## Abstract

The chemical compositions of constituent minerals of metamorphic rocks of the area around Lützow-Holm Bay in Antarctica are described along with their optic properties. The mineralogy and paragenesis of metamorphic rocks are interpreted as that the metamorphic rocks in this terrane belong to the granulite facies.

## INTRODUCTION

The first Japanese Antarctic Research Expedition was organized for international collaboration during the I. G. Y. (1958-1959). Subsequently, the first and fourth wintering teams surveyed the geology of the bedrock area around Lützow-Holm Bay. The geological structure of this area has been described by TATSUMI and KIKUCHI (1959), and by KIZAKI (1962). Age determination of rock-forming minerals was made by NICHOLAYSON, BUERGER, TATSUMI and AHRENS (1961), and SAITO, TATSUMI and SATO (1961).

In this paper, the chemical compositions of some rock-forming minerals from the metamorphic rocks of this area are presented, together with the petrography of the host rocks.

## OUTLINE OF GEOLOGY AND PETROGRAPHY

The bedrocks of this area are metamorphic rocks and granites. The metamorphic rocks are classified into the following five groups:

1) Ultrabasic and basic granulites.
2) Pyroxene gneiss.
3) Garnet gneiss.
4) Marble.
5) Quartzite.

Among these five rock types, pyroxene and garnet gneisses are predominant. Basic and ultrabasic granulites occur as lenses in these gneisses. It is probable that the metamorphic rocks of this area were derived from a sequence of rocks consisting dominantly of shale and andesite, containing intercalated beds of ultrabasic and basic rocks, limestone and chert. Contact between the pyroxene and garnet gneisses and the basic granulites is usually concordant to the schistosity of the former.

The age of metamorphism, according to SAITO, TATSUMI and SATO (1961), is 470 million years as estimated from the average isotopic U-Pb age of euxenite from a granite pegmatite. NICHOLAYSON, BUERGER, TATSUMI and AHRENS (1961) have given 500 million years from the Rb-Sr ages of biotite from granite pegmatites and a basic granulite.

Mineral assemblages of the principal rock types are listed below :

***1)* Ultrabasic and basic granulites**

a. Clinopyroxene+hornblende+plagioclase+potasssium feldspar ±quartz. (Here " ± " means "present or absent".)
b. Clinopyroxene+orthopyroxene+hornblende+plagioclase+potassium feldspar ±quartz.
c. Clinopyroxene+orthopyroxene+garnet.
d. Clinopyroxene+orthopyroxene+garnet+plagioclase.
e. Clinopyroxene+orthopyroxene+garnet+hornblende+plagioclase.
f. Clinopyroxene+orthopyroxene+hornblende+plagioclase+potassium feldspar ±quartz.

Among 104 thin sections of basic granulites, 43 contain biotite, 15 contain garnet and only 28 contain quartz. Assemblage of diopside+garnet was observed in 6 samples which are free from quartz, and assemblage of hypersthene + plagioclase is quite common. This suggests that assemblage of clinopyroxene+garnet is stable in the terranes of granulite facies and that this assemblage does not serve as a criterion for distinguishing the granulite from eclogite facies, unless detailed chemical environments are known.

Assemblage of potassium feldspar+orthopyroxene+garnet, which is chemically equivalent to $TiO_2$-free biotite, has not been observed.

***2)* Pyroxene gneisses**

a. Clinopyroxene+orthopyroxene+hornblende+plagioclase+biotite ±quartz.
b. Clinopyroxene + hornblende + biotite + plagioclase + potassium feldspar ± quartz.
c. Orthopyroxene + hornblende + biotite + plagioclase + potassium feldspar ± quartz.

Biotite occurs in most of the pyroxene gneisses, although its amount is subordinate. Pyroxene-free gneisses with andesitic compositions also occur in some parts of the area. Table 1 lists optical properties of the constituent nimerals of the pyroxene gneisses.

***3)* Garnet gneisses**

a. Garnet+biotite+plagioclase+potassium feldspar+quartz.
b. Garnet+plagioclase+potassium feldspar+quartz.

Garnet-free pelitic gneiss with assemblage of biotite+plagioclase+potassium feldspar+quartz are often associated with garnet-bearing pelitic gneiss.

***4)* Marble**

a. Forsterite+diopside+pargasite.
b. Forsterite+diopside+calcite.
c. Diopside+pargasite+scapolite.
d. Pargasite+phlogopite+scapolite+calcite.
e. Phlogopite+spinel+calcite.

**5) *Quartzite***

Quartzite in this region consists almost entirely of quartz with a minor amount of plagioclase.

## HOST ROCKS OF ANALYZED MINERALS

Chemical analyses were made for 3 rocks and 16 rock-forming minerals. Chemical compositions of the analyzed rocks are listed in Table 2. The host rocks of the analyzed minerals are described below.

***Ultrabasic and basic granulites***

***Specimen JARE 57110905:*** Hypersthene-hornblende-garnet rock from Skarvnes, containing subordinate green spinel, ilmenite, pyrite and pyrrhotite. The whole rock (No. 3 in Table 2) and the garnet (No. 2 in Table 8) were analyzed.

***Specimen JARE 57012501:*** Pyroxenite from Ongul Island consisting almost entirely of diopside and bronzite. The diopside (No. 1 in Table 5) and bronzite (No. 1 in Table 3) were analyzed.

***Specimen JARE 57020905:*** Basic granulite from Langhovde. The rock consists of hypersthene, salite, hornblende and plagioclase. The hypersthene (No. 3 in Table 3) and hornblende (No. 3 in Table 6) were analyzed.

***Pyroxene gneiss***

***Specimen JARE 57110802:*** Pyroxene gneiss from Skarvnes. The rock consists of hypersthene, salite, hornblende, biotite, andesine, potassium feldspar (perthite) and subordinate apatite, ilmenite, pyrrhotite and pyrite. The whole rock (No. 1 in Table 2) and constituent hypersthene (No. 5 in Table 3), salite (No. 2 in Table 5), hornblende (No. 2 in Table 6) and biotite (No. 3 in Table 9) were analyzed.

***Specimen JARE 57112402:*** Pyroxene gneiss from Langhovde. The rock is composed of hypersthene, hornblende, salite, potassium feldspar and andesine, with subordinate apatite, ilmenite, pyrrhotite and pyrite. The hypersthene (No. 4 in Table 3), hornblende (No. 1 in Table 6) and biotite (No. 2 in Table 9) were analyzed.

***Specimen JARE 57012602:*** Pyroxene gneiss from Ongul Island. The rock is composed of hypersthene, hornblende, biotite and andesine with subordinate ilmenite, pyrite and pyrrhotite. The hypersthene (No. 2 in Table 3) was analyzed.

***Garnet gneiss***

***Specimen JARE 57110506:*** Garnet gneiss from Langhovde. The rock is composed of garnet, biotite, potassium feldspar, plagioclase and quartz. The whole rock (No. 2 in Table 2), garnet (No. 1 in Table 8) and biotite (No. 1 in Table 9) were analyzed.

In addition to these, a crystal of ferrohypersthene, ***specimen HK 57072502*** (No. 6 in Table 3), was analyzed. The specimen was collected by a member of the first Expedition Party.

## CHEMISTRY OF MINERALS

### *Pyroxenes*

Six orthopyroxenes and two clinopyroxenes were analyzed. The analyses of the orthopyroxenes are shown in Table 3, and their atomic ratios and optic properties in Table 4. The analyses, atomic ratios and optic properties of the clinopyroxenes are shown in Table 5. The analyzed orthopyroxenes are not associated with garnet and this may be the reason why they are poor in $Al_2O_3$ as compared with more typical orthopyroxenes of granulite facies rocks. The distribution coefficients of Mg and $Fe^{2+}$ between coexisting ortho- and clinopyroxenes, i. e.,

$$K = \left(\frac{X_{Mg}}{X_{Fe}}\right)_{\text{clinop}} \times \left(\frac{X_{Fe}}{X_{Mg}}\right)_{\text{orthopyroxene}}$$

are 2.0 for *specimen JARE 57012501* and 1.7 for *specimen JARE 57110802*, agreeing with the values given by BARTHOLEMÉ (1962) for metamorphic pyroxene assemblages.

### *Hornblende*

Three hornblendes were analyzed. Their analyses are shown in Table 6, and their atomic ratios, molecular compositions and optic properties are shown in Table 7. All analyzed hornblendes have a similar composition as expressed below:

$$(Na, K)_{0.7}Ca_2Mg_2Fe^{2+}Ti_{0.2}Al_{0.8}{}^{VI}Al_{1.9}{}^{IV}Si_{6.1}O_{22}(OH)_2$$

($Fe^{3+}$ is included in Al)

This composition is close to the ideal formula of hastingsite, i. e., $NaCa_2(Mg, Fe)_4AlAl_2Si_6O_{22}(OH)_2$.

### *Garnet*

Two garnets were analyzed; one is from a garnet gneiss and the other from an ultrabasic granulite. Their analyses, atomic ratios and physical constants are shown in Table 8. The garnet from the basic granulite contains a fairly large amount of MgO.

### *Biotite*

Three biotites were analyzed. Biotite occurs rather commonly in various kinds of gneisses and basic granulites. The analyses, atomic ratios and optic properties are shown in Table 9. As can be seen in the table, all of the analyzed biotites contain a fairly large amount of $TiO_2$ and have low $Fe^{2+}/(Fe^{2+}+Mg)$ ratios.

### *Feldspars*

Potassium feldspar is orthoclase, with $2V_X$ ranging from 40° to 70°. The value of $2V_X$ is variable even in one and the same crystal. Usually, the core has a lower value of $2V_X$ than the rim, and this suggests that retrograde transition from orthoclase to microcline occurs in the periphery of potassium feldspar crystal. Perthite is common.

In plagioclase, antiperthite structure is commonly observed.

### *Opaque Minerals*

The most common oxide mineral is ilmenite with exsolution intergrowths of hematite. Hematite, magnetite, and rutile have not been observed.

## CONCLUDING REMARKS

Our petrological study of the area adjacent to Lützow-Holm Bay was made chiefly on rocks of basic and intermediate compositions. Thus our knowledge is too limitted to discuss the petrology of this area in regard to the granulite facies problem.

The geological significance of this area in reference to a subdivision of the granulite facies has been discussed in another paper in which more date on pelitic gneisses are presented (BANNO, TATSUMI, OGURA, and KATSURA, 1964). The relationship between the alumina content in orthopyroxene and the mineral assemblages in the granulite facies has also been discussed in a separate paper (BANNO, 1964).

### Acknowledgements

Our thanks are due to Dr. A. MIYASHIRO and Dr. R. B. FORBES for critical reading of the manuscript.

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(*Manuscript received June 23, 1964*)

*Table 1. Optical properties of constituent minerals of pyroxene gneiss and associated basic granulites.*

| Sample No. | Hornblende | | | Orthopyroxene | | Clinopyroxene | K-feldspar | Plagioclase | Biotite | Quartz |
|---|---|---|---|---|---|---|---|---|---|---|
| | $\gamma$ | 2Vx | Z axial color | $\gamma$ | 2Vx | 2Vz | 2Vx | | | |
| 57110402 | 1.698 | 54° | dark brownish green | 1.728 | n.d. | 54° | 58°, 55°, 53° | + | + | + |
| 57110802 | 1.697 | 48° | light olive | 1.712 | 53° | 55° | 54° | + | + | − |
| 57112105 | 1.705 | 63° | light olive | absent | | absent | 45°, 36° | + | + | + |
| 57110602 | 1.705 | 66° | light olive | n.d. | n.d. | absent | 55° | + | + | + |
| 57110401 | 1.702 | 66° | light olive | n.d. | 50° | n.d. | 63° | + | + | + |
| 57102701 | n.d. | n.d. | olive | n.d. | n.d. | n.d. | 77°, 73°, 73°–61°* | + | + | + |
| 57112301 | n.d. | 47° | dark green | 1.733 | n.d. | n.d. | n.d. | + | − | + |
| 58011001 | n.d. | n.d. | grass green | 1.725 | n.d. | absent | n.d. | + | + | + |
| 57112402 | 1.702 | 44° | dark brown | 1.724 | 69° | n.d. | n.d. | + | + | − |
| 57110801 | 1.704 | 62° | dark brown | 1.727 | 54° | 57° | 53° | + | + | + |
| 57110601 | 1.704 | 62° | olive | 1.719 | 51° | absent | 52°–60°* | + | + | + |
| 57080901 | 1.703 | n.d. | dark yel. green | 1.727 | 52° | absent | 50°, 45°, 42° | + | + | + |
| 57110905 | 1.688 | 66° | light olive | 1.729 | 62° | absent | absent | − | + | + |
| 57112401 | n.d. | 76° | yellowish brown | n.d. | 50° | n.d. | n.d. | + | + | − |

\+ *present*

− *absent*

n.d. *present but not measured*

* 2V *is variable in single crystal.*

*Table 2. Chemical compositions of pyroxene gneiss, garnet gneiss and basic granulite.*

Analyst : T. KATSURA

| | 1 | 2 | 3 |
|---|---|---|---|
| $SiO_2$ | 56.81 | 64.32 | 40.47 |
| $TiO_2$ | 1.01 | 0.83 | 1.29 |
| $Al_2O_3$ | 17.33 | 15.56 | 11.50 |
| $Fe_2O_3$ | 1.87 | 1.15 | 5.87 |
| FeO | 5.55 | 6.57 | 15.26 |
| MnO | 0.13 | 0.11 | 0.24 |
| MgO | 3.46 | 5.22 | 16.64 |
| CaO | 6.55 | 2.24 | 5.86 |
| $Na_2O$ | 3.54 | 1.82 | 1.29 |
| $K_2O$ | 2.24 | 1.64 | 0.30 |
| $H_2O$ + | 0.85 | 0.45 | 1.27 |
| $H_2O$ − | 0.14 | 0.11 | 0.17 |
| $P_2O_5$ | 0.26 | 0.18 | 0.16 |
| $Cr_2O_3$ | n.d. | 0.045 | |
| Total | 99.74 | $100.24_5$ | 100.32 |

*1. JARE 57110802 Pyroxene gneiss.*
*2. JARE 57110506 Garnet gneiss.*
*3. JARE 57110905 Basic granulite.*

*Table 3. Chemical compositions of orthopyroxenes.*

Analyst : T. KATSURA

| | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| $SiO_2$ | 54.59 | 51.99 | 50.59 | 49.49 | 49.76 | 48.06 |
| $TiO_2$ | 0.04 | 0.04 | 0.16 | 0.25 | 0.19 | 0.15 |
| $Al_2O_3$ | 0.25 | 0.21 | 0.50 | 1.62 | 0.73 | 1.21 |
| $Fe_2O_3$ | 2.17 | 1.51 | 1.71 | 1.19 | 1.70 | 1.23 |
| FeO | 12.52 | 23.38 | 27.10 | 28.01 | 28.54 | 37.37 |
| MnO | 0.47 | 0.52 | 0.82 | 0.57 | 0.76 | 1.16 |
| MgO | 29.28 | 21.10 | 18.23 | 17.88 | 17.47 | 10.41 |
| CaO | 0.21 | 0.47 | 0.40 | 0.00 | 0.10 | 0.43 |
| $Na_2O$ | 0.20 | 0.05 | 0.07 | 0.00 | 0.08 | 0.13 |
| $K_2O$ | 0.00 | tr. | 0.00 | tr. | 0.03 | 0.05 |
| $H_2O$ + | 0.13 | 0.27 | 0.09 | 1.01 | 0.65 | 0.12 |
| $H_2O$ − | 0.00 | 0.04 | 0.09 | 0.17 | 0.07 | 0.02 |
| $P_2O_5$ | 0.004 | tr. | 0.006 | n.d. | n.d. | tr. |
| Total | $99.86_4$ | 99.58 | $99.76_6$ | 100.19 | 100.08 | 100.34 |

*1. JARE 57012501 Bronzite from pyroxenite.*
*2. JARE 57012602 Hypersthene from pyroxene gneiss.*
*3. JARE 57020905 Hypersthene from basic granulite.*
*4. JARE 57112402 Hypersthene from pyroxene gneiss.*
*5. JARE 57110802 Hypersthene from pyroxene gneiss.*
*6. HK 57072502 Ferrohypersthene. Crystal.*

*Table 4. Atomic ratios (O=6) and optic properties of orthopyroxenes.*

| | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Si | 1.960 | 1.964 | 1.982 | 1.927 | 1.942 | 1.937 |
| $Al^{IV}$ | 0.011 | 0.010 | 0.018 | 0.073 | 0.034 | 0.058 |
| $Fe^{3+IV}$ | 0.029 | 0.026 | | | 0.022 | 0.005 |
| $Al^{VI}$ | | | 0.005 | 0.001 | | |
| $Fe^{3+VI}$ | 0.019 | 0.017 | 0.050 | 0.035 | 0.028 | 0.032 |
| Ti | 0.001 | 0.001 | 0.005 | 0.007 | 0.005 | 0.005 |
| $Fe^{2+}$ | 0.0375 | 0.739 | 0.888 | 0.912 | 0.931 | 1.275 |
| Mn | 0.014 | 0.016 | 0.027 | 0.019 | 0.025 | 0.040 |
| Mg | 1.564 | 1.215 | 1.064 | 1.037 | 1.015 | 0.633 |
| Ca | 0.008 | 0.019 | 0.017 | 0.000 | 0.004 | 0.018 |
| Na | 0.014 | 0.003 | 0.005 | 0.000 | 0.006 | 0.005 |
| K | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.002 |
| $\alpha$ | 1.678 | n.d. | 1.708 | 1.709 | 1.712 | 1.731 |
| $\beta$ | 1.682 | n.d. | 1.721 | 1.721 | 1.727 | 1.742 |
| $\gamma$ | 1.692 | n.d. | 1.724 | 1.724 | 1.729 | 1.747 |
| 2Vx | 104° | n.d. | 56° | 69° | 53° | n.d. |

*Table 5. Chemical compositions, atomic ratios (O=6) and optic properties of clinopyroxenes.*

Analyst: T. KATSURA

| Wt % | 1 | 2 |
|---|---|---|
| $SiO_2$ | 52.61 | 49.60 |
| $TiO_2$ | 0.11 | 0.25 |
| $Al_2O_3$ | 0.90 | 1.37 |
| $Fe_2O_3$ | 0.44 | 3.00 |
| FeO | 4.33 | 10.55 |
| MnO | 0.23 | 0.33 |
| MgO | 17.17 | 12.32 |
| CaO | 22.91 | 20.53 |
| $Na_2O$ | 0.00 | 0.41 |
| $K_2O$ | tr. | 0.04 |
| $H_2O$ + | 0.72 | 1.20 |
| $H_2O$ − | 0.09 | 0.05 |
| $Cr_2O_3$ | 0.27 | n.d. |
| Total | 99.78 | 99.65 |

| Atomic ratios and optic properties | 1 | 2 |
|---|---|---|
| Si | 1.963 | 1.917 |
| $Al^{IV}$ | 0.037 | 0.062 |
| $Fe^{3+}$ | | 0.021 |
| $Al^{VI}$ | 0.002 | |
| $Fe^{3+}$ | 0.006 | |
| Ti | 0.003 | 0.007 |
| $Fe^{2+}$ | 0.112 | 0.341 |
| Mn | 0.007 | 0.011 |
| Mg | 0.951 | 0.710 |
| Ca | 0.915 | 0.850 |
| Na | 0.000 | 0.028 |
| K | 0.000 | 0.003 |
| $\alpha$ | 1.682 | 1.695 |
| $\beta$ | n.d. | 1.705 |
| $\gamma$ | 1.702 | 1.719 |
| 2Vz | 58° | 54° |

1. *JARE 57012501 Diopside from pyroxenite.*
2. *JARE 57110802 Salite from pyroxene gneiss.*

*Table 6. Chemical compositions of hornblendes.*

Analyst: T. KATSURA

| | 1 | 2 | 3 |
|---|---|---|---|
| $SiO_2$ | 40.85 | 40.55 | 39.15 |
| $TiO_2$ | 2.49 | 2.24 | 1.88 |
| $Al_2O_3$ | 12.67 | 12.18 | 13.57 |
| $Fe_2O_3$ | 3.57 | 5.05 | 4.58 |
| FeO | 14.12 | 14.42 | 15.08 |
| MnO | 0.15 | 0.20 | 0.30 |
| MgO | 9.91 | 9.55 | 9.42 |
| CaO | 11.40 | 11.08 | 10.93 |
| $Na_2O$ | 1.44 | 1.40 | 2.03 |
| $K_2O$ | 1.76 | 1.64 | 1.29 |
| $H_2O$ + | 2.01 | 1.88 | 1.66 |
| $H_2O$ − | 0.22 | 0.14 | 0.13 |
| Total | 100.59 | 100.33 | 100.02 |

1. *JARE 57112402 Hornblende from pyroxene gneiss.*
2. *JARE 57110802 Hornblende from pyroxene gneiss.*
3. *JARE 57020905 Hornblende from basic granulite.*

*Table 7. Atomic ratios (O=22, anhydrous basis), optic properties and molecular compositions of hornblendes.*

| | 1 | 2 | 3 |
|---|---|---|---|
| Si | 6.129 | 6.119 | 5.938 |
| $Al^{IV}$ | 1.871 | 1.881 | 2.062 |
| $Al^{VI}$ | 0.369 | 0.285 | 0.362 |
| $Fe^{3+}$ | 0.404 | 0.573 | 0.522 |
| Ti | 0.281 | 0.254 | 0.214 |
| $Fe^{2+}$ | 1.771 | 1.819 | 1.911 |
| Mn | 0.019 | 0.025 | 0.038 |
| Mg | 2.215 | 2.147 | 2.128 |
| Ca | 1.832 | 1.790 | 1.775 |
| Na | 0.418 | 0.409 | 0.597 |
| K | 0.337 | 0.315 | 0.249 |
| ($H_2O$) | 1.001 | 0.946 | 0.839 |
| $\alpha$ | 1.672 | 1.673 | 1.682 |
| $\beta$ | 1.691 | 1.690 | 1.693 |
| $\gamma$ | 1.702 | 1.697 | 1.701 |
| 2Vx | 48° | 54° | 70° |
| Cm | 0.562 | 0.403 | 0.700 |
| Tiam′ | 0.236 | 0.508 | 0.428 |
| St′ | 0.436 | 0.428 | 0.200 |
| Ed′ | 0.537 | 0.570 | 0.746 |
| Ts′ | 1.232 | 1.376 | 1.420 |
| Tr | 4.985 | 4.755 | 4.500 |

*Table 8. Chemical compositions, atomic ratios (O=12) and physical properties of garnets.*

Analyst: T. KATSURA

| | Wt % | | | Atomic ratio and phys. prop. | |
|---|---|---|---|---|---|
| | 1 | 2 | | 1 | 2 |
| $SiO_2$ | 38.74 | 38.53 | Si | 2.937 | 3.002 |
| $TiO_2$ | 0.07 | 0.09 | Al | 1.974 | 1.979 |
| $Al_2O_3$ | 22.09 | 22.12 | $Fe^{3+}$ | 0.169 | 0.095 |
| $Fe_2O_3$ | 2.97 | 1.66 | Ti | 0.004 | 0.005 |
| FeO | 23.23 | 25.35 | $Fe^{2+}$ | 1.473 | 1.610 |
| MnO | 0.47 | 0.98 | Mn | 0.030 | 0.029 |
| MgO | 11.20 | 8.12 | Mg | 1.265 | 0.918 |
| CaO | 1.10 | 3.21 | Ca | 0.089 | 0.260 |
| $Na_2O$ | 0.23 | 0.18 | Na | 0.034 | 0.027 |
| $K_2O$ | 0.11 | 0.04 | K | 0.011 | 0.004 |
| $H_2O$ + | 0.05 | 0.38 | $n_D$ | 1.80 | 1.81 |
| $H_2O$ − | 0.02 | 0.06 | $a_0$ | 11.53 | 11.52 |
| $Cr_2O_3$ | 0.07 | n.d. | | | |
| Total | 100.35 | 100.72 | | | |

*1. JARE 57110506 Garnet from garnet gneiss.*
*2. JARE 57110905 Garnet from basic granulite.*

*Table 9. Chemical compositions, atomic ratios (O=22, anhydrous basis) and γ refractive indices of biotites.*

Analyst: T. KATSURA

| | Wt % | | | | Atomic ratios (O=22) and γ | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | | 1 | 2 | 3 |
| $SiO_2$ | 37.66 | 36.33 | 36.51 | Si | 5.373 | 5.460 | 5.512 |
| $TiO_2$ | 4.86 | 5.22 | 5.22 | $Al^{IV}$ | 0.627 | 0.540 | 0.488 |
| $Al_2O_3$ | 17.09 | 14.46 | 13.75 | $Al^{VI}$ | 2.248 | 1.681 | 1.958 |
| $Fe_2O_3$ | 0.77 | 1.40 | 2.74 | $Fe^{3+}$ | 0.082 | 0.159 | 0.311 |
| FeO | 9.71 | 17.30 | 17.47 | Ti | 0.521 | 0.589 | 0.592 |
| MnO | 0.00 | 0.07 | 0.13 | $Fe^{2+}$ | 1.158 | 2.174 | 2.114 |
| MgO | 17.59 | 12.28 | 11.62 | Mn | 0.000 | 0.009 | 0.016 |
| CaO | 0.00 | 0.00 | 0.05 | Mg | 3.740 | 2.750 | 2.613 |
| $Na_2O$ | 0.22 | 0.19 | 0.28 | Ca | 0.000 | 0.000 | 0.016 |
| $K_2O$ | 9.30 | 8.96 | 8.93 | Na | 0.062 | 0.055 | 0.082 |
| $H_2O$ + | 2.53 | 3.29 | 2.84 | K | 1.692 | 1.717 | 1.719 |
| $H_2O$ − | 0.04 | 0.47 | 0.32 | ($H_2O$) | 1.118 | 1.558 | 1.429 |
| $Cr_2O_3$ | 0.16 | n.d. | n.d. | Cr | 0.015 | — | — |
| | | | | γ | n.d. | 1.655 | 1.651 |
| Total | 99.93 | 99.97 | 99.86 | | | | |

*1. JARE 57110506 Biotite from garnet gneiss.*
*2. JARE 57112402 Biotite from pyroxene gneiss.*
*3. JARE 57110802 Biotite from pyroxene gneiss.*