

Assembly and Breakup of Supercontinents

A Story of the Changing Map Patterns of the Earth

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The history of earth is replete with the story of assembly and break up of continental blocks. More than 180 million years ago, all the continental blocks were clustered into one supercontinental framework, called the Pangea, surrounded by a single ocean. New evidence cropped up recently which indicated existence of a still older Rodinia supercontinent whose dismembered fragments had later reassembled to form the younger Pangea supercontinent.

The Earth is a Living Planet

There was a time when the earth-scientists were divided amongst themselves on the question of permanency of oceans and continents, into *fixist* and *mobilist* groups. The situation changed dramatically with emergence of the concept of the new global tectonics¹ about three decades ago. Mobility of continents and oceans on the surface of the earth is now an accepted fact.

Truly speaking, the earth we live on is a living planet. This is in striking contrast to the other terrestrial planets such as Venus, Mars, Mercury and the moon (truly a satellite) all of which are dead, showing no sign of 'life'. What actually is keeping the earth 'alive' is the continuous flow of heat through the fracture systems, which are present in the uppermost rigid layer, called lithosphere (*Figure 1*). The volcanoes that belch out molten lava and ash and the earthquakes that regularly shake the crust violently provide evidence that the solid earth is also 'alive and kicking'.

The Concepts of Moving Plates

As an exercise if we plot the epicentres of known earthquakes and the sites of the volcanic eruptions, for which we have known

¹ Tectonics is a subject, which deals with the deformation in the earth's crust. Global tectonics relates to processes on a global scale.

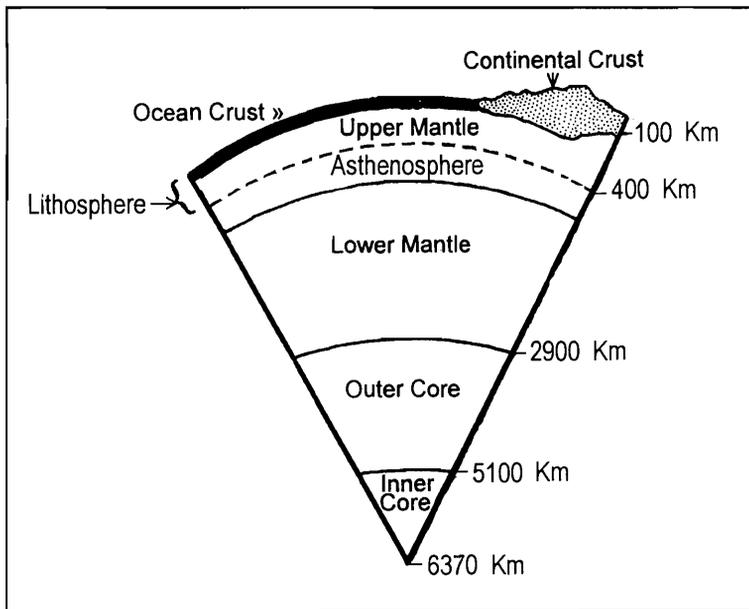


Figure 1. A schematic wedged section through the earth, showing its internal constituents. The crust, the uppermost shell is of two types: continental (made up predominantly of granitic rocks) and oceanic (made up mainly of basalt). The crust together with the rigid upper mantle constitutes the lithosphere, which overlies the hot and semi-plastic asthenosphere. Thickness of the crust is exaggerated compared to other units (scale: approximate).

records, on a map of the world, at the end of the exercise we may be surprised to find that the earth's surface has been divided into smaller segments of 'stable areas' (virtually free of earthquakes and volcanoes) bounded by narrow strips of unstable zones (Figure 2). The stable areas are called 'plates' mainly because of their inverted saucer-like shape. The narrow unstable zones are called mobile belts, as these are the sites of concentrated movements. The plates are the fundamental units of the earth's lithosphere, which are in constant interactions. These interactions, called plate tectonics, are not only the cause of major changes in the surface landscape, but also the pattern of distribution of earth's continents and oceans. All of us are aware of the changing geopolitical map of the world. But do we know about the extremely slow but perceptible modification in the size, shape and position of oceans and continents? The earth-scientists tell us that the continental fragment which is now Indian shield², moved more than 7000 kilometres during the last 180 million years, or that every year India is losing nearly five centimetres of its land due to ducking of the Indian shield under the Himalaya; or that the Pacific ocean is regularly getting reduced in size.

² A shield is a region made up of very old rocks which remained stable (not affected by deformation) over a long period of time.

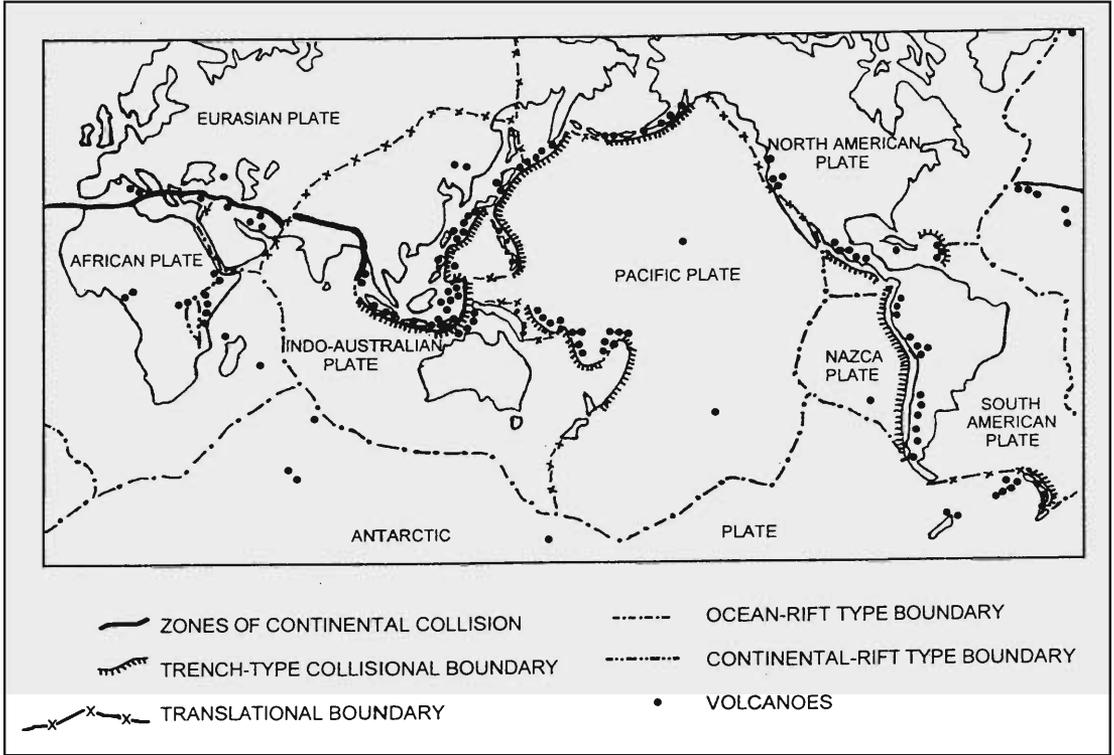


Figure 2. A sketch map of the world showing distribution of plates of different sizes and shapes separated by mobile belts or plate boundaries, which are defined by chains of earthquake epicentres and volcanoes.

The Pangea Supercontinent

We wish that God had videotaped the records of all the changes in the crust that took place during the last 180 million years. The rewinding of the tape would take us back to a totally different map of the world. In that 180 million-year old world, the continents, which are now widely separated, would have appeared close to each other, forming a single mass of continents. Alfred Wegener, a German meteorologist, was the first to attempt a scientific reconstruction of the palaeo-world. He named the reconstituted supercontinent (the cluster of all continents) as *Pangea* (meaning all lands) (*Figure 3*). The continuous stretch of ocean that encircled the rest of the palaeo-world has been described as the *Panthalasha* (meaning all oceans).

Very much like solving a jigsaw puzzle, the reconstruction of the supercontinent framework is a complex exercise of piecing together the continental fragments based on the configurations

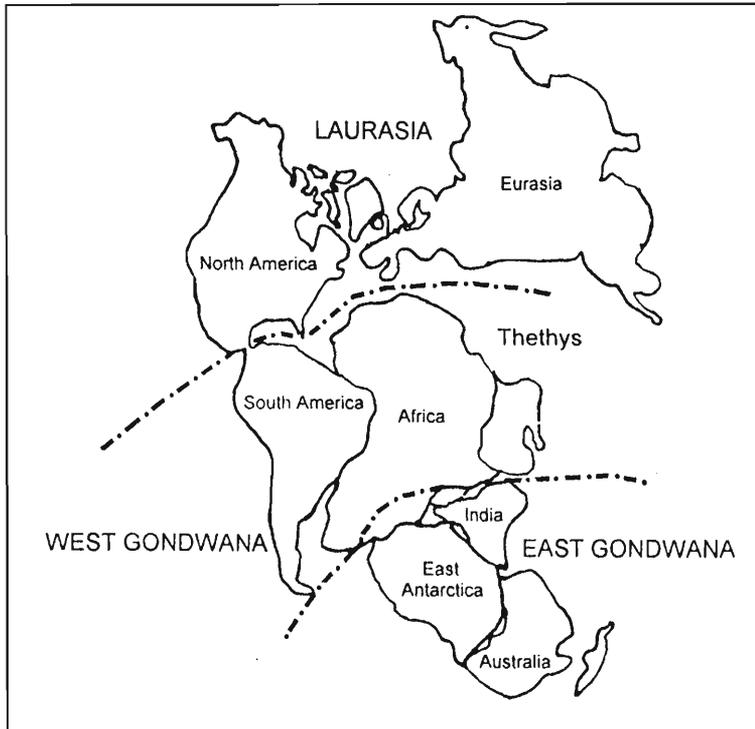


Figure 3. An outline of the Pangea supercontinent indicating the position of the Tethys, and the continental blocks making up the Laurasia, East Gondwana and West Gondwana.

of continental shore lines. The supercontinent reconstruction also takes into consideration the shelf bathymetry (a feature that indicates morphology and depth of submerged areas of continental blocks), geological correlation of rock formations, fossil evidence, and lastly but most importantly, on the reconstruction of the *apparent polar wandering path* (APWC) based on the palaeo-magnetic study³. APWC is a useful tool in resolving the jigsaw fit of the continental fragments. Studies made by the earth-scientists during the second half of the present century on the above lines have confirmed existence of the Pangea supercontinent.

Palaeo-magnetic studies coupled with isotope dating of rocks have helped in the reconstruction of the stages of integration of smaller fragments into a single unit of the Pangea supercontinent. Close to the end of the Palaeozoic, about 200 million-years ago, the process of integration of the Pangea supercontinent was completed by suturing of two large continental blocks, the Laurasia (comprising North America⁴, Greenland and Eurasia)

³ A weak magnetism is created in rocks during its formation by the orientation of magnetic particles in the line with ambient field, which is known as remanent magnetisation. Palaeo-magnetic data based on remanent magnetism indicate relative position of poles at the time of formation of rocks. Since the polar positions are fixed, any apparent change in the polar position would mean change in the position of a crustal block relative to the poles. The curve drawn from different 'polar position' is called the *Apparent Polar Wandering Curve* (APWC).

⁴ All the geographical names are according to the present geopolitical situations, and the geographical co-ordinates are according to the positions in the present day map.

and the Gondwanaland (comprising mainly South America, India, Australia and Antarctica). Some disagreements, however, prevail amongst the earth-scientists on the position of parts of China, Mongolia, and certain areas of south-east Asia in between the Laurasia and Gondwanaland. A significant aspect of the Pangea integration is the closing of a palaeo-ocean, called '*Proto-Atlantic*' or *Iapetus Ocean*, whose western coastline was along the north-eastern North America and the eastern coastline followed north-western parts of Scandinavia, Britain and Africa.

The largest component of the Pangea, the Gondwanaland had assembled earlier, between 600 to 740 million-years ago, through the suturing of two fragments, the East Gondwana (comprising India, Australia and Antarctica) and the West Gondwana (comprising Africa and South America). A huge Pacific-sized palaeo-ocean named '*Mozambique Ocean*' is believed to have existed between the two Gondwana fragments.

Was There a 'Father' Supercontinent of Pangea?

Assembly and the subsequent breakup of the Pangea are not the only change that the earth's crust had undergone since it started forming, almost immediately after evolution of the planet about 4600 million-years ago. Very recently the earth-scientists have come forward with a novel idea of an older supercontinent, which they named Rodinia⁵. The Rodinia supercontinent is believed to have existed earlier than 1000 million-years before present. In the reconstructed framework of the Rodinia, the Laurentia (North America-Greenland combine) has been placed in the centre-stage surrounded on its northern, western, southern and eastern sides by Siberia, Australia-Antarctica, Kalahari and Congo (including Sao Francisco of South America) and Amazonia-Baltica, respectively (*Figure 4*). A significant common feature of the Rodinia assembly is presumed to be the Grenvillian orogen (more than 1000 million-year old belt of mountain building like the recent Himalaya). Understandably, therefore, the reconstruction of the Rodinia hinges on the possible extension

⁵ The Rodinia is derived from the Russian word '*roditi*' meaning to procreate. The implication is that the Rodinia is the father of the later Pangea.

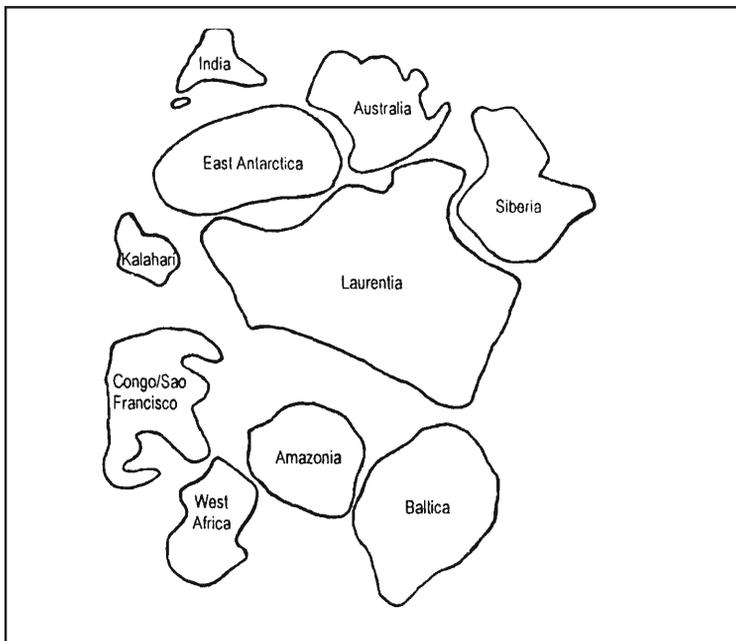


Figure 4. A cartoon diagram showing the possible configuration of the Rodinia supercontinent.

of the Grenvillian orogen around the East Antarctica into India and Australia.

Fragmentation of Rodinia started a little later than 1000 million-years before present. In the process of fragmentation, the interior regions of the Rodinia supercontinent became the external margins of the later Gondwanaland, whereas the external margin of the former became landlocked within the interior Gondwanaland.

Another significant development between the breakup of the older supercontinent and the assembly of a new Gondwana is the welding of disparate fragments (from the Rodinia breakup) into a single Africa. The zones of the suture are very popularly known as the Pan-African orogenic belts. South America is also believed to have a similar growth history.

The new idea of Rodinia supercontinent preceding the 'Wegenerian' Pangea has attracted attention of large number of earth-scientists during the last decade of the present century. However, one disquieting aspect of the new concept is that the proposed configuration of the Rodinia differs significantly from

that suggested earlier on the basis on available palaeo-magnetic data. The confirmation of the Rodinia framework may prove to be one of the most challenging research activities in the emerging century.

Geological information on the possible supercontinent framework in the early years of the earth's history is still vague and hazy. In the present state of our knowledge the older earth is a domain of 'terra incognita'. However, as more and more light is being thrown onto the dark early world, it is possible that in future we will know more about the processes of assembly and dismemberment of a still older supercontinent which could be the ancestor of the Pangea and the Rodinia.

Acknowledgement

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Suggested Reading

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While still in his early twenties, Thomas Alva Edison (1847-1931) pledged resolutely to 'keep a full record' of his career. And he was true to his word, as is borne witness by a staggering array of more than 3,500 notebooks housed in the archives of the great inventor's laboratory and machine shop at the Edison National Historic Site in West Orange, NJ.

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