



# Indian Institute of Technology, Kanpur

## Department of Earth Sciences

ES0213A: Fundamentals of Earth Sciences

### Lecture 08. Concept of Plate Tectonics - I

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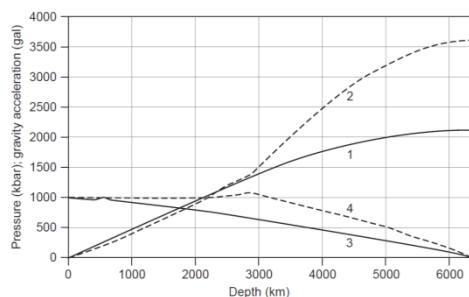
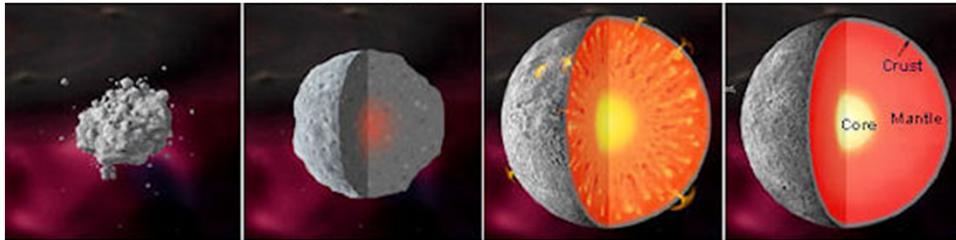
### Aims of this lecture



- Origin of the Theory – Continental Drift
- Evidences and Problems

Reference: Chapter 3, Marshak's Book

## Layered structure of the Earth



### Pressure distribution

1: young Earth;  
2: present-day Earth;

### Gravity acceleration

3: young Earth;  
4: present-day Earth.

## Layered structure of the Earth

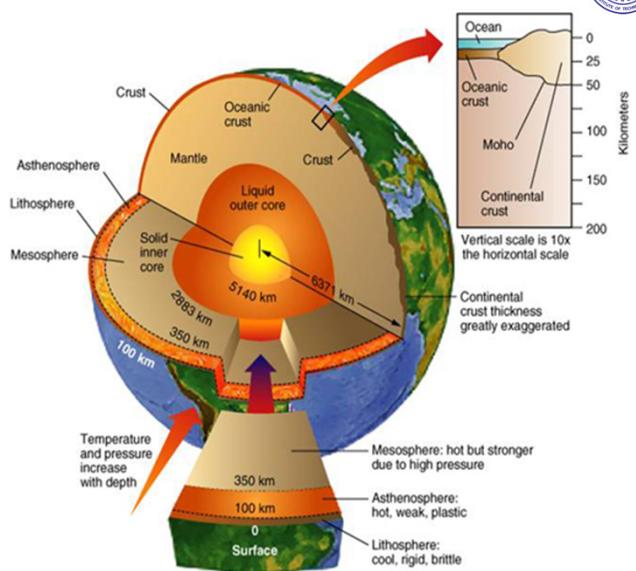


### Compositional Layers

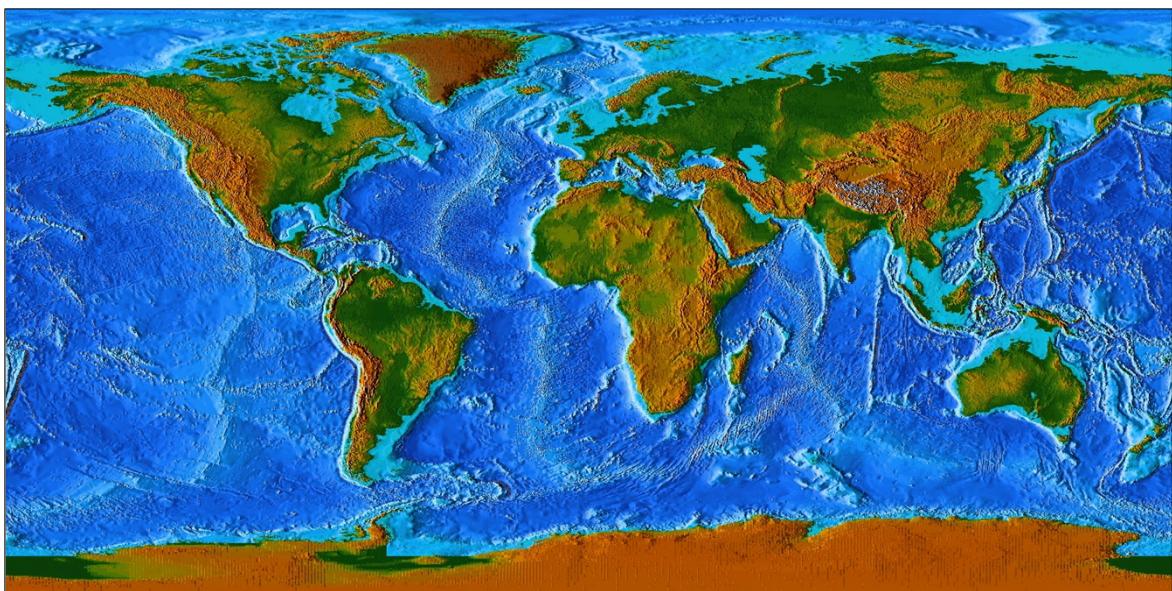
- Crust (Si, Al, Ca)
- Mantle (Mg, Fe, Si, Al, Ca)
- Core (Fe, Ni)

### Mechanical Layers (Strength & Rheology)

- Lithosphere (Brittle)
- Asthenosphere (Ductile & Viscous)
- Mesosphere (Viscous, but extremely strong)



## The surface of the Earth



## The surface of the Earth



### WHY??

- ... are the continents where they are?
- ... are the oceans where they are?
- ... are the mountain ranges where they are?
- ... do we have earthquakes and volcanoes?

## Historical developments



**Abraham Ortelius** (1527-1598), a Dutch cartographer suggested:

Americas were "torn away from Europe and Africa ... by earthquakes and floods" and went on to say: "The vestiges of the rupture reveal themselves, if someone brings forward a map of the world and considers carefully the coasts of the three continents ....

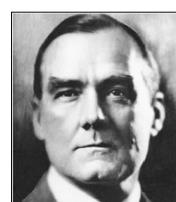
[*Thesaurus Geographicus, 1556*]



## Historical developments

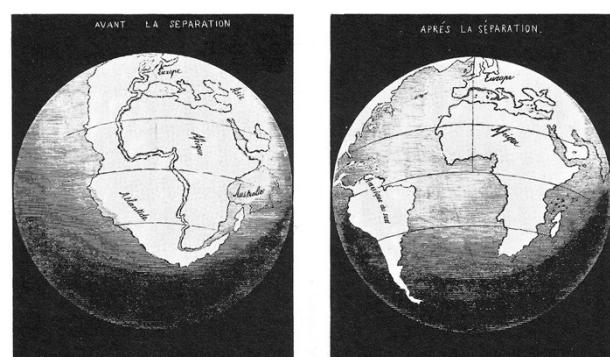


**Antonio Snider-Pellegrini** (1802–1885), a French geographer and scientist prepared two maps of the world.



In 1858, Snider-Pellegrini published his book, *La Création et ses mystères dévoilés* ("The Creation and its Mysteries Unveiled"). He proposed that all of the continents were once connected together during the Pennsylvanian Period. He based this theory on the fact that he had found plant fossils in both Europe and the United States that were identical. He found matching fossils on all of the continents.

<https://peoplepill.com/>



## Scientific developments

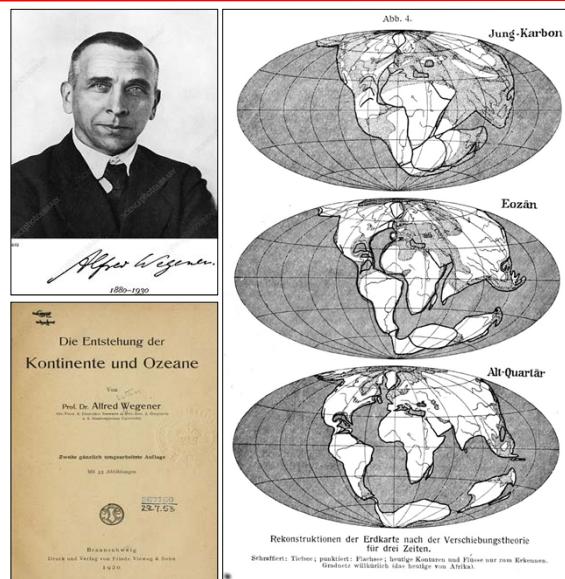
**Alfred Lothar Wegener** (1880-1930), a German polar researcher and geologist proposed “**CONTINENTAL DRIFT**” in **1910** and coined a term Urkontinent (Primal Continent / Pangaea: All-Earth).

... received heavy criticisms

In **1913** he published his book “*Die Entstehung der Kontinente und Ozeane*” with evidences to support his theory. In an series of later editions, he revised and polished his arguments (last edition, 1929).

... received heavier criticisms

Alfred died in 1930 during an expedition in Greenland.



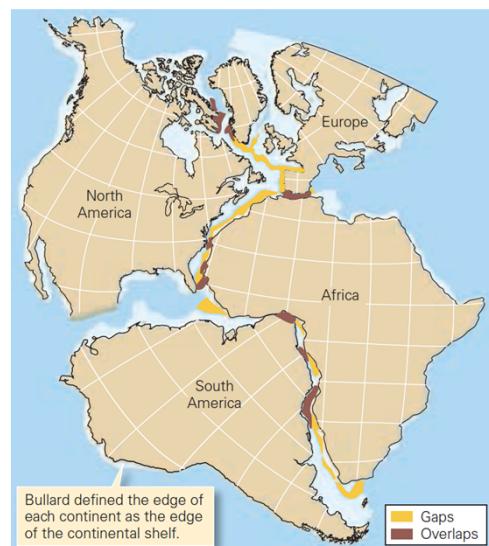
## Evidence A: Fit of the Continents

Before Wegener, geologists viewed the continents and oceans as “immobile”—fixed in position throughout geologic time.

After a convincing world map (~1500); scientists observed that:

- Northwestern coast of Africa looks like it could tuck in against the eastern coast of North America, and the bulge of eastern South America could nestle cozily into the indentation of southwestern Africa.
- Australia, Antarctica, and India could all connect to the southeast of Africa, while Greenland, Europe, and Asia could pack against the northeastern margin of North America.

**CRITICISM:** Fine, but what moved the heavy continents apart?



## Evidence B: Locations of Past Glacier Deposits

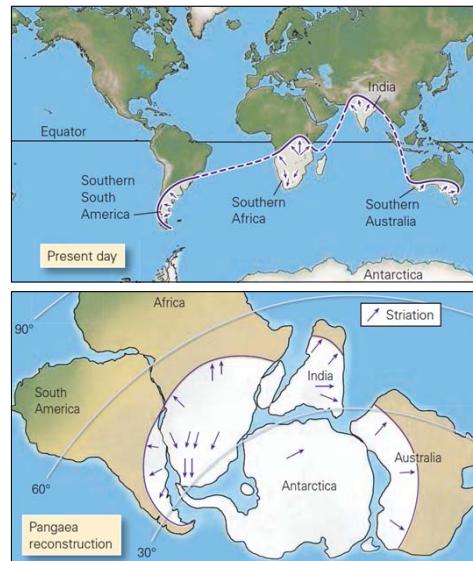


Glaciers deposit characteristic sediments and they record the palaeoflow (ancient flow) directions. When the ice melts, it leaves the characteristic sediment deposit. Thus, the occurrence such deposits at a location serve as evidence that the location was covered by a glacier in the past. Large areas of land were covered by glaciers during discrete time intervals of Earth history called *ice ages*.

Wegener noticed glacier deposits in South America, southern Africa, southern India, Antarctica, and southern Australia; also, most striations associated with these deposits seemed to point from the sea into the continents (exact reverse of the present day condition).

This is only possible if continents had been united in Pangaea, with the southern part of Pangaea lying at polar latitudes.

**CRITICISM:** Fine, but what moved the heavy continents apart?



## Evidence C: Distribution of Climatic Belts

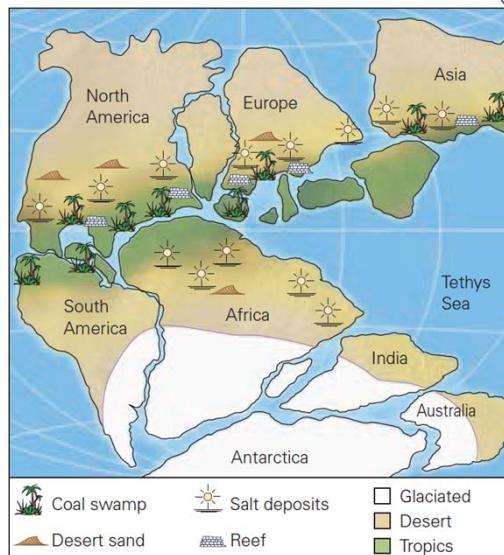


If the southern part of Pangaea had straddled the South Pole, then, southern North America, southern Europe, and northwestern Africa would have straddled the equator and would have had tropical or subtropical climates.

- In the jungles of tropical regions, thick deposits of plant materials transformed into coal and hydrocarbons (can migrate).
- In the clear, shallow seas of tropical regions, large reefs made from the shells of marine organisms develop.
- In subtropical regions, on either side of the tropical belt, where desert climates exist, salt deposits.

The distribution of late Paleozoic coal, reef, sand-dune, and salt deposits could define climate belts on Pangaea.

**CRITICISM:** Fine, but what moved the heavy continents apart?

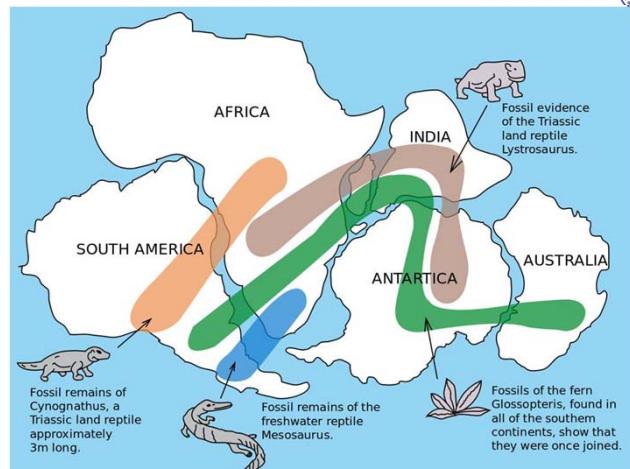


## Evidence D: Distribution of Fossils

Land dwelling animals and plants cannot swim across vast oceans and they evolve independently on different continents. During a period of Earth history when all continents were in contact, however, land animals and plants could have migrated relatively easily among many continents.

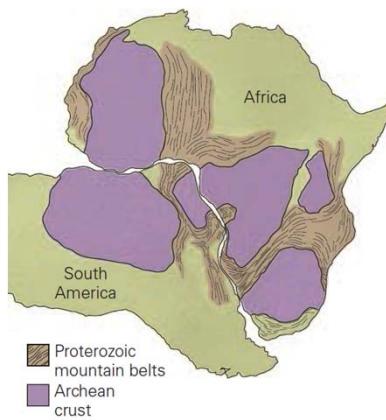
Fossil occurrences of land-dwelling species that existed during the late Paleozoic and early Mesozoic Eras (between 300 and 210 Ma) reveal that these species had indeed existed on several continents.

This requires the continents to have been adjacent to one another in the late Paleozoic and early Mesozoic Eras

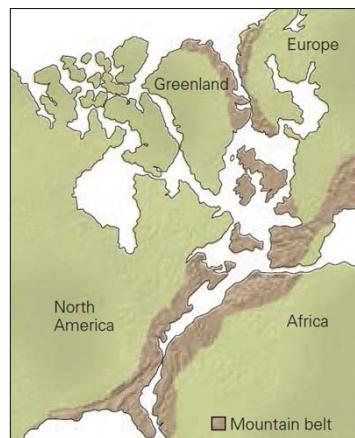


**CRITICISM:** Well, could best be explained by these being fixed land masses which over time were connected and disconnected by periodic flooding; birds can carry the seeds. Even then, what moved the heavy continents apart?

## More Evidences: Matching Geological units



The same distinctive Precambrian (before 541Ma) rock assemblages occurred on the eastern coast of South America and the western coast of Africa, regions now separated by an ocean.



The Appalachian mountain belt of the USA and Canada closely resemble those of mountain belts in southern Greenland, Great Britain, Scandinavia, and northwestern Africa regions.

## Wegener's further arguments

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Wegener had compiled a strong case for continental drift. But, he could not adequately explain how or why continents moved.

Wegener's writings gave the impression that continents somehow "plowed" through the ocean floor like the keel of a ship plows through water, but that's not possible because ocean floor rock is too strong.

Wegener also suggested that centrifugal force, due to the Earth's spin, drove continental movement, but that's not possible because the force isn't strong enough.

... it took 30 more years after Wegener's death, to prove that his theory was correct. In these 30 years, geologists learned how to determine the age of rocks, how to analyze *earth's past magnetic field (palaeomagnetism)* and how to "see" the ocean floor (bathymetry).

## Next Lecture

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Wegener was correct !!