Convincing evidence of Earth expansion

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In the present paper all possible convincing evidences have been given on the phenomenon of Earth expansion.

Key-words—Earth expansion, Terella models, uniformitarianism.

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साराँश

पृथ्वी प्रसार के विश्वासप्रद प्रमाण

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प्रस्तुत शोध-पत्र में पृथ्वी-प्रसार के सभी सम्भाव्य विश्वासप्रद प्रमाणों और माडलों की विस्तृत विवेचना की गई है।इसके अतिरिक्त विभिन्न शोध-कर्ताओं ने इस विषय में जो परिकल्पनायें अथवा प्रस्ताव प्रस्तुत किये हैं उनकी भी समीक्षा की गई है ।

I. THE STRUGGLE FOR RECOGNITION OF THE EARTH EXPANSION THEORY

Geology has advanced phenomenally in the twentieth century. New concepts of global tectonics have been developed, one after the other with the result the assumption must be challenged that the size of earth has remained constant through time. There is no proof to indicate a constant earth size; in contrast, there are many geological indicators which support earth expansion. Some of these are discussed, particularly those of the last 190 million years.

In the early part of this century Professor Alfred Wegener laid the foundation of modern geology with his continental drift theory first published in 1915. Unfortunately, in 1930, he was killed in Greenland. As is so typical, many scientists remained cynical and did not accept Wegener's hypothesis. It is reported (Frankel, 1976, p. 307) that one reviewer in the Geographical Review (1922) Wrote: " Wegener himself does not assist his reader to form an impartial judgment. Whatever his own attitude may have been originally, in his book, he is not seeking truth; he is advocating a cause, and is blind to every fact and argument that tells against it. " Despite such common resistance, Wegener's new ideas sparked advancement in global tectonics.

Hilgenberg (1933) presented his expanding terrella models which indicated that the Earth had expanded about 40 per cent during the past (Text-figure 1) Of course, his view was not accepted but he published a book dealing with the theory of growing earth. At that time, Wegener's Continental drift theory was skeptically considered. Even in 1976, it was again criticised by Frankel. How could the rigid continents drift from each other? This was considered impossible and most of all, the old dogma of Uniformitarianism

Text-figure 1— Christopher Otto Hilgenberg's expanding terrella models of 1933.

that the earth had never changed its size since its accretion made the earth expansion theory an opinion contrary to the established dogma. Hilgenberg's terrella models were considered a heresy and soon forgotten, but the idea of an expanding earth lingered on.

After World War II, scientists began considering the earth expansion theory. Egyed (1957) and Jordan (1964) published very convincing findings. But the most successful advocate and spokesman of the earth expansion theory was Professor Carey (1983, 1988) from the University of Tasmania, New Zealand. He accepted the new theory for the first time in 1955. He spent years striving to convince geologists of the validity of the theory.

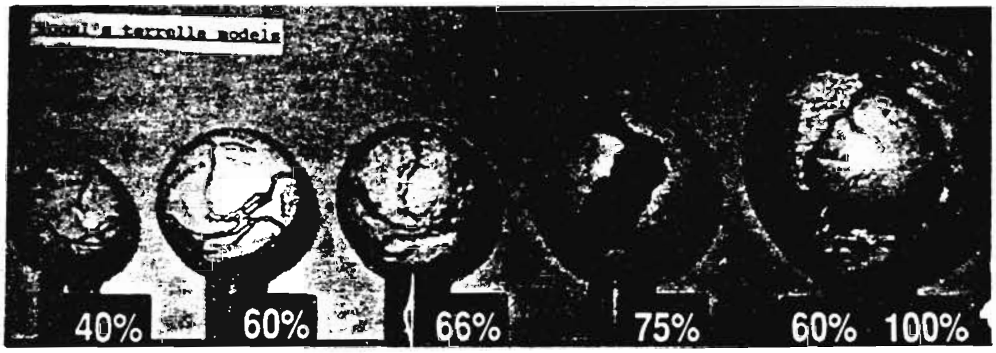
In 1977, Vogel began constructing his first epoch-making terrella model (Text-figure 2). At that time he was unaware of Carey's publications and Hilgenberg's terrella models. But he followed the discussion concerning the new plate tectonic ideas, especially the drift of India from the Gondwanalands, and also Wegener's inspiring lectures. He started experiments with global models and discovered that on models of 55 to 60 per cent of the earth's present size, the continents with shelves of about 200 m isobath nearly cover the surface of the globe. He calculated that the continents without shelves would fit on a globe approximately 40 per cent the size of the present earth. Vogel realized that this was a theoretical possibility because the continental shelves could only have formed after the brittle upper continental crust had broken into pieces.

By 1990, he had constructed a series of six terrella global models (46%, 55%, 60%, 75% and 84% of the Earth's present size) which clearly show the growth of the Pacific Ocean, the Atlantic Ocean and the break-up of the Gondwanalands.

Vogel (1989) also wrote that the theory of earth expansion begins with the assumption that the Pangaea Sea nearly covered the surface of a smaller earth until the Paleozoic. A reconstruction of the 60 per cent terrella model enclosed within transparent spheres of a glass model of earth's present size (Text-figure 3) indicates that the continental plates, in general, seem to be fixed on the lithosphere and perhaps also on the asthenosphere of the upper mantle. Since Palaeozoic, it appears that according to seafloor spreading, the continental plates have been pushed by a ± radial outward pressing of the continents from the mantle and by filling the growing gaps with new oceanic crust. This phenomena cannot be accidental. It would be a strange and odd coincidence for any theory except the expansion of Earth.

Carey (1988, p. 267) remarked that Vogel's 60 per cent terrella model inside a transparent globe of the present earth was compared with Dr Kenneth Perry's computer reconstruction of the opening of the Atlantic Ocean. Perry demonstrated by direct computation that this geometry is compatible with a radially expanding earth.

I became convinced of Vogel's terrella models when I tried an experiment with simple materials that can be repeated easily by anyone. One needs an accurate globe of the world, an air balloon, such as children play with, and some sheer fabric. On the fabric, the outline of the continents are traced along their extended shelves, as presented by the globe, and then carefully cut out. The balloon is inflated to



Text-figure 2— Vogel's Terrella Models.

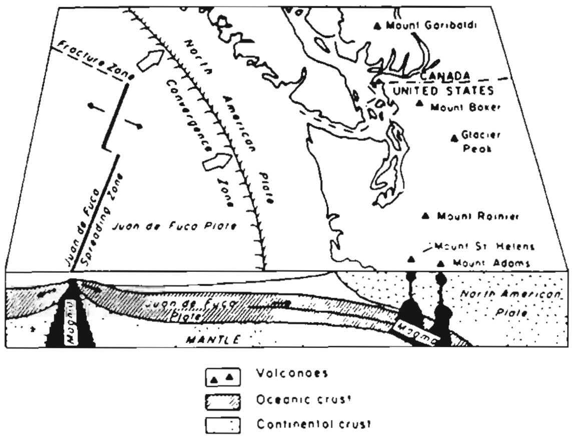
Text-figure 3— Vogel's 60% terrella models enclosed in a glass model of Earth's present size.

two-thirds the size of the globe and the "continents" are taped to it according to their arrangement on this "globe". According to Vogel's construction (Text-figure 2), this arrangement will cover the balloon, leaving narrow spaces between some of the landmasses. Thus, one has proof-in-hand of Vogel's 60 per cent terrella model.

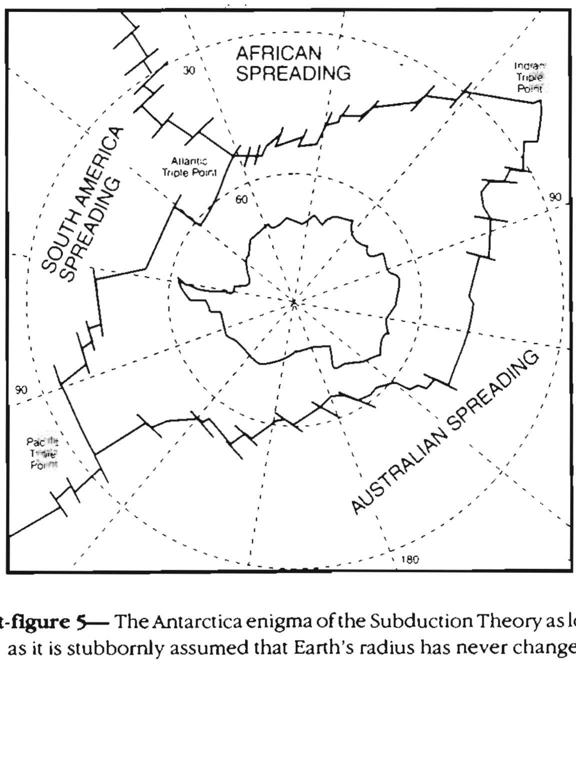
Recently, the earth expansion theory has attracted more attention. In 1981, Carey organized a well-attended symposium. Of 54 papers presented , 38 favoured earth expansion; 12 were undecided and four opposed it. The evidences cited in the opposing four papers were easily refutable.

In 1967, the National Oceanographic Data Center in Washington, announced plans to begin the task of exploring the last frontiers on earth—the oceans. In January 1969 the ship, Glomar Challenger, completed its first 18 months of deep sea drilling operations. Most of the geoscientific communities of the world thereafter accepted the concept of seafloor spreading (Text-figure 4).

It finally became established that, geologically speaking, the South Atlantic Ocean had been widening with astonishing speed since Early Cretaceous. Yet, the accepted medieval assumption that the earth's radius was constant and had not changed since the beginning of the creation of the earth is maintained by most scientists. Now an area equal to the oceanic increment had to be found. The partly subducted De Fuca Plate west and beneath the western part of the North American continent was observed and a solution was adapted, namely, that any excess lithosphere was consumed in the oceanic trenches. This new "subduction theory" was accepted in the case of the De Fuca Plate and in some other places, but not in the case of Antarctica (Text-figure 5) and Africa (Text-figure 6). In both areas the ap-



Text-figure 4—Juan de Fuca Crustal Plate.

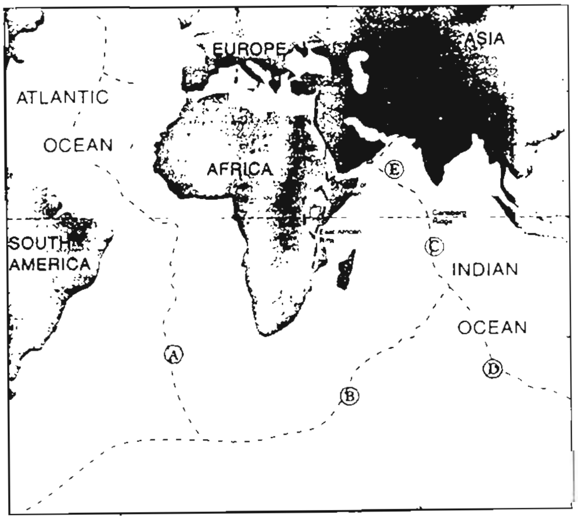


Text-figure 5— The Antarctica enigma of the Subduction Theory as long as it is stubbornly assumed that Earth's radius has never changed.

plication of the subduction theory becomes an unsolvable enigma.

The Antarctica enigma, in the case of the subduction theory, is expressed in Text-figure 5. Antarctica is surrounded by mid-oceanic ridges. From there the ocean floor is spreading on all sides toward Antarctica. Consequently, during the last 154 million years, Antarctica has been surrounded by a new ocean floor which is coming from the mid-oceanic ridges. It has doubled the size of the area and is ongoing. According to the subduction theory, the new seafloor had to be swallowed within Antarctica, but no sign of such subduction exists. If one would accept the earth expansion theory and study Vogel's 60 per cent terrella model enclosed in a glass model of earth's present size, the "Antarctica subduction myth," as Carey calls it, would be solved.

African enigma is another problem refuting the support of the subduction theory (Text-figure 6). Attacking the subduction myth with another argument which he called the African paradox (p. 382), Carey (1983) opined that like all continents, Africa is surrounded by mid-oceanic ridges and ocean floor. Like Antarctica, it is surrounded by new ocean crust which is coming from the mid-oceanic ridges. This seafloor spreading began about 150 Ma at the beginning of the Mesozoic Earth Expansion Phase and is



Text-figure 6— The Africa Enigma. Africa is surrounded by mid-oceanic ridges (**A**: Mid-Atlantic Ridge; **B**: Southwest Indian Ocean Ridge; **C**: and **D**: Mid-Indian Ocean Ridge; **E**: Carlsberg Ridge).

still ongoing. As in the case of Antarctica, the seafloor spreading inflated the African area twice the size. Without earth expansion, this ocean floor crust would have to be removed by subduction.

According to Carey (1988, p. 175) the increase of the Antarctica Complex and Atlantic increase would involve subduction somewhere east and Africa's Indian Ocean accretion would mean subduction somewhere west. The elderly plate theory demands a subduction- sink somewhere within Africa that has swallowed an area of crust greater than the area of the whole of Africa. Where is it? asks Carey. On the contrary, between the Atlantic and Indian Ocean spreading mid-oceanic ridges, there is only an expanding ocean floor around the African continent. The great rift valley system of latitudinal extension is itself a spreading ridge. Earth expansion is the only possible explanation (Carey, 1988).

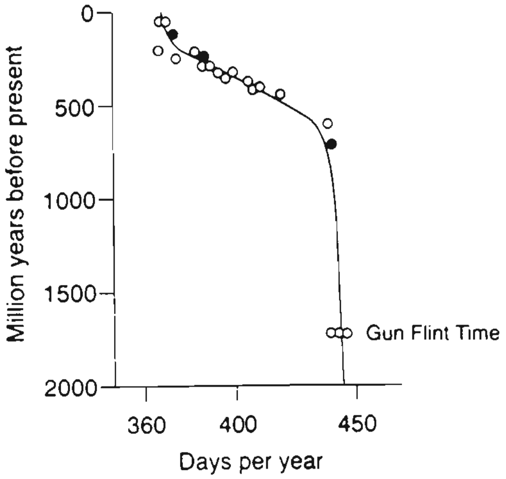
The African enigma is another support to the earth expansion theory (Koziar 1980). In his article concerning the expansion of the oceanic bottoms and its connection with the hypothesis of expanding earth, he too raised the question: where is the subduction not sinking and not being able to swallow the new seafloor crust around Africa? (Text-figure 6).

A very important proof for the Earth Expansion Theory was published by Pannella (1972, 1976), who reported the growth patterns of tidal invertebrates the— "Paleontological clocks." As the diameter of the Earth expanded, its rotational speed must have decreased proportionately, resulting in fewer days per year. A careful interpretation of the growth patterns of fossil invertebrates, the so-called "paleontological clocks", Could provide valuable clues regarding the decreasing rotational speed of the Earth's outer shell, the crust.

Pannella explained that physiological, biochemical and physical activities, which control growth processes in these organisms, follow internal and external rhythms. The circadian rhythms of organisms tend to synchronize with daily external astronomical environmental fluctuations. Consequently, daily growth increments are produced in certain calcifying tissues of many animals (Text-figure 7).

Pannella carefully investigated the growth patterns of many fossil invertebrates (molluscs, brachiopods and corals) and of stromatolites from Precambrian to Recent times, and re-examined the reports of earlier investigators. Studies of Phanerozoic material included two nautiloids from the Silurian of Nova Scotia, and his reports on the Paleozoic generally agree with those of earlier authors.

According to Pannella (1976) " Growth patterns in living intertidal and shallow-subtidal bivalve shells record tidal fluctuations of sea level. Organic lines correspond to low tides and inorganic layers are deposited at flooding tides. From this record it is possible to reconstruct tidal curves. Tidal growth patterns are distinguishable from other types. Fossil growth patterns can be used to determine the tidal curves of palaeoceans and palaeoseas. To prove this theory, Pannella proposed that tidal growth patterns in recent mollusc bivalve shells was a void of fossil remains from Upper Cretaceous to Triassic time. From Paleozoic sediments and, subsequently,



Text-figure 7— Growth patterns of the Invertebrates - the "Paleontological Clocks". The variations in the number of days per year since Gunflint time (CA 1, 800 MYA). The circles represent data obtained from growth time pattern measurements as published by Pannella 1982). The black dots indicate data reported by Lambeck (1978). As the diameter of the Earth expanded, its rotational speed must have decreased proportionately, resulting in fewer days per year. Pannella's careful interpretation of the growth patterns of fossil invertebrates and stromatolites, the so-called "paleontological clocks" seemed to indicate that the year had 390 days per year at about 200 MYA, about 400 days per year at about 400 MYA, about 420 days per year about 600 MYA and about 450 days per year in early Proterozoic, the Gunflint Formation of ca. 1,800 MYA. (Adapted from Kremp, 1981, Fig. 146) The oldest traces of life and the advancing organization of the Earth, part III).

Precambrian sediments, hundreds of stromatolites ranging in age from 570 million years to over 1800 million years were examined and graphs of tidal growth patterns through time were developed. The stromatolites were obtained from the Belt Supergroup of Montana, the Canadian Gunflint and correlative American Biwabik Formation of the Animikie Series, and the Limestones of the Bulawayan Group.

Although Pannella's interpretation of changes in the length of the year since Precambrian Gunflint time contradicted the data he had obtained in his study of Paleozoic invertebrates and convinced that the most reliable data from the stromatolites of the Gunflint series indicate a year of 450 days (Panella, 1972).

However, Pannella intended, as he puts it: " to provide evidence on the length of lunar month and year in the geologic past. The obvious conclusions are that the Moon has been associated with Earth since at least Early Precambrian times, that all theories implying a late capture of the Moon should be revised, and that the calculated secular changes in the Earth's rotation [as found by him for the Phanerozic; see Text-figure 7] can not be accepted as representative for all geological history" (Pannella, 1972).

The findings of Lambeck (1978) support that the Cenozoic, Mesozoic and Paleozoic growth patterns agree completely with Pannella's results. Lambeck (1978) also provided additional data on invertebrate growth patterns to fill the gap between Upper Cretaceous to Triassic time. Talobre (1981) remarks: "Scrutton and Lambeck have independently reviewed the bivalve, coral and stromatolite evidence for changes in the length of the day and month. There were 420 days in the year at the Cambrian, 390 days at the Carboniferous, and 375 days at the Late Jurassic. The lengthening of the day during these periods was very slow. It was respectively 8 ms, 10 ms, and 1.5 ms per year."

Lambeck's data fit remarkably well to Pannella's curve. Pannella's curve also complements the assumed increase of the Earth's diameter since Gunflint times, as was proposed by Lambeck (1978) which may perhaps be accepted as the best evidence of Earth expansion.

In a personal communication, Pannella remarks: " I never subscribed the theory of an uniform deceleration the earth's rotation which geophysicists extrapolated from historical data at a 2 ms/century; if anything, the biological data pointed toward a variable rate throughout the earth's history."

In 1980, Glakson discussed the geosynclinal evolution and geochemical affinities of Early Precambrian systems. At first he was very skeptical about the Earth Expansion Theory, but his research convinced him that the Earth has indeed expanded since the Precambrian.

Noel (1989) is also a significant contributor on the expanding Earth theory. Scalera (1988, 1989, 1990) studied Vogel's terrella models and became convinced of the validity of earth expansion theory and supported the new concepts in global tectonics since that time.

II. IS LYELL'S UNIFORMITARIAN DOGMA USEFUL FOR GEOLOGISTS?

The question may be raised: Why do so many geologists consider the Earth expansion theory a heresy?

I observed that many "modern" geologists, especially in the English-speaking countries, are still influenced by Lyell's Law of Uniformitarianism which was established in 1830 and was preceded by King Charles II. There are four Laws of Uniformitarianism established in 1662. The reason seems to be as follows :

The "heretic geologic research" began in May 1532 when Copernicus published his book *'De revolutionibus orbium coelestium'* in which he tossed out he medieval concept of the earth as a disk and the center of the universe. Instead he elevated the sun in its place.

The inquisition could not stop astronomic research. Galileo, born in Italy, developed an excellent telescope and discovered Jupiter planet in 1960. The Dutch Christian Hugens (1629-1695) improved his telescope and discovered the new planet Saturn. Then improvements in the telescopes remained continued and good telescopes were developed.

At the end of the 18th century, Hutton (1726-1797) developed his geologic theories. He did not know at that time that earth was some 4.5 billion years old, but believed that it was at least several million years old. In 1788, Hutton wrote about the concept that "the present is the key to the past." This idea assumes that geologic processes in the past operated according to the same natural laws that apply today. Indeed, his concept is a practical one for geologic research, but when one makes the assumption that the past is unchangeable and permanent as to the present, then" the present is not anymore the absolute key to the past" (Serjeant, 1990, p. 101).

At the beginning of the 19th century, theories of an "infancy catastrophism" still persisted.

Lyell (1797-1875) also had a strong opinion that Hutton's geological teaching, although very understandable, might be used against the iron laws of Uniformitarianism of 1662. Therefore, in 1830, he named Hutton's concept of 1788 the "Uniformitarianism Law." Lyell's approach had the effect of stimulating investigations into contemporary geologic processes, and it simplified investigations of Earth history by eliminating it from immediate consideration of the "infancy catastrophism" theories, and in this way, Lyell popularized the Uniformitarian idea.

In 1839, when Lyell had announced the Uniformitarianism Law, Darwin (1809-1882) boarded the Beagle to sail around the world for five years. In 1859 his famous work — *Origin of the Species* was published and in 1871 the *Descent of Man.* The conflict between Darwin's theory and the spiritual history of man caused a great popular outcry against Darwin in several countries. He was denounced as an atheist by many of his contemporaries. But after his death, he is still accepted by most educated people everywhere and is no longer regarded as hostile to religious interests.

I hope this will be the case with Professor Warren Casey and his concept of an expanding Earth; this is not an antireligious theory as the uniformitarians see it, and not at all against the Laws of Uniformitarianism of 1662. Science has advanced and it will continue to do so.

Some forty years ago, Professor Robert Potonié, my teacher, could not understand why older paleontologists almost aggressively rejected the organ-species names for the fossil pollen and spores of the Lower Tertiary which he investigated and not to use the generic names of similar plants of the present. This, he thought, was absolutely necessary for the advancement of palynology. Now, this is no longer a problem.

Finally, to draw a conclusion, the question must be asked: Is Lyell's uniformitarianism law of 1830 still useful for geology in every aspect with its dogma " the present is the key to the past?" Taylor's (1993) have recently questioned it when they reported their findings of a plush polar forest in the central Transantarctic Mountains near the Beardmore Glacier (approximately 80° to 85° south) which grew there in the Upper Permian with numerous leaves and seeds of the *Glossopteris* plants. Thus, they stated, "The present is not the key to the past." A check of Vogel's 60% and 66% terrella model would explain the geographical position of Antarctica at the Upper Permian time. It is impossible to assume that geologic conditions have not changed since the Archean age.

For many decades, beginning in 1830, Lyell's uniformitarian theory was justified. But the strict Lyellian uniformitarian dogma is maintained perhaps by too many geologists today. As boyer reports "Charles Darwin obtained a copy of Lyell's *Principles of Geology* Shortly before boarding the Beagle for the voyage which led him to his theory. Although Lyell was slow to accept the transmutation of species, he strongly urged Darwin to publish his ideas. In Darwin's *Origin of Species,* the emphasis is on slow, gradual processes operating over eons of time, which is the hallmark of Lyellian uniformitarianism. If Boyler's report is right, then my conclusion would be that the very conservative uniformitarians, clinging to ancient traditions, should think about Lyell's development. Lyell did advance. Life advanced from the oldest micro-organisms to man. Why should the advancing of "Mother Earth" be excluded? The Earth expansion theory, like Darwin's theory, is not atheistic and not hostile to religious interests. Uniformitarians, please do not stand in the way of advancing science, but think and openly discuss the published indications which seem to prove the Earth expansion theory, repeated in this paper. It is impossible to assume that any geologic conditions never changed since Archean age. The present is not the key for the past.

III. PFEUFER'S HYPOTHESIS OF THE EXPANSION OF EARTH

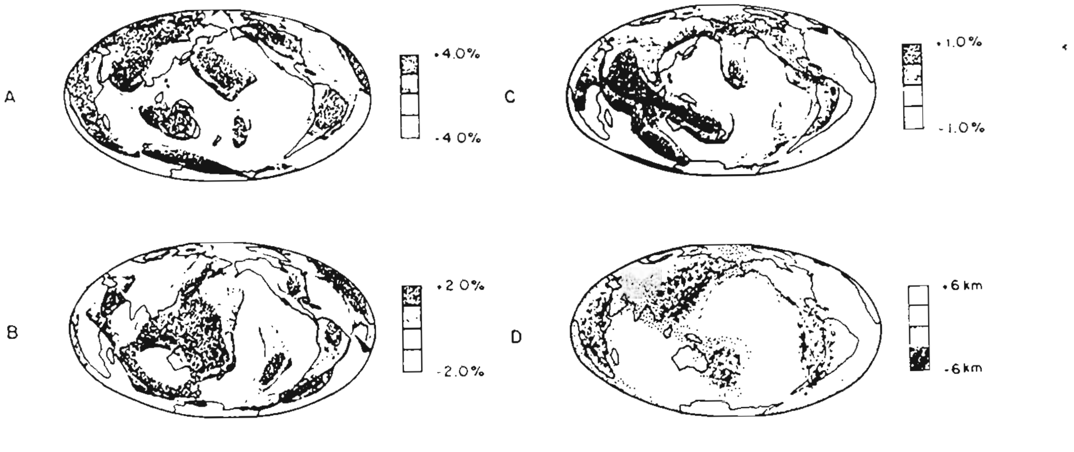
Pfeufer's article (1981, 1992), written in German, is translated and summarized here. His ideas explain the fundamental and new epoch-making reasoning for Earth expansion. According to him the Earth expansion took place in number of dimensions.

1. *The origin of our planet*—In the beginning our planet was probably a stellar body, surrounded by a huge gaseous envelope. The extremely high pressure of these tremendous gases caused the melting. The gravitational power of the Sun caused a gradual decrease of the gaseous envelope and the consequence was a slow cooling of the earth. Thus an outer shell was formed. Around 4,000 (million years ago) the earth-radius was perhaps less than 40 per cent of its present size.

The beginning pressure-release of the dwindling gaseous envelope could have caused some negligible expansion of the radius of earth during some 500 million years of the Archean time. But very little is known because of the steady attacks of the atmosphere, the water and the gigantic meteorite impacts occurring at that time on Earth.

We do not know the amount of the huge original gaseous envelope which was attracted by the gravitational power of the Sun. But one thing is fairly certain. At the end of the Archean time, around four billion years ago, cooling and condensation of the water vapours of leftover gaseous envelope began and the primordial atmosphere and a hydrosphere were slowly created. We now call it the Panthalassa Sea which obviously covered the entire globe. It is very possible that Panthalassa was not an ocean with a basaltic floor and mid-oceanic ridges surrounding the globe. The Mesophytic Tethys Sea may have been a remnant of the Panthalassa Sea.

Around 3.9 billion years ago, the major episode of meteorite impacts ended. The oldest known rocks of the Isua metaquartzite were formed in southwestern Greenland (65°N: 50°W) about 3.75 billion years ago. By that time the Cryptophytic Eon began. This was the time when protenoids could evolve to protenoid microspheres in the aqueous environment of the Panthalassa Sea.



Text-figure 8— Global image maps of Earth's interior from the bottom of the crust to the core/mantle boundary. **A**. Seismic velocity anomalies at a depth of 150 km in the asthenosphere, **B**. Velocity anomalies 670 km deep, just below the 670 km discontinuity area, **C**. Velocity anomalies 1,200 km deep and **D**. *Topography of Core/Mantle Boundary*.

Geologists knew very little about the Precambrian until the beginning of the 20th century. By 1912, it was believed that the first life on Earth developed in little ponds of the continent at the beginning of the Cambrian or shortly before. With the burgeoning technological age of the 1960s and 1970s, knowledge of the Precambrian increased rapidly. There is now good deal of information available about traces of the advancing organization of life during the Cryptophytic and Proterophytic Eons of the Precambrian.

2. *Thermic expansion and its causes*—The thermic expansion may have begun at Cryptophytic time around 3,500 to 3,800 Ma. Apparently, this was the beginning of the development of a fluid in outer core of the earth which is indicated by the oldest existence of magnetic reversals (Jeanloz, 1983; Krauss, 1986; Strobach, 1991).

There are three important reasons for the thermic expansion of the Earth.

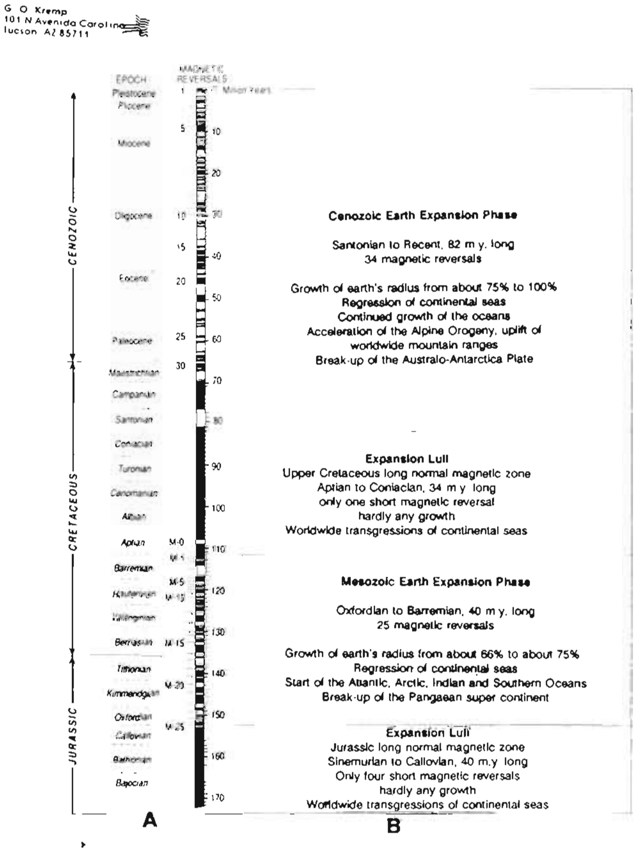
(a). According to Strobach (1985), the Fe/Ni-belt of the Outer Core contains a small percentage of sulfur, methane, hydrogen, helium and other elements (up to 10%). Through the "Freezing to the bottom process" the surface of the solid Inner Core receives permanently pure iron particles from the fluid Outer Core. The radius of the Innercore grows slowly through this process. Heat generated from this process is released and the Outer Core is slowly heated more and more. It follows that the fluid convection currents are becoming more and more intense. This heat increase produces higher temperatures not only in the Outer Core but also in the Mantle of the Earth. Consequently, an enlargement of the earth radius followed with the Earth expansion. Courtillot and Besse (1987, fig. 5, p. 1155) call the fringe surrounding the Inner Core—the Mush Zone.

(b). Dziewonski and Woodhouse (1987) were the first to visibly construct the outer core through seismic measurement (see Text- figure 8). Their global image map of the core/mantle boundary shows a difference of 12 km between the depressions and the elevations.

This topography means an additional source of heat, established by the conversion of gravitational energy to thermal energy (Parker, 1983), because the quicker movement of the Earth's mantle over the surface of the Outer Core is producing *friction heat*. According to Vogel's (1960) investigations, it seems possible that these elevations began to develop on the outside of the Outer Core in Paleozoic time. According to Lay (1989) and Courtillot and Besse (1987) the friction heat produced an astonishing difference of 800°K between the core/mantle boundary and the lower most parts of the mantle. This difference of 800°K is certainly an indication that the Outer Core did heat up remarkably, perhaps since Mesozoic time.

(c) For a long time it was thought that radioactive decay processes in the Outer Core of the earth played a minor role in the additional production of heat. But in 1985, Vink, Morgan and Vogt (in Pfeufer, 1992) found that hotspot/plumes coming from the D" boundary layer contain unusual amounts of gaseous elements and elements with a greater ionic radius (e.g., calcium), but also unusually great amounts of isotopes of radioactive decay processes. This would mean an additional source of heat (see Text-figure 2 Core/Mantle structure).

The progressive increase of heat energy led to three effects: (i) it produced more intensive convection currents in the Outer Core fluid and in the mantle on the Earth; (ii) it helped the transformation of the high pressure mineral facies to lower pressure stages and by this to higher expansion rates; (iii) it led to the birth of hotspot/plumes because of the excessive heat.



Text-figure 9— **A**, Magnetostratigraphic geologic time scale of the last 170 million years, and **B**, an interpretationof the last two Earth expansion cycles.

3. *Continental driftings and their causes*— Pfeufer summarizes his discussion on this question as follows. Temporary tiltings of the rotation axis of the earth can be caused by : (a) impacts of huge asteroids, (b) gigantic eruptions of volcanoes, (c) enormous shiftings of the material in the fluid Outer Core by convection currents or (d) according to Wells (1966) formation of continental ice domes.

4. *The diminishing of rotation speed of the earth by an increase in its volume*— For this fact, Pfeufer cites the investigations of Lambeck (1978) and Pannella (1976). As discussed in the preceding pages of this paper the so-called "paleontological clocks" seem to indicate that the year had about 375 days in Late Cretaceous time, about 396 days in the Middle Devonian, about 424 days in the Cambrian and perhaps 450 days at Gunflint time (about 1800 Ma).

IVA. GEOMAGNETIC POLARITY TIME SCALES : A POSTULATION OF EARTH EXPANSION EVIDENCE

For the last several decades, new concepts of global tectonics have been developing. Assumptions that Earth has never changed its size since inception has lost its credibility. Vogel's epoch-making terrella models indicate that the Earth has grown one third in size since the Paleozoic. This can be proven by geological evidence and the test of Heezen's geomagnetic polarity time scale (Text-figure-9).

This geologic time scale was completed in 1978, and finally published by UNESCO in Paris in 1984. Ms. Tharp (personal communication) remembers that Heezen, very early in his career, recognized and suggested that our earth was expanding (Heezen, 1959). This concept was based on studies of the ocean floor from bottom soundings, rock dredgings, seismic refraction, and earthquakes. In one of his publication, (Heezen (1960) suggested that a phase change at the core/mantle boundary may have caused the expansion. He agreed with the suggestions of other investigators that changes in the density of matter associated with phase changes in the material in the interior could have made the earth without any decrease in the gravitational constant. However, Heezen's hypothesis was shot down from several points. Actually the acceptance of continental drift led to plate tectonics and the concept of an expanding earth no longer seemed necessary. Now, however, 30 years later, it appears that the plate tectonic theory needs some adjustment.

Other important information for the final map of the Indian Ocean was obtained in Heezen and Tharp's (1964) physiographic diagram of the Indian Ocean.

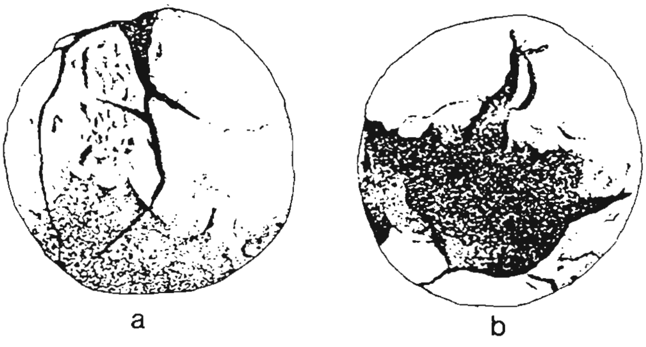
Text-figure 9 (side A) shows a magnetostratigraphic geologic time scale of the last 170 million years while (side B) shows the interpretation of the last two earth expansion cycles. The scale on side A is the Magnetic Polarity Scale. The black sections indicate that this was a time period of "normal magnetism" on which a magnetic needle would have pointed toward the North Pole of the Earth. All white sections indicate that the magnetism was reversed and a magnetic needle would have pointed to the South Pole. The long uninterrupted black section of the Middle Cretaceous time indicates that a long normal magnetic zone occurred during Cretaceous time. According to Heezen *et al.* (1978), it began in the Aptian about 113 million years ago and ended at the end of the Coniacian. This long normal magnetic zone (like all others shown in black) comes from normal magnetized dikes of midoceanic ridges; those in white are from reversely magnetized dikes.

At this point I should note that my assumption, made in my first report (Kremp, 1991, fig. 15, p. 249) about the last two cycles of earth expansion, concerning the growth of the earth's radius, is not absolutely correct. I assumed at that time that the earth dilated from 60 to 66 per cent in the Triassic, from 66 to 75 per cent perhaps in the Upper Mesozic and from 75 to 100 per cent of its present size perhaps in the Cenozoic Expansion phase. In Coniacian time was the earth dilated to 73 per cent or was it already 78 per cent? No one has tested this problem until now and no one has prepared a geologic map which will give the answer.

Heezen *et al.* (1978) developed their geologic time scale after investigations of deep sea drillings in which magnetic anomaly lineations were found in the Indian Ocean. According to them, the span of the Reversed Magnetic Polarity No. 29 (the geologic time of the cataclysmic eruptions at the Cretaceous/Tertiary border time was between 65.5-65.0 Ma. Since then four more geomagnetic polarity time scales have been published in which the span of polarity R 29 somewhat varies; according to Larson and Pitman (1972), it was around 65 Ma; according to Harland *et al.* (1982) the span of polarity R29 lies between 65.4-64.8 Ma; according to Berggren *et al.* (1985) between 66.8-66.1 Ma, and according to Haq *et al.* (1987) between 65-63.8 Ma. These geologic time scales were developed independent of each other and differ only in very minor details. But it is strange that these important geologic time scales did not impress the geologists who still insist that the earth has never expanded.

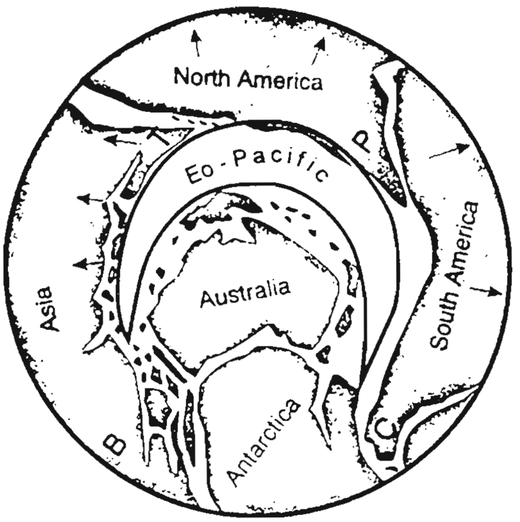
Wyllie (1976) estimated sequences of polarity reversals occurring over the past 500 million years, which are thought quite significant.

Larson and Pitman (1972) also published their magnetostratigraphic geologic time scale which covered from the Pliocene to the Upper Jurassic time and it is quite possible that Wyllie may have been influenced by their work. Wyllie's measurements for this time period are in complete agreement with all known geologic time scales; therefore, his work on the older geologic sections should be just as accurate. Furthermore, Wyllie's Triassic "Mixed Polarity Interval" and his Upper Ordovician "Mixed Polarity Interval" are in complete agreement with the Russian edition of *Paleomagnitologiya* of 1982 which had been translated later in 1987 by the Germans. Wyllie's estimates of the Ordovician to Triassic sequences of polarity reversals are discussed in Section IVB.



Text-figure 10— Two views of the fracture pattern of a plaster covered inflated ball bladder; (a), in a wider gap and (b), redrawn from L. Egyed and Lissee, 1969.

"Jaw" means the bones of the mouth in which the teeth are fixed. Jawbone is the bone of the jaw in which the teeth are fixed.



Text-figure 11— Origin of the Eo-Pacific.

A. Paleozoic Time Scales

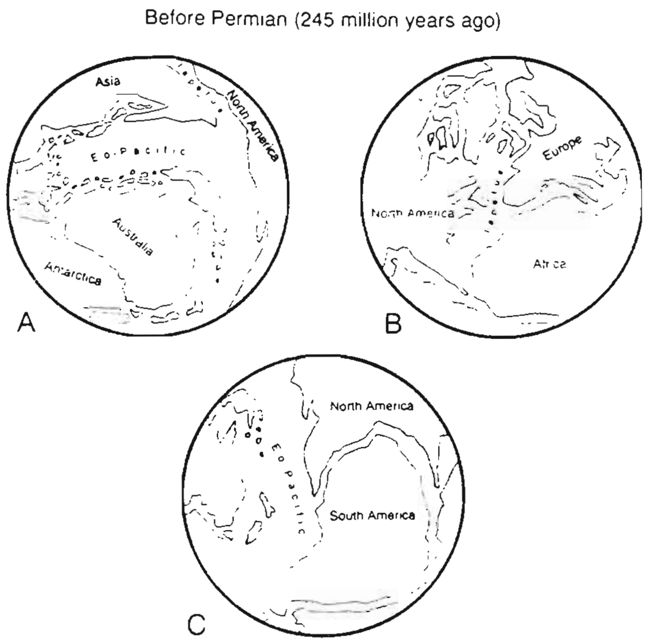
IV. A-1 Upper Cambrian to ordovician expansion phase (from about 510 to 438 Ma)

During Ordovician time, the size of the Earth was perhaps between 55 and 60 per cent of its present size, as evidenced by Vogel's terrella models. According to Pfeufer (1981, 1992) during the *thermic expansion* of the Earth which began about 3,500 to 3,800 Ma, the surface of the ± solid Inner Core received pure iron particles on its "Mush Zone" from the fluid Outer Core. Consequently, the Inner Core expanded slowly. Heat, generated from this process, was released to the Outer Core and to the mantle, and the Earth expanded slowly.

Unfortunately, not much is known of the Ordovician geologic epoch in North America. However, Stanley (1989, p. 343) states: Late in the Ordovician Period, the Iapetus Ocean narrowed as Laurentia and Baltica moved closer together. Could it important to note here that the Iapetus Ocean was connected to the Eo-Pacific Ocean, which originated about 1,000 Ma. Both existed from Precambrian time (Text-figure 12, indicating that the Iapetus Ocean was an extension of the Eo-Pacific). It is commonly believed that the Pacific Ocean is about 200 Ma old. This is an apparent error. According to Glikson (1980), a peak of thermal activity occurred around 1,000 Ma at the beginning of the Greenville Regime and the crust of the Earth cracked. Plate tectonic movements began and touched off a complex pattern of continental fragmentation and drifting.

In 1981, Carey postulated that the present Pacific Ocean is the late widening of the original Cordilleran Rift, which opened about 1000 million years ago, became an equatorial geo-syncline between the Americas and the Asia Australia-Antarctica complex and slowly widened to its present extent. At this point, it may be helpful to offer an illustration of the results of a simple experiment conducted by Egyed and Iissee in 1969 (Text-figure 10) which may clarify what apparently occurred about 1100 million years ago, or some 100 million years before the geotectonic stresses of the Greenville Regime reached their maximum.

Two views of Egyed's and Iissee's experiment with the fracture pattern of a plaster-covered inflated ball bladder (Text-figure 10) may help to visualize the pattern of the Earth's crust about 1100 million years ago, when numerous fractures developed (ensialic



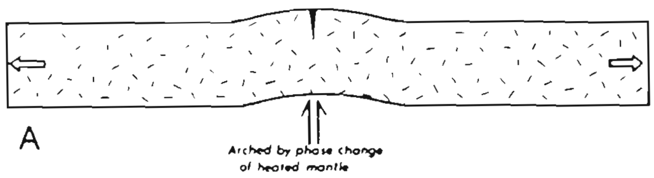
Text-figure 12— The presence of the Eo-Pacific Ocean and the Iapetus Ocean at Early Paleozoic time (demonstrated on three figures of K. Vogel's 60% of present size terrella models).

rifts and "Wilson-cycle" sutures and a wider gap of the Eo-Pacific Ocean).

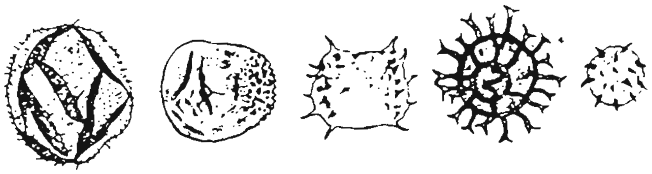
According to Vogel's terrella models (1990) this was the beginning of the opening of the Pacific developed from an older Eo-Pacific (Text-figure 11) which was bent sickle-shaped around Australia Vogel's (1990, p. 28) describes as the oldest areas of the Pacific are situated in the northeastern part. The concentration of numerous seamounts and guyots in this region may be a result of the evolution in this part of the Pacific. Because of its huge dimensions, it has not been sufficiently explored until today" (see Text-figure 12 which shows that the Iapetus Ocean is an extension of the Eo-Pacific).

Wyllie's time scales indicate that the Earth did not expand without interruption, but in little steps, and Vogel is very careful to state when the Earth had grown to 60 per cent of its present size. Was it already in Ordovician time or in the Devonian? Unfortunately, we are still missing paleogeographic maps of various stages. Nevertheless, the Iapetus Ocean already existed in Ordovician time and probably even earlier.

In the Ordovician (perhaps in the Cambrian) relatively active expansion phases seem to have occurred. This is indicated through the abundance of orogenesis on all continents. According to Troger's (1984) "Abriss der Historischen Geologie" details are reported in the following orogenesis. In *North America* existed already The Cordilleran Orogeny, the Appalachians orogenic belt and the Ouachita-Orogeny in the southeastern end of the Appalachians; in *South America*, the Andes orogeny; in *Africa* one in the north east part of the continent; in *Europe* one in Middle Europa and another in the Mediterranean; in *Asia* one extended in the western part of Russia, another in north-west Siberia, and one in south-west Asia; and in *Australia*, one on the



Text-figure 13— Phase A of Carey's "Simple model of an orogen (adopted from Carey, 1989).



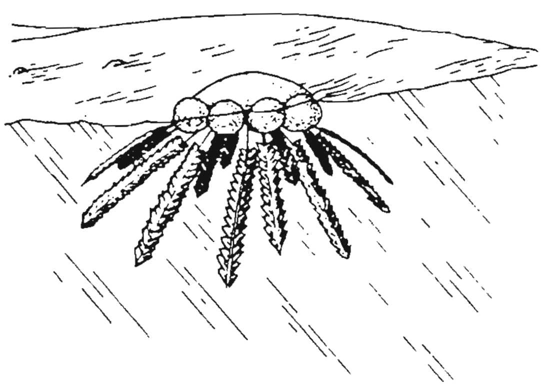
Text-figure 14— Various types of Acritarchs from the Baltic area of the USSR of Cambrian in age.

western coast trees, thus a total of at least eleven orogenes are known.

Carey (1988, p. 246) reports that the first thrust of the Appalachian-Orogeny occurred in the Middle Ordovician (Text-figure 13). Perhaps another followed at the Ordovician/Silurian transition time, one in the Late Devonian and perhaps the last one in Late Carboniferous time.

The hills and mountains that now are called the Appalachians were formed by subsequent rejuvenation of the region—a process consisting of uplifts in the Paleozoic and followed later by slow erosion of resistant bodies of the rock and more rapid erosion of weak ones. Because the original Appalachian formed so long ago, only a few details are known about the geologic framework in which this orogeny developed.

In contrast to the Appalachian system, the Caledonian orogeny of Wales (England) is known in greater detail. Based on fossil graptolites, 15 zones of fossils have been indexed in the Atlantic province of England. It should be noted that also in the Pacific province of North America 10 sections were worked



Text-figure 15— A graptolite community: *Diplograptus* attached to a float in a mid-Ordovician seascape.

out and can be compared with that of the Province of Wales in England. The Iapetus suture, south of Scotland, had already occurred in the Cambrian.

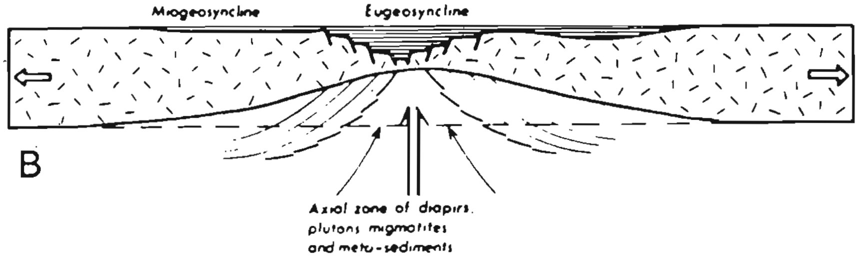
Stanley (1989, p. 343) based on geological evidences reported that in Late Ordovician time the sea-level stood unusually high throughout the world. This may have been caused by the events of the growing Eo-Pacific as well as by the remaining remnants of the Panthalassa Sea. The life of the Ordovician consisted of simple bacteria and algae (Text-figure 14) and a fauna of graptolites (Text-figure 15). Consequently, the algae and the graptolites lived in the waters at an advantageous time. However, the Earth expanded and the sea levels dropped slowly; then the orogenic belts started to develop (Text-figure 13). A serious extinction was in the air.

According to Berry (1979) the graptolite biogeographic regions and provinces were well-developed in the early part of the Ordovician. The Atlantic region included most of Europe, North Africa, and northern Argentina, Bolivia, and Peru in South America. Pacific Region faunas are known from North America, western Argentina, Australia and Asia. Temperature appears to have been the primary control of regions. The Pacific Region was tropical and subtropical and the Atlantic Region was situated in relatively cooler waters... Some regions began to break down in about mid-Ordovician time. Increased current circulation and narrowing of the warm water areas of the seas apparently occurred at about the same time. Most graptolite texa became extinct in the last phase of Ordovician, as a consequence of widespread lowered sea levels and climatic cooling during glaciation. Early Silurian faunas were rich, but extinctions took place at several intervals, commencing early in the Wenlock/Middle Silurian. By Devonian time all graptolites became extinct.

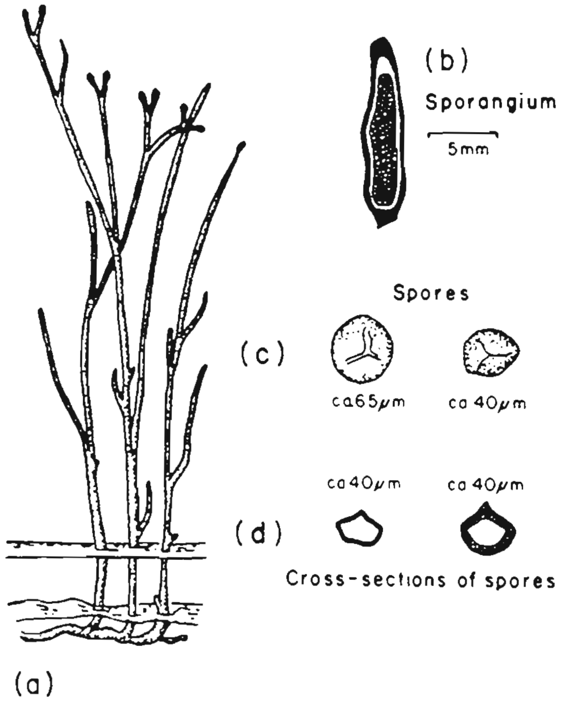
Late in the Ordovician Period, after an interval during which the sea stood unusually high throughout the world, global sea levels dropped. At the same time, *a mass extinction* eliminated many groups of marine life (Stanley, 1989). According to the Earth expansion theory, this is easily understood. When in Ordovician time, at least eleven orogenesis occurred. This means a considerable expansion phase according to phase A of Carey's "Simple model of an orogen" (Text-figure 13). At about the Ordovician/Silurian transition time an additional diapir occurred. This means that an intrusive rock body pierced upward through the overlying rock (Text-figure 16). At this stage many of the trilobites and acritarchs lost their environment and a considerable mass extinction occurred of the same magnitude as experienced by the dinosaurs at Cretaceous/Cenozoic transition time. Colbath (1986) worked extensively on the terminal Ordovician extinction in phytoplankton associations of the southern Appalachians and reported (p. 943) evidences from other regions which suggest that the extinction was widespread and may have been worldwide."

IV. B-2 The Silurian Expansion Lull (from about 438 to 408 Ma)

Carey (1988, p. 236-239) in his orogen model reports that the beginning of the primary stretching of the continental crust first led to a thinning and then to the formation of the *Miogeosyncline.* Although the surface of the continental crust steadily sinking, the mantle diapir below rises steadily. At this stage, during the expansion lull when the continental crust



Text-figure 16— Cycle B of Carey's developments of the simple model of an orogen.



Text-figure 17— *Rhynia*, a psilophyte and member of the Rhyniophyta group; **(a)** reconstruction of *Rhynia gwynee-vaughani* from the Devonian of Rhynie, Scotland, **(b)** longitudinal section of sporangium, **(c)** spores found in sporangium of *Rhynia*, **(d)** cross section of other spores.

became thinner, the central zone developed an *Eugeosyncline.*

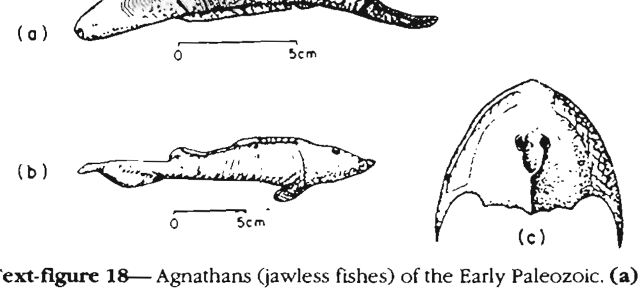
According to (1988, p. 376) a geosyncline is a long narrow depression in the earth's crust, which continues to sink for millions of years while it fills with sediments to a thickness of several kilometers. The more active belt it contains, the more the Eugeosyncline suffers volcanism, seismicity, faulting, generation of granites, deformation and an uplifting, i.e., *progenesis.* In contrast, à parallel belt, i.e., the miogeosyncline has a steady subsistence of several kilometers without the volcanism, the seismicity or orogenesis. Carey's orogen model of 1988, Cycle B, fits well with that of Troger's (1984) paleogeography of the Silurian.

The Silurian Epoch continued for about 30 million years, the shortest of the Paleozoic. There were many orogenic developments in this epoch during which the oceans formed. The also characterizes the Silurian expansion lull. It is clear from Troger's report (p. 162, fig. 46) that in Ordovician time in North America, the Cordilleran orogen, the Ouachita orogen, and the Appalachian orogenic belt hàd already begun to form. All consisted of ocean development. The Andes orogen developed at the west coast of South America, on the north side of Antarctica and on the southeast side of Australia other orogens began to form a connection to the ocean. But most significant is that in the Silurian time great areas of North America were covered with continental seas; so too in South America (the Amazon Basin), Siberia the Tunguska-Epicontinental sea and also large areas in northwest Africa. All these "Miogeosynclines" were perhaps remnants of the Panthalassa Sea.

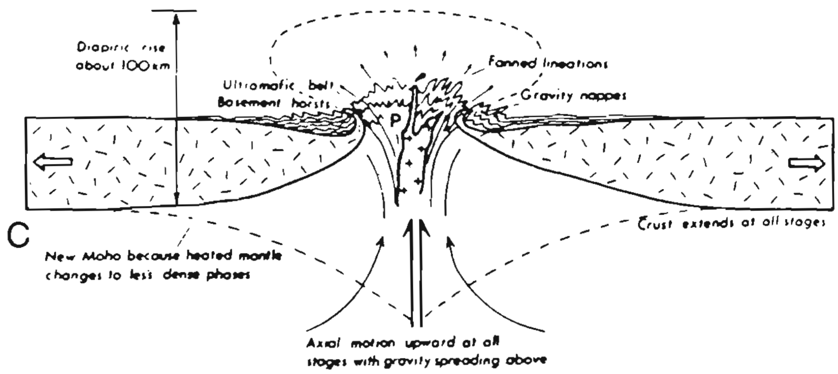
Of this period, not much paleogeographic information is known. However, Stanley (1989, p. 382) writes, " Many important Middle Paleozoic groups of marine life, depleted during the great mass extinction at the end of the Ordovician Period, re-expanded at the start of the Silurian Period. " Again, this was a similar event of the Paleocene when the extinction was over and new vegetation evolved.

At the beginning of this century, scientists believed that land plant life had advanced from Precambrian sea-water ponds. Later, it became obvious that all algae-like plants lived and drifted in the sea-water. The question arose: when did the land-plants conquer the barren environments of dry lands?

Palynologists had found the first trilete spores in Silurian sediments. Consequently, for a long time, it was accepted that land plants had invaded the barren lands in Silurian time, when they had developed a rigid vascular system of stalks or stems, roots, and real



Text-figure 18— Agnathans (jawless fishes) of the Early Paleozoic. **(a)** restoration of *Jamoytius*, Middle Silurian, England; **(b)** restoration of *Cephalaspis (Hemicyclapsis*, Silurian; about 21 cm in length, and **(c)** skull of *Cephalaspis*.



Text-figure 19— Cycle C of Carey's development of the simple model of an orogen. Phase C lasted from the beginning of the Devonian until the Pennsylvanian time.

leaves to make their lives and that of their descendants successful.

In 1962, Potonié discovered the *Rhynia* a psilophyte, developed simple trilete spores in their sporangia (Text-figure 17). The conclusion was that the parent land-plants might not have developed in Silurian time, but in Middle Devonian when zonate and monolete spores were also found. It may be that fungi and lichens were the "first land plants" which conquered the continental dry lands because they did not have to float permanently in the water.

Fungal hyphae have been found associated with the roots of many land plants before the Devonian. They likely existed in a symbiotic relationship with these plants. Lichens may have been the descendants of green algae which had originally shared a symbiotic state with Ascomycetes or other fungi; therefore, lichens may be regarded as the real ancestors of the higher land plants.

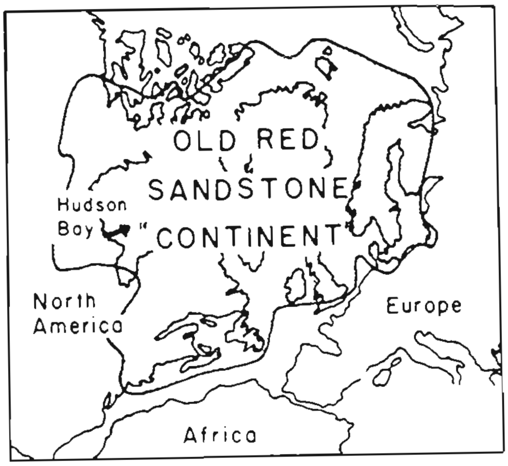
And what of the animals that existed in the Silurian? Troger (1984) reports that many different animals lived in the warm extended seas. Arthropods, brachiopods, bryozoans, chitinozoans, coelenterates, conodonts, echinodermates, graptolites, molluscs, ostracods, stromatoporids, trilobites and vertebrates (Agnathans - jawless fishes).

The oldest known vertebrates in the fossil record are represented by dermal fragments of a Jawless "fish" found in the Late Cambrian sediments of Wyoming, U.S.A. (Repetski, 1978), which has been temporarily classified as the infraphylum Agnatha.

Similar type of ancient vertebrate, known as Anatolepis has also been found in Ordovician rocks of Australia, North America, Greenland and Spitsbergen.

The earliest unequivocal vertebrate remains are those of the Agnathans (Text-figure 18), jawless fishes of the Early Paleozoic. Many of the Agnathans have been referred to as the Ostracoderms, a subgroup of the Agnathans which appears to have inhabited shallow marine environments rather than to have been washed in from freshwater streams and estuaries after death (Dineley & Loeffler, 1979).

Fragmentation and dispersal of the Early Paleozoic continents provided conditions favouring an increase in faunal diversity. Unfortunately, this



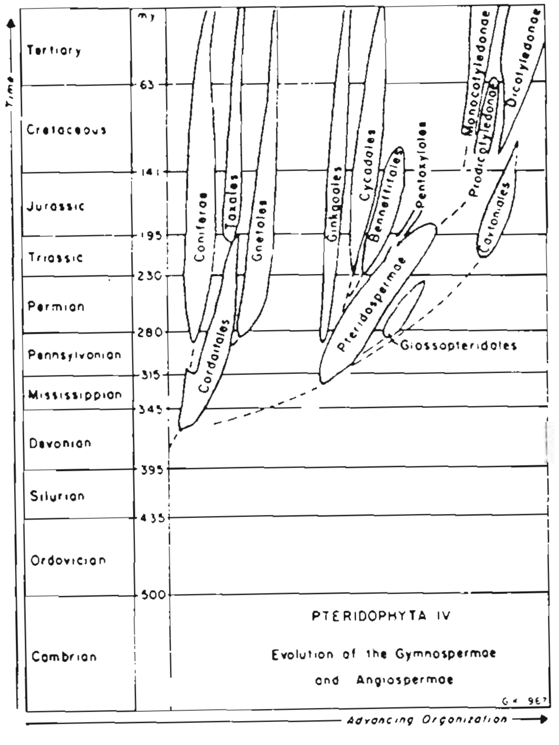
Text-figure 20— Paleogeography of the Old Red Sandstone "Continent." (from Goldring & Langanstrassen, 1979).

crucial period in the development of the vertebrates is poorly documented by fossils. Whatever the reason may have been for their scarcity, vertebrates had evolved a notable diversity of forms by Ordovician times.

By the beginning of the Silurian, four major groups of Ostracoderms were present. While by the Late Silurian, they had begun to exploit the available range of aqueous environments. Their remains are found in shallow marine, brackish, and even fresh water sediments. In this era, they were joined, in marginal marine environments at least.

IV. B-3 The Devonian Expansion Phase (about 408-360 Ma)

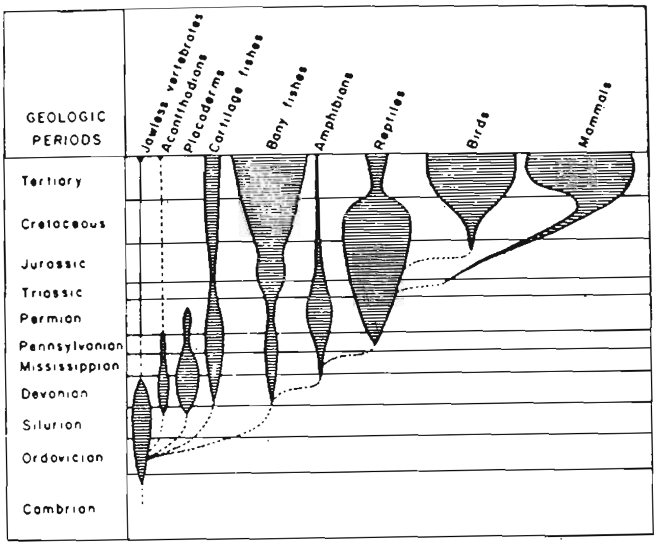
Phase of Carey's (1988) model is a simple model of an orogen. It is also known as "Folding and Thrusting." After the stretching of the curst has thinned it to zero, the continuing and accelerating ascent of the deep *Diapir* begins to drive out the sediments, which then spreads laterally at the surface. Consider the



Text-figure 21— Possible advancing of the life of the seed plants (Gymnospermae and Angiospermae).

point marked P in Text-figure 19 in the middle of the rising orogen at the level of the former land surface. It is being driven upward by the rising diapir below but pressing down on its weight of the pile above. The two vertical forces squeeze it to spread sideways. The rate of spreading depends on the size of the overburden load and the *viscosity* (stickiness) of the materials. If this rate is less than the rate of the rising diapir, the orogen must rise higher, increasing the overburden load at C (at the general surface level away from the orogen). The height of the orogenic zone continues to rise in this way until the sideways flow matches the rate at which the diapir is pushing from below. The surface of the orogenic zone then ceases to rise, but the orogen continues to spread laterally and will continue to spread as long as the diapir is rising, piling *nappe* [a sheet] on nappe.

Carey assumed (1988, p.246) that in the Middle Ordovician, an active tumor rose in North Carolina, and its rapid erosion spread a fan of marine clastic sediments 2400 m thick over Kentucky, while less than 1000 m accumulated elsewhere along the Appalachian front. In the Late Ordovician (or at the Ordovician/Silurian transition time), an active tumor regurgitated in Maine and spread a thick fan of sediment across Vermont and far into Quebec. In the Late Devonian, a clastic fan up to 2700 m thick spread



Text-figure 22— Simplified family tree of the vertebrates, showing their range and relative abundance through time and their advancing organization.

across West Virginia, Pennsylvania and Upper New York State while only 600 m was deposited in Tennessee and about 30 m in Alabama. In the Late carboniferous a regurgitation tumor rose in Georgia to spread a fan of sediments up to 3000 m thick across George and Alabama. These events are logical in Carey's diapiric model.

The Old Red Sandstone "Continent" included the British Isles in mid-Devonian time (Text-figure 20). The Iapetus suture which divided Scotland from Wales during Early Devonian time (see Section IV-B-1) had ceased to exist because of Earth expansion. Text-figure 12 shows that the Iapetus existed as a ± narrow furrow between North America and Europe (and Africa). The sediments of the rising Caledonide orogenesis of England and Scandinavia were deposited in the neighboring Iapetus as a thick sequence of red shales, sandstones, conglomerates and also lava streams. At that time, the Iapetus between North America and Europe was still not an "Atlantic Ocean" —Text-figure 12. This did not occur before the Triassic. Evidence of this old "continent" crops out in a great belt extending from central and southern Ireland to the Bristol Channel area, Wales and Welsh borders. It is mostly concealed by younger rocks in central and southeastern England.

The development of Middle and Upper Devonian miospore zonation in eastern Europe makes it possible to understand that the Cordaitales land plants had already developed in Devonian time.

The Devonian Period was crucial in vertebrate evolution. While most of the ostracoderms are well known from strata below the Upper Silurian, no placoderms and only a few acanthodians are known with certainty before the Devonian (Text-figure 21).

The higher fishes (Superclass Pisces of the Gnathostoma) are aften divided into two large groups: (1) the sharks and their relatives (Chondrichthyes), and (ii) the bony fishes (Osteichthyes). Both these groups appeared in the Devonian, and it is possible that they may have originated at some time in the Silurian Period, although there is no fossil evidence to prove this inference.

Sharks apparently evolved rapidly in Upper Paleozoic time, but many species had died out by the end of the Permian, with only a comparatively limited number continuing to the present. Sharks are generally considered to be "primitive" fishes, but it is also to be kept in mind that sharks appear in the fossil record somewhat later than the bony fishes. Thus, it is possible that their cartilaginous skeletal structure is a secondary development, and that the bone structure seen in ostracoderms, placoderms, and the first bony fishes is actually more primitive.

The mass extinction in Baltica might have occurred at the Devonian/Carboniferous transition time. Schönlaub (1991) reported an 800 m deep drilling in the Carnic Alps of Austria where corals had died out, probably because the sea level rose too high at the Devonian/Carboniferous transition time. The expanding Earth especially at the end of Devonian time-seems to again have changed the "living rooms" and by this, forced another mass extinction. However, in Pennsylvanian time, it again offered chances for a new and advancing life (Text-figure 22).

IVA 4. The Permo-Carboniferous Expansion Lull (about 360 to 250 Ma)

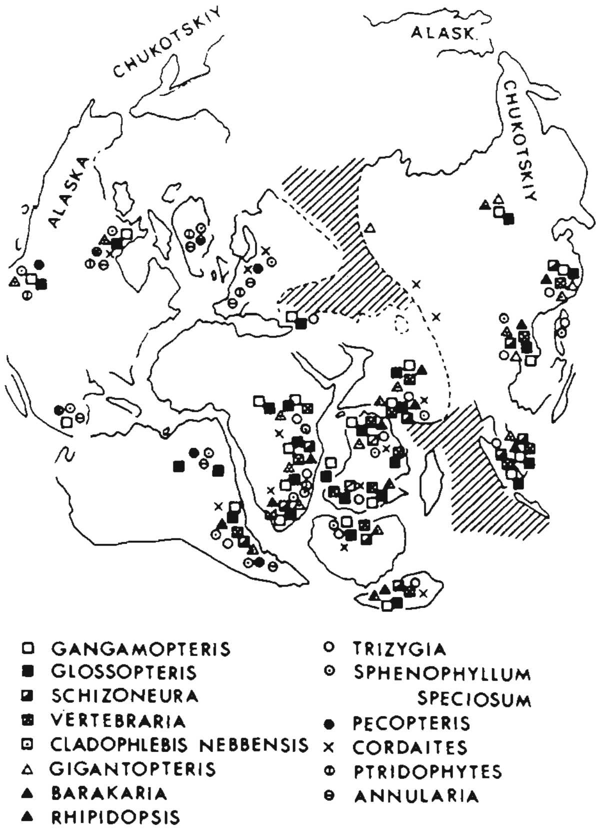
Detailed sequences of the polarity reversals of the Permo-Carboniferous time are still missing. Wyllie (1976) believes that at this period a reversed polarity prevailed. The Russian *Paleomagnitologiya* of 1982 indicates the same, with six polarity changes at about 336, 324, 320, 317, 310 and 296 Ma. This could indicate a somewhat restless time of the fluid outer core during the middle of the Carboniferous and also in the Lower Permian at 296 Ma. However, in general, this period between 360 to 250 Ma appears to have been an expansion lull, as the geological evidence indicates the formation of coal seams (original swamps with an abundance of tree growth). The well known Carboniferous swamps produced coal seams that commonly occur within depositional cycles of transgressions with regressions of shallow seas.

In the North of the Variscan mountains, which had been formed in the past by an orogeny, a sedimentation of Carboniferous coal seams spread from Ireland over northern France to Belgium, the Netherlands, northwestern Germany, Poland, Romania and the southwestern part of Russia. In this area, many clastic sediments were deposited alternated with marine and limnic clays, in which the formation of extended peat swamps developed.

According to Schönlaub's (1991) the Carnic Alps of Austria were about 688-800 m thick with sediments in the Auerning Formation of the Upper Carboniferous, and during the Permian an additional layer of more than 800 sediments was deposited. However, all the Permian sediments were then bent to folds, tilted and pressed into each other and finally elevated above the sea level. Consequently, the Carnic Alps were born, probably during the Triassic expansion phase.

In the Gondwanaland the situations were different; very few coal seams have been deposited, but tillites have been found in several areas. Tillites are glacial sediments, heterogeneous, ploughed up and deposited by glaciers.

In 1928, Wegener was able to piece the continents together to form a *Pangaea.* Looking at his assemblage of Pangaea, he assumed that in the Paleozoic all continents were combined closely with each other. Of course, he did not know that at that time the Earth was only some 60 per cent of its present size and all continents were packed together. Hilgenberg's (1933) and Vogel's (1983) terrella models had not yet been constructed and it was not possible to experiment as described in the beginning (Text-figures 1 and 2).



Text-figure 23— Pangaea: floral distribution (after Ahmad, 1983).

Vogel's terrella models indicate that all the continents of the Gondwanaland clustered around the South Pole. But now it is known from many that a rich vegetation of *Glossopteris* trees grew in the southern "polar region." How could this be? is still to be resolved.

Geologists are of the opinion that the Permo/Carboniferous world was marked by major climatic changes and can be recognized by the rocks and fossils:

1. During the Carboniferous Period glaciers spread over the south polar region of Gondwanaland and then began to recede during Permian time. Glacial tillites (heterogeneous sediments ploughed up and deposited by glaciers) are found in this region.
2. Marine life of the Permo/Carboniferous interval did not differ markedly from the Late Devonian time except for the absence of several groups that died out during the Late Devonian mass extinction.
3. The floras that flourished in Late Carboniferous time continued to dominate into the Early Permian Period but subsequently declined.
4. A general drying of climates at low latitutes during the Permian Period led to a contraction of coal swamps and to the extinction of spore-producing plants and amphibians (the reptile-vertebrate class Amphibia) both of which required moist conditions
5. At the same time, seed-plants and other animals called mammal-like reptiles appeared on the Earth.
6. A great mass extinction took place near the end of the Paleozoic Era. Only a few lycopods (club mosses) remained on Earth, while the taller cordaites disappeared altogether.

In 1983, Ahmad described the paleogeography of the *Tethys* region during the Late Paleozoic and Early Mesozoic based on paleontological studies and concluded that ever since the beginning of the

Paleozoic, no deep ocean, which separated Gondwanaland from Laurasia, Angaraland and Cathaysia, existed, e.g., the Tethys was not a real ocean but a epicontinental sea. The Tethys had been referred to frequently without clear definition of its spread in space and time. Further confusion resulted from the plate tectonics hypothesis, which needed an ocean north of India. Accordingly, the Tethys became a wide ocean, which closed, reopened, then closed again, with an imaginary trench somewhere in central Asia subducting some 5000 km of oceanic crust before disappearing completely.

Originally Tethys was conceived on negative evidence—the absence of similar fauna and flora respectively on Gondwanaland and Laurasia (including Angaraland and Cathaysia). However, closely related vertebrates, insects, freshwater molluscs, and floras are known from both side of the hypothetical ocean, which is thus reduced to an inland sea. Knowing what would have occurred about 4000 million years ago when the gaseous envelope of the Earth cooled down and fell on the Earth as water, we may now assume that the Tethys inland sea was a remnant of the Panthalassa which finally disappeared in the Mesozoic (perhaps previously in the Carboniferous) when the Earth grew and grew.

Ahmad (1978) concluded on the basis of distribution of paleontologic facts that the fauna of epicontinental seas made the existence of Tethys ocean impossible.

A Pangaea floral distribution (Text-figure 23) as described by Ahmad (1983), is also against the outdated assumption that the "Present is the Key for the Past."

Ahmad (1983) is correct in his assumption that the Tethys was not an ocean but an inland sea. But when did the Tethys dry out? Perhaps this could have occurred in the Devonian Expansion phase. The fact is that the Tethys did not exist in recent times when Ahmad investigated the fossil traces of the aquatic seafloor. Did a sea present in the Triassic time in the Tethys region? This would contradict the investigations of many paleontologists who conclude that huge mass extinctions occurred in the Guadelupian age (which perhaps occurred several million years before the Permo/Triassic transition time). It is generally assumed this mass extinction was caused as a result of global, i.e., change towards an arid situation.

According to (1989) the Paleozoic Era ended with what may have been the greatest mass extinction in global context, to strike the Earth's advancing life after vertebrate animals had invaded the land on a grand scale, and terrestrial vertebrates were among its primary victims. Nearly 20 families of Permian therapsids failed to survive into Triassic time, but the extinction of therapsids did not occur as a single event in the latest Permian time. Rather, there were several pulses of extinction, with taxa of large body size suffering the heaviest losses each time and new taxa evolving from smaller survivors. It has been suggested that the extinctions resulted from climatic changes that altered the terrestrial plant communities at the base of the therapsid's wood web. The Permian was indeed a time of floral change.

Late Paleozoic coal deposits in India, Australia, southern Africa and South America were found to contain a group of fossil plants that were collectively designated the Glossopteris flora. The most conspicuous is the genus *Glossopteris* (others are *Merianopteris*, *Sphenopteris*, *Sphenophyllum*, *Schizoneura* and *Gangamopteris*). The glossopteris flora of the Permian probably grew close to the South Pole, where the glacial tillites were found. It was obviously adapted to moist conditions. But in the Early Triassic age when the moist conditions began to dry out, the Glossopteris flora gave way to the Dicroidium flora (the gymnosperms of the Triassic).

In the marine realm, the Permian crisis completely swept away the fusulinids (Foraminifer) which had been highly successful in mid-Permian seas, and also the rugose corals, tabulates (reef builders) and trilobites (many-legged arthropods) although the latter two groups were very much in decline before the crisis began. The ammonoids (cephalopod molluscs) hung on by a thread: only a handful of their species survived into the Triassic Period. The brachiopods, bryozoans and stalked echinoderms surffered heavy losses, and the bivalve and gastropod molluscs were struck moderately hard.

It is difficult to determine the pattern of marine extinction in time and space, because marine stratigraphic sections that span the Permo-Triassic boundary without interruption are rare. Disconformities represent the crucial interval in nearly all continental areas. Because global sea level fell in Late Permian time (causing continental surfaces to experience erosion rather than deposition). Permo-Triassic boundaries are located in southern China, where paleontologists recognize a final Permian interval, the Changzingina Stage, which is not well represented by strata on modern continents.

Also in southern China, the Permian extinction was obviously not, geologically speaking, instantaneous. In fact, it occurred as a series of steps, beginning millions of years before any of the marine extinctions just described. The first heavy extinction took place in the Guadalupian age.

IV. B-5 The Lower Triassic Expansion Phase (about 253-228 Ma)

Haq *et al.* (1907) published the magnetostratigraphic time scale of the Silurian and Jurassic time periods. According to their investigation, the Triassic Expansion Phase might have lasted from 253 to 228 Ma. Then another expansion lull with few magnetic reversals might have begun and perhaps lasted until the Oxfordian time about 150 Ma. However, this is not absolutely clear. They have reported that between 201-159 Ma some 31 magnetic reversals might have occurred, which could not yet be formally established and may be subject to modification when additional magnetic data become available. Stanley (1989) reported a marine mass extinction probably occurred at the end of the Triassic Era (about 208 Ma) and also another one of a "minor marine mass extinction" occurred at the end of the Late Jurassic Period (about 164 Ma). Tröger (1989) expressed some doubts about these geologic assumptions. He believes that these assumptions can be determined only with the help of "Maximum Virenzperiodes" which may have occurred at the Upper Triassic and Jurassic, or perhaps by another "Maximum Virenzperiode" in the Lower Jurassic. The Virenzperiodes means "Virescent" beginning to grow and "viresco" for growing green. Such developments were helped in the Mesozoic essentially by the maximal developments of the ammonites.

In 1986, a second drilling 330 m deep was undertaken on the 1990 m high Kammleiten Mountain in the Carnic Alps. The core reached from the Triassic down to the Upper Permian layers. On the basis of this work Schönlaub (1991) expressed the following facts.

In the Permian/Triassic transition zone a definite change of the aquatic invertebrates occurred. Many died out and other new species evolved. During Permian, the climate in the northern hemisphere had become warmer and drier, and new conifers and other gymnosperms emerged. The drilling confirmed the "fauna-jump" which had been observed worldwide. A somewhat higher content of quartz was observed on the boundary and in somewhat higher layers (about 40 m higher) an unusual raising of the yield of *Iridium*, sulfur, iron, arsenic and cobalt were found. However, the iridium content was essentially lower than found at 65 Ma in the Cretaceous/Paleocene transition time. Traces of volcanic activities could also be recognized. It is now hypothesized that an iridium-laden hotspot/plume had exploded shortly after the beginning of Mesozoic time.

Recently an international group of scientists has found the base of the eruptions that created the flood of molten basalt in the Siberian Traps, that is a widely expanded area of volcanic rock, some 870 miles in diameter bordering Lake Baikal. According to Campbell *et al.* (1992), the outburst began about 246 Ma. The era of mass extinctions at the Permian/Triassic transition time points to Siberian volcanoes and perhaps to the findings of Schönlaub's (1991) mass extinction, the small iridium deposits and traces of volcanic activities in the Carnic Alps.

The catastrophe of the Permian/Triassic transition time swept the Earth clean of animal groups from trilobites in the ocean to ferocious reptile carnivores living on land and opened ecological niches for a host of animals, including the dinosaurs of the Mesozoic era that followed.

Some workers believe that the eruptions created the flood of molten basalt in the Siberian Traps occurred in something less than 600,000 years. This would be similar to the 800,000 years at the 29 magnetic reversal period at Cretaceous/Tertiary time.

Pfeufer (1992) found that at some undetermined time, a sizeable difference developed between the depressions and the elevations on the outside of the fluid Outer Core (see Text-figure 5). This new topography at the border of the mantle would mean an additional source of heat. He called it a Friction heat, caused by the quicker movement of the Earth's mantle over the surface of the outer core. This might have started at the beginning of the Mesozoic time. It could be the reason why the Siberian Traps exploded and why the first hotspot/plume in the Carnic Alps erupted. The Triassic Expansion Phase began with the terminal Permian extinction. However, a new and advancing life developed in the *marine regions.* By the end of the great extinction that brought the Paleozoic Era to a close, several previously diverse groups of marine life had vanished and others had become rare. Gone were fusulinid foraminifera, lacy bryozoans, rugos corals and trilobites. Most common in the Lower Triassic rocks are molluscs. The ammonoids made a dramatic recovery after almost total annihilation in the terminal Paleozoic extinction although only two ammonoid genera are thought to have survived the Permian crisis. The Lower Triassic rocks have yielded more than 100 genera of ammonoids. Other groups of marine life were slower of recover, but in the Late Triassic time, the seas were once again richly populated.

Sea floor life— Bivalve and gastropod molluscs were less severely affected by the Permian extinction than many other groups. In fact, bivalves, like ammonoids, are frequently found in the Lower Triassic rocks although their diversity is somewhat limited. Both bivalves and gastropods expanded in number and variety to become among the most important groups of Early Mesozoic marine animals. In addition to ammonoids and bivalves, brachiopods made the greatest showing in Triassic rocks. All other marine invertebrates are rare.

Presumably many kinds of planktonic organisms left no fossil record, but a few types are well represented in Early Mesozoic rocks. Acritarchs left a meagre record which indicates that they had not recovered from the great extinction that had taken place near the end of the Devonian Period. Higher in the food chain, the ammonoids and the belemnoids played major roles as swimming predators. The ammonoid's evolutionary recovery following the Permian crisis led to great success throughout the Mesozoic. Paleozoic ray-finned bony fishes gave rise to forms that were successful in Early Mesozoic time but were still more primitive than most of their modern-day descendants. The scales that covered the bodies of these fish were diamond-shaped. Sharks were also represented in Early Mesozoic seas. One particular prominent groups, the hybodonts had already diversified by the end of Paleozoic time. Some had teeth like those of bony fishes and were adapted for crushing shell fish. The living Port Jackson shark of Australia, a descendant of the hybodonts, has similar teeth and feeds on molluscs. Many of the reptiles that emerged in the Early Mesozoic seas were creatures that resembling the sea monsters. Among these were the placodonts, which, like many Early Mesozoic fish, were blunt-toothed shell crushers. The broad, armoured bodies of placodonts gave these animals the appearance of enormous turtles. Cousins of the placodonts were the nothosaurs which have been found in Early Triassic deposits and seem to have been the first reptiles to invade the marine realm. Nothosaurs had paddle-like limbs, resembling those of modern seals, and it seems likely that, like modern seals, they were not fully marine, but instead lived along the seashore, periodically plunging into the water to feed on fish. Although the placodonts and nothosaurs did not survive the Triassic Period, a group of more fully aquatic reptiles evolved from the nothosaurs in mid-Triassic time and these reptiles, known as *Plesiosaurs*, played an important ecologic role for the reminder of the Mesozoic Era. Plesiosaurs apparently fed on fish and, in Cretaceous time, attained the proportions of modern predatory whales, reaching about 12 meters in length. By far the most fish-like reptiles of Mesozoic seas were the *ichtyosaurs*, or "fish-lizards", many of whose species must have been top predators in marine food webs. The ichtyosaurs, however, had upright tail fins rather than the horizontal pair of real flukes that propel dolphins through the water. Ichtyosaurs were fully marine and thus could not easily lay eggs; instead they bore live young. In fact, skeletons of ichtyosaur embryos have been found within the skeletons of adult females. Surprising as it may seem, the last important group of Early Mesozoic marine reptiles to evolve were the early crocodiles which were related to the dinosaur. Although crocodiles evolved in Triassic time as terrestrial animals, some were adapted to the marine environment by earliest Jurassic time.

Terrestrial life— The presence of dinosaurs gave the biotas of large continents an entirely new character, but Mesozoic land-plants were also distinctive. Because these plants were positioned at the base of the food webs to which the dinosaurs belonged, the Mesozoic *gymnosperm flora* do not appear to have undergone a dramatic mass extinction at the close of the Paleozoic Era. In effect, the transition from the Late Paleozoic flora to the Mesozoic flora began before the start of the Mesozoic Era. Ferns, were dominant in the Triassic fossil floras. Although some of the trees that stood above Triassic ferns were sphenopsids and lycopods, most belonged to three divisions of gymnosperms that had already become established during the Permian: the cycads, cycadeoids and the ginkgos. The trees that belonged to these three dominant groups are united as gymnosperms because they were all characterized by exposed seeds. With the possible exception of the pine family, all modern conifer families were present in Early Mesozoic time. Cycads are less familiar plants. Cycadeoids, which were closely related to the cycads, are extinct.

Terrestrial animals — The age of dinosaurs begins. during Late Permian and Early Triassic time, much of the supercontinent of Pangaea stood above sea level. Under such circumstances, one would think that terrestrial deposits spanning the boundary and recording the history of land animals from Late Permian time into the Triassic would be abundant and easy to find. Unfortunately, this is not the case. Just below the Permian-Triassic boundary in both regions, most of the dozens of genera of Late Permian mammal-like reptiles disappeared suddenly from the fossil record, making a major mass extinction. What remained at the begining Triassic were a few predatory genera and the large herbivore Lystrosaurus, which is famous for its fossil occurrence on many of the now widely dispersed fragments of the Gondwanaland. Lystrosaurus became the proof that India was indeed connected to Asia from the beginning and had not drifted from the Paleozoic time to the Eocene from the southern polar regions to Tibet (as has been proven by Meyerhoff *et al.*, 1978).

IV. B-6 The Upper Triassic to Middle Jurassic Expansion Lull (about 228-150 MYA)

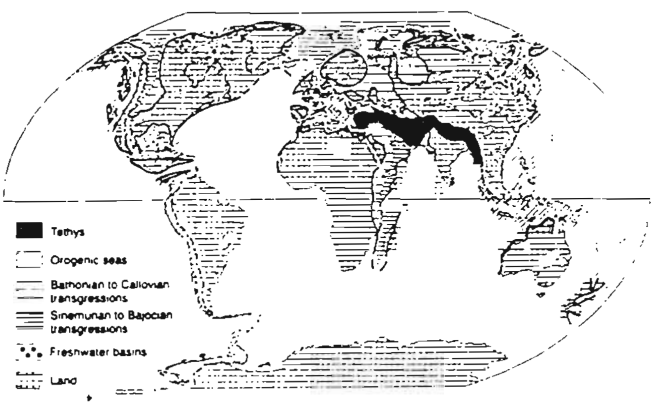
The question might be presented: Why did the expansion lull begin again after the 25 million years long Triassic expansion phase?

The answer is that the expansion lulls seemed to have occurred in the Paleozoic after every expansion phase. Of course, the geologic record of the Paleozoic is not well known and the reasons are not so easily explained, but in the Mesozoic the geological record slowly becomes clearer. In the Triassic Period most volcanic activities, in addition to the iridium-laden superplume hotspots, came directly from the Outer Core border. This meant an immense heat loss had occurred, and for the next 58 million years, the Earth could not expand again. It had to recover itself, collecting more heat during this time. It is like we humans need rest after a strenuous workout. According to Lovelock (1989) the heat-engine (or in Lovelock's terminology "heat-organism") of the Earth must also recover for some time and so it happened: the Earth rested.

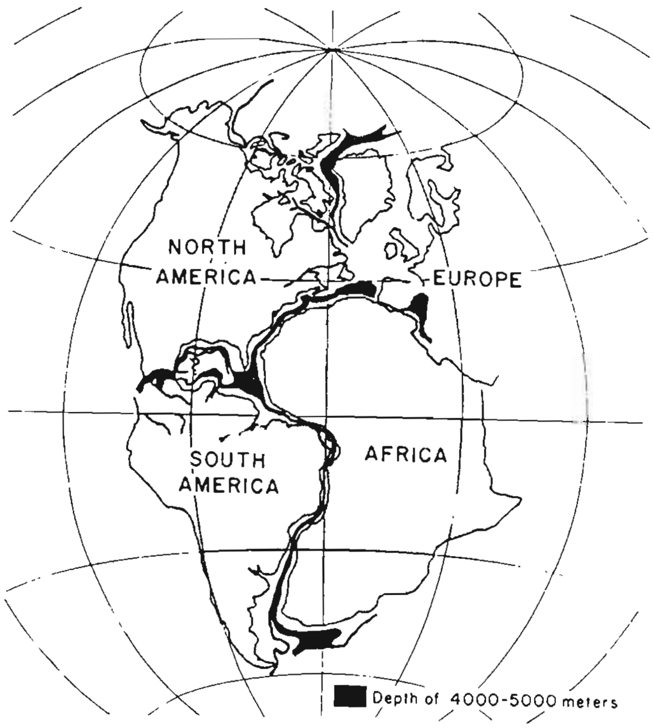
Tröger (1984) remarked that the worldwide transgressions of continental seas during the Lower and Middle Jurassic and the Upper Cretaceous periods were the largest transgressions of the world since Mesozoic time. In the United States the expansion of Sundance Sea of the Jurassic Period supports Tröger's view. The Sundance Sea invaded western North America during the Jurassic Period, but tectonic activity drove the sea from the western interior, leaving a foredeep where the nonmarine Morrison Formation accumulated (see Text-figure 23). In Europe, nonmarine depositions prevailed, e.g., the Tethys continental sea in the Boreal transgressions. All of the continents remained close together until the end of Jurassic time but as rifting began, the Tethyan Seaway spread westward between Spain and North Africa.

The magneto-stratigraphy of this period has probably most thoroughly been investigated by Haq *et al.* (1987). According to their time measurements, which may not be absolutely positive, it ended about 150 Ma at Early Oxfordian time and began about 228 Ma in the Middle Carnian Formation of Late Triassic time. Their magnetostratigraphic table shows an unclear sector between the Bathonian (Middle Jurassic) and the Sinemurian or the Hettangian Formation of Lower Jurassic about 210 Ma. This sector, according to the authors, may have experienced a change of 32 magnetic intervals.

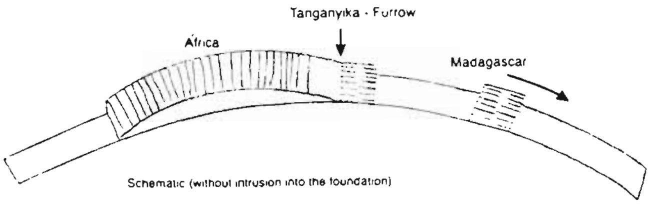
According to Stanley (1989) the diversity of Advancing Life during the Upper Triassic Expansion lull was as follows. Although the mammal-like reptiles diversified during the Triassic Period to play an important ecologic role once more, they barely survived into the Jurassic Period. Nonetheless, they left an important legacy in the form of the true mammals, which evolved at the near end of the Triassic Period. Mammals, which are endotherms with hair and which suckle their young, are the dominant large animals of modern terrestrial habitats, but they remained small and peripheral throughout the Mesozoic Era. Apparently no species grew larger than a house cat. Their problem seems to have been the dinosaurs which also evolved during the Late Triassic interval and quickly rose to dominance. Dinosaurs were also small at first, but their advantage over primitive mammals might have been that they were extremely agile. They inherited their locomotory capacity from their ancestors, the .*thecodont* which evolved during the Triassic Period. The first dinosaurs resembled bipedal thecodonts (that is, thecodonts travelled on their hind legs). Dinosaurs did not become gigantic before the end of the Triassic but during Triassic times they did reach a length of more than 6 meters (or 20 feet). The crocodiles, like the dinosaurs, evolved from thecodonts in Late Triassic time. Two other important groups became established in Triassic times. One were the amphibians (frogs) of small body size. Frog-like skeletons have also been found in Triassic rocks. The other group was the turtles, although the earliest turtles lacked the ability to pull their heads and tails fully into their protective shells. By Late Triassic time, mammal-like reptiles declined in diversity. Those which remained existant, lived with the increasing numbers of dinosaurs. Vertebrate animals late in the Triassic Period, invaded the air for the first time as the *pterosaurs* came into being. These animals had long wings and hollow bones that served them to facilitate flight. Some species had long tails (like *Rhamphorynchus*, found in the Solnhöfen Limestone of Germany). The structure of the pterosaur skeleton reveals that those flying reptiles were capable of flying by flapping their wings but the great length of the wings suggests that most species flapped their wings primarily when taking off and then, once air-borne, employed air currents to soar without much flapping. The behaviour of pterosaurs when not in



Text-figure 24— Worldwide transgressions of continental seas during the expansion lull of the Jurassic Long Normal Magnetic Zone (Sinemurian to Callovian) without consideration of continental drift.



Text-figure 25— The break-up of western Pangaea. This map illustrates the supercontinent's western region about Oxfordian time.



Text-figure 26— The break-apart of Madagascar from Africa in Tertiary time.

flight has been widely debated. Most species appear to have been able to walk and also to climb adaptly using their hooklike claws (Stanley, 1989).

Perhaps near the end of Triassic time, Pangaea began to break apart, but continental movement was so slow that even by the end of the Middle Jurassic time, the newly forming continental fragments were hardly separated.

The Triassic Period may have ended with a severe mass extinction. The crisis struck both on the land and in the sea. In the marine realm, about 20 per cent of all families of animals suffered extinction. Conodonts and placodont reptiles died out altogether along with species of bivalves, ammonoids, plesiosaurs and ichthyosaurs, although all of these groups recovered in Jurassic time. The terrestrial victims included most genera of mammal-like reptiles and large amphibians. It seems now evident that there were two pulses of Late Triassic extinction on the land—one at the end of the Norian age, the final stage of this period and one at the end of the preceding Carnian age. The timing of exinction in the seas is not quite clear, but many genera died out during the last phase of the Norian.

According to Stanley's (1989) collections, the advancing life during the Jurassic Expansion lull until the Oxfordian time was as follows:

Life in the ocean—Many kinds of planktonic organisms in the Jurassic seas left no final fossil record. Dinoflagellates, which existed in the Paleozoic Era, underwent extensive diversification during mid-Jurassic time. The calcareous nannoplankton, another important group of algae, made their first appearance in earliest Jurassic time. Today, these floating algae are concentrated in tropical seas.

Terrestrial life—*Crocodiles* evolved in Triassic time as the terrestrial animals. Some were adapted to the marine environment by earliest Jurassic time. Frogs, which were and remained amphibians, were of small body size. Unfortunately, the known fossil record of Early Jurassic is too poor to permit the piecing together of details of the *dinosaur's* great rise to dominance. The cycads, cycodeoids, conifers, and ginkgos formed the forests of the Jurassic Period.

Ferns of the Jurassic Period were less conspicuous as undergrowth than those of Triassic time.

IV. B-7 The Mesozoic Expansion Phase (from the Jurassic Oxfordian (about 150 Ma) to the Cretaceous Barremian (about 114 Ma)

The exact age of the beginning of Oxfordian time remained unknown for quite some time. The rich ammonite fauna with its authigenic glauconite found in central Europe finally enabled Fischer and Gygi (1989) to determine the exact age. These authors subdivided the critical zone into four ammonite zones. The K-Ar dates of these glauconite zones were between 149.2 to 145.9 Ma. Fischer and Gygi (1989, p. 1595) report that the Callovian/Oxfordian boundary varies as much as 14 mg in the various numerical geological time scales of the Jurassic Period. They explain that this is because age measurements of high-temperature minerals from plutonic rocks are often difficult to correlate with biostratigraphic zones. On the other hand, the time of formation of many glauconites can be accurately correlated with the biochronologic time scale.

Geologists assume that the break-up of the western part of the old Pangaea Supercontinent began in Oxfordian time, but when and what cused the breakup? This has puzzled geologists, especially the question about what could possibly break-up a line of thousands of miles of rift between Africa and South America? This is a problem if one is convinced of the medieval Statical Earth Assumption that the Earth has maintained a constant size for the past three or four thousand million years. This assumption has been accepted, unquestioned and unexamined for several hundred years (Text-figure 24). According to Sclater and Tapscott (1979), North America, South America, Greenland, Europe and Africa, which had formed one huge expanse of land, started to rift apart as molten magma from the deep interior of the Earth welled up between them. The creation of new crust by the outward flow of magma separated the northern continents from Africa and South America. This explanation is universally accepted. We now know that this break-up of western Pangea did not occur 65 million years ago but about 150 Ma. Yet Sclater's and Tapscott's explanation left many geologists puzzled. How, at the beginning of the Oxfordian time, could western Pangaea violently break-up? Ehrensperger (1988) determined how Madagascar could break-apart from Africa around Tertiary time. He concluded that when the Earth did indeed expand, its radius straightened out more and more, but the rigid continents could not follow the ± elastic mantle. This was the case for Africa.

It was impossible for the now greater bent of the African continent to sink into the mantle. Consequently, its tension forced the continent to break-up from its underside (Text-figure 25). This, explained why Madagascar finally broke away from the African continent. I, too, am convinced that the same problem forced the western Pangaea to break apart in Oxfordian time. Possibly this process began many millions of years ago during Jurassic time and was completed about 150 Ma. The same process may also have occurred when Australia broke apart from Antarctica (Text-figure 26).

According to Ehrensperger (1988) when the Americans were able to install a reflector on the moon, the astronauts could accurately measure the distance between the Moon and Earth and they found that the distance becomes greater by 4 cm per year. Ehrensperger believes the validity of this expansion formula should be examined. This would mean that the distance between the sun and the earth would be greater by about 15.77 m per year: each year is 0.0022 longer than the preceding year.

It has become known that the huge Parana Flood basalts (also Calle Serra Geral Basalt) of southern Brazil, parts of Paraguay, Uruguay and northern Argentina started to erupt about 154 Ma, had its peak eruption about 125 ± 5 Ma and continued to erupt in a volatile way until about 100 Ma. Apparently these eruptions coincided with similar eruptions in Namibia in Southwestern Africa which may have covered about 500,000 km^2 of the area (Rampino & Stother, 1988). The Oxfordian break-up of the western part of the Old Pangaea supercontinent (about 150 Ma) indicates a convincing case for Earth expansion. A few years ago, the Ontong Java Plateau in the South Pacific Ocean was discovered. Its lava beds cover twice the area of Alaska. This superplume reached its peak about 120 Ma and may have subsided about 60 millions years later.

The break-up of the western Pangaea continent, the opening of the North Atlantic, the South Atlantic, the Indian Ocean and the continued growth of the Pacific Ocean (since it originated as Eo-Pacific about 1200 Ma) may have caused another heat loss of the Earth's "heat engine," and the newly discovered Ontong Java lava bed may have helped provide the following "rest pause" that is the Cretaceous expansion lull.

Stanley (1989) is of the view that the most spectacular geographic development of Mesozoic Era was the fragmentation of Pangaea, an event that began in the Tethyan region. As the Triassic Period progressed, the Tethyan Seaway spread farther and farther inland, and eventually the craton began to rift apart. The Tethys subsequently became deep, narrow arm of the ocean separating what is now southern Europe, from Africa. Then, during the Jurassic Period, this rifting propagated westward, ultimately separating North and South America. South America and Africa, however, did not separate to form the South Atlantic until the Cretaceous Period; in fact, all of the Gondwanaland continents remained attached to one another until Cretaceous time. North America began to break away from Africa in mid-Jurassic time. Interestingly, this rifting generally followed the old Hercynian suture. Rifting occurred as some of the arms of a series of triple junctions joined, tearing Pangaea into three parts.

When continental fragmentation begins in an arid region near the ocean, evaporite deposits often form in that region. Thus, as rifting began in Pangaea, extension produced normal faults between Africa and the northern continents; zones bounded by such faults sank, and water from the Tethys to the east periodically spilled into the trough and evaporated. Evaporites that were precipitated in this trough are now located on opposite sides of the Atlantic, both in Morocco and offshore from Nova Scotia and Newfoundland.

During Middle and Late Jurassic time, one arm of rifting passed westward between North and South America, giving rise to the modern Gulf of Mexico. The early intermittent influxes of seawater into this rift, apparently from the Pacific Ocean, caused great thicknesses of evaporites to accumulate. Today, these evaporites, which are known as the Louann Salt, lie beneath the Gulf of Mexico and in the subsurface of Texas. Because its density is low, the Louann Salt has in some places pushed up through younger sediments to form salt domes, many of which are overlain by valuable reservoirs of petroleum. The rifting that forms the South Atlantic did not begin until Early Cretaceous time, when the record shows that salt deposits formed after seawater spilled inland from the south.

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