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An analysis of apparent polar wander path for southwest Japan suggests no relative movement with respect to Eurasia during the Cretaceous

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ABSTRACT

To test the hypothesis that southwest Japan was involved in large-scale tectonic movement with southward translation as far as 2000 km with respect to Eurasia during the Cretaceous, we examined Cretaceous paleomagnetic poles from southwest Japan to compare with those from Eurasia. Red and gray sandstone samples from the Upper Cretaceous Onogawa Group were collected from twelve sites in the Onogawa Basin in the western part of southwest Japan for paleomagnetic analysis. This group formed over the time span in which the proposed tectonic event is hypothesized to have occurred. A characteristic remanent magnetization component was isolated from red sandstone at ten sites; it is interpreted to be of primary Late Cretaceous origin. The primary directions combined with previously reported data provide a mean direction ($D = 76.8°$, $I = 44.6°$, $\alpha_{95} = 11.1°$, $N = 15$) and a paleomagnetic pole (24.4°N, 202.6°E, $A_{95} = 11.0°$) for the Onogawa area. This pole is consistent with other Late Cretaceous poles from a wide area of southwest Japan, and a mean Late Cretaceous pole (28.4°N, 202.5°E, $A_{95} = 7.5°$, $N = 6$) is calculated and regarded as representative of this region. The Late Cretaceous pole, together with mid- and Early Cretaceous poles, constitutes an apparent polar wander path (APWP) for southwest Japan during the Cretaceous. After restoration of post-Cretaceous tectonic rotation, each Cretaceous pole for southwest Japan shows agreement with the coeval poles for Eurasia; therefore, it is unlikely that the previously proposed tectonic model that includes southward translation of southwest Japan occurred in the Late Cretaceous. Southwest Japan is considered to have behaved as a stable part of the Eurasian continental margin during the Cretaceous.

1. Introduction

An apparent polar wander path (APWP) provides important information regarding the drift history of a continent, cratonic block, or continental fragment through geological time. Researchers can use APWPs to assess the speed of drift and rotation of a continent and to identify large tectonic events such as continental collisions (Muttoni et al., 1996; Suganuma et al., 2006; Torsvik et al., 2012). For example, from 600 Ma, the Gondwana APWP records the amalgamation of Gondwana and the opening of the Rheic and Paleo-Tethys Oceans (Stampfli et al., 2013).

The APWPs for the cratonic blocks that form Eurasia have also been analyzed to reconstruct the paleogeographic evolution of the region (Cocks and Torsvik, 2011; Meert, 2014). Because Eurasia formed through multiple collisions of a number of blocks, APWPs contribute particularly to constraining the timing of the complete amalgamation of neighboring blocks; amalgamated blocks will move together with shared positions of coeval paleomagnetic poles. For example, the APWP for the North China Block, one of the major blocks that compose Eurasia, has been consistent with that of the South China Block since the Late Jurassic, which suggests that the 'composite Chinese block' formed near the boundary between the Middle and Late Jurassic (Gilder and Courtillot, 1997).

For southwest Japan, which is located at the eastern margin of Eurasia (Fig. 1a), the APWP from the mid-Cretaceous onward (Fig. 1b) has been interpreted by Kodama and Takeda (2002) to suggest tectonic movement relative to Eurasia in the Late Cretaceous. These authors argued that the inner arc of the southwestern Japanese Islands (here termed southwest Japan) was translated ~2000 ± 900 km southward to its present latitude, associated with dextral strike-slip movement along the Eurasian continental margin during the Late Cretaceous (Fig. 1c). Kodama and Takeda (2002) attributed large-scale faulting to the collision of the Okhotsk microcontinent north of the inferred position of

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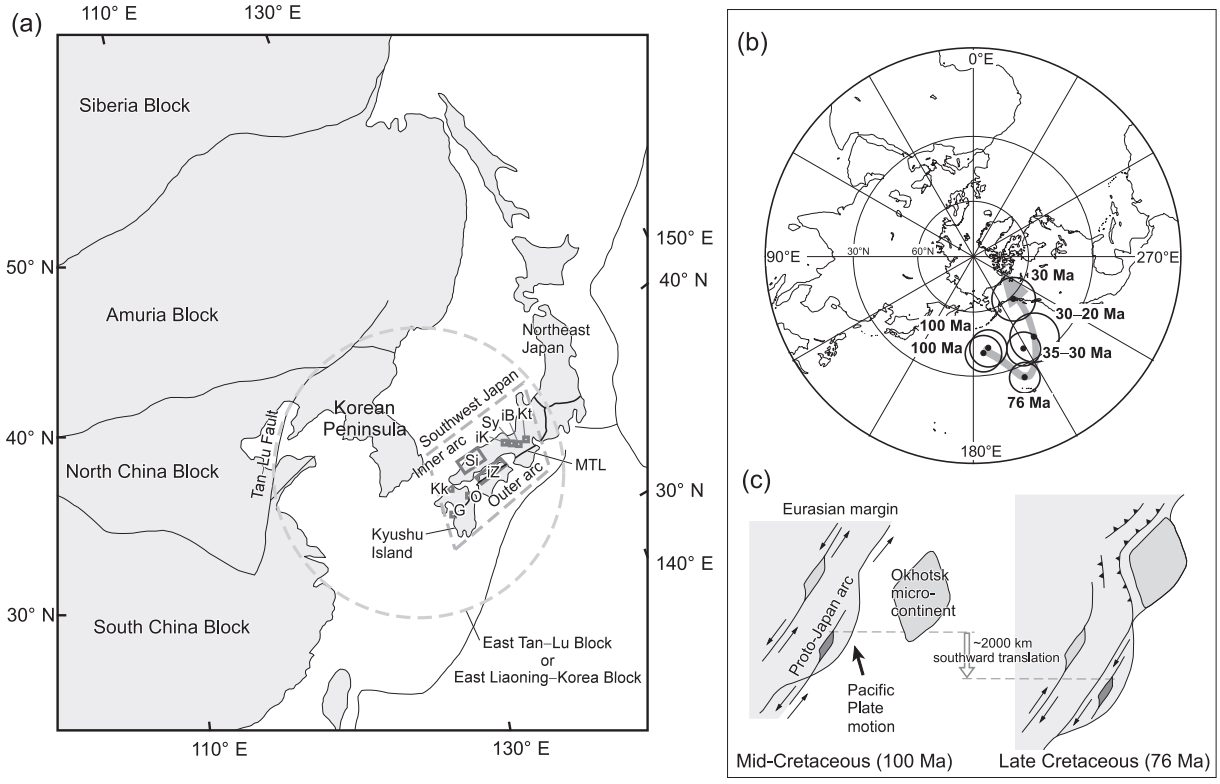

Fig. 1. (a) Outline tectonic map of East Asia and the Japan Arc. Kt: Koto area; iB: Ibaraki area; Sy: Sasayama area; iK: Ikuno area; iZ: Izumi area; Si: San'in area; O: Onogawa area (study area); G: Goshonoura area; Kk: Kita-Kyushu area. MTL is the Median Tectonic Line that demarcates southwest Japan into the inner and outer arcs. (b and c) Previously proposed apparent polar wander path for southwest Japan and tectonic model by Kodama and Takeda (2002).

southwest Japan. However, this tectonic scenario seems inconsistent with the previously proposed model that invokes coast-parallel northward translation of geological domains along the Eurasian margin in association with large-scale sinistral faulting during the mid- to Late Cretaceous (Golozoubov et al., 1999; Win et al., 2007; Uno et al., 2011).

Two considerations in particular are relevant to evaluate the tectonic scenario proposed by Kodama and Takeda (2002). One is comparison of the paleomagnetic polar wander of southwest Japan with that of Eurasia. The proposed tectonic movement of southwest Japan is based only on the shape of its Cretaceous APWP track, with which the coeval Eurasian APWP has not previously been compared. The second consideration is that Kodama and Takeda (2002) constructed the southwest Japan APWP using paleomagnetic data only from the mid-Cretaceous onward because of a lack of data from the Early Cretaceous or earlier. An Early Cretaceous paleomagnetic direction for southwest Japan has since become available (Uno and Furukawa, 2005), and its addition to the database may clarify the APWP of southwest Japan. Further study must be undertaken to establish a representative APWP for southwest Japan to compare with that of Eurasia.

The Upper Cretaceous Onogawa Group in the Onogawa area, western part of southwest Japan (Fig. 1a) was chosen as the site of our investigation. These deposits are of a suitable age because they formed during the time in which the Cretaceous tectonics proposed by Kodama and Takeda (2002) would have taken place. A paleomagnetic pole from the Onogawa Group is incorporated into the southwest Japan APWP database. We report that an analysis of the newly constructed APWP for southwest Japan suggests no relative movement with respect to Eurasia during the Cretaceous.

2. Geological setting and sampling

The Late Cretaceous Onogawa Group is exposed in eastern Kyushu, southwest Japan (Fig. 1a), and distributed along the ENE–WSW-trending Onogawa Basin demarcated by the Tsukano–Taketa faults to the north and Usuki–Yatsushiro tectonic line to the south. The Onogawa Group developed as a left-lateral, strike-slip pull-apart basin succession (Taira and Tashiro, 1987; Teraoka et al., 1992). It consists mainly of sandstone and conglomerate with acid tuff intercalations (Teraoka et al., 1992). Within the study area, the Onogawa Group is divided into eight formations; from youngest to oldest these are the Mizugajo, Takeyama, Ugaku, Inukai, Shibakita, Nakakawarauchi, Okukawarauchi, and Ryozen Formations (Teraoka et al., 1992). Based on paleontological data, the ages of the first two, next three, and the following two formations are Santonian, Coniacian, and Turonian, respectively, within the Late Cretaceous. The lowermost Ryozen Formation lacks fossils in the study area, but its deposition is estimated to have ceased by the end of the Turonian (Teraoka et al., 1992). The lower part of the Ryozen Formation was deposited under non-marine conditions and yields red clastics; the remaining formations were deposited in marine conditions. Folding of the Onogawa Group occurred soon after deposition (Teraoka et al., 1992).

Samples of red sandstone from the Ryozen Formation (sites NH1–NH6 and NH9–NH13) and gray sandstone from the Inukai Formation (site NH8) of the Onogawa Group were collected at twelve sites in the Onogawa Basin for paleomagnetic analysis (Fig. 2). Bedding planes at the sampling sites have roughly consistent N–NE strikes, with dips of 60–128°. The bedding attitudes at each site show little variation, and were determined on the basis of several bedding planes on which tilt correction was performed.