RADIOMETRIC AGE AND MINERALOGY OF MUSCOVITE FROM A GRANITE PEGMATITE TRANSGRESSING THE HIDA METAMORPHIC COMPLEX IN THE UPPER KATAKAI RIVER AREA, TOYAMA PREFECTURE, CENTRAL JAPAN

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1. INTRODUCTION

In the course of his study on the Hida metamorphic complex in the upper Katakai River area, the author was impressed by the occurrence of beautiful muscovite bearing drusy granite pegmatite in a massive granodiorite penetrating the Hida metamorphic complex. Muscovite forms large crystalline "books" in the pegmatite. Chemical, optical, X-ray properties and K-Ar radiometric age on this muscovite are described in this paper to provide further data on the mineralogy of the muscovite and on the petrology and geology of the Hida metamorphic complex.

As far as has been observed, the Hida metamorphic complex is everywhere separated from the Palaeozoic rocks either by faults or by intervening outcrops of younger igneous and sedimentary rocks. For this reason the age of the complex has not been precisely determined, and has been a subject of dispute among geologists (See e.g., MINATO, HUNAHASHI, and GORAI, 1965; and SUWA, 1965).

In the Kurobe River area the Hida metamorphic complex is unconformably overlain by the lower Jurassic formation. Both the Hida metamorphic complex and the lower Jurassic formation are intruded discordantly by the post-kinematic Cretaceous tonalite–granodiorite, called the Kitamata–dani tonalite.

The Hida metamorphic complex occurs widely throughout the upper Katakai River area, and is intruded by a massive granodiorite which includes the granite pegmatite.

So far the mutual relation between the massive granodiorite and the Kitamata–dani tonalite is ambiguous. Some authors consider that both granitic rocks are of the same period, and some other authors consider that the massive granodiorite may be older than the Kitamata–dani tonalite. These authors' classifications are not based on any rigorous geological evidence.

As a result of the present K–Ar dating, it has been definitely shown that the massive granodiorite is of Triassic age and is quite distinct from the Cretaceous Kitamata–dani tonalite.

In the following, a sketch of the geology and petrography of the Hida metamorphic complex, the Triassic massive granodiorite, and the Cretaceous Kitamata–dani tonalite in this area is given, and then the mineralogy and the radiometric age on the muscovite concerned is described. Finally, the results are briefly discussed.

2. GEOLOGICAL SETTING

A. HIDA METAMORPHIC COMPLEX

A geological map of the upper Katakai River and the Kurobe River areas (Fig. 1) is based chiefly on the author's data and the published geological maps (ISHII, 1937; ISHIOKA and SUWA, 1954 and 1956; HIRAYAMA et al., 1955; and OHTA, 1961).

The schist, amphibolite, lepite, marble, gneissose granite, and porphyroblast gneiss, occurring in the upper Katakai River, run NNW (N 5° to 35°W) with a westerly dip of 50° to 80°. The elongation of beds of the marble and the gneissoity of the porphyroblast gneiss indicate the trend. The micro–folding has an axis plunging 30° in the direction of N 25°W. The rock type and structure of the Hida metamorphic complex in this area are similar to those of Eboshi–yama group in the lower Kurobe River area (ISHIOKA and SUWA, 1954 and 1956), though the mineral composition is somewhat different.

In this area, andalusite and muscovite occur; sillimanite and pyralspite are scarce, and staurolite, kyanite, cordierite, and potassium feldspar are lacking in rocks of pelitic and psammitic composition. On the other hand, in the lower Kurobe River area staurolite, pyralspite, and muscovite occur, and kyanite, andalusite, and microcline are scarce, and sillimanite and cordierite are lacking in rocks of pelitic and psammitic composition. Staurolite, pyralspite, kyanite, and andalusite occur in rocks without microcline.

As may be seen in the above statement, the Hida metamorphic complex in this area is a southern extension
Fig. 1. Geological map of the Kurobe River and the upper Katakai River areas, Toyama Prefecture.

Petrological descriptions on the Hida metamorphic complex in the upper Katakai River area are treated in a separate paper (Suwa, 1966).

B. TRIASSIC MASSIVE GRANODIORITE

In the upper Katakai River area, the Hida metamorphic complex is intruded by the Triassic massive granodiorite. Petrographical character of the granodiorite is slightly variable from place to place: biotite may or may not exceed muscovite in amount, and sometimes garnet and tourmaline occur in small amounts.

In the massive granodiorite, no gneissose structure is observed, and pegmatite derivatives are sometimes observed and basic xenolith is scarce. The granodiorite is characterized by the microcline showing perthite texture and by the plagioclase showing no zoning.

At the contact between the massive granodiorite and a marble of the Hida metamorphic complex, pyroxene syenite is sometimes found to occur, e.g., near Mt. Sogadake (Suwa and Ishoka, 1957).

At the Sankaidan–dake in the upper Katakai River area, hornblende–biotite tonalitic granodiorite which has abundant plagioclase with intense zoning occurs in the massive muscovite bearing biotite granodiorite body. This tonalitic granodiorite seemingly is a member of the Cretaceous Kitamata–dani tonalite and the massive biotite granodiorite is considered to be intruded by this tonalitic granodiorite body. Both the tonalitic granodiorite and the massive biotite granodiorite are overlain by the garnet bearing biotite dacite flow.

The massive granodiorite is cut by a muscovite pegmatite with clean–cut boundaries, where the pegmatite occurs as a vein with a width of five centimeters, and the granodiorite is sometimes interwoven with the small muscovite pegmatite body. The muscovite occurring as a large crystalline "books" is collected from this muscovite pegmatite.

As is clearly shown below, the muscovite crystal concerned is of the Late Triassic age. Therefore, the massive granodiorite is probably of Triassic age and it is considered to occur along the western margin of the Kitamata–dani tonalite body, which runs from north to south along the Kurobe River.

C. CRETACEOUS KITAMATA–DANI TONALITE

The Hida metamorphic complex is overlain unconformably by the sandstone and conglomerate of the Kuruma Group of lower Jurassic in the Kurobe River area.

The Kitamata–dani tonalite, penetrating the Hida metamorphic complex, is a large tonalite body trending NS along the Kurobe River, and contact metamorphism of the Kuruma Group by the tonalite converts it into a biotite hornfels, e.g., at the Kozu–dani valley situated about 9 km NE of the village of Unazuki (Ishoka and Suwa, 1954).

According to Ito (1966), schists and phyllites around Mt. Asahi–dake belonging to the Hida marginal metamorphic belt are extensively thermally metamorphosed by the intrusion of the Kitamata–dani tonalite.

The Kitamata–dani tonalite, therefore, is dated geologically as post–Jurassic and is probably Cretaceous. The radiometric age for the biotite in the Kitamata–dani tonalite at the Kurobe River area is 88±9 m.y., corresponding to Cretaceous (personal communication of Nagasawa).

The majority of the Kitamata–dani tonalite is hornblende–biotite tonalite. Petrographically, the tonalite is somewhat variable from place to place, especially the amount of potassium feldspar; disappearing entirely in most places where the amount of hornblende is large, i.e., from hornblende–biotite tonalitic granodiorite to biotite–hornblende tonalite.

In the Kitamata–dani tonalite, no gneissose structure is observed, the basic xenolith content is somewhat less and pegmatite derivatives are scarce. The tonalite is characterized by abundant plagioclase showing intense zoning. Beautiful silvery molybdenite crystals are sometimes studded in the tonalite.

The Kitamata–dani tonalite is intruded by the aplite granite and lithoidite and is overlain by the dacite flow.

3. CHEMICAL COMPOSITION OF THE MUSCOVITE

Chemical analysis has been made on muscovite from the muscovite pegmatite in the massive granodiorite (Suwa and Nozaka, 1965). The result is shown in Table I. The data indicate that the ferrous and ferric iron contents in this muscovite are both higher than those of common muscovite, i.e., its composition is pure muscovite molecule (K₂Al₃Si₃Al₂O₁₀(OH)₄) 68.6%, ferrorruminusovite molecule (K₂Al₂Fe³⁺Si₃Al₂O₁₀(OH)₄) 12.6%, ferrophengite molecule (K₃Fe⁺⁺Al₃Si₃Al₂O₁₀(OH)₄) 10.1%, and picrophengite molecule (K₃MgAl₃Si₃Al₂O₁₀(OH)₄) 8.7%.

4. OPTICAL AND X–RAY PROPERTIES OF THE MUSCOVITE

The three principal refractive indices of the muscovite crystal for D line, measured by immersion method, are α = 1.557, β = 1.589, γ = 1.594, the muscovite is biaxial negative of 2Vₜ = 42.5°.
Table 1. Chemical composition of the muscovite (Analyzed by Y. SUWA)

<table>
<thead>
<tr>
<th>Wt. %</th>
<th>Atomic prop</th>
<th>Atoms per structural unit (O, OH) = 24</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO₂</td>
<td>Si</td>
<td>0.7513</td>
</tr>
<tr>
<td>TiO₂</td>
<td>Ti</td>
<td>0.0043</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>Al&lt;sup&gt;V&lt;/sup&gt;</td>
<td>0.6890</td>
</tr>
<tr>
<td>FeO</td>
<td>Fe&lt;sup&gt;III&lt;/sup&gt;</td>
<td>0.0512</td>
</tr>
<tr>
<td>FeO</td>
<td>Fe&lt;sup&gt;II&lt;/sup&gt;</td>
<td>0.0125</td>
</tr>
<tr>
<td>MnO</td>
<td>Mn</td>
<td>0.0031</td>
</tr>
<tr>
<td>MgO</td>
<td>Mg</td>
<td>0.0107</td>
</tr>
<tr>
<td>CaO</td>
<td>Ca</td>
<td>0.0064</td>
</tr>
<tr>
<td>Na₂O</td>
<td>Na</td>
<td>0.0000</td>
</tr>
<tr>
<td>K₂O</td>
<td>K</td>
<td>0.2094</td>
</tr>
<tr>
<td>Rb₂O</td>
<td>Rb</td>
<td>0.0001</td>
</tr>
<tr>
<td>PbO</td>
<td>Pb</td>
<td>0.0000</td>
</tr>
<tr>
<td>H₂O⁺</td>
<td>H</td>
<td>0.5352</td>
</tr>
<tr>
<td>H₂O⁻</td>
<td>O</td>
<td>2.9066</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total 100.22</td>
</tr>
</tbody>
</table>

2V<sub>x</sub>=42.5°  
\( \alpha = 1.557 \)  
\( \beta = 1.589 \)  
\( \gamma = 1.594 \)

Polytype : 2M₁

Muscovite molecule : 68.6%  
Ferrimuscovite molecule : 12.6%  
Ferrophengite molecule : 10.1%  
Picrophengite molecule : 8.7%

Powder patterns were taken up by a Norelco Geiger counter X-ray diffractometer using copper Kα radiation. Pure silicon was used as the internal standard. X-ray diffraction data of the muscovite are shown in Table 2. The muscovite is found to be 2M₁ (twolayer monoclinic) polytype, and the unit cell dimension obtained from the powder X-ray diffraction data in Table 2 is: \( a = 5.19 \) Å, \( b = 9.01 \) Å, \( c = 20.04 \) Å, and \( β = 95.5^\circ \).

The unit cell dimensions \( b \) and \( c' \) were determined from the 2θ angles for the reflections (060) and (0010) respectively, and \( a' \) from the 2θ angles for (202) and (020) and from the already known values of \( b \) and \( c' \). And the angle \( β \) was determined from the 2θ angles for (314), (135), (133), (138), and (131) and from the already known values of \( a', b, \) and \( c' \). The values of \( a \) and \( c \) were then calculated from \( a', c', \) and \( β \).

5. POTASSIUM–ARGON DATING OF THE MUSCOVITE

Ar<sup>40</sup>/K<sup>40</sup> age determination was made on the muscovite sample separated from the muscovite pegmatite in the massive granodiorite penetrating the Hida metamorphic complex. Radiometric age determination was carried out by HIROSHI NAGASAWA.

The analytical datum and the computed radiometric age are given in Table 3. The radiometric age for the muscovite is 188±8 million years (m.y.), corresponding to the Late Triassic. No correction for an atmospheric contamination of argon is carried out because the error produced by a contamination of atmospheric argon is smaller than the mechanical error of the instrument used.

6. DISCUSSION

1. The radiometric Ar<sup>40</sup>/K<sup>40</sup> age of 188×10<sup>6</sup> yr on the muscovite crystal in the pegmatite indicates that the massive granodiorite in the upper Katakai River area is of upper Triassic age and that this Triassic massive granodiorite is considered to be quite distinct from the Cretaceous Kitama–dani tonalite.

So far the mutual relationship between the massive granodiorite and the Kitama–dani tonalite is ambiguous. Both granitic rocks have been considered to be of the same period (Post Jurassic) by some authors, e.g., by HIRAYAMA et al. (1955).

OHTA (1961) considered that the massive granodiorite might be a late– or post–kinematic granite batholith in the Hida metamorphic belt and might be older than the Kitama–dani tonalite. His classification is, however, tentative and is not based on any rigorous geological evidence.

Geological boundary between the Triassic massive granodiorite and the Cretaceous Kitama–dani tonalite still remains ambiguous, though the former granodiorite is considered to occur along the western border of the latter tonalite as is shown in Fig. 1. This problem remains for future investigation.

2. The radiometric age of 188×10<sup>6</sup> yr on the muscovite crystal also indicates that the age of the Hida
A : The muscovite crystal from a muscovite pegmatite in the massive granodiorite penetrating the Hida metamorphic complex. Circa 980 m above sea level, Higashi-mata-dani main stream in the upper Katakai River area, Toyama Prefecture. ×1.6

B : Granodiorite dike penetrating amphibolite, a member of the Hida metamorphic complex. Circa 980 m above sea level, Higashi-mata-dani main stream in the upper Katakai River area, Toyama Prefecture.
Table 2. Powder X-ray diffraction data for the muscovite

<table>
<thead>
<tr>
<th>2θ_CuKα, obs</th>
<th>d_obs</th>
<th>d_calc</th>
<th>I</th>
<th>hkl</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.89°</td>
<td>9.96 Å</td>
<td>9.976 Å</td>
<td>100</td>
<td>002</td>
</tr>
<tr>
<td>17.77</td>
<td>4.99</td>
<td>4.988</td>
<td>34</td>
<td>004</td>
</tr>
<tr>
<td>19.81</td>
<td>4.48</td>
<td>4.481</td>
<td>22</td>
<td>110</td>
</tr>
<tr>
<td>19.89</td>
<td>4.46</td>
<td>4.432</td>
<td>24</td>
<td>111</td>
</tr>
<tr>
<td>20.10</td>
<td>4.42</td>
<td>4.396</td>
<td>8</td>
<td>021</td>
</tr>
<tr>
<td>20.63</td>
<td>4.31</td>
<td>4.296</td>
<td>7</td>
<td>111</td>
</tr>
<tr>
<td>21.59</td>
<td>4.12</td>
<td>4.107</td>
<td>7</td>
<td>022</td>
</tr>
<tr>
<td>22.47</td>
<td>3.96</td>
<td>3.966</td>
<td>5</td>
<td>112</td>
</tr>
<tr>
<td>22.93</td>
<td>3.88</td>
<td>3.868</td>
<td>14</td>
<td>113</td>
</tr>
<tr>
<td>23.83</td>
<td>3.73</td>
<td>3.731</td>
<td>13</td>
<td>023</td>
</tr>
</tbody>
</table>

Table 3. Ar⁴⁰/K⁴⁰ age determination on the muscovite sample from a pegmatite in the upper Katakai River area (Analyzed by H. Nagasawa)

<table>
<thead>
<tr>
<th>K₂O (% content)</th>
<th>K⁴⁰ (ppm)</th>
<th>Ar⁴⁰ (10⁻⁶/yr)</th>
<th>Ar⁴⁰/K⁴⁰</th>
<th>Age (m.y.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.86</td>
<td>0.585</td>
<td>5.30</td>
<td>0.0115</td>
<td>188±8</td>
</tr>
</tbody>
</table>

Constants: λₘ = 0.585 × 10⁻¹⁰/yr
λ = 5.30 × 10⁻⁶/yr
K⁴⁰ abundance = 1.19 × 10⁻⁴ gm/gm-K.

Table associated with the intrusion of the “Hunatsu” type granite and others.

Many examples of discordant age patterns in minerals by a post-crystallization metamorphism have been found (Moorbath, 1965).

In many cases there is clear petrological and field evidence that subsequent metamorphism has occurred. These examples are Baltimore gneiss of Maryland (Tilton et al., 1958, 1960; and Davies et al., 1962), Giants Range granite of Minnesota (Goldich et al., 1957), Southern Appalachian granites and pegmatites (Aldrich et al., 1959), Precambrian basement rocks of Finland (Wetherill et al., 1962), Lewisian basement complex of north-west Scotland (Giletti et al., 1961; and Long and Lambert, 1963), Pennine zone of the Italian Alps (See Moorbath, 1965) and others.

Several examples of discordant age patterns have been found in rocks where there is no sign of any mineralogical and textural changes, e.g., Precambrian basement rocks of Colorado in the vicinity of the Lower Tertiary Eldora Stock (Hart, 1961 and 1963), Precambrian basement rocks of northern Michigan (Aldrich et al., 1965), and the contact zone surrounding the Duluth gabbro of Minnesota (See Moorbath, 1965).

The Triassic massive granodiorite is homogeneous and shows no gneissose structure. The correlation of the massive granodiorite with the “Hunatsu” granite still remains ambiguous. More precise petrographical classification of the granitic rocks in the Hida metamorphic belt becomes necessary to establish the metamorphic history.

3. Wetherill et al. (1955) showed that the Ar⁴⁰/K⁴⁰ ratio for micas was higher than that for the feldspar from the same rock from seven geologic settings. Aldrich et al. (1956) also showed similar result.

The various radiometric datings, e.g., Rb-Sr method, on muscovite and on its co-existing minerals remain for future investigation.

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富山県片貝川上流地方において飛騨変成岩類を貫入するペグマタイト中の
白雲母の放射年代と鉱物学的性質

譚 訪 兼 位

（要）

I 片貝川上流地方の飛騨変成岩類は、北西一南東の走向、50°〜80° 西傾斜の同斜構造を示し、黑部川下流地方の鳥帽子山型変成岩の南の延長と考えられる。
II 片貝川最上流では、飛騨変成岩類を非調和的に貫いて塊状の花崗閃緑岩が分布する。この花崗閃緑岩中には岩塊状または脈状のペグマタイトが脇生し、ペグマタイト中に、白雲母の大きな板状結晶が産出する。
III この花崗閃緑岩体の東縁にそって北又谷トーナル岩体が黒部川主流にそって南北方向に広く分布する。北又谷トーナル岩体は飛騨変成岩類とそれを不整合に覆う来馬川を共に貫く白亜紀の貫入岩体である。

これまで、この花崗閃緑岩体は莫然と北又谷トーナル岩体として一括されたり、あるいは一応別別されたりしていた。

II ペグマタイト中の白雲母の化学的、X線的、光学的諸性質は表示したとおりであるが、とくにこの白雲母は Fe'' と Fe' に富み、Fe'/Fe'' 比が高く、ferrimuscovite 分子と ferrophengite 分子がそれぞれ 10% をこ

I この白雲母の K-Ar 法による放射年代は 1.9 億年（三叠紀）である。このことは、次の 2 つのことを示

（1）飛騨変成作用の主要時期は三叠紀より若い。
（2）花崗閃緑岩体は三叠紀に貫入した。それ故、白

久野らによる飛騨変成岩類中の黒雲母の放射年代（三

また、この花崗閃緑岩体と船津花岡岩体との対比は、

今後の検討にまちたい。

地

Asahi-dake 朝日岳
Baba-dani 祖母谷
Eboshi-yama 鳥帽子山
Hayatsuki River 早月川
Higashi-mata-dani 東又谷
Hunatsu 船津
Katakai River 片貝川
Kitamata-dani 北又谷
Kozó-dani 小僧谷

Kurobe River 黒部川
Kuruma Group 来馬統
Minami-mata-dani 南又谷
Otosawa 仏沢
Sankaidana-daki 三角棚
Shirouma-dake 白馬岳
Sogadake 僧ヶ岳
Unazuki 字奈月
Yatazo-dani 弥太蔵谷