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Special Exhibition, "Jadeite", and Collection of Jadeite-bearing Rocks in NSM

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Abstract Special exhibition "Jadeite" was held in National Science Museum from November 2004 to February 2005. For the special exhibition, jadeite-bearing rocks were collected from all the ten localities in Japanese Islands and many gemstones in jadeite-deposits in the world were purchased or donated. Jadeite rock specimens in NSM are now around two hundreds due to this new collection. In addition to this increase of collection, it is worth to note that NSM and Fossa Magna Museum discovered three new minerals from jadeite-rocks at Itoigawa area; itoigawaite, rengeite, and matsubaraite. This is an example of special exhibition as driving force for the enhancement in collection building.

Key words: jadeite, jadeite-rock, museum collection, National Science Museum.

Introduction

Jadeite or "jade" is one of most popular gemstones in Orient. Jadeite with gem quality is call as '*hisui*' in Japanese. The National Science Museum (NSM) had a special exhibition on jadeite from 13th of November 2004 to 13th of February 2005. The authors have been in charge of preparation of the special exhibition in these years.

The name of "jade" is usually used not only for jadeite, but also for nephrite. These two different materials are distinguished from each other in Asia. Jadeite is much valuable than nephrite. The culture of jadeite artifacts in Japan has the longest history in the world, ca 5,000 years. The culture was suddenly disappeared before 8th Century as a mystery in Japanese history. The discovery of jadeite from Itoigawa in 1938 was an impact for historians as well as for geologists. This special exhibition is the first comprehensive exhibition on jadeite from viewpoints of natural and social sciences.

Jadeite is an important mineral in geology as a geothermometer and/or geobarometer. Occurrence of jadeite is confined to serpentinite zone in the high-pressure metamorphic belt. So far jadeite-deposits have been developed in several localities in the world. Among them, great mass of jadeite as gemstones is from Myanmar.

Jadeite with gem quality occurs at Itoigawa area in Japan, but is rare. Ancient jadeite-artifacts have been found in several hundreds localities, mostly in graveyard, in Japan. It is now accepted that the jadeites artifacts were brought parentally from Itoigawa area, because deposit in Myanmar was established in early 18th Century. Ten occurrences of jadeite-rocks have been rec-

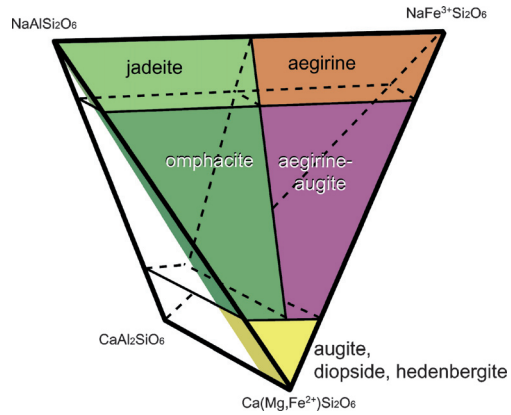

Fig. 1. CNMMN-IMA nomenclature rule on clinopyroxenes based on the chemical composition.

ognized in Japan, though they are poor in quality as a gemstone.

Jadeite and Jadeite-bearing Rocks

Jadeite is the major constituent of '*hisui*', the hard jade, and is a member of pyroxene group minerals. Pyroxenes are silicates having single chains of SiO_4 tetrahedra in their crystal structures. The members of pyroxenes are divided into two groups with arrangement of SiO_4 chains in crystal structure, clinopyroxenes and orthopyroxenes. The chemical compositions of pyroxenes can be expressed with general formula of $ABSi_2O_6$, where A is relatively larger cations such as Na^+ and Ca^{2+}, and B is relatively smaller cations having octahedral coordination such as Al^{3+}, Fe^{3+}, and other transition metals. The mineral species are defined by their chemical compositions and crystal structures. Clinopyroxenes, as well as the other minerals, occur as solid solutions. Species of clinopyroxenes are determined by their chemical compositions according to the definition of the Commission on New Minerals and Mineral Names, International Association of Mineralogy (CNMMN, IMA) as depicted in Fig. 1. Jadeite is a silicate and is a clinopyroxene of sodium aluminum. Although the ideal chemical formula of jadeite can be given as $NaAlSi_2O_6$, a part of Na is replaced with Ca and that of Al with Fe and other transition metals in naturally occurred jadeite. Consequently, the chemical formula for jadeite is often given as $(Na, Ca)(Al, Fe, Mg)Si_2O_6$.

Jadeite-rock consists of jadeite and other minerals, and is sometimes as called as jadeitite. A translucent jadeite-rock with constituents of jadeite exceeding 90% and gem quality is defined as '*hisui*' in gemology. Other jade, such as the nephrite, the soft jade, or aventurine cannot be called as '*hisui*'.

'*Hisui*' is a unique gemstone, because it is not a single crystal of mineral as a diamond and a ruby, but is a rock. A specimen of '*hisui*' can be not only a mineral specimen of jadeite, but also a rock specimen of jadeite-rock.

Forming Mechanism of Jadeite

Jadeite crystallized under the condition of high pressure and low temperature. Such a condition for formation of jadeite can occur at subduction zone (Fig. 2). As described above, jadeite is an important mineral in geology as indicators for the pressure and temperature for the formation

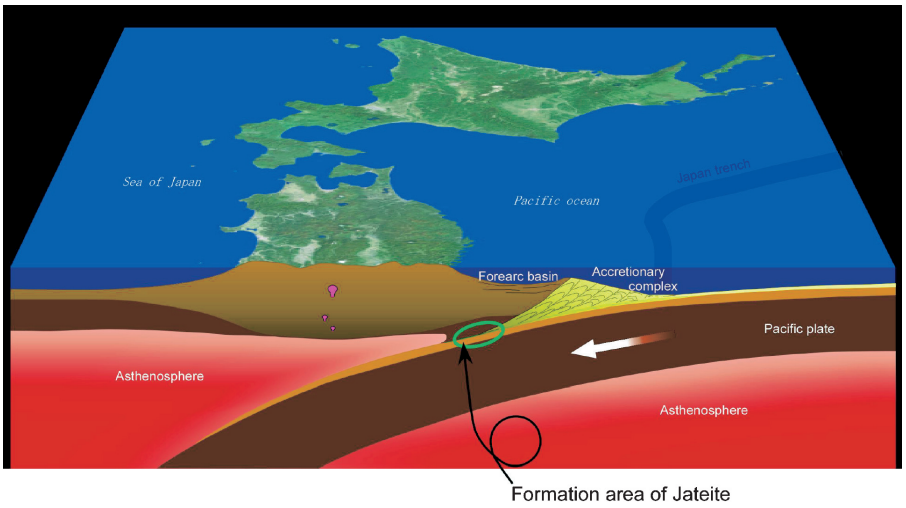

Fig. 2. Schematic illustration of subduction zone.

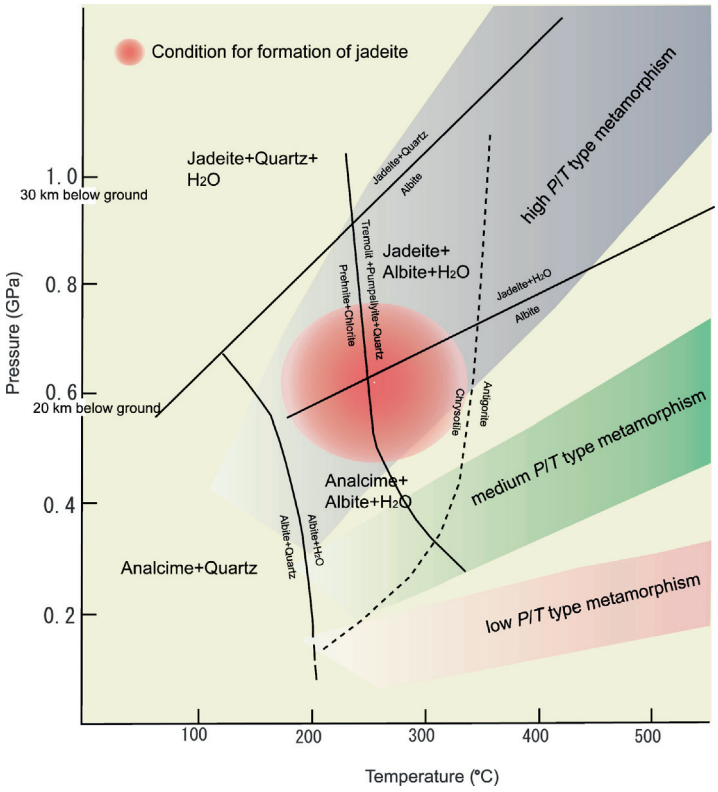

Fig. 3. Pressure-temperature diagram showing the conditions of jadeite formation.

of rocks. A jadeite-rock with quartz is more significant to estimate the pressure condition for the formation of rock (Fig. 3). The assemblage of jadeite and quartz with albite, sodium feldspar, brings us the history of formation and decomposition of jadeite. The relation of these three minerals can be described as $NaAlSi_3O_8$ (albite)$\leftrightarrows NaAlSi_2O_6$ (jadeite)$+SiO_2$ (quartz).

Fig. 4. Jadeite from Ash Creek, Mendocina Co., California, U.S.A. (NSM-MF13365) in Sakurai Collection.

Fig. 5. Euhedral crystals of jadeite from Mogaki, Shimonita, Kanra, Gunma Prefecture, Japan (NSM-M23414).

Jadeite-rock with gem quality, '*hisui*', occurs as aggregates of fine grains of jadeite crystals. The hardness of jadeite is comparable to the other pyroxenes, and is not so high (6–7 in Mhos' scale). However, the texture of tangled crystals of jadeite with random orientations makes the jadeite-rocks extremely tuff. The origin and formation mechanism of quartz-free jadeite-rock is under the discussion, because the metamorphic formation of jadeite from albite can not be explained with the above equilibrium (*e.g.*, Miyajima, 2004). Euhedral crystals of jadeite were found in natrolite ($Na_2Al_2Si_3O_{10}\cdot 2H_2O$) matrix of jadeite-rock from Itoigawa (Miyajima, 2004). This observation indicates that the jadeite crystals are not products of solid-solid reaction, but are results of hydrothermal reaction.

Jadeite with hydrothermal origin is known to occur at few localities. They are usually crystals visible to the naked eye. Ash Creek, Mendocina Co., California, U. S. A. is the most typical locality in the world (Fig. 4). The crystals of jadeite were found at two localities in Japan. One is Mogaki, Shimonita, Kanra, Gunma Prefecture (Fig. 5), and the other is Tsugaike, Otari, Nagano Prefecture (Fig. 6).

The other research problem is the source of sodium for the formation of jadeite. Some geologists suggest that the origin of sodium comes from sodium chloride in seawater subducting with accretionary prism on an oceanic plate. However, it has not been accepted as a dogma.

NSM Mineral Collection of Jadeite

A total of 109 specimens of jadeite have been registered in the NMS mineral collection, of which 78 are Japanese and the other 31 are from abroad. Some of jadeite specimens have values as gems. Among them, the specimen NSM-MF6028 is the most expensive (Fig. 7). This ornament with a shape of green pepper is made of jadeite from Myanmar with high quality, and was donated by Mr. K. Suwa in 1969. Another great donation was made by Mr. H. Tamiya. His donation consists of 15 Japanese and 13 foreign specimens of jadeite from major localities over the world. These specimens with high quality were one of thrusts for the special exhibition on jadeite. Nine specimens are the Sakurai Mineral Collection. Among the fifteen purchases, the recent 6 specimens from foreign origins are purchased with the budget for special exhibition. The 18 new arrivals are donations as assists for the special exhibition from Mr. K. Hirokawa, Mr. U. Honma and Prof. S. Kobayashi, and specimens collected by us in the scientific activity of the

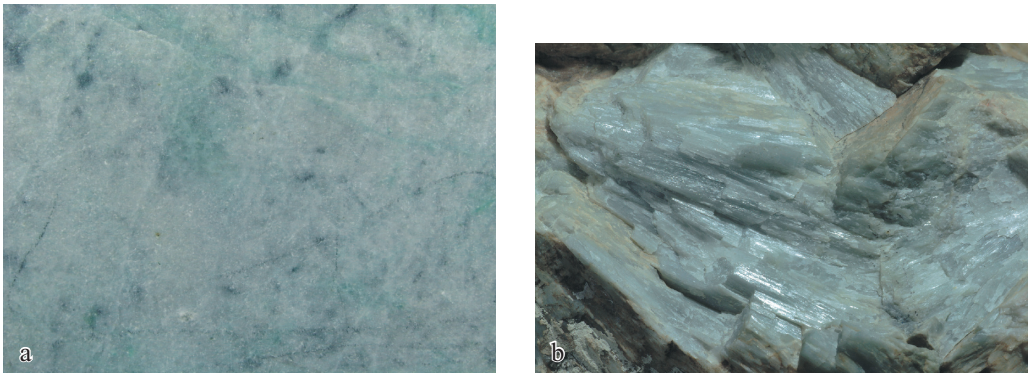

Fig. 6. Jadeite from Tsugaike. a: A macrophotograph of NSM-M27711. b: Crystals of jadeite in the specimen of Fossa Magna Museum.

Fig. 7. Treasure specimen of jadeite of NSM, Tokyo (NSM-MF6028). The length is ca. 4 cm.

project for the special exhibition.

The NSM collection covers major localities of jadeite all over the world, Myanmar, Guatemala, Kazakhstan, Ural and Itoigawa. Some old specimens were registered as from China and Siam. However, it can be concluded that they are from Myanmar through China or Thailand. Such misunderstandings are made in some major museums. All of the known localities of jadeite are also covered with the NSM minerals collection.

NMS Rock Collection of Jadeite-rock

Among 40,000 rock specimens, only 7 jadeite-baring rocks had been registered before the

special exhibition on jadeite held in 2004. They were collected as a part of the high-pressure metamorphic rocks in the Kurosegawa belt. More than 30 jadeite-bearing rocks were newly collected or donated for the exhibition. Most of them are from two localities, Yorii and Shimonita, in the Sanbagawa metamorphic belt. Several jadeite-bearing rocks in Myanmar were donated by Mr. T. Mitsuishi. They are not specimens with gem quality, but are important for petrological study because of specific mineral assemblages including omphacite or sodic amphibole.

Locality of Jadeite in Japan

The major localities of jadeite distribute along high-pressure metamorphic belts with critical high-pressure mineral, glaucophane (Fig. 8). The island arc of Japan is located at the edges of Pacific and Philippine Sea plates. A total of ten localities of jadeite in Japan are described here (Fig. 9).

Hokkaido

Jadeite-rocks occur in serpentinite melange of high-pressure Kamuikotan belt. They are confirmed at a few localities in Asahikawa City and its suburban area. The content of jadeite sometimes exceeds 80% in a small part of several cm^3 in the rock specimen. However, the averaged content of jadeite is less than 50%. These jadeite-rocks contain chlorite and epidote, and are green to dark green in color (Fig. 10). It is hard to distinguish them from green rocks, which do not contain any jadeite, from appearances.

Sangun metamorphic belt

Renge metamorphic belt runs from north shore of middle Honshu Island to northern Kyushu (Fig. 9). Suo metamorphic belt is adjacent to Renge belt in western Japan. These two high-pressure metamorphic belts are jointly called as Sangun metamorphic belt. A total of 5 localities of jadeite have been described in Sangun metamorphic belt. Among them, Itoigawa City and Ohmi Town are the most famous localities of jadeite in Japan. The latter has been recently merged into Itoigawa City.

Itoigawa is at the east end of Renge metamorphic belt, and is the most famous locality of

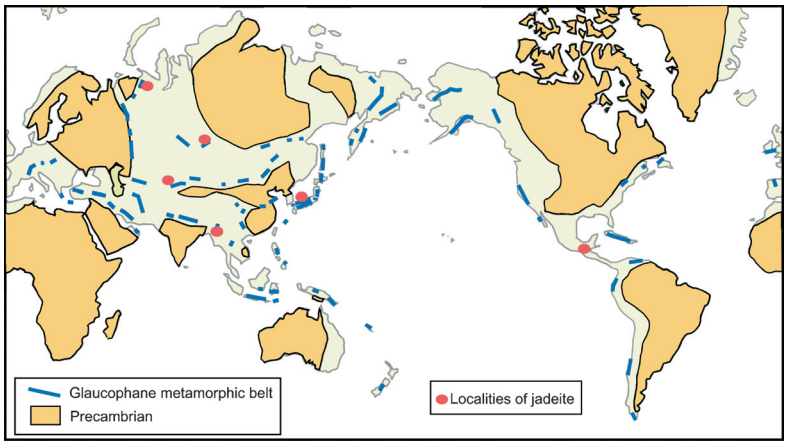

Fig. 8. Distribution of major localities of jadeite. Metamorphic belts with glaucophane are indicated for comparison.

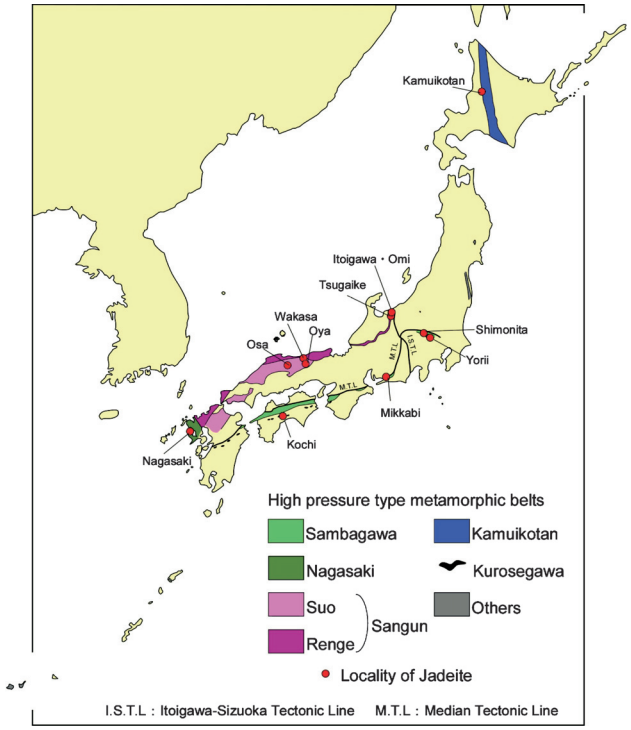

Fig. 9. Distribution of 10 known localities of jadeite-rocks in Japan.

Fig. 10. Jadeite from Fukagawa, Hokkaido (NSM-M28700).

jadeite with high quality in Japan. The specimens were collected on the riverbeds of Kotaki (Fig. 11) and Ohmi (Fig. 12) rivers running through serpentinite zone, and from seashore from Itoigawa City in Niigata Prefecture to Kurobe City in Toyama Prefecture. Jadeite-rocks were rarely found as boulders in soil after rockslide at upstream of Ohmi River. However, no specimen of jadeite could be found on the outcrop. In this area, huge boulders exceeding 1 ton can be observed on the riverbed. Figure 13 shows the most giant boulder in Japan. The weight is estimated not less than 100 tons. The major parts of jadeite localities are protected from illegal mining as the natural treasures. Many of recent specimens of jadeite-rock collected in Itoigawa are white in color. Green, blue and purple jadeites, as well as black jade, can be rarely observed in Itoigawa.

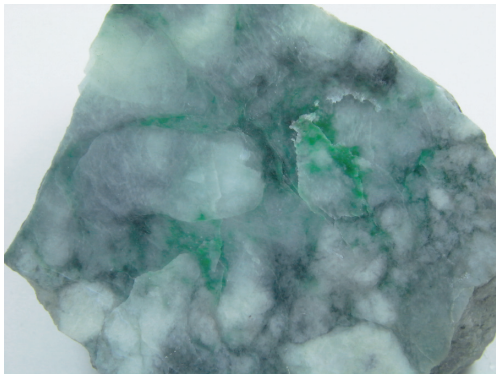

Fig. 11. Jadeite from Kotaki, Itoigawa (NSM-M15044).

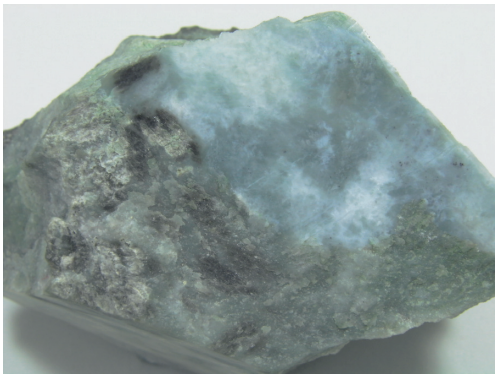

Fig. 12. Jadeite from Ohmi, Itoigawa (NSM-M17975).

Fig. 13. The largest boulder of jadeite at Hashidate, Ohmi, Itoigawa, Niigata Prefecture, Japan.

Jadeite from Tsugaike shows characteristic occurrence mode with coarse grains of crystals (Fig. 6), and usually associated with albite. The albite has been often misunderstood as quartz in thin section observation under a microscope.

Pure white jadeite occurs from Kabo, Oya (Fig. 14). Albitite with the similar appearance of white color was also found at the locality. In the albitite from Kabo, crystals of pale blue corundum and pale purple paragonite can be observed. Recently, stronalsite, a rare strontium silicate mineral, was identified in the jadeite-rock.

Jadeite rock from Wakasa is in serpentinite zone neighboring to Oya. Some boulders of jadeite-rock pale blue or grayish green in color were collected at Wakasa (Fig. 15). Recently, the second occurrences of itoigawaite and niigataite, new minerals found in jadeite-rocks in Itoigawa, were recognized in the jadeite-rock from Wakasa (Shimobayashi and Yamada, 2003, Shimobayashi, 2004).

Jadeite-rock from Osa is white in color, and occurs with various sizes in weathered soil. The surface is covered with brownish weathered layer (Fig. 16). The specimen consists of not only jadeite, but also the other minerals such as stronalsite.

These four localities are in the serpentinite zones as well as Itoigawa as described above. No significant difference can be observed among the thin sections of these jadeites in serpentinite. Some common minerals can be observed within the jadeite-rocks. In addition, the ages determined with zircon are equivalent to 500 Ma. These suggest that jadeites crystallized in the ser-

Fig. 14. Jadeite from Kabo, Oya (NSM-M18423).

Fig. 15. Jadeite from Wakasa. An unregistered specimen in the Sakurai Collection.

pentinite zones under the same formation mechanism. We have possibilities to find jadeite in the other serpentinite zones site in the Sangun belt.

Sanbagawa metamorphic belt

This high-pressure type metamorphic belt runs from the Kanto Mountains to eastern Kyushu along the southern side of Median Tectonic Line (Fig. 9). Although metamorphic rocks of the belt in Shikoku have been investigated in detail, no jadeite-bearing rock has been found in the Sanbagawa belt in Shikoku. On contrary, Jadeite-bearing rocks were found at two localities, Yorii and Shimonita, in the Kanto Mountains, and one, Mikkabi at north of Hamanako Lake.

Jadeite-bearing rocks with white jadeite distribute to form a mound at Yorii. It is possibly surrounded by serpentinite. The major constituents of jadeite-rock are white jadeite, quartz and albite replacing jadeite (Fig. 17). The maximum content of jedeite is 50%. Jadeite in this area was first recognized by detailed chemical analysis with an electron micro-probe analyzer in 1980s. Although these specimens from Yorii are rare samples of jadeite associated by quartz in Japan, they have no value as gems.

Jadeite occurs in association with calcic amphibole at Shimonita. In rare cases, the content of jadeite exceeds 80%. The jadeite-rock is dull green owing to presence of omphacite and epidote group minerals (Fig. 18). Texture of pillow lava was observed in the jadeite rock. It may suggest that ocean-floor basalt is one of the candidates for the source rock of jadeite-rock. A specimen with euhedral crystals of jadeite in fissure is in the Sakurai collection (Fig. 5). Mode of occurrence is similar to that from Ash Creek, California.

Jadeite occurs as white veins with thickness of 2–3 cm in metagabbro at Inasa, Hamamatsu City (Fig. 19). The veins consist totally of jadeite, but have no gem quality.

Shikoku

Jadeite-bearing rocks rarely occur in serpentinite of the Kurosegawa belt running from Kochi City to Ino Town (Fig. 9). They are classified into two groups; grayish rocks including quartz and greenish rocks of lawsonite and glaucophane (Fig. 20). The former could be found as boulder as small as 20 cm, but the latter as boulder with dimension of several meters in serpentinite. They are not transparent or translucent, and have similar appearance to ordinal hard metamorphic rocks. The content of jadeite is less than 60% in the both cases.

Fig. 16. Jadeite from Osa (NSM-M27313).

Fig. 17. Jadeite-rock from Yorii (NSM-R-133423).

Kyushu

Jadeite-bearing rocks associated with serpentinite were found at two localities in Nagasaki metamorphic belt, Mie and Kinkai of Nagasaki City. The latter is the most recent description of occurrence of jadeite in Japan (Shigeno et al., 2005). The approximate concentration of jadeite is 50%, but it exceeds 80% in a limited part of the specimen. They are pale green in color, and locally omphacite is the main constituent instead of jadeite. Muscovite, potassium feldspar and quartz are included in the rocks with pale blue green color (Fig. 21). The maximum size of jadeite-rock is about 2 m, and limited numbers of boulders can be observed.

Origin of Colors in '*Hisui*'

The origins of variety in color observed for '*hisui*' can be classified into two reasons. On comes from the color of jadeite in '*hisui*', and the other from inclusion minerals at grain boundary of jadeite crystals. A pure jadeite with ideal formula, $NaAlSi_2O_6$, has no origin of color and is white. Some substitutions of transition metals, such as Fe and Cr, in crystal structure of jadeite are origin of color in jadeite. We have a variety in color of jadeite: green, blue, purple and so on. Iron oxides and graphite at grain boundary of jadeite-rock as inclusions are origin of red and black colors, respectively. Inclusions of amphiboles and serpentines are often the origin of green color of jadeite-rocks. The combination of colors of jadeite crystals and inclusions bring wider range of variety in color for jadeite-rocks. However, less has been known on the origin of color for jadeite. As inclusions can be the origin of color in '*hisui*', a bulk analysis such as X-ray fluorescent spectroscopy is inadequate, and an analysis is required for grain by grain. An electron micro-probe analysis is one of the most appropriate techniques. It has been said that the origin of green color for green jadeite is Cr^{3+} replacing Al^{3+} in the crystal structure of jadeite.

Special Exhibition on Jadeite at NSM

The special exhibition on jadeite opened from November 2004 to February 2005 at the Ueno Exhibition Hall of the National Science Museum. We have more than ninety thousands of visitors for the exhibition. It was the first-ever complete exhibition focusing on jadeite with scientific background. It consisted of 4 categories of displays.

Fig. 18. Jadeite-rock from Shimonita (NSM-R-133426 & 427).

Fig. 19. White vein of almost pure jadeite from Mikkabi (NSM-M22241).

Part 1: The Science of Jadeite

The scope of this exhibition is exhaustive. Jadeite is found in a kaleidoscopic range of colors: white, green, blue, lavender, red, yellow and black. Over 100 pieces of jadeite ore are included, with one gigantic specimen weighing over 1 ton. The exhibition also offers an introduction to jadeite from a mineralogical and geological perspective, covering its origins and major jadeite-bearing regions in Japan and around the world giving visitors the chance not only to view jadeite but to touch it as well.

Part 2: Cultural History of Jadeite

From the Jomon to the Tumulus period, we find jadeite pieces processed into ritual and magical implements, as well as personal adornments and ‘magatama’, a comma-shaped gem, or an ornamental bead in the shape of an embryo. Jadeite became highly prized as a sacred stone. Pieces similar in style have been excavated on the Korean peninsula, dating from that region’s Three Kingdoms period, similar to finds from Japan’s Tumulus period. These finds offer clear evidence that jadeite was transported to Korea during that time. In addition to the world’s oldest jadeite large bead (an oblong ornamental bead), unearthed in Yamanashi Prefecture, this exhibition introduces examples from the Sannaimaruyama ruins in Aomori Prefecture and Yoshinogari ruins in Saga Prefecture, as well as magatama from the Three Kingdoms period in Korea.

Jadeite mysteriously disappeared from Japan’s cultural landscape in the Nara era, not to return to these shores until after World War I. This long hiatus draws a veil over ancient Japan’s jadeite culture, leaving frustrating gaps in our understanding of its history.

From the Manai ruins, a complex of ruins behind the main shrine of Izumo Shrine, a jadeite magatama of the highest quality has been discovered, accompanied by a bronze halberd. These treasures are presently in the safekeeping of Izumo Shrine. Originally suspected of having arrived from Myanmar, the artifact is now recognized as Itoigawa jadeite, as jadeite-working did not commence in Myanmar until a much later period.

Okuninushi no Mikoto (Shinto deity of Izumo dynasty and son or son in law of Susano), a figure revered at Izumo Shrine, married both Princess Nunagawa, of the kingdom of Koshi where the jadeite ore is collected, and Princess Tagiri, one of the three goddesses of Munakata, of northern Kyushu.

Fig. 20. Jadeite-rocks from Kochi (NSM-R-129212 & 117953).

Fig. 21. Jadeite-rock from Kinkai, Nagasaki Prefecture, Japan (NSM-M28649).

The discovery of this jadeite ornament and bronze halberd, representing both cultural areas, testify that the personages entombed in the Manai ruins were people of great importance in the Izumo region.

Part 3: Jadeite Treasures from China's Qing-dynasty

"Jade" have been prized in China throughout history. Until the era of the Qing dynasty, the "Jade" used in China was nephrite, a soft rock, different from jadeite. The emperor Qianlong who was especially fond of collecting "Jade", ushered in a golden age of gem-cutting technique in China. It was at this time that the mining of jadeite began in Myanmar, and the creation of masterpieces in jadeite began in the Middle Kingdom.

This exhibition includes 44 of the finest examples of jadeite carving and ornamentation from the collection of the Palace Museum in Beijing. Among them, six ornamentations are designated as national treasure of People's Republic of China. These precious items are displayed in Japan for the first time.

Part 4: The Allure of Jadeite

The jadeite so beloved by the Chinese emperors began to be imported into Japan in large quantities at the end of the Meiji era. From the time of this "jadeite boom" to the present, jadeite has remained a popular form of ornamentation with the Japanese people. This exhibition showcases some of the most elegant examples of modern Japanese jadeite, dating from the 1920 s to the present and encompassing modern forms such as necklaces, pendants, rings and brooches. The pieces on display feature splendidly crafted motifs, from fruits and vegetables to fish. While the themes vary from one period to the next, the allure of jade is undiminished to the present day. The theme of first part is the "Science of Jadeite". Following is "Cultural History of Jadeite", which is the oldest culture of jadeite in the world.

Hands-on Exploration Seminar and Lectures

"Magatama-making class" was opened for students of primary schools and junior-high-schools on every Sunday during the exhibition period. Specialists from other institutions in addition to us explained the appeal and science of jadeite for 150 general audiences as a series of lectures. The first lecture entitled 'the finest examples of jadeite jewelry' was made by Hiroshi

Fig. 22. Itoigawaite in jadeite-rock of ‘*lavender hisui*’.

Miyajima, Assistant Curator of Fossa Magna Museum at Itoigawa. Tsutomu Kishima, Curator, Choujagahara Archeological Museum at Itoigawa continued the second lecuture on ‘jadeite in the Jomon Period’. An attractive topic on: ‘appraising jadeite jewelry’ was introduced by Hiroshi Kitawaki, Assistant Director, Technology Laboratory, Gemmological Association of All Japan. Satoshi Matsubara capped the series with ‘enjoying jadeite’.

New Mineral Species in Jadeite-rocks

A series of mineralogical and petrological investigations, as one of activities of the project for special exhibition on jadeite at NSM, was carried out on jadeite-rocks from Itoigawa area with Fossa Magna Museum at Itoigawa. During the investigations, we found three new minerals; itoigawaite, rengeite, and matsubaraite.

Itoigawaite, $SrAl_2Si_2O_7(OH)_2 \cdot H_2O$, is a new member of the lawsonite group, and is the Sr analogue of lawsonite (Miyajima et al., 1999). It is transparent, blue in color with vitreous luster. It occurs in a thin veinlet cutting a lavender-colored Ti-bearing jadeitite (Fig. 22). The veinlet includes irregularly-shaped aggregates composed of minute tabular crystals of itoigawaite up to 50 mm across and minute jadeite crystals with interstitial natrolite aggregates. The name is for the locality.

Rengeite, $Sr_4ZrTi_4Si_4O_{22}$, is a new member of the perrierite-chevkinite group (Miyajima et al., 2001). It is transparent, dark brown with adamantine luster. It occurs as anhedral grains in close association with titanite, zircon and tausonite in a pebble of blue titanian omphacite-jadeite rock in a boulder of lavender-colored Ti-bearing jadeitite and in a boulder of green jade. The name is for Mt. Renge near the locality and the Renge metamorphic belt where jadeitite deposits are found. The crystal structure analysis revealed that rengeite is the Sr and Zr-analogue of perrierite (Miyawaki et al., 2002).

Matsubaraite, $Sr_4Ti_5(Si_2O_7)_2O_8$, is another new member of the perrierite-chevkinite group found in jadeitite (Miyajima et al., 2002). It is Sr and Ti-analogue of perrierite-(Ce) or Zr-free analogue of rengeite. It is transparent, grey with blue tint with adamantine luster. It occurs as long prismatic euhedral to subhedral crystal with interstitial natrolite in a boulder of lavender-colored Ti-bearing jadeitite. The mineral is named after the first author in recognition of his

works on strontium dominant minerals from Japan.

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