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THE ALPINE CHROME ORES FROM JAPAN

by

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(with 2 Tables and 5 Figures)

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Abstract

The author proposes a tentative model of classification of the Alpine chrome ores in this paper and the various types of chrome ore from Japan have been assigned to the positions in the classification model.

Mineralogical study on chrome ore has recently remarkably advanced according to the development of modern instruments such as EMPA. Thus the ferritchromite surrounding the hostchromite from the Wakamatsu Mine, southwestern Japan, has become to be chemically discussed. Reflectivity, hardness (VHN), chemistry and lattice constant of ore-forming chromites representing the several types of chrome ore from Japan are reported and finally the mutual relations between these elements are interpreted. It is noteworthy that reflectivity and lattice constant of chromite may correspond to its Cr_2O_3 content.

Introduction

As well known, only chromite is profitable as chrome ore forming mineral among various chrome minerals because of its abundant occurrence and concentration grade. The Alpine chromite deposits taking podiform are generally found in serpentinized harzburgite or dunite in orogenic belts.

The chemical formula of chromite has been theoretically confirmed as $\text{R}''(\text{Mg,Fe})\text{O} \cdot \text{R}'''(\text{Cr,Al,Fe})_2\text{O}_3$, while the chemistry of natural chromite from Japan extends within the restricted field belonging to aluminian chromite to chromian spinel.

In general, colour of chromite is reddish brown or chocolate in thin section, but occasionally opaque mineral which forms rim of individual chromite crystal is microscopically recognized. This opaque mineral was previously studied by Spangenberg (1943) and this part was named ferritchromite distinguished from hostchromite which forms the core of the crystal, and he assumed that this part is attributed to the conversion of hostchromite by means of addition of MgO and Al_2O_3 . Bamba (1952) reported that this opaque mineral may be characterized by richness of magnetite molecule through its reflectivity obtained by microscopic observation. Afterwards, Golding and Bayliss (1968) confirmed that the ferritchromite is characterized by richness of Cr_2O_3 and

FeO, and poorness of Al_2O_3 and MgO compared with the chemistry of related hostchromite, and considered that the ferritchromite might have been converted by oxidation of chromite.

Ottemann (1966) examined the lattice constant of ferritchromite and compared with that of hostchromite from Greece, and he obtained the results that the former shows 8.34Å and the latter 8.24Å respectively. Engin and Aucott (1971) advanced the chemical study of the Alpine chrome ores from Turkey through the EPMA analysis. They came to a conclusion that accessory chromite scattering in harzburgite is characterized by richness of Al_2O_3 and poorness of Cr_2O_3 compared with ore-forming chromite. The ferritchromite was contemporaneously examined by EPMA and it was clarified that ferritchromite is rich in Fe and Cr, and the ferritchromite includes simultaneous clinopyroxene and tremolite. Consequently they concluded that the ferritchromite might have been formed through the hydrothermal process.

Recently, the present author classified the Alpine chrome ores from Japan and examined the reflectivity, hardness (VHN), chemistry and lattice constant of chromites belonging to the classified several types of chrome ore from Japan. The results obtained and the mutual relations of these elements are reported in this paper. Chemistry, reflectivity and hardness of the ferritchromite from Wakamatsu Mine, southwestern Japan, have been also examined. Thus the newly obtained knowledges on the ferritchromite are added in this paper.

Classification of chrome ores from Japan

It is a matter of course that the classification of chrome ore should be treated from the view point of ore genesis. The chromite forms ore deposits which can be classified into two main types by Thayer (1969): Stratiform type and Podiform type. The former clearly results from gravity differentiation and is generally associated with pyroxenites in layered intrusions, of which the Bushveld Complex is the classic example. The podiform chromite deposits are in marked contrast and are usually found in pods or lenses in ultramafic rocks of orogenic belts. Typical examples have been described from California, Cuba, Yugoslavia, Greece, Turkey, Iran, India, Phillipines and Japan. The podiform type chromite deposits are mostly found in the Alpine orogenic belt, thus this type of chromite deposit is frequently called "Alpine chromite deposit" and the ore is called "Alpine chrome ore".

The Alpine chrome ore is generally classified into following four types:

1. Massive, 2. Nodular, 3. Disseminated, 4. Stratiform.

Among these, the former two are commonly related to the formation of

chlorite, and the chromite which forms massive and a kind of nodular ore is frequently called "Chloritic chromite".

The chrome ores from Japan were previously classified from outward seeming by Suzuki (1942) as follows:

- | | |
|--------------------------------|---|
| 1. Massive | 6. Super fine-grained disseminated |
| 2. Fine-Nodular | 7. Banded |
| 3. Coarse-Nodular | 8. Brecciated |
| 4. Coarse-grained disseminated | 9. Chain-textured |
| 5. Fine-grained disseminated | 10. Corrosive coarse-grained disseminated |

Suzuki (1942) pointed out that the ores from 1 to 4 and 9 are attributed to hydrothermal origin and the others to orthomagmatic origin. It seems that the chrome ores converted into the deformed had been treated as target for the classification. Thus many species of chrome ore were reported in his paper.

The present author proposes a classification model of the Alpine chrome ores based on the recently obtained knowledges as given in Table 1.

Table 1 Classification of the Alpine chrome ores

1 Massive	Compact ore*: Hirose, Wakamatsu Mines (Tottori Pref.)	
	Nittoh, Hatta, Nukabira, Yahata Mines (Hokkaido Pref.)	
	Compact occluding disseminated ore*: Nittoh Mine (Hokkaido Pref.)	
2 Nodular	Obicular textured ore	
	Chain textured ore*:	Wakamatsu Mine (Tottori Pref.)
	Nodular chromitite*:	Wakamatsu Mine
	Sorted nodular ore*:	Wakamatsu Mine Mitsui-Chiroro Mine (Hokkaido Pref.)
3 Disseminated	Massive chromitite*: Wakamatsu, Hirose Mines	
	(Tottori Pref.) Nittoh Mine (Hokkaido Pref.)	
	Lineated chromitite*: Nukabira Mine (Hokkaido Pref.)	
4 Stratiform	Sorted chromitite	
	Banded ore*:	Akaishi Mine (Ehime Pref.) Mizuta Mine
	(Okayama Pref.)	
	Gneissic chromitite	

* chrome ore found in Japan

General characters of chromites from Japan

According to the author's classification of chrome ores, several kinds of chromite related to the different ore types are presented in this paper.

Chromite which forms massive ore

Massive chromite ores in Japan are produced from Nittoh, Hatta, and Nukabira Mines, Hokkaido, Takase Mine, Okayama Pref. and Wakamatsu and Hirose Mines, Tottori Pref. Some representative chromites related to the massive ore are described in this paper.

Chromite from Nittoh Mine. It occurs as compact aggregates of coarse-grained subhedral crystals. In this compact dense ore, patches, 2 – 3 cm of dimension, being composed of disseminated chrome ore are enclosed as shown in Fig. 1-(6). The origin of the peculiar ore texture has been interpreted that the patches should be a kind of remnant of primarily formed ore which represented ortho-magmatic phase, and the compact ore may be a regenerated product from the former in hydrothermal phase (Bamba, 1963). This idea is obtained from the presence of chlorite in the compact ore facies whereas antigorite is dominant in the patches. Microscopically, the coarse-grained chromite is reddish brown in thin section and no ferritchromite is observed. Negative crystals are found in compact ore as shown in Fig. 2-(11). The chromite disseminated in the patches is also reddish brown in thin section and its crystal-form is subhedral.

Lattice constant of the coarse-grained chromite which forms the massive ore and its chemical composition are given as follows:

$$a = 8.308\text{\AA}$$

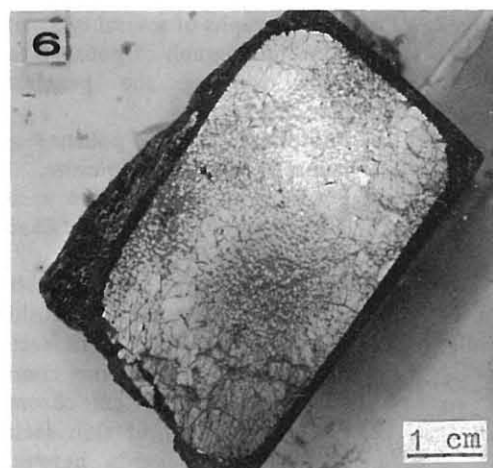
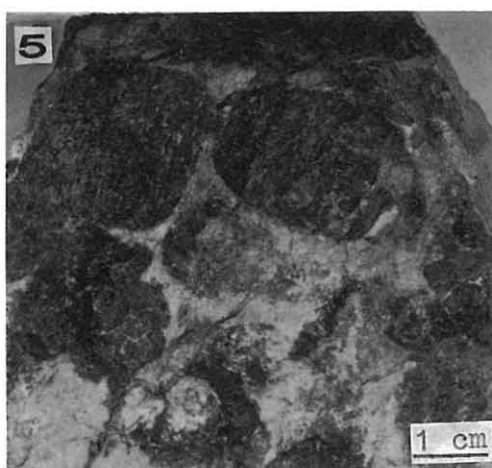
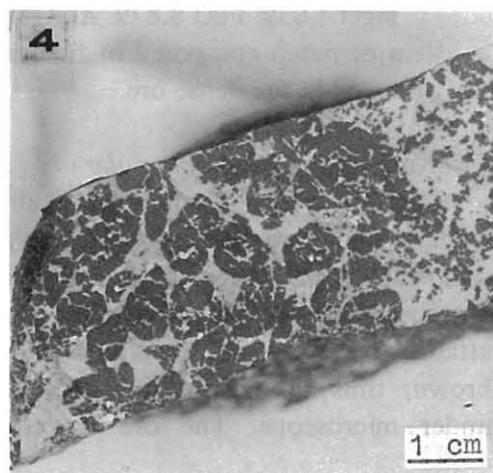
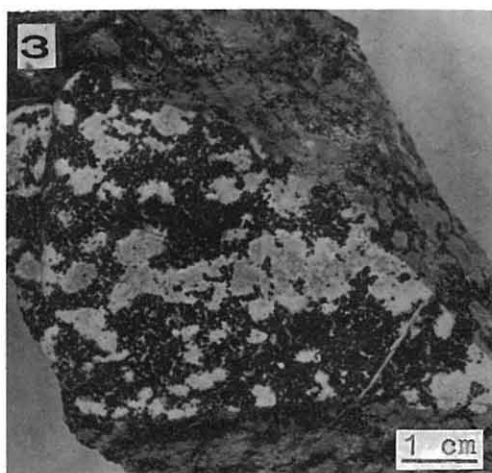
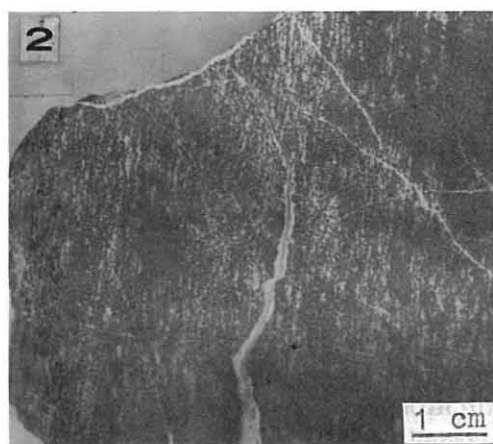
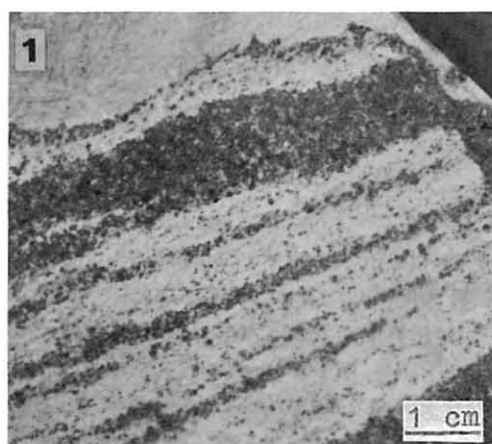
$$\text{MgO } 14.85\% \text{ FeO } 14.15\% \text{ Al}_2\text{O}_3 \text{ } 9.25\% \text{ Cr}_2\text{O}_3 \text{ } 58.28\%$$

Kaemmererite and uvarovite taking vein-form or network-vein are common in the massive ore.

Chromite from Takase Mine, Okayama Pref. The feature of the compact dense ore from this mine is seemingly quite similar to that from the Nittoh Mine while the colour of the chromite in thin section is yellowish brown and is associated with abundant ferritchromite along the cleavage. Lattice constant and chemistry of the chromite were examined. The results obtained are given as follows:

Fig. 1 Photographs of several types of chromite ore from Japan

- 1) Banded ore from the Akaishi Mine, Ehime Pref.
- 2) Linedated chromitite from the Nukabira Mine, Hokkaido
- 3) Chain-textured ore from the Wakamatsu Mine, Tottori Pref.
- 4) Nodular ore poikilitically enclosing gangue minerals from the Wakamatsu Mine, Tottori Pref.
- 5) Nodular ore from the Wakamatsu Mine
- 6) Compact ore associated with patches of disseminated ore from the Nittoh Mine, Hokkaido



$$a = 8.245\text{\AA}$$

MgO 14.45% FeO 18.76% Al_2O_3 22.24% Cr_2O_3 40.21%

This chromite is characterized by poorness of Cr_2O_3 and richness of Al_2O_3 when compared with that from the Nittoh Mine.

Chromite from Wakamatsu Mine, Tottori Pref. Presence of hematite and abundant ferritchromite is one of the characteristic features of massive chrome ore from the Wakamatsu Mine. The mode of occurrence of hematite under ore-microscope is given in Fig. 2-(8). Hematite takes lenticular-form or granular-form along the cleavage of chromite being associated with ferritchromite. The chromite is coarse-grained and subhedral. Chemistry of the chromite is given as follows:

MgO 4.03% FeO 8.87% Al_2O_3 31.61% Cr_2O_3 37.71%

Vein or patch composed of fine-grained disseminated chromite is occasionally observed in the dense ore.

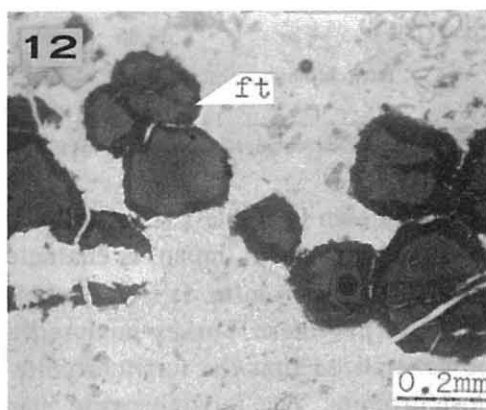
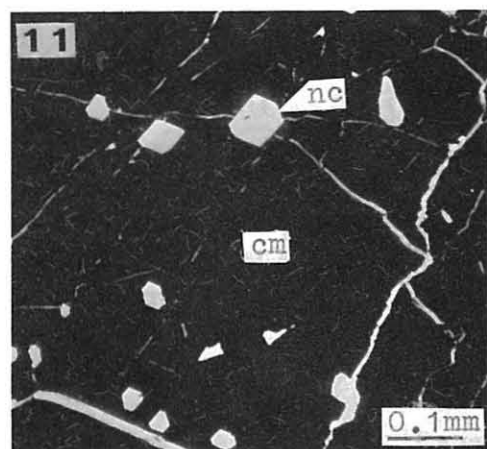
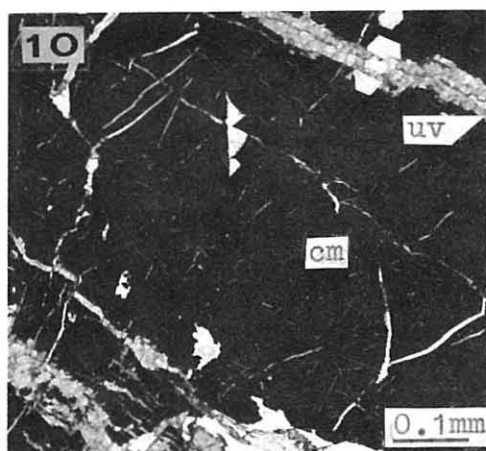
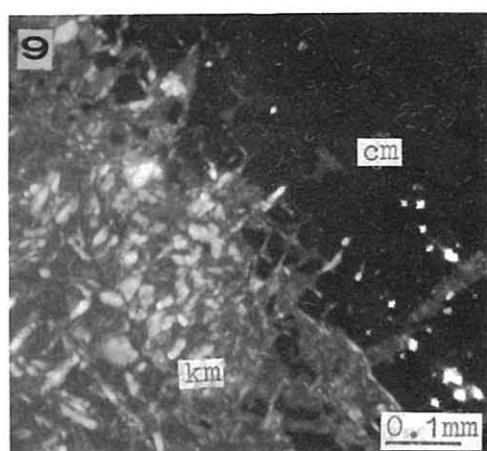
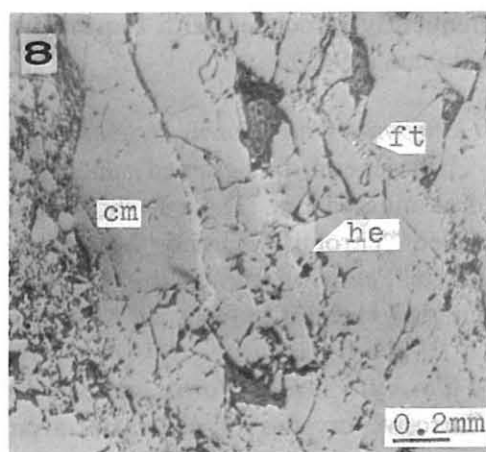
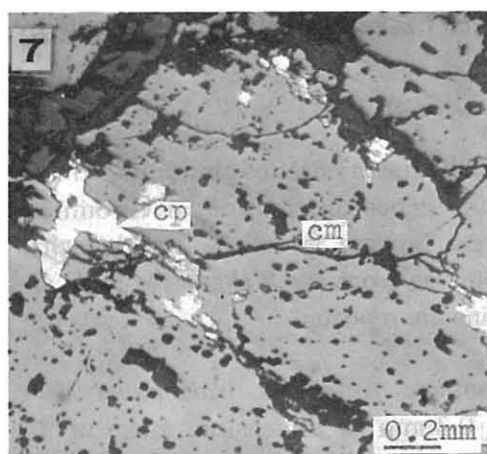
Chromite which forms nodular ore

Typical nodular chrome ore is abundant in the Wakamatsu Mine. Strictly speaking, the ore belongs to the type of "Nodular chromitite poikilitically enclosing gangue minerals" as shown in Fig. 1-(4).

The dimension of nodule consisting of aggregates of chromite and chlorite attains to 1 – 2 cm. The colour of the chromite in thin section is light reddish brown, thus the ferritchromite is easily distinguishable from hostchromite under microscope. The ore is extremely abundant in ferritchromite and

Fig. 2 Photomicrographs of several types of chromite ore from Japan

- 7) Photomicrograph of polished section of compact chromite ore from the Nittoh Mine showing the paragenesis with chalcopyrite. cp: chalcopyrite cm: chromite
 - 8) Photomicrograph of polished section of compact chromite ore associated with hematite and ferritchromite. he: hematite cm: chromite ft: ferritchromite
 - 9) Photomicrograph of thin section of banded chromite ore associated with Kämmererite from the Akaishi Mine, Ehime Pref. km: Kämmererite cm: chromite
 - 10) Photomicrograph of thin section of compact ore associated with uvarovite from the Suehiro Mine, Tokushima Pref. uv: uvarovite cm: chromite
 - 11) Photomicrograph of thin section showing the mode of occurrence of the negative crystals in the compact ore from the Nittoh Mine, Hokkaido nc: negative crystal cm: chromite
 - 12) Photomicrograph of thin section of chromitite from the Wakamatsu Mine showing the relation between hostchromite and ferritchromite. ft: ferritchromite
- The core of chromite is called hostchromite.



frequently associated with tourmaline which has been determined as dravite by Kitahara (1966).

Chromite which forms disseminated ore

In general, fine-grained euhedral or subhedral crystals of chromite form the disseminated ore. The ore showing homogeneous distribution of chromite is called "chromitite", and the ore showing flowage is called "lineated chromitite", respectively. In this paper, chromitite from the Wakamatsu Mine and lineated chromitite from the Nukabira Mine are reported.

Chromite which forms massive chromitite from the Wakamatsu Mine. Corrosive crystals of chromite, around 0.3 mm of dimension, make up the massive chromitite attaining to 50% of concentration grade. The individual grains of chromite are generally enclosed by ferritchromite as shown in Fig. 2-(12). The chemistry of the chromite associated with ferritchromite is given as follows:

MgO 16.69% FeO 18.65% Al_2O_3 27.32% Cr_2O_3 32.36%

Chemistry of the hostchromite and related ferritchromite from the Wakamatsu Mine has been recently examined by EPMA. The results obtained are given in Table 2.

Table 2 Chemical composition of hostchromite and the associated ferritchromite from Wakamatsu Mine, southwestern Japan

	MgO	FeO	Al_2O_3	Cr_2O_3	Total
hostchromite	16.42	14.62	28.18	40.08	99.30
	17.12	13.66	28.28	40.57	99.63
	16.40	13.93	27.95	40.37	98.65
	16.85	13.17	28.32	40.40	98.74
ferritchromite	12.22	25.99	14.25	44.32	96.78
	11.19	24.38	11.78	47.11	94.46

EPMA analysis was carried out in Geological Survey of Japan. (Analyst: K.Niida)

As shown in Table 2, chemistry of the ferritchromite from the Wakamatsu Mine, southwestern Japan, is characterized by richness of Fe and Cr compared with the hostchromite. It is very similar to the chemistry of the ferritchromite from southwestern Turkey analysed by Engin and Aucott (1971). Thus it may be generalized that the ferritchromite is rich in Fe and Cr compared with the hostchromite. The ferritchromite might have been formed by removal of Mg and Al through oxidation process of chromite.

Chromite which forms lineated chromitite from the Nukabira Mine. The feature of this chrome ore is given in Fig. 1-(2). Chromite crystals, 0.2 mm in size, are aligned showing lineated structure. The colour of the chromite in thin section is reddish brown and no ferritchromite is associated. The chemistry of the separated chromite is given as below:

MgO 11.55% FeO 16.62% Al_2O_3 13.67% Cr_2O_3 52.29%

The lattice constant of the chromite is as follows:

$$a = 8.314\text{\AA}$$

Chromite which forms banded ore

Chrome ore from the Akaishi Mine, Ehime Pref. belongs to the banded ore based on the author's classification. An example is given in Fig. 1-(1). Anhedral chromites, 0.1 – 1.0 mm in size, are concentrated displaying a typical banded structure. A few centimeter to 10 cm thick of black coloured layer consisting mainly of chromite is interbanded with light coloured layer which is composed of olivine cumulates.

The chromite is reddish brown in thin section, and ferritchromite is not observable. The chemical composition and lattice constant of this chromite are as follows:

MgO 5.18% FeO 28.96% Al_2O_3 14.79% Cr_2O_3 47.96%

$$a = 8.327\text{\AA}$$

Ore-microscopic study of chromite

Mode of occurrence of hematite, ferritchromite and chalcopyrite in chrome ore. Though the chrome ores from Japan are composed mainly of chromite, hematite and ferritchromite are ore-microscopically observed in the ore from the Wakamatsu Mine. Besides, some sulphide minerals such as chalcopyrite and pyrite are microscopically found in the ore from the Nittoh Mine. Generally speaking, sulphide minerals occur taking vein-form or network-vein which implies that these are hydrothermal origin. The hematite from the Wakamatsu Mine shows lenticular-form in small scale along the cleavages of chrome ore but some of them take an irregular form implying that hematite partially replaced the ferritchromite (Fig. 2-(8)). It is notable that the hematite is abundant in the ore which is characterized by the presence of ferritchromite, thus it seems that the ferritchromite may be closely related to the formation of hematite. Perhaps ferritchromite and hematite might have been formed as the results of oxidation of chrome ore.

Reflectivity and hardness of chromite and ferritchromite.

For the examination of hardness, MVK Hardness Tester, Akashi Manufac-

turing Co. was used, and for the examination of reflectivity, Berek's Slit Microphotometer, Leitz Co. was used. As standard examples for the measurement of reflectivity, SrTiO_3 Prism (No. 353) and Glass Prism (No. 477), Leitz Co., were prepared. In order to obtain the straight-line relationship between the angle of rotation of nicol and reflectivity on the logarithmic coordinate paper, above-noted standards are quite useful.

The results obtained by using the preceding instruments are given in Figure 3 which shows the relationship between reflectivity and VHN of

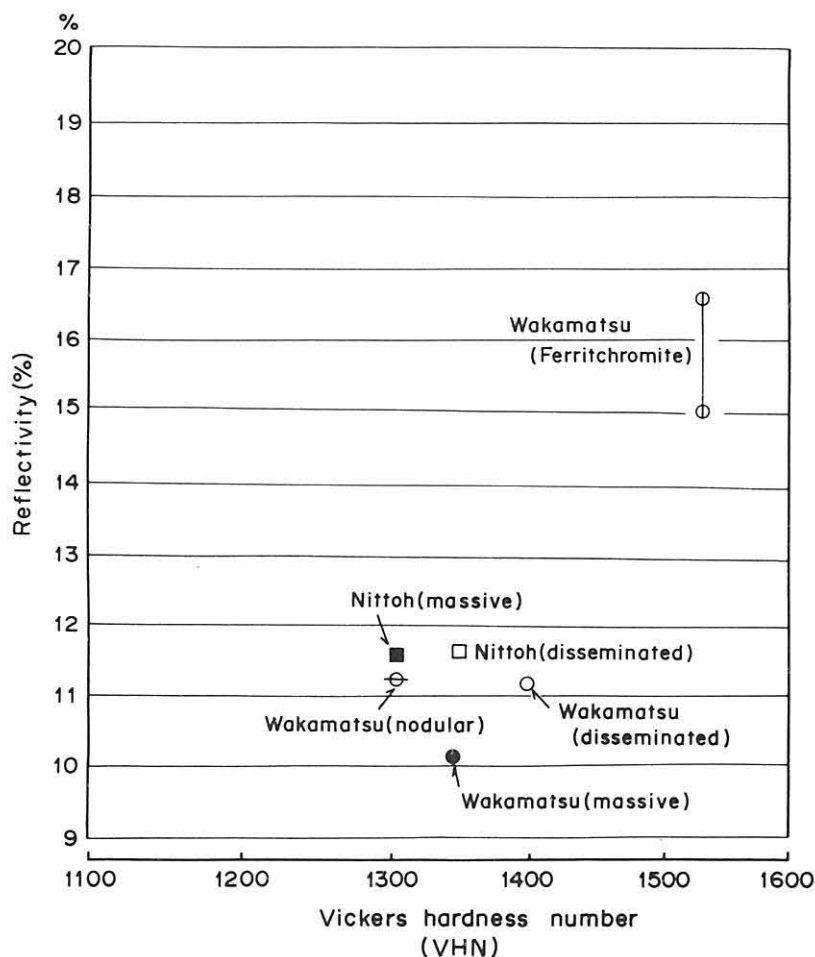


Fig. 3 Relationship between reflectivity and VHN of chromites from Japan. Massive ore-forming chromite shows small VHN and the ferritchromite shows higher reflectivity and larger VHN compared with hostchromite.

chromite belonging to the several types of chrome ore from Japan.

As illustrated in Fig. 3, VHN of chromite which forms massive ore is

smaller than that of the disseminated one. Ferritchromite is larger in VHN and shows higher reflectivity compared with hostchromite.

Relationship between Cr_2O_3 content and lattice constant of chromite

As well known, MgO , FeO , Al_2O_3 and Cr_2O_3 are the main compositions of chromite. The chromite from Japan shows wide variation in its chemical composition. Thus the relationship between Cr_2O_3 content of chromite and its lattice constant was investigated: As given in Fig. 4, it is clear that the grade of Cr_2O_3 content corresponds to the increase of lattice constant. When the Cr_2O_3 content of chromite is more than 50%, lattice constant becomes to be stable.

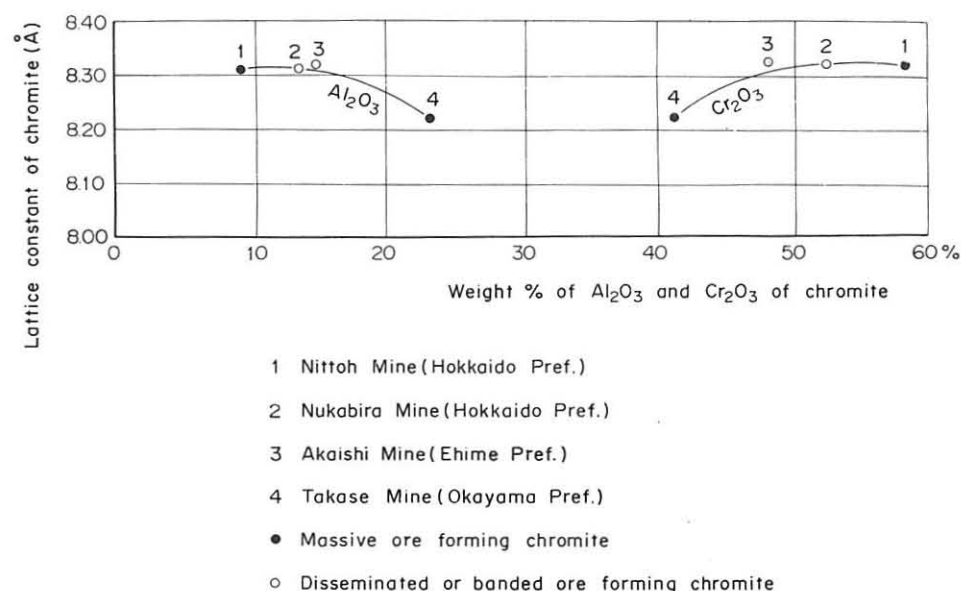


Fig. 4 Diagram showing the relationship between lattice constant and weight % of Al_2O_3 , and Cr_2O_3 of chromites from Japan.

Relationship between reflectivity of chromite and its Cr_2O_3 content

As preceding notes, wide variation of Cr_2O_3 content is recognized on the chromites from Japan, e.g. chromite from the Wakamatsu Mine shows around 35% of Cr_2O_3 while that from the Nittoh Mine shows more than 50% of Cr_2O_3 and the chrome ore from the Takase Mine shows 40% grade.

Relationship between reflectivity and Cr_2O_3 content of above-noted chromites were investigated. The results obtained are given in Fig. 5. The

chromite from the Nittoh Mine (60% of Cr_2O_3) shows the highest reflectivity and the chromite from the Wakamatsu Mine (37% Cr_2O_3) shows lower reflectivity as compared with the former and so on. Thus it is estimated that the reflectivity of chromite corresponds to the grade of Cr_2O_3 content.

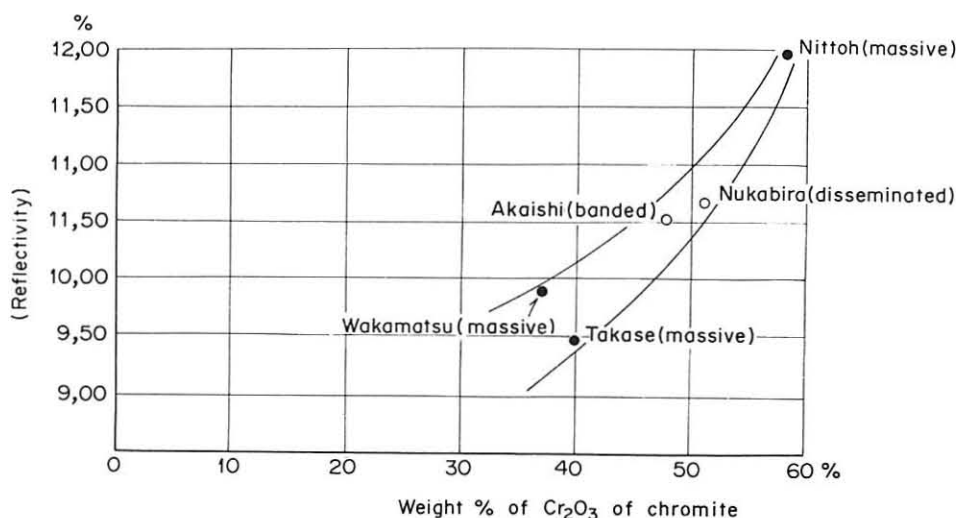


Fig. 5 Relationship between reflectivity and Cr_2O_3 content of chromites from Japan.

Acknowledgements

The study of chrome ore in Japan had been carried out by the late Emeritus Professor Jun Suzuki, Hokkaido University. The present author continued this research subject under the kind guidance of him at the beginning of the study. From this time onwards until today, the author has been greatly indebted to Nittoh, Hatta, and Nukabira Mines, Hokkaido, Wakamatsu, and Hirose Mines, Tottori Pref., Takase Mine, Okayama Pref. and Akaishi Mine, Ehime Pref. for their excellent cooperation in preparing chrome ores.

EPMA analysis of ferritchromite and hostchromite was carried out in Geological Survey of Japan by Dr. K. Niida, Hokkaido University. Messrs. K. Aohara, and T. Katoh of the same University cooperated for the measurements of reflectivity, hardness and lattice constant of chromite. The author would like to express sincere thanks to the above-stated persons for their inestimable assistance.

It is author's pleasure to dedicate this paper to Prof. Kenzo Yagi on the occasion of his retirement from the Hokkaido University.

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