A CONTRIBUTION TO THE STUDY OF ACCESSORY MINERALS OF IGNEOUS ROCKS

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Introduction

Within the last few years ever increasing interest has been shown in the possibility of using the accessory minerals of igneous rocks for purposes of correlation. It is perhaps unfortunate, however, that before attempts were made to use the accessories for this purpose, the methods were not subjected to a thorough test on some group of igneous rocks whose age was beyond doubt. For some years the writer has been endeavouring to apply such a test. The method used has been to examine the heavy mineral suites of a number of granites, including, in particular some single composite granite mass of known age: in the case of the latter to see what amount of variation there is between the suites of specimens collected from different positions and heights in the same intrusion: and then to compare the results with those obtained from other granites with a view to determining:

(a) Whether the range of variation in the heavy minerals of one composite granite mass is less than that between two granites of different ages.

(b) The amount of variation in granites of the same age, whose size and cooling history are different.

The present contribution deals briefly with the first part of the subject, the study of the accessories of a single composite intrusion.

Methods Employed

Unfortunately methods of separating and investigating the accessory minerals of igneous rocks are far from standardised, and the comparison of independent results is consequently quite unnecessarily complicated. The author has, in the main, modelled his methods on those of A. W. Groves (1927A, B; 1930), only departing from them where it seemed that some alteration was desirable.

In collecting from any igneous mass specimens were chosen to cover as wide a range of texture and composition as possible. Approximately 100 grams of each rock were crushed with frequent sieving through a $\frac{1}{2}$ mm. mesh sieve, and the powdered rock washed to remove rock flour.

Twenty grams of each sample were separated quantitatively in a funnel filled with bromoform (Sp. Gr. 2.88). The proportion of "heavy minerals" obtained in this way and expressed as a percentage is the "Index Figure" to which Groves attaches considerable importance. The heavy crop (in the case of acid igneous rocks) frequently consists of a gram or more of material which is much more than can be conveniently mounted. Accordingly it was separated by means of the electro-magnet into two fractions referred to below as magnetic and non-magnetic fractions. The whole of the non-magnetic residue was in every case mounted and examined; and it was with the object of obtaining an amount which could conveniently be mounted in its entirety that the weight of 20 grams was selected as the standard quantity for separation. The danger that so small an amount would not furnish a representative sample of the rock was as far as possible obviated by always crushing 100 grams and well mixing the powder before weighing out the 20 grams.

The magnetic fraction of the heavy crop was treated with a small horse-shoe magnet, and the material extracted tested for pyrrhotite: sufficient of the remainder to fill half a dozen slides was mounted for examination. In most cases, owing to the deep colour of the magnetic accessories, it was found desirable to crush them further to pass a $\frac{1}{4}$ mm. sieve before mounting.

In work of this kind, by far the most difficult task that faces the investigator is that of indicating the amounts of the several minerals present. Many workers have made no attempt to do this and have been content to include such terms as "plentiful," "scarce," or "local" in the description of the minerals. Others, including Groves, estimate proportions by eye, dividing the minerals into a number of categories of abundance: Groves has five of these, namely—Abundant, Very Common, Less Common, Scarce, Rare. The method has obvious limitations, introducing as it does the personal factor to a great extent. A distinct advance is made by J. T. Stark (1934) in a study of certain granites from Central Colorado. After separating in bromoform he weighs the sample, extracts the magnetite by means of a horse-shoe magnet and weighs the residue. The latter is mounted and every grain counted. The result is an accurate quantitative record of the heavy minerals present: but the method is only applicable to rocks poor in ferro-magnesian minerals.

The author's earliest efforts at estimating mineral proportions were similar to those of Stark. After separation by means of the electro-magnet, the two fractions were weighed and counts made of the whole of the non-magnetic material and of half a dozen slides mounted from the magnetic residue. The results when recorded give a series of mineral analyses averaging 90 per cent ferro-magnesian minerals, 5 per cent iron ores, and the remaining 5 per cent divided among some dozen or more accessory minerals. As will be seen by referring to the specimen analysis of the Jersey "Newer Granite" from La Moye, under this system the very minerals which it is desired to study are completely overshadowed by the less significant ferro-magnesians and iron ores.

In consequence of the obvious disadvantages of this method it was decided to count the minerals of the non-magnetic fraction only. Of the minerals in the magnetic fraction, the ferro-magnesians in most cases are not accessories, and are better studied in thin sections than in "crushes." The latter remark also applied in a minor degree to magnetite, pyrrhotite and ilmenite, the other common constituents of the magnetic fraction: but in addition it is an extremely difficult matter to identify small grains of these minerals and the result of counts would not be sufficiently accurate to justify the extra time and labour involved.

The procedure finally adopted by the author is therefore as follows:

(1) To examine both magnetic and non-magnetic fractions and to record all mineral species present in the heavy crop.
(2) In the description of minerals, to concentrate on the true accessories, paying minor attention to such species as biotite and hornblende, which flood the sample.
(3) By counting, to calculate accurately the proportions of the minerals in the non-magnetic fraction.

In evolving this method, the author has had the following three aims in view:

(a) The procedure adopted must be applicable equally readily to both acid and basic rocks;
(b) Some more accurate quantitative data than that provided by Groves must be obtained;
(c) The more laborious and involved the method, the less the chance of other workers conforming to it. Consequently, repeated separations by the electro-magnet and various heavy liquids have been avoided.

As an example of the advantage of the "counting method" over the method of eye-estimation, an analysis of the heavy minerals of the La Moye granite from Jersey in the Channel Islands (average of half a dozen specimens) is compared with one given by Groves (1927 B) (average of two samples). In the following table are set out:

(a) Minerals divided into five categories by eye-estimation (as determined by Groves).
(b) Mineral percentages as determined by the author by grain counts.
(c) Minerals divided into five categories on basis of percentages in column (*b*).

	(*a*)	(*b*)	(*c*)
Biotite	5	59.46	5*
Hornblende	5	24.78	5*
Chlorite	3	4.81	4
Magnetite	4	2.82	4*
Ilmenite	3	0.96	3*
Limonite	—	1.24	3
Pyrite	—	0.14	1
Zircon	4	0.60	2
Apatite	4	0.69	2

Sphene	4	0.91	3
Fluorite	5	0.91	3
Topaz	1	0.40	2
Tourmaline	—	0.02	1
Muscovite	—	0.03	1
Rutile	—	0.06	1
Sillimanite	1	0.02	1*
Epidote	3	0.71	2
Clino-zoisite	3	0.19	1
Opaque grains (unidentified)	—	1.60	

* Indicates mineral which falls into same category in both columns (*a*) and (*c*).
Groves' five categories represent:
5. Abundant. 4. Very Common. 3. Less Common. 2. Scarce. 1. Rare.

The discrepancies between columns (*a*) and (*b*) are obvious. For example Category 5 includes biotite, hornblende and fluorite, with percentages of 59.46, 24.78 and 0.91 respectively: while Category 3 includes chlorite, ilmenite, epidote and clino-zoisite (4.81, 0.96, 0.71 and 0.19 per cent). In column (*c*) the author has attempted to apply Groves' indices of relative abundance to the percentages and in respect of only five out of the eighteen mineral species listed do the two columns (*a*) and (*c*) agree. It is surely evident that not only is eye-estimation not sufficiently delicate for the work in hand, but that the method is positively inaccurate and misleading.

In addition to the counting of the mineral species in the nonmagnetic fraction, the author has felt that some quantitative methods should be applied to the widespread zircon and apatite which often possess distinctive and easily recognisable varietal features. The difficulty was to decide which features should be selected for quantitative study: since there are generally some half a dozen of more—colour, size, crystal form, presence or absence of inclusions, zoning, etc.—all of which vary independently of one another. In any sample there will be certain varietal peculiarities which appear to merit quantitative study—e.g. the ratio of dusky zoned zircons to clear zircons, or the ratio of apatites with rod-like cores to those without. But often a ratio so easily calculable in one rock is quite obscure in another—e.g., the zircons may form a regular series from the clear to the dusky variety: yet for purposes of comparison it is essential that the same ratios be calculated for every rock type. The author has selected the following, since they can readily be calculated in any sample:

(1) Percentage of five types of zircon present:—
  (a) Roughly equidimensional crystals.
  (b) Short stout crystals—ratio of length to breadth between 1:1 and 2:1.
  (c) Medium elongated crystals—ratio of length to breadth between 2:1 and 4:1.

(d) Very elongated crystals—ratio of length to breadth greater than 4:1.
(e) Anhedral grains.

(2) Percentages of the following types of apatite:—
(a) Stout prismatic crystals—ratio of length to breadth less than 4:1.
(b) "Needle shaped" crystals—ratio of length to breadth greater than 4:1.
(c) Anhedral grains.

(3) Relative proportions of euhedral and anhedral apatite.

(4) Relative proportions of apatite and zircon.

The Granites of the Mourne Mountains

After consideration of various possibilities it was decided that among British granites, the most suitable example of a large composite intrusion was the Tertiary complex of the Mourne Mountains in County Down, Northern Ireland. The area has been described in detail by J. E. Richey (1927), who recognises four types of granite marking successive (and closely connected) intrusions resulting from ring fracturing followed by subsidence of a central block: for the full details the reader is referred to Richey's paper.

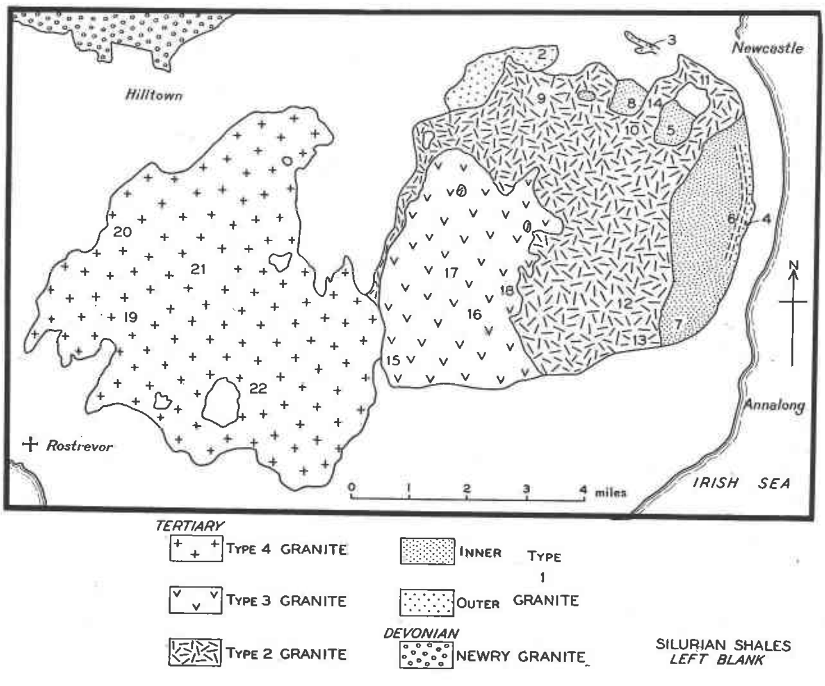

Fig. 1. Map of Mourne Mountains granite complex, to show location of samples.

The Heavy Minerals. On Richey's map (Fig. 1) are marked the 22 localities from which specimens of the granite were collected. In Table 1 the heavy minerals present in each sample are recorded: the percentages of the non-magnetic heavy accessories are given in Table 2: while Table 3 contains the quantitative data recording the types of zircon and apatite present.

For purposes of comparison the most prominent characteristics of the suites of the four types of granite are listed together in Table 4. It will be seen that there are no clear cut differences between the four suites. There is not a single case of any mineral, or even a variety of a mineral which is present in all the samples of any type and absent from all the samples of another. In the case of the zircons there is no variety which is dominant in all the samples of any one granite type. The most one can say is that in the majority of samples such a variety of zircon is dominant. With minerals like sphene, epidote and the pneumatolytic group, the distinctions are even more ill defined. Consequently the author feels convinced that in the majority of cases it would be impossible to refer a specimen from the Mourne Mountains to any of the four types by a study of its accessory minerals alone. And this despite the fact that it is generally possible to distinguish the several types in hand specimen and thin section. Admittedly in certain very favourable circumstances the accessory minerals might yield some evidence as to the type of granite being examined. For example, abundant hornblende, decided dominance of the medium elongated type of zircon and absence of epidote would strongly suggest a Type 1 granite. On the other hand absence of these characteristics (as for example in Sample 6) is no evidence that the granite belongs to one of the other types.

Examination of Table 4 suggests that Type 3 has features sufficiently distinctive to impress the stamp of individuality upon it. A low percentage of zircon (say <15 per cent) together with complete absence of apatite and an Index Figure not above 2.1 (the maximum value obtained for a Type 3 granite) should surely be sufficient to determine a sample as belonging to this group. But these three criteria are all exhibited by Samples 3 and 4 (Type 1 granite) and Sample 10 (Type 2 granite). In at least two of these cases examination of a single thin section would have been sufficient to place them in their correct group. It thus appears that, as far as the distinguishing of the four intrusions of the Mourne Mountains is concerned, the complicated process of isolating, examining and counting the accessory minerals is far less accurate than the simple and old established method of relying on thin sections. The evidence all goes to show that not only can rocks alike in hand specimen and thin section yield distinctive heavy minerals suites, but also that rocks markedly different in hand specimen and thin section can yield very similar heavy mineral suites. In other words, similarities and differences in the essential mineral content of these rocks are *not* reflected in their accessory minerals.

Variation in Fluorite and Zircon within the Complex. Careful record has been kept of the approximate altitude from which each sample was collected with the object of noting whether the accessories show any changes in character between the highest and lowest parts of the granites exposed. The pneumatolytic minerals are those most likely to be affected, and their probable irregular distribution has been commented on:

(ii) By A. K. Wells (1931) who claims that these minerals will be most abundant in the higher parts of an intrusion where the fluxes are concentrated.

(ii) By R. W. Marsden (1935) who suggests that these minerals will only occur where the fugitive constituents of the magma are unable to escape. Consequently they will be present in the lower parts of the intrusion, but absent from the higher regions where the fluxes were able to escape into the overlying roof.

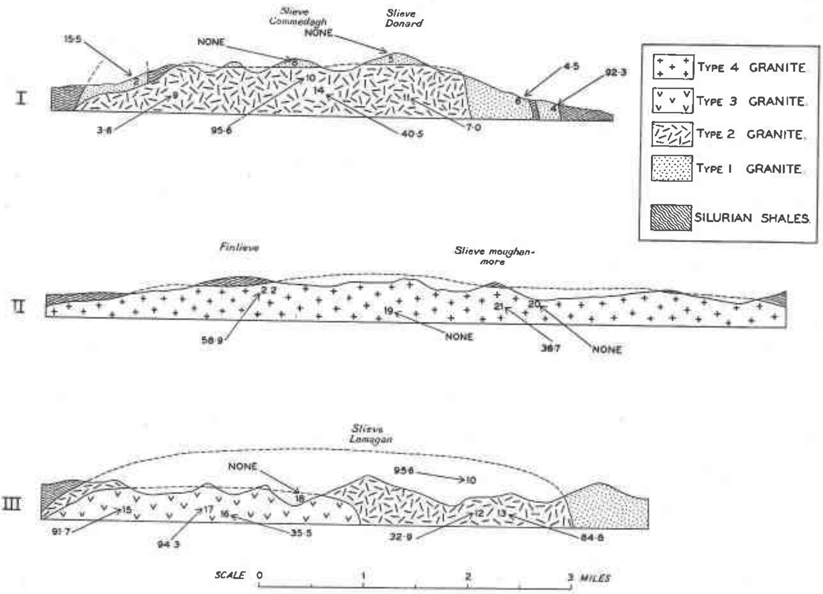

FIG. 2. Distribution of fluorite in the Mourne Mountains granites.

In any granite mass it is not the actual height from which the various specimens were collected that is significant, but their relative distances from wall and roof-rock. Of the two, the latter is the more important: but in granites which have been completely un-roofed it must remain an unknown factor. In the Mourne Mountains, however, not only are there preserved a number of roof-pendants of shale, but also we have remnants of the earlier granites forming the roof into which the later granites were intruded. The complex is, therefore, a particularly suitable one for an investigation of the effect of proximity to roof-rock on the pneumatolytic minerals.

In Fig. 2 the author has reproduced three of the sections across the Mountains given by Richey, and has superimposed on them the numbers of nineteen out of the twenty-two samples examined, together with the percentage of fluorite present in each case. Samples collected from points off the lines of section have been, where possible, projected onto the sections at the correct height.

In Section 1 it will be seen that Samples 5, 8 and 2 collected from near the floor of the Type 1 granite yield in two cases no fluorite and in the third only 15.5 per cent (of the non-magnetic heavy accessories). Sample 4, near the junction of this granite with the shale roof yields 92.3 per cent, while Sample 6 further from the contact yields only 4.5 per cent. In the Type 2 granite, Sample 10 with 95.6 per cent, fluorite is close beneath the roof of Type 1 granite capping Sleive Commedagh, while Samples 14, 11 and 9 at successively greater distances from the roof yield 40.5 per cent, 7.0 per cent and no fluorite respectively.

In Section 2 the figures for the Type 4 granite show that Samples 22 and 21 with 58.9 per cent and 36.7 per cent of fluorite respectively are in close proximity to roof-pendants of shale, while Samples 19 and 20, further removed from these pendants, yield no fluorite.

In Section 3 the results are less conclusive. In the Type 2 granite Samples 12 and 13 which are well removed from the roof of the intrusion yield 32.9 and 84.8 per cent of fluorite respectively. Samples 17, 15 and 16 of the Type 3 granite which are at successively greater depths below the roof yield normal descending percentages—94.3, 91.7 and 35.5, but Sample 18, which is in close proximity to the roof and might be expected to be rich in fluorite, is quite devoid of the mineral.

Taken by and large, however, the results for fluorite appear to bear out Wells' contention that the pneumatolytic accessories tend to be concentrated in the higher parts of an intrusion. Unfortunately in the Mourne Mountains complex, pneumatolytic minerals other than fluorites are present in such minute quantities that no conclusions can be drawn from their distribution.[1]

Brammal (in Groves, 1930) has found that on Dartmoor, there is some slight difference in habit between the zircons of the highest and lowest portions of the granite exposed, and it might be expected that a similar state of affairs would obtain in the Mourne Mountains. It has been

[1] The minerals beryl and topaz, which are well developed in drusy cavities, are absent or very rare as true accessories in the granites.

established by experimental work on the crystallisation of salts that the habit of the crystals can be varied by controlling the physical conditions under which they form. It is not unreasonable, therefore, to assume that the same general statement should be true of rock-forming minerals, not excepting the accessories that form at high magnetic temperatures. The differences of crystal development are very real, and in the present state of our knowledge there is no other known set of factors that could control habit but physical conditions or chemical variations in the environment of the growing crystals.

Since the highest and lowest exposures of granite in the Mourne Mountains are separated by rather more than 2000 feet, the complex appears to be well suited to demonstrate the influence of at least one of these factors upon the crystal habit of the zircons: complications, however, are introduced by the presence of four distinct intrusions each of which be considered separately—and the rather unusual form of these intrusions. The samples of Types 2, 3 and 4 can be dealt with in a standard manner, treating each type separately and calculating the average percentage of each variety of zircon present in three "height zones."[2] The three zones, selected with regard to the various heights from which specimens were available are as follows:—

(1) 500′–800′ (2) 900′–1200′ (3) 1300′ upwards

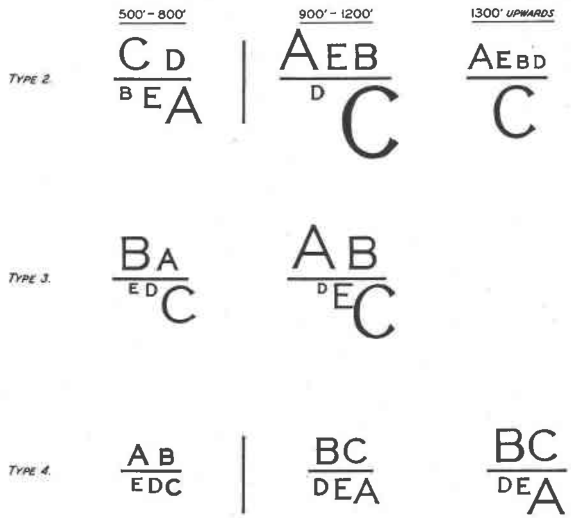

FIG. 3. Diagrammatic representation of variation of zircon in the Mourne Mountains granites.

[2] The form of the Type 1 granite intrusion makes it impossible to apply the same treatment to it.

For each of these three height zones the average percentage of the five types of zircon in Table 3 has been calculated and also the positive or negative deviation from the average for the whole complex. The results are represented diagrammatically in Fig. 3. For each height zone[3] a symbol is given in which A, B, C, D and E indicate the five varieties of zircon. Above a central horizontal line are placed the letters corresponding to the types of zircon which have a percentage above the average for the whole complex: below the line are the letters corresponding to the types which are below the average. The type which is most above the average is placed at the left above the line, and the type most below the average at the right below the line: while the size of the letters used gives some indication of the relative surplus or deficit of each type. Set out in this manner certain facts are immediately obvious.

In the Type 2 granite the symbols for the two higher zones are very similar (the only difference being a slight deficit of D in one zone and a slight surplus in the other), but are markedly different from the symbol for the lowest zone: in the Type 4 granite exactly the same occurs. It is noteworthy that in both cases the type of zircon which is most above the average in the lowest zone is also most below the average in the other two zones. It, therefore, appears that in these two types of granite there is a noticeable difference in the character of the zircon above and below the 400′ level.

In the Type 3 granite the symbols for the two lower zones (the only ones available) are very similar. If there is any change in the character of the zircon of this intrusion it occurs either below the 500 foot level or above 1200 feet. It is not, of course, to be expected that variation of the zircon in the three types will be apparent at the same altitude since each type was intruded separately and at a different level.

It appears, therefore, that in the two intrusions most suitable for an investigation, there is quite an appreciable change in the character of the zircon between the highest and lowest samples collected. It must be remembered that in neither case was the vertical range more than 1000 feet and consequently one feels that in the comparison of separate but co-magnetic granites which have been eroded to levels differing by several thousand feet—as may frequently be the case—there are liable to be major differences in the habits of the zircons from the separate masses. In fact as Wells (1931) has expressed it: "The Dartmoor type of zircon, if it exists, may well give place in depth to the St. Austell type."

[3] Owing to the low ground occupied by the Type 3 granite, none of the samples from it falls in the third zone—1400′ upwards.

Summary and Conclusions

Methods of separating the heavy accessory minerals of igneous rocks are discussed and the necessity of using quantitative methods stressed.

From a consideration of the Mourne Mountains granite complex it is evident that the degree of variation between the accessory mineral suites from the four intrusions is of the same order as the variation between different samples of any one of the intrusions, both as regards the occurrence of mineral species and their varietal characteristics.

Both the nature of the zircon and the quantity of the fluorite present appear to be affected to a considerable degree by the distance from the roof of the intrusion and consequently before using these minerals as a basis for correlation of two or more granites one must be satisfied that one is sampling approximately the same level in the different masses.

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TABLE 1. HEAVY ACCESSORY MINERALS FROM THE MOURNE MOUNTAINS GRANITES

		Approx. Altitude (feet)	Index Figure	Normal accessories									Pneumatolytic accessories					Secondary accessories						
				Biotite	Hornblende	Zircon	Apatite	Sphene	Pyrrhotite	Magnetite	Ilmenite	Orthite	Anatase	Rutile	Tourmaline	Topaz	Fluorite	Chlorite	Epidote	Zoisite	Clinozoisite	Limonite	White Mica	Haematite
Sample	1	1800	2.5	x	x	x	x			x	x			x		x	x	x	x			x	x	
Outer	2	1400	3.7	x	x	x	x				x	x			x		x	x					x	
	3	1000	0.8	x		x					x						x	x				x		x
	4	600	0.3	x		x				x		x		x			x	x				x	x	x
Type I																								
	5	2700	7.3	x	x	x	x	x		x		x			x					x		x		
Inner	6	900	1.3	x		x		x		x	x						x	x	x				x	x
	7	800	2.4	x		x	x				x			x			x	x	x				x	x
	8	2000	1.4	x	x	x					x							x					x	x
Type II	9	1200	1.5	x		x			x		x					x		x	x			x	x	x
	10	1900	2.1	x		x					x						x	x	x			x	x	x
	11	1300	2.0	x		x					x	x				x	x	x	x			x	x	x
	12	700	4.5	x		x	x	x		x	x			x			x	x	x			x		
	13	600	2.0	x		x	x	x		x		x		x			x	x						x
	14	1400	3.1	x		x		x		x							x	x	x			x	x	
Type III	15	700	0.8	x		x		x		x							x	x	x					x
	16	500	2.1			x		x		x							x	x	x		x		x	
	17	900	2.1	x		x					x		x				x	x					x	x
	18	1100	0.6	x		x		x		x	x	x						x				x	x	
Type IV	19	600	3.0	x	x	x	x	x			x	x						x	x			x		
	20	1000	1.0	x		x	x	x			x	x						x	x			x	x	x
	21	900	1.3	x		x	x	x		x	x						x		x					x
	22	1600	2.5	x		x	x			x					x		x	x	x		x	x		x

TABLE 2. PERCENTAGES OF NON-MAGNETIC ACCESSORIES FROM THE MOURNE MOUNTAINS GRANITES

		Approx. Altitude (feet)	Index Figure	Normal accessories				Pneumatolytic accessories					Secondary accessories			
				Zircon	Apa-tite	Sphene	Or-thite	Ana-tase	Ru-tile	Tour-maline	To-paz	Fluor-ite	Epi-dote	Zois-ite	Clino-zoisite	White Mica
Type I, Outer	Sample 1	1800	2.5	18.7	3.0				1.0		2.0	47.6	1.7			26.0
	2	1400	3.7	68.4	10.2		0.9			0.5		15.5				4.5
	3	1000	0.8	11.4								88.6				
	4	600	0.3	3.9			2.3		0.3			92.3				1.2
Type I, Inner	5	2700	7.3	36.2	12.8	47.4	1.5			1.0				1.1		
	6	900	1.3	73.5		2.9						4.5	14.7			4.4
	7	800	2.4	11.1	0.8				0.1			87.1	0.5			0.4
	8	2000	1.4	97.7												2.3
Type II	9	1200	1.5	91.8							3.6		3.2			1.4
	10	1900	2.1	3.5								95.6	0.3			0.6
	11	1300	2.0	56.7			1.9				3.8	7.0	4.5			26.1
	12	700	4.5	46.6	10.5	4.1			0.9			32.9	5.0			
	13	600	2.0	13.6	0.3	1.0	0.1		0.2			84.8				
	14	1400	3.1	31.3		11.7						40.5	9.0			7.5
Type III	15	700	0.8	6.7		0.9						91.7	0.7			
	16	500	2.1	6.6		41.1						35.5	9.7		1.2	5.9
	17	900	2.1	2.4				0.4				94.3				2.9
	18	1100	0.6	10.8		3.2	0.5									85.5
Type IV	19	600	3.0	68.6	5.2	8.7	9.3						8.1			
	20	1000	1.0	88.3		3.6	2.5						4.1			1.5
	21	900	1.3	30.2	2.3	3.9						36.7	25.6			1.3
	22	1600	2.5	15.1	1.0					1.2		58.9	19.5		4.3	

TABLE 3. QUANTITATIVE DATA OF ZIRCON AND APATITE FROM THE MOURNE MOUNTAINS GRANITES

	Sample	Approx. Altitude (feet)	Index Figure	Zircon (a) Equi-dimensional	Zircon (b) Stout	Zircon (c) Medium elongated	Zircon (d) Much elongated	Zircon (e) Anhedral	Apatite (a) Stout prismatic	Apatite (b) Needle-shaped	Apatite (c) Anhedral	Ratio anhedral:euhedral apatite	Ratio apatite:zircon
Type I, Outer	1	1800	2.5	2.8	19.4	61.2	2.7	13.9	50.7		49.3	1:1	1:6
	2	1400	3.7	5.1	30.9	48.3		15.7	42.9		57.1	4:3	1:7
	3	1000	0.8	15.7	23.9	48.1		12.3					
	4	600	0.3		12.5	49.8		37.7					
Type I, Inner	5	2700	7.3	2.2	15.4	68.1	14.3		32.5		67.5	2:1	1:3
	6	900	1.3	14.8	35.2	31.5		18.5					
	7	800	2.4	7.7	21.5	58.5	6.1	6.2	40.8		59.2	3:2	1:14
	8	2000	1.4	32.5	41.1	1.1		25.3					
Type II	9	1200	1.5	26.1	39.9	12.3		21.7					
	10	1900	2.1	17.9	27.5	27.2	9.1	18.3					
	11	1300	2.0	30.3	42.7	14.6	4.5	7.9					
	12	700	4.5	2.3	22.1	51.2	9.3	15.1	55.6		44.4	3:4	1:4
	13	600	2.0	7.2	40.6	37.7	8.7	5.8	52.1		47.9	1:1	1:45
	14	1400	3.1	14.4	35.4	20.5		29.7					
Type III	15	700	0.8	13.6	31.8	38.6	2.3	13.7					
	16	500	2.1	25.9	51.9	7.4		14.8					
	17	900	2.1	21.4	46.4	25.0		7.2					
	18	1100	0.6	34.9	36.5	14.3	4.8	9.5					
Type IV	19	600	3.0	19.3	36.4	31.8		12.5	55.4		44.6	3:4	1:13
	20	1000	1.0	13.8	39.7	37.9		8.6					
	21	900	1.3	1.7	41.4	44.8		12.1	61.7		38.3	5:8	1:13
	22	1600	2.5	3.1	42.3	43.7		10.9	83.3		16.7	1:5	1:15

TABLE 4. COMPARISON OF THE ACCESSORY MINERAL SUITES OF THE FOUR TYPES OF GRANITE FROM THE MOURNE MOUNTAINS

	Type I	Type II	Type III	Type IV
1. Average Index Figure	2.5	2.5	1.4	2.0
2. Hornblende	Present in half the samples.	Absent.	Absent.	Present in a quarter of the samples.
3. Zircon	Percentage present 40.1%. Medium elongated type dominant—Samples 6 & 8 exceptions.	Percentage present 40.6%. Stout type dominant—Sample 12 an exception.	Percentage present 6.6%. Stout type dominant—Sample 15 an exception.	Percentage present 50.5%. Stout and medium elongated varieties in approximate equal proportions dominant.
4. Apatite	Present in half the samples. Anhedral crystals dominant over euhedral.	Present in one-third of the samples.	Absent.	Present in three-quarters of the samples. Euhedral crystals dominant over anhedral.
5. Sphene	Present in a quarter of the samples.	Present in half the samples.	Present in three-quarters of the samples.	Present in three-quarters of the samples.
6. Pneumatolytic Minerals	Reasonably well represented. One member present in most samples.	Well represented. At least one member present in each sample.	Represented only by fluorite.	Poorly represented. Only present in half the samples.
7. Epidote	Poorly represented. Present in half the samples only.	Well represented. Present in five-sixths of the samples.	Poorly represented. Present in half the samples only.	Very well represented. Present in every sample.