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Article

# Petrography and chemical composition of the constituent minerals of jadeitites from the Osayama ultramafic body in the Renge metamorphic belt, southwest Japan

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**Abstract**

A jadeitite block probably derived from serpentines of the Osayama ultramafic body in the Renge metamorphic belt is described petrographically. The jadeitite (Osa-1) consists mostly of jadeite, with subordinate omphacite, diopside, wollastonite, pectolite, prehnite, grossular, calcite, vesuvianite, Naamphibole, Na-Caamphibole, phlogopite, serpentine, chlorite and chromite. The clinopyroxenes in Osa-1 are classified into jadeite, omphacite and diopside. The chemical compositions of clinopyroxenes depend on the mode of their occurrence. Clinopyroxenes forming columnar crystals in the massive jadeitite portions consist of jadeite ($Jd_{84-100}$), and columnar or acicular crystals in fracture zones are omphacite ($Jd_{32-45}$). Clinopyroxenes occurring in veins are classified into jadeite-omphacite ($Jd_{74-83}$), omphacite ($Jd_{41-54}$) and diopside ($Jd_{0-9}$). Clinopyroxenes occurring as aggregates of acicular crystals are diopside ($Jd_{0-2}$).

Ca-rich minerals such as diopside, prehnite, vesuvianite, calcite, wollastonite, pectolite and grossular occur within veins or along cracks in a matrix consisting mostly of jadeite. This suggests that infiltration of Ca-rich fruid occurred at the later stage of a formation of the jadeitites within the serpentinite body.

**Key words**: Renge metamorphic belt, chemical compositon, jadeitite, omphacite, diopside, pectolite, wollastonite, grossular, prehnite, chlorite, vesuvianite, amphibole

## Introduction

Jadeitites and jadeite-bearing metamorphic rocks frequently occur as tectonic blocks or enclaves in serpentinite bodies or serpentininte mélanges. In the Renge belt (Nishimura, 1998), which is a high-P/T metamorphic belt exposed in the Inner Zone of Southwest Japan, jadeitite blocks have been reported from the Omi-Kotaki area in Niigata Prefecture (Chihara, 1958), the Oya area in Hyogo Prefecture, the Wakasa area in Tottori Prefecture (Masutomi, 1966) and the Osayama area in Okayama Prefecture (Kobayshi et al., 1989).

We have found a jadeitite block from the Osayama area, and present a systematic description of the jadeitites from the outermost rim to the interior of the block and chemical compositions of the constituent minerals in this paper. We will discuss an interaction between jadeitite block and serpentinite matrix.

## Geology of the Osayama area

The Sangun metamorphic belt has been considered to be a major high P/T metamorphic belt in the Inner Zone of Southwest Japan. Recently, the Sangun metamorphic belt was divided into two tectonic units based on the metamorphic ages and conditions of metamorphism (Nishimura, 1998). One is an older unit and named as the Renge belt (330～280 Ma), and the other is a younger unit and named as the Suo belt (230～160 Ma).

The protoliths of the Renge metamorphic rocks consist mainly of pelitic rocks, basaltic rocks and cherts, and they suffered high-P / T metamorphism ranging from the glaucophane facies to the epidote amphibolite facies. There occur tectonic blocks within serpentinite bodies, and the tectonic blocks include metagabbro, amphibolite and metagranite (Nishimura and Shibata, 1989). The Suo belt is characterized by high-P/T schists closely related to the weakly metamorphose Permian accretionary rocks of the Akiyoshi belt.

The area of the present study probably belongs to the Renge belt, and there occurs a large ultramafic body, which is named as the Osayama ultramafic body. The Osayama body is about 6 km across, and it is in contact with the Yamaoku Formation on the north by a fault and the Sangun schists on the east probably by a fault. The Osayama body is unconformably covered with the Kyomiyama conglomerate of Early Cretaceous. The serpentinites of the western parts of Osayama body are intruded by Late Cretaceous granitic rocks, and suffered a contact metamorphism (Nozaka and Shibata, 1995).

The Osayama ultramafic body consists mainly of harzburgite with small amounts of dunite and metagabbro, but most of the ultramafic rocks are severely serpentinized (Kobayashi et al., 1987; Nozaka and Shibata, 1994, 1995). The northeastern part of the Osayama ultramafic body forms a serpentinite melange, which has tectonic blocks with diverse sizes (10 cm to 1.5 km), litholgies and

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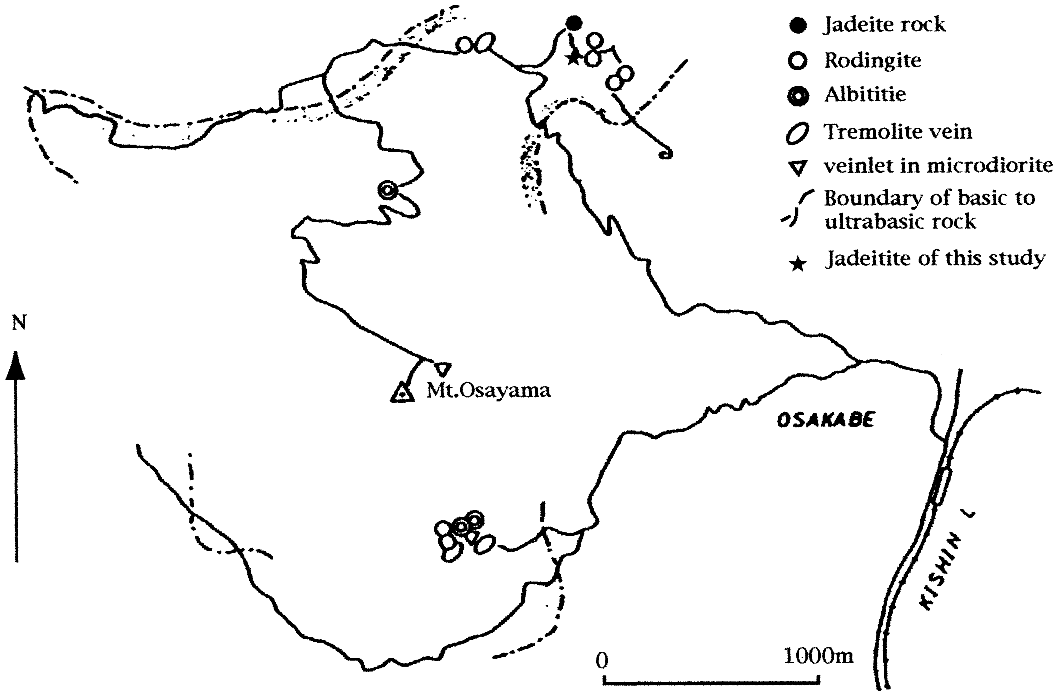


**Fig. 1.** Sample locality of the jadeitie (Osa-1) (after Kobayashi et al., 1987).

metamorphic conditions. The tectonic blocks within the serpentinite matrix include spotted schists, non-spotted schists, garnet-glaucophane schists, metagabbros, metadiabases, metadolerites, rodingites, albitites, omphacitites, jadeitites, stilpnomelane schists, pelitic schists and actinolite-tremolite rocks (Watanabe et al., 1987; Kobayashi et al., 1987; Tsujimori and Takasu, 1994; Sakamoto and Takasu, 1996; Nozaka, 1997). The P-T conditions of the tectonic blocks have been estimated as 6-12 kbar and 250-530℃ (Tsujimori and Takasu, 1994).

In the Osayama area, jadeitites occur as veins with several meters in width (Kobayashi et al., 1987) and blocks with approximately 1 m across within serpentintes (Fig. 1). We have found a boulder (80 cm in diameter) consisting mainly of jadeitites partly rimmed by serpentine-chlorite rocks.

## Petrography of jadeitites

The Jadeitite (Osa-1) has been collected as a loosed block which is rimmed by thin serpentine-chlorite rock . It is mostly massive, and white and gray in color. Four portions from the outermost rim of serpentine-chlorite rocks (Osa-1-1), through Osa-1-2 and Osa-1-3, to the interior (Osa-1-4) of the block are systematically described below.

### 1. Osa-1-1

Osa-1-1 is derived from the marginal part of the jadeitite block together with thin skin of serpentine-chlorite rocks. It is divided into five domains from the outside to the interior, i.e. serpentine-chlorite rock, vesuvianite-rich zone, prehnite-rich zone, omphacite-rich zone and massive jadeitite.

The serpentine-chlorite rock consists mainly of chlorite with subordinate serpentine and accessory chromite. A schistsity defined by preferred orientation of chlorite and serpentine is developed. Chlorite is of subhedral tabular crystal (<0.1 mm). Serpentine is of anhedral tabular crystal (<0.1 mm). Chromite is granular and is very fine-grained (< 0.03 mm).

The vesuvianite-rich zone is approximately 2 mm in width, and it consists mainly of vesuvianite with subordinate chlorite, wollastonite, diopside and calcite. It also contains accessory phlogopite. A schistsity defined by preferred orientation of chlorite is developed, and the schistsity plane is folded. Vesuvianite and wollastonite define a mineral lineation due to their parallel arrangement on the schistosity plane. Vesuvianite is of anhedral columnar crystal (<0.1 mm in length). Chlorite shows anhedral to subhedral tabular crystal (<0.1 mm across) and is colorless. Wollastonite is of anhedral columnar crystal (<0.1 mm). Diopside occurs as aggregate of acicular crystals (<0.1 mm in length). Very fine-grained calcite (<0.03 mm) occurs as aggregate. Phlogopite occurs as very fine-grained anhedral tabular crystal (<0.03 mm across).

The prehnite-rich zone is approximately 1.5 mm in width, and consists mainly of prehnite with subordinate calcite, grossular, vesuvianite and wollastonite. It also contains accessory amounts of diopside, phlogopite and gehrenite-like mineral. Veins (<0.5 mm in width) consisting of very fine-grained vesuvianite, wollasotnite and gehrenite-like mineral occur within the prehnite-rich matrix. The prehnite-rich matrix is composed of fine-grained prehnites (<0.01 mm) together with a small amount of wollastonite (<0.01 mm) and gehrenite-like mineral (<0.01 mm). Diopside occurs as anhedral to subhedral acicular crystal (<0.01 mm) in a vein approximately 0.02 mm in width. Calcite occurs as subhedral columnar grain (< 1.5 mm). Grossular occurs as tiny granular grain (<0.03 mm).

The omphacite-rich zone of approximately 1.5 mm in width consists mainly of omphacite and jadeite with accessory pectolite, wollastonite, grossular, Na amphibole and Na-Ca amphibole. There are network veins approximately 0.05 mm in width in the fractures of jadeite aggregates. The veins are composed of omphacite, wollastonite and pectolite. Omphacite occurs as aggregate of anhdral to subhedral acicular crystals (<0.01 mm) with wollastonite in the veins. Wollastonite occurs as aggregate of anhedral acicular crystals (<0.01 mm) in the veins. Pectolite occurs in the veins of approximately 0.01 mm in width and it is anhedral tiny crystal (<0.01 mm). Jadeite is of subhedral to anhedral acicular crystal (<0.1 mm). Grossular is of anhedral granular crystal (<0.1 mm), and it occasionally shows a distinct zoning detected by back-scattered electoron image. Na-amphibole occurs as aggregate of subhedral columnar crystal (<0.05 mm) together with omphacite and Na-Ca amphibole. Na-Ca amphibole is colorless and is of subhedral columnar crystal (<0.05 mm). There are fracture zones (<0.2 mm in width) consisting of omphcite, jadeite and Na-Ca amphibole. In the fracture zones, omphacite occurs as anhedral acicular crystal (<0.02 mm) in the interstice of subhedral columnar crystals of jadeite (<0.1 mm) and Na-Ca amphibole (<0.05 mm).

A part of massive jadeitite consists mainly of jadeite with accessory pectolite and wollastonite. Jadeite is of subhedral to anhedral columnar crystal (<2.0 mm). Pectolite has two modes of occurrence; one occurs in interstice of jadeite crystals with wollastonite, and the other occurs in the veins together with wollastonite. Pectolite is of anhedral columnar crystal (<0.5 mm). Wollastonite occurs as subhedral to anhedral columnar crystal (<0.05 mm).

**2. Osa-1-2**

Osa-1-2 consists mainly of jadeite with a small amount of omphacite, pectolite, wollastonite, grossular and albite. There are two modes of occurrence of veins. One is black vein (0.1 mm in width), which consists of fine-grained (<0.1 mm) pectolite, wollastonite, grossular and albite. The other is colorless vein (0.5 mm in width), which consists of pectolite and wollastonite in the interior, and of omphacite in the margin. In the interior of the vein, pectolite is of anhedral columnar crystal (<0.2 mm), and wollastonite is of anhedral acicular crystal (<0.05 mm). At the margin of the veins, omphacite occurs as subhedral to euhedral acicular crystal (<0.1 mm). The omphacite vein from the margin of the colorless vein inject into the interstice among jadeite crystals. Jadeite occurs as euhedral to subhedral columnar crystal with radial arrengement. The size of jadeites varies from 0.1 mm to 5.0 mm in length. Pectolite (<2.0 mm) and wollastonite (<1.0 mm) are of acicular crystals and both of them have the same mode of occurrence as their in the part of the massive jadeitite of Osa-1-1. Albite occurs only in the vein and as unhedral tiny granular crystal (approximately 0.01 mm across).

**3. Osa-1-3**

Osa-1-3 consists mainly of jadeite with small amount of pectolite, grossular and calcite. Jadeite occurs as euhedral to subhedal columnar crystal (<5.5 mm in length), and it shows the same mode of occurrence as Osa-1-2. Pectolite has three modes of occurrence; the first type occurs as anhedral columnar crystal (<0.5 mm) occurring at the interstice of jadeite crystals, the second type occurs as aggregate (approximately 5.0 mm) of anhedral granular crystals of pectolite (<0.1 mm), and the third type occurs in veins which are composed of anhedral pectolite (<0.1 mm) with grossular. Some pectolites in the veins include anhedral columnar jadeite (<0.1 mm). Grossular is euhedral to subhedral granular crystal (<0.1 mm) in veins mainly of pectolite. Calcite shows two modes of occurrence; one is of euhedral to anhedral columnar crystal (<0.1 mm), and the other occurs as anhedral crystal (<0.1 mm) in the interstice of jadeite crystals.

**4. Osa-1-4**

Osa-1-4 consists mainly of jadeite with small amounts of pectolite and grossular, and it also contains accessory amounts of calcite. There are fracture zones (<0.1 mm in width) consisting of pectolite and subgrained jadeite. In the fracture zones, pectolite occurs as subhedral acicular crystal (<0.1 mm) in the interstice of subhedral columnar jadeites (<0.1 mm).

Jadeite in the matrix occurs as euhedral to subhedral columnar crystal (< 3 cm in length) with radial arrangement. Pectolite(<0.5 mm) in the matrix occurs in the interstice of columnar jadeites. Grossular always occurs closely associated with pectolite, and is of euhedral granular crystal (<0.3 mm). Some grossulars show skeletal crystal structure, and it includes anhedral columnar jadeite (<0.1 mm). The inside of skeletal crystal is filled by pectolite, continuing to the outside of the skeletal crystal. Calcite (<0.05 mm) occurs as anhedral granular inclusion within pectolite and jadeite in the massive matrix.

## Chemical compositions of the constituent minerals

The chemical compositions of minerals have been analyzed by EPMA (JEOL JXA–8800 M) installed at the Research Center for Coastal Lagoon Environments, Shimane University. The analyses were performed at 15 kV of accelerating voltage, $2\times10^{-8}$A of specimen current and 3–

5 $\mu$ m of probe diameter, following the correction method of Bence and Albee (1968). The chemical compositions of the minerals are shown in Tables 1–7.

**1. Clinopyroxenes**

Clinopyroxenes in the sample of Osa-1 are chemically classified into three groups, i.e. jadeite, omphacite and diopside following Morimoto (1988). $Fe^{3+}$ in clinopyroxene was estimated based on $Fe^{3+}=4-2Si-2Ti-Al+Na$. The jadeite and aegirine components were estimated based on $NaAl^{VI}$ and $NaFe^{3+}$, respectively. There are four modes of occurrence of the clinopyroxenes, i.e. (1) columnar crystals in the massive jadeitite portions, (2) columnar or acicular crystals in fracture zones, (3) acicular crystals in veins, and (4) aggregate of acicular crystals (Fig. 2).

(1) Clinopyroxines of columnar crystals in the massive jadeitite portions are chemically classified into jadeite ($Jd_{84-100}$). Some of them have relatively high aegirine molecules (Ae) up to 9.0 mol.%.

(2) Clinopyroxenes of columnar or acicular crystals in fracture zones are chemically classified into omphacite ($Jd_{32-45}$) and jadeite ($Jd_{89-100}$). Aegirine molecules of omhacite are up to 6.1 mol.%.

(3) Clinopyroxenes in veins are chemically classified into jadeite-ompacite ($Jd_{74-83}$), omphacite ($Jd_{41-54}$) and diopside ($Jd_{0-9}$). Omphacites have relatively high aegirine molecules up to 8.5 mol.%.

(4) Clinopyroxenes of aggregate of acicular crystals are classified into diopside ($Jd_{0-2}$). Aegirine molecules are up to 2.5 mol.%.

There are compositional gaps at $Jd_{9-31}$, $Jd_{54-75}$ and $Jd_{84-89}$. The positions of the compositional gaps correspond with those shown by Takasu et al. (2000), and they described the lower the jadeite molecule, the higher the aegirine molecule of the clinopyroxenes along jadeite-diopside join. However, the clinopyroxenes along the jadeite-diopside join of the present study do not show the tendency.

**2. Pectolites**

Pectolites in the sample of Osa-1 show the chemical compositions close to the ideal pectolite composition, $Ca_2NaH(SiO_3)_3$ (Table 2). The contents of Al, Fe, Mn, Mg and K in the pectolites are negligible (Table 2).

**3. Wollastonites**

Wollastonites in the sample of Osa-1 show the chemical compositions similar to the ideal formula of wollastonite (Table 3). They contain very low FeO (< 0.22 wt.%) and MnO (< 0.11 wt.%).

**4. Garnets**

Garnets in the sample of Osa-1 show the chemical compositions close to the ideal formula of grossular (Table 4). Some garnets contain low $TiO_2$ (< 0.28 wt.%), FeO (< 2.31 wt.%) and MgO (< 0.28 wt.%).

**5. Prehnites**

Prehnites in the sample of Osa-1 show the chemical compositions of the ideal formula of prehnite (Table 5). Some prehnites contain small amount of FeO (< 0.20 wt.%) and MgO (< 0.42 wt.%).

**6. Chlorites**

Chlorites in the sample of Osa-1 range in Fe/(Mg+Fe) from 0.02 to 0.19, and are classified into clinochlore (Table 6).

**7. Vesuvianites**

Vesuvianites in the sample of Osa-1 show the chemical compositions of the ideal formula of vesuvianite (Table 7). They contain very low $TiO_2$ (<1.01 wt.%) and MnO (<0.16 wt.%).

**8. Amphiboles**

Amphiboles in the sample of Osa-1 are chemically classified into eckermanite and richterite (Leake et al., 1997) (Fig. 3, Fig. 4). $Fe^{3+}$ of amphiboles were estimated by normalizing that the sum of the cations from Si to Mn is 13 (Leake et al., 1997). $Mg/(Fe^{2+}+Mg)$ in eckermanites ranges from 0.91 to 0.97, and Si ranges from 7.77 to 7.94. $Mg/(Fe^{2+}+Mg)$ in richterites ranges from 0.90 to 0.93, and Si ranges from 7.57 to 7.98.

## Discussions and conclusion

A boulder size loosed block of jadeitite (Osa-1) from the Osayama area in the Sangun metamorphic belt has been petrographically described and the chemical compositions of the constituent minerals have been analysed by an EPMA.

The sample of Osa-1 consists mainly of jadeite with subordinate omphacite, diopside, pectolite, wollastonite and grossular, and it also contains such accessory minerals as prehnite, calcite, vesuvianite, chrolite, serpentine, phlogopite, chromite, sodic amphibole and sodic-calcic amphibole. Relatively Ca-rich minerals i.e. calcite, wollastonite, pectolite, grossular, diopside and prehnite, occur as veins and along cracks within the matrix consisting mostly of jadeites. These occurrences of Ca-rich minerals suggest that the jadeitite experienced the event of infiltration of Ca-rich fluid as already suggested by Takasu et al. (2000).

Clinopyroxenes from the jadeitite are classified into jadeite, omphacite and diopside, and they contain low aegirine molecules (<9.0 mol.%). There are compositional gaps at $Jd_{9-31}$, $Jd_{54-75}$ and $Jd_{84-89}$. The positions of the compositional gaps along the jadeite-diopside join are similar to those already revealed by Takasu et al. (2000).

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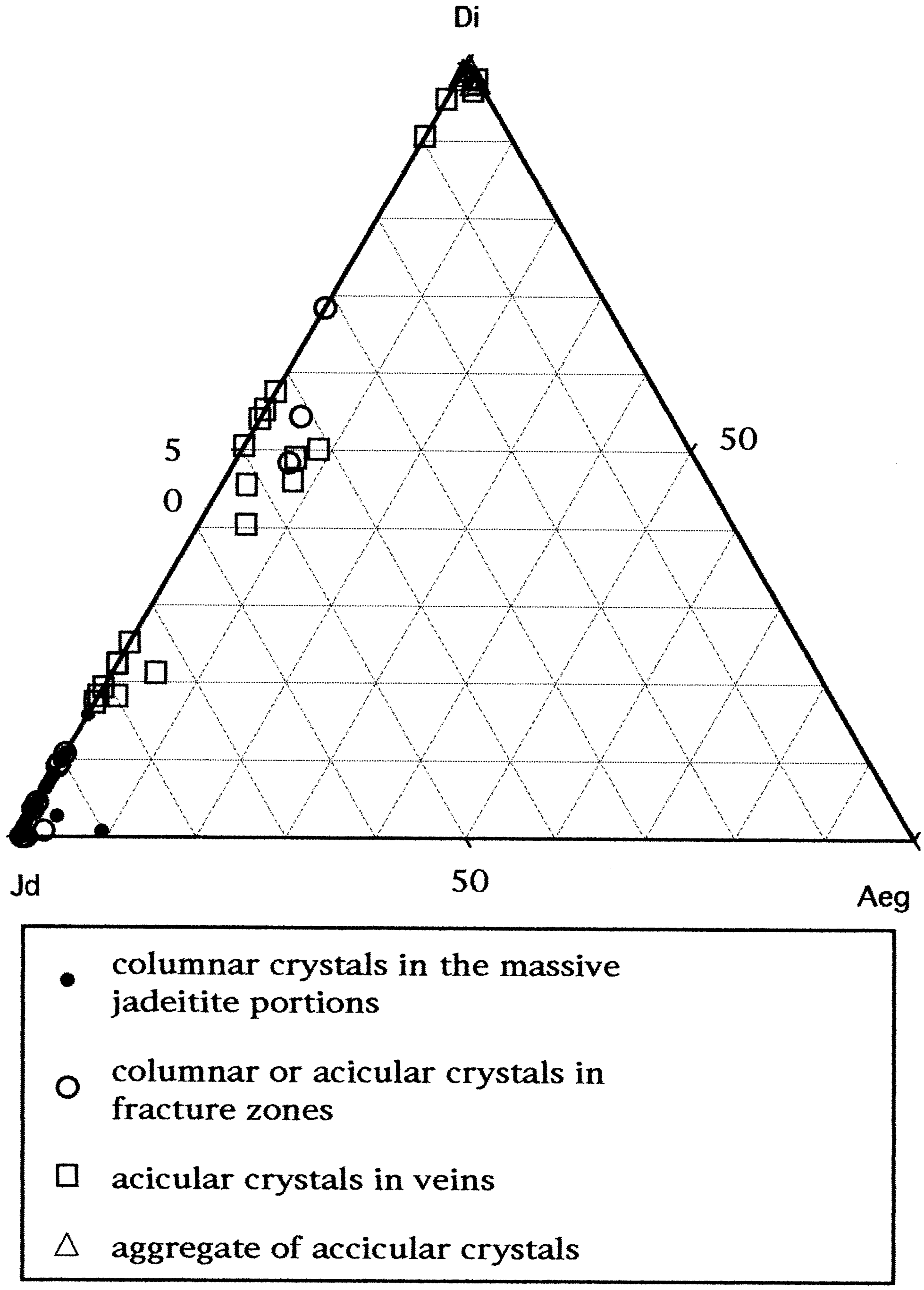


**Fig. 2.** Chemical composition of clinopyroxenes from the jadeitite (Osa-1).
Jd: jadeite, Aeg: aegirine, Di: diopside

University and Mr. Y. Miyagi of Tohoku University for their discussions on chemical compositions of clinopyroxenes and amphiboles in the jadeitites.

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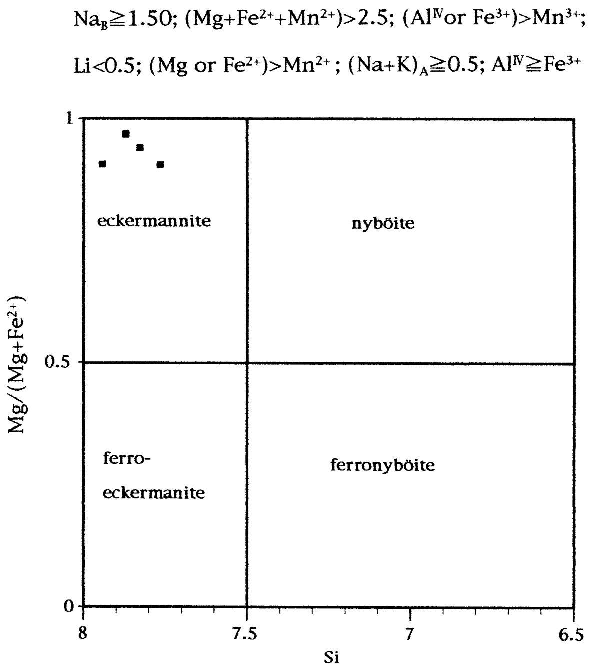


**Fig. 3.** Chemical composition of Na amphiboles from the jadeitite (Osa-1).

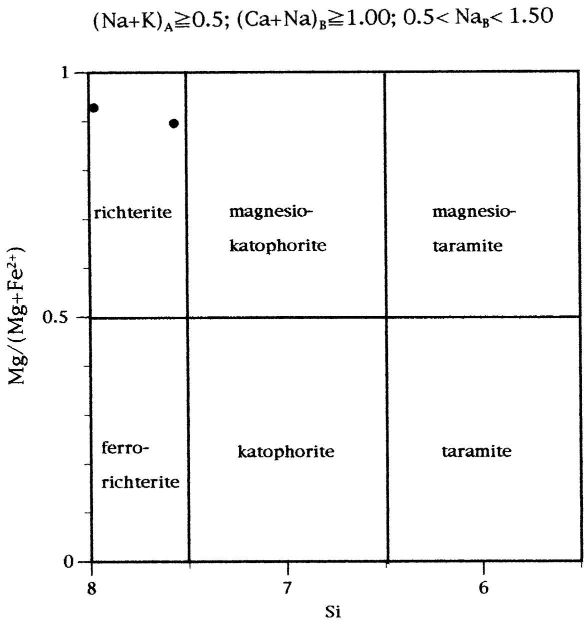


**Fig. 4.** Chemical composition of Na-Ca amphiboles from the jadeitite (Osa-1).

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（要　旨）

**柏原由芙子・高須　晃，2002，大佐山超苦鉄質岩体に産するひすい輝石岩中の構成鉱物の岩石学と化学組成，島根大学地球資源環境学研究報告，20，133-142**

岡山県大佐山地域の蓮華帯超苦鉄質岩体中に包有されていたと考えられるひすい輝石岩の転石について，岩石記載と構成鉱物の化学組成の分析を行った．このひすい輝石岩は表面に蛇紋石 - 緑泥石岩が薄く付着している．ひすい輝石岩の構成鉱物は主にひすい輝石であり，その他にオンファス輝石，透輝石，珪灰石，ペクトライト，ぶどう石，灰ばんざくろ石，方解石，ベスブ石，緑泥石，その他，少量の Na 角閃石，Na-Ca 角閃石，金雲母を伴う．単斜輝石の化学組成はひすい輝石岩中の産状によって異なり，塊状ひすい輝石岩部分の柱状結晶はひすい輝石，細い破砕帯中の柱状または針状結晶はオンファス輝石とひすい輝石，細い脈または針状結晶の集合体として産する単斜輝石は透輝石である．Ca に富む鉱物がひすい輝石からなる塊状基質部の割れ目または脈中に産することより，ひすい輝石岩の形成後に Ca に富む流体の浸透の影響を受けた可能性を示唆する．

Table1 Chemical compositions of clinopyroxenes.

| Sample | Osa1 | Osa1 | Osa1 | Osa1 | Osa1 | Osa1 | Osa1 | Osa1 | Osa1 | Osa1 | Osa1 | Osa1 | Osa1 | Osa1 | Osa1 | Osa1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | 1m,k9 | 1m,k13 | 1m,k13 | 1m,k13 | 1m,k13 | 1m,k13 | 1m,k13 | 1m,k14 | 1r,k14 | 1r,k14 | 1r,k14 | 1r,k14 | 1r,k14 | 1r,k14 | 1r,k14 | 1r,k14 |
| wt% | 21 | 5 | 7 | 28 | 31 | 36 | 38 | 5 | 10 | 12 | 14 | 15 | 47 | 56 | 57 | 63 |
| $SiO_2$ | 58.82 | 53.57 | 52.81 | 54.05 | 53.46 | 53.69 | 52.50 | 53.77 | 58.14 | 58.53 | 57.15 | 57.73 | 58.75 | 55.61 | 58.43 | 58.38 |
| $TiO_2$ | 0.02 | 0.07 | 0.00 | 0.04 | 0.01 | 0.00 | 0.01 | 0.02 | 0.00 | 0.00 | 0.06 | 0.00 | 0.00 | 0.40 | 0.00 | 0.01 |
| $Al_2O_3$ | 25.13 | 0.85 | 1.34 | 0.93 | 0.75 | 0.59 | 2.03 | 0.38 | 25.20 | 23.91 | 18.18 | 22.06 | 25.30 | 9.89 | 24.68 | 25.50 |
| FeO | 0.16 | 4.14 | 3.85 | 4.64 | 4.63 | 4.16 | 3.93 | 0.98 | 0.06 | 0.96 | 0.97 | 3.13 | 0.01 | 2.13 | 0.04 | 0.08 |
| MnO | 0.02 | 0.11 | 0.13 | 0.10 | 0.07 | 0.09 | 0.09 | 0.26 | 0.01 | 0.02 | 0.02 | 0.02 | 0.06 | 0.01 | 0.03 | 0.05 |
| MgO | 0.01 | 16.45 | 15.81 | 15.82 | 15.97 | 16.68 | 15.99 | 17.45 | 0.02 | 0.51 | 4.30 | 0.44 | 0.00 | 9.72 | 0.03 | 0.01 |
| CaO | 0.67 | 25.16 | 26.18 | 24.90 | 25.39 | 25.50 | 25.95 | 25.85 | 0.32 | 0.97 | 6.58 | 0.75 | 0.24 | 14.00 | 0.31 | 0.22 |
| $Na_2O$ | 14.84 | 0.36 | 0.24 | 0.50 | 0.29 | 0.30 | 0.38 | 0.04 | 15.29 | 13.92 | 11.66 | 14.82 | 15.00 | 6.82 | 15.11 | 15.38 |
| $K_2O$ | 0.02 | 0.04 | 0.06 | 0.04 | 0.03 | 0.03 | 0.04 | 0.03 | 0.03 | 0.22 | 0.03 | 0.04 | 0.04 | 0.06 | 0.03 | 0.05 |
| $Cr_2O_3$ | 0.00 | 0.00 | 0.01 | 0.03 | 0.02 | 0.01 | 0.00 | 0.01 | 0.00 | 0.00 | 0.01 | 0.02 | 0.02 | 0.00 | 0.03 | 0.00 |
| total | 99.67 | 100.74 | 100.43 | 101.04 | 100.60 | 101.05 | 100.89 | 98.79 | 99.07 | 99.04 | 98.95 | 99.00 | 99.43 | 98.63 | 98.67 | 99.68 |
| Si | 1.990 | 1.958 | 1.941 | 1.971 | 1.962 | 1.959 | 1.921 | 1.978 | 1.981 | 2.000 | 1.992 | 2.002 | 1.990 | 1.995 | 1.996 | 1.977 |
| Ti | 0.000 | 0.002 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | 0.002 | 0.000 | 0.000 | 0.011 | 0.000 | 0.000 |
| Al | 1.002 | 0.037 | 0.058 | 0.040 | 0.032 | 0.025 | 0.087 | 0.017 | 1.012 | 0.963 | 0.747 | 0.902 | 1.010 | 0.418 | 0.994 | 1.018 |
| Fe | 0.004 | 0.126 | 0.118 | 0.141 | 0.142 | 0.127 | 0.120 | 0.030 | 0.002 | 0.027 | 0.028 | 0.091 | 0.000 | 0.064 | 0.001 | 0.002 |
| Mn | 0.001 | 0.003 | 0.004 | 0.003 | 0.002 | 0.003 | 0.003 | 0.008 | 0.000 | 0.001 | 0.001 | 0.001 | 0.002 | 0.000 | 0.001 | 0.001 |
| Mg | 0.001 | 0.896 | 0.866 | 0.860 | 0.873 | 0.907 | 0.872 | 0.957 | 0.001 | 0.026 | 0.224 | 0.023 | 0.000 | 0.520 | 0.002 | 0.001 |
| Ca | 0.024 | 0.985 | 1.031 | 0.973 | 0.998 | 0.997 | 1.017 | 1.019 | 0.012 | 0.035 | 0.246 | 0.028 | 0.009 | 0.538 | 0.011 | 0.008 |
| Na | 0.973 | 0.025 | 0.017 | 0.035 | 0.021 | 0.021 | 0.027 | 0.003 | 1.010 | 0.922 | 0.788 | 0.997 | 0.985 | 0.474 | 1.001 | 1.010 |
| K | 0.001 | 0.002 | 0.003 | 0.002 | 0.001 | 0.002 | 0.002 | 0.002 | 0.001 | 0.010 | 0.001 | 0.002 | 0.002 | 0.003 | 0.001 | 0.002 |
| Cr | 0.000 | 0.000 | 0.001 | 0.002 | 0.001 | 0.001 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.002 | 0.002 | 0.000 | 0.002 | 0.000 |
| total | 3.996 | 4.036 | 4.040 | 4.028 | 4.034 | 4.041 | 4.049 | 4.015 | 4.019 | 3.984 | 4.028 | 4.047 | 3.999 | 4.023 | 4.009 | 4.020 |
| O | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| Jd | 97.30 | 0.00 | 0.00 | 1.07 | 0.13 | 0.00 | 0.85 | 0.00 | 99.28 | 92.23 | 73.86 | 90.19 | 98.49 | 41.34 | 99.00 | 99.51 |
| Ae | 0.00 | 2.54 | 1.74 | 2.44 | 99.81 | 2.11 | 1.82 | 0.29 | 0.72 | 0.00 | 4.91 | 9.00 | 0.00 | 4.40 | 1.00 | 0.49 |
| Aug | 2.70 | 97.46 | 98.26 | 96.49 | 0.06 | 97.89 | 97.33 | 99.71 | 0.00 | 7.77 | 21.23 | 0.81 | 1.51 | 54.26 | 0.00 | 0.00 |

| Sample | Osa1 | Osa1 | Osa1 | Osa1 | Osa1 | Osa1 | Osa1 | Osa1 | Osa1 | Osa1 | Osa1 | Osa1 | Osa1 | Osa1 | Osa1 | Osa1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | 1r,k14 | 1r,k14 | 1m,k16 | 1m,k16 | 1m,k16 | 1m,k16 | 1m,k16 | 1m,k16 | 1m,k16 | 1a,001 | 1a,001 | 2p,k1 | 2p,k1 | 2p,k14 | 2p,k14 | 2p,k14 |
| wt% | 65 | 73 | 1 | 2 | 6 | 7 | 10 | 12 | 30 | 12 | 17 | 7 | 16 | 6 | 7 | 8 |
| $SiO_2$ | 58.47 | 58.13 | 58.21 | 55.70 | 58.10 | 55.72 | 55.30 | 55.43 | 57.51 | 57.96 | 55.48 | 59.59 | 60.15 | 57.19 | 57.15 | 57.23 |
| $TiO_2$ | 0.00 | 0.05 | 0.01 | 0.25 | 0.01 | 0.30 | 0.26 | 0.12 | 0.06 | 0.10 | 0.90 | 0.01 | 0.00 | 0.07 | 0.07 | 0.14 |
| $Al_2O_3$ | 25.09 | 24.28 | 25.52 | 11.02 | 25.43 | 12.08 | 11.30 | 10.68 | 25.07 | 23.30 | 11.34 | 25.42 | 25.39 | 19.69 | 18.77 | 19.71 |
| FeO | 0.20 | 0.58 | 0.12 | 2.64 | 0.06 | 2.44 | 2.83 | 3.06 | 0.35 | 1.23 | 2.08 | 0.06 | 0.02 | 1.27 | 1.32 | 1.38 |
| MnO | 0.00 | 0.07 | 0.03 | 0.24 | 0.01 | 0.14 | 0.14 | 0.18 | 0.06 | 0.00 | 0.00 | 0.03 | 0.03 | 0.00 | 0.04 | 0.00 |
| MgO | 0.05 | 0.29 | 0.02 | 8.48 | 0.00 | 7.74 | 8.20 | 8.34 | 0.00 | 0.73 | 8.75 | 0.00 | 0.00 | 3.53 | 3.99 | 3.14 |
| CaO | 0.23 | 0.67 | 0.21 | 13.50 | 0.39 | 12.30 | 13.00 | 13.76 | 0.42 | 1.42 | 12.57 | 0.26 | 0.19 | 5.73 | 6.28 | 5.03 |
| $Na_2O$ | 14.59 | 14.96 | 15.68 | 7.75 | 15.57 | 8.32 | 7.76 | 7.32 | 15.64 | 13.88 | 7.85 | 14.89 | 15.34 | 12.32 | 11.95 | 12.14 |
| $K_2O$ | 0.06 | 0.05 | 0.04 | 0.05 | 0.04 | 0.05 | 0.03 | 0.05 | 0.03 | 0.04 | 0.01 | 0.02 | 0.02 | 0.05 | 0.06 | 0.04 |
| $Cr_2O_3$ | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | 0.00 | 0.00 | 0.00 | 0.01 | 0.03 | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.00 |
| total | 98.68 | 99.08 | 99.84 | 99.62 | 99.63 | 99.08 | 98.82 | 98.94 | 99.16 | 98.69 | 98.98 | 100.29 | 101.15 | 99.85 | 99.64 | 98.83 |
| Si | 1.994 | 1.988 | 1.971 | 1.986 | 1.972 | 1.988 | 1.985 | 1.992 | 1.967 | 1.994 | 1.979 | 1.998 | 2.001 | 1.975 | 1.982 | 1.990 |
| Ti | 0.000 | 0.001 | 0.000 | 0.007 | 0.000 | 0.008 | 0.007 | 0.003 | 0.001 | 0.003 | 0.024 | 0.000 | 0.000 | 0.002 | 0.002 | 0.004 |
| Al | 1.008 | 0.978 | 1.019 | 0.463 | 1.017 | 0.508 | 0.478 | 0.452 | 1.011 | 0.945 | 0.477 | 1.005 | 0.996 | 0.802 | 0.767 | 0.808 |
| Fe | 0.006 | 0.017 | 0.003 | 0.079 | 0.002 | 0.073 | 0.085 | 0.092 | 0.010 | 0.035 | 0.062 | 0.002 | 0.001 | 0.037 | 0.038 | 0.040 |
| Mn | 0.000 | 0.002 | 0.001 | 0.007 | 0.000 | 0.004 | 0.004 | 0.006 | 0.002 | 0.000 | 0.000 | 0.001 | 0.001 | 0.000 | 0.001 | 0.000 |
| Mg | 0.002 | 0.015 | 0.001 | 0.451 | 0.000 | 0.412 | 0.439 | 0.447 | 0.000 | 0.037 | 0.465 | 0.000 | 0.000 | 0.182 | 0.206 | 0.163 |
| Ca | 0.008 | 0.024 | 0.007 | 0.516 | 0.014 | 0.470 | 0.500 | 0.530 | 0.016 | 0.052 | 0.480 | 0.009 | 0.007 | 0.212 | 0.233 | 0.188 |
| Na | 0.964 | 0.992 | 1.030 | 0.536 | 1.025 | 0.575 | 0.540 | 0.510 | 1.037 | 0.926 | 0.543 | 0.968 | 0.990 | 0.825 | 0.803 | 0.818 |
| K | 0.003 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.001 | 0.002 | 0.001 | 0.002 | 0.000 | 0.001 | 0.001 | 0.002 | 0.002 | 0.002 |
| Cr | 0.000 | 0.000 | 0.000 | 0.000 | 0.002 | 0.000 | 0.000 | 0.000 | 0.001 | 0.002 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 |
| total | 3.985 | 4.019 | 4.035 | 4.045 | 4.034 | 4.039 | 4.040 | 4.034 | 4.046 | 3.996 | 4.031 | 3.984 | 3.996 | 4.036 | 4.036 | 4.013 |
| O | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| Jd | 96.44 | 96.59 | 99.02 | 44.84 | 92.60 | 92.60 | 92.60 | 92.60 | 92.60 | 92.60 | 45.55 | 96.83 | 98.98 | 77.66 | 74.86 | 79.78 |
| Ae | 0.00 | 2.59 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.07 | 0.00 | 0.00 | 0.00 | 0.00 | 2.06 |
| Aug | 3.56 | 0.82 | 0.98 | 55.16 | 7.40 | 7.40 | 7.40 | 7.40 | 7.40 | 7.40 | 48.38 | 3.17 | 1.02 | 22.34 | 25.14 | 18.16 |

* Total Fe as FeO

Table1 (Continued)

| Sample | Osa1 | Osa1 | Osa1 | Osa1 | Osa1 | Osa1 | Osa1 | Osa1 | Osa1 | Osa1 | Osa1 | Osa1 | Osa1 | OSa1 | OSa1 | Osa1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | 2p,k14 | 2p,k14 | 2p,k14 | 2p,k14 | 2p,k14 | 2n,k2 | 2p,k14 | 2p,k14 | 2p,k14 | 1b,003 | 1b,003 | 1b,003 | 1b,003 | 1b,017 | 1b,017 | 3r,k15 |
| wt% | 9 | 10 | 11 | 12 | 13 | 3 | 1 | 12 | 22 | 11 | 12 | 13 | 31 | 46 | 48 | 2 |
| $SiO_2$ | 59.05 | 58.32 | 57.10 | 57.36 | 56.05 | 57.59 | 58.04 | 58.73 | 57.38 | 54.07 | 53.86 | 53.26 | 58.82 | 53.80 | 53.18 | 60.26 |
| $TiO_2$ | 0.00 | 0.05 | 0.08 | 0.04 | 0.21 | 0.01 | 0.01 | 0.00 | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.14 | 0.02 | 0.00 |
| $Al_2O_3$ | 25.40 | 24.14 | 20.64 | 19.43 | 13.40 | 25.99 | 25.43 | 24.76 | 20.82 | 0.12 | 0.05 | 0.27 | 25.82 | 1.46 | 1.21 | 25.72 |
| FeO | 0.04 | 0.16 | 1.12 | 1.47 | 3.65 | 0.00 | 0.02 | 0.20 | 0.66 | 0.85 | 0.53 | 1.48 | 0.03 | 4.73 | 4.22 | 0.01 |
| MnO | 0.00 | 0.02 | 0.01 | 0.00 | 0.12 | 0.02 | 0.00 | 0.01 | 0.01 | 0.44 | 1.02 | 0.36 | 0.00 | 0.14 | 0.09 | 0.00 |
| MgO | 0.00 | 0.68 | 2.70 | 3.34 | 6.32 | 0.01 | 0.00 | 0.11 | 3.20 | 18.39 | 18.16 | 17.52 | 0.00 | 14.68 | 14.53 | 0.00 |
| CaO | 0.03 | 1.06 | 4.38 | 5.64 | 11.49 | 0.47 | 0.15 | 0.67 | 4.88 | 26.22 | 26.33 | 26.13 | 0.29 | 25.33 | 26.53 | 0.15 |
| $Na_2O$ | 15.28 | 14.70 | 12.72 | 12.42 | 8.69 | 14.94 | 15.87 | 14.67 | 12.60 | 0.02 | 0.02 | 0.05 | 16.13 | 0.73 | 0.35 | 15.07 |
| $K_2O$ | 0.05 | 0.05 | 0.06 | 0.10 | 0.08 | 0.06 | 0.04 | 0.05 | 0.03 | 0.03 | 0.05 | 0.04 | 0.02 | 0.04 | 0.04 | 0.03 |
| $Cr_2O_3$ | 0.00 | 0.00 | 0.01 | 0.00 | 0.03 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.02 | 0.01 | 0.00 |
| total | 99.84 | 99.19 | 98.82 | 99.81 | 100.04 | 99.08 | 99.56 | 99.20 | 99.63 | 100.16 | 100.01 | 99.11 | 101.12 | 101.08 | 100.19 | 101.22 |
| Si | 1.992 | 1.988 | 1.982 | 1.984 | 1.984 | 1.961 | 1.972 | 1.996 | 1.974 | 1.966 | 1.965 | 1.964 | 1.968 | 1.965 | 1.962 | 2.000 |
| Ti | 0.000 | 0.001 | 0.002 | 0.001 | 0.006 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.004 | 0.001 | 0.000 |
| Al | 1.009 | 0.970 | 0.844 | 0.792 | 0.559 | 1.043 | 1.018 | 0.992 | 0.844 | 0.005 | 0.002 | 0.012 | 1.019 | 0.063 | 0.052 | 1.006 |
| Fe | 0.001 | 0.005 | 0.032 | 0.043 | 0.108 | 0.000 | 0.000 | 0.006 | 0.019 | 0.026 | 0.016 | 0.046 | 0.001 | 0.145 | 0.130 | 0.000 |
| Mn | 0.000 | 0.001 | 0.000 | 0.000 | 0.004 | 0.000 | 0.000 | 0.000 | 0.000 | 0.014 | 0.031 | 0.011 | 0.000 | 0.004 | 0.003 | 0.000 |
| Mg | 0.000 | 0.034 | 0.140 | 0.172 | 0.334 | 0.000 | 0.000 | 0.006 | 0.164 | 0.997 | 0.988 | 0.963 | 0.000 | 0.800 | 0.799 | 0.000 |
| Ca | 0.001 | 0.039 | 0.163 | 0.209 | 0.436 | 0.017 | 0.005 | 0.024 | 0.180 | 1.022 | 1.029 | 1.032 | 0.010 | 0.991 | 1.049 | 0.005 |
| Na | 0.999 | 0.972 | 0.856 | 0.833 | 0.596 | 0.986 | 1.045 | 0.967 | 0.840 | 0.001 | 0.001 | 0.003 | 1.047 | 0.051 | 0.025 | 0.970 |
| K | 0.002 | 0.002 | 0.003 | 0.004 | 0.003 | 0.002 | 0.002 | 0.002 | 0.001 | 0.002 | 0.002 | 0.002 | 0.001 | 0.002 | 0.002 | 0.001 |
| Cr | 0.000 | 0.000 | 0.000 | 0.000 | 0.003 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.001 | 0.000 | 0.000 |
| total | 4.004 | 4.012 | 4.023 | 4.038 | 4.032 | 4.011 | 4.043 | 3.992 | 4.024 | 4.033 | 4.036 | 4.033 | 4.046 | 4.026 | 4.024 | 3.982 |
| O | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| Jd | 99.91 | 95.84 | 82.63 | 77.56 | 54.30 | 98.64 | 98.95 | 96.65 | 81.77 | 0.00 | 0.00 | 0.00 | 98.70 | 2.64 | 1.32 | 1.32 |
| Ae | 0.00 | 0.00 | 0.00 | 0.00 | 5.35 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 4.70 | 4.23 | 4.23 |
| Aug | 0.09 | 4.16 | 17.37 | 22.44 | 40.35 | 1.36 | 1.05 | 3.35 | 18.23 | 100.00 | 100.00 | 100.00 | 1.30 | 92.67 | 94.45 | 94.45 |

| Sample | Osa1 | Osa1 | Osa1 | Osa1 | Osa1 | Osa1 | Osa1 | Osa1 | Osa1 | Osa1 |
|---|---|---|---|---|---|---|---|---|---|---|
| No. | 3r,k15 | 3r,k15 | 3r,k15 | 3r,k15 | 3r,k15 | 3,003 | 4b,k13 | 4b,k1 | 4b,k15 | 4b,k15 |
| wt% | 7 | 10 | 38 | 39 | 40 | 6 | 7 | 7 | 2 | 3 |
| $SiO_2$ | 59.25 | 58.31 | 58.89 | 59.51 | 58.93 | 59.27 | 58.71 | 59.56 | 59.72 | 58.55 |
| $TiO_2$ | 0.00 | 0.00 | 0.01 | 0.00 | 0.02 | 0.00 | 0.01 | 0.01 | 0.00 | 0.00 |
| $Al_2O_3$ | 25.29 | 25.19 | 25.51 | 25.70 | 25.75 | 25.57 | 25.90 | 25.12 | 25.75 | 25.32 |
| FeO | 0.08 | 0.10 | 0.04 | 0.06 | 0.03 | 0.08 | 0.00 | 0.06 | 0.00 | 0.11 |
| MnO | 0.00 | 0.02 | 0.00 | 0.02 | 0.00 | 0.00 | 0.00 | 0.01 | 0.04 | 0.00 |
| MgO | 0.01 | 0.00 | 0.01 | 0.03 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.01 |
| CaO | 0.54 | 0.13 | 0.07 | 0.23 | 0.06 | 0.34 | 0.24 | 0.21 | 0.08 | 0.08 |
| $Na_2O$ | 14.32 | 14.78 | 15.25 | 15.35 | 15.01 | 15.67 | 16.07 | 14.57 | 15.36 | 15.30 |
| $K_2O$ | 0.06 | 0.05 | 0.03 | 0.06 | 0.02 | 0.05 | 0.05 | 0.03 | 0.03 | 0.01 |
| $Cr_2O_3$ | 0.01 | 0.03 | 0.03 | 0.01 | 0.04 | 0.00 | 0.01 | 0.00 | 0.01 | 0.02 |
| total | 99.54 | 98.61 | 99.83 | 100.96 | 99.85 | 100.99 | 100.99 | 99.58 | 100.99 | 99.40 |
| Si | 2.000 | 1.990 | 1.987 | 1.987 | 1.985 | 1.982 | 1.967 | 2.008 | 1.991 | 1.986 |
| Ti | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Al | 1.006 | 1.013 | 1.014 | 1.011 | 1.022 | 1.008 | 1.022 | 0.998 | 1.012 | 1.012 |
| Fe | 0.002 | 0.003 | 0.001 | 0.002 | 0.001 | 0.002 | 0.000 | 0.002 | 0.000 | 0.003 |
| Mn | 0.000 | 0.001 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 |
| Mg | 0.000 | 0.000 | 0.000 | 0.002 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Ca | 0.019 | 0.005 | 0.003 | 0.008 | 0.002 | 0.012 | 0.009 | 0.007 | 0.003 | 0.003 |
| Na | 0.937 | 0.978 | 0.997 | 0.993 | 0.980 | 1.016 | 1.044 | 0.952 | 0.993 | 1.006 |
| K | 0.003 | 0.002 | 0.001 | 0.002 | 0.001 | 0.002 | 0.002 | 0.001 | 0.001 | 0.000 |
| Cr | 0.001 | 0.002 | 0.002 | 0.000 | 0.003 | 0.000 | 0.001 | 0.000 | 0.000 | 0.002 |
| total | 3.968 | 3.994 | 4.006 | 4.006 | 3.995 | 4.023 | 4.045 | 3.970 | 4.001 | 4.012 |
| O | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| Jd | 93.71 | 97.78 | 99.73 | 99.33 | 98.01 | 98.98 | 95.23 | 99.23 | 99.27 | 99.79 |
| Ae | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Aug | 6.29 | 2.22 | 0.27 | 0.67 | 1.99 | 1.02 | 4.77 | 0.77 | 0.73 | 0.21 |

* Total Fe as FeO

Table 2 Chemical compositons of pectolites.

| sample | Osa1 | | | | Osa1 | Osa1 | | | Osa1 | Osa1 | | | Osa1 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | 1b | | | | 1b | 2b | | | 2c | 2d | | | 2d | | | |
| | 1 | 2 | 8 | 9 | 10 | 1 | 3 | 11 | 4 | 11 | 12 | 16 | 17 | 18 | 25 | 26 |
| $SiO_2$ | 53.02 | 52.55 | 52.71 | 52.39 | 52.77 | 52.96 | 53.07 | 52.97 | 53.10 | 51.92 | 52.52 | 52.22 | 52.33 | 51.94 | 51.84 | 52.15 |
| $Al_2O_3$ | 0.03 | 0.00 | 0.04 | 0.01 | 0.48 | 0.02 | 0.00 | 0.00 | 0.03 | 0.02 | 0.01 | 0.04 | 0.00 | 0.01 | 0.02 | 0.01 |
| FeO | 0.09 | 0.00 | 0.01 | 0.06 | 0.02 | 0.00 | 0.11 | 0.06 | 0.06 | 0.00 | 0.08 | 0.05 | 0.10 | 0.00 | 0.01 | 0.00 |
| MnO | 0.20 | 0.13 | 0.10 | 0.05 | 0.03 | 0.08 | 0.06 | 0.09 | 0.01 | 0.04 | 0.02 | 0.05 | 0.00 | 0.07 | 0.06 | 0.08 |
| MgO | 0.02 | 0.02 | 0.01 | 0.00 | 0.01 | 0.01 | 0.05 | 0.02 | 0.00 | 0.00 | 0.00 | 0.04 | 0.02 | 0.02 | 0.02 | 0.02 |
| CaO | 33.62 | 33.75 | 33.85 | 33.48 | 32.93 | 33.51 | 33.28 | 33.75 | 33.64 | 32.97 | 32.88 | 33.01 | 32.66 | 33.24 | 33.11 | 33.03 |
| $Na_2O$ | 9.16 | 9.01 | 8.90 | 9.09 | 9.13 | 9.70 | 9.41 | 9.53 | 9.21 | 9.11 | 9.17 | 8.97 | 9.03 | 9.14 | 9.05 | 9.11 |
| $K_2O$ | 0.03 | 0.04 | 0.04 | 0.04 | 0.04 | 0.05 | 0.07 | 0.04 | 0.04 | 0.04 | 0.02 | 0.06 | 0.05 | 0.02 | 0.05 | 0.02 |
| total | 96.16 | 95.51 | 95.64 | 95.11 | 95.42 | 96.33 | 96.04 | 96.45 | 96.10 | 94.09 | 94.70 | 94.44 | 94.18 | 94.43 | 94.15 | 94.42 |
| Si | 2.979 | 2.974 | 2.977 | 2.977 | 2.978 | 2.974 | 2.984 | 2.972 | 2.983 | 2.980 | 2.991 | 2.984 | 2.994 | 2.974 | 2.976 | 2.982 |
| Al | 0.002 | 0.000 | 0.003 | 0.000 | 0.032 | 0.001 | 0.000 | 0.000 | 0.002 | 0.001 | 0.001 | 0.003 | 0.000 | 0.001 | 0.001 | 0.001 |
| Fe | 0.004 | 0.000 | 0.000 | 0.003 | 0.001 | 0.000 | 0.005 | 0.003 | 0.003 | 0.000 | 0.004 | 0.002 | 0.005 | 0.000 | 0.001 | 0.000 |
| Mn | 0.009 | 0.006 | 0.005 | 0.002 | 0.002 | 0.004 | 0.003 | 0.004 | 0.001 | 0.002 | 0.001 | 0.002 | 0.000 | 0.003 | 0.003 | 0.004 |
| Mg | 0.002 | 0.002 | 0.000 | 0.000 | 0.001 | 0.001 | 0.004 | 0.001 | 0.000 | 0.000 | 0.000 | 0.003 | 0.001 | 0.002 | 0.001 | 0.001 |
| Ca | 2.024 | 2.047 | 2.048 | 2.038 | 1.991 | 2.016 | 2.005 | 2.029 | 2.025 | 2.028 | 2.006 | 2.021 | 2.002 | 2.039 | 2.036 | 2.023 |
| Na | 0.998 | 0.989 | 0.974 | 1.001 | 0.999 | 1.056 | 1.026 | 1.036 | 1.003 | 1.014 | 1.012 | 0.994 | 1.002 | 1.015 | 1.007 | 1.010 |
| K | 0.002 | 0.003 | 0.003 | 0.003 | 0.003 | 0.004 | 0.005 | 0.003 | 0.003 | 0.003 | 0.002 | 0.005 | 0.004 | 0.001 | 0.003 | 0.002 |
| total | 6.020 | 6.022 | 6.010 | 6.025 | 6.007 | 6.056 | 6.032 | 6.048 | 6.019 | 6.028 | 6.016 | 6.014 | 6.008 | 6.034 | 6.028 | 6.024 |
| O | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 |

| sample | Osa1 | | | | Osa1 | Osa1 | Osa1 | | | Osa1 |
|---|---|---|---|---|---|---|---|---|---|---|
| No. | 2d | | | | 2e | 4b | 1',a001 | | | 1'b017 |
| | 27 | 28 | 29 | 32 | 11 | 4 | 64 | 65 | 66 | 17 |
| $SiO_2$ | 51.76 | 51.81 | 51.91 | 52.02 | 52.77 | 53.60 | 52.08 | 52.40 | 52.14 | 53.73 |
| $Al_2O_3$ | 0.02 | 0.00 | 0.02 | 0.01 | 0.00 | 0.00 | 0.02 | 0.03 | 0.05 | 0.31 |
| FeO | 0.06 | 0.08 | 0.06 | 0.04 | 0.00 | 0.00 | 0.17 | 0.23 | 0.22 | 0.09 |
| MnO | 0.00 | 0.03 | 0.03 | 0.01 | 0.00 | 0.00 | 0.59 | 0.51 | 0.30 | 0.00 |
| MgO | 0.03 | 0.02 | 0.03 | 0.03 | 0.01 | 0.00 | 0.03 | 0.02 | 0.04 | 0.00 |
| CaO | 32.92 | 33.24 | 33.02 | 33.11 | 33.23 | 34.24 | 33.44 | 33.45 | 33.46 | 34.20 |
| $Na_2O$ | 9.32 | 9.02 | 9.03 | 9.05 | 9.12 | 8.90 | 9.24 | 8.99 | 9.12 | 8.79 |
| $K_2O$ | 0.03 | 0.02 | 0.05 | 0.04 | 0.05 | 0.02 | 0.03 | 0.05 | 0.03 | 0.03 |
| total | 94.14 | 94.22 | 94.15 | 94.30 | 95.17 | 96.75 | 95.597 | 95.679 | 95.347 | 97.16 |
| Si | 2.973 | 2.973 | 2.978 | 2.980 | 2.990 | 2.987 | 2.957 | 2.967 | 2.963 | 2.980 |
| Al | 0.001 | 0.000 | 0.002 | 0.000 | 0.000 | 0.000 | 0.001 | 0.002 | 0.003 | 0.020 |
| Fe | 0.003 | 0.004 | 0.003 | 0.002 | 0.000 | 0.000 | 0.008 | 0.011 | 0.010 | 0.004 |
| Mn | 0.000 | 0.001 | 0.001 | 0.000 | 0.000 | 0.000 | 0.028 | 0.024 | 0.014 | 0.000 |
| Mg | 0.002 | 0.002 | 0.002 | 0.002 | 0.001 | 0.000 | 0.002 | 0.002 | 0.003 | 0.000 |
| Ca | 2.026 | 2.044 | 2.030 | 2.032 | 2.017 | 2.044 | 2.035 | 2.029 | 2.037 | 2.032 |
| Na | 1.038 | 1.004 | 1.004 | 1.005 | 1.001 | 0.961 | 1.018 | 0.987 | 1.005 | 0.945 |
| K | 0.002 | 0.002 | 0.004 | 0.003 | 0.003 | 0.001 | 0.002 | 0.004 | 0.002 | 0.002 |
| total | 6.046 | 6.030 | 6.025 | 6.024 | 6.013 | 5.994 | 6.052 | 6.027 | 6.039 | 5.984 |
| O | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 |

* Total Fe as FeO

Table 3 Chemical compositions of wollastonites.

| sample | Osa1 | Osa1 | | | | Osa1 | | Osa1 |
|---|---|---|---|---|---|---|---|---|
| No. | 1a | 2a | | | | a001 | | b017 |
| | 12 | 6 | 21 | 24 | 26 | 6 | 36 | 4 |
| $SiO_2$ | 51.33 | 52.55 | 51.55 | 51.87 | 51.57 | 50.28 | 49.98 | 49.90 |
| $Al_2O_3$ | 0.05 | 0.00 | 0.02 | 0.03 | 0.02 | 0.01 | 0.03 | 0.99 |
| FeO | 0.22 | 0.13 | 0.06 | 0.09 | 0.20 | 0.05 | 0.00 | 0.22 |
| MnO | 0.11 | 0.00 | 0.04 | 0.03 | 0.06 | 0.06 | 0.13 | 0.07 |
| MgO | 0.01 | 0.04 | 0.03 | 0.02 | 0.05 | 0.06 | 0.08 | 0.12 |
| CaO | 46.90 | 48.15 | 48.41 | 48.36 | 48.45 | 48.40 | 48.30 | 48.64 |
| total | 98.62 | 100.87 | 100.12 | 100.40 | 100.35 | 98.84 | 98.52 | 99.94 |
| Si | 1.005 | 1.005 | 0.997 | 0.999 | 0.996 | 0.989 | 0.986 | 0.972 |
| Al | 0.001 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | 0.001 | 0.023 |
| Fe | 0.004 | 0.002 | 0.001 | 0.001 | 0.003 | 0.001 | 0.000 | 0.004 |
| Mn | 0.002 | 0.000 | 0.001 | 0.000 | 0.001 | 0.001 | 0.002 | 0.001 |
| Mg | 0.000 | 0.001 | 0.001 | 0.001 | 0.001 | 0.002 | 0.002 | 0.003 |
| Ca | 0.983 | 0.987 | 1.003 | 0.998 | 1.002 | 1.019 | 1.021 | 1.015 |
| total | 1.995 | 1.995 | 2.003 | 2.000 | 2.004 | 2.011 | 2.013 | 2.017 |
| O | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |

* Total Fe as FeO

Table 4 Chemical compositions of grossulars.

| sample | Osa1 | Osa1 | Osa1 | Osa1 |
|---|---|---|---|---|
| | 1c | 2c | 4a | 4b |
| wt% | 40 | 3 | 13 | 2 |
| $SiO_2$ | 38.50 | 38.97 | 39.88 | 39.48 |
| $TiO_2$ | 0.28 | 0.00 | 0.00 | 0.01 |
| $Al_2O_3$ | 22.78 | 21.25 | 22.73 | 23.85 |
| FeO | 1.24 | 2.31 | 0.04 | 0.04 |
| MnO | 0.07 | 0.11 | 0.01 | 0.00 |
| MgO | 0.00 | 0.28 | 0.00 | 0.00 |
| CaO | 37.26 | 35.24 | 37.59 | 37.95 |
| $Cr_2O_3$ | 0.01 | 0.01 | 0.00 | 0.00 |
| total | 100.14 | 98.16 | 100.26 | 101.32 |
| Si | 2.911 | 3.003 | 2.986 | 2.928 |
| Ti | 0.016 | 0.000 | 0.000 | 0.000 |
| Al | 2.030 | 1.930 | 2.006 | 2.084 |
| Fe | 0.078 | 0.149 | 0.003 | 0.003 |
| Mn | 0.004 | 0.007 | 0.001 | 0.000 |
| Mg | 0.000 | 0.032 | 0.000 | 0.000 |
| Ca | 3.019 | 2.910 | 3.016 | 3.015 |
| Cr | 0.002 | 0.001 | 0.000 | 0.000 |
| total | 8.061 | 8.033 | 8.011 | 8.030 |
| O | 12 | 12 | 12 | 12 |

* Total Fe as FeO

Table 5 Chemical compositions of prehnites.

| sample | Osa1 | | |
|---|---|---|---|
| No. | 1c | | |
| | 1 | 2 | 25 |
| $SiO_2$ | 42.75 | 42.81 | 43.00 |
| $TiO_2$ | 0.01 | 0.01 | 0.00 |
| $Al_2O_3$ | 24.84 | 24.03 | 25.15 |
| FeO | 0.08 | 0.20 | 0.04 |
| MnO | 0.00 | 0.03 | 0.00 |
| MgO | 0.00 | 0.42 | 0.00 |
| CaO | 26.92 | 26.99 | 26.96 |
| $Na_2O$ | 0.14 | 0.06 | 0.04 |
| $K_2O$ | 0.04 | 0.05 | 0.03 |
| total | 94.77 | 94.59 | 95.22 |
| Si | 2.967 | 2.981 | 2.967 |
| Ti | 0.000 | 0.000 | 0.000 |
| Al | 2.032 | 1.973 | 2.045 |
| Fe | 0.005 | 0.012 | 0.002 |
| Mn | 0.000 | 0.001 | 0.000 |
| Mg | 0.000 | 0.044 | 0.000 |
| Ca | 2.002 | 2.014 | 1.993 |
| Na | 0.019 | 0.009 | 0.005 |
| K | 0.004 | 0.005 | 0.002 |
| total | 7.028 | 7.039 | 7.014 |
| O | 11 | 11 | 11 |

* Total Fe as FeO

Table 6 Chemical compositions of chlorites.

| sample | Osa1 |
|---|---|
| No. | 1d |
| | 2 |
| $SiO_2$ | 33.58 |
| $TiO_2$ | 0.00 |
| $Al_2O_3$ | 15.22 |
| FeO | 1.82 |
| MnO | 0.24 |
| MgO | 35.19 |
| CaO | 0.09 |
| $Cr_2O_3$ | 0.03 |
| total | 86.16 |
| Si | 6.337 |
| Ti | 0.000 |
| Al | 3.384 |
| Fe | 0.287 |
| Mn | 0.038 |
| Mg | 9.900 |
| Ca | 0.018 |
| Cr | 0.014 |
| total | 19.978 |
| O | 28 |

* Total Fe as FeO

Table 7 Chemical compositions of vesuvianites.

| sample | Osa1 | | Osa1 | |
|---|---|---|---|---|
| No. | 1c | | 1f | |
| | 45 | 12 | 2 | 5 |
| $SiO_2$ | 35.37 | 35.59 | 36.18 | 35.54 |
| $TiO_2$ | 0.01 | 1.10 | 0.07 | 0.01 |
| $Al_2O_3$ | 17.52 | 16.70 | 16.63 | 14.74 |
| FeO | 3.65 | 2.34 | 4.10 | 5.78 |
| MnO | 0.16 | 0.02 | 0.00 | 0.03 |
| MgO | 2.83 | 3.12 | 2.67 | 3.01 |
| CaO | 35.96 | 35.89 | 35.67 | 34.98 |
| total | 95.51 | 94.75 | 95.32 | 94.07 |
| Si | 17.486 | 17.621 | 17.908 | 18.023 |
| Ti | 0.004 | 0.408 | 0.024 | 0.003 |
| Al | 10.208 | 9.748 | 9.698 | 8.806 |
| Fe | 1.509 | 0.968 | 1.698 | 2.449 |
| Mn | 0.069 | 0.009 | 0.002 | 0.011 |
| Mg | 2.084 | 2.302 | 1.970 | 2.273 |
| Ca | 19.047 | 19.040 | 18.919 | 19.005 |
| total | 50.406 | 50.096 | 50.218 | 50.571 |
| O | 73 | 73 | 73 | 73 |

* Total Fe as FeO

Table 8 Chemical compositions of amphiboles.

| sample | Osa1 | | Osa1 | | | |
|---|---|---|---|---|---|---|
| No. | 1f | | 1f | | | |
| | 60 | 61 | 64 | 70 | 75 | 77 |
| $SiO_2$ | 56.68 | 56.95 | 53.78 | 55.40 | 57.06 | 56.55 |
| $TiO_2$ | 0.14 | 0.14 | 0.17 | 0.01 | 0.02 | 0.03 |
| $Al_2O_3$ | 6.23 | 4.79 | 6.60 | 5.12 | 4.71 | 3.32 |
| FeO | 3.70 | 3.16 | 4.98 | 5.56 | 4.19 | 4.31 |
| MnO | 0.03 | 0.06 | 0.12 | 0.18 | 0.01 | 0.08 |
| MgO | 18.04 | 19.25 | 17.76 | 17.77 | 18.27 | 18.80 |
| CaO | 1.65 | 2.68 | 3.94 | 2.28 | 2.70 | 3.41 |
| $Na_2O$ | 9.71 | 8.84 | 8.66 | 9.76 | 8.83 | 8.09 |
| $K_2O$ | 0.14 | 0.22 | 0.14 | 0.08 | 0.24 | 0.29 |
| total | 96.30 | 96.09 | 96.14 | 96.15 | 96.05 | 94.87 |
| Si | 7.861 | 7.912 | 7.593 | 7.812 | 7.961 | 8.010 |
| Ti | 0.015 | 0.015 | 0.018 | 0.001 | 0.003 | 0.003 |
| Al | 1.017 | 0.784 | 1.098 | 0.851 | 0.775 | 0.554 |
| Fe | 0.429 | 0.367 | 0.587 | 0.656 | 0.489 | 0.510 |
| Mn | 0.004 | 0.008 | 0.014 | 0.021 | 0.002 | 0.010 |
| Mg | 3.729 | 3.987 | 3.737 | 3.735 | 3.801 | 3.971 |
| Ca | 0.244 | 0.399 | 0.596 | 0.344 | 0.404 | 0.517 |
| Na | 2.610 | 2.382 | 2.370 | 2.668 | 2.387 | 2.221 |
| K | 0.025 | 0.040 | 0.026 | 0.014 | 0.043 | 0.053 |
| total | 15.933 | 15.892 | 16.038 | 16.102 | 15.864 | 15.847 |
| O | 23 | 23 | 23 | 23 | 23 | 23 |

* Total Fe as FeO