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A NATURAL COBALT ANALOGUE OF PENTLANDITE

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Much pertinent information regarding the synthetic (Fe, Co, Ni)$_9$S$_8$ pentlandites is to be found in the literature of inorganic chemistry. This information is well summarized in the work of Ibrahim (1959). The homogeneous π-phase, (Fe,Ni)$_9$S$_8$, with the atomic ratio Ni:Fe close to one, is isostructural with Co$_9$S$_8$(Lindqvist *et al.*, 1936). Cobalt, however, has been shown to be present in natural pentlandites in amounts ranging from nil to about 2.9 wt.-% (Ibrahim, 1959).

Further evidence for the existence of natural solid solution along the nickel pentlandite—cobalt pentlandite join is obtained by observing the change in chemical composition in some pentlandites of Northern Karelia in Finland. Pentlandites rich in cobalt have been recognized at several localities in Northern Karelia, associated with copper and iron sulfides. In the following, the pentlandite of Varislahti and Savonranta pyrrhotite deposits as well as of the Outokumpu mine (Vähätalo, 1953) will be described. The name cobalt pentlandite is here adopted for the natural pentlandite rich in cobalt. The mineral was first noticed in 1957 as a minor constituent of the Varislahti sulfide deposit. Of the several cobalt minerals (linnaeite-siegenite, cobaltite, safflorite), cobalt pentlandite is the most abundant and has the widest geographical distribution. It is found associated with other sulfides, notably pyrrhotite. It occurs as exsolved lamellae as well as separate crystals rarely exceeding 4 mm. in diameter. Crystals have cubic cleavage. The color is more lustrous than that of nickel pentlandite.

The results of the chemical analyses are shown in Table 1. By comparing the analyses 4 and 5, it will be seen that the pentlandite in the lamellae shows the higher nickel content. The nickel pentlandite associated with pyrrhotite (analysis no. 7) is found in the Outokumpu ore as an especially rare accessory mineral in the parts of the contact zones of ore and serpentine (Vähätalo, 1953).

In Fig. 1 the cobalt and nickel pentlandites are plotted according to atomic percentages of the three cations.

X-ray powder diffraction patterns were made of some concentrates using a 114.6 mm. diameter camera and x-ray diffractometer technique. The results obtained were corrected by using silicon as a standard. The powder data of cobalt pentlandite (analysis no. 3) are shown in Table 2 together with those of nickel pentlandite (ASTM 8–90).

TABLE 1. CHEMICAL COMPOSITION OF SOME PENTLANDITES

	1	2	3	4	5	6	7
Co	49.33	46.52	42.73	30.94	22.77	18.84	1.92
Ni	9.06	9.11	9.78	21.10	23.52	26.98	31.82
Fe	10.32	11.57	13.22	15.62	20.46	21.10	32.30
S	31.29	32.80	34.25	32.34	33.25	33.07	33.96

1–2. Pyrrhotite-cubanite-chalcopyrite ore. Vrl-15, Varislahti, Kuusjärvi parish.
3. Pyrrhotite-chalcopyrite-pyrite ore. 285 Mpl 2, Outokumpu mine.
4–5. Pyrrhotite-chalcopyrite-pyrite ore. X area, Outokumpu mine.
6. Pyrrhotite ore. Sr-Sä 35, Säimen, Savonranta parish.
7. Lenticular body of pyrrhotite in skarn rock. 320 Mp 3, Outokumpu mine.

As may be expected from the variability in chemical composition, the lattice constants also vary slightly. The following results show that there is a general increase in lattice constants of pentlandites with decrease in Co:(Fe,Ni) ratio:

	a_0
Outokumpu, analysis No. 7	$10.067_5 \pm .001$ Å
Outokumpu, analysis No. 4	$9.999_8 \pm .001$ Å
Varislahti, analysis No. 2	$9.969_7 \pm .001$ Å
Co_9S_8, synthetic (Ibrahim, 1959)	$9.929 \pm .002$ Å

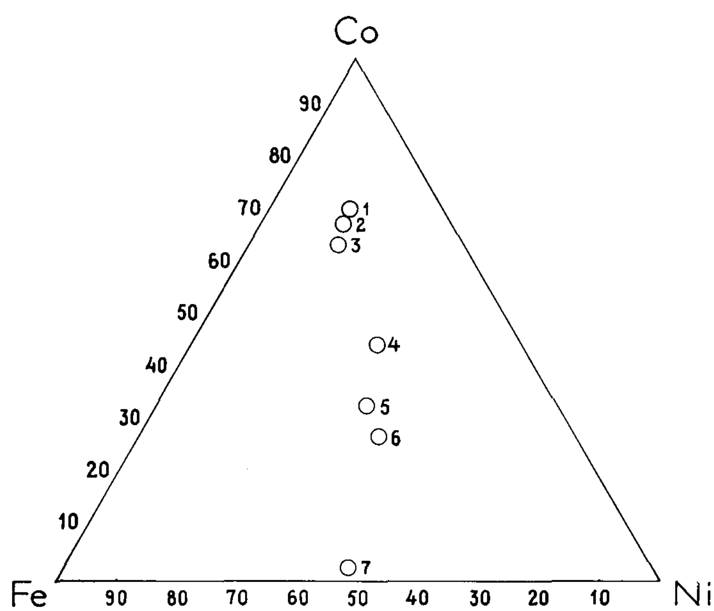

FIG. 1. Atomic per cent diagram of pentlandites, analyses 1–7.

TABLE 2. X-RAY POWDER SPACING DATA FOR NATURAL COBALT PENTLANDITE AND NICKEL PENTLANDITE

hkl	Cobalt Pentlandite (analysis No. 3)		Nickel Pentlandite (ASTM 8–90)	
	d (Å)	I	*d* (Å)	I
111	5.75	m	5.78	30
002	4.97	vw	5.01	5
022	3.52	vw	3.55	5
113	3.008	vs	3.03	80
222	2.878	m	2.90	40
004	2.496	vvw	2.51	5
133	2.288	mw	2.30	30
024	2.237	vvw	2.25	5
115, 333	1.918	s	1.931	50
044	1.763	vs	1.775	100
135	1.686	vw	1.697	5
335	1.522	w	1.530	10
226	1.505	w	1.514	10
355, 731	1.298	mw	1.307	20
008	1.246	mw	1.255	20
157, 555	1.151	w	1.160	5
119, 357	1.097	vvw	1.105	5
139	1.045	w	1.052	$5a_1$
448	1.018	m	1.025	$20a_1$
159, 377			0.9704	$5a_1$
088			0.8878	$5a_1$
579			0.8068	$5a_1$
0·4·12			0.7941	$10a_1$

Optical properties of the cobalt pentlandites are similar to the optical properties of nickel pentlandite. Under microscope the color is slightly lighter than that of nickel pentlandite.

As can be seen from the measurements kindly made by Mr. Lauri Hyvärinen of the Geological Survey of Finland, the Vickers-hardness (M_{H50}) falls off slightly with decreasing cobalt content:

Varislahti, analysis No. 1	310 kg./mm.^{2}
Outokumpu, analysis No. 4	280 kg./mm.^{2}
Kotalahti, nickel pentlandite	260 kg./mm.^{2}
Savonranta, analysis No. 6	245 kg./mm.^{2}

Grinding hardness of cobalt pentlandite is slightly lower than that of pyrrhotite.

The etch reactions are similar to those obtained with the nickel pentlandite: negative with KOH, $HgCl_2$, KCN, HCl, and $FeCl_3$. A reaction occurs with HNO_3: a bright blue stain with cobalt pentlandite but a brown stain with nickel pentlandite.

Some qualitative studies of *x*-ray powder patterns showed a loss of intensity of pentlandite lines during heating at about 350° C. (20 times for 2 minutes in air). Spinel (M_3S_4) pattern appeared, increased in intensity, and the siegenite member of the M_3S_4 group was the final product, when the pentlandite structure disappeared.

This work is part of a program being conducted by the Outokumpu Company. Acknowledgement is made gratefully to Mrssrs. Jorma Kinnunen, M.A., and Lasse Kosomaa, M.A., for providing the chemical data obtained, and to Mr. P. Westerlund, Min.Eng., for his help in flotation of some samples for final purification.

The authors wish to express their appreciation to the Outokumpu Company for permission to publish this paper.

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PEACOCK MEMORIAL PRIZE

The Walker Mineralogical Club announces that it has awarded its Peacock Memorial Prize (1958) of two hundred dollars "for the best scientific paper on pure or applied mineralogy, including crystallography, mineralogy, petrology, ore genesis, and geochemistry," submitted by a graduate student, to

Mr. R. L. Moxham,
1395 Birch Avenue,
Burlington, Ontario.

a graduate student in the Department of Geology, Hamilton College, McMaster University. The subject of Mr. Moxham's paper was "Minor Element Distribution in Some Pyroxenes of Metamorphic Origin." He did his work under Professor Denis M. Shaw, Chairman of the Department of Geology, Hamilton College, McMaster University.

The Walker Mineralogical Club announces at this time that it is offering the Peacock Memorial Prize again in 1959. A copy of the announcement and conditions follows.

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1. The author of the paper shall be any graduate student enrolled in a Canadian university, a Canadian graduate student enrolled in any university, or any graduate student on a Canadian subject.

2. The paper, written in French or English, will be accepted for competition up to two years after completion of the work, even though the author may be enrolled no longer as a graduate student.

3. The paper may be in the form of: (a) a thesis,
(b) a paper ready for publication,
(c) a printed publication.

4. The paper may offer new or refined observations; or a significant synthesis and interpretation of existing data; or some new or improved application of mineralogy to useful ends; or the results of other work of sufficient interest and value.

5. Each paper must be accompanied by a letter from the candidate's supervisor stating the nature and extent of the assistance he may have given to the work submitted.

6. The paper is to be addressed to:
The Secretary, Walker Mineralogical Club,
100 Queen's Park, Toronto 5, Ontario.

7. CLOSING DATE OF THIS COMPETITION—December 31, 1959.

If no paper of sufficient merit is received, the prize will not be given. All papers submitted will be returned to their authors as soon as the judging is completed. Announcement of the award will be made in the appropriate publications.

Eighth National Clay Conference

On October 12, 13, and 14, 1959, the Eighth National Clay Conference will be held on the University of Oklahoma campus at Norman, Oklahoma under the auspices of the Clay Minerals Committee of the National Academy of Sciences-National Research Council.

A field trip will be arranged for either Sunday, October 11 or Thursday, October 15, probably to the Wichita Mountains in southwest Oklahoma to visit clay occurrences of geological interest.

Two symposia of invited papers will be held on the subjects of "Clay-Water Systems" and "Clay Mineral-Geochemical Prospecting Methods." In addition to these special symposia there will be general sessions of contributed papers. All those having contributions should contact Professor C. G. Dodd, Chairman, Eighth National Clay Conference, University of Oklahoma, Norman, Oklahoma. The title and a letter of intent should be sent in by June 1, and a 250 word abstract by July 1.

Further information and a preliminary announcement of the Conference may be obtained by writing Professor Dodd.

Bequest to Columbia University

Columbia University has announced what is believed to be one of the largest single bequests in Columbia's 205-year history. This bequest, from the late Henry Krumb, is expected to total nearly $6 million immediately, and eventually may amount to about $10 million. About one-half is directed to be applied toward the cost of a proposed Engineering Center on the Morningside campus. A similar amount is to be used for improving and building up the School of Mines.

Organic Geochemistry Section of the Geochemical Society

A group of organic and petroleum geochemists plan to organize an Organic Geochemistry Section within The Geochemical Society. The purpose of this section is to offer a common forum for research workers who are active in the various fields of organic and petroleum geochemistry. Recent advances in these fields indicate the desirability of the exchange of ideas and of their coordination with modern concepts of inorganic geochemistry and geology. The interest shown by earth scientists in The General Petroleum Geochemistry Symposium, which was held recently at Fordham University, supports this view.

Plans are being made to organize the Organic Geochemistry Section at the 1959 annual meetings of the Geological Society of America and The Geochemical Society in Pittsburgh, Pennsylvania, November 2–4. Information regarding this section may be obtained from the members of the Interim Executive Committee, who are listed below. The members of this committee invite suggestions and comments regarding this matter. It would be helpful if interested individuals could, in advance of the annual meeting, signify their intention to affiliate with the Section, whether or not they plan to attend the meeting.

The only requirements for affiliation with the Section are membership in the Geochemical Society and an interest in organic geochemistry. Membership in the society is open to individuals who have a bachelor's degree or its equivalent in a natural science and an interest in applying that science to geologic problems. Dues are $2.00 per year. Application blanks can be obtained from the Secretary, Professor Konrad B. Krauskopf, Department of Geology, Stanford University, California.

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