Press Releases

February 12, 2015
JAMSTEC

Successfully Reproduced Process of Continental Drift from Breakup of Pangea to Present-day Continental Distribution, Revealing Its Driving Force
- Cold Plums Formed Himalayas! -

1. Overview

Dr. Masaki Yoshida and Dr. Yozo Hamano, Department of Deep Earth Structure and Dynamics Research, Japan Agency for Marine–Earth Science and Technology (JAMSTEC: Asahiko Taira, President) carried out numerical simulations of 3-D spherical mantle conviction[*1] using supercomputer facilities. As a result, they successfully reproduced the process of continental drift from breakup of the supercontinent Pangea[*2] at 200 Ma to the present-day continental distribution and the Earth's mantle interior that can't be observed from the Earth's surface. This is the world's first achievement to reveal that mantle convection under Earth-like conditions is a major factor for breakup of the supercontinent Pangea and the subsequent continental drift, which have been a mystery for 100 years since the theory of continental drift was proposed first by Alfred Wegener[*3].

These findings strongly support evidence based on JAMSTEC's large-scaled researches on the oceanic plate structures (as reported on March 31, 2014). Unlike exiting models, this numerical simulation model developed for this study is revolutionary since it allows highly viscous continental materials to deform and drift independently under convective force of the ambient mantle.

In addition, these study results indicate that mantle flow pattern as driving force of continent drift depends on thermal insulation effect[*4] in the supercontinent and cold plum[*5] of mantles in the boundary of continents and oceans.

One of the most famous events in the history of continental drift after the Pangea breakup is formation of the Himalayas and Tibetan Plateau. During the breakup of Pangea, the Indian subcontinent[*6] became isolated from the southern part of Pangea called Gondwanaland and moved northwards across the Tethys Ocean to collide with Eurasia, which resulted in the formation of Himalayans. These simulations approximately reproduced the high speed of northward drift of the Indian subcontinent. It was also revealed that a major factor of the northward drift of the Indian subcontinent was the large-scale cold mantle downwelling that developed spontaneously in the North Tethys Ocean.

The Himalayas and Tibetan Plateau brought not only a monsoon climate in Asia but also cooling of the Earth. Revealing the high speed of northward drift of the Indian subcontinent and driving force of Himalayans and Tibetan Plateau is likely to bring a significant progress in elucidating the origin of current climate system on the Earth.

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These study results have been posted on *Scientific Reports*, an online journal from the publishers of *Nature* on February 12 (JST: 19:00).
Title: Pangea breakup and northward drift of the Indian subcontinent reproduced by a numerical model of mantle convection
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*1 **Numerical simulations of 3-D spherical mantle conviction**

A long time scale of more than several 1 million years causes fluid motion of mantles consisted of rocks. In mantles, due to different temperatures between the Earth's surface and core - mantle boundary (approx. 2,500 to 3,500 degrees C), heat conviction or mantle conviction is occurring. In the numerical simulations of 3-D spherical mantle conviction, conviction starts simply by providing temperature fields as the initial condition. Therefore, numerical simulations based on basic formulas for mantle conviction allow us to obtain temperature fields and velocity fields at a fixed time interval.

*2 **Supercontinent Pangea**

A supercontinent that existed on the Earth 300 million years ago, which was proposed by Alfred Wegener[*3]. Based on geological evidence, it was formed 300 million years ago and began to break apart about 200 million years ago. A northern half of the Pangea was called Laurasia (present Eurasia and North American continent) and southern Gondwana (present African, South American and Australian continents and India.) Wegener considered that the Indian subcontinent was connected with Eurasia when the Pangea was formed. The northward drift of the Indian subcontinent was found only after 1950s when magnetic anomalies in Indian Ocean basins were confirmed.

*3 **Alfred Wegener (1880-1930)**

A German meteorologist. In 1912, he first presented a theory of continental drift. In 1915, he published it in full in “The Origin of Continents and Oceans (Die Entstehung der Kontinente und Ozeane).”In the third edition of the book published in 1922, he called a supercontinent “Pangea.”He died during his Greenland expedition in 1930.

*4 **Thermal insulation effect of supercontinents**

It refers to phenomenon in which supercontinents act as “thermal blankets “for mantles. As a result, mantles beneath the large mass produce heat with disintegration of radioactive elements (uranium, thorium and potassium) in the mantles or increase temperature with heat of mantle flow ascending from the depth of the mantles. In 1982, it was first proposed by Dr. Don L. Anderson, California Institute of Technology, in *Nature*. In 1999, Yoshida (Hiroshima University at that time) and his team confirmed it for the first time by using numerical simulations of 3-D spherical mantle convection (*Geographical Research Letters*).

*5 **Cold plume**

Cylindrical or sheet-like cryogenic zones descending into the mantle.
They are generated from subducting oceanic plates from subduction zones on the Earth's surface or oceanic plates separated from the Earth's surface.

*6 **Indian subcontinent**

The present Indian Peninsula (Indian subcontinent) originally existed in the southern hemisphere as part of the supercontinent Pangea. With breakup of the Pangea, it moved toward the north hemisphere at a high speed (up to 20 cm a year) around 40 million to 50 million years ago, and collided with the Eurasian plate.

*7 **Tethys Ocean**

It is a wedge-shape ocean existed between the continents of Laurasia and Gondwana used to form the supercontinent Pangea. Refer to figure 3.

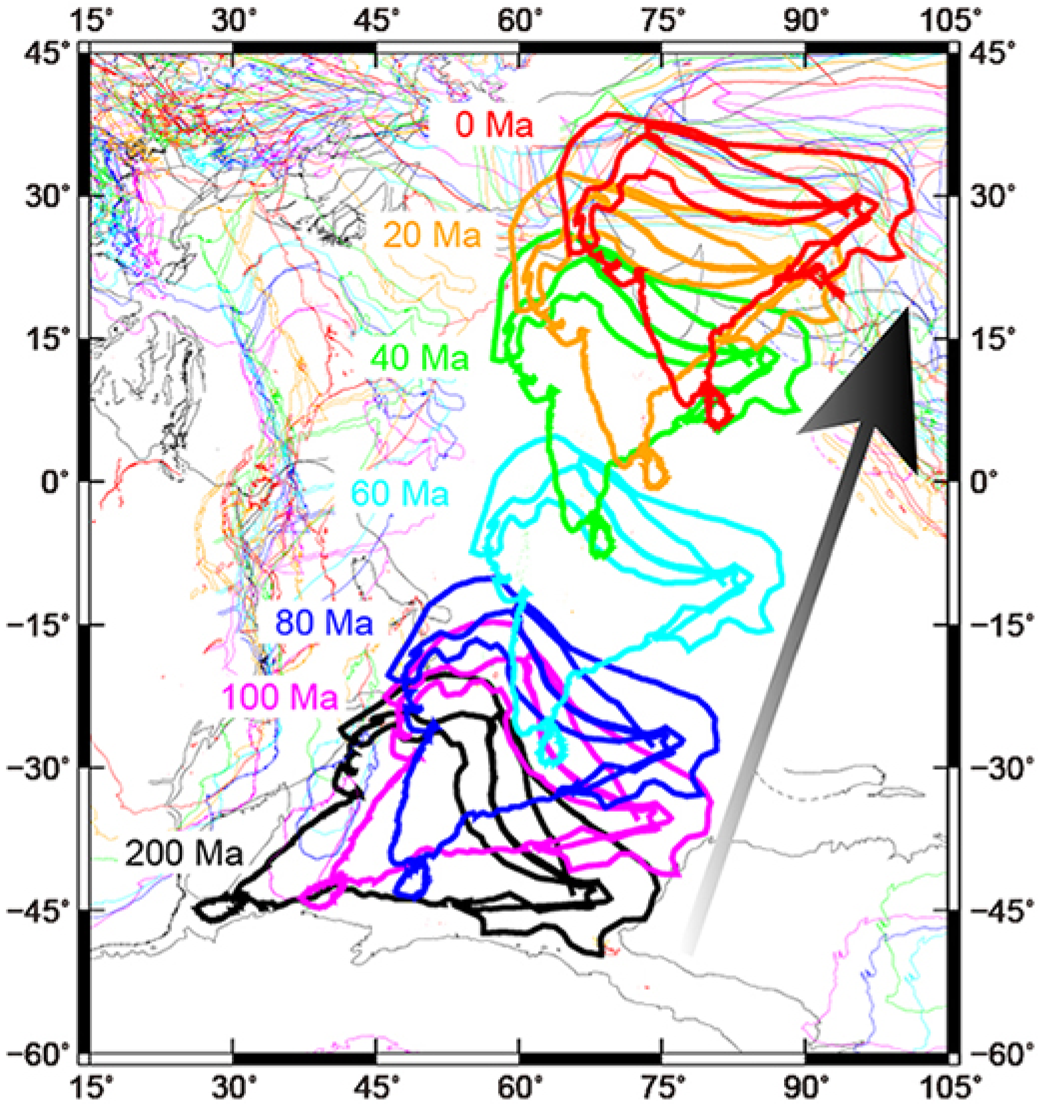


Figure1 : High-speed northward drift of the Indian subcontinent estimated based on precise geological and paleomagnetic data (Seton et al. 2012, Earth-Sci. Rev.). Time sequence of drifting continental blocks at each age from 200 Ma to the present. The Indian subcontinent that moved towards the north and collided with Eurasia is highlighted in thick contour lines.

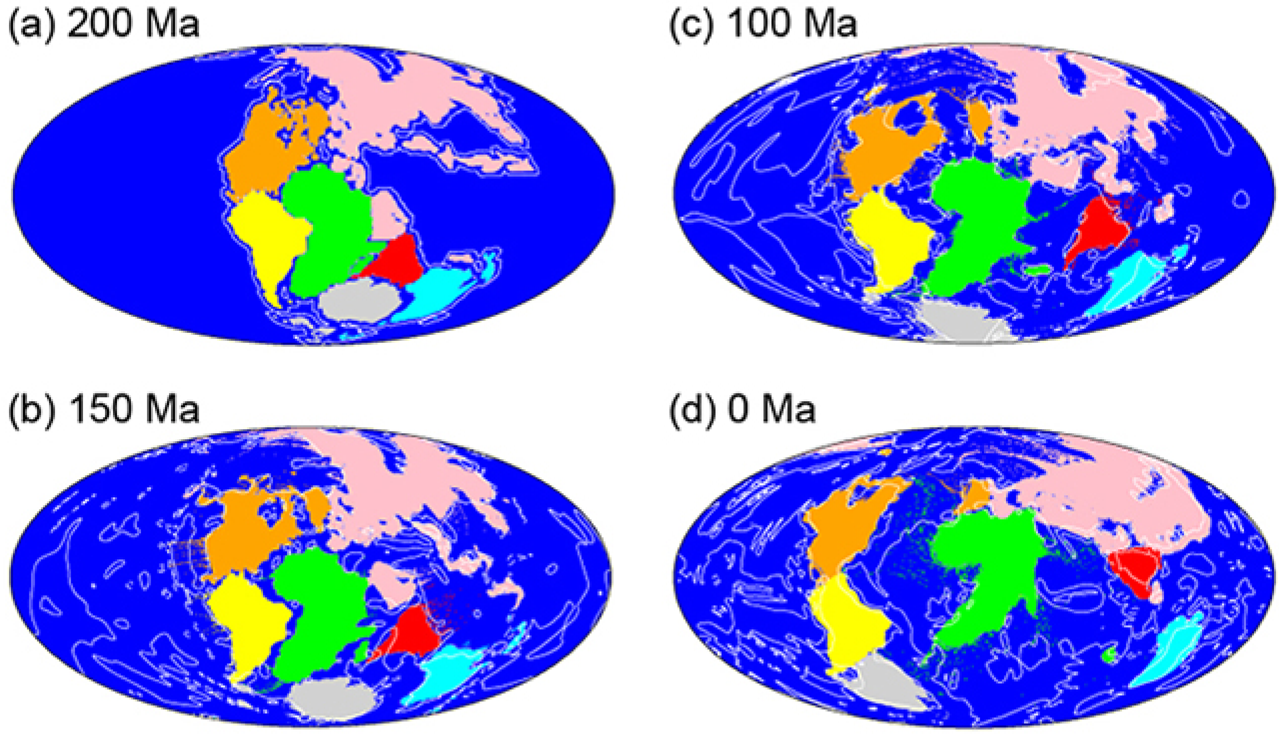
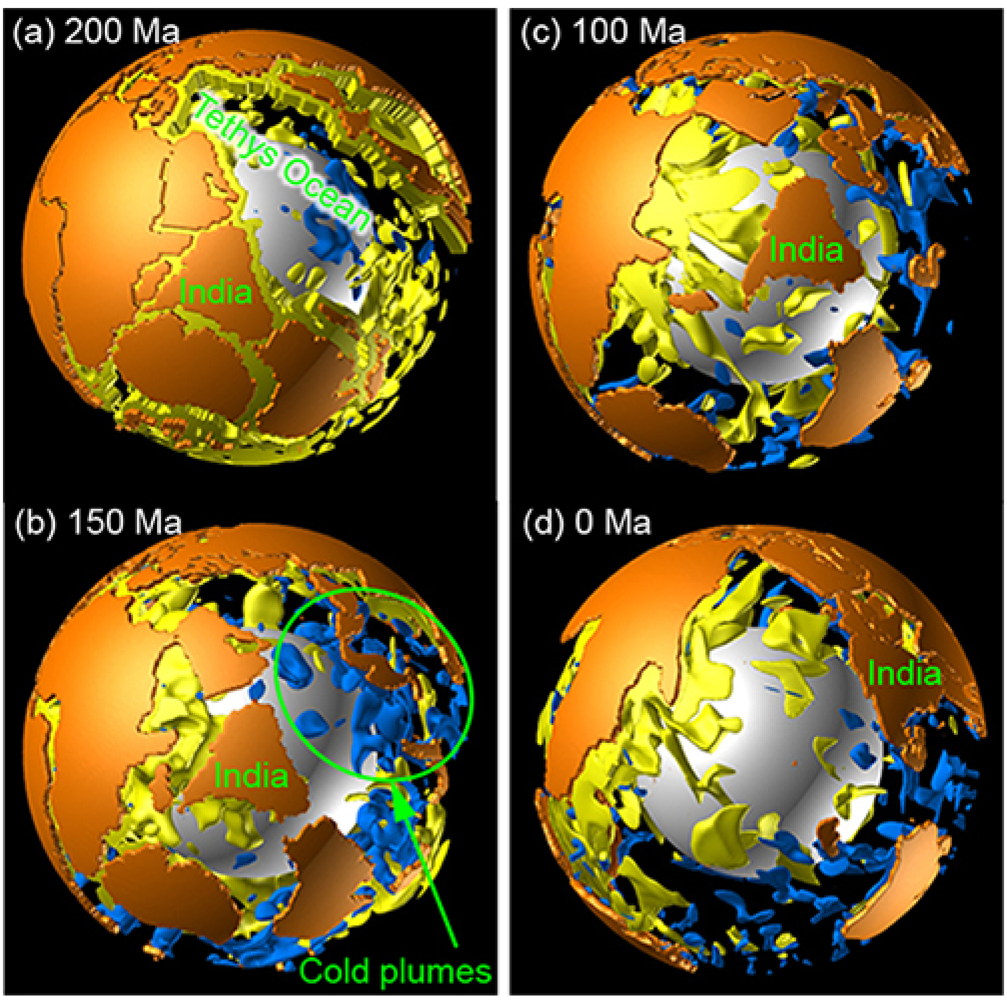


Figure2 : Examples from simulation results, showing time sequence of positions of drifting continents.
(a) 200 million years ago (b) 150 million years ago (C) 100 million years ago (d) Present



(Video)

Figure 3 : Time sequence of 3-D views of mantle convection and drifting continents. Each age corresponds to the figure 2. The temperature of the blue equivalent phases is 250 degrees lower than the average temperature at each depth, and the temperature of the yellow equivalent phases 100 degrees higher. The orange-colored areas on the surface show location of continents.

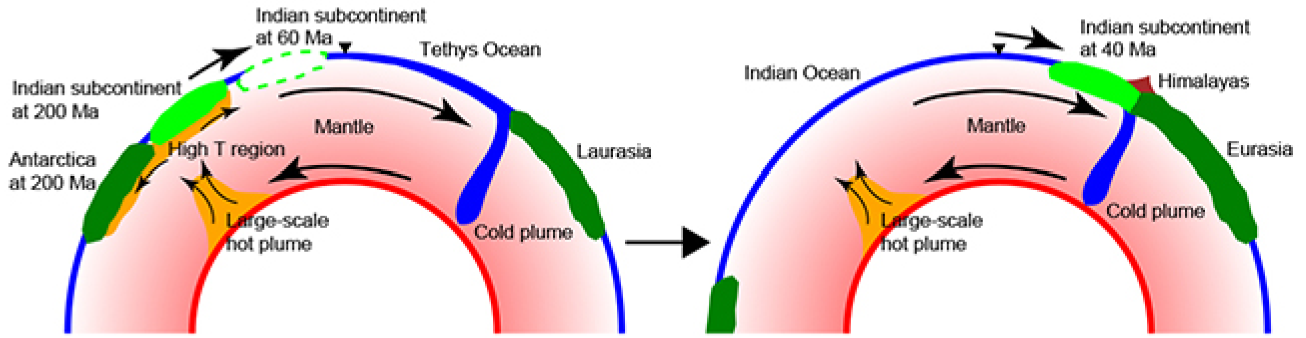


Figure 4 : Diagram showing the mechanism of high speed of the northward drift of the Indian subcontinent.

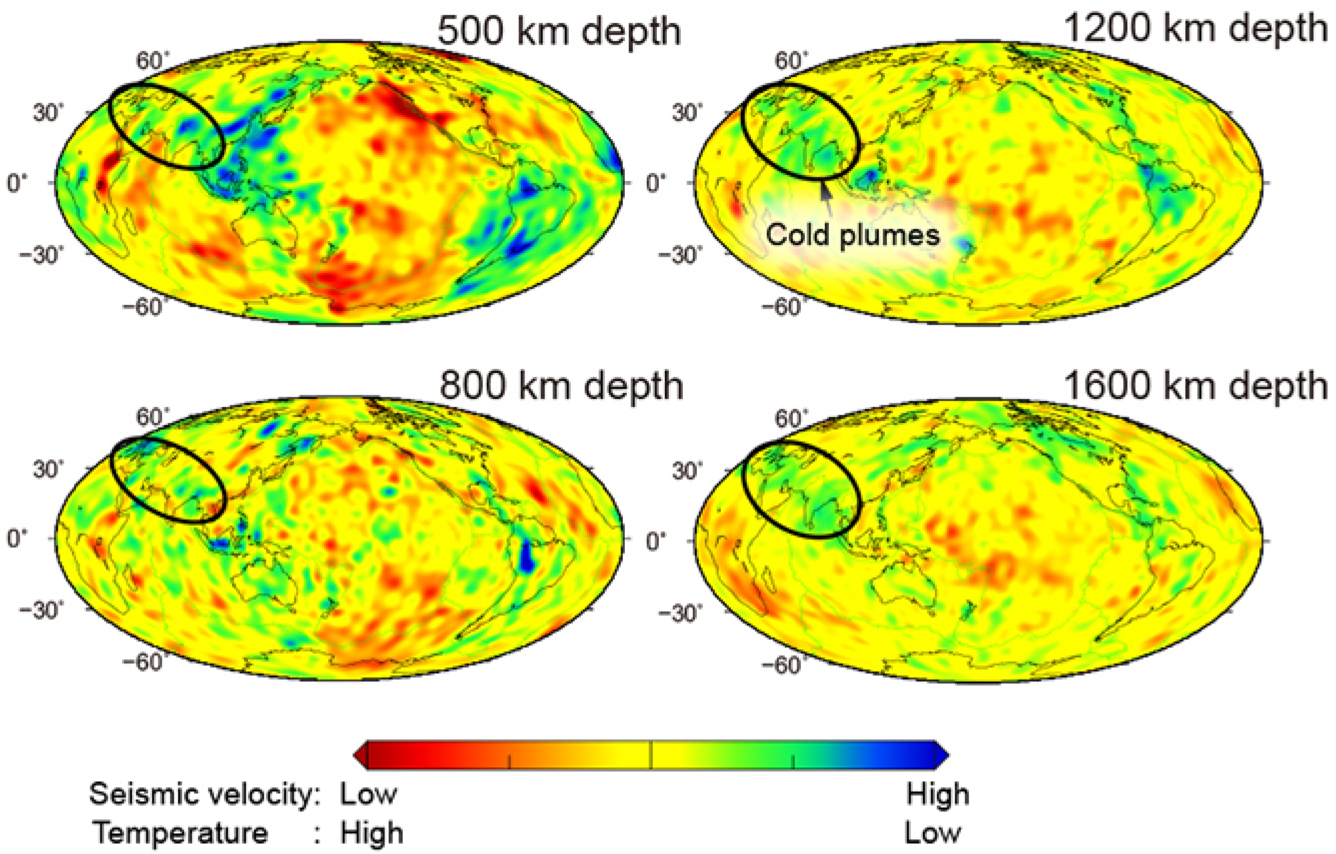
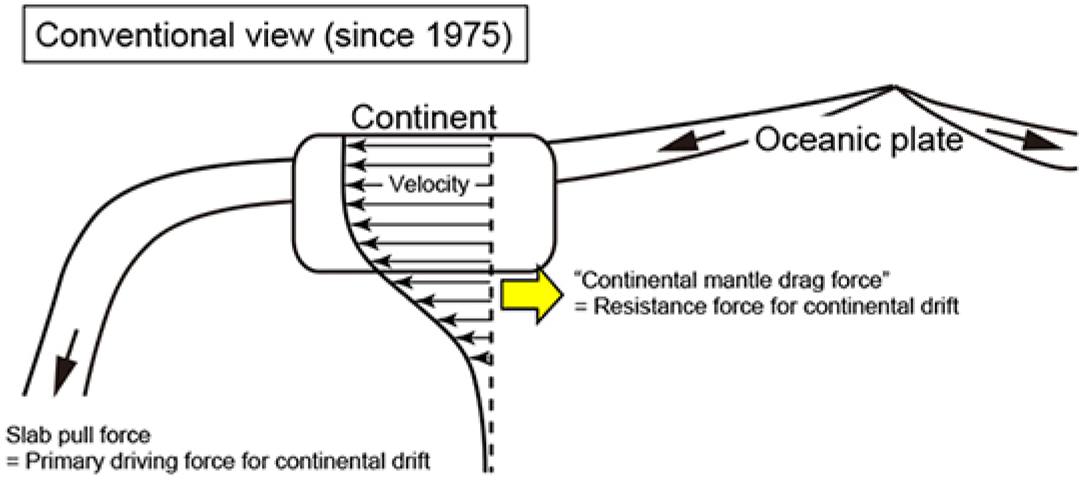


Figure 5 : High velocity anomalies under the present Indian subcontinent and the Mediterranean in seismic tomography data. Each cross-section diagram shows data at depth of 500 km, 800 km, 1200 km and 1600 km, respectively. These data are based on Ritsema et al. (2011, Geophys. J. Int.)



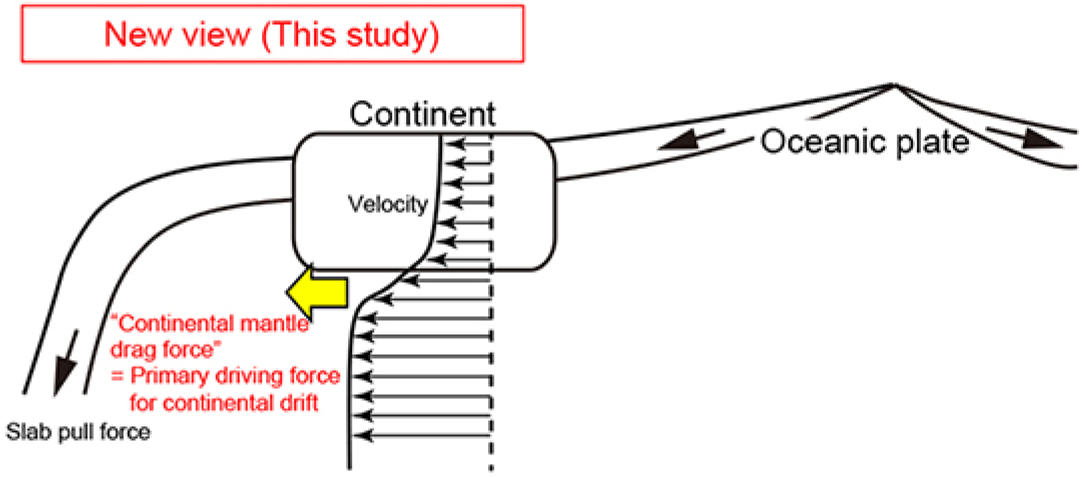


Figure 6 : Two theories of driving force for continental drift
The top shows a theory that has been prevailed since 1975 (Forsyth & Uyeda, 1975, Geophysics. J. R. Astron. Soc.). Here, "mantle drag forces beneath plates" act as resistance to continental drift. As indicated in the bottom, however, the results of simulations suggest that "mantle driving forces beneath plates" act as a major factor of continental drift.

Supplementary

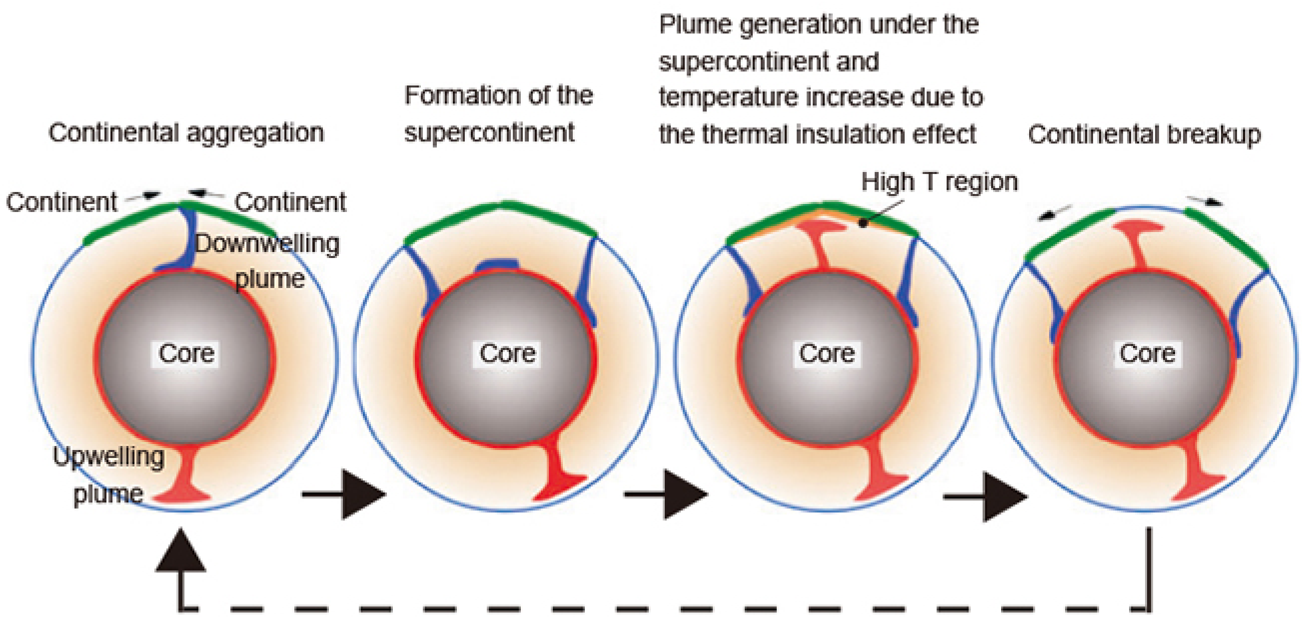


Figure 7 : Mechanism of upwelling plumes beneath Pangea and high temperature anomaly due to the thermal insulation effect.
(Yoshida & Santosh, 2011, Earth-Sci. Rev.; Heron & Lowman, 2014, J. Geophys. Res.)

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