pegmatites. Several parallel granite pipes (14 were counted) which dip northwest at 10° occur near the southwest end of the sheet. They are elliptical, circular, and semicircular in cross-section and are from 5 to 10 cm across. Most are pegmatitic but some are of granodiorite grading upwards to granite pegmatite. The pegmatite sheets penetrate the overlying veined diorite for a few centimetres but the pipes neither extend out of the meladiorite nor do they connect with the pegmatites, although one is within a few centimetres of pegmatite and could have arisen from it.

Hommet Paradis. On the northeast side of Hommet Paradis (fig. 1) there is a mass of mela-diorite up to 20 m thick which dips at 35° to 293°. It is much affected by minor faulting but can be traced along the strike for some 30 m. Near its base it contains acid pegmatite which connects downwards into the vein system of the diorites. At the top it merges by reduction in the amount of amphibole into the veined diorite. Above the meladiorite there is a 90 cm layer of coarse-grained diorite containing euhedral amphiboles up to 10 mm across in a leucocratic groundmass. These amphi-boles are in places arranged in perfectly planar layers some 20 mm thick and parallel to the surface of the meladiorite. This diorite passes gradationally upwards into another meladiorite some 70 cm thick, the sharply marked top of which is over-lain by further coarse-grained diorite containing appinitic veins and patches of pegmatitic appinite up to 15 by 60 cm, with hollow-shell amphiboles measuring 40 by 3 mm. A metre of this diorite is followed by yet another meladiorite, 1.5 m thick, which also has a sharply defined planar top and an undulating transitional base penetrated by coarse-grained veins of leuco-appinite. More normal veined diorite with sporadic amphibole clots which extend for several metres above the mela-diorites occurs above this sheet. The main mela-

diorite encloses small masses of coarse-grained leucodiorite with amphiboles some 10 mm across, and these bodies have diffuse wispy margins against the meladiorite. Northwest of these exposures, and on the higher part of the island there are another two meladiorites which wedge out over some 5 m and have transitional margins, irregular bases and contain acid pegmatites.

Omptolle and Croix Besnard. On the east side of the higher parts of the small island of Omptolle (fig. 1) meladiorite is exposed over an area of some 40 by 100 m and this provides some of the best evidence for regarding the meladiorites as other than igneous. The dark rocks do not have sharp bounding surfaces but have gradational tops, and fade out laterally over a few metres. Elsewhere the typical irregular base is present but the meladiorite fades out both vertically and laterally. The base of one part of the meladiorite is coplanar with the veins of the veined diorite and is particularly fine-grained and melanocratic against them. The lower parts of the cliffs at Croix Besnard display structures similar to those on the island and layers with sharply marked tops occur in the lower parts of the cliff. These cannot be traced for more than a few metres and contain less green amphibole than usual.

Fort Doyle and Banque au Mouton. At Fort Doyle (fig. 1) the reefs contain abundant secondary amphibole (best seen at low water mark) and layers of amphibole from 10 cm to more than a metre thick dip S at 20° and cross the normal veined diorite. The layers have the usual gradational margins and contain leucopegmatite veins and possibly pipes. One meladiorite body has a circular outcrop and vertical attitude, and relict appinitic veins and patches are preserved in this mass. At Banque au Mouton secondary amphibole occurs in layers which cross the layered structure in the diorite. These layers of secondary amphibole generally dip south at 20° but are not precisely parallel. They are conspicuous over a thickness of a few metres and are made of isolated amphibole crystals in a groundmass of unchanged diorite.

Comments on field relationships. The field evidence shows a close temporal and genetic affinity between the meladiorites, the pegmatites, and the acid pipes. Because of this association, Elwell *et al.* (1960) suggested that the meladiorites were intruded into the veined diorite as a series of sheets and that the pipes were formed by the rise of palingenetic acid magma from the leucocratic vein system, and other underlying leucocratic rocks, into the still mobile, largely uncrystallized, meladiorite. The pegmatites were interpreted as fissure infillings. The suggestion that the meladiorites were emplaced as intrusions derived from the

interpretation placed upon the origin of the pipes and veins. Indeed, the authors point out that 'it could be maintained that ... their (the meladiorites) relation to the veined diorite is not an intrusive one'. (Elwell *et al.*, 1960, p. 92). We would agree and believe that it is difficult to interpret the margins of the meladiorites as intrusive unless the metamorphic formation of amphibole and mica has completely obliterated the margins of the original mafic intrusions. Further, the shapes of the meladiorites and the way in which they fade out and reappear along the strike argues against an intrusive origin. Sometimes, particularly at the lateral terminations of the dark masses, the bases are extremely irregular but the tops are smooth and almost planar. In detail it has been noticed that some of the layers become darker upwards and that locally there are leucocratic streaks reminiscent of the veins in the veined diorite. If the meladiorites are not of intrusive but metamorphic or metasomatic origin, perhaps formed by concentrated growth of the mafic spots, then the interpretation previously used to account for the formation of the granitic pipes and acid pegmatites also comes into question: their anatectic origin may remain plausible but their interpretation as intrusive into molten meladiorite may not.

Petrography of the Beaucette rocks

Elwell *et al.* (1960) have given detailed petrographic accounts of the veined diorites, leucocratic veins, and pipes and we give only a brief summary here. Modal analyses of the host rocks and the veins are given in Table V. The dioritic portion of the veined diorite conforms well with Streckeisen's (1967) definition of diorite. The host diorites are even-grained rocks with an average grain-size of about 0.5 mm (fig. 5). The colour index is patchily variable but typically about 40. Plagioclase and green amphibole are present in about equal amounts and are accompanied by chlorite, quartz, biotite, accessory apatite, and opaque minerals; K-rich feldspar is virtually absent. The amphibole is for the most part moulded on plagioclase which forms subhedral crystals frequently with a sericitized core and a clear rim of variable width. Some of the feldspars are replaced by prehnite flakes and small grains of amphibole occasionally occur either singly or in clusters within the feldspars. Biotite forms large plates, sometimes with bent cleavages, and is altered marginally to opaque minerals and possibly feldspar. Prehnite is common as lensoid masses along the mica cleavages and occurs throughout the mica-bearing diorites and granodiorites. Chlorite is present in only minor amounts
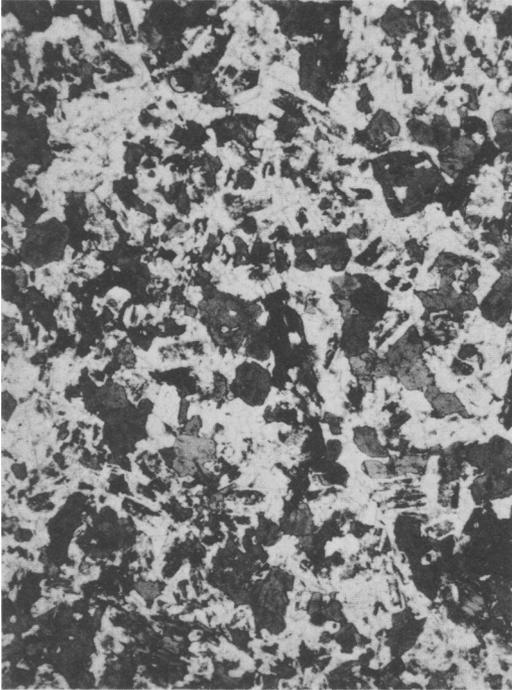
FIG. 5. Photomicrograph of veined diorite, Beaucette, BB11, NE Guernsey. Plane polarized light; long dimension of photograph, 8 mm.

while quartz forms mosaics of sutured grains each surrounded by a pellicle of chlorite or prehnite.

The quartz diorites contain more quartz and feldspar and have better formed amphibole crystals than the diorites. Spots composed of actinolitic hornblende and Mg-biotite occur within the diorites and less often in the veins of quartz diorite. These spots are typically circular in outline but some are elongate. When sparse and isolated they tend to be about 5 mm in diameter but as they become more abundant they also become larger and can be up to 10 by 6 mm (fig. 6). The actinolitic hornblende in the spots is pale green and faintly pleochroic. Pale brown biotite is associated with the actinolite; both minerals form aggregates of roughly equant grains each about 0.2 to 0.3 mm across. The actinolite grains often contain small octahedra, probably of magnetite, and tiny rounded quartz blebs. Some of the actinolites contain exsolution lamellae, about 2 μm wide, of another amphibole.

The meladiorites consist of an aggregate of patches or spots of actinolitic hornblende and Mg-biotite which are in such close contact that the host dioritic material is preserved only in the interstices between them. Two textural elements are apparent: circular to lensoid masses of equant grains of actinolitic hornblende identical to those which form the dark spots in the veined diorite, and smaller patches or elongate areas of pale brown, randomly orientated Mg-biotite. The biotite flakes usually form either a skin separating the amphibole areas or discrete patches with rather diffuse margins. Some of the biotites contain thin strips of chlorite or, more commonly, prehnite along the cleavage. Biotite occurs also within the amphiboles either as individual flakes or as parallel strips along the cleavage planes. Feldspar, for the most part, is lacking: where it is present it is invariably intermediate plagioclase with intensely sericitized cores and clear rims. Only rarely are complete crystals preserved; the rims appear to be the first parts to be replaced by amphibole so that turbid, sericitized areas, partially altered to biotite or actinolitic hornblende remain within some of the amphibole spots and mark the positions of feldspars that have been virtually replaced. Similarly, the green magnesio-hornblende which is
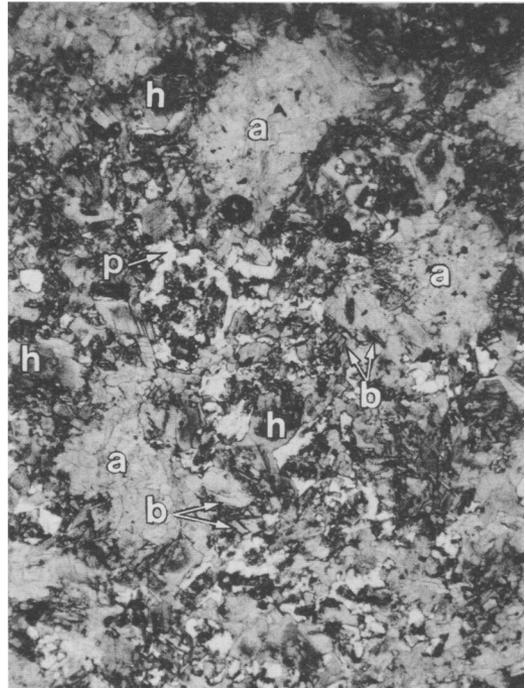

FIG. 6. Photomicrograph of actinolite-Mg-biotite spots in veined diorite, BB11, Beaucette, NE Guernsey. Plane polarized light; long dimension of photograph 8 mm. Actinolite (a), biotite (b), magnesio-hornblende (h), plagioclase (p).

associated with plagioclase in the veined diorites is patchily altered to pale green actinolitic hornblende near to the spots.

Composition of the igneous complex

The Guernsey layered gabbros are rich in Al_2O_3 and poor in MgO and SiO_2 compared with many from elsewhere. The compositions of the poikilitic, generally pyroxene-rich rocks correspond with those of class 4 basalts of Cameron and French (1977) (fig. 7) and are essentially anorthositic gabbros. The composition varies according to the modal proportion of feldspar but the analyses given in Table I are representative. The bojite compositions are closer to class 3 basalts, in that they
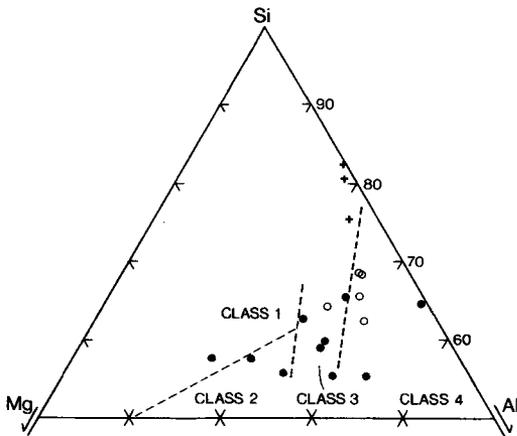

FIG. 7. Atoms % Si-Al-Mg for rocks from the northern igneous complex, Guernsey. Solid circles: St. Peter Port gabbro; open circles: Bordeaux diorite; crosses: granitic rocks. Basalt classification after Cameron and French 1977); Class 1; typically tholeiites and olivine tholeiites; Class 2: alkaline olivine basalts; Class 3: calc-alkaline island arc and continental margin high-alumina basalts; Class 4: generally basaltic andesites.

resemble high-alumina calc-alkaline basalts; they also have much higher total iron and both suites are strongly oxidized. The dykes in the gabbro have compositions which straddle the tholeiite and alkali olivine basalt fields and divide, forming a compositional series from high-MgO tholeiites to compositions resembling the bojites. The appinites and dioritic patches, which may be generated from the gabbros, have similar compositions to the gabbros but have enhanced SiO_2 and Na_2O. The MgO/Al_2O_3 ratios of the patches are within the gabbroic range but the appinites appear to be depleted in total iron relative to the corresponding gabbros.

The compositions of the diorites, quartz diorites, and granodiorites of the western part of the complex fall into three clusters and only a few rocks have compositions between these clusters. The three clusters form a chemical sequence which plots on the same line as the composition of the l'Ancresse granodiorite. The major element oxide ratios of the sequence from diorite to granodiorite match those of the more aluminous gabbros. Conversely, the diorites in the east of the complex and the appinitic diorites tend to have oxide ratios which resemble those of the bojites. In comparison with volcanic suites, the rocks as a whole are more calcic than the usual calc-alkaline association and only the appinitic diorites and some of the diorites of the eastern part of the complex correspond with a continental calc-alkaline association.

Composition of the Beaucette rocks

Veined diorites. From the chemical points of view the more basic parts of the veined diorites are typically gabbroic and their compositions correspond with those of basic calc-alkaline rocks. Some of the diorites near to the veins are closer to quartz diorite in composition using the subdivision of Hietanen (1963) based on normative or-ab-an. The veins themselves are chemically and modally quartz diorite.

Large specimens of veined diorite were cut into parts distinguished by their mineralogy or texture and then separately analysed, care being taken to select specimens as free as possible from actinolite-Mg-biotite spots. One specimen was divided into nine portions and the analyses are given in Table VI. In addition, amphiboles from two of these fractions ,were separated and analysed. The analyses show that the compositional variation of the veined diorite is in keeping with mixtures of magnesio-hornblende (Leake, 1968) and plagioclase; this shows particularly well in fig. 8. Despite the patchy variation in colour index and texture the diorites have a relatively uniform composition (fig. 8) but significant variations occur in the amounts of Mg and total Fe which increase slightly with amphibole content and are balanced by slight decreases in Na, Si, and Al. Those parts of the rocks containing larger and more euhedral amphiboles have a higher Fe^{3+}/Fe^{2+} ratio than the rest of the rock.

The quartz diorite veins are richer in Al and Si than the host diorites and the rocks show a systematic decrease in Mg and Ca with increase in Thornton–Tuttle (1960) differentiation index (fig. 9) though Na and K remain roughly constant. This is consistent with their being richer in plagioclase and quartz than the main host diorites.
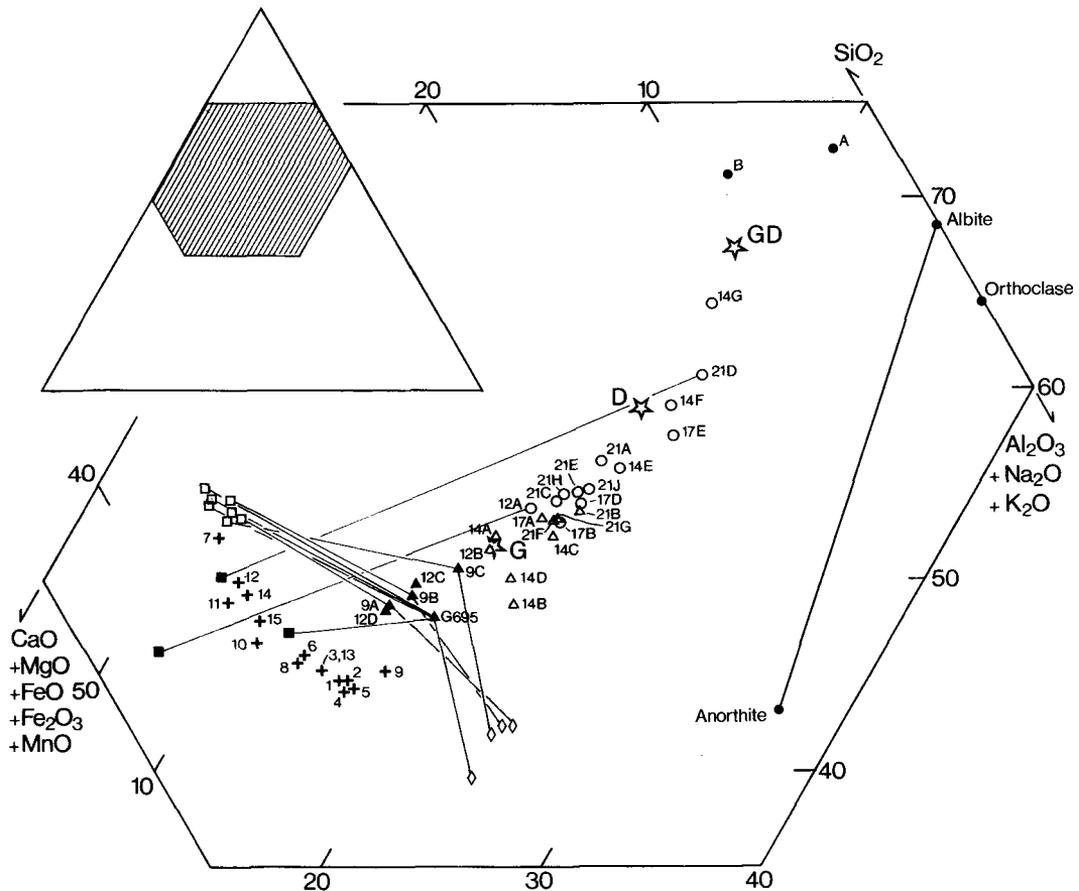
FIG. 8. Weight % $SiO_2 - Al_2O_3 + Na_2O + K_2O - CaO + MgO + FeO + Fe_2O_3 + MnO$ for rocks and minerals from the northern igneous complex, Guernsey. Beaucette area. Solid circles: granitic pipes; open circles: quartz–normative diorite; open triangles: diorite; solid triangles: meladiorite. Amphiboles from other areas in N. Guernsey are shown by crosses. Tie-lines join actinolitic hornblende (open squares), Mg-biotite (diamond) and magnesio-hornblende (solid squares) to rock composition. G, D, and GD identify, respectively, average gabbro, diorite, and granodiorite of Le Maitre (1976). Numbers identify specimens in Tables II, VII and VIII; the prefix BB is omitted for clarity.

Meladiorites. The meladiorites are of particular interest chemically in having high Mg and K with respect to Si. The K content is considerably greater than that of the veined diorites and quartz diorites. The Guernsey diorites as a whole are notably poor in K; the most acid parts of the veins and the granite at Beaucette have K_2O values that rarely exceed 1.5% and are usually 1% or less. Only in the upper parts of the granite pipes and in some of the pegmatites associated with the meladiorites is K-feldspar present in appreciable quantity. The plot of $100K_2O/(Na_2O + K_2O)$ (fig. 9) is unusual in showing marked K_2O enrichment in the mela-diorites. MgO in the meladiorite ranges from 12 to 15%, roughly three times the normal amount in dioritic rocks. This combination of moderately low SiO_2 and high MgO with, for this suite, relatively high K_2O clearly derives from the presence of appreciable amounts of biotite and actinolite.

Specimens of meladiorite showing junctions with veined diorite were divided into portions and the rocks and minerals analysed (Tables VII and VIII). These analyses show that the composition of the veined diorites gradually approaches that of the meladiorites as the number of actinolite-biotite spots increases, the chemical sequence being an almost linear progression between the veined diorite and the spots. In specimen BB9 Fe and Mg increase towards the meladiorite while Al, Ca, and Si decrease, in keeping with the increase in amphibole at the expense of feldspar. A similar

progression is shown by specimen BB12 in which Fe, Mg, K, and H_2O increase and Si, Al and Na decrease towards the meladiorite.

It is apparent from fig. 8 that the meladiorites are removed from the field of diorite composition towards the combined actinolite and biotite compositions. Of the other igneous rocks, only certain dykes show similar levels of Mg and Al but compared with these the meladiorites have less than a third the Ti and more than three times the amount of K. The progressive changes in composition of the veined diorites towards the meladiorites is a striking feature which requires explanation and, if the meladiorites are to be interpreted as intrusions, it must also be said that their unusual compositions are not easily related to the remainder of this igneous association.

Mineralogy of the Beaucette rocks

Amphibole. The dominant amphibole of this rock suite is a dark green hornblende which occurs in both the veined diorites and the meladiorites. Contrasting with this is the pale green, weakly pleochroic amphibole of the dark spots; analyses of both are given in Table VIII.

The dark green amphibole is magnesio-hornblende as defined by Leake (1968). It contains moderate amounts of Al_2O_3 (6 to 10%) and slightly less than half the A sites are occupied. The distinction between this and the pale green actinolitic hornblende is most clearly made on the basis of the contents of Ti and Al^{IV}. Whereas the darker

hornblendes have Al^{IV} ranging from 0.9 to 1.3 atoms per formula unit (fig. 10), the actinolitic hornblendes contain around 0.5. Ti is never high but is markedly and systematically lower in the actinolitic hornblendes than in the magnesio-hornblendes (fig. 10).

The field and petrographic evidence that the actinolitic hornblende is secondary is in keeping with its composition for, despite the low Si content of the rocks, the Si in the amphibole is high. Nockolds and Mitchell (1948) were among the first to suggest a correlation between amphibole composition and rock type, noting that amphiboles with high Si and hence low Al^{IV} were commonly secondary. The Al^{IV} content of amphiboles is probably controlled by several factors including temperature, pressure and perhaps oxygen fugacity as well as environmental composition. The relative importance of these factors is uncertain but it is probable that, for a given rock composition and pressure, high temperatures would favour the substitution of Al for Si and it therefore seems likely that the spots grew both later and at a lower temperature than the magnesio-hornblende. Leake (1971) has presented data which indicate that low temperatures and high pressures favour high contents of Al^{VI}. The proportion of Al^{VI} is much the same in both kinds of amphibole, in agreement with the reasonable deduction that the different amphiboles grew at similar pressures and the differences in temperature of final equilibration were probably small. Leake (1971) also suggests that amphiboles from igneous rocks normally
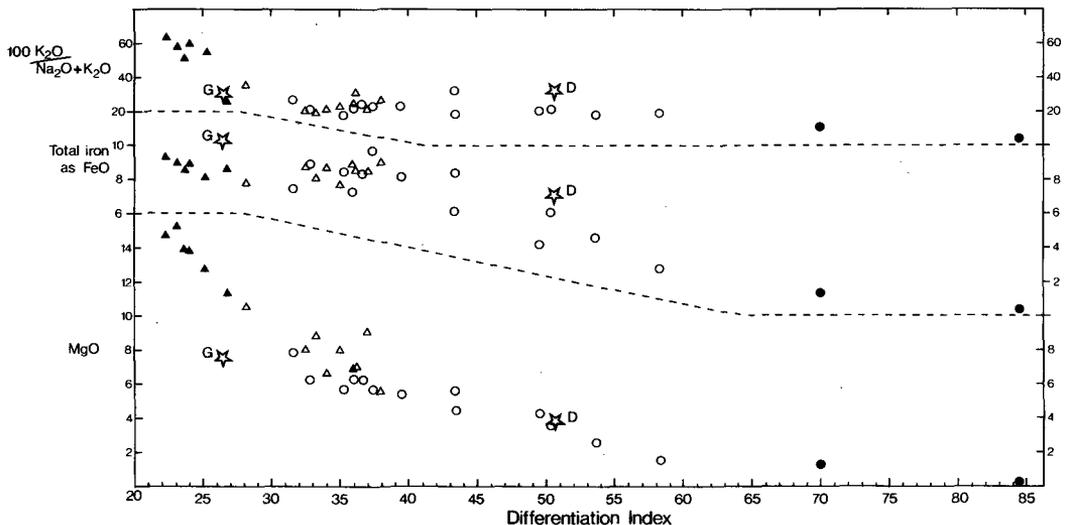
FIG. 9. Thornton–Tuttle differentiation index *vs.* selected oxides and oxide ratios for rocks from Beaucette, NE Guernsey. Symbols as in fig. 8.
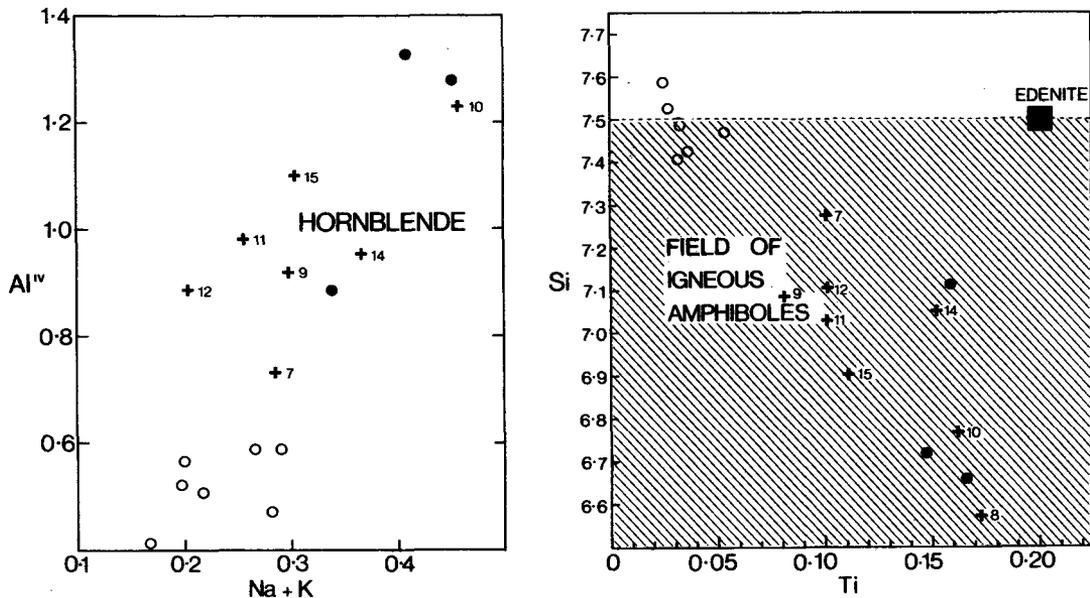
FIG. 10. Si vs. Ti and Al^{IV} vs. Na + K (atoms) for amphiboles from the northern igneous complex, Guernsey. Open circles: actinolitic hornblende, solid circles: magnesio-hornblende, both from Beaucette, amphiboles from elsewhere in N. Guernsey are shown by crosses: numbers refer to analyses in Table II. Field of igneous amphiboles after Leake (1971).

contain less than 7.5 atoms of silicon per half unit cell. For the actinolitic hornblendes the Si content ranges from 7.4 to 7.6 atoms and clearly straddles the boundary between igneous and metamorphic compositions (fig. 10). A limit can also be placed on the composition of igneous amphiboles in a plot of Si against (Ca + Na + K) (Leake 1971) and again the Beaucette actinolitic hornblendes fall close to the boundary, while the magnesio-hornblendes lie within the igneous field. If the amount of Ti in amphiboles is temperature-dependent (Ernst, 1968), then the fact that the magnesio-hornblende contains five times as much Ti as the actinolitic hornblende occurring in the same rocks is a further indication that the latter formed at a relatively low temperature. Spear (1976), in an experimental study of the effects of temperature, fluid pressure, and oxygen fugacity on the composition of the Ca-amphiboles in basaltic systems, has shown that, for a given oxygen fugacity, Al, Ti, and Na rise, and Si falls with increasing temperature. Assuming for the Guernsey diorites moderate oxygen fugacities near the QFM buffer, the Si, Al, and Ti contents of the actinolitic hornblendes when compared with Spear's results, indicate temperatures of equilibration of around 550 to 600°C. The evidence from the compositions of the amphiboles thus seems to be consistent with growth of the actinolitic hornblende under sub-

solidus conditions close to the boundary between igneous and metamorphic states at high water pressures. The meladiorites cannot have been fluid when the actinolitic hornblendes formed for the spots are stress-orientated, but the magnesio-hornblendes are not aligned and exhibit more normal magmatic textures.

Exsolution textures in amphibole. Exsolution textures (fig. 11) have been observed in many of the grains of actinolitic hornblende in the spots of beaucette. The lamellae are about 2µm wide and attempts to determine their composition with the electron microprobe were unsuccessful because of their small size. Single-crystal X-ray diffraction patterns obtained by J. E. Chisholm (pers. comm., 1978) indicate that the exsolved phase is possibly a magnesian amphibole such as cummingtonite but the small size of the lamellae made precise identification difficult. The lamellae are orientated parallel to {$\bar{1}01$} of the host amphibole and seem to be absent from those actinolitic hornblendes containing small blebs of quartz but the reason for this is obscure. The exsolution textures are like those described and figured by Ross et al. (1969); all the amphiboles listed by them as showing exsolution lamellae are from metamorphic rocks mainly of low grade. Ross et al. (1968) and Cameron and Papike (1979) suggest that this exsolution is likely to result when the M4 sites are not fully

occupied by Ca and Na atoms, the deficiency being made good with smaller Fe, Mn, and Mg atoms. At high temperatures, the thermally expanded structure can accommodate ions of different radii but, on cooling, the structure becomes unstable and exsolves into two phases one with Ca in $M4$ and the other with Mg, Fe or Mn in $M4$. Analyses of the Guernsey actinolitic hornblendes indicate that $(Ca + Na)$ is close to 2.00 atoms per half unit cell, whereas in the magnesio-hornblendes the total is nearer 2.15 atoms. Further, recalculation of the analyses indicates that the availability of R^{2+} atoms for the $M4$ sites is greater for the actinolitic hornblendes than for the magnesio-hornblendes. Compositionally therefore the actinolitic amphiboles are on the threshold of those compositions which would on cooling give exsolution lamellae, and this agrees well with the observations that the lamellae are thin and not always readily visible. Cameron (1971) has studied the phase relationships along the join $Mg_{3.5}Fe_{3.5}Si_8O_{22}(OH)_2$–$Ca_2Mg_{2.5}Fe_{2.5}Si_8O_{22}(OH)_2$ at 2 kbar PH_2O and has shown that a wide miscibility gap separates actinolite and cummingtonite. The solvus is markedly asymmetric

FIG. 11. Photomicrograph of exsolution lamellae in actinolitic hornblende, BB14, Beaucette, NE Guernsey. Plane polarized light; long dimension of photograph 0.2 mm.

with a maximum at about 700°C and from the phase diagram it would appear likely that the present minerals equilibrated at a temperature of around 600°C or less.

Biotite. The biotite is a pale brown variety which, although not restricted to the meladiorite layers, is nevertheless markedly subordinate to amphibole in the vein diorites. It is much more abundant in the meladiorites and accounts for the relatively high K_2O contents (around 2%) of these rocks compared with those of the vein diorites. Biotite occurs in close association with actinolitic hornblende in the dark spots. Although the spots locally have a preferred orientation, there is no sign that the biotites within them have any corresponding alignment. Prehnite is present here and there along the cleavages but only rarely does it form the bulbous masses so common in diorites (Phillips and Rickwood, 1975). Prehnite replacing biotite along the cleavage is more common in the body of the rock than the spots. Four biotites from the meladiorites have been analysed; three were separated from meladiorites and analysed by wet methods, while the fourth is a microprobe analysis, also of a biotite from a meladiorite layer (Table VIII).

The mica compositions fall within the range of Mg-biotite (Foster, 1960) and are more magnesian than those commonly occurring in diorites or gabbros (Heinrich, 1946; Engel and Engel, 1960); however, the compositions are not so extreme as to lie outside the range of igneous biotites. The biotites contain a greater than usual proportion of trivalent atoms; in part this is due to Fe^{3+} but the microprobe analysis (14), in which total iron is reported as Fe^{2+}, shows also a greater than normal content of trivalent atoms, mainly due to a relatively high content of Al. Ti is uniformly low, but SiO_2 at around 40% is rather high for an igneous biotite. Even so, the amount of Al^{IV}, at slightly more than 2 atoms per formula unit, together with that in the octahedral position, is not markedly different from that of most Mg-biotites. The relatively high Si and low Al^{IV} contents of the biotite are consistent with the distribution of these elements in the actinolitic amphibole and again argue formation at relatively low temperatures (Harry, 1950). The $Fe^{3+}/(Fe^{2+} + Fe^{3+})$ ratio of these biotites is about 0.24, indicating moderate oxygen fugacities under which conditions Mg-biotites are stable over a wide range of temperature and pressure (Eugster, 1956). Accordingly, information derived from the biotite compositions cannot be taken as being indicative of the conditions of formation of the spots. What can be said, however, is that the compositions are consistent with the indications from the amphibole that the spots
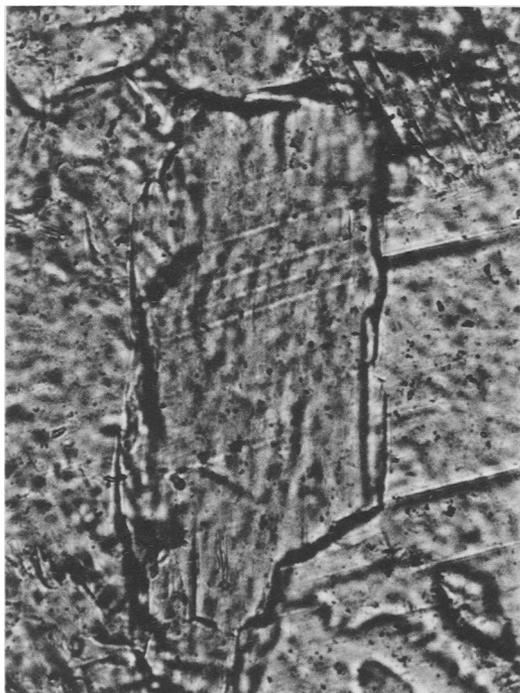
formed below normal magmatic temperatures and at moderate oxygen fugacities.

Analyses are given in Table III of six biotites from the Bordeaux diorite and Chouet granodiorite. All contrast with those from the meladiorite in being poorer in Mg and richer in Fe and are typical of biotites commonly found in diorites and grano-diorites in association with amphiboles (de Albuquerque, 1973). The presence of 'normal' biotites in the diorite–granodiorite complex further emphasizes the unusual chemical composition of the meladiorite layers.

Discussion

Several different mechanisms may have con-tributed to the formation of the meladiorites: they may be interpreted as rafts or screens caught up in the veined diorite and modified by reciprocal reaction; as intrusions into the veined diorites, which have reacted with their host as Elwell *et al.* (1960, 1962) suggested; as layered structures inherited from a previous formation; or as the result of metasomatic recrystallization. Metamorphism alone, or combined with any of these other mechanisms, could also have influenced the present form of the sheets.

The extremely regular geometry of the mela-diorites and of the layers and trains of spots, the restriction of the granitic pipes and pegmatite sheets to the meladiorites, and the way in which the pegmatites merge with the quartz diorite veins in the veined diorites, seem to rule out an origin for the meladiorites as screens, rafts or inclusions. The way in which the meladiorites fade and reappear along plane surfaces is equally difficult to reconcile with such an origin.

Elwell *et al.* (1960, 1962) envisaged intrusions of hot ultrabasic magma remelting the surrounding veined diorite so as to produce an acid fraction which rose diapirically into the meladiorite magma as pipes. The inclination of these pipes was ex-plained as resulting from laminar flow within the meladiorite magma. This interpretation is difficult to reconcile with the way in which the meladiorites pass vertically and laterally into lines of amphi-bole–mica spots formed of identical minerals to those in the meladiorites, and the fact that chemically, mineralogically and texturally these rocks are metamorphic rather than igneous.

Even if allowance is made for the effects of later metamorphism, it is hard to see why intrusions should have such gradational margins, be lensoid and without obvious cross connections, and why the supposedly remelted material forming the rods and pegmatite veins is potassic when the veined diorites from which they arise are so deficient in

this element throughout the pluton. Reaction between the presumed meladiorite intrusions and the veined diorites might tend to obscure any original intrusion contacts, but it is difficult to account for the preservation of veined diorites between the meladiorites and for the ghosts of the veins within them.

The diorites of N. Guernsey, like so many other dioritic complexes, contain amphiboles which are dominantly either equant or elongate, giving dioritic and appinitic textures respectively. Some-times these two textural types are interlayered, sometimes not, but in both disposition and relative proportions they match the textures of the St. Peter Port gabbro. Like the diorite, the gabbro is also markedly altered, and shows widespread develop-ment of appinite and hornblendite. The scale and direction of layering in the diorites and gabbros are very similar. It is, therefore, at least possible that much of the diorite represents altered and remobilized rocks akin to the layered gabbro. Remobilization of the newly solidified gabbro following the introduction of water seems to have occurred locally and it is possible that the mela-diorites depend at least for their orientation if not their substance on structures inherited from earlier gabbro.

If the meladiorites had formed entirely as a result of Mg–K metasomatism with the formation of abundant new amphibole and mica along parti-cular and parallel structural planes, then it is hard to see why these planes were chosen unless they were inherited in some way from earlier rocks. On the other hand, given such a structural control, a metasomatic explanation readily accounts for the form and distribution of the spots, and the way in which they aggregate to form meladiorite layers. The subsolidus growth of substantial quantities of amphibole and biotite to form meladiorite with a concomitant reduction in feldspar results in an increase in density of the rock and hence a possible reduction in its volume. Reduction in volume of the melanocratic rocks may provide a mechanism and space for the release into them of the material now forming the pipes and pegmatite sheets. The chemical and mineralogical compositions of the meladiorites are in keeping with this model but it is the field evidence that is most convincingly in its favour. The principal difficulties to its acceptance derive from the requirement for an acceptable metasomatic process which includes a source for the metasomatizing materials. Hofmann (1972) compares diffusional and infiltrational meta-somatic processes and lists criteria which allow distinctions to be made between them. The rela-tionships described here are more in keeping with infiltration than with diffusion. The rocks may have

been formed by a one-way process as evidenced by the presence of monomineralic or bimineralic layers with sharp fronts (upper surface) and more gradational rear surfaces, showing a lack of equilibrium across the metasomatic front.

Conclusions

The veined diorites formed at magmatic temperatures either by direct magmatic crystallization of magnesio-hornblende and intermediate plagioclase, or by the growth of these minerals from earlier, possibly gabbroic phases under conditions of temperature and pressure within the range at which dioritic rocks would be magmatic. We cannot distinguish between these two possibilities from the field evidence but experience of dioritic rocks elsewhere leads us to admit recrystallization of pre-existing rocks as a strong possibility. The primary amphibole crystallized at temperatures of 800 °C or more and was followed by the subsolidus growth of actinolitic hornblende and Mg-biotite at moderate oxygen fugacities and at temperatures above the actinolite–cummingtonite solvus, i.e. about 700 to 800 °C. The exsolution lamellae in the actinolitic hornblende in the spots indicate slow cooling at subsolidus temperatures of around 600 °C. The recrystallization of the St. Peter Port gabbro is most simply explained in terms of the formation of diorites and related rocks while the gabbro was still hot. The protracted history of formation of the diorites and the subsequent emplacement of the Cobo adamellite and l'Ancresse granodiorite would point to the possibility of later intrusions preventing the earlier bodies from cooling rapidly. During such a period of slow cooling between, say, 800 and 600 °C metasomatic processes may have taken place, resulting in the formation of the meladiorite layers, the mafic spots, and the segregation of the associated granitic pipes and pegmatites. Some of the quartz diorite veins in the veined diorite may also have formed at this time, for there is undoubtedly a link between some of the pipes and the quartz diorite veins and between some of the pegmatites and the vein system in the diorites. It is also clear that the system was maintained in a stress field below the solidus for a period sufficient to account for the orienta-

tion of the spots. Potassium must have been an important element in the metasomatic process; it is required for the meladiorites as much as for the granite pipes and pegmatites and the formation of both rocks seems to require the maintenance of a high water-rich gas pressure. Given a hydrous environment, Na, K, and Si mobility, and a temperature in the vicinity of 700 to 800 °C, it would not be surprising to find granitic melt separating as a leucosomatic phase. Possibly, reduction in volume accompanying the increase in density produced by the formation of amphiboles and micas in abundance in the meladiorites may have permitted the segregation of acid fluid and such a cognate relationship for the formation of meladiorites, the pipes, and the acid pegmatites is precisely what is required by the field association. The pegmatites plainly connect with the leucocratic veins and enlarge as they enter the meladiorites as though entering shrinkage cracks. There is much feldspathization around the pipes but none surrounding the veins in the veined diorites, again pointing to the geat mobility of K in the formation of the pipes.

The sheets at Beaucette may be unusual but we believe that metasomatic processes such as those which operated here have occurred elsewhere. In the Caledonian diorites, particularly those of Donegal, it is possible to find widespread evidence of recrystallization and metasomatism which commonly resulted from the influence of later intrusions (French, 1966). Also, in dioritic rocks in both Jersey and Alderney there are to be found occasional spots of actinolitic hornblende, individual crystals of which contain exsolution lamellae of another amphibole. Such occurrences easily go unnoticed, but they could indicate late stage amphibole growth throughout the plutons of the Channel Islands which, in N. Guernsey, was more than usually significant. Adams (1976) refers to anomalous groups of young K–Ar hornblende ages in the range 495 to 515 Ma from the fine-grained diorites in NE Guernsey, N. Herm, and Alderney and speculated that they might reflect the fine-grained nature of the amphiboles and their complex parageneses. We suspect that the late subsolidus growth were have described could be the cause of these anomalously young dates.

[TABLES I–VIII OVERLEAF]

TABLE I   Chemical analyses and CIPW norms of rocks from the St Peter Port Gabbro

	1	2	3	4	5	6	7	8	9	10
SiO_2	40.10	43.14	46.62	44.27	44.47	44.91	45.54	49.79	51.53	52.61
TiO_2	2.89	1.39	1.06	1.13	1.47	1.47	1.96	1.10	0.79	0.17
Al_2O_3	18.45	21.98	13.53	16.18	17.18	10.02	17.23	15.41	17.51	24.12
Fe_2O_3	6.56	4.26	2.64	2.86	5.47	5.57	4.06	2.63	1.67	1.72
FeO	7.53	5.02	6.77	6.99	6.29	7.60	6.43	6.49	4.12	0.77
MnO	0.21	0.16	0.21	0.22	0.25	0.20	0.14	0.20	0.13	0.01
MgO	7.31	5.92	12.23	10.68	7.19	14.12	6.92	7.79	4.66	0.42
CaO	10.26	11.26	9.89	11.02	10.70	10.55	11.10	8.91	9.53	10.08
Na_2O	2.05	1.92	1.56	1.88	2.56	1.65	3.23	3.49	6.06	4.70
K_2O	1.36	1.33	0.84	0.66	0.84	0.60	0.79	1.19	1.16	2.28
H_2O^+	2.87	3.15	4.02	3.34	3.58	3.03	3.09	3.33	3.27	3.35
P_2O_5	0.30	0.35	0.17	0.21	0.28	0.05	0.08	0.13	0.48	0.15
Total:	99.89	99.88	99.54	99.44	100.28	99.77	100.57	100.46	100.91	100.38

CIPW norms

	1	2	3	4	5	6	7	8	9	10
or	8.04	7.86	4.96	3.90	4.96	3.55	4.67	7.03	6.86	13.48
ab	10.23	14.38	13.20	15.65	20.99	13.96	19.46	29.53	31.74	33.49
an	37.13	47.43	27.44	33.77	32.91	18.17	30.19	22.87	17.16	37.99
ne	3.85	1.01	-	0.14	0.36	-	4.26	-	10.58	-
di	9.39	4.89	16.39	15.66	14.65	26.87	19.50	16.51	21.78	2.26
wo	-	-	-	-	-	-	-	-	-	3.40
hy	-	-	16.57	-	-	7.03	-	2.60	-	-
ol	12.69	11.52	10.72	20.21	11.45	16.18	9.61	12.37	4.49	-
mt	9.51	6.18	3.83	4.15	7.93	8.08	5.89	3.81	2.42	2.02
hm	-	-	-	-	-	-	-	-	-	0.33
il	5.49	2.64	2.01	2.15	2.79	2.79	3.72	2.09	1.50	0.32
ap	0.71	0.83	0.40	0.50	0.66	0.12	0.19	0.51	1.13	0.35
DI	22.12	23.25	18.16	19.69	26.32	17.51	28.39	36.56	49.58	50.37

DI = Thornton-Tuttle differentiation index   ANALYST: W. J. FRENCH

1. Gabbro layer with acicular amphiboles, Spur Point
2. Gabbro layer with ophimottled amphiboles, Spur Point
3. Basic dyke in layered gabbro, Richmond Corner
4. Hornblende dyke in layered gabbro, Richmond Corner
5. Basic dyke in layered gabbro, Spur Point
6. Basic dyke in layered gabbro, Kempt Rock
7. Appinitic dyke in layered gabbro, Kempt Rock
8. Diorite, from mergent patch in gabbro, Kempt Rock
9. Appinitic diorite from patch in gabbro, Kempt Rock
10. Leucocratic veins in appinitic diorite, Kempt Rock

TABLE II   EPMA analyses of amphiboles and a pyroxene from the northern igneous complex, Guernsey

	AMPHIBOLES															PYROXENE	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
SiO_2	42.00	42.89	42.91	41.74	41.73	43.32	49.55	43.22	48.75	44.08	46.45	47.84	43.81	48.32	46.22	51.29	SiO_2
TiO_2	4.76	3.34	2.85	2.61	3.72	2.64	0.91	1.45	0.76	1.37	0.88	0.92	2.77	0.85	1.01	0.55	TiO_2
Al_2O_3	12.30	12.21	11.41	12.58	12.62	10.60	5.52	10.96	10.20	8.77	7.59	7.73	11.71	8.04	9.14	2.42	Al_2O_3
FeO	12.65	12.60	12.77	13.21	11.48	14.38	10.95	15.96	13.86	16.87	16.66	15.35	14.97	17.14	17.77	8.64	FeO
MnO	0.15	0.15	0.23	0.17	0.13	0.18	0.14	0.29	0.29	0.46	0.42	0.31	0.28	0.47	0.37	0.26	MnO
MgO	12.61	13.33	12.99	12.12	5.58	15.77	10.13	10.86	10.54	11.36	11.66	11.33	11.89	10.63	14.26		MgO
CaO	11.50	11.64	11.53	11.72	11.57	11.57	11.91	11.85	10.98	11.51	11.63	12.05	10.87	11.14	21.08		CaO
Na_2O	2.16	2.22	1.79	2.12	2.56	1.30	0.83	1.44	1.87	1.13	0.62	0.44	1.82	1.28	0.83	0.39	Na_2O
K_2O	0.77	0.84	0.76	0.80	0.56	0.84	0.27	0.33	0.33	0.60	0.39	0.39	0.45	0.28	0.35	0.00	K_2O
Total:	98.90	99.22	97.24	97.27	97.95	96.48	95.85	95.63	97.90	95.33	96.00	96.69	98.67	99.14	97.46	99.02*	

Number of atoms on the basis of 23 (O, OH, F, Cl) for amphiboles; 6 oxygens for pyroxene

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
Si	6.14	6.24	6.36	6.22	6.13	6.51	7.27	6.58	7.08	6.77	7.02	7.11	6.42	7.05	6.90	1.929	Si^{iv}
Al^{iv}	1.86	1.76	1.64	1.78	1.87	1.49	0.73	1.42	0.92	1.23	0.98	0.89	1.58	0.95	1.10	0.071	Al^{iv}
Σ	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	2.00	
Al^{vi}	0.26	0.33	0.36	0.43	0.32	0.39	0.22	0.55	0.82	0.36	0.37	0.46	0.45	0.43	0.51	0.036	Al^{vi}
Ti	0.52	0.37	0.32	0.31	0.41	0.30	0.10	0.17	0.08	++0.16	0.10	0.10	0.31	0.09	0.11	0.272	Fe
Mg	2.75	2.89	2.87	2.69	2.97	2.61	3.45	2.30	2.35	2.41	2.56	2.58	2.48	2.59	2.36	0.008	Mn
$Fe^{*\prime}$	1.47	1.41	1.45	1.57	1.30	1.70	1.23	1.98	1.68	2.07	1.97	1.86	1.76	1.89	2.02	0.800	Mg
																0.850	Ca
Σ	5.00	5.00	5.00	5.00	5.00	5.00	4.97	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	0.029	Na
Fe^{2+}	0.08	0.12	0.13	0.08	0.11	0.11	0.11	0.05	---	0.10	0.13	0.05	0.08	0.20	0.20	0.004	Cr
Mn	0.02	0.02	0.03	0.02	0.02	0.02	0.04	--	--	0.06	0.05	0.04	0.03	0.06	0.05		
Ca	1.80	1.81	1.83	1.87	1.82	1.86	1.87	1.91	1.71	1.84	1.91	1.91	1.86	1.70	1.75	2.07	
Na	0.10	0.05	0.01	0.03	0.05	0.01	0.00	0.00	0.29	0.00	0.00	0.00	0.03	0.04	--		
Σ	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00		
Na	0.51	0.58	0.51	0.58	0.68	0.37	0.24	0.43	0.24	0.34	0.13	0.13	0.49	0.32	0.24		
K	0.14	0.16	0.14	0.15	0.11	0.16	0.05	0.06	0.06	0.12	0.08	0.08	0.08	0.09	0.05		
Ca	--	--	--	--	--	--	--	0.03	--	0.05	0.06	0.01	--	--	0.03		
Σ	0.65	0.74	0.65	0.73	0.79	0.53	0.29	0.52	0.30	0.51	0.32	0.22	0.58	0.37	0.34		
Mg/(Mg+Fe)	0.64	0.65	0.64	0.62	0.68	0.59	0.72	0.53	0.58	0.53	0.55	0.57	0.57	0.55	0.52		

En 41.63
Wo 44.23
Fs 14.15

FeO^* = Total iron as FeO
+ includes 0.13% Cr_2O_3
++ includes 0.04 atoms MnO

ANALYST: J. WESTCOTT

1. Kaersutite, core of amphibole in 'acicular' gabbro.
2. Ferroan pargasite, rim of amphibole in 'acicular' gabbro.
3. Pargasitic hornblende, core of amphibole in 'poikilitic' gabbro.
4. Ferroan pargasite, 'diorite' patch in gabbro.
5. Core of brown ferroan pargasite, pegmatitic pocket in gabbro.
6. Green-brown edenitic hornblende, pegmatitic pocket in gabbro.
7. Actinolitic hornblende, rim of green amphibole in pegmatitic pocket in gabbro.
8. Magnesio-hornblende, core of green-brown amphibole, in older homogeneous diorite.
9. Magnesio-hornblende, rim of amphibole 8.
10. Brown-green magnesio-hornblende, homogeneous diorite.
11. Green-brown magnesio-hornblende, acicular diorite.
12. Magnesio-hornblende, rim of amphibole in appinitic pocket in diorite.
13. Ferroan pargasitic hornblende, core of amphibole 12.
14. Green magnesio-hornblende, Chouet granodiorite.
15. Green magnesio-hornblende, Chouet granodiorite.
16. Clinopyroxene, ophitic gabbro.

TABLE III   EPMA analyses of biotites from the northern igneous complex, Guernsey

	1	2	3	4	5	6
SiO_2	35.85	36.45	34.66	37.48	37.17	36.63
TiO_2	3.72	3.82	4.06	3.88	4.50	4.48
Al_2O_3	14.35	15.10	14.05	14.52	15.21	14.99
$FeO*$	18.00	18.54	20.63	21.29	20.60	19.85
MnO	0.23	0.14	0.28	0.26	0.22	0.24
MgO	11.46	11.58	10.81	10.46	10.96	10.62
CaO	0.12	0.00	0.20	0.00	0.09	0.11
Na_2O	0.00	0.00	0.00	0.00	0.00	0.00
K_2O	9.59	9.17	8.69	9.89	9.38	9.16
Total:	93.32	94.80	93.38	97.78	98.13	96.08

Numbers of atoms on the basis of 22 (O, OH, F, Cl)

	1	2	3	4	5	6
Si	5.59	5.57	5.46	5.63	5.53	5.55
Al^{iv}	2.41	2.43	2.54	2.37	2.47	2.45
Σ	8.00	8.00	8.00	8.00	8.00	8.00
Al^{vi}	0.22	0.28	0.07	0.21	0.20	0.23
Ti	0.44	0.44	0.48	0.44	0.50	0.52
Fe	2.34	2.37	2.72	2.68	2.56	2.52
Mn	0.03	0.02	0.04	0.03	0.03	0.03
Mg	2.66	2.63	2.54	2.34	2.43	2.40
Σ	5.69	5.74	5.85	5.70	5.72	5.70
Ca	0.02	0.00	0.03	0.00	0.01	0.02
Na	0.00	0.00	0.00	0.00	0.00	0.00
K	1.91	1.79	1.75	1.90	1.78	1.77
Σ	1.93	1.79	1.78	1.90	1.79	1.79

$FeO*$ = Total iron as FeO   ANALYST: J. WESTCOTT

The biotites are from the following rocks:

1.   homogeneous diorite   4.   appinitic pocket in acicular diorite
2.   older diorite   5.   coarse-grained Chouet granodiorite
3.   acicular diorite   6.   fine-grained Chouet granodiorite

TABLE IV   Chemical analyses and CIPW norms of rocks from the Bordeaux diorite and
                  Chouet granodiorite, Guernsey

	1	2	3	4	5	6	7	8	9
SiO_2	53.11	49.69	49.82	52.21	57.55	58.07	65.21	70.74	75.00
TiO_2	0.66	1.93	1.23	0.83	0.85	0.63	0.70	0.24	0.09
Al_2O_3	20.56	17.74	20.13	17.04	18.54	18.92	15.76	13.78	13.45
Fe_2O_3	2.94	2.35	2.77	2.57	1.04	2.66	1.77	0.92	0.59
FeO	4.12	6.69	6.17	6.46	5.10	2.98	2.75	1.57	0.36
MnO	0.13	0.17	0.20	0.13	0.14	0.08	0.09	0.08	0.02
MgO	2.90	3.55	4.30	6.05	3.17	3.05	1.76	0.75	0.26
CaO	8.31	6.20	7.24	8.78	6.20	7.07	3.57	2.08	0.24
Na_2O	2.59	3.60	3.82	3.40	3.81	4.27	3.84	4.06	3.69
K_2O	1.53	4.59	1.54	0.96	1.39	1.06	2.09	2.88	4.50
H_2O^+	2.99	3.01	2.02	1.49	1.96	1.18	2.09	2.82	1.50
P_2O_5	0.19	0.22	0.26	-	0.20	-	0.10	0.10	0.03
Total:	100.03	99.74	99.68	99.92	99.95	99.97	99.73	100.02	99.73

CIPW norms

	1	2	3	4	5	6	7	8	9
Q	8.64	-	-	0.28	9.28	9.63	23.70	29.95	35.47
C	-	-	-	-	-	-	-	0.93	0.44	2.15
or	9.04	27.13	9.10	5.67	8.22	6.27	12.35	17.02	26.60
ab	21.91	20.24	32.32	28.77	32.24	36.13	32.49	34.35	31.22
an	39.96	18.69	33.73	28.40	29.39	29.33	17.06	9.67	0.99
ne	-	5.54	-	-	-	-	-	-	-
di	0.02	8.75	0.40	12.32	0.05	4.60	-	-	-
hy	11.52	-	7.74	17.69	15.23	7.78	6.98	3.74	0.71
ol	-	8.81	7.41	-	-	-	-	-	-
mt	4.26	3.41	4.02	3.73	1.51	3.86	2.57	1.33	0.86
il	1.23	3.66	2.34	1.58	1.61	1.20	1.33	0.46	0.17
ap	0.45	0.52	0.61	-	0.47	-	0.24	0.24	0.07
DI	39.59	52.91	41.42	34.72	49.74	52.03	68.54	81.32	93.29

DI = Thornton-Tuttle differentiation index   ANALYST: W. J. FRENCH

1.   Older homogeneous diorite, Fort Doyle.
2.   Bordeaux diorite, l'Ancresse.
3.   Diorite in 'fine-grained' Chouet granodiorite, Mont Cuet quarry.
4.   Typical veined diorite, Beaucette.
5.   "Fine" granodiorite (quartz diorite), Chouet.

6.   Typical vein in veined diorite, Beaucette.
7.   Coarse Chouet granodiorite, Mont Cuet quarry.
8.   L'Ancresse granodiorite.
9.   Cobo adamellite.

TABLE V   Modes of diorites and quartz diorites
                         from Beaucette, Guernsey

			DIORITE			QUARTZ DIORITE		
Quartz	0.8	1.1	1.7	4.9	3.6	9.7	9.6	19.5
Plagioclase	50.4	48.5	49.4	60.2	49.1	48.6	49.4	61.7
Hornblende	45.6	43.6	44.7	30.0	43.7	33.6	33.2	15.4
Biotite	1.5	2.0	2.9	4.0	1.5	6.3	7.0	2.0
Chlorite	0.3	0.2	0.1	0.1	-	1.0	-	-
Opaques	0.8	0.8	0.7	0.4	0.4	0.8	0.7	0.9
Accessories	0.1	0.5	0.1	-	1.8	-	0.1	0.5
Prehnite	0.5	0.7	0.4	0.4	-	-	-	-

TABLE VI   Chemical analyses and CIPW norms of vein diorite
                     and meladiorite, Beaucette, Guernsey

	BB21F	BB21G	BB21B	BB21C	BB21H	BB21E	BB21J	BB21A	BB21D
SiO_2	51.78	52.20	52.22	52.73	53.01	53.34	53.66	54.90	59.80
TiO_2	0.90	0.86	1.11	1.18	0.69	0.81	0.78	1.08	0.60
Al_2O_3	16.36	16.60	17.08	16.38	16.24	16.95	17.22	16.62	19.08
Fe_2O_3	3.18	3.51	2.78	3.70	2.66	1.60	3.06	2.49	1.90
FeO	5.71	5.72	6.53	6.42	6.00	5.90	5.37	6.18	2.95
MnO	0.14	0.13	0.13	0.12	0.10	0.12	0.10	0.10	0.06
MgO	7.03	6.96	5.62	5.69	6.30	6.32	5.40	4.43	2.52
CaO	8.68	8.33	8.31	8.00	8.42	8.86	8.36	7.79	7.06
Na_2O	3.24	3.48	3.56	3.25	3.39	3.46	3.55	3.48	4.21
K_2O	1.47	1.10	1.32	1.00	1.10	1.04	1.08	1.51	0.93
H_2O^+	1.37	1.21	1.40	1.46	1.78	1.68	1.40	1.39	1.05
H_2O^-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total:	99.86	100.10	100.06	99.93	99.69	100.08	99.98	99.97	100.16

CIPW norms

	BB21F	BB21G	BB21B	BB21C	BB21H	BB21E	BB21J	BB21A	BB21D
Q	-	-	-	3.89	1.50	0.52	3.01	4.97	12.51
or	8.69	6.50	7.80	5.91	6.50	6.15	6.38	8.92	5.50
ab	27.41	29.44	30.12	27.50	28.68	29.27	30.04	29.44	35.62
an	25.76	26.43	26.73	27.16	25.85	27.65	27.87	25.27	30.42
di	13.91	11.97	11.79	10.14	12.89	13.23	11.00	10.94	3.72
hy	13.68	17.34	15.32	16.27	17.31	17.72	14.37	13.37	7.44
ol	2.72	0.48	0.76	-	-	-	-	-	-
mt	4.61	5.09	4.03	5.36	3.86	2.32	4.44	3.61	2.75
il	1.71	1.63	2.11	2.24	1.31	1.54	1.48	2.05	1.14
DI	36.10	35.94	37.92	37.30	36.68	35.94	39.43	43.33	53.63

DI = Thornton-Tuttle differentiation index   ANALYST: W. J. FRENCH

TABLE VII   Chemical analyses and CIPW norms of veined diorites and meladiorites from Beaucette, Guernsey

	G695	BB12D	BB9A	BB14B*	BB9B	BB12C	BB14D*	BB9C	BB12B	BB14A*
SiO_2	46.43	46.90	47.20	47.26	48.12	48.32	48.75	49.30	49.98	50.89
TiO_2	0.63	0.63	0.37	0.77	0.36	0.64	0.91	0.35	0.72	0.75
Al_2O_3	13.42	12.51	12.55	15.74	13.20	13.10	16.04	13.51	15.09	14.08
Fe_2O_3	2.38	2.13	2.23	2.68	2.16	1.79	2.84	2.20	1.91	2.67
FeO	6.49	7.02	7.23	5.67	6.92	6.93	6.15	6.21	6.09	6.07
MnO	0.19	0.14	0.19	0.18	0.19	0.13	0.18	0.18	0.13	0.19
MgO	11.32	15.22	14.70	8.86	13.81	13.95	8.05	12.71	10.50	9.15
CaO	11.65	9.43	9.51	10.94	9.71	9.35	10.74	9.80	9.41	9.36
Na_2O	3.42	1.40	1.19	4.43	1.41	1.61	3.61	1.62	2.40	3.68
K_2O	1.20	1.91	2.08	1.08	2.05	1.70	0.95	1.93	1.33	1.03
H_2O^+	2.87	2.44	2.25	2.39	2.10	2.25	1.78	2.06	2.20	2.13
H_2O^-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total:	100.00	99.73	99.50	100.00	100.03	99.77	100.00	99.87	99.76	100.00

CIPW norms

	G695	BB12D	BB9A	BB14B*	BB9B	BB12C	BB14D*	BB9C	BB12B	BB14A*
Q	-	-	-	-	-	-	-	-	-	-
C	-	-	-	-	-	-	-	-	-	-
or	7.09	11.29	12.29	6.38	12.12	10.05	5.61	11.41	7.86	6.09
ab	8.77	11.85	10.07	14.29	11.93	13.62	22.71	13.71	20.31	30.76
an	17.73	22.21	22.76	19.88	23.64	23.50	24.76	23.89	26.48	18.86
ne	10.92	-	-	12.56	-	-	4.25	-	-	0.18
di	32.10	19.61	19.53	27.56	19.63	18.30	22.94	19.76	16.19	22.13
hy	-	0.67	3.79	-	4.20	7.46	-	9.04	11.19	-
ol	15.87	27.38	24.87	11.59	22.59	20.78	12.11	16.15	11.40	14.55
mt	3.45	3.09	3.23	3.89	3.13	2.60	4.12	3.19	2.77	3.87
il	1.20	1.20	0.70	1.46	0.68	1.22	1.73	0.66	1.37	1.42
DI	26.78	23.14	22.36	33.23	24.05	23.67	32.57	25.12	28.17	37.03

	BB14C*	BB17B	BB17A	BB12A	BB17D	BB14E*	BB17E	BB14F*	BB14G*	B*	A*
SiO_2	51.01	51.82	52.01	52.27	52.80	54.67	56.34	58.17	62.60	70.61	72.17
TiO_2	0.75	0.73	0.78	0.74	0.70	0.59	0.66	0.45	0.28	0.16	0.03
Al_2O_3	16.98	17.21	16.17	15.58	17.70	17.34	18.76	17.91	17.95	15.57	17.91
Fe_2O_3	2.33	2.72	2.38	2.33	2.41	2.28	3.42	1.49	1.10	0.58	0.02
FeO	5.51	6.46	6.59	5.41	6.27	4.07	3.02	2.88	1.84	0.89	0.37
MnO	0.17	0.12	0.13	0.12	0.12	0.13	0.09	0.07	0.04	0.02	0.01
MgO	8.08	6.23	6.64	7.84	5.71	5.60	3.59	4.32	2.58	1.24	0.21
CaO	8.88	9.09	9.24	9.46	8.46	8.27	7.08	7.96	6.73	5.36	2.09
Na_2O	3.43	3.26	3.36	2.92	3.40	4.36	4.33	4.26	4.29	4.22	6.39
K_2O	1.01	0.82	0.93	1.09	0.77	0.97	1.19	1.09	0.98	0.51	0.26
H_2O^+	1.85	1.50	1.58	2.21	1.48	1.72	1.36	1.40	1.61	0.84	0.54
H_2O^-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total:	100.00	99.96	99.81	99.97	99.82	100.00	99.84	100.00	100.00	100.00	100.00

CIPW norms

	BB14C*	BB17B	BB17A	BB12A	BB17D	BB14E*	BB17E	BB14F*	BB14G*	B*	A*
Q	-	0.30	-	0.44	1.94	0.80	6.74	6.97	16.08	31.34	28.92
C	-	-	-	-	-	-	-	-	-	-	3.32
or	5.97	4.85	5.50	6.44	4.55	5.73	7.03	6.44	5.79	3.01	1.54
ab	29.02	27.58	28.43	24.71	28.77	36.89	36.64	36.04	36.30	35.70	54.07
an	27.96	29.91	26.30	26.19	30.77	24.88	28.24	26.53	26.83	22.04	10.37
ne	-	-	-	-	-	-	-	-	-	-	-
di	12.93	12.34	15.87	16.65	9.12	12.95	5.46	10.37	5.29	3.64	-
hy	7.93	18.15	15.32	18.54	18.37	12.59	8.15	9.24	5.98	2.28	1.15
ol	9.54	-	1.88	-	-	-	-	-	-	-	-
mt	3.38	3.94	3.45	3.38	3.49	3.31	4.96	2.16	1.59	0.84	0.03
il	1.42	1.39	1.48	1.41	1.33	1.12	1.25	0.85	0.53	0.30	0.06
DI	34.99	32.73	33.93	31.59	35.26	43.42	50.41	49.45	58.17	70.05	84.53

DI = Thornton-Tuttle differentiation index   *silica by difference   ANALYST: W. J. FRENCH

G695	Meladiorite, small quarry N of Beaucette Battery	BB14 G	Quartz diorite vein in vein diorite
BB12 C & D	Meladiorite	BB17 A, B, D	Vein diorite
BB9 A, B, C	Meladiorite, N of Beaucette Battery, same horizon as G695	BB17 E	Quartz diorite vein in vein diorite
BB12 A & B	Vein diorite with amphibole spots	A	Interior of acid rod in meladiorite
BB14 A-D	Vein diorite	B	Outer zone of acid rod in meladiorite
BB14 E & F	Margin of quartz diorite vein in vein diorite		

TABLE VIII   Analyses of amphiboles and micas from Beaucette, Guernsey

	AMPHIBOLES										MICAS			
	PALE GREEN							DARK GREEN						
	1	2	3	4*	5*	6*	7*	8	9*	10*	11	12	13	14*
SiO_2	52.12	53.06	52.11	53.55	52.69	52.09	52.49	48.50	44.68	44.94	40.61	40.40	40.23	38.91
TiO_2	0.29	0.25	0.30	0.22	0.33	0.48	0.31	1.43	1.47	1.31	0.76	0.85	0.96	0.20
Al_2O_3	5.95	5.10	5.52	4.17	5.86	4.69	5.46	6.41	10.23	9.70	16.06	16.55	16.90	16.76
Fe_2O_3	2.43	2.45	2.55	-	-	-	-	5.12	-	-	3.21	3.14	3.73	-
FeO	7.77	7.62	8.01	9.55+	10.13+	9.70+	9.65+	11.00	12.50+	12.22+	9.20	9.28	9.40	15.15+
MnO	0.26	0.26	0.26	0.24	0.27	0.25	0.21	0.35	0.22	0.24	0.10	0.10	0.10	0.00
MgO	16.08	15.91	16.01	17.30	16.52	16.86	15.84	11.82	13.39	13.67	17.15	17.00	16.88	19.68
CaO	11.97	12.34	12.40	12.03	12.03	12.06	12.43	12.03	11.70	11.70	1.46	1.98	2.21	0.20
Na_2O	0.68	0.83	0.84	0.47	0.58	0.60	0.61	0.97	1.00	1.21	0.35	0.38	0.34	0.00
K_2O	0.44	0.30	0.31	0.19	0.22	0.17	0.25	0.36	0.61	0.54	7.53	6.44	6.04	7.26
H_2O^+	1.88	1.92	1.90	-	-	-	-	1.86	-	-	3.68	3.72	3.70	-
H_2O^-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total:	99.87	100.04	100.21	97.72	98.63	96.90	97.25	99.85	95.80	95.53	100.11	99.84	100.49	98.16

Numbers of atoms on the basis of 24(O,OH,F,Cl)   (23(O,OH,F,Cl) for EPMA analyses of amphiboles; 22(O,OH,F,Cl) for EPMA analyses of micas

	1	2	3	4*	5*	6*	7*	8	9*	10*	11	12	13	14*
Si	7.42	7.53	7.41	7.59	7.43	7.48	7.50	7.11	6.67	6.72	5.85	5.80	5.75	5.54
Al^{iv}	0.58	0.47	0.59	0.41	0.57	0.52	0.50	0.89	1.33	1.28	2.15	2.20	2.25	2.46
Σ	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
Al^{vi}	0.41	0.38	0.34	0.29	0.40	0.27	0.42	0.22	0.47	0.43	0.57	0.61	0.59	0.35
Ti	0.03	0.03	0.03	0.02	0.04	0.05	0.03	0.16	0.17	0.15	0.08	0.09	0.10	0.02
Fe^{3+}	0.26	0.26	0.27	-	-	-	-	0.57	-	-	0.35	0.34	0.40	-
Mg	3.41	3.36	3.39	3.66	3.47	3.61	3.37	2.58	2.98	3.05	3.68	3.64	3.59	4.17
Fe^{2+}	0.89	0.90	0.95	1.03	1.09	1.07	1.15	1.35	1.38	1.37	1.11	1.12	1.12	1.80
Mn	-	0.03	0.01	-	-	-	0.03	0.04	-	-	0.01	0.01	0.01	-
Σ	5.00	4.96	4.99	5.00	5.00	5.00	5.00	4.92	5.00	5.00	5.80	5.81	5.81	6.34
Fe^{2+}	0.04	-	-	0.10	0.10	0.09	-	-	0.18	0.16				
Mn	0.03	-	0.02	0.03	0.03	0.03	-	-	0.03	0.03	Ca 0.23	0.31	0.34	0.03
Ca	1.83	1.88	1.89	1.83	1.82	1.86	1.90	1.89	1.87	1.88	Na 0.10	0.11	0.09	-
Na	0.10	0.12	0.09	0.04	0.05	0.02	0.10	0.11	-	-	K 1.38	1.18	1.10	1.32
Σ	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.08	2.07	Σ 1.71	1.60	1.53	1.35
Na	0.08	0.10	0.14	0.09	0.11	0.14	0.07	0.17	0.29	0.35				
K	0.08	0.05	0.06	0.03	0.04	0.03	0.05	0.07	0.12	0.10				
Σ	0.16	0.15	0.20	0.12	0.15	0.17	0.12	0.24	0.41	0.45				
$\frac{Mg}{Mg+Fe}$	0.79	0.79	0.78	0.76	0.74	0.76	0.75	0.66	0.66	0.67				

1	Actinolitic hornblende BB9A	6*	Actinolitic hornblende G695
2	Actinolitic hornblende BB9B	7*	Actinolitic hornblende G695
3	Actinolitic hornblende BB9C	8	Magnesio-hornblende BB21D
4*	Actinolite G695	9*	Magnesio-hornblende G695
5*	Actinolitic hornblende G695	10*	Magnesio-hornblende G695

11	Mg-biotite	BB9A
12	Mg-biotite	BB9B
13	Mg-biotite	BB9C
14	Mg-biotite	

* = Electron microprobe analysis   Analyses: 1, 2, 3, 8, 11, 12, 13 - W. J. FRENCH

+ = Total iron as FeO   Analyses: 4*, 5*, 6*, 7*, 9*, 10*, 14* - R. F. SYMES

REFERENCES

Adams, C. J. D. (1976) *J. Geol. Soc. Lond.* **132,** 233–50.

Bishop, A. C. (1963) *Proc. Geol. Assoc.* **74,** 289–300.

Cameron, E. P., and French, W. J. (1977) *Mineral. Mag.* **41,** 239–51.

Cameron, K. L. (1971) *Carnegie Inst. Washington Yearb.* **70,** 145–53.

Cameron, M., and Papike, J. J. (1979) *Fortschr. Mineral.* **57,** 28–67.

de Albuquerque, C. A. R. (1973) *Geochim. Cosmochim. Acta,* **37,** 1779–802.

Drysdall, A. R. (1957) *The petrology of the plutonic complex of north Guernsey.* Unpubl. Ph.D. thesis, Univ. of Southampton.

Elwell, R. W. D., Skelhorn, R. R., and Drysdall, A. R. (1960) *Geol. Mag.* **97,** 89–105.

———— (1962) *J. Geol.* **70,** 215–26.

Engel, A. E. J., and Engel, C. G. (1960) *Geol. Soc. Am. Bull.* **71,** 1–57.

Ernst, W. G. (1968) *Amphiboles, crystal chemistry, phase relations and occurrence.* Heidelberg, Berlin, New York (Springer-Verlag), 125 pp.

Eugster, H. P. (1956) *Carnegie Inst. Washington Yearb.* **55,** 158–61.

Foster, M. D. (1960) *U.S. Geol Surv. Prof. Pap.* **354B.**

French, W. J. (1966) *Proc. R. Ir. Acad.* **64B,** 303–22.

Harry, W. T. (1950) *Mineral. Mag.* **29,** 142–9.

Heinrich, E. W. (1946) *Am. J. Sci.* **244,** 836–48.

Hietanen, A. (1963) *U.S. Geol. Surv. Prof. Pap.* **344D.**

Hofmann, A. (1972) *Am. J. Sci.* **272,** 69–90.

Leake, B. E. (1968) *Geol. Soc. Am. 98 Spec. Pap.*

——(1971) *Mineral Mag.* **38,** 389–407.

Le Maitre, R. W. (1976) *J. Petrol.* **17,** 589–637.

Nockolds, S. R., and Mitchell, R. L. (1948) *Trans. R. Soc. Edinb.* **61,** 533–75.

Phillips, E. R., and Rickwood, P. C. (1975) *Lithos,* **8,** 275–81.

Roach, R. A. (1967) *Rep. Trans. Soc. Guernes.* **17,** 751–75.

Ross, M., Papike, J. J., and Shaw, K. W. (1969) *Mineral. Soc. Am. Spec. Pap.* **2,** 275–99.

———— and Weiblen, P. W. (1968) *Science* **159,** 1099–102.

Spear, F. S. (1976) *Carnegie Inst. Washington Yearb.* **75,** 775–9.

Streckeisen, A. L. (1967) *Neues Jahrb. Mineral., Abh.* **107,** 144–240.

Thornton, C. P., and Tuttle, O. F. (1960) *Am. J. Sci.* **258,** 664–84.