

Mineralogy of Some Laterite Ores from Sebuku Island, Indonesia

by

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Abstract

The minerals constituting laterite are mostly in very minute grains and very little was known concerning their nature. A suit of laterite ores from Sebuku Island, Indonesia, was studied mineralogically. The major constituent minerals are identified to be goethite, gibbsite, magnetite-maghemite, chromite, spinel, hematite, and quartz. These minerals are described in detail, and separated specimens of two magnetite-maghemite samples and a chromite sample are analysed partially. Three samples of the ore are chemically analysed and four spectrographic analyses are made of the ores and a ferromagnetic concentrate. The state of iron, aluminum, chromium, magnesium, and water, as well as the behavior of minor elements in the ore are discussed.

Introduction

The process of laterization, weathering of rocks, and formation of soils have been investigated intensively and the geochemical aspects of laterite formation is now known in some detail through the works of Harder (1952), Gordon and Tracey (1952), Pickering (1962), and many others. These studies, however, were conducted from geochemical point of view and little is known concerning the nature of the individual minerals constituting the ore.

As laterite is formed through process of weathering, the material has the following mineralogical characteristics. The mineral composition varies with and is indicative to a certain extent of the degree of laterization; considerable amounts of elements other than iron such as aluminum, chromium, nickel, magnesium, water, and others are contained in the ore; the ore is composed of very minute mineral grains. The small grain size of the constituent minerals makes mineralogical studies extremely difficult and this is one of the reasons for the lack of systematic mineralogical investigation of the material.

There is a large number of laterite deposits in the world and the total reserve is estimated to be in the order of billions of tons. A very small portion of these ores with higher nickel content has been used for source of nickel, but the bulk of the deposits is left unexploited in spite of the fairly high concentration of iron.

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The possibility of using these ores for source of iron has been investigated from various aspects during the last thirty years and such researches have become increasingly active recently. The industrial use of the material, however, is not yet underway and the main obstacles for the utilization of laterite for the above purpose can be summarized as follows. The fairly high content of impure elements, notably chromium and nickel in forms difficult to separate from iron; the powdery state of the ore; high content of water; and the iron content not high enough to compensate for the other shortcomings. Of these, the content of chromium and nickel is the major problem while others do not impose serious technical difficulties. Thus, the separation of chromium and nickel from iron becomes the prime importance in the utilization of the ore. The existence of chromite and garnierite has been shown in some laterite ores, but the nature of these minerals is unknown and little else has been reported concerning the state of the elements which constitute the ore.

The present work was undertaken as an attempt to clarify the overall mineral composition of the ore and with the hope that it will also serve as a step towards solving the problems for utilization.

The work was carried out as a part of the Special Project for the Utilization of Indonesian Laterite Ores under the auspices of the Science and Techniques Agency, Government of Japan. The research was done in the laboratories of the Geological Survey of Japan using the laterite ores sent to the Government of Japan through the courtesy of the Government of Indonesia. The ores are from Sebuku Island, Indonesia.

Chemical Composition of Laterite Ores

The major constituents of ferruginous laterite ores are Fe, Al, and H₂O. Smaller amounts of Cr, Ni, Mg, Si, and Ca are usually present. The chemical composition of the ores fall into the following general range. Fe 45-55; Al 3-5; Ni 0.2-1.3; Cr 1.5-3; H₂O...10 percent.

The results of the chemical analyses of the ores sent to Japan from Sebuku Island are shown in Table 1. Sample 1 is a porous and fairly well cemented material and it is probably from the upper horizon as grass roots are attached to it. Sample 2 is a comparatively hard and compact ore, while sample 3 is a soft friable specimen. Analysis 4 is the result of analysis carried out by the Nisso Steel Co., and it represents the average chemical composition of the ores. The stratigraphic horizons of samples 2 and 3 are unknown. The chemical compositions of laterites from other localities are listed in Table 2. From these data, it is seen that the material in question is rather low in nickel content. The content of chromium is also not very high for laterite. The amount of aluminum, however, is fairly high, and iron and water contents are those of average laterite. Therefore, the ore is not a very appropriate one for the study of chromium and nickel minerals.

According to Kumamaru (1962), the average grade of the ores of Sebuku Island is as follows and it seems that the composition of the present material is within the range of the average ore of this locality. Fe 48-51; Cr₂O₃ 2.5-3.5; Al₂O₃ 9-12; SiO₂ 2-4; H₂O 10-12 percent.

The determination of minor elements in these ores and in ferromagnetic concentrate separated from the laterite was carried out by A. Ando by spectrographic methods. The result is shown in Table 3. Samples 1 and 3 correspond to those of Table 1 and sample 5 is a specimen which contains fair amount of magnetic minerals. Sample 6 is a magnetic concentrate consisting approximately of 70 percent magnetite-maghemite and 30 percent goethite, and it is free of chromite. It is

Table 1 Chemical analyses of laterite ores of Sebuku Island

	1	2	3	4
Fe	48.70	48.58	42.59	51.46
Ni	0.18	0.22	0.11	0.22
Co	0.02	0.02	0.02	
Cr	1.39	0.69	1.76	1.84
SiO ₂	2.04	5.00	1.10	
Al ₂ O ₃	9.30	9.05	15.05	9.68
MgO	0.20	0.17	0.11	0.12
CaO	0.31	0.23	0.13	0.31
P	0.10	0.03	0.14	0.125
S	0.20	0.09	0.22	0.147
MnO	0.08	0.05	0.03	
H ₂ O(+)	13.43	12.54	16.34	12.49
H ₂ O(-)	1.94	1.82	2.71	4.4
Cu				0.005

Analyst; 1, 2, 3, K. Isono, 4, Nisso Steel Co.

Table 2 Chemical analyses of laterite ores

	1	2	3	4
Fe	47.8	50.3	51.6	51.5
Ni	0.7	0.4	0.7	0.02
Cr	2.9	1.2	1.4	1.25
SiO ₂	1.3	0.8	5.9	2.5
Al ₂ O ₃	7.9	8.4	5.4	9.8
MgO		0.5		0.3
P	0.01	0.04		0.06
MnO		0.6	0.7	0.1
H ₂ O(+)	13.6	14.3	11.0	
H ₂ O(-)	26.8			

1. Surigao, Mindanao.
2. Larona, Celebes.
3. Goro, New Caledonia.
4. Conakry, Guinea.

From Scheibe von, E.A., 1954.

interesting to note that the magnetic concentrate contains much higher amounts of almost all of these elements with the possible exceptions of Ag, Ga, and Bi. This seems to indicate that in this laterite at least, minor elements are concentrated in the ferromagnetic mineral and/or in material closely associated with it.

Table 3 Minor elements in laterite ores and ferromagnetic concentrate

	1	3	5	6
Ni	1,800*	1,100*	(36,000)	(5,000)
Co	200*	200*	(1,000)	(3,000)
Cr	13,900*	17,600*	31,000	20,500
V	250	250	100	300
Mn	620*	230*	310	1,600
As	—	—	—	—
Sb	—	—	—	—
Bi	7	5	5	5
Sn	10	10	10	10
Ge	—	?	3	3
Ga	7	8	10	5
In	—	—	—	—
Tl	—	—	—	tr.
Cu	30	30	100	150
Pb	25	10	20	40
Zn	100	100	200	600
Ag	—	10	8	5
W	—	—	—	—
Mo	5	5	5	5
Be	—	—	—	5
B	2	—	—	2
Sr	—	—	—	—
Ba	10	10	12	20

Analyst; Atsushi Ando.

() ; Approximate values.

* ; Chemical analyses by K. Isono.

1, 3, 5; laterite ores of Sebuku Island.

6; Ferromagnetic concentrate separated from No. 3.

Mineralogy

The mineral composition of laterite is complex and the individual mineral grains are small in size. The major constituent minerals of the Sebuku ore identified are as follows.

Goethite	HFeO_2
Gibbsite	$\text{Al}(\text{OH})_3$
Chromite	$(\text{Fe, Mg})(\text{Cr, Al})_2\text{O}_4$
Magnetite-maghemite	$\text{Fe}_3\text{O}_4\text{-}\gamma\text{Fe}_2\text{O}_3$
Magnetite	Fe_3O_4
Hercynite	$\text{Fe}(\text{Al, Cr})_2\text{O}_4$

Hematite	Fe_2O_3
Quartz	SiO_2

Also very weak X-ray diffraction pattern similar to that of garnierite was observed. The content of the mineral, however, is so small that it could not be determined.

Of the above minerals, goethite is the major constituent, and gibbsite is the following abundant mineral. There are some specimens which contain up to 30 percent ferromagnetic mineral, but most specimens contain 2-5 percent and the average content of ferromagnetic mineral is estimated to be in the vicinity of 5 percent. A small amount of chromite exist and the amount is approximately 2 percent of the ore. Hematite is present in small quantity and less than 1 percent of the ore is hematite. Hercynite is present in small amount and quartz is also present in minute amount. This ore does not contain clay minerals, this is possibly due to complete laterization.

Goethite

Goethite is the most important mineral of laterite ore and it constitutes about 70-80 percent or more of the ore in question.

This mineral, due to the process of formation, consists of very minute grains. Many attempts were made to separate the mineral, but complete isolation was not possible. Main impurities were chromite and gibbsite.

Optical properties

The mineral is brown, red, or yellow in thin sections and in some parts where the mineral grains are compacted, it is opaque (Plates 1 and 2). Under crossed nicols, it is yellowish red because of internal reflection. Optical data were not available because of the fine grain size. The refractive indices are high and are over 2.

Chemical composition

Samples pure enough for chemical analyses were not obtained and in order to check the chromium and nickel content of the mineral, approximately 0.1 gram of goethite concentrate was heated for a few minutes in hydrochloric acid of 1 : 10 concentration. Most of goethite was dissolved by this treatment, after cooling and filtration, the filtrate was evaporated to dryness. The residue and the dried filtrate were then checked for chromium and nickel content by semi-quantitative X-ray fluorescent analyses in vacuum. The residue consisted mainly of chromite and contained considerable amount of chromium whereas the dried filtrate contained less than 0.2 percent Cr. The Ni content of residue was approximately 0.10-0.20 percent and that of the filtrate was barely detected which is much less than 0.1 percent.

From these experiments, the writers conclude tentatively that the chromium content of goethite is very small and nickel is not contained in significant amount in the mineral. These evidences, however, are not conclusive and work on the chemical composition of goethite of this laterite is continuing in the writers' laboratories and the results will be reported in the near future.

X-ray diffraction

The result of X-ray diffraction of goethite is shown in Table 4. It agrees well with the data reported in ASTM 8-97.

Gibbsite

Gibbsite is one of the most important source of aluminum in the bauxite and laterite deposits. In the ores from Sebuk Island, most of the aluminum in the ore exists as gibbsite. Gibbsite constitutes approximately 10-20 percent of the ore in most cases.

Gibbsite and spinels form crystals of microscopic dimensions a few of which attain 3 mm in diameter (Plates 3 and 4). Most of the grains observed under the microscope are 0.1-0.2 mm and they occur filling cracks within goethite. There are, however, considerable amount of gibbsite dispersed within goethite in sub-microscopic dimensions and these can be identified only by X-ray diffraction.

Optical properties

The optical properties of gibbsite in these ores are as follows.

Colorless, $\alpha=1.574$, $\beta=1.574$, $\gamma=1.598$,

optic axial angle $0-2^{\circ}(+)$

The refractive indices of this gibbsite is fairly high. Those reported by previous workers range from $\alpha=\beta=1.566$ $\gamma=1.585$ Larsen(1921) to $\alpha=\beta=1.577$ $\gamma=1.595$ Achenbach (1931). Generally, the refractive indices of gibbsite fall within the range of $\alpha=\beta=1.565-1.577$, $\gamma=1.585-1.595$. These variations of chemical composition seem to be the result of the variation of hydroxyl content of the mineral.

Chemical composition

Gibbsite forms relatively pure $Al(OH)_3$, and the aluminum is not replaced by other metallic ions. A pure sample of gibbsite was separated and checked for impure elements by X-ray fluorescent analysis. A very small amount of iron was detected, but neither chromium nor nickel was present. The iron is due to small amount of goethite mixed in the sample.

X-ray diffraction

Gibbsite crystal has monoclinic symmetry and the unit cell dimensions are $a_0 = 8.695$, $b_0 = 5.077$, $c_0 = 9.703 \text{ \AA}$, $\beta=85^{\circ}48'$ (ASTM 7-324).

Table 4 X-ray diffraction data for goethite

1		2		
dÅ	I	hkl	dÅ	I
4.94	20	020	5.0	20
4.15	100	110	4.21	100
3.34	20	120	3.37	20
2.68	85	130	2.69	80
		021	2.57	20
			2.51	10R
		040	2.48	20
2.42	60	111	2.44	70
2.24	30	121	2.25	20
2.17	35	140	2.18	40
		220	2.09	5
		131	2.00	10
		041	1.920	10
1.79	20	211	1.803	20
		141	1.774	5
1.696	55	221	1.719	50
		240	1.689	20
		060	1.660	10
1.599	30	231	1.602	20
1.560	20	151	1.563	30
1.496	30	250	1.507	20
			1.468	10R
1.450	30	061	1.456	5
		022	1.452	20
		112	1.420	5

1. Goethite in laterite from Sebuk. CoK α radiation.

2. ASTM 8-97.

The powder diffraction data are laid out in Table 5. The 002 reflection at 4.84 Å has a very strong intensity and in all diffraction patterns taken of bulk ore and semi-pure goethite samples, gibbsite can be observed by this reflection. Care is necessary, however, because it can be confused with the 111 reflection of spinels near 4.8 Å.

Magnetite-maghemite

It is generally believed that some of the magnetite of the original rocks remain in the laterite ores.

In the case of the ore from Sebuk Island, there are black ferromagnetic minerals. These again are so fine grained that complete isolation was not possible. The material was ground to size smaller than 325 mesh and magnetic separation in water was attempted. This produced concentrate with fair amount of goethite attached. This process was repeated for a dozen times and the material was then

Table 5 X-ray diffraction data for gibbsite

1		2		
dÅ	I	hkl	dÅ	I
4.84	100	002	4.85	320
4.35	20	110	4.37	50
		200	4.32	23
		112	3.306	15
3.19	60	11 $\bar{2}$	3.187	12
		103	3.112	7
2.46	25	021	2.454	23
		004	2.420	20
2.38	10	31 $\bar{1}$	2.388	27
2.28	8	312	2.285	5
2.23	10	022 21 $\bar{3}$	2.244	10
2.16	2	312	2.168	7
		11 $\bar{4}$	2.085	2
2.05	8	313	2.043	17
1.99	10	023	1.993	11
		123	1.960	2
1.92	10	41 $\bar{1}$	1.921	11
1.799	20	314	1.799	13
1.746	15	024	1.750	16
1.679	8	314	1.689	13
1.655	5	224	1.654	3
		421	1.638	2
		22 $\bar{4}$ 51 $\bar{1}$	1.593	3
		422 512	1.584	2
1.578	5	230 503	1.573	3
		40 $\bar{4}$	1.555	1
		231	1.551	1
			1.486	2
			1.477	1
1.454	5		1.457	9

1. Gibbsite in laterite from Sebuku. CuK α radiation.
2. ASTM 7-324.

washed several times by ultrasonic cleaner. Under binocular microscope, the separated material was inferred to consist of 90-95 percent magnetite and 5-10 percent impurities whose main constituent was goethite. Two samples of concentrate, one from porous ore and the other from compact ore were prepared by the above process. They are labeled M₁ and M₂ respectively.

Physical properties

The material is ferromagnetic, is black with metallic luster, and has black streak. Polished sections of the isolated grains were studied under reflecting microscope. Both samples were found to contain approximately 10 percent magnetite,

less than 5 percent chromite and spinel, and 85–90 percent of the sample consisted of material with white reflection with bluish tint, and the reflection was considerably weaker than that of magnetite. Some of the grains of this material has altered to goethite, and the amount of it is probably in the order of 5 percent or less. Kinoshita et al. (1963) reported the existence of an unidentified mineral X in laterite from Homonhon, Philippines. Mineral X has the color of reflection between that of magnetite and maghemite and it occurs closely associated with the two minerals. It is highly probable that the mineral X is identical with the ferromagnetic mineral described here.

The mineral grains of this mineral are mostly monominerallic and intricate intergrowths of magnetite, maghemite, chromite, and others as reported by Kinoshita et al. (1963) were observed only in minor amount.

Chemical composition

The two samples of this ferromagnetic material were chemically analysed.

Table 6 Chemical analyses of magnetite–maghemite

	M ₁	M ₂	1	2	3	4
FeO	6.07	9.25	27.93	15.30	8.67	2.40
MgO			0.14	0.30	tr.	—
MnO			0.07	1.43	—	—
CaO			0.03	0.43	tr.	—
NiO	0.53	1.40	—	—	—	—
Fe ₂ O ₃	82.89	77.78	69.88	73.75	89.15	85.30
Al ₂ O ₃			0.34	2.96	0.04	—
V ₂ O ₃			0.02	0.31	—	—
Cr ₂ O ₃	2.45	3.16	0.07	—	—	—
TiO ₂			0.16	0.35	1.37	—
SiO ₂			1.07	2.35	1.15	—
H ₂ O			n.d.	3.02	—	3.10
Rem			—	—	—	4.30
Total	91.95	91.59	99.71	100.19	100.38	95.10

M₁; Mineral in laterite from Sebuku. Analyst; K. Isono.

M₂; " " " "

1; Maghemo-magnetite from Bovey Tracy, England. Basta, 1959.

2; Maghemo-magnetite from Uganda. Broughton, Chadwick, and Deans, 1950.

3; Magnetite and maghemite from California. Newhouse and Glass, 1936.

4; Maghemite from California. Sosman and Posnjak, 1925.

Table 7 Recalculation of the analyses of M₁ and M₂

	M ₁		M ₂	
FeO	2.0	2.6	5.0	6.7
Fe ₂ O ₃	72.9	96.0	67.0	90.0
Cr ₂ O ₃	0.5	0.7	1.0	1.4
NiO	0.5	0.7	1.4	1.9
Total	75.9	100.0	74.4	100.0

The result is shown in Table 6, together with the analyses of the minerals of magnetite-maghemite series. The amount of samples purified was so small that it was not possible to make a complete analysis. The remaining constituents are inferred to be Al_2O_3 , MgO , H_2O , and others. Table 7 shows the recalculated values with the contents of 5 percent chromite, 5 percent goethite and 10 percent magnetite subtracted. When the values of Table 7 are recalculated on the assumption that the material is a solid solution of magnetite-maghemite, the ratio of the molecular contents will be as follows.

	M_1	M_2
Magnetite	8	21
Maghemite	92	79

The above values are admittedly approximation, but it does show that the minerals are of the composition of approximately $Mg_1 Mh_9$ and $Mg_2 Mh_8$. It also shows that approximately 0.7 percent Cr_2O_3 and NiO are contained in M_1 and 1.4 percent Cr_2O_3 and 1.9 percent NiO in M_2 .

From the above data, it is inferred that both M_1 and M_2 are minerals of magnetite-maghemite series with 0.4-0.8 percent Cr and 0.4-1.1 percent Ni with the composition of 80-90 molecular percent $\gamma-Fe_2O_3$.

X-ray diffraction

Magnetite and maghemite show similar X-ray diffraction pattern, but maghemite has weak reflections which do not occur in magnetite pattern. Both of these minerals had been considered to have reverse spinel type structure. Oosterhout and Rooymans (1958) discovered weak X-ray reflections of maghemite which cannot be indexed by cubic symmetry and proposed a tetragonal cell with c-axis three times the length of a-axis, and considered the tetragonal maghemite to be the ordered phase and the cubic material to be the disordered phase. Powder X-ray diffraction pattern of M_1 and M_2 are laid out in Table 8 together with the data of other minerals of magnetite-maghemite series, the reflections are indexed for cubic lattice.

The unit cell dimension a_0 calculated from the data in Table 8 are shown in Table 9. It is seen that a_0 of M_1 and M_2 are considerably smaller than the value for magnetite and they are closer to that of maghemite. The a_0 of maghemite, however, is not definite and many values have been reported, such as the following. 8.31 Å (Newhouse and Glass 1936), 8.322 Å (Hägg 1935), 8.34 Å (Rooksby 1961).

On the other hand, Basta (1959) asserted that the term maghemite should be reserved for material with chemical composition close to $\gamma-Fe_2O_3$ and unit cell dimension between 8.30 and 8.35 Å. He also proposed that of the minerals of $Fe_3O_4-\gamma-Fe_2O_3$ solid solution series, those containing less than 50 percent $\gamma-Fe_2O_3$ be called maghemomagnetite and those with more than 50 percent $\gamma-Fe_2O_3$ be

called magnetomaghemite. Magnetite and maghemite, however, have different physical properties such as color, X-ray diffraction pattern and others. And the validity of the above nomenclature must be further confirmed for cases when the physical properties are closer to those of magnetite while the chemical composition and the unit cell dimension are closer to those of maghemite. Such is the case of the ferromagnetic mineral in the laterite ores from Sebuku Island, and together with the high concentration of minor elements in the minerals, the ferromagnetic material in laterite ores warrant further detailed mineralogical study.

Chromites and spinel

It is known that chromite exists in laterite, and the mineral is believed to be the main source of chromium. Spinel also occur in these ores and these minerals are generally believed to have existed from the original rocks and resisted laterization.

Chromite and spinel occurring in laterite ores of Sebuku are larger in grain size than other minerals (Plates 5,6,7,8). There are grains which attain diameter of 0.1 mm, and minerals in the range of 0.02-0.05 mm are observed most widely under the microscope. There are, however, many grains of barely observable dimensions.

The content of these minerals is very small and both constitute less than 5 percent of the ore.

The minerals were separated by heavy liquid and magnetic methods. The minerals were then washed with 1:10 HCl and thus attached goethite was removed. Magnetic separation was employed again for accurate separation and the material was used for chemical analyses.

In this ore, three kinds of chromite and a spinel were identified. The spinel is believed to be hercynite. Of the three chromites, two could not be separated from each other and the content of hercynite was so small that it was not possible to analyse it chemically.

Optical properties

The optical constants of chromites could not be measured. The color of the minerals are as follows.

Chromite 1	Black	opaque in thin sections
2	"	"
3	"	opaque and partly dark red in thin sections
Hercynite	"	pale blue to pale yellow in thin sections
Refractive index :	hercynite	n=1.82

Chemical composition

The theoretical composition of chromite is FeOCr_2O_3 , but FeO is replaced by MgO and Cr_2O_3 by Al_2O_3 and Fe_2O_3 . Some of the previous data are suspect

Table 10 Chemical analyses of chromites

	Ch 1 & 2	1	2
FeO	23.47	22.21	11.35
NiO	0.06		
MgO	9.22	8.63	14.83
Fe ₂ O ₃	4.10	4.39	3.79
Al ₂ O ₃	13.75	19.14	14.03
Cr ₂ O ₃	45.31	44.61	55.51
SiO ₂		0.98	
Total	95.91	99.96	99.51

Ch 1 & 2 ; Chromite in laterite from Sebuku. Analyst ; K. Isono.
 1 ; Chromite, Dainichi mine, Japan. Junichi Kitahara, 1950.
 2 ; Chromite, ASTM 9-353.

of the purity of the sample, and in this work care was taken concerning this problem.

One chromite concentration consisted of two kinds of chromites and this was clearly observed by X-ray diffraction, these chromites were tentatively labeled chromite-1 and chromite-2. All available methods were employed in order to separate these two chromites, but it was not successful. The ratio of chromites 1 and 2 is probably in the order of 5 : 4.

The mixture of chromites 1 and 2 was concentrated in enough quantity for partial chemical analysis. The result of the analysis is shown in Table 10 together with previously published data. It is seen that the chemical composition of the mixture is quite similar to that of chromite from Dainichi mine.

X-ray fluorescent analysis of chromite-3 showed over 30 percent Cr.

X-ray diffraction

As mentioned in the preceding paragraph, three kinds of chromites were identified by X-ray diffraction. The powder X-ray data are shown in Table 11.

The unit cell dimensions calculated from the data of Table 11 are as follows.

Ch-1	Ch-2	Ch-3	ASTM 9-353
8.25	8.21	8.17	8.22 Å

The cell edge of chromite increases with the increase of chromium content up to 8.310 Å with 51.5 percent Cr₂O₃. The data obtained here agree well with the result of chemical analyses.

The possibility of either Ch-1 or Ch-2 being spinel with smaller content of chromium was considered, but with the cell edge, the fact of Ch-3 containing large quantity of chromium, and the optical properties of the mixture Ch-1 and -2, the writers have come to the conclusion that both are chromites.

Hematite and quartz

Hematite occurs associated with goethite. The amount is very small and it is

Table 11 X-ray diffraction data for chromites

Ch-1		Ch-2		Ch-3		ASTM 9-353		
dÅ	I	dÅ	I	dÅ	I	dÅ	I	hkl
4.78	50	4.76	60	4.73	60	4.76	20	111
2.93	25	2.91	40	2.90	50	2.92	20	022
2.49	100	2.47	100	2.46	100	2.49	100	113
2.063	50	2.055	45	2.045	50	2.07	50	004
						1.687	5	224
1.590	25	1.581	45	1.572	30	1.593	60	333 115
1.462	35	1.454	75	1.447	50	1.466	70	044
						1.265	10	335
						1.249	5	226
						1.197	5	446
						1.108	5	246
						1.081	50	355 137
						1.038	20	008

Ch-1; Chromite in laterite from Sebuku. FeK α radiation.
 Ch-2; " " " "
 Ch-3; " " " "

not an important mineral of the suit of ores in question.

A small amount of quartz occurs in the ore. It is possible to misidentify it with gibbsite. This mineral is also of very little significance to the ore.

Water

Generally, laterite contains from 10 to 15 percent water. The constituent minerals of the ore which contain hydroxyl in its structure are goethite and gibbsite. The water content of goethite and gibbsite are theoretically 10.14 and 34.65 percents respectively. Since in the present case, the iron and aluminum are almost all in the form of goethite and gibbsite, it is possible to calculate the approximate amount of water in these two minerals from the iron and aluminum content of the ore. From such calculations, the water in goethite is 7 percent and that of gibbsite is 5 percent of the ore. Thus the total water contained in the two minerals amount to approximately 12 percent. As the average content of H₂O (+) is 12-13 percent, it is concluded that most of the H₂O (+) content of the ore exists in the structure of goethite and gibbsite.

Acid soluble chromium

It has been known that acid soluble chromium exists in laterites and as chromite is generally considered to be insoluble in acid, the soluble chromium was believed to be contained in other minerals. It is shown through this work that the magnetite-maghemite mineral contains chromium. This mineral is acid soluble and at least a part of the acid soluble chromium exists in the ferromagnetic iron oxide.

There are, however, complicated aspects to this problem and definite conclusions cannot be drawn at present. The writers are continuing work on this matter, and the results will be reported in the near future.

Conclusion

The major elements which constitute the suit of laterite ores in question exist in the following forms.

Iron : Most of the iron exists as goethite HFeO_2 , and a small portion exists in the minerals of magnetite-maghemite series and chromite. Over 90 percent of the iron contained in the ore is in goethite.

Aluminum : The major aluminum mineral is gibbsite $\text{Al}(\text{OH})_3$, and a part is contained in chromite and spinel. The aluminum other than that in gibbsite is probably less than 1 percent.

Chromium : The chromium content of the ores is 1.3-1.7 percent and the major part is in chromite $(\text{Mg,Fe})(\text{Cr,Al})_2\text{O}_4$ and about 5 percent of the total chromium is in ferromagnetic iron oxide. It is believed that at least a part of the acid soluble chromium is in magnetite-maghemite.

Nickel : The content of nickel in this suit of ores is 0.1-0.2 percent. It was not possible to determine the major nickel containing mineral. A very minor amount of nickel is contained in chromite and ferromagnetic mineral.

Magnesium : The content of magnesium is MgO 0.1-0.2 percent. The major magnesium containing mineral is chromite.

Water : The water is almost all contained in goethite and gibbsite. Heating for 3 hours at 400°C removes most of the water.

The state of the major elements of the laterite ore from Sebuku Island is thus described. Other elements in the ore are minor in content and was not studied in this project.

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インドネシア セブク島産ラテライトの鉱物学的研究

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要 旨

インドネシアセブク島産ラテライトについて鉱物組成、各種元素の鉱石中の状態などを明らかにする目的をもって鉱物学的研究を行なった。

一般にラテライトを構成する鉱物は非常に細粒であるため、個々の鉱物に関する研究には多くの困難を伴ない、従来発表された鉱物学的データは皆無に近い。今回は可能な限り各種鉱物の単体分離を行ない、その鉱物学的性質を記載した。鉱石3個、クロム鉄鉱1個、磁鉄鉱—磁赤鉄鉱2個について化学分析を行ない、鉱石3個、強磁性鉱物濃集標本1個について分光法による微量元素の定量を行なった。

このラテライトを構成する鉱物は針鉄鉱、水ばん土、クロム鉄鉱、磁鉄鉱—磁赤鉄鉱、赤鉄鉱、尖晶石、石英が確認され、この他に珪ニッケル鉱らしきX線回折線を認めたが、微量であるため確認するには至らなかった。鉄、アルミニウム、クロム、ニッケル、マグネシウム、水などの元素の鉱石中の状態ならびに微量元素の分布について考察した。

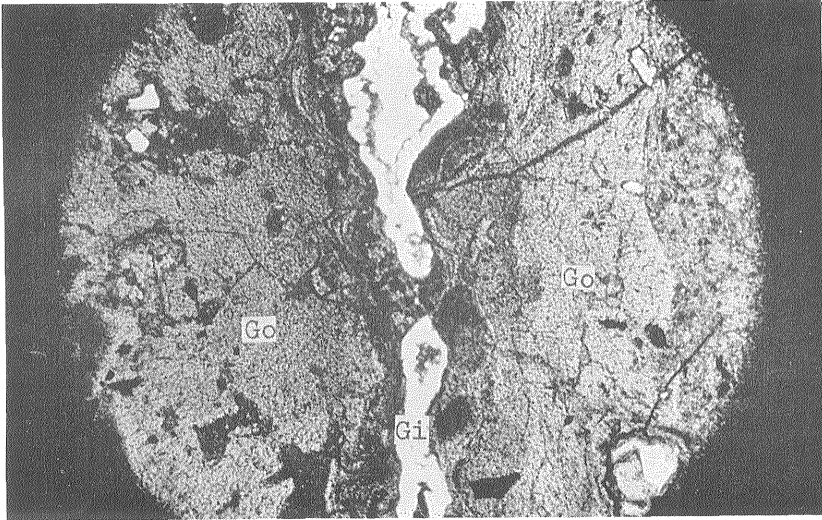


Plate 1 Goethite Go and gibbsite Gi in laterite.
Plane polarized light. $\times 60$

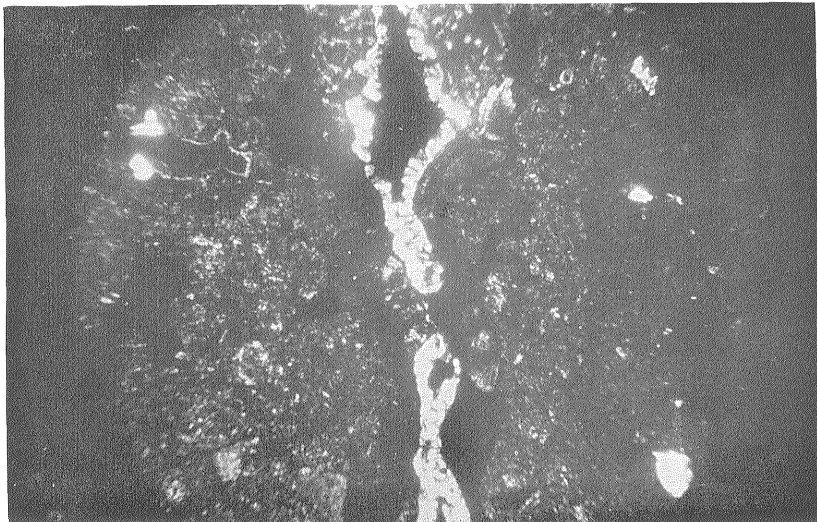


Plate 2 Same as Plate 1.
Crossed nicols.

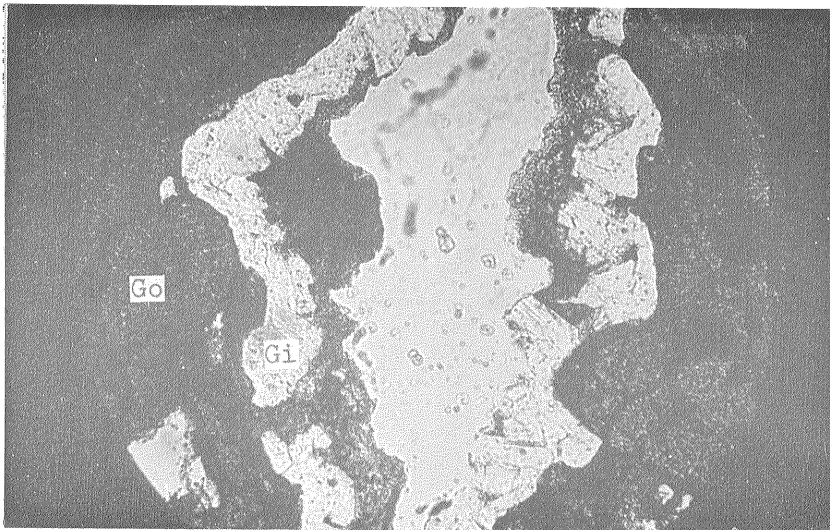


Plate 3 Goethite Go and gibbsite Gi in laterite.
Plane polarized light. $\times 200$

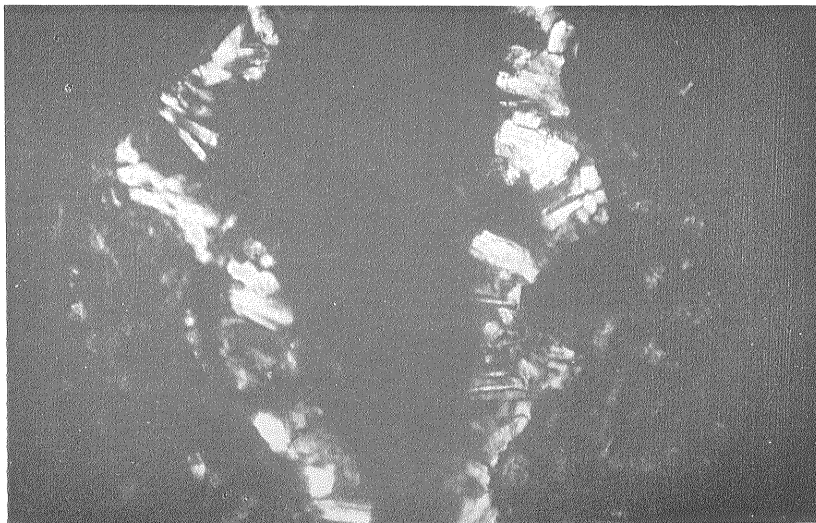


Plate 4 Same as Plate 3.
Crossed nicols.



Plate 5 Chromite Cr and goethite Go in laterite.
Plane polarized light. $\times 200$

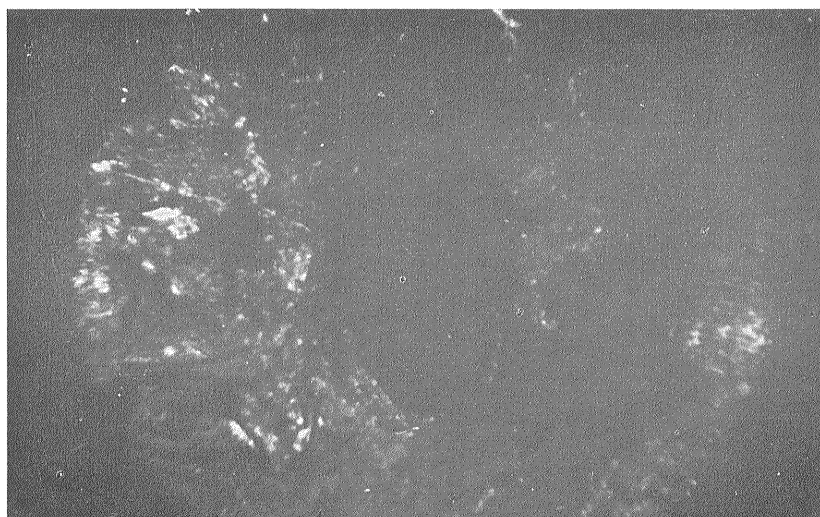


Plate 6 Same as Plate 5.
Crossed nicols.

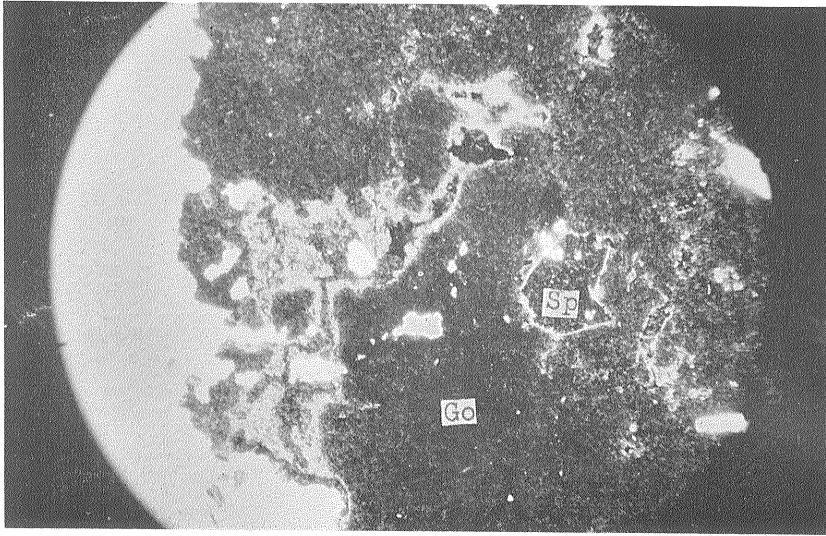


Plate 7 Spinel Sp and goethite Go in laterite.
Plane polarized light. $\times 100$

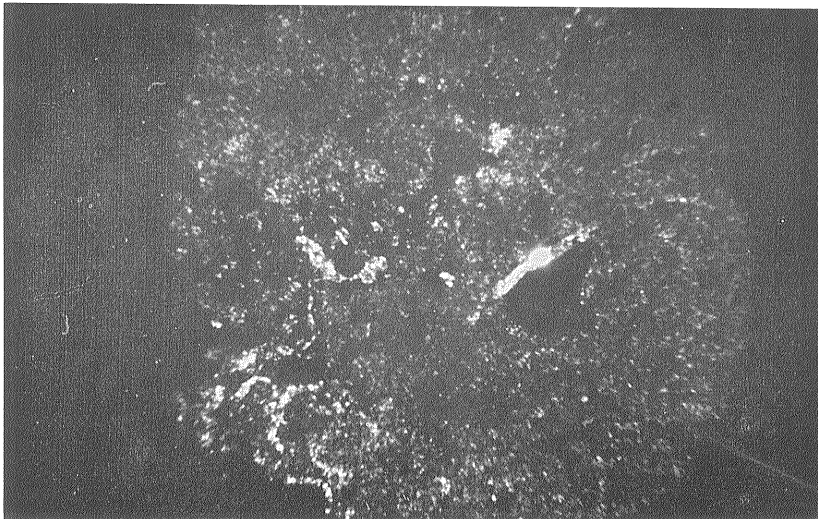


Plate 8 Same as Plate 7.
Crossed nicols.