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Article

Modes of occurrence and chemical compositions of garnets from the Seba pelitic schists in the Sambagawa metamorphic belt, central Shikoku, Japan

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Abstract

The Seba area is situated in the central part of the Besshi district of central Shikoku, and is composed of the Sebadani metagabbro mass and surrounding Seba basic schists. Eclogitic assemblages are sporadically preserved in both the Sebadani metagabbro and the Seba basic schists. The Sebadani metagabbro mass is surrounded by the Seba basic schists and a thin layers of pelitic schists and siliceous schists intercalated elsewhere within the Seba eclogitic basic schists. Pelitic schists consist mainly of garnet, omphacite, phengite, chlorite, and quartz, along with small amounts of epidote, amphiboles (sodic, sodic-calcic and calcic-amphibole), albite, biotite and carbonaceous matter. Rutile, titanite, calcite, chloritoid, K-feldspar, tourmaline apatite and zircon are occasionally present as accessory minerals. The garnets in the Seba pelitic schists exhibit three modes of occurrence. Garnet 1 (Grt 1) occurs as porphyroblasts in the matrix, garnet 2 (Grt 2) showing composite zoning occurs adjacent to the Sebadani metagabbro contact, and garnet 3 (Grt 3) is found as fine grains in the matrix. The mineral assemblage of inclusions in the cores and rims of the Grt 1 garnets suggests a prograde path of eclogitic metamorphism from the epidote blueschist facies, through the epidote amphibolite facies, to the eclogite facies. The cores of the composite zoned garnets (Grt 2) underwent the same eclogite facies metamorphism with the Grt 1 garnets, which is correlated with the second high-pressure metamorphic event of the Onodani eclogite. The rims of the Grt 2 garnets probably underwent another eclogite facies metamorphism. Fine-grained garnets in the matrix (Grt 3) probably record similar *P-T* histories as the rims of the Grt 2 garnets.

Key words: Sambagawa (Sanbagawa), Besshi district, Seba pelitic schists, zoned garnet, spessartine.

Introduction

Compositional zoning of garnet provides important information about the metamorphic history of certain rocks. Growth zoning records *P-T* variations for prograde metamorphism (Spear *et al*., 1984), whereas diffusive zoning can be applied to estimate unroofing rates (Lasaga, 1983). The chemical zoning of garnets in the Sambagawa metamorphic belt generally shows normal zoning, with decreasing MnO content from core to rim (e.g. Takasu, 1984; Sakai *et al*., 1985; Banno *et al*., 1986). However, different types of garnet zoning have been reported from the Sambagawa metamorphic belt in central Shikoku, including reverse zoning (e.g. Itaya, 1978; Takasu, 1979, 1984; Higashino *et al*., 1981), resorption-overgrowth (e.g. Takasu, 1986; Takasu and Fujita, 1994), and sector zoning (e.g. Takasu and Kondo, 1993; Kitamura *et al*., 1993; Shirahata and Hirajima, 1995).

The Sambagawa high-*P*/*T* metamorphic belt stretches throughout southwestern Japan over a length of ～800 km. The Sambagawa rocks represent the deepest exposed part of the Mesozoic accretionary complexes. The type of metamorphism was classified as high-pressure intermediate facies series by Miyashiro (1973), and formed in a subduction-zone setting (e.g., Takasu *et al*., 1994; Wallis, 1998). The dominant rock types within the belt are pelitic, psammitic, siliceous and basic schists that were derived from sedimentary rocks, and basaltic lavas and their derivatives. All have undergone regional high-*P*/*T* metamorphism in a subduction environment.

The Sambagawa belt exposed in central Shikoku consists of the Oboke nappe complex and the structurally overlying Besshi nappe complex. The Oboke nappe complex consists of low-grade psammitic and pelitic schists with minor amounts of basic, siliceous and conglomeratic schists, whereas the Besshi nappe complex is dominated by pelitic schists with intercalated basic schists, and minor amounts of siliceous and calcareous schists. The ages of the peak metamorphism of the Oboke and the Besshi nappe complexes are 77-70 Ma and 100-90 Ma, respectively (Takasu and Dallmeyer, 1990). In the Besshi district the metamorphism is divided into four zones based on index minerals in the pelitic schists (e.g. Higashino, 1975, 1990; Enami, 1983). These are the chlorite (300-360˚C, 5.5-6.5 kbar), garnet (425-470˚C, 7-8.5 kbar), albite-biotite (470-590˚C, 8-9.5 kbar) and oligoclase-biotite zones (585-635˚C, 9-11 kbar) (Fig. 1; Enami, 1983; Enami *et al*., 1994).

A number of eclogite-bearing bodies are scattered throughout the albite and the oligoclase biotite zones in the high-grade portions of the metamorphic sequence in the Besshi district (e.g. Banno *et al*., 1976; Takasu, 1984, 1989; Kunugiza *et al*., 1986, Aoya, 2001; Ota *et al*., 2004, Kabir and Takasu, 2010a, b) (Fig. 1). Eclogites occur in the Besshi district, mainly within block-like bodies of varying size and

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lithology (Kunugiza *et al*., 1986; Takasu, 1989; Takasu *et al*., 1994). The *P-T* conditions estimated for the eclogite-bearing bodies are distinct from those of surrounding Sambagawa schists, and show variable *P-T* histories (Takasu, 1989).

The Seba area in the central part of the Besshi district is composed of the Sebadani metagabbro mass and surrounding Seba basic schists (Takasu and Makino, 1980; Takasu, 1984). Eclogitic mineral assemblages are sporadically preserved in both the Sebadani metagabbro and the Seba basic schists (Naohara and Aoya, 1997; Aoya, 2001). The Sebadani metagabbro mass is surrounded by the Seba basic schists and a thin layers of pelitic schists. The Sebadani metagabbro is considered to have undergone eclogite-facies metamorphism at conditions of 720-750˚C and 12-24 kbar (Takasu, 1984). The Onodani eclogites preserved within the Seba basic schists have a complex metamorphic history, undergoing three different metamorphic episodes during multiple burial and exhumation cycles (Kabir and Takasu, 2010a). The pelitic schists intercalated within the Seba eclogitic basic schists also underwent eclogite facies metamorphism of 520-550˚C and *c*. 18 kbar (Zaw Win Ko *et al*., 2005, Kouketsu *et al*., 2010). As a consequence of this complex metamorphic history, garnets in the Seba pelitic schists exhibit a diversity of modes of occurrence and variable chemical compositions.

In this study we describe the modes of occurrence and chemistry of zoned garnets in the Seba pelitic schists. The mineral abbreviations used in the text, tables, and figures follow Whitney and Evans (2010).

Petrography and mode of occurrence of garnets

The pelitic schists intercalated within the Seba eclogitic basic schists consist mainly of garnet, omphacite, phengite, chlorite and quartz, with small amounts of epidote, amphiboles (sodic, sodic-calcic and calcic-amphibole), albite, biotite and carbonaceous matter. Rutile, titanite, calcite, chloritoid, K-feldspar, tourmaline, apatite and zircon are occasionally present as accessory minerals. A schistosity is defined by preferred orientation of coarse-grained phengite (< 3.5 mm).

Garnets in the Seba pelitic schists have three distinct modes of occurrence. Garnet 1 (Grt 1) occurs as porphyroblasts in the matrix, garnet 2 (Grt 2) exhibiting composite zoning occurs adjacent to contact with the Sebadani metagabbro, and garnet 3 (Grt 3) is found as fine grains in the matrix. Garnet porphyroblasts in the matrix (Grt 1) occur as euhedral to subhedral porphyroblastic grains up to 3 mm across (Fig. 2), optically zoned from pale orange-colored cores to colorless rims (Fig. 2b). Inclusion trails within these porphyroblastic garnets commonly show orientation parallel to the matrix schistosity; however, they also occasionally show sigmoidal pattern (Fig. 2c). Their cores contain inclusions of sodic / sodic-calcic / calcic-amphibole (glaucophane, taramite,

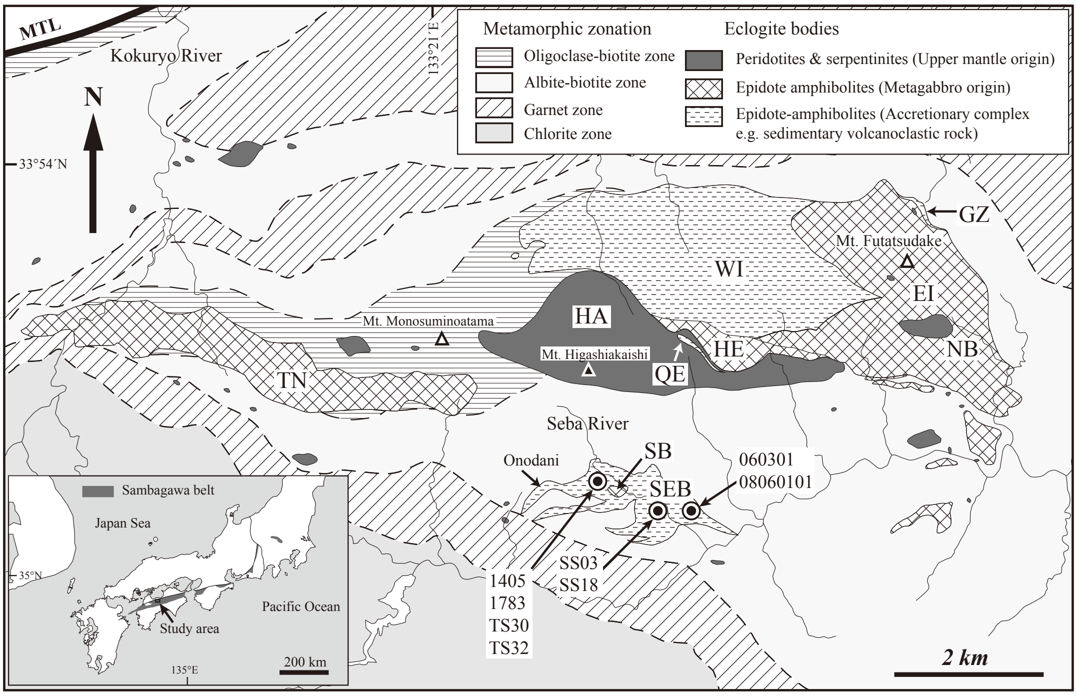

Fig. 1. Geological and metamorphic zonal map of the Sambagawa metamorphic belt in the Besshi district, central Shikoku, Japan (compiled from Takasu and Makino, 1980; Takasu, 1989; Higashino, 1990; Kugimiya and Takasu, 2002; Sakurai and Takasu, 2009; Kabir and Takasu, 2010a). SB, Sebadani metagabbro mass; SEB, Seba basic schists, TN, Tonaru metagabbro mass; WI, Western Iratsu mass; EI, Eastern Iratsu mass; HA, Higashi-akaishi peridotite mass; QE, Quartz eclogite mass; HE, Hornblende eclogite mass; NB, Nikubuchi peridotite mass; GZ, Gazo eclogite mass; MTL, Median Tectonic Line.

Mg-taramite, Mg-hornblende, Mg-hastingsite and pargasite), muscovite, paragonite, epidote, chlorite and titanite (Fig. 2d-e), whereas their rim contain inclusions of epidote, chlorite, sodic-calcic amphibole (barroisite, Fe-barroisite and katophorite), phengite, paragonite, rutile, titanite, K-feldspar (Or > 0.98), tourmaline and quartz (Kabir and Takasu, 2009). The rims also contain polyphase inclusions of barroisite + epidote ± paragonite; barroisite / katophorite + epidote + phengite ± paragonite ± albite ± chlorite; Fe-barroisite + epidote ± chlorite ± biotite; epidote + phengite ± barroisite ± albite ± chlorite, barroisite / katophorite + phengite + chlorite and phengite + epidote ± chlorite ± K-feldspar (Kabir and Takasu, 2009). Porphyroblastic garnets are partly replaced by chlorite and biotite (Fig. 3a-b).

Some garnets in the matrix within pelitic schists adjacent to the Sebadani metagabbro contact occur as euhedral to subhedral porphyroblastic grains up to 5 mm across (Grt 2). The composite zoning of this garnet type has previously been described by Takasu (1986) (Fig. 3c-f). Two zones (core and rim) were identified based on their texture and chemical composition. The core of Grt 2 garnets contain inclusions of omphacite (Jd 29-57 mol%; Aeg 0-21 mol%), epidote (Ps 3-26), Na-Ca / Ca-amphiboles (barroisite, Mg-taramite, Mg-hornblende, tschermakite, pargasite, actinolite), phengite (Si 6.53-7.27 pfu), paragonite, chloritoid (X_{Mg} 0.15-0.19), albite (An < 3), quartz, titanite, ilmenite and carbonaceous matter (Kabir and Takasu, 2011). The cores of Grt 2 garnets also contain polyphase inclusions of Mg-hornblende + epidote + titanite + quartz, omphacite + Mg-hornblende, epidote + albite + calcite + chlorite, epidote + paragonite, chloritoid + paragonite ± ilmenite and aggregates of Mg-hornblende + quartz (Fig. 3d-f). Their rims contain inclusions of phengite (Si 6.51-6.72 pfu), epidote (Ps 4-28), Na-Ca / Ca-amphiboles (barroisite, Mg-hornblende, tschermakite, pargasite), albite (An < 4), rutile, titanite, ilmenite, quartz and carbonaceous matter, and also symplectitic aggregates of barroisite + albite and Mg-hornblende + albite (Fig. 3d-f).

Fine grained garnets (Grt 3) found in the matrix occur as euhedral to subhedral grains up to 0.3 mm across (Figs. 3c and f). They mostly lack inclusions.

Omphacite (X_{Jd} 0.26-0.39) occurs in the matrix as anhedral relict crystals up to 0.2 mm across, and is mostly replaced by aggregates of chlorites. Amphiboles occur in the matrix as subhedral to anhedral prismatic grains up to 2 mm long, some of which are zoned from barroisite and Mg-katophorite cores to Mg-hornblende rims. Rutile is found as inclusions in the rims of the porphyroblastic garnets (Grt 1), but also occurs as discrete grains. Rutile in the matrix is mostly rimmed by titanite (Fig. 2c). Titanite occurs as inclusions in the cores and rims of Grt 1 garnets as discrete grains, but some is also present in the matrix (Fig. 2c). Phengite in the matrix occurs as euhedral to subhedral grains up to 2 mm across, some of which are rimmed by biotite.

Garnet Chemistry

Chemical composition and compositional zoning of the garnets in the Seba pelitic schists were investigated in Shimane University, using JEOL JXA 8800M and 8530F electron microprobe analyzers. Analytical conditions used for quantitative analysis were 15 kV accelerating potential, 20 nA specimen current, and 5 μm beam diameter. Conditions for color map analysis were probe current 2.5E-08, dwell time 80 msec, numbers of pixels X: 600, Y: 600, and pixel size (μm) X: 2.20, Y: 2.20. Correction procedure was carried out as described by Bence and Albee (1968). Ferric iron contents in garnet were estimated using charge balance $\mathrm{Fe}^{3+} = 8\text{-}2\mathrm{Si}\text{-}2\mathrm{Ti}\text{-}\mathrm{Al}$ (O = 12). Na (< 0.09 wt%), K (< 0.07 wt%) and Cr (< 0.05 wt%) contents are negligible.

The porphyroblastic garnets (Grt 1) have almandine-rich composition (X_{Alm} 0.48-0.65), with variable amounts of the grossular (X_{Grs} 0.17-0.36), spessartine (X_{Sps} 0-0.32) and pyrope (X_{Prp} 0.01-0.13) components. Three zones (core, mantle and rim) were identified based on chemical composition (Table 1; Figs. 4a, 5a). The mantles and rims defined by the chemistry correspond to the rims identified optically. The garnets show prograde zoning, with X_{Sps} decreasing sharply from the core to the mantle (0.28-0.05), and gently decreasing toward the rim (0.05-0.01) (Fig. 5a-c). X_{Grs} increases from the core to the mantle (0.18-0.35), albeit with some fluctuation, and then decreases to the rim (0.35-0.27). Pyrope contents increase gently from core to rim (X_{Prp} 0.02-0.10).

Composite zoned garnets (Grt 2) exhibit resorption between the core and the rim (Figs. 3d-f, 4b and 5d-f). The cores of these garnets are characterized by a zoning showing decreasing X_{Sps} (0.28-0.01), and increasing X_{Prp} (0.03-0.14) and X_{Grs} (0.06-0.24), with some fluctuation, and increase and then decrease of X_{Alm} (0.56-0.67 to 0.58) from the core toward the core-rim boundary. Composition changes abruptly at the boundary between the core and the rim (Fig. 4b). The rims of Grt 2 garnets also show prograde zoning, with increase and then decrease of X_{Alm} (0.62-0.68-0.58), decrease of X_{Sps} (0.13-0.01) and X_{Prp} (0.05-0.13), and increase of X_{Grs} (0.13-0.28 pfu) towards the outermost rims. The compositions of the cores of the Grt 2 garnets correspond to those of the single-zoned porphyroblastic garnets (Grt 1).

The compositional zoning of the fine-grained garnets (Grt 3) in the matrix is similar to that of the rims of composite-zoned garnet (Grt 2). Matrix garnets show growth zoning, with decreasing X_{Sps} (0.07-0.01) and increasing X_{Alm} (0.57-0.67), X_{Grs} (0.24-0.61) and X_{Prp} (0.04-0.13) from core to rim.

Discussion and Conclusions

The variety of the modes of occurrence and wide range of chemical compositions of the garnets (Grt 1-3) in the Seba pelitic schist suggest a variety of equilibrium metamorphic

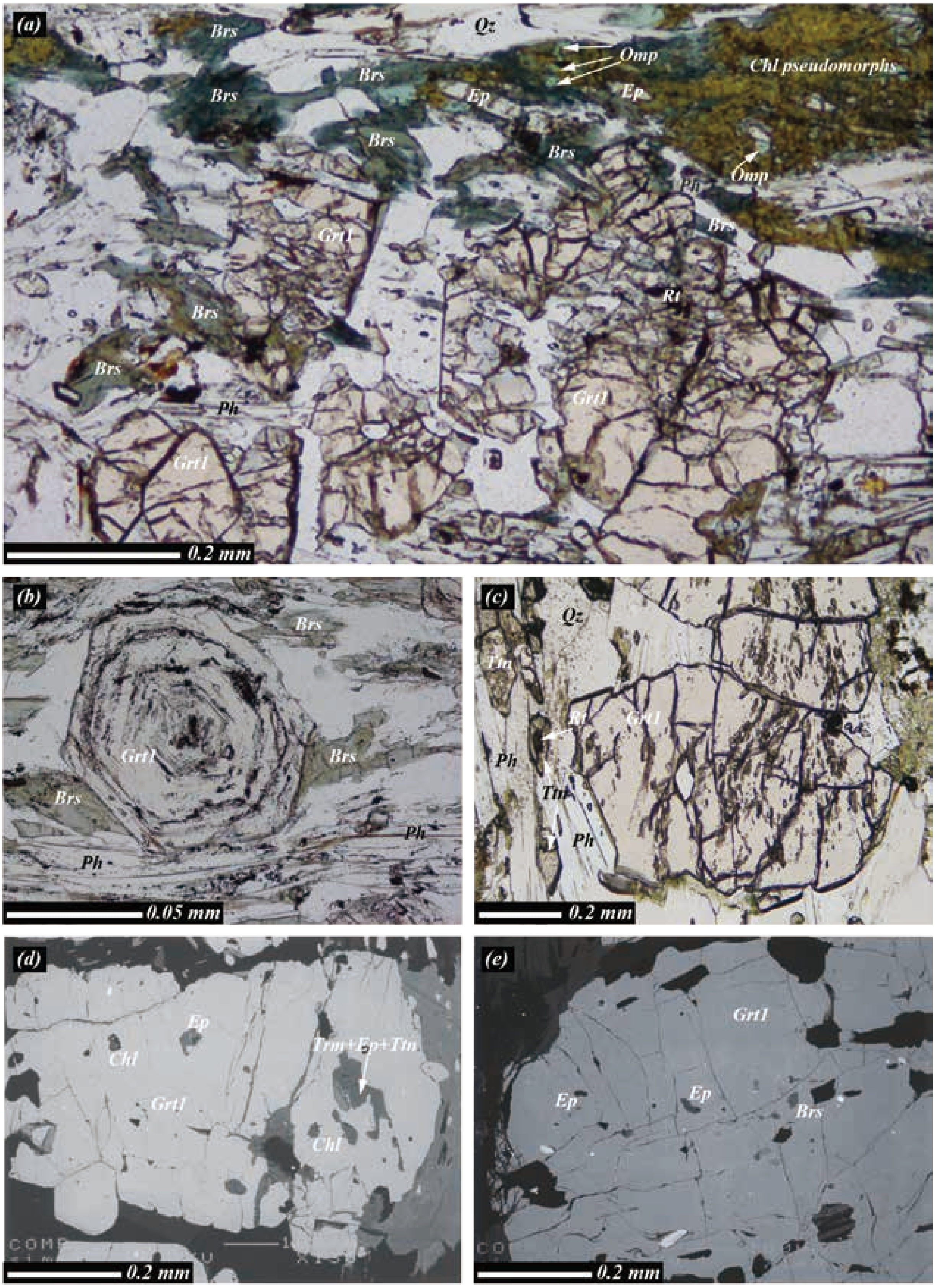

Fig. 2. Photomicrographs and backscattered electron images showing textural relationships of minerals in the Seba pelitic schists. (a) Garnet (Grt 1) and omphacite, amphibole (barroisite), phengite, epidote and quartz in the matrix of the Seba pelitic schists. (b-c) Matrix porphyroblastic garnet (Grt 1) and other matrix minerals (barroisitic amphibole phengite, rutile, titanite and quartz). (d) Garnet (Grt 1) containing inclusions of taramitic amphibole, epidote, titanite and chlorite. (e) Matrix garnet (Grt 1) containing inclusions of barroisitic amphiboles and epidote.

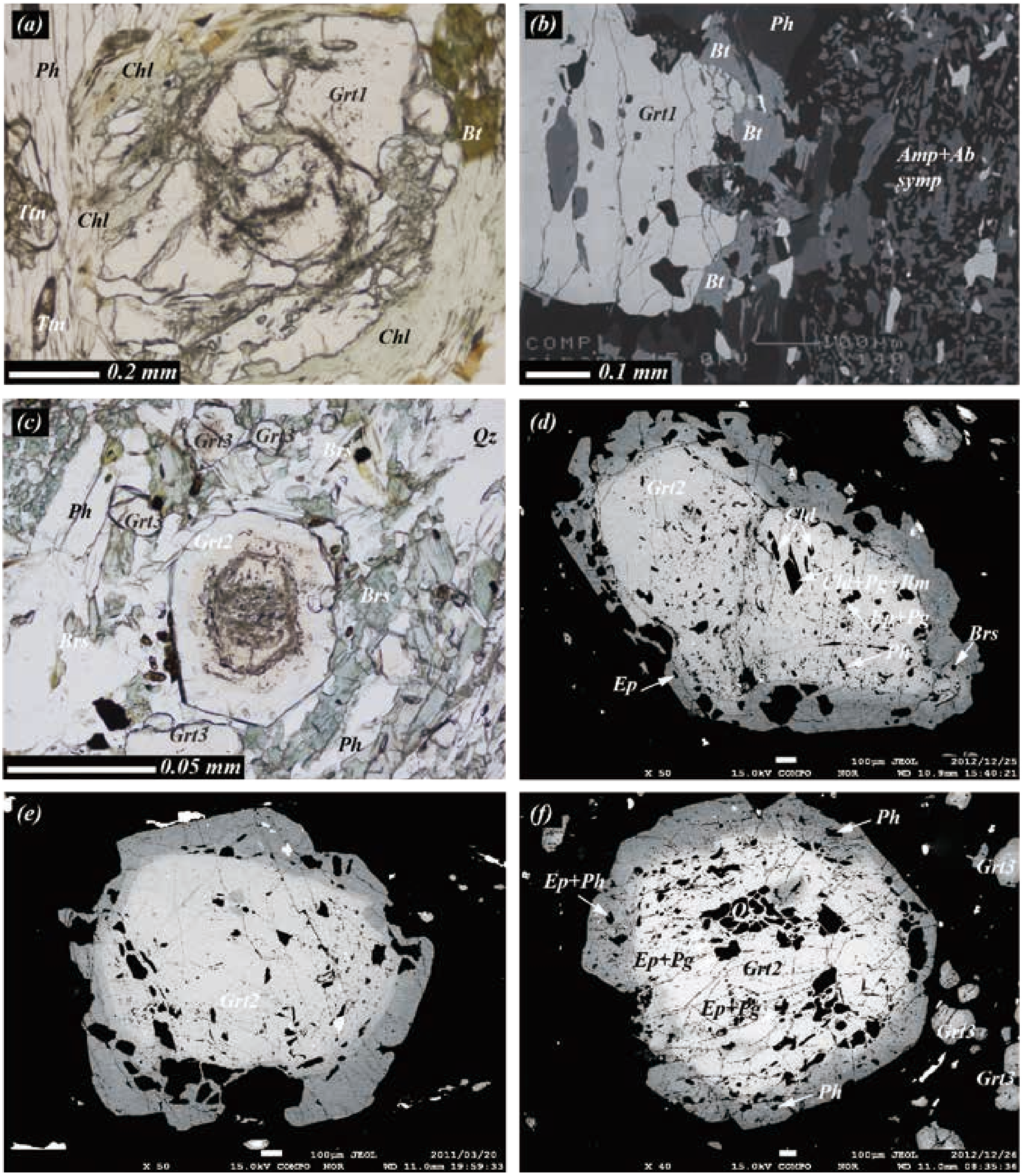

Fig. 3. Photomicrographs and backscattered electron images of the Seba pelitic schists. (a-b) Garnet (Grt 1) partly replaced by chlorite and biotite. Actinolite and albite symplectites after omphacite occur in the matrix (b). (c) Composite-zoned matrix porphyroblastic garnet (Grt 2) and fine-grained garnet (Grt 3) with other matrix minerals (barroisitic amphibole and phengite). (d-f) Composite-zoned porphyroblastic garnet (Grt 2) and fine-grained garnet (Grt 3) and inclusion minerals within the garnet cores and rims.

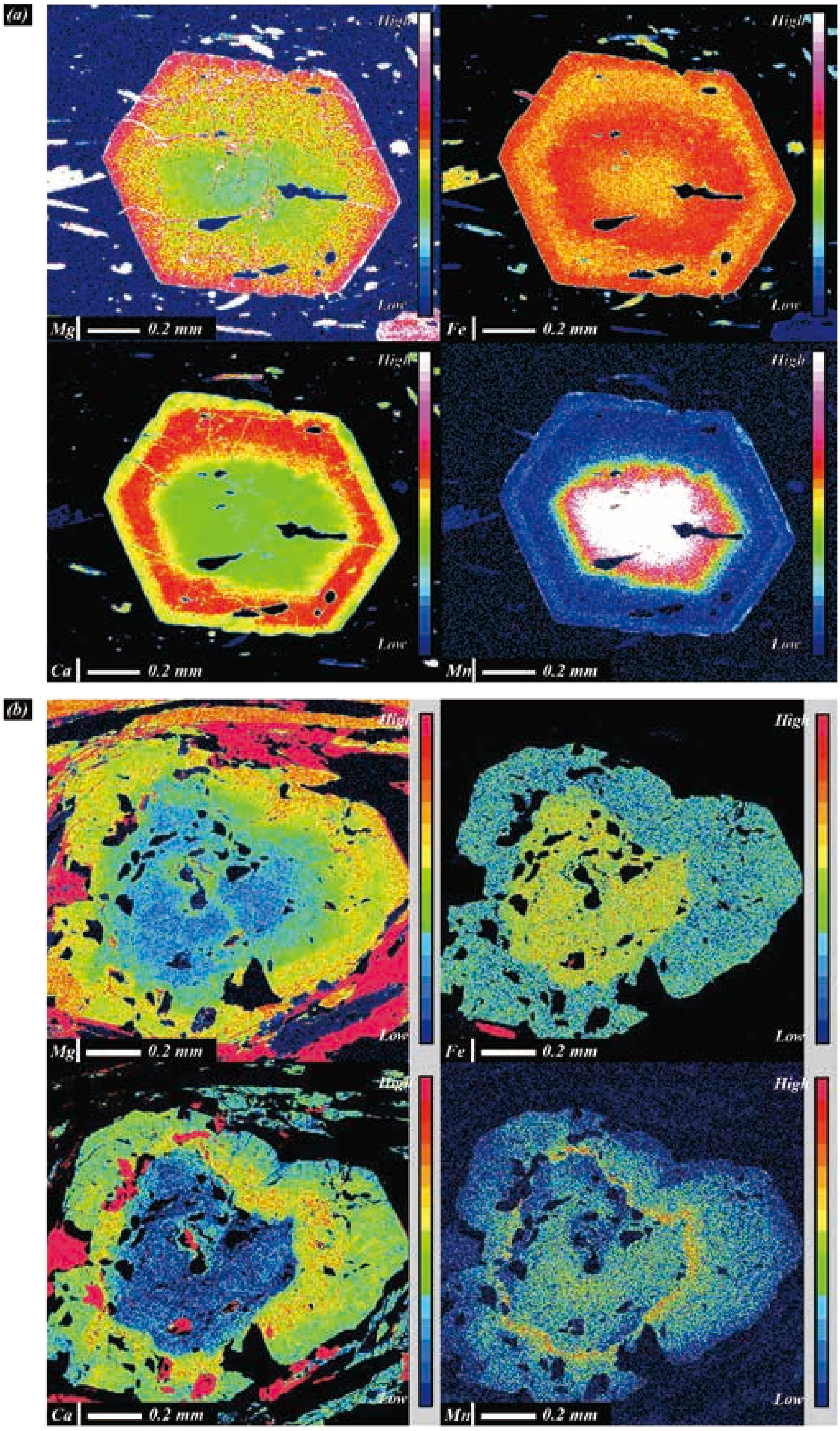

Fig. 4. Elemental color map (Mg, Fe, Ca and Mn) of a garnet (Grt 1) in the matrix showing continuous compositional zoning consisting of a Mn-rich core (X_{Sps} 0.32), Ca-rich mantle and Fe^{2+}-Mg-rich rim (a), and a garnet (Grt 2) in the matrix showing discontinuous compositional zoning, consisting of Mn enrichments in the core (X_{Sps} 0.28), and the boundary between the core and rim (X_{Sps} 0.13) (b).

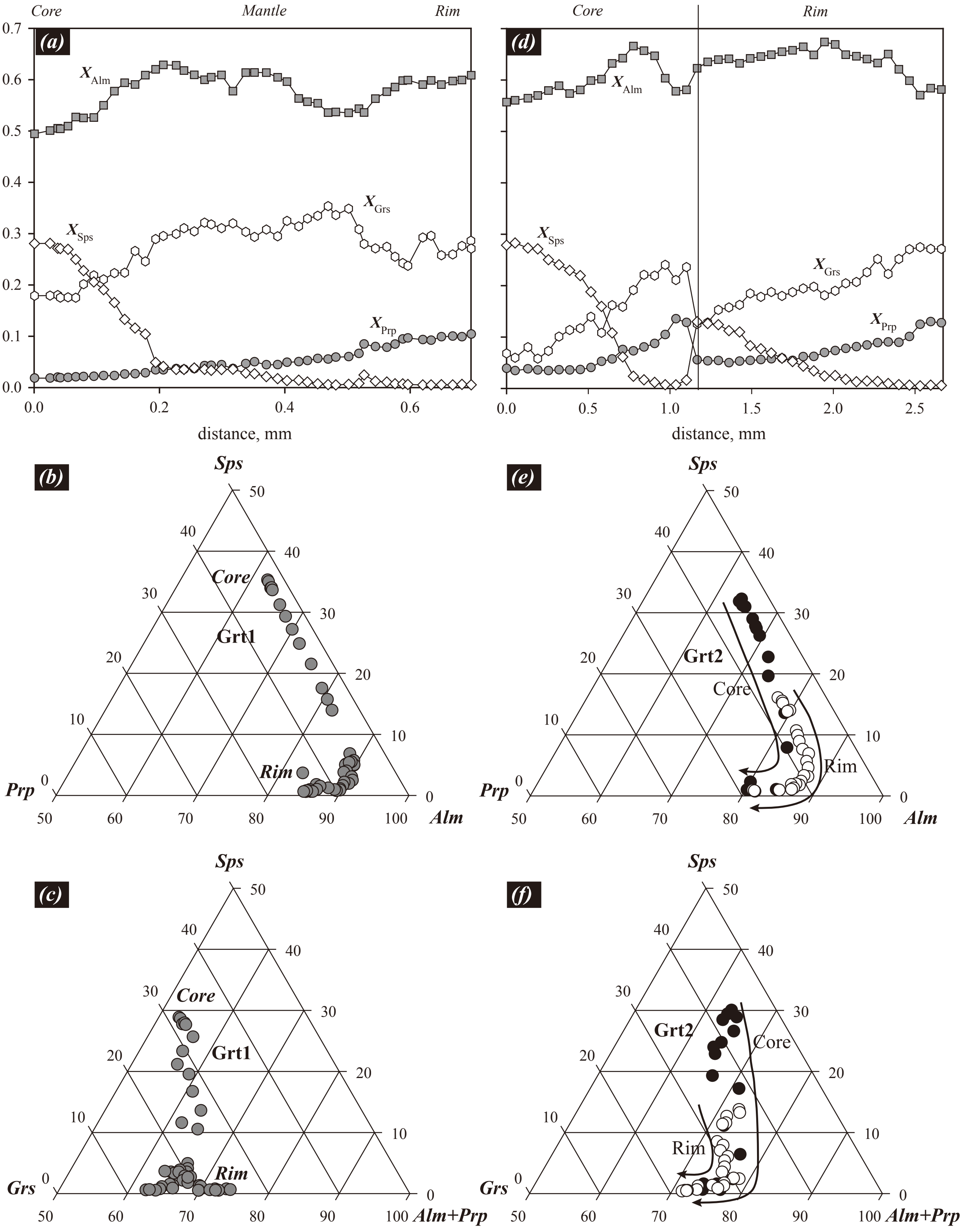

Fig. 5. Chemical compositions of zoned garnets from the Seba pelitic schists. (a-c) Compositional profile of garnet (Grt 1) from core to the rim in terms of X_{Alm}, X_{Prp}, X_{Grs} and X_{Sps} contents. (d-f) Compositional profile of Grt 2.

P-T conditions. The textures of the minerals, chemical compositions, and thermobarometry suggest two different metamorphic events are represented by the zoning of the garnets (Grt 1-3), i.e. a first high-pressure metamorphic event, and a second high-pressure metamorphic event.

The mineral assemblages in the cores and rims of the Grt 1 garnets in the pelitic schists reveal a prograde path of eclogitic metamorphism from the epidote blueschist facies, through the epidote amphibolite facies, to the eclogite facies, during the first high-pressure metamorphic event. The peak metamorphic conditions are estimated as 615-660°C and 18.5-22 kbar from the schistosity forming minerals (Kabir and Takasu, 2009), which are correlated with the second high-pressure metamorphic event (Kabir and Takasu, 2010a).

The cores of the composite-zoned garnets (Grt 2) correspond to the zoning profile of the garnet porphyroblasts in the matrix (Grt 1). This suggests that the cores of the complex zoned garnets record the same eclogite facies metamorphism as the Grt 1 garnets. The rims of the Grt 2 garnets also shows a growth zoning, and probably record another eclogite facies metamorphism (Takasu, 1986). Fine-grained garnets in the matrix (Grt 3) show similar compositional zoning as the rims of the Grt 2 garnets, suggesting a similar *P-T* history.

The Onodani area is located near the Seba area in the Besshi district, and eclogite localities in both areas are situated within the same basic schist unit (e.g. Takasu and Makino, 1980). The Onodani eclogites experienced three episodes of prograde metamorphism (Kabir and Takasu, 2010a). The first eclogite facies metamorphism is deduced from the minerals preserved in the spessartine-rich cores of the porphyroblastic garnets (530-590°C and 19-21 kbar), whereas the second high-pressure metamorphic event (eclogite facies) is deduced from the schistosity forming mineral assemblages (630-680°C and 20-22 kbar). The third high-pressure metamorphism of the epidote-amphibolite facies is identified from amphibole-rich veins or randomly oriented amphiboles (540-600°C and 6.5-8 kbar). The eclogite facies high-pressure metamorphic events are correlative with the second high-pressure metamorphisms of the Onodani eclogites.

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（要　旨）

Kabir, Md F.・高須　晃，2012 四国中央部三波川変成帯瀬場泥質片岩中のざくろ石の産状と化学組成．島根大学地球資源環境学研究報告，31，9-22.

四国中央部別子地域中央部に位置する瀬場谷周辺には瀬場谷変斑れい岩体とそれをとりまく瀬場塩基性片岩が分布している．エクロジャイトの鉱物組み合わせが瀬場谷変斑れい岩と瀬場塩基性片岩中に部分的に保存されている．瀬場谷変斑れい岩体を取り囲むように泥質片岩の薄層と瀬場塩基性片岩が分布している．また，瀬場塩基性片岩中には泥質片岩の薄層を挟在する．瀬場塩基性片岩中の泥質片岩はざくろ石，オンファス輝石，フェンジャイト，緑泥石及び石英を主要構成鉱物とし，その他に少量の緑れん石，角閃石（Na, Na-Ca, Ca 角閃石），曹長石，黒雲母，と炭質物からなる．その他に，ルチル，チタン石，方解石，クロリトイド，カリ長石，電気石，りん灰石とジルコンを含む場合がある．瀬場泥質片岩中のざくろ石には3種の産状がある．ざくろ石1（Grt1）は斑状変晶として産出する．ざくろ石2（Grt2）は瀬場谷変斑れい岩体に隣接する泥質片岩中にみられるざくろ石で，複合累帯構造を示す．ざくろ石3（Grt3）は泥質片岩の基質中の細粒のざくろ石である．Grt1のコアとリムに包有される鉱物組み合わせは，大野谷エクロジャイトの第2高圧変成イベントのエクロジャイト変成作用に対応し，昇温変成経路が緑れん石青色片岩相から緑れん石角閃岩相を経てエクロジャイト相に至るものであることを示す．Grt2のコアはGrt1と同じエクロジャイト相変成作用を受けた．Grt3の基質にみられる細粒のざくろ石はGrt2のリムと同様のP-T履歴を記録していると考えられる．

Table 1. Representative chemical compositions of garnets from the Seba pelitic schists.

Sample	S 060301																		
Analysis	13	32	35	68	111	119	3	4	6	10	11	13	14	18	19	20	21	22	23
Mode	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1
							Core	→	→	→	→	→	→	→	→	→	→	→	→
SiO_2	37.76	38.05	38.04	37.05	37.31	36.55	37.77	37.82	38.14	37.45	36.44	36.82	36.66	36.30	36.38	36.58	36.72	36.74	38.12
TiO_2	0.10	0.10	0.10	0.14	0.08	0.15	0.17	0.23	0.14	0.15	0.17	0.13	0.19	0.16	0.12	0.20	0.16	0.10	0.18
Al_2O_3	21.29	21.24	21.29	21.41	21.51	21.31	21.38	21.35	21.33	21.34	21.30	21.05	21.41	21.25	21.26	21.48	21.48	21.41	21.32
FeO*	29.01	27.14	27.73	27.67	27.39	27.57	28.13	28.21	27.97	28.22	27.69	27.96	28.19	28.42	28.52	28.05	28.61	28.09	28.51
MnO	0.86	1.98	1.60	1.41	1.38	1.93	2.70	2.60	2.17	2.11	2.27	2.11	2.06	1.91	2.18	2.28	2.13	2.00	1.45
MgO	2.38	1.73	1.75	2.72	2.74	1.86	1.69	1.75	1.62	1.78	1.71	1.77	1.76	1.80	1.79	1.74	1.85	1.86	1.93
CaO	8.81	10.00	10.01	9.33	9.12	9.77	9.46	9.09	9.71	9.42	9.86	9.40	9.59	9.67	9.59	9.63	9.42	9.53	9.75
Total	100.21	100.23	100.52	99.73	99.52	99.14	101.29	101.05	101.08	100.47	99.44	99.25	99.86	99.50	99.84	99.94	100.37	99.72	101.26
Cations on the basis of 12 oxygens																			
Si	2.99	3.02	3.01	2.94	2.97	2.93	2.98	2.99	3.01	2.97	2.92	2.96	2.93	2.91	2.91	2.92	2.92	2.93	3.00
Ti	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Al	1.99	1.99	1.99	2.00	2.01	2.01	1.98	1.99	1.98	2.00	2.01	1.99	2.01	2.01	2.00	2.02	2.01	2.01	1.97
Fe^{3+}	0.01	0.00	0.00	0.10	0.04	0.10	0.05	0.01	0.00	0.05	0.13	0.08	0.11	0.16	0.17	0.13	0.14	0.11	0.01
Fe^{2+}	1.91	1.80	1.84	1.74	1.78	1.75	1.81	1.85	1.84	1.83	1.73	1.80	1.77	1.74	1.73	1.74	1.76	1.77	1.86
Mn	0.06	0.13	0.11	0.10	0.09	0.13	0.18	0.17	0.14	0.14	0.15	0.14	0.14	0.13	0.15	0.15	0.14	0.13	0.10
Mg	0.28	0.20	0.21	0.32	0.32	0.22	0.20	0.21	0.19	0.21	0.20	0.21	0.21	0.21	0.21	0.21	0.22	0.22	0.23
Ca	0.75	0.85	0.85	0.79	0.78	0.84	0.80	0.77	0.82	0.80	0.85	0.81	0.82	0.83	0.82	0.82	0.80	0.82	0.82
Total	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
X_{Prp}	0.09	0.07	0.07	0.11	0.11	0.08	0.07	0.07	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.08
X_{Alm}	0.64	0.60	0.61	0.59	0.60	0.59	0.61	0.62	0.61	0.61	0.59	0.61	0.60	0.60	0.59	0.60	0.60	0.60	0.62
X_{Grs}	0.25	0.28	0.28	0.27	0.26	0.29	0.27	0.26	0.27	0.27	0.29	0.27	0.28	0.28	0.28	0.28	0.27	0.28	0.27
X_{Sps}	0.02	0.04	0.04	0.03	0.03	0.04	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.04	0.05	0.05	0.05	0.05	0.03

**Total Fe as FeO*

Sample	S 060301																		
Analysis	24	25	27	28	29	32	33	34	40	41	42	43	44	45	46	47	48	49	21
Mode	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1
	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	Rim	
SiO_2	37.57	37.80	37.92	37.88	37.92	38.19	38.10	38.27	37.21	37.47	37.15	37.43	37.42	36.73	37.20	37.43	37.40	37.55	37.11
TiO_2	0.09	0.19	0.12	0.14	0.14	0.17	0.20	0.18	0.11	0.14	0.07	0.08	0.10	0.06	0.08	0.10	0.14	0.12	0.11
Al_2O_3	21.46	21.61	21.39	21.45	21.41	21.35	21.40	21.40	21.80	21.46	21.79	21.68	21.94	21.73	21.61	21.69	21.43	21.55	19.24
FeO*	29.07	28.94	28.67	29.10	29.24	28.61	29.12	28.36	28.50	28.42	28.95	28.90	28.87	28.82	28.37	27.30	27.34	28.18	28.14
MnO	1.46	1.21	1.17	1.21	0.98	1.12	1.07	0.91	1.02	1.03	1.05	1.04	1.30	1.44	1.55	1.60	1.61	1.53	1.16
MgO	2.05	2.14	2.00	2.07	2.17	2.10	2.09	2.15	2.54	2.56	2.77	2.75	2.84	2.83	2.78	2.67	2.66	2.70	7.15
CaO	9.17	9.39	10.12	9.33	9.30	9.62	9.05	9.71	9.40	9.03	8.64	8.43	8.70	8.65	9.23	9.75	9.92	9.57	6.98
Total	100.87	101.29	101.38	101.17	101.15	101.15	101.02	100.98	100.57	100.11	100.43	100.29	101.16	100.25	100.83	100.54	100.49	101.20	99.88
Cations on the basis of 12 oxygens																			
Si	2.97	2.97	2.97	2.98	2.98	3.00	3.00	3.01	2.93	2.97	2.93	2.96	2.93	2.90	2.92	2.95	2.95	2.94	2.90
Ti	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.01	0.01
Al	2.00	2.00	1.98	1.99	1.98	1.98	1.99	1.98	2.02	2.00	2.03	2.02	2.02	2.02	2.00	2.01	1.99	1.99	1.77
Fe^{3+}	0.06	0.04	0.06	0.04	0.03	0.00	0.00	0.00	0.10	0.04	0.10	0.05	0.10	0.16	0.14	0.09	0.10	0.12	0.43
Fe^{2+}	1.86	1.86	1.82	1.88	1.89	1.88	1.92	1.87	1.78	1.84	1.81	1.86	1.79	1.74	1.72	1.71	1.70	1.73	1.41
Mn	0.10	0.08	0.08	0.08	0.06	0.07	0.07	0.06	0.07	0.07	0.07	0.07	0.09	0.10	0.10	0.11	0.11	0.10	0.08
Mg	0.24	0.25	0.23	0.24	0.25	0.25	0.24	0.25	0.30	0.30	0.33	0.32	0.33	0.33	0.33	0.31	0.31	0.32	0.83
Ca	0.78	0.79	0.85	0.79	0.78	0.81	0.76	0.82	0.79	0.77	0.73	0.71	0.73	0.73	0.78	0.82	0.84	0.80	0.58
Total	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
X_{Prp}	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.10	0.10	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.29
X_{Alm}	0.62	0.62	0.61	0.63	0.63	0.62	0.64	0.62	0.61	0.62	0.62	0.63	0.61	0.60	0.59	0.58	0.57	0.59	0.49
X_{Grs}	0.26	0.27	0.29	0.26	0.26	0.27	0.25	0.27	0.27	0.26	0.25	0.24	0.25	0.25	0.27	0.28	0.28	0.27	0.20
X_{Sps}	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.04	0.04	0.04	0.03	0.03

**Total Fe as FeO*

Sample	S 060301		S 08060101																
Analysis	2	3	8	58	2	22	2	1	25	55	58	61	63	70	71	77	85	1	2
Mode	Grt 3	Grt 3	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1
	Core	Rim																Core	→
SiO_2	37.65	37.88	36.65	37.36	38.46	38.58	37.33	38.79	39.26	39.15	38.81	38.91	39.03	37.90	39.20	38.65	39.17	37.55	37.38
TiO_2	0.10	0.12	0.20	0.22	0.05	0.08	0.13	0.13	0.08	0.07	0.13	0.07	0.08	0.12	0.04	0.11	0.08	0.20	0.08
Al_2O_3	20.51	20.73	20.53	20.87	21.37	21.59	20.54	20.98	21.77	21.28	21.44	21.62	21.33	20.77	21.48	21.38	21.60	20.78	20.83
FeO*	26.66	28.80	29.57	26.48	26.15	24.98	25.75	26.30	25.92	27.16	27.92	27.08	26.00	25.06	24.85	25.86	25.85	22.66	23.23
MnO	3.19	0.59	0.87	1.24	0.43	0.64	5.83	0.55	0.75	0.78	0.61	0.50	0.56	8.16	0.82	0.34	0.30	12.83	13.94
MgO	1.28	2.43	2.08	1.27	1.79	2.90	0.89	2.54	2.41	2.77	2.48	2.76	2.74	0.59	2.85	1.51	3.21	0.48	0.37
CaO	11.09	9.12	9.69	12.10	12.58	10.93	8.98	10.52	10.65	9.91	9.93	9.95	11.10	8.38	11.24	12.43	10.28	6.95	5.47
Total	100.49	99.66	99.59	99.53	100.83	99.69	99.44	99.81	100.83	101.13	101.31	100.89	100.84	100.98	100.48	100.27	100.49	101.45	101.29
Cations on the basis of 12 oxygens																			
Si	2.99	3.02	2.93	2.98	3.01	3.04	3.02	3.07	3.07	3.06	3.03	3.04	3.05	3.03	3.06	3.05	3.06	3.00	3.00
Ti	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.01	0.00	0.01	0.00
Al	1.92	1.95	1.94	1.96	1.97	2.00	1.96	1.96	2.01	1.96	1.97	1.99	1.96	1.95	1.98	1.99	1.99	1.96	1.97
Fe^{3+}	0.08	0.00	0.17	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02
Fe^{2+}	1.69	1.92	1.81	1.73	1.71	1.65	1.74	1.74	1.70	1.77	1.82	1.77	1.70	1.67	1.62	1.71	1.69	1.49	1.54
Mn	0.21	0.04	0.06	0.08	0.03	0.04	0.40	0.04	0.05	0.05	0.04	0.03	0.04	0.55	0.05	0.02	0.02	0.87	0.95
Mg	0.15	0.29	0.25	0.15	0.21	0.34	0.11	0.30	0.28	0.32	0.29	0.32	0.32	0.07	0.33	0.18	0.37	0.06	0.04
Ca	0.94	0.78	0.83	1.04	1.06	0.92	0.78	0.89	0.89	0.83	0.83	0.83	0.93	0.72	0.94	1.05	0.86	0.59	0.47
Total	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
X_{Prp}	0.05	0.10	0.08	0.05	0.07	0.12	0.04	0.10	0.10	0.11	0.10	0.11	0.11	0.02	0.11	0.06	0.13	0.02	0.01
X_{Alm}	0.56	0.63	0.61	0.58	0.57	0.56	0.58	0.59	0.58	0.60	0.61	0.60	0.57	0.56	0.55	0.58	0.57	0.50	0.51
X_{Grs}	0.31	0.26	0.28	0.35	0.35	0.31	0.26	0.30	0.31	0.28	0.28	0.28	0.31	0.24	0.32	0.36	0.29	0.20	0.16
X_{Sps}	0.07	0.01	0.02	0.03	0.01	0.01	0.13	0.01	0.02	0.02	0.01	0.01	0.01	0.18	0.02	0.01	0.01	0.29	0.32

**Total Fe as FeO*

Table 1. (continued)

Sample	S 08060101																		
Analysis	3	4	5	8	9	10	11	12	13	14	15	18	19	20	22	23	24	25	26
Mode	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1
	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→
SiO_2	37.63	37.34	37.37	37.40	37.83	37.84	37.72	37.73	37.71	37.91	38.24	37.99	38.15	38.12	38.14	38.06	38.23	38.18	38.14
TiO_2	0.17	0.13	0.19	0.13	0.17	0.18	0.11	0.13	0.08	0.09	0.12	0.09	0.11	0.15	0.08	0.11	0.08	0.07	0.11
Al_2O_3	20.64	20.48	20.69	20.85	20.74	20.71	20.73	20.66	20.62	20.74	20.82	20.75	20.84	20.96	20.93	20.89	21.04	21.03	21.03
FeO*	22.32	21.93	22.10	23.36	24.03	23.67	25.48	26.02	25.88	26.79	26.66	28.39	28.64	29.37	27.99	27.51	27.18	27.43	27.33
MnO	12.90	13.27	13.27	11.34	10.17	9.14	8.63	8.13	7.23	6.31	5.75	2.58	2.03	1.68	1.83	1.79	1.25	1.02	0.82
MgO	0.39	0.43	0.43	0.49	0.47	0.47	0.56	0.54	0.55	0.59	0.63	1.19	0.85	0.89	0.96	0.94	1.00	1.07	1.13
CaO	6.72	6.67	6.93	6.90	7.50	8.32	8.06	7.84	8.16	8.76	9.11	9.36	9.82	9.85	10.57	10.87	11.27	11.17	11.33
Total	100.77	100.25	100.98	100.47	100.89	100.34	101.28	101.04	100.23	101.19	101.32	100.36	100.44	101.02	100.51	100.18	100.05	99.96	99.89
Cations on the basis of 12 oxygens																			
Si	3.03	3.02	3.00	3.01	3.03	3.04	3.01	3.02	3.04	3.02	3.04	3.03	3.04	3.03	3.03	3.03	3.04	3.04	3.04
Ti	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.00	0.01
Al	1.96	1.95	1.96	1.98	1.96	1.96	1.95	1.95	1.96	1.95	1.95	1.95	1.96	1.96	1.96	1.96	1.98	1.98	1.98
Fe^{3+}	0.00	0.00	0.02	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fe^{2+}	1.50	1.48	1.46	1.57	1.61	1.59	1.68	1.74	1.74	1.78	1.77	1.89	1.91	1.95	1.86	1.83	1.81	1.83	1.82
Mn	0.88	0.91	0.90	0.77	0.69	0.62	0.58	0.55	0.49	0.43	0.39	0.17	0.14	0.11	0.12	0.12	0.08	0.07	0.06
Mg	0.05	0.05	0.05	0.06	0.06	0.06	0.07	0.06	0.07	0.07	0.07	0.14	0.10	0.11	0.11	0.11	0.12	0.13	0.13
Ca	0.58	0.58	0.60	0.60	0.64	0.72	0.69	0.67	0.70	0.75	0.78	0.80	0.84	0.84	0.90	0.93	0.96	0.95	0.97
Total	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
X_{Prp}	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.05	0.03	0.04	0.04	0.04	0.04	0.04	0.04
X_{Alm}	0.50	0.49	0.49	0.52	0.54	0.53	0.56	0.57	0.58	0.59	0.59	0.63	0.64	0.65	0.62	0.61	0.61	0.61	0.61
X_{Grs}	0.19	0.19	0.20	0.20	0.21	0.24	0.23	0.22	0.23	0.25	0.26	0.27	0.28	0.28	0.30	0.31	0.32	0.32	0.32
X_{Sps}	0.29	0.30	0.30	0.26	0.23	0.21	0.19	0.18	0.16	0.14	0.13	0.06	0.05	0.04	0.04	0.04	0.03	0.02	0.02

**Total Fe as FeO*

Sample	S 08060101																		
Analysis	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
Mode	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1
	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→
SiO_2	38.35	38.60	38.46	38.36	38.45	38.30	38.64	38.67	38.73	38.41	38.79	38.67	38.25	38.36	38.50	38.63	38.35	38.29	38.66
TiO_2	0.10	0.09	0.09	0.10	0.05	0.07	0.07	0.06	0.07	0.09	0.08	0.09	0.11	0.08	0.10	0.12	0.08	0.08	0.12
Al_2O_3	21.41	21.42	21.17	21.13	21.21	21.24	21.19	21.32	21.44	21.15	21.43	21.52	21.36	21.47	21.18	21.27	21.54	21.69	21.17
FeO*	27.41	27.35	26.83	26.91	27.75	26.31	25.63	25.88	24.97	25.55	25.74	26.27	25.70	25.84	25.09	25.65	26.12	26.80	26.82
MnO	0.71	0.62	0.70	0.70	0.58	0.40	0.34	0.28	0.32	0.31	0.26	0.35	0.31	0.49	0.97	0.83	0.57	0.49	0.33
MgO	1.24	1.24	1.35	1.36	1.32	1.37	1.36	1.35	1.50	1.49	1.55	1.55	1.57	1.64	1.82	1.93	1.88	1.86	2.03
CaO	11.23	11.96	11.74	12.00	11.47	12.18	12.94	13.00	13.13	12.84	12.92	12.41	12.71	12.43	12.40	11.81	11.70	11.31	11.23
Total	100.44	101.27	100.34	100.56	100.84	99.85	100.17	100.56	100.16	99.84	100.76	100.87	100.01	100.30	100.05	100.22	100.23	100.53	100.36
Cations on the basis of 12 oxygens																			
Si	3.04	3.03	3.04	3.03	3.03	3.04	3.05	3.04	3.05	3.04	3.04	3.03	3.02	3.02	3.04	3.05	3.02	3.01	3.05
Ti	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.00	0.01	0.01	0.00	0.00	0.01
Al	2.00	1.98	1.97	1.97	1.97	1.99	1.97	1.98	1.99	1.97	1.98	1.99	1.99	1.99	1.97	1.98	2.00	2.01	1.97
Fe^{3+}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fe^{2+}	1.81	1.79	1.78	1.78	1.83	1.75	1.69	1.70	1.65	1.69	1.69	1.72	1.70	1.70	1.66	1.69	1.72	1.76	1.77
Mn	0.05	0.04	0.05	0.05	0.04	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.06	0.06	0.04	0.03	0.02
Mg	0.15	0.14	0.16	0.16	0.16	0.16	0.16	0.16	0.18	0.18	0.18	0.18	0.19	0.19	0.21	0.23	0.22	0.22	0.24
Ca	0.95	1.01	1.00	1.02	0.97	1.04	1.10	1.10	1.11	1.09	1.09	1.04	1.08	1.05	1.05	1.00	0.99	0.95	0.95
Total	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
X_{Prp}	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.08	0.07	0.07	0.08
X_{Alm}	0.61	0.60	0.60	0.59	0.61	0.59	0.57	0.57	0.56	0.57	0.57	0.58	0.57	0.57	0.56	0.57	0.58	0.59	0.59
X_{Grs}	0.32	0.34	0.33	0.34	0.32	0.35	0.37	0.37	0.38	0.37	0.37	0.35	0.36	0.35	0.35	0.34	0.33	0.32	0.32
X_{Sps}	0.02	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.01

**Total Fe as FeO*

Sample	S 08060101																		
Analysis	46	47	48	49	50	51	52	53	1	4	2	3	4	5	6	7	8	10	11
Mode	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1
	→	→	→	→	→	→	→	Rim			Rim	←	←	←	←	←	←	←	←
SiO_2	38.60	38.34	38.49	38.59	38.66	38.37	38.33	38.55	37.58	37.99	38.05	37.53	37.90	38.06	37.65	37.77	37.61	37.66	37.38
TiO_2	0.12	0.13	0.13	0.09	0.14	0.08	0.11	0.04	0.13	0.11	0.01	0.11	0.07	0.05	0.11	0.14	0.06	0.09	0.11
Al_2O_3	21.32	21.20	21.26	21.37	21.27	21.25	21.17	21.14	21.15	21.24	21.56	21.24	21.82	21.64	21.15	21.16	21.17	21.11	21.43
FeO*	26.85	27.16	27.95	27.82	27.43	27.30	27.51	27.52	27.58	28.35	25.34	27.48	25.72	25.38	27.89	27.49	27.88	27.68	27.39
MnO	0.38	0.39	0.31	0.20	0.28	0.26	0.23	0.29	0.74	0.74	0.97	0.32	1.13	0.98	0.37	0.42	0.45	0.23	0.43
MgO	2.08	2.08	2.15	2.38	2.31	2.31	2.34	2.42	1.50	1.65	2.68	2.04	2.65	2.77	2.26	2.15	2.18	2.07	2.16
CaO	10.70	10.83	10.60	10.48	10.31	10.33	10.22	10.07	12.15	11.14	11.53	10.40	11.51	11.70	10.51	10.66	10.08	10.73	10.55
Total	100.04	100.12	100.89	100.93	100.39	99.89	99.91	100.03	100.83	101.22	100.14	99.13	100.79	100.58	99.94	99.79	99.43	99.58	99.45
Cations on the basis of 12 oxygens																			
Si	3.05	3.03	3.02	3.02	3.05	3.04	3.04	3.05	2.96	2.98	2.99	3.00	2.96	2.98	2.98	3.00	3.00	3.00	2.98
Ti	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.01	0.01	0.00	0.01	0.00	0.00	0.01	0.01	0.00	0.01	0.01
Al	1.99	1.98	1.97	1.97	1.98	1.98	1.98	1.97	1.96	1.97	2.00	2.00	2.01	1.99	1.98	1.98	1.99	1.98	2.01
Fe^{3+}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.05	0.02	0.00	0.06	0.05	0.04	0.01	0.01	0.02	0.03
Fe^{2+}	1.78	1.80	1.84	1.82	1.81	1.81	1.82	1.82	1.72	1.81	1.64	1.84	1.62	1.61	1.81	1.82	1.85	1.83	1.80
Mn	0.03	0.03	0.02	0.01	0.02	0.02	0.02	0.02	0.05	0.05	0.06	0.02	0.07	0.07	0.02	0.03	0.03	0.02	0.03
Mg	0.24	0.24	0.25	0.28	0.27	0.27	0.28	0.29	0.18	0.19	0.31	0.24	0.31	0.32	0.27	0.25	0.26	0.25	0.26
Ca	0.91	0.92	0.89	0.88	0.87	0.88	0.87	0.85	1.03	0.94	0.97	0.89	0.96	0.98	0.89	0.91	0.86	0.91	0.90
Total	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
X_{Prp}	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.10	0.06	0.06	0.10	0.08	0.10	0.11	0.09	0.08	0.09	0.08	0.09
X_{Alm}	0.60	0.60	0.61	0.61	0.61	0.61	0.61	0.61	0.58	0.61	0.55	0.61	0.55	0.54	0.60	0.60	0.62	0.61	0.60
X_{Grs}	0.31	0.31	0.30	0.29	0.29	0.29	0.29	0.29	0.35	0.31	0.32	0.30	0.32	0.33	0.30	0.30	0.29	0.30	0.30
X_{Sps}	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.03	0.02	0.01	0.01	0.01	0.01	0.01

**Total Fe as FeO*

Table 1. (continued)

Sample																			
Analysis	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Mode	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1
	←	←	←	←	←	Core	→	→	→	→	→	→	→	→	→	→	→	→	→
SiO_2	38.09	38.26	38.00	37.80	37.99	37.74	37.61	37.49	37.78	37.77	37.73	37.88	38.10	38.10	37.54	38.24	38.17	38.19	38.53
TiO_2	0.03	0.12	0.14	0.09	0.10	0.15	0.14	0.11	0.12	0.11	0.06	0.10	0.08	0.00	0.03	0.04	0.04	0.06	0.06
Al_2O_3	21.63	21.44	21.28	21.14	21.19	21.32	21.52	21.24	21.42	21.06	21.43	21.50	21.38	21.33	21.24	21.60	21.48	21.68	21.59
FeO*	24.69	24.72	28.41	28.04	28.33	27.70	28.30	27.75	27.97	27.47	28.67	26.85	25.66	25.16	25.80	25.52	25.43	24.88	25.16
MnO	0.98	1.05	0.35	0.38	0.35	0.33	0.39	0.40	0.49	0.37	0.46	0.82	0.88	0.98	1.06	1.00	0.97	0.97	0.89
MgO	2.66	2.53	2.16	2.13	2.04	2.14	2.20	2.30	2.27	2.20	2.28	2.62	2.83	2.72	2.71	2.80	2.79	2.82	2.83
CaO	12.01	11.77	10.21	10.29	10.23	10.54	10.48	10.51	10.35	10.34	10.17	11.12	11.36	11.42	11.26	11.48	11.28	11.46	11.56
Total	100.10	99.88	100.55	99.87	100.22	99.90	100.63	99.81	100.39	99.32	100.81	100.89	100.29	99.71	99.64	100.69	100.15	100.05	100.63
Cations on the basis of 12 oxygens																			
Si	2.99	3.01	3.00	3.00	3.01	2.99	2.96	2.97	2.98	3.01	2.97	2.96	2.99	3.01	2.97	2.99	3.00	3.00	3.01
Ti	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Al	2.00	1.99	1.98	1.98	1.98	1.99	2.00	1.99	1.99	1.98	1.99	1.98	1.98	1.98	1.98	1.99	1.99	2.01	1.99
Fe^{3+}	0.01	0.00	0.01	0.01	0.00	0.00	0.06	0.05	0.03	0.00	0.07	0.08	0.03	0.00	0.08	0.03	0.01	0.00	0.00
Fe^{2+}	1.61	1.63	1.87	1.85	1.88	1.83	1.80	1.79	1.81	1.83	1.82	1.68	1.65	1.65	1.62	1.64	1.66	1.63	1.64
Mn	0.07	0.07	0.02	0.03	0.02	0.02	0.03	0.03	0.03	0.02	0.03	0.05	0.06	0.07	0.07	0.07	0.06	0.06	0.06
Mg	0.31	0.30	0.25	0.25	0.24	0.25	0.26	0.27	0.27	0.26	0.27	0.31	0.33	0.32	0.32	0.33	0.33	0.33	0.33
Ca	1.01	0.99	0.86	0.88	0.87	0.90	0.88	0.89	0.87	0.88	0.86	0.93	0.95	0.97	0.95	0.96	0.95	0.96	0.97
Total	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
X_{Prp}	0.10	0.10	0.08	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.09	0.10	0.11	0.11	0.11	0.11	0.11	0.11	0.11
X_{Alm}	0.54	0.54	0.62	0.62	0.62	0.61	0.61	0.60	0.61	0.61	0.61	0.56	0.55	0.55	0.55	0.55	0.55	0.55	0.55
X_{Grs}	0.34	0.33	0.29	0.29	0.29	0.30	0.30	0.30	0.29	0.29	0.29	0.31	0.32	0.32	0.32	0.32	0.32	0.32	0.32
X_{Sps}	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02

**Total Fe as FeO*

Sample																			
Analysis	31	32	33	34	35	40	41	42	43	44	45	46	47	48	56	62	63	64	66
Mode	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1
	→	→	→	→	→	→	→	→	→	→	→	→	→	Rim	Rim	←	←	←	←
SiO_2	38.22	37.97	38.35	38.02	37.95	38.01	38.08	37.81	37.88	37.83	38.02	38.13	37.98	38.18	37.51	37.68	37.61	37.99	37.35
TiO_2	0.04	0.00	0.03	0.11	0.06	0.11	0.11	0.08	0.06	0.02	0.08	0.00	0.08	0.05	0.14	0.10	0.11	0.17	0.18
Al_2O_3	21.86	21.61	21.42	21.15	21.30	21.32	21.31	21.42	21.46	21.62	21.49	21.66	21.44	21.50	21.01	21.22	21.44	21.35	21.40
FeO*	26.54	27.00	27.57	28.22	28.02	28.37	27.75	28.64	26.83	26.81	25.80	26.22	25.60	25.37	27.91	27.86	28.14	27.70	27.89
MnO	0.78	0.59	0.50	0.42	0.35	0.29	0.21	0.35	0.64	0.67	0.99	1.06	1.00	1.13	0.52	0.35	0.49	0.49	0.43
MgO	2.75	2.66	2.29	2.13	2.14	1.96	1.93	2.16	2.58	2.74	2.81	2.81	2.68	2.72	2.57	1.82	1.85	1.79	1.69
CaO	11.09	10.97	10.55	10.32	10.71	10.54	10.75	10.29	10.81	10.97	11.13	10.96	11.65	11.58	9.94	10.35	10.84	11.19	10.93
Total	101.27	100.80	100.72	100.37	100.53	100.60	100.13	100.74	100.26	100.66	100.32	100.83	100.43	100.53	99.60	99.39	100.49	100.68	99.87
Cations on the basis of 12 oxygens																			
Si	2.97	2.97	3.01	3.00	2.99	3.00	3.01	2.98	2.98	2.96	2.98	2.98	2.98	2.99	2.98	3.01	2.97	2.99	2.97
Ti	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01
Al	2.00	1.99	1.98	1.97	1.98	1.98	1.99	1.99	1.99	2.00	1.99	1.99	1.98	1.98	1.97	2.00	2.00	1.98	2.01
Fe^{3+}	0.04	0.06	0.00	0.01	0.03	0.01	0.00	0.05	0.04	0.08	0.03	0.05	0.05	0.03	0.05	0.00	0.05	0.01	0.03
Fe^{2+}	1.68	1.70	1.81	1.86	1.82	1.86	1.84	1.84	1.73	1.68	1.66	1.66	1.62	1.63	1.80	1.86	1.81	1.82	1.82
Mn	0.05	0.04	0.03	0.03	0.02	0.02	0.01	0.02	0.04	0.04	0.07	0.07	0.07	0.07	0.04	0.02	0.03	0.03	0.03
Mg	0.32	0.31	0.27	0.25	0.25	0.23	0.23	0.25	0.30	0.32	0.33	0.33	0.31	0.32	0.30	0.22	0.22	0.21	0.20
Ca	0.92	0.92	0.89	0.87	0.90	0.89	0.91	0.87	0.91	0.92	0.94	0.92	0.98	0.97	0.85	0.89	0.92	0.95	0.93
Total	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
X_{Prp}	0.11	0.10	0.09	0.08	0.08	0.08	0.08	0.08	0.10	0.11	0.11	0.11	0.11	0.11	0.10	0.07	0.07	0.07	0.07
X_{Alm}	0.57	0.57	0.60	0.62	0.61	0.62	0.61	0.62	0.58	0.57	0.55	0.56	0.54	0.54	0.60	0.62	0.61	0.60	0.61
X_{Grs}	0.31	0.31	0.30	0.29	0.30	0.30	0.30	0.29	0.31	0.31	0.31	0.31	0.33	0.32	0.28	0.30	0.31	0.31	0.31
X_{Sps}	0.02	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01

**Total Fe as FeO*

Sample	SS 03					SS 18				1405									
Analysis	72	97	80	85	118	2	5	12	20	3	4	5	6	8	9	10	11	13	14
Mode	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 1	Grt 3	Grt 3	Grt 3	Grt 3	Grt 3	Grt 3	Grt 3	Grt 3	Grt 3	Grt 3
	←	Core																	
SiO_2	37.56	37.64	37.84	37.57	36.93	38.23	38.21	38.16	38.23	37.47	37.32	37.45	37.33	37.41	37.17	37.39	37.21	37.31	37.18
TiO_2	0.14	0.13	0.06	0.10	0.03	0.09	0.11	0.06	0.07	0.05	0.05	0.04	0.08	0.11	0.12	0.09	0.11	0.07	0.10
Al_2O_3	21.11	21.20	21.65	24.33	21.32	21.86	21.74	21.82	21.47	21.13	20.96	21.20	21.10	20.89	21.06	20.87	20.85	20.83	20.77
FeO*	26.88	26.77	29.03	20.94	29.08	25.76	25.33	25.20	25.51	29.44	29.40	29.46	29.88	30.31	30.22	30.34	30.50	30.28	30.30
MnO	0.38	0.35	1.00	0.55	1.26	1.08	1.63	1.10	1.33	0.45	0.40	0.64	1.46	1.36	1.29	1.26	1.31	1.27	1.43
MgO	1.60	1.61	2.58	1.03	2.49	3.27	2.86	3.31	3.22	1.64	1.55	1.56	1.78	1.53	1.34	1.37	1.32	1.28	1.30
CaO	11.44	11.65	8.16	15.81	7.99	11.04	11.04	10.72	10.32	9.57	9.32	9.40	8.49	8.62	8.76	8.40	8.32	8.37	8.24
Total	99.12	99.35	100.32	100.32	99.09	101.33	100.92	100.36	100.15	99.75	99.00	99.75	100.13	100.21	99.95	99.72	99.61	99.42	99.31
Cations on the basis of 12 oxygens																			
Si	3.00	3.00	2.99	2.92	2.96	2.96	2.98	2.98	3.00	2.99	3.01	2.99	2.98	2.99	2.98	3.01	3.00	3.01	3.00
Ti	0.01	0.01	0.00	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.00	0.01
Al	1.99	1.99	2.02	2.23	2.02	2.00	2.00	2.01	1.99	1.99	1.99	2.00	1.98	1.97	1.99	1.98	1.98	1.98	1.98
Fe^{3+}	0.00	0.00	0.00	0.00	0.06	0.07	0.03	0.02	0.00	0.02	0.00	0.01	0.05	0.04	0.04	0.00	0.02	0.00	0.01
Fe^{2+}	1.80	1.79	1.92	1.36	1.89	1.60	1.62	1.63	1.67	1.95	1.98	1.96	1.95	1.98	1.99	2.04	2.04	2.04	2.04
Mn	0.03	0.02	0.07	0.04	0.09	0.07	0.11	0.07	0.09	0.03	0.03	0.04	0.10	0.09	0.09	0.09	0.09	0.09	0.10
Mg	0.19	0.19	0.30	0.12	0.30	0.38	0.33	0.39	0.38	0.20	0.19	0.19	0.21	0.18	0.16	0.16	0.16	0.15	0.16
Ca	0.98	1.00	0.69	1.32	0.69	0.92	0.92	0.90	0.87	0.82	0.80	0.80	0.73	0.74	0.75	0.72	0.72	0.72	0.71
Total	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
X_{Prp}	0.06	0.06	0.10	0.04	0.10	0.13	0.11	0.13	0.13	0.07	0.06	0.06	0.07	0.06	0.05	0.05	0.05	0.05	0.05
X_{Alm}	0.60	0.60	0.64	0.48	0.64	0.54	0.54	0.55	0.56	0.65	0.66	0.65	0.65	0.66	0.67	0.68	0.68	0.68	0.68
X_{Grs}	0.33	0.33	0.23	0.46	0.23	0.31	0.31	0.30	0.29	0.27	0.27	0.27	0.24	0.25	0.25	0.24	0.24	0.24	0.24
X_{Sps}	0.01	0.01	0.02	0.01	0.03	0.02	0.04	0.02	0.03	0.01	0.01	0.01	0.03	0.03	0.03	0.03	0.03	0.03	0.03

**Total Fe as FeO*

Table 1. (continued)

Sample	1405																		
Analysis	15	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
Mode	Grt 3	Grt 3	Grt 3	Grt 3	Grt 3	Grt 3	Grt 3	Grt 3	Grt 3	Grt 3	Grt 3	Grt 3	Grt 3	Grt 3	Grt 3	Grt 3	Grt 3	Grt 3	Grt 3
SiO_2	37.50	37.19	37.28	37.23	36.95	37.60	37.01	37.21	37.33	37.16	37.21	37.34	37.46	37.38	37.41	37.35	37.48	37.42	37.41
TiO_2	0.11	0.06	0.13	0.09	0.14	0.10	0.05	0.13	0.12	0.10	0.14	0.09	0.10	0.08	0.10	0.11	0.04	0.04	0.07
Al_2O_3	21.04	20.75	20.87	20.95	20.91	20.85	20.94	20.92	20.81	20.85	21.01	21.00	20.95	21.13	20.87	20.99	20.80	21.05	21.12
FeO*	29.73	30.28	31.22	30.86	30.33	30.92	30.48	30.21	29.90	30.41	29.81	30.50	29.80	30.04	30.44	30.01	29.57	27.94	25.68
MnO	1.35	1.44	1.60	1.54	1.45	1.24	1.44	1.35	1.19	1.27	1.42	1.20	1.29	1.39	1.43	1.39	1.64	2.30	2.87
MgO	1.22	1.10	1.20	1.05	1.09	1.10	1.07	1.02	1.05	1.09	1.07	1.12	1.16	1.21	1.25	1.35	1.56	1.38	1.48
CaO	8.69	8.28	7.91	8.34	8.27	8.38	8.69	9.18	8.77	8.80	8.81	8.70	8.80	8.63	8.52	8.77	8.12	9.06	10.77
Total	99.64	99.10	100.20	100.05	99.13	100.19	99.67	100.02	99.16	99.67	99.46	99.95	99.56	99.85	100.01	99.98	99.20	99.19	99.40
Cations on the basis of 12 oxygens																			
Si	3.01	3.01	2.99	2.99	2.99	3.01	2.98	2.98	3.02	2.99	3.00	3.00	3.01	3.00	3.00	2.99	3.02	3.01	2.99
Ti	0.01	0.00	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.00	0.00	0.00
Al	1.99	1.98	1.97	1.98	2.00	1.97	1.99	1.98	1.98	1.98	2.00	1.99	1.99	2.00	1.97	1.98	1.98	2.00	1.99
Fe^{3+}	0.00	0.00	0.03	0.03	0.00	0.00	0.05	0.04	0.00	0.03	0.00	0.01	0.00	0.00	0.01	0.02	0.00	0.00	0.02
Fe^{2+}	2.00	2.05	2.07	2.05	2.05	2.07	2.01	1.99	2.02	2.02	2.01	2.04	2.01	2.02	2.03	1.99	2.00	1.88	1.70
Mn	0.09	0.10	0.11	0.10	0.10	0.08	0.10	0.09	0.08	0.09	0.10	0.08	0.09	0.09	0.10	0.09	0.11	0.16	0.19
Mg	0.15	0.13	0.14	0.13	0.13	0.13	0.13	0.12	0.13	0.13	0.13	0.13	0.14	0.14	0.15	0.16	0.19	0.17	0.18
Ca	0.75	0.72	0.68	0.72	0.72	0.72	0.75	0.79	0.76	0.76	0.76	0.75	0.76	0.74	0.73	0.75	0.70	0.78	0.92
Total	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
X_{Prp}	0.05	0.04	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.06	0.06	0.06
X_{Alm}	0.67	0.68	0.69	0.68	0.68	0.69	0.67	0.66	0.68	0.67	0.67	0.68	0.67	0.67	0.67	0.66	0.67	0.63	0.57
X_{Grs}	0.25	0.24	0.23	0.24	0.24	0.24	0.25	0.26	0.25	0.25	0.25	0.25	0.25	0.25	0.24	0.25	0.23	0.26	0.31
X_{Sps}	0.03	0.03	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.05	0.06

**Total Fe as FeO*

Sample	1405																		
Analysis	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	52	53	54
Mode	Grt 3	Grt 3	Grt 3	Grt 3	Grt 3	Grt 3	Grt 3	Grt 3	Grt 3	Grt 3	Grt 3	Grt 3	Grt 3	Grt 3	Grt 3	Grt 3	Grt 3	Grt 3	Grt 3
SiO_2	37.91	37.72	37.80	37.91	37.82	37.82	37.91	37.86	37.97	37.92	37.83	38.12	37.69	38.10	38.06	37.93	37.82	37.84	37.85
TiO_2	0.06	0.04	0.05	0.08	0.09	0.06	0.08	0.17	0.10	0.16	0.15	0.13	0.10	0.08	0.10	0.03	0.06	0.04	0.08
Al_2O_3	21.40	21.39	21.22	21.22	21.21	21.14	21.34	21.12	21.18	21.25	21.28	21.35	21.23	21.55	21.29	21.39	21.40	21.27	21.29
FeO*	25.86	26.21	26.38	25.21	25.84	26.18	26.14	24.81	25.21	24.98	24.88	25.21	25.75	25.15	25.40	26.09	26.46	26.11	26.25
MnO	2.34	2.07	1.92	1.61	1.19	1.24	1.49	1.39	1.44	1.23	1.13	1.20	1.22	0.99	0.99	0.99	0.86	0.87	0.76
MgO	1.54	1.62	1.79	1.70	1.65	1.79	1.93	1.78	1.98	2.14	2.23	2.24	2.42	2.54	2.97	2.93	2.59	2.54	2.62
CaO	10.79	11.11	10.92	11.77	12.06	11.47	11.27	12.36	11.82	11.78	11.64	11.84	10.86	11.01	10.38	10.03	11.01	10.88	10.88
Total	99.90	100.16	100.07	99.48	99.85	99.70	100.16	99.49	99.69	99.46	99.13	100.08	99.27	99.43	99.19	99.40	100.20	99.55	99.72
Cations on the basis of 12 oxygens																			
Si	3.01	2.99	3.00	3.02	3.00	3.00	3.00	3.01	3.01	3.01	3.01	3.00	3.00	3.02	3.02	3.01	2.98	3.00	2.99
Ti	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00
Al	2.00	2.00	1.98	1.99	1.98	1.98	1.99	1.98	1.98	1.99	1.99	1.98	1.99	2.01	1.99	2.00	1.99	1.99	1.98
Fe^{3+}	0.00	0.02	0.02	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.01	0.02
Fe^{2+}	1.72	1.72	1.73	1.68	1.71	1.74	1.72	1.65	1.67	1.66	1.65	1.66	1.71	1.67	1.68	1.73	1.69	1.72	1.72
Mn	0.16	0.14	0.13	0.11	0.08	0.08	0.10	0.09	0.10	0.08	0.08	0.08	0.08	0.07	0.07	0.07	0.06	0.06	0.05
Mg	0.18	0.19	0.21	0.20	0.19	0.21	0.23	0.21	0.23	0.25	0.26	0.26	0.29	0.30	0.35	0.35	0.30	0.30	0.31
Ca	0.92	0.94	0.93	1.00	1.02	0.98	0.95	1.05	1.00	1.00	0.99	1.00	0.93	0.93	0.88	0.85	0.93	0.92	0.92
Total	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
X_{Prp}	0.06	0.06	0.07	0.07	0.06	0.07	0.08	0.07	0.08	0.08	0.09	0.09	0.10	0.10	0.12	0.12	0.10	0.10	0.10
X_{Alm}	0.58	0.57	0.58	0.56	0.57	0.58	0.57	0.55	0.56	0.55	0.55	0.55	0.57	0.56	0.56	0.58	0.57	0.57	0.57
X_{Grs}	0.31	0.32	0.31	0.34	0.34	0.32	0.32	0.35	0.33	0.33	0.33	0.33	0.31	0.31	0.30	0.28	0.31	0.31	0.31
X_{Sps}	0.05	0.05	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02

**Total Fe as FeO*

Sample	1783																		
Analysis	55	56	57	58	59	60	61	1	2	3	4	5	6	7	8	9	10	11	12
Mode	Grt 3	Grt 3	Grt 3	Grt 3	Grt 3	Grt 3	Grt 3	Grt 2	Grt 2	Grt 2	Grt 2	Grt 2	Grt 2	Grt 2	Grt 2	Grt 2	Grt 2	Grt 2	Grt 2
								Rim	←	←	←	←	←	←	←	←	←	←	←
SiO_2	37.90	38.01	38.14	38.14	38.02	38.16	38.28	37.73	37.93	38.18	37.97	37.94	38.47	38.02	37.51	37.73	37.55	37.95	37.90
TiO_2	0.02	0.11	0.04	0.06	0.06	0.10	0.09	0.07	0.03	0.09	0.06	0.04	0.08	0.06	0.11	0.10	0.11	0.09	0.21
Al_2O_3	21.35	21.39	21.37	21.29	21.42	21.70	21.59	21.46	21.50	21.56	21.49	21.48	21.57	21.54	21.38	21.42	21.55	21.69	21.52
FeO*	25.82	26.04	26.08	26.45	26.24	26.36	26.51	26.46	26.56	26.40	25.62	25.91	26.32	26.99	26.57	25.90	25.59	26.10	26.40
MnO	0.76	0.74	0.61	0.70	0.66	0.56	0.54	0.59	0.36	0.36	0.41	0.33	0.46	0.48	0.61	0.59	0.66	1.01	0.60
MgO	2.67	2.59	2.72	2.70	2.80	2.81	3.08	3.28	3.21	3.05	3.10	3.08	2.97	2.81	2.58	2.62	2.64	2.67	2.30
CaO	10.65	10.94	10.63	10.66	10.63	10.47	10.63	9.74	10.16	10.23	10.35	10.71	10.31	10.54	10.81	11.07	10.93	11.28	11.19
Total	99.16	99.81	99.58	100.00	99.84	100.16	100.71	99.34	99.73	99.87	99.00	99.50	100.18	100.43	99.58	99.43	99.02	100.79	100.13
Cations on the basis of 12 oxygens																			
Si	3.01	3.00	3.02	3.01	3.00	3.00	2.99	2.99	2.99	3.01	3.01	3.00	3.02	2.98	2.97	2.99	2.99	2.97	2.99
Ti	0.00	0.01	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01
Al	2.00	1.99	1.99	1.98	1.99	2.01	1.99	2.00	2.00	2.00	2.01	2.00	2.00	1.99	2.00	2.00	2.02	2.00	2.00
Fe^{3+}	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.02	0.00	0.00	0.00	0.00	0.03	0.05	0.01	0.00	0.06	0.00
Fe^{2+}	1.72	1.72	1.73	1.74	1.73	1.73	1.71	1.74	1.73	1.74	1.70	1.71	1.73	1.74	1.71	1.71	1.70	1.65	1.74
Mn	0.05	0.05	0.04	0.05	0.04	0.04	0.04	0.04	0.02	0.02	0.03	0.02	0.03	0.03	0.04	0.04	0.04	0.07	0.04
Mg	0.32	0.30	0.32	0.32	0.33	0.33	0.36	0.39	0.38	0.36	0.37	0.36	0.35	0.33	0.31	0.31	0.31	0.31	0.27
Ca	0.91	0.93	0.90	0.90	0.90	0.88	0.89	0.83	0.86	0.86	0.88	0.91	0.87	0.89	0.92	0.94	0.93	0.94	0.95
Total	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
X_{Prp}	0.11	0.10	0.11	0.11	0.11	0.11	0.12	0.13	0.13	0.12	0.12	0.12	0.12	0.11	0.10	0.10	0.10	0.10	0.09
X_{Alm}	0.57	0.57	0.58	0.58	0.58	0.58	0.57	0.58	0.58	0.58	0.57	0.57	0.58	0.58	0.58	0.57	0.57	0.55	0.58
X_{Grs}	0.30	0.31	0.30	0.30	0.30	0.30	0.30	0.28	0.29	0.29	0.30	0.30	0.29	0.30	0.31	0.31	0.31	0.32	0.32
X_{Sps}	0.02	0.02	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01

**Total Fe as FeO*

Table 1. (continued)

Sample	1783																		
Analysis	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Mode	Grt 2	Grt 2	Grt 2	Grt 2	Grt 2	Grt 2	Grt 2	Grt 2	Grt 2	Grt 2	Grt 2	Grt 2	Grt 2	Grt 2	Grt 2	Grt 2	Grt 2	Grt 2	Grt 2
	←	←	←	←	←	←	←	←	←	←	←	←	←	←	←	←	←	←	←
SiO_2	37.50	37.68	37.76	37.45	37.30	37.47	37.37	37.30	37.49	37.48	37.42	37.60	37.94	37.60	37.73	37.77	37.65	37.63	38.02
TiO_2	0.08	0.04	0.05	0.02	0.05	0.08	0.02	0.03	0.06	0.02	0.00	0.00	0.05	0.01	0.03	0.03	0.05	0.05	0.02
Al_2O_3	21.29	21.34	21.32	21.43	21.21	21.25	21.31	21.18	21.30	21.17	21.35	21.22	21.26	21.12	21.31	21.38	21.17	21.37	21.36
FeO*	26.10	26.45	26.99	26.75	26.98	26.66	25.87	26.33	26.26	25.51	25.13	26.74	27.70	27.79	28.35	27.88	28.09	28.03	27.57
MnO	0.65	0.54	0.73	1.19	2.10	2.06	3.20	3.45	3.65	3.84	4.89	3.33	0.83	0.61	0.81	0.92	0.89	0.92	0.92
MgO	2.09	2.06	1.55	1.44	1.33	1.35	1.25	1.25	1.18	1.26	1.65	1.80	2.44	2.50	2.76	3.02	2.91	2.95	2.91
CaO	11.43	11.39	11.44	11.35	11.28	11.25	10.45	10.59	10.67	10.53	9.17	10.02	10.04	9.74	9.08	9.05	9.16	9.34	9.14
Total	99.13	99.49	99.83	99.64	100.26	100.11	99.47	100.13	100.61	99.80	99.61	100.70	100.25	99.37	100.06	100.06	99.94	100.30	99.93
Cations on the basis of 12 oxygens																			
Si	2.99	2.99	3.00	2.98	2.96	2.98	2.99	2.97	2.97	2.99	2.99	2.97	3.00	3.00	2.99	2.98	2.98	2.97	3.01
Ti	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Al	2.00	2.00	2.00	2.01	1.99	1.99	2.01	1.99	1.99	1.99	2.01	1.98	1.98	1.98	1.99	1.99	1.98	1.99	1.99
Fe^{3+}	0.01	0.01	0.00	0.02	0.08	0.04	0.00	0.07	0.06	0.02	0.00	0.08	0.02	0.02	0.04	0.04	0.06	0.08	0.00
Fe^{2+}	1.73	1.75	1.79	1.76	1.71	1.73	1.73	1.69	1.69	1.68	1.68	1.69	1.81	1.83	1.84	1.80	1.80	1.77	1.82
Mn	0.04	0.04	0.05	0.08	0.14	0.14	0.22	0.23	0.24	0.26	0.33	0.22	0.06	0.04	0.05	0.06	0.06	0.06	0.06
Mg	0.25	0.24	0.18	0.17	0.16	0.16	0.15	0.15	0.14	0.15	0.20	0.21	0.29	0.30	0.33	0.36	0.34	0.35	0.34
Ca	0.98	0.97	0.97	0.97	0.96	0.96	0.90	0.90	0.91	0.90	0.79	0.85	0.85	0.83	0.77	0.77	0.78	0.79	0.77
Total	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
X_{Prp}	0.08	0.08	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.07	0.07	0.10	0.10	0.11	0.12	0.12	0.12	0.11
X_{Alm}	0.58	0.58	0.60	0.59	0.58	0.58	0.58	0.57	0.57	0.56	0.56	0.57	0.60	0.61	0.62	0.60	0.60	0.60	0.61
X_{Grs}	0.33	0.32	0.32	0.32	0.32	0.32	0.30	0.30	0.30	0.30	0.26	0.29	0.28	0.28	0.26	0.26	0.26	0.27	0.26
X_{Sps}	0.01	0.01	0.02	0.03	0.05	0.05	0.07	0.08	0.08	0.09	0.11	0.08	0.02	0.01	0.02	0.02	0.02	0.02	0.02

**Total Fe as FeO*

Sample	1783																		
Analysis	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
Mode	Grt 2	Grt 2	Grt 2	Grt 2	Grt 2	Grt 2	Grt 2	Grt 2	Grt 2	Grt 2	Grt 2	Grt 2	Grt 2	Grt 2	Grt 2	Grt 2	Grt 2	Grt 2	Grt 2
	←	←	←	←	←	←	←	←	←	←	←	←	←	←	←	←	←	←	←
SiO_2	37.75	37.41	37.51	37.67	37.85	37.81	37.38	37.15	37.13	37.41	37.36	37.38	37.31	37.11	37.03	37.32	37.32	37.48	37.21
TiO_2	0.05	0.04	0.11	0.08	0.10	0.03	0.09	0.02	0.02	0.05	0.07	0.08	0.12	0.17	0.10	0.14	0.25	0.53	0.35
Al_2O_3	21.26	21.27	20.87	21.11	21.29	21.19	20.96	20.91	20.92	20.85	20.51	20.49	20.35	20.56	20.57	20.51	20.59	20.83	20.65
FeO*	28.00	27.77	27.88	27.51	28.22	28.40	28.62	29.35	29.79	30.65	29.70	30.23	30.57	30.61	29.52	29.58	28.42	27.13	25.75
MnO	0.95	0.94	0.93	0.91	0.97	0.98	1.13	1.08	1.22	1.48	1.87	1.88	1.86	2.11	2.16	2.26	2.43	3.21	4.43
MgO	2.90	2.81	2.71	2.79	2.70	2.71	2.40	2.45	2.26	1.90	1.68	1.65	1.61	1.63	1.88	1.95	1.99	2.22	1.80
CaO	9.28	9.57	9.61	9.10	8.96	9.10	8.85	8.82	8.30	8.63	8.28	8.32	8.08	8.10	7.90	8.14	8.54	9.38	9.18
Total	100.19	99.81	99.62	99.17	100.09	100.21	99.43	99.78	99.62	100.97	99.46	100.02	99.89	100.29	99.17	99.88	99.55	100.78	99.37
Cations on the basis of 12 oxygens																			
Si	2.98	2.96	2.98	3.00	3.00	2.99	2.99	2.96	2.97	2.96	3.01	3.00	3.00	2.97	2.99	2.99	2.99	2.96	2.99
Ti	0.00	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.02	0.03	0.02
Al	1.98	1.99	1.96	1.98	1.99	1.97	1.97	1.96	1.97	1.95	1.95	1.93	1.93	1.94	1.96	1.94	1.95	1.94	1.95
Fe^{3+}	0.06	0.08	0.07	0.00	0.01	0.04	0.04	0.11	0.08	0.12	0.03	0.06	0.06	0.10	0.05	0.07	0.04	0.07	0.03
Fe^{2+}	1.79	1.76	1.79	1.83	1.86	1.84	1.87	1.85	1.91	1.91	1.97	1.96	1.99	1.95	1.94	1.91	1.87	1.72	1.70
Mn	0.06	0.06	0.06	0.06	0.07	0.07	0.08	0.07	0.08	0.10	0.13	0.13	0.13	0.14	0.15	0.15	0.17	0.22	0.30
Mg	0.34	0.33	0.32	0.33	0.32	0.32	0.29	0.29	0.27	0.22	0.20	0.20	0.19	0.19	0.23	0.23	0.24	0.26	0.22
Ca	0.79	0.81	0.82	0.78	0.76	0.77	0.76	0.75	0.71	0.73	0.71	0.71	0.70	0.69	0.68	0.70	0.73	0.79	0.79
Total	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
X_{Prp}	0.11	0.11	0.11	0.11	0.11	0.11	0.10	0.10	0.09	0.08	0.07	0.07	0.06	0.07	0.08	0.08	0.08	0.09	0.07
X_{Alm}	0.60	0.59	0.60	0.61	0.62	0.61	0.63	0.62	0.64	0.64	0.65	0.65	0.66	0.65	0.65	0.64	0.62	0.58	0.57
X_{Grs}	0.26	0.27	0.27	0.26	0.25	0.26	0.25	0.25	0.24	0.25	0.24	0.24	0.23	0.23	0.23	0.23	0.24	0.27	0.26
X_{Sps}	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.03	0.03	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.07	0.10

**Total Fe as FeO*

Sample	1783							TS 30-32											
Analysis	51	13	6	3	5	2	9	24	25	32	33	36	4	5	6	19	20	30	31
Mode	Grt 2	Grt 2	Grt 2	Grt 2	Grt 2	Grt 2	Grt 2	Grt 2	Grt 2	Grt 2	Grt 2	Grt 2	Grt 2	Grt 2	Grt 2	Grt 2	Grt 2	Grt 2	Grt 2
	←	←	←	←	←	←	Core												
SiO_2	37.26	37.88	37.54	37.06	37.31	37.45	37.32	37.09	37.45	37.75	37.85	37.95	37.54	37.34	36.88	37.39	37.48	38.20	38.03
TiO_2	0.24	0.25	0.26	0.27	0.19	0.30	0.23	0.07	0.00	0.03	0.04	0.06	0.03	0.06	0.05	0.10	0.03	0.01	0.05
Al_2O_3	20.49	20.78	20.61	20.44	20.81	20.51	20.56	21.14	21.67	21.38	21.42	21.54	21.69	21.68	21.26	20.74	21.02	21.43	21.65
FeO*	24.81	23.44	22.98	22.98	22.12	22.45	22.16	24.66	26.05	27.04	26.45	26.70	25.69	25.54	31.23	29.16	29.74	26.61	26.06
MnO	5.72	6.60	7.90	8.19	8.70	9.27	9.51	4.73	1.33	0.75	0.74	0.72	0.47	0.67	0.51	1.09	1.18	0.68	1.01
MgO	1.68	1.46	1.47	1.27	1.32	1.23	1.11	1.25	3.20	1.67	1.89	1.66	2.42	2.79	1.98	2.25	2.22	2.97	2.92
CaO	9.05	9.83	8.95	9.24	9.19	9.07	8.89	10.67	10.22	11.79	11.83	12.00	11.80	11.73	7.44	9.09	8.82	10.43	10.74
Total	99.26	100.22	99.71	99.44	99.64	100.29	99.78	99.61	99.92	100.39	100.22	100.61	99.64	99.80	99.36	99.82	100.49	100.32	100.48
Cations on the basis of 12 oxygens																			
Si	3.00	3.02	3.01	2.99	2.99	2.99	3.00	2.97	2.95	2.98	2.99	2.99	2.97	2.94	2.97	2.98	2.97	3.00	2.98
Ti	0.01	0.01	0.02	0.02	0.01	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Al	1.94	1.95	1.95	1.94	1.97	1.93	1.95	1.99	2.01	1.99	1.99	2.00	2.02	2.01	2.02	1.95	1.96	1.98	2.00
Fe^{3+}	0.03	0.00	0.00	0.05	0.02	0.04	0.02	0.06	0.09	0.05	0.03	0.02	0.04	0.10	0.04	0.08	0.09	0.02	0.03
Fe^{2+}	1.64	1.56	1.54	1.49	1.47	1.46	1.47	1.59	1.62	1.74	1.72	1.74	1.65	1.58	2.06	1.87	1.88	1.73	1.67
Mn	0.39	0.45	0.54	0.56	0.59	0.63	0.65	0.32	0.09	0.05	0.05	0.05	0.03	0.04	0.03	0.07	0.08	0.05	0.07
Mg	0.20	0.17	0.18	0.15	0.16	0.15	0.13	0.15	0.38	0.20	0.22	0.19	0.28	0.33	0.24	0.27	0.26	0.35	0.34
Ca	0.78	0.84	0.77	0.80	0.79	0.78	0.77	0.91	0.86	1.00	1.00	1.01	1.00	0.99	0.64	0.78	0.75	0.88	0.90
Total	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
X_{Prp}	0.07	0.06	0.06	0.05	0.05	0.05	0.04	0.05	0.13	0.07	0.07	0.06	0.10	0.11	0.08	0.09	0.09	0.12	0.11
X_{Alm}	0.54	0.52	0.51	0.50	0.49	0.48	0.49	0.53	0.55	0.58	0.57	0.58	0.56	0.54	0.69	0.63	0.63	0.58	0.56
X_{Grs}	0.26	0.28	0.25	0.27	0.26	0.26	0.25	0.31	0.29	0.33	0.33	0.34	0.34	0.34	0.22	0.26	0.25	0.29	0.30
X_{Sps}	0.13	0.15	0.18	0.19	0.20	0.21	0.21	0.11	0.03	0.02	0.02	0.02	0.01	0.02	0.01	0.02	0.03	0.02	0.02

**Total Fe as FeO*