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Survival of Serpentinite Against Granite Invasion

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Introductory Remarks

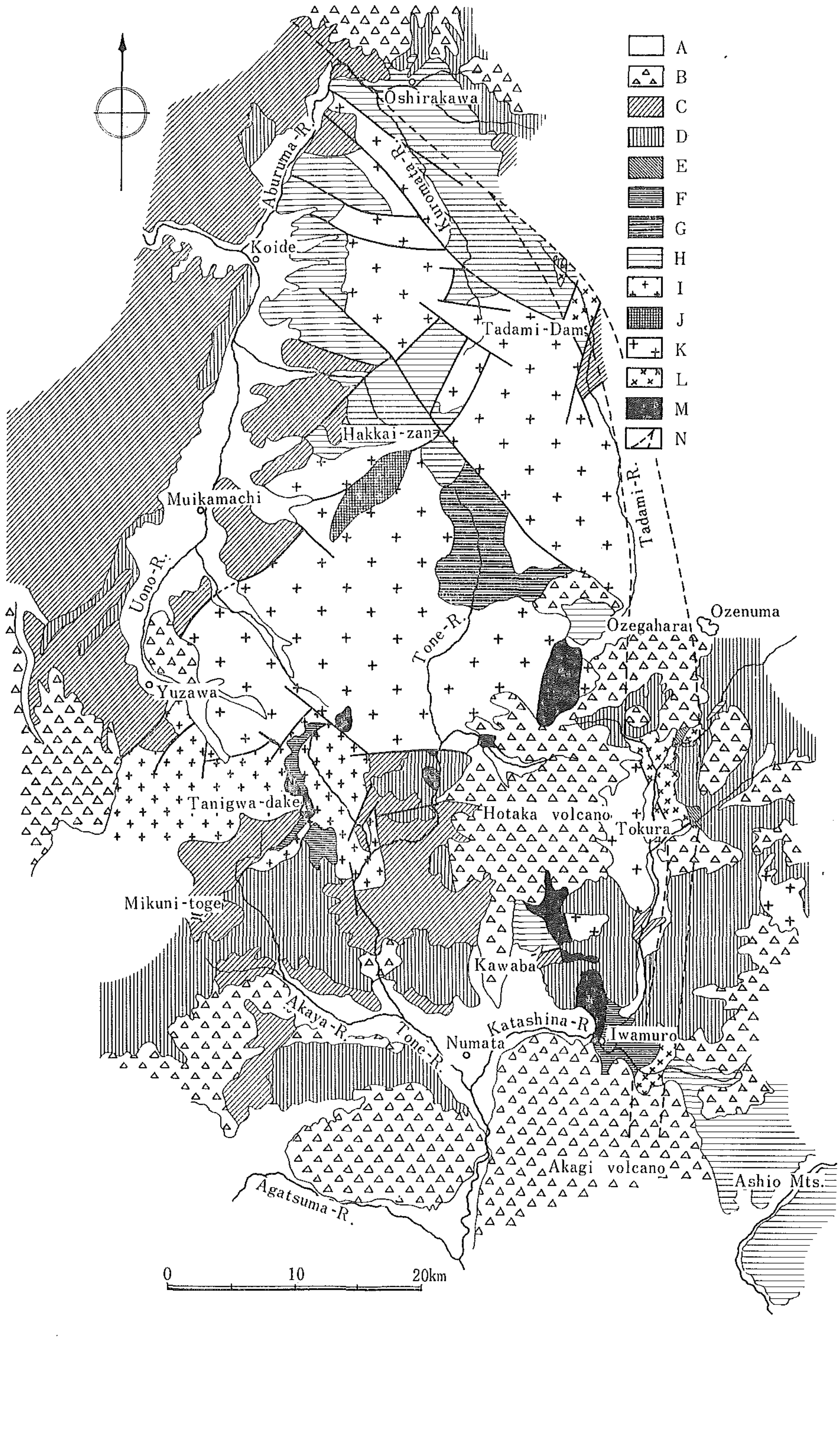
Several masses of serpentinite had long been known in northern Gunma Prefecture of central Japan. The fact that they occur in granite aroused the writer's interest. The result of survey by the writer and his colleagues reveals that they are the remnants of the former Joetsu Metamorphic Belt consisting mainly of crystalline schists. Another fact that the serpentinite masses alone remain while most of the metamorphic rocks disappeared stimulated the writer to meditate on the phenomenon of survival of serpentinite. He is now of the opinion that the higher density of serpentinite in contrast to the lower ones of granite and crystalline schists is responsible for that phenomenon.

Outline of the Geology and Mode of Occurrence of the Serpentinite

The area belongs to the Okutone Belt (N. YAMASHITA, 1964, 1970), which is one of the meridional belts of southern Northeast Japan. The geology of the area, according to Y. HAYAMA *et al.* (1969), is as follows. In this area the sediments and volcanics of the Neogene and Quaternary Periods, though fairly thick in some parts, make the upper structure, and lie on the lower structure with remarkable discordance. The lower structure is composed mainly of the Cretaceous-Palaeogene Sudagai Granite (Y. KIZAKI and F. ARAI, 1955) and the probable Palaeozoic Chichibu Formation. The Sudagai Granite is represented generally by leucocratic biotite granite. It is medium to coarse-grained, but porphyritic in some parts.

The Upper Triassic Okutone Formation and the Lower Jurassic Iwamuro Formation are also the constituents of the lower structure, though they are rather small in area. Along the eastern margin of the Okutone Belt there occur the Katashina Basic Rocks which define the Katashina Tectonic Zone. Also the Upper Jurassic or the Lower Cretaceous Tokurazawa Formation occurs in this Zone as small patches.

The serpentinite masses are scattered, as seen in the geological map (Fig. 1), at random in the granite area. Though somewhat elongated meridionally, they



A
B
C
D
E
F
G
H
I
J
K
L
M
N
Oshirakawa
Aburuma-R.
Kuromata-R.
Koide
Tadami-Dam
Hakkai-zan
Muikamachi
Uono-R.
Tadami-R.
Tone-R.
Ozegahara
Ozenuma
Yuzawa
Tanigwa-dake
Hotaka volcano
Tokura
Mikuni-toge
Kawaba
Katashina-R.
Iwamuro
Akaya-R.
Tone-R.
Numata
Akagi volcano
Ashio Mts.
Agatsuma-R.
0
10
20km

are rather round or irregular in outline. They are composed mostly of serpentinite. The relic minerals are olivine, orthopyroxene and chromite, and the original ultrabasic rocks are considered to have been largely dunite with some harzburgite. They are intruded and metamorphosed by the Cretaceous-Palaeogene granite. In some cases radial aggregates of tremolite formed by contact metamorphism are distinct.

An interesting fact is that the serpentinite masses are associated generally with patches of crystalline schists though they are really small in area. The metamorphic rocks are characterized by such minerals as albite, muscovite, chlorite, epidote, garnet and glaucophane.

Another interesting fact is that the Lower Jurassic and Neogene formations of this area contain the same kinds of crystalline schists as pebbles and boulders of conglomerates. In some areas the crystalline schist pebbles are abundant and attain 30 cm in diameter. Also pebbles of serpentinite are found in the Lower Jurassic Iwamuro Formation.

The mode of occurrence of the crystalline schists as patches and pebbles shows that the area had been a regional metamorphic belt. This metamorphic belt, now extinct but once existent, is called the Joetsu Metamorphic Belt (Y. HAYAMA *et al.*, 1969).

Survival of the Serpentinite Masses

As concluded by Y. HAYAMA *et al.*, the area had been the metamorphic belt consisting mainly of glaucophane-bearing crystalline schists. The belt is considered as an extension of the Sangun Metamorphic Belt of Southwest Japan, which is characterized also by glaucophane-bearing crystalline schists. In other words, it is considered that the serpentinite masses alone survived at the time of granite invasion while nearly all of the crystalline schists vanished.

To examine this idea of survival of serpentinite a test is performed as follows. The area of each mass is measured on geological maps. And it is compared with that of other provinces. They are shown in Tables 1 and 2. As understood from the values in these tables the serpentinite masses in question are smaller in average than those of other provinces. But the smaller area is rather insignificant when

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Fig. 1. Compiled geological map of the Joetsu district (Y. HAYAMA *et al.*, 1969)
Legend, A : Quaternary sediments, B : Quaternary volcanics (mainly andesite), C : Tertiary sediments, D : Tertiary volcanics (mainly liparite), E : Tokurazawa Formation (Upper Jurassic or Lower Cretaceous), F : Iwamuro Formation (Lower Jurassic), G : Okutone Formation (Upper Triassic), H : Palaeozoic sediments and metamorphic derivatives, I : Tertiary quartz diorite, J : Diorite-gabbro complex, K : Cretaceous or Palaeogene Sudagai Granite, L : Katashina Basic Rocks, M : Ultrabasic rocks (mainly serpentinite), N : Katashina Tectonic Zone

Table 1. Area of ultrabasic rock masses of Japan (H. HIRANO, 1967)

No.	name of mass	geological setting	location (Pref. or Reg.)	area(km^2)
1	Teshio	Kamuikotan Belt	Hokkaido	160
2	Kamitanbetsu	Kamuikotan Belt	Hokkaido	95
3	Horokanai	Kamuikotan Belt	Hokkaido	49
4	Biei	Kamuikotan Belt	Hokkaido	16
5	Horoman	Hidaka Belt	Hokkaido	43
6	Hayachine	boundary betw. N/S Kitakami	Iwate	61
7	Miyamori	S Kitakami Belt	Iwate	120
8	Tanigawadake	Joetsu Belt	Niigata/Gunma	3.1
9	Kurouchiyama	Mikabu Belt	Gunma	1.8
10	Ogawara	Mikabu Belt	Nagano	2.3
11	Amafu	Mikabu Belt	Aichi	4.2
12	Ryumonzan	Sanbagawa Belt	Wakayama	1.0
13	Higashiakaishiyama	Sanbagawa Belt	Ehime	5.0
14	Happo-oné	Circum Hida Belt	Nagano	33
15	Oyeyama	N of Maizuru Zone	Kyoto	31
16	Izushi	N of Maizuru Zone	Hyogo	14
17	Sekimiya	N of Maizuru Zone	Hyogo	57
18	Wakasa	N of Maizuru Zone	Tottori	6.8
19	Oshima Peninsula	Maizuru Zone	Fukui	9.9
20	Tari	Sangun Belt	Okayama/Hiroshima	36
21	Ube	Sangun Belt	Yamaguchi	3.5

Table 2. Area of serpentinite masses of the Joetsu district (H. ISHII)*

No.	name of mass	area (km^2)
1	Shibutsuyama	21.0
2	Yunokoya	1.2
3	Sudagai	0.4
4	Takaragawa	1.9
5	Asahidake	2.2
6	Kasagatake	1.5
7	Tanigawadake**	10.8
8	Tokusa	11.2
9	Kawaba	2.1
10	Tateiwa	0.6
11	Iwamuro	3.7

* "Geological Map of Gunma Prefecture" (F. ARAI, 1962) is used as the base map, from which the serpentinite masses are abstracted as shown in Figure 2. Two or three masses that are apparently separated from each other by overlying younger formations are combined as shown by the dotted lines.

** The area of the Tanigawadake Mass is reported by H. HIRANO (Table 1, No. 8) as 3.1 km^2.

the crystalline schists are taken into consideration, of which more than ninety-nine per cent is now extinct. It means that the serpentinite masses alone survived.

Why does serpentinite alone survive?

The reason of survival of the serpentinite masses is considered as due to density-relation between granitic magma, serpentinite and crystalline schist.

The serpentinite pebbles and boulders in the Lower Jurassic Iwamuro Formation relate that the ultrabasic rocks were existent already as serpentinite at the time of granite invasion which is of late Cretaceous or early Palaeogene.

I. KOYAMA (1931) presents forty values of density of granites from various places of Japan. The mean of the values ranging from 2.61 to 2.72 is 2.65. On the other hand, the mean value of density of serpentinite, according to the same author, is 2.80, though it is obtained merely from three values ranging from 2.74 to 2.89. K. KUROKAWA (1970) reports eight values of density of ultrabasic rocks from the Komori Mass, Kyoto Prefecture. The mean density of the eight values

Table 3a. Density of serpentinite from the Joetsu district (H. ISHII)*

mass	specimen	density-a	density-b	number of specimens measured
Shibutsuyama	Kasagatake-1	2.97	2.94	2
Shibutsuyama	Kasagatake-2	2.97	2.95	2
Takaragawa	Takaragawa-1	2.63	2.61	2
Takaargawa	Takaragawa-2	2.65	2.64	2
Takaragawa	Takaragawa-3	2.63	2.62	1
Tokusa	Kozumi-1	3.01	2.99	2
Tokusa	Kozumi-2	2.77	2.73	1
Tokusa	Kozumi-3	3.06	3.02	1
Tokusa	Kozumi-4	3.02	2.99	1
Tokusa	Takahira	3.15	3.14	3
Iwamuro	Kuriotoge-1	2.88	2.87	3
Iwamuro	Kuriotoge-2	2.95	2.89	1
Iwamuro	Kuriotoge-3	2.72	2.71	1
Iwamuro	Shiizakatoge	2.98	2.97	2
Iwamuro	Iwamuro-1	3.08	3.08	3
Iwamuro	Iwamuro-2	2.92	2.90	1
Iwamuro	Iwamuro-3	2.95	2.94	1
Iwamuro	Iwamuro-4	2.69	2.67	1
Mean		2.89	2.87	

* The samples were collected and measured by H. ISHII. Density measurement was performed in two ways, i.e. by an air comparison pycnometer (Beckman-Toshiba, 390) (density-a in this table) and also by a balance (density-b).

Table 3b. Density of basic rocks from the Katashina Tectonic Zone (H. ISHII)*

rock type	specimen	density-a	density-b	number of specimens measured
diorite	Up-Katashina	2.84	2.82	3
gabbro	Kasashinabashi	2.98	2.98	2
gabbro	Tokura-1	2.91	2.90	2
gabbro	Tokura-2	2.98	2.95	2

* See the footnote for Table 3a.

Fig. 2. Serpentinite masses of the Joetsu district

Name of mass, 1 : Shibutsuyama Mass, 2 : Yunokoya Mass, 3 : Sudagai Mass, 4 : Takaragawa Mass, 5 : Asahidake Mass, 6 : Kasagatake Mass, 7 : Tanigawadake Mass, 8 : Tokusa Mass, 9 : Kawaba Mass, 10 : Tateiwa Mass, 11 : Iwamuro Mass ranging from 2.53 to 3.10 is 2.82. Somewhat larger values, 2.88 in the average, of density are obtained this time by H. ISHII on the specimens collected from several localities of the area in question, and they are shown in Tables 3a and 3b.

The difference in density of granite and serpentinite, about 0.2 in the present state, would have been larger, because the granite must have been in liquid phase while the serpentinite must have been in solid phase. The density of the crystalline schists is not measured this time, but it is regarded as nearly equal to or nearer to that of granite. Thus, the serpentinite masses were drowned in the granite magma on account of their higher density while crystalline schists were held upward to be once saved but to be eroded out ultimately. The writer believes that the higher density of serpentinite than that of crystalline schist must be the principal reason of the survival of serpentinite in the vanished Joetsu Metamorphic Belt.

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