Petrography and geochronology of the Paleogene Deokdong and Girimsa Granites in eastern part of the Kyeongsang Basin, Korea: Implications for Eocene-Oligocene magmatism in SE Korea and SW Japan

Yong Hun Kim***, Shigeru Iizumi* and Hiroo Kagami**

*Department of Geoscience, Shimane University, Matsue 690, Japan
**Graduate school of Science and Technology, Niigata University, Niigata 950-21, Japan
***Present address: Hyundai Heavy Industries Co., LTD., Chonha-Dong, Dong-Ku, Ulsan 682-792, Korea

Petrographical, petrochemical and Rb-Sr geochronological data are presented for two Paleogene granitic stocks (the Deokdong and Girimsa Granites) in the eastern part of the Kyeongsang Basin, southeast Korea. Both granites intrude the Eocene Wangsan Formation, and are unconformably overlain by Lower Miocene sedimentary and volcanic rocks. They are I-type and magnetite series granitoids, in common with most other Cretaceous-Paleogene granitic rocks in the Kyeongsang Basin. The Deokdong and Girimsa Granites have whole rock isochron ages of 42.1±5.9 (2σ) and 34.3±3.3 (2σ) Ma, with low initial Sr isotope ratios of 0.70542±0.00030 (2σ) and 0.70570±0.00030 (2σ), respectively. The initial Sr isotope ratios are comparable with those of the majority of the Cretaceous-Paleogene granitic rocks in the Kyeongsang Basin, and also compare well with those of Cretaceous-Paleogene granitic rocks in the San’in Belt and northern Kyushu, southwest Japan. This suggests that the Cretaceous-Paleogene granitic rocks in the Kyeongsang Basin and in the San’in Belt and northern Kyushu of southwest Japan were derived from isotopeally similar source materials. The new and previously reported age data suggest that felsic to intermediate magmatism continued intermittently from the Cretaceous into the late Paleogene in the eastern part of the Kyeongsang Basin, although magmatism had practically ceased in the greater part of the basin by the end of Paleocene. Geochronologically, the two granites can be correlated with the Paleogene Namariyama Intrusives in the San’in Belt of southwest Japan. Taking the distribution of the Eocene-Oligocene igneous rocks into account, it is suggested that Cretaceous-Paleogene magmatism migrated to a narrow belt along the East Sea (Japan Sea), in both Korea and southwest Japan. The geochronological and Sr isotope data obtained in this study are consistent with the suggestions that the Eocene-Oligocene magmatism can be ascribed to upwelling of a mantle plume, which probably initiated the opening of the East Sea (Japan Sea).

Keywords: Granite, Paleogene, Rb-Sr isochron, Kyeongsang Basin, Korea, San’in Belt, Southwest Japan

I. Introduction

Cretaceous-Paleogene granitic rocks and co-magmatic volcanic rocks are widely distributed in the Kyeongsang Basin, southeast Korea (Fig. 1). This voluminous intermediate to felsic magmatism in southeast Korea, as well as contemporaneous magmatism in southwest Japan, is considered to have taken place in relation to subduction of the Kula-Pacific Ridge at the eastern margin of the Eurasian continent, before the Southwest Japan Arc drifted away.

(Manuscript received, February 12, 1997; accepted for publication, July 22, 1997)
from the continent (e.g. Uyeeda and Miyashiro, 1974; Kinoshita and Ito, 1988).

The volcanic and intrusive rocks in the Kyeongsang Basin are mostly Cretaceous-Paleocene in age (Kim and Lee, 1983; Lee et al., 1987; Jin et al., 1991; Lee et al., 1995 and others), although Eocene to Oligocene radiometric ages have been reported for volcanic and intrusive rocks from the eastern part of the basin (Lee and Ueda, 1977; Shibata et al., 1979; Lee, 1980; Lee, 1987; Jin et al., 1988, 1991; Kim et al., 1995). Based on geological and available geochronological data, Yoon (1989) pointed out that an Eocene formation (the Wangsan Formation), composed mainly of intermediate lavas and pyroclastic rocks, forms the basement for the Miocene Pohang and Yangnam sedimentary Basins in southeastern Korea, and suggested that some granitic plutons occurring in and around the Wangsan Formation are probably Eocene or younger in age. Recently, Kim et al. (1995) reported Rb-Sr whole rock isochron ages ranging from 59.5 to 39.7 Ma for four granitic plutons in the eastern part of the basin. These geological and geochronological data indicate that the magmatism continued into the late Paleogene in eastern part of the basin.

The Cretaceous-Paleogene felsic to intermediate magmatism in southwest Japan, on the other hand, is divided into several volcano-plutonic cycles, spanning 110 Ma to 30 Ma. Cretaceous volcanic and intrusive rocks are widely distributed in southwest Japan, but Paleogene igneous rocks occur only in northern coastal area of the district (Murakami, 1974; Iizumi et al., 1985; Kagami et al., 1988). This may indicate that the site of the Cretaceous-Paleogene magmatism migrated towards the East Sea (Japan Sea) side with time both in Korea and southwest Japan.

In this report, we present petrographical and petrochemical data for two granitic plutons
(Deokdong and Girimsa Granites) occurring in and around the Eocene Wangsan Formation (Fig. 2). We have also reexamined Rb-Sr whole rock isochron ages of the two granites, and correlate the Eocene to Oligocene magmatism in Korea with that in southwest Japan. Examining temporal and spatial change in the site of the magmatism is important to understand the mechanism of voluminous felsic to intermediate magmatism at continental margins.

II. Outline of Geology

Thick Cretaceous sedimentary and volcanic sequences (Kyeongsang Supergroup) underlain by Precambrian basement comprise the Kyeongsang Basin in southeast Korea. The Kyeongsang Supergroup is subdivided into the Shingdong, Hayang, and Yuchon Groups in ascending order (Fig. 1) (Chang, 1987). Shingdong and Hayang Groups are composed mainly of fluvio-lacustrine sedimentary rocks with small amounts of volcaniclastic rocks and lavas, whereas the Yuchon Group consists mainly of intermediate to felsic volcanic rocks (Chang, 1987). The study area, easternmost area of the Kyeongsang Basin (about 10 km east of Kyeongju), is underlain by the Hayang Group, which is composed of alternating beds of thermally metamorphosed psammitic and pelitic rocks (Fig. 1). The Hayang Group is discordantly intruded by Cretaceous-Paleogene granitic rocks, and is unconformably overlain by the Eocene Wangsan Formation (Yoon, 1989; 1990). The Wangsan Formation consists of felsic to intermediate lavas and pyroclastic rocks, predominated by dacitic and andesitic crystal and lapilli tuffs, with intercalated welded tuffs. These pyroclastic rocks frequently contain lithic fragments of granites and metamorphosed sediments of the Hayang Group.

Shibata et al. (1979) reported a K-Ar K-feldspar age of 44.7±1.1 Ma for a rhyolite lava
from the Wangsan Formation. Jin et al. (1988) reported K–Ar whole rock ages ranging from 64.8 ± 0.9 Ma to 38.8 ± 0.6 Ma for the Wangsan Formation and other volcanic rocks in the eastern part of the Kyeongsang Basin. The Wangsan Formation is unconformably overlain by lower to middle Miocene sedimentary and volcanic rocks in the Neogene Yangnam and Pohang Basins (Fig. 1) (Yoon, 1989). The lower Miocene Series, which occurs only in the Yangnam Basin, comprises terrestrial sedimentary rocks and intermediate to basic volcanic rocks. The middle Miocene Series, which consists mainly of marine sedimentary rocks, occurs in both the Yangnam and Pohang Basins (Yoon, 1990).

The Deokdong Granite, a small, slender stock about 400 m wide and 1.2 km long, occurs near the boundary between the Cretaceous Hayang Group (Kyeongsang Supergroup) and the Eocene Wangsan Formation (Fig. 2). The Deokdong Granite intrudes the alternating beds of sandstone and shale of the Hayang Group, with sharp contacts. As aplites and quartz veins derived from the Deokdong Granite penetrate pyroclastic rocks of the Wangsan Formation at the northern margin of the body, the Deokdong Granite is younger than the Wangsan Formation.

The Girimsa Granite is an elliptical stock with a long axis of about 6 km, intruding pyroclastic rocks of the Wangsan Formation (Figs. 1 and 2).

III. Petrography and petrochemistry of the granites

The predominant rock type of the Deokdong Granite is fine- to medium-grained equigranular biotite granite, which is mainly composed of plagioclase, K-feldspar, quartz, biotite, zircon, apatite, magnetite and ilmenite. This equigranular granite frequently grades into granite porphyry and granophyre, which are the dominant rock types at the northern margin of the body. Granite porphyry and granophyre occasionally contain flaky muscovite in miarolitic cavities. Although granite porphyry and granophyre rarely show magnetic susceptibility lower than 1.0 × 10⁻³ SI units, the equigranular granites commonly have magnetic susceptibility greater than 2.0 × 10⁻³ SI units.

Medium- to coarse-grained equigranular granite are the dominant rock types of the Girimsa Granite. The main constituent minerals are plagioclase, quartz, K-feldspar, biotite, apatite, sphene, zircon, magnetite and ilmenite. Prismatic green hornblende occurs occasionally as an accessory phase in the coarse-grained granite. This equigranular biotite granite sometimes grades into coarse-grained porphyritic granite, which contains granular quartz and interstitial K-feldspar up
Fig. 4. Variation diagrams.
open circle, Deokdong Granite; filled circle, Girimsa Granite.
to 8 mm in size. The rocks commonly show magnetic susceptibility higher than $2.5 \times 10^{-3}$ SI units.

Modal compositions of representative samples from the two granitic stocks are given in Figure 3. Apart from three samples, which plot in the granodiorite or alkali feldspar granite fields, samples from both stocks plot in the granite field. The Deokdong Granite tends to have slightly higher plagioclase and quartz contents than does the Girimsa Granite, although both have similar modal mafic mineral contents ranging from 1 to 9 percent.

Whole rock major and trace elements were measured with X-ray fluorescence spectrometry (JEOL, JSX60S7) in the Geology Department of Shimane University, following the methods described by Kobayashi et al. (1981) and Ichikawa et al. (1987). The results are listed in Table 1. Although both granites are felsic, and have similar silica contents ranging from 69 to 77 percent, the Deokdong Granite has slightly higher TiO$_2$, Al$_2$O$_3$, CaO, Sr and lower K$_2$O, Rb, Y and Nb contents than does the Girimsa Granite (Fig. 4). In terms of Rb- (Y+Nb), all samples from the Deokdong Granite plot in the field typical of volcanic arc granite (Fig. 5). On the other hand, samples from the Girimsa Granite have higher Y+Nb contents, and straddle the fields of both volcanic arc granite and within plate granite. Nevertheless, both granites are comparable with Cretaceous–Paleogene granitic rocks from the eastern part of the Kyeongsang Basin (Fig. 5). As compared with Cretaceous–Paleogene granitic rocks with similar Rb contents in the San’in Belt of southwest Japan, the most samples from the Deokdong Granite are slightly low in Y+Nb content. In contrast with this, samples from the Girimsa Granite have comparable or higher Y+Nb contents than the granitic rocks in the San’in Belt (Fig. 5).

As shown in Table 1, all granitic rocks from the Deokdong and Girimsa Granites have molecular Al$_2$O$_3$/CaO+Na$_2$O+K$_2$O values less than 1.1. Taking their whole rock chemistry, petrography and magnetic susceptibility into account, the Deokdong and Girimsa Granites are I-type (Chapell and White, 1974) magnetite series granitoids (Ishihara, 1977), in common with most of the Cretaceous–Paleogene granitic rocks in the Kyeongsang Basin and the San’in Belt of southwest Japan.
Table 2. Rb and Sr contents and Sr isotope ratios of the Deokdong and Girimsa Granites

<table>
<thead>
<tr>
<th>Sample</th>
<th>Rb&lt;sub&gt;ppm&lt;/sub&gt;</th>
<th>Sr&lt;sub&gt;ppm&lt;/sub&gt;</th>
<th>Rb/Sr</th>
<th>Rb&lt;sup&gt;87&lt;/sup&gt;Sr</th>
<th>Rb&lt;sup&gt;87&lt;/sup&gt;Sr</th>
<th>2σ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deokdong Granite</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>K-47</td>
<td>130</td>
<td>230</td>
<td>1.64</td>
<td>0.70651</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>K-50</td>
<td>112</td>
<td>108</td>
<td>3.00</td>
<td>0.70712</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>K-118</td>
<td>116</td>
<td>105</td>
<td>3.20</td>
<td>0.70715</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>K-46</td>
<td>144</td>
<td>61</td>
<td>6.83</td>
<td>0.70974</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>K-41</td>
<td>136</td>
<td>68</td>
<td>5.79</td>
<td>0.70873</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>K-45</td>
<td>138</td>
<td>75</td>
<td>5.32</td>
<td>0.70873</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Girimsa Granite</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>K-86</td>
<td>142</td>
<td>194</td>
<td>2.12</td>
<td>0.70666</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>K-134</td>
<td>143</td>
<td>55</td>
<td>7.52</td>
<td>0.70930</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>K-256</td>
<td>181</td>
<td>51</td>
<td>10.3</td>
<td>0.71058</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>K-237</td>
<td>147</td>
<td>34</td>
<td>12.5</td>
<td>0.71225</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>K-255</td>
<td>149</td>
<td>20</td>
<td>21.6</td>
<td>0.71529</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Rb and Sr were determined by XRF.

Fig. 5. Rb-(Nb+Y) diagram.
open circle, Deokdong Granite; large filled circle, Girimsa Granite; small filled circle, Cretaceous granitic rocks from the southeastern part of the Kyeongsang Basin (Hong, 1985 and Lee et al., 1996); end field of solid curve, granitic rocks from the San' in Belt, southwest Japan (Kagami et al., 1992). syn-COLG, syn-collision granites; WPG, within plate granites; ORG, ocean ridge granites; VAG, volcanic arc granites. Discrimination lines from Pearce et al. (1984).

IV. Rb-Sr whole rock isochron ages

Rb and Sr concentrations and Sr isotope ratios were determined for whole rock samples from the Deokdong and Girimsa Granites. The Rb/Sr ratio of each sample is estimated to have maximum error of 5 percent based on the reproducibility of the data for standard samples JG-1a and JB-1a. Sr isotope ratios were measured at the Institute for Study of the Earth's Interior, Okayama University, using a MAT261 (modified from MAT260) mass spectrometer equipped with five Faraday cups.

Extraction method for Sr and mass spectrometric analysis essentially follow Kagami et al. (1982). Measured <sup>87</sup>Sr/<sup>86</sup>Sr ratios were normalized to <sup>86</sup>Sr/<sup>88</sup>Sr = 0.1194. Blanks for the whole procedure were 0.55 ng Sr. The Sr isotope ratio for NBS987 was measured three times during this study, with a mean ratio of 0.710232 ± 0.000012 (2σ<sub>mean</sub>). Isochron ages were calculated after York (1966).

Analytical results are listed in Table 2, and the whole rock isochron diagrams are shown in Figure 6. Six whole rock samples from the
Deokdong Granite define an isochron age of 42.1 ± 5.9 Ma (2σ) with an initial ratio of 0.70542 ± 0.00030 (2σ). On the other hand, the Girimsa Granite gives a younger whole rock isochron age of 34.3 ± 3.3 Ma (2σ), with a similar initial Sr isotope ratio of 0.70570 ± 0.00030 (2σ). Calculating ages and initial Sr isotope ratios after Kullerud (1991), using four whole rock samples, Kim et al. (1995) reported a comparable Rb-Sr whole rock isochron age of 45.6 ± 0.1 Ma with an initial ratio of 0.70539 ± 0.00001 for the Deokdong Granite. However, a whole rock isochron determined by two whole rock samples for the Girimsa Granite (Kim et al., 1995) gives an older age of 39.7 ± 0.1 Ma, with a similar initial Sr isotope ratio of 0.70564 ± 0.00001.

V. Discussion: Eocene–Oligocene magmatism in SE Korea and SW Japan

As mentioned earlier, the Girimsa Granite has higher modal K-feldspar content and higher lithophile elements such as K₂O, Rb, Y and Nb than does the Deokdong Granite. Both granites, however, have comparable and low initial Sr isotope ratios, indicating that their granitic magmas were derived from source material (probably lower crust) with similar geochemical characteristics.

Previously reported initial Sr isotope ratios of the granitic rocks in the Kyeongsang Basin are variable, ranging from 0.704 to 0.713 (Choo and Kim, 1981; Choo et al., 1982; Lee, 1987 and others). However, some of these data were determined by the whole rock–mineral isochron method, which in some cases gives higher initial ratios than the whole rock isochron method, because minerals such as biotite and feldspar have lower closure temperatures in the Rb–Sr isotope system than the whole rock. Based on the whole rock isochron method, Jin (1988) stated that initial Sr isotope ratios of most granitic rocks from the Kyeongsang Basin were lower than 0.707. Recently reported initial Sr isotope ratios for Cretaceous–Paleogene granitic and volcanic rocks in the Kyeongsang Basin are in a range from 0.7049 to 0.7072, and are mostly lower than 0.7065 (Lee et al., 1995; Kim et al., 1995; Kim et al., 1996). The Eocene Deokdong and Oligocene Girimsa Granites have initial Sr isotope ratios comparable with that range. Lee et al. (1995) pointed out that the initial Sr isotope ratios of the Cretaceous granitic rocks in the Kyeongsang Basin tend to become gradually higher from west to east. Our data is consistent with this observation, since the Deokdong and Girimsa Granites, which occur in the easternmost area of the Kyeongsang Basin, have relatively higher initial Sr isotope ratios.

Based on initial Sr and Nd isotope ratios, Kagami et al. (1992) divided Cretaceous–Paleogene granitic rocks in southwest Japan into North, Transitional, South and Northern Kyushu Zones. The granitic rocks of the North and Northern Kyushu Zones generally have initial Sr isotope ratios less than 0.706 (Shibata and Ishihara, 1979; Iizumi et al., 1984; Sudo et al., 1988; Kagami et al., 1992; Osanai et al., 1993; Rezanov et al., 1994), whereas most Transitional and South Zone granitic rocks have initial Sr isotope ratios greater than 0.707. The Deokdong and Girimsa Granites, and other Cretaceous granites in the Kyeongsang Basin, have similar initial Sr isotope ratios to the Cretaceous–Paleogene granitic rocks of the North Zone and northern Kyushu of southwest Japan, suggesting that these granitic magmas were derived from sources (probably lower crust) with similar isotopic characteristics. Cretaceous granitic rocks outside the Kyeongsang Basin, however, commonly have initial Sr isotope ratios greater than 0.708 (Kim et al., 1996; Shin and Kagami, 1996; Iizumi et al., unpublished data), indicating that the magma source with low Sr isotope ratios
existed only beneath the Kyeongsang Basin in southeast Korea and the North Zone and Northern Kyushu Zone in southwest Japan.

Although previously reported age data indicate that most granitic rocks in the Kyeongsang Basin are late Cretaceous-Paleocene (Lee, 1987; Jin et al., 1981; 1988; 1991; Lee et al., 1995 and others), younger Eocene to Oligocene radiometric ages have been reported for volcanic and intrusive rocks from the eastern part of the basin. Lee and Ueda (1977) and Lee (1980) reported K-Ar whole rock, biotite and salic mineral ages ranging from 115 to 41 Ma for granitic rocks mostly from the eastern part of the Kyeongsang Basin. Jin et al. (1988; 1991) reported K-Ar biotite and whole rock ages ranging from 80 to 25 Ma for volcanic and granitic rocks in eastern part of the Basin. Kim et al. (1995) reported Paleogene Rb-Sr whole rock isochron ages (39.7 Ma, 42.2 Ma, 45.6 Ma and 59.5 Ma) for four granites, including the Deokdong and Girimsa Granites, also from eastern part of the Kyeongsang Basin. Previously reported age data of the Eocene to Oligocene igneous rocks from the Kyeongsang Basin are compiled in Figure 7. Except for one K-Ar whole rock age data (42 Ma) for a hornblende-biotite granite from near Taegu, in the western part of the Kyeongsang Basin, Eocene and Oligocene volcanic and granitic
rocks are confined to the eastern part of the basin. This indicates that the magmatism was practically extinct in the greater part of the Kyeongsang Basin by the end of Paleocene, but continued on into the Oligocene at the eastern margin.

The Deokdong and Girimsa Granites, and most other Eocene-Oligocene igneous rocks, occur on the eastern side of the Yangsan Fault, which extends from Yeonghahae to Pusan in a NNE-SSW direction (Fig. 1). There are two different views about the movement of the Yangsan Fault. Reedman and Um (1975) and Otsuki and Ehiro (1978) considered that the Yangsan Fault was a dextral strike-slip fault, which was active in the early Miocene during the opening of the Japan Sea. It is inferred that the eastern block of the Yangsan Fault was situated 25 km (Otsuki and Ehiro, 1978) or about 150 km (Kinoshita and Ito, 1988) NNE of its present position during Cretaceous-Paleogene times. On the other hand, Yoon (1986) and Yoon and Kim (1990) stated that the Yangsan Fault resulted from block movements caused by magmatism during the late Cretaceous to early Miocene. In either case, however, it is supported that the Eocene to Oligocene magmatism thus took place at the eastern margin of the Korean Peninsula.

Geochronologically, the Deokdong and Girimsa Granites and other Eocene granitic rocks in the Kyeongsang Basin can be correlated with the Eocene to Oligocene Namariyama Intrusive Rocks (Sasada et al., 1979; Iizumi et al., 1985) of the San’in Belt in southwest Japan (Fig. 8). In the San’in Belt, magmatism continued intermittently from the Late Cretaceous to Holocene, and intense granite plutonism occurred in the late Cretaceous-Paleocene and also in the Eocene-Oligocene. The Eocene to Oligocene Namariyama Intrusives and older, related felsic to intermediate volcanic rocks, comprise elliptical cauldrons along the coast of the San’in Belt (Iimaoka et al., 1988). The Eocene Wangsan Formation is correlatable with these volcanic rocks (Fig. 8).

Based on geological and geochronological data, Iizumi et al. (1985) pointed out that the Cretaceous-Paleogene felsic to intermediate magmatism in southwest Japan migrated toward the Japan Sea side with time. As described earlier, Eocene to Oligocene igneous rocks in the Kyeongsang Basin are restricted to the eastern coastal areas. These geologic and geochronological lines of evidence support the suggestion (Fujita and Ganzawa, 1982; Kagami et al., 1988; 1995) that Paleogene magmatism, especially Eocene to Oligocene magmatism, took place in a narrow belt on the eastern margin of the Eurasian Continent.

Uyeda and Miyashiro (1974) suggested that the mid-oceanic Kula-Pacific Ridge probably collided with Japan and descended beneath it in late Cretaceous time, and that this high temperature ridge subduction caused unusually widespread magmatism on the continental margin. The concept of ridge subduction has been accepted and supported by many authors for the Cretaceous-Paleogene magmatism in

<table>
<thead>
<tr>
<th>Age (Ma)</th>
<th>eastern part of the Kyeongsang Basin, Korea</th>
<th>San’in Belt, southwest Japan</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-30</td>
<td>Eocene-Oligocene Granites (Girimsa Granite)</td>
<td>Namariyama Intrusives</td>
</tr>
<tr>
<td>40</td>
<td>Deokdong Granite</td>
<td>Paleogene Volcanic Rocks</td>
</tr>
<tr>
<td>50</td>
<td>Wangsan Formation</td>
<td></td>
</tr>
<tr>
<td>70</td>
<td>Cretaceous-Paleocene Granites (Boilhwa Granites)</td>
<td>Inbi Intrusives</td>
</tr>
<tr>
<td>80</td>
<td></td>
<td>Cretaceous Volcanic Rocks</td>
</tr>
<tr>
<td>90</td>
<td></td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>Kyeongsang Supergroup</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 8. Correlation of Cretaceous-Paleogene magmatism in South Korea and Southwest Japan (data sources: Yoon, 1989; Sasada et al., 1979; Iizumi et al., 1985 and this study). O, Oligocene; E, Eocene; P, Paleocene; C, Cretaceous.
Korea and southwest Japan (e.g. Kinoshita and Ito, 1986; 1988; Nakajima, 1994). Kinoshita and Ito (1986) stated that the Cretaceous-Paleogene felsic magmatism in southwest Japan migrated both eastward and northward with time, and suggested that this migration was caused by the Kula-Pacific ridge subduction. Nakajima (1994) pointed out that the Cretaceous Ryoke and San'yo granites in southwest Japan show an along-arc variation of the systematic eastward younging from 100 Ma to 70 Ma, and ascribed this along-arc variation to the oblique subduction of the Kula-Pacific ridge beneath the Eurasian Continent. However, Nakajima (1994) suggested that the Paleogene granitic rocks in the San’in Belt may well be regarded as to have been formed in a separate tectonic setting from the Cretaceous Ryoke and San’yo granitic rocks, since the granitic rocks in the San’in Belt show different areal age distribution pattern from the Ryoke and San’yo granitic rocks.

Examining isotope age data of Cretaceous-Paleogene igneous rocks in southwest Japan, Kagami et al. (1988) pointed out that igneous rocks with the ages younger than 75 Ma are distributed in a narrow zone along the East Sea (Japan Sea) coast, and suggested that the magmatism should be considered in relation to the geological situation surrounding the East Sea (Japan Sea). The Cretaceous intermediate to felsic magmatism, which was taken place widely in the southern part of Korea and southwest Japan could be ascribed to the Kula-Pacific ridge subduction. As suggested by Kagami et al. (1988) and Nakajima (1994), however, the Paleogene magmatism, especially the Eocene to Oligocene magmatism which occurred in a narrow belt along the East Sea (Japan Sea), should be ascribed to different mechanism from the ridge subduction.

Based on petrological, geochemical and Sr and Nd isotopic data on Cretaceous to Miocene igneous rocks in the central San’in district, southwest Japan, Sawada et al. (1989) suggested that geochemical character of the lower crust and upper mantle beneath the San’in district were gradually changed during the late Paleogene by injection of basic magmas which were probably derived from upwelling depleted mantle. Supporting this idea, Kagami et al. (1995) suggested that this upwelling mantle may have been the depleted peridotite megalith (Ringwood, 1985), and that this upwelling of the megalith involved the Paleogene magmatism around the East Sea (Japan Sea). Spatial distribution of the Eocenic and Oligocene igneous rocks in Korea and their low initial Sr isotope ratios are consistent with these suggestions.

Acknowledgements: The authors are grateful to Professor Yoon, Sun of Pusan National University and staff members of the Department of Geoscience, Shimane University for their valuable suggestions and encouragement during this study. We would like to thank Dr. Barry Roser of the Department of Geoscience, Shimane University for reviewing and improving the manuscript. We are grateful to two anonymous reviewers for their constructive comments and suggestions. This research was partly supported by Grant in Aids for Scientific Research to S. Izumi (Nos. 06452094 and 07045015) from the Japanese Ministry of Education, Science, Sports and Culture.

References


*Korean with English abstract
**Japanese with English abstract
***Japanese
韓国、慶尚盆地東部に分布する古第三紀德洞および砥林寺花崗岩の記載岩石学的・年代学的研究：南東韓国および西南日本における始新世～漸新世火成活動

金 竜勲・飯泉 滋・加々美寛雄

韓国慶尚盆地東部に産する徳洞および砥林寺花崗岩について、記載岩石学的およびRb-Sr法による年代学的研究を行った。両花崗岩は始新世火山岩類を貫くストックで、Iタイプ磁鉄隕系に属する。徳洞花崗岩は42.1±5.9 Ma (2σ)、砥林寺花崗岩は34.3±3.3 Ma (2σ)を示し、Sr同位体初生値はそれぞれ0.70542±0.00030 (2σ)および0.70570±0.00030 (2σ)の低い値を示す。初生値は慶尚盆地の他の花崗岩類、西南日本の山陰帯・北九州のものとほぼ一致し、類似したマグマソースが推定される。韓半島および西南日本ともに始新世および漸新世の火成活動は東海（日本海）に沿う限られた地域に分布しており、幅広い白亜紀の火成活動は、時間と共に比較的幅の狭い地域に収束していったことを示している。これらのデータは、始新世～漸新世の火成活動は縄文の形成に関係したマントルブリュームの上昇に関連したとの従来の見解と矛盾しない。

Kyeongsang Basin, 慶尚盆地; Deokdong Granite, 徳洞花崗岩; Girimsa Granite, 砥林寺花崗岩; Namariyama Intrusives, 鈴山侵入岩類