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# Serpentine Sandstone from Hokkaido

By

Hakuyu OKADA

## Abstract

A peculiar sandstone, in which grains are almost wholly made up of serpentine discs, was found in the Tertiary deposits in Hokkaido.

This sandstone can be called washed serpentine graywacke, in which the serpentine discs are mineralogically identified largely as lizardite. In spite of the mineralogically immature character, the sandstone comprises very well-rounded grains. The composition of the sandstone indicates that serpentinite was the main source and that crystalline schists of the glaucophane facies was the subordinate one.

This sandstone is warrantably referred to the lower Middle Miocene Takinoue Formation of the Kawabata Series which is called a kind of "molasse" type sediments. It presents a peculiar example of post-orogenic sediments derived from the Kamuikotan metamorphic belt with little transportation.

## Introduction

Sandstones of a single clastic constituent are very rarely known not only at home but even abroad, except for certain types of arenites such as orthoquartzite. Therefore, it is very significant both petrologically and tectonically that rather a monomineralic sandstone composed almost wholly of serpentine grains was found in Hokkaido. In particular it is diagnostically noteworthy that an easily weatherable material like serpentine presents a sole make-up of the arenite. The discovery has already been briefly reported in Japanese by MATSUMOTO *et al.* (1963).

Serpentine and/or serpentinite materials are known in sediments of various ages in California (WILLIAMS *et al.*, 1955, Fig. 103), England and Italy (MILNER, 1962, p. 83, 177) as well as in the Tertiary and Quaternary sediments in Hokkaido (for instance, IMAI, 1921; UWATOKO and TIBA, 1937; MATSUI, 1951; HASHIMOTO and SASA, 1962; SASA, personal communication, 1962; KANNO and OGAWA, 1963). The Permian Otani Conglomerate in the Hida Massif, central Honshu (KANŌ, 1961) may be another example. In these examples, however, occurrence is always erratic.

As to boulders and cobbles of serpentinite in the Tertiary conglomerates of Hokkaido, opinions have been repeatedly given on their tectonic significance by some authors (UWATOKO and TIBA, 1937; NAGAO, 1938; MITA and TASHIRO, 1951; SUZUKI, 1952; TAKAO, 1952; HUNAHASHI, 1957 and so on). The newly found serpentine sandstone is likewise of great interest as an indicator of tectonic

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environments which controlled the Tertiary sedimentation in Hokkaido. In this paper petrography of the serpentine sandstone is described in detail and some comments are added on its geologic significance.

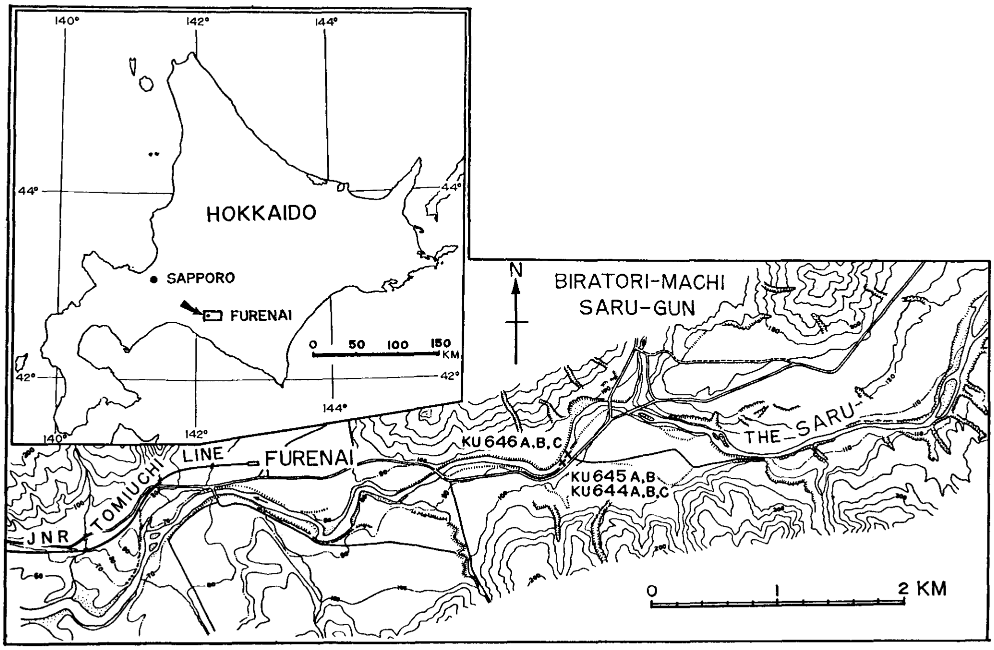


Fig. 1. Topographical map showing a locality of sandstone samples. Inset is a regional map of Hokkaido.

## Location

The sandstone to be described is exposed in a narrow strip of about 100 m long on the right bank of the River Saru, about 2400 m east of the J.N.R. Furenai Station, Biratori-machi, Saru-gun, Province of Hidaka in central Hokkaido [lattitude 42°43′35″ N and longitude 142°19′50″ E] (Fig. 1). The rock was discovered and the specimens were collected in August 1961 by MATSUMOTO, ORITA and me.

All the specimens used in this study (Table 1) are preserved in the Department of Geology, Kyushu University, Fukuoka.

## Geologic Setting

### *1. Geologic framework and ultrabasic rocks*

Before proceeding further, it is pertinent to give some accounts of the geologic framework in central Hokkaido.

Table 1. List of specimens used

| Sample No. | Rock name | Locality | Collectors |
|---|---|---|---|
| KU 644A | Washed serpentine graywacke | Right bank of the Saru, 2.4km east of the Furenai Station, Biratori-machi, Saru-gun, Hokkaido [lat. 42°43′35″ N, long. 142°19′50″ E] (北海道沙流郡平取町振内) | T. MATSUMOTO, H. OKADA and Y. ORITA |
| KU 644B | Ditto | Ditto | ——, ——, —— |
| KU 644C | Ditto | Ditto | ——, ——, —— |
| KU 645A | Ditto | Ditto | ——, ——, —— |
| KU 645B | Ditto | Ditto | ——, ——, —— |
| KU 646A | Ditto | Ditto | ——, ——, —— |
| KU 646B | Serpentine graywacke | Ditto | ——, ——, —— |
| KU 646C | Washed serpentine graywacke | Ditto | ——, ——, —— |
| | Ortho-chrysotile | Hamao, Kashii-machi, Fukuoka City, Kyushu (福岡市香椎町浜男) | H. SHIROZU |
| | Antigorite | Jingadao, Sasaguri-machi, Kasuya-gun, Fukuoka Prefecture, Kyushu (福岡県粕屋郡篠栗町陣ヶ田尾) | —— |
| | Lizardite | San-oh, Sasaguri-machi, Kasuya-gun, Fukuoka Prefecture (福岡県粕屋郡篠栗町山王) | —— |
| | Serpentine | Akaishi Mine, Doi-machi, Uma-gun, Ehime Prefecture, Shikoku (愛媛県宇摩郡土居町赤石鉱山) | M. YAMAGUCHI |
| Hr 1 | Washed serpentine graywacke | River-bed of the Uryu, 1.5 km east of the Soeushinai Station, Horokanai-machi, Uryu-gun, Hokkaido [lat. 44°12′30″ N, long. 142°09′40″ E] (北海道雨竜郡幌加内町添牛内) | W. HASHIMOTO and S. KANNO |
| Hr 2 | Sandy siltstone | Upper stream of the Sanjissen-zawa, 4 km southwest of Kyoei, Horokanai-machi, Uryu-gun, Hokkaido [lat. 44°14′50″ N, long. 142°06′10″ E] (北海道雨竜郡幌加内町共栄西南方，三十線沢) | S. KANNO |

This area is topographically of the meridional backbone of Hokkaido, where longitudinally run in roughly parallel a pair of metamorphic belts called the Hidaka metamorphic belt to the east and the Kamuikotan metamorphic belt to the west. Between them there are patches of Cretaceous and Tertiary deposits (Fig. 2).

The Hidaka metamorphic belt is composed of hornfels, phyllite, migmatitic rocks, gneiss and amphibolite, accompanied with intrusive bodies of granite, grabbro and peridotite. According to MIYASHIRO (1961), this metamorphic belt belongs to the andalusite-sillimanite facies of metamorphism. These metamorphics and intrusives are thought to represent a core of the orogenic belt resulted from the crustal movements during the period of Cretaceous to Tertiary.

The Kamuikotan metamorphic belt consists largely of crystalline schists of the glaucophane-schist facies (MIYASHIRO, 1961). In addition, this belt is ac-

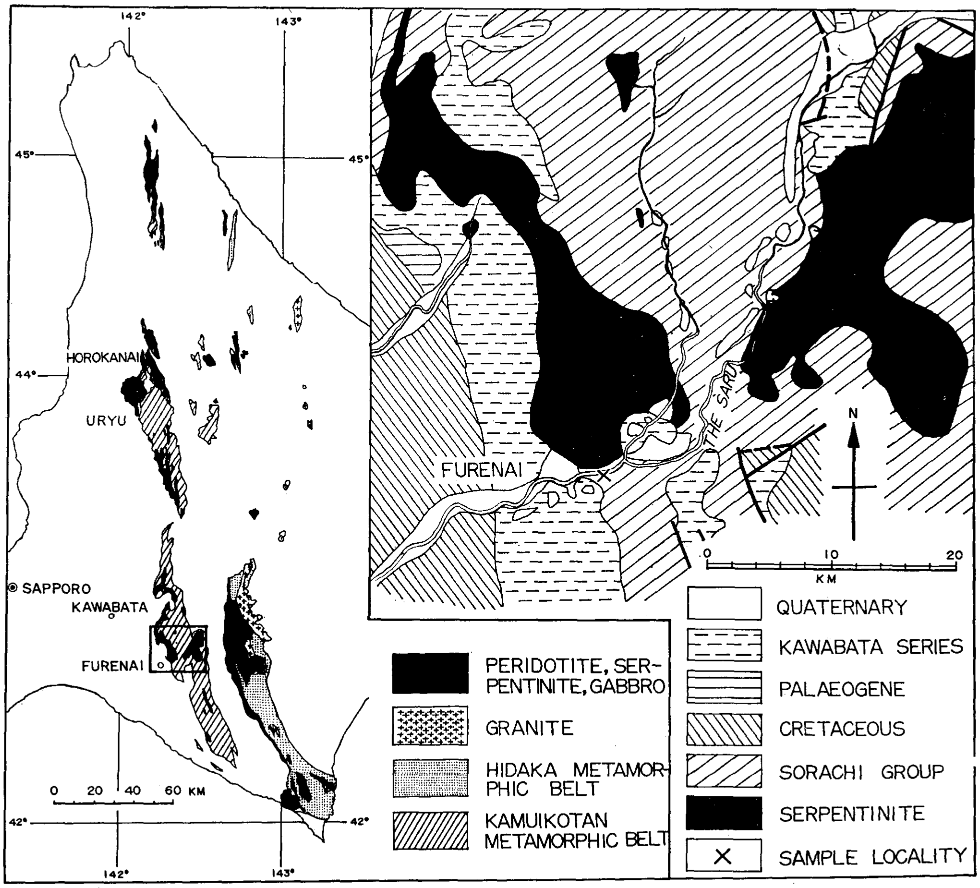


Fig. 2. Map showing a geologic framework of central Hokkaido on the left (after HUNAHASHI, 1957) and a geologic sketch map of the sampling area (adapted from GEOLOGICAL SURVEY OF HOKKAIDO, 1958).

companied by some serpentinite masses on a large scale. Within this belt is located the Tertiary sandstone described here.

While the ultrabasic rock occurs in the Kamuikotan metamorphic belt as large masses of serpentinite, it is found as small bodies of unaltered peridotite in the Hidaka metamorphic belt. Petrologic description of these ultrabasic rocks was given in an excellent way by SUZUKI (1952). According to him, they are classified by their petrographic nature into five main types: (1) massive serpentinite showing mesh structure, with or without relict minerals, (2) schistose serpentinite, (3) talcose serpentinite, (4) actinolite-fels and (5) peridotite.

### 2. *Sedimentary rocks*

As is shown in the Geologic Map of Hokkaido, scale 1 : 200,000 (GEOLOGICAL SURVEY OF HOKKAIDO, 1958), the Jurassic-Neocomian Sorachi Group, the post Aptian Cretaceous Lower to Upper Yezo Groups and Hakobuchi Group and the

Neogene Tertiary "Kawabata Series" are distributed in central Hokkaido partly covered with Quaternary sediments and volcanic ejecta.

In the Furenai area now under question the Neogene Tertiary is represented by the "Kawabata Series" in the age of the Lower to Middle Miocene. Although its stratigraphic definition may be still debatable, the Kawabata Series in the type area, about 34 km northwest of Furenai, consists of the Takinoue Formation in the lower and the Kawabata Formation in the upper part, and is as a whole characterized by coarse clastics of littoral to shallow-sea deposits which exhibit a sedimentary feature to be called a molasse (NAGAO, OTATSUME and SAITO, 1933). Especially the Takinoue Formation is very distinctive in the frequent occurrence of huge boulders as big as a few metres or more, sometimes over 10 m, which are fairly well rounded. Such a feature leads some geologists to call Nagelfluh-type deposits. It is, moreover, of great interest that such gigantic boulders are mostly of serpentinite.

The whole thickness of this series is estimated to be more than 1000 m in the type section.

### 3. *Beds of the serpentine sandstone*

The beds in question display much restricted exposure, as mentioned in the foregoing chapter (p. 24). So far as an outcrop is observed, they seem to be in a fault relation with a serpentinite mass which may have been their bedrock, and are composed mainly of alternative beds of serpentine sandstone and glauconitic siltstone. In general the present sandstone contains abundantly fossils of sea-shells and aggregates of fragments of precisely indeterminable microfossils as small calcareous or coquinoid lenses. According to KANNO's identification (in MATSUMOTO *et al.*, 1963) of those shells, they are *Glycymeris miyagiensis* KANNO (1960, pp. 208-209, pl. 32) and indicate the age of the Lower to Middle Miocene. These glycymerid shells are more or less subject to deformation probably due to later tectonic movements.

## Petrographic Description

### 1. *Gross features*

The beds of the serpentine sandstone, each 1 to 2 m thick, are intercalated with thinner glauconitic siltstone beds. Sometimes the sandstone grades into the siltstone with no distinct boundary. The serpentine sandstone, in spite of its rather massive appearance, presents a disposition of serpentine discs in parallel with the bedding, so that platy partings of a few centimetres thick are apt to form along this texture. Neither grading nor cross-lamination is observed even on a microscopic scale. Bivalved glycymerid shells occur also in concordance with the bedding plane, together with fragments of odd valves. Irregular calcite veinlets are often seen.

This serpentine sandstone looks dusky yellow green (5 GY 5/2)* due to the bulk of serpentine grains.

General appearance of the sandstone is displayed on Plate 4 (Figs. 1, 2).

### 2. *Texture*

The detrital grains of serpentine show a definite disposition as stated above, but lamination resulted from that arrangement is not obvious. Serpentine discs are quite variable in size, at the largest measuring as long as 5 mm. They are mostly more or less well rounded and disc-like. Even in a group of much prolonged forms terminal margins of each grain are remarkably well abraded. According to the visual roundness chart prepared by KRUMBEIN (1941), the average roundness of serpentine discs is estimated at 0.6 to 0.7 (Pl. 5, Figs. 1, 2). In the case of the sandstones from another area (Horokanai) it is also just alike (Pl. 5, Figs. 4, 5).

### 3. *Major constituents*

*Technique.*—Major mineral constituents have been observed through thin-sections under the microscope. For certain minerals the X-ray identification was applied. Especially for the determination of the kinds of serpentine mineral, an X-ray diffraction analysis is reliable. For this purpose, tips of sandstone specimens were emmerged into the 1 normal hydrochloric acid to dissolve away calcite which coagulates sand grains all together. Then, the residuals were separated for serpentine concentrates with the Frantz Isodynamic Magnetic Separator.

A relative abundance of major constituents was measured by the use of a microintegrator.

*Description.*—Major constituents identified are: serpentine, calcite, chloritic

Table 2. Major constituents of serpentine sandstones

| Major constituents / Samples | Quartz | Feldspar | Serpentine discs | Shell fragments | Calcite cement | Clay matrix | Iron mineral | Glauconite | Metamorphic rock fragments | total (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| KU 644A | + | | 85 | 2 | 12 | | 1 | | | 100 |
| KU 644B | + | | 61 | 9 | 28 | | 2 | | | 100 |
| KU 644C | + | | 65 | 6 | 29 | | + | | | 100 |
| KU 646B | 4 | + | 50 | | + | 39 | 1 | 4 | 2 | 100 |
| KU 646C | + | | 74 | 4 | 22 | | + | | | 100 |
| Hr 1 | 4 | | 53 | 4 | 28 | + | 1 | + | 10 | 100 |

Symbole + stands for less than 1 percent.

* Colour designation after E. N. GODDARD [Chairman] (1951).

matrix, iron minerals, quartz, chert, feldspar, glauconite and metamorphic rock fragments, which are presented in Table 2.

The serpentine which makes up the bulk of this sandstone is divided into the two morphological types; ovoidal lamellae and much prolonged laths. The former is usually massive and/or of aggregates of fibrolamellar and flamboyant radial textures, presenting in general a mesh structure due to cross-fiber veinlets. The latter occurs in crystal aggregates with a columnar or fibrous texture. This texture is mostly in parallel with, but occasionally crosses the axis of a prolonged grain. Optical elongatoin of each serpentine fiber is always positive.

Table 3. X-ray powder data of serpentine separated from the serpentine sandstone [Sp. No. KU 644 A]

| *d* (Å) | I | Remarks |
|---|---|---|
| 7.28 | 10 | Serpentine |
| 4.58 | 2 | Serpentine |
| 3.66 | 6 | Serpentine |
| 2.51 | 2 | Lizardite |
| 2.44 | 2 | Clino-chrysotile+Lizardite |
| 2.16 | 1/2 | Lizardite |
| 1.536 | 2 | Serpentine |

Note: FeK$\alpha$, Scannig speed 2°/min., Time constant 2.5 secs., Slits 2–2–0.6 mm.

According to the X-ray powder pattern, the main constituent is lizardite, and to a more limited extent clino-chrysotile is contained (see Table 3). This identification was made on the basis of WHITTAKER and ZUSSMAN's scheme (1956).

The calcite occurs mostly as a cementing matter which constitutes up to 29 percent of the rock, and partly as bioclastic fragments of several percent. The cementing calcite is more or less coarsely crystallized.

Of other constituents, quartz is discernible in every sample but usually in amount of less than 1 percent. A few grains of indeterminable plagioclase are found in most of the samples. They are angular and exhibit albite twinning. In a specimen (Sp. KU 646 B) crystals of plagioclase showing zonal structure are detected, which may be of volcanic origin.

The rest of the major constituents is too infrequent in occurrence to characterize the sandstone.

### *4. Accessary heavy minerals*

*Technique.*—Heavy minerals were separated by the use of Thoulet's solution (S. G. = 2.9) as a heavy liquid. For determination and frequency counts of the heavy minerals the heavy residues obtained were mounted in balsam. Chromite and magnetite were specially identified by the X-ray diffraction analysis (Table 4).

Table 4. X-ray powder data of magnesiochromite and magnetite separated from the serpentine sandstones

| Magnesiochromite | | | Magnetite | | |
|---|---|---|---|---|---|
| *hkl* | *d* (Å) | I | *hkl* | *d* (Å) | I |
| 111 | 4.78 | 3 | 022 | 2.96 | 6 |
| 022 | 2.92 | 3 | 113 | 2.53 | 10 |
| 113 | 2.49 | 10 | 222 | 2.42 | 1 |
| 004 | 2.07 | 6 | 004 | 2.10 | 4 |
| 115<br>333 | 1.595 | 6 | 115<br>333 | 1.613 | 5 |
| 044 | 1.466 | 7 | 044 | 1.482 | 6 |

Notes: a) Magnesiochromite and magnetite are separated from Sp. No. KU 644A.
b) Experimental data: FeK$\alpha$, Scanning speed 2°/min., Time constant 2.5 secs., Slits 3-2-0.4 mm.
c) *hkl* is cited from BERRY and THOMPSON (1962).

*Heavy mineral assemblages.*—The heavy minerals identified are listed in Table 5, in which their relative abundance and amount are also shown.

Table 5. Heavy minerals of serpentine sandstones

| Heavy minerals / Sample No. | Magnetite | Non-opaques | total (%) | Non-opaques: Zircon, Euhedral: colourless | Zircon, Euhedral: pale pink | Zircon, Rounded: colourless | Zircon, Rounded: pale pink | Zircon: purple | Garnet | Tourmaline | Epidote | Augite | Hypersthene | Hornblende: brown | Hornblende: brownish green | Hornblende: green | Magnesiochromite | Chlorite | Biotite | Rutile | Glaucophane | Pumpellyite | total (%) | Weight percentage of heavy minerals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| KU 645A | 51 | 49 | 100 | + | | | | | 1 | | + | | | | 1 | + | 98 | | | | | | 100 | 0.01 |
| KU 645B | 57 | 43 | 100 | | | | | | 6 | | 2 | + | + | | 1 | | 91 | | | | | | 100 | 0.01 |
| KU 646A | 41 | 59 | 100 | + | + | | | | 6 | + | 5 | + | | | 5 | + | 83 | | | | 1 | | 100 | 0.05 |
| KU 646B | 65 | 35 | 100 | 9 | 3 | 1 | 1 | 1 | 5 | + | 20 | 6 | 11 | 1 | 6 | 10 | 23 | 1 | 1 | | + | | 100 | 0.01 |
| KU 646C | 64 | 36 | 100 | | 1 | | | | 2 | | 2 | | | | 1 | 1 | 93 | | | | | | 100 | 0.2 |
| Hr 1 | 55 | 45 | 100 | 1 | + | | + | + | 1 | | 5 | | | 1 | 7 | 53 | 24 | | | 1 | 4 | 2 | 100 | 0.12 |
| Hr 2 | 45 | 55 | 100 | 1 | | | | | | | 2 | | | 1 | 10 | 18 | 64 | | | | 4 | + | 100 | 0.46 |

Symbole+ stands for less than 1 percent.

The association of the heavy minerals of the present sandstone is very simple as a whole. Particular species of magnesiochromite and magnetite (Table 4) are prevalent (Pl. 5, Fig. 3), and a few kinds of other heavy minerals occur in a small amount (Table 5). The predominance of the magnesiochromite-magnetite suite definitely corresponds to the dominance of serpentine discs as major constituents.

As can be understood from the specimen KU 646 B, the magnesiochromite-magnetite suite is to a small extent contaminated with the influx of the suites of augite-hypersthene-brown hornblende probably derived from andesitic volcanic rocks and of epidote-green hornblende-glaucophane of the metamorphic origin. The influx of the metamorphic suite seems to be commoner than that of the volcanics.

### 5. *Chemical composition*

*Technique.*—A chemical analysis was made in a conventional way of the specimen KU 644 A, which was selected on account of its freshness and freedom from calcareous fossil fragments.

Table 6. Chemical composition

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| $SiO_2$ | 20.70 | 40.26 | 38.45 | 64.7 | 74.43 |
| $TiO_2$ | | | | 0.5 | 0.83 |
| $Al_2O_3$ | 0.84 | 1.21 | 3.24 | 14.8 | 11.32 |
| $Fe_2O_3$ | 3.72 | 8.25 | 3.26 | 1.5 | 0.81 |
| $FeO$ | | | 5.16 | 3.9 | 3.88 |
| $MnO$ | 0.32 | 0.40 | | 0.1 | 0.04 |
| $MgO$ | 18.80 | 36.88 | 36.32 | 2.2 | 1.30 |
| $CaO$ | 26.90 | 0.55 | 0.87 | 3.1 | 1.17 |
| $Na_2O$ | | | 0.25 | 3.1 | 1.63 |
| $K_2O$ | | | — | 1.9 | 1.74 |
| $P_2O_5$ | | | | 0.2 | 0.18 |
| $SO_3$ | | | | 0.4 | |
| $CO_2$ | | | | 1.3 | 0.48 |
| $H_2O_+$ | | | — | 2.4 | 2.15 |
| $H_2O_-$ | | | — | 0.7 | 0.20 |
| S | | | | 0.2 | 0.12 |
| C | | | | | 0.17 |
| $Cr_2O_3$ | 0.06 | 0.35 | | | |
| Loss on ignition | 29.10 | 12.32 | 12.53 | | |
| Total | 100.44 | 100.22 | 100.08 | 101.0 | 100.45 |

1. Washed serpentine graywacke; Sp. No. KU 644A; colour 5GY 5/2 (dusky yellow green) [Analyst: Mitsuo NAKAMURA].
2. Lizardite [Analyst: Mitsuo NAKAMURA]; from San-oh, Sasaguri-machi, Kasuya-gun, Fukuoka Pref. (Coll. H. SHIROZU).
3. Serpentinite in the Kamuikotan metamorphic belt, Takadomari, Uryu-gun, central Hokkaido (SUZUKI, 1953, p. 200)
4. Average of 23 graywackes in PETTIJOHN (1957, table 52).
5. Subgraywacke from the Carboniferous Stanley shale (PETTIJOHN, 1957, table 54).

Table 7. Distribution of minor elements

| No. | Sample No. | Name of mineral or rock | | | | |
|---|---|---|---|---|---|---|
| | | | B | Be | Co | Cu |
| 1 | KU 644A | Washed serpentine graywacke | ** | | — | — |
| 2 | KU 645A | Washed serpentine graywacke | ** | | — | — |
| 3 | | Ortho-chrysotile | — | — | — | — |
| 4 | | Antigorite | | | — | — |
| 5 | | Lizardite | — | | — | |
| 6 | | Serpentine | | — | | * |

Notes: a) Signs for the intensity of the spectrographic line: ***** very strong, **** strong, *** moderate, ** weak, * very weak, — faintly visible.
b) In Nos. 3–6 mineralogic names are used after WHITTAKER and ZUSSMAN (1956).

In addition, spectroscopic analysis was attempted on a few selected samples by the use of Shimadzu QF-60 Quartz Spectrograph. Experimental informations are as follows: 7 second exposure; Fuji Process Plate; FD 131 developing solution. The elements present were determined mostly by the lines between 2500 Å and 3500 Å, for other lines above and below are not clear enough for identification of elements in this experiment.

*Chemical composition.*—The data of chemical analysis are presented in Table 6, together with some published data of sandstones, lizardite and serpentinite for comparison.

As to the trace elements, 10 chemical elements as shown in Table 7 have been traced besides the major components detected in the above chemical analysis.

The distribution of elements is as follows:

1) Common elements: B, Ni
2) Less common elements: Co, Cu, Ga, Sb, Ti, Zn
3) Uncommon element: Pb

This distribution is compared with that of some available samples of serpentines.

*Remarks.*—The chemical analysis of the serpentine sandstone confirms its unusual composition, as is expected from the mineral composition of the sandstone. Table 6 shows that the serpentine sandstone represents a peculiar type in a chemical composition which is remarkably different from that of the normal graywackes and subgraywackes presented by PETTIJOHN (1957) (Table 6, Analysis Nos. 1, 4, 5). On the other hand, it is apparent that the composition of this sandstone is rather closer to that of serpentinite (Table 6, Analysis Nos. 1, 2, 3). Unexpected results are that the $Cr_2O_3$ content is low for a flood of serpentine material in this sandstone and at the same time the content of $Al_2O_3$ is extremely low as compared with average sandstones. $Cr_2O_3$ seems to be more diluted in the sandstone unlike that in the serpentinite. The low content of $Al_2O_3$ is simply because the present sandstone is free from clay matrix. Hence, the sandstone shows such a negligible amount of $Al_2O_3$ as orthoquartzites do. The $SiO_2$ content

| Elements | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Ga | Na | Ni | P | Pb | Sb | Ta | Te | Ti | V | W | Zn |
| * | | *** | | — | — | | | — | | | — |
| — | | **** | | | — | | | — | | | — |
| — | | * | | | | | | | | | — |
| — | | * | | — | | | | | | | — |
| — | — | ** | | | — | | | | | | — |
| | | * | | — | — | | | | | | |

is considerably depressed by the calcite as a major constituent of the serpentine sandstone.

Concerning the distribution of trace elements, this sandstone likewise closely resembles serpentinites (Table 7).

## Discussion

### *1. Sandstone pattern*

On the basis of the sandstone classification of PETTIJOHN (1957, Table 48), the present sandstone falls in the field of graywacke, but clay matrix of the sandstone is almost completely removed by washing, and the void resulted from that process is filled with calcite. Especially diagnostic feature is that serpentine grains are the most significant constituent making up the sandstones while quartz grains are little in quantity. Likewise noteworthy is that the sand grains are much rounded in spite of the immature nature in composition.

In these distinctive characters this sandstone is very eccentric like certain examples of Miocene and Cretaceous graywackes in New Guinea (EDWARDS, 1947 a, b), as compared with the normal graywackes presented by PETTIJOHN (1957, pp. 301-321). Therefore, to manifest the character of the present sandstone, it may better be called for the most part washed serpentine graywacke.

### *2. Correlation*

The problem to be further commented on is the correlation of the strata of serpentine sandstones.

Plentiful fossil shells of *Glycymeris miyagiensis* KANNO obtained from the present sandstone (p. 27) suggest the age of the Lower to Middle Miocene (KANNO, personal communication, 1962). According to KANNO, this species is known from the Horoshin Formation (or the Horoshin Shell Sandstone of UWATOKO and TIBA, 1937) in HOKKAIDO and its equivalents in other areas. The Horoshin Formation is correlated to the lower Middle Miocene Takinoue Formation of the Kawabata Series mentioned in the preceding (p. 27) in fossil contents as well as in lithofacies.

UWATOKO and TIBA (1937) stated that the Horoshin Formation consists mainly of an alternation of conglomerate, serpentine sandstone and shale, pointing out that the sandstone contains glaucophane and glauconite in appreciable amount. So that, this corresponds very well to the present serpentine sandstone besides the fossil evidence.

Thus, not only from a palaeontological respect, but from such lithological and petrological features, the strata in question are with certainty comparable with the Horoshin Formation and the contemporary Chikubetsu Formatoin (KANNO and MATSUNO, 1960) in the Horokanai area, northern part of central Hokkaido (Fig. 2).

The Chikubetsu Formation in the above area consists, at its basal part, of fossiliferous sandstones more or less rich in serpentine discs. Petrological examination of those sandstones* shows that some are almost equal to the present serpentine graywacke as is shown in Table 2 (Sp. No. Hr 1) and Figures 4 and 5 on Plate 5. A remarkable feature of the sandstone is that, in addition to much amount of magnesiochromite of the serpentinite origin, glaucophane as well as pumpellyite are more significant as accessary heavy minerals than in the present sandstones (Table 4, Sp. Nos. Hr 1 and 2).

Besides the above, lithological characters of the Middle Miocene Sasakizawa Conglomerate Formation (UWATOKO and TIBA, 1937; MATSUI and SHIMURA, 1949) are very suggestive of its correlation to the present strata, although any petrological examination is not yet made of that formation. Moreover, it is noteworthy that glycymerid shells from this formation described as "*Glycymeris vestitoides*" by MATSUI and SHIMURA (1949) seem to be more similar to *Glycymeris miyagiensis* than to the type *G. vestitoides* NOMURA (1935), as KANNO (personal communication, 1963) also agrees to that point.

Therefore, in all these respects it is warrantably concluded that the present strata are of the Takinoue Stage of the Kawabata Series and are precisely correlated with the formations stated above within the same geologic framework. This conclusion is also acceptable from the view point of tectonic history.

### 3. *Provenance and tectonic environment of sedimentation*

Considering the major constituents and heavy mineral suites of the sandstone as described in the preceding pages, the provenance was mostly in serpentinite masses and partly in crystalline schists and as rather accidental admixture in andesitic volcanic rocks.

On the petrological as well as geological evidence the Kamuikotan metamorphic belt, which consists mainly of glaucophane-bearing crystalline schists accompanied by ultrabasic rock masses, certainly had played an important role of main and direct source to the sediments. This is also clearly verified by the contemporary deposits of the Horoshin and Chikubetsu Formations in that they

* Prof. W. HASHIMOTO and Dr. S. KANNO of Tokyo University of Education have kindly offered through Prof. T. MATSUMOTO some of their collections for this study.

contain considerable amount of pumpellyite and/or glaucophane as stated above. As is well known, in the Kamuikotan metamorphic belt ultrabasic rocks are almost completely serpentinized (SUZUKI, 1952), and crystalline schists produced under the glaucophanitic regional metamorphism are characterized by the jadeite-pumpellyite-glaucophane suite as well as the epidote-hornblende suite (MIYASHIRO, 1959, 1961).

In addition, the remnants of andesitic volcanic rocks suggest volcanism during or prior to the sedimentation. MATSUI (1951) also reported that volcanic activities were distinct during the Kawabata Epoch. However, available data are too poor to trace centres of volcanic activities. Further, according to MATSUI's (1951) research of conglomerates of the Kawabata Series in its type area and IIJIMA's heavy mineral study (IIJIMA, 1959) of that series, acid plutonic rocks could be also one of the contributors to the sediments, source area of which was traced far to the Hidaka metamorphic belt, but no positive evidence in favour of this inference was extracted from the present study of the serpentine sandstone.

Now, source areas of the serpentine sandstones do not seem to have been much apart from the site of deposition. Although no experimental works on abrasion resistance have been done on serpentine as well as serpentinite, their resistance to mechanical abrasion must be considerably low, judging from experimental data of other minerals (COZZENS, 1931; THIEL, 1940). Therefore, the abundance of serpentine material in this sandstone contradicts with long transportation. Even winnowing process within a short distance could produce well abraded grains of serpentine. The material may have come from the serpentinite cliff immediately on the back of their depositional site. Likewise, metamorphic terrain may have been so close to the depositional site that it could leave glaucophane and other metamorphic minerals there.

In this connection, it is an interesting fact that KANNO (personal communication, 1962) has recently confirmed the contemporary Chikubetsu Formation overlying the serpentinite body with nonconformity. On the contrary, TAKEHARA (1951) and MITA and TASHIRO (1951) stated in their geological studies of Tertiary sediments in the Ishikari coal field that some serpentinite blocks in the Kawabata Series have been brought into by intrusion subsequent to the Miocene Kawabata Series and prior to the Pliocene Takigawa Series, and TAKEHARA went on to say that this was another period of serpentinite intrusion, that is, post-Kawabata period, in addition to the older, pre-Tertiary serpentinite intrusion. In the meanwhile, so far as the area which I have studied is concerned, serpentinite masses which were main contributors to the present sediments are due to the intrusion of at least early Tertiary orogenic epoch.

The fact that the less transported debris of serpentine are unexpectedly well rounded seems to record the effect of wave and current agitations in the site of deposition. Thus, water agitation removed clay or finer detritus from sands and, instead, calcite cement was subsequently introduced.

From this and other reasonings it can be inferred that rather steep mountains of serpentinites and other metamorphics stood near the depositional site.

## Concluding Remarks

The serpentine sandstone is significant in that it represents a certain type of the post-orogenic sediments related to the Cretaceous-Tertiary crustal movements in Hokkaido, called the Hidaka orogeny by some authors.

In the backbone of Hokkaido, there is a pair of metamorphic belts, the Kamuikotan and the Hidaka (Fig. 2), as is well explained by MIYASHIRO (1961). Such a tectonic framework is said to have been completed at least by the Miocene. The present serpentine sandstone of the lower Middle Miocene was certainly derived from an upheaved area of that Kamuikotan belt.

Thus, the present material should be evaluated as representing one of the sedimentary rock types characteristic of the orogenic belts.

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Hakuyu OKADA

Serpentine Sandstone from Hokkaido

# Plates 4–5

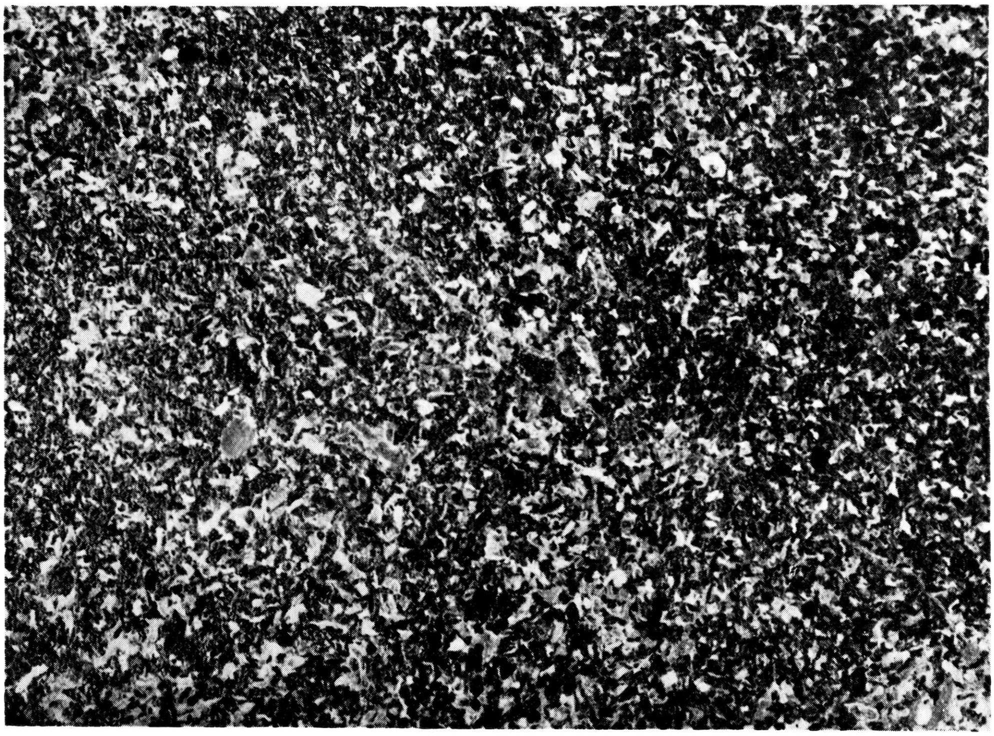
# Plate 4

## Explanation of Plate 4

Fig. 1. Serpentine sandstone with glycymerid shells from Furenai, Hokkaido [Sp. No. KU 644 A]. ×0.8

Fig. 2. Polished surface of the same specimen as above. ×2.

1



2

H. Okada : Serpentine Sandstone

# Plate 5

## Explanation of Plate 5

Figs. 1, 2, 4, 5. Photomicrographs of the washed serpentine graywackes, showing well-rounded serpentine grains.

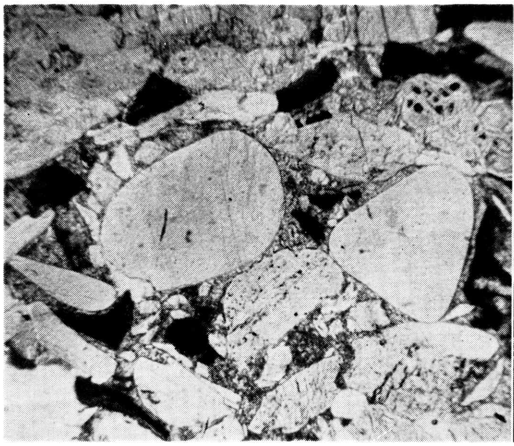
1a. Sp. No. KU 646 C from Furenai, Hokkaido. Ordinary light. ×25.

1b. Ditto. Crossed nichols. ×25.

2. Sp. No. KU 646 A from Furenai. Ordinary light. ×25.

4, 5. Sp. No. Hr 1 from the Chikubetsu Formation, Horokanai, Hokkaido. Ordinary light. ×30.

Fig. 3. Heavy residue of the serpentine sandstone, showing the concentrate of magnesiochromite (black) [Sp. No. KU 646 A]. Ordinary light. ×75.



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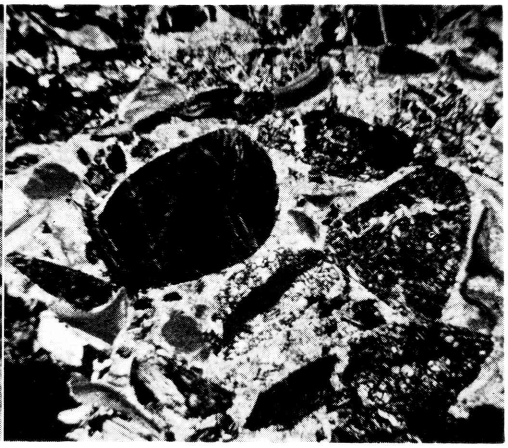

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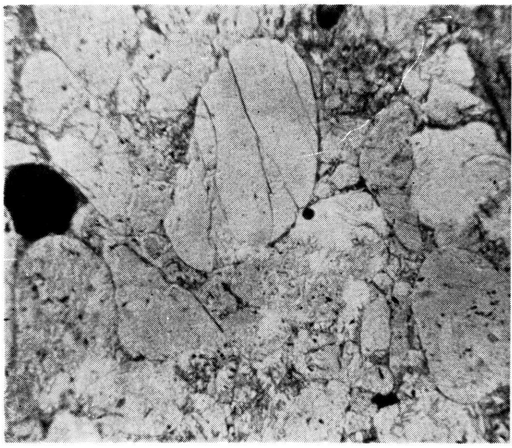

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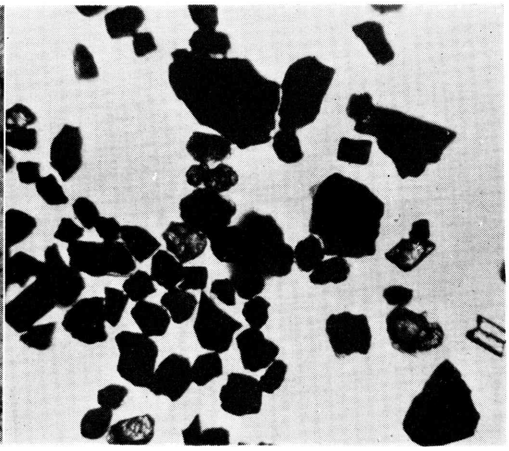

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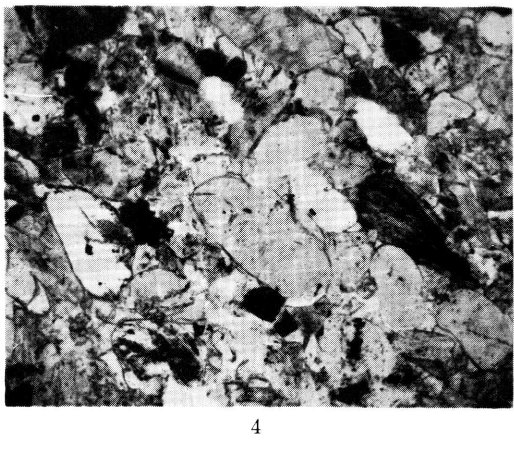

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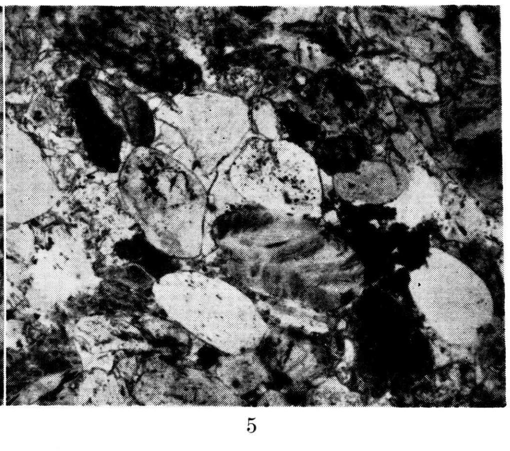

5

H. OKADA : Serpentine Sandstone