The albite-dolerites of Guernsey, Channel Islands

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The albite-dolerite dykes of Guernsey form a highly distinctive suite of ENE-WSW trending post-Cadomian basic intrusions, emplaced very late in the geological evolution of the island and possibly of Upper Palaeozoic age. The mineralogy and bulk-rock chemistry of the albite-dolerites indicate an alkaline olivine basalt affinity, which separates them clearly from earlier basic dykes associated with the Cadomian orogeny. The albite-dolerites have been subjected to a very low-grade metamorphism which has resulted in the formation of marked textural variations. The dykes are thought to have beer, emplaced during a period of minor extension in the cratonised crust of the Armorican Massif, perhaps related to the early phases of the Hercynian earth movements.

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Introduction

Guernsey comprises two major geological units: the Southern Metamorphic Complex (S.M.C.) and the Northern Igneous Complex (N.I.C.) (Drysdall 1957; Roach 1957, 1966). Both are cut by minor intrusions of acidic, intermediate, and basic compositions. While the earliest intrusive sheets can be shown to predate the tectono-metamorphic episode producing the Icart Gneiss (dated at c.2000Ma), by far the majority of them are related to the late Precambrian-earliest Palaeozoic Cadomian orogenic cycle (Roach 1977). These minor intrusions are abundant in the S.M.C. and in the oldest member of the N.I.C. (the St Peter Port Gabbro), but are much less frequent in the other members of the N.I.C. Two suites of minor intrusions, however, clearly post-date events associated with the Cadomian. The earlier of these is a distinctive suite of albite-dolerites, which, at one locality is cut by a lamprophyre dyke belonging to a suite of minettes and kersantites associated with the Hercynian cycle (see below).

This paper outlines the field relationships, petrography, and both whole-rock and mineral chemistry of the albite-dolerites. They are shown to be of alkaline olivine basalt composition with a primary mineralogy partly replaced by a low temperature metamorphic assemblage, the nature of which is briefly considered.

Previous work and field relationships

These dykes were first mentioned by Hill and Bonney (1884), who described in them pink feldspathic patches, up to 1.5cm across, which often contained grey vitreous material thought to be quartz. Roach (1957) described the petrography of the dykes and named them the albite-dolerites. He subsequently, in Roach (1966), renamed them the Perelle-type albite-dolerites after their occurrence on the foreshore reefs in Perelle Bay on the west coast of the island.

The distribution of these dykes is shown in Fig. 1, where it can be seen that the number of intrusions forming the suite is not very large, some 19 dykes, assuming that all the occurrences are separate intrusions. The locations of these individual intrusions are given in Table 1.

Most of the intrusions are confined to the S.M.C. (cf. Roach 1957, 1966 for definition). However, the dyke in Fermain Bay cuts across diorite sheets considered to be related to the St Peter Port Gabbro (the Havelet-type diorite sheets of Roach 1966). Recently, an albite-dolerite dyke has been found cutting the St Peter Port Gabbro at Le Banc Imbert, St Sampson. No dykes of this type are known to cut the later members of the N.I.C., i.e. the Bordeaux Diorites or the L'Ancresse or Cobo Granites. However, in the S.M.C., the albite-dolerites cut hornblende microdiorite dykes which Roach *et al.* (in press) have equated with similar intermediate sheets cutting the Bordeaux Diorites of the N.I.C.

The albite-dolerites are generally found as thin, steeply dipping sheets up to 4m thick which trend in an ENE-WSW direction, cutting across all pre-existing structures, including the numerous metadolerite intrusions of the Vazon dyke swarm described by Lees and Roach (1987). They often exhibit columnar jointing and spheroidal weathering. Some minor pinch-and-swell structures may be observed along strike. These rocks are highly distinctive in the field because of the presence of whitish or pinkish feldspathic patches. Individual dykes are usually porphyritic, but can be aphyric. Well developed chilled margins are usually present. Occasionally, a crude banding orientated approximately parallel to the contacts is seen, e.g. the more southerly dyke at Mont Chinchon slip, Perelle Bay.

The albite-dolerites are traceable for up to 2km along strike on the reef platforms of the west coast of Guernsey, where they may be seen to have been little affected by any subsequent faulting (cf. Lees and Roach 1987, Figs. 2a and 2c). On a broader scale, the dykes appear to occupy three or four narrow belts across the island (Fig. 1), possibly reflecting zones of more well developed jointing in the heterogenous basement formations.

The albite-dolerite dykes were emplaced very late in the geological evolution of Guernsey (cf. Lees and Roach 1987, Table 1), after all deformation and metamorphism associated with the Cadomian orogeny had ceased. They are, however, cut by mica-lamprophyre dykes which are generally assumed to be of Hercynian age (a K/Ar biotite mineral date of 296±8 Ma was obtained by Adams (1967, 1976) from a ?minette dyke at Petit

Table 1. Locations of the albite-dolerite dykes on Guernsey.

|	Grid Reference	Locality
(1)	24107510- 24207515	S of Pleinmont Watch Tower, Torteval
(2)	23637569- 23707575	Pleinmont Point, Torteval
(3)	24087613 - 24387633	Les Pezeries, Torteval
(4)	25057645 - 25157650	Fort Grey, Rocquaine Bay
(5)	24757815- 25107830	L'Eree
(6)	24437830- 24757845	Fort Saumarez
(7)	24257850- 25507905	Lihou Island to La Rocque
(8)	26107888- 26337895	Mont Chinchon Slip, Perelle Bay, lst dyke
(9)	26157883- 26237885	Mont Chinchon Slip, Perelle Bay, 2nd dyke
(10)	26557918- 26757925	Fort Richmond, Perelle Bay
(11)	26437975 - 26837983	Gros Point, reefs off Fort Richmond, Perelle Bay
(12)	27237958 - 27537963	Fort Le Croq, west Vazon Bay
(13)	27787963- 28087973	Reefs in middle of Vazon Bay
(14)	35758175- 35908180	Banc Imbert, Vale Castle, St Sampson
(15)	34457827 - 34507829	Castle Cornet, St Peter Port
(16)	33757595 - 33807600	S side of Fermain Bay, SE Guernsey
(17)	33257493 - 33337495	E side of Jerboug Peninsula, Divette
(18)	33507596 - 33527500	Petit Port, Moulin Huet Bay
(19)	31527450- 31637460	W side of Icart Point, St Martin
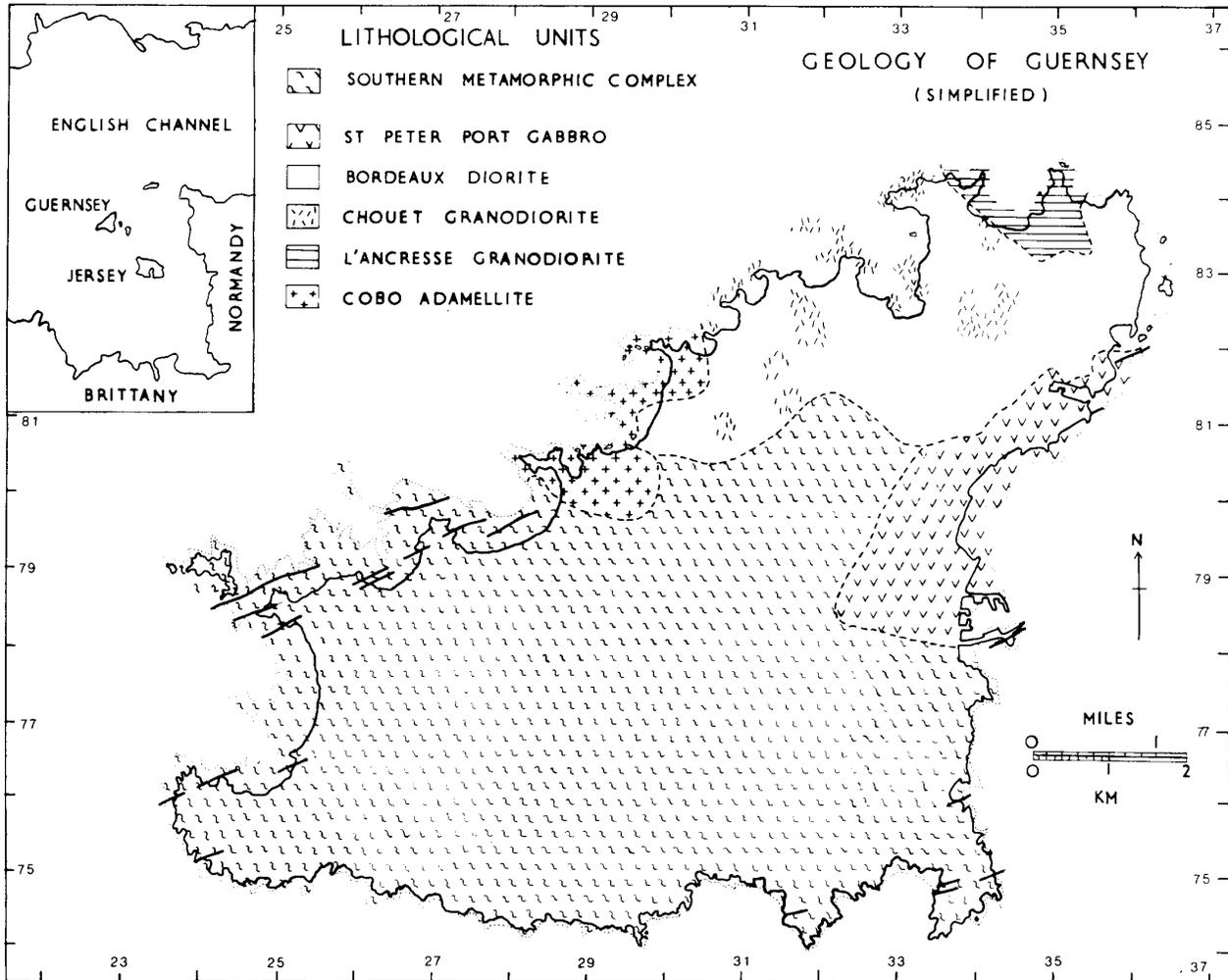
Figure 1. Simplified geological map of Guernsey showing the locations and trends of the albite-dolerite dykes (solid black lines).

Port, St Martin). Current views on the time span occupied by the Cadomian in the Channel Islands region would favour an age of c.450-400Ma for its end, based on isochron ages obtained on post-orogenic granites in both Guernsey and Jersey (Bland 1985; Roach *et al.* 1986; Strachan *et al.* in press). Such upper and lower constraints would thus indicate the Upper Palaeozoic as the most likely period for intrusion.

Analytical methods

Bulk rock chemical analyses were performed by XRFS using an ARL 8420 automatic sequential spectrometer at Keele. REE were determined using ICP-AE at RHBNC, London, by Dr J.N. Walsh, and low level incompatible elements by INAA methods at URR Risley by Dr G.R. Gilmore. Mineral analyses were obtained using a Cameca (Camebax) microprobe at the University of Manchester, Department of Geology. Operating conditions were 15kv, 10^{-8} A, with a spot size of c.3μm, except for hydrous phases when the beam was defocussed. Calibration is against metals, oxides and silicates. An estimate of the accuracy of this technique is reported by Dunham and Wilkinson (1978). Full listings of analyses are available on request from the first author.

Mineralogy

Primary mineralogy

The primary mineralogy of the albite-dolerites was essentially clinopyroxene and plagioclase, with minor olivine.

Clinopyroxene and plagioclase both form phenocryst phases. Following petrographic analysis, two samples, one from the dyke at L'Eree and the other from that at Castle Cornet, which exhibit a whole variety of primary and secondary phenomena, were chosen for detailed study.

The textures of the albite-dolerites are varied. However, the clinopyroxene is always pristine while the plagioclase feldspar is usually rather turbid and on occasions quite altered. Three types of texture have been observed in the dykes. The commonest textural type is that where pale brown plates of clinopyroxene ophitically enclose euhedral plagioclase, with individual ophitic plates up to 0.5mm in diameter; some of the crystals show optical zoning. The clinopyroxene has clearly crystallised after the plagioclase. In contrast to this first fabric type, clinopyroxene may take the form of discrete pale brown euhedral crystals exhibiting oscillatory zoning, which may have grown simultaneously with plagioclase. In the third type of doleritic texture, both clinopyroxenes and plagioclase feldspars, the former often being continuously zoned with distinct rims, are found as phenocrysts and as groundmass minerals.

Low-temperature mineral assemblages

No deformational fabrics have been observed in the albite-dolerites and, as described in the previous section, the igneous texture is largely retained. Superimposed upon this igneous fabric is a low-temperature assemblage of "metamorphic"
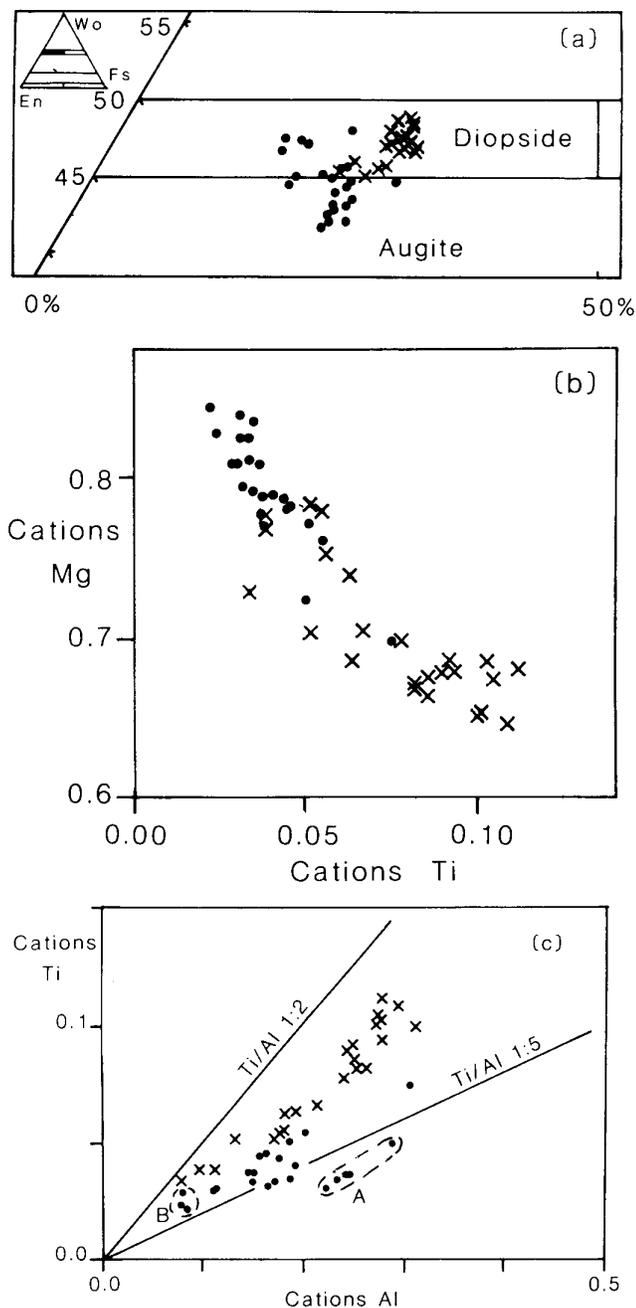
Figure 2. Compositional variation of clinopyroxenes in the albitedolerites. (a) Part of the pyroxene trapezohedron showing the range of compositions; (b) binary plot of Mg and Ti showing strong correlation; (c) binary plot of Ti and Al showing variation of minor components. Dots represent the compositions obtained on a sample taken from the dyke at Castle Cornet, while the crosses are from the dyke at L'Eree.

minerals, which is the cause of the highly distinctive appearance of these rocks in the field. These minerals are chlorite, albite, epidote, prehnite and pumpellyite. No amphibole is found in these rocks.

In thin section, it is possible to observe and locate where the new assemblages nucleate. New low-temperature minerals can occasionally be found as pseudomorphous replacements of the original minerals, the best examples of which are the chlorite replacement of olivine and the prehnite replacement of plagioclase feldspar. The secondary phases are multigranular with a random orientation within the original crystals. The distribution of fully prehnitised plagioclase appears to be

random, with individual completely altered crystals surrounded by other plagioclases in which little or no prehnite has developed. There is no epitaxial growth of one phase over another, e.g. actinolite on pyroxene (Bevins and Rowbotham 1983; Rowbotham 1985), as the temperatures of alteration do not appear to have been sufficiently high to stabilise the growth of actinolite.

The site of nucleation of neoblasts is not random as some of the secondary silicates always seem to develop within or upon the same primary phases. Prehnite, pumpellyite and epidote are all formed within feldspars, sometimes individually, occasionally two of the three, and rarely all three in the same plagioclase crystal. Where the alteration is more severe, neoblastic growth also takes place at grain boundaries, along cleavages and fractures. In the interstitial sites between the plagioclase feldspars and clinopyroxenes, chlorite often develops with a radiating habit and across these crystals prehnite, pumpellyite and/or epidote grow. Texturally these multiphase sites appear to reflect alteration of interstitial finer-grained material which may originally have been mesostasis or even glass.

Some of the albite-dolerites have vesicles present which have been filled with secondary silicates; indeed the fluids passing through these rocks may have gained access by infiltration along cracks, joints or vesicles. The mineralogy within the vesicles often exhibits the presence of sequential growth of low temperature minerals - chlorite, prehnite, pumpellyite, epidote and newly developed pure albite. The pumpellyite is highly pleochroic within these vesicles which may be indicative of a high iron content. The optics of these pumpellyites are similar to those from Builth Wells cited in Bevins and Rowbotham (1983) where the A1 was replaced by Fe up to a maximum of 50%.

Some dykes (e.g. Mont Chinchon slip) have a particular development of alteration, where the rock is full of irregular white patches up to 1cm in diameter. These patches are areas of the most intense alteration where the igneous fabric has been replaced by a fine-grained mat of calcium aluminium silicates.

Mineral chemistry

Compositional trends in clinopyroxenes

The clinopyroxenes in the albite-dolerites are dominantly of diopside and augite composition, following the classification of Morimoto (1988) (Fig. 2a). These analyses, which include both phenocryst and groundmass clinopyroxenes, are typical of those developed in alkali basalt sills and dykes (Wilkinson 1956; Henderson and Gibb 1987). Substitution between the main quadrilateral components (Ca^{+2}-Mg^{+2}-Fe^{+2}) are limited in extent; Ca^{+2} varies between 0.8 and 0.9 cations per formula unit; Fe^{+2} between 0.16 and 0.32 cations per formula unit; and Mg^{+2} between 0.64 and 0.85 cations per formula unit. With the exception of these quadrilateral components, Al^{+3} and Ti^{+4} are the most important of the minor elements present in the clinopyroxenes. The entry of Ti^{+4} into the pyroxene structures is thought to be facilitated by the presence of Al^{+3}. Tracy and Robinson (1977) have suggested that a coupled substitution involving Ti^{+4} may be of the type:

$$Fe^{+2} + Ti^{+4} + 2Al^{+3} = 2Mg^{+2} + 2Si^{+4}$$
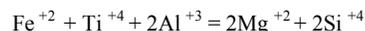
and this has been supported both by experiment (Sack and Carmichael 1984) and variation in mineral chemistry of clinopyroxenes from alkaline dolerite intrusions such as the Lugar Sill (Henderson and Gibb 1987). The clinopyroxenes from the albite-dolerites show that there is a strong negative correlation between Mg^{+2} and Ti^{+4} (Fig. 2b; Table 2) and provide additional support for the above coupled substitution. Therefore as the clinopyroxene becomes more Fe^{+2} rich the proportion of $CaTiAl^2O^6$ molecule increases.

If this were the sole coupled substitution involving Al^{+3} in the clinopyroxene structure the ratio Ti^{+4}:Al^{+3} would be 1:2, whereas it varies between 1:2 and 1:6 (Fig. 2c). This lower ratio

Table 2. Average composition of the mineral components in the albite-dolerites.

	Clino-pyroxene	Plagio-clase	Prehnite	Pump-ellyite	Chlorite
No. of Points	47	15	11	9	21
SiO_2	50.92	67.82	44.01	34.46	30.16
Al_2O_3	2.20	20.23	22.12	25.03	19.04
TiO_2	1.36		0.15		
Fe_2O_3					
FeO	9.05	0.28	2.10	4.23	23.83
Cr_2O_3	0.20				
MnO	0.12		0.06	0.25	0.58
MgO	13.67			2.07	17.19
CaO	21.46	0.38	26.27	22.72	0.36
Na_2O	0.31	11.26	0.10		
K20			0.05		
Total	99.29	99.97	94.86	88.76	91.16
Si	1.92	2.97	6.15	6.01	6.01
Al^{IV}	0.08	1.04			
Al^{VI}	0.02		3.64	4.86	4.48
Fe^{3+}					
Fe^{2+}	0.29	0.02	0.25	0.58	3.97
Cr^{3+}	0.01				
Mn	0		0.01	0	0.01
Mg	0.77			0.51	5.11
Ca	0.87	0.02	3.93	4.01	0.01
Na	0.02	0.96	0.03		
K			0.01		
Recalc'n basis	6(O)	8(O)	22(O)	16(C)	28(O)

(O is Oxygen and C is Cations)

of Ti to Al implies that there is at least a second coupled substitution in which Al^{+3} is involved in the clinopyroxenes, which may be of a type which involves the substitution of Al^{+3} in both octahedral and tetrahedral sites in the clinopyroxene structure. That this substitution may be valid can be demonstrated by the increased amount of Al^{+3} in the structure above that necessary for Ti^{+4} entry into clinopyroxene.

The relationships between the major and minor components of the Guernsey albite-dolerite clinopyroxenes are comparable to those from the Lugar Sill (Henderson and Gibb 1987), but the concentration range in both Al^{+3} and Ti^{+4} is more restricted. The Ti:Al ratio of the Lugar Sill clinopyroxenes is fairly constant (1:4), whereas the Guernsey examples are more variable (i.e. 1:2-1:6). The Ti:Al ratio in the sample from L'Eree is constant at 1:3 (r=0.965) both for between- and within-grain variation. In the Castle Cornet sample, however, this constant ratio is absent. There is a relatively greater variation between discrete crystals (r=0.605), though a tight clustering of composition within individual pyroxene grains (Fig. 2c).

Chemistry of the secondary phases

A detailed study of the mineralogical and chemical features of the extensive alteration of the albite-dolerites will be published elsewhere. Here, only a summary, sufficient to establish the metamorphic grade of the assemblage, will be given. Each of the major alteration phases will be considered in turn.

(1) Chlorite

Chlorite commonly occurs as either a groundmass or olivine pseudomorphous replacement phase, or as vesicle infill material. The majority of the analyses are brunsvigites (Hey 1954) in which there are small amounts of Ca^{+2} and Na^{+1}. The main substitution in these minerals is

$$Mg^{+2} = = Fe^{+2}$$
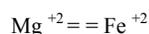
These compositions are typical of prehnite-pumpellyite to greenschist facies metamorphic temperatures (Coombs *et al.* 1976).

Table 3. Correlation matrix for cations in the clinopyroxenes of the albite-dolerites.

Al	Ti	Mg	Fe^{+2}	Ca	
-0.962	-0.908	0.8	-0.19	-0.609	Si
	0.786	-0.707	-0.005	0.599	Al
		-0.917	0.502	0.551	Ti
			-0.594	-0.601	Mg
				-0.125	Fe^{+2}

(2) Feldspar

Although the igneous fabric has been preserved, the chemistry of the majority of the feldspars is now almost pure albite (An_{0-3}) in composition, but occasionally there is the development of potassium feldspar (0.9 atom K^{+1}). Both compositions are interpreted as secondary. Unlike plagioclase feldspar described from metadolerites in Wales (Bevins and Rowbotham 1983), or from hydrothermally altered submarine basalts (Mevel 1981), there is no preservation of unaltered igneous plagioclase compositions.

(3) Prehnite

This phase is ubiquitous in the albite-dolerites and is located in many different sites. Notwithstanding this, there is no apparent difference in chemical composition in the different nucleation sites and the maximum replacement of $Fe^{+3} = = Al^{+3}$ is 0.4 atoms per O_{20} $(OH)_4$, These compositions are more restricted than those quoted by Bevins and Rowbotham (1983) for the Welsh metadolerites.

(4) Pumpellyite

The optical properties of pumpellyite differ according to nucleation site. They are colourless to pale green when formed in feldspars and are aluminous pumpellyites (Table 3) with a restricted $Fe^{+3} = = Al^{+3}$ replacement, the maximum Fe^{+3} being 1.3 atoms per formula unit per 16 cations. Unfortunately, the highly pleochroic pumpellyite has yet to be analysed. It has been suggested that the substitution of Fe^{+3} for Al^{+3} is dependent on metamorphic grade or temperature (Coombs *et al.* 1976) and that aluminous pumpellyites are indicative of higher grade than the ferriferous varieties. This suggestion, however, has been challenged by Offler *et al.* (1981) and Bevins and Rowbotham (1983), who concluded that factors such as intensity of alteration or fluid chemistry may also influence the composition of pumpellyite. The presence of optically and chemically quite distinct pumpellyite compositions in the various alteration sites supports the contention that the controls on pumpellyite composition are complex and not merely due to either variation in metamorphic grade (Kawachi 1975) or bulk rock chemistry (Oliver and Leggett 1981).

Bulk rock chemical composition

The composition of the clinopyroxenes in basaltic rocks has often been considered a reliable indicator of the chemical affinity of the basic rocks in which they are found. Those occurring in the albite-dolerites show these rocks to belong to the alkaline olivine basalt series. Such a diagnosis is confirmed by the bulk rock chemistry of the suite.

Table 4 gives the chemical composition of members of the albite-dolerite suite, from which it can be seen that rocks are thoroughly basaltic in their chemical character, SiO_2 ranging between 44.1% and 52.0%. The total iron (Fe_2O_3) and MgO contents indicate that the rocks are basic, but the relatively low MgO contents point to their having formed from a well-evolved magma. Enhanced contents of K_2O (0.22 - 3.37) and P_2O_5 (0.22 - 0.98) are also noticeable, though TiO_2 only ranges between 1.54% and 3.59%. All these features are typical of mildly alkaline rocks of basaltic composition.

Further chemical characterisation using major elements is made uncertain by the extensive post-emplacement alteration which these rocks have undergone, as outlined above. However, certain lines of evidence indicate that there has been little or no metasomatic addition or loss of the usually highly mobile LIL (large ion lithophile) elements to the dykes. These are:

Table 4. Average major and trace element chemical composition and ranges for the albite-dolerites. Based on 16 samples for the major elements and 11 for the traces.

	Mean	Std Devn	Min.	Max.
SiO_2	46.54	2.10	44.06	51.95
TiO_2	1.54	0.56	1.54	3.59
Al_2O_3	16.01	0.78	15.01	17.58
Fe_2O_3	2.97	0.81	1.58	4.13
FeO	7.03	1.59	4.29	9.13
MnO	0.21	0.07	0.13	0.42
MgO	6.39	1.01	4.61	7.69
CaO	8.56	1.94	5.14	12.26
Na_2O	3.15	0.44	2.18	4.04
K_2O	1.7	0.98	0.22	3.37
P_2O_5	0.55	0.30	0.22	0.98
Totalk	4.72	1.18	3.25	7.41
$TotFe^3$	10.28	1.67	7.61	13.35
Rb	57.8	27.0	20	108
Sr	332.3	109.3	187	511
Y	33.5	3.6	29	40
Zr	205.9	47	146	292
Nb	17.6	5.3	13	32
Ni	36.5	9.9	23	56
Cr	62.5	37.6	35	139

preservation of good chilled margins; the nature of the country rocks, i.e. heterolithic crystalline basement of dominantly calc-alkaline granitoid type; the lack of any indication that the country rocks immediately adjacent to the dyke contacts have undergone metasomatism. It is thus considered that the alteration, extensive as it is, represents a local rearrangement of elements which is probably isochemical at the level of sampling. The binary plot of total alkalis against silica shows a good positive correlation (r=0.92), with all the points lying well into the alkali field, using the discriminant of Kuno (1968). Similarly, in the AFM ternary plot, the field occupied by the suite lies well away from the FeO_T-MgO baseline, and also shows a weak iron enrichment, both typical of mildly alkaline basalt suites. CIPW norms calculated for the albite-dolerites are all either nepheline or olivine normative. The normative identification is consistent within different samples taken from the same dyke, so it is probably not a function of alteration.

Trace elements are probably much more useful in characterising altered rocks, especially those elements which are considered to be essentially immobile in the low grade metamorphic conditions under which these rocks were altered, e.g. Zr, Y, Nb, and to a more limited extent, Ti, Th, P, REE. Both Y and Nb have positive correlations with Zr (r=0.51 for Y, r=0.87 for Nb), indicating that all three are probably behaving incompatibly during crystallisation. Their contents are relatively high for basic rocks: Zr ranges between 146 and 292ppm; Y between 29 and 40ppm; and Nb between 13 and 32ppm. The Zr/Y ratio ranges between 5.00 and 8.85, Y/Nb between 1.03 and 2.43, and Zr/Nb between 9.13 and 13.29.

The compatible elements Ni and Cr both have relatively low concentrations, indicating that the albite-dolerites are relatively evolved basaltic rocks. Using Zr as an index of fractionation, there is little indication, using Ni, that olivine has played any significant role (Fig. 3a). Cr variation, however, shows a distinctly arcuate trend, indicating that some clinopyroxene fractionation may have occurred (Fig. 3b).

The four chondrite-normalised REE profiles of different albite-dolerite dykes show a common pattern, but are not parallel (Fig. 4). All have relatively high concentrations of REE, with total REE contents ranging between 93 and 214ppm. The profiles are smooth showing LREE enrichment, 50 to 100 times chondritic, relative to 10 to 20 times chondritic for the HREE. La/Yb ratios vary between 4.7 and 20.1. The non-parallelism of the profiles precludes a simple fractionation of the three-major phases. However, there is a markedly high correlation between total REE
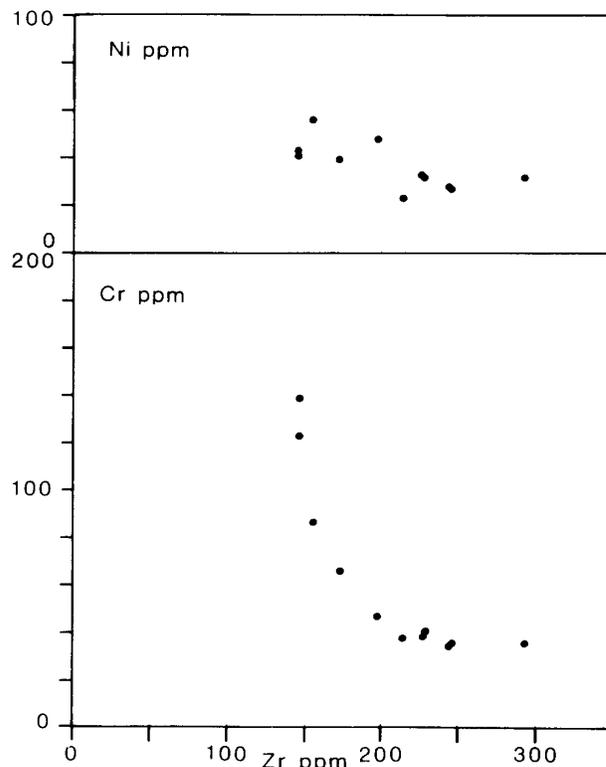

Figure 3. Binary plots showing the variation of the compatible elements (a) Ni and (b) Cr with Zr in eleven samples of albite-dolerite.

and P_2O_5 (t=0.965) which might indicate apatite as a controlling factor.

The MORB-normalised incompatible element diagram (spidergram) (Pearce 1983) shows remarkably smooth and consistent profiles for the four dykes plotted (Fig. 5), with steady enrichment as incompatibility increases (i.e. Yb to Sr). The coherent element pair Ta-Nb have enrichments between 4 and 10 times MORB. The non-parallelism of the profiles for the LIL elements Ba to Sr must be due to alteration. However, the K/Rb ratios for the suite, with two or three exceptions, are fairly tightly grouped, between 322 and 454, indicating that the behaviour of this pair remains coherent. The smoothness of the profiles is also interrupted by P and Ti, which show slight depletions; a feature often seen in evolved basalt suites.
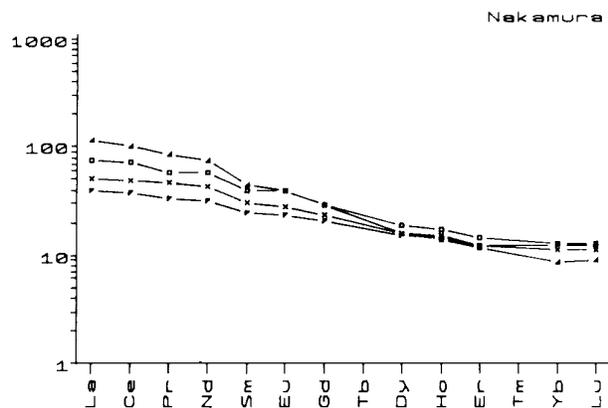

Figure 4. Chondrite-normalised REE diagram (using the normalising values in Nakamura 1974) for four albite-dolerite dykes.
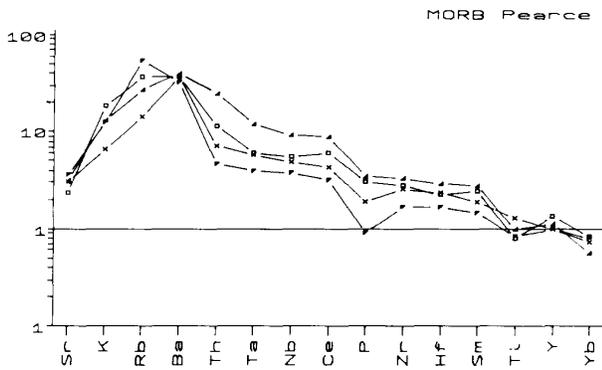
Figure 5. MORB-normalised incompatible element diagram (after Pearce 1983) of four albite-dolerite dykes.

The geochemical character of the albite-dolerites is consistent with their being mildly alkaline or transitional basalts, i.e. their high alkali content for their low SiO_2 content; their ne-or ol-hy-normative compositions; their enhanced contents of immobile elements such as Zr, Y, Nb, and high Zr/Y ratios; markedly LREE-enriched REE profiles; their markedly and consistently enriched MORB spidergram profiles. Such magmas are characteristic of continental intraplate volcanism, usually in extensional environments (Pearce and Norry 1979).

Discussion and conclusions

Evidence has been brought forward in this paper for the presence in Guernsey of mildly alkaline basaltic magmatism in the interval between the Cadomian and Hercynian orogenic episodes. This magmatism is now represented by a minor suite of dykes - the Perelle-type albite-dolerites - having an ENEWSW trend, which are the last of the numerous suites of basic dykes cutting the Cadomian and pre-Cadomian plutonic complexes which make up the island.

The model put forward for the Cadomian orogeny by Auvray (1979), Lees (1986), and Brown *et al.* (in press) is that of an active continental margin adjacent to a presumably south-easterly dipping subduction zone. An episode of extensional basic magmatism, along NE-SW lines, thought to be the last related to the Cadomian in the Channel Islands, has been described from SE Jersey by Lees (1986). This Jersey Main Dyke Swarm is of mature calc-alkaline type, but there is evidence to indicate a possible transition to dykes with intraplate characteristics at the end, which may accord with it being derived from a decayed subduction system (Lees, in press). The albite-dolerites fit in well with such a transition, being characteristic of continental intraplate basaltic magmatism. They may well be linked to alkaline-olivine basalt magmatism in Jersey, as exhibited by the Wolf Cave Gabbro (Wells and Wooldridge 1931; Lees and Rowbotham, in preparation), and with the well-developed suite of "Hercynian" basic dykes in N Brittany (Velde 1970; Lees, in preparation). The overall magmatic signature of all three groups of dykes, as shown by their spidergram profiles, is very similar, all indicative of intraplate magmatism from an enriched mantle source. The spidergrams show little evidence of any subduction zone signature. Either the enrichment in LIL elements characteristic of such signatures (Pearce 1983), and well evident in the basic rocks of the Jersey Main Dyke Swarm (Lees 1986), has been flushed from the mantle source region by the time of formation of these intraplate magmas or they have been produced from a source situated at a level below that influenced by Cadomian subduction.

Derivation from an enriched mantle source is characteristic of basic rocks in the Channel Islands and N Brittany from before the onset of the Cadomian orogenic episode (e.g. Lees *et al.*

1987), which might indicate the persistence of a subcontinental mantle lithosphere beneath the region into the Upper Palaeozoic. Alternatively, the source could be located at a much lower level in the mantle, below the asthenosphere, with small levels of partial melting of garnet-peridotite mantle source below the depleted upper mantle layer.

The orientation of the albite-dolerite dykes in Guernsey points to extension in the Upper Palaeozoic in a NNW-SSE direction. Further south, in Jersey and in Cotes du Nord, Brittany, the extension is orientated E-W. Such variation in orientation of the dyke suites across the Armorican Massif region probably reflects local responses in this cratonised orogenic belt to an overall stress pattern, possibly related to the early Hercynian geotectonic configuration.

The nature of the intensive low temperature alteration of the albite-dolerites must remain somewhat problematical. That this metamorphism is not an end-magmatic hydrothermal one may be seen from the complete absence of any amphibole phases in these rocks and the lack of alteration of the clinopyroxenes. Extensive development of prehnite and pumpellyite would tie the P-T conditions for the alteration to between 1 and 4kb and c.225-325°C using the collation scheme for low-grade metamorphism of basaltic assemblages of Liou *et al.* (1985). The metamorphism of the albite-dolerites could be due to residual fluids trapped after crystallisation had been completed, or due to an imposed low grade regional or burial metamorphism, perhaps related to the Hercynian. There is very little evidence for a demonstrably post-Cadomian low grade regional metamorphism in Guernsey, apart from the low temperature assemblage here described for the albite-dolerites. This may, however, merely be the result of the lithologies of the other rocks on the island being unsuitable for reflecting it.

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