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KANOITE, $(Mn^{2+}, Mg)_2[Si_2O_6]$, A NEW CLINOPYROXENE IN THE METAMORPHIC ROCK FROM TATEHIRA, OSHIMA PENINSULA, HOKKAIDO, JAPAN

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Abstract Kanoite, $(Mn^{2+}, Mg)_2[Si_2O_6]$, a new clinopyroxene, is monoclinic, $P2_1/c$, $a_0=9.739$ Å, $b_0=8.939$ Å, $c_0=5.260$ Å, $\beta=108.56°$, $Z=4$. The strongest diffractions in the X-ray powder pattern are 3.211(100)(220), 3.021(90)($\bar{2}21$), 2.921(80)($\bar{3}11$), 2.910(90)(310), 2.493(40)(002), 1.627(40)($\bar{5}31$). Electron microprobe and supplementary wet chemical analyses gave SiO_2 50.20, Al_2O_3 0.04, Fe_2O_3 0.39, FeO 2.64, MnO 31.19, MgO 15.08, CaO 0.57, Na_2O 0.03, K_2O 0.03, total 100.17%. It is optically biaxial positive, $2V=40°—42°$, refractive indices *n*s $\alpha=1.715(2)$, $\beta=1.717(2)$, $\gamma=1.728(2)$; optical orientation $b=Y$, $c\wedge Z=+42°$. Colourless in thin section. It is light pinkish brown in fresh colour and with a vitreous luster. Streak white. Cleavage {110} perfect. Hardness(Mohs)=6. Density 3.66 g/cm^3(meas.); 3.60 g/cm^3(calc.). Polysynthetic twin on {100} is common.

It occurs as minute grains intergrown with manganoan cummingtonite in metamorphosed manganese ore enclosed in a quartz-rich biotite-garnet gneiss exposed as a reef at the seashore near Tatehira, Oshima Peninsula, Hokkaido.

The name is for Dr. Hiroshi KANO, Professor of Petrology, Akita University, for his geological and petrographical contributions to metamorphic rocks in Japan especially those forming the basement of Japanese Islands.

Occurrence

In Oshima Peninsula, Hokkaido, metamorphic rocks forming basements of Neogene formations are exposed in many places. One of them is the seashore near Tatehira(Fig. 1), where metamorphic rocks called Tatehira metamorphic rocks derived from cherts, pelitic and basic volcanic rocks are found. The grade of metamorphism is hornblende hornfels facies (KOBAYASHI, 1974). Kanoite was found in manganese-rich layers comprising manganese silicates, carbonate and oxide in contact with a quartz-rich biotite-garnet gneiss, which forms a reef near the seashore together with the manganese-rich layers.

In the uppermost level of the reef is a yellow brown spessartine-manganoan cummingtonite-quartz rock underlain by a pink pyroxmangite-manganoan cummingtonite rock, which is intervened from quartz-rich biotite-garnet gneiss by a thin wedge of rhodochrosite-rich rock. In these manganiferous rocks, a few spessartine-bearing quartz veins are developed. Along the west shore of the reef the pyroxmangite-manganoan cummingtonite rock involves a black stained kanoite-bearing seam, which has 1—2 cm thick and about 30 cm long along the strike. As shown in Plate I(a and b), the seam has a banded structure, each band being easily distinguished by its colour, composed in descending order, of dark brown sonolite-galaxite band, greyish tephroite-galaxite band, white rhodochrosite band, brown kanoite band and pink pyroxmangite band.

The kanoite-bearing band consists of kanoite, manganoan cummingtonite and spessartine. with minor pyroxmangite. The grain size of kanoite is 0.1×0.1 mm in maximum and this

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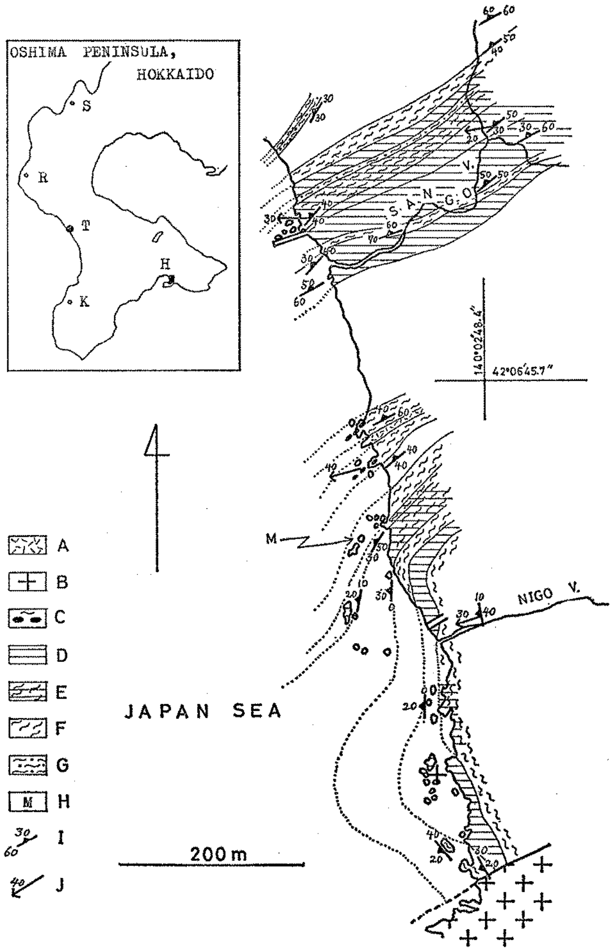

Fig. 1. Geologic map of the Tatehira area.
A: Propyrite, B: Quartz diorite, C: Metamorphosed diabase with boudinage structure, D: Quartzite, E: Metamorphic rock derived from slate, F: Metamorphic rock derived from siliceous slate, G: Metamorphic rock with garnet porphyroblasts, H: The shore reef composed mainly of manganoan minerals, I: Dip and strike of foliation, J: Lineation, M: Locality of kanoite (42° 06′ 39.9″ N, 140° 02′ 44.9″E). Inserted locality map, H: Hakodate, K: Kaminokuni, R: Raruishi, S: Suttsu, T: Tatehira.

is smaller than that of pyroxmangite in neighbouring band, reaching 10×5 mm in maximum dimension. Smaller pyroxmangite grains are occasionally found in kanoite-bearing band and they are considered as relics replaced by kanoite. Under the microscope, kanoite is characterized by polysynthetic twin on {100}(Plate I, d). Smaller grain size of kanoite and its polysnthetic twinning made the accurate determination of some optical properties so difficult.

Physical and Optical Data for Kanoite

Kanoite has light pinkish brown in fresh colour and with a vitreous luster. Streak is white. Perfect cleavage is developed along {110} as in ordinary clinopyroxenes. Hardness(Mohs) is 6. Density is 3.66 g/cm^3(meas.); 3.60 g/cm^3(calc.).

Optical properties and optical orientation are given in Table 1 and Fig. 3 respectively.

Unit Cell and X-ray Powder Data

Since the fine grain size impeded the X-ray single crystal study, the unit cell data were obtained from the X-ray powder pattern in terms of the analogy with those of clinoenstatite and monoclinic $MnSiO_3$ synthesized by AKIMOTO & SYONO (1972)(Table 2). All the unit cell edges have dimensions between those of these two materials well reflecting the

Table 1. Optical and physical properties of Kanoite.

α	1.715±0.002
β	1.717±0.002
γ	1.728±0.002
$2V_Z$	40—42°
$c \wedge Z$	42°
b=Y,	O. A. P. (010)

Cleavage : {110} good. $\{1\bar{1}0\} \wedge \{110\} \simeq 88°$
Twinning: {100}, polysynthetic, common.
Colour : Colourless in thin section.
Hardness (Mohs) : 6.
Density : 3.60g/cm^3 (calc.), 3.66g/cm^3 (meas.)

Table 2. Unit cell parameters of synthetic monoclinic $MnSiO_3$, kanoite and clinoenstatite.

	$MnSiO_3$	KANOITE	CLINOENSTATITE
a (Å)	9.864	9.739	9.620
b (Å)	9.179	8.939	8.825
c (Å)	5.298	5.260	5.188
β	108.22°	108.56°	108.33°
$D_{calc.}$	3.82g/cm^3	3.60g/cm^3	3.18g/cm^3

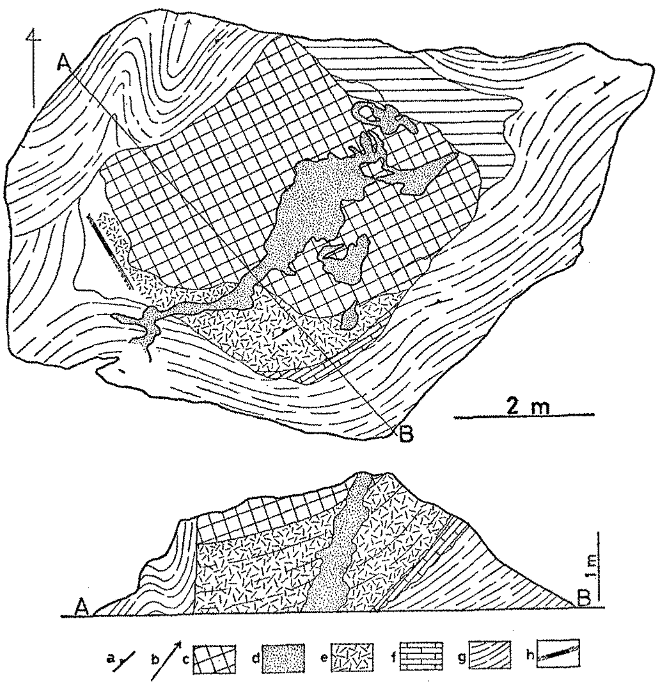

Fig. 2. Sketch map and vertical section of the reef containing manganese minerals.

a: Foliation, b: Folding axis, c: Spessartine-manganoan cummingtonite rock, d: Quartz vein, e: Pyroxmangite-rich rock, f: Carbonate, g: Quartz-rich biotite-garnet gneiss, h: Kanoite-bearing seam.

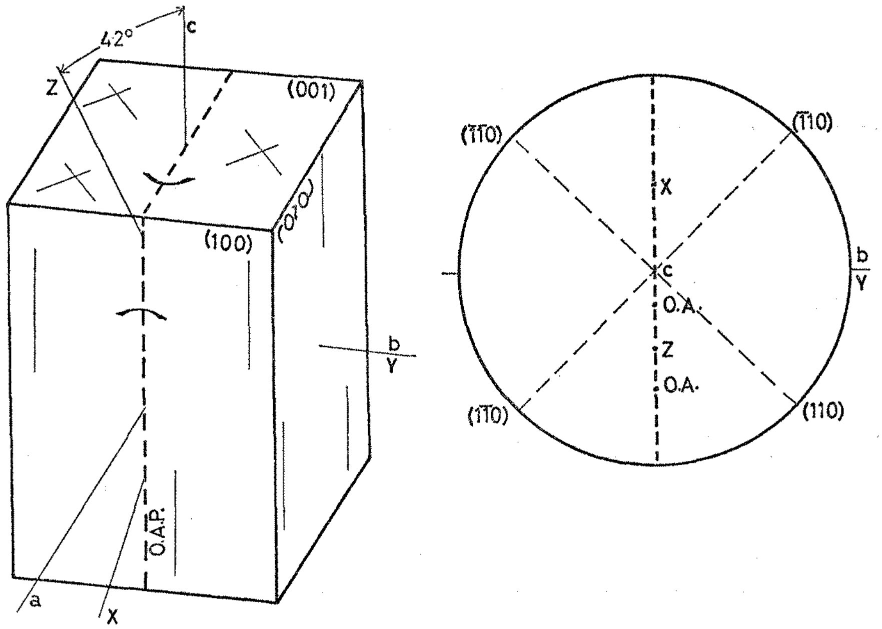

Fig. 3. Optic orientation of kanoite.

difference in ionic radii of Mg and Mn^{2+}.

X-ray powder data obtained by diffractometer method are given in Table 3 and Fig. 4, the latter graphically showing those for related phases. X-ray powder data for kanoite are closely related to those for ferropigeonite

Table 3. X-ray powder pattern of kanoite.

I/I_0	$d_{obs.}$(Å)	$d_{calc.}$(Å)	hkl
2	6.42	6.422	(110)
5	4.621	4.616	(200)
5	4.447	4.446	($\bar{1}$11)
3	3.367	3.367	($\bar{1}$21)
10	3.322	3.328	(021)
100	3.211	3.211	(220)
90	3.021	3.022	($\bar{2}$21)
80	2.921	2.926	($\bar{3}$11)
90	2.910	2.910	(310)
30	2.573	2.576	($\bar{1}$31)
40	2.493	2.493	(002)
20	2.462	2.463	(221)
15	2.371	2.368	(131)
20	2.237	2.237	(311)
30	2.144	2.147	($\bar{3}$31)
25	2.049	2.050	($\bar{4}$02)
15	2.038	2.040	(041)
5	2.009	2.012	(240)
5	1.826	1.826	(331)
10	1.809	1.808	(510)
10	1.786	1.788	(132)
5	1.732	1.732	(421)
40	1.627	1.629	($\bar{5}$31)
20	1.548	1.546	(350)
20	1.487	1.490	(060)
30	1.392	1.393	(531)

(MORIMOTO & GÜVEN, 1968), similar to those for clinoenstatite and synthetic monoclinic $MnSiO_3$ as just stated, and comparable remotely to johannsenite. The observed diffractions were satisfactorily eliminated from the X-ray powder data obtained for the mixture of kanoite, spessartine and manganoan cummingtonite after the confirmation of good correspondence.

Although the extinction rule deciphered from the indices allocated to observed diffractions leads to many possible space groups, the appearance of ($\bar{1}$21) suggests the space group to be $P2_1/c$ from the supposed isostructural relation to clinoenstatite, provided that the mineral ought to have a space group hitherto known in pyroxenes.

Chemical Analyses

Electron microprobe and supplementary wet chemical analyses of kanoite are given in Table 4 in which those of associated spessartine and manganoan cummingtonite are also tabulated. The calculation on the basis

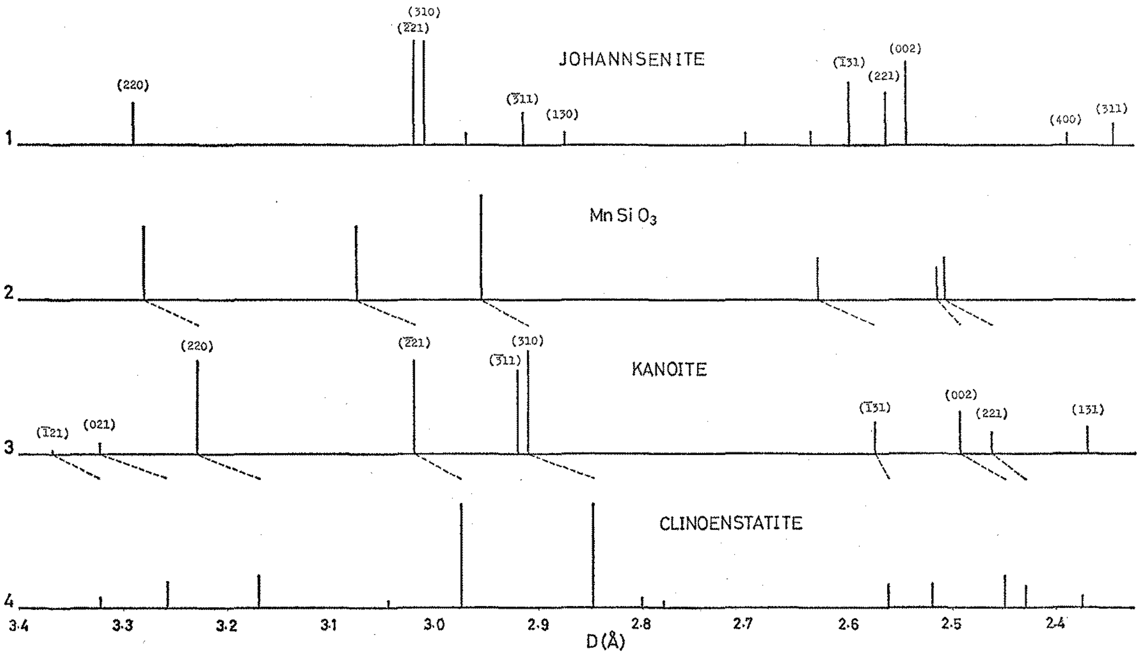

Fig. 4. X-ray powder patterns of clinopyroxenes.

1. Johannsenite ($Ca_{.45}Mg_{.03}Fe_{.05}Mn_{.47}$) SiO_3 from Borieva deposits, Bulgaria. JCPDS Card No. 18—299, 2. Synthetic $MnSiO_3$ (AKIMOTO & SYONO, 1972), 3. Kanoite from Tatehira, Hokkaido, Japan, 4. Synthetic clinoenstatite. JCPDS Card No. 19—769.

Table 4. Chemical composition of kanoite, manganoan cummingtonite and spessartine.

	1	2	3	4	5	6
SiO_2	49.87	50.59	50.14	50.20	54.27	36.13
Al_2O_3	0.04	0.04	0.03	0.04	0.19	20.77
Fe_2O_3	——	——	——	0.39***	——	——
FeO	3.06*	3.15*	3.11*	2.64***	2.94*	1.93*
MnO	31.16**	31.21**	31.19**	31.19**	18.39**	39.94**
MgO	15.01	15.17	15.06	15.08	20.04	1.53
CaO	0.58	0.59	0.65	0.57	0.48	0.67
Na_2O	——	——	——	0.03***	——	——
K_2O	——	——	——	0.03***	——	——
Total	99.72	100.75	100.18	100.17	96.31	100.97

Numbers of ions on the basis of 6 oxygens for kanoite, 23 oxygens for manganoan cummingtonite and 24 oxygens for spessartine.

	1		2		3		4		5		6	
Si	1.972	1.974	1.977	1.979	1.973	1.974	1.973	1.987	7.932	7.965	5.882	6.000
Al^{IV}	0.002		0.002		0.001		0.002		0.033		0.118	
Al^{VI}	——		——		——		——		——		3.867	4.000
Fe^{3+}	——		——		——		0.012		——		0.133	
Fe^{2+}	0.101	2.053	0.103	2.044	0.102	2.051	0.087	2.040	0.359	7.077	0.130	6.125
Mn	1.043		1.033		1.039		1.040		2.277		5.507	
Mg	0.885		0.883		0.833		0.885		4.366		0.372	
Ca	0.024		0.025		0.027		0.024		0.075		0.116	
Na	——		——		——		0.002		——		——	
K	——		——		——		0.002		——		——	

Analyses 1—3, kanoite; 4, average of anal. 1 to 3; 5, manganoan cummingtonite; 6, spessartine.
* : Total Fe as FeO, ** : Total Mn as MnO, *** : are obtained by ordinary analytical method (analyst : S. IIZUMI), Anals 1—3, 5 and 6 by EPMA (analyst : K. TAZAKI), —— : Not determined.

of O=6 leads to the empirical formula as tabulated proving it to be a member of pyroxene. If expressed by the end member molecules, it becomes $Wo_1En_{43}Fs_5[MnSiO_3]_{51}$. Thus the ideal formula of kanoite is $(Mn^{2+}, Mg)_2[Si_2O_6]$ or $Mn^{2+}Mg[Si_2O_6]$.

Concluding Remarks

The chemical analyses, X-ray powder and optical studies of this mineral warrant it to be a new clinopyroxene with the ideal formula $(Mn^{2+}, Mg)_2[Si_2O_6]$ and probable clinoenstatite structure.

The author wishes to call this mineral kanoite in honour of Dr. Hiroshi KANO, Professor of Petrology, Akita University, for his eminent contribution to the studies on metamorphic rocks forming the basement of the Japanese Islands. The present mineral and name have been approved by the Commission on New Minerals and Mineral Names, I. M.A. Type material is preserved at Shimane University, Matsue, Shimane Prefecture, and Department of Geology, National Science Museum, Tokyo, Japan.

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The author wishes to express his sincere gratitude to Prof. J. ISHII, who carried X-ray diffraction study for the author, especially in order to delineate the difference of 2θCu between (3̄11) and (310) of kanoite. The author is indebted to Drs. K. TAZAKI and S. IIZUMI, who kindly alalysed kanoite. Thanks are due to Messrs. K. OGURA and J. MAEDA, who helped the author in the field work. The author wishes to express his sincere thanks to Prof. K. YAGI, Drs. R. H. GRAPES and A. KATO, who read the manuscript and gave constructive advices. Financial aid for this study was provided by the Japanese Ministry of Education.

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北海道渡島半島館平産新鉱物，加納輝石，$(Mn^{2+}, Mg)_2[Si_2O_6]$．

小　林　英　夫

（要　旨）

渡島半島西岸の館平の珪質黒雲母ザクロ石片麻岩に見いだされるノジュール状岩塊には，マンバンザクロ石，マンガンカミントン閃石，テフロカンラン石，ソノ石，パイロクスマンジャイトなど多様なマンガン鉱物を産する．このなかのパイロクスマンジャイトとマンガンカミントン閃石に富む部分に，薄層をつくる単斜輝石，マンバンザクロ石の集合がある．この単斜輝石は，その光学的性質と粉末X線，EPMA の示す諸事実から，斜ガンカキ石と AKIMOTO & SYONO により合成された単斜 $MnSiO_3$ 結晶のほぼ中間に位置する，理想組成 $(Mn^{2+}, Mg)_2[Si_2O_6]$ をもった鉱物であることが明らかになった．筆者は，この単斜輝石を，秋田大学加納博教授の日本列島基盤岩類の研究に対する大きな貢献をたたえ，加納輝石と命名した．

地　名

Hakodate	函　館
Hokkaido	北海道
Kaminokuni	上ノ国
Oshima	渡　島
Raruishi	良留石
Suttsu	寿　都
Tatehira	館　平

Explanations of Plate

a, b: Polished surface of hand specimen of the rock containing kanoite.

c: Photomicrograph of kanoite. //polar.

d: Ditto, +polars. Kanoite and spessartine constitute granoblastic structure. Kanoite shows polysynthetic twinning.

C: Carbonate, C. v.: Carbonate vein, Cum: a manganoan cummingtonite, G: Galaxite, K: Kanoite, P: Pyroxmangite, S: Spessartine, T: Tephroite.

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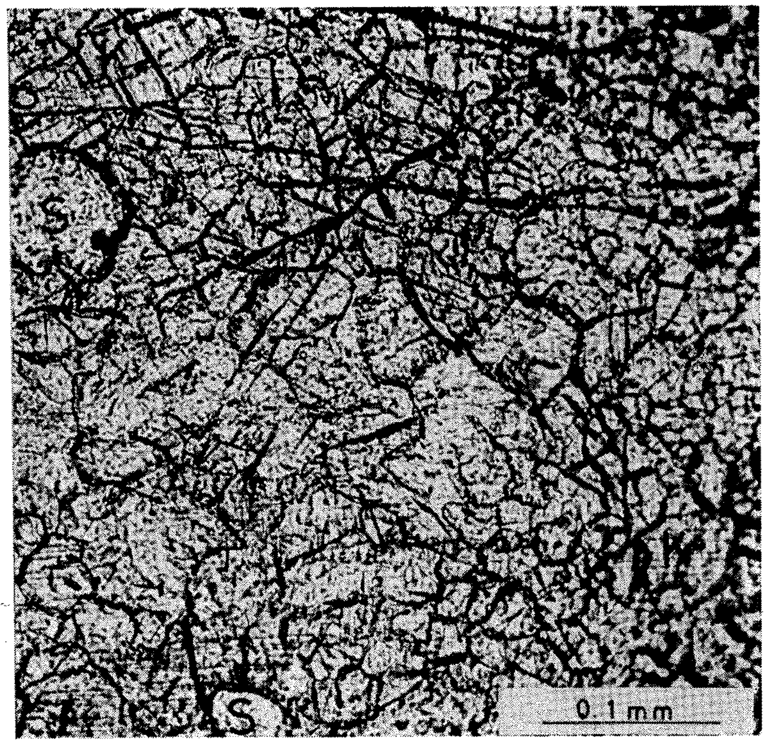

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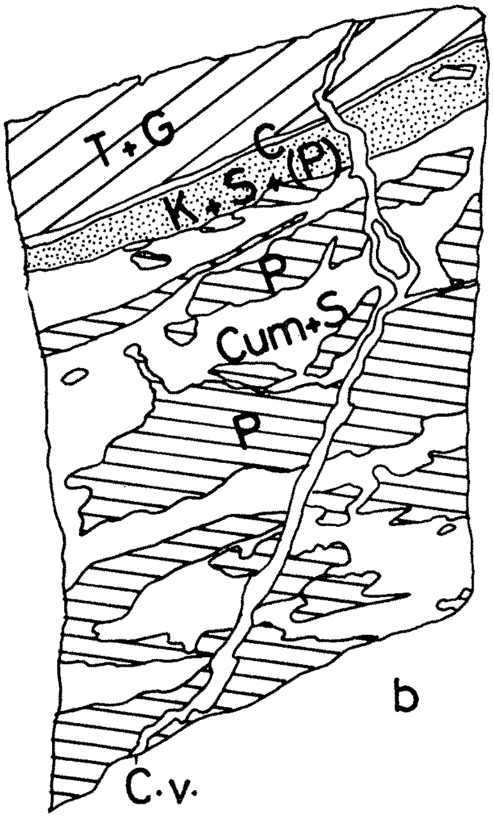

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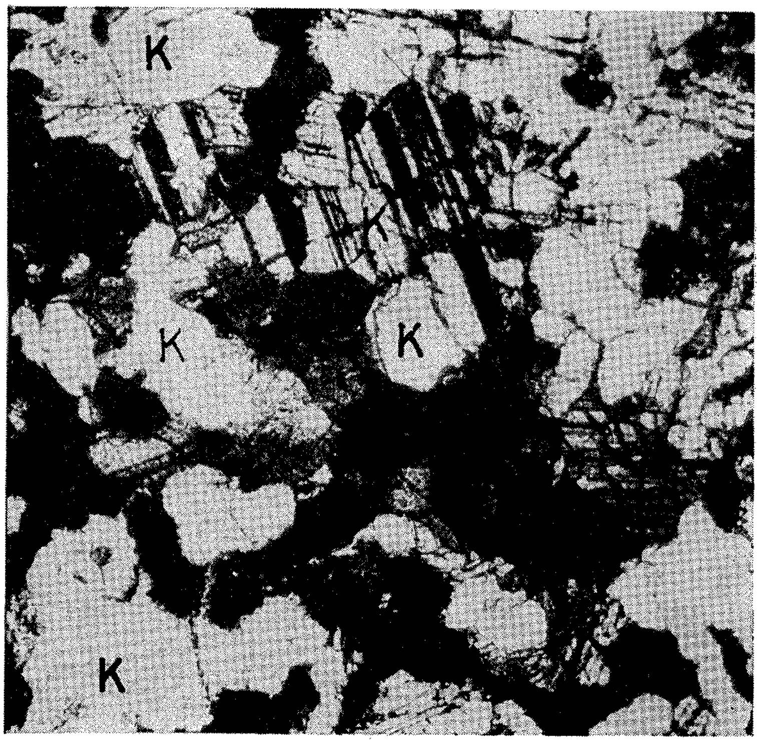

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