The expanding Earth: a sound idea for the new millennium

Giancarlo Scalera
Istituto Nazionale
di Geofisica e Vulcanologia
Via di Vigna Murata 605
00143 Roma, Italy

Abstract

A short review of the more relevant modern arguments in favour of the conception of the Earth in expansion is provided. The advantage of the expanding planet idea is a common explanation of several outstanding problems coming from palaeontology, palaeomagnetism, geology and climatology. All these problems should be regarded as be a sort of distortion effects, which arise if we try to reconstruct the situation of old geologic times adopting the modern Earth's radius – the distortions become larger and larger as we came back in time. As a consequence the expanding Earth could be considered a natural generalization of the plate tectonic. A strong support to this generalization came from the simple and united explanation that can be found in the expanding Earth of the classical geodynamic phenomena of the polar motion and the true polar wander by an inversion of the paleogeographic position of the triple points. The conviction is expressed that basic information about this old global tectonic conception should be provided in secondary school and university courses.

Introduction

Only in the second half of the XIXth century and up to 1930, the planetary expansion idea found a strong supporter in the Italian Roberto Mantovani (Parma, 1854 - Paris, 1933), who expressed the first main concepts of a global Pangea break-up (Scalera, 1997, 2001b) in several papers (one of these was quoted by Wegener in its famous book), and in 1888 in a book of Yarkovski (1844-1902) with argument that linked ether physics to gravity and chemistry.

Mantovani expressed clearly the concept of an Earth completely covered by a continental crust, which suffered a progressive distension and fracturation in large plates by an increase of the inner volume due to thermal expansion of the material – plasma – contained in the Earth under the crust. The Mantovani ideas were developed successively in Germany, for nearly half a century, by Hilgenberg (1933, 1965, 1974), in Russia by Bogolepow (1922) and more episodically by some others (Scalera, 2001; Scalera and

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Why expanding Earth? – A book in honour of O.C. Hilgenberg. INGV, Rome, 181-232.

Braun, 2001). In the next generation the names of Blinov (1987), Carey (1975,1976), Creer (1965), Dearnley (1965), Egyed (1956, 1969), Owen (1981,1983ab, 1992), Milanovsky (1980), Chudinov (1998), Shields (1979,1983,1996), Kremp (1992), Davidson (1983, 1997) are to be noted.

This line of research has appeared increasingly important especially because much palaeontological evidence – somewhat paradoxical if an explanation is sought in the constant radius view – can be resolved all contemporaneously, while a plethora of different solution have to be proposed for each of them in constant radius global tectonics.

The reason for this paper is mainly to explain the point of view of a minority, sometime considered heretical minority, but which has no acrimony towards the plate tectonicists majority, especially because the development of the expanding Earth theory goes parallel to the development of plate tectonics, being possible progress in expansionism only if the huge international efforts of plate tectonicists to create new databases, and to get new results, allow new and better grounded interpretations in the expanding planet view.

General overview

Subduction

Many versions of the expansion of the Earth exist and the main difference among them is the acceptation or the rejection of the subduction process. Certainly the expanding Earth subduction process is at variance with the plate tectonic concept. While the many thousands of kilometres (up to more than a hemisphere: the Pantalassa) of subduction admitted in plate tectonics is unacceptable, few hundreds of kilometres of subduction could not disturb expansion tectonics.

But the more recent high-resolution global mantle tomographic models (Fukao *et al.* 2001) provide images of subduction zones very different from the expected ones. The narrow high velocity zones under the Asiatic circum-Pacific arcs appear not prolonged toward the lower mantle but deflected horizontally into or under the 400-700km transition zone, and a horizontal flow must be admitted (Fukao *et al.* 2001). In some cases the leading edge of the cold 'slab' appears to have an upward tendency. In this new imaging, the total length of the deformed 'subducted slab' does not exceed a thousand kilometres and the problem arises of why this system appears so strongly blocked (Fukao *et al.* 2001). This is at variance with rheological theoretical simulation (Ranalli, 2000; Ranalli *et al.*, 2000) of a subducing oceanic slab which, when it reaches the depth of 700 km, its own increasing downgoing buoyancy being able to drive the slab towards the bottom of the mantle. Moreover laboratory scale experiments

(Faccenna, 2000) with different kind of slabs (stiff or weak) show that stiff slabs tend to curl like wood shavings not in agreement with the Benioff zone geometry. Weak slabs tend to initiate retrograde subduction, with retrograde trench migrations and an opening of the back-arc basins proportional to the backing of the trenches. All things that suggest a limited extent of subduction, and a too delicate equilibrium among rheological parameters which the actual Earth cannot easily fulfil.

Concomitant high resolution imaging of the mantle plumes under the major hot spots (Rhodes and Davies, 2001) shows that the plumes can be followed up to at least 800 km nearly vertically in the mantle, without the strong deviation from the vertical that should impose a convective circulation. The interpretation of these new results in the expanding Earth theory could be simpler: a thousand kilometres is the maximum length the 'subduction' (if any) has covered from Triassic to the present time. On these bases, in more radical views, the subduction process should be heavily revised or replaced with a new concept closer to reality, and probably all the plate tectonics paradigm should be deeply transformed in a more general view on other philosophical foundations. Possible non-subductive models can be proposed (Chudinov, 1998; Scalera, 1994, 1998) in describing the trench-arc-back-arc zones.

Distortions

Global expansion tectonics has projections to the past and to the future increasingly different from the constant radius tectonics projections. The situation is analogous to the distortion of space-time as we pass from slow velocity to velocities comparable to the velocity of light *c*. As a consequence we must drop Newtonian mechanics, continuing to use it within the limit of low velocities, and adopt the more general relativistic mechanics. Likewise we can observe typical distortions going in the deep geological past because the sialic crust, once covering the whole surface of an ancient smaller globe cannot adapt itself to the modern larger size of the globe. Indeed, large tears are observable in the Pangea reconstruction that appears crossed by huge artifactual inlets like the Tethys Sea, Arctic Sinus, Austral Sinus, *ecc.*. The largest of the inlets, the Tethys, is the most problematic one because of the proportionally large geological, palaeontological and geophysical problem posed to the scientific community. Another expression of the distortions has to be considered: the alleged existence of a more-than-hemispheric Pantalassa, age greater or equal to Triassic, a huge amount of oceanic lithosphere which has to have been completely consumed during the Post-Triassic times – a process too difficult to imagine. A symptom of the improbable existence of a so large Pantalassa is the inexistence of any remains of Pre-Triassic ocean floor that should be present in each of the many 'tears,' or sinus, of the Pangea, and the complicate models that are proposed to eliminate the ancient sea floor crust in all these gulfs. In view of the increasing difficulty encountered by the subduction concepts (Fukao *et al.* 2001), it appears very hard to try to explain the disappearance of Tethys, Arctic Sinus, Austral Sinus, *ecc.* In the expanding Earth framework there is no need to explain disappearance of such high areal amount of marine inlets, because these areas did not exist or were very small and narrow indeed.

Coincidence of maximum ocean floor ages

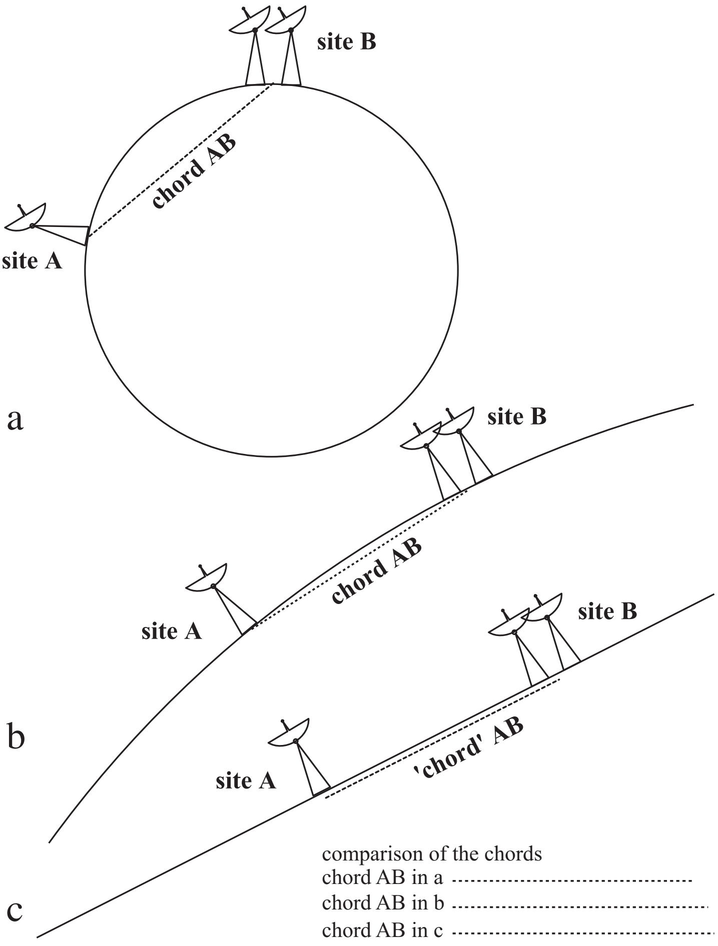
A related complementary argument is the equality of the maximum age of the sea-floor in all the oceans, Mediterranean Sea included. The maximum age is the Jurassic and because the independence of the spreading rates of the different oceans (*e.g.* the Pacific spreading rate is up to five times the Atlantic one) a Pacific spreading rate only a little less than the actual should have been sufficient to expose the Trias Pacific sea-floor, while a spreading rate only a little greater should have erased the Jurassic Pacific sea-floor. On the contrary, adopting an expanding Earth view the huge Pantalassa lost any reason to be hypothesized, the Pangea's tears disappear and all the oceans have started their spreading roughly at the same time.

Differences in the Recent

The two conceptions, constant and variable radius, are nearly coincident for the Recent situation and plate kinematics – the more conspicuous differences arise in the analysis of the Pacific Hemisphere. The GPS (Global Positioning System) and VLBI (Very Long Baseline Interpherometry) data are generally analysed without taking into account a possible increase of the Earth's radius. A global analysis performed by Heki *et al.* (1989) has given as a result a generalized annual contraction of the VLBI baselines, proportional to the baseline length. This can be easily explained by an increase of the radius because such a radius increase, if not inserted into the computation, is underhandly equivalent to a decreasing of the geocentric angle between the two stations, and erroneously interpreted as a contraction of their distance. Gerasimenko (1993) has accurately selected the sites of GPS and VLBI geodetic stations, discarding the stations on orogenetic locations, and – leaving the radius as a free parameter – has obtained an annual radius increase of ≈ 4 mm/year. While on the basis of my palaeogeographical reconstructions the mean annual radius increase is of nearly 1.5 cm/y, the new awareness of the Earth today in a minimum of its sea-floor half spreading rate (McElhinny and McFadden, 2000) could support an expansion rate of only a few millimetres per year, in agreement with the Gerasimenko results.

Fig.1

Problematic VLBI computations.
In this figure all the parabolic antennas in a, b and c are oriented in the same direction in the celestial reference frame.
The radius of the Earth increase from a (R = 6371 km) to c (R = ∞). Each antenna in site B has the same angle with respect to the local reference frame. Albeit the chords from site A to site B also increase passing from a to c, see the comparison, if the observer does not take into account the increase in radius, he can reach a wrong conclusion claiming that because in c the three antennas have the same angle in the local reference frame, then the distance of the site A from site B is zero. A spurious contraction of the chords hides the real Earth's expansion.



A new analysis of Nasa data has been performed now by Gerasimenko (this book, pag.972-424) using only the Nasa chords *as they are* and adopting a cool criterion of selection not based on geological considerations but discarding vertical displacements of the VLBI stations greater than 4mm (in absolute value). With these rules the detected possible expansion is reduced to nearly zero. In my opinion the impossibility of detecting the Earth's expansion from the Nasa chords can come from a basic problem in Nasa's chords themselves. As explained in Fig.1, if the observer computations, based on the angular VLBI raw data, are performed without taking into account the radius gradient, a spurious contraction of the chords is overimposed on the real Earth's expansion. It is evident that a vicious circle, difficult to avoid, is present, and that a new computation methodology should be found.

Change of perspective view

The classic paper of Jason Morgan *Rises, Trenches, Great Faults, and Crustal Blocks* which appeared in 1968 in the *Journal of Geophysical Research*, was the first attempt of synthesis on the sphere of the plate tectonics principia. The concept of transform-fault becomes central to the deduction of the rotation poles and the sense of motion of the plates. The readers of Morgan's paper do not immediately understand why the shorter transform-faults were preferred to the longer and better delineated fracture zones as direction indicators of the plate motion. From the reading between the lines of the work it is finally possible to understand that the possibility of adopting the fracture zones in place of the transform fault was initially considered valid by the author and by his colleagues, but that this eventuality was felt as strongly embarrassing if applied to the interpretation of the Pacific plate motion. Morgan, in the discussion of the ocean bottom zone off the western North American coasts, writes:

> 'This old fracture zones [Mendocino, Pioneer] indicate that the Pacific once moved away from North America toward trenches off New Guinea and Philippines. About 10 m.y. ago this pattern changed, and the Pacific now moves toward the Japan and Aleutian trenches.'

Indeed, the very long fracture zones of the North Pacific connect the American coast from Canada to California to the deep-sea trench north of New Guinea. It is easy to realize that Morgan and his successors must not have used with complete generality the fracture zones as they could have done in the Atlantic case, and then they were compelled to retreat on the transform faults, hypothesizing a radical change in the direction of the Pacific floor motion. This change should have happened only few million years ago, practically today, with respect to a Pacific maximum sea-floor age of 180 Ma, and then this Morgan interpretation appears highly untenable. As matter of fact seismicity exists (see figure in Morgan 1968) also on the segment of the fracture zone that, south of Juan de Fuca, continue up to the American coasts. But Morgan in the quotation reported before seems to be willing to assert that the same fracture zones *are* indicators of movement direction (*indicate that*). All of this makes clear to us how uneven and tormented the years were in which the principia of plate tectonics were formulated. In any case a Pacific plate moving for nearly 180 Ma away from North America means, in the old Morgan interpretation and assuming an increasing Earth's radius, that Laurentia has moved away from the trenches off New Guinea.

This change of perspective – with the assumption of a more convenient one not in conflict with a constant Earth's radius – was followed by other different attempts to frame the Pacific crust, and its volcanic ranges, in a coherent kinematical pattern. Noteworthy is the attempt to interpret the trend, in age and in shape, of the long volcanic chain Emperor-Hawaii and of its elbow west of the Hess Plateau. The two branches of the chain and their two different directions are interpreted as the result of two different subsequent directions of motion of the Pacific ocean-floor, 180-60 Ma and 60-0 Ma, on a fixed sublithospheric plume, but both the directions do not agree with the trend of the fracture zones which should have indicated, at least in the past, the displacement of the oceanic plate.

In the expanding Earth tectonics, however, just the principle rejected by the pioneers of plate tectonics should be assumed. The great fracture zones should be regarded as the main direction traces of the plate motion, and this should be valid also in the North East Pacific, where the Juan de Fuca transform faults seem to indicate a different trend. Moreover, this so clear fallacy of the transform zones as indicators of the plate kinematics should became an element for consideration of the possibility to provide a more realistic account of the way progressively a fracture zone came in existence, with a growing edge connected to a transform fault. The disagreement in the directions of the transform and fracture zones, on which the choice of the originators of plate tectonics was based, should come about naturally based on a new explanation, which should show us the reason why it is better to favour the fracture zone direction as a kinematical trace.

This need to revise the old kinematical concepts and to made new assumptions, also comes from the inadequacy, banally evident, of the classic principia of plate tectonics with respect to the presence of the so called triple points.

The triple point paradox

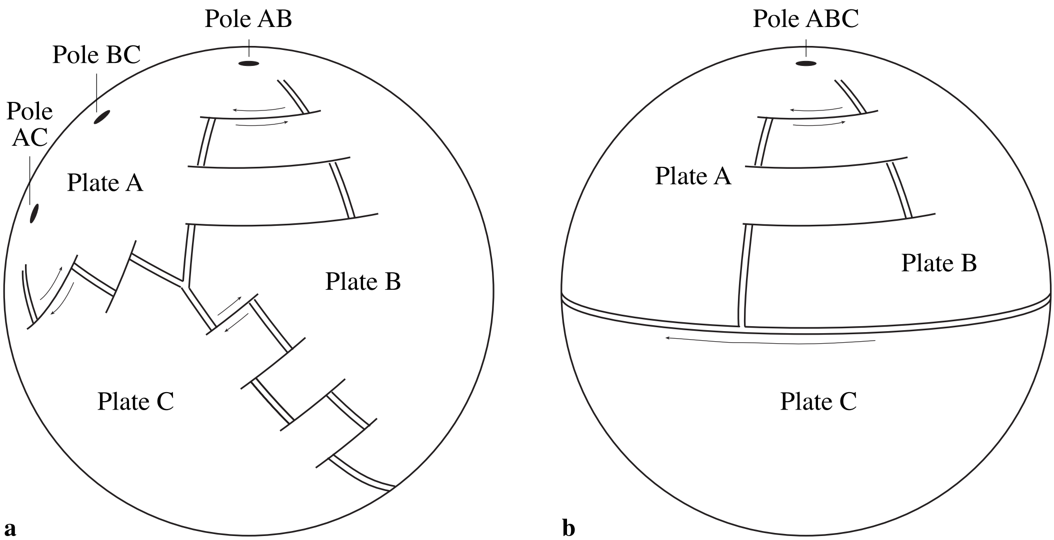
On the sphere the lithospheric plates are hypothesized to move diverging two by two rotating in opposite directions around an imaginary Eulerian pivot, called the common single rotation pole. But great problems arise in the zones where three plates borders together – as petals of a clover – in an only point called triple point. It is possible to prove that such principle of the common rotation pole cannot generally be applied to all three plates' pairs, and then that this fundamental assumption of plate tectonics is weak, although it is claimed to be deduced from observations. A strict application of the geometric rules of plate tectonics implies that the triple points should non exist because they are not deducible from the rules without paradoxes. In particular the concepts of common rotation point and of transform fault as kinematical index turn out to be mutually in conflict, and the elimination of one or both of them become necessary.

Plate tectonics prescribes that the motion between two plates is governed by the rotation around the common pole, a Euler's pole, because only in this manner is it possible to assign to the transform faults a role of directional trace of the mutual plate movement. Why their extensions, the fracture zones, are not used in the same sense, is not explicit in the theory, even if some clues can be sensed by from historical considerations.

If the prescription is strictly applied to a triple point zone, as represented in Fig.2a, we must assign contemporaneously two different common rotation points to each plate, a clearly paradoxical thing (Cronin, 1992). In Fig.2b a triple point allowed by plate tectonics is represented, it is a banal solution with all the three common rotation points coincident at the same point, and with a plate, the B plate, in a state of transcurrent motion with respect to at least one of the other two A and C plates. The more then evident non-applicability of plate tectonics to the triple points, along all the mid-oceanic ridges, poses the serious problem of the reliability of the plate motion models like the NOUVEL and similar.

Fig.2

The triple point paradox. If we have to apply the plate tectonics rules, in the general triple point case, we must assign, say, to the plate A two different common rotation pole, the first common with B and a second common with C. This is impossible.



Shape conformities in the Pacific

An argument linked to the preceding one about fracture zones is the existence of shape conformities in the Pacific hemisphere (Scalera, 1993), which are unexplained (but also not admitted) by plate tectonics.

Discussions about the significance of the matching similarities in global geotectonics are very old. The cartography developed starting from a few decades after Columbus' journeys allowed many people to express definite ideas concerning an ancient contact between Africa and South America (Scalera 2001), and, in 1858, a book by Antonio Snider Pellegrini was published containing two maps which illustrate the reconstruction of a supercontinent and its subsequent dispersal. The next palaeogeographical map was drawn by Wegener, only fifty years later, and was published in his more grounded book of geological and geophysical

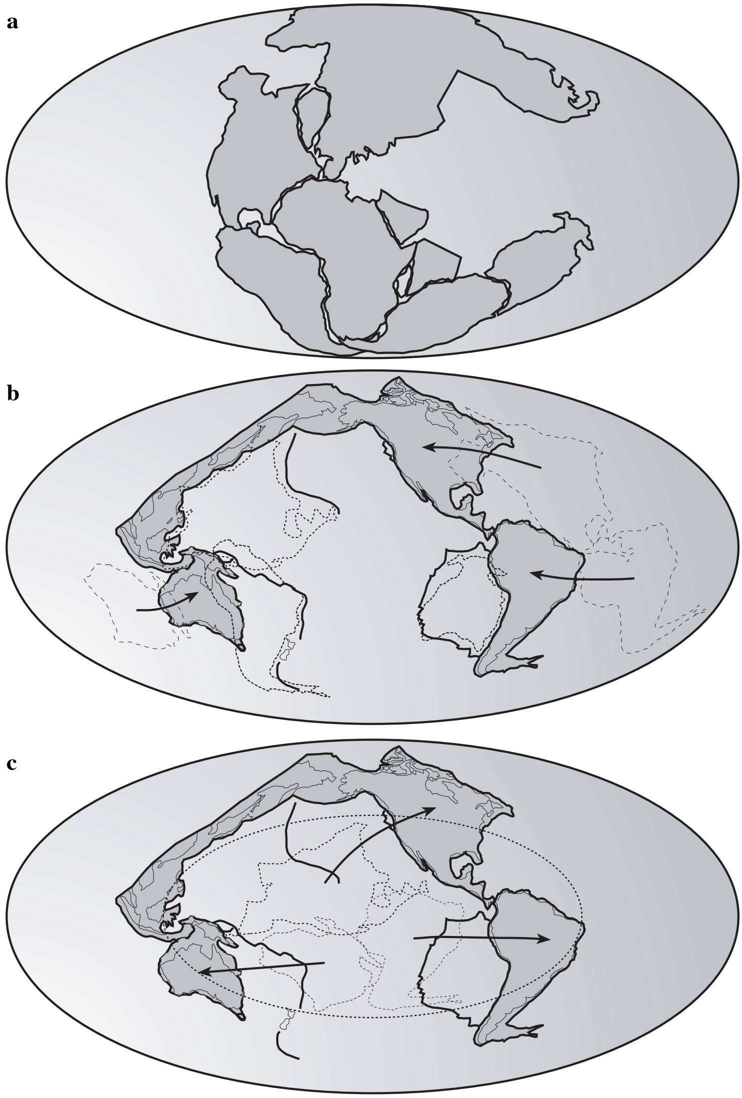


Fig.3
Shape conformities in the Pacific Hemisphere.
a) The classical reference Pangea.
b) Besides the classic similarities of shape observed between opposite coasts in the Atlantic, some conformities are observable in the Pacific periregion among continents and basins, e.g. between Laurentia and the North-Western Pacific basin (bounded by trenches north of New Guinea, Asian trenches and Emperor Hawaii volcanic chain), between Australia and Nazca basins and between South America and the Coral-Tasman Sea. It is truly impossible for this pairs of similarities to have been created if the path of the continents have followed the arrows connecting in b) the Pangea positions of the continents and their Recent positions.
The basin conformities of the continents are on the opposite side of the destination hemisphere!
In c) it is easy to appreciate that if the Earth was once, before the Pangea break-up, smaller than the modern Earth, approximately half radius Earth, the displacements of the continents from Pangea (which covers all the planet) towards the modern positions is mostly radial (with rotations), coming from starting positions which are mere overimpositions and juxtapositions of all the conformities.

correlations. The existence of similarities among coastal profiles is therefore the origin of the conjectures, which led to modern mobilistic tectonic theories.

From the point of view of the expanding Earth theory also the Pacific basin should have come from fractures and spreading of a continuous sialic crust (initially without oceans) which completely covered a smaller-radius globe. It is therefore a valid expansionist research problem to search for traces of these fractures in the Pacific, expecting that it was possible to detect them as it has been in the Atlantic.

Indeed, a class of similarity actually does exist in the Pacific hemisphere and it is particularly relevant (Fig.3). Chile's continental scarp can be matched towards west, to the eastern Australian cordillera, while the east South American outline goes in correspondence to the Tonga Kermadec Maquarie lineament. This is an 'entire surface shape similarity.' The same type of similarities can be found between the Australia and Nazca basins, and in the northern part of the Pacific, between Laurentia and the North-Western Pacific basin (bounded by trenches north of New Guinea, Asian trenches and Emperor Hawaii volcanic chain), where the North American Cordillera matches the equatorial trenches northward and eastward of New Guinea, with – moreover – the ovoidal plate of Juan de Fuca and Gorda fitting the New Britain plate one (Scalera, 1988, 1993).

The detected high number of continent-basin conformities is a proof of their non-fortuitousness, and also a proof of some sort of intrinsic mutual consistence. Comparing the modern position of the continents around the Pacific basin and the position they had about 200 Ma ago – according to one of the possible classical Pangea reconstructions (Fig.3ab) – it seems practically impossible that the circumpacific continents, which are progressively moving away from the centre of the ancient supercontinent, be today placed near conformal 'imprinted images' of surfaces of very far basins.

The presence of conformities is impossible also if a 'cycle of the supercontinent' is hypothesized, with a conformity considered as the trace of a previous position of the block, or the trace of its slow eradication from a deeper layer, placed near a series of trenches like the ones in the NW Pacific. In this case the conformal basin should undergo the subduction process as soon as the cycle of the supercontinent reverts its motion, and the conformity, considering the North Pacific sea-floor age pattern, should be completely erased at a stage of the cycle like the present intermediate one.

The presence of shape conformities is then both a support to the expanding Earth view – in which all the conformities came to overimposition and juxtaposition on a Paleozoic Earth of radius half of the Recent one (Fig.3c) – and to the new importance to be given to the long ocean-floor fracture zones as indicators of the paths of the continents. The displacements of the continents from the Pangea (which covered all the planet) towards the modern positions is mostly radial, coming from a starting position which is from mere overimpositions and juxtapositions of all the conformities. A further meaning of the conformities is their total incompatibility with a large scale subduction of thousand of kilometres of ocean floor, remaining only a compatibility with only a few hundred kilometres of subduction, indicated by modern tomography (Fukao *et al.* 2001). The Emperor Hawaii long volcanic chain appears now not as the trace of the motion of the Pacific plate on a mantle plume, but as a tectonic discontinuity.

Palaeontologic paradoxes

The main advantage of the global expansion hypothesis is the immediate disappearance of many palaeontologic paradoxes, which are present if a classic Pangea reconstruction is adopted. To provide a starting example, palaeontology provides some clues, which suggest an analogous behaviour of the Pacific basin with respect to the other oceanic basins. I can here quote only a selected choice of a few cases among the numerous which effectively exist. Stait and Burrett (1987) report a strong similarity of Ordovician nautiloids of Tasmania with Asiatic and Laurentian ones. In the Silurian, an anomalous correspondence can be recognized in the strong similarity between the planctonic floras (74 species) of the Canning Basin in Western Australia and the planctonic floras (41 species) of Yowa, USA (Colbath, 1990). Devonian vertebrate fossils of South America have been found displaying close similarities with correspondent faunas of Antarctica, Australia and South China (Goujet and Janvier, 1984). These facts testify to an extremely narrow marine barrier between the two zones, and are in perfect agreement with my Triassic palaeogeographic reconstruction, where West Australia is very near to the Cordilleran zone of Laurentia (Scalera, 1990), and it could be expected to be nearer in the Palaeozoic.

Fossil bones of the Triassic reptile Lystrosaurus have been found in Gondwana, in India, but also in many places of Eurasia, which should have been separated by the wide Tethys Sea from Gondwana in the Triassic. Following Colbert (1991), the global distribution of the Lystrosaurus sites could be more easily explained if Eurasian sites were near the Gondwana sites, with closure of the interposed wide Tethys. The same conclusion, on another basis, is reached by Ahmad (1983), Chatterjee (1984, 1987) Chatterjee and Hutton (1986), Sahni (1984), Sahni *et al.* (1987), Tripathi and Singh (1987), Smith (1988) and Patterson and Owen (1991), also concerning the northern and western boundary of India. Analogous links are typical for several different saurus of Indochina or, more generally, of north Gondwana of the Mesozoic age – which are linked to central and northern Asia or European species – suggesting an active interchanging across a very narrow Tethys sea (Buffetaut, 1989a, 1989b; Buffetaut *et al.*, 1989; Astibia *et al.*, 1990). Ager (1986) develops similar reasoning using the distributions of brachiopods, and Stöcklin (1984, 1989) reaches the same conclusion for the Afghanistan-Pamir-Pakistan region on the basis of geological evidence. All the quoted papers are in conflict both with the long and isolated journey of India before its hypothesized collision with Laurasia, and with the large extension of the Tethys Sea which both are the incorrect results of palaeogeographic reconstructions performed on an Earth of constant radius.

I list below some main palaeontologic problems that have arisen in the plate tectonics framework:

1) The Cataysian flora
2) Tethyan faunas on Cordilleran margins
3) The Antarctic flora
4) The Cretaceous Pacific Barrier
5) The Cimmerian terrains northern migration and the Eurasian flora in North Gondwana.
6) The long and isolated trip of India
7) The palaeoclimatic distortions: warm and equable climate in Mesozoic

Cataysian flora

The problem of the so-called Cataysian flora was recognized early in the history of modern palaeontology. Many floristic species typical of East Asia have been found on the opposite side of the Pacific (La Greca, 1989; Sluys, 1994; Briggs, 1996; Hallam, 1994), while the East Pacific Barrier was at its maximum (Grigg and Hey, 1992). In the constant radius view, the East Pacific Basin, from Hawaii and more equatorial seamount and Darwin Rise to the Laurentia western margin, was at its maximum extension in the Triassic and should have prevented any mixing of fauna and flora between the opposite Pacific coasts (Newton, 1988; AA.VV., 1988).

The solution of the paradox in plate tectonics has been to hypothesise a number of small continental fragments, which started a trip from East Asia, near the equator, moving north-eastward with the hypothesized predecessor of the Cocos and Nazca plates (the Farallon and Kula) reaching then the West Laurentian coasts with a velocity unusually high considering the greater length of the great circle distance across the more-then-hemispheric Pantalassa (Ben-Avraham *et al.*, 1981; Zonenshain and Kuzmin, 1997). They become then a mosaic of little fragments, called Wrangellia terrane, located today in the North-western margin of North America.

In the expanding Earth framework, the proximity between Laurentia and Asia increases going back through geologic time and the paradox is completely overcome in the Triassic – a geologic time when only a very narrow and shallow Pacific is depicted in the expanding Earth palaeogeography.

The Tethyan faunas on Cordilleran margins

The biogeographic anomaly of the Paleozoic and Early Mesozoic Tethyan faunas consists in the presence of faunas which are typical of Tethys sea on rocks of the Cordilleran margins of North and South America (Newton, 1988). Plate tectonics explains the anomaly appealing to the eastward displacement of several micro-plates which carried (traveling through an entire hemisphere) the fauna from East Asia to the Western Americas. A different and more attenuated version of this solution appeals to micro-plates in the middle of the Pacific, colonized using the interposed islands as 'stepping-stones' which, only after their colonization, started a journey towards the Cordilleras. A second solution proposes the existence of marine corridors between the Tethys and the Pacific, from Iberia through the two Americas, which have never been found. Only terrigenous sediments exist where they have been proposed. A third solution, adopted by Newton (1988) is the possible West-East diffusion both of biotas along island chains, and of larvae by marine streams. The greater size of the ancient Pacific is a strong limitation for this last proposal. All the problems inherent to these solutions are extensively discussed by Newton (1988) and in a debate with several authors (AA.VV. vs. Newton, 1988). A Pacific of a reduced extension in the Paleozoic and Early Mesozoic is the obvious alternative valid in the expanding Earth theory.

Antartic floras

Many links of the Antartic flora have been found, in the course of the exploration of this continent, with the flora of the Northern Hemisphere from Paleozoic to Mesozoic (Truswell, 1991). In particular numerous Antarctic pollens and floras are similar to some European and North American ones, and strong affinity exists in the Jurassic flora with India and Europe. Very important is the paradox of the Cretaceous flora, fossil forests which show indisputable signs of long growing seasons, equability of light and frost-free conditions, typical of temperate or low latitudes (Truswell, 1991), a fact incompatible with the classic Pangea reconstruction and with the paleomagnetic data. In a paleogeography based on expanding Earth the paradox disappears, with Antarctica located on intermediate latitudes.

The Pacific Barrier

The East Pacific Barrier is a marine barrier extending from Hawaii, the Line islands, the Marquesas islands to the western shore of the Americas. It is the most effective barrier to dispersal of the modern shallow water fauna. Fossil records testify that this has been true throughout all the Cenozoic, but that the barrier was less effective in limiting the faunal dispersal during the Cretaceous (Grigg and Hey, 1992). This factual reality could be better explained in an expanding Earth framework in which the Cretaceous Pacific has a reduced extent with the exclusion of just the Cenozoic area occupied by the barrier. The remaining Cretaceous area today has a very uneven topography, numerous seamounts and islands, which suggest a similar topography even in the geological past. The faunal diffusion from island to island and finally to American shores should have been easier in the Cretaceous with these conditions. The above examples (and many others) are tied together, showing a strong continuity through geological time, and the whole of it suggests a progressive opening of the Pacific Basin starting from a very narrow size.

Cimmeria northern migration incompatibility

An analogous problem came from the necessity to have biogeographical communication from North Gondwana toward South Eurasia in pre-Mesozoic time. A solution has been found by assuming a rapid (in a geologic time sense) migration of elongated and narrow fragments which a paleorift detached from North Gondwana, and then – after paleorift evolved in an expanding mid-oceanic ridge – transported north to a collision with Eurasian southern margins (Meetcalfe, 1993; Briggs, 1996; Yang, 1998). But in a paper on Late Palaeozoic, Nie Shangyou, Rowley and Ziegler (1990) says:

> 'It is of particular interest that the Cathaysian floras also existed in northern parts of Gondwana, an important fact not often recognized. [... ...] Land connections were required [... ...] between the Cathaysian microcontinents and those of Gondwana, while many of them appear to have had separate tectonic histories. The nature and location of these 'land-bridges' are not now understood and remain as a major challenge to the Palaeozoic palaeogeographic reconstructions.'

It is evident that these typically northern fossils found in Gondwana are at variance with the drift toward north of the Cimmerian fragments and of the related sea-floor expanding ridge. The solution recently adopted by some biogeographers is to dispose a number of East Asiatic fragments to form a garland of terrains connecting Australia to East Asia, constituting just a land-bridge, which is very difficult to admit if a mid-oceanic ridge is migrating north across the wide Tethys Sea.

The expansion of the Earth, with a Triassic sialic crust covering nearly completely – exception made for shallow and narrow oceans like the Red Sea – a globe of radius 3300 km is an evident solution to this paradoxical paleogeography.

India in the Pangea

The problem of the paleoposition of India is linked to the general problem of the inconsistency of the palaeontologic results (see a number of papers in the book by McKerrow and Scotese, 1990) which claim land connection (impossible or artifactual in reconstructions in which modern radius is adopted) between Eurasia and Gondwana, and at global level between the opposite Pacific coast (Shields, 1979, 1983).

Geological constrains lead Stöcklin (1981) to claim:

> '[... ...] repeated rifting and compression along old lineaments, with repeated opening and closing of narrow, Red Sea type oceanic troughs between rigid continental blocks may have been the fundamental mechanism in the tectonic evolution of Iran – rather than long-distance continental migration with subduction and consumption of gigantic volumes of oceanic crust as assumed in most current plate tectonic models for the Middle-East.'

The same, in my opinion, should be valid for India, and also for other Asiatic regions (Scalera, 2001a).

Many ways to solve the difficulty of the Indian position have been proposed (Chatterjee, 1984; Chatterjee and Hotton, 1986, 1992; Scalera, 2001a) and the nearly 100 Ma long trip of India has been modelled basing the reasoning upon several starting points. For example the solution of Chatterjee, similar to that reported by Raffi and Serpagli (1993), with the Indian west margin (and Madagascar, in Raffi e Serpagli) constantly sliding near Africa, is completely incompatible with the solution of Ridd (1971), based on geology, in which the Indian east margin has to be very near, possibly facing Indochina. The problem also arises in the paleopole data, which, in Carboniferous and Permian, give a position of India with its southern tips awkwardly and impossibly facing central Africa.

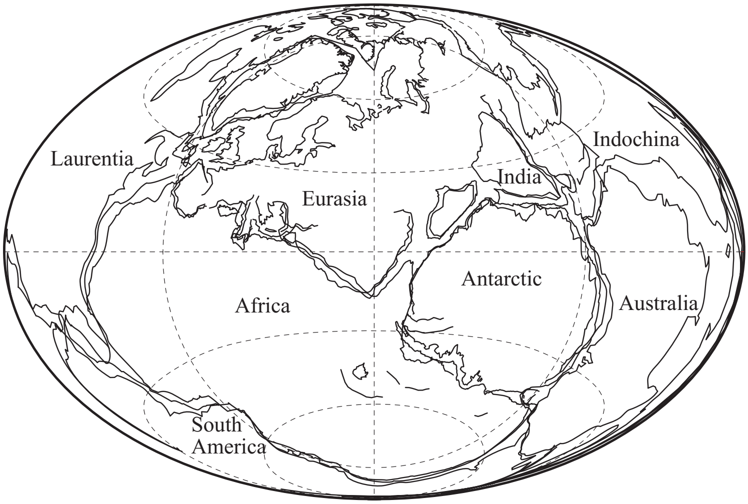


Fig.4

The Pangea reconstruction in the Triassic, Radius 3300 km. The reconstruction has been performed using the GPMDB (Global Paleomagnetic Database) of McElhinny and Lock (1990,a,b) and the data extraction facilities at the Web Site of the Norge Geologiske Undersøkelse NGU (The Geological Survey of Norway; http://www.ngu.no/). The clockwise rotation of India happened in the time window 110-85 My, does not be judged too rapid, because it has the same rotation rate of other little plates, e.g. Iberia and Corsica-Sardinia. This analogy can be extended if we note that there is a correspondence and symmetry between the counter clockwise rotation of Spain and Sardo-Corso block to the West of Eurasia, and the clockwise rotation of India and Siberia to the East.

The solution, in planetary expansion paleogeography, is more satisfactory, with the Indian western margin connected to Antarctica and the formerly considered southern paleopoles restored to their true essence of northern paleopole (Scalera, 2001). In this solution (Fig.4) Indian eastern margin is connected, or divided only by narrow and shallow sea, to Indochina, which in turns is now connected to West Australia. India is still part of North Gondwana but has not completely lost its contact with southern Eurasia, from which it is separated from a narrow Tethys marine region (Stöklin, 1981,1984,1989), and its strong connection to Africa should be viewed as analogous to the modern presence of Elephants, Tigers and other south western taxa. Many paleontological constraints (Chatterjee, 1984; Chatterjee and Hotton, 1986; Carey, 1975, 1976; Dickins and Shah, 1987; Dickins *et al.* 1992, 1993; Carey, 1975, 1976; Owen,1983b,1992) can be put in mutual agreement by this new Indian paleoposition in Pangea, assuming an Earth's radius equal to 3300 in the Triassic.

Further support to this paleoposition is the absence of identified linear magnetic anomalies just off the coasts where India, in the Triassic, was joined to the Antarctic continents. This can be a sign that the strong clockwise rotation of India has not permitted the recording of linear anomalies on the bottom of the Cooperation Sea (Scalera, 2001a). The same reasoning could be applied to the scarcity or absence or low quality of paleopole data of India in the Jurassic-Cretaceous lapse of time, the lapse of the rotation of the Indian fragment, considering that the high rotation rate could have raised the incertitude statistical parameters toward unacceptable high values. Then India has to be considered a fragment of Eurasia which has rotated clockwise with the same rotation rate typical of other important Eurasian fragments such as the Sardinia-Corsica block and Iberian peninsula (counterclockwise rotations).

Considering the difference among the solutions of the paleontologic problems in the plate tectonics view (land bridges like the Aleutine, and east Asiatic Indochinese-Australian connection; quick trips of small fragments like Cimmerian, quick trips of the Cordilleran accreted terrains, India as a further accreted terrane; introduction of larger biogeographical provinces), I reaffirm that the admission of the expansion of the Earth has the advantage of providing a unified solution for all the different cases.

The case of Madagascar

In this new Pangea (Fig.4), a not completely solved problem is still the position of Madagascar. Some paleontologic clues (Battail *et al.*, 1987; Wright and Askin, 1987) indicates that also Madagascar may have undergone a strong rotation, similar to that of India, leaving completely free the contact between Antarctica and the Antarctic Peninsula with Africa. Recently some Triassic fossils of primordial mammals, (*Ambondro Mahabo*, a little rodent; and thoots of *Tribosfenidis*, a group which include most actual mammals) have been found in Madagascar sediments, and this is judged surprising because they are located in the ‘ wrong’ hemisphere (Flynn *et al.*, 1999; Flynn *et al.*, 1999). Till now the northern hemisphere has been considered the zone of origin of mammals. If this discovery remains isolated, it will constitute a strong support for the northern position of Madagascar as proposed in my Triassic reconstruction. All this argument deserves to be greatly developed in depth.

Fig.5

The latitutinal trend of the temperature trough the geological time (modified from Crowley and Zachos, 2000). The distorsion with respect to the modern curve is more and more marked going into more old periods.

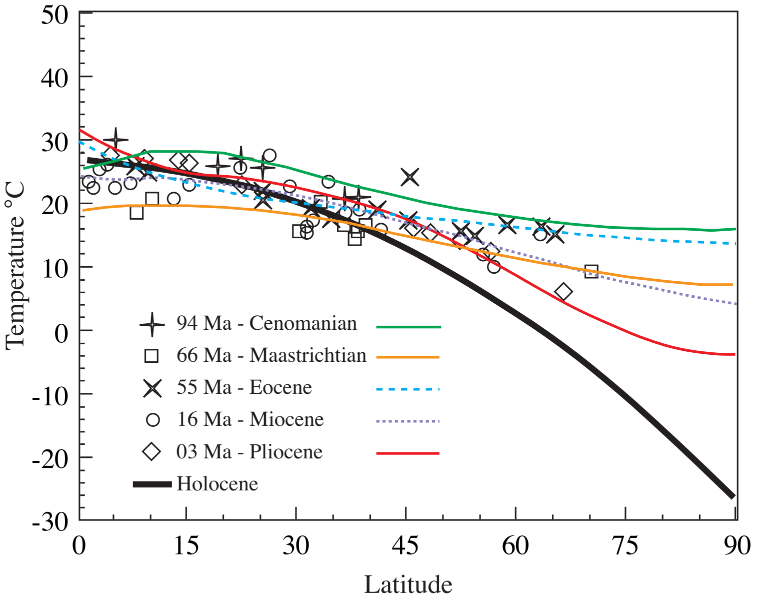


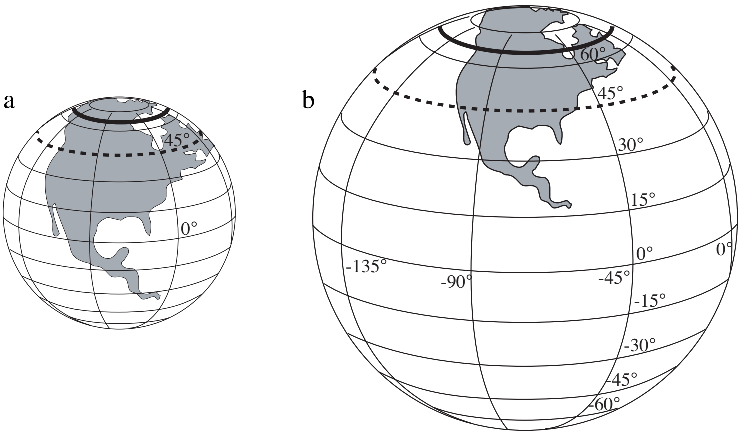
Fig.6

The influence of the Earth expansion on the ancient climate. On a half radius Earth a), the polar circle encloses an area only a fourth of the modern area in b). As consequence the polar circle or a glaciation with ices reaching intermediate latitudes, 45°, occupy a lesser continental area (1/4) on a half radius Earth. If people erroneously assume the radius of the Earth to be constant, the climate of the old epochs can be judged abnormally mild, presenting fossils of non-glacial flora and fauna enclosed in a modern size polar circle. The existence of warm and equable climate in the Meso-Cenozoic is an outstanding problem of paleoclimatology.

Climatologic distorsions

A classical problem of climatology is the warm and equable climate that Earth experienced in long lapses of geological time along the Mesozoic (Fig.5) and also in older epochs (Barron, 1983; Sloan and Barron, 1990; Vakhrameev, 1991; Huber *et al.*, 1995; Huber *et al.*, 2000). In Mesozoic, the absence, or the extremely reduced size, of the polar ice caps has been reported together with the presence of fossils of thermophilic flora in the Artic and Antarctic (Vakhrameev, 1991).

Different models have been proposed to explain this phenomenon, and a possible connection has been found with the thermohaline circulation – a heat interchange process between oceans and atmosphere (Weaver *et al.*, 1999; Marotzke, 1991;



Marotzke and Willebrand, 1991). The models propose a more intense poleward oceanic heat flow from the ocean to the atmosphere, because of differences in oceanic salinity and/or air contents of CO_2, and are able to grossly explain, with some criticity, the higher Mesozoic temperatures deduced from the fossil indicators. But also they leave large uncertainty areas, and the discussion about the validity of this global heath circulation model is still active (Barron and Washington, 1982; Barron and Peterson, 1989; Schmidt and Mysak, 1996; Jayne and Marotzke, 2001; Royer *et al.*, 2001).

If we consider that a modern continental plateau that ranges for a three quarters of the Pole-to-equator meridian in latitude could range in the Mesozoic – on a smaller radius Earth – on the entire latitudinal distance from Pole to Equator, it became immediately evident that measuring the paleotemperatures (Crowley and Zachos, 2000) assuming erroneously the modern radius, we could find a range of values from equatorial temperatures to temperate ones, the last of which extend too much toward the pole.

On an expanding Earth in fact (Fig.6), coming back in geological time, the polar ice cap becomes smaller and smaller with respect to the continents that, on the contrary, become larger and larger with respect to the decreasing total surface area of the globe (Scalera, 2001a). The small dimension of the ice cap in the Paleozoic and in the Archean with respect to the continents could make it very difficult to determine the Pole position from geological records. In the expanding Earth framework all this appears as an expected natural phenomenon (Fig.6).

Earth rotation, polar motion and true polar wander

The argument that played a major role in the decision of the scientific community in favour of the constant radius theory was the belief that a substantial increase in size of the planet should have had an observable effect on its rotational dynamic (Runcorn, 1964). A doubling of the Earth's radius should have had as consequence a nearly halved length of the day (LOD) in the Palaeozoic, which was not confirmed from the palaeontologic data. The expanding Earth was excluded on these bases, and also today this opinion is repeated in well-documented review papers on paleorotation of our planet (Williams, 2000). In my opinion the relation of some Earth rotation parameters if an expansion of the planet is hypothesized must be re-discussed.

Preliminary considerations

The rotation pole is today drifting towards 79°W at a speed of more than 10 cm/y (3.5 marcs/y) (Dick, 2000; Dickman, 2000). The continental drift does not seem able to operate such rapid latitude variation, because it is more effective on longitudinal variation. It is simple to put this situation in relation to expanding Earth theory.

If a radius of 3300 km is assumed (Scalera, 2001) in Triassic, ≈220 Ma ago, then my estimated annual rate of radius increase is:

$$\frac{dR}{dt} = \frac{(6370 - 3300) \text{ km}}{220 \text{ My}} \cong 14.0 \text{ mm/y}$$

This value is an average upon the entire geological time window. The Recent global minimum expansion rate (map of Fig. 5.19 in McElhinny and McFadden, 2000 – based on Müller *et al.* 1997) could hinder the geodetic revelation of unambiguous global expansion, because the minimum phase of the pulsation could give place to a minimum of tectonic activity, which could lead to a near-zero rate of global expansion.

The accurate or not-accurate selection of the geodetic stations on which to ground the search for a radius variation can also have an influence on the difficulty at detecting geodetically this minimum or near zero rate of expansion. This possibility is supported by an analysis of space tracking data (Gerasimenko, 1993) in searching for change of Earth dimensions, which, using LAGEOS and VLBI data for stable non-orogenic continental regions, has indicated an increase of the Earth's radius of +4.15±0.27 mm/y. Then Gerasimenko's results could be considered the actual Recent value, while the maximum expansion rate – in the McElhinny and McFadden (2000) map – in the Early Cretaceous time could correspond to a Cretaceous radius gradient of a few centimetres per year.

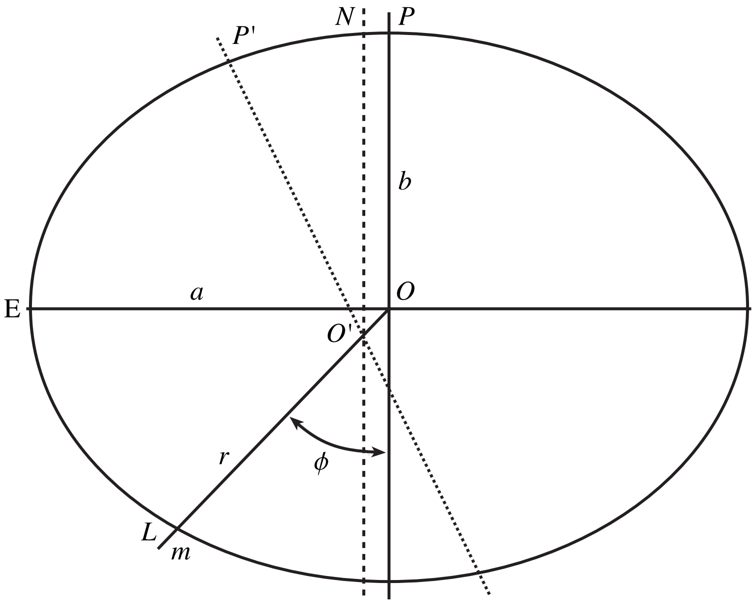


Fig.7
A simplified representation of a rotating planet. a and b are the equatorial and the polar radius; r is the radius at latitude L; P is the initial position of the principal inertia pole and of the rotation pole. If a mass m is inserted in a point of latitude L (colatitude ϕ), a displacement of the geocenter from O to O′ happens, with a displacement of the principal axis of inertia from P to P′ and of the rotation axis from P to N. The contribution of NP to the total polar motion is opposite in the two hemispheres. While the rotation axis N remains steady in the celestial reference frame, the entire planet reorients itself until P′ goes in coincidence with N. This is the main contribution to polar motion.

I then assume here that today the Earth pulsation is at a minimum and as consequence I conservatively assume that today the radius increase rate is, *e.g.*, 7 mm/year, a value very near that of +4.15±0.27 mm/y found by Gerasimenko (1993). If a completely asymmetrical growth of the planet radius of 0.7cm/y, 1.4 cm/y in diameter, centred on an equatorial point, is assumed, then a pole displacement of 0.7 cm/y will be observed in the direction of that longitude (Fig.7, Fig.8). This value of the polar displacement is evidently not sufficient – one order of magnitude less – to explain the real Polar displacement of more than 10.0 cm/y (Dickman, 2000). The conclusion is that effective displacements or depositions or subtractions of mass happen in some non-equatorial Earth regions, surface areas or deep volumes, or both, which have preponderant effects on the Polar motion with respect to the effects of the pure equatorial asymmetrical volume variation.

More quantitative considerations

In the case of a rigid Earth (Schiaparelli, 1883, 1891), it is possible to prove, referring to Fig.7 and neglecting higher order smaller terms, that when a mass m (with $m \ll M_T$=Earth's mass) is added in a point L at a colatitude ϕ:

$$PP' \cong \frac{br^2m}{2(B-A)}\sin(2\phi) - r\frac{m}{M_T}\sin\phi. \quad (1)$$

In (1) B and A are the polar and equatorial moment of inertia, and the term

$$NP = r\frac{m}{M_T}\sin\phi$$

arises from the displacement of the centre of mass from O to O' and is normally neglected (Schiaparelli, 1891) because it is considered small in comparison with the first term if the mass transport on the Earth happens with a roughly casual spatial distribution and with a probability nearly equal zero to happen very near the equator. Then, the relation to compute the inertial pole displacement in the rigid case is:

$$PP' \approx 506\, r\frac{m}{M_T}\sin(2\phi).$$

If a more realistic viscoelastic behaviour of the Earth is taken into account (Lambek, 1980, 1988; Spada, 1992,1997) the introduction of the Love numbers k' leads to a similar relation:

$$PP' \approx \frac{br^2 \cdot m(1+k')}{2(B-A)} \cdot \sin(2\phi).$$

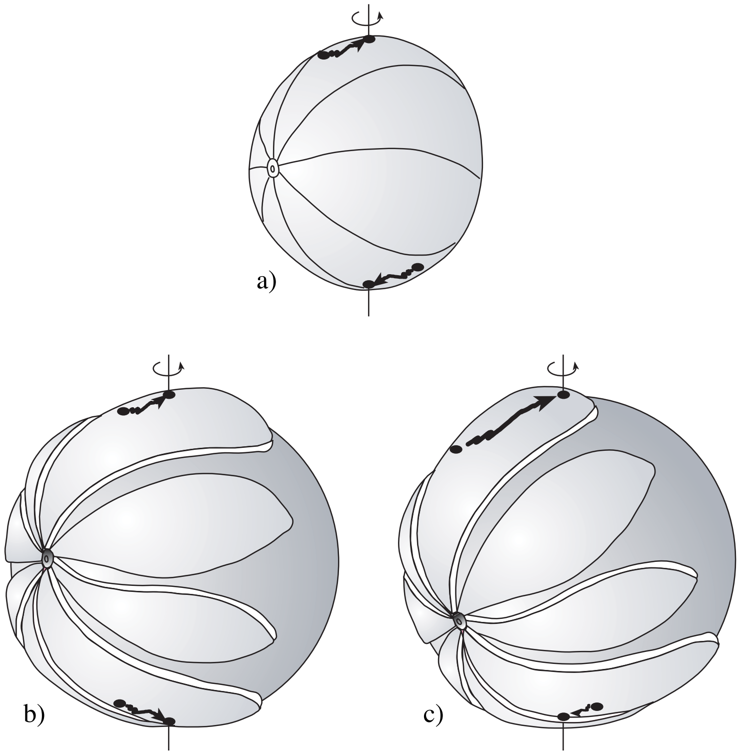


Fig.8

a) The secular Polar Motions for North Pole and South Pole are symmetrical if Earth has constant size. The two Poles drift rotating in the same direction roughly along the same meridian circle.

b) If Earth is asymmetrically expanding with the expansion centered on the equator, the first term of equation (1) is zero and only the second term, linked to the center of mass displacement, prevails. In the case shown in b, with mass emplacement perfectly equatorial, the two paths drift towards the zone of maximum expansion with an equal rate.

c) If the emplacement of new mass is at intermediate latitude, in this case southern latitude, the length of the Northern and Southern path of the Polar secular Motion are the sum or the difference of the first and the second term of equation (1) respectively, and then have different lengths.

The influence of the small second term of equation (1) is important to detect the expansion of a planet, but on the Earth the polar motion databank, from 1850 to 2002, contains only the data of the northern hemisphere. Today the integration of this databank with the few years old geocenter databank could be helping to detect expansion. This figure is based on the 'orange peel' figure of Owen (1981).

Considering that the factor (1+k') assumes values smaller than 1 with k' ranging nearly linearly from a surface value k'=-0.30 to an upper-lower mantle boundary value k'=-0.45, the viscoelastic formula leads to numerical values for PP' few tenths of percents smaller than the values in the rigid case. I will adopt the rigid case framework in this simplified considerations, because the rheology of the inner Earth's materials is still not well known, because the true viscoelasticity of the Earth's interior, if the planetary expansion is true, should be derived from a specific variable radius model, and because the probable absence of mantle convection in the expanding Earth framework leads towards a more rigid behaviour of the planet as a whole.

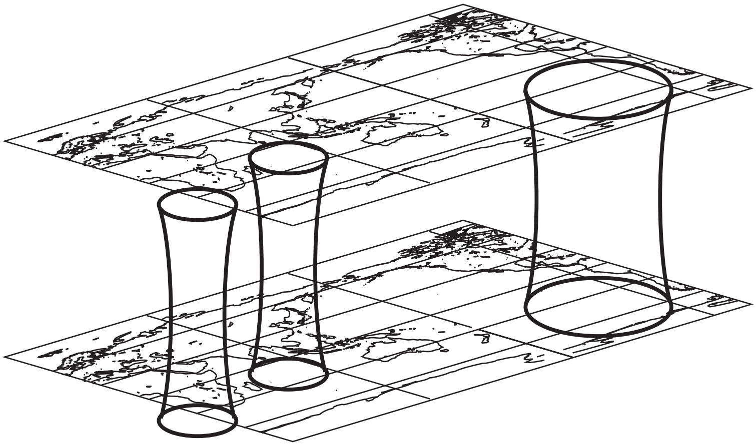
Where the emplacement happens

The direction of the polar motion is ≈79°W. This fact has been variously interpreted, invoking different geological processes but only the hypothesis of the glacial rebound (Peltier, 1976; Peltier and Jiang 1996; Sabatini *et al.*, 1982) has found more general consensus because the northern Canadian Shield and Siberia, were once covered by ice caps, on the real extents of which an ongoing debate is active today (Clark *et al.*, 2001).

Nearly, in the same direction the Nazca plate and superplume are located, in the southern hemisphere, with the maximum sur-

Fig.9

The global pattern of the mantle flow as revealed by global seismic tomography (very simplified; from web site source and Su et al., 1992,1994). The major upwellings of mantle material are sketched under the Bouvet, Indian and Pacific triple points, with pipes, whose section is proportional to the observed ocean floor expansion rate.



face expansion, the triple point, at a latitude of ≈30°S (Fig.9). This superplume, revealed by seismology by global tomographic methods (Su, Woodward, and Dziewonski, 1992, 1994) could be interpreted as the main expression of the asymmetrical global expansion.

I have then to test, with some rough computation, under which limits on mass accretion this situation is relevant for an expanding Earth. I do not still consider, in this section, the possibility that a cosmologically induced increase of mass, with a still unknown physical process, happens, with spherical symmetrical distribution, in Earth's deep body. I consider then only a rough model in which progressively, in a geological time scale, a part of the Earth's mass is asymmetrically expelled from the deep interior of the planet, raising vertically in the main tomographically revealed superplumes, like a diapiric process. No hypothesis is made on the composition and progressive differentiation of this slow mass flow.

For example, if a mass $10^{-11} M_T$ (M_T=Earth's mass) was annually added on the geographic point 30°S, 79°W, near Nazca, the following PM drift would be obtained:

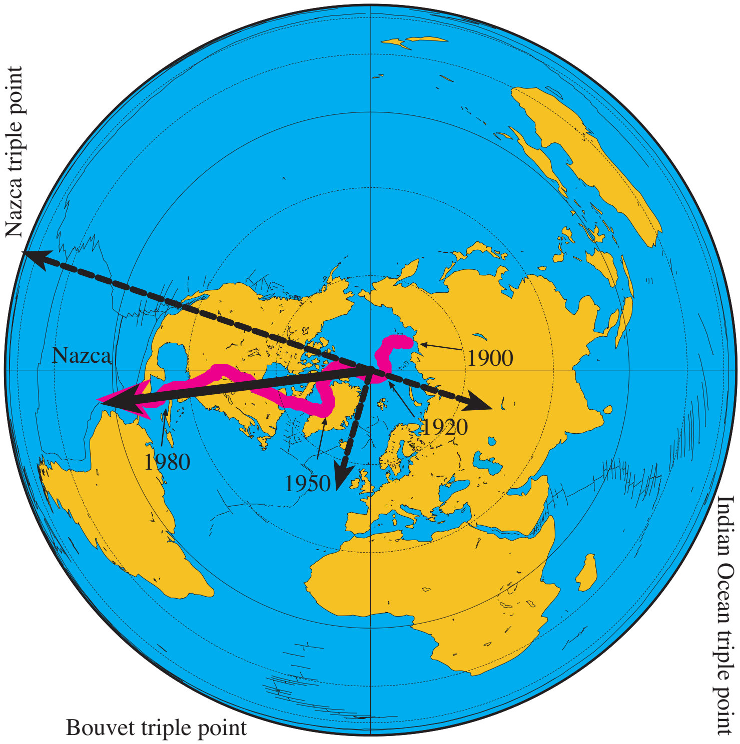
$$PP' \approx 506 \cdot r \frac{m}{M_T} \sin(2\phi) = 506 \cdot 6370 \cdot 10^5 \cdot 10^{-11} \cdot \sin(240°) \approx -2.7 \text{cm/y}.$$

A factor 4 or 5, applied to $10^{-11} M_T$ is then sufficient to reach the value of the observed annual polar drift of ≈ 10.0 cm/y.

In Fig.10 the real path of the mean rotation pole from 1900 to 1990 is shown, superimposed (in a different scale) on the Lambert equivalent polar plot of the geography. The mean direction of the PM is directed slightly eastward from the Nazca triple point (the above mentioned 79°W versus the triple point longitude of ≈ 115°), and this means that one must take into account the other two main risings of mantle material in the Atlantic Ocean, the South

Fig.10

The secular drift of the rotation Pole, the red path with arrow, is shown superimposed to the geography (not at the same scale). A rough vectorial sum, neglecting the different latitude, is represented in black broken lines among the three major hypothesized contribution to PM provided by the Nazca, South Atlantic and Indian triple points, which are sketched in Fig 3. A ratio of 1/4 is assumed between South Atlantic and Pacific vector magnitude as well as between Indian and Pacific vector. With those simplified assumptions the resultant vector, in black arrow, is in good agreement with the observed PM averaged secular drift.



Atlantic Bouvet triple point, and in the Indian Ocean triple point, which are sketched in Fig.9. If a ratio of 1/4 between each of the other two minor expanding rate and the Pacific expansion rate is assumed, and if the different latitude of the three emplacing point is neglected, the vectorial sum of the three contributions gives a resultant vector in good longitudinal agreement with the observed PM mean drift vector (Fig.10).

The need for an increase of mass?

A number of papers have been dedicated to, or have mentioned, the problem of a possible change of the Earth's inertia moment (Runcorn, 1964; Burša, 1990; Williams, 2000), but all of the authors have made explicitly or implicitly the assumption that a volumetric expansion is associated necessarily to an increase of the inertial moment and then a strong increase of the LOD should be observed, more pronounced with respect to the paleontological data indication.

On the other hand, an increase of mass of only one or few parts on 100 billion per year, asymmetrically emplaced, appears insufficient to take in account a many-fold increase of the Earth's volume during the time lapse from Palaeozoic to Recent, a lapse of 300 million years. A difference of orders of magnitude is present. Then, in the expanding Earth framework, the mass increase deduced from secular Polar Motion, or radially unbalanced mass displacement, should be considered only a little portion of the new absorbed mass. The unbalanced mass could also derive from the contrast of density between the quick expansion of the basaltic Pacific hemisphere with respect to the slower expansion of the continental hemisphere. Only a few percent of the total mass increase should be considered unbalanced and the possibility is not excluded of a concomitant chemical differentiation of the total accreted mass, with the heavier chemical compounds dropping towards the core-mantle boundary and the inner core.

Assuming a simplified situation with an expanding Earth retaining its average density during geological time, an estimate of the annual mass increase *dM/dt* is possible on the basis of the variable-radius paleogeographical reconstruction, adopting an initial radius r = 3000 km:

$$\frac{dM}{dt} = \frac{[M_T\text{-}(5.5\text{g/cm}^3\cdot\frac{4}{3}\pi r^3)]}{300\text{Ma}} = \frac{(5.97\cdot10^{27}\text{g}-1.86\cdot10^{27}\text{g})}{3.0\cdot10^8\text{y}} = 1.37\cdot10^{19}\text{g/y},$$

which is in the magnitude order of 10^{-9} of the Earth's mass M_T= $5.97\cdot10^{27}$g, versus an annual asymmetrically emplaced mass *dm/dt* (evaluated from Polar motion) in the order of $K\cdot10^{-11}M_T$. Then:

$$\frac{dm}{dt} = K\cdot\frac{5.97\cdot10^{27}\text{g}}{10^{11}\text{y}} = K\cdot5.97\cdot10^{16}\text{g/y},$$

with the adimensional value of K ranging around 4-5, to reach the value of the observed secular Polar Drift. Assuming the value of K= 4, it is possible to compute the value of the ratio of the accreted mass emplaced asymmetrically:

$$\frac{dm/dt}{dM/dt} = \frac{K\cdot5.97\cdot10^{16}}{1.37\cdot10^{19}} = 1.74\cdot10^{-2}.$$

The asymmetrically unbalanced emplaced mass m should be then around 0.02 the annual total mass increase which has been roughly evaluated from the paleogeography and from simplified assumptions on the density, without take into account other possible significant contributions to the inertial pole motion due to material flows on the surface or in the interior of the planet (Peltier, 1981; Spada *et al.*, 2000; Sabadini *et al.*, 1983).

The slowing down of the Earth

While the asymmetrically emplaced mass must contribute to the slowing down of the Earth's spin, the more consistent total mass increase *dM/dt* can also contribute to the slowing down, but could well give place and contribute to a more general differentiation process which also involves the pre-existing mantle and fluid core and which influences the Earth's rotation with a positive contribution to the spin acceleration, a process which compensates for the slowing down.

It is possible to try to evaluate the *upper limit* of the inertial moment variation produced by the asymmetrically extruded mass, $24 \cdot 10^{16}$g. It is clearly unrealistic to hypothesize a displacement from the bottom of the mantle to the Earth's surface. Before it spreads azimuthally, the mass is slowly displaced distributed on a large section of a vertical column, the area of which is difficult to evaluate. Then I can suppose that only a vertical upward displacement of few centimetres or millimetres per year could really happen distributed on large ocean-floor-ridge area, because this is the only way not to conflict with the geodetic observations, a conflict which could become unavoidable assuming larger uprise rates.

All the following considerations should be considered largely conjectural because we do not know absolutely how the total accreted mass $1.37 \cdot 10^{19}$ g/y and the pre-existing mass, in ongoing differentiation, contribute to the variation of the thickness of the different Earth's strata and to the redistribution of the inertial moment.

I can evaluate the slowing down of the Earth in the simplified idealized case of an injected mass, $24 \cdot 10^{16}$g, in the Nazca triple point. The inertia moment variation due to the idealized extrusion of the asymmetrical emplaced mass is:

$$\Delta I = 24 \cdot 10^{16} \cdot (R \cdot \cos(30°))^2 = 7.6 \cdot 10^{30} \text{gm}^2,$$

which is small, nearly 10^{-10} times, with respect to the Earth polar inertia moment $8 \cdot 10^{40}$gm^2. This means that an equivalent value should be compensated by differentiation in the mantle and in the liquid core. Applying the law of the conservation of the angular momentum $I_1\omega_1=I_2\omega_2$, it is possible to evaluate ω_2, and the annual angle of delay with respect to an unaffected Earth.

$$\omega_2 = \omega_1 \cdot \frac{I_1}{I_2} = \frac{7.292115 \cdot 10^{-5} \text{ rad/s} \cdot 8.0394 \cdot 10^{40} gm^2}{(8.0394 \cdot 10^{40} + 7.6 \text{x} 10^{30}) \text{gm}^2} =$$

$$= 7.292114999 \cdot 10^{-5} \text{rad/sec}$$

which is different from ω_1 only on the ninth decimal ($\omega_1 - \omega_2$ is in the order of 10^{-15}) and the annual angular delay is only in the order of 10^{-5} geographical degrees. The lengthening of the day, ΔLOD, is in the order of magnitude of 10^{-1} ms/century.

But it is better to evaluate the variation of inertial moment to be compensated if a spherically symmetric shell of material, thickness 1cm, is symmetrically emplaced eventually by a spherical radial 1cm growth of the core-mantle bundary. Assuming

3.0 g/cm^3 the Earth average surface density and 5.0 g/cm^3 the mean lower mantle density, 2.0 g/cm^3 the difference between the mantle and the upper mantle-lithosphere density, and finally 5.0 g/cm^3 the difference between the mantle and the fluid core density, in this oversimplified Earth model the annual increase of mass is in the right magnitude order, 10^{-9} of the Earth mass. The variation of moment of inertia can be evaluated from the assumed values with the sum of three contributions:

$$\Delta I = \Delta I_{\mathrm{surf}} + \Delta I_{700\mathrm{km}} + \Delta I_{2900\mathrm{km}}.$$

The computation takes in consideration the spherical redistribution of the volumes as $1/r^2$, and gives an annual angle of delay of the mantle with respect to the inner core in the order of magnitude of 10^{-3} geographical degrees. In both cases, for asymmetrical and symmetrical mass emplacements, the annual angle of superrotation of the core due to effects of an expanding Earth is small in comparison to the range of the seismologically detected angles, 0,1°-3.0°, and probably in the range of non-detectability by seismological methods (Song and Richards, 1996; Su *et al.*, 1996; Nataf, 2000; Vidale, 2000) using the data in the time window covered by the actual seismic catalogues.

The ΔLOD, in this symmetrical emplacement case, rises to a value in the order of magnitude of few tens of milliseconds per century, while the observed value is around 2.4 msec/century. In the best case of a symmetrical contribution to the expansion of few millimetres per year, I have obtained a secular ΔLOD of 20.0 msec/century. The hypothesis must then be made of a still active geochemical differentiation in the mantle and in the liquid core, which could be able to compensate – at least partially – for slowing down due to expansion. This means a transport of mass from the mantle and the fluid core toward the inner core surface. The annual inertial moment to be compensated is of the order of magnitude of 10^{-9} of the Earth's moment, but no model of the requested mass transport exists up to now. A differentiation of the type here requested has been recently proposed in the theoretic geodynamo model of the Earth interior, where the mechanism able to sustain the material flow in the convection tubular cells is the solidification heat released by the iron which is deposited on the surface of the inner core (Buffet *et al.*, 1996; Kutzner and Christensen, 2000).

Also it should be remembered that at least a partial contribution to the compensation of the slowing down could be provided from the variation of the J_2 geoidal coefficient due to the global glacial rebound (Argus *et al.*, 1999). But nobody knows the combined effect, on the Earth's rotation and shape over very long lapses of time, of a number of phenomena, among which those shown in Fig. 11, and an underestimated meteorologic phenomenon, well

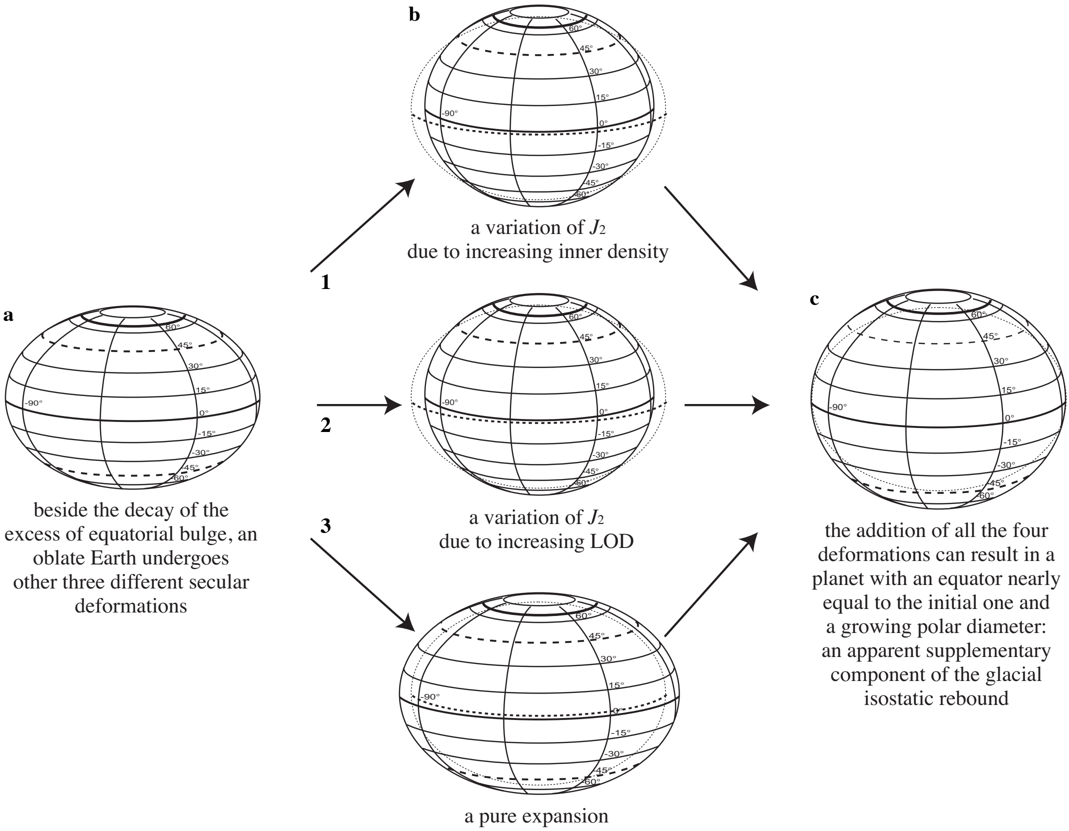


Fig.11
Beside the glacial rebound and the decay of the excess of equatorial bulge, other processes can affect the J_2 variation.
It is possible to show that the effects 1 and 2 are small if compared with the observed J_2 time derivative.
The third process, the pure expansion, has an opposite effect on the length of the equator and could be hidden by all the others.

known in studies of comparative planetology: the thermal tides of the atmospheres act as a force that opposes the slowing down of the planets, an effect considered of particular importance for the rotation story of the planet Venus (Pollak, 1990).

True polar wander and expanding Earth

The existence and meaning of a true polar wander (TPW) has intrigued the geophysical community from the beginning of paleomagnetism (Goldreich and Toomre, 1969; McElhinny, 1973), but no definitive linking of this phenomenon with other geophysical processes has been found. The discussion about TPW has been still very hot in the last years (Sager and Koppers, 2000; Cottrell and Tarduno, 2000; Prevot *et al.*, 2000).

An explanation of the TPW has been sought in the global pattern of the convective cells, not considering the fact that mantle convection and hot spot concepts are incompatible. The synthetic path derived from these modelisations of the mantle convection (Richards *et al.*, 1997) is in overall disagreement with the observed path (if we accept the 'hot spot' frame as at least a rough approximation of a really fixed reference frame). Other models

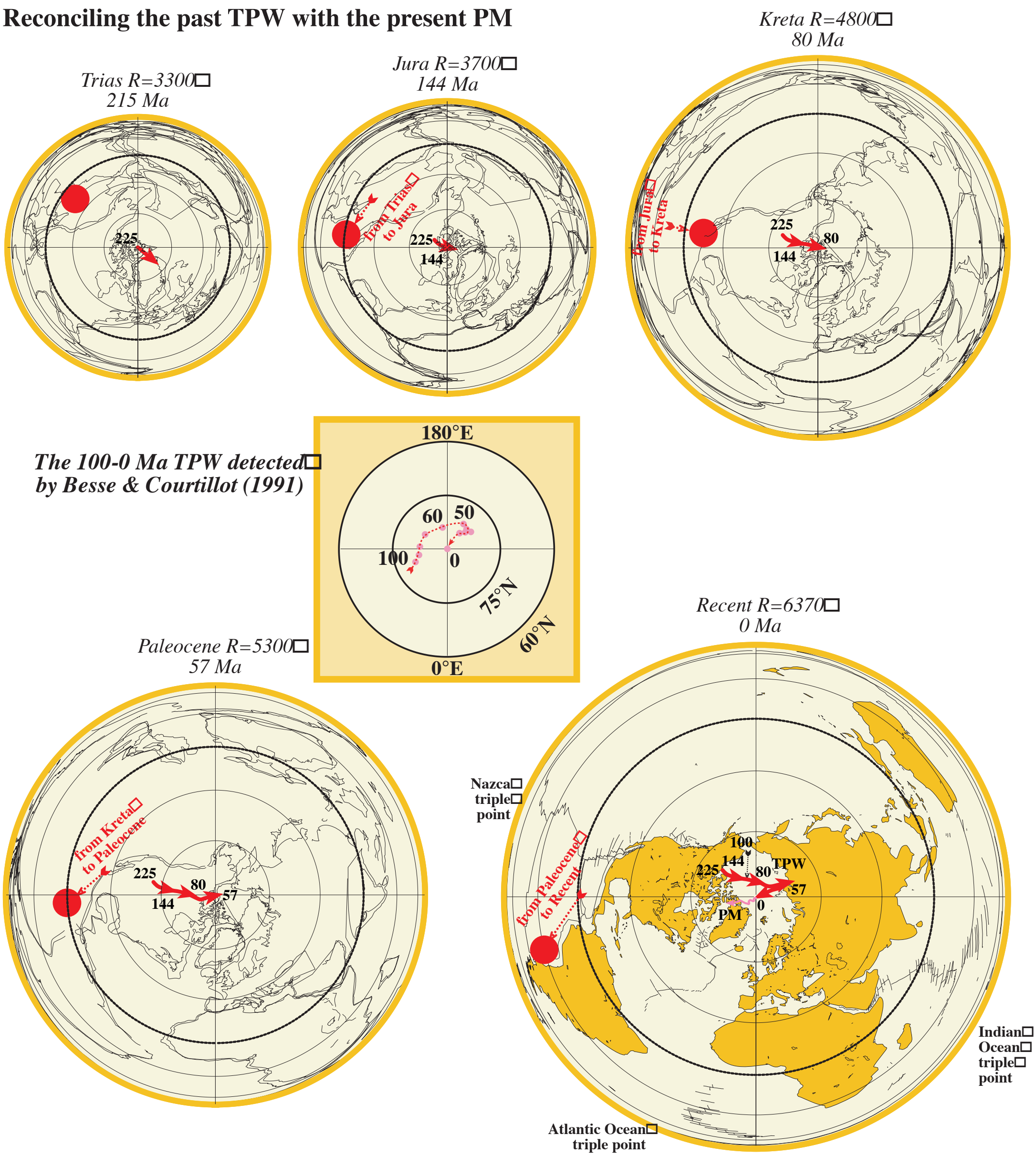


Fig.11
The reconstruction of the possible True Polar Wander (TPW) as it came from the asymmetric expanding Earth interpretation. The red filled circle are the estimated positions of the resultant of a vectorial sum of the

(Steinberger and O'Connell, 1997) try to put in relation the TPW to the advection of mantle density unhomogeneities. This kind of model reaches a greater similarity between the true and the computed TPW, but cannot avoid other problems.

The modern TPW, namely the polar motion (PM) – the secular drift of the rotation pole observed today by astro-geodetic methods – is explained not with the same model of global convection used for the TPW explanation, but with the influence of the so called glacial rebound (Peltier, 1976; Sabadini *et al.*, 1982;

contribution of mass emplacements due to the triple points. In the central box the observed TPW by Besse & Courtillot is represented. The expanding Earth paleogeography, if inverted towards the geodynamics, is able easily to explain the TPW path and its slowing down and coming back around 50Ma, and to reconcile TPW and modern PM. Considering that the paleogeographical maps was not constructed with attention to the TPW and that we do not know all the different factors of damping of the PM drift rate, and that the hot spot reference frame is not a guaranteed optimal fixed frame in the planetary expansion framework, the overall good agreement of the observed TPW and the reconstructed TPW (on the actual PM rate basis), is new evidence favouring the expanding Earth geodynamics.

Peltier and Jiang, 1996). The main difficulty in this view is the estimation of the extensions and thicknesses of the paleo-icecap on Canadian and Siberian shields respectively (Clark *et al.*, 2001). Moreover the glacial rebound can sustain a TPW only for few million years or, more realistically, fraction of a million year, while TPW is active on a hundreds-of-million-year time scale. This is an unacceptable double or multiple explanation of the same phenomenon.

The hypotheses I have made concerning the influence of the superplumes on global increasing radius geodynamics (Scalera, 2001), and my palaeogeographic reconstructions, are in favour of a slow drift, through geological time, of the Pacific superplume (Fig.11) from its Triassic position near Asia, northern hemisphere, towards its actual southern hemisphere position, under Nazca triple point (see the succession of maps in Fig.11). Both the pattern and ages of the Western Pacific ocean floor volcanism and the Darwin Rise appear as the trace of the slow south-eastern displacement of the superplume. This migration from North-West to South-East, passing the equatorial line, should also have had other detectable geodynamic consequences, namely in the data of TPW and PW.

Also in this case I made simplified assumptions in order to try to reproduce, at least roughly, the already known paths of the True Polar Wander (Andrews, 1985; Besse and Courtillot, 1991). I assume:

1) The modern observed Polar Motion is the actual modern expression of the True Polar Wander, and the actual rate of drift (little more then 10 cm/y, equivalent to nearly 1 geographical degree every million year) can be applied, with corrective factors, to the geological past.

2) The epoch of the equator crossing of the superplume is assumed to be around 50 Ma.

3) A corrective factor $q<1$ should be applied to take into account the slowing down of the PM as the accreted mass flow approaches the equator. The slowing down is influenced by the factor $\sin(2\phi)$ which has a maximum if $\phi=\pi/4$. The Nazca triple point is today at 32°S and then I can assume $q=1/3$ for the lapse of time from the crossing of the equator up to the present time.

4) From Triassic to the Recent time, fluctuations of the tectonic activity have happened (McElhinny and McFadden, 2000) with a minimum today and a maximum at 25-30 Ma and so on. In the present paper I do not apply any corrective factor for this because the correlation of the maximum spreading rate to the intensity of the superplume rising, albeit possible, may be largely conjectural.

With these four assumptions I am able to reconstruct the TPW path going back in geologic time from the Recent to the Palaeocene, 57 Ma, and then from the Palaeocene back to the Cretaceous, Jurassic, and finally Triassic. In the paths from Recent to Palaeocene and from Palaeocene to Cretaceous I apply the corrective factor q=1/3 because of the reasoning explained in the above point 3).

The resulting reconstructed TPW in Fig.11 can be compared with the observed TPW of Besse and Courtillot (1991) from 100 Ma to 0 Ma (see the box in Fig.11). It is noticeable that the magnitude and the oscillating path of the observed TPW, with turning point near 50 Ma, albeit roughly, is fairly reproduced by my paleogeographical series of reconstructions with simple assumptions on diapirical rise of mantle materials. A further advantage is that it is possible to represent in the same figures the TPW and the PM as one the prolongation of the other. Finally, I trust in the possibility of better fitting the real TPW path by taking into account the different contribution of the other ocean-floor expansions.

My geodynamical inversion of paleogeographical reconstruction is more in agreement with the advective model proposed by Steinberger and O'Connell (1997), which takes into account the rising of the low-density zone of the mantle as revealed by seismic tomography and the plate motion in the Tertiary. But the results of Steinberger and O'Connell (1997) present a nearly constant rate of TPW (see the equal intervals every 10 Ma in their Fig.1) and cannot explain the slowing down of the TPW near the inversion point at 50-40 Ma, which is evident in the shortening length of the intervals near the inversion point in the Besse and Courtillot TPW evaluation. This is explained in my diapirical model, in the expanding Earth framework, because the PM rate decreases and becomes zero under the influence of the $\sin(2\phi)$ factor as the adding of mass approaches and crosses the equator.

Chandler Wobble excitation and damping

In this section only a brief and incomplete account of the possibility of exciting the Chandler wobble only by asymmetrical emplacement of mass will be provided. It is well known (Munk and MacDonald, 1975; Lambeck, 1979, 1980, 1988) that to solve the problem of the Earth's rotation, the Liuville equation, a generalization of the Euler equation to a non-rigid body, must be solved. A linearised form of the Liuville equation is derived from a more complete form neglecting terms that are very small (Spada, 1992):

$$\frac{j}{\sigma}\frac{dm}{dt} + m = \Psi \ .$$

The notation is complex and $m = jm_x + m_y$, and Ψ is the excitation

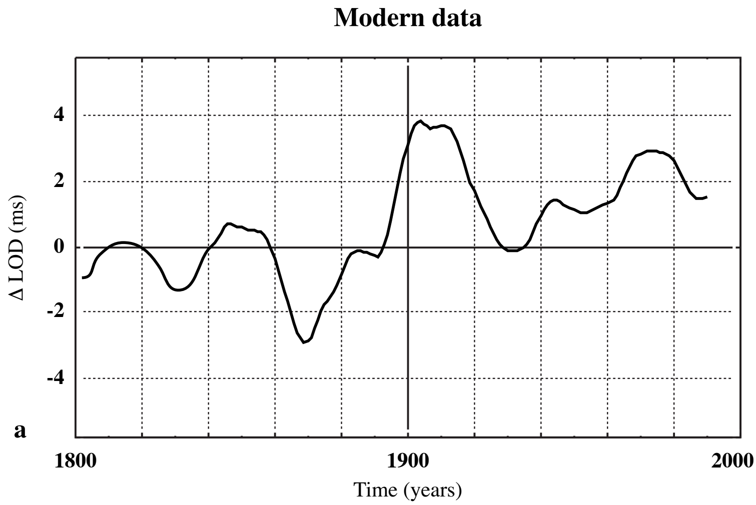


Fig.12

The secular variation of the length of day (LOD).
a) In the short term, from data from the last two centuries.
b) In the deep historical time (simplified from Stephenson, 1997).

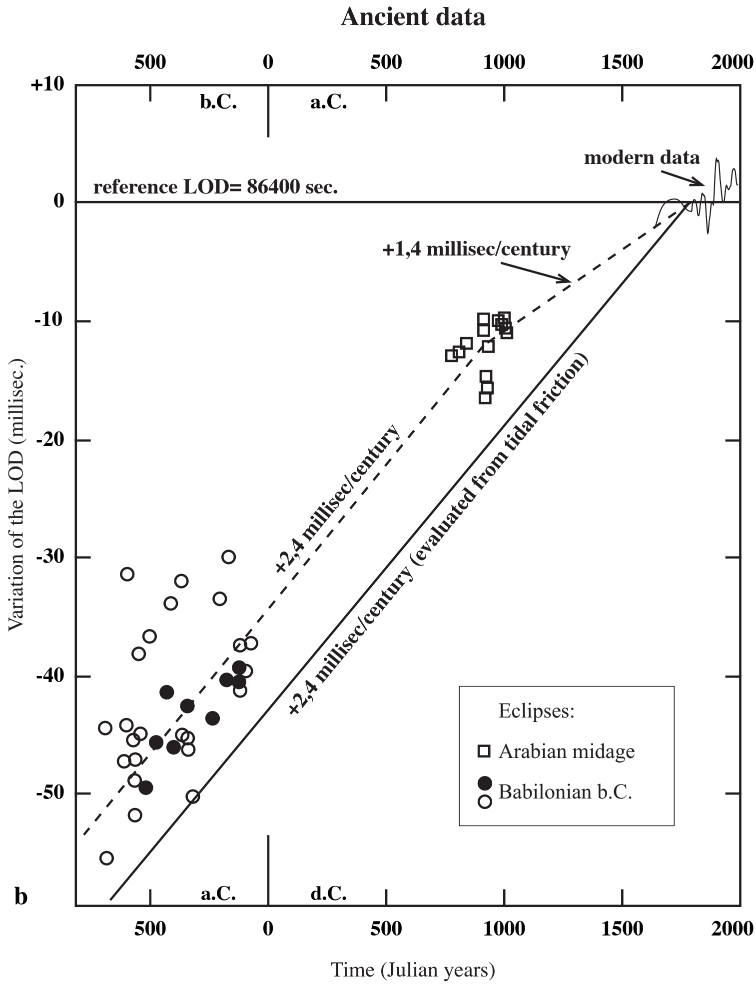
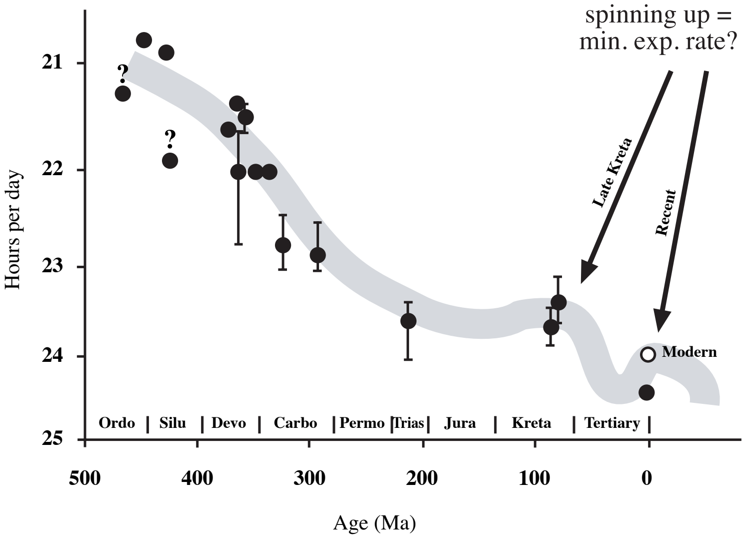


Fig.13
Long period variations of the length of day (LOD). The paleo-LOD as derived from the paleontologic data. The figure is redrawn from Williams (2000) with strong simplifications and no different symbols for different fossils. Only data from corals, bivalves, and brachiopods are extracted from the Williams compilation, and the geologic time has been started at 500 Ma. Although caution should be exerted in considering this data (see for example the strong underestimation of the Tertiary data nearest to the modern one) the maximum of the overall trend (the large grey band) in the end of Cretaceous (the time of the Deccan traps is around 65Ma) is in agreement with the minimum global expansion rate recognizable in the same period in the half spreading map of McElhinny & McFadden (2000). The interpretation is possible of a pulsating global expansion, with fluctuation of the expansion rate from short (tens of years, capable of continuously exciting the Chandler Wobble) to very long periods. When the Earth enters a period of minimum or zero expansion rate, a stability or a decrement of the LOD is possible because of the continued differentiation of the inner materials and possible prevailing of its decremental contribution to the Earth's inertia moment.



function of the polar motion, which is proportional to the position of the rotation pole in the x-y plane. The solution of the Liuville linearised equation is:

$$m = m_o e^{j\sigma_o t} ,$$

which if represented in the plane m_x-m_y describes a cycloid around the shifting pole of rotation Ψ (Spada *et al.*, 1999). The problem of this solution, in presence of damping (internal friction due to viscosity of the Earth), is that the amplitude of the coils of the Chandler component is progressively attenuated by a damping factor, usually an exponential one, and the cycloid transforms in a linear path (see fig.2.7 in Spada, 1992). The motion resolves in a straight line without the circular Chandlerian motion. What is the cause of the Chandler motion still remain unexplained in absence of other excitation sources.

A plethora of hypothesis could be formulated to avoid this *impasse*:

1) Some special non-linear terms should be added to the Liuville equation that make possible a concomitant excitation of the Chandler wobble.

2) The influence of earthquakes on excitation of Chandler wobble.

3) The role of other surface mass transport (erosion-sedimentation) (Spada *et al.*, 2000) or geo-fluid circulation (Chao *et al.*, 2000).

4) A strong non uniformity in time, also on our historical time scale, of the asymmetrical mass emplacement (and differenti-

ation) which can result in a casual succession of lapse of time of the excitation lasting, and in a casual phase of the starting and ending of the perturbation with respect to the initial circular Eulerian wobble (an example of this in Spada *et al.*, 1999).

No indication in favour of point 1) is coming from literature. The influence of collective action of earthquakes 2) is hypothetical if not disproved (Spada, 1997). Also 3), the role of the currents in geo-fluids, is still an open problem, while the erosion and sedimentation geological processes (Spada *et al.*, 2000) have negligible effect on PM, and act in a different direction. Then, among the items of this incomplete list I prefer the point 4) because the data series of the length of day (LOD) presents the right characteristics of irregular variations. As it can be seen in Fig.12 (Scalera, 1999; data from Morrison, personal communication; Jordi *et al.*, 1994; Stephenson, 1997) strong irregular oscillations of the LOD are typically on periods of few decades and on longer lapses of time as witnessed by ancient eclipses (Stephenson, 1997). And, as further element of disturbance, the Markowitz oscillation (nearly three decades in periods) is superimposed on the secular PM path (Markowitz, 1970; Poma *et al.*, 1987). Very long periods of variation, and related considerations, are shown in Fig.13. The concomitant presence of these phenomena could be an indication that irregular mass displacements happen in the interior of the Earth's body, – on very different time scales – which asymmetrically displaced parts can be capable of exciting the Chandler Wobble against the continuous viscous damping. This asymmetrically and non-uniformly displaced mass can well be in relation to the major superplumes diapirical expansion and to the overall Earth's expansion. In any case the entire matter deserves a more careful investigation.

Clues of a universal planetary expansion

Strong progress has been recently made in the knowledge of the solar system planets and their satellites, especially with the surveys of the space probes. Many signs of expansion have been detected on the planetary bodies and some of them have been interpreted as due to some 'plate tectonics' active on the planets at some time. In this very short review my aim is to examine the evidence of episodes of expansion on planet and satellites reporting the different possible interpretations.

Internal planets

Mercury has been photographed only partially by space probes. On the known surface a number of less craterized basins or planes exist that can be judged to be younger than the other part of terrains. Strong similarities subsist, in morphology and age contrasts,

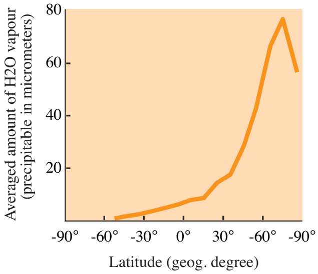


Fig.14

Mean water vapour in the Martian atmosphere as function of latitude. Atmospheric H_2O is concentrated in northern hemisphere, where basaltic flows are present. Although this is explained by a greather occurrence of dust storms on the southern hemisphere, which could protect the South CO_2 Ice Cup from the Sun light, the question can be posed in an expanding planets view of a possible analogy between the Earth's Pacific basaltic hemisphere, where juvenile water sources are suspected to exist, and the Martian northern one.

with respect to the Moon's Maria. The greatest basin, Caloris Maris, is bounded by concentric circular chains of mountains, broken radially by long linear fractures. Antipodally to Caloris the zone of 'strange terrains' is located, that are commonly interpreted as the results of a focalisation of the seismic waves produced by the impact that generated the Caloris basin. Also this is a similarity with the terrestrial Moon, where antipodally to the maria the high terranes exist. Moreover the radial graben departing from Caloris, because fracturing of the annular muntain belt, are then younger than the ring-like hills, and as consequences could be interpreted as the results of a slow asymmetrical expansion centered on Caloris Maris. The same antipodality is observable on the Earth, where to the maximum expansion region, Nazca, the antipodal European-Mediterranean region of minimum expansion corresponds. Likewise it happens on Mars, where all the younger northern hemisphere, not linked to impacts, is antipodal to higher and older terranes of the southern hemisphere (Fig.14). Venus' situation is less clear, but the coronae are concentrated in the northern hemisphere and can be interpreted as the surficial result of a diapirical material rise.

Moons of the external planets

Many of the same characteristics of Mercury, Earth, Moon, Mars, can also be recognized on the satellites of the external planets. Bimodal distributions of terrains ages are present on a number of satellites like Ganymede, Europa, Enceladus, Tethys, Dione, Rhea, Iapeto, Ariel, Miranda, and this bimodality can be interpreted as an asymmetrical expansion that has happened discontinuosly through geological time. The other satellites present situation less clear but symptoms of expansions – like rift, grabens, long and large tectonic valleys, perfectly circular craters without ejecta – are not laking on them.

Very impressive is the presence, on many of these moons, of a large dominant crater without ejecta (*e.g.* in Tethys, Mimas, Phobos, *etc*…) that could be interpreted as the beginning of the asymmetrical emplacement of the diapirical rising of inner material, which in the next stages of the planetary body evolution can become the large 'resurfacing' today observable in most of them.

Earth

The planet Earth presents a strong bimodality of terranes, continental and oceanic, with different mean ages. The younger the ocean floors are, the older the continental crust and litosphere. The style of crust production seems to have evolved from prevailing granitic to prevailing basaltic around 200 Ma ago. The presence of a geological liquid strata, composed essentially of water and dissolved NaCl, the Oceans, has luckily preserved the shape of the continental fragments after their separation – a fact that did not occur on other solar system planetary bodies – allowing the possibility of reconstructing the ancient mutual positions and contacts of the fragments. But while some geologists interpret the continents as wandering on the globe surface driven by internal forces like convective fluxes, and find jigsaw-like similarity only on some Oceans, other geologists find such similarities also on the greatest Ocean and interpret the break-up of the old continental lithosphere due to global expansion.

In conclusion all the planets appear to have undergone at least one episode of expansion, and on the bodies where this expansion is more clearly delineated, the Earth, Ganimede, Enceladus, the increase in size is judged very important. This is a symptom, that this phenomenon could be more likely linked to a general physical cosmological process, and not to a contingent one.

Causes of the expansion

In the course of time a number of different causes of the Earth's expansion have been proposed, depending on the cosmogony and cosmology accepted by each author. Essentially two lines of thought can be recognized: a cosmogonical and a cosmological one (Fig.15).

1) The *cosmogonical hypothesis* has been defended in the works of Hugh Owen (1992). The idea is that the primeval solar system was not formed by progressive accretion of dust in a rotating discoidal Laplace nebula, but that the planets were the results of a super nova explosion that shot into space little droplets of high density matter that today may constitute the innermost core of the planetary bodies. The sun formed on a collapsed supernova core. The inner planets are constituted of matter coming from the inner part of that star – heavier elements like iron, sulfur and silicon –, and the outer planets of chemical species of the outer layers of that star – mostly hydrogen, helium and other light elements. The progressive transformation of the denser phases into lighter chemical phases could be the cause of the expansion of the Earth and of the other planets (Fig.15, left side). In favour of this view, cosmochemical evidence has been recently presented by Oliver Manuel (2000). Essentially the evidence is that in meteorites all primordial helium is accompanied by 'strange xenon,' and helium associated with strange xenon is present in Jupiter. Helium and strange xenon could come from the outer layer of a supernova that created the solar system. All this has historical roots in the conceptions of the French naturalist Buffon, which propose solar catastrofic origins for the planets, and more recently in a conception of Hoyle of a Sun constituted of a large iron core (Oliver Manuel, 2000).

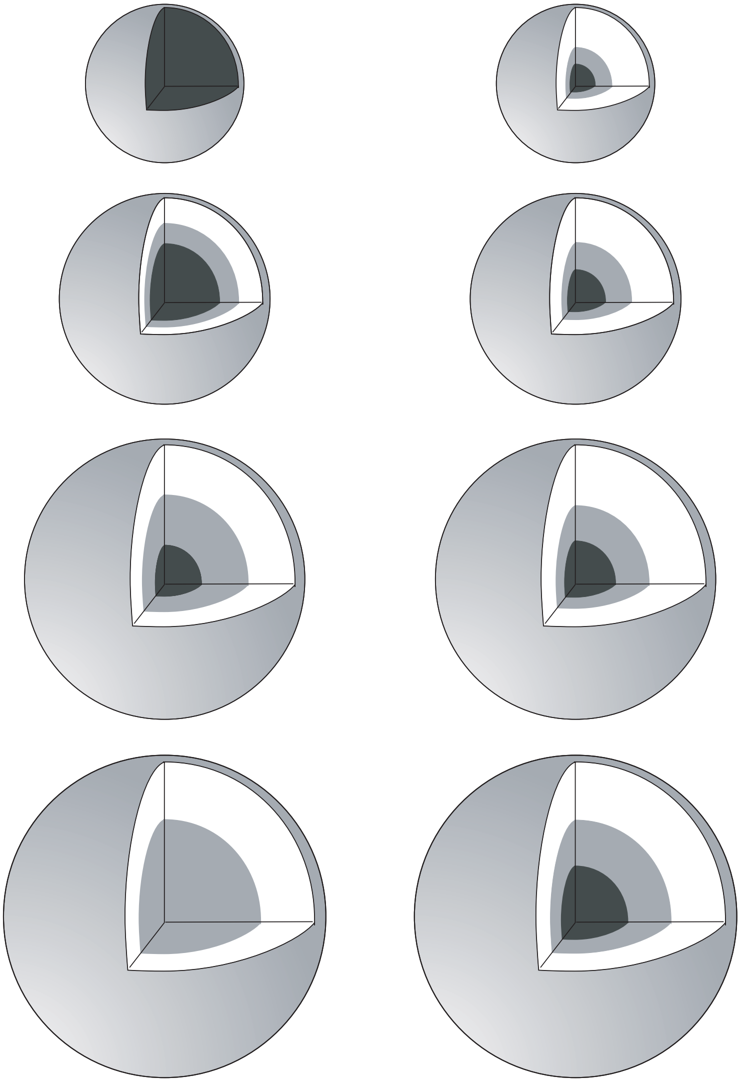


Fig.15

Two different ways of evolution of an expanding planet.

Left:
the planet is a fragment of superdense matter coming from the explosion of a supernova. This matter undergoes slow change of phase towards less dense states. As a consequence the inner superdense core decreases in size until it is completely exhausted, at this point of its evolution the planet ceases to expand.

Right:
an unknown cosmological causation is providing a matter source where the matter density is already higher (multiplyng creation, following Dirac). The inner core grows together to the mantle, and the expansion does not cease. the planet passes through a succession of different stages: terrestrial planet, Jupiter like planet, little dwarf star, and so on.

2) The *cosmological view* has many branches. The classical one was the view adopted by Hilgenberg of a hydrodynamic behaviour of the gravitational field, linked to the Riemann (1826-1919) equation. Hilgenberg's space is a dynamic space flowing towards the centers of attraction – centroid of a planet. It also transports some amount of energy that cannot escape (cannot flow in the opposite direction) from the deepest interior of the planetary body and finally, in an unknown physical process, it turns into ordinary matter. The expansion, contrary to the cosmogonic case, does not stop, driving the planet through a succession of stages culminating in a star steadly more massive until it eventually becomes a black hole (Fig.15, right side).

Other branches of this view try to assume that the planets absorb from space some exotic species of matter, like parts of the long serched for 'dark matter,' or exotic particles, or wimps, or some other massive but elusive matter. Modern physics is serching today to explain the difference between the universe baryonic mass deduced from the deuterium abundance and the total mass of universe hypotesized to be near critical density. The anomalous behaviour of the fall-velocities of the stars near the Sun, which are 30-50% higher than expected considering the visible mass of the stars, is considered evidence of the presence of a huge amount of mass non detectable by optical tools (Trimble, 1987). The problem becomes increasing important when structure of increasing dimension are considered. Rotation curves of galaxies cannot be explained without the presence of undetected dark matter. Dynamics of cluster and supercluster of galaxies are the most affected by the problem. This branch – the absorption of otherwise elusive matter – produces stronger problems as that concerns the spin variation of the planet, because the absorption must be considered as a succession of inelastic collisions, which produces a stronger despinning with respect to the case of a new-born matter with zero velocity in a co-moving reference frame.

3) A further possibility is the coexistence of both the cosmogonic and the cosmological cause of expansion.

It is not simple to argue which of the two conceptions, cosmogonic or cosmologic, or a combination of the two, is the more probable way to provide a coherent explanation of the inner process leading to the expansion of the planet, and it is to be admitted that in the expanding Earth theory easy physics still does not exists, like the easy convective flux physics which has been a long standing problem-solving occasion for plate tectonics adherents (Nunan, 1988).

Albeit the cosmogonic hypothesis could seems more acceptable to the geoscience community, it is also true that the recent results of the appearance of neutrino solar flux in the SNO (Sudbury Neutrino Observatory) experiment (no sensitivity to non-electron neutrinos) and at the Superkamiokande (Japan) experiment (low sensitivity to non-electron neutrinos) are in good agreement with the standard solar model and attribute the long-standing problem of a too low neutrino flux to the conversion of these elusive particles to τ and μ neutrinos. To compare two experiments which use different apparatuses and methodology is always very difficult, but, if this interpretation of the comparison is confirmed, little possibility for a Sun with an iron core remains. But at the moment a definitive judgement should be postponed, and the solution of the problem should be considered still open, waiting for new results from neutrino physics expected in the experiments underway in Italy (Gran Sasso Laboratory, Borexino experiment), in Greece (Nestor experiment) and others, very useful also for a refraction-free neutrino tomography of the Earth.

A simple-minded cosmological experiment

Also a consideration is need about the fact that a confirmation of the recent neutrino physics results requires an Earth's deep interior not necessarily of iron, a conception that can be linked to a possible coordinated growth of outer core and mantle. Then, although I cannot provide any decisive proof, my prejudices tend to prefer the latter cosmological hypothesis, of which I indistinctly see some links with the unsolved problem of dark matter, in the sense that dark matter may not exist at all or could have a very limited importance, and that the gravitational anomalies we observe as a violation of the virial theorem in the bound cluster and supercluster and in the rotation of galaxies may be due to the increase of mass of the celestial bodies and to other related effects.

On this subject, many years ago, I performed a very simple computerized experiment searching for the macroscopical effect of a possible increase of gravity having a doubling time of hundreds of Ma. The oversimplified virtual experiment is described in a paper of 1994 (Scalera, 1994). A number of test masses were successively thrown, in the same plane, in a central gravitational field which increases exponentially, only imposing the condition that the masses spiralize with regularity without large differences among them.

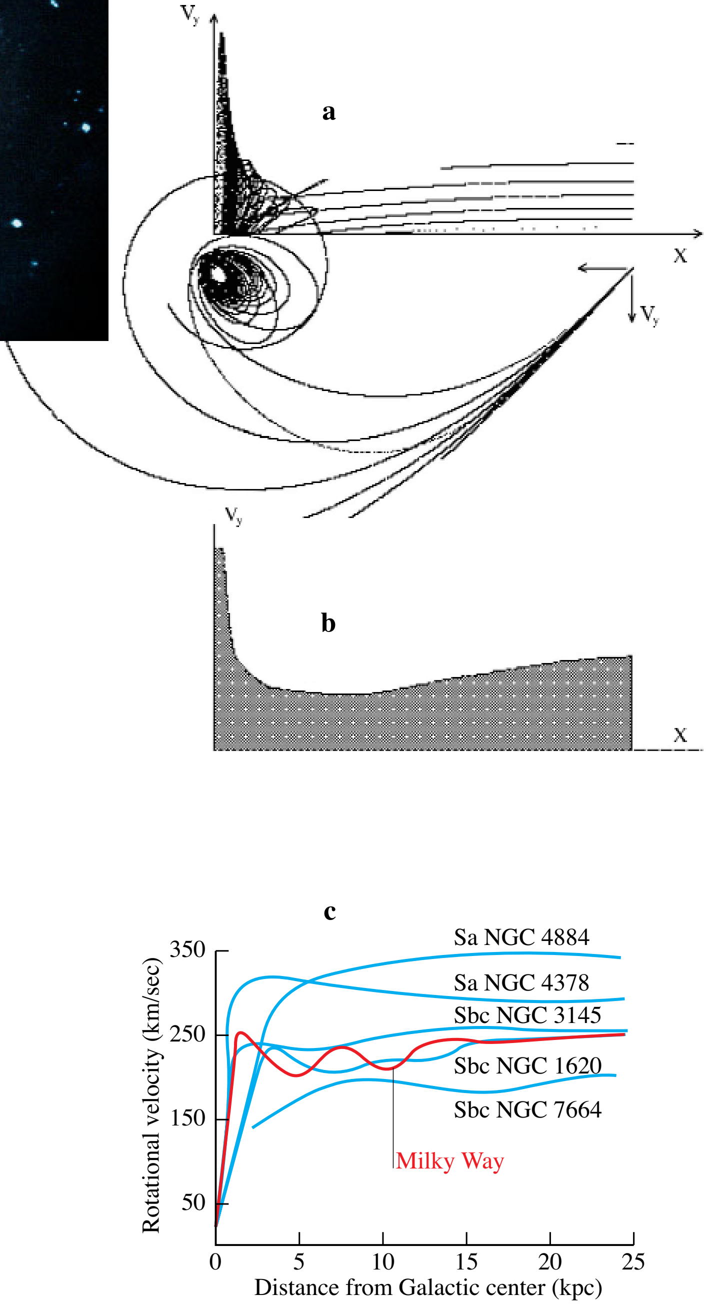
The virtual observer is considered very far from the center of attraction (near the infinity) on the plane of the open orbits and can measure only the component of the velocity of the masses along the line mass-observer. The graphic part of the program plots this component of the velocity of each i-th mass (Fig.16a) and a curve envelope is traced because it more strictly represents the obseved 'present time' of all the series (Fig.16b). The resulting envelope is very similar to the observed curves of the velocity of rotation of the galaxies versus the distance from the center (Fig.16c). The virial relation between kinetic and potential energy in bound systems is not respected and an eccess of kinetic energy is detected from the virtual observer if him, because unaware, do not take in account the increase of mass of the system. The bound system appears to him as unbound as that concerns total energy.

There is also a dependence of the kind of spiralization from both the doubling time τ of the gravity field and the 'period' T of the open orbits (period is an improper word, T is the time to run over 360° of the open orbit) of a test mass.

1) If $T >> \tau$ the orbit is elongated and near a straight line,
2) if $T \approx \tau$ the orbit is a spiral resemblig the galaxies arms,
3) and if $T << \tau$ the orbit became virtually an elliptical one.

Fig.16

A spiral galaxy is constituted by young blue stars in the far edges of the arms, while the stars become older and older coming towards the central bulge. This is a clue that the real trip of a star is not an ellipse around the galaxy center but the same spiral arm. This is possible if the gravitational field increases with the time.



In a) on the right, a very simplified experiment is performed. Some test masses are thrown, at different times, in a central gravitational field which increases exponentially in time.
In a) the component V_y of each test mass velocity, in direction of the observer (located at the infinity) is shown. The V_y axes pass on the center of the field and the x-axes is in the same scale of the true paths of the test masses.
In b) the envelope of all the curves of the V_y components is represented. This is the only 'observable quantity' for the virtual observer, and an astonish remblance exists between the curve in b) and the anomalous velocity curves which have been found for many galaxies.
In c) the observed rotational velocity for six spiral galaxies.

Order	Suborder	Infraorder	Family	Weigth□ ton	Length□ mt	Posture□ Bip./Quad.
Dinosaurs	Saurischia – Theropoda	Coelurosauria	*Archaeopterygidae*		1.0	B
			Compsognathidae	0.003	0.6-0.9	B
			Coelophysydae	0.03	0.6-3.0	B
			Coeluridae		1.2-2.4	B
			Halticosauridae		≈5.5	B
			Noasauridae		≈2.4	B
		Ornithomimosauria	*Ornithomimidae*	>0.1	3.5-6.0	B
			Garudimimidae	≈0.12	≈3.5	B
			Deinocheridae	**≈6.0**	>10.0	B
		Deinonychosauria	*Troodontidae (Saurornitidi)*		≈2.0	B
			Dromaeosauridae		1.8-4.0	B
			Therizinosauridae	**≈5.0?**	≈11.0	B-B Q?
		Carnosauria	*Allosauridae*	1.5-4.0	10.-13.	B
			Spinosauridae	≈4.0	≈15.0	B
			Megalosauridae	>2.0	7.0-9.0	B
			Tyrannosauridae	**7.5**	>12.0	B
			Abelisauridae	1.0-4.0	≈11.0	B
			Dryptosauridae	>1.5?	>20	B
			Torvosauridae	**≈5.5**	≈10.0	B
			Baryonychidae	>2.0	≈9.0	B Q
			Ceratosauridae	<1.0	3.5-6.0	B
			Itemiridae			B
			Aublysodontidae	≈0.2	≈2.5	B
			Eustreptospondylidae ?		≈7.0	B
		Oviraptorosauria	*Avimimidae*		≈1.5	B
			Caenagnathidae		≈2.0	B
			Oviraptoridae		≈1.8	B
			Ingeniidae		≈1.4	B
	Saurischia – Sauropodomorpha	Prosauropoda	*Anchisauridae*	.03	2.0-3.0	B Q
			Plateosauridae		5.0-6.0	B Q
			Blikanasauridae			Q
			Melanorosauridae	2.-4.0?	6.0-12.	Q
			Yunnanosauridae		≈2.0	B Q
		Sauropoda	*Camarasauridae*	**≈20**	12.-18.	Q
			Brachiosauridae	**>60.0**	10.-25.	Q
			Diplodocidae	**<18.0**	16.-27.	Q
			Titanosauridae	**<50.0**	9.-21.	Q
			Vulcanodontidae		≈6.5	Q
			Cetiosauridae	**>10.0**	9.-18.	Q
			Barapasauridae	**>10.0**	≈18.0	Q
			Euhelopodidae	**<25.**	10.-27.	Q
			Dicraeosauridae	**≈6.0**	13.-20.	Q
			Chubutisauridae ?	**10.0?**	≈23.0	Q
	Saurischia – Segnosauria		*Segnosauridae*		5.0-9.0	B
			Enigmosauridae		≈7.0	B ?
	Herrerasauria		*Staurikosauridae*	0.1	2.0-3.0	B
			Herrerasauridae	<1.5?	2.0-11.	B
	Ornithischia	???	*Fabrosauridae*		≈1.0	B
		Ornithopoda	*Hypsilophodontidae*		1.0-2.5	B
			Iguanodontidae	**<5.5**	4.0-9.0	B-B Q
			Hadrosauridae	**>5.0?**	3.5-15.	B-B Q
			Dryosauridae		2.5-6.5	B-B Q
			Lambeosauridae	E	4.0-15.	B Q
			Camptosauridae	E	1.0-7.0	B-B Q
			Thescelosauridae		≈3.5	B-B Q
			Heterodontosauridae		≈1.2	B Q
		Scelidosauria	*Scelidosauridae*		≈4.0	Q
			Scutellosauridae		0.5-1.5	B-B Q
		Stegosauria	*Stegosauridae*		3.0-9.0	Q
			Huayangosauridae		≈4.0	Q
		Ankylosauria	*Nodosauridae*		2.0-8.0	Q
			Ankylosauridae	≈3.0?	5.0-11.	Q
		Pachycephalosauria	*Pachycephalosauridae*		1.0-5.0	B
			Chaoyoungosauridae			B
			Homalocephalidae		0.5-3.0	B
		Ceratopsia	*Ceratopsidae*	**<8.5**	2.0-9.0	Q
			Protoceratopsidae	≈0.1	1.0-3.0	B Q
			Psittacosauridae		≈2.0	B-B Q

Fig.17
All the dinosaurs families, with indication of posture, length and weigth. In bold the weigths greater or equal to 5.0 tons. It is a paleontologyc and mechanical problems the high weigth of bipeds like Deinocheridae (Ormithomimosauria) and Tyrannosauridae (Carnozavria), and their possibility to walk and run with a bone structure like birds or arboreal animals.

These three conditions are all experienced in successive times by each test mass, which after a sufficient amount of time spiralizes elliptically in a limited region resembling the galactic nucleus. The argument is also in favour of a galactic evolutive sequence starting from open spirals and ending on the elliptical galaxies in few billion years. It is also in favour of considering in a new way the spiral arms of galaxies, which in this simulation are the paths along which the stars aproach to the galactic nuclei. Dark matter do not exists in this view, and the long time searched fossils of galaxies are nothing but the same irregular and spiral galaxies which evolve in elliptical galaxies and then in massive black holes. The observation that the proportion between spiral and elliptical galaxes do not change greatly going far in the space (high red shift), and consequently in time, could be an evidence in favour of this view.

I am certain that this simple-minded computer simulation cannot have any pretense to be the solution of the complicate problems of astrophysics, but could be indicative of how an adherent to expansionism could consequently link Earth to cosmology, linking also the morphology of the galaxies to the process of new mass creation because of yet unknown cosmological processes. My only hope is that the virtual experiment could be remade by some expert in the field introducing more complications on the already performed constant-mass super-computer simulations.

Paleogravity

About the paleogravity topics different views exsist, and the conclusions of some of these are in complete disagreement with an increasing gravity (Stewart 1977), and in a case in favour of a sensible decrement of gravity (Hladil, 1991). Considering the above described possible cosmological links, I am oriented to prefer the case for an increasing gravity.

The possibility that paleogravity could be lesser and lesser going back through geological time has been defended on different bases. The first topic says that the Dinosaur sizes and their bone architecture (especially the giant biped Dynos) are not suitable to walk and, still more difficult, to run (Fig.17). Neiman (1990) discussed the position of the heavy tail of the biggest quadruped dinosaurs, whose traces of dragging on the ground near the fossil footmarks are extremely rare. Another piece of paleontological evidence is the posture of biped dinosaur whose weight was up to 7-8 tons. From the complete catalogue of the known dinosaur genera it is possible to verify that nearly 73% of their families are biped or biped-quadruped. Moreover their posture was not plantigrade but tridigital (tridactyl), and the posterior digit is typical of arboricol species. Also their shorth arms could have been suitable for arboricol life. This typical posture is adopted today only by birds, very light animals, and heavier species are now all plantigrade (canguroes and similar) or quadruped.

From the vegetal realm it is possible to note a progressive decrease of the dimensions of the trees, whose maximum height depends on the possibility to transfer water and sop to higher leaves, and then directly from gravity. The most important group of plants, from angiosperm to gymnosperm and so on have decreased in size on the average through Mesozoic and Cenozoic, and this can be undoubtedly interpreted as evidence of lesser Mesozoic gravity. On these bases a stronger point can be made: it is possible that a progressive increasing of gravity has been a fundamental drive-factor in biological evolution? The evolutive passage from transversal to columnar legs, from the bipartite heart of fishes to tripartite heart of reptils to tetrapartite hearts of mammals (capable of pumping blood towards higher heads and against greater gravity), from gigantic size to more moderate size of animals, all seems to bear witness to this.

Another argument has been proposed by Mann and Kanagy (1990), but it was discussed on the basis of a different data-set by Neiman (1990). Fossil heaps of loose materials show angle of repose higher than the present ones going back through the geological time scale. The maximum recorded values of the angle exceed the modern ones up to 30°-40° (*e.g.* some Silurian values) while the more conservative estimate of different effects, assuming the big-bang cosmology and plausible variations in the Earth's spin, assigns only 10° of possible increase. The evidence based on the fossil heaps seems to me convincing and not artifactual because we have to espect the contrary bias of a progressive compactation of the strata. Angles of repose up to 60° testify to a gravity lower than the modern one. The work of Leo Maslov (this book) seems to indicate the necessity of an increasing gravity for an expanding Earth.

Concluding remarks

I fully understand the reclutance of people to accept expanding Earth. It required tens of centuries to pass from flat Earth to spherical Earth. And only after the trips of Columbus and Magellan (with the final evidence coming from the loss of a day) Earth became a globe, but people comforted themselves hoping that at least the globe was motionless and located in the Aristotelian centre of the Universe. A new scientific revolution needed to put Earth in rotation and in orbital motion around the Sun. Strong philosophical-religious dogmas and political events prevented for at least two centuries the complete acceptance of the Copernican system and of the conceptions of Galilei and Kepler (Scalera, 1999). Mobilism in Earth sciences, timidly proposed in the 17th century in the religious book of Plaçet (1666), was favoured by the mechanicism of Descartes. But strong variation in Earth size (progressive contraction) was proposed in the seven days of Genesis in the book of Snider Pellegrini (1858). Expansion of our planet was defended by the Italian Roberto Mantovani up to 1933. The scientific community accepted a rotating, orbitating body and moreover on Wegener's drifting continents only after the Second World War, and today we try to convince scientists to live on a planet in expansion. Truly very hard.... considering that to archieve this task we may have to change more concepts then just the geological conceptions. In Hilgenberg's ideas there existed a beginning of a different and more complete description of space-time. From the static and geometric, motionless, space of Einstein, Hilgenberg passed to a universal medium which is essentially movement. The Hilgenberg space is moving toward the planet and the Einsteinian principle of equivalence becomes perfectly symmetrical: we need a force to be put in acceleration in space, and we feel a force (gravitation) if space is accelerating with respect to us. Space transports a still unexperienced form of energy and consequently the planets grow. Hilgenberg conceptions are cosmology and a cosmology very different from and more general than the modern currently accepted expanding Universe. Probably his conception of space-time will be the next step in the physics awareness of the scientific and philosophical community.

The expanding Earth view has gained more ground only in recent years through the discovering that using its optics it is possible to reveal important facts and resolve some outstanding problems of the constant radius view. A simple list of a few topics:

1) While plate tectonics do not expect the existence of similarities of coastal contours between the opposite Pacific coasts (and do not search for them), expanding Earth expects these similarities, like the Atlantic similarities, and, by cartographic experiments, is able to find them (Scalera, 1993).

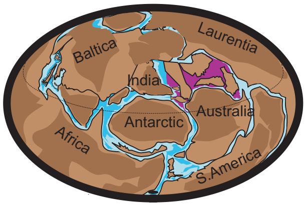
2) Plate tectonics have not been able to give a definite solution to the problem of the paleoposition of the Indian microcontinent in the Pangea. Expanding Earth provides an elegant solution in agreement with the paleopole data, palaeontology and the geology. India was connected to Antarctica along its western margin, in the zone of the actual Cooperation Sea. This solution is univocal, while many, many solutions exist for India and Indian Ocean peri-continents in the plate tectonics framework.

3) Expanding Earth can also provide a plain and easily understandable explanation of some astro-geodetic phenomena like the Polar Motion and True Polar Wander. Also in this case plate tectonics do not provide a unique solution to these problems.

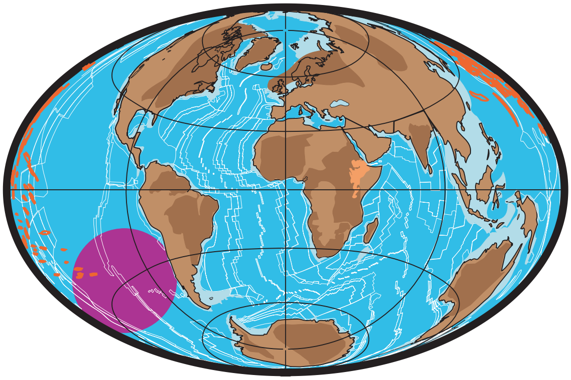
Fig.18

In the expanding Earth paleogeography the evolution of the Mediterranean sea has a more favourable projection into the Future. This region, that plate tectonics claims to be destined to a complete closing, in the expanding Earth view will continue to remain open. The expansion rate of the Mediterraneum is less than the opening rate of the other Oceans because the central Eurasian region is antipodal to the Pacific triple point of maximum expansion rate. The region of maximum asymmetrical expansion (see the violet zones in figs. Trias-Future) migrates from the Northern Hemisphere to the Southern one leaving behind a track of sea-floor volcanoes and the Darwin Rise.

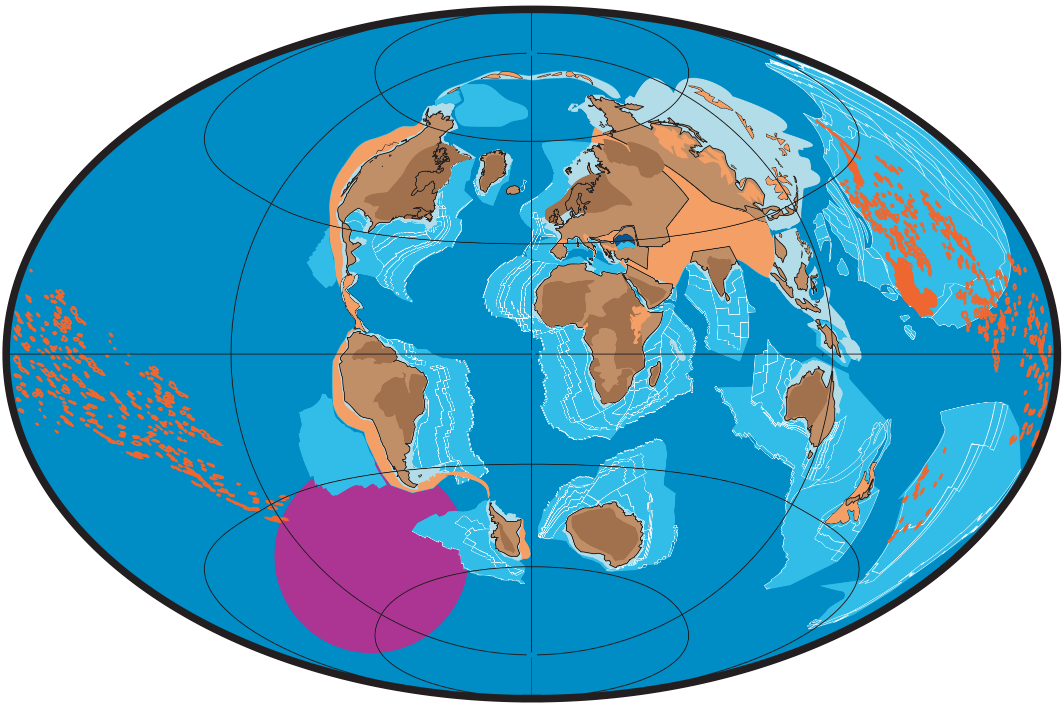
Triassic -220 My R=3300 km



Recent 0 My R=6370 km



Future +250 My R=9000 km



4) It is possible today to overcome the major *scolio* of planetary dilatation, namely the difficulty of revealing the expansion (which should be in the range of dR/dt= 1-2 cm/y averaged by 250 Ma, and only a few millimeters today) by geodesic methods, considering the new global map of the Half Spreading Rate of McElhinny and McFadden (2000) in which it is evident that today we are at a minimum of ocean floor spreading and then of global expansion.

5) As for projections into the future, plate tectonics and expanding Earth are different. While plate tectonics forecast at 250Ma a coming back of the continents toward Africa, with the complete closure of the Atlantic and Indian oceans and of the Mediterranean (Scotese, 1997), the expanding Earth framework consents to prolong the same tectonic state of evolution along all the Mesozoic, Cenozoic, Recent and Future geologic time, forecasting a further spreading of all the oceans, and then a more favourable destiny for the Mediterranean Sea (Fig.18).

Many other topics could be added and I have mentioned only some of them on which I have focused my recent research. But a plethora of other convincing arguments are actually besieging plate tectonics and I am convinced that not many years will pass before a new revolution changes the ever mobile world of Earth sciences. In conclusion I can say that all the problems in expanding Earth theory not related to the deep inner structure and composition of the planet have found a satisfactory explanation; on the contrary the problems connected with the interior of the planet, in connection with the causes of the expansion are still very far from a solution. But because expansion tectonics is now developed as far as petrology is concerned, geologic interpretation, palaeogeography etc. (see all the other papers of the contributors to this volume, and the bibliographic databases) I am convinced that the expanding Earth has been sufficiently developed now to be transmitted at least as complementary didactical material to the classroom from intermediate to university public instruction.

In my experience of active research I have found it very useful to think and eventually combine relevant facts and opinions in different global tectonic conceptions. Then my wish is that university courses, also of few weeks, will be dedicated to old and new concepts in global tectonics, in which the main aim must be to form a new modern generation of professional geoscientists, a new generation more open-mind, more willing to accept minority conceptions, more prepared to accept a new change in perspective, but remaining respectful of the results, databases and new techniques coming from the old conception, without which no progress could have been possible.

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