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journal or publication title	Proceedings, International Symposium of the Kanazawa University 21st-Century COE Program
volume	1
page range	42-47
year	2003-03-16
URL	http://hdl.handle.net/2297/6361

Proceedings: International Symposium of the Kanazawa University 21st-Century COE Program Vol. 1 (2003)
Edited by Naoto KAMATA

Pre-Miocene Paleogeographic Linkage Between the Korean Peninsula and the Japanese Islands

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Abstract – At present the Japanese Islands are separated from the East Asia continent by the East/Japan Sea. This study presents five pieces of geological evidence indicating that prior to an opening of the East/Japan Sea the Japanese Islands were connected to the East Asian continent through the Korean Peninsula. They are 1) Precambrian rocks in the Oki-Hida belt, Japan, 2) orthogneiss and limestone clasts in Kamiaso Conglomerate in the Mino terrane, Japan, 3) distribution of dinosaur fossils in Korea and Japan, 4) quartzite gravels in Japan and 5) radiolaria-bearing chert pebbles in Early Cretaceous sediments in Korea.

I. Introduction

The East/Japan Sea is situated between the East Asia continent and Japanese Islands separating Japanese Islands from the continent (Fig. 1). The location of the Japanese Islands near the Asian continent during the Cretaceous with subsequent southward drift in the Tertiary is generally accepted [1, 2, 3]. Southward drift is explained by differential rotation of Southwest and Northeast Japan based on paleomagnetic studies [1, 3] and by strike-slip fault systems initiated in the Eocene [2]. Southwest Japan was rotated clockwise through about 45° with respect to the Korean Peninsula and Northeast Japan was rotated about 40° [4]. This differential rotation occurred concurrently at about 15Ma [4]. According to evidence from the East/Japan Sea including geochronological data [5], marine magnetic anomaly patterns [6, 7, 8] and ODP Leg 127 drilling results [5, 9, 10, 11, 12, 13] the Japan Arc rifted from the Asian continent due to an opening of the East/Japan Sea, and was drifted to the present position later than 19Ma.

The Korean Peninsula and Japanese Islands have quite different geological histories. Nonetheless both regions share several lines of geological evidence indicating that they were once connected to each other prior to an opening of the East/Japan Sea that occurred in the Middle Miocene. This presentation is not concerned with the timing and mode of the opening of the East/Japan Sea, but is concerned with the paleogeography of pre-Miocene time, including how the margins of the rifted arcs are fitted to continental margins before drift. Five pieces of geological evidence will be provided to relate Japanese Islands with East Asia continent through the Korean Peninsula. The areas mentioned in this presentation are shown in Fig. 1.

II. The Oki-Hida Belt, Japan

A. The Oki belt

The Oki belt comprises 2.0 Ga to 250 Ma medium-pressure-type gneiss and granite complex [13]. The highest metamorphic grade reaches the upper amphibolite to granulite facies. Protolith is continental sedimentary rocks with minor amount of mafic igneous rocks [14]. The Oki belt is considered to be of continental affinity and is at present isolated from mainland Asia, as it was rifted and detached by the Miocene opening of a back-arc basin, the East/Japan Sea [4, 15]. Judging from the lithologic and chronological similarity, the Oki belt is regarded as an eastern extension of the Precambrian rocks of the Sobaeksan (Yeongnam) massif in South Korea [16, 17].

B. The Hida belt

The Hida belt in central Japan appears to extend westwards to Oki Island and comprises various types of medium-pressure-type metamorphic and igneous rocks with ages from Precambrian (?) to Mesozoic. Non- to weakly metamorphosed middle to upper Paleozoic shelf sequences occur fragmentally in the periphery of the belt. Many Japanese geologists have long recognized the notion that the Hida gneiss region contains Precambrian basement rocks formed in the southern margin of the Sino-Korean (North China) block (e.g., [18]). Some studies considered that the Hida belt was a microcontinent that collided with the eastern edge of the Sino-Korean block in the late Paleozoic [19, 20, 21]. Structural studies revealed that the Hida belt in the craton margin later thrusted southward onto the Permian-Jurassic accretionary complexes, forming a large nappe [16, 22, 23]. The existence of medium-pressure type metamorphism at 250-220 Ma in the Hida belt was interpreted to be a consequence of collision between Sino-Korean and South China blocks [16, 24]. In contrast to common belief, the majority of radiometric age data obtained by various methods indicate Paleozoic to Mesozoic ages, and Precambrian age data are quite limited. Suzuki and Adachi reported CHIME (Chemical Th-U-total Pb isochron) ages ranging from 2000 to 300 Ma for zircon grains in the Hida gneisses and interpreted that the Hida gneiss was not metamorphosed in Precambrian time but in 250 Ma, and that the older isotopic dates are ages of detrital zircons [13]. A recent

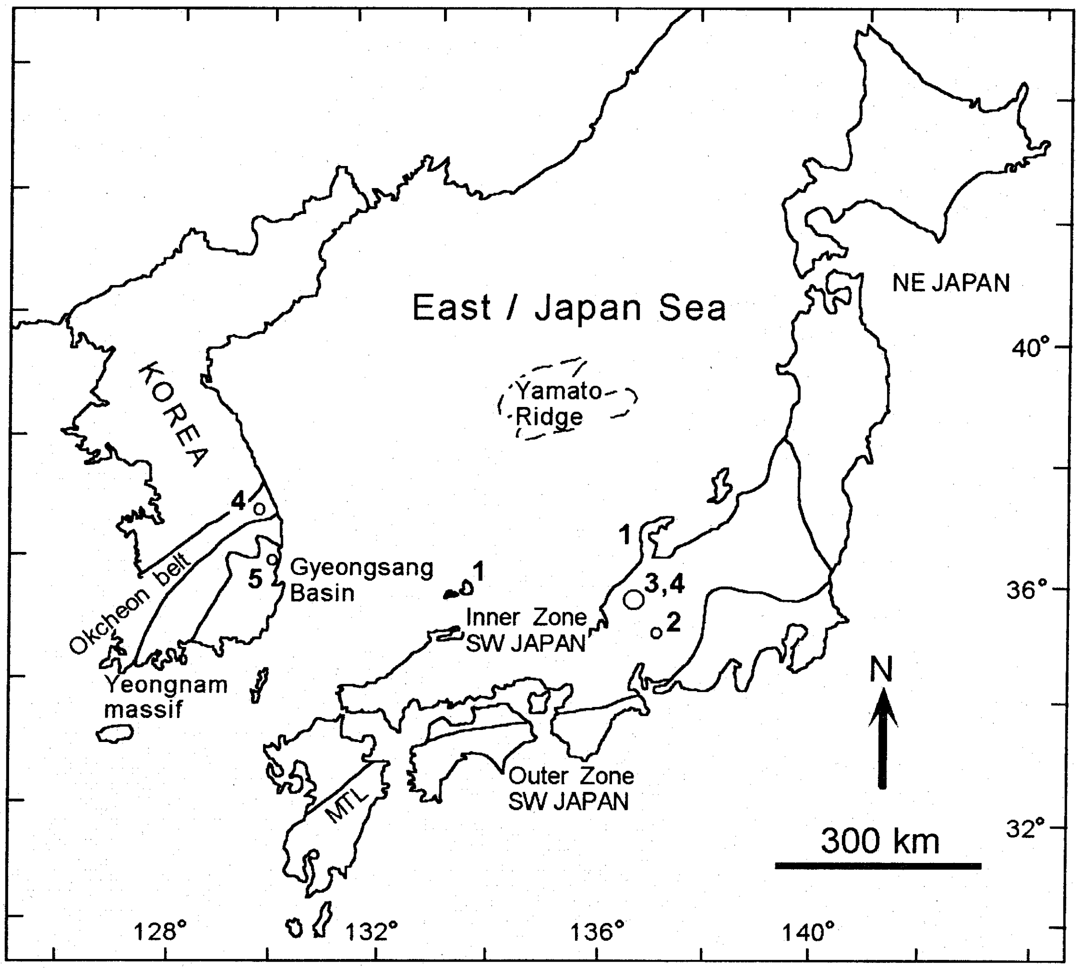

Fig. 1. Map showing tectonic divisions of the Korean Peninsula and Japanese Islands described in the text. 1: Oki/Hida belt, 2: Kamiaso Conglomerate, 3: Dinosaur fossils, 4: Quartzites and 5: Radiolaria-bearing chert pebbles.

study by Arakawa, Saito and Amakawa identified three main stages of igneous activities in the Hida belt: mafic meta-volcanic rocks (amphibolites) at late Silurian, mafic dikes at Middle Carboniferous and granite-diorite plutons at Late Triassic to Early Jurassic, all formed at the continental margin or continental arc tectonic environment [25]. They proposed two possible models for the Paleozoic to early Mesozoic formation and evolution of the Hida belt. One is that the Hida belt was formed in an eastern margin of the Sino-Korean block (northern part of the Korean Peninsula) and later developed as the eastern extension of the suture zone between the Sino-Korean and South China blocks. The unique occurrence of middle to late Paleozoic shelf strata with Boreal fauna in the periphery of the Hida belt [26, 27] suggests a strong link between the Hida belt and Sino-Korean block. The other is the model in which the Hida belt was developed as a part of the vast suture zone (East Central Asian Orogenic Belt) to the north, which is situated between the Siberian and Sino-Korean blocks.

III. Kamiaso Conglomerate, Central Japan

Some intraformational conglomerates are known to occur in the Mino terrane, a Jurassic accretionary complex; one of the best studied examples is the Kamiaso conglomerate exposed along the Hida River gorge in the Kamiaso area, north of Nagoya City. The Kamiaso conglomerate is known as the oldest-rock-bearing conglomerate in Japan. The Kamiaso conglomerate consists of four conglomerate beds within the turbidite [28]. Clasts of the conglomerate are angular to well-rounded pebbles, cobbles and boulders of sedimentary, igneous and metamorphic rocks in coarse-grained graywacke matrix, of which sedimentary clasts of sandstone, shale, chert limestone and marl are most common. The Kamiaso conglomerate is interpreted to be submarine debris-flow deposits [29]. Paleocurrent analyses of the turbidites in the Kamiaso conglomerate indicate that the clastic materials were transported from the north [30, 31]. Among various clasts orthogneiss and limestone clasts are dealt here for consideration.

A. Orthogneiss clasts

Orthogneiss clast comprises about 10% of the total clasts [28]. A Rb-Sr whole-rock isochron age of 2050±30 Ma has been reported by Shibata and Adachi [32]. A well-rounded zircon grain yields an exceptionally old CHIME age of 3040±180 Ma, but most euhedral zircons of magmatic origin are concentrated around 2050 Ma [33]. CHIME ages of many monazite grains are between 1750 and 1500 Ma, but rarely a narrow portion of several monazite cores gives a CHIME age of 2670±100 Ma [33]. The ages of the 2050 Ma isochron age for the orthogneiss clasts closely correspond to the Rb-Sr whole-rock isochron age (2060±50 Ma) of Imwon granite gneiss, central eastern Korea (northeastern end of the Yeongnam massif) whose age was recalculated by Adachi and Suzuki [33] from the data of Kim, Joo and Jo [34].

B. Limestone clasts

Some limestone clasts of the Kamiaso conglomerate contain Middle Carboniferous fusulinaceans: *Fusulinella laxa, Eoschubertella obscura, Pseudoendothyra* sp., *Profusulinella* cf. *prisca timanica, Profusulinella* cf. *fukujiensis, Pseudostaffella kremsi* and *Verella* sp. [33]. The fusulinacean faunas are similar to those of limestone beds of the Pyeongan Supergroup in the Yeongweol and Samcheok coalfields, eastern central Korea, rather than those of the Hida Marginal Belt [33, 35].

IV. Dinosaur Fossils in Korea and Japan

Dinosaurs are terrestrial animals and thus the occurrence of dinosaur fossils in Japanese Islands indicates that the Japanese Islands were connected to the continent during the time when the dinosaurs roamed on the Earth surface. In this section, the occurrence of dinosaur fossils in Korea and Japan will be reviewed.

A. Korea

Abundant dinosaur fossils including dinosaur footprints, eggs and nests, teeth and bones have been found from the Cretaceous non-marine deposits of Korea. Dinosaur bone fossils were found in fluvial deposits of Early Cretaceous age. Characteristically, preservation of dinosaur bone fossils was aided by calcareous pedogenesis. Dinosaur tracks are the most distinctive, and some tracksites are among the most famous in the world. Until now, 27 dinosaur track localities have been discovered from Upper Cretaceous nonmarine deposits including the Gyeongsang Basin and several small basins, and mainly dinosaur tracks have been found from the coastal areas in southern part of the Korean Peninsula [36]. Dinosaur tracks are of orninthopods, theropods, pterosaurs and sauropods. Dinosaur tracks usually occur in the lacustrine deposits in which thinly interlamininated fine-grained sandstones and siltstones-mudstones are prevailing. Dinosaur eggshell fragments were reported from Lower Cretaceous deposits, but several complete fossil eggs and clutches were recently found in Upper Cretaceous deposits (e.g., [37]).

B. Japan

Many dinosaur body and footprint fossils have been found at various localities in Japan. Japanese dinosaur fossils, except in a very few cases, are mostly isolated teeth and bones [38]. All dinosaur fossils are found in Cretaceous strata. The dinosaur localities other than the Tetori Group, Kanmon Group, Mifune Group and Goshoura Group are located within the Outer Zone of the Japanese tectonic divisions. The localities in the Outer Zone are of shallow marine sediments, and the dinosaur fossils are allochthonous. On the other hand, the Tetori, Kanmon, Mifune and Goshoura groups are terrestrial sediments, and dinosaur fossils are more or less autochthonous. Also, dinosaur fossils from these groups are all from the Early Cretaceous. Among these groups, the Tetori Group, which ranges from the middle Jurassic to Early Cretaceous of central Japan, has produced most of the dinosaur fossils found in Japan to date [38]. Dinosaur fossils have been found from the upper parts of the Tetori Group. They include theropods, sauropods, and ornithopods, and important members include a dromaeosaurid and an iguanodontid [38]. Co-occurring taxa include crocodiles, turtles, ganoid fishes and birds. The dinosaur fauna of the Tetori Group is Early Cretaceous in age, and it represents a fauna that lived in wet lowland area in a warm, humid climate located on the Far East Asian continental edge [38].

V. Quartzite Gravels in Japan

There are many strata containing quartzite gravels across the Japanese Islands. The question then arises as to the provenance of the quartzite gravels. In the present Japanese Islands there have been discovered no such matured quartzite rocks [39]. Accordingly, the source of the quartzite gravels in Japanese Islands must be thought in some other areas. The quartzitic rocks from which the quartzitic gravels were derived must have been originally formed in eolian to beach environments in a continental setting. Actually, orthoquartizte is one of the most typical cratonic sedimentary rocks. In addition, quartzose rocks are more common and abundant in the Proterozoic to lower Paleozoic due to the tectonically stable continental blocks superimposed by intense weathering and strong abrading transport agents such as wind, surf, and longshore currents. The lack of land plants cover until the Silurian or Devonian also must have helped to produce these supermature quartz arenites, which virtually disappear

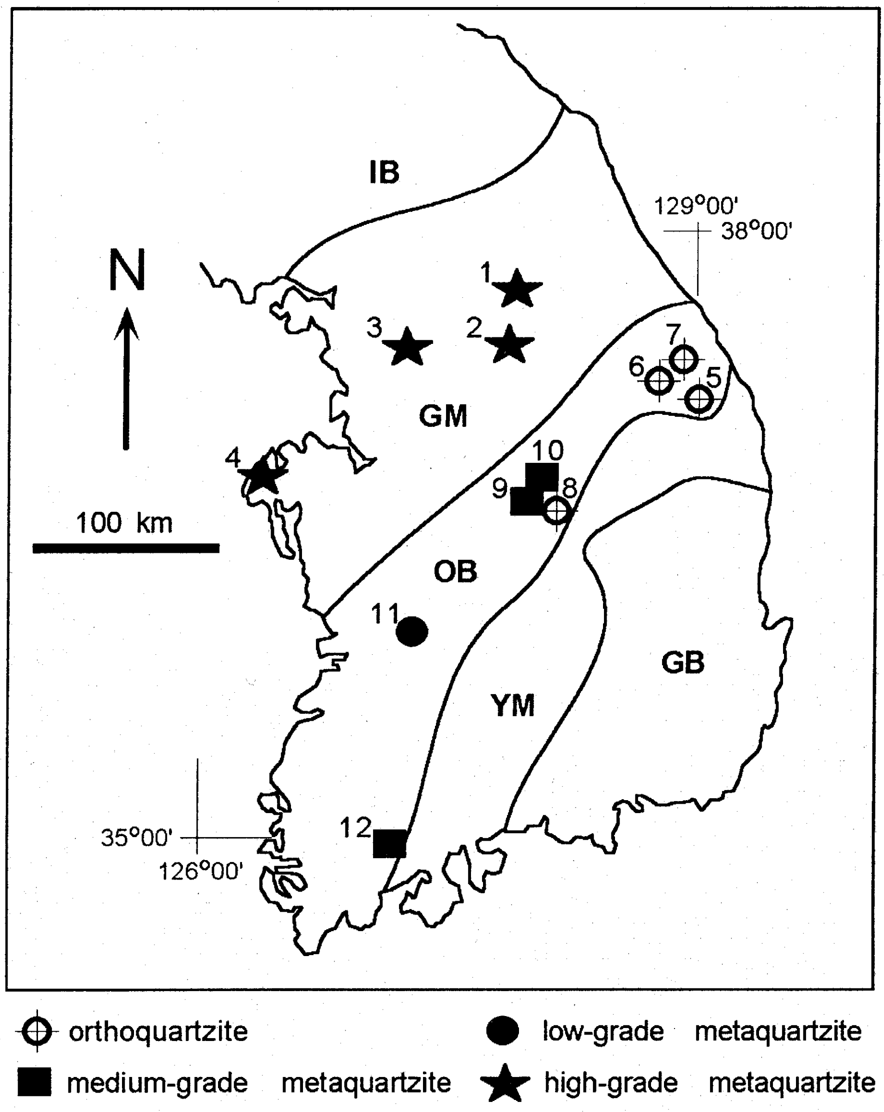

Fig. 2. The simplified map showing the distribution of quartzite types in the southern Korean Peninsula [42]. IB: Imjingang belt, GM: Gyeonggi massif, OB: Okcheon belt, YM: Yeongnam massif and GB: Gyeongsang Basin.

after the early Paleozoic. As an example this study presents some results of a study on quartzite gravels occurring in the Tetori Group in central Japan (the Inner Zone).

The Tetori Group is a representative Middle Jurassic to Lower Cretaceous deposit in central Japan. It is subdivided into three subgroups, namely, the Kuzuryu, Itoshiro and Akaiwa subgroups with decreasing age. The depositional environments of the Tetori Group changed with time from shallow marine environments (Kuzuryu Subgroup) to brackish environments (Itoshiro Subgroup) and to nonmarine environments (Akaiwa Subgroup) [40]. Quartzite gravels are abundantly included in conglomerates of the basal parts of the Itoshiro and Akaiwa subgroups. They are predominantly subrounded to rounded pebbles and cobbles, and are pink, reddish purple, gray, white and bluish gray in color. Considering no existence of quartzite strata in Japan the quartzite clasts of the Tetori Group are commonly interpreted to have been derived from Precambrian quartzite in East Asia: the Sinian System of China and the Sangweon System of North Korea (e.g., [41]). However, textural observation suggests that they were not derived from Precambrian quartzites of China and North Korea but from Precambrian and lower Paleozoic quartzites of South Korea.

The Korean Peninsula is composed of variably aged rocks from the Precambrian to the recent. Quartzite beds occur only in Precambrian and Paleozoic sequences. In the southern peninsula twelve quartzite strata occur in the Gyeonggi massif and Okcheon belt (Fig. 2). All quartzites in the Gyeonggi massif are of Precambrian in age and are characterized by high-grade metaquartzites, whereas those in the Okcheon belt are diverse from orthoquartzite to medium-grade metaquartzite [42]. Comparison of textural characteristics of Tetori Group quartzite gravels suggests that the most probable source rocks for the Tetori quartzite gravels would be the Lower Cambrian Jangsan Formation, distributed in eastern central Korea (NE Okcehon belt), as well as Late Proterozoic quartzose strata, which was newly discovered in the same area recently [43]. The paleocurrent data indicate that the Kamiaso conglomerates were derived from the north [30]. The proposed source area agrees with the paleocurrent data after correction of the clockwise rotation of Southwest Japan.

VI. Radiolaria-bearing Chert Pebbles in Cretaceous Sediments in Korea

The Lower Cretaceous Gyeongsang Supergroup distributed in the southeastern Korean Peninsula contains three strata having chert-pebble conglomerate beds. The Gyeongsang Supergroup is composed of sediments deposited in nonmarine environments including alluvial fan, fluvial and lacustrine settings. The chert pebbles in conglomerates contain many radiolarian faunas ranging in age from Late Permian to Late Jurassic [44, 45, 46]. In the Korean Peninsula Permian to Jurassic marine chert sequences are not exposed. The directions of paleocurrent for the sediments containing radiolaria-bearing chert pebbles are mainly from NE to SW [44, 47]. It was revealed that the radiolarian faunas are similar to those of Jurassic accretionary complexes of Southwest Japan such as the Mino-Tamba-Ashio and Chichibu terranes [44, 45, 46]. Based on terrane analysis [48], the Mino-Tamba belt was located northeast of the Gyeongsang Basin during Cretaceous time, which indicates that the paleo-drainage was connected between the nonmarine Gyeongsang Basin, Korea and the Mino-Tamba-Ashio terrane in Japan. Also, the occurrence of chert pebbles derived from the Jurassic accretionary complexes suggests that Permian accretionary complexes, which are supposed to have been located between the Gyeongsang Basin and the Jurassic accretionary complexes, were peneplained and thus, they did not act as a possible sediment source. Or the Jurassic accretionary complexes might have covered more widely over the Permian accretionary complexes and the present distribution of the Jurassic accretionary complexes may be resulted from exhumation. The erosion of the Jurassic accretionary complexes is known to have started during Late Jurassic time at least in the Outer Zone and possibly in the Inner Zone and became intensified during the Early Cretaceous [49].

Acknowledgements

This research was supported by the Korea Science and Engineering Foundation (R01-2000-000-00056-0) and by the Korea Research Foundation (DS0071). Thanks to Prof. Shoji Arai for invitation to the Kanazawa International Symposium and Dr. Ken-ichiro Hisada for help in the field and research collaboration.

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