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SHRIMP zircon age of a Proterozoic rapakivi granite batholith in the Gyeonggi massif (South Korea) and its geological implications

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Abstract – A large rapakivi granite batholith in the Neo-Archaean/Palaeoproterozoic Odesan complex, northeastern Gyeonggi massif, South Korea, has been dated at 1839 ± 10 Ma using SHRIMP U–Pb analysis of zircons. The age, petrological and geochemical characteristics of this batholith are similar to those of the rapakivi granite batholiths exposed in the Rangnim massif of North Korea and in the Miyun–Chengde complex of North China. The country rocks of these rapakivi granite batholiths are also comparable; all are composed of granitic gneisses and banded iron formation (BIF)-bearing supracrustal rocks metamorphosed to amphibolite- to granulite-facies. This study provides new evidence for the suggestion that the Gyeonggi and Rangnim massifs may share an affinity with the Precambrian basement of the North China craton. The study provides new insight into the possible eastward extension of the Sulu orogenic belt in the Korean peninsula and further provides evidence to correlate the Korea basement to a possible global 2.1–1.8 Ga supercontinent.

Keywords: rapakivi, granite, SHRIMP data, zircon, South Korea.

1. Introduction

Since ultrahigh-pressure metamorphic rocks were first discovered in the Sulu belt, eastern China (Fig. 1), attention has been focused on the question of whether the Sulu belt extends eastwards to the Korean Peninsula. High-pressure metamorphic rocks have been found in the Korean Peninsula, and metamorphic and granitic rocks with Mesozoic isotopic ages have been reported (Lee & Cho, 1995; Lee *et al.* 1997; Zhai & Liu, 1998; Lee *et al.* 2000; Lee & Cho, 2003; Sagong, Cheong & Kwon, 2003). For example, garnet amphibolites from the Yeoncheon complex and retrograded garnet granulites from Bibong complex record peak pressure of 8–13 kbar (Ree *et al.* 1996) and 17–21 kbar (Oh *et al.* unpub. data), respectively. Some researchers argue that the Rangnim, Gyeonggi and Yeongnam massifs have a similar early crustal evolution history, and have suggested that they were formerly parts of the North China craton (Kim & Jon, 1993; Lan *et al.* 1995; Cheong, Kwon & Park, 2000). Others have argued against this interpretation. Some consider that the Gyeonggi massif belongs to the Yangtze craton, while the Rangnim and Yeongnam massifs belong to the North China craton and the Imjingang and Ogcheon belts represent an eastern extension of the Sulu collisional belt (Yin & Nie, 1993; Cluzel, Lee & Cadet, 1991). Others suggest that the Imjinggang belt represents an extension of the Sulu belt, and the Rangnim massif and Gyeonggi massif (including the Yeongnam massif) are correlated to the North China and the Yangtze cratons, respectively (Chough *et al.* 2000; Lee & Cho, 2003).

With regard to the high-pressure metamorphic events, the comparative study of the basement rocks of the different massifs is important for understanding partial continental collisions in Korea. Kim & Cho (2003) and Kwon, Oh & Kim (2003) recently reported *c.* 1900 Ma granitic intrusions in the northeastern Yeongnam massif. Kim & Cho (2003) and Zhai & Liu (2003) suggested a possible correlation of this magmatic event with the Lüliang Movement in the North China Craton. In contrast, Kwon *et al.* (2003) emphasized that there are magmatic events of about 1400 Ma and 617 Ma in the Yeongnam massif, which have been rarely reported from the North China craton and commonly in the Yangtze craton. Lee *et al.* (2003) reported a 742 Ma age for an alkaline metagranitoid in the Gyeonggi massif and considered this massif as a possible extension of the Yangtze craton, based on the observation that rift-related magmatism was widespread there in the Neoproterozoic era. However, Lee *et al.* (2000) reported *c.* 1.9 Ga metamorphic ages for high-pressure granulites and amphibolites in the Hwacheon complex, on the northern margin of the Gyeonggi massif. High-pressure amphibolites are similarly exposed in the Palaeoproterozoic Hwanghae

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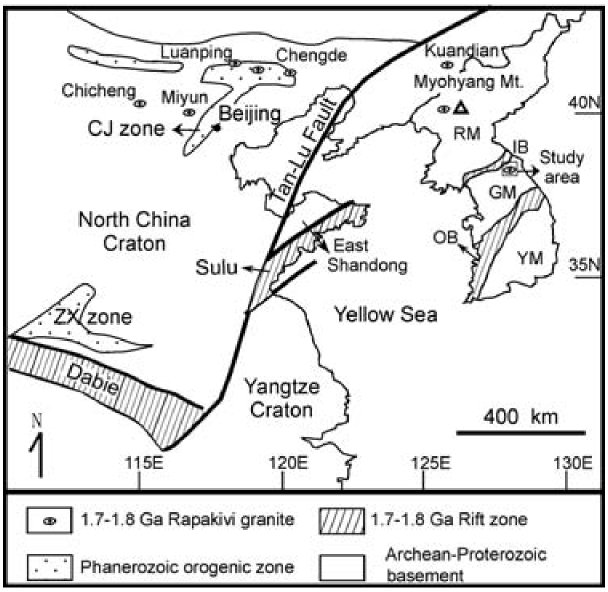

Figure 1. Sketch geological map of the North China craton and the Korea peninsula. RM – Rangnim Massif; IB – Imjinggang Belt; OB – Ogcheon Belt; GM – Gyeonggi Massif; YM – Yeongnam massif; CJ zone – Chengde – Jixian rift zone; ZX zone – Zhongtiao – Xionger rift zone.

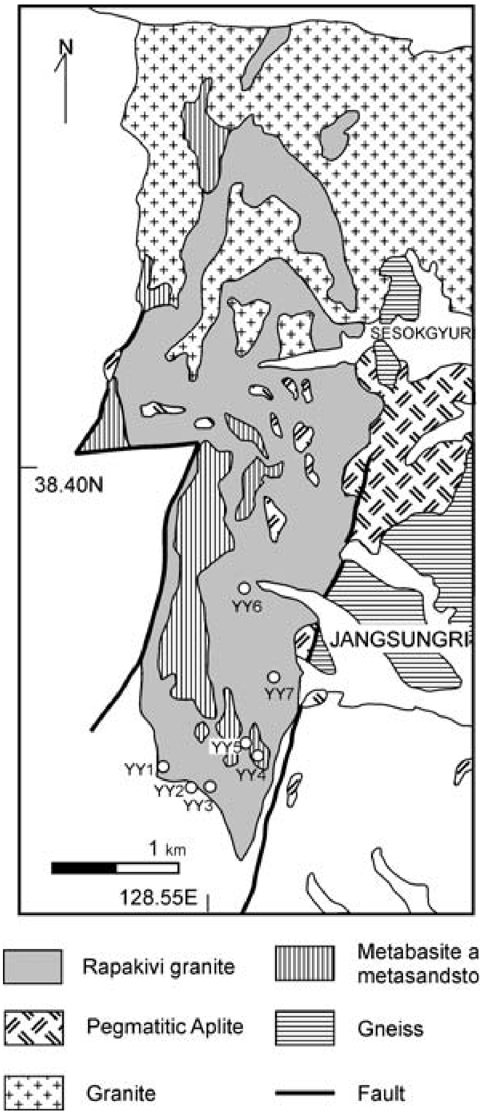

Figure 2. Sketch geological map of the Yangyang district in the Gyeonggi massif.

complex in the north of the Imjingang belt in North Korea (Zhai & Liu, 1997). The Hwanghae, Hwacheon and Yeoncheon complexes are considered to be the same unit of the Lower Proterozoic sequences by Na & Kim (1988) and Paek (1993). High-pressure granulites and amphibolites occur widely in the North China craton as lenses, such as those in the Qixia–Laixi complex in East Shandong, the Miyun–Chengde complex, the Huai'an complex, the Hengshan complex and the Huangtuyao complex in the northern-central North China craton. High-pressure granulites and garnet amphibolites with 1.9–1.8 Ga metamorphic ages are considered an important marker of the North China craton (Zhai & Liu, 1997). These metamorphic rocks are suggested to represent a Palaeoproterozoic collisional event (Zhao *et al*. 1999) or an uplifting event of the lowermost crust (Zhai & Liu, 2003). Metamorphic and magmatic events of 800–700 Ma and 230–200 Ma can be traced within the North China craton and along its northern and eastern margins. They have been interpreted as representing extensional tectonic events in the craton (Shao, Zhang & Li, 2002; Zhai *et al*. 2003), although these two events were much weaker than those in the Yangtze craton.

In this study, we report a SHRIMP zircon age of 1839 ± 10 Ma for a rapakivi granite from the Yangyang district in the northeastern part of the Gyeonggi massif. The typical Proterozoic anorogenic magmatic association of rapakivi granites associated with anorthosites and gabbros with 1.9–1.7 Ga ages occurs in Miyun, Chengde and Luanping in central North China (Yu *et al*. 1996), in Kuandian in northeastern China (Ge, Lin & Fang, 1991; Xiao *et al*. 2004) and in the Myohyang Mountains of the Rangnim massif, North Korea (Ryong, 1993). The rapakivi granites and their country rocks in the Gyeonggi massif are comparable to those of the Rangnim massif and the North China craton. Therefore, we interpret the results as evidence that the Rangnim and Gyeonggi massifs comprise parts of the same Precambrian basement sequence belonging to part of the North China craton.

2. Rapakivi granite

2.a. General geology

A large rapakivi granite batholith occurs in the Odesan complex in the northeastern part of the Gyeonggi massif. The Odesan complex consists of orthogneiss, rapakivi granite, amphibolite and metasedimentary rock (Lee & Kim, 1968; Kim, 1977). The study area is located in the Yangyang district of the Odesan complex (Fig. 2), where the largest iron mine in Korea is exposed, with about ten million tons of total iron reserve (So, Kim & Son, 1975; Kim, 1977). The orthogneisses consist mainly of granitic, migmatitic, banded and augen gneisses. The amphibolites are composed of hornblende, plagioclase, quartz, and minor components such as sphene, apatite, epidote and biotite. Magnetite quartzite and mica quartz schist are the major types of metasedimentary rocks. The rapakivi granite bodies were formerly called syenite or porphyritic syenitic granites because of their high $K_2O + Na_2O$ contents and high K_2O/Na_2O ratios (Lee & Kim, 1968; Na & Kim, 1988). They form a large batholith in the whole and are widely exposed along a belt extending from the Yangyang district, southwards to Gaein Mountain. The contact relationship between the rapakivi granites and their country rocks is commonly intrusive but faulted in some places. The rapakivi granites are composed mainly of coarse-grained plagioclase, K-feldspar, hornblende, biotite and quartz. On the basis of texture, Lee & Kim (1968) classified the rapakivi granites into four texture types: porphyritic–gneissic, porphyritic–massive, gneissic and massive. Minor Jurassic granites locally occur in the northern Yangyang district.

2.b. Petrography and geochemistry

The rapakivi granites show petrographic features of the typical classic rapakivi granites in southern Finland (Haapala & Rämö, 1990, 1999) and in Miyun, North China (Yu *et al.* 1990; Rämö *et al.* 1995; Yu *et al.* 1996). Rapakivi granites are rich in K-feldspar (> 50 %) and poor in quartz (< 20 %). Plagioclase is mostly ordered in a range of An from 8 to 23. Alkali feldspar is mainly microcline and orthoclase, and occurs in two generations present in ovoidal porphyritic textures and in groundmass. Mafic minerals are Fe-rich hornblende and biotite ($Fe/(Mg+Fe) = 0.76–0.90$). Magnetite, apatite and fluorite occur in the matrix and in ovoidal alkali feldspars.

Ovoidal porphyritic alkali feldspars are distributed homogeneously in the rapakivi granite from the central to marginal parts. The diameter of an ovoidal feldspar ranges from 2–4 cm to 30 cm, with an average of 8 to 10 cm. Most of them are mantled by plagioclase with a sharp and irregular contact (Fig. 3). Regular compositional changes occur from the centre to the margin of ovoidal feldspar, with a K_2O decrease from 15.5 wt % to 10.8 wt % and a Na_2O increase from 0.36 wt % to 3.47 wt %. Fine- or medium-grained hornblende, biotite and magnetite occur as inclusions in the ovoidal alkali feldspars, and are regularly concentrated as inner rings and fill along fissures between the feldspar crystals. Chemical analyses of the rapakivi granites are shown in Table 1.

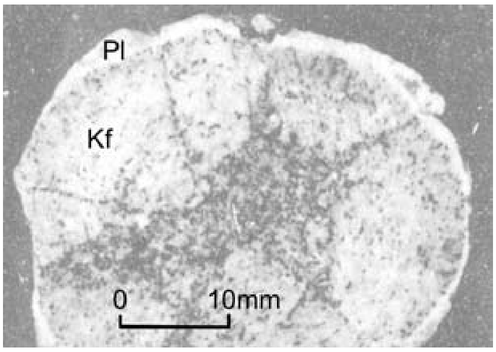

Figure 3. Feldspar porphyritic crystal of rapakivi granite (YY-15a). Pl – plagioclase; Kf – K-feldspar.

3. SHRIMP analytical method and zircon age

The rapakivi granite sample (YY7) for the SHRIMP U–Pb zircon dating was collected from a fresh outcrop exposed in the Yangyang mine. Zircons were extracted from about 5–10 kg of rock, using standard density and magnetic separation techniques. More than 100 grains of zircon were mounted in epoxy discs together with the Temora (417Ma) and SL13 zircon standards and these were then polished to expose the centres of the zircon grains. Cathodoluminescence (CL) images

Table 1. Major element analyses for rapakivi granites

	YY-1	YY-4	YY-6	YY-7a	YY-10	Myohyang	Shachang	Chicheng
SiO_2	66.98	70.32	63.35	66.24	61.67	70.56	68.86	68.68
TiO_2	0.51	0.24	0.38	0.22	1.56	0.4	0.48	0.74
Al_2O_3	14.92	14.56	16.72	15.22	15.07	13.99	14.61	14.24
Fe_2O_3	1.31	0.41	0.83	1.96	2.03	1.08	1.39	3.03
FeO	2.02	1.37	2.34	1.16	3.67	2.47	1.84	1.68
MnO	0.05	0.04	0.05	0.01	0.05	0.05	0.05	0.07
MgO	0.47	0.31	2.51	0.77	2.61	0.33	0.39	0.55
CaO	1.88	1.19	0.15	1.32	2.5	1.44	1.62	1.57
Na_2O	3.31	4.38	4.14	6.19	4.35	2.85	3.19	3.13
K_2O	5.8	5.57	6.49	5.96	5.5	5.47	5.76	5.37
P_2O_5	0.14	0.08	0.07	0.1	0.09	0.04	0.12	0.18
Los	2.42	0.99	2.43	0.59	0.51	0.99	1.5	1.04
Total	99.81	99.46	99.46	99.74	99.61	99.67	99.81	100.28
K_2O/Na_2O	1.75	1.27	1.57	0.96	1.26	1.91	1.8	1.71

Note: Analyses at Institute of Geology and Geophysics of the Chinese Academy of Sciences using a XRF-1500 Sequential X-Ray Fluorescence Spectrometer (SHIMADZU).

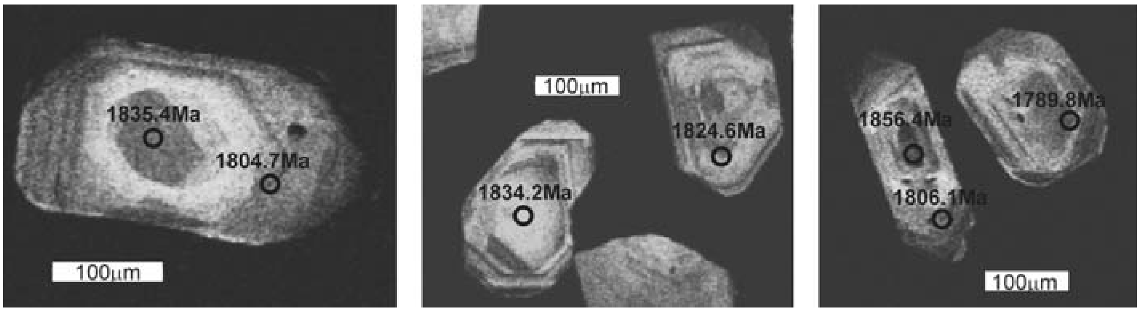

Figure 4. Representative cathodoluminescence images of zircons.

Table 2. SHRIMP analytical results for rapakivi granite sample YY7

Spot no.	^{206}Pbc (%)	U (ppm)	Th (ppm)	^{232}Th/ ^{238}U	^{206}Pb* (ppm)	^{206}Pb/^{238}U age (Ma)	^{207}Pb*/^{206}pb age (Ma)	^{207}Pb*/ ^{206}Pb*	± %	^{207}Pb*/ ^{235}U	± %	^{206}Pb*/ ^{238}U	± %
YY-18-1	0.48	40	26	0.67	11.5	1839 ± 44	1817 ± 42	0.1111	2.3	5.06	3.6	0.3302	2.8
YY-18-2	0.19	98	79	0.84	27.2	1805 ± 37	1848 ± 22	0.1130	1.2	5.03	2.7	0.3231	2.4
YY-18-3	0.13	141	150	1.10	40.6	1864 ± 38	1843 ± 15	0.11268	0.85	5.21	2.5	0.3353	2.3
YY-18-4	0.13	172	124	0.75	47.0	1780 ± 38	1826 ± 13	0.11161	0.72	4.89	2.5	0.3180	2.4
YY-18-5	0.23	119	74	0.64	34.3	1865 ± 40	1811 ± 20	0.1107	1.1	5.12	2.7	0.3356	2.5
YY-18-6	0.13	126	126	1.04	35.4	1824 ± 37	1831 ± 17	0.1119	0.92	5.05	2.5	0.3269	2.3
YY-18-7	0.44	62	44	0.72	17.6	1825 ± 39	1814 ± 28	0.1109	1.6	5.00	2.9	0.3272	2.4
YY-18-8	0.50	56	48	0.89	15.9	1834 ± 39	1831 ± 37	0.1119	2.0	5.08	3.2	0.3291	2.5
YY-18-9	0.36	64	47	0.76	17.9	1825 ± 39	1822 ± 29	0.1114	1.6	5.02	2.9	0.3272	2.4
YY-18-10	–	88	94	1.10	24.3	1790 ± 37	1867 ± 18	0.1142	0.99	5.04	2.6	0.3200	2.4
YY-18-11	0.09	199	81	0.42	50.4	1666 ± 34	1852 ± 14	0.11321	0.77	4.60	2.4	0.2949	2.3
YY-18-12	0.47	67	38	0.59	19.4	1856 ± 39	1824 ± 27	0.1115	1.5	5.13	2.8	0.3337	2.4
YY-18-13	0.25	103	96	0.96	28.8	1806 ± 37	1849 ± 22	0.1131	1.2	5.04	2.7	0.3234	2.4
YY-18-14	0.10	264	158	0.62	72.6	1786 ± 41	1843 ± 11	0.11267	0.63	4.96	2.7	0.3193	2.7

(1) Errors are 1-sigma; Pbc & Pb* are common and radiogenic portions, respectively. (2) Error in calibration is 0.55 % (not included in the above errors but required when comparing data from different mounts). (3) Common Pb corrected using measured ^{204}Pb.

of YY7 zircons, performed on a JEOL scanning electron microscope, show obvious internal zoning but no metamorphism over the growth margin. The same sample mount was used for the U–Pb analysis on a SHRIMP II mass spectrometer at the Beijing Analysis Center of Ion Microprobe, Chinese Academy of Geosciences, following the standard operating techniques detailed in Miao *et al.* (2002). Full details of the SHRIMP method were first reported by Compston, Williams & Mayer (1984), Williams & Claesson (1987) and Compston *et al.* (1992). Circular to oval areas of 20–30 µm were analysed on the morphologically distinct domains chosen using CL images (Fig. 4). Data collection was performed for five scans in dynamic mode. Correction for the common Pb contribution was made using the measured ^{204}Pb and the model common Pb composition of Stacey & Kramers (1975). Isotope ratio and age uncertainties are given at the 95 % (2σ) confidence level.

The analytical results and corresponding ages of the fourteen euhedral zircon grains from the Yangyang rapakivi granite are given in Table 2. These grains give ^{206}Pb/^{238}U ages ranging from 1780 ± 38 Ma to 1864 ± 44 Ma and ^{207}Pb/^{206}U ages ranging from 1811 ± 20 Ma to 1867 ± 18 Ma. Weighted average of the ^{206}Pb/^{238}U ages yields a value of 1839 ± 10 Ma (Fig. 5). Since analyses cluster around the concordia, we interpret the mean ^{206}Pb/^{238}U age as the crystallization age of the Yangyang rapakivi granite.

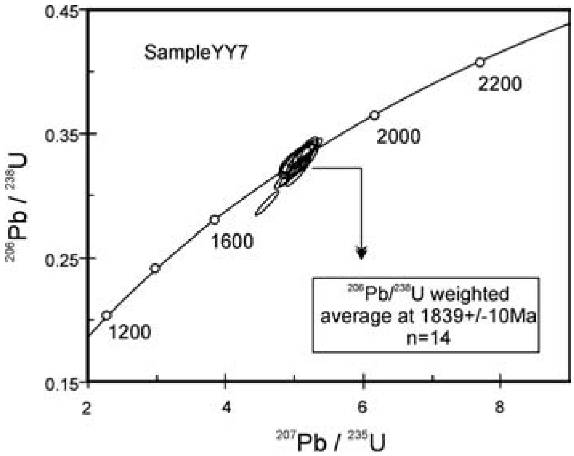

Figure 5. SHRIMP analytical data of zircon grains from a rapakivi granite.

4. Discussion

The Yangyang rapakivi granite batholith in the Gyeonggi massif was previously regarded as a

Phanerozoic syenite (Lee & Kim, 1968). Rapakivi granites are usually associated with gabbro, leucogabbro and anorthosite, representing an anorogenic magmatic association in an extensional setting, resulting from mantle upwelling and lithosphere thinning, notably in the Palaeo- to Mesoproterozoic era (Haapala & Rämö, 1990, 1999; Windley, 1995). Therefore, we consider that the study on the Yangyang rapakivi should be significant for understanding the Precambrian evolution of the cratons in China and Korea and the correlation to a pre-Rodinia supercontinent.

(1) Based on characteristics of the Precambrian basement and Palaeozoic sedimentary cover rocks, the Sino-Korea craton is made up of North China, northeastern China and northern Korea or the whole Korean Peninsula (Huang *et al*. 1977; Kim & Jon, 1993; Lan *et al*. 1995). All of the old rocks in the Sino-Korea craton underwent two important metamorphic episodes at ~2.5 Ga (the Wutai Movement) and ~1.8 Ga (the Lüliang Movement); however, this craton escaped from overprints in 1.4 Ga and 1.0–7.0 Ga, which strongly influenced the Yangtze craton (Zhao *et al*. 1993). The metamorphic event at 1.8 Ga was strongly tectonic–metamorphic, leading the metamorphosed basement of the North China craton as a whole to uplift to the surface. This event was followed by rifting and an anorogenic rapakivi–anorthosite–gabbro magmatism (Zhai & Liu, 2003). Nevertheless, a high-grade metamorphic age of 2.75 Ga and K-feldspar granite of ~1.9 Ga in South China (Qiu *et al*. 2000) and ~1.4, ~1.0 and ~0.8 Ga magmatic and metamorphic isotope ages in North China (Shao, Zhang & Li, 2002) were reported recently. These data may imply that both the North China and Yangtze cratons must have undergone a more complicated Precambrian evolution than realized up to now. However, it is commonly accepted that the basement rocks of these two cratons have individual characteristics: (1) the ~2.5 Ga and ~1.8 Ga events represent two key evolutionary stages for the North China craton that finally formed at ~1.8 Ga. The 1.0–0.8 Ga magmatic–metamorphic event was very weak and was merely found in the northern and eastern margins; (2) the ~1.8 Ga event was very weak in the Yangtze craton, while the 1.0–0.8 Ga magmatic–metamorphic event can be regarded as a key evolutionary stage, which is interpreted to be correlated with the assembly and the subsequent breakup of Rodinia.

(2) In the North China craton, a rapakivi anorogenic magma association is exposed in the Archaean rocks in the Miyun–Chengde area. This association is genetically related to volcanic rocks in the Palaeo-/Mesoproterozoic Chengde-Jixian (CJ) and the Zhongtiao-Xiong'er (ZX) continental rift zones (Zhao *et al*. 1993; Rämö *et al*. 1995; Yu *et al*. 1994; Zhai *et al*. 2004; Zhai & Liu, 2003). Isotopic ages of the rapakivi granite, anorthosite and volcanic rocks range from 1950 Ma to 1715 Ma (Xie & Wang, 1988; Yu *et al*. 1996; Zhao *et al*. 2002*b*, 2003). Other Mesozoic rapakivi granite bodies occur in Chicheng, Luanping and Kuandian (Fig. 1). The rapakivi granite in the Myohyang Mountains of the Rangnim massif, North Korea, occurs as a large intrusive batholith. The central part of the batholith comprises coarse- to mega-grained porphyritic granite, while the marginal areas are composed of medium-grained ones. Porphyritic K-feldspar has a characteristic oligoclase shell and an inner ring composed of hornblende and biotite. Associated with the rapakivi granite batholith are some leucogabbro and gabbro bodies; altogether they form an anorogenic magmatic association (Zhai & Liu, 2003). The rapakivi granites have K–Ar and Rb–Sr ages of 1909–1870 Ma (Ryong, 1993) and U–Pb zircon ages of 1890–1810 Ma (Choi Yueng-Cheng, pers. comm. and unpub. report, 1997).

(3) The country rocks of the above-mentioned rapakivi granites are similar. They are granitic gneisses and metamorphic supracrustal rocks of granulite–amphibolite facies, which consist of amphibolite or mafic granulite, mica schist, sillimanite-bearing argillaceous and magnetite quartzite. In the Miyun, Chengde and Kuandian areas, the country rocks are locally termed the Miyun, Dantazi and Kuandian complexes. These rocks formed between 2.71 Ga and 2.64 Ga and were subjected to two metamorphic overprints in 2.6–2.46 Ga and 1.9–1.75 Ga (Jiang, 1987; Bai *et al*. 1993; Zhao *et al*. 1993; Lu, Yang & Li, 1995; Yu *et al*. 1996). High-pressure granulites, occurring as lenses in granitic gneisses and metamorphosed supracrustal rocks, yield metamorphic ages of 1.88–1.79 Ga (Mao *et al*. 1999).

In the Myohyang Mountains, North Korea, rapakivi and leucogabbro bodies intruding the Huichon complex have a formation age of 2.6–2.8 Ga and metamorphic ages of 2.46–2.52 Ga and 1.8–1.9 Ga (Kim & Jon, 1993; Paek, 1993). Zhai & Liu (1997) reported that high-pressure granulite and garnet amphibolite, showing similar petrological characteristics to those in Chengde and Miyun, occur as lenses in granitic gneiss in the Kaesong district in southern Rangnim massif.

(4) The rapakivi granites as well as the country rocks in the Gyeonggi massif have very similar characteristics and metamorphic histories to those exposed in the Rangnim massif and in the northern North China craton. The Neoarchaean/Palaeoproterozoic rocks are termed the Gyeonggi complex or the Odesan complex. Their U–Pb zircon and Sm–Nd ages mainly cluster at ~2.7 Ga, 2.61–2.43 Ga and 2.0–1.7 Ga (Paek, 1993; Lee *et al*. 2000; Cheong, Kwon & Park, 2000). These rocks are considered to be temporal equivalents to the Anshan, Fuping and Liaohe complexes in the North China craton (Kim, 1978; Zhang, 1984; Na & Kim, 1988; Kim & Jon, 1993; Paek, 1993; Lee *et al*. 2000). The 1.84 Ga rapakivi granite reported in this paper seems to provide evidence that the Gyeonggi massif and the Rangnim massif probably originate from the

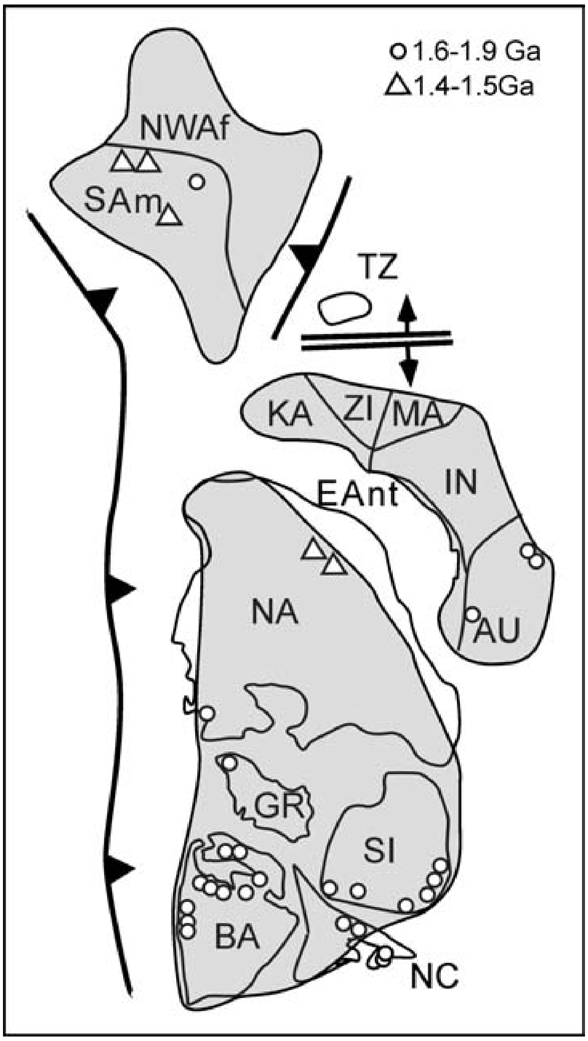

Figure 6. Distribution of *c.* 1.8 Ga rapakivi granites in reconstruction of the Columbia supercontinent (after Rogers & Santosh, 2002). Data of rapakivi granites from Haapala & Rämö, 1999; Yu *et al.* 1996 and Xiao *et al.* 2003. SI – Siberia; BA – Baltica; GR – Greenland; EAnt – coastal zone of East Antarctica correlative with marginal orogenic belts in Australia, India and South Africa; AU – Australia; NA – North America; NC – North China; IN – India; MA – Madagascar; ZI – Zimbabwe; KA – Kalahari; SAm – South America; NWAf – Northwestern and central Africa; TZ – Tanzania.

same Precambrian basement, and they may belong to the North China craton, although more definite proof is needed. A comparative study on basement rocks is important for comprehensive understanding of the continental evolution of Korea; distinguishing the affinity of the Korean continental blocks is still hampered by the similarity in the early crustal evolution of continental blocks in East Asia.

(5) The 1.84 Ga rapakivi granite found in South Korea may have significant implications for global tectonics and reconstruction of the pre-Rodinia supercontinent. Although there are Archaean and Phanerozoic granite complexes that can be considered as rapakivi suites, most rapakivi granites are Proterozoic in age (generally 1.8–1.0 Ga). Considering the spatial and temporal distribution of the Proterozoic rapakivi–anorthosite magmatic association, Windley (1978) suggested there was a global-scale continental amalgamation and subsequent breakup before 1400–1300 Ma. Zhao *et al.* (2002*a*) undertook an important review on the 2.1–1.8 Ga orogenic belts and suggested an amalgamation at 2.1–1.8 Ga worldwide before the formation of Rodinia. This amalgamation formed the so-called Columbia supercontinent (Rogers & Santosh, 2002). Figure 6 shows the distribution of *c.* 1.8 Ga rapakivi granites in a reconstruction of the Columbia supercontinent suggested by Rogers & Santosh. Comparing anorogenic magmatic rocks from the North China craton and the Baltic craton, Qian (1997) suggested that these two cratons may have been a continent during the Proterozoic era. The 1.8 Ga rapakivi granites and anorthosites in the North China craton and the Rangnim massif, rapakivi granites in the Gyeonggi massif and anorthosites in the Yeongnam massif (Park, Kim & Song, 2001) seemingly constitute a Precambrian anorogenic magmatic belt. We therefore follow Qian's (1997) suggestion and further consider that this anorogenic belt might be correlated to the prominent belt of the rapakivi granites and anorthosites in northern Europe across North America (Asviola *et al.* 1999; Haapala & Rämö, 1999).

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