Autometasomatic gneisses of the Currywongaun-Doughruagh syntectonic intrusion, Connemara Ireland

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ABSTRACT. The Currywongaun and Doughruagh masses of northern Connemara represent a section through a syntectonic, partially layered intrusion formed of ultra-basic cumulates all having plagioclase of around An_{94}. Differentiation and contamination of the magma from which these cumulates were precipitated ultimately produced an acid residuum which was responsible for the hydrous metasomatism of the earlier formed ultrabasic rocks resulting in the extensive formation of quartz–amphibole–anorthite gneisses in the petrogenetically 'upper' parts of the intrusion. Coexisting Ca-rich and Ca-poor amphiboles in the gneisses are interpreted as 'frozen' reaction intermediates that were in local equilibrium. The bulk-rock chemical data presented confirm that the compositions of the quartz-rich gneisses can be attributed almost entirely to the addition of Si to the ultrabasic rocks, coupled with the removal of Mg and Ca. The data also suggest that Zr, which reaches around 1000 ppm in some of the gneisses, may have been 'mobile' under these conditions of hydrothermal metasomatism.

THE Currywongaun–Doughruagh intrusion is situated on the northern side of the Connemara antiform (fig. 1) and is regarded as belonging to the same magmatic event as the ultrabasic and basic masses of south Connemara (Leake, 1970). All these syntectonic bodies are characterized by unusually calcic plagioclase, although the Curry-wongaun–Doughruagh ultrabasic rocks probably represent an extreme, with plagioclase of around An_{94} throughout the intrusion, and are further distinguished by lacking olivine.

Kanaris-Sotiriou and Angus (1976) described the general petrogenesis and structural configuration of the Currywongaun–Doughruagh intrusion, which was interpreted as a folded sequence of ultrabasic cumulates, in part layered, which had locally been converted to quartz-rich gneiss, with late-stage acid pegmatites and granitic dykes intruding the earlier-formed parts of the intrusion. The metasomatic effects of the reaction between the acid pegmatite veins and ultrabasic wall-rocks were reported by Kanaris-Sotiriou and Angus (1979).

In south Connemara the extensively developed quartz diorite gneiss is associated with the basic and ultrabasic bodies. Leake (1969) concluded that this quartz diorite gneiss had crystallized from a differentiate of the same magma that had earlier produced the basic and ultrabasic rocks. No such association is apparent at Currywongaun–Dough-ruagh at the present level of exposure, although within the contact of the intrusion considerable areas of ultrabasic rock have been replaced by the quartz-rich gneisses which are the subject of this paper. This type of silicified ultrabasic rock has
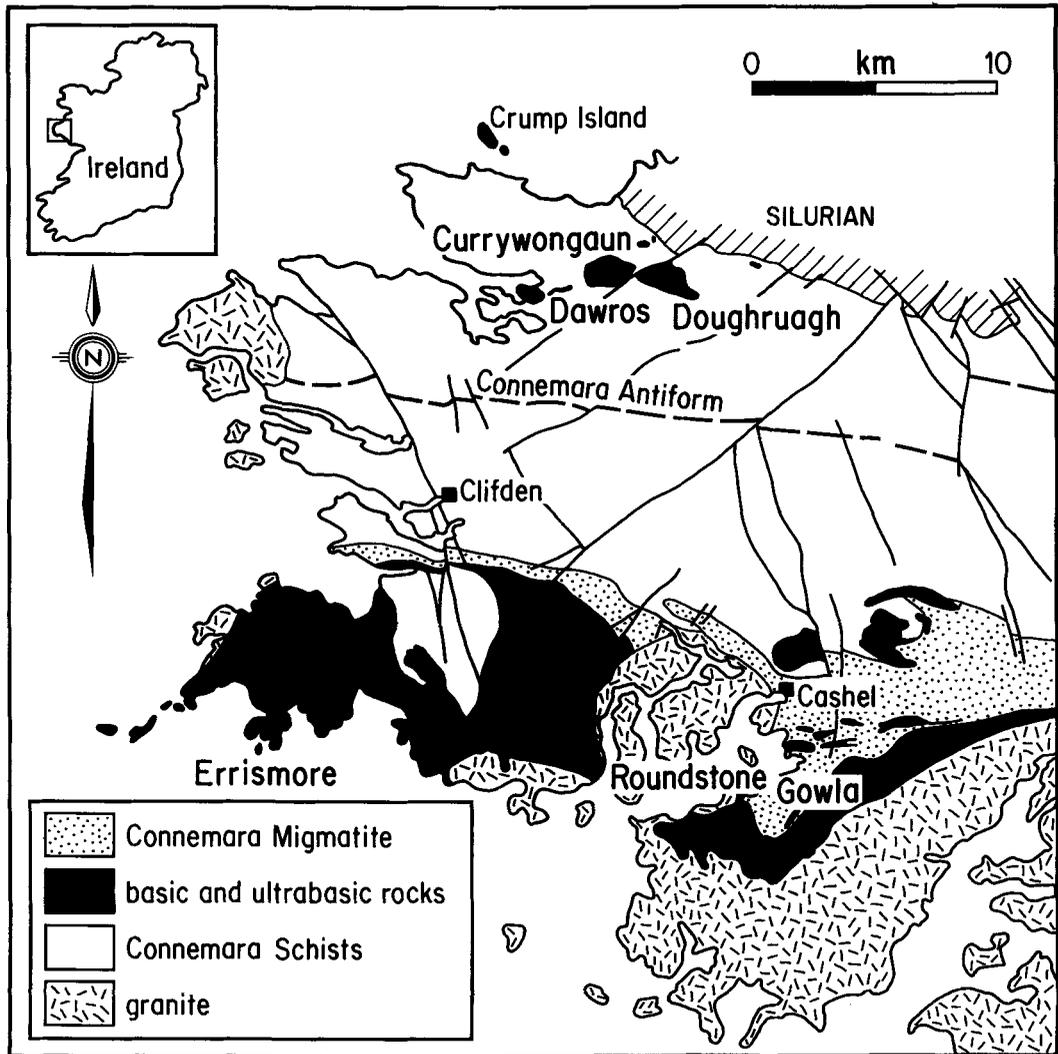
FIG. 1. Geological map of western Connemara (after Leake, 1970) showing location of the Currywongaun-Doughruagh intrusion.

only a limited occurrence in south Connemara and is markedly different in composition from the migmatitic quartz diorite gneiss which predominates there.

Field evidence. The distribution of rock types within the Currywongaun-Doughruagh intrusion is shown in fig. 2. The quartz-rich gneiss is concentrated within the Doughruagh part of the intrusion which, according to our previous work on the ultrabasic rocks (Kanaris-Sotiriou and Angus, 1976), represents the petrogenetically 'upper' or later parts of the intrusion, each part of which 'youngs' towards a central, roughly NW–SE fold

axis. There is also strong evidence that acid pegmatite, either as veins or as the matrix of agmatites, occurs in greater volumes in Doughruagh, particularly towards the east. This also conforms with the view that this area of Doughruagh represents the 'youngest' or most highly differentiated region of the intrusion, being close to the original roof, a conclusion that is further reinforced by the presence in the east-central area of Doughruagh of country rock screens that have been hornfelsed or undergone partial anatexis. Although not shown in fig. 2 the foliation within the quartz-rich gneiss has been mapped throughout the intrusion and indi-
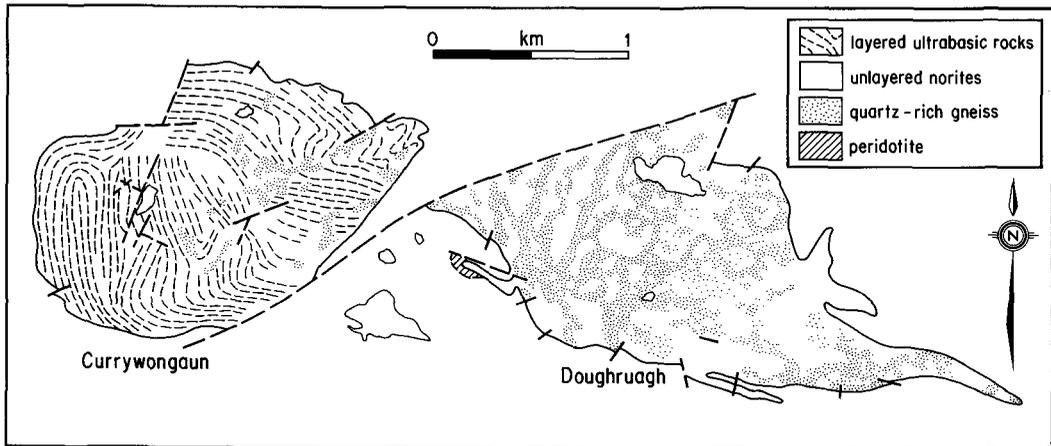
FIG. 2. Distribution of rock types within the Currywongaun–Doughruagh intrusion (after Kanaris-Sotiriou and Angus, 1976).

cates a fold pattern in Doughruagh similar to that deduced from layering attitudes for Currywongaun. There is no evidence that the quartz-rich gneiss (or the acid pegmatite) occurs outside the contact of the intrusion, where the envelope rocks are largely Connemara schists which become hornfelses closer to the intrusion.

The relative chronology of the different lithologies represented in the Currywongaun–Doughruagh intrusion is clearly displayed at many localities. Fig. 3 illustrates one such exposure where layered ultrabasic rocks (anorthosites, norites, and pyroxenites) have been diffusely converted to quartz-rich gneisses and subsequently injected by an acid pegmatite vein. Exposures of typical quartz-rich gneiss (see fig. 4) give a strong impression that the gneiss is essentially ultrabasic rock that has been replaced by quartz to varying degrees, often leaving irregular patches and streaks of highly amphibolized ultrabasic parent rock within the gneiss. The quartz-rich gneiss characteristically possesses a coarse foliation as illustrated in figs. 4 and 5. Although most of the gneiss occurs within the unlayered, massive norites of Doughruagh, some localities within Currywongaun show that where the gneiss has formed within layered rocks it may follow the pre-existing structure of the parent rock.

The typical quartz-rich gneiss probably accounts for more than 95% of the gneiss within the intrusion, but localities have been recorded where a fine-grained type of gneiss of otherwise similar appearance to the normal coarse-grained gneiss occurs. The fine-grained variant appears to have been mobile at some stage: it is sometimes apparently chilled against the coarse-grained gneiss

(fig. 5) and occasionally net-veins the latter (fig. 6) in which localities the fine-grained gneiss is evidently intrusive and post-dates the coarse-grained gneiss.

Mineralogy. The layered ultrabasic rocks of Currywongaun consist of varying proportions of orthopyroxene (around Fs_{15-30}), augite and anorthite, whereas in Doughruagh little variation in the proportions of the constituent minerals occur, the rocks being massive norites composed of anorthite, orthopyroxene (around Fs_{30-40}) and clinopyroxene, often with some secondary amphibole.

The gneisses range in composition from only slightly silicified ultrabasic rocks (generally norites) with a few percent of quartz to those containing up to 60% quartz. The other important constituent minerals of the gneisses include amphiboles, plagioclase, and magnetite, and in some instances, biotite, chlorite, apatite, and zircon. Rarely, small grains of orthopyroxene have been recognized in the gneisses, but no clinopyroxene.

The texture of the quartz-rich gneisses is variable; some exhibit a strong foliation (fig. 7) in which quartz foliae up to about 1 cm in length are deformed around the relict plagioclases which tend to be preserved as equidimensional grains with opaques and amphiboles forming trails in between the quartz foliae or in pressure shadows adjacent to the relict plagioclases. In some instances the foliation is less obvious (fig. 8) and disappears close to the contact with the ultrabasic rock where there is no evidence of a change in grain size of the quartz-rich gneiss. The ultrabasic rocks adjacent to such contacts have been completely amphibolized.
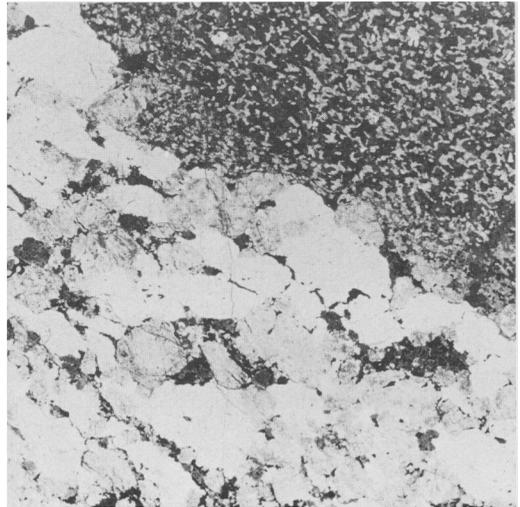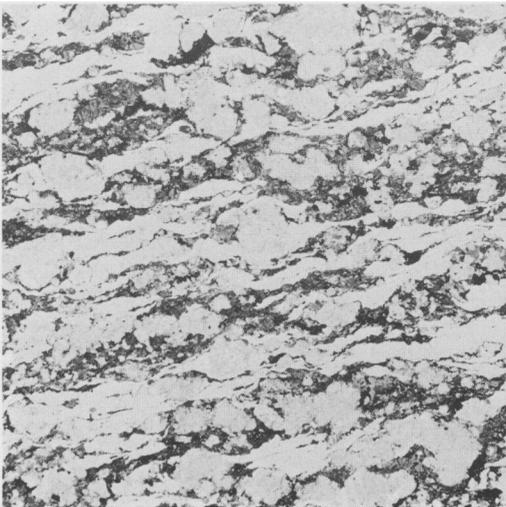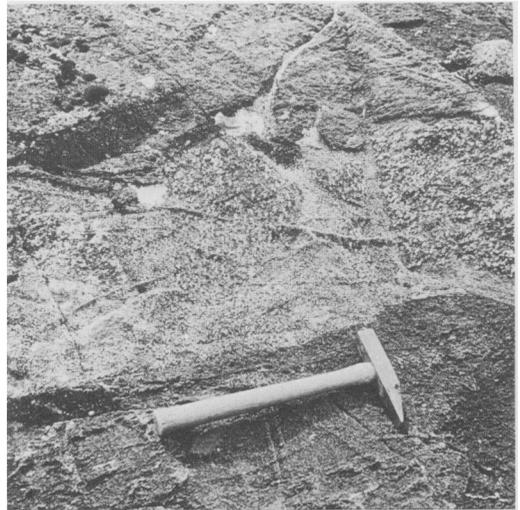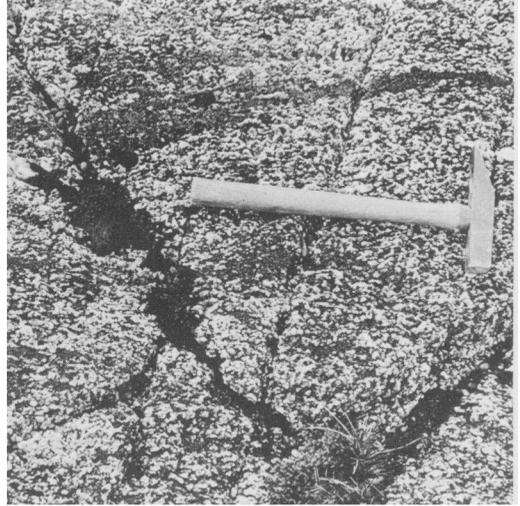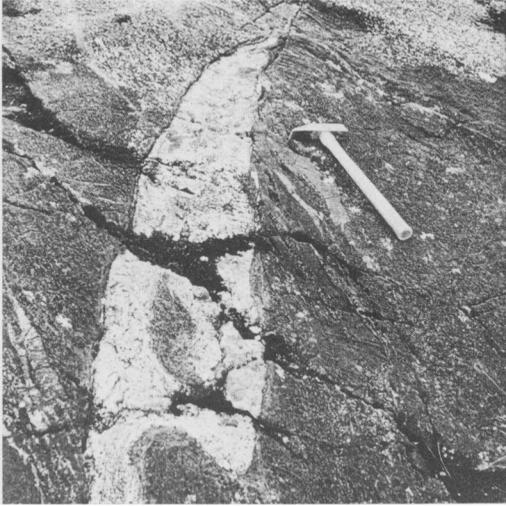
In thin sections of the gneisses, the plagioclase is frequently seen to be in the process of replacement by quartz and does not exhibit a porphyroblastic habit, indicating that this mineral is probably a relict from the ultrabasic rocks. Consequently both plagioclase and orthopyroxene grains from the gneisses were analysed by microprobe to enable a comparison to be made with the original ultrabasic rock mineral compositions. The results are presented in Table I.

There is little doubt that the plagioclase in the gneisses (An_{84-94}) is the original feldspar from the ultrabasic rocks in which plagioclases of composition close to An_{94} occur throughout Currywongaun and Doughruagh. The slightly more

TABLE I. *Average chemical analyses of relict minerals*

	Plagioclase			
Sample no.	C203	D026	D105	D144
No. of analyses	5	6	5	
SiO_2	46.5	45.4	44.4	46.5
Al_2O_3	35.0	35.4	36.3	34.7
CaO	17.3	17.6	18.5	16.6
Na_2O	1.61	1.32	0.67	1.73
K_2O	0.01	0.01	0.02	0.00
Total	100.4	99.7	100.1	99.5
An%	86	88	94	84

	Orthopyroxene	
Sample no.	C203	D105
No. of Analyses	5	5
SiO_2	51.3	52.0
Al_2O_3	4.12	1.23
TiO_2	0.06	0.08
FeO	22.2	25.3
MgO	21.2	19.5
CaO	0.10	0.51
MnO	0.53	0.74
Cr_2O_3	0.01	0.00
Total	99.5	99.3
Fs%	37	42

sodic nature of some of the gneiss plagioclase can only be attributed to the introduction of Na, although any recrystallization of the plagioclase that might have occurred is not immediately obvious. Similar observations were made by Leake (1969) on the plagioclases from silicified ultrabasic rocks from the Cashel district of south Connemara, for which compositions outside the range of those found in the associated parent ultrabasic rocks were determined and yet no recrystallization of the plagioclases in the silicified rock was evident. Leake (1969) attributed this, at least in part, to distortion of the optical determinations by straining of the plagioclases. However, it seems possible to us that in the plagioclases from the Currywongaun–Doughruagh gneisses, a homogeneous change of composition may have occurred by metasomatic reaction that did not involve recrystallization.

The analysed orthopyroxenes from the gneisses (Table I) are richer in ferrosilite than might be expected if they are to be regarded simply as relicts from the ultrabasic rocks and some process of removal of Mg (which occurs on a bulk-rock scale—see later) could be proposed.

It is clear that most of the mafic mineral content of the ultrabasic rocks has been replaced by amphibole (or occasionally chlorite and biotite) in the gneisses and it is inevitable that this process was neither isochemical on a single crystal scale nor uniform throughout the range of gneiss compositions. This is reflected in the microprobe analyses of the amphiboles given in Table II. Most of the gneisses have homogenous amphibole crystals that are of a hornblende composition, the amphibole from sample D105, for which an average analysis is presented, being typical (a magnesiohornblende). Some of the quartz-rich gneisses, however, contain two types of amphibole in close association, with green tschermakitic hornblende rimming a colourless core of cummingtonite (Table II). There have been numerous citations of this type of amphibole association in metamorphic rocks (e.g. Choudhuri, 1970; Livingstone et al., 1973; Sampson and Fawcett, 1977; Stephenson and

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FIGS. 3–8 (*opposite*). FIG. 3 (*top left*). Exposure illustrating relative chronology of the different lithologies. Layered ultrabasic rock (see near hammer) partially converted to gneiss (top) prior to intrusion by an acid pegmatite vein containing blocks of gneiss. FIG. 4 (*top right*). Exposure of typical quartz-rich gneiss on western flank of Doughruagh, showing streaks of less silicified ultrabasic rock. FIG. 5 (*centre left*). Contact between normal quartz-rich gneiss (right) and fine-grained variety (left) with possible chill at contact. FIG. 6 (*centre right*). Exposure illustrating intrusive character of fine-grained 'gneiss'. Here fine-grained 'gneiss' net veins disrupted blocks of normal coarse-grained gneiss. FIG. 7 (*bottom left*). Thin sections of strongly foliated quartz-rich gneiss showing plagioclase relicts (cloudy) around which are deformed quartz foliae. Area is approximately 23 mm square. FIG. 8 (*bottom right*). Thin section of contact between quartz-rich gneiss and ultrabasic rock (norite). Note the absence of any reduction of grain towards the contact. Area is approximately 23 mm square.

TABLE II. *Average chemical analyses of amphiboles*

Sample no.	D105	D144-RIM	D144-CORE
No. of analyses	7	3	4
SiO_2	49.1	43.4	52.9
Al_2O_3	7.69	13.3	2.21
TiO_2	0.69	0.69	0.09
FeO	13.5	17.5	23.0
MgO	14.0	10.0	17.6
CaO	11.6	10.3	0.84
Na_2O	0.12	0.92	0.00
K_2O	0.32	0.30	0.00
MnO	0.20	0.29	0.59
Cr_2O_3	0.01	0.00	0.00
H_2O^*	2.06	2.01	2.04
Total	99.3	99.1	99.3

	D105		D144-RIM		D144-CORE	
Si	7.01	} 8.00	6.27	} 8.00	7.75	} 8.00
Al	0.99		1.73		0.25	
Al	0.31		0.54		0.13	
Fe^{3+}?	0.89		1.54		0.11	
Ti	0.07	} 5.00	0.07	} 5.00	0.01	} 5.00
Mg	2.98		2.24		3.84	
Fe^{2+}?	0.72		0.57		0.91	
Mn	0.02		0.04		0.00	
Fe^{2+}?	0.00		0.00		1.90	
Mn	0.00	} 1.81	0.00	} 1.85	0.07	} 2.10
Ca	1.78		1.59		0.13	
Na	0.03		0.26		0.00	
Na	0.00	} 0.06	0.00	} 0.06	0.00	} 0.00
K	0.06		0.06		0.00	
Classification†	magnesio-hornblende		tschermakitic hornblende		cummingtonite	

* Calculated water.
?Fe^{3+}/Fe^{2+} calculated from oxygen deficiency with respect to 23(0). Formulae calculated on the basis of cations (excluding Ca, Na, and K) = 13.00 with the exception of D144-RIM.
† Nomenclature after Leake (1978).

Hensel, 1979). Kisch and Warnaars (1969) investigated the $Mg/(Mg+Fe)$ ratios of thirty-one coexisting metamorphic hornblende–cummingtonite pairs and related these ratios to the Al content of the calcic amphibole and in turn to the composition of the plagioclase in the same rock. They showed that in amphibole pairs associated with oligoclase the $Mg/(Mg+Fe)$ ratio for the hornblende was always *less* than that for the cummingtonite and that the hornblendes of such pairs were Al-rich, i.e. contained 2.13–2.79 Al atoms per unit formula. For more calcic plagioclase (greater than about An_{45}) the $Mg/(Mg+Fe)$ for the hornblende became *greater* than that for the cummingtonite and the hornblende less aluminous (less than 2.00 Al atoms per unit formula). The analysed hornblende–cummingtonite pair from Doughruagh (sample D144, Table II) has an $Mg/(Mg+Fe)$ ratio of 0.515 for the hornblende and 0.566 for the cummington-

ite, the hornblende having 2.23 atoms of Al in the formula unit. This pair therefore, in spite of being associated with An_{84} plagioclase, have compositions that might correspond, on the basis of Kisch and Warnaars work, to a much more sodic plagioclase.

Clearly the development of these amphiboles will depend upon the activities of chemical species required for the growth of the minerals, and in an isochemical metamorphic system these activities will relate to the mineralogy of the rock alone since equilibrium will be approached on a bulk-rock scale. In a metasomatic system, however, such a relationship is unlikely to hold, the activities of the reacting species being largely dependent upon incoming components, and only 'local' equilibrium may be attained (see Carswell et al., 1974). This is almost certainly the reason for the departure of the Doughruagh hornblende–cummingtonite pair from the findings of Kisch and Warnaars (1969), the metasomatic amphibole pair representing 'frozen' reaction intermediates that were in local equilibrium but which were not in equilibrium with the rock as a whole. Since the metasomatic amphiboles have equilibrated with the metasomatic fluids rather than the relict minerals, the bulk-rock mineralogy can have little *direct* influence over the composition of the new minerals.

The existence of a miscibility gap between calcic and Fe–Mg amphiboles has been discussed by some workers in relation to the origin of coexisting amphibole pairs (Sampson and Fawcett, 1977; Stephenson and Hensel 1979); the general conclusion seems to be that cummingtonite coexists stably with hornblende. Some published accounts of the origin of hornblende–cummingtonite pairs conclude that the cummingtonite had formed from the orthopyroxene and later reacted to form hornblende (Livingstone et al., 1973). Such an origin for the hornblende-rimmed cummingtonite in the quartz-rich gneisses seems plausible, the parent ultrabasic rocks usually containing considerable amounts of orthopyroxene. The following schematic reactions may therefore be proposed:

$$7(Mg,Fe^{2+})SiO_3 + H_2O + SiO_2 \rightleftharpoons$$
orthopyroxene

$$(Mg,Fe^{2+})_7Si_8O_{22}(OH)_2$$
cummingtonite

$$3(Mg,Fe^{2+})_7Si_8O(OH)_2 +$$
cummingtonite

$$14CaAl_2Si_2O_8 + 4H_2O \rightleftharpoons$$
anorthite

$$7Ca_2(Mg,Fe,Al)_5(Si,Al)_8O_{22}(OH)_2 + 10SiO_2$$
hornblende
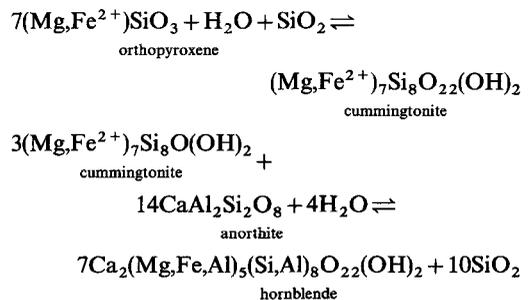
Chemistry. Representative chemical analyses of the quartz-rich gneisses, determined by X-ray fluorescence with the exception of Na_2O are presented in Table III which includes average values for Currywongaun and Doughruagh norites.

TABLE III. *Representative analyses of quartz-rich gneisses and average norites*

	D Average norites	C	Quartz-rich gneisses			
	(8)	(12)	D026	D144	D203	C159
SiO_2	45.44	48.60	71.83	51.98	78.17	63.89
Al_2O_3	16.66	15.83	11.46	16.56	10.07	13.88
TiO_2	0.69	0.18	0.79	1.88	0.42	1.17
Fe_2O_3	4.22	1.84	2.89	4.42	1.56	4.51
FeO	8.29	7.75	3.10	7.88	1.43	4.58
MgO	9.67	14.11	1.95	5.30	1.15	3.15
CaO	13.06	10.33	5.75	7.74	4.40	7.63
Na_2O	0.30	0.24	0.64	0.96	1.27	0.26
K_2O	0.10	0.18	0.28	0.90	0.47	0.11
MnO	0.12	0.08	0.05	0.16	0.01	0.02
P_2O_5	0.01	0.01	0.30	0.41	0.03	0.01
S	0.22	0.12	0.07	0.08	0.07	0.12
H_2O^+	1.63	1.13	0.95	1.67	1.60	1.16
Total	100.29	100.34	100.02	99.90	100.61	100.43
Ni	67	154	5	40	1	12
Co	74	71	52	61	63	69
Mn	1488	1223	728	1547	336	622
V	373	163	96	257	46	192
Cr	213	504	22	138	8	33
Zn	85	55	56	133	26	47
Cu	72	71	31	44	24	25
Rb	6	8	10	30	15	1
Sr	194	169	219	303	275	173
Y	—	—	4	14	—	—
Zr	36	10	413	973	98	18
Pb	5	3	10	15	12	5
Ba	45	52	121	366	85	33

D indicates Doughruagh, C Currywongaun.

It is obvious that SiO_2 is the most variable component and other major constituents for all available analyses have therefore been plotted against weight % SiO_2 in figs. 9 and 10. These plots demonstrate that the other quantitatively important components (CaO, MgO, Fe_2O_3 and Al_2O_3) decrease systematically with increasing SiO_2 content of the gneiss. However, this may be simply a dilution effect resulting from the addition of quartz to the original ultrabasic rock components. K_2O and Na_2O are higher in the gneisses than in the parent norites but there is no regular variation with SiO_2 content. The TiO_2 content appears to reach a maximum at low levels of introduced SiO_2 and then to decrease systematically with further silicification.

Those trace elements originally present in the norite (Ni, Mn, Cr, Zn, Cu, V) also show a systematic decrease with increasing SiO_2, whereas Rb, Sr, Y, Zr, Pb, and Ba all occur in greater amounts in the gneisses than in the parent norites but do not vary regularly with SiO_2 and appear to have been introduced sporadically as do K, Na, Ti, and P. Of the trace elements, the concentration of Zr in the gneisses is remarkable, up to 1000 ppm of Zr occurring in some of the gneisses, by comparison with only 10–40 ppm Zr in the average norites. This is unexpected because although the data on the metasomatic behaviour of Zr is sparse, the evidence to date suggests (e.g. Vlasov, 1966, p. 302) that Zr is usually mobile only in conjunction with alkali metasomatism. Clearly this is not the case here as alkalis are only present in very small amounts in the quartz-rich gneisses where unusually high concentrations of Zr occur as zircon grains. The possibility therefore exists that Zr may be mobile in hydrothermal metasomatic environments that are not dominated by alkalis.

It is interesting to note that maxima in the distribution of certain introduced elements such as K, Ti, and Zr occur at only moderate levels of introduced Si which could imply that these elements were introduced at an early stage in the metasomatic episode and were 'fixed' in advance of the main influx of Si.

Assessment of any net gain or loss of components as a result of metasomatic processes is notoriously difficult and ideally volume changes must be allowed for. However, in this instance, the interchange of major components may be demonstrated on a scale unlikely to be affected by a change in volume and movement of components has been assessed from calculations designed to eliminate dilution effects due to the introduction of Si, Ti, Na, K, and P, with the bulk rock chemical analyses being converted to Barth standard cells (atomic percentages scaled to be equivalent to a total of 160 oxygen atoms) in an attempt to minimize the influence of any volume change. The calculations were based only on the Doughruagh quartz-rich gneisses for which there was little doubt as to the composition of the starting material due to the very small variations in the ultrabasic rock compositions in that part of the intrusion. For each acid gneiss, the effects of adding the required amounts of Si, Ti, Na, K and P to the average Doughruagh norite composition in order to reproduce the exact amounts of these components in the individual gneisses were assessed by reducing all the 'non-added' components in proportion, by the amount of components added, as in the example in Table IV.
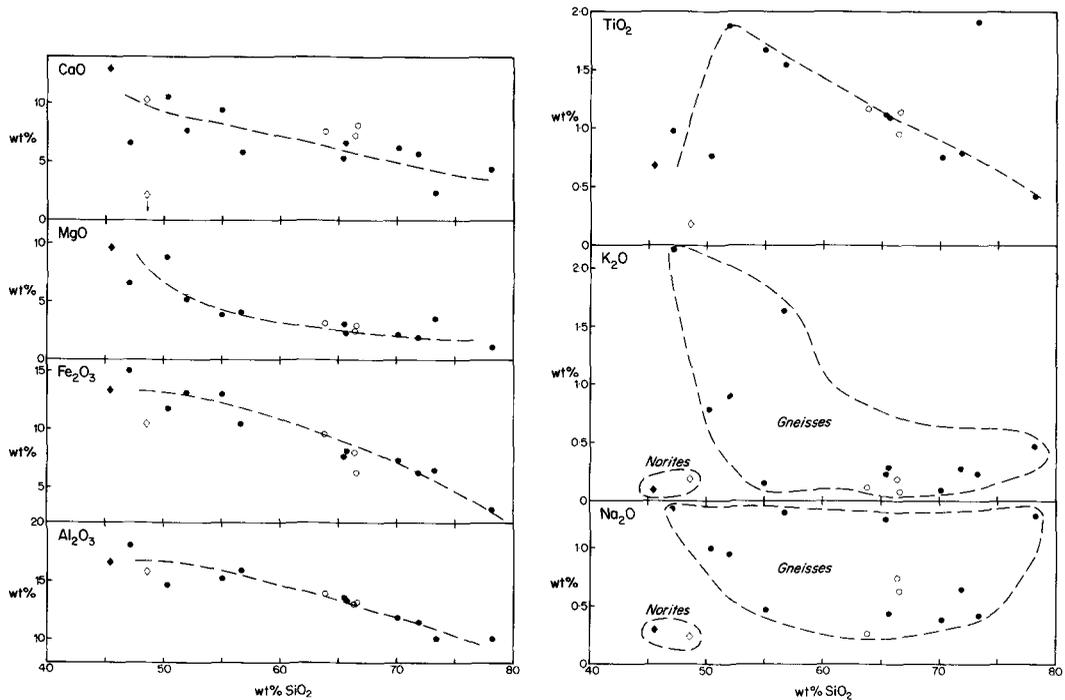
FIGS. 9 and 10. FIG. 9 (*left*). Variation between components of the quartz-rich gneisses, illustrating the systematic inverse relationship between SiO_2 and the other main constituents (derived from parent ultrabasic rock). Solid symbols—Doughruagh; open symbols—Currywongaun; diamonds—average norite; circles—quartz-rich gneisses.
FIG. 10 (*right*). Variation of selected introduced components with SiO_2 content. (Symbols as in fig. 9.)

TABLE IV. *Calculation of removed constituents in gneiss*

Doughruagh average norite		Net added	Predicted by dilution ×0.6458	Actual Qtz-rich Gn. D026	Δ
Si	43.43	+18.80	=	62.23	—
Al	18.77		12.12	11.70	−0.42
Ti	0.50	+ 0.01	=	0.51	—
Fe^t	9.67		6.24	4.13	−2.11
Mg	13.78		8.90	2.52	−6.38
Ca	13.38		8.64	5.34	−3.30
Na	0.56	+ 0.52	=	1.08	—
K	0.12	+ 0.19	=	0.31	—
Mn	0.10		0.06	0.04	+0.02
P	0.01	+ 0.22	=	0.22	—
Total		+19.73			

Δ is discrepancy. All atoms per cent are based on 16O (O).
Non-added components = 55.70 (Al + Fe^t + Mg + Ca + Mn).
Dilution factor = (55.70 − 19.73)/55.70 = 0.6458.

Discrepancies (Δ's) between the observed and predicted concentrations of non-added elements are plotted on fig. 11 against the amounts of Si

required to exactly reproduce the Si contents of each gneiss. Although we do not regard our approach as anything other than a reasonable approximation, any errors will apply equally to all components of each gneiss and the following comparative conclusions can be drawn from fig. 11 with some confidence.

The large negative discrepancies in Mg and Ca can only be interpreted as a net loss of these components from the parent norite on conversion to quartz-rich gneiss. This loss appears to have been most rapid during initial silicification as Δ Mg approaches a constant value after the introduction of only relatively small (about 7%) amounts of Si, and Δ Ca displays only a slight suggestion of higher negative values with continued silicification. The discrepancies for Mg are, on average, about twice as large as those for Ca which probably reflects the greater rate of removal of Mg by comparison with Ca, at least in the initial stages.

Al, however, appears to have been relatively 'immobile' with positive discrepancies at low silicification levels and small negative discrepancies at higher levels of added Si. Total Fe behaves in a similar manner to Al, but displays somewhat
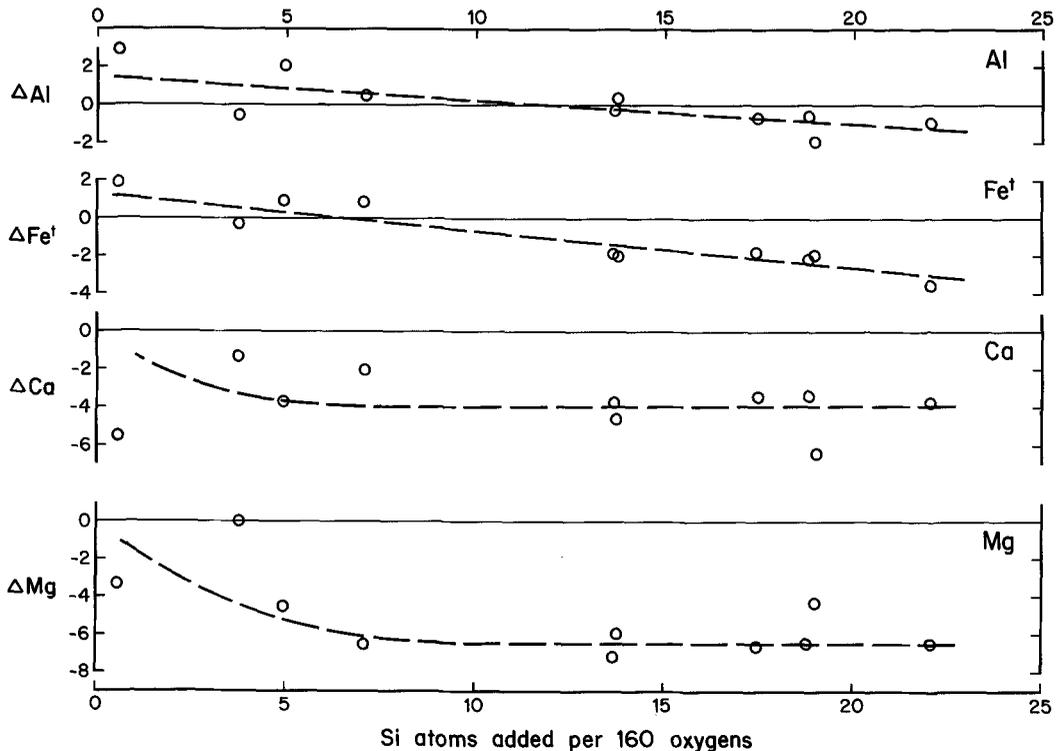
FIG. 11. Relationship between amount of Si added to individual gneisses and the discrepancies (Δ) between observed concentrations of other components and those predicted by dilution calculations (see text). The larger discrepancies of Mg and Ca suggest a higher degree of 'mobility' of these components relative to Al and Fe.

greater negative discrepancies than Al at higher silicification levels, suggesting that Fe is removed more rapidly than Al as the introduction of Si becomes more advanced. (By 'mobility' we mean here the relative rate at which a particular component was liberated (or fixed) by comparison with the rate at which the introduced Si reacted to crystallize as quartz.)

The small positive discrepancies of Fe and Al below about 7% added Si correspond almost exactly to the stage in the conversion process where Mg and Ca are removed most rapidly and in greater amounts than that of introduced Si. This removal, in the initial stages of the more 'mobile' components (Mg and Ca) has therefore resulted in a slight relative enrichment of the least 'mobile' components (Al and Fe).

The relative 'mobility' of the major outgoing components may therefore be summarized as: Mg > Ca ≫ Fe > Al.

Discussion. Our chemical model for the origin of the quartz-rich gneisses involves the introduction into ultrabasic parent rocks of Si, minor amounts of alkalis and certain trace elements coupled with

the removal of Mg and Ca, and to a lesser extent Fe (and Al). This mechanism raises the question as to the ultimate site of 'fixation' of the released components. The clue to solving this appears to lie in the fact that ultrabasic rocks adjacent to the areas of quartz-rich gneiss are frequently heavily amphibolized, suggesting that the liberated Mg, Ca, and Fe contributed to the formation of hornblende (and magnetite) in otherwise unmetasomatized ultrabasic rocks. This may be evidence for the activity of a 'basic front' proceeding in advance of the silicifying fluids.

Further geochemical support for these conclusions comes from the fact that they echo on a very large scale what was found for a small scale phenomenon in the same intrusion: the reaction between acid pegmatite veins and orthopyroxenite wall rocks (Kanaris-Sotiriou and Angus, 1979) resulted in the latter being converted to amphibolerich reaction borders (~ 10 cm thick) with the release of Mg and Fe, producing additional amphibole, and accompanied by the formation of magnetite. In addition, the amounts of amphibole in the norites of the much more silicified Doughruagh

part of the intrusion are considerably greater than in the Currywongaun ultrabasic rocks, where quartz-rich gneisses are also more subordinate. We can only speculate as to the nature and origin of the acid metasomatizing fluids. However, there is some evidence to support the conclusions that the source of the fluids was within the intrusion, the fluids being related to the magmatic sequence, and hence that the gneisses may be regarded as *auto-metasomatic*. The quartz-rich gneiss does not occur in the local country rocks and there is no other evidence for any metasomatic interchange between the intrusion and its country rocks such as was demonstrated by Leake (1980) in describing the development of metasomatic calc–magnesian silicate rocks formed in Dalradian metasediments close to ultrabasic lenses in eastern Connemara.

There seems little doubt that the metasomatic fluids were hydrous, judging by the extensive development of amphibole in ultrabasic rocks adjacent to the gneisses. It is also apparent from the composition of the quartz-rich gneisses that the fluids were rich in silica and unusually poor in alkalis. We have shown previously (Kanaris-Sotiriou and Angus, 1979) that the acid pegmatite, which occurs in quite large volumes in the Doughruagh part of the intrusion has a pronounced hydrating effect on the ultrabasic rocks it intrudes and we consider it likely that the hydrous metasomatic fluids emanated from this late-stage acid pegmatite liquid. There is some experimental evidence for the differential partition of Si and alkalis between acid melts and hydrous vapours in equilibrium with such melts (e.g. Tuttle and Bowen, 1958; Morey and Hesselgesser, 1951; Luth and Tuttle, 1969) and we provisionally suggest that such a partition, with Si becoming concentrated in the hydrous vapour, could account for the alkali-poor nature of the fluids.

The normal differentiation of a basic magma is unlikely to produce an adequate quantity of the acid material required for the formation of the acid pegmatites and the quartz-rich gneisses. However, the occurrence of considerable numbers of largely digested xenoliths in the Currywongaun ultrabasic rocks suggests that extensive assimilation of semi-pelitic country rocks, together with possible partial fusion of roof material, could have produced some of the extra acid material that seems necessary. It should be pointed out, however, that the apparent relative volumes of acid and ultrabasic material in the Currywongaun–Doughruagh intrusion may be irrelevant if considered in isolation from the rest of the Connemara basic to ultrabasic igneous suite, and indeed (as pointed out by Professor Leake, pers. comm.) there may be no problem in deriving the quantities of acid material necessary if considered in a regional context, since there seems little doubt (Leake, 1970) that the Connemara basic and ultrabasic bodies are simply disrupted parts of much larger original intrusions.

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