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ABSTRACT

Because Pangaea comprised a hard, brittle granitic crust, the laws of brittle fracture apply in its fragmentation. Application of these laws to map Pangaea revealed crucial evidence that ice caps caused it as well as continental shift. Three sound scientific dating methods emerging from the evidence substantiate biblical chronology.

INTRODUCTION

The concept of "Pangaea," all continents once joined together in a single primordial continent, was suggested in 1922 by Alfred Wegener.[36] A symposium held in 1958 at the University of Tasmania[4] promoted "International Geophysical Year," and results confirmed it to the extent that Pangaea, its rupture and continental drift have been generally accepted since then. Maps of the reassembly of Pangaea by Carey[4] and duToit[19] are about the same as the most recent maps of Pangaea shown in modern geological texts and in the Cambridge maps of 1983.[35] New maps of the continental margins and ocean ridges appeared as inserts, a part of the globe at a time, in National Geographic from October 1967 to October 1970. Their 12"-diameter 1974 globe map was used in this study along with their 16"-diameter globe map of 1981 and a 6' x 4' (24 square foot) wall map also dated December 1981.

Hapgood and Campbell[23] explained the rupture of Pangaea as due to overgrown ice caps. I concluded their model was really the only proper explanation.[6,9] Geologist Eardley joined me[12] in showing "terrestrial expansion"[4,20,24,25] cannot apply, also shown independently by Beck.[2] Then the laws of viscosity were applied to terrestrial rheidity showing that the "plate tectonics" model based on mantle convection currents[5,21,24] is equally unlikely because, at the pressures and temperatures involved, the forces exerted on the crust by the postulated mantle convection currents should be too low by more than five orders of magnitude.[8,13,22] Although Eardley accepted Pangaea and continental drift, his geological colleages did not for at least the next ten years. But Eardley was opposed in this collaboration so strongly he withdrew from our final paper.[8] Yet his presidential address to the National Association of Geology Teachers[19] carried similar implications in showing global correlation of uplifts at the poles and downwarping at the equator, no doubt following the sudden disappearing ice caps. The dating of this global effect was at that very time being done for the northern depression zones showing a time less than 10^4 years ago both for Canada[21] and Fennoscandia.[26] The reverse of this global effect was obviously prior to the rupture of Pangaea. Otherwise there could have been no northern polar ice cap to bring about the downwarping at the pole in the first place. In other words, with Canada separated from Greenland and in turn from Fennoscandia, an ice cap of appreciable depth would simply flow <u>down hill</u> into the Atlantic Ocean.

Pangaea had to have ruptured in tension because the continental crust is granite, a very hard, brittle solid with a tensile strength of 0.075 kilobars, a compressive strength over twelve times greater and increasing with confinement, and a poisson ratio of 0.26. Because mantle convection currents cannot apply enough force, the only other conceivable force to break apart a twenty-mile-thick granitic crust is that exerted by great ice caps resting in deep bowl-shaped depressions on the poles. The depths of depression and the total weights involved are known from the size of the split zone, the Arctic and Atlantic basins formed and the measured depressions.[6,26] This applies also to when the uplifts at the north zone began and how rapidly they have taken place since then.[21,26]

In this article the types of fractures involved in the fragmentation of Pangaea are first considered in light of the principles of brittle fracture. Examples are then pointed out and used in a reassembly of Pangaea (Figure 1). Two quantitative dating methods and a qualitative one are discussed and applied to show a very recent rupture of Pangaea and when civilizations known and described in secular history really began. During this study an important discovery was made that appears to advance radiocarbon chronometry tremendously, and this is outlined in a separate article.

PRINCIPLES OF FRACTURE PERTINENT IN THE RUPTURE OF PANGAEA

Based on the principles of brittle fracture and the National Geographic maps, Pangaea may be seen to have ruptured by the propagating and branching type of crack fractures that travel in granites at 1.2 ± 0.2 miles per second sustained by stress waves having velocities of 3.5 ± 0.5 miles per second.[1,10,27,30,32] Otherwise the "slip-stick" type of crack fracturing would be observed along the continental margins. Slip-stick does occur along the ocean rift and ridges, but this was due to aftereffects in the a-periodic relief of the stresses that were generated by the primary earth-shattering waves. While not considered quantitatively, the time required for most of continental drift was months or years, not megayears, based on the magnitude of the forces applied and terrestrial rheidity. Thus "shift" is a better description than "drift." The splitting "load" that initiated the breakup of Pangaea was in excess of 10^{13} tons based on at least 2000 feet average depth of the northern (ice cap) depression zone (not considering the elastic component) and a diameter of about 3000 miles. The forces responsible for continental drift were one or two orders of magnitude greater, telescoping thusly by ice driving into the fracture zones following the initiation of crack fracturing.

Threshold Initiation Triple-Branch or TB Cracking

Three branches of cracks radiating outward from a point of initiation in a hard, brittle solid branching at about 120° from each other are generally observed in high-speed photography irrespective of the magnitude and nature of the initiation. In threshold initiation these three branches are the only ones to develop. Photo I shows a typical example of a near threshold initiation showing also the beginning of a second stage and deviations mostly at long range from the ideal 120°-angle pattern. It is only inhomogeneities in the solid and assemetrically applied forces that cause deviations from the 120° angle between branches of the initiation TB. But it is necessary to use a circular plate or one without corners or only at long range to show an ideal initiation TB because corners guide cracks away from them. For example, with a square plate of appropriate size, four fractures radiate together from the threshold initiation point in order to stay as far away from the corners as possible and they thus cut the plate into four approximately square plates, each having about a fourth the area of the original plate.[29,32,33] This illustrates an appreciable time lag in the beginning of the cracking process after the forces are applied showing that the solid must first dilate significantly (beyond its elastic limit) before a crack may begin to propagate. Thus the initiation TB signals its beginning many microseconds ahead of time.

Photo I. A near threshold TB in a circular mild-steel plate initiated by a small charge of explosive at the center.

Overinitiation TB Cracking

In the explosive initiation of cracking of hard, brittle solids, the energy is usually much greater than for threshold initiation. Yet the triple branch (TB) at about 120° between branches is always the first stage. With enough overinitiation a second stage, or secondary TB, develops a short time later approximately bisecting each of the three 120° angles of the first stage to give rise to a total of six branches about 60° from each other. A trinary TB follows, if the energy of initiation is sufficient, to effectively bisect the 60° angles producing a total of twelve (six new) cracks so that the angle between them is then about 30°. Still a fourth stage may develop to give a total of twenty-four branches at about 15° from each other if the initiator is strong enough. In this event one sees bisects of bisects of bisects. All these stages of crack initiation may be seen at once in a single frame of a microsecond-per-frame photographic sequence, as in Photo II. Of course, each stage may be seen as it develops by observing each frame of the sequence. The four stages are recognized in Photo II by the lengths of the fracture. Note three branches lead all the others, another three follow, followed by still shorter, stage-three cracks and a fourth stage just beginning. An overinitiation TB will be pointed out in the maps of NGS. The delay between stages in the overinitiation process shows that dilation is always necessary in the initiation of each separate stage of the crack initiation of propagating crack fractures. It also shows how tensile forces are brought into play in the use of explosives to initiate crack fracturing. These principles are well known in rock mechanics.[1,10,11,27,30,32,34]

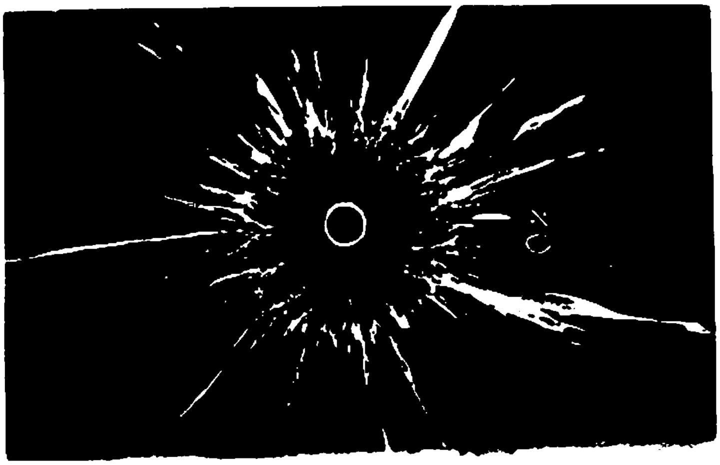


Photo II. An overinitiation TB in Plexiglas showing four stages of initiation -- From a microsecond-per-frame sequence taken from Reference 30. (It shows not only crack initiation but a shock wave zone at the center.)

Bifurcation TB Cracking of Hard, Brittle Solids

When driven by strong enough forces, the energy builds up regularly in each propagating crack until it reaches a critical level. At this stage bifurcation occurs to produce two transmitted branches ideally at 120° from each other, one 60° to the right and the other 60° to the left of the incident crack in order to conserve momentum. That is, $M \cos 60° = M \cos (-60°) = M/2$, where M is the final momentum of the incident crack at the point of bifurcation. Again it is only variable prestresses and inhomogeneities in the solid that cause the the angle of this type of TB to deviate from 120°. Many bifurcating TB crack fractures are seen in the NGS maps.

Coupled Triple Branch Cracking

Two bifurcating TB cracks may couple together with one branch of each common to both if they occur closely enough together[29,34] thus giving rise to a fracture pattern having the shape >——<. The length of the branch-in-common may be about doubled in the extreme in an explosive-initiated, coupled TB by introducing an unloaded borehole between two loaded ones thusly >——o——<. It may be nearly tripled by introducing two such unloaded holes between loaded ones. Moreover, if boreholes are separated more than the distance for coupling, the two branches tend to point toward each other, even with unloaded holes between them, thusly >——o—— ——o——<. The coupled TB is, of course, responsible for multiple (hexagonal) cracking in the case of uniform solids like glass driven by a relatively constant load. The coupled TB was involved one at a time or multiple to produce hexagons or pentagons in the rupture of Pangaea and later in continental shift.

Fork Cracking of Hard, Brittle Solids

The "fork" is also the result of bifurcation of an incident propagating crack in a hard, brittle solid, but it differs in the following ways from the bifurcating TB: (a) Forks are caused by localized prestresses, bifurcating TB cracks involving broadly applied prestresses. (b) The angle between the transmitted branches of the fork is in general 60° or less. (c) The sum of the (vector) momenta of the two branches of the fork is always greater than in the bifurcating TB cracking, the additional momentum coming from the relief, or partial relief, of the localized prestress(es). In studies of fork cracking of hard, brittle solids, Bowden, et al., found that the length of a segment of a chain of forks varies inversely as the square of the prestress.[30] This is a special case of a more general law applicable to all propagating and branching cracking processes. Photo III shows a double fork at 60° and 40° in a locally prestressed, hardened steel plate.

Fork Burst (FB)

Photo IV shows four frames of a microsecond-per-frame sequence of a fork burst in the "hard rock 'Norite'."[3,30] The fork burst is of special interest in connection with two seen in the NGS maps at the south end of the Urals and north of Lake Eyre in Australia. A fork burst usually terminates a cracking chain because it requires the available momentum to be divided up among an excessive number of transmitted branches of cracks.

Single Branch, Sharp-Angle Changes (SB Cracking)

The SB, without crack bifurcation but only a sharp angle change, is common when assymetric prestresses are involved. Any such change involves momentum to be transferred, but only

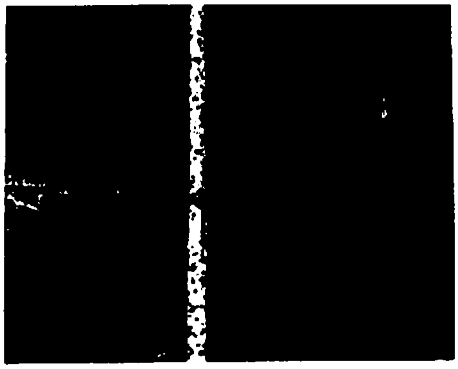


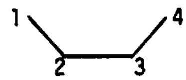
Photo III. A 60° and 40° double fork in a locally prestressed steel plate.

Photo IV. A fork burst in the "hard rock, 'Norite'" -- From Bieniawski.[3,30]

M cos $\Delta\theta$ of this can come from the incident crack. The remaining M - M cos $\Delta\theta$ comes from the relief of prestress. Here $\Delta\theta$ is the angle change of the SB cracking process. Greenland was carved out of Pangaea by nine SB changes and one coupled TB. Indeed, SB crack fractures were common in the rupture of Pangaea.

Coupled Single-Branch Crack Fractures

Coupled SB propagation cracking is also a common and important aspect of the cracking of hard, brittle solids. It is observed, for example, in the cracking of glass and improperly cured concrete. The coupled TB has the ultimate effect of turning a propagating crack fracturing chain by a total of 120°. It is made up of two 60° SB cracks both changing in the same direction or rotation. For example, the sinstral coupled SB has the shape



where 1-2 is the incident segment, 2-3 the intermediate crack segment, and 3-4 is the transmitted crack, each segment designated by its end points. The SB involves partial or full relief of a local prestress and the coupled SB that of two SBs joined together. Point 2 is where most of the momentum from the relief of prestress flows into and supports the propagation of the crack. Several examples of coupled SB crack fracturing are seen in the NGS maps. They are responsible, for example, for the shapes of Africa and South America. Also it is generally possible to determine the direction of travel of a crack by the effects of the greater impulse at point 2. The fork is also useful in determining direction because of the small (60° or less) angle change in the fork.

Multiple Spall Fracturing of Hard, Brittle Solids

Based on the laws of TB, SB, and F cracking, the pressures (energy density) the stress waves required to produce them are about four times greater than is required simply to support the propagation of a crack. When bifurcation occurs, the crack retains only a small fraction of the initial energy, most of the energy for cracking being returned to the solid in the form of waves directed transversely to the direction of the crack propagation. Because cracking is sudden it sends out secondary waves (seismic waves) to add to the transverse component of the primary waves driven by the forces that cause the propagating and branching crack process. These waves may themselves produce fractures by interaction with an interface. Based on the Goranson laws[10,11,30,32] of an interaction of stress waves with interfaces, the following equations apply to the transmitted pressures p_t and the reflected ones p_r relative to the incident pressure p_i and the impedances I_t and I_i of the transmitted and incident media, respectively. (I is density times velocity.)

$$p_t = 2I_t p_i/(I_t + I_i); \quad p_r = p_i(I_t - I_i)/I_t + I_i)$$

At a "free surface" (air on one side and solid on the other) $I_t/(I_t + I_i) \doteq 0$, so $p_t \doteq 0$, $p_r = -p_i$, and the wave is reflected as a tension wave. At a rock-water interface $I_t \doteq 0.1\ I_i$, and about 80 percent of the energy of the incident wave is reflected as a tension wave. For a basalt-granite interface, however, I_t is about 20 percent greater than I_i, so there is but little reflection and mostly transmission of the stress-wave energy, i.e., about $p_t \doteq 1.1\ p_i$ and $p_r \doteq 0.1\ p_i$.

The tension in a reflected wave cannot exceed the tensile strength of the medium. If p_r is greater in absolute magnitude than the tensile strength t_0, single or multiple spalling will take place, as illustrated in Figure 2 for the free surface, with the granite-water interface being much the same.

Plastic and Shock-Wave Fractures and Distortions

The stress waves that sustain propagation and branching of cracks in a very hard, brittle solid like granite are generally elastic waves and, except for cracking, may leave no permanent damage in the solid when the intensities in the waves are less than in plastic flow. At higher pressures, however, they propagate as plastic or shock waves, depending on their magnitude, and leave distortions as well as fractures. The difference between plastic and shock wave propagation is that the solid is only softened within the plastic wave, but it is melted at least in the front of the shock wave where the pressure is at its maximum. Softening and melting in plastic and shock waves, respectively, are due mostly to the high pressure rather than a temperature rise also involved. But the pressure falls rapidly progressively behind the wave front. Therefore, at some distance behind the front the medium may suddenly reharden or resolidify within the plastic or shock wave, respectively. Thus the solid is left in a permanently distorted state and usually also under permanent compression.

Solids are able to support both transverse and dilatational waves, but fluids support only dilatational waves. The distortions are created while the medium is either melted (shock waves) or softened (plastic waves). Therefore, shock waves leave transverse fractures and distortions, but plastic waves leave both transverse and parallel fractures and distortions because the material was molten or just softened, respectively, when they were made. By this means the magnitude of the pressures involved may usually be determined in the damage caused by these waves.

CRACK FRACTURING OF PANGAEA

The most important application of the principles of brittle fracture in the case of Pangaea is in locating the point of the initiation triple branch (TB). Because this point is necessarily common to two or three continents now separated, the first problem is to provide a careful enough reassembly of Pangaea to see if it can be located. To best accomplish this, all continents should really be fitted back together as carefully as Africa and South America. If the carey-duToit[4,19] model is correct, the initiation TB should be found close to their hinge point, the Bering Strait.

The key to locating the primary initiation triple branch and its point A of initiation in the rupture of Pangaea is Greenland. Anyone accepting the Carey-duToit reassembly of Pangaea, which apparently practically all geologists do because all modern maps are essentially the same,[35] should have realized this as to the mechanism of opening up the Arctic Basin and the Atlantic Basin. Carey described it as a 28° "sphenochasm," or jaw-like opening with the hinge at Bering Strait. But his description was given without the benefit of the NGS maps of continental margins. With these maps the situation is seen to be more complex. Instead of a hinge at a point, the opening of Pangaea appears to have involved the whole Aleutian Arc, about a 41° dextral rotation and a 600-mile translation rather than only a 28° rotation. Roughly 6° of the initial rotation were erased when India collided with Asia. A 600-mile translation of North America relative to Eurasia is indicated by the average width of the Bering Abyssal Plain and the separation of three spall ranges: the Aleutian Arc (a series of islands pulled apart from about a 1900-mile segment of a great circle), the Alaskan Range (separated about 600 miles from Koryak Range) and Brooks Range (continuous with the Rockies) pulled about 600 miles from Kolyma and Chucki Ranges, due allowance being given to Carey's "Alaskan orocline." The 600-mile translation is needed to fit Grand Bank and Fleming Cap into the nearly 120° angle of the bifurcation TB at the northeast corner of the Norwegian Sea. Nansen Fracture Zone is also about 600 miles long. Although a part of the Earth Girdling Rift and Ridges (EGRR), this zone simply followed a prefracture at this place. Nansen Fracture Zone thus appears to measure the translation accurately. The 6° reverse rotation following the collision of India with Asia is registered by three abyssal plains on the east side of Asia, roughly diamond in shape: Okhotsk, Japan, and China Sea Abyssal Plains. The 6° angle is obtained from the term

$$2 \sin^{-1} x/2y \doteq \sin^{-1} x/y$$

where x is the maximum width and y is the distance from the center of each to the center of the Aleutian Arc. This reverse rotation apparently separated Italy from Africa based on an apparent print of the "boot" of Italy in Africa. At one stage of continental shift Italy and Arabia must have jammed into Eurasia backed by Africa and were still in contact when India collided to build the Himalayas. The latter collision left Italy attached to Europe, and the gap between the "foot" and its print in Africa may thus measure the separation caused by this impact. It is about 550 miles, and $\sin^{-1} x/y$ is thus also about 6° for this situation.

Arabia was only partly pulled away from Eurasia in the collision of India with Asia, as seen by the Oman Abyssal Plain and the stretching that caused the point at the Strait of Hormuz. The rest of the separation may be found between Arabia and Africa and abyssal plains in the Black and Caspian Seas in order to account for the 6° reversal at this position. Other effects of the reverse rotation due to the collision of India may be the Bay of Biscay "sphenochasm" and that which separated Sardinia from Corsica. In addition, there is a double "nematath," or taffy-like stretching, that created the points at the Strait of Gibralter, evidently in the same way as that on Arabia at Hormuz.

Reorientation of Greenland

Greenland fits nicely into the Arctic Basin, and placing it there brings the primary initiation TB sharply into focus. That Greenland came out of the Arctic Basin is indicated because this basin is really an abyssal plain, not a "sunken continent" as some have supposed. The branches of the EGRR now in the Arctic Basin are no deterrent to fitting Greenland into this basin because the EGRR developed after continental shift. (The word "shift" in place of "drift" is intended not only to imply a rapid process but also to distinguish between the initial process and the "drift" of today, also caused by ice accumulating on Greenland and Antarctica.)

The two branches of the EGRR were not there, and Greenland moved out, so the reorientation of Lomonosov Ridge is possible and it fits along the north side of the basin. Also Iceland, now part continental crust and part volcanic, seems to fit into the northeast corner of the Arctic Basin. Two of the ten sides of Greenland show shear fracture leaving lands in the northwest part of the basin together with thin sections that fill small gaps in this region. The rest of the structures at this position are basal shears, like such structures in the Atlantic Basin as Santos Ridge, Rio Grande Rise, Walvis Ridge, and Bermuda Rise. These had to have come out from beneath South America and/or Africa in order to permit fitting these two continents together. The reorientation of the Queen Elizabeth Islands into the southeast corner of the Arctic Basin shown in Figure 1 is seemingly also dictated by their shapes and that of the basin.

The best argument for the fit of Greenland into the Arctic Basin is that it reveals the initiation TB and shows it to be a threshold type. Greenland seems to have formed by one of the three branches of this initiation TB. The point A to Iceland fracture is a result of continental shift, not a primary part of the initiation of cracking. Also branch 9A in Figure 1 of Greenland merely finished the crack fracture chain that carved out Greenland, so it too is not a primary part of the threshold initiation TB. The nearly 80° southern tip of Greenland is consistent with this mechanism.

The length of each segment of a crack fracture chain should get progressively longer as the driver steadily loses energy. On this basis Greenland was cut out of Pangaea starting with the northwest branch of the initiation TB in a series of nine SB crack fractures and one coupled TB crack fracture. This was apparently the result of working of the principle of least action, in this case a maximum relief of prestresses by a minimum angle change. In other words, the maximum ice load was inside the boundaries of Greenland thus generating the nine sinstral angle changes, only one SB being dextral. This fit of Greenland shows another important correlation wherein the most intensive branch 78, the coupled TB, has its bifurcation point coincident with the Mackenzie Cone, and its third branch connects to the Brooks Range, in turn connecting to the Rockies via a crack fracture now twisted and misaligned by shifting land masses. The third branch of the bifurcation TB at point 8 is not apparent, probably because crack fractures in the Northwest Territories were too extensive for it to be identified. However, the situation would be the same even if segment 78 were a coupled SB rather than a coupled TB.

Secondary Overinitiation TB Under Southern Ice Cap

An interesting result emerges in applying the principles of brittle fracture in fitting of Australia and Antarctica into Pangaea showing what appears to be a secondary initiation TB at point B, Figure 1, which corresponds to one corner of the Great Australian Bight bordered on the south by one of the nine branches of this (two-and-a-half) overinitiation TB. It is an arc rather than a straight-line fracture, the top part having broken off and evidently fragmented. The segments of each chain are shorter for this secondary TB than in the primary initiation TB at the north pole of Pangaea consistent with a greater energy involvement. In other words, this secondary TB was probably initiated by the combined effects of the southern ice cap and seismicity. Several conditions indicate this: (a) The direction of the crack fractures is seen from forks and the coupled SB that separated Antarctica from South America and Africa to be westerly. (b) The direction of the main crack fractures, both out from point B and at the south ends of Africa and South America, is perpendicular to the main north-to-south rift that separated these two continents, probably due to the collision of oppositely traversing seismic waves. Branches running parallel to this seismicity were almost closed and broken into ridges. (c) The spalls off Australia broke completely away on both sides. (d) The forks and fork bursts from this overinitiation, though not now easily seen—apparently caused by closure due to great seismicity, seem to be characteristic of an initiation TB crack fracturing.

Table I gives approximate angles and crack fracture lengths between bifurcations and SB angle changes for the crack fractures radiating outward from the two initiation TB points A and B.

Spall Fractures in Pangaea

Spall fractures practically circled Pangaea, but there is little if any evidence of any fractures resembling spalls along the fracture zones within Pangaea showing that they are not associated with dykes of the type postulated in the theory of plate tectonics. The Aleutian Arc is a triple-spall series. Figure 1 identifies others. The spalls around Pangaea were triple nearest the poles and double far removed. They are either clearly seen, may be identified by land masses separated from the main continent, or else have been obliterated by subsequent continental collisions. The approximately 4000-mile fracture ridges from Mount Ararat (and the Atlas Mountains) to Panama are not spalls but rather a double shear known as the Tethys Shear Zone caused by opposite senses of rotation in the northern and southern hemispheres. The triple spall zones between Bering Strait and Cape Horn are used in the next section to determine the actual connection between Laurasia and Gondwanaland. They were along the front of the ice-cap thrust via the Atlantic "rhombochasm" or parallel opening, and thus they appear today for the most part as mountain ranges rather than open rifts. The triple spalls on the east side of Pangaea were not subjected nearly as strongly to these thrust forces by reason of the coriolis forces due to ice moving from the poles toward the equator.

Spalling should have taken place only above the ocean floor, i.e., only about 6000 meters deep into the continent, but once started fractures could propagate to the base of Pangaea if necessary to permit shifting. Continental drift may not always have involved the roots, rather possibly shears at the level of the ocean basins. This is indicated for Iceland and particularly India based on the nature of the basins underlying the Indian Ocean.

Shear Zones Parallel and Transverse to the Main Crack Fracture Zone

Ice driving into the primary crack fracture from point A to point B, by moving from the north polar regions toward the equator, brought into play the powerful coriolis forces.[9] These were oppositely directed rotations and apparently largely responsible for the complicated fractures from the Norwegian Sea (and Grand Bank) to Spain (and Florida), and for the Tethys Shear Zone from the Atlas Mountains of northern Africa to Panama. In the former zone there were combination shear and crack fractures. Crack fractures produced the Jan Mayen Ridge and Fracture Zone and the two parts of the nearly separated Rockall Plateau which appears to be a near spall zone with some lateral stretching. Shears also characterize the fractures between Florida, Blake Plateau and Inner and Outer Ridges, the Bahamas, now on the west side, and Fearoe, Rockall and Voring Plateau on the east side of the Atlantic Rift and Ridge.

The Tethys Shear Zone comprised, besides the Atlas Mountains, the Mediterranean Ridge, Sardinia, Balearic Islands, Ampere Seamount, and other small rises on the east side, and Lessor Antilles and Aves Ridges on the west of the EGRR. Besides shears, there were sphenochasms between Sardinia and Corsica, Spain and France, in the Gulf of Mexico, and between Yucatan and Honduras, all needing to be taken into account in the reassembly of Pangaea, as was pointed out by Carey. Cuba, Greater Antilles, Hispaniola, Jamaica, Puerto Rico, and the many smaller islands of the Caribbean were also separated largely by shears in addition to crack fractures. No effort has been made to determine where each goes except for Cuba, Greater Antilles, and the Bahamas, the fits of which seem obvious.

The Coastal Range From Panama to Baja, Lower California

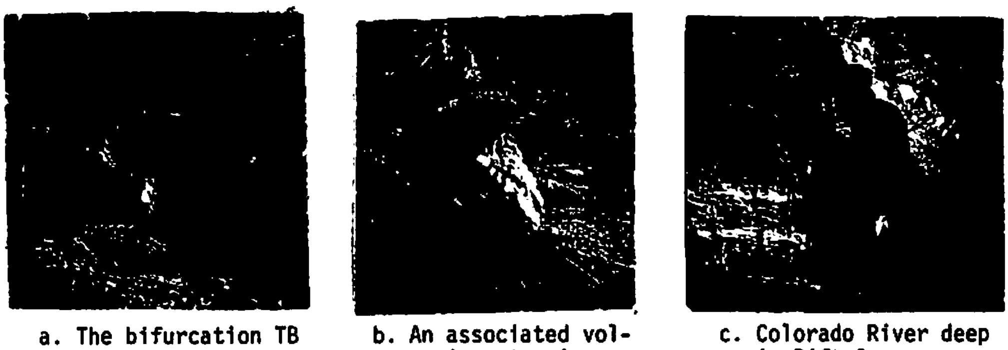
An important key in the reassembly of Pangaea is recognition of what happened to the coastal spall zone between Panama and Lower California. Sierra Madre del Sur is one section of this spall. It has pulled away from the otherwise unbroken section to the north, the other end of which is Baja Peninsula which was connected in Pangaea with the mainland (Mexico) in the peculiar notch some 250 miles from the sharp-angle change of the continental margin where the East Pacific Rise (ERS, Figure 1) cuts into the continent. The south end of Sierra Madre del Sur was initially connected with the Isthmas of Panama. When these sections are all rejoined, the rhombochasm, sphenochasms, and oroclines in this general area are all closed and/or straightened out and the proper orientations made, the space between North and South America will permit the proper fit.

Two Important Coupled SB Crack Fractures at Cape Horn and Cape of Good Hope

The primary effect of powerful secondary or seismic waves from crack fracturing both from the north and the south was to create first the coupled SB fracture with its characterizing segment about 525 miles wide between Antarctica and Falkland Plateau seen on the northwest of Antarctica. This in turn provided the impulse needed, together with seismicity, to form the shorter, about four times more energetic, coupled SB between Africa at Agulhas and Falkland Plateau. The actual form of this coupled SB can be inferred from the shape of Africa at its south end; it is roughly an (extended) isoseles triangle south of the equator. It turned the propagating crack fracture around by 120°. There are two long crack fractures that originated at the east side of the coupled SB south of Cape Horn, and they indicate that the direction of the propagating fracture was from east to west. Any other compensating condition would have left its mark. For example, the coupled SB at Natal, the most easterly part of Brazil, left evidence of a powerful shock wave distortion pattern identified with the primary crack fracturing at this position. This was a double coupled SB with the characterizing segment (2 to 3) about 1200 miles long and the other about a fourth as long, from Natal to Rio de Janeiro and from Natal to Recife, respectively. There are also the basal shears, Santos, Rio Grande Rise, and others revealing the effects of this particular combination coupled SB. Furthermore, it made the characteristic (extrapolated) 60° angle of the easternmost point of South America. The shock wave pattern goes into Africa about 700 miles toward Lake Chad from the base of the "skull" of Africa. Lake Chad itself may be due to the subsequent relief of a compression left by the shock wave. Incidentally, Gemini VI photographed what seems to be a bifurcation-type TB roughly another 600 miles beyond the shock pattern ending just before Lake Chad (Photo 62 of the December 16, 1965, flight over the Sudan, seen in NASA's book on the Gemini flights). The conclusion is justified from these considerations that it was likely seismic wave collisions that caused both the secondary, overinitiation TB at point B, the splitting off of Antarctica from Australia, and the two coupled SB crack-fracture patterns that made the separations between South America, Africa, and Antarctica.

Western North America Crack Fractures, and Plastic and Shock Wave Distortions

A nearly 400-mile-wide, 2000-mile-long rectangle of shock and plastic wave fractures and distortions occurred between Bering Strait and Colombia. These were associated with the Alaskan sphenochasm, continental shift, and the EGRR, with the second of these responsible for much of it and for pulling apart the spall ranges in this region. South of the Columbia River Basin the shock and plastic waves were enough less intense to be able to see underlying crack fractures. They appear in the shape of an irregular hexagon and an attached pentagon. There are at least three bifurcation TB fractures at the corners marked C in Figure 1. Photographs V show one of them at Supai Monument in the Grand Canyon together with closely associated fractures. Another TB radiates outward from the Shiprock Monument, best seen by flying over it. Crack fractures are seen radiating out from this famous landmark in northwestern New Mexico at close to 120° from each other in a nearly perfect bifurcation TB.



a. The bifurcation TB | b. An associated volcanic extrusion | c. Colorado River deep in Rift Canyon

Photos V. A bifurcation TB in the Grand Canyon near Supai Indian Village.

Shift of India and Australia

India not only shifted about 4000 miles but also rotated sinstrally about 60°. Furthermore, Australia broke away from Antarctica close to perpendicular to A-B.

To understand these effects it is first necessary to map the straightening of the now highly distorted regions of southeast Asia and the southeastern Pacific, i.e., the deep trenches built when Australia shifted northward. It is desirable to know by careful mapping how much the collisions of Africa and Italy distorted southern Eurasia. For this purpose a 12"-

diameter, smooth globe was used, together with measurements from the 12"-diameter NGS maps of the continental margins and ocean basins, in order to avoid the inevitable distortions in attempts to display these features on a plane surface. From this study it appears that Pangaea actually circled the globe. This is evidently why southeastern Asia and the whole southeastern Pacific happened to get so highly distorted. That is, Australia was simply thrust a bit off center against this region in continental shift. By mapping the straightening of all these bends on a globe map, the Isa-Yap Philippine-Ryudyu trench system disappears into a line, as do the three abyssal plains of Okhotsk, Japan, and China Seas (Figure 1). Gondwanaland is then seen to be about as Carey and duToit described the positions of India, Antarctica, and Australia in Pangaea and during continental drift. They also learned this by using a globe to reassemble Pangaea. The collision of India with Asia left enough of the original shorelines to be able to see how far India penetrated into Asia, and this also is indicated roughly in Figure 1.

CONTINENTAL COLLISIONS

The nature of the collisions of Italy, Arabia, and India with Eurasia are greatly elucidated by applying the principles of brittle fracture.

The Alps, Balkans, and Carpatheans

One of the first effects of continental shift was the formation of the about 4000-mile-long and 50- to 100-mile-wide (double) shear, the Tethys Shear Zone. Later this zone was apparently rejoined by welding due to collisions from Ararat to Panama when Africa drove into Eurasia. Still later, when India drove into Asia to form the Himalayas, the initial 41° rotation was reversed about 6°, the welds of the Tethys Shear Zone were broken, and it again separated from between Laurasia and Gondwanaland. The initial stage of this collision built the Alps, Balkans, and Carpatheans with characteristic transverse ridges and valleys perpendicular to the direction of the impact. Even the decaying shock waves from this tremendous collision may be seen in the form of shallow ridges and valleys some 50 to 60 miles apart in France and western Germany. The hills and valleys in Spain and Britain are both transverse and parallel to the direction of the waves, so plastic rather than shock waves evidently created these effects.[15] The rift between Scotland and England and two parallel rifts and a near rift corresponding to the boundaries and longitudinal center of Rockall, respectively, apparently tended toward spalls. Also they are in the path of the waves from the collision of Africa involving Italy's collision with Europe and the building of the Alps. The English Channel may be a stretching, like the depression in the (north-south) middle of Rockall suggesting a double spall and two near spalls but actually ending in simply plastic stretching of the crust due to the collision of Africa with Europe. In this connection powerful seismic waves may have produced enough heat to account for increased plasticity in this region.[16,17]

When India collided with Asia and drove it back 6°, the weld between Africa, the Tethys Shear Zone, and Europe was broken to produce the (crack-fracture) sphenochasm between Spain and France. The points at Gibralter on either side of the strait are likely plastic distortions due to this pull-back, which is the best evidence that the near spalls mentioned above were plastic deformation zones indicating the magnitude of heating by this great impact and the powerful shears in continental shift.

Taurus, Ararat, Caucasus and Zagros Mountains

Arabia was squeezed between Africa and Asia in continental shift to build these mountains. The same sort of shallow, transverse ridge-valley patterns seen in France and West Germany may also be seen in the center of Arabia. Also the pull-back in the collision of India is registered in the abyssal plains of the Black Sea, the south end of the Caspean Sea, and the Oman Abyssal Plain. It is also seen in the plastic stretching to produce the sharp point in Arabia at the Strait of Hormuz demonstrating, as with Gibralter, heating by the three closely related events: the rupture of Pangaea, continental drift, and continental collision rendering the crust at some places plastic enough to overshadow brittle fracture. As with the Alps, these effects were small in comparison with the powerful impacts that created Taurus, Ararat, the Caucasus and the Zagros Mountains.

Great African Rift Valley (GARV)

The collision of Africa with Eurasia and the squeezing of Arabia between them caused the GARV. Characteristic of all such impacts, the GARV was at the decaying end of an initial shock, followed by plastic wave distortions and then brittle fracture revealing directions of the waves that created these effects. The GARV had its origin in the plastic wave distortions corresponding to the highlands of Ethiopia and Kenya, decaying into crack fractures, still associated with plastic wave distortions, to form the near hexagon or pentagon surrounding Lake Victoria. This lake corresponds to the depression needed to relieve the coupled SB fractures corresponding to three of the corners of this crack-fracture pattern.

There were two, possibly three, TB fractures in these patterns. Unlike SBs, they of course needed no impulse compensation. The south end of the hexagon (or pentagon) and three of its sides correspond to the GARV. One branch of the coupled TB at its south end runs into the continental margin of Africa where Madagascar was located before the rupture of Pangaea. That it does not correspond to any earlier crack fracture, nor does it run into Madagascar, as well as its decrease in magnitude in progressing southward, demonstrate the direction of propagation of this great rift. Kilimanjaro, the highest peak in Africa, corresponds to one of the TBs in this hexagonally rifted zone.

Himalayas and Hindu-Kush-to-Okhotsk Shock, Plastic, and Crack Fracture Zone

The impact of India with Asia was far more intense than the other two mentioned above. It started as a powerful impact that drove hundreds of miles into and under Asia, like the imprint of a detonation wave on a steel plate (Photo VI. As with India, the penetration seen in this photograph is followed by plastic-wave fractures and distortions and brittle fracture, the latter seen as a triple spall and a near initiation TB at 120° between the transmitted branches in Photo VI.)

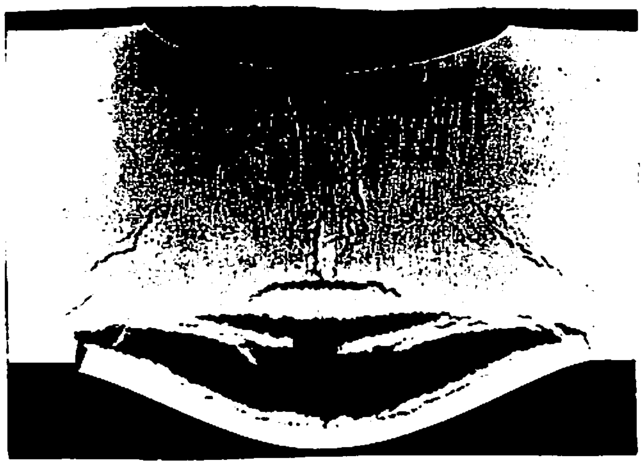


Photo VI. Cross section of mild steel plate impacted by detonation shock wave showing first the shock wave depression, next plastic wave distortions and fractures, a triple spall (nearly a quintruple one), and nearly an initiation TB. (From J. S. Rinehart and J. Pearson, Behavior of Metals Under Impulsive Loads, Am. Soc. Metals, Cleveland, 1954.)

The impact of India produced, besides the main shock wave distortions, shock wave patterns on the corners of India and plastic wave patterns toward the center. On the east side, shock distortions changed to plastic ones after about 1000 miles, then to a crack fracture zone, Khing Range, at about 1500 miles from the Himalayas. On the west corner initial shock patterns are fewer in number but closer together and extend about 500 miles from the Hindu Kush before decaying into plastic wave patterns and then elastic wave fractures. Between these two ends there are two shock wave zones in about the first 100 miles. The Plateau of Tibet is a plastic wave distortion region with the Kunlun Mountains being a crack-fracture range starting about 300 miles from the Himalayas. These shock and plastic wave distortions produced ridges, six or seven in number, making sharp (about 30°) angles with Tein Shan, the range formed in the rupture of Pangaea by crack fractures via a TB from Norway, another in the Black Sea, and a third in Kara Kum. The wave was a shock for half the way but a plastic wave before reaching the Altai Range, as seen by the long parallel range between the transverse Altai Range and the last shock wave pattern.

Beyond the Altai Range, fractures become prominent with plastic wave distortions still more so. There is a bifurcation TB on the west side of Okhotsk Sea. The Okhotsk Abyssal Plain is situated at the southeast corner of the diamond-shaped crack fracture zone that went around the Okhotsk Sea. The entire Hindu-Kush-to-Okhotsk highly distorted and fractured zone is ample proof of catastrophic continental shifts and continental collisions.

EARTH GIRDLING RIFT AND RIDGES (EGRR)

Because the EGRR occurred after both the rupture of Pangaea and its shifts, its path was predetermined mostly by compressions locked in by shock and plastic wave distortions produced in continental shift. It was these locked-in compressions that supported the rifting in the EGRR. Where these compressions were small or absent, prefractures determined the path, i.e., in these cases the EGRR followed earlier fractures. The widest and by far the most powerful opening of the rift was in the Atlantic and between Baja and Alaska. Elsewhere propagation was probably sustained largely by the overpowering compressions in these two regions.

There is basically only one primary rift in each of the two branches of the EGRR, but shock-wave distortions with accompanying fractures were produced all the way along the EGRR. They are the lateral ridges and valleys. The crack fractures along the EGRR were caused chiefly by shocks decaying to plastic waves to create lateral distortions and rifting. These fractures permitted more sudden adjustment of the prestresses, and the combined effects effectively eliminated the initial gravity anomalies that surely developed in the two most strongly compressed areas but not at all in those regions where the rift simply followed prefractures, as along the 600-mile-long Nansen Fracture Zone.

There was considerable slip-stick fracturing transverse to the rift and at angles somewhat different than transverse. It is pronounced in the Indian Ocean where the intermittent slippage was along the cracks formed by India when it shifted, possibly without its roots, across this area. Slip-stick is revealed by the different lengths of the lateral displacements and disalignment of the main rift.

Factors concerning the EGRR pertinent to the present discussion are: (a) The ocean crust is weaker than the continental crust. (b) Melting without sudden resolidification of the ocean crust took place within the most intense shock waves in this region. As for (a) the continental crust is much thicker than the ocean crust, but differences are greater than can be accounted for by thickness. They are seen by the fact that the shock-wave distortions show up over distances only about a fifth as great for the continent as for the ocean crust, e.g., the ridges paralleling the San Joaquin Valley. On the west side of the rift there are about a hundred miles of continental crust. Beyond that the shock-wave patterns show up over 1500 miles into the Pacific. East of the San Joaquin Valley the ridges, although only about 20 miles (the depth of the continent) apart extend eastward less than 500 miles. The 20-mile separation of ridges shows that fracturing also accompanied the distortions by buckling of the crust which occurs most readily when the distance apart of ridges is about the same as the depth.

(b) Melting of the ocean crust without immediate resolidification is demonstrated dramatically by a zone about 150 to 200 miles wide and about 1500 miles long adjacent to the west coast of North America south of the Mendocino Fracture Zone and another covering nearly all of the ocean floor north of Mendocino to Kamchatka. In these regions shock-wave patterns are missing in the ocean crust but not in the continents closer to the rift valley. They show up again farther out into the Pacific where shock intensities had decayed appreciably. The ridge-valley patterns are readily apparent between San Joaquin Valley and the west coast. This may be explained by the possibility there was enough heating by the combined processes of the rupture of Pangaea, continental shift, and the EGRR so that sudden resolidification within the shock wave did not take place in the ocean crust because permanent heating was too great. However, it did take place in the continental crust even though the intensity of the shock wave was greater, i.e., closer to the main rift.

DATING THE RUPTURE OF PANGAEA

Nonequilibrium (NER) from Equilibrium Radiocarbon (ER) Dating of the Rupture of Pangaea

Farrand and Gajda[21] published ER ages vs. uplifts for nine locations along the fossil shorelines of the receding Hudson Bay as the land masses gradually uplifted toward isostatic equilibrium after the sudden denudation in the loss of a great ice cap, in my judgment due to the rupture of Pangaea. "Sudden denudation" is clear from the shape of these waves. Indeed their uplift-in-time vs. ER-age curves have the same shape as the uplifts for any isostatic unbalance, e.g., the corresponding uplifts on the other side of the split zone, in Fennoscandia determined by direct measurements of their rates and total amounts of uplift as described by Heiskanen and Vening-Meinesz[26] and treated in the last section of this paper. Farrand and Gajda then concluded: "Radiocarbon dates and uplift curves show this uplift is truly glacio-isostatic." The maximum values of the dates read from the end points of the age vs. uplift curves, corresponding therefore to the time the uplifts began average 8600 ± 1900 BP. Farrand and Gajda studied ages of a marine life that had lived along the fossil shorelines. Keith and Anderson[31] showed that such life is generally contaminated with old carbon from sea water and gave an average ER age of 1750 ± 600 years for living specimens as a correction for dating when such anomalies occur. If this correction is applied to the average beginning time of these nine curves, the average after the correction is 6850 BP. Subtracting from this the 1963 correction of Lingenfelter (575 years) gives an ER age of 6275 BP. When the NER correction[15] is applied to this result, the nonequilibrium radiocarbon (NER) age is 4950 BP or 3000 BC. (There is unfortunately inherent in this value an error of ± 460 years from Keith and Anderson's stated variation plus another ± 1660 years from the spread in the assymtotic results read from the Farrand-Gajda curves.)

Paleomagnetic Dating of the End of Pangaea

Continental drift obviously caused the north magnetic pole to move out of position. Because the relaxation time of paleomagnetism is comparable to that of the uplifts and radiocarbon as to order of magnitude,[33] it should still be seen as is the case. Hope[28] described it as a fossil magnetic pole in Ellesmere Island, and the apparent magnetic pole to which the magnetic lines of force point in the eastern part of the Arctic Basin come together to form a single magnetic pole in the reassembly of Pangaea. The very existence of this fossil magnetic pole is proof that Pangaea broke up only a few thousand years ago, consistent with NER and gravity anomaly dating of this rupture. That is, it would take only about 30,000 years for the remnant magnetization to become nondetectable if, as indicated by the studies of Nagata,[33] the half life of paleomagnetism is comparable to those of radiocarbon and gravity anomalies.

Fennoscandian Uplifts From Gravity Anomaly Dating

The initially rapid uplifts in Fennoscandia, at first immediate to relieve the elastic component of the total depressions, with the elastic and plastic depressions initially totaling over 2000 feet, have decayed exponentially since their beginning in a manner characteristic of sudden unloading of the crust and in no possible way related to melting of the ice cap in place. They were analyzed by Heiskanen and Vening-Meinesz[26] by accurate methods of classical physics. For simplification, the physical constants involved, each of known (constant) value, are combined in a single constant ζ_0. The appropriate equations are then

$$\zeta = \zeta_0 e^{-kt} \tag{1}$$

$$\dot{\zeta} = \frac{d\zeta}{dt} = -k\zeta_0 e^{-kt} \tag{2}$$

and

$$-k = \dot{\zeta}/\zeta. \tag{3}$$

Here ζ is the uplift at time t near the center of the gravity anomaly, $\dot{\zeta}$ is its rate of change in time, and k is the reciprocal "relaxation time" t_m^{-1} ($\tau/0.693 = t_m$ where τ is the half life of the exponental decay process.) Heiskanen and Vening-Meinesz gave $k = 6 \times 10^{-12}$ per second, so the relaxation time is 5280 years. They also gave 270 meters for the total uplift to date, and 200 meters yet to go to establish isostasy. Therefore, from the equation (after integration)

$$-\ln(1-\zeta/\zeta_0) = kt, \tag{4}$$

the time since the beginning of the uplift is 4500 years, or about 2550 BC based on about when this work was done. This shows that Genesis 7:11 referring to breaking up of "all the fountains of the great deep" was a historical recording of the terrific catastrophe. Eber may not have learned what had happened to Pangaea until a hundred years later which may be why he named his son Peleg for the rupture of Pangaea (Genesis 10:25) a hundred years after the event.

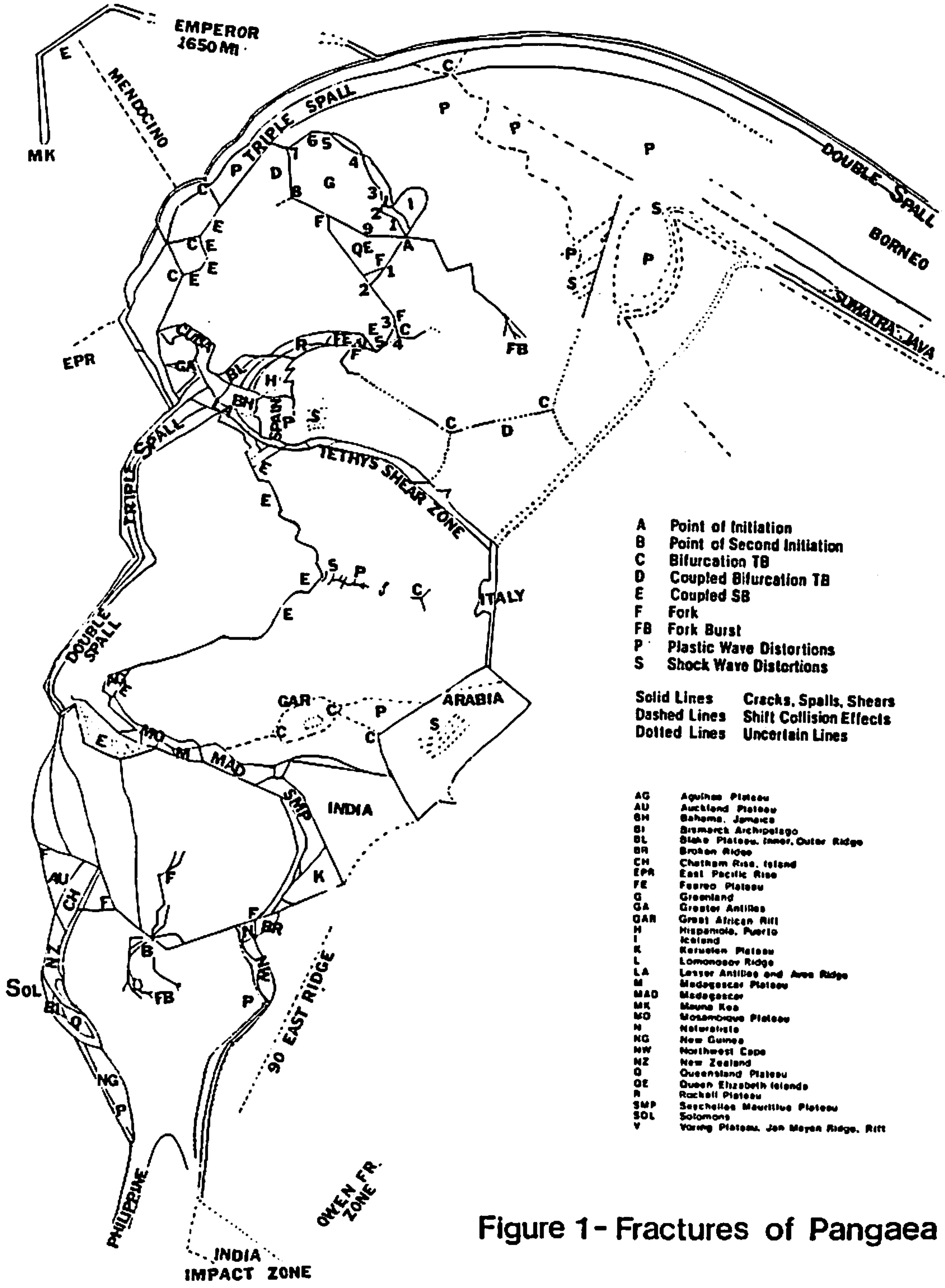


Figure 1 - Fractures of Pangaea

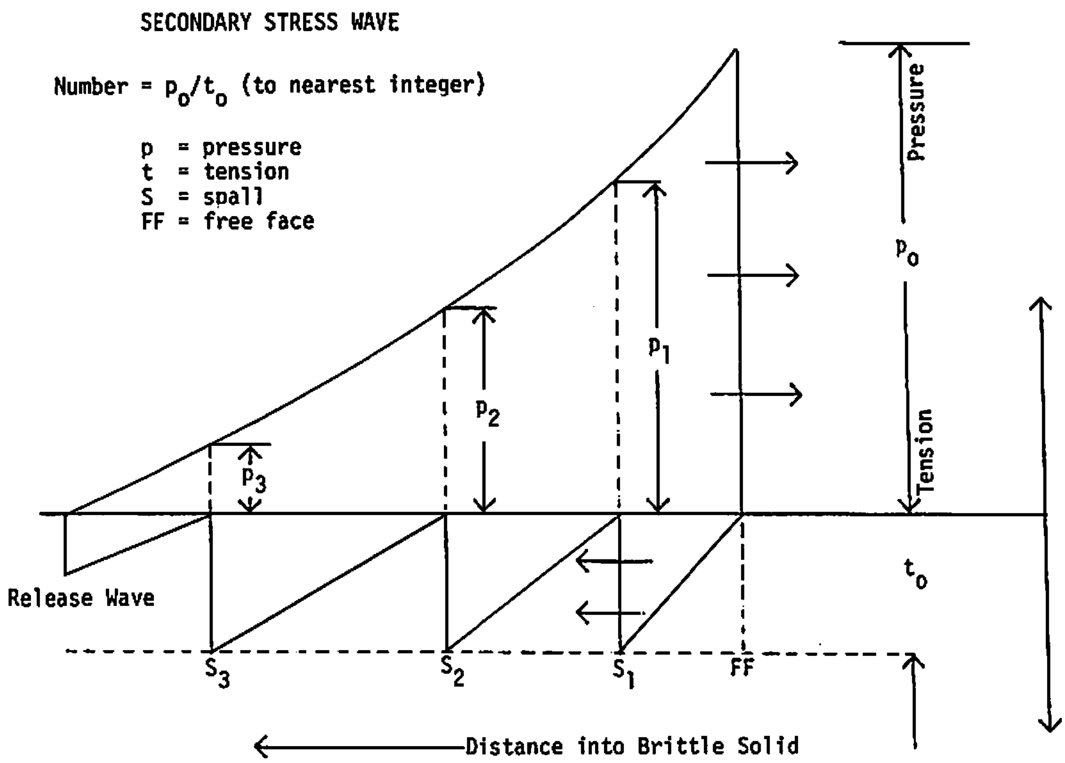


FIGURE 2 - Mechanism of a Triple Spall From a Free Surface

Table I - Approximate Angle Changes and Lengths Along Initiation Triple Branch Chains

Primary Initiation TB at A

Angle No.	Angle Δθ	Type Change	Segment No.	Segment Miles
North-South Branch (A to 1 = 0°)				
1	0/60	F	A1	340
2	-60	SB	12	310
3	20/40	F	23	310
Fleming/Grand Bank			35	530
4	-60/60	TB	34	340
Greenland Branch (A to 1 = -120°)				
1	-35	SB	A1	210
2	35	SB	12	230
3	-30	SB	23	280
4	-20	SB	34	490
5	-45	SB	45	510
6	-45	SB	56	260
7	-60	Coupled	67	390
8	-60	TB	78	630
9	-20	SB	89	1150
A	-80	Terminal	9A	410
Urals Branch (A to 1 = 240 or -120°)				
1	60	SB	A1	390
2	-80	SB(?)	12	390
3	100	SB(?)	23	390
4	-40	SB	34	390
5	45	Fork Burst	45	660
Forks	30		5F1	120
	15		5F2	320
	-15		F2F3	90
	-30		5FF4	50

Note: The average length of crack fracture between segment changes is greater than 1000 miles in South America and Africa.

Secondary Initiation TB at B

Angle No.	Angle Δθ	Type Change	Segment No.	Segment Miles
Wilkes Subglacial Basin Branch (B to 1 = 0°)				
1	60	SB	B1	130
2	-60	SB	12	130
3	60	SB	23	130
4	-60	SB	34	130
5	60	SB	45	410
6	-60	F	56	280
7	-60	F	57	390
Wilkes Subglacial Basin (B to 1 = 30°)				
1	-50	SB	B1	195
2		an arc	12	720
Great Australian Bight (B to 1 = 60°)				
1	30	Arc	B1	390
Main Branch - Right (B to 1 = 90°)				
1	-60	SB	B1	670
2		TB	B2	1220
Australia - First Right (B to 1 = 120°)				
1	-60	SB	B1	350
2		F		530
Australia - Second Right (B to 1 = 180°)				
1	-60	SB	B1	410
2		FB	12	500
Australia - Third Right (B to 1 = 210°)				
1	-30	SB	B1	340
2		FB		260
Australia - Fourth Right (B to 1 = 240°)				
1	-40	SB	B1	530
2		FB*	12	600
Main Branch - Left (B to 1 = 300°)				
1	15/-15	F	B1	600
F1R	-60	SB	FF1	ca500
F1L	-60	SB	SB	600

*complicated and uncertain

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DISCUSSION

Question #1: *Was there enough temperature and thermal conduction time to allow for postulated plastic flow in continental granite?*

Question #2: *The Andes range is not mentioned in this paper. Is this range the result of forward-thrust frontal-edge crustal buckling?*

Question #3: *You speak of Earth Girdling Rifts and Ridges (EGRR) as being formed later than and providing stress relief from the results of the break-up of Pangaea through explosion-like processes. You identify the initiation points and approximate timing of Pangaea break-up. Do you have thoughts as to the where and when of EGRR initiation and propagation?*

Comment: *This technical paper is a tremendously valuable contribution to geomorphology. With his illuminating brittle fracture mechanical experimentation at explosive rates, he provides a model of required pre-stresses, governing triple branch and single branch/coupling cracking geometry with accompanying regional plastic flow and spalling. Who else has provided a really plausible basis for shapes in the big jig-saw puzzle pieces of Pangaea break-up and reassembly? His three short-term-time answers on dating are similarly valuable for creationism.*

The professional and pained cry of bio- and geo-scientists is to "Stay in your own field of expertise and don't pretend to be an expert in our discipline." This logic does not hold water. Kekule and Cooper deduced the structure of benzene ring from a background of building architecture and Michael Ventris, a linguistic novice, unravelled Minoan B Script to the astonishment of translation scholars unsuccessful after 70 years. A Swiss patent clerk forever shook the foundation of Newtonian physicists. Why then couldn't a physical chemist/metallurgist and internationally recognized explosives authority of Nobel Award stature provide a needed fresh breeze into the geology and geography of our planet?

Burton E. Tew, Jr.
Magna, Utah

It is one of three great merits of the author to have introduced the non-equilibrium model of ^{14}C dating. The observed discrepancy between the present rates of formation and decay of ^{14}C is a strong hint to a young age of the earth's atmosphere and provides an impressive reduction of any high ^{14}C ages found in the literature. It would be desirable that all creationists familiarize themselves with non-equilibrium ^{14}C dating for which this article supplies the analytical, graphical, and numerical tools. A detailed presentation of the problems and results of dendrochronology would have been of interest.

Prof. Dr. Hermann Schneider
Heidelberg, Germany

CLOSURE

Question #1: The rates of plastic flow in the granite corresponding to isostatic unbalance in the earth's crust are accurately known. The depression zones beneath the ice sheets formed in but a few thousand years as shown by the definitive studies by Heiskanen and Vening-Meinez. In the rupture itself, which required only a few hours, there was no plastic flow but only brittle fracture. Continental shift, following fragmentation of Pangaea, had to involve plastic flow, but prior to the continental collision which took place, primarily only at the level of the "Moho," and in the parts of the ocean crust that had to be bent downward on the advancing edge and upward on the trailing edge to permit the shifting. The forces of ice driving into the fractures from the poles were ample to cause this flow in a relatively short but unknown period. However, considering the circumstances it appears that no more than a few months were required for most of the shifting. The marks of rapid plastic and some shock (melt) flow associated with continental collisions toward the end of the shifting were carefully described not only in this paper but also in my book, Prehistory and Earth Models, unfortunately now out of print. Of course these problems were first addressed by Hapgood and Campbell in their book of 1958, The Earth's Shifting Crust. Their work, incidentally, was endorsed by Nobel Laureates Albert Einstein and Percy Bridgeman of high pressure fame.

Question #2: The Andes (and Rockies) originated, according to my model, in spall fractures. It was the westward thrusting under the drive of the ice caps that caused these fractures to buckle into the great Cordillera and related ranges. The answer is thus yes, "the Andes range . . . was the result of forward-thrust frontal edge crustal buckling."

Question #3: By applying principles of (propagating-type) brittle fracture one may determine the direction of crack propagation in the crack-fracturing of britle solids. The article points this out and identifies the points of initiation under the two great ice sheets of Pangaea which caused Pangaea to break up by tensile fracture, and its fragments, the continents, to shift rapidly thereafter.

The questions raised by Mr. Tew are particularly helpful by way of emphasizing the main thrust of my article. I wish to thank him also for his interesting comment. It is not at all uncommon for outsiders to see situations largely hidden from the view of insiders who see the trees but not the forest. The fresh approach should be welcomed by one and all irrespective of the field of endeavor. In many circles it is, but when it is not one may logically surmise a basic underlying weakness of the endeavor.

While I greatly appreciate Mr. Tew's remarks I feel obliged to point out that the "Nitro-Nobel Medallian" awarded me in Sweden in 1969 does not even approach in prestige the tremendous Nobel Prizes. The fact that the medal is actually identical on its front face with the medals of Nobel prizes awarded annually in Sweden is perplexing to many, as it was to me when I received it in the Nobel Foundation Building in Stockholm in May 1969. It is to be recognized as a signal honor on par, for example, with my E. V. Murphree Award of the American Chemical Society of 1968 and my 1973 Chemical Pioneer Award of the American Institute of Chemists. U. S. District Court of Utah Judge Alden Anderson was required to analyze this award when the adverse party challenged me in citing it in my qualifying testimony. An affidavit by De. Per Anders Persson, of the committee in Sweden that nominated me, provided part of the basis together with other documents and circumstances connected with it in the case Robin Ritter, et al., vs. Ingersoll-Rand, Civil No. C-82-113A, ruled in April 1985. His ruling placed in proper perspective as one of two (each shared) prizes given relating to the hundredth anniversary of Alfred B. Nobel's monumental developments in the field of explosives.

I am especially appreciative of the generous and sagascious comment of Professor Schneider. I heartily endorse his admonition for one and all to familiarize themselves with the bases of the non-equilibrium radiocarbon model for the reasons he gave, that it will clear up many discrepancies, some of which I pointed out in connection with new and important evidence supporting the non-equilibrium radiocarbon dating method.

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