

A Comparative Study of Jadeite, Omphacite and Kosmochlor Jades from Myanmar, and Suggestions for a Practical Nomenclature

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Jadeitite boulders from north-central Myanmar show a wide variability in texture and mineral content. This study gives an overview of the petrography of these rocks, and classifies them into five different types: (1) jadeitites with kosmochlor and clinoamphibole, (2) jadeitites with clinoamphibole, (3) albite-bearing jadeitites, (4) almost pure jadeitites and (5) omphacites. Their textures indicate that some of the assemblages formed syn-tectonically while those samples with decussate textures show no indication of a tectonic overprint. Backscattered electron images and electron microprobe analyses highlight the variable mineral chemistry of the samples. Their extensive chemical and textural inhomogeneity renders a classification by common gemmological methods rather difficult. Although a definitive classification of such rocks is only possible using thin-section analysis, we demonstrate that a fast and non-destructive identification as *jadeite jade*, *kosmochlor jade* or *omphacite jade* is possible using Raman and infrared spectroscopy, which gave results that were in accord with the microprobe analyses. Furthermore, current classification schemes for jadeitites are reviewed.

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Introduction

The word *jade* is derived from the Spanish phrase for *piedra de ijada* (Foshag, 1957) or ‘loin stone’ from its reputed use in curing ailments of the loins and kidneys. In former times, jade simply included nephrite (Werner, 1774) and jadeite (Damour, 1863); therefore, its nomenclature was rather

simple. Jadeite jade is usually a green massive rock consisting of jadeite ($\text{NaAlSi}_2\text{O}_6$; see Ou Yang, 1999; Ou Yang and Li, 1999; Ou Yang and Qi, 2001). Nephrite jade, a rock mainly composed of the amphibole tremolite [$\text{Ca}_2(\text{Mg,Fe})_5\text{Si}_8\text{O}_{22}(\text{OH})_2$], shows a similar colour and massive structure, and can be difficult to visually separate from jadeite



Figure 1: The Hutton-Mdivani necklace sold for US\$27.44 million at Sotheby's Hong Kong auction in April 2014—a world-record price for a piece of jadeite jade jewellery. It features 27 colour-matched beads (15.4–19.2 mm in diameter) that consist of translucent bright green Imperial jadeite. Photo by Luc Phan, © Swiss Gemmological Institute SSEF.

jade. Microscopically, jadeite jade shows a mixed texture of granular and fibrous polycrystalline aggregates, while nephrite mainly shows a fibrous structure. International bodies such as CIBJO have agreed to use the terms *jadeite jade* or *nephrite jade* for the two materials (CIBJO, 2013). Serpentine and other green rocks are not accepted under the jade umbrella. The most valuable jade variety is so-called *Imperial jadeite*, consisting of pure intense green translucent material from Myanmar (e.g. Figure 1).

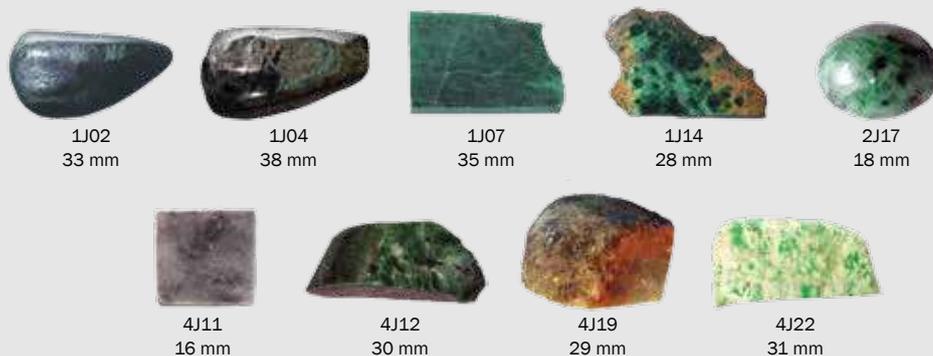
In the 1960s, Dr Eduard Gübelin described an interesting new gem material also originating from the Burmese jadeite area: Maw-sit-sit (Figure 2). It is a rock composed of many minerals, and ranges from white to green and black (Gübelin, 1964–1965, 1965). It was later found that maw-sit-sit contained the first terrestrial occurrence of ureyite ($\text{NaCrSi}_2\text{O}_6$; cf. Harlow and Olds, 1983), later renamed kosmochlor (Ou Yang, 1984; Harlow and Olds, 1987; Hänni and Meyer, 1997). It became evident that jadeite-related rocks are often composed principally of both pyroxenes and amphiboles, and frequently represent members of solid-solution series. Isovalent ionic substitution such as $\text{Al}^{3+} \leftrightarrow \text{Cr}^{3+}$ and coupled substitution such as $\text{Na}^+ + \text{Al}^{3+} \leftrightarrow \text{Ca}^{2+} + (\text{Mg}^{2+} + \text{Fe}^{2+})$ are both common. In addition, samples may contain a variety of non-pyroxene minerals, such as clinoamphibole (mainly sodic and sodic-calcic amphiboles), albite, chromite and others (cf.

Harlow and Olds, 1987; Htein and Naing, 1994; Shi et al., 2005a, 2012). Furthermore, individual mineral grains may show pronounced chemical zoning (e.g. Harlow and Olds, 1987; Shi et al., 2005a, 2009, 2012). These factors pose a major problem to gem testing laboratories, firstly for the identification of the mineral constituents and their amounts by straightforward non-destructive procedures, and secondly due to the absence of

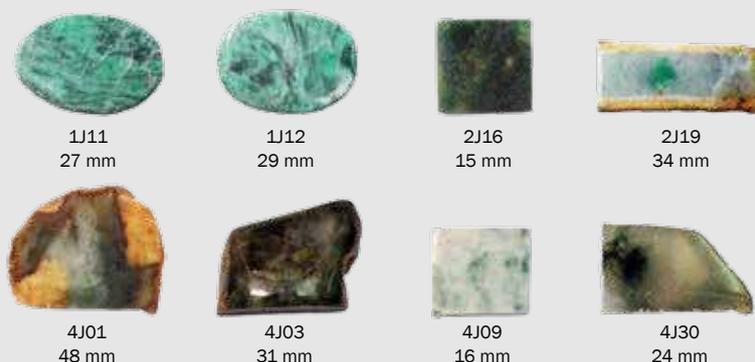
Figure 2: Kosmochlor is one of the many constituents of maw-sit-sit, a rock that also commonly contains chromian jadeite, albite, clinocllore, amphibole and chromite. The cabochon shown here weighs 12.09 ct and the polished cobble is 128.02 g (65.7 × 45.3 mm). Photo by Tay Thye Sun.



a. Jadeitites with Kosmochlor and Clinoamphibole (JKC)



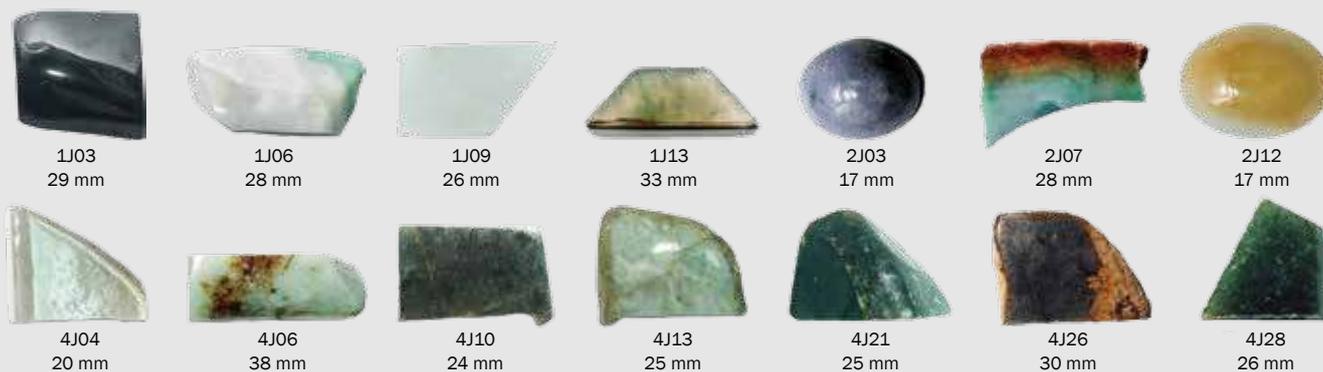
b. Jadeitites with Clinoamphibole (JC)



c. Albite-bearing Jadeitites (ABJ)



d. Jadeitites (J)



e. Omphacites (O)



Figure 3: The samples studied for this report are grouped here according to their classification into five groups based on thin-section investigations. The longest dimension of each piece is shown under the sample number. Photos by Tay Thy Sun.

a simple terminology that can be applied to such a complex gem material.

In 2006, the term *fei cui* was officially implemented by the Hong Kong government to cover jadeite* gemstones. This umbrella term is used for jadeite, omphacite and kosmochlor jades (Ou Yang et al., 2003; Prosperi et al., 2011). The expression *fei cui* or 翡翠, when used in the course of any trade or business to describe an object, means it is a granular to fibrous polycrystalline aggregate that is composed solely or principally of jadeite, omphacite and/or kosmochlor, or any combination of these minerals (cf. www.gahk.org/attachment/fcteststd2.pdf). However, under this regulation, any rock containing one or more of these three minerals can now be sold in the same category as jadeite jade.

Most jadeite jade in the market comes from the classic Uru River area (Kyaukseimyo) in northern Myanmar (Chhibber, 1934; Bender, 1983; Hughes et al., 2000; Harlow et al., 2014). For the trade it should not be a problem to communicate to consumers that such material may fall into a number of categories, including some that are more rare and others that are more common. However, for the gemmologist and research scientist, the questions arise: What do these Burmese jades consist of, and how common are omphacite, kosmochlor and mixed members of these pyroxenes? These questions have become even more pertinent with the recognition that there is material circulating in the trade with the appearance, colour and gemmological properties of fine-quality jadeite jade, but it is actually omphacite jade (e.g. McClure, 2012).

Materials and Methods

Eighty-eight samples of rough and cut (slabs and cabochons) 'Burmese jade' were collected in jade markets in Myanmar, Singapore and Hong Kong. From these, petrographic thin sections were cut and polished for 39 of the samples that we considered representative of what one

would expect to encounter as cut jades in the marketplace (Figure 3).

Mineral abbreviations used in this article are after Whitney and Evans (2010), except for the following: Q = quadrilateral pyroxenes (diopside-hedenbergite-enstatite-ferrosilite), Cr-Jd = chromian jadeite and Cr-Omp = chromian omphacite. *Chromian* is used to refer to material with <0.01 Cr³⁺ per formula unit (cf. Morimoto et al., 1988).

Gemmological and Petrographic Methods

All 88 samples were visually examined, and their refractive indices were determined by either the spot method or by normal readings from flat-polished surfaces. Specific gravity was determined hydrostatically for all of these samples, and they also were examined with a desk-model prism spectroscope.

The mineralogy and micro-textures of the 39 petrographic thin sections were studied using a Leica DMRX polarized light microscope.

Chemical Analysis

The compositions of rock-forming minerals in the 39 thin sections were quantitatively measured by electron microprobe. The main focus of this investigation was the various types of clinopyroxene. Chemical analyses were performed with a JEOL JXA-8600 electron microprobe at the University of Basel, Switzerland. The instrument was equipped with an ultra-dry silicon energy-dispersive X-ray detector (Noran System 7 spectral imaging system by Thermo Scientific). The accelerating voltage was 15 kV and beam current was 20 nA, and we used a peak counting time of 30 seconds for all elements. Data correction was performed using the Proza (ϕρZ) method. To avoid volatilization of Na we chose a beam size of 10 μm. As the analyses were performed without the use of standards, an overall error of 2% is assumed. Ferric iron in the clinopyroxenes was estimated according to stoichiometry, following the method of Droop (1987). Ferric iron in amphibole was calculated using the min-max method (see Appendix 2 of Leake et al., 1997) using the intermediate value of Fe³⁺. The quantitative results obtained with the microprobe permit calculation of the end-member percentages in solid solutions (e.g. from the jadeite-kosmochlor series).

* *Jadeite* is the name of a mineral, while *jadeitite* is the petrographic name for a rock composed predominantly or entirely of jadeite (synonymous with *jadeite jade*). Likewise, *omphacite* is a mineral name and *omphacitite* is a rock composed primarily of that mineral.

Following the recommendation of S. I. Liu (pers. comm., 2013), backscattered electron (BSE) imaging was done at low magnification in a scanning electron microscope at the University of Basel to investigate the mineralogical composition of the samples. With this technique, the amount of non-jadeite constituents in a polymineralic rock can be quickly estimated, since a relatively higher mean atomic weight (e.g. due to Ca, Fe or Cr) shows up as a brighter image. For example, in the BSE image of sample 4J12, which consists of jadeitite with kosmochlor and clinoamphibole, pure jadeite appears dark grey and omphacite as well as chromian jadeite appear distinctly brighter (Figure 4).

Chemical data obtained by the electron microprobe are very precise and quantitative, but the instrument is expensive and needs a professional technician to operate it, making it impractical for gem labs. Energy-dispersive X-ray fluorescence (EDXRF) spectroscopy used in gem labs has an excitation spot that is too large to resolve individual components of Burmese jade, and also it is only a qualitative technique (without a careful and painstaking standardization procedure). Furthermore, Na is too light an element for measuring with this technique. However, EDXRF is suitable to check for the presence of Ca, to give an indication of the presence of omphacite or sodic-calcic amphibole.

Raman Spectroscopy

Confocal Raman micro-spectroscopy was used to non-destructively characterize individual mineral grains in all 39 of the polished thin sections. We used a Bruker Senterra Raman dispersive microscope spectrometer equipped with a green laser (532 nm). The high resolution of this method (measurement of spots with diameters of 1–3 μm is possible) even allows the identification of complex mineral intergrowths and mineral zoning. For clinopyroxenes, we only measured spots that had been previously analysed by the electron microprobe, to have an absolutely certain identification of the mineral and to avoid sub-microscopic intergrowths or exsolution lamellae. Measurements were performed at 20 mW with a 100 second counting time; we used objective lenses with 50 \times and 100 \times magnification, and an aperture of 25 μm .

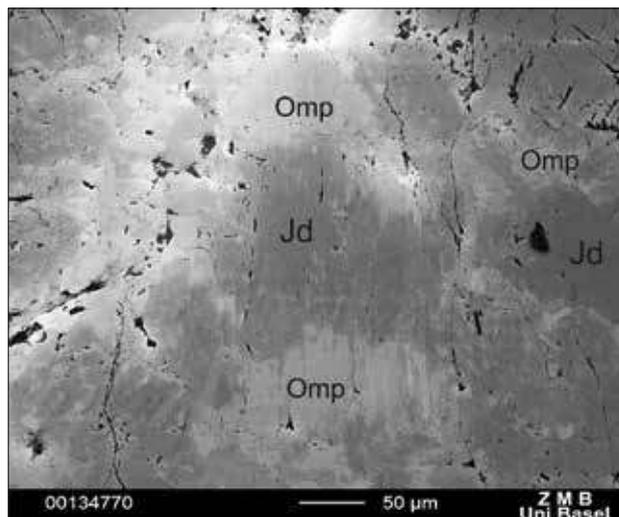


Figure 4: Backscattered-electron imagery of sample 4J12 (jadeitite with kosmochlor and clinoamphibole) shows a jadeite grain (Jd; appears dark) mantled by omphacite (Omp; appears bright). Note also the presence of omphacite along jadeite grain boundaries and fractures. Image by Marcel Düggelein.

Mineral identification was performed using the RRUFF database (Downs, 2006) and our own Raman database at the mineralogical institute in Basel.

Infrared Spectroscopy

Mineral identification also was accomplished using Fourier-transform infrared (FTIR) spectroscopy, performed with a Bruker Lumos FTIR microscope at Bruker's laboratories in Fällanden, Switzerland. Two samples (2J17 and 4J22) were analysed, as well as four additional cabochons from author HAH's collection. Data were collected in the range of 7000–650 cm^{-1} with a resolution of 4 cm^{-1} . The accuracy was $\leq 0.05 \text{ cm}^{-1}$ at 1576 cm^{-1} , and the spectral resolution was $< 2 \text{ cm}^{-1}$. A mercury-cadmium-telluride (MCT) detector cooled with liquid nitrogen was used. Time-resolved measurements were performed by averaging eight interferograms per spectrum, for a total acquisition time of 8 seconds. Reflection IR measurements of two polished thin sections containing jadeite + omphacite (section 4J12) and chromian jadeite + kosmochlor (2J17) also were undertaken. The size of the measured spots ranged from 15 \times 40 μm to 60 \times 100 μm . We measured several spots with minerals showing different crystallographic orientations, which had little effect on the main IR bands.

Results

Gemmological Data

The gemmological and petrographic data for each of the 39 samples that were also cut into thin sections are reported in an online data depository on *The Journal's* website. The colour of the samples ranged from light to dark green (coloured by Cr), lavender (coloured by Mn and/or Fe; see Harlow and Shi, 2011), yellow to brown (coloured by Fe) and black. Kosmochlor-bearing samples were spotted dark green within a lighter green and white matrix. Our samples of omphacite appeared black, and only the use of transmitted light revealed a dark to very dark green colour.

For our jadeite samples, spot RI values mostly ranged from 1.65 to 1.66, whereas the omphacites had a slightly higher RI (1.67–1.68). The SG of our jadeites was variable but most values fell in the range 3.27–3.35, while the omphacites varied from 3.26 to 3.36. The large variations in SG can be explained by mineral compositional zoning and the presence of impurities such as clinoamphibole and kosmochlor.

The absorption spectra of the jadeites revealed a typical sharp line at 437 nm, which was sometimes masked in green chromian jadeite, the latter showing absorption lines at 630, 655, and 690 nm (as documented by Liddicoat, 1981). The omphacites showed no distinctive absorption line (as mentioned by Okano et al., 2009).

Petrographic Examination

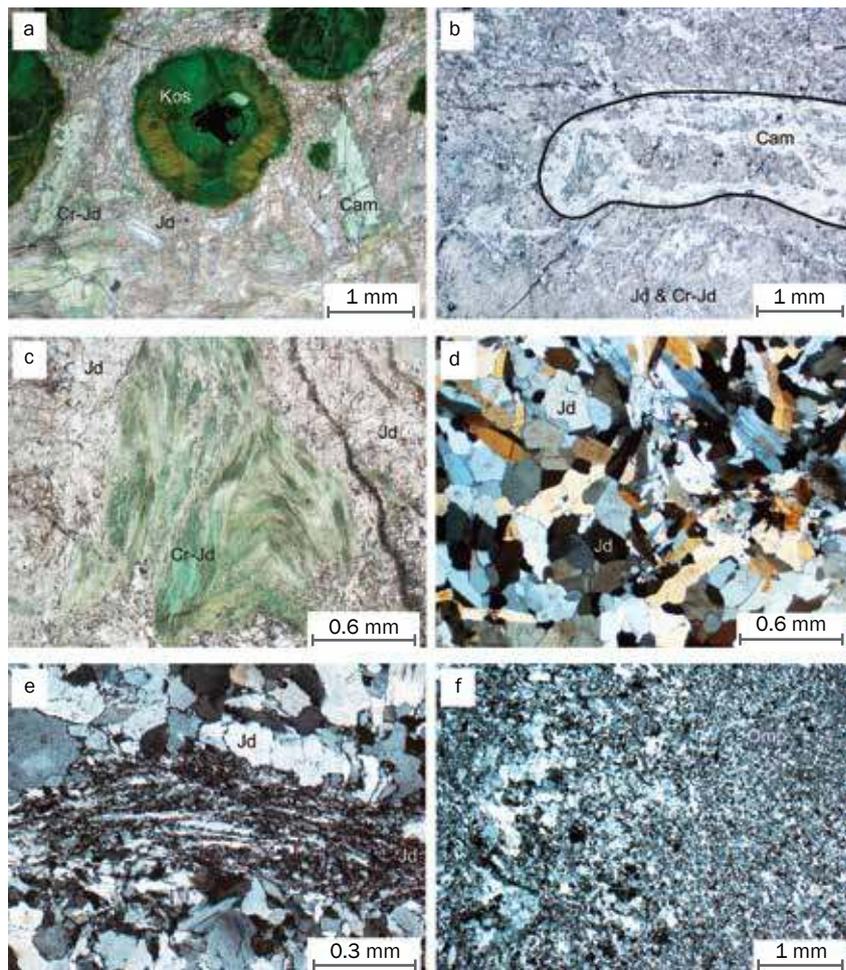
Microscopic examination allowed us to visually identify the mineral content and study the micro-textures in the samples. The following groups of jadeite-bearing rocks could be distinguished.

Jadeites with Kosmochlor and Clinoamphibole (JKC): Samples belonging to this category are 1J02, 1J04, 1J07, 1J14, 2J17, 4J11, 4J12, 4J19 and 4J22 (Figure 3a). These rocks consist mainly of jadeite (modal vol.% estimated at 60–75%; some with additional chromian jadeite) and variable amounts of kosmochlor (1–25%), omphacite (0–10%), clinoamphibole (10–39%), phlogopite (up to 3%), and chromite, as well as other rare accessories like titanite (<1%). In hand specimen, they ranged

from green to dark green with nearly opaque spots (2J17). Some samples were entirely dark green (1J07), while others showed dark green veins. A wide variety of different micro-textures were observed. Sample 2J17, for example, contained aggregates of radiating kosmochlor formed around chromite grains, which were embedded in a matrix of randomly oriented short-prismatic jadeite crystals (Figure 5a), similarly described by Shi et al. (2005a, 2009). Long-prismatic, faintly yellow (in thin section) clinoamphibole prisms formed isolated crystals and some sheaf-like clusters. Other samples like jadeite schist 1J02 showed compositional banding with jadeite-rich, clinoamphibole-rich and kosmochlor-bearing layers. The minerals were aligned parallel to the compositional banding, with fractures oriented oblique to the layering. Secondary limonite and zeolite were found in some specimens, and biotite (appearing 'olive' green in thin section) rimmed and filled fractures in larger jadeite crystals.

Jadeites with Clinoamphibole (often with Chromian Jadeite; JC): Samples in this category are 1J11, 1J12, 2J16, 2J19, 4J01, 4J03, 4J09 and 4J30 (Figure 3b). These rocks consist of jadeite and chromian jadeite (60–99%), omphacite (0–10%), clinoamphibole (10–40%), and accessory opaques and titanite (<1%). They looked quite variable in hand specimen, such as white with small green spots (4J09), dark green (2J16), and striped green and dark grey (1J11 and 1J12), which was due to the presence of chromian jadeite (bright green in 1J11), omphacite (4J30) or dark amphibole (4J03). In thin section, a distinct compositional banding of jadeite- and clinoamphibole-rich layers and lenses was visible. The main foliation, which was oriented parallel to this banding, experienced an intense micro-folding with partially isoclinal fold structures (Figure 5b). Polygonal arc structures of minerals in fold hinges point to pre-crystallization folding and mimetic crystallization (i.e. recrystallization that reproduces pre-existent textures; Spry, 1969; see also Hibbard, 1995, p. 297). There were a number of jadeites that lacked chromian jadeite (e.g. 2J19, 4J01, 4J03, 4J09 and 4J30). According to our Raman investigation, the clinoamphiboles in these rocks consisted of sodic-calcic (richterite) and sodic (arfvedsonite) varieties.

Figure 5: These photomicrographs show the texture and mineralogy of selected samples. (a) Dark green radiating aggregates of kosmochlor with chromite cores are surrounded by a matrix of jadeite, chromian jadeite and clinoamphibole in JKC-type sample 2J17. (b) An isoclinally folded layer of clinoamphibole (low-relief mineral Cam; folding is shown by the black line) is surrounded by jadeite and chromian jadeite in JC sample 1J12. (c) Green chromian jadeite prisms show intense micro-folding and are bordered by colourless jadeite in ABJ sample 2J18. (d) Jadeite prisms show a decussate texture in J sample 2J03. (e) An ultramylonitic shear zone with dynamically recrystallized jadeite grains (centre) cuts through randomly oriented, larger jadeite grains in J sample 4J13. (f) Patchy sections of larger omphacite grains are present in a fine-grained matrix of omphacite crystals in O sample J274. Photos a–c are in plane-polarized light, and d–f are in cross-polarized light. Photos by L. Franz.



Albite-bearing Jadeitites (with Chromian Jadeite or Omphacite; ABJ): Samples of this category (1J05, 2J18 and 4J27; Figure 3c) show wide petrographic variability. Sample 1J05, for example, consisted of almost pure jadeite (99%) with <1% albite and omphacite. Other samples showed darker green veins and irregular spots due to the presence of chromian jadeite (e.g. 2J18). Macroscopically, the albite-bearing jadeitites often resembled the darker samples from the second group, however they contain no amphibole. Thin-section examination showed a distinct compositional banding of medium-grained jadeite-rich layers alternating with fine-grained layers rich in chromian jadeite, with the latter displaying a distinct mineral alignment and local micro-folding (Figure 5c). The semi-polygonal arc structures in the fold hinges point to syn-crystallization folding according to Misch (1969). Accessory minerals were albite (forming angular inclusions in jadeite) and rare titanite. Secondary limonite was found as brownish staining at the rim and along fractures in the samples.

Jadeitites (without Chromian Jadeite; J): Fourteen samples (1J03, 1J06, 1J09, 1J13, 2J03, 2J07, 2J12, 4J04, 4J06, 4J10, 4J13, 4J21, 4J26 and 4J28; Figure 3d) consisting of pure and almost pure jadeitites (92–100%) are grouped into this category. Macroscopically, these rocks often appeared homogeneous with a broad range of colour, from yellowish white to distinctly green or brown. Besides jadeite, the samples contained minor amounts of omphacite (2J07 and 4J06), vesuvianite (4J04), amphibole (4J04; grunerite/cummingtonite according to Raman spectroscopy), analcime (4J06 and 4J13) and phlogopite (4J13). Accessory minerals were disordered graphite (identified by Raman spectroscopy in 4J10 and 4J13) occurring as tiny inclusions in jadeite and also rare titanite. Secondary minerals consisted of biotite and limonite present along the rim and in fractures of jadeite (1J03). Furthermore, tiny fibres with a low RI were zeolite (probably natrolite) that formed at the expense of analcime (4J06). Viewed with the microscope (e.g. Figure 5d), the jadeitite fabrics were rather variable, with most of them showing

a medium-grained decussate texture (i.e. the axes of contiguous jadeite crystals lie in diverse, crisscross directions without any alignment; Spry, 1969; see also Yardley et al., 1990, p. 89). Some of the rocks showed a fine-grained foliated texture with aligned jadeite prisms and micro-folds, while others contained shear bands made up of dynamically recrystallized jadeite neoblasts surrounding coarser-grained porphyroclastic rock fragments (Figure 5e).

Omphacitites (O): The omphacitites (J270–J274) in this study were easily distinguished from the jadeitites by their very dark green colour and almost opaque appearance (Figure 3e). Thin sections of two samples (J271 and J274) proved to be monomineralic omphacitite without any accessory minerals or secondary alteration. While sample J271 displayed a homogeneously fine-grained texture, sample J274 showed an inhomogeneous size distribution with patchy sections yielding larger, irregular omphacite crystals in a matrix of tiny omphacite prisms (Figure 5f).

Electron Microprobe Analysis

Chemical data for eight representative samples are plotted in jadeite-aegirine–quadrilateral pyroxene (Jd–Ae–Q) diagrams following Morimoto et al. (1988) and in a kosmochlor–(jadeite+aegirine)–quadrilateral pyroxene diagram to highlight the wide variability of the mineral composition within the rocks (Figure 6).

In all the investigated samples, jadeite and omphacite crystals revealed distinct chemical inhomogeneities due to zoning or variations from crystal to crystal, which are described in detail below. Selected microprobe analyses of clinopyroxenes are listed in Table I. The entire dataset is available via *The Journal's* online data depository.

Jadeitites with Kosmochlor and Clinoamphibole:

Clinopyroxenes from these rocks show obvious chemical variations, which is particularly evident for jadeite from sample 2J17. The BSE image (Figure 6a) shows distinct zoning with dark, Na-rich sections (cf. spot 3; $\text{Jd}_{90.6}\text{Ae}_{4.3}\text{Q}_{5.2}$), bright, Na-poor sections (cf. spot 2; $\text{Jd}_{74.3}\text{Ae}_{15.2}\text{Q}_{10.4}$) and intermediate sections (cf. spot 1; $\text{Jd}_{85.6}\text{Ae}_{8.9}\text{Q}_{5.4}$; see Table I). Such a pronounced mineral zoning in

jadeitites from Myanmar was already described by Harlow and Olds (1987). Jadeite from sample 4J12 showed a compositional range of $\text{Jd}_{71.6-96.8}\text{Ae}_{8.6-0.1}\text{Q}_{19.8-3.1}$ while omphacite yielded a composition of $\text{Jd}_{34.9-50.8}\text{Ae}_{8.8-6.8}\text{Q}_{56.3-42.4}$ (plotted in Figure 6a).

When data for these two samples are plotted in Figure 6b, it becomes evident that Cr-bearing pyroxene in sample 4J12 is mainly chromian omphacite (represented in the diagram by the Jd+Ae apex), whereas sample 2J17 contains major amounts of both chromian jadeite and kosmochlor. The data reveal a distinct compositional gap between kosmochlor and chromian jadeite as well as between chromian jadeite and jadeite, which suggests a solvus between these phases similar to the jadeite-omphacite–Ca–Mg–Fe–pyroxene solvi (Davidson and Burton, 1987; Green et al., 2007). (A *solvus* separates a homogeneous solid solution from a field of several phases that may form by exsolution.) Electron microprobe analyses furthermore showed that the clinoamphibole in sample 2J17 is mainly katophorite and subordinately winchite according to the classification of Hawthorne et al. (2012).

Jadeite with Clinoamphibole:

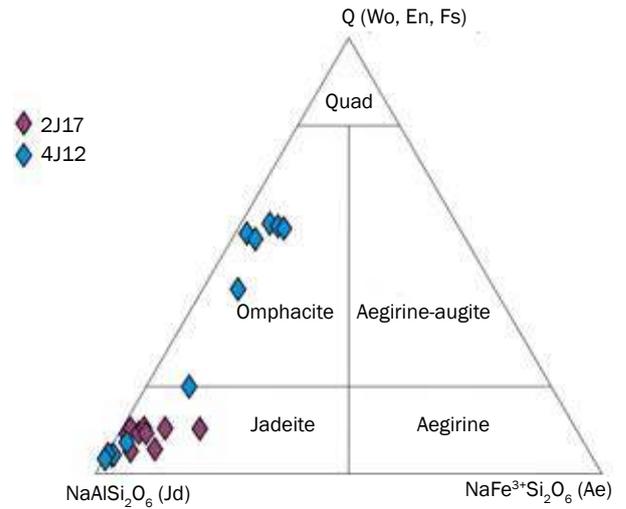
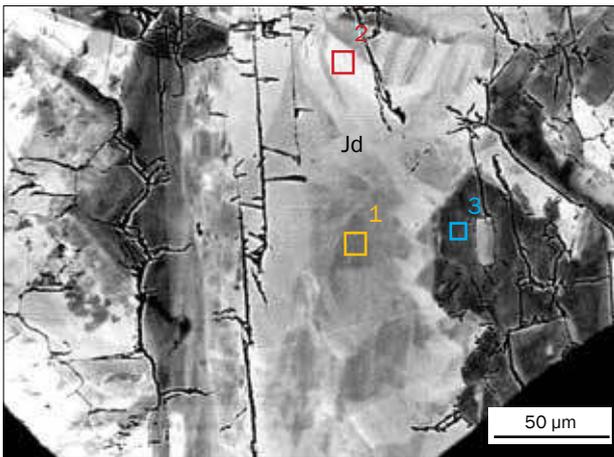
Sample 4J30 contained jadeite with a compositional range of $\text{Jd}_{83.5-97.5}\text{Ae}_{2.3-0.2}\text{Q}_{14.2-2.3}$, including some crystals revealing a distinct decrease in Na from core to rim. Omphacite in this sample formed solitary grains in contact with clinoamphibole (katophorite and richterite) and showed an intense irregular zoning pattern. Its composition ranged from $\text{Jd}_{41.8-62.8}\text{Ae}_{8.4-4.2}\text{Q}_{49.8-33.0}$ (plotted in Figure 6c).

Albite-bearing Jadeitites:

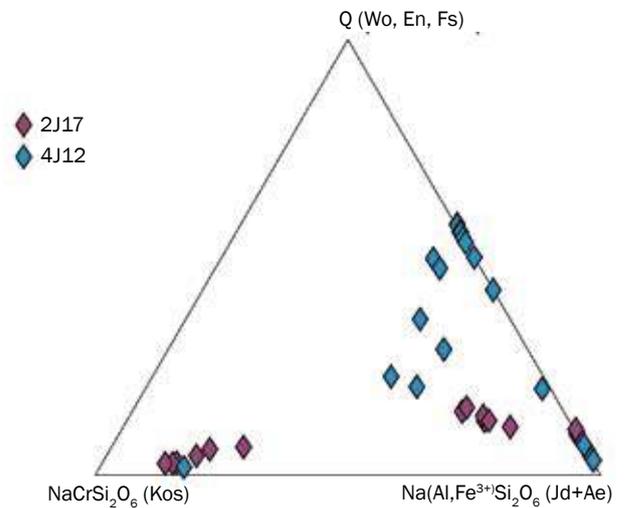
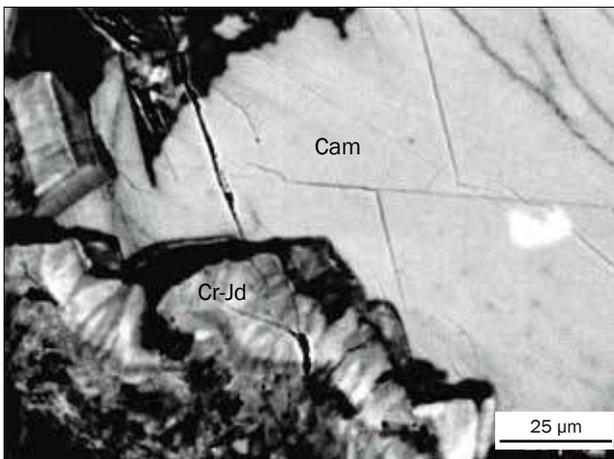
Sample 1J05 contained jadeite with patchy Na-rich and Na-poor sections showing a compositional variation of $\text{Jd}_{82.6-96.5}\text{Ae}_{4.4-0.2}\text{Q}_{13.0-3.3}$. Omphacite formed inhomogeneous rims on jadeite and showed a compositional range of $\text{Jd}_{40.3-55.8}\text{Ae}_{1.1-5.1}\text{Q}_{58.7-39.1}$ (plotted in Figure 6d). The albite in sample 1J05 was close to the end member ($\text{Ab}_{97.9-99.9}\text{An}_{0.2}\text{Or}_{0.0-0.1}$).

Jadeitites: Samples 4J06 and 4J26 contain clinopyroxenes that have a very similar composition to the foregoing samples, with jadeite ranging from $\text{Jd}_{83.0-98.0}\text{Ae}_{1.6-0}\text{Q}_{15.5-2.0}$ and omphacite varying from $\text{Jd}_{36.8-55.5}\text{Ae}_{6.5-1.7}\text{Q}_{56.7-42.7}$ (plotted in Figure 6e). Similar to the albite-bearing jadeitites,

a. Jadeitites with Kosmochlor and Clinoamphibole



b. Jadeitites with Kosmochlor and Clinoamphibole



c. Jadeitites with Clinoamphibole

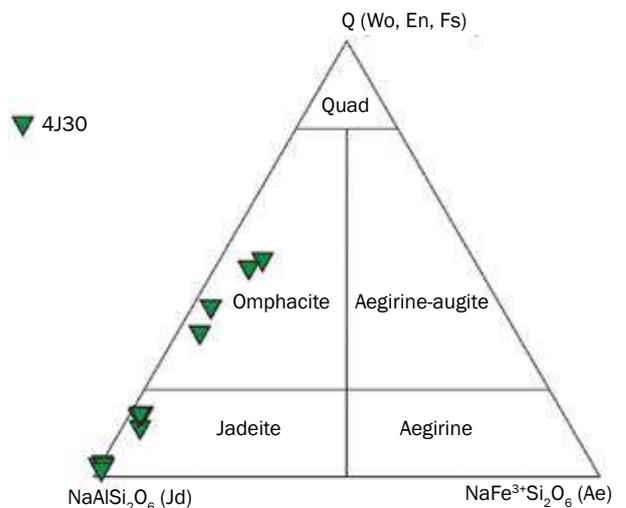
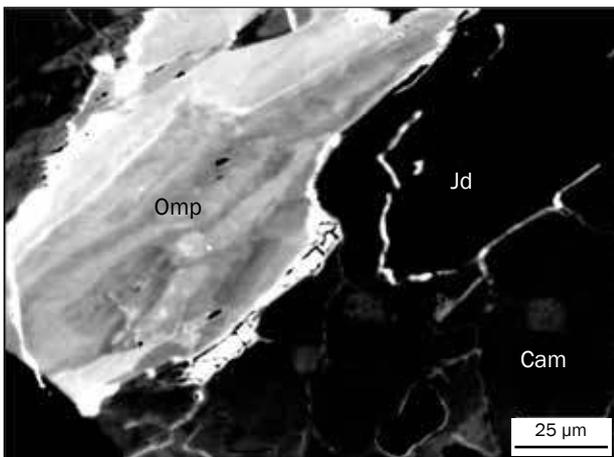
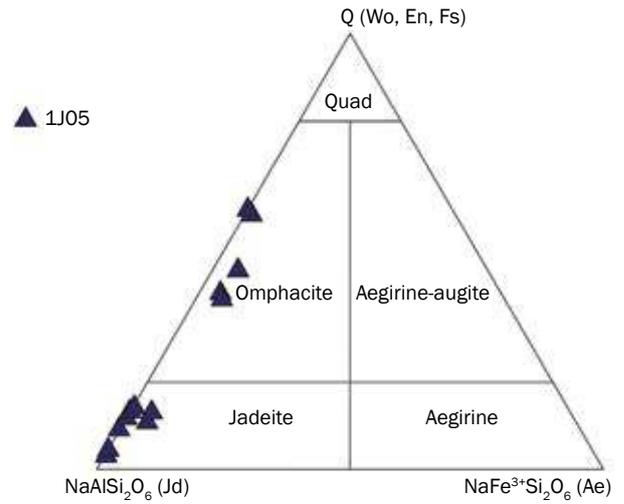
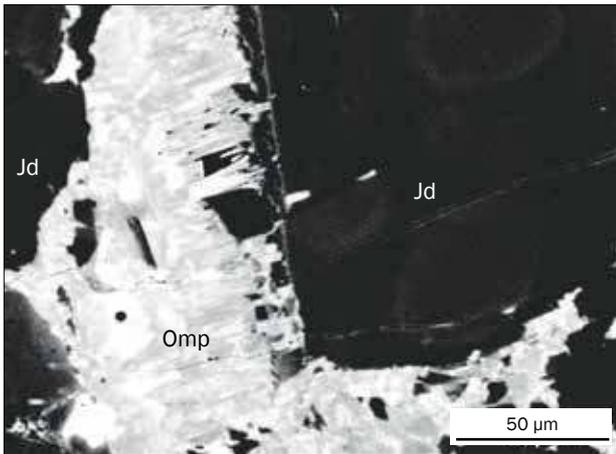
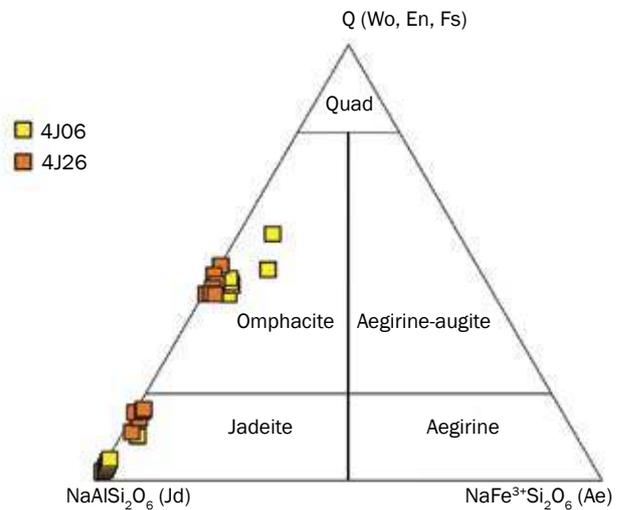
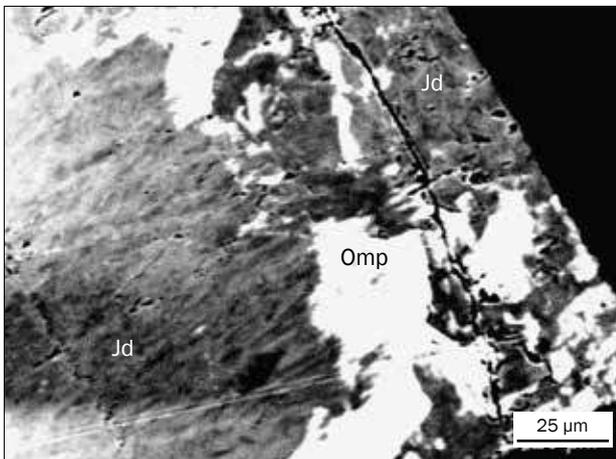


Figure 6: Electron microprobe data of pyroxenes are shown with BSE images of some of the corresponding areas that were analysed. The microprobe data are plotted in the Jd-Ae-Q diagram of Morimoto et al. (1988), except for Figure 6b which shows a Kos-(Jd+Ae)-Q diagram. The data for all samples demonstrate distinct compositional gaps between jadeite and omphacite, except for omphacite sample (f) which does not contain any jadeite. BSE images: (a) JKC-type sample 2J17 shows distinct

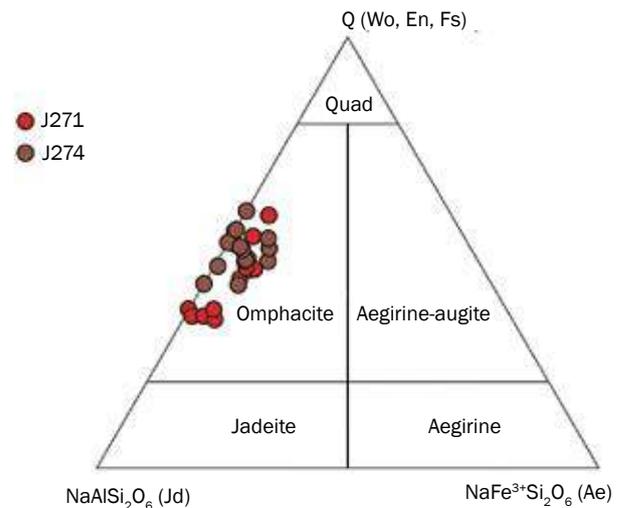
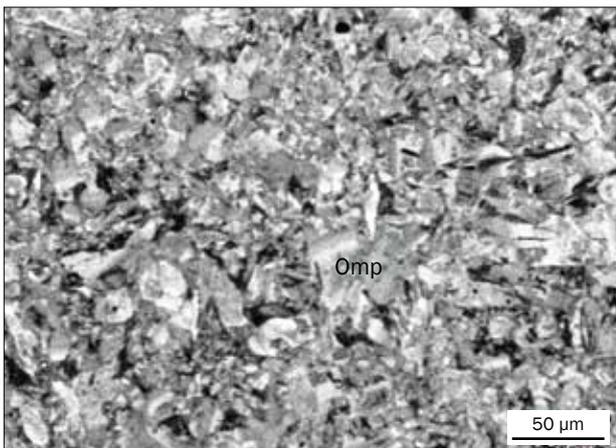
d. Albite-bearing Jadeitites



e. Jadeitites



f. Omphacitites



chemical zoning within a jadeite crystal. (b) This portion of sample 2J17 consists of a clin amphibole crystal that is rimmed by chromian jadeite. (c) JC sample 4J30 shows an inhomogeneous omphacite next to jadeite and clin amphibole crystals. (d) In ABJ sample 1J05, a jadeite crystal is rimmed by irregularly zoned omphacite. (e) J sample 4J26 displays a patchy replacement of jadeite by omphacite. (f) O sample J271 consists of an intergrowth of small omphacite crystals. Images by C. de Capitani.

Table I: Selected microprobe analyses of clinopyroxenes from jadeitites with kosmochlor and clinoamphibole (JKC), jadeitites with clinoamphibole (JC), albite-bearing jadeitites (ABJ), jadeitites (J) and omphacitites (O).*

Sample No.	2J17						4J12		
Rock type	JKC						JKC		
Spot	F2 1	F2 2	F2 3	F2 K 1	F2 K 6	F2 K2 2	F3 1	F3 3	F1 1
Mineral	Jd			Kos		Cr-Jd	Cr-Omp	Omp	Jd
SiO ₂	57.59	57.12	58.42	53.35	53.79	56.22	54.66	55.57	58.55
TiO ₂	nd	0.07	nd	0.03	0.02	0.01	3.24	0.07	0.03
Al ₂ O ₃	22.78	19.43	23.59	2.90	5.24	12.93	3.54	9.78	25.13
Cr ₂ O ₃	0.02	nd	0.02	29.55	23.86	6.26	5.10	0.03	0.01
Fe ₂ O ₃	3.56	5.96	1.70	nd	1.54	7.08	8.39	2.95	0.06
MgO	1.91	2.76	1.81	0.71	1.45	2.80	7.44	10.50	1.23
CaO	0.29	1.79	0.30	0.05	0.68	2.33	7.40	13.54	nd
MnO	nd	0.12	nd	0.03	nd	0.10	nd	0.23	0.01
FeO	nd	nd	nd	0.16	0.57	0.29	1.59	1.43	nd
Na ₂ O	14.20	13.35	14.33	13.21	13.01	12.70	9.48	6.21	14.99
Total	100.35	100.60	100.17	99.99	100.15	100.72	100.84	100.31	100.01
Cations (O=6)									
Si	1.959	1.964	1.976	1.988	1.981	1.984	1.981	1.967	1.973
Ti	nd	0.002	nd	0.001	0.001	nd	0.088	0.002	0.001
Al	0.913	0.787	0.940	0.127	0.227	0.538	0.151	0.408	0.998
Cr	0.001	nd	0.001	0.871	0.695	0.175	0.146	0.001	nd
Fe ³⁺	0.091	0.154	0.043	nd	0.043	0.188	0.229	0.079	0.001
Mg	0.097	0.141	0.091	0.039	0.080	0.147	0.402	0.554	0.062
Ca	0.011	0.066	0.011	0.002	0.027	0.088	0.287	0.514	nd
Mn	nd	0.003	nd	0.001	nd	0.003	nd	0.007	0.000
Fe ²⁺	nd	nd	nd	0.005	0.017	0.008	0.048	0.042	nd
Na	0.936	0.890	0.940	0.955	0.929	0.869	0.666	0.426	0.980
Total	4.007	4.008	4.002	3.989	4.000	4.000	4.000	4.000	4.016
End-members (mol%) after Morimoto et al. (1988)									
Jd	85.6	74.3	90.6	97.6	77.9	64.5	23.6	35.9	96.8
Ae	8.9	15.2	4.3	0	15.9	23.2	40.8	7.5	0.1
Q	5.4	10.4	5.2	2.4	6.2	12.3	35.6	56.6	3.1

* Ferric iron is calculated according to Droop (1987). Potassium was analysed for, but not detected in any of these samples. Abbreviation: nd = not detected.

omphacite formed rims around jadeite but also appeared as relatively homogeneous crystals in sheared zones. A distinct compositional gap exists between jadeite and omphacite (e.g. Figure 6e; see also Green et al., 2007), which has been observed in other jadeitites but curiously not mentioned in the literature for those from Myanmar.

Omphacitites: The fine-grained omphacitites show a decussate intergrowth of omphacite crystals with distinctly variable composition. The BSE image of sample J271 (Figure 6f) shows an

aggregate of bright, Na-poor and darker, Na-rich omphacite crystals. Similar mineral intergrowth phenomena were observed in sample J274. The composition of omphacite in these rocks ranged from $Jd_{36.4-63.6}Ae_{4.9-0}Q_{58.7-36.4}$ (plotted in Figure 6f).

Raman Spectroscopy

With this method a reasonably good identification of the different pyroxenes was possible. Jadeite shows a prominent band at 700 cm⁻¹, with weaker bands at 1039, 991, 575, 524, 374 and 203 cm⁻¹ (Figure 7a). In contrast, omphacite shows a main band at 684 cm⁻¹, and weaker

4J30		1J05		4J06		4J26		J271		J274	
JC		ABJ		J		J		O		O	
F1 1	F3 3	F2 7	F1 9	F2 7	F2 1	F1 4	F1 8	F3 xt 4	F1 4	F2 4	F3 1
Jd	Omp	Jd	Omp	Jd	Omp	Jd	Omp	Omp		Omp	
59.05	57.30	58.65	56.57	58.70	56.82	57.87	57.27	56.35	55.44	56.16	56.98
0.02	0.05	nd	0.05	0.01	0.29	0.09	0.13	0.16	0.05	0.15	0.15
25.03	16.24	25.24	15.19	24.77	13.04	21.94	14.16	15.71	10.27	10.21	14.77
nd	0.03	nd	0.02	0.01	0.01	nd	0.01	nd	0.01	0.02	nd
0.07	1.67	0.09	2.03	0.24	1.15	0.62	0.67	1.94	1.89	2.91	nd
0.91	7.20	1.29	8.27	1.58	9.35	3.89	9.22	7.81	12.41	10.47	8.54
nd	7.69	nd	9.16	0.20	10.94	2.96	9.88	8.61	13.93	12.43	9.52
nd	0.04	nd	0.01	0.02	0.01	0.05	nd	0.14	0.13	nd	nd
nd	nd	nd	nd	nd	0.56	nd	0.25	nd	nd	1.13	1.58
14.92	9.95	14.74	8.89	14.49	7.97	12.64	8.48	9.45	6.06	6.81	8.45
100.00	100.17	100.01	100.19	100.02	100.14	100.06	100.07	100.17	100.19	100.29	99.99
1.987	1.976	1.974	1.960	1.977	1.979	1.966	1.983	1.954	1.949	1.978	1.979
0.001	0.001	nd	0.001	0.000	0.008	0.002	0.003	0.004	0.001	0.004	0.004
0.993	0.660	1.001	0.620	0.983	0.535	0.878	0.578	0.642	0.426	0.424	0.605
nd	0.001	nd	0.001	0.000	0.000	nd	0.000	nd	0.000	0.001	nd
0.002	0.043	0.002	0.053	0.006	0.030	0.016	0.017	0.051	0.050	0.077	nd
0.046	0.370	0.065	0.427	0.079	0.485	0.197	0.476	0.404	0.650	0.550	0.442
nd	0.284	nd	0.340	0.007	0.408	0.108	0.367	0.320	0.525	0.469	0.354
nd	0.001	nd	0.000	0.001	0.000	0.001	nd	0.004	0.004	nd	nd
nd	0.000	nd	nd	nd	0.016	nd	0.007	nd	nd	0.033	0.046
0.974	0.665	0.962	0.597	0.946	0.538	0.832	0.569	0.635	0.413	0.465	0.569
4.002	4.003	4.005	4.000	4.001	4.000	4.001	4.001	4.013	4.018	4.000	3.999
97.5	62.8	96.5	55.8	95.0	51.2	83.0	55.5	58.7	36.4	39.4	57.5
0.2	4.3	0.2	5.1	0.6	3.0	1.6	1.7	5.0	4.9	7.6	0
2.3	33.0	3.3	39.1	4.4	45.8	15.5	42.7	36.3	58.7	53.1	42.5

bands at 1016, 567, 382, 144 and 76 cm^{-1} (Figure 7b). Chromian jadeite has its maximum band at 364 cm^{-1} and two prominent bands at 1025 and 685 cm^{-1} (Figure 7c). Kosmochlor shows a main band at 418 cm^{-1} and four characteristic bands between 1058 and 951 cm^{-1} (Figure 7d). Although the Senterra Raman spectrometer was not equipped with a depolarizer, crystal orientation had only a small effect on the intensity of these bands and almost no effect on their position, according to our measurements taken with the beam parallel to the a-, b- and c-axes of the crystals.

Many of the jadeite crystals in the investigated samples had dark, elongate inclusions in their core that were identified as graphite by Raman spectroscopy.

Infrared Spectroscopy

Figure 8 shows the FTIR spectra of jadeite, omphacite, chromian jadeite and kosmochlor, which can be distinguished easily by the relative height of their prominent absorption bands at 689–665 cm^{-1} and 643–623 cm^{-1} . The jadeite spectrum (Figure 8a) shows a distinctly greater absorbance at 643 cm^{-1} than at 689 cm^{-1} , which is the opposite for

omphacite (Figure 8b). Here, the band at 629 cm^{-1} shows a weaker absorbance than the one at 665 cm^{-1} . For chromian jadeite (Figure 8c) the bands at 671 and 631 cm^{-1} show almost identical absorption, while kosmochlor (Figure 8d) reveals a pronounced absorption at 671 cm^{-1} and a distinctly smaller absorption at 623 cm^{-1} . These results could also

be reproduced for the four additional cabochons from author HAH's collection.

Discussion

Pyroxene Mineralogy and the Genesis of Burmese Jadeite-bearing Rocks

Ideally, the composition of jadeite should not depart greatly from $\text{NaAlSi}_2\text{O}_6$. In most natural jadeite, at least 80% of the pyroxene's M1 site is occupied by Al, and at least 80% of the M2 site is taken by Na (Deer et al., 1997). Omphacite, on the other hand, is chemically much more complex. It is essentially a solid solution of jadeite and diopside with some aegirine. Omphacite is simplistically defined as $\text{Jd}_{50}(\text{Di}+\text{Hd})_{50}$, but may show a considerable range of jadeite, diopside and hedenbergite, and may also contain aegirine and kosmochlor components (see Morimoto et al., 1988; García-Casco et al., 2009). Following the classification of Morimoto et al. (1988; see Figure 6), the compositional ranges

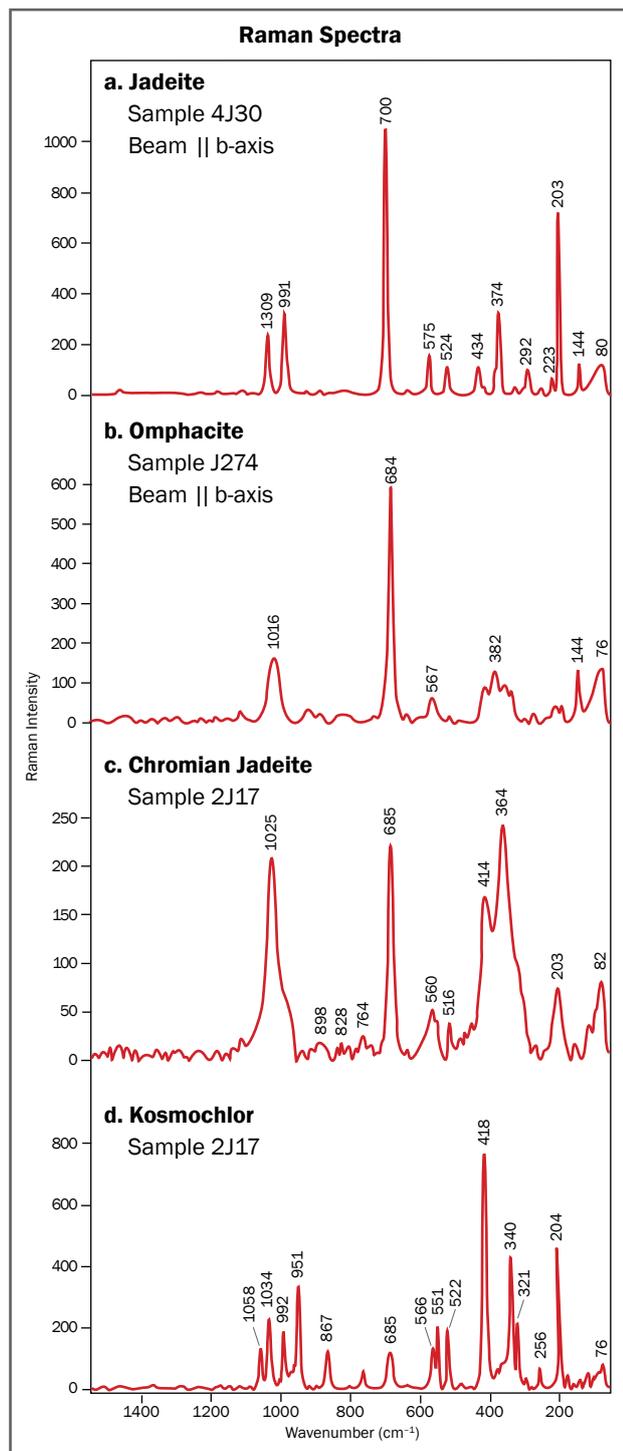


Figure 7: Raman spectra of selected minerals are shown for: (a) jadeite, (b) omphacite, (c) chromian jadeite and (d) kosmochlor.

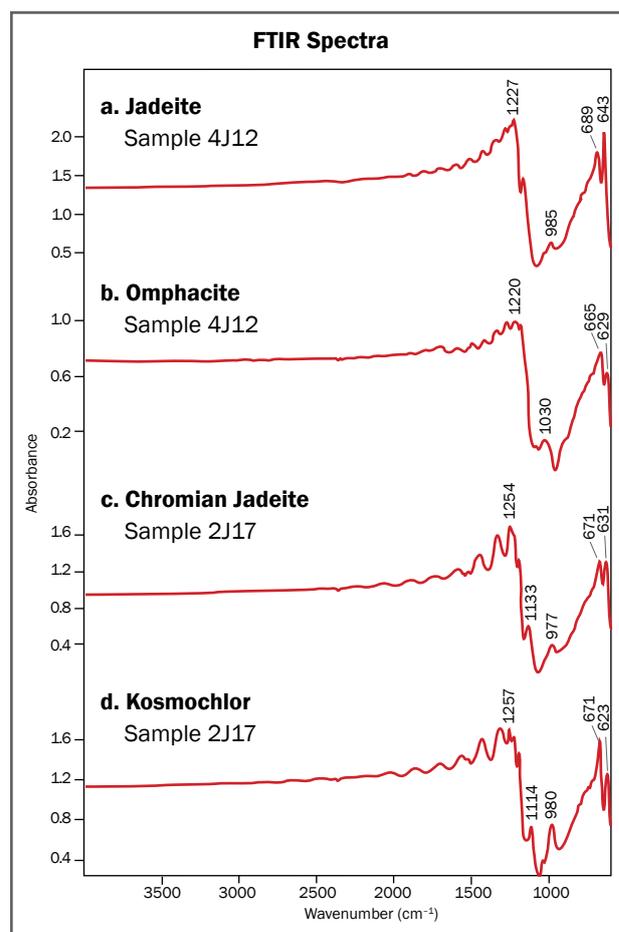


Figure 8: Representative FTIR spectra are shown for: (a) jadeite, (b) omphacite, (c) chromian jadeite and (d) kosmochlor.

of the quadrilateral (Ca-Mg-Fe) pyroxene, the Na-Al pyroxene (jadeite), and the Na-Fe³⁺ pyroxene (aegirine) are as follows: Omphacite lies within the area defined by $0.2 \leq \text{Na}/(\text{Na}+\text{Ca}) \leq 0.8$, and $\text{Al}/(\text{Al}+\text{Fe}^{3+}) \geq 0.5$, while jadeite lies in the field defined by $\text{Na}/(\text{Na}+\text{Ca}) \geq 0.8$ and $\text{Al}/(\text{Al}+\text{Fe}^{3+}) \geq 0.5$. If we follow this mineralogical classification strictly, a sample should not be called *jadeite* if it contains less than 80% Al as compared to Mg+Fe²⁺, less than 50% Al as compared to Fe³⁺, and less than 80% Na as compared to Ca. Furthermore, two temperature-dependent miscibility gaps between jadeite and Ca-Mg-Fe pyroxene have been described by several investigators (Davidson and Burton, 1987; Green et al., 2007; García-Casco et al., 2009; Harlow et al., 2011). At temperatures of 400°C, for example, they lie roughly between Na/(Na+Ca) ratios of 0.5–0.95 and between 0.2 and 0.4. This is also clearly visible in the ternary plots of Figure 6.

Apart from the chemical, and hence mineralogical, differences between omphacite and jadeite, there are also differences in the crystal structures of the two minerals, due to the differences in pressure and temperature of their formation. Although both minerals are clinopyroxenes crystallized in the monoclinic system, jadeite belongs only to one space group (C2/c), while omphacite has three polymorphs with symmetry C2/c, P2/n and P2 (Gaines et al., 1997). The crystallographic differences between jadeite and omphacite justify using separate terms (*jadeite jade* and *omphacite jade*) for referring to rocks composed predominantly of each mineral (see also Ou Yang et al., 2011).

The investigation of thin sections for this study has revealed the following facts: Several samples showed indications of pre- and syn-crystallization folding (i.e. polygonal arc textures, mineral alignment and micro-folds). Other samples had randomly oriented, decussate textures and lacked any tectonic overprint. Coarse-grained jadeitites with recrystallized textures (as described by Shi et al., 2009) were not observed in this study, which may be due to our randomly acquired samples. While the omphacitites often showed a monomineralic composition, the jadeitites mostly displayed complex mineral associations that usually included sodic and sodic-calcic amphiboles (e.g. arfvedsonite, richterite and katophorite). In some

samples, both jadeite and omphacite were present; in many cases (e.g. samples 4J12 and 1J05), the jadeite appears to be the older phase, because it was rimmed by omphacite. In some samples (e.g. 4J39), the presence of omphacite next to clinoamphibole (richterite) created macroscopically clearly visible, millimetre-sized green spots in a white matrix consisting of jadeite. Omphacite also occurred as prismatic crystals in foliated layers, in shear bands and in fractures, which points to late metasomatic processes (addition of Ca) along the foliation and shear zones. A compelling feature of most of the investigated rocks was the marked chemical zonation of jadeite and omphacite, indicating rapid growth of these minerals at relatively low temperatures (cf. Shi et al., 2003; 2005b; 2012; Oberhänsli et al., 2007). According to Harlow et al. (2014), jadeitite in Myanmar occurs along the intersection of the Burmese Western and Eastern provinces along an offset of the Sagaing Fault. The primary occurrences of jadeitite consist of dykes or veins within serpentinites, which formed by crystallization from fluids during high-pressure metamorphism (Harlow and Sorensen, 2005; Shi et al., 2005b; Yi et al., 2006; Nyunt, 2009). Investigations of Goffé et al. (2000) on jadeitites from northern Myanmar point to subduction-related metamorphic conditions of approximately 400°C at 1.5 GPa. Due to these relatively low temperatures and the short time of the metamorphic overprint during the subduction process, mineral homogenization by diffusion was not possible.

Gemmological Identification of Burmese Jadeite-bearing Rocks

The identification of these Burmese rocks simply by their appearance is problematic. Omphacitite tends to be darker in appearance than jadeitite, although some jadeitite can be dark (as seen in Figure 9 and noted in Harlow et al., 2014) and omphacite jade also may have a lighter tone resembling jadeite jade (McClure, 2012). However, compared to jadeitite, omphacitite typically appears less transparent when viewed with transmitted light and tends to be greyish green.

A short summary of the gemmological properties of jadeite, omphacite and kosmochlor jades is given in Table II. Our findings confirm that it is sometimes possible to separate jadeite- from omphacite-dominant rocks using basic

Figure 9: The translucent medium-dark green carvings in this diamond necklace are jadeite jade (spot RI readings of 1.65–1.66), while those in the earrings had a higher RI of 1.67. This, combined with their slightly darker appearance, suggests the presence of an omphacite component. All of the carvings are 2–3 mm thick, and the largest ones measure 2.7 cm long. Photo by Tay Thye Sun.



gemmological properties such as RI, SG and the 437 nm absorption line. However, the samples analysed in this study reveal that Burmese jadeites are not so pure after all, as they contain various modal proportions of clinoamphibole, kosmochlor, omphacite and other minerals. Our investigations show some similarities to the grouping by Htein and Naing (1994), who describe monomineralic (pure) and polymineralic (impure) jade, although some additional accessory minerals such as rutile and ilmenorutile were found by those authors (see also Htein and Naing, 1995). Predominantly monomineralic samples can be inhomogeneous due to solid solution and solvi, as well as chemical zoning. While some high-quality jadeites are homogeneous and monomineralic, a large number of greyish, greenish and dark stones sold as jadeite jade have a complex polymineralic composition. Our studies reveal that in other than pure jadeite, clinoamphibole or omphacite also contribute

to variable RI and SG. Therefore, the use of RI spot readings and SG values does not lead to a rigorous identification. This is particularly true for the SG of jadeite samples containing abundant clinoamphibole (e.g. 1J02 and 1J04), which had much lower values of 3.16 and 3.25, respectively. However, the RI values of both these samples were still within the typical jadeite jade range of 1.65–1.66. Nevertheless, the 437 nm absorption line was not detected, in contrast to pure jadeite.

Among the more advanced methods available in a well-equipped gemmological laboratory, Raman micro-spectroscopy is the best technique for jade identification. With an appropriate database it is possible to non-destructively analyse spot-by-spot the composition of a rock being tested. In addition, micro-FTIR spectroscopy can provide a good distinction between jadeite, chromian jadeite, omphacite and kosmochlor. A high-resolution analytical apparatus like the Bruker Lumos micro-FTIR spectrometer should be used. Our FTIR

Table II: Gemmological properties of jadeite, omphacite and kosmochlor jades from Myanmar.*

	Jadeite jade	Omphacite jade	Kosmochlor jade
Colour	Colourless, white, lavender, brown, yellow, green and dark green	Dark green to black	Green to black; uneven
Transparency	Transparent to opaque	Translucent to opaque	Opaque
RI	1.65–1.67	1.66–1.68	1.68–1.75
SG	3.25–3.40	3.30–3.45	3.35–3.50
Magnification	Fine-to-coarse grained, granular to fibrous texture	Fine grained, fibrous texture	Fibrous and radiating aggregates
Absorption spectrum	437 nm line; chromian jadeite shows lines at 630, 655 and 690 nm	No 437 nm line or Cr ³⁺ absorption	None observed

* Data from this study, Webster (1995), and www.gahk.org/attachment/fcteststd2.pdf.

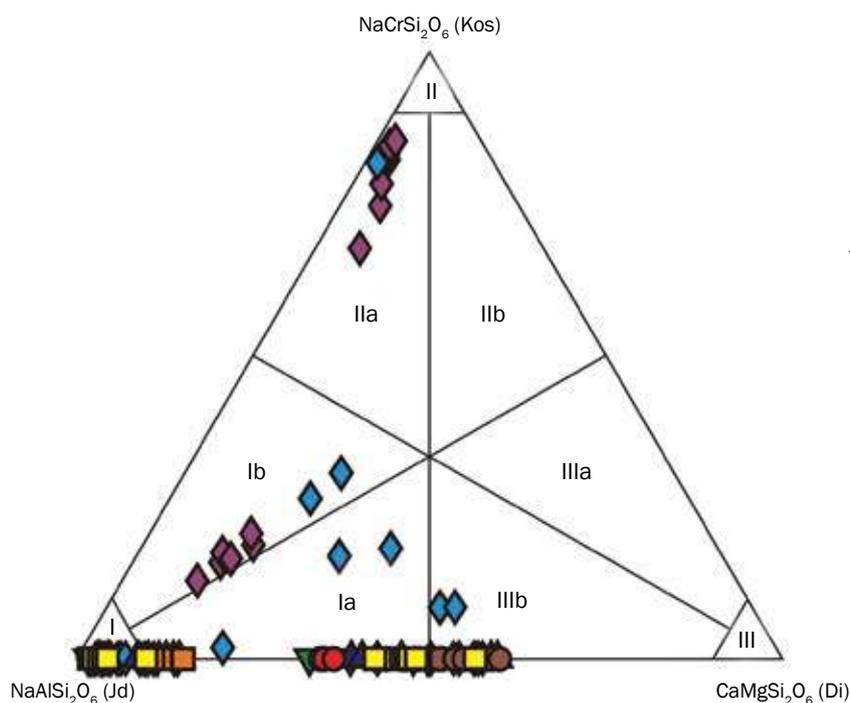


Figure 10: Electron microprobe analyses from this study are plotted in the kosmochlor-jadeite-diopside diagram of Ou Yang and Ng (2012). In the classification scheme proposed by those authors, the fields define pure jadeite (I), jadeite with minor omphacite (Ia), chromium-containing jadeite (Ib), pure kosmochlor (II), jadeite-containing kosmochlor (IIa), diopside-containing kosmochlor (IIb), pure diopside (III), kosmochlor-containing diopside (IIIa) and jadeite-containing diopside (IIIb). For the key to symbols, see Figure 6.

spectra gave equally satisfactory identifications as Raman spectroscopy and the electron microprobe. With these micro-analytical methods, tiny grains down to 1 μm (Raman) or 5 μm (FTIR) can be investigated. Raman or FTIR spectroscopy of larger analytical areas may yield mixed spectra that are not useful for identification, especially for samples that were not previously investigated microscopically and with microprobe analysis.

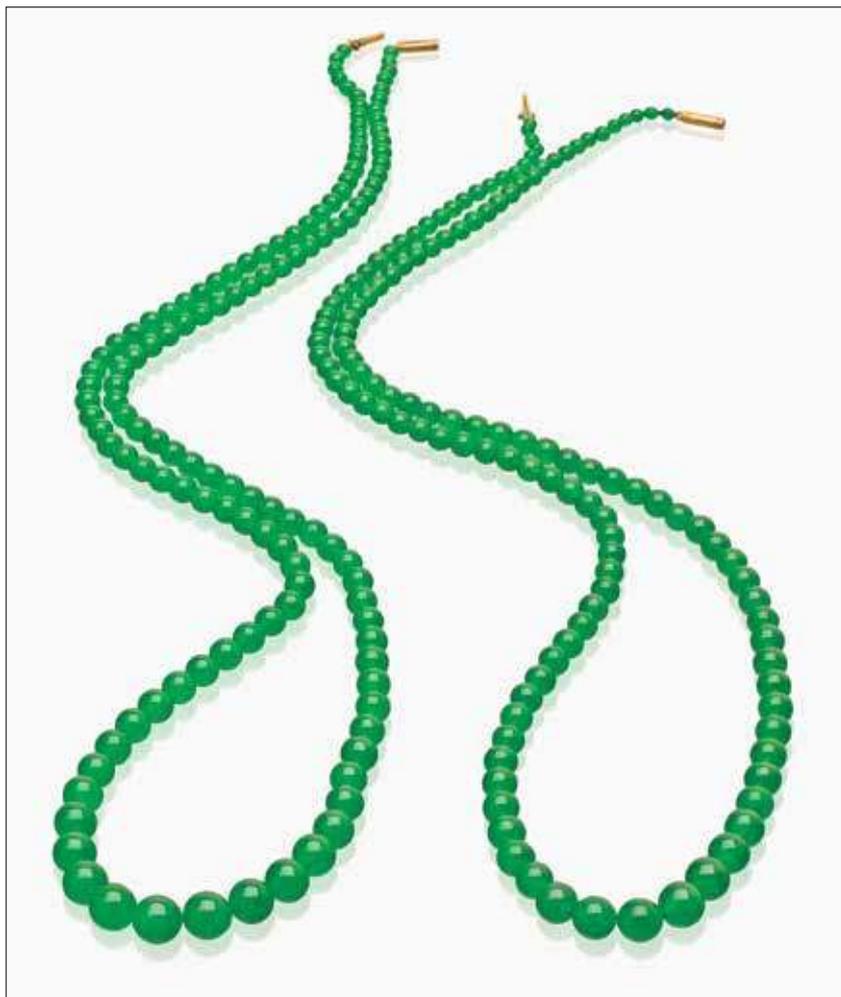
Current Classification/Nomenclature and Proposal for a New System

As a consequence of the results of this study, the present terminology of jadeitic gem materials should be seriously reconsidered. Such rigid schemes as the ternary jadeite–diopside–kosmochlor diagram of Ou Yang and Ng (2012) may be applied to monomineralic samples with a homogeneous mineral composition, but they are not appropriate for polymineralic samples. This becomes evident from Figure 10, in which we have plotted our microprobe analyses using the classification diagram of Ou Yang and Ng (2012). Jadeitites with kosmochlor fall into a large area ranging from the jadeite field (I) to the jadeite-containing kosmochlor field (IIa), while jadeitites, albite-bearing jadeitites and jadeitites with clinoamphibole plot in the fields for pure jadeite (I), jadeite with minor omphacite (Ia) and jadeite-

containing diopside (IIIb). Due to their mineral chemical variability, even the monomineralic omphacitites cover a broad field from jadeite-containing diopside (IIIb) to jadeite with minor omphacite (Ia). Furthermore, the scheme does not consider minerals like clinoamphibole, albite or phlogopite, which are common constituents of the jade rocks.

Similarly, Hänni (2007) started from the assumption of a monomineralic composition, which may be true for some pure-appearing green jadeitites (e.g. Figure 11). However, as demonstrated in this investigation, many jadeitites and kosmochlor-bearing jadeitites from Myanmar are polymineralic and extremely inhomogeneous due to their textures and complex mineral zonation patterns. Furthermore, such observations have also been made for jadeitites from Kenterlau-Itmurundy (Lake Balkhash, Kazakhstan; Ernst et al., 2013) and a number of other locations (for an overview, see Harlow et al., 2014). In many cases, the rocks display strong compositional variability with complex mineral intergrowths of micrometre size. Common gemmological methods of investigation like RI, SG and energy-dispersive X-ray fluorescence spectroscopy (EDXRF) are not applicable to such small-scale structures. The rigorous identification of all the phases present is only possible using polarization microscopy of

Figure 11: The pure, translucent appearance and high quality of the beads in these necklaces suggests that they consist only of jadeite with little or no impurities. Each of the necklaces is composed of 127 Imperial jadeite beads in graduated sizes ranging from 3.45 to 10.15 mm in diameter. They are approximately 75.5 and 79.5 cm long, and sold for HK\$42,680,000 at the Sotheby's Hong Kong auction in October 2013. Photo by Luc Phan, © Swiss Gemmological Institute SSEF.



thin sections and electron microprobe analysis, which is unfeasible for gem samples.

An appropriate non-destructive approach used by gemmological laboratories should employ Raman or FTIR analysis to assess the composition of jadeite-bearing rocks and identify them correctly. As an example, we suggest that 20 spots on the surface of a medium-grained sample should be analysed. (The total number of analysed points should, of course, depend on the texture and grain size of the sample, with more points necessary for heterogeneous and finer-grained samples and fewer points needed for coarse-grained specimens.) When the same result is obtained for 15 of these spots (75%), this should be used to name the sample. Therefore, if 15 out of 20 analysed points were jadeite and the remaining spots were kosmochlor or omphacite, the rock should be called kosmochlor-jadeite jade or omphacite-jadeite jade, respectively. We propose that *jade* should be used as part of the

name, as this word has traditionally been used for the classification of such polymineralic rocks.

The International Mineralogical Association (IMA) has already established a nomenclature framework that has been useful for mineralogists worldwide since 1988, and jadeite, kosmochlor and omphacite are all mineral names that are accepted by the IMA. According to the nomenclature given by CIBJO, we suggest using the terms *jadeite jade*, *kosmochlor jade* and *omphacite jade* to describe gems that consist predominantly of these constituents. As described above, we propose analysing a grid on a sample, with the most abundant mineral used to determine the name. This method would provide a simple and helpful tool for jade dealers and gemmologists who have some basic training to understand the complexity of jade classification. It is hoped that such a practical classification will be widely accepted, thus making the trading of jade easier.

Fei Cui and Jade Terminology

The use of the term *fei cui* by the Hong Kong government to refer to a granular to fibrous polycrystalline aggregate composed of jadeite, omphacite and/or kosmochlor is in accordance with Chinese tradition. However, we feel that the terms *jadeite jade*, *kosmochlor jade* and *omphacite jade* are more in-line with the mineralogical and scientific nomenclature of jade identification. Nevertheless, the term *fei cui* can be added as an optional modifier. In such a case, an example of this terminology would be 'jadeite jade (*fei cui*)'—rather than the wording '*fei cui* (jadeite jade)' that is currently used in Hong Kong. In English, the latter format could imply that all *fei cui* is jadeite jade, which would be misleading.

Conclusion

This study shows a wide diversity in the jadeite-bearing rocks from Myanmar that are used for decorative and jewellery purposes. Petrographic and micro-chemical studies reveal that these rocks exhibit extensive chemical and textural inhomogeneities, which render a classification by common gemmological methods rather difficult. With the help of thin-section investigations in combination with electron microprobe analysis, five different groups of jadeite and omphacite rocks were recognized. These rocks display a wide range of mineral content and rock fabric, resulting in quite a variable macroscopic and microscopic appearance.

With the recognition of this diversity, and with more advanced instrumentation available in gemmological laboratories, there is a call for revising the former jade nomenclature. We propose analysing a sample using Raman or FTIR spectroscopy on a point grid, with the most abundant mineral giving the name (i.e. *jadeite jade*, *omphacite jade* or *kosmochlor jade*).

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