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Tittel Ultrabasic rocks of the Iveland-Evje area				
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"ULTRABASIC ROCKS OF THE IVELAND-EVJE AREA".

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date: April 1968.

SUMMARY:

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INTRODUCTION:

The general petrographic investigation accompanying the 1967 regional geological mapping project indicated that there might exist some kind of relationship between the occurrences of ultrabasic rock material and some of the sulphide mineralizations in the Iveland-Evje basic complex.

As a first attempt at clarifying this relationship, chemical analyses for Ni, Co, Cu, Fe, Ca, Mg and S were made of 22 specimens of ultrabasic material from various parts of the area. Thin sections were prepared for 15 of these analyzed specimens. Additional data, in the form of less complete chemical analyses or thin section descriptions of other ultrabasic specimens from the area, have also been incorporated in this report. Only material collected by A/S Sulfidmalm, has been included in Table I.

In the present report, the chemical and mineralogical data are presented, and an attempt is made at analyzing the material and

interpreting it in light of the problematics of Ni-exploration in the area.

CHEMICAL DATA:

Data of this nature are most conveniently analyzed by means of graphical methods. Because of the predominance of low values combined with a large spread of a minority of values, a direct plotting of the results in a normal coordinate system fails completely in bringing out any essential features. Following E. Grip (1961), the ratios $Cu/(Cu+Ni)$ and $Co/(Co+Ni)$ were calculated, and frequency histograms were constructed for these transformed values, see Fig. 1 a and b. A diagram showing the relation between sulphur and the $Cu/(Cu+Ni)$ ratios was also prepared, Fig. 2, but no trend comparable to that in E. Grip (1961) Fig. 25, can be recognized.

In addition to the ore metals, our data included also the Mg and Ca contents of the ultrabasic specimens, and Fig. 3 shows %Ca plotted versus %Mg. The $Mg/(Mg+Ca)$ ratios were calculated, and their frequency distribution is shown by the histogram Fig. 4a. Fig. 4b illustrates the relation between sulphur content and the $Mg/(Mg+Ca)$ ratios. Plots of the $Cu/(Cu+Ni)$ ratios versus the $Mg/(Mg+Ca)$ ratios and of the $Co/(Co+Ni)$ ratios versus the $Mg/(Mg+Ca)$ ratios are shown in Fig. 5 a and b respectively.

For our purpose, geographical areal variation as well as the quantitative relationships are of interest, and on the above described diagrams, the corresponding map unit coordinates have therefore been added for each plotted specimen.

Comments to the diagrams:

Fig. 1a shows that most specimens have more Ni than Cu, the ones with the highest Ni/Cu ratio coming from map units E8, E9, E10, F10 and D11. Specimen 36 F 9 is noted for its high Cu/Ni ratio.

As seen from the original data in Table I, there is little variation in the Co-content of the investigated ultrabasics, the values being in the range 0.01 to 0.02 mostly. For this reason, it is the Ni-content, above anything else, that accounts for the shape of the histogram in Fig. 1b.

The only information conveyed by Fig. 2 is that the sulphide content of the ultrabasics is generally low and that there is no apparent correlation between Cu/Ni ratio and sulphide content.

In fig. 3, there is an interesting variation in the Ca/Mg ratio. There seems to be two groupings, one around Ca:Mg = 1:2, the other in the region Ca:Mg = 1:9. There are also some values in the intermediate space, and there is a single one from map unit B 13 which plots on the Ca-side of the line Ca = Mg. The Ca-Mg space has been tentatively divided into four sectors: Ca-types, Ca/Mg-types, Mg/Ca-types and Mg-types. Observing the distribution map unit-wise, there is a conspicuous clustering of Mg-types in the central part of the Iveland-Evje area, the Mg/Ca forming a zone around it, and with Ca/Mg and Ca-types constantly plotting in the outer zones of the basic complex. A similar trend is brought out by Fig. 4a, where the existence of two distinct groups of ultrabasics is indicated. Also here, the B 13 sample stands out, forming a group of its own.

From Fig. 4b, there is no correlation between Mg/Ca ratio and sulphide content of the ultrabasic rocks. One observes that all specimens with a noteworthy sulphide content are from the map units F 9, F 10 and F 11 in the central part of the Iveland-Evje complex, but until further evidence is accumulated, no importance should be attached to this. Fig. 5a indicates a correlation between high Mg/Ca ratio and high Ni/Cu ratio, and from Fig. 5b it becomes clear that those rocks with the highest Mg content are also those with the highest Ni content. The clustering of more than 60 % of the analyzed specimens in the domain of high Ni and high Mg is quite conspicuous, and even more important is the fact revealed by the map unit distribution in this diagram, which shows the 'high Ni and high Mg'-ultrabasics to be located entirely within a small central part, while the other ultrabasics (low Ni - low Mg) are consistently restricted to the outer areas of the Iveland-Evje basic complex.

PETROGRAPHICAL DATA:

Table I shows besides the chemical data also the essential results of microscopical examination of the ultrabasic rocks. On the basis of Table I, the investigated ultrabasics seem to fall into two main groups, one peridotite-harzburgite group characterized by a notable content of one or more of the minerals olivine, serpentine and ortho-pyroxene. The other group, which for simplicity might be referred to as the hornblendite group, is characterized by a predominance of clin amphibole, mostly with subordinate amounts only of other minerals. What makes the term hornblendite unsatisfactory, is the fact that the clin amphibole of these rocks rarely is the common, dark green hornblende.

In some cases cummingtonite predominates, in other cases there might be actinolite or, most commonly, a light green clin amphibole of the hornblende group. Quite often there is more than one type of clin amphibole present. What this actually means, is that there is no such clear division into two petrographic groups of ultrabasics, but rather two extremes with a gradual transition between them. At the one end, there are a number of specimens with olivine-serpentine or olivine-hypersthene which represent more or less fresh peridotite-harzburgite. Then there are representatives of the transitional stage with dominance of anthophyllite and/or cummingtonite. With increasing Ca-content there come tremolite-rich rocks which again are succeeded by rocks with light greenish hornblende. The second extreme is represented by monomineralic hornblendite made up chiefly of green, common hornblende.

The freshest rocks point to the existence within the Iveland-Evje area of peridotitic as well as harzburgitic types of primary ultrabasic material, but so far, no differences in mode of occurrence have been noted between the olivine-rich and the more pyroxene-dominated ultrabasics of the area.

As for differences between the first-mentioned groups of ultrabasics, the "hornblende group" is characterized by variable but higher SiO_2 -content than the peridotite-harzburgite group, and possibly, this second group can be explained as originally peridotite-harzburgite which has after its emplacement been metamorphosed under the metasomatic introduction of SiO_2 . Conceivably this might have taken place during the regional granitization accompanying the intrusion of the Høvringsvann granite. It should be noted, however, that the "hornblende group" differs from the peridotite-harzburgite also in a predominance of "calcium-minerals" compared to the "magnesium-minerals" of the first group. Since a replacement of magnesium by calcium is not readily seen as a direct consequence of some granitization process, the possibility should be kept open, that we are here dealing with ultrabasics, the primary compositions of which were actually different.

DISCUSSION OF THE RESULTS:

From the point of view of ore potential, the results of the chemical analyses are generally discouraging. It should be pointed out, however, that the reason for analyzing these ultrabasic rocks was not to find out whether they would be of mineable grade with respect to Ni or Cu, but in search of some geochemical patterns which could help towards an understanding of the nature of the ultrabasic material in the Iveland-Evje area.

For this reason Mg and Ca determinations were included. As a supplement to the chemical data, thin section investigations of a majority of the analyzed specimens were added. The more important results of this study have been summed up in Fig's 6 and 7.

Essentially, the petrographic data point to the existence of a central area (E10, E11), where primary ultrabasic material has been preserved from thorough metamorphism, whereas outside this central area ultrabasics have suffered more or less complete neocrystallization accompanied by more or less pronounced metasomatic changes. Apparently, there is a gradual increase in degree of metamorphic alteration of the ultrabasic material as one moves away from the above mentioned central area. According to the model of Barth (1947), this could be explained by the central part of the "amphibolite body" having escaped the granitization processes. The increase in SiO_2 and H_2O required for a peridotite to be transformed to a hornblendite would then be a direct consequence of the increasing degree of granitization as one moves towards the outer zones of the Iveland-Evje basic complex.

Paralleling the trend of increasing SiO_2 and H_2O content, however, is the trend from largely "magnesium-minerals" forming the major constituents of the ultrabasics in the central portion of the Iveland-Evje area, towards the notably calcium-rich hornblendites of the outer parts. This fact is also brought out by the chemical data, and some thought should be given to whether or not this can be understood as a consequence also of the granitization process.

When it comes to the chemical data, these acquire considerable significance when studied from the point of view of geographical areal variation. In Fig. 6 those map units have been marked, specimens from which gave values which fall in the high Ni and high Mg corner of the graphs Fig. 5a and 5b. It is interesting to note that also on the basis of these geochemical properties, the central part of the Iveland-Evje area (Litjern-Mølland-Eptevann) marks itself out. It seems unlikely that any granitization process should systematically influence the Ni/Cu, Ni/Co and Mg/Ca ratios so as to create the pattern here observed, and this pattern is rather seen as reflecting some fundamental property of the Iveland-Evje complex. In Fig. 6 the Mg/Ca ratio is shown in colour, using the divisions established in Fig. 3. This shows that, in addition to the central area mentioned above, map unit D16 also falls within the high Mg/Ca class. To extend, on the basis of this one observation, the area of particular interest southwards in the direction of D16 might, however, be to extend the data a bit too far.

It might be stated, though, that this special study has pointed to the central part of the Iveland-Evje area as an outstanding geochemical feature. How this geochemical Ni-high anomaly based on ultrabasics relates to the distribution pattern of possible Ni-ore bodies remains to be understood. Attention is drawn to the coincidence of this geochemical feature with the center of the gravity high anomaly over the Iveland-Evje area noted by Scott Smithson (). A/S Sturidmalm's geological mapping in 1967 also outlined this part of the area as central with respect to the occurrence of fresh, noritic gabbro.

Petrographical data

Rock name

		Chemical data							Petrographical data											
Spec. nr	Map unit	Ni	Co	Cu	Fe	S	Ca	Mg	Olivine	Serpentine	Hypsthene	Ortho-amphibole	Diopside	Clino-amphibole	Chlorite	Fluorapatite	Talc	Quartz	Barnet	Rest
7 F10	F10	0.35	0.02	0.17	11.1	2.1	4.3	25.-				X		■				X		
21 E10	E10	0.10	0.01	0.08	12.5	0.69	2.2	8.8						■				+		
V-V 14	E10	0.14	0.02	0.02	10.1	0.23	1.2	17.5	+		○			○						
3 F.N.	B13	0.02	<0.01	0.02	20.4	0.14	5.5	5.-						■				X		Plag.
36 F9-VV	F9	0.19	0.03	1.6	21.5	8.2	1.3	10.-						■				X		
27 D9	D9	0.06	0.01	0.03	7.5	0.14	2.3	10.-						■						
4 F.N.	D16	0.03	0.01	0.09	19.-	0.55	0.9	10.-						■				.		
17 A9	D9	0.04	<0.01	0.03	14.4	0.17	1.1	12.5						■		+		X		
27 A9	E9	0.05	0.01	0.19	8.1	2.9								■				.		
9 D11	D11	0.11	0.01	0.03	10.7	0.29	2.6	17.5	○	○				X				.		
34 F11	F11	0.25	0.02	0.14	10.7	3.0	2.1	16.-	○		○		X	■				.		
24 H9	H9	0.02	<0.01	0.01	8.2	0.29	5.8	10.-					X	■				.		
31 E7	E7	0.04	0.01	0.02	7.0	0.17	5.5	11.-						■				.		
6 F.N.	D16	0.03	0.02	0.01	11.0	0.10	4.0	7.5						■				.		
17 E10	E10	0.13	0.01	0.02	12.6	0.26	1.2	18.-	○	X				○					X	
3 D4	D4													■						
3 D4	D4													■		○		X		
0/1	F10								X	X	X			X	.		.		X	
V-V 14 x	E10								X	.				.	X		.			
17 B E5	E5													■						
6 E8	E8								X					■		○		.		
3 E.O. Klegg	F10	0.15	0.02	0.03	10.3	0.3	0.9	20.-						■						
14 E9	E9	0.17	0.01	0.03	9.1	0.32	1.8	17.5						■						
34 F9-J	F9	0.35	0.04	0.26	26.1	12.6	1.8	7.5						■						
13 D11	D11	0.07	0.01	0.02	7.6	0.16	5.5	10.-						■						
10 F3	F3	0.07	0.01	0.04	7.3	0.23	4.5	11.-						■						
8 D5	D5	0.02	<0.01	0.02	12.9	0.22	4.8	8.8						■						
15 E8	E8	0.11	0.01	0.02	9.0	0.20	3.1	15.5						■						

Symbols, mineral constituents:

- Dominant >60%
- Major 30%-60%
- X Essential 10%-30%
- +

• Accessoric

TABLE I. Ultrabasics of the Ireland-Sive area.

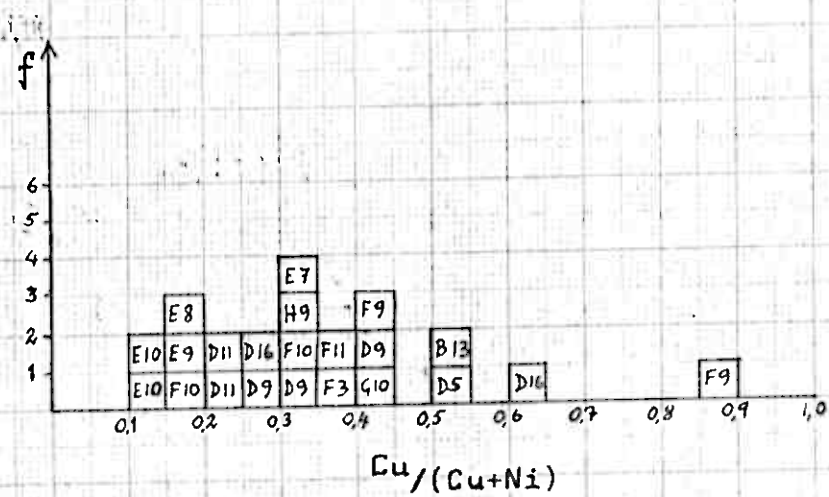


Fig. 1a

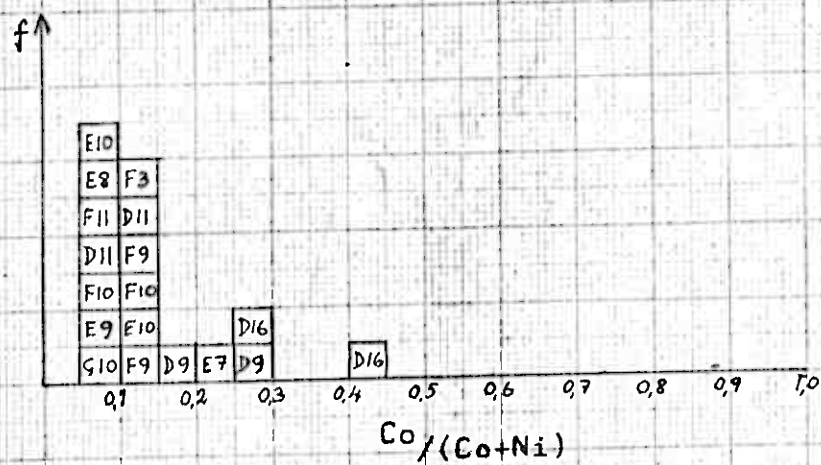


Fig. 1b

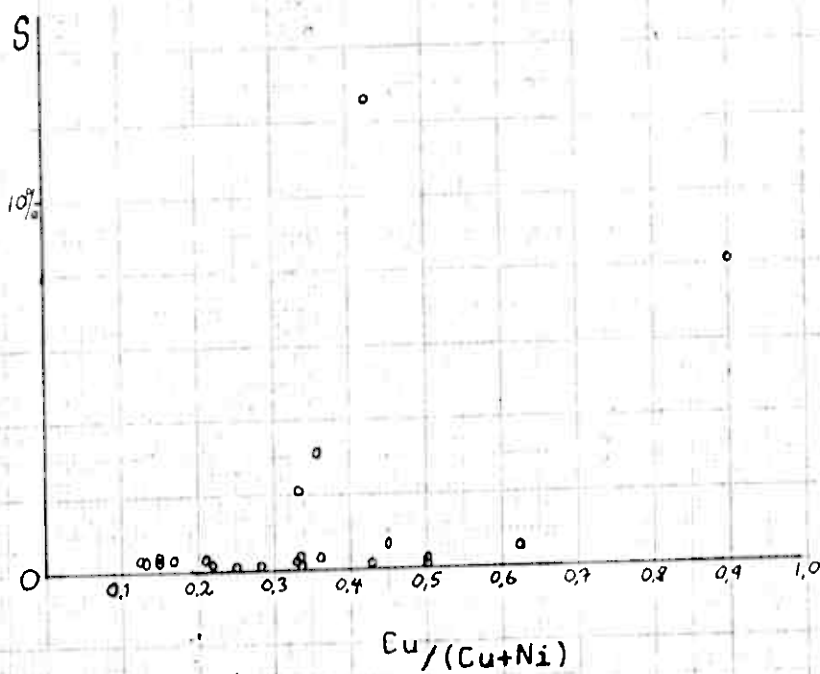


Fig. 2

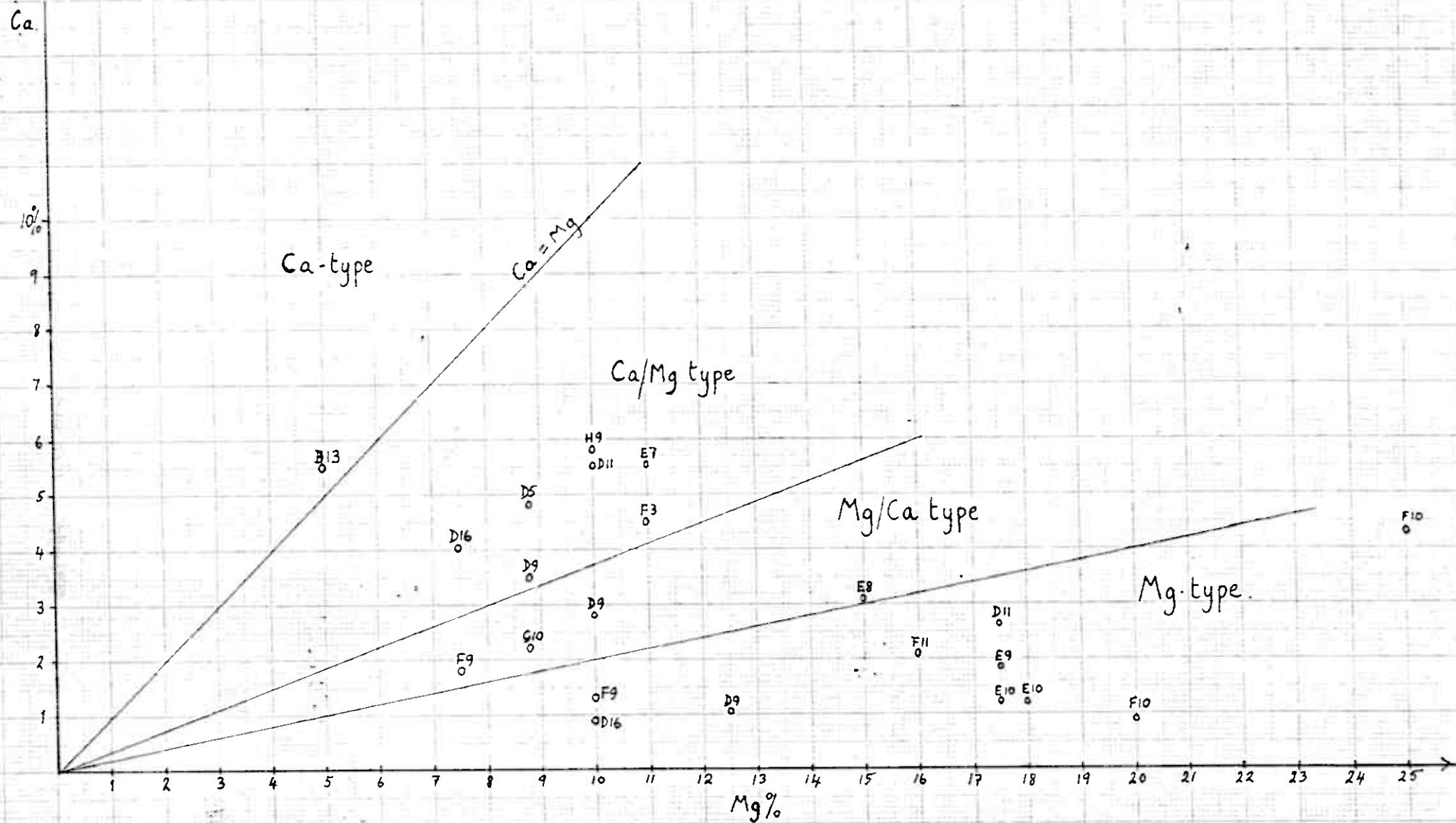


Fig. 3

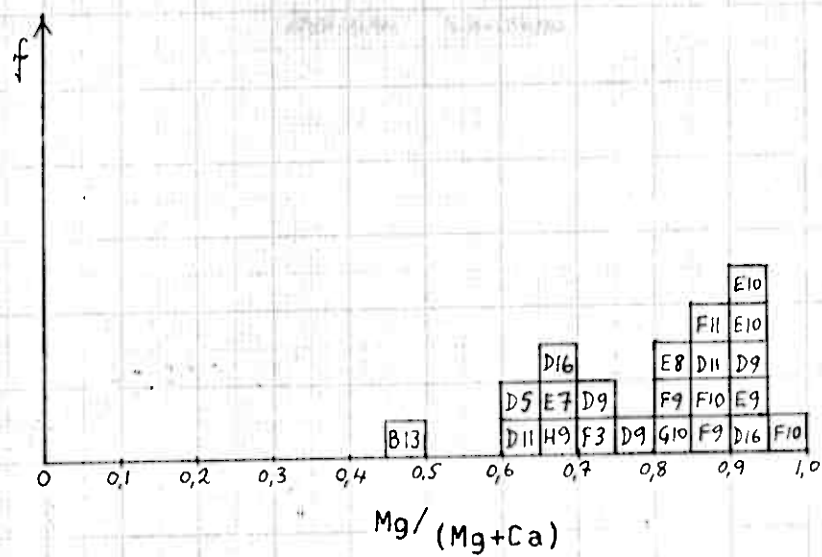


Fig. 4a

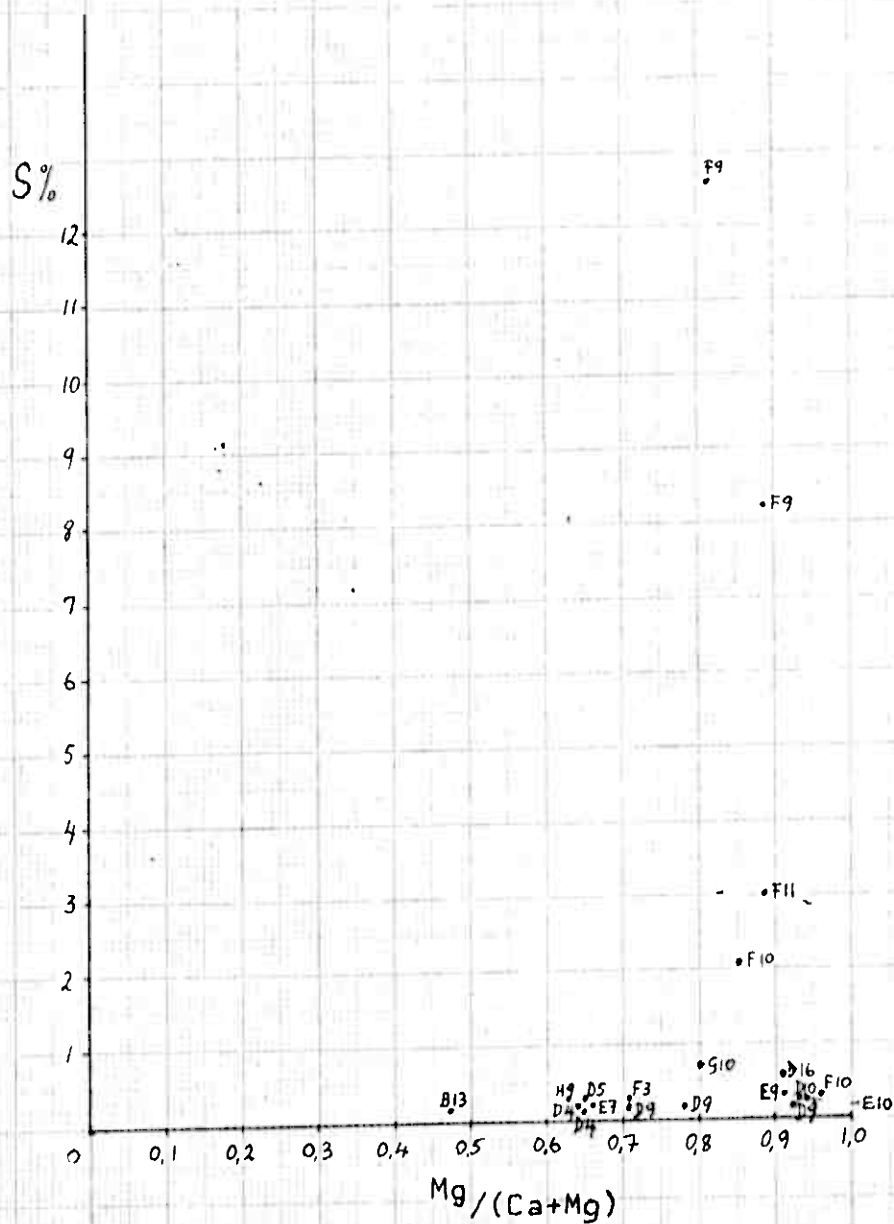


Fig. 4b

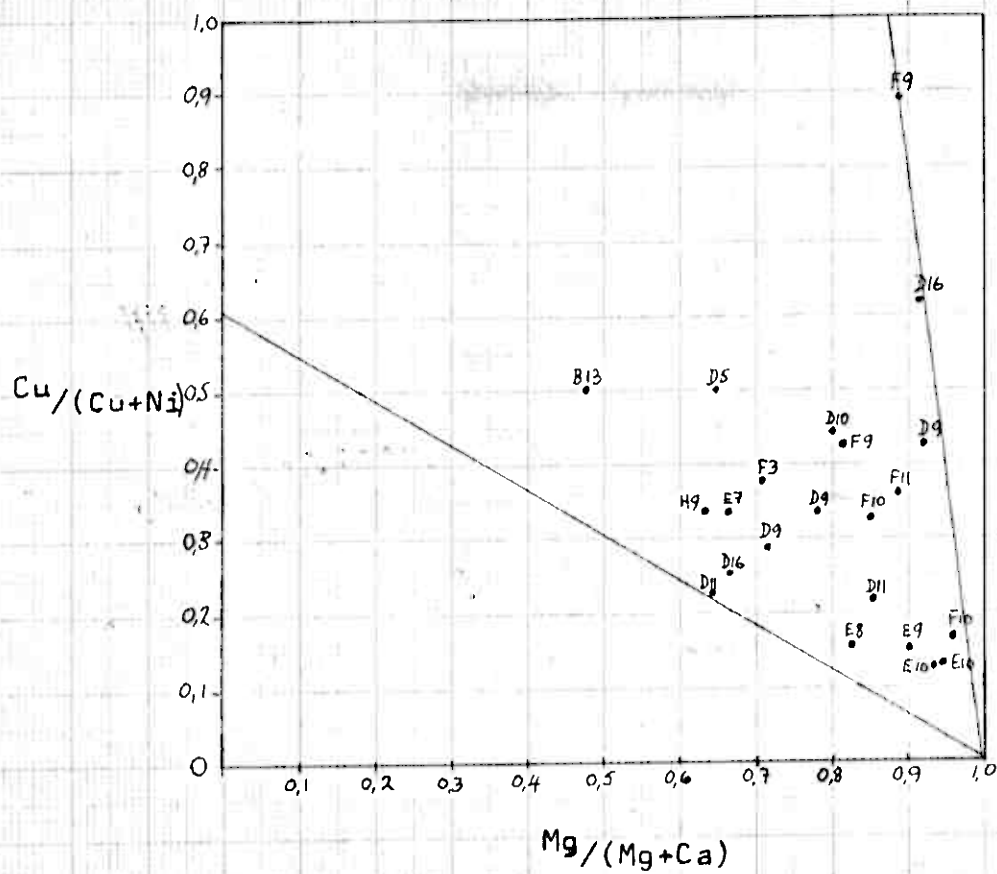


Fig. 5a

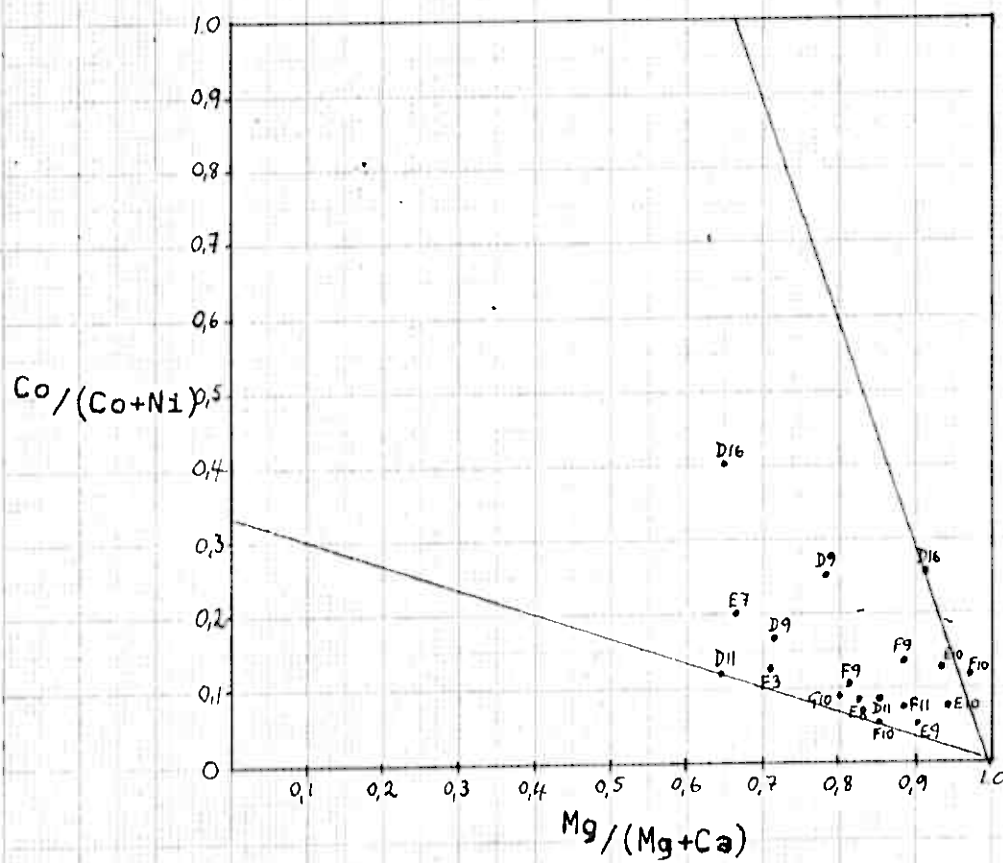


Fig. 5b

