Introduction

The Ojika Peninsula, Miyagi Prefecture, is geologically well-known as one of the typical fields of the Mesozoic formations in Northeast Japan. However, petrological studies on the igneous rocks associated with these formations have been scarcely done, excepting those on granitic varieties in the Kinkazan Islet to the southeast of the Ojika Peninsula, petrographically described by Sendō and Ueda (1963) in detail. Gabbroic or dioritic rocks in the Ojika Peninsula are intruded into these formations, occurring as rather small masses, and comprise the various kinds of rock type, varying from ultramafic to intermediate varieties. Also the Kasagai gabbroic rocks, which have been found out by Takizawa (1970), one of the authors, during his surveying for the geological sheet map of 1:50,000 "Yori-iso", are similar varieties to the Ojika gabbroic rocks.

The authors describe just briefly the petrography and petrochemistry of these intrusive rocks in this paper.

Geological Setting

Geological map of the Ojika Peninsula and its neighbouring islets is shown in Figure 1. The Mesozoic system of the Ojika Peninsula is composed of the Inai and Ojika Groups, and the Yamadori Formation which is mainly composed of volcanic rocks; and their ages are estimated from biochronology to be Triassic, Jurassic, and Cretaceous, respectively. These Mesozoic sediments of the Inai and Ojika Groups have been injected by rocks of the Ojika Gabbroic Complex, isotopic age of which is estimated to be about 120 m.y. from hornblende and biotite in them (Kawano and Ueda, 1965), described in this paper, and the marginal parts of these sediments are markedly altered into hornfelsic rocks. And many dikes, with very small dimension, such as andesite and diorite porphyrite, are also sporadically intruded into these groups and formation.

The geotectonic zone, "Kinkazan Tectonic Line", under a small strait of the Kinkazan-seto between the Ojika Peninsula and Kinkazan Islet, accompanied with serpentinite, has been guessed by Iot et al. (1972), and it is presumed to run towards the north, though lying itself beneath the sea.

The Kasagai Islet is isolated from other islets such as Ashi-jima, Eno-shima and Hirasima, on the eastern outside sea of the Ojika Peninsula. This islet had not been geologically known in detail until surveyed by Takizawa (1970, 1972); the islet was preferably considered to be constituted by a member of the Inai Group by many geologists (Hanzawa et al., 1962 and others).

Geology of the Kasagai Islet is practically composed of only hornblende gabbros and their related rocks, which are named the Kasagai Gabbroic Complex by us, as described in the succeeding chapters, rarely including the sedimentary inclusions metamorphosed into clinopyroxene-bearing gneissose hornfels and others.

The detailed geology of the Ojika Penin-
Fig. 1. Geologic map of the Ojika Peninsula and its neighbouring area, Miyagi Prefecture.
and it’s vicinity will be given in the several sheet maps, “Kinkazan”, “Yoriiso” and so on, of scale 1:50,000 and their explanatory texts by F. Takizawa and others, in near future.

**Petrography**

Gabbroic complexes in the Ojika Peninsula and Kasagai Islet are petrographically similar to each other; their distribution is shown also in Figure 1.

The Ojika Gabbroic Complex:
Gabbroic and dioritic rocks of the Ojika Gabbroic Complex are intruded into the Mesozoic Ojika and Inai Groups as rather small masses with the dimension of about 5.0 km or less long and 0.15~1.0 km wide, extending to N-S direction. The principal rock types in the Ojika Complex is roughly divided into hornblende pyroxenite, hornblende-pyroxene gabbro, hornblende gabbro and quartz diorite; especially, the rock-mass of the eastern-most side, as shown in Figure 1, contains all kinds of these rock types, which seem to be graded into each other, though hornblende-pyroxene gabbro is predominant as well in other masses.

A lot of andesitic dikes in the Ojika Peninsula are also found sporadically, though they are not described in this paper. They are probably concerned with the volcanism associated with the Yamadori Formation.

*Hornblende clinopyroxenite* occurs only in the small part of the northern tip of the above-mentioned mass of the easternmost side. Clinopyroxene is the most dominant mineral, subhedral crystal of 0.5~1.0 cm across; probably it is diopsidic (2V= (+)55°, γ=1.709). Hornblende is pale green~brownish green in colour, rather euhehedral with 2V= (-)87° and γ=1.666, usually 1.0~5.0 mm long, sometimes occurring in the small druse, and also in some case included in pyroxene crystal. Colourless tremolitic amphibole occurs as needle crystal, presumably of secondary product as well as serpentine, chlorite and calcitic carbonate. Iron ore is rare. Photomicrograph of this rock is given in Plate I-1.

*Hornblende pyroxene gabbro* is the most ordinary type of the Ojika Gabbroic Complex, even in the mass containing the above-mentioned hornblende pyroxenite as well as in others, and accordingly occupies a greater part of the respective mass. It is mainly composed of diopsidic clinopyroxene, brown~green hornblende and plagioclase accompanied with biotite and iron ore. Secondary products are chlorite, epidote, white mica, needle and colourless amphibole, sphene and calcitic carbonate, frequently with a small amount of quartz. The amount of hornblende is variable even in the same mass. Clinopyroxene is subhedral, 0.1~0.5 cm across, and almost colourless with 2V= (+)65° and γ=1.712. Hornblende is larger in grain-size, about 5 mm in length and about 2 mm in width (2V= (-)83°, γ=1.670). Plagioclase is euhedral or subhedral, 0.5 mm~1.0 mm in width and twinned almost after albite law, generally with compositionally zoning, and is presumable to be labradorite to bytownite, judging from the determined results by the zonal method after Chudoba (1933).

*Hornblende gabbro* is the intermediate type between hornblende-pyroxene gabbro and quartz diorite. It is mainly composed of plagioclase (An₈₃, γ=1.578), brown hornblende (2V= (-)85°, γ=1.675) and a small amount of quartz, with or without biotite and clinopyroxene. Relicts of clinopyroxene included in hornblende are often observed in the thin section. Its photomicrograph is given in Plate I-2.

*Quartz diorite* occupies a great part of some masses. It is mainly composed of compositionally zoned plagioclase, green hornblende (γ=1.661), biotite, quartz and iron ore, accompanied with secondary minerals such as chlorite, epidote, sericite, sphene and calcitic carbonate. Relicts of clinopyroxene included in the hornblende are rarely seen in the thin section. Megascopically, however, it is difficult to discriminate quartz diorite from hornblende gabbro in the fields.

The Kasagai Gabbroic Complex:
The Kasagai Islet is geologically constituted
Fig. 2. Distribution map of rock types of the Kasagai Gabbroc Complex.

Almost by gabbroic rocks, the Kasagai Gabbroc Complex, as shown in Figures 1 and 2. The gabbroic rocks of the complex are divided into the following rock types: fine- or medium-grained hornblende gabbro (core of “ball gabbro”), poikilitic hornblende gabbro, medium- or coarse-grained hornblende gabbro and pegmatitic gabbro. Dike-formed metadiabasic rock is found only in rather massive hornblende gabbro in the southern half of the islet. A small amount of metamorphosed sediments, original age of which is unknown, are included in medium-grained gabbroic rocks just as xenolithic mass at northeastern part of the islet.

Fine- or medium-grained hornblende gabbro occurs only as a “ball”-like rounded inclusion in the coarser-grained hornblende gabbro, in the restricted area as represented in Figure 2. This attitude of occurrence is so curious that some geologists named it as “Ball gabbro” (Plate II-1). It has, however, no concentric and compositionally zoned structure which marks the characteristic feature of the “ball diorite” or “orbicular rock” as named by SEDERHOLM (1928), LEVESON (1966), NOZAWA (1969) and others. The rock is mainly composed of plagioclase (An$_{60}$–$70$), bluish grass-green amphibole which is probably altered from the primary hornblende or clinopyroxene, sometimes included in this amphibole as relics, and secondary minerals such as chlorite, sericite and microscopically colourless needle amphibole. These minerals are about 0.5 mm or less in widths. Hornblende gabbro occurring as the matrix of this “ball”-like or “conglomeratic” rock, resembles the rock type of medium- or coarse-grained hornblende gabbro, described below. Photomicrograph of the rock containing both of “ball gabbro” and its matrix is given in Plate II-2.

Poikilitic hornblende gabbro occurs as specific rock facies of medium- or coarse-grained hornblende gabbro containing much of large crystals of brown hornblende, about 3 cm in width, in which small crystals such as plagioclase, clinopyroxene and aggregate of secondary minerals are included, showing the poikilitic structure. Generally, it is mainly composed of brown hornblende (2V=($-180^\circ$, $y=1.672$), plagioclase (An$_{85}$, $y=1.583$) and rarely clinopyroxene (2V=($+52^\circ$, $y=1.715$), occurring only as inclusion as mentioned above. Secondary products are epidote, chlorite, sphene, colourless amphibole, etc.

Medium- or coarse-grained hornblende gabbro is, generally speaking, the most ordinary type in the islet, regardless of containing some varieties. It is mainly composed of plagioclase (An$_{85}$, $y=1.582$), brown hornblende (2V=($-179^\circ$, $y=1.679$), and sometimes biotite accompanied with iron ore as accessory minerals; secondary products are chlorite, calcitic carbonate, sericite, sphene, epidote and colourless green needle amphibole. In the northern central part of the islet, the rock grades into the poikilitic hornblende gabbro. The rock in the southern part is, however, mostly rather homogeneous and rarely contains a small amount of quartz. Dike-formed metadia-
Table 1. Association of principal minerals from the Ojika and Kasagai Gabbroic Complexes.

<table>
<thead>
<tr>
<th>Ojika Gabbros</th>
<th>Cpx</th>
<th>Hb</th>
<th>Bi</th>
<th>Pl</th>
<th>Qz</th>
<th>Kasagai Gabbros</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hornblende pyroxenite</td>
<td>⊙</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Fine- or medium-grained gabbro</td>
</tr>
<tr>
<td>Hornblende-pyroxene gabro</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>Poikilitic hornblende gabbro</td>
</tr>
<tr>
<td></td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>Hornblende gabbro (Medium- or coarse-grained)</td>
</tr>
<tr>
<td></td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>Pegmatitic hornblende gabbro</td>
</tr>
<tr>
<td>Hornblende gabro</td>
<td>Δ</td>
<td>●</td>
<td>Δ</td>
<td>●</td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>Quartz diorite</td>
<td>Δ</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td></td>
</tr>
</tbody>
</table>

Cpx: clinopyroxene, Hb: hornblende, Bi: biotite, Pl: plagioclase, Qz: quartz.
⊙: showing a large amount..., ●: showing a small amount..., Δ: showing “with or without”...

Table 2. Chemical compositions and their C. I. P. W. normative compositions of gabbroic rocks from Ojika Peninsula and Kasagai Islet, Miyagi Prefecture.

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO₂</td>
<td>51.26</td>
<td>44.57</td>
<td>46.27</td>
<td>50.96</td>
<td>43.51</td>
<td>42.05</td>
<td>39.39</td>
<td>40.47</td>
<td>39.85</td>
<td>42.93</td>
<td>36.29</td>
</tr>
<tr>
<td>TiO₂</td>
<td>0.52</td>
<td>0.68</td>
<td>0.42</td>
<td>0.17</td>
<td>1.64</td>
<td>0.75</td>
<td>1.30</td>
<td>0.68</td>
<td>0.07</td>
<td>1.18</td>
<td>0.05</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>19.97</td>
<td>20.57</td>
<td>11.18</td>
<td>3.79</td>
<td>16.56</td>
<td>25.83</td>
<td>19.29</td>
<td>20.48</td>
<td>22.97</td>
<td>17.45</td>
<td>1.39</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>3.71</td>
<td>4.63</td>
<td>3.61</td>
<td>1.81</td>
<td>3.49</td>
<td>0.94</td>
<td>5.71</td>
<td>4.67</td>
<td>3.09</td>
<td>3.42</td>
<td>4.05</td>
</tr>
<tr>
<td>FeO</td>
<td>8.48</td>
<td>6.98</td>
<td>6.89</td>
<td>4.37</td>
<td>8.99</td>
<td>6.36</td>
<td>6.94</td>
<td>6.01</td>
<td>5.37</td>
<td>9.28</td>
<td>2.81</td>
</tr>
<tr>
<td>MnO</td>
<td>0.16</td>
<td>0.19</td>
<td>0.19</td>
<td>0.12</td>
<td>0.19</td>
<td>0.10</td>
<td>0.13</td>
<td>0.11</td>
<td>0.13</td>
<td>0.21</td>
<td>0.13</td>
</tr>
<tr>
<td>MgO</td>
<td>3.98</td>
<td>6.06</td>
<td>11.48</td>
<td>9.05</td>
<td>5.42</td>
<td>8.81</td>
<td>9.37</td>
<td>10.19</td>
<td>7.91</td>
<td>48.20</td>
<td></td>
</tr>
<tr>
<td>CaO</td>
<td>8.44</td>
<td>11.63</td>
<td>16.10</td>
<td>17.10</td>
<td>10.43</td>
<td>15.71</td>
<td>14.09</td>
<td>13.17</td>
<td>12.14</td>
<td>11.55</td>
<td>0.07</td>
</tr>
<tr>
<td>Na₂O</td>
<td>2.77</td>
<td>1.94</td>
<td>0.80</td>
<td>0.55</td>
<td>1.82</td>
<td>1.05</td>
<td>1.42</td>
<td>0.97</td>
<td>0.87</td>
<td>1.79</td>
<td>0.75</td>
</tr>
<tr>
<td>K₂O</td>
<td>0.69</td>
<td>0.26</td>
<td>0.23</td>
<td>0.14</td>
<td>0.63</td>
<td>0.29</td>
<td>0.21</td>
<td>0.30</td>
<td>0.19</td>
<td>0.40</td>
<td>0.22</td>
</tr>
<tr>
<td>P₂O₅</td>
<td>0.22</td>
<td>0.22</td>
<td>0.12</td>
<td>0.11</td>
<td>0.31</td>
<td>0.15</td>
<td>0.14</td>
<td>0.12</td>
<td>0.28</td>
<td>0.06</td>
<td></td>
</tr>
<tr>
<td>H₂O (+)</td>
<td>2.41</td>
<td>1.75</td>
<td>2.35</td>
<td>1.25</td>
<td>2.24</td>
<td>1.73</td>
<td>1.69</td>
<td>2.87</td>
<td>4.12</td>
<td>2.41</td>
<td>5.55</td>
</tr>
<tr>
<td>H₂O (-)</td>
<td>0.75</td>
<td>0.27</td>
<td>0.31</td>
<td>0.36</td>
<td>0.38</td>
<td>0.39</td>
<td>0.42</td>
<td>0.54</td>
<td>0.71</td>
<td>0.34</td>
<td>0.62</td>
</tr>
</tbody>
</table>


Or 4.06 1.56 1.33 0.83 3.73 1.72 1.17 1.78 1.11 2.39 2.39
Ne — — — — — — — — — — —
An 40.00 46.62 26.24 7.45 35.14 64.89 45.65 50.60 58.19 38.36 38.36
Dₐ(ₐ) 0.21 4.05 22.94 31.98 6.15 5.14 9.72 5.78 0.52 7.19 7.19
Dₐ(ₐ) 0.13 2.47 15.22 24.98 3.89 2.60 6.91 4.13 0.37 4.94 4.94
Dₐ(ₐ) 0.07 1.35 4.99 3.42 1.86 2.42 1.94 1.15 0.11 2.85 2.85
H₂O(a) 9.74 6.13 4.34 10.47 2.20 — — — — — —
H₂O(a) 5.21 3.37 1.43 1.44 1.06 — — — — — —
O₁(ₐ) — — — — — — — — — — —
O₂(ₐ) 5.38 6.73 5.24 2.62 5.08 1.37 8.31 6.80 4.50 4.96 4.96
Il 0.79 1.29 0.81 0.32 3.12 1.43 2.48 1.25 0.32 2.25 2.25
Sp 0.54 0.54 0.30 0.27 0.74 0.27 0.37 0.34 0.30 0.67 0.67

Total 96.34 97.78 97.25 98.08 97.17 97.47 97.46 96.29 95.12 97.10 97.10
D. I. 34.27 17.96 8.09 5.49 19.14 7.96 8.21 8.71 7.75 17.29 17.29

1) Quartz diorite from Ojika Peninsula, Miyagi Prefecture (KI 68-40), 2) Hornblende gabro, ditto (KI 68-42), 3) Hornblende pyroxene gabro, ditto (KI 68-32), 4) Hornblende pyroxeneite, ditto(KI 68-34), 5)* Pegmatitic gabbro from Kasagai Islet, Ojika-gun, Miyagi Prefecture (KI 68-10), 6) Hornblende gabro, ditto (KI 68-15), 7)* Poikilitic hornblende gabbro, ditto (KI 68-11b), 8)* “Ball”-gabbro-matrix (hornblende gabro), ditto (KI 68-12), 9)* “Ball”-gabbro-core (fine-or medium-grained hornblende gabro), ditto (KI 68-13), 10)* Metadiabase, ditto (KI 68-16), 11) Serpentinitized peridotite from Kinkazan-Islet, Miyagi Prefecture (KI 68-51a).

basic rocks, with 5~10 m in width, are often injected into the rock of this facies in the southern part of the islet. It is mainly composed of zoned plagioclase and brownish green hornblende (2V = (−)84°) with a small amount of iron ore, and secondary products are epidote, sphene and calcitic carbonate.

*Pegmatitic hornblende gabbro* in the northern part of the islet is intruded into the above-mentioned hornblende gabbros, excepting “ball gabbro”, as vein, about 1 m in width. Zoned plagioclase and hornblende (2V = (−)81°, γ = 1.671) are common constituents, with accessory apatite, zircon and iron ore. Secondary products are albite feldspar, epidote, clorite, sphene and calcitic carbonate. Crystal sizes of most of hornblendes are often over 10 cm long, and of some one, to 20 cm; and the growing directions of c-axis of the hornblendes are just right cross to the elongation of this vein. Photomicrograph of this rock is given in Plate I-3.

Associations of principal minerals from the Ojika and Kasagai Gabbroic Complexes are summarized in Table 1.

**Petrochemistry**

Ten specimens for the chemical analyses are selected from representative rock types of the Ojika (Nos. 1 to 4) and Kasagai Gabbroic Complexes (Nos. 5 to 10, TAKIZAWA, 1972). The results are shown in Table 2, with their normative compositions. A specimen, No. 11, serpentinized peridotite on the Kinokan Tectonic Line (Iga et al., 1972), was just added for comparison with the ultramafic rock of the Ojika Gabbroic Complex.

It may be chemically characteristic feature of these two complexes, as given in Table 2, that some of gabbroic rocks are very poor in SiO₂ (weight percent), and normative nephelines are calculated, especially in those from the Kasagai Gabbroic Complex.

Figure 3 is a variation diagram showing the relation between the contents of oxides and Differentiation Index (D.I., Q+Or+Ab+Le+Ne+Kp contents of C. I. P. W. norm values), originally proposed by THORNTON and TUTTLE (1960). The trends of differentiation for the Ojika and Kasagai Gabbroic Complex are represented in this figure; the dashed curves are for those of the Ichinohe Alkali Plutonic Complex. The Ichinohe Alkali Plutonic Complex occurs in the Paleozoic formation at Ichinohe, Iwate Prefecture (see index map in Fig. 1) and represents the alkali gabbro-quartz syenite association (ONUKI and TIBA, 1964). Although rocks of the Ojika and Kasagai Complexes do not contain the alkali felspsar, their chemical compositions are somewhat similar to those of Ichinohe Complex. However, rocks of the Ojika and Kasagai Gabbroic Complexes together are limited to only rather earlier stage of differentiation; besides, those of the Ichinohe Alkali Plutonic Complex presumably are rather in later stages than the Ojika and Kasagai. So far as Fig. 3 is concerned, it does not seem that the trends of differentiations for the Ojika and Kasagai Gabbroic Complexes correspond to that for the Ichinohe Complex.
GABBRIOIC COMPLEXES IN THE OJIKA PENINSULA

Fig. 4. MgO-ΣFeO-(Na₂O+K₂O) diagram.


A triangular diagram of MgO-ΣFeO-(Na₂O+K₂O) for gabbroic rocks of the Ojika and Kasagai Complexes is shown in Figure 4, with points plotted for the Kinkazan Granitic Rocks after Sendō and Ueda (1963). The dashed line represents the trend of that for the Ichinohō Alkali Plutonic Complex after Onuki and Tiba (1964). The diagram indicates that gabbroic rocks of the Ojika and Kasagai Complexes might be derived from a common magma source through similar process of the differentiation, judging from the fact that plotted positions for the Kasagai Gabbroic Complex correspond to the trend of those for the Ojika Gabbroic Complex. Besides, the trend for the Ichinohō Complex is also plainly somewhat different from that for other two complexes; on the other hand, that for the Kinkazan Granitic Rocks is uncertain.

Relationship between the Ojika and Kasagai Gabbroic Complexes

The Ojika and the Kasagai Gabbroic Complexes are distributed separately each other over the sea. Geologically, however, both of them are in the western side of the expected northern extension of the “Kinkazan Tectonic Line” which is a great fault zone between the Ojika Peninsula and the Kinkazan Islet, so that we have considered that the Kasagai Gabbroic Complex may belong to the northeastern extension of the Ojika Complex judging from their petrographical affinities as mentioned above.

Anyway, the Kasagai Gabbroic Complex is not so different from the Ojika Complex in their petrographical and petrochemical characteristics. As seen in the Figure 4, the rocks of the Kasagai Gabbroic Complex are plotted on or near the curve for the Ojika Gabbroic Complex, though the variations of oxides against D.I. for rocks of these complexes do not always seem to correspond to each other. This fact suggests that both of them might be comagmatic, in conclusion. However, there are not any geological evidences directly to support this suggestion because of their separated occurrences. The Kinkazan Granites would be also difficult to be correlated geologically with the rocks of the Ojika Complex because of the presence of the “Kinkazan Tectonic Line”.

References

Chudoba, K. (1933), The determination of the feldspar in thin section. (Translated by Kennedy, W.Q.), Thomas Murby & Co.
Hanzawa, S., Onuki, Y. and Kitamura, S. -editors, (1962), Geological map of Miyagi Prefecture, Scale 1 : 200,000, Miyagi-ken.**
Igi, S., Takizawa, F. and Katada, M. (1972), Some problems concerning the structural geology of the Kinkazan Islet, Miyagi Prefecture, Japan. Earth Science (“Chiyukagaku”) vol. 26, p. 139—148.**
SACHIO IGI, MASATO KATADA, FUMINORI TAKIZAWA & TOMOHITO ABE 1974–3

——— (1972), Report on “ball-gabbro”, a new natural monument designated by the Miyagi Prefecture. Educational Committee of Miyagi Prefecture, 13 p.**

* In Japanese with English abstract.
** In Japanese.

### Explanation of Plates

Plate I

1. Photomicrograph of hornblende clinopyroxene from the Ojika Gabbroic Complex (KI 68-33). Crossed two polaroids.
3. Photomicrograph of pegmatitic hornblende gabbro from the Kasagai Gabbroic Complex (KI 68-10). One polaroid.

Plate II

1. “Ball”-like rounded fine- or medium-grained gabbro (FG) in coarse-grained hornblende gabbro (CG) from the Kasagai Gabbroic Complex.
   - Locality: Kasagai Islet, Ongaawa-cho, Ojika-gun, Miyagi Prefecture.
2. Photomicrograph of “Ball”-like gabbro and its matrix from the Kasagai Gabbroic Complex (HO 6-a). One polaroid.