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Thermal isostasy below the arabian shield and platform: implications caused by red sea spreading

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Thermal isostatic compensation for the Arabian Shield and Platform is investigated here by an analysis of gravity field, deep seismic refraction profile and heat-flow data. Regression relationships between elevation and gravity anomalies found for the geologic provinces of Arabian Shield and Platform are examined first using both point-values as well as the averaged anomalies over ? degree and 1 degree areas. These suggest for grossly different isostatic status prevailing for the geologic provinces in response to crustal dynamics. The composite terrain-corrected Bouguer anomaly and Airy-Heiskanen Isostatic anomaly maps for Arabian Shield and Platform are prepared using these data sets. The gravitational attraction of the Moho was determined from the 30 arc-seconds topography data; calculation of isostatic correction was made assuming 2.67 g/cm3 and 3.3 g/cm3 densities for the crust and top mantle respectively. A mean thickness of 40 km is used for isostatic data reduction. Mass/unit area under the crustal columns at the assumed level of compensation at 40 km depth for Arabian Shield and Platform is constructed and compared with those for other shield regions in the world. Thermal isostatic compensating model for ASP is constructed using the available deep crustal seismic refraction results and heat-flow data for the Arabian Shield. For modeling, the digitized elevation data are examined in details to look for geological mass anomalies in upper crust. Once these effects are isolated, the long wavelength isostatic anomalies are ascribed to crust-mantle configuration below the Arabian Shield and Platform. The results suggest that the elevated Asir Igneous Province (that initially formed as a magmatic arc but later accreted to the Arabian Shield) is largely uncompensated, whereas, the isostatic compensation for the Arabian Shield and Platform is more complete. Tectonic implications for the moving Arabian lithosphere due to Red Sea spreading for the last 26 M.Y. in influencing the thermal isostatic compensation status is discussed.

Keywords: thermal isostacy, arabian shield, red sea, gravity, Saudi Arabia, isostatic anomalies

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Radiolaria-bearing bedded chert in the Central Plain of Thailand: its geologic age and correlation.

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Geotectonic division of Thailand has been established based on fundamental differences of regional geological and stratigraphical features, including the origin of granitoids series, distribution of ultra-mafic rocks which represent position of tectonic suture lines, and fusuline and radiolarian paleontological paleontological data. In the Central Plain of Thailand, however, the tectonic division is vague due to the scarceness of Paleozoic and Mesozoic information by the covering of thick Quaternary sediments. Recently, occurrence of Permian radiolarians from siliceous rocks in the Nakhon Sawan and Uthai Thani areas in the Central Plain has been reported (Saesaengseerung et al., 2007). However, tectonic implication of Paleozoic and Mesozoic rocks distributed in the Central Plain, in other word, extension to the Central Plain of the tectonic divisions such as the Sibumas Block, Inthanon Zone, and Sukhothai Zone which are well established in Northern Thailand, has not been well known.

Recently, we made field survey in Sukhothai, Nakhon Sawan, Uthai Thani, and Kanchanaburi provinces in the Central Plain. Chert beds distributed in the Sukhothai, Nakhon Sawan and Uthai Thani areas are gray or red in color. It is generally recrystallized by contact metamorphism. Under the microscope, the chert is composed mainly of a microcrystalline quartz matrix with radiolarian tests and quartz veins. Poorly preserved radiolarians have been detected from those exposed in eight localities of these areas. Sakmarian (middle Cisuralian) to Capitanian (late Guadalupian) radiolarians such as Albaillella asymmetrica, Pseudoalbaillella fusiformis, Ps. globosa, Follicucullus scholasticus are obtained.

At Bo Phloi in the Kanchanaburi area, we examined green to greenish gray chert. Under the microscope, radiolarian tests are observed to be embedded within a clay-rich cryptocrystalline quartz matrix. Calcareous foraminiferal tests have often been obtained from the chert by acidic treatment. Moreover, a lot of thin-shelled bivalves, probably Daonella or Halobia, are found in several horizons of the chert. It also yields well-preserved Middle Triassic (Anisian) radiolarians such as Eptingium manfredi, Pseudostylosphaera japonica, Triassocampe coronata, and others.

Based on the radiolarian occurrence and lithology, the Permian chert in the Nakhon Sawan and Uthai Thani areas are correlated with the Khanu Chert distributed in the Sukhothai area of the Sukhothai Zone in Northern Thailand.. On the other hand, the Triassic chert exposed at Bo Phloi in the Kanchanaburi area clearly exhibits hemipelagic deposition on the eastern margin of the Sibumasu Block, based on its lithlogy, radiolarian age, and faunal content characterized by possessing calcareous tests of thin-shelled bivalves and foraminifers.

Keywords: Central Thailand, Sibumasu Block, Sukhothai Zone, radiolarians, Permian, Triassic

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Rb-Sr ages of granitic rocks from the Hua Hin area, Thailand

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The granitic rocks are widely distributed in the Hua Hin area, Thailand. This area is located in the Main-Rang Province (Cobbing et al., 1986) consists mainly of S-type granitic rocks, whose ages range from early Late Triassic to late Early Jurassic (ca. 230-180 Ma) (Sone and Metcalfe, 2008). The petrogenesis of these granitic rocks is explained by partial melting of the Sibumasu crust subducted beneath the Palaeo-Tethys accretionary complex (Sone and Metcalfe, 2008). However, the timing of magma activity and characteristic of source material of granitic rocks in the Hua Hin area are poorly understood. In this paper, we address Rb-Sr isotopic study of granitic rocks from this area.

The granitic rocks in the Hua Hin area are composed of foliated granitic rocks and non-foliated granitic rocks. The formers are the Hub Kapong Gneissic Granite, Hua Hin Gneissic Granite and Pran Buri Gneissic Granite. The Hub Kapong and Hua Hin Gneissic Granites are partly weakly mylonitized K-feldspar porphyritic biotite granite. Some of the Hub Kapong Gneissic Granite includes tourmaline. Parts of Hua Hin Gneissic Granite include garnet and tourmaline. Sillimanite is also contained in some of them (Kawakami et al., 2010). The Pran Buri Gneissic Granite is mylonitic biotite granite. Non-foliated granitic rocks are stock bodies intruded into the Hub Kapong Gneissic Granite, and composed of biotite to two-mica granite. These granitic rocks have peraluminous chemical composition. The Hub Kapong and Hua Hin Gneissic Granites and non-foliated granitic rocks indicate low magnetic susceptibility (SI=1.3-21.5x10^{-5}), but the Pran Buri Gneissic Granite indicates high value (SI=185-455x10^{-5})(Yoshimoto et al., 2010).

The Hub Kapong and Hua Hin Gneissic Granites give Rb-Sr whole-rock isochron ages of 202+/-22Ma (SrI=0.7259+/-0.0024;N=13) and 209+/-14Ma (SrI=0.7258+/-0.0034;N=10), respectively. Because of dispersion, errors of age and SrI are slightly big. The dispersion might be due to effects of deformation and metamorphism. The Pran Buri Gneissic Granite does not give significant isochron age. A body of non-foliated granitic rocks gives a Rb-Sr whole-rock isochron ages of 84+/-13Ma (SrI=0.7356+/-0.0015;N=4). These ages indicate timing of magmatic activity in the Hua Hin area, and accord with U-Th-Pb monazite ages (213Ma(core), 83Ma(rim)) of metamorphic rocks from this area (Nakano et al., 2010).

Keywords: Rb-Sr whole-rock isochron age, granitic rocks, Hua Hin, Thailand

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Geochemistry of sandstone related to Paleo-Tethys subduction zone in the Inthanon Zone, northern Thailand

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The Paleo-Tethys was opened in response to lifting of the North China, South China, Tarim and Indochina blocks from Gondwana during Devonian, and closed by collision between the Indochina Block and the Sibumasu Block, in the Late Triassic time (Metcalfe, 1999). The Inthanon Zone, northern Thailand has been regarded as the convergence margin of the Paleo-Tethys, and it is important zone to represent diversifying of Gondwana and history of collision within Southeast Asia region.

According to Ueno and Hisada (1999), the Inthanon Zone is composed of the Devonian to Triassic radiolarian ribbon-chert and the Carboniferous to Permian carbonate rocks from the seamount, which correspond to Paleo-Tethysian rocks. The Ordovician limestone, metamorphic rocks and sedimentary rocks also crop out the Inthanon Zone. These rocks correspond to the Sibumasu Block. Therefore, the Inthanon Zone is interpreted to represent nappes of Paleo-Tethysian rocks which thrust over a marginal part of the Sibumasu block. Moreover, melange-type rocks were proposed from the Inthanon Zone by Hara et al (2009), and they concluded that the accretionary complex bearing melange was formed by the Paleo-Tethys subduction. Therefore, in this study, the Carboniferous sandstones which from the Sibumasu Block and sandstones in melanges were analyzed petrographically and geochemically for understanding their provenances.

The mode composition was determined about the Carboniferous sandstones from the Sibumasu block and sandstones in melanges on the basis of Gazzi-Dickinson method. From the Dickinson diagram (Dickinson et al., 1983), sandstones from the Sibumasu Block are quartzose sandstones which composed of well-rounded quartz grains characterized by continental sandstones. They are plotted intracraton or quartzose-recycling area on the diagram. On the other hand, sandstones in melanges are mostly lithic including many volcanic fragments, and plotted quartzose to lithic-recycling on the diagram.

Both sandstones from the Inthanon Zone were carried out geochemical analyses for major elements, trace elements and REEs. Major elements were determined by XRF analysis using a PANalytical Axios PW4400/40 housed at the Geological Survey of Japan. Trace elements and REEs were determined by XRF (Rigaku RIX3000) and ICP-MS (Agilent 7500a) housed at Niigata University. Result of major elements analyses, sandstones from the Sibumasu Block were propensity plotted around the Passive Margins area using Fe_2O_3 + MgO %-TiO_2 %, Fe_2O_3 + MgO %-Al_2O_3 / SiO_2, Fe_2O_3 + MgO %-K_2O / Na_2O, Fe_2O_3 + MgO %-Al_2O_3 / (CaO + Na_2O) diagrams that proposed by Bhatia (1983). Result of trace elements and REEs analyses, sandstones from the Sibumasu Block were plotted in the Passive Margins area, and sandstones in melanges were plotted in the Continental Island Arc area using La-Th-Sc, Th-Sc-Zr, La / Sc-Ti / Zr, Sc / Cr-La / Y diagrams that proposed by Bhatia and Crook (1986).

These results suggest that quartz sandstones from the Sibumasu Block are characterized as continental origins without the arc fragments; whereas, lithic sandstones in melanges are strongly affected to clastics which derived from the arc. Based on geochemical analyses, quartzose sandstones and lithic sandstones from the Inthanon Zone indicate different characteristics of their own provenances. In the late Permian to Triassic time, the arc (the Sukhothai Zone) developed in western to southern margin of the Indochina block. We concluded that the accretionary complex by the Paleo-Tethys subduction, which was matured by supply of clastics from the Sukhothai arc.

Keywords: Paleo-Tethys, Inthanon Zone, sandstone, provinance, geochemistry

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Mode of occurrence of zircon in metagranites from the Pranburi-Hub Kapong area, Thailand

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The metagranites and pelitic-psammitic metamorphic rocks are widely exposed from Pranburi to Hub Kapong, central Thailand. The EPMA dating of monazite (so-called CHIME monazite dating, Suzuki et al., 1994) in a high-grade pelitic metamorphic rock from the south of the study area revealed that the monazite core is 213 Ma and the rim is 83 Ma (Nakano et al., 2010). Yuhara et al. (2011) dated the metagranites by the Rb-Sr whole-rock isochron method. The Hub Kapong gneissic granite that crops out in the north gave 202+/-22 Ma, and the Hua Hin gneissic granite at the central area gave 209+/-14 Ma. The non-foliated granitic rocks in the central area gave 84+/-13Ma. The large error is attributed to the later metamorphism and deformation that postdated granite crystallization. This study aims to constrain the timing of granite crystallization and metamorphism through textural observation and U-Pb dating of zircon by LA-ICPMS.

The foliation of the Hua Hin gneissic granite is defined by the arrangement of Bt +/- Si, and this body is metamorphosed. Zircon in this metagranite has euhedral oscillatory zoning and likely magmatic in origin. Under the cathode luminescence (CL) image, detrital cores and dark overgrowths on them are commonly recognized.

The Hub Kapong gneissic granite is a two-mica granite and muscovite can be metamorphic in origin (Kawakami et al., 2010). This metagranite characteristically contains xenotime-zircon intergrowth of magmatic origin (e.g., Viskupic et al., 2005). Xenotime shows mosaic-like zoning and includes a lot of bright Th-bearing phases under the back scattered electron (BSE) image. It also has many tiny holes and shows spongy texture. Zircon shows idiomorphic oscillatory zoning under BSE image, while it is dark and shows mosaic-like texture under CL image. Rarely, zircon as well includes bright Th-bearing phases under BSE image, and shows spongy texture. This kind of spongy zircon is considered to form by a dissolution-reprecipitation process in a fluid (Geisler et al., 2007). Therefore, zircon in the Hub Kapong gneissic granite would be originally magmatic, but some of them may have experienced the dissolution-reprecipitation process. Yuhara et al. (2011) interpreted that 83 Ma age preserved in the monazite from the pelitic metamorphic rock is likely due to intrusion of the non-foliated granitic rocks. Since the non-foliated granitic rocks are scattered around the Hub Kapong gneissic granite, it is probable that the intrusion of the non-foliated granitic rocks are responsible for the formation of the spongy zircon in the Hub Kapong gneissic granite. These possibilities will be tested through the zircon U-Pb dating by the LA-ICPMS.

Keywords: granite, Thailand, zircon, metamorphism, fluid

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Geochemical character of metamorphosed mafic rocks from the collision boundary between Shan-Thai and Sibumasu craton in

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The collision boundary between Shan-Thai craton and Sibumasu craton is distributed from the Nujiang area in Yunnan province of China to the Khanom area in western Thailand, through Myanmar and The Inthanon area of Thailand (Osanai et al., 2010). Especially in the Inthanon area, the metamorphic ages were determined as 210 Ma (Nakano et al., 2010). This boundary is important for understanding the tectonic evolution of multiple collision orogeny during Permian-Triassic Asian continent growth. This study focus to metamorphosed mafic rocks that consider to have distributed between of those cratons before collision.

The metamorphosed mafic rocks from the collision boundary between the Shan-Thai and The Sibumasu cratons appear as blocks or Layers in granitic gneiss and pelitic gneiss. In the Nujiang area, the metamorphic rocks indicate greenschist? to amphibolite?facies conditions. Variations of the metamorphosed mafic rocks are clinopyroxene amphibolite, amphibolite and epidote?hornblende schist. The metamorphic rocks from the Inthanon area and the Khanom area suggest amphibolite?facies conditions. Major mineral assemblages of the metamorphosed mafic rocks from the Inthanon area are garnet + hornblende, clinopyroxene + hornblende and hornblende. Hornblendes are usually green?brownish color and show graonblastic texture. On the other hand, in the Khanom area, mineral assemblages of metamorphosed mafic rocks are clinopyroxene + hornblende, hornblende and epidote + hornblende.

The bulk chemical compositions of amphibolite and mafic schist from the Nujiang area show SiO2 = 46.2-51.7 wt. %, XMg = 0.45-0.72 and various Nb/Y ratios ranging from 0.09 to 0.82. They are plotted within the fields between with-in plate basalts and MORB in some discrimination diagrams. Furthermore, the chondrite normalized REE patterns show two patterns; LREE-enriched pattern (OIB type) and flat pattern (E- to T-MORB type). These geochemical characters and mode of occurrence indicate that they would be derived from oceanic crust, which are distributed between the Shan-Thai craton and the Sibumasu craton before collision.

Keywords: Inthanon, Khanom, Nujiang, Metamorphosed mafic rock, Geochemistry, Collision boundary

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Permo-Triassic high-grade metamorphism recorded in metamorphosed bauxites from the Red River shear zone, Vietnam

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The Red River shear zone is left-lateral shear zone caused by collision of the Indian subcontinent to the Eurasian continent at the Tertiary. Although most metamorphic rocks were reset by the deformation, recent chronological works have revealed presence of the former Permo-Triassic thermal event. However, the details of such thermal event are obscures. Here, we report metamorphic evolution and the age of aluminous granulite from the shear zone.

The whole rock chemistry of the granulites is extremely rich in Al_2O_3 (36.7-50.9 wt%), TiO_2 (5.5-13.0 wt%), and $Fe_2O_3{}^{total}$ (24.9-35.3 wt%) and poor in SiO_2 (7.9-24.1 wt%), MgO (0.5-1.0 wt%), Na (75-258 ppm analyzed by ICP-MS), and K (mostly lower than 100 ppm analyzed by ICP-MS). HFSEs and REEs also show high concentrations (e.g., Ga, 37-74 ppm; Y, 41-102 ppm; Zr, 367-724 ppm; Nb, 44-99 ppm; La, 43-187 ppm; Ce, 90-357 ppm; Pr, 10-38 ppm; Nd, 45-172 ppm; Sm, 10-37 ppm) whereas LILEs are depleted (Rb, 0.3-4.6 ppm; Sr, mostly $<$30 ppm; Ba, mostly $<$15 ppm). These features strongly suggest that the protolith of the aluminous granulites is lateritic bauxite.

The granulites commonly contain garnet, corundum, sillimanite, hercynite, and ilmenite with minor monazite, apatite, and zircon. Garnet includes kyanite, staurolite, ilmenite, siderite, and rutile. Kyanite, staurolite, siderite, and rutile are not observed in the matrix and they appear only as inclusion phases. Ilmenite occurring in the matrix contains sillimanite inclusions. Based on the petrographical observations and isochemical phase diagram using whole rock chemistry suggests former eclogite-facies ($>$1.8 GPa at 790 C) metamorphism and subsequent decompression under granulite-facies condition ($>$1000 C at 1.5 GPa).

In-situ U-Pb zircon dating was carried out using LA-ICP-MS system, Kyushu University. Based on the CL image, zircon is commonly zoned and sometimes contains dark core portion. Preliminary result is that there are several $^{206}Pb/^{238}U$ ages (including discordant ages) from the Permian to Tertiary but the Tertiary ages were obtained only from zircon occurring in the matrix. Permian-Triassic ages (265-230 Ma) were mostly detected from the dark core and some are from zircons included in garnet. Only the dark core includes large number of high-density (Ave. 1.15 g/cm^3) CO_2 fluid inclusions. Garnet, corundum and staurolite also contain CO_2 fluid inclusions and their densities are also high (Ave. 1.00 g/cm^3, 1.07 g/cm^3 and 1.09 g/cm^3, respectively). These features strongly suggest that the dark cores had been in equilibrium with the garnet, corundum and staurolite that had formed under high-grade (eclogite- to granulite-facies) metamorphic conditions mentioned above.

Although further chronological works are now in progress, present study will suggest that the Permo-Triassic thermal event in the Red River shear zone is high-grade metamorphic event and it should be related with collision between the South China and Indochina cratons.

Keywords: metamorphosed bauxite, metamorphic evolution, Permo-Triassic, Red River shear zone, Vietnam

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A Preliminary View of Metamorphic Rocks in Indonesia Region

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Indonesian archipelago formed by reassembly of fragment rifted from Gondwana that arrived at the Eurasian subduction margin. A Cretaceous active margin is interpreted along Sumatra into western Java continued through southeastern Kalimantan into western Sulawesi, as suggested by the distribution of high pressure-low temperature subduction-related metamorphic rocks. Present-day, geology of Indonesia is the result of Cenozoic subduction and collision and situated at the boundaries of Eurasia, Indo-Australia, and Pacific-Philippine Sea plate.

Previous study by Hall (2002) suggests that in western Sumatra, Paleozoic sediments and volcanic rocks interpreted part of Indochina-East Malaya block that separated from Gondwana. In eastern Sumatra, there are Carboniferous sediments belong to Sibumasu block separated from Gondwana. Permian and Triassic granites of Thai-Malay tin belt extend into western Indonesia are the products of subduction and post-collisional magmatism in Triassic. In the southwestern Kalimantan, the Paleozoic age is represented by Carboniferous to Permian metamorphic rocks. Cretaceous granitoid plutons intrude the metamorphic rocks in Schwaner Mountains. Northwestern Kalimantan may mark as a subduction margin continuing south from East Asia.

On the east side of Indonesia, geology of Sulawesi caused by convergence between Australian, Pacific, and Eurasia plate. In eastern Sulawesi, collision resulted in thrusting of Australian continental rocks. The Banda Arc including Timor-Tanimbar-Seram islands, situated between Indo-Australian, Eurasian and Caroline plate. From the inner to outer side of the following belts, have been distinguished: ophiolite, metamorphic, and thrust-fold belt. The geology of Papua is involving interaction between Australian and Pacific plate. Lithotectonic of Papua can be divided from north to south are collided arc, ophiolite and metamorphic belt, fold-thrust belt, and foreland basin.

Purpose of this study is to understanding in detail Indonesian tectonic regime from the study of metamorphic rocks. In this preliminary view, 16 samples taken by GRDC (Geological Research and Development Centre) Indonesia have been observed petrographically and five samples from those have been analyzed by EPMA.

Seven samples from West Papua including Kaimana, Ransiki, Maar and Enarotali area are slate with the composition of quartz, muscovite, and chlorite. On the Steenkool area are biotite gneiss and white schist suggest greenschist to amphibolite facies. Biotite gneiss has composition of biotite, quartz, muscovite, plagioclase and k-feldspar. White schist has composition of quartz, muscovite and chlorite. Four samples from Kendari - southeast Sulawesi are mica schist with composition of quartz, muscovite, chloritoid and chlorite suggest greenschist facies. One sample amphibolite from Central Java shows composition of hornblende (XMg 0.62-0.70), garnet (almandine), sphene, epidote, quartz and minor minerals of plagioclase and k-feldspar.

Four samples from Schwaner Mountains, West Kalimantan, have been observed in petrography and EPMA analyses. The samples can be divided into three groups by name, which are metatonalite, metagranitoid and biotite schist. Mineral assemblages for metatonalite are quartz, plagioclase (An36-50), k-feldspar, hornblende (XMg 0.53-0.64), biotite, sphene, apatite and clinopyroxene. While on metagranitoid is shows assemblages of quartz, plagioclase (An22-23), k-feldspar, biotite, sphene, epidote and apatite. Biotite schist mineral assemblages show quartz, plagioclase (An83-85), k-feldspar, biotite, epidote and muscovite.

Detailed field observation and new collecting samples with EPMA, bulk chemistry analyses and age dating determinations are needed to understanding in details geological evidence constrain from metamorphic petrology on the Indonesian region. These steps will be held during March 2011 on the South Sulawesi and Central Java and the result will be presented on the conference.

Keywords: metamorphic rock, Indonesia, tectonic, South Sulawesi, Central Java, Schwaner Mountains

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Blueschists along the suture zone between the Ergun block and the Xing'an block in Inner Mongolia, northeastern China

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Blueschists and related metamorphic rocks are exposed in the Toudaoqiao area of the Honghuaerji-Yimin district in the Inner Mongolia, northeastern China. These HP metamorphic rocks occur along the Tayuan-Xiguitu fault, separating the Ergun block and the Xing'an block. The HP metamorphic area belongs to the eastern segment of the Xingmeng Orogenic Belt (Li and Oyang, 1998), and it is located in the eastern parts of the Central Asian Orogenic Belt (Sengor et al., 1993). The blueschists and the related metamorphic rocks have been found in 1980's, and preliminary geological study was performed (Ye et al., 1994). According to them, there are phyllites, glaucophane-albite-chlorite-epidote schists, chlorite-quartz schists, and albite-chlorite-glaucophane schists. The mineral assemblages suggest typical LT-HP conditions.

We have had an opportunity to have a field survey in the Toudaoqiao area, and collected blueschists and other metamorphic rocks. The blueschists consist mainly of chlorite, epidote, glaucophane, with subordinate amounts of white mica, quartz, albite, hematite, apatite and titanite. A schistosity is well defined by orientation of glaucophane and chlorite. Glaucophane is of euhedral to subhedral prismatic crystal with size up to 0.3mm long. It is partly replaced by chlorite along the rim and the cleavage. The chlorite is euhedral to subhedral, and its size is up to 0.3mm across. Epidote is of anhedral rounded grain with size up to 0.1mm across. White mica is of anhedral platy crystal, and its size up to 0.2mm across. Texture and the mineral assemblage of the blueschists suggest the metamorphic conditions of typical epidote-blueschist facies.

The HP metamorphic rocks in the Toudaoqiao area is located along the Tayuan-Xiguitu fault, that is supposed to be the boundary between the Ergun block and the Xing'an block (Ge et al., 2005; Sui et al., 2006). In the eastern side of the fault, there occour significant Xinlin ophiolite (Li, 1991) and the Tahe granite (Ge et al., 2005), and these indicate a suture zone. The collision is supposed to take place in the Early Paleozoic time(Ge et al., 2005). The precise study of the other parts of the fault have never been done so far. The present study on the metamorphic rocks, in the western part of the Tayuan-Xiguitu fault will contribute to better understanding the collision tectonics between the Ergun block and the Xing'an block.

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Keywords: high P/T metamorphism, blueschist, Tayuan-Xiguitu fault, northeastern China

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Multiple subduction and collision system in Mongolia

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The collage tectonics of micro-continents formed the Central Asia during Proterozoic to Mesozoic time in terms of the multiple accretion and collision. Mongolia is made up of the four micro-continents; i.e, Baltica, Siberia, North China and Tarim. There are four geological division; continental blocks, subduction complexes, sedimentary basins and Cenozoic cover sequences. The petrological study including geochronology and isotopic geochemistry of various types of igneous rocks provides us some information for tectonic processes during the assembly of microcontinents. Here, we address geochemistry and geochronology of igneous rocks, mainly granitic rocks and discuss magmatic history of the western part of Mongolia.

The study area, western part of Mongolia, is underlain by low- to high-grade metamorphic rocks accompanied by sedimentary rocks and intrusive rocks. The granitic rocks mainly intrude metamorphic rocks with various metamorphic grades. The metamorphic rocks are composed mainly of pelitic gneisses and amphibolites in the northern part of Bulgan, western Mongolia, the Mongolian Altai Mountains. The pelitic gneiss locally contains Grt, St and Ky as porphyroblasts, suggesting medium-pressure type amphibolite-facies conditions (Nakano et al., 2010). Grt-Ms granite intrudes Grt-St-Ky gneiss as post-kinematic dikes or stocks. Grt-Ms granite is free from any deformations. The chemical compositions of Grt-Ms granite show 71-75 wt% in SiO2 and peraluminous (alumino-saturation index: A/CNK=1.02-1.29). Other geochemical characters indicate enrichment of K2O, Rb and depression of Nb, Y. On the other hand, syn-kinematic deformed granitic rocks containing garnet grains are exposed on the Hanhohiyn Mountains, north-west Mongolia. Bt-Ms granite and Hbl-Bt diorite occur as stocks around Tsagaanhayrhan. The granitic rocks show granoblastic texture with or without foliation, and tonalite to granodiorite in compositions. SiO2 contents range from 63 to 66 wt% and alunimo-saturation index is more than 1.1. These granitic rocks, high-Sr granite are characterized by high-Ba and -Sr contents similar to some collision related granitic rocks. Hbl-Bt diorite possesses 52 wt% in SiO2 and A/CNK=0.82 and the chemical composition of the diorite is similar to that of within-plate basalt. In addition to these granitic rocks, pink-colored granites occur probably as stocks in the southeastern part of the Hanhohiyn Mountains. These granites contain pink-colored K-feldspar and show no sings of deformation features. Their chemical compositions are consistent with alkali granite having 70-73 wt% in SiO2 and 8-11 wt% in total alkali, and the pink-colored granites possess low-Ba and -Sr contents.

We conducted monazite EMP dating for selected samples from both regions. Grt-Ms granite from the northern part of Bulgan gave an age of 262 Ma, whereas the syn-kinematic granite and the high-Sr granite from the Hanhohiyn Mountains show ages of 506 Ma and 493 Ma, respectively. It is considered that the magma activities of each region occurred at different ages or events.

Various types of intrusive rocks are exposed on the Mongolian orogenic belt. Most of granitic rocks from both regions are plotted within the fields between volcanic arc granite and syn-collisional granite in some discrimination diagrams. Therefore, the magmatic processes combined with metamorphic evolution in the western part of Mongolia were formed by multiple subduction and collosion events during formation of Central Asian Orogenic Belt.

Keywords: Mongolia, Central Asia Orogenic Belt, Continental collision zone, Subduction zone, EMP monazite ages

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Petrology and geochronology of metamorphic rocks in the Hanhohiyn Mountains, the northwestern part of Mongolia.

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Mongolia is situated in the Central Asian Orogenic Belt (e.g. Mossakovsky et al., 1993), which extends between the Siberian craton, Baltica craton, North China craton and Tarim craton. It is composed of subduction-accretion complexes and developed from c. 1000 Ma to c. 250 Ma (Windley et al., 2007). Metamorphic rocks are partly distributed in the western part of Mongolia. Metamorphic history would be a key for understanding the tectonic evolution of this area, however detailed study on metamorphic rocks has not been well-documented, including geochronology.

Recent fieldwork of the Japan-Mongolia Joint Geological Research has identified several occurrences of high-grade metamorphic rocks in the Mongol-Altai Mountains and Hanhohiyn Mountains (e.g. Nakano et al., 2010). In this study, we report petrology and monazite U-Th-Pb EPMA ages on metamorphic rocks occurring in the Hanhohiyn Mountains.

Hanhohiyn Mountains is located in the northwestern part of Mongolia. The mountains are mainly composed of marble, metaquartzite and pelitic gneisses intercalating with lenticular garnet-amphibolite, garnet-orthopyroxene gneiss and so on.

Pelitic gneiss is mainly composed of quartz, plagioclase (An=31), garnet (Alm68Sps8Prp20Grs4), biotite (XMg=0.53) and sillimanite. Kyanite occurs only as inclusions in garnet and plagioclase, which indicates that kyanite is prograde relic. Most minerals have almost homogeneous chemical composition. Metamorphic condition for quartz+plagioclase+garnet+biotite+sillimanite assemblage is estimated as 650-700 degree of Celsius and 5.5-6 kbar based on the garnet-biotite thermometer and the GASP barometer. Monazite grains in pelitic gneiss show slight chemical heterogeneity and occur in matrix and as inclusions in the major constitute minerals. The monazites yield 500-510 Ma which would be interpreted as the timing of metamorphism within the sillimanite stability field.

In the Central Asian Orogenic Belt, at least two distinct age clusters are recognized: 250-300 Ma and 480-510 Ma. Ca. 500 Ma ages have been recognized at the marginal region of the Siberia Craton including the Hanhohiyn Mountains. This suggests that the Hanhohiyn Mountains would record the early stage event related to the formation of the Asia continent.

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Keywords: Hanhohiyn Mountains, Mongolia, metamorphic rocks, monazite EPMA dating