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MUSLIM ARTS COLLEGE
Thiruvithancode, Kanyakumari, Tamilnadu, India.
LEMURIA RESEARCH FORUM
FIRST INTERNATIONAL CONFERENCE



CERTIFICATE

This is to certify that Dr/Mr/Mrs/Ms Dr. C. Amose (HOD Public).....
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Pangea The Super Continent and its Break up.....


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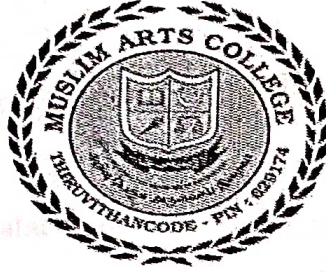

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PANGAEA, THE SUPER CONTINENT AND ITS BREAK UP

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Abstract:

The making of pangea is the result of large-scale amalgamation of continents and micro-continents, which started at the end of the Neoproterozoic with the formation of Gondwana. As pieces were added to Gondwana on its South American, Antarctica and Australia side were detached from its African and Australia side were detached from its African and South Chinese side Cadomia was reaccruted to Gondwana but the other continent was accreted to Baltica, north-China, Laurussia or Lurasia. Finding the origin of these numerous terranes is a major geological challenge. The theory of plate tectonics offered new and more scientifically sound explanations for a number of observed geological phenomena. The collision of continental plates created lofty mountains like Himalayas. Madagascar and India began to separate from Antarctica. Australia split from Antarctica and moved quickly northward. The break up of pangea continues today in red sea rift and east African rift. The expansion of the temperate climate may have contributed to the diversification of the angiosperms.

Introduction:

There are spectacular developments taken place in the field of Earth science, during the last few decades. The scientists determines the earth began its life about 4.6 billion year ago, and the continents probably began forming about 4.2 billion years ago as the earth continued to cool¹. Further scientist determined that our earth in made up of four main layers such as SIAL (Silca and Aluminum) layer, SIMA(Silica and Magnesium) layer, NIFE (Niccil and Furus) layer and core. The core is located at the centre of the earth which have full of molten magma. The top layer floats on the magma or mantle. Several scientists suggested that the continental masses had the almighty to move across the earth's surface. There continental drifts were called as Pangaea. Pangaea is a super continent which makes lot of changes in the world.

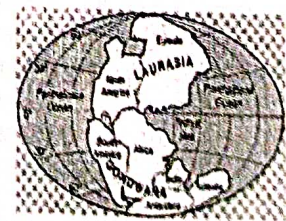
Pangaea super continent:

Pangaea or Pangea² was a super continent that existed during the late Paleozoic and early Mesozoic eras.³ It assembled from earlier continental units approximately 335 million years ago, and began to break apart about 175 million years ago.⁴ In contrast to the present Earth and its distribution of continental mass, Pangaea was centred on the Equator and surrounded by the super ocean Panthalassa. Pangaea is the most recent super continent to have existed and the first to be reconstructed by geologists. The name Pangaea or Pangea is derived from Ancient Greek pan (which means, all, entire, whole and Gaia which means, Mother Earth or land).⁵

Scientific theory of Alfred Wegener:

The concept that the continents once formed a contiguous land mass was hypothesised by, with corroborating evidence, Alfred Wegener, the originator of the scientific theory of continental drift, in his 1912 publication 'The Origin of Continents'. He expanded upon his hypothesis in his book 'The Origin of Continents and Oceans', in which he postulated that, before breaking up and drifting to their present locations, all the continents had formed a single supercontinent that he called the "Urkontinent".⁶

Wegener originally proposed that the breakup of Pangaea was due to centripetal forces from the Earth's rotation acting on the high continents.⁷ However, this mechanism was easily shown to be physically implausible, which delayed acceptance of the Pangaea hypothesis. Arthur Holmes proposed the more plausible mechanism of mantle convection, which, together with evidence provided by the mapping of the ocean floor following the Second World War, led to the development and acceptance of the theory of plate tectonics⁸. This theory provides the now widely-accepted explanation for the existence and breakup of Pangaea.



The super continent

¹ Richard curle's book, wonders of the past. P.8

² Oxford Dictionaries-meaning of Pangea

³ Everyman's "Encyclopaedia"

⁴ Royers J.J.W. Santhosh M.continents and super continents
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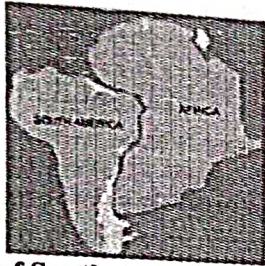
⁶ Lewis C.T, pangaeus in A Latin Dictionary. Newyork. 1879.

⁷ Sudha Sheshalan & Srikanthi, Lemuria Kumari Kandam-
Chennai 1981

Evidence of existence

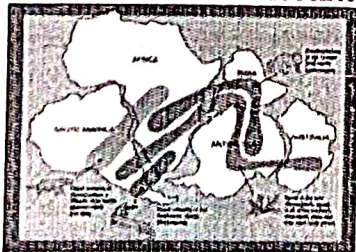
The geography of the continents bordering the Atlantic Ocean was the first evidence suggesting the existence of Pangaea. The seemingly close fit of the coastlines of North and South America with Europe and Africa was remarked on almost as soon as these coasts were charted. The first to suggest that these continents were once joined and later separated may have been Abraham Ortelius in 1596. Careful reconstructions showed that the mismatch at the 500 fathoms (3,000 feet; 910 meters) contour was less than 130 km (81 mi), and it was argued that this was much too good to be attributed to chance⁹.

Additional evidence for Pangaea is found in the geology of adjacent continents, including matching geological trends between the eastern coast of South America and the western coast of Africa. The polar ice cap of the Carboniferous Period covered the southern end of Pangaea.¹⁰ Glacial deposits, specifically till, of the same age and structure are found on many separate continents that would have been together in the continent of Pangaea.



Best fit of South America and Africa

Fossil evidence for Pangaea includes the presence of similar and identical species on continents that are now great distances apart.¹¹ For example, fossils of the therapsid *Lystrosaurus* have been found in South Africa, India and Antarctica, alongside members of the *Glossopteris* flora, whose distribution would have ranged from the polar circle to the equator if the continents had been in their present position; similarly, the freshwater reptile *Mesosaurus* has been found in only localized regions of the coasts of Brazil and West Africa.¹²



Presence of similar and identical species (fossils) on continent

Paleomagnetic study of apparent polar wandering paths also support the theory of a supercontinent. Geologists can determine the movement of continental plates by examining the

orientation of magnetic minerals in rocks; when rocks are formed, they take on the magnetic properties of the Earth and indicate in which direction the poles lie relative to the rock. Since the magnetic poles drift about the rotational pole with a period of only a few thousand years, measurements from numerous lavas spanning several thousand years are averaged to give an apparent mean polar position.¹³ Samples of sedimentary rock and intrusive igneous rock have magnetic orientations that are typically an average of the "secular variation" in the orientation of magnetic north because their remanent magnetizations are not acquired instantaneously. Magnetic differences between sample groups whose age varies by millions of years is due to a combination of true polar wander and the drifting of continents. The true polar wander component is identical for all samples, and can be removed, leaving geologists with the portion of this motion that shows continental drift and can be used to help reconstruct earlier continental positions. The continuity of mountain chains provides further evidence for Pangaea¹⁴. One example of this is the Appalachian Mountains chain, which extends from the southeastern United States to the Caledonides of Ireland, Britain, Greenland, and Scandinavia.

Pangaea supercontinent

Pangaea is only the most recent supercontinent identified in the geologic record. The forming of supercontinents and their breaking up appears to have been cyclical through Earth's history.¹⁵ There may have been several others before Pangaea.



Tectonic plates

Paleomagnetic measurements help geologists determine the latitude and orientation of ancient continental blocks, and newer techniques may help determine longitudes. Paleontology helps determine ancient climates, confirming latitude estimates from paleomagnetic measurements, and the distribution of ancient forms of life provides clues on which continental blocks were close to each other at particular geological moments¹⁶. However, reconstructions of continents prior to the breakup of Pangaea, including the ones in this section, remain partially speculative, and different reconstructions will differ in some details.

⁹ Vergilius Mario, Publis, Op.cit, P.421.

¹⁰ Sudha Sheshian & Srikanth, op.cit, P.148

¹¹ Vergilius Mario, Publis, op.cit, P.427

¹² Ibid.

¹³ Roger J.J.W; santhosh; M. op.cit,p

¹⁴ "Pangaea", online Etymology Dictionary

¹⁵ Usener. H. Scholia Lucani Bellum Civile. Vol-1

¹⁶ Rogers. J.J.W, Santhosh M.op.cit; p.147

Previous supercontinents:

The fourth-last supercontinent, called Columbia or Nuna, appears to have assembled in the period 2.0–1.8 billion years ago (Ga). Columbia/Nuna broke up and the next supercontinent, Rodinia, formed from the accretion and assembly of its fragments. Rodinia lasted from about 1.3 Ga until about 750 million years ago, but its exact configuration and geodynamic history are not nearly as well understood as those of the later supercontinents, Pannotia and Pangaea.¹⁷

According to one reconstruction, when Rodinia broke up, it split into three pieces: the supercontinent of Proto-Laurasia, the supercontinent of Proto-Gondwana, and the smaller Congo craton. Proto-Laurasia and Proto-Gondwana were separated by the Proto-Tethys Ocean¹⁸. Next Proto-Laurasia itself split apart to form the continents of Laurentia, Siberia, and Baltica. Baltica moved to the east of Laurentia, and Siberia moved northeast of Laurentia. The splitting also created two new oceans, the Iapetus Ocean and Paleasian Ocean. Most of the above masses coalesced again to form the relatively short-lived supercontinent of Pannotia. This supercontinent included large amounts of land near the poles and, near the equator, only a relatively small strip connecting the polar masses. Pannotia lasted until 540 Ma, near the beginning of the Cambrian period and then broke up, giving rise to the continents of Laurentia, Baltica, and the southern supercontinent of Gondwana¹⁹.

Formation of Euramerica (Laurussia)

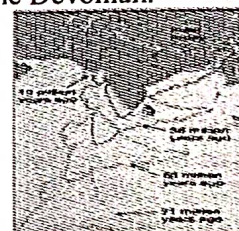
In the Cambrian period, the continent of Laurentia, which would later become North America, sat on the equator, with three bordering oceans: the Panthalassic Ocean to the north and west, the Iapetus Ocean to the south, and the Khanty Ocean to the east²⁰. In the Earliest Ordovician, around 480 Ma, the microcontinent of Avalonia – a landmass incorporating fragments of what would become eastern Newfoundland, the southern British Isles, and parts of Belgium, northern France, Nova Scotia, New England, South Iberia, and northwest Africa – broke free from Gondwana and began its journey to Laurentia. Baltica, Laurentia, and Avalonia all came together by the end of the Ordovician to form a landmass called Euramerica or Laurussia, closing the Iapetus Ocean. The collision also resulted in the formation of the northern Appalachians. Siberia sat near Euramerica, with the Khanty Ocean between the two continents²¹. While all this was happening, Gondwana drifted slowly towards the South Pole. This was the first step of the formation of Pangaea.



Laurussia

Collision of Gondwana with Euramerica

The second step in the formation of Pangaea was the collision of Gondwana with Euramerica. By the middle of the Silurian, 430 Ma, Baltica had already collided with Laurentia, forming Euramerica, an event called the Caledonian orogeny. Avalonia had not yet collided with Laurentia, but as Avalonia inched towards Laurentia, the seaway between them, a remnant of the Iapetus Ocean, was slowly shrinking. Meanwhile, southern Europe broke off from Gondwana and began to move towards Euramerica across the Rheic Ocean. It collided with southern Baltica in the Devonian.²²



Position of India at various times

By the late Silurian, Annamia and South China split from Gondwana and started to head northward, shrinking the Proto-Tethys Ocean in their path and opening the new Paleo-Tethys Ocean to their south²³. In the Devonian Period, Gondwana itself headed towards Euramerica, causing the Rheic Ocean to shrink. In the Early Carboniferous, northwest Africa had touched the southeastern coast of Euramerica, creating the southern portion of the Appalachian Mountains, the Meseta Mountains, and the Mauritanide Mountains, an event called the Variscan orogeny²⁴. South America moved northward to southern Euramerica, while the eastern portion of Gondwana (India, Antarctica, and Australia) headed toward the South Pole from the equator. North and South China were on independent continents. The Kazakhstania microcontinent had collided with Siberia.²⁵ (Siberia had been a separate continent for millions of years since the deformation of the supercontinent Pannotia in the Middle Carboniferous.)

The Variscan orogeny raised the Central Pangean Mountains, which were comparable to the modern Himalayas in scale. With Pangaea now stretching from the South Pole across the equator and

the Northern Hemisphere, an intense monsoon climate was established, except for a perpetually wet zone immediately around the central mountains.²⁶

Formation of Laurasia

Western Kazakhstan collided with Baltica in the Late Carboniferous, closing the Ural Ocean between them and the western Proto-Tethys in them (Uralian orogeny), causing the formation of not only the Ural Mountains but also the supercontinent of Pangaea.²⁷ This was the last step of the formation of Pangaea. Meanwhile, South America had collided with southern Laurentia, closing the Rheic Ocean and completing the Variscian orogeny with the formation of the southernmost part of the Appalachians and Ouachita Mountains. By this time, Gondwana was positioned near the South Pole, and glaciers were forming in Antarctica, India, Australia, southern Africa, and South America. The North China block collided with Siberia by Jurassic, completely closing the Proto-Tethys Ocean.²⁸

By the Early Permian, the Cimmerian plate split from Gondwana and headed towards Laurasia, thus closing the Paleo-Tethys Ocean, but forming a new ocean, the Tethys Ocean, in its southern end. Most of the landmasses were all in one. By the Triassic Period, Pangaea rotated a little, and the Cimmerian plate was still travelling across the shrinking Paleo-Tethys until the Middle Jurassic. By the late Triassic, the Paleo-Tethys had closed from west to east, creating the Cimmerian Orogeny.

Opening of the Atlantic:

There were three major phases in the break-up of Pangaea. The first phase began in the Early-Middle Jurassic (about 175 Ma), when Pangaea began to rift from the Tethys Ocean in the east to the Pacific Ocean in the west. The rifting that took place between North America and Africa produced multiple failed rifts. One rift resulted in a new ocean, the North Atlantic Ocean.²⁹

The Atlantic Ocean did not open uniformly; rifting began in the north-central Atlantic. The South Atlantic did not open until the Cretaceous when Laurasia started to rotate clockwise and moved northward with North America to the north, and Eurasia to the south.³⁰ The clockwise motion of Laurasia led much later to the closing of the Tethys Ocean and the widening of the "Sinus Borealis", which later became the Arctic Ocean. Meanwhile, on the other side of Africa and along the adjacent margins of east Africa, Antarctica and Madagascar, new rifts were forming that would lead to the

formation of the southwestern Indian Ocean that would open up in the Cretaceous.³¹

Break-up of Gondwana

The second major phase in the break-up of Pangaea began in the Early Cretaceous (150–140 Ma), when the landmass of Gondwana separated into multiple continents (Africa, South America, India, Antarctica, and Australia). The subduction at Tethyan Trench probably caused Africa, India and Australia to move northward, causing the opening of a "South Indian Ocean"³². In the Early Cretaceous, Atlantica, today's South America and Africa, finally separated from eastern Gondwana (Antarctica, India and Australia). Then in the Middle Cretaceous, Gondwana fragmented to open up the South Atlantic Ocean as South America started to move westward away from Africa. The South Atlantic did not develop uniformly; rather, it rifted from south to north.³³



Super Continent before the split

Also, at the same time, Madagascar and India began to separate from Antarctica and moved northward, opening up the Indian Ocean³⁴. Madagascar and India separated from each other 100–90 Ma in the Late Cretaceous. India continued to move northward toward Eurasia at 15 centimeters (6 in) a year (a plate tectonic record), closing the eastern Tethys Ocean, while Madagascar stopped and became locked to the African Plate³⁵. New Zealand, New Caledonia and the rest of Zealandia began to separate from Australia, moving eastward toward the Pacific and opening the Coral Sea and Tasman Sea.

Opening of the Norwegian Sea

The third major and final phase of the break-up of Pangaea occurred in the early Cenozoic (Paleocene to Oligocene). Laurasia split when North America/Greenland (also called Laurentia) broke free from Eurasia, opening the Norwegian Sea about 60–55 Ma. The Atlantic and Indian Oceans continued to expand, closing the Tethys Ocean³⁶.

Meanwhile, Australia split from Antarctica and moved quickly northward, just as India had done more than 40 million years before. Australia is currently on a collision course with eastern Asia. Both Australia and India are currently moving northeast at 5–6 centimeters (2–3 in) a year.

³¹ Ibid p.147

³² 'Lemuria-Kumari kandan', op.cit,p.143

³³ Ibid.p.144

³⁴ Ibid.P.145

³⁵ ..

Antarctica has been near or at the South Pole since the formation of Pangaea about 280 Ma. India started to collide with Asia beginning about 35 Ma, forming the Himalayan orogeny, and also finally closing the Tethys Seaway; this collision continues today.³⁷ The African Plate started to change directions, from west to northwest toward Europe, and South America began to move in a northward direction, separating it from Antarctica and allowing complete oceanic circulation around Antarctica for the first time. This motion, together with decreasing atmospheric carbon dioxide concentrations, caused a rapid cooling of Antarctica and allowed glaciers to form. This glaciation eventually coalesced into the kilometers-thick ice sheets seen today.³⁸ Other major events took place during the Cenozoic, including the opening of the Gulf of California, the uplift of the Alps, and the opening of the Sea of Japan. The break-up of Pangaea continues today in the Red Sea Rift and East African Rift.³⁹

Climate change after Pangaea

The breakup of Pangaea was accompanied by outgassing of large quantities of carbon dioxide from continental rifts. This produced a Mesozoic CO₂ High that contributed to the very warm climate of the Early Cretaceous. The opening of the Tethys Ocean also contributed to the warming of the climate. The very active mid-ocean ridges associated with the breakup of Pangaea raised sea levels to the highest in the geological record, flooding much of the continents. Major force changes at the Pangaea plate limits at the end of the Triassic provoked its break up, through the opening of the proto-caribbean, central Atlantic, Alpine-Tethys Oceanic Seaways. The expansion of the temperate climate zones that accompanied the breakup of Pangaea may have contributed to the diversification of the angiosperms⁴⁰. Major force changes at Pangean plate limits at the end of the Triassic provoked its break up, through the opening of the proto-caribbean, central Atlantic Alpine-Tethys Oceanic sea ways.

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³⁷ Ibid P.145

³⁸ Ibid P.146

³⁹ Rogers, J.J.W; Santhosh M.op.cit.P.147

⁴⁰ Ibid P.148