

Note on the distribution of some minor elements in coexisting ortho- and clino-pyroxene

BY

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Orthorhombic and monoclinic pyroxene have been successfully separated in two Norwegian hypersthene-gabbros and in a banded basic inclusion in one of them. When treated with methylene-iodide (sp.gr. 3.3), the clinopyroxene floated in contrast to the orthopyroxene which accumulated at the bottom. A purification of these concentrates was obtained with a Franz Isodynamic Separator due to the higher magnetic susceptibility of the orthopyroxene.

To test the influence of the major elements on the minor element distribution, some determinations of Al, Mg and Fe have been included in table I. Not enough pyroxene was separated for complete analyses. Two analyses of pyroxenes from a banded gabbro in Lofoten are shown in the table, though the concentrates obtained were not of sufficient purity.

The trend of the distribution of the minor elements is well demonstrated for five of the ferrides. Ti, Cr, V and Fe^{3+} are enriched in the clinopyroxene, Mn in the associated orthopyroxene.

The high contents of Al in the orthopyroxene are noteworthy. Al is divided between tetrahedral and octahedral coordinations in pyroxene. Due to the works of WAGER and DEER (1939), EDWARDS (1942), NOCKOLDS and MITCHELL (1948) and MUIR (1954) it is well known that the orthorhombic pyroxene is relatively enriched in iron compared to the associated monoclinic pyroxene. This is confirmed by the present analyses, table II. According to RAMBERG (1952) this indicates that the amount of tetrahedrally coordinated Al is greater in the rhombic than the monoclinic pyroxene, but this is contrary to experience. NOCKOLDS and MITCHELL (1948) have suggested that Al in tetrahedral position controls the distribution of the three-valent trace elements in coexisting pyroxenes, thus balancing the positive charges introduced in the Y-group by the three-valent ions. In the present case, Al replaces Si in the orthopyroxene as well, and electric neutrality will be maintained in the lattice even by quite large substitutions of Cr^{3+} and V^{3+} . It is known that Ti^{4+} and Fe^{3+} may replace Si in the pyroxenes (KUNO 1955), and it seems to be a natural assumption that Al^{3+} , Fe^{3+} , Ti^{4+} , Cr^{3+} , and V^{3+} divide themselves between tetrahedral and octahedral positions in the pyroxenes according to

Table I. Analyses of associated orthorhombic and monoclinic pyroxenes.

	Al ₂ O ₃	Fe ₂ O ₃	MgO	FeO	Ti	Cr	V	Ni	Co	Mn	N _γ
Orthopyroxene, hyp.-gabbro, Skjaekerdal	3.20	0.20	25.20	15.48	0.36	0.05	0.02	0.07	0.011	0.27	1.693 ± 0.002
Clinopyroxene, «	4.79	0.34	15.80	7.19	0.84	0.11	0.04	0.10	0.011	0.14	1.697 ± 0.002
Orthopyroxene, hyp.-gabbro, Raana	2.66	0.42	25.57	15.50	0.38	0.16	0.04	0.04	0.010	0.19	1.695 ± 0.002
Clinopyroxene, «				6.98	0.72	0.25	0.08	0.05	0.007	0.05	1.698 ± 0.002
«					0.90	0.25	0.07	0.02	0.006	0.10	
Orthopyroxene, saxonite, «					0.30	0.23	0.03	0.03	0.009	0.12	
Orthopyroxene, banded inclusion, Raana				12.98	0.37	0.06	0.03	0.02	0.009	0.28	1.687 ± 0.002
Clinopyroxene, «	3.73	0.26	16.30	5.72	0.49	0.07	0.06	0.01	0.005	0.14	1.687 ± 0.002
Orthopyroxene, banded gabbro, Lofoten					0.25		0.01	0.005	0.009	0.40	1.707 ± 0.002
Clinopyroxene, «					0.50		0.02	0.006	0.008	0.24	1.712 ± 0.002

The minor constituents are determined spectrographically.

Table II. Iron enrichment of coexisting pyroxenes.

	Fe	atomic
	Fe + Mg	%
Orthopyroxene, hyp.-gabbro, Skjaekerdal26	
Clinopyroxene « « «20	
Orthopyroxene, banded inclusion, Raana20	
Clinopyroxene « « «16	

physical and chemical conditions prevailing at the time of their formation. These ions are more easily accepted in the structure of the clinopyroxene.

Mn follows Mg^{2+} and Fe^{2+} , and the contents of the latter divalent ions are always highest in the orthopyroxene. The amount of Mn in the orthopyroxene is approximately twice as high as the clinopyroxene, and so are the contents of $Mg^{2+} + Fe^{2+}$.

Assuming that Ni and Co substitute for Mg^{2+} and Fe^{2+} , we should expect an enrichment of these elements in the orthopyroxene. The failure, however, to determine exactly the behavior of Ni and Co is probably due to admixed particles of pyrrhotite and pentlandite. As these sulphides seemed to be absent in the banded inclusion of the Raana gabbro, the analyses of the pyroxenes separated from this ought to be the most reliable. Thus there may be some indication of an enrichment of Ni and Co in the orthopyroxene. Regarding the distribution of Ni among the pyroxenes, we are faced with a problem known to all petrologists: the association of nickelbearing sulphides and norites. SHAND (1950) believed that Ni originally was concentrated in the magnesian minerals of the noritic rocks. And SULLIVAN (1948) suggested that the orthopyroxene possibly was unable to incorporate as much Ni as the monoclinic pyroxene, making Ni available for ore deposition. Sullivan's proposition does not find support from the present investigation.

Visual examination of the spectrographic plates shows that Ga (camouflaged by Al) and Sc (substituting for the pair (Mg, Fe) or Ca) are enriched in the clinopyroxene of Skjaekerdalen, whereas Mo and Pb is slightly enriched in the associated orthopyroxene. Zr was not present in detectable amounts.

Thanks are due to Prof. T. F. W. Barth for helpful suggestions.

Statens råstofflaboratorium, november 1957.

LITERATURE

- EDWARDS, A. B. (1942): Differentiation of the dolerites of Tasmania. *Journ. Geol.*, 50, 451–480, 579–610.
- KUNO, H. (1955): Ion substitution in the diopside-ferro-pigeonite series of clinopyroxenes. *Am. Min.*, 40, 70–93.
- MUIR, I. D. (1954): Crystallization of pyroxenes in an iron-rich diabase from Minnesota. *Min. Mag.*, 30, 376–388.
- NOCKOLDS, S. R. and MITCHELL, R. L. (1948): The geochemistry of some caledonian plutonic rocks: a study in the relationship between the major and trace elements of igneous rocks and their minerals. *Trans. Roy. Soc. Edinburgh*, Vol. LXI, Part II.
- RAMBERG, H. (1952): Chemical bonds and the distribution of cations in silicates. *Journ. Geol.*, 60, 331–355.
- SHAND, S. J. (1950): Eruptive rocks.
- SULLIVAN, C. J. (1948): Ore and granitization. *Ec. Geol.*, 43, 471–498.
- WAGER, L. R. and DEER, W. A. (1939): The petrology of the Skaergaard intrusion, Kangerdlugssauk, East Greenland. *Medd. om Grønland* 105, 1–352.

Manuscript received November 23, 1957.

Printed August 1958.

Tron dheims-feltet—Gneisområdet—Jotunheims-området.

Bemerkninger til Ivar Hernes's avhandling.

S u m m a r y: In a recent paper in this journal by Ivar Hernes on "Connections between the Trondheim and Sunnhordland Regions, Caledonides of Norway" Mr. Hernes maintains that the Trondheim Region has its continuation in the north-western gneiss area of southern Norway, and, secondly, that the Jotunheim Region occupies a less central position in the Caledonian orogen than the Trondheim Region. There is nothing to object to this. The same views were brought forward for the first time about 20 years ago by Olaf Holtedahl and must now be said to be generally accepted. But Mr. Hernes is to blame for not duly having cited the writings of Holtedahl and subsequent writers on the same subject. A reader not well acquainted with Norwegian geology and literature must get the impression that the concepts mentioned above were new and invented by Mr. Hernes.

I de første perioder i sin siste avhandling skriver Hernes (1957, s. 247): "The traditional view put forward in Norwegian geological discussions has been to draw the links between the Trondheim region