G. Scalera & S. Cwojdziński (eds.)
Selected Contributions to the Interdisciplinary Workshop
THE EARTH EXPANSION EVIDENCE – A Challenge for Geology, Geophysics and Astronomy
Erice, 4-9 October 2011

Distensional Mediterranean and World Orogens

Their Possible Bearing to Mega-Dykes' Active Rising

Giancarlo Scalera

INGV – Istituto Nazionale di Geofisica e Vulcanologia, Via di Vigna Murata 605 – 00143 Roma, Italy (giancarlo.scalera@ingv.it)

Abstract. An overview of the modern progresses of the expanding Earth conceptions as they come out from new data and their possible interpretations is provided in this paper. The starting point of this review is the new detailed 3D distributions of relocated hypocenters laying under orogenic belts. The similarity of the hypocentral patterns under the Tethyan orogenic belts, and under the South American Pacific orogenic margin is considered to be a major font of information on which to build a more realistic global geodynamic model. Clusters and filaments of hypocenters are recognizable instead of regular patterns. These clusters taper downwards, leading to the idea of a deep origin in narrow regions of disturbance, besides other important facts that witness in favour of surfaceward movements of deep material along what can be called "mega-dykes". The outpouring of the material on the surface produces gravitational nappes and their overthrust on the sediments of the pre-existing trough, forcing them on a burial path which emulate the subduction process, but without reaching depths greater than 50-70 km. Phenomenons like metamorphism, mixing, migmization, upward transport of fragments of the buried lithosphere etc. are possible at the boundary between uplifting material and down-pushed crust and lithosphere. Additional clues can be collected that confirm the new proposed framework. The astronomical indications of a coseismic displacement of the instantaneous Earth's rotation axis in the occasion of the great Sumatra (M_w=9.3) and Honshu (M_w=9.0) earthquakes are especially significant because in complete disagreement with the plate tectonics modelled axis shift and in agreement with the shift expected in the new conception. Because of analogous opposite predictions of the length of day variation following the extreme magnitude earthquakes (ΔLOD<0 vs ΔLOD>0), future improvements of the time measurement techniques could allow a final choice between rival geodynamical models.

Key words. Expanding Earth – Isostatic vs. diapiric rising – Mega-dykes – South American volcano-seismic correlation – Polar Motion correlations – Asymmetrical Earth

1. Introduction

Because its complexity, the Mediterranean region is believed to be a great natural laboratory from which extract data from different fields of geosciences and integrate them in a general framework of knowledge.

While the intention is good, the practice is somewhat different. The European geosciences community has undergone in the last after-war period, especially starting from the end of the sixtieth, a strong influence of the mobilistic ideas (Wegener, 1912a, 1912b, 1915).

These ideas were reworked – in the sixtieth and seventieth – in a new global tectonics, which avoided some inadequacies of the continental drift – like the navigation of the continental fragments in a sea of simatic material –, proposing the new concept of global cycle of new emplaced

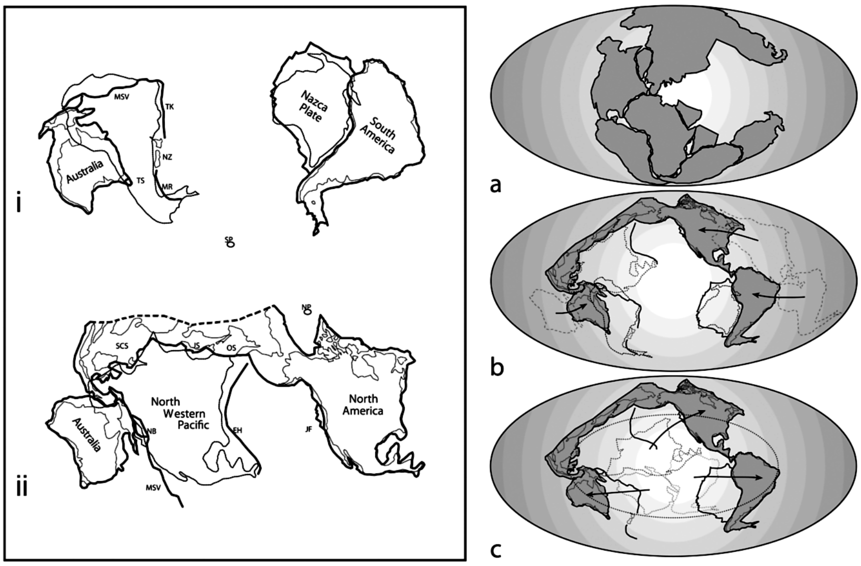


Fig. 1. Conformities in the Pacific hemisphere and their meaning. On the left: i) – Conformities and symmetry continent-basin and viceversa in Southern Hemisphere. South America corresponds in shape to Tasman and Coral sea basin, and Australia corresponds in shape to Nazca plate. Solid lines represent coast contour. Bold lines represent major tectonic discontinuities as continental shelves margins, trenches and spreading ridges. A computer aided rotations of Australian and South American continental shelves contours on the Nazca and Coral sea is shown. ii) – Conformities and symmetry continent-basin and viceversa in Northern Hemisphere. North America corresponds in shape to North Western Pacific. Juan de Fuca plate corresponds in shape to New Britain ovoidal plate. Solid lines represent coast contours. Bold lines represent major tectonic discontinuities as continental shelves margins, trenches and spreading ridges. The broken bold line is an arbitrary boundary between Asia (not represented in figure) and East Asiatic trench arc back-arc zones. A computer aided rotations of the North American continental shelves and Juan de Fuca plate contours has been performed. SCS = South China Sea; JS = Japan Sea; OS = Ochotsk Sea; ZF = Zodiac Fan; EH = Emperor Hawaii volcanic chain; JF = Juan de Fuca plate; NB = The little New Britain ovoidal plate; MSV = Manus, Salomon, Vityaz trenches; TK = Tonga Kermadec trench; NZ = New Zealand; MR = Macquarie ridge; CS = Coral Sea; TS = Tasman Sea; NP = North Pole; SP = South Pole. On the right: a) – Reference Pangea. The supercontinent has been reconstructed following the classic work of Bullard, Everett and Smith (1965) and Smith and Hallam (1970). b) – All the conformities among continents and basins together with the (dotted) outlines of Australia, Laurentia and South America in the positions which they assume in the reference Pangea. It is hard to imagine that the conformities could be formed by convergence of Laurentia, South America and Australia towards the Pacific. c) – It is more easy to imagine that if the Earth was once – before the Pangea break-up – smaller than the modern Earth (approximately an half radius Earth) the displacements of the continents from Pangea (which covers all the planet) towards the modern positions are mostly radial (with rotations), coming from starting positions which are mere overimpositions and juxtapositions of all the conformities.

material along the mid-oceanic expanding ridges and of disappearance (called subduction) of a same amount of material in the trench-arc zones, toward the deep Earth's interior.

The "New Gobal Tectonics" was rapidly accepted because it saved the old concept of compressional origin of the fold belts that was deeply rooted in both European and American Universities (Brouwer, 1981; Scalera, 2012).

The process of the sea floor expansion has been substantiated through a number of observable field evidence, while the subduction (unobservable directly) concept has ever encountered several opposition because paradoxes and counterevidence that was remarked very early (Hilgenberg, 1974; Carey, 1975; Pratsch, 1978; Scalera, 2012). The presence of shape conformities in the pacific hemisphere (Scalera, 1993, 2003) is the main proof of the impossibility of the large scale subduction occurrence (Fig. 1) and it asks for a new distensional interpretation for the active margin regions.

But it is in the Mediterranean that the subduction concept undergoes particularly strong difficulties, which are due firstly to the need of adapt the complex and peculiar geologic-tectono-geodynamic situation of the region to the framework of a theory that was born in a specific cultural tradiction and inspired by large oceans and very long active margins like the circumpacific ones. The small scale tectonic structures recognizable around the Mediterranean and the attempts to treat this sea/ocean as a contracting sea in the last phases of its closure – after older phases in which it was named Tethys, Neo Tethys, Paleo Tethys etc. (see figures in Ferrari et al., 2008) – encountered a lot of insurmountable problems.

The main of these outstanding problems is the hardly reconcilable coexistence of distensional structures and opening inner seas (e.g. Tyrrhenian, Aegean) with a doctrine that prescribes a compression and a shortening of distances between Africa and Eurasia. The many different solutions until now proposed possess somewhat of fantastic attitude in pursuing an higher-rank mobilism that albeit still not completely well defined on the surface, is sometime proposed with profusion of details for the subducted slab. The slabs, in the attempt to fulfil too many contrasting boundary condition, have to be very narrow, have to migrate horizontally in the mantle, and the slow dance of all these slabs in the depth of the Earth – each in a different and also disharmonic direction – is the more astonishing spectacular but unfortunately invisible natural phenomena ever alleged to exist.

Multi-disciplinary evidence converge in make clear that we deal in the Mediterranean with strong clues of an extrusion of matter and energy from the depths of the planet along mega-dykes. There is no need of the large scale subduction (hundreds of kilometers, or more than a thousand of underthrust), while a smaller amount of underthrust can be admitted (few tens of kilometers). The same conclusion can be drawn with a sort of generalization of the Mediterranean evidences. The same patterns of clusterized deep seismicity can be found in other regions of the world, and in South America the Pacific margin, an area previously considered as site of an huge subduction plane, this plane can be resolved in a series of

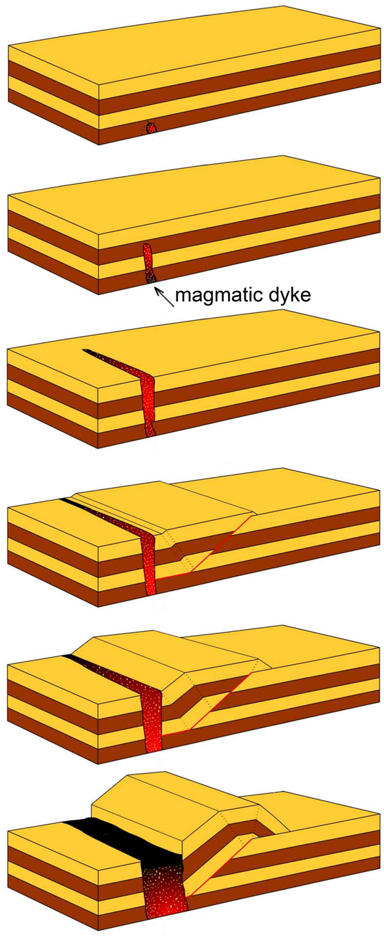


Fig. 2. The extrusion of material along deeply generated mega-dykes can become the driving idea of a new geodynamics. The concept of thrust faults produced by the rising of material was treated by Walker & Walker (1954). To their concepts the drawing of G. Dachille is inspired.

flanked "quanta" – each of them analogous or "twin" to the South Tyrrhenian "quantum" or single cluster of deep seismicity.

Moreover, the South American Pacific margin shows some new correlation processes and regularities that provide further support the mega-dykes view. Volcano-seismic correlation events occur with a pulsation of 45-50 years, which meaning could be a deep common drive mechanism for all the margin. The possibility to put these volcano-seismic events in correlation to the PM Markowitz oscillation – credited to have its cause on the core-mantle boundary – must be investigated with a longer window of data, but the clear existence of similar phenomenons of correlation of the Cascadia regional seismicity (Rogers & Dragert, 2003; Rubinstein et al., 2010) with the shorter Chandler Wobble (14 months PM oscillation) is an indirect invitation to continue this kind of researches that envisage a link between the surface and the deep interior of the Earth.

This new conception coming from seismic and volcanic data is in conflict with plate tectonics as that concerns both the coseismic polhody perturbations and the coseismic planetary spin perturbation. The possibility to collect new data of polhody shifts in the occasion of extreme magnitude earthquakes and eventually to reach a precision level higher than the actual in the LOD time measurement will constitute the true "crucial experiment" able to discriminate between plate tectonics and an expanding Earth in which a driving phenomenon on the active margins can be the extrusion of deep material along mega-dykes (Fig. 2).

Plate tectonics has certainly contributed to the progress of the geosciences in an enormous number of interrelated fields, and as consequence the great databases collected by a well coordinated sheer army of researchers constitute today the solid ground over which we can exercise our critical spirit hoping to build a new theoretical edifice. The old theory has been the first step in recognizing and systematizing the mobility of large lithospheric blocks. Its mobilism was confined grossly to a horizontal one, and possible variation of the Earth radius was – whether with awareness or good faith – discounted *a priori*.

We should not be pitiless toward old and renowned scientists that have granted the professional training of at least two generations of young researchers and have accumulated and forwarded knowledge – perhaps partial knowledge, but this is normal in the science. New conceptions that will follow plate tectonic are all the same destined to be partial, they will be more complete but inevitably incomplete, and they will be criticized by future generations in search of new world-views more adherent to nature. I will try to show how urgent is today the need to make a further step toward a more complete view of the Earth's geodynamics.

2. The Mediterranean

The Mediterranean surface area is about 3.106 km^2 and its average depth is 1500 m. In some regions the depth exceed 3000 m – up to about 5000 m – making the basin like to an ocean. It is an inner sea separated by narrow straits from the Atlantic and from the Black Sea. A maximum sea-floor age at the Jurassic-Cretaceous boundary characterizes the older Eastern basin, which is crossed by the Mediterranean Ridge (different interpretations of it in: Reston et al., 2002). Active WSW spreading both of the Aegean arc and the Western Anatolian orogen seems to be supported by geodetic measurements (Serpelloni et al., 2007).

Two great depressions of different ages, the Tyrrhenian and the Balearic, separated by the Sardinia-Corsica block, constitute the western Mediterranean basin. The Tyrrhenian basin is younger (few million years or Recent in its southern boundary) and deeper (up to 3500 m). Its uneven topography is rich in seamounts and volcanoes especially in its southern part, whose volcanic emissions contain many different geochemical signatures (Serri, 1997; Serri et al., 2001; Peccerillo, 2002, 2003; Trua et al., 2004; Panza et al., 2007).

Oceanic crust floors the Mediterranean sea basin in the Liguro-Provençal basin, Ionian, Libyan, Levantine, and Tyrrhenian seas. Submerged continental crust constitutes the floor of the Adriatic, Aegean and Tunisian Seas, and of all the bordering continental margins. The structure of Mediterranean is geologically very complex, and – for the reason already stated in the introduction – the tries to understand its evolution in the currently accepted theory have been not yet fully successful.

The main Mediterranean active tectonic structures are the two young arcs, Calabrian and Aegean – with a spread in SE and SW direction respectively – where a shallow, intermediate and deep (up to 400km) seismicity occurs. The Anatolian Peninsula shifts westward along the North Anatolian fault: the Jordan system of transform faults allows a southward drift of the Levantine region: a westward drift of the African plate is indicated by the Azores-Gibraltar strike-slip: and finally a large amount of minor fault structures still is awaiting for a definite geodynamic interpretation, like the Sicily channel grabens, the Malta extensional scarp, the Cephalonia transform fault and so on. Important regions of continental extension are the rift system of the Rhine Graben, the Bresse Graben, and some Iberian Peninsula grabens.

Thrust focal mechanisms characterize the Calabrian and Sicilian arc earthquakes. The deep foci of the Sicily-Calabrian arc Wadati-Benioff zone are currently ascribed to the effect of a lithospheric slab in a state of ongoing subduction (Giardini and Velonà, 1991). Different interpretations ascribe the crustal earthquakes to gravity tectonics (Lavecchia et al., 2007; among others) and the deeper seismic events to ascending intrusions (Scalera, 1998, 2006).

On the Apennines, a tensional stress state is recognizable from fault plane solutions (Scalera, 1997; Selvaggi, 2001; Vannucci et al. 2004) and from stress data coming from the breakout of crustal perforations (Montone et al, 1997). On the advanced front of Apennines toward the Adriatic sea, typical inverse fault solutions can be found (Lavecchia et al. 2003). Also in this case gravity tectonics can be invoked.

On the Aegean arc and the Anatolia peninsula, analogous reinterpretations of the shallow and deep seismicity can be proposed, making resort to gravity spreading and back arc intrusions. Typical thrust fault plane solutions are widespread on the outer Aegean arc (near the trench), and normal fault solutions are present on the back-arc basin, on the Peloponnesus and on Anatolia south of the northern Anatolian fault. Strike slip dextral solutions characterize the North Anatolian fault.

A general view of the hypocentral distribution of the Mediterranean deep earthquakes shows an uneven pattern that hardly can be ascribed to a regular convergence of Africa toward Eurasia (albeit with a substantial westward component). The possibility of reconstruct the Pangea as a fair mosaic, should be considered a guarantee of a limited amount of deformations of the involved plates during their slow decoupling, starting from Triassic. Then we should expect a regular distribution of hypocenters on Wadati-Benioff near-planar zones.

Instead we observe (Fig. 4) a very different pattern characterized by a large round-shaped basin of hypocenters (maximum depth 200 km on a pair of spots) around the Aegean sea, a short tube-like near-vertical concentration of hypocenters (maximum depth 180 km) in the Vrancea region (the zone of maximum curvature of the southern Carpathian fold belt), another tube-like concentration of hypocenters under the southern Tyrrhenian sea (maximum depth 500 km; Fig. 5) that starts near-vertical and bends toward Europe going toward the maximum depths. Some rare deep focus earthquakes are located under the Gibraltar Strait inner zone.

These sparse and narrow zones of deep events does not ask for the necessity of subduction – at least large scale subduction. If we cannot ascribe to the subduc-

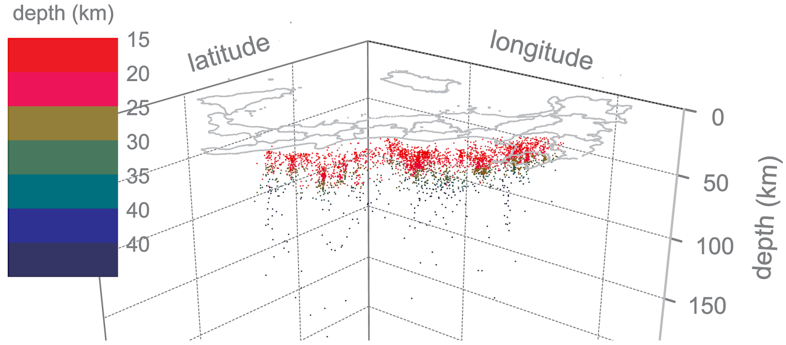


Fig. 3. Non uniform distribution of Italian seismicity along the Apennines and Calabrian-Sicilian arc. The filamentous pattern of hypocenters is similar to many other multi-filamentous patterns of foci that are observable in most Wadati-Benioff zones around the world. Data from the Italian Catalogue of Earthquakes; vertical scale is exaggerated.

tion process the occurrence of deep seismic events, we cannot escape the conclusion that the involved process leading to deep earthquakes must be different and that in absence of subduction also the orogenic processes and the fold belts building cannot be of pure compressional origin (Cwojdziński, 2012).

The Mediterranean deep seismicity – Only isolated filaments of hypocenters exist in the Mediterranean region, which investigation can strengthen conclusions already reached (Scalera, 2007a; 2008) about the possibility to rule out large scale subduction in the active margins, allowing only the occurrence (supported by large observational evidence) of few tens of km of over- and under-thrusts.

Along huge segments of the Africa-Eurasia contact, where a continuous Wadati-Benioff zones should be present with intermediate and deep hypocenters, only intracrustal seismicity is detected. Few well circumscribed zones show hypocenters depth up to 200 km, and only in one zone the depth reaches 500 km. It is a common creed of most geoscientists – without a valid explanation – that in the Mediterranean region the subduction mostly occurs aseismically.

Apennines and South Tyrrhenian deep seismicity – In Italy, the unevenness of the hypocenters pattern – typically a festoons pattern – is a characteristic of all the Apennines (Fig. 3), where seldom the hypocentral depths overcome 50 km (Chiarabba et al., 2005). The mountain belt axis is in a present state of collapse – as shown by focal mechanisms, geodetic surveys (Serpelloni et al., 2006) and other evidence (Salustri Galli et al., 2002). Then, the festoons of crustal earthquakes can be interpreted as mechanical fractures associated to the intrusions of wedges of deeper materials.

The presence of a subducting slab is incompatible with this hypocentral distribution (Fig. 3), which instead can be considered manifestation of more general processes and movements of the mantle materials and a replica at smaller scale of a the clusterized pattern that hypocenters follows at larger scale. Geodetic works (Devoti et al. 2002) provide indications that the Apennines' seismicity cannot be considered a result of the convergence of Africa and Europe.

Evidence that the South Tyrrhenian nearly vertical (more than 70°) hypocenters' distribution (Fig. 4, Fig. 5) is not associated to the so called "slab pull" and "roll back" – needing a tensional state of the slab – is growing. Using GPS data, Hollenstein et al. (2003) have shown that in the time window 1994-2001 the paths of crustal motion of the Calabrian-Sicilian arc have been in disagreement with the surface displacements modelled by "roll back". Recent investigations (Argnani et al., 2007; among others) have reached sim-

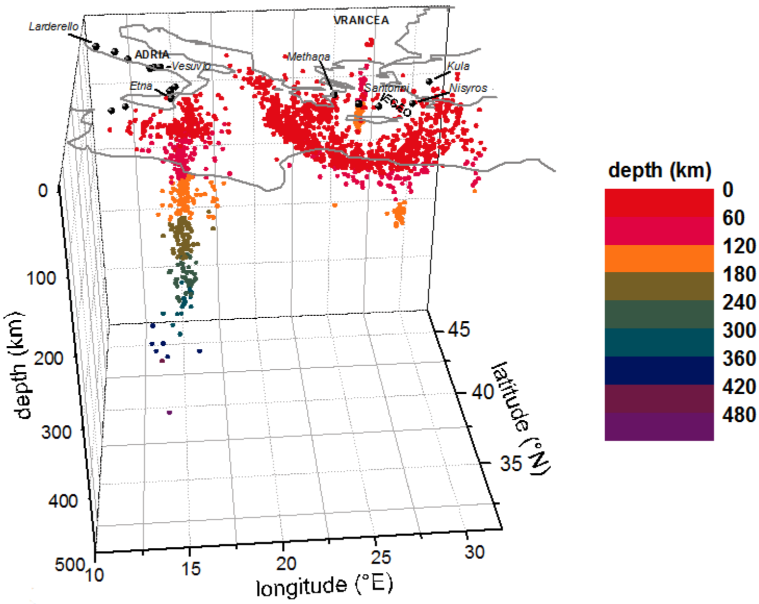


Fig. 4. The deep earthquakes zone under the Messina Strait reaches the depth of 500 km, starting as a near vertical column up to 200 km depth and then tapering along a lower slope. A similar but shorter near-vertical clustering of hypocenters is recognizable in Romania, Vrancea region, depth up to 180 km. These "single-filaments" typical pattern are similar to many other "multi-filamentous" structures that are observable in most Wadati-Benioff zones around the world and lead to an interpretation different from plate tectonics subduction. It can be considered more realistic an oblique uprising of matter and energy along these clusters, which could be clues of existence of "mega-dykes". Italian data from the Italian Seismicity Catalogue (Castello et al., 2006); Mediterranean data from Engdahl et al. (1998); vertical scale is exaggerated.

ilar results. Considering these new geodetic evidence, the causative phenomena for deep earthquakes should be searched in processes different from subduction.

Additional evidence from seismological active and passive methods – The Deep Crust Project (CROP) surveys (Morelli, 1998; 2003; Scrocca et al., 2003), and the reinterpretation with integrations of the DSS profiles (Cassinis et al., 2003) have not detected subducted slabs under the Italian region. The intrinsic limitations of the method put the maximum depth of resolvable reflectors to 40-50 km. The imaging of most underthrusts have not well defined boundaries and their small angles of dipping are not in agreement with the seismic tomography (see the high velocity anomalies in Amato & Cimini, 2001; Cimini & Gori, 2001). The question of the subduction is leaved open by some interpreters of the profiles. Some geologists (e.g. Lavecchia et al., 2002; among others), after to have pondered the well resolved difference between the Tyrrhenian realm crust and the Adriatic crust, have abandoned the hypothesis of a subduction under the Apennine, speaking of nearly continuous Moho from Tyrrhenian to Adriatic.

Indeed several clues are in favour of the Apennines in a state of nascent rifting:

i) The evidence of a collapsing narrow belt along the Apennines bounded by two lines of more frequent VII MCS degree occurrence (Boschi et al., 1995).

ii) This collapsing belt is confirmed by seismogeodetic observations (Salvi et al., 1997; Barchi et al., 2003; Hunstad et al., 2003; they evaluate a spreading of the belt of 2.5-5.0 mm/yr).

iii) The breakouts of wells up to 7 km deep (Montone et al., 1997).

iv) The focal mechanisms of earthquakes up to a depth of 20 km (see Fig. 3a in Scalera, 2005a).

v) The lack of a mantle lid (Mele et al., 1996, 1997) beneath the Apennine crust (from a Pn, Sn, Lg analysis).
vi) The presence of carbonatites (Stoppa & Woolley, 1997) that are signs of rising of hot mantle material (Lavecchia & Stoppa, 1996; Bell & Tilton, 2002; Lavecchia et al., 2002) under the crust in a tensional stress tectonic environment.
vii) The indication of the possibility of narrow rising of higher density mantle material from body wave tomography (Cimini & Gori, 2001; Cimini & Marchetti, 2006).

Continuing this analysis with the tomography under all the Mediterranean (Piromallo & Morelli, 2003), a wide zone of higher velocity (from 37°N to 50°N and from 5°W to 45°E: an extension virtually equal to the $3 \cdot 10^6$ km^2 area of the Mediterranean basin) has been detected – starting at the deep of 450 km and well defined up to 650 km – practically filling all the Mediterranean transition zone.

Several ad hoc interpretations are possible (Piromallo & Faccenna, 2004; among others) that resort to cold descending materials (rollback). Contrariwise, this vast anomaly can be considered indication of a rising of the mantle discontinuities already found by Berry & Knopoff (1967), Panza & Scalera (1978), Scalera et al. (1981a, b) using the seismic surface waves dispersion.

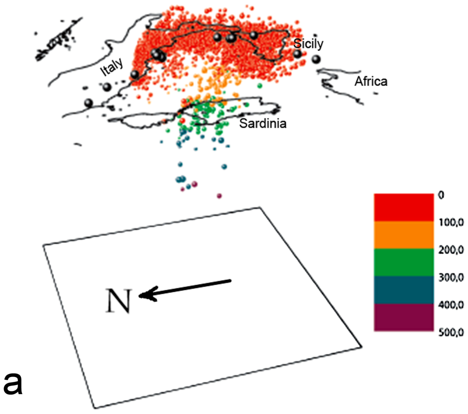
More properly, it is possible to interpret the rising of the discontinuities and the associated velocity anomalies as a consequence of the opening of the Mediterranean basin formerly proposed on the ground of geological reasons by Glangeaud (1957) and Chudinov (1980). A quantitative analysis shows that the opening of the Mediterranean basin needs an emplacement of a volume of a new mantle material equal to the volume of a geometric ideal solid having basis $3 \cdot 10^6$ km^2 (the Mediterranean surface area) and height of 100 km (approximate thickness of lithosphere). The resulting volume of $3 \cdot 10^8$ km^3 is less than the estimated volume of $6 \cdot 10^8$ km^3 of the high velocity anomaly in the transition zone ($A = 3 \cdot 10^6$ km$^2 \times h = 200$ km), then its value is consistent with this source of uplifted mantle material.

A further clue is the presence of a long alignment of positive magnetic anomalies from Ancona to Calabria in the map of total magnetic field intensity (Chiappini et al., 2000; Caratori Tontini et al., 2004), which is at the western margin of the Adriatic lithosphere, where possible extrusion of the magnetic basement can occurs (Speranza & Chiappini, 2002). Speranza & Chiappini (2002) try to put in agreement the observed and the computed magnetic field along the CROP 03 profile. This profile needs for high magnetic susceptibility materials – possibly volcanic – intruding in the crust like great dykes.

The same uplift of the basement and a step in the Moho (a Moho deeper under the Adriatic realm) have been observed by Mele & Sandvol (2003) and Mele et al. (2006) identifying the P-to-S phases converted at the Moho discontinuity beneath each station and estimating crustal thicknesses from the time delay of this phases with respect to the direct P arrivals. The Moho sections deduced from the CROP 03 and CROP 11 profiles and the basement step envisaged by magnetic surveys have been then confirmed by this independent method. With these uneven basement and Moho surfaces, the low propagation velocity of Pn and Sn under the Apennine (Mele et al., 1996, 1997; Mele, 2012, this volume) could be accounted for.

Then, because all the clues described in this section, an interpretation of the tectonic transport that does not resort to subduction and to its roll-back is desirable. A surfaceward movement of mantle material, which can be envisaged more active near the boundary of the Adriatic lithosphere, can be proposed as solution for all these additional evidence and as probable cause of deep erosion and vertical transport of lithospheric fragments along mega-dykes.

Aegean deep seismicity – A nearly perfect semicircular ring deepening toward



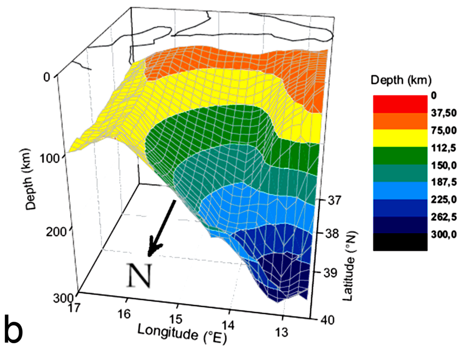


Fig. 5. Details of the Messina Strait seismicity. a) – The deep to subcrustal seismicity under the Calabrian-Sicilian arc is arranged like a emicircular crown of a tree over its trunk. No planar subduction is discernible. b) – The density of the hypocenters is like a funnel tapering towards N-O. This kind of "macro-structures" that are isolated in the Mediterranean region, are instead sequential on other regions like the South American Pacific Margin (see Fig. 7). The South American clusters are greater than the Tyrrhenian one but extremely similar. The isostatic rising of material along deeply generated mega-dykes can constitute the basic idea for a new geodynamics. .

the centre of the back-arc with a slope between 30° and 50°, defines the Aegean earthquakes pattern (Fig. 4). The foci are distributed on an irregular conical surface, mostly not overcoming 60 km in depth, but reaching higher depths (up to 180 km) on two well delimited clusters: the first under the eastern tip of Crete, and the other under the southern Anatolia, where ideally Hellenic and Cyprus arcs meet.

A "more complex trajectory of mantle flow than hitherto thought" has been revealed under the Aegean by recent seismic tomography (Widiyantoro et al., 2004), confirming the tendency of the high velocity anomaly to bend on a horizontal segment along the transition zone that Fukao et al. (2001) have found at global scale.

Unresolved problems come from the tries to reconcile the geodetically determined relatively quick motion of the western Anatolia toward SE with the tensional state of the Aegean seafloor shown by fault plane solution (McClusky et al., 2000; England, 2003; Serpelloni et al., 2007; among others). The collision and intrusion of the Arabian block into Anatolia give the impression of being a clumsy solution if we remember that the investigations of Mart et al. (2005) on the Levant Rift system (Jordan Rift, Lebanese Splay, El Gharb Rift) cannot escape to describe this region as a continental breakup evolving towards an emerging oceanic spreading center.

Another possible interpretation for both the rifting state of Aegean and the west Anatolia' kinematics can be found resorting to a possible southwestward horizontal flow of mantle material caused by the progressive detachment of Africa from Eurasia – this flow being the twin-flow of the southeastward Tyrrhenian flow. Both these flows are expected consequences of a slow opening of the Mediterranean (Scalera, 2005a, 2006a).

Similar new solutions can be applied – in agreement with the orogenic model proposed in the next sections – to the situation of north-west Africa, where the Atlas fold-belt lies on an elongated region that was firstly involved in a rifting and then in a tectonic inversion with consequent uplifting and folding (Ramdani, 1998; Missenard et al., 2006; Sébrier et al., 2006). This inversion is today currently interpreted as caused by the starting of a compressive regime, but in my interpretation it can be more simply the result of isostatic forces and phase changes activated by the rifting.

Vrancea deep foci – An outstanding problem for Earth' sciences is the tubular and nearly vertical distribution of deep foci in Vrancea (Romania) near the Southern Carpathian arc (Fig. 4). The tomographic images (Van der Hoeven et al., 2004; Weidle et al., 2005; Martin et al., 2005; Raykova & Panza, 2006) – performed with different methods – are all in agreement in revealing an high velocity body, which displays a resemblance with the Calabrian arc tomography (Cimini & Marchetti, 2006).

The high velocity anomaly under Vrancea extends nearly vertically up to the transition zone, but the hypocenters does not overcome 180 km in depth. Their occurrence is generally interpreted to be caused by the final stage of a subduction, slab roll-back and plate boundary retreat (Weidle et al., 2005; Tomek and PANCARDI Team, 2006). On the contrary, the regional geological evidence are in favor of an uplift of the crustal layers, with extensive inversions of the stratigraphic orders, with older layer thrust on younger ones – a clear indication of extrusion of the deep crust (see Fig. 3 in Knapp et al., 2005). As a matter of fact, both in the results of the seismic refraction line VRANCEA'99 (Raileanu et al., 2005) and in the associated density model that fits the observed Bouguer anomaly profile (Nicolescu and Rosca, 1992; Raileanu et al., 2005) subduction is neither presumed nor needed.

In the map of the metamorphic facieses of Carpathian and Pannonian Basin (Strutinski et al., 2006) a complete absence of exposed metamorphism in a larger region centered on Vrancea has been revealed. Earthquakes seem to be working in the present time in association to a mantle upwelling of the region in producing and surfaceward transporting the still buried – by a nearly 1000 m sedimentary cover (Strutinski, 2008) – metamorphism. It is then a more economic hypothesis to link the hypocenters to a surfaceward flow of mantle materials. The isolated spot of deep hypocenters of Vrancea can be interpreted as the remains or last stages of a process of surface emplacement of deep materials that is still to be completed with the cooperation of erosion.

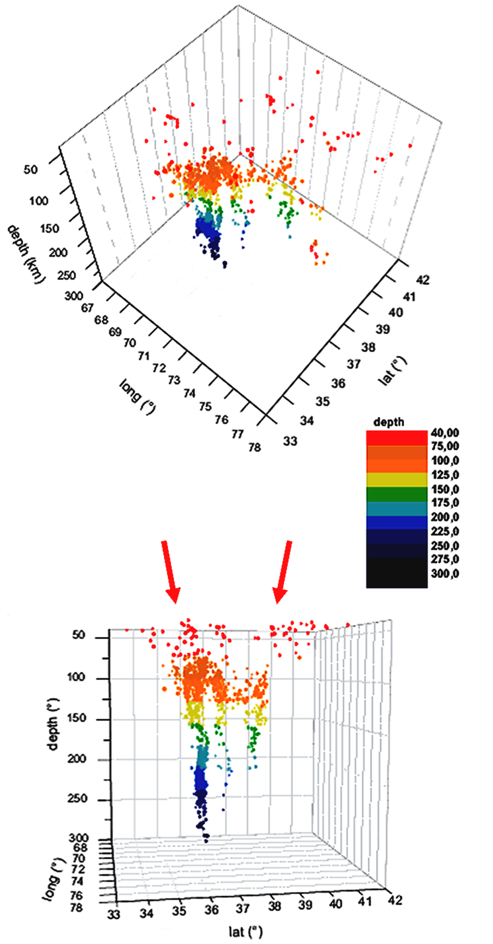


Fig. 6. Two different views of the clusters of deep hypocenters on the western Himalayan syntaxial zone. The two red arrows indicate the opposite slopes some clusters have, an evidence hardly compatible with the subduction conception. Slow intrusions of mega-dykes is a better interpretation.

The Western Alps syntaxial zone - Ivrea zone – In the "land hemisphere" the filaments of foci have a propensity to be located under the region of maximum curvature of the mountain belts. The main examples are the Western and Eastern Himalayan Syntaxial zones (eastern in Fig. 6), the Southern Carpathian "syntaxial" zone (Vrancea), the Southern Apennines (Calabrian arc) "syntaxial" zone, and the Aegean one.

It should be considered as a strange gap a lack of a plume of deep hypocenters under the syntaxial zone of Western Alps. Indeed only 9 hypocenters with depth greater than 50 km was reported in the database 1991-1997 of Cattaneo et al. (1999), of which only two greater than 70 km and one overcoming 100 km. But further 9 hypocenters deeper than 50 km are listed in the time window 1998-2002 of the Catalogo Sismico Italiano (Italian Seismic Catalogue; Castello et al., 2006), of which one is at 180 km. The presence there of one of the few deep crustal exposures in the world – the Ivrea Zone – is a further evidence of the link of these plumes to phenomena of uplifting of deep materials. The possible nearly extinction of this kind of plume under the Western Alps – while it is not still extinct under Vrancea – can be a clue of a relatively rapid variation through geologic time, with their enhancements and extinguishments whose time windows are still unknown.

First general deductions – The well established state of uplift of both the Himalayan corner zones (Zeitler et al., 2001; among others) can be added to the evidence of active uplift in the Eurasian syntaxial zones. Few clusters of hypocenters with depth up to 300 km are present under the Western and Eastern Himalayan Syntaxial zones (eastern in Fig. 6), proposing the problem of the existence of single isolated filaments and of their implications.

The zones I have above concisely scrutinized display their peculiar as well their common reasons to increase the doubts about the real existence of a large scale (hundreds of km and more) subduction under the active margins. But the argument I feel is decisive to exclude an ongoing (at least since Jurassic) subductive process in the Mediterranean region is the simple inspection of the 3D map in Fig. 4. No mechanical underthrust process involved in the alleged collision of Africa and Eurasia can produce such a singular pattern of few isolated and well-delimited plumes of foci, leaving completely free from deep foci all the long margin of interaction between the two continents – from the Rif to Atlas, to Adriatic, to Dinarides and to Anatolia.

Completely different are the slopes and the directions of immersion of the four deep plumes clearly distinguishable in Fig. 4. Their nature of isolated spots as well the same patterns observable all around the circum-Pacific active margins (Scalera 2007a, 2008) witness in favor of disturbances having their origin and episodic activation in the depth. Nevertheless, more clearly than in the opposite emisphere, the isolated Mediterranean deep hypocentral clusters lead to the idea of their association to a vertical displacement of material or to a boundary of it (Wezel, 1986).

This rising material should be thought as involved in the building of the overhanging fold-thrust belt and of the associated basin. The preferred zones of occurrence of the deep hypocentral plumes – in the maximum curvature zones of the fold belts – may be could be also in direct or indirect link to the complex history of decoupling of the African and Eurasian plates, of which the long and continuous fold belt Carpathian-Alps-Apennines-Atlas-Rif is one of the still not deciphered tracks.

3. Different clues of a different Mediterranean geodynamics

The exotic terranes: allochthonous or autochthonous? – A number of allochthonous terranes can be recognized all along the dry lands of the Mediterranean basin. In the plate tectonics view, they are defined allochthonous because belonging – as origin site – to the opposite shore of the Tethys sea, and only successively displaced – crossing the Tethys – on the shore where today we observe them (Ferrari et al., 2008). The main alleged exotic terranes are:

The Kabylies, little fragments of Variscan age and European origin today making part of the orogenic belt of Western North Africa (Tunisia, Morocco).

The Adriatic fragment, a large fragment of African origin that is alleged to have crossed the Tethys in northward direction in few tens of millions years.

Many fragments of African origin, of Cadomian age (≈550 Ma) are present in Balkan, Greece, internal Hellenides, Bulgaria, which correlate with analogous terranes of Turkey. They are interpreted as have collided against Europe in late Jurassic (Himmerkus et al., 2006).

Other Gondwanic slivers of Pan-African and Codomian ages can be recognized in the orogenic belts of Western Europe and Asia.

All these exotic fragment along Mediterranean opposite shores and Eurasian orogens constitute a general situation in which also the alleged long trip of India can be framed. In particular for India, a series of argument, whether paleomagnetic, or geologic or paleontologic, can be proposed about the link of India both with Laurasia and Gondwana (Sahni, 1984; Ahmad, 1978, 1982; Scalera, 2001, 2003).

The paradoxical presence of little or intermediate size (India) fragments of the same geologic unities on different shores of the Paleo-Tethys and Tethys has been currently resolved with rapid drift of the fragments from a continent to the other (Cavazza et al., 2004). The Cimmerian block trip is a well known example. The need for such unlikely long trips – with opposite directions – can be discarded if an Earth of lesser size is recognized. The presence of fragments on the opposite shores becomes a case similar to the presence of analogues orogenic structures on Laurentia (Appalachian) and Eurasia (Caledonides), which has been normally resolved as a result of the cutting of the orogen by the opening of the Atlantic ocean.

If the continents Gondwana and Laurasia were in contact before Mesozoic, starting their separation during Triassic, all these allochthonous terranes can instead be considered autochthonous ones. The fragments were autochthonous and were detached from the main continental block not by isolated trips across wide Tethyses, but by trips performed always attached to the "continents of destination". In this manner, due to the irregular shape of the fracture lineament between two continents, also the paradox of the trips of little fragments in opposite directions disappears.

Rotated fragments – In addition to the above mentioned fragments that are already incorporated in one of the faced coast of Mediterranean, a number of rotated fragments come from their original position connected to European mainland occupying today a position in the middle of the sea floor basin. They have drifted in a opposite direction with respect to the one prescribed by plate tectonics, namely that of Africa moving towards Europe. In few million years the Balearic Islands have rotated clockwise of about 30°, opening the Valencia Trough. The Sardinia Corsica block has rotated counter-clockwise of about 22° (Speranza, 1999; Gattacceca, 2001, founds an higher value; Speranza et al., 2002) – starting in Neogene – towards the centre of the Western Mediterranean.

The Iberian Peninsula has performed a counter-clockwise rotation during the Cretaceous, opening the Gulf of Biscay and setting the geologic conditions for the Neogene uplift (Ollier, 2003) of the Pyrenean orogen. All these rotations are well documented in the paleomagnetic and geologic records (Vially and Tremolieres, 1966; Vigliotti and Langenheim, 1995, Scalera et al. 1993, 1996).

The rotation and southward drift of these fragments need free space toward the south or a southern subduction zone where to consume the new crust created between these fragments and Europe. The "roll-back" concept hypothesized by plate tectonic (Faccenna et al., 2001; Gueguen et al., 1998; among others) cannot provide explanation for these drift of fragments. A better interpretation is a stretching of the crust with a north-south oscillating spreading axis in a situation of incipient opening of an ocean.

The absence on the Mediterranean sea floor of well defined symmetrically coupled magnetic anomalies (Zanolla, Morelli & Marson, 1997, 1998) is observable also in the first stage of the Atlantic opening (see the Magnetic Anomaly Map of the World; Korhonen et al 2007). Remnants of a large Tethys would have shown remnants of parallel anomalies. Then their absence favors the condition of Mediterranean as to be an ocean in a first stage of its opening.

Messinian evaporites – The Mediterranean, at least the eastern basin, was an open ocean in the geological past (called the Tethys Ocean), and ever more open going back through time from Recent to Triassic. This is in disagreement with the evaporite deposition started with the "salinity crisis of Messinian" near 6 Ma ago, which covers nearly all the Mediterranean (Hsü et al., 1973; Cita, 1972, 1982).

Indeed, if we admit that shortly before the Messinian a compression has closed the western and eastern connections with other oceans, it should be expected that this compression has continued until to Recent, building more efficient barriers against the adjacent oceans. Making a similitude, if the envisaged collision of India against Asia has built up the Himalayan orogen, analogous orogens should have been built in the eastern and western Mediterranean collision zones in the Messinian. But, in Alboran domain and on Betics, rifting tectonics are documented (Orozco, 1997; Alonso-Chaves & Rodriguez-Vidal, 1998) up to lower Miocene, with N-S extensions. Carbonatites, indicating rifting conditions, occur on the Rif mountains of Morocco (Mourtada et al., 1997), south of Gibraltar.

Deposition of evaporites is a characteristic phenomenon in the first spreading phases of a young and narrow ocean. The proto-Atlantic evaporites of Middle Cretaceous (Aptian, 119-113 Ma) are thick layers ($\leq$ 2000 m) deposited along South American and African Atlantic coasts, followed in the Albian (113-97 Ma) by open-sea facies sediments. Then the Mediterranean evaporites could have the same origin as the Atlantic ones.

The evolution of the Mediterranean can alternatively be interpreted as a transition from a little epicontinental basin – in which the balance between water contributions (precipitation, fluvial, juvenile) and evaporation was in favour of contributions – toward a basin of greater dimension where evaporation was predominant on adduction, followed by the opening of the Gibraltar gate.

Geochemistry of the Tyrrhenian and peri-Tyrrhenian magmatism – The Tyrrhenian and peri-Tyrrhenian magmatism are parts of a continental and oceanic type volcanism – active from the Mesozoic to Present –, having wider display on the Dinarides, Hellenides, Balkans and on the Anatolian orogen. The South Tyrrhenian arc of volcanic islands Alicudi, Filicudi, Salina, Panarea, Stromboli, is the emerged part of a longer series of submerged apparatuses Lametini, Alcyone, Palinuro. Both emerged and submerged units, and others, produced basaltic magmas similar to those of Asiatic island arcs (IAB). An uniformity in the emission products should be expected in the Tyrrhenian, but coexistence in the same restricted region of IAB, OIB, MORB, is observed (Serri, 1997; Serri et al., 2001; Trua et al., 2004). The IAB-like volcanic centers in the South Tyrrhenian constitute a nearly complete circle, which leads to the paradox of too many different and convergent subduction directions. A circular zone of subduction is impossible.

This South Tyrrhenian paradox is a facet of a general inexplicable situation: the alleged convergent subductions towards the centre of the Pannonian basin, the analogous situation on the Southern Apennines and the Calabrian-Sicilian arc, and a similar pattern for the Aegean arc. The Tyrrhenian and the Aegean Wadati-Benioff seismofocal zones suggest contrasting divergent subduction directions. Moreover, the spatial longitudinal continuity of the hypothesized lithospheric consumption between the Calabrian and Aegean regions would require a continuous Wadati-Benioff zone, but no interposed subduction zone is really present.

Further examples of the heterogeneity of the magma chemistry in the Tyrrhenian region are the contiguity of the OIB facies of the Ustica Island both with the west side of the circle of IAB sources Alicudi, Filicudi, Salina, Panarea, Stromboli, and with the east side of the submarine volcanic unity Anchise, with IAB character. A number of heterogeneous sources have been sampled more northerly in the middle of the basin and over the adjacent dry land. The lineament of IAB islands Salina, Lipari, Vulcano prolongs up to the OIB Etna Sicilian volcano. The geochemical characteristics of Lipari and of other near volcanic centers – currently ascribed to the subduction-linked IAB group – can be alternatively explained with an uplift of asthenospheric material with an associated rising of the 1000°C isotherm up to the Moho in few million years and consequent consumption and mixing of the lithosphere and ascending materials (Crisci et al., 1991; Esperanza et al.,1992). Bell et al. (2006) reach a similar interpretation, and instead of the IAB, OIB, MORB nomenclature, an isotope taxonomy is proposed, which links the source of the igneous rocks to a rising mantle plume. The subduction is not a required condition.

Indeed where subduction has been hypothesized until now, the emplacement of sparse carbonatite fields makes the problems more urging a solution. Carbonatites, typical of the African rift and other rift zones, have been found in Central Italy, in Southern Italy (Vulture volcanics) and in the Morocco Rif, south of Gibraltar (Stoppa & Woolley, 1997; Mourtada et al., 1997).

All the European intraplate volcanism should be explained in a coherent frame (Macera et al. 2003; Lustrino & Wilson, 2007). This problem is to explain the ocean island basalt without recycling subducted products, but simply by a specific mantle source. The concept of a plume source both for intraplate continental volcanics and for OIBs is today acceptable, but interpretative and mechanical difficulties remain as that concerns the postulated rising of hot material, namely a diapirical rising. A different realistic interpretation could be an isostatically rising column. The volcanic products on the surface could be the final decompression and differentiation process of an otherwise denser rising mantle material with characteristics more or less near to the continental geochemical signatures.

Peccerillo (2002, 2003, 2005) analyzing the geochemical signatures of the Plio-Quaternary magmatic products from north to south of the Apennines up to Sicily and Aeolian arc, has found a progressive north-south change of the characteristics, with infinite variations but with a clear tendency to prograde from continental signature toward a open ocean signatures. Abandoning the roll-back schema that Peccerillo prefers (Peccerillo & Martinotti, 2006; Panza et al., 2007), his results can be interpreted in harmony with the general interpretation of an opening Mediterranean, in which the rising of mantle material along mega-dykes can happen progressively more and more free from contamination of continental lithosphere origin.

Similar indications came from the incorporation in the orogens of HIMU and EM-1 mantle source (Gasperini et al., 2000; Hanan, 2000), whose geochemical properties can found a coherent interpretation in a possible lithospheric and continental crust erosion from below, with the Mediterranean being a continuously nascent ocean (Scalera, 2005b), and rejecting the hypothesis of old crust and deep sea sediment recycling. In an ever narrow and slowly enlarging Tethys, and then Mediterranean (Scalera, 2005b), it is plausible that the basalts emplacements occurred always in proximity of continental lithosphere. Additionally, adopting a noncollisional view and an expanding Mediterranean to interpret the orogens, the paleogeographical paradox of the too scarce amount of microcontinent's continental crust stored in Alpine orogens (up to two orders of magnitude in the Alps;

Polino et al., 1990; Stöckhert & Gerya, 2005) disappears.

Helium isotopes and other clues – The investigations of the emissions of terrestrial gas relate the presence of high values of the ratios $^3He/^4He$ to deep source of magma (Allegre et al., 1983; Sano et al., 1989; Inguaggiato and Pecoraino, 2000; and others), rising from undepleted mantle regions where primordial Helium is trapped. Values of the ratios $^3He/^4He$ are particularly high in southern Italy on the Eolian volcanic arc. The ratios decrease as the distance increases from the Tyrrhenian back-arc toward the forearc region. The commonly accepted cause of low ratios in the forearc regions is the radioactive decay of Uranium and Thorium.

Emanations of CO_2 on continental sites indicate a crust-lithosphere disturbance (Doglioni et al., 1996). Strong emissions of CO_2 occur in the shallow seismicity zone of the Irpinia region (site of the 1980 Irpinia earthquake, M=5.6, and site of the lower mean recurrence time for events exceeding VIII MCS, T= 20.0 yr ± 12.0 yr; Basili et al., 1990). In the eastern part of the same region anomalous high values of $^3He/^4He$ ratios are recorded (Fig. 4a) near the Mt. Vulture volcanic apparatus (Sano et al., 1989; Inguaggiato and Pecoraino, 2000).

A map of CO_2 of mantle origin in spring waters has been compiled by Chiodini et al. (2004, 2011) for central-southern Italy. The studied area does not cover Calabria and Sicily, where strong emissions of CO_2 occur. Chiodini et al. (2004) propose a link between gas emission and release of seismic energy, which epicenters are located on the boundary between high and low gas emanation. Their result supports the analysis of Scalera (1997) in which a relation among seismic energy and volcanic rock emplacements in Italy was found (see Fig. 2c in Scalera, 2005a).

All these are clues of motion of materials from the depth toward the surface in a opposite direction with respect to the hypothesis of the "subduction". The clues support a 'channel' of communication – maintained open and active by a tensional stress along the Wadati-Benioff zone – between underlithospheric materials and surface. Seismic profiles all along the northern margin of Sicily (Pepe et al., 2000) have already evidenced a tensional state of the crust. Then, the real tectonic and geodynamic panorama is very different from that expected for a pure compression and a closing of an oceanic basin. Mega-dykes emplacements – to which all a series of geodynamic phenomenons are linked, like seismicity and volcanic activity – are a reasonable alternative to be taken into consideration.

4. South American 3D pattern of the Wadati-Benioff zone

Classical 2D plots of vertical sections of pattern of hypocenters under the Central Andes (see an example in Fig. 7b) show regular dipping pattern of hypocenters up to 300 km depth, with a tendency towards a lower slope in the lithosphere (0-100 km) and a long zone of absence of seismic foci between 350 km and 500 km. Instead, abandoning the classical 2-D images, if 3-D plots of the hypocenters of very large areas are drawn, filaments of hypocentres are recognizable (Fig. 7a) instead of a regular pattern (data from the catalogue of the relocated events by Engdahl et al., 1998). These filaments are real features of the hypocenters' distribution because their separation can easily reach the order of magnitude of several degrees (Fig. 7a, Fig. 8a).

The filaments can be thought as an alignment of a series of single filaments, each like the South Tyrrhenian one.

The three-dimensional views (Fig. 7a) show that all the South American Wadati-Benioff zone – from Colombia to Cape Horn – is characterised by strong inhomogeneities in the hypocentral spatial distribution, with focal zones tapering toward deep points. In Fig. 7a, the vertical scale has been greatly enhanced to highlight the unexpected pattern of these seismofocal zones. The brown circles repre-

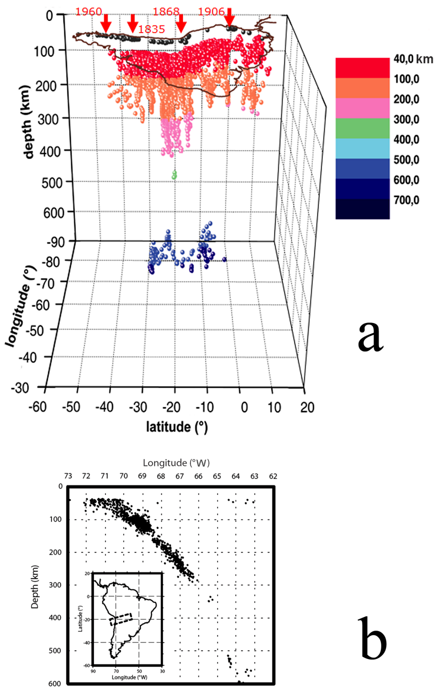


Fig. 7. The South American deep earthquakes under the Pacific Andean margin. – a) Three-dimensional large scale plotting of South American Wadati-Benioff zones, with depth greater or equal to 40 km (data from the catalogue of the relocated events by Engdahl et al., 1998). The characteristic of the Wadati-benioff zones is the filamentous distribution of the hypocenters, a fact that is at odds with the accepted two-dimensional iconography of plate tectonics in which a planar (deep angle around 45°) or spoon like pattern should be observed. – b) An example of the classical two-dimensional plotting of the South American Wadati-Benioff zones, with hypocentral depth greater or equal to 40 km. The section is under the central part of the South American Cordillera. Only adopting this kind of narrow sections a subduction can be imagined.

sent the seventytwo volcanoes along the Andes Cordillera, which has been active in historical time (data from Smithsonian Institution, 2006; Siebert et al., 2011). The volcanic provinces are grossly divided in relation to the seismofocal zone features. Some North-South gaps in the deep hypocentral pattern are in relation to gaps and lower density of the volcanoes distribution, adding further elements to the possible stronger-than-supposed link between seismic and volcanic phenomena (Scalera, 1997).

Geomorphic and tectonic field studies of the Andes point toward a rapid uplift of the Cordillera from Miocene, and the creation of the Interandean Depression as result of a lateral spreading (Coltorti and Ollier, 2000), which is at odd with a compressional origin of the orogen. Very problematic, in a region in which subduction is credited to be in a steady-state activity at least from Cretaceous, is the young age of the uplifting and the tectonic standstill that allowed a recognized planation phase of the Cordillera (Coltorti and Ollier, 2000). A different font of energy for mountain building should then be searched for, in agreement with the requirements of this paper.

In conclusion of this brief and incomplete review: using a more general, wider scale, ad three-dimensional view, together with higher quality data (Engdahl et al., 1998), it is possible to recognize that Wadati-Benioff zones do not correspond to what is prescribed by plate tectonic theory, and to what we expect to see having in mind the narrow hypocenters vertical sections of the classical seismological iconography (e.g. Fig. 7b). Filaments of hypocentres characterize the large scale 3-D plots of the catalogue of the relocated events. The filaments have the tendency to taper in depth, leading to the idea of a narrow deep origin of the disturbance, which propagates and becomes progressively wider toward the surface. Instead of a downgoing subduction they evoke the image of trees, or smoke coming out of chimneys.

This situation is recognizable on several WBZ (East Asian Arcs, Indonesia, South America, Himalayas etc.), and a question can naturally be posed if single filaments can be observed. Single filaments are indeed the ones observable in the Mediterranean region, under the southern Tyrrhenian Sea and under the Romanian region Vrancea, posing severe problems to a hypothetical subduction occurring narrow-ribbon-like.

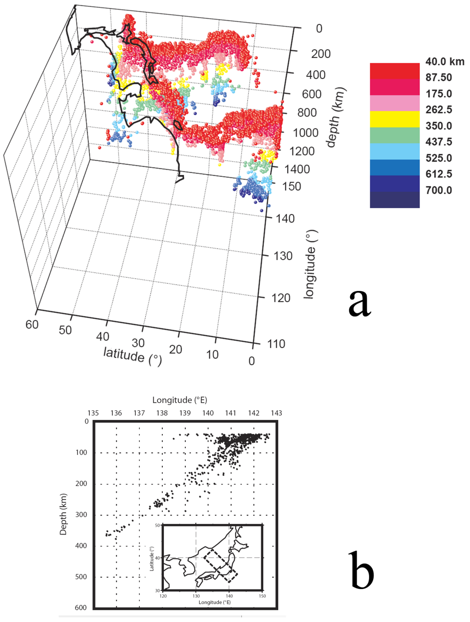


Fig. 8. The East Asian deep earthquakes under the Pacific margin. – a) Three-dimensional large scale plotting of the Wadati-Benioff zones, with depth greater or equal to 40 km (data from the catalogue of the relocated events by Engdahl et al., 1998). The characteristic of the Wadati-benioff zones is the filamentous distribution of the hypocenters, a fact that is at odds with the accepted two-dimensional iconography of plate tectonics in which a planar (deep angle around 45°) or spoon like pattern should be observed. – b) An example of the classical two-dimensional plotting of the East Asian Wadati-Benioff zones, with hypocentral depth greater or equal to 40 km. The section is under the central part of the Japan Arc. Only adopting this kind of narrow sections a subduction can be imagined.

If those filaments are taken as basic features in constructing a new paradigm of Wadati-Benioff zones, there is little place for a downgoing slab. It seems more credible that an upward migration of matter and energy along mega-dykes could be involved, in accord to what indicated by the analysis of the polhody displacement during the great Sumatran earthquake and – with less certainty – during the recent Honshu quake.

5. Space and time – polhody and LOD

Besides the refined methods of relocation of the earthquakes hypocenters (Engdahl et al., 1998) that have shown an unsuspected pattern of the deep and intermediate seismicity – a "quantization" incompatible with the subduction – new evidence that the alleged subductive dynamics on the Wadati-Benioff zone (WBZ) is invalid are coming from coseismic phenomenons of the recent great and shallow earthquakes (Sumatran quake: Scalera, 2007; Han et al., 2006; Honshu quake: Han et al., 2011; among others)

The great Sumatra earthquake has allowed the observation of a sudden displacement of the instantaneous rotation pole of the Earth (Bianco, 2005). The analysis of the displacement (Scalera, 2005ac, 2007a) has evidenced that the rotation axis moved exactly following the meridian of the epicenter, going nearly 3 milliarcsec (≈ 10.0 cm) farer from the epicenter (Fig. 9). Trivial rational mechanics rules make clear that additional mass has been emplaced in the earthquake zone coming from below (Scalera, 2007c), following a mechanism of extrusion and a path different from the one prescribed by plate tectonics. The true fault plane solution can be the conjugate plane of the focal mechanism preferred by plate tectonics, and an additional non-elastic movement of mass or flow, beside the elastic fracture, is needed to fulfil all the seismological parameters (Scalera, 2007a).

An independent confirmation that surfaceward movement are involved in the great Sumatra earthquake come from the analysis of the data of the GRACE satellites (Han et al., 2006). Variations of surface gravity of -15 μGal east of the Sunda trench, and a symmetrical anomaly of +15 μGal west of the trench were observed. These anomalies does not fit a fault dislocation without a substantial lateral and vertical expansion of the oceanic crust. Initially, Han et al. (2006) adopted a subhorizontal slip in agreement with the alleged focal mechanism, but the fit to the gravity data was poor. Their suggestion of

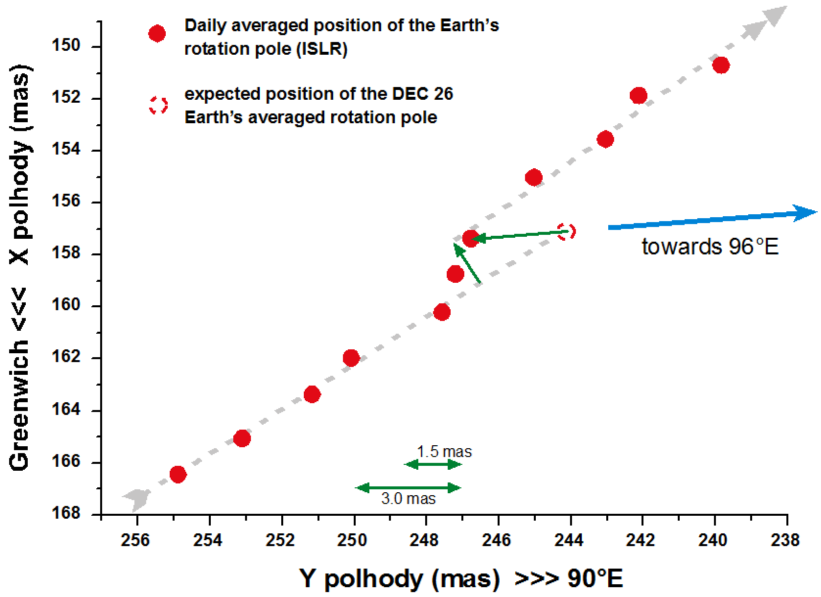


Fig. 9. The displacement of the Earth's rotation axis produced by the great Sumatran quake of December 26 2004. The direction of the axis shift is toward an azimuth opposite to the hypocentral zone azimuth and at odd with respect to the plate tectonics forecasting. Only an extrusion of subcrustal material can explain both this axis shift and the DORIS gravimetric survey.

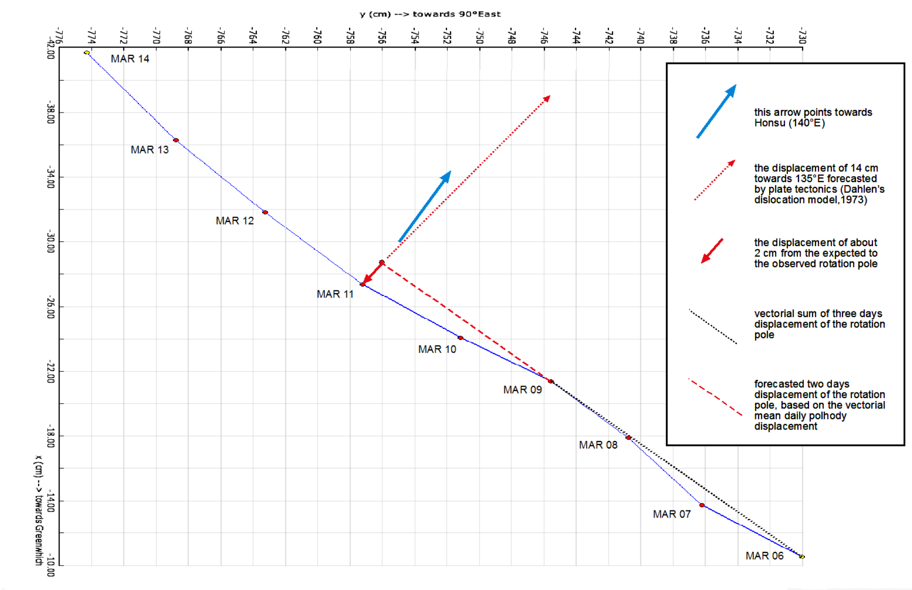


Fig. 10. The displacement of the Earth's rotation axis produced by the Honshu quake of 11 March 2011 (M_w=9.1). The polhody from March 6 to March 14 is plotted (by IERS web-site facilities). The direction of the axis shift is toward an azimuth opposite to the hypocentral zone azimuth and at odd with respect to the 14 cm plate tectonics forecasting. Only an extrusion of subcrustal material can explain both this axis shift and the DORIS gravimetric survey.

local expansion supports the class of models proposed in this paper.

To get new evidence of displacements of the Earth axis caused by an earthquake we should wait for future extreme magnitude events, but also a great earthquake like the Honshu Tohoku event (11 March 2011; M_w=9.1) have produced some effects. In Fig. 10 the polhody from March 6 to March 14 2011 has been plotted using the IERS web-site facilities. Instead of a coseismic displacement of the instantaneous rotation pole of 14 cm toward 135°E as forecasted by Gross (see Buis comment, 2012) using the Dahlen (1971, 1973) dislocation model, a tendency of a little displacement toward an opposite direction (away from the Honshu hypocentral region) can be deduced. Also in this case an extrusion of material is favored and the gravimetric data have confirmed (Han et al., 2011; Zhou et al., 2012):

> *This is the characteristic spatial pattern of the coseismic gravity change after undersea thrust earthquakes accompanied by crustal dilatation.* (Han et al., 2011)

Similar GRACE results and interpretations have been published for the Maule quake (27 February 2010; M_w=8.8) (Han et al., 2010; Heki & Matsuo, 2010)

6. The need for an higher precision ΔLOD and polhody

The Earth axis displacement produced by an extruded mass m_e is (following a simple formula valid for $m_e << $ Earth mass; Schiaparelli, 1883, 1891)

$$PP' = m_e \cdot \frac{R_p R_E^2}{2(B-A)} \cdot \sin(2\phi) \ ,$$

(R_p = polar radius; R_E = radius at the extrusion site; ϕ = colatitude; A and B = the Earth polar and equatorial inertial moments) from which the extruded mass can be known:

$$m_e = PP' \cdot \frac{2(B-A)}{R_p R_E^2 \cdot \sin(2\phi)} \ .$$

This mass m_e, passing from R_E to $R_E + \Delta R$, has an initial inertial moment

$$I_{m_e} = m_e (R_E \cdot \cos\phi)^2 \ ,$$

and a final inertial moment

$$I'_{m_e} = m_e((R_E + \Delta R) \cdot \cos\phi)^2 \approx$$

$$\approx m_e \cdot \cos^2\phi \cdot (R_E^2 + 2R_E \Delta R).$$

From the above equations we can know the variation of the inertial moment due to the mass extrusion and its effects on Earth's rotation

$$\Delta I = I'_{m_e} - I_{m_e} = 2m_e \cdot R_E \Delta R \cdot \cos^2\phi \ .$$

And then (with $\omega_E = 2\pi/LOD_E$= the Earth unperturbed angular velocity, and ω_2 = the planet's angular velocity after the mass extrusion caused by the extreme magnitude earthquake) from the conservation of the angular momentum

$$I_E \cdot \omega_E = (I_E + \Delta I) \cdot \omega_2 \ ,$$

$$\Delta LOD = LOD_2 - LOD_E = LOD_E \cdot \frac{\Delta I}{I_E} \ .$$

Because an extrusion produces a $\Delta I > 0$, and a consequent $\omega_2 < \omega_E$, the LOD should increase ($\Delta LOD > 0$).

Instead, the evaluation performed in the currently accepted geodynamics provide values of $\Delta LOD < 0$. Gross & Chao (2006) compute a decrease of the length of day of 6.8μs for the 2004 Sumatran earthquake (M_w=9.3) and decreases of 1.8μs and 1.2μs for the Honshu (M_w=9.0) and Maule (M_w=8.8) quakes respectively. They evaluate the present uncertainty (1σ) as 20μs, and then also extreme magnitude earthquakes – like the 1960 Chilean quake (M_w=9.5) – would be under the detectability limit as that concerns the ΔLOD.

Consequently, to get an higher precision level in the ΔLOD measurements is of fundamental importance in confirming the expansion tectonics framework. Both the ΔLOD and the polhody shift during the extreme magnitude earthquakes can constitute a sort of "crucial experiment" in Earth sciences.

7. A new model of orogenic evolution

Isostasy – All the aforementioned clues point to vertical displacements of materials as main process in causing earthquakes, orogenesis and volcanic phenomena. Then – without using the subduction concept – a different model of the evolution of thrust-fold belt, (Fig. 11, Fig.12), should be searched for. In this initial proposed formulation the sketch of the orogen's evolution phases is similar to the series of phases that can be recognised going from south to north on Apennines and Alps, and at a more mature stage on the Himalayas.

This simple and idealised model begins with a set of horizontal layers from the surface to the lower mantle (Fig. 12a). If the environment becomes progressively tensional, a stretching of the lithosphere evolves and a furrow appears on the surface (Fig. 12b). The furrow depth increases, but because of isostasy a maximum of a ten of kilometres can be attained on the Earth's surface (see the east Asia margin' trenches; See also Hilgenberg, 1974, for a first explanation of the oceanic trenches depth). The crust grows thin, and an asymmetrical geometrical change starts to evolve at the lithosphere and upper mantle bottoms, with uplifts of the layer interfaces (Fig. 12b). The asymmetry is caused by isostasy, which shapes the inverted troughs at the mantle interfaces – and their evolution – more pronounced than the surface ones. The water eventually fills the trough on the surface of the stretched crust, which can evolve in a sedimentary basin (Fig. 12b).

Phase transformations – Without other associated physics process, both a mere horizontal tensional stress and strain state and an isostatically uprising materials, cannot cause the uplift of the topography and a consequent orogenic process. Instead, if phase changes (Green & Ringwood, 1970; Ringwood, 1991) toward less-packed lattice are associated with the tensional state and with the upward movement of the rising materials, then the growing volume can lead – under specific conditions – to a non uniform-in-time updoming of the topography (Fig. 5c). The slow and complex events that finally evolve into a thrust-fold belt (Fig. 12cd) are so prepared. We can speak of phase changes triggered by deep isostatic uplift. In this model the orogenic process is helped by the buoyancy effect due to the Clapeyron slope of the phase changes (Fig. 11).

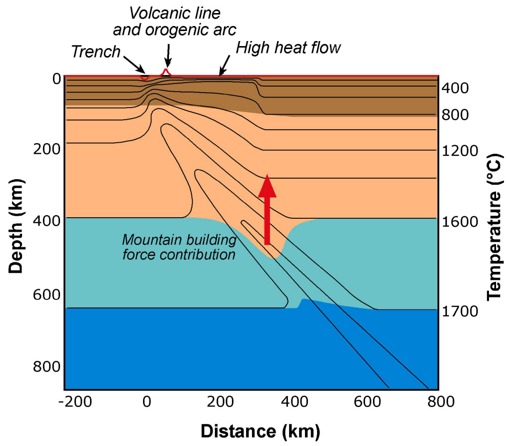


Fig. 11. The new physical-chemical model of an active margin. The positive anomalies of seismic velocity underneath the trench-arc zones – revealed by seismic tomography – are interpreted as intrusions of isostatically surfaceward transported material. In this case the isotherms are also transported toward the surface thus locally influencing the depth to which the phase transition occurs. This last effect is opposite to the one in the subductive model and a protuberance of lower density material is created in the denser transition zone. The buoyancy of this protuberance, together with the excess of volume involved in phase transitions toward less-packed lattice, contributes to the extrusion and lateral pushing of material on the surface, namely to orogenesis.

At the 400 km discontinuity (Fig. 11) the surfaceward transport of the isotherms causes a downward displacement of the phase boundaries, and a protuberance of lower density material surrounded by a denser one is created, with a net tendency to buoyancy. Instead, at the 700 km discontinuity, a reverse Clapeyron slope induces a contrary directed force, but of lesser magnitude. The total force is then of buoyancy, and its effects can be directly linked to the topographic doming and folding.

The materials that are changing phases (with increasing volume) along all the

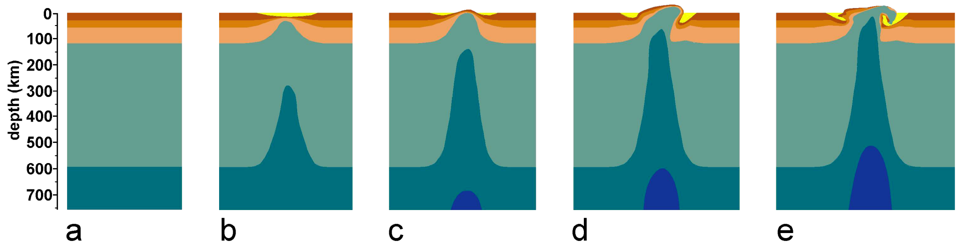


Fig. 12. The proposed non-collisional model of fold-belt building (in this figure only the flux of the materials is represented, without taking into account the phase transitions, which are represented in Fig. 11). Only a bivergent situation – like Apennines – is shown here, but monovergent situations can be envisaged. Starting from left, a tensional situation produces a stretching of crust, lithosphere and mantle. Due to the necessity for isostatic compensation (no more than a ten of kilometres in depth can be attained on the earth's surface. See e.g. Hilgenberg, 1974) the greater effect of the stretching appears as a strong uplift of the lithospheric and mantle strata. On this uplifting column an excess of space becomes necessary because the mantle material must undergo phase changes toward more unpacked crystal structures (Green & Ringwood, 1970; Ringwood, 1991). This surplus of increasing volume of the decompressed material is sufficient not only to fill the space between the vertically split lithosphere and mantle, but it can also produce updoming of the crust, and subsequent relatively quick (centimetres per year) uplift. An effect facilitating driving of the uplift is the downward displacement of the phase transition zones due to the effect of the Clapeyron curve slope (see Fig. 11) Then the created true orogen can undergo lateral pushing by intrusion of underlying material, erosion, summital collapse and gravitational spreading, with final denudation of metamorphosed crustal material previously buried by gravity nappes, together with several kinds of mantle facies. Different rates of rifting – and evolution of the rifting rate through geological time – can lead to different kinds of orogens from continental to mid-oceanic-ridge ones.

isostatically uplifting column could cause seismicity (surface, intermediate and deep) driven both by phase changes and mechanical fractures (in the brittle surface part of lithosphere). The filaments or clusters of deep hypocentres – which are today clearly resolved by relocation methods – can be explained with occurrence of seismically activated zones by irregular and slow episodic cascade processes of phase changes and mass and energy surfaceward transmigration in a laterally non-homogeneous mantle – in terms of composition, thermal distribution, stress and strain and amount of vertical isostatic displacement.

Extrusion and gravitational spreading – The extrusion of the exceeding volume of materials toward the surface – and, depending from the rifting rate, their eventual occupation of room above the sea level – will cause the pushing and warping of crustal layers, the possibility of the doming zone to be affected by gravitational spreading and erosion, all phenomena well documented on fold belts (Ollier & Pain 2000; Ollier, 2002, 2003). The lateral pushing of these externally outpoured materials can well cooperate with gravity-pull in the building of the observed large amounts of sub-horizontal overthrusting (Scrocca et al., 2003). Indeed, it was never possible to explain these overthrusts by gravitational spreading alone (Viti et al. 2006).

Around the initial furrow, the azimuthally different geological and physical conditions can lead to either asymmetrical or symmetrical spreading (mono-vergence or bi-vergence) of the extruded material. The spreading can lead the nappes to overthrust the sediments of the pre-existing trough and its underlying crust, driving them in a burial-path that simulates the subduction, but without trips longer than 50-70 km (Fig. 12e). Then, observable overthrusts and underthrusts – of which copious geological documentation exists – should not be confused with the hypothesis of large scale subduction.

Metamorphism – At the interface between uplifting mantle material and down-pushed crust and lithosphere (Fig. 12e), besides an upward transport of eroded fragments of the buried lithosphere, and thanks to non-lithostatic overpressures due to deviatoric stress and large earthquakes, metamorphism (also HP one), mixing, migmization, inverted metamorphism etc. can occur. Both the "granite series" (Read, 1957; Pitcher, 1993) and the HT/HP-UHP metamorphic facies exposed on the Earth's surface can be explained as a consequence of the "piston" of the increasing volume phase changes. This "one-way piston" avoids the never resolved "two way path" paradox of the plate tectonics (Ernst, 1999, 2005).

8. Tectonic effects of the deep phase changes

Inner increase of volume and uplift of fold belts – Following Ritsema (1970), the intermediate and deep (up to 700 km) earthquakes can be explained by fast phase transformations (with propagation of strain and of instability conditions, starting from a metastable state). In my interpretation, their explanation is the same but the phase transformations occur along the isostatic uplift path, and not along the subduction downward trip.

In Table 1 the volume variations for phase changes of typical mantle mineralogical species are listed (Anderson, 1989). In Table 2 the densities of the most known five mantle phases at their depths of stability are listed (Anderson, 2005). Beside, the variations of volume passing from each phase to the next, and the total volume variation for the complete succession of four phase transitions – more than 20% – are shown.

Hypothesizing that the geofracture between two plates is very deep – e.g. it reaches the lithosphere thickness – and hypothesizing that the γ-spinel (330 km) is transported in the upward flow, then an increase in volume of more than 7% can be potentially sufficient generate, in the Earth's interior, an additional uplift of more than 20 km. Above the Earth surface, this uplift, considering the limiting factors of the initial creation of a basin or of a trench (up to 9 km of depth) and of the of erosion, can still build up a fold belt.

Phase Transition	*Volume variation (cm^3/mol)*
Mg_2SiO_4	
α-olivine → β-spinel	- 3.13
β-spinel → γ-spinel	- 0.89
α-olivine → γ-spinel	- 4.02
β-spinel → oxides	- 4.03
γ-spinel → oxides	- 3.14
γ-spinel → (perovs.+ magnesiowüstite)	- 3.84
(γ-spinel + stishovite) → 2 ilmenite	- 0.79
(β-spinel + stishovite) → 2 ilmenite	- 1.89
$MgSiO_3$	
2 pyroxene → (β-spinel + stishovite)	- 7.99
2 pyroxene → (γ-spinel + stishovite)	- 9.09
pyroxene → ilmenite	- 4.94
Ilmenite → perovskite	- 1.91
pyroxene → perovskite	- 6.83
pyroxene → garnet	- 2.74
SiO_3 (q) → stishovite	- 9.70

Table 1. Volume variations for phase changes of typical mantle mineralogical species (Anderson, 1989)

Greater depth of detachments (as those in Fig. 11) lead to greater internal uplifts of layers and then greater excess of volume coming from phase changes. The presence of erosion prevents high uplifts of the topographic surface, and only heights around 8.0 km are observable today. The values of uplift deduced by the model are in agreement with those (topographic + eroded) evaluated by geological clues on the real fold belts.

This model can also explain the observed non-uniformity in time of the fold belts evolution. The periods of relatively quick orogenic growth can be associated to the overcoming of one or more mineralogical phases, during their trip of isostatic uplift, of the opportune conditions of depth, temperature, pressure, or contact with suitable fluid catalysts, by which to be able to gradually turn into lighter phases.

If the rates of rifting of two pairs of plates are different, it cannot be expected the same rates of surface uplift. Probably, the difference between continental fold belts and mid-oceanic ridges (marine oro-

Phase and typical depth		Density (g/c³)	ΔV/V	ΔV/V total
α-olivine	(85 km)	3.31		
			4.8 %	
β-spinel	(220 km)	3.47		
			2.3 %	
γ-spinel	(330 km)	3.55		22 %
			10.4 %	
Ilmenite	(570 km)	3.92		
			4.6 %	
Perovskite	(710 km)	4.10		

Table 2. The densities of the five most common phases at their typical depths (Anderson, 1989, 2005), together with the volume variations passing from each mineralogical phase to the next, and the total volume variation – more than 20% – expected for a complete succession of five phase transitions.

gen) is maintained by the different rifting rates of the two involved pairs of plates. In fact, the higher rifting rates of the mid-oceanic ridges cannot allow the growing volume to reach and overcome sea level, and then folds underthrusts and overthrusts are unlikely to occur. In both the situations – a low or a high rifting rate – the orogenic process initial phases lead to the shaping and evolution of tectonic structures that resemble the framework of the geosynclines tectonics (Aubouin, 1965). It is the rifting rate that determines whether the early narrow basin – e.g. resembling the Red Sea trough – evolves into an ocean sea-floor divided by a mid-oceanic ridge or it is filled by sediments, successively undergoing uplift and folding like in the geosynclines scheme. Large ophiolitic fields (e.g. Zagros, Oman) and occurrence of salt domes (Gulf of Mexico) should be expected to be emplaced in regions whose rifting rates oscillate between values sufficient to build dry-land fold belts and the lower values leading toward a full oceanic evolution.

In this model it is also more easily explained the relation between the magma temperature and its iron content (low T/low Fe; high T/high Fe). As a matter of fact, the provenance of a magmatic body from an uplifted column of a formerly deeper mantle material characterised by a higher-iron-content (Rohrbach et al., 2007), also means its provenance from a mantle region of surfaceward displaced isotherms.

Role of Clapeyron curve slope in facilitating the orogenic uplift – If the material flow is downward as in the old view of plate tectonics, the Clapeyron curve slopes on the P-T diagram of the phases (slope > 0) produce an uplift of the 410 km and 520 km interfaces between olivine and β-spinel and between β-spinel and γ-spinel. Contrariwise, because a Clapeyron slope < 0, a less pronounced downward displacement occurs at the 650 km interface between γ-spinel and perovskite+magnesiowüstite. The net force created by these two opposite doming is directed toward the Earth interior and is called – in plate tectonics – "slab pull".

If the subduction is discarded, and the model proposed in this paper is adopted, a surfaceward flow of material must be considered, and the effects of the Clapeyron slope at the upper and lower boundaries of the transition zone are inverted. A subsidence of the 410 km and 520 km discontinuities besides an uplift of the 650 km boundary have to result (Fig. 11).

The formula of the elevation or lowering of the phase boundary is (Turcotte and Schubert, 2001):

$$h_b = \gamma \cdot \frac{(T_o - T_a)}{\rho_o \cdot g};$$

with (values for the 410 km boundary): γ= slope of the Clapeyron curve dp/dT($\approx 4 \cdot 10^6$ Pa/°K); T_o = temperature (°K) at the undisturbed boundary; T_a = the higher temperature (°K) of the uplifting material at the same depth as the undisturbed boundary; ρ_o = density ($\approx$3700 kg/m^3) of the ascending material at the same depth; g = gravity acceleration at the same depth ($\approx$10 m/s^2).

$$h_b = -11\text{km}/100°\text{K}.$$

Then, if an adiabatic ascending with uplift of the isotherms of several hundreds of °K occurs, the lowering of the phase boundary can reach several tens of km, exceeding a hundred km in the case of ΔT>

1000 °K. These values – an uplifted boundary – are envisaged in classical rheological studies of subducting slabs (Ranalli, 2000). Realistically an adiabatic transport of very deep material, say from 2000 km depth, can raise the temperature of the transition zone by $\Delta T \approx 700$ °K. Then the bulging expected for a upward flow of material is less then that expected for a downward flow. But also in this case the effect is not a negligible one.

The main effect of the downward bulging of the 410 km and 520 km discontinuities for a surfaceward flow is an additional floating buoyancy force of the column because steep troughs of low-density material are inserted for a depth of tens of kilometres into a higher density mantle material. Instead of "slab pull" we can speak of a "flow push" (Fig. 11). This situation facilitates the rising of the column and the surface building of folded structures. The concomitant effect of the excess of volume and of the buoyancy caused by the upward displacement of the phase transitions make this proposed framework more harmonious than the old conceptions in explaining the orogenic phenomena.

Nonlithostatic overpressures and the HP/UHP phases – Many efforts has been devoted in the last few decades to explain the presence of high pressure metamorphism (HP metamorphism) and ultra-high pressure (UHP) metamorphism on continental orogens (see review of the field by Platt, 1986; Ernst, 2000, 2001, 2005; Searle et al., 2001; Chopin, 2003; among others). The facts ascertained are that the exhumed UHP assemblies are mostly old continental crust, that the size of these exposed facies is small and sheetlike, and that a rapid decompression took place. Alleged evidence of progressively higher depths of provenance of the metamorphosed facies (from 2 Gp to recently reported 6 Gp for microdiamonds; Chopin, 2003) have led the UHP assemblies to be considered and presented as the irrefutable proof of the real existence of subduction, and consequently as the definitive confirmation of the plate tectonics schemata. In my opinion, this is a misunderstanding, both because the burial of crustal and lithospheric material is not synonymous with subduction, and because the alleged great depth of burial can be exaggerated by not considering several possible concomitant processes.

The presence of fluids and gaseous compounds is also a source of strong variation in the P and T condition of phase changes (Ernst, 2005). CO_2 is reputed to favour crystal formation and also to increase the order of magnitude of the viscosity of the material in which it is dissolved. The presence of a deep source and rising of CO_2 can be a factor in the generation of deep and intermediate earthquakes. Also, the probable presence of water in the mantle (Lawrence and Wysession, 2006) at considerable depths, the existence of the LVZ – depth 60-150 km – and the revealed seismic anisotropy similarly ascribable to water circulation or trapping under the orogens can be recalled (Babuška et al., 1993; Crampin, 1999; Mainprice et al., 2000; Margheriti et al., 2003; among others) as sources of PT conditions in phase transitions.

Although static tectonic overpressure is limited by the typical mechanical strength of rocks ($\approx$1 kb), earthquakes can be additional factors in creation of an impulsive condition of very high stress, which in turn can be the cause of phase transformation of little slice-like portions of materials. Deviatoric stress has long been recognized as a factor in decreasing the depth (and the hydrostatic pressure) needed to produce facies like coesite, blue shists, eclogite and many other HP-assemblies (Carey, 1976). In other words, deviatoric stress is a source of localized overpressure. The tectonic environments in which the phase transformations happen – orogenic continental belts and trench-arc-backarc active margins – are unquestionably centres of significant deviatoric stress.

Earthquakes are the most important circumstantial evidence for local storing and releasing of deviatoric stress. The mere existence of the earthquakes in the brittle portion of the lithosphere (the first few tens of kilometres of depth) is at odds with the existence of the "two-way" subduction channel – a low viscosity channel. Finally, the possibility that lenses-like HP-UHP exhumed fragments could be mechanical products (an anvil effect; see Mancktelow 1995) of major earthquakes occurrence at depths not exceeding a few tens of kilometres should be considered.

Heat and mass transfer from the Earth's interior – Starting from more than forty years ago, Polyak has defended in a series of paper several clues that converge in favour of a surfaceward transport of silicate mantle mass (Polyak & Smirnov, 1966; Polyak, 2005). The topic has been for long time controversial because some problems in the errors associated to the measurements of the heat flow, but finally averaged values on large area have made more grounded the argument. The $^{3}He/^{4}He$ isotope ratio increases toward areas of higher heat flow, and heat flow decreases toward areas of higher continental age. Using these evidence together with other clues, Polyak (2005) deduces that a mere transport of heat by fluid migration is not sufficient to modelize the observed pattern of data.

Only a surfaceward transport of silicate matter can explain the observation. This result is based only on collection of measurement data and no assumption is made on global tectonic or geodynamic conceptions. But this does not prevent Polyak (2005) to find that these intrusions of deep silicate mantle are present under rifts, mid oceanic ridges, island arcs. Albeit he speaks of intruding diapirism and not of isostatic rising, the result is an important support to the new model of fold-belts building described in the preceding sections.

9. Petroleum origin and productivity

The aforementioned tectonic overpressures (Mancktelow, 1995; Mancktelow & Gerya, 2008), together with the higher temperatures available in this model at shallower depth, can bear a relation with the synthesis of biogenic and abiogenic hydrocarbons. Indeed Glasby et al (1984) argued that most HCs fields occurs in areas of higher than normal thermal gradient, and the above proposed model lead just to higher gradients that are produced by the isostatic uplift of very deep materials (from and above the transition zone). These higher gradients together with uplifted contents of mantle metals (catalysts) and hydrogen, can favour the occurrence of the conditions leading to the development of the Fischer-Tropsch reaction. Occurrence of strong earthquakes – in some periods of the thrust-fold belts building – should be also considered a further supply of energy.

The becoming very near, practically adjacent, of the coming-from-depth reducing materials and the upper mantle oxidizing zone can constitute, in association with tectonic and seismic overpressures, the real forge zone – a sort of tectonic pile – of hydrocarbons as well as of many kinds of metamorphisms.

This topic has been developed in greater details in a separate paper, which is part of this volume (Scalera, 2012).

10. South American volcano-seismic events

The South American volcanic provinces (black circles in Fig. 7 represent volcanoes that erupted in historical time) are roughly divided in relation to the seismofocal zone features. Some North- South gaps in the intermediate-depth hypocentral pattern (100 km $\leq$ depth $\leq$ 300 km) are in relation to gaps and lower density of the volcano distribution, adding further proof on behalf of the possible stronger-than-supposed link between seismic and volcanic phenomena (Scalera, 1997, 2006).

A clear correlation between extreme magnitude earthquake and volcanic eruptions can be recognizable on the Andean Cordillera region. The catalogue of the eruptions on the three volcanic province of the Andes is sufficiently complete beginning at the half of 19th century. The great seismic events of 1868 (M= 8.5),

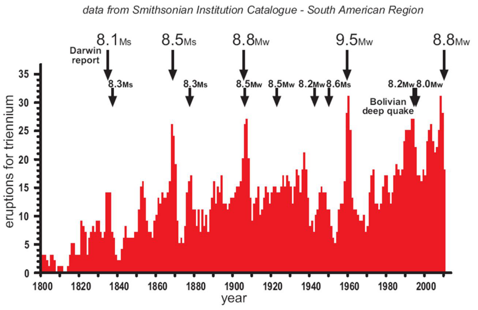


Fig. 13. Using the complete catalogue of eruption data of the Andean belt from 1800 to 2010, the triennial number of eruptions along the time axis has been plotted. All the non-discredited data have been used. Cusps of eruptions coinciding with the occurrence of great-magnitude earthquakes are very clear. In 1994, the occurrence of very deep and strong seismic event in Bolivia (M = 8:2; depth=641 km, data USGS, 2007) is preceded by a decennium of increased rate of eruptions.

1906 (M= 8.8), 1960 (M= 9.5), 2010 (M= 8.8) correlate to an increased rate of eruption for year and for triennium (Fig. 13). This correlation has been found so evidently only on the South American Pacific margin, and this uniqueness can be put in relation to the proximity of the Andes volcanoes to the maximum ocean expansion rate of Nazca triple point. Also this evidence of earthquake-eruptions correlation – not forecasted by plate tectonics – is in favor of a rising of mantle material instead of subduction (Scalera, 2007a).

During his trip around the world Darwin (1840) wrote about the eruptions associated to the Conception earthquake of 1835. Casertano's survey (1962, 1963) following the 1960 great Chilean earthquake found some evidence of a link between eruptions and the seismic event. Scalera (2008) using the data in the Smithsonian Institution Catalog of volcanic eruptions (Siebert et al., 2011) revealed that South-American Wadati-Benioff zone earthquakes with magnitude greater than 8.4 are associated to an enhanced rate of volcanic eruptions, but without determine the causal chain between the two phenomena. The Chilean Maule earthquake of 27 February 2010 (M=8.8) – occurred at five decades from the 1960 one – has been the occasion to rework all the data in searching for a preferred causal direction eruptions-earthquakes or earthquakes-eruptions or from a third more general cause (e.g. mantle ascending movements) to both eruptions and earthquakes. An average return period of about 45 years was deducible from the data for the time window 1800-2010.

Many people have proposed the triggering of eruptions by earthquakes at different distances from the hypocentral region (Uffen and Jessop, 1963; Latter, 1971; Carr, 1977; Barrientos, 1994; Linde & Sacks, 1998; Hill et al., 2002; Manga & Brodsky, 2006; Walter, 2007). The possibility of a triggering of earthquakes by volcanic activity has been proposed by a scant group of people (Critikos, 1946; Kimura, 1976; Acharya, 1982, among others), and the mutual influence of volcanic activity on great earthquakes occurrence and viceversa by Coulomb stress time variations has been investigated by Nostro et al. (1998) on Southern Italian region.

Interaction between volcanoes and earthquakes has been hypothesized carried by three physical phenomenons: static stress variations, viscoelastic relaxation, dynamic stress induced by seismic body waves and surface waves. Earthquakes and volcanoes are credited to be mutually linked only through the action these three physics interaction processes (Nostro et al., 1998; Hill et al., 2002).

An alternative conception deserving to be scrutinized is the non-compressional framework of mountain building (Scalera, 2007b, 2008). The isostatic uplift along dykes swarms or mega-dykes of mantle material in a distensional environment can contemporaneously provide explanation of a wide number of geological phenomena.

An advantage of this schema is the possibility to explain the great shallow earthquakes not as subhorizontal slip of a subducting lithosphere but as sudden vertical movements – along the complementary perpendicular fault plane of the focal mechanism (Scalera, 2007c) – under the forearc. This alternative interpretation

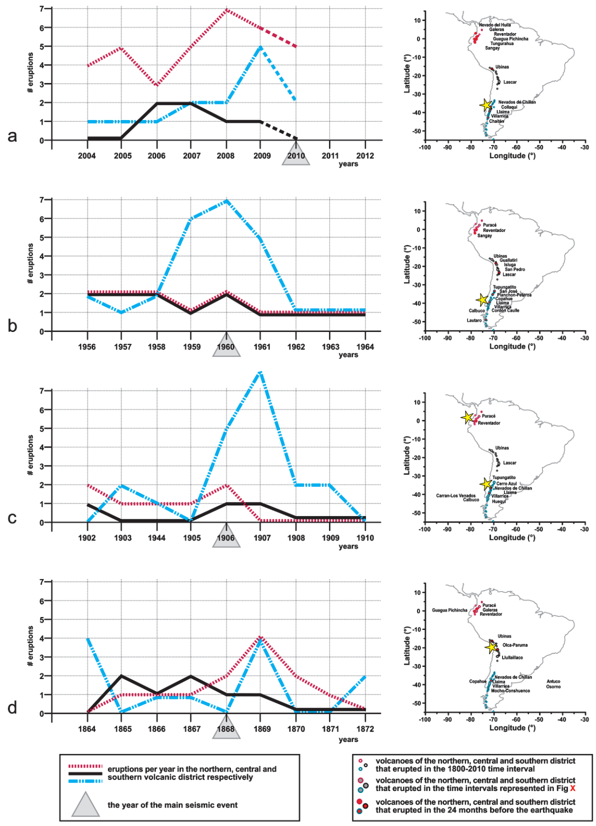


Fig. 14. Details of the eruptions rates on the three South American volcanic districts. The stars in the maps indicate the hypocenters of the main seismic events. The trend toward a precursory occurrence of a higher eruption rate is clear passing from the 1868 to the 2010 correlation event. The central volcanic district seems passive in producing high eruption rates – also in the occasion of the 1868 earthquake that occurs near the central district. Southern district is involved in all the four events. The higher eruption rates of both northern and southern districts in 1868 and 2010 are a clue of a link of the phenomenon to global geodynamics.

framed in an asymmetrically expanding planet can allow a common secular process involving the complete South American Pacific margin and linked to Polar Motion anomalies.

The more important clue in the Recent of the actual existence of an hemispheric phenomenon that is linked to mass extrusion and emplacement come from the space-time characteristic of the volcano-seismic correlation events on South American Pacific margin. Passing from the older coincidence events to the 2010 one (Fig. 13 and Fig. 14abcd), it is clear the trend – as soon as the data have become more precisely located on the time axis – of an enhanced rate of eruptions before the main seismic event.

The 1868 event (Fig. 14d) – No aerial data were available. The news was collected only by visual witness by either inhabitant of localities nearest the volcanic apparatuses or people passing for a direct inspection. The dates of the eruptions were possibly confused with the observation dates, displacing the events many months ahead and possibly one or more years ahead.

The peaks of eruptions after the quake, in Fig. 14d can be false.

The 1906 event (Fig. 14c) – This event is a pair of great earthquakes (Ecuador, January 31, M=8.8, Lat=01.0N,

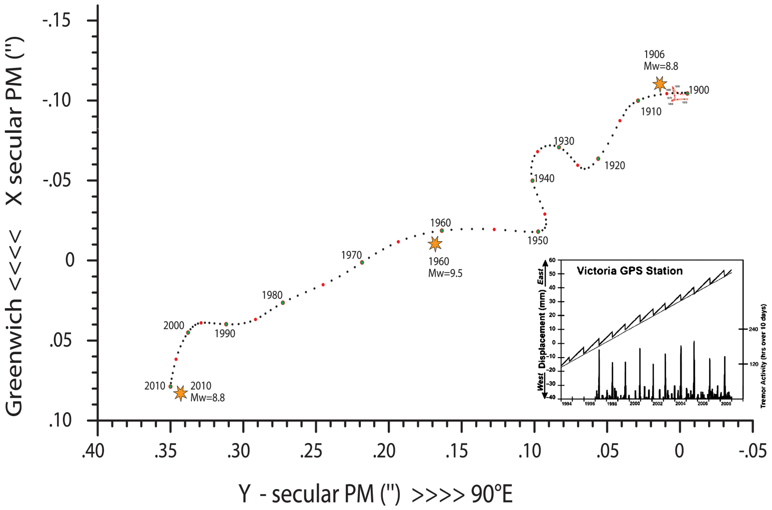


Fig. 15. Path of the Secular Polar Motion starting from the first available data (1846). The data before 1900 show an inextricable loop. The three stars represent the time of the volcano-seismic correlation events along the PM path. The correlation events of 1960 and 2010 occur ten years after a lustrum of nearly total stasis of the PM (on 1945-1950 and 1995-2000), but the same cannot be observed for the 1906 event because the unreliability of the pre-1900 PM data. This synchronicity must be confirmed or confuted by new future data. If with a longer set of PM data and volcano-seismic events the conjecture will be confirmed it would mean that we are in presence of the first phenomenon that puts in communication the Earth surface with its deep interior (Markowitz oscillation is credited to be caused by flows of liquid core). An asymmetrical expansion of the Earth is also supported. In the insert the ≈ 14 monts periodicity (Chandler Wobble period) of the tremors and surface displacement on the western North American margin (insert redrawn and simplified from Rogers & Dragert, 2003; Rubinstein et al., 2010).

Lon=81.5W; Chile, August 16, M=8.4, Lat=33.0S, Lon=72.0W) separated by a long distance (3500 km). In Fig. 14c only the southern district appears to have a peak of eruptions correlated to the earthquakes. This time the maximum is one year after the seismic event but the growing of the eruptions amount starts in the same year of the quake.

Then the real distribution on the time axis can be different and considering the reasons explained above in the preceding 1868 case, it may be that some of the real onsets have occurred many months before and also one year before.

The 1960 event (Fig. 14b) – The earthquake occurred (1960, Chile, Lat=38.0S, Lon=72.3W, M=9.5) when more modern scientific instrumentations (seismometry entered in a more advanced status) and surveying facilities (quick transportations, airplanes, helicopters) were available (Tazieff, 1962).

The maximum eruption rate is in the same year and the growing of the rate starts before the quake occurrence.

The 2010 event (Fig. 14a) – All the onset dates of the eruptions are known thanks to improvements of satellite, aeronautical and land remote digital surveillance methods. The rates of eruptions occurred in the northern and southern volcanic district increased from one-two erup/year to five in 2009. The northern volcanic district was particularly active in the interval 2007-2009, while – unexpectedly – the central district with its one or two eruptions/year does not contribute to the constitution of the volcano-seismic correlation event. It is then to be considered as well grounded the statement of a precursory nature of the northern and southern volcanic activity in this case.

All this has the meaning of a coordinated behavior of the entire South American Pacific margin from Ecuador to Cape Horn. Albeit it should be the subject of future investigations with adding new data as soon as ready (a work not for a single researcher, but for a succession of generations of geophysicists), the agreement with a conception that admits as main processes on the Earth the extrusion of mass and energy from the deep interior should be recognized.

11. An integrated explanation?

The clue of a possible synchronicity – On the same plot in Fig. 15 both the secular polar motion (from 1846 to 2009; data of PM from IERS web facilities) and the time of occurrence of the volcano-seismic events of correlations are represented. Fig. 15 shows that:

i) – Only three volcano-seismic events can be correlated to the series of PM data 1846- 2009, namely the events of 1906, 1960 and 2010 (Fig. 3).

ii) – The PM data preceding 1900 are not homogeneous with the 1900-2009 ones.

iii) – The volcano-seismic events of 1960 and 2010 occur about 12 years after a five-years window of stasis of the secular PM (a very low velocity, witnessed by the extreme proximity of the annual averaged points in the plot). Albeit the data are not against the same mutual pattern between the event of 1906 and the PM data of the last decade of the XIX century, the non-homogeneity of data do not allow a conclusion.

To ascertain the reality of this further correlation (synchronism with the Markowitz oscillation of PM; Poma et al. 1991) a greater amount of volcano-seismic events is needed, and the next expected volcano-seismic correlation will happen within 40-50 years. However, analogous synchronicities between seismicity tremors and a different periodicity of the Polar Motion have been already discovered – e.g. the 14 months periodicity of the Chandler Wobble is strongly related to the seismicity of the western margin of North America (Rogers & Dragert, 2003; Rubinstein et al., 2010), giving support to the plausibility of the abobe described Markowitz synchronism.

The acceleration of the PM after the five-years of stasis – and before and later the volcano-seismic event – can be easily interpreted as the influence of an enhanced extrusion of mantle material along mega-dykes.

Polar Motion (PM) and the True Polar Wander (TPW) – To divide different aspects of a phenomenon in different phenomenons that have different explanations is a serious anomaly for a Paradigm (in the sense of Kuhn, *The Structure of Scientific Revolutions*, 1962).

Geophysical phenomenons arbitrarily split by the current theory are the Polar Motion (PM) and the True Polar Wander (TPW). The PM is the slow shift – few centimeters per day – of the instantaneous axis of rotation of the Earth. Its secular drift toward Canada – about 1°/My – has been explained by flows of the mantle in response to the isostatic imbalance produced by differential deglaciations of the continental shelves of Canada and Eurasia. This mechanism cannot be extended beyond the duration of glaciations, i.e. a few tens of thousands of years, or perhaps hundreds of thousands of years, and only with difficulty to a million years ago. Beyond this time, this cause of the PM is no longer available, while the displacement of the pole of rotation can be followed, using paleomagnetic methods, to times more ancient than 100 million years and this phenomenon is called True Polar Wander (TPW) (Besse & Courtillot, 1991, 2002).

The latest segment of the TPW is, as can be expected, in perfect prolongation of the segment drawn from the geodetic data of the last 150 years, which we call PM. But the TPW, in the impossibility to resort to the glaciations, is explained differently from the PM. It uses temporal variations of the shape of the geoid through the geologic time, which could be caused by the

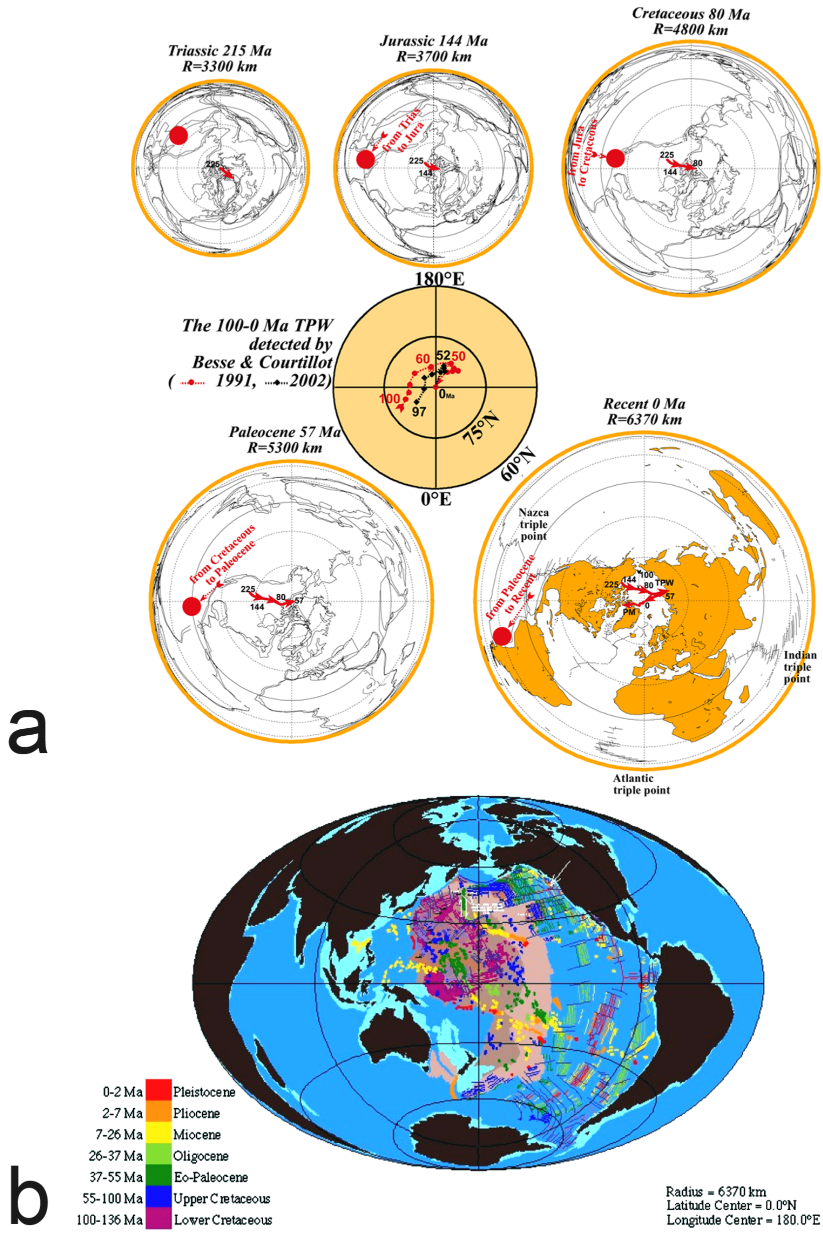


Fig. 16. An integrated explanation of several evidence. a)– Reconstruction of the probable TPW during an asymmetric expansion of the Earth. The red circles represent the points of maximum expansion through geological time. It is possible to roughly reproduce the TPW path from Canada to Asia, the "stasis" at 40-50 Ma and the coming back toward Canada as revealed by Besse & Courtillot (1991, 2002) (box in the center) by a simple migration of the point of maximum expansion from the northern hemisphere to the southern one. Stasis occurs when it crosses the equator. The TPW is then a prolongation of the current secular PM (drawn in pink, not to scale). b)– The ages of Pacific volcanism. At least three major elongated volcanic provinces can be recognized in the Pacific Basin, which ages decrease going from North toward South-East. The pattern of the ages along these ocean-bottom volcanic chains is compatible with the paleogeographic reconstructions showed in a), constituting a strictly connected tie among Paleogeography, Paleomagnetism, Astrogeodesy, Geochronology, Volcanism. See the text for further explanations.

convection of the Earth's mantle (another process entirely hypothetical).

An explanation that not separates PM from TPW but uses a single cause related to global tectonic processes can be found scrutinizing the paleogeography of the expanding Earth (Fig. 16a). The Earth expands asymmetrically and is growing and emplacing mass more quickly on the side of Pacific, which is larger than the other oceans and shows a higher expansion rate. The slow migration of the positions of the dominant Nazca triple point and of the less important Atlantic and Indian ones is able to account for the drift of the pole, its period of stagnation at around 50 million years (when the Nazca triple point crossed the equator coming from the Northern Hemisphere towards the Southern one), and finally the coming back towards its current position (Scalera, 2003). The TPW extends with continuity in the modern secular PM: they return to be the same thing.

In the expanding Earth schema both the TPW path and the PM can be explained by assuming an emplacement of mass extruded from the interior and migrating – with modality that are still unknown – from the initial opening of the Pacific in the North Hemisphere towards the actual Nazca region.

The pattern of volcanic chains in the Pacific – The Emperor Hawaii Volcanic Chain and all the Pacific Volcanism is another factual reality that can be explained in a consequent manner.

In Fig. 16b I have plotted the data extracted from the Unesco Geologic Map (1976). Besides the Emperor-Hawaii progression of ages only two other long progressions of volcanic ages can be recognized in the Pacific basin (Fig. 16b). The first starts with a largely dispersed distribution of volcanic apparatuses of Lower and Upper Cretaceous age, located north and east of Marianas, and ending – becoming progressively younger and more narrow – at the Austral Seamount (Isles Marotiri, east of Isles Cook). The second, also very dispersed, starts south of Hawaiian chain with the same Lower and Upper Cretaceous age, and ends – becoming narrow – at the Isles Pitcairn, showing recent volcanism.

The different shapes, dimensions and characteristics of the three volcanic lineaments are not compatible with a rigid and coherent movement of the Pacific crust on a motionless plume, as stated by plate tectonics theory. The only thing that can be affirmed is a general tendency of the volcanic activity to follow, with a space-delay of thousands kilometers, the enlarging boundary of the Pacific plate on the mid-oceanic spreading ridge. A new working hypothesis could be the trapping of deep magmatic chambers on both sides of the mid oceanic ridge, in correspondence with deep discontinuity crossing the axis of the ridge, and their becoming active on the ocean-floor when they go up sufficiently near to the surface.

The Emperor-Hawaii volcanism is distributed on a very narrow band, while the other two are wider, going back through time. This fact can support the role of the Emperor-Hawaii as a boundary between two plates (Scalera, 1991a,b, 1993) along which the volcanic activity is emplaced preferentially. In fact a great difference can be noted between the eastern and western side of Emperor, the eastern one characterized by transform faults and parallel fracture zones, and a western one characterized by an uneven topography containing many isolated seamounts, canyons, seamount chains and level differences.

The pattern of the ages along these ocean-bottom volcanic chains is compatible with the reconstructions showed in Fig. 16a, and a strong connection among Paleogeography, Paleomagnetism, Astrogeodesy, Geochronology, Volcanism is indicated, which can make resort to the unifying phenomenon of mantle material extrusion.

The asymmetric Earth – Many efforts to explain some asymmetric characteristics of the global tectonics have been made (Bostrom, 1971; Stevenson & Turner, 1977; Marotta & Mongelli, 1998; Doglioni et al., 1999; Carminati & Doglioni, 2012) but unfortunately these explanations were biased by the implicit or explicit assumptions of plate tectonics kinematics principia and by the consequent geodynamics.

Albeit some forces acting on the Earth body are at least qualitatively correctly envisaged (Bostrom, 1971, 2000) – as the forces originated by the Earth-Moon interaction – a more complete and realistic view about the global tectonics asymmetries can be built only on the basis of the general geodynamics of the expanding Earth. The main flows of the mantle materials in the expansion global tectonics are not moving along closed cycles of convective cells, but are mainly extrusion flows along surfacewards paths.

These surfaceward directed flows must undergo the laws of the classical physics of fluid-dynamics. Being the Earth a rotating body, the inertial forces, like the Coriolis ones, must be of great importance in influencing the final pattern of the flows, producing a typical expected deformation of shapes.

The Earth is rotating from West toward Est and consequently each vertical motion directed from the depths towards the surface will be deviated away from the perfect verticality by the Coriolis force, undergoing a bending toward West. Obviously, the extrusion of mantle materials does not occur along perfectly vertical tracks, but following already existing discontinuity lines. For example the emerging flows adjacent to the western continental margins must be borned already with a bending to west, and a more pronounced bending will be the result of the long time of action of the inertial force. If, on the contrary, the flows are near the eastern continental margins, starting already with an eastward bending, the Coriolis force will make them more vertical.

As a matter of facts, the characteristics of the actual active margins (Stevenson & Turner, 1977) are exactly as expected in the geodynamics of the expanding Earth. The Pacific ocean-floor volcanism is more developed on the western side of the median ridge (see Fig. 16b), and also this is caused by the prolonged westward action of the Coriolis force that possibly is able to detach "macro-drops" of rising materials and to lead them along more bending paths.

Also the asymmetric topography across the rift zones, the compositional, thermal and density asymmetries, must find an integrated explanation in which the first cause of asymmetry is the Earth's rotation and the consequent inertial forces. In the same way that the gravity force operates as a sort of filter that drives the lighter compounds towards the surface and the heavier ones towards the geocenter, the Coriolis force constitutes an "East-West filter". It can drive the heavier minerals towards west – were they appears as constituting a "fertile mantle", while a "depleted mantle" is the result to east.

12. A dramatically open problem

Finally, a truly important – but unsolved – problem should be mentioned. In the new orogenic model proposed in this paper the flow of the extruding material can have an additional characteristic. The efficiency of the extrusion should have an inverse relationship to the overall rate of expansion of the Earth.

In Fig. 17, the *Half Spreading Map of the Oceans* (Müller et al., 1997; McElhinny & McFadden, 2000) shows three minima (in Recent, Late Cretaceous, Late Jurassic) and the Recent minimum is correlated to the so-called "Neotectonic Period" (Ollier, 2003; Ollier and Pain, 2000) – the last few million year time window – in which most fold-thrust belts have having a new orogenic activity.

If the global rifting activity – driven by a global expansion – stops, the metastable states of the uplifted material continue to convert to lighter and bulkier phases. Because the "room" size is in these periods horizontally constant, the material in course of phase change can expand only towards the surface, extruding and giving all the appearance of a time-coordination among far and unrelated fold belts.

If this coincidence and link between Neotectonic Period and Half

Spreading Recent minimum is real, others "Neotectonic Periods", namely periods of few million years of nearly simultaneous uplift of fold belts, should be found in the geological past.

A simple tectono-cartographic experiment can be performed using the Maps of *Ocean Floor Ages* and of *Half Spreading Rates* (Larson et al., 1985; Müller et al., 1997; McElhinny & McFadden, 2000; Müller et al., 2008), with considerations about the "Neotectonic Period" (Ollier & Pain, 2000; Ollier, 2003). In Fig. 17 if the minima of the Half Spreading Rate of Atlantic and Pacific (the white circle series, numbered 1-3 in the upper map) are transferred on the Ocean Floor Age Map below, the ages of the three minima are individuated: Recent, Cretaceous-Cenozoic boundary and Late Jurassic. Obviously the three ages are affected by some incertitude.

In the Recent – and in the past time lapse of about 10Myr – the Neotectonic Period of reactivation and uplifting of orogens is in course. Because of the relation that can be hypothesized among the slowing down of the global expansion, the consequent slowing down of the continental rifts, and a mechanism of accelerated extrusion of mantle material under the fold belts that can be interpreted as "Neotectonic Period", it should be investigated if analogous "Neotectonic Periods" have occurred during the Half Spreading slowing down at the two time boundaries individuated by the tectono-cartographic experiment – Cretaceous-Cenozoic and Jurassic-Cretaceous.

A "Neotectonic Period" is by definition a period of accelerated uplift of thrust-fold-belts, and main indicators of these periods can be considered the ophiolitic belts (Dilek, 2003) which can record several thousand of meters of upheaval. The continental volcanic rocks are emplaced on the orogenic regions, without a neat regular distribution. The ophiolites, instead, are emplaced on arched narrow lineaments (dotted lines) from the Dinarides-Hellenides to the Aegean arc and to the Anatolian fold belt (Fig. 18). At least two elongated ophiolitic belts are present in the Balkan Peninsula that can be prolonged towards the interiors of the Anatolians Peninsula (Fig. 18). The age of these facies are very debated (Hoeck et al., 2006; among others) and the more ancient of the belts can be referred as Triassic in age. This can be meaningful because what is important is not the absolute age of the ophiolites but their "uplift and final emplacement" age, which can well be Late Jurassic. The same line of reasoning can be applied to younger ophiolitic belts.

The continuity and parallelism of these long arched distributions of ophiolites is evidence in favor of an unitary tectonic process that operates till the Recent with the ongoing opening of the Aegean backarc basin and with the past and present tectonic activity of the neighbouring orogenic zones (Hellenides, Dinarides, Anatolic).

The three lineaments of ophiolites along Dinarides and Pontides, are evidence in favour of a succession of tectonic activity phases. The actual external Aegean trench and the adjacent "Mediterranean ridge" should be considered the present phase. Their continuity from Europe to Turkey is definitely not in accord with the interpretations of the ophiolitic belts as relics of oceans that closed completely, The conflict arises because the Aegean backarc basin is in a tensional stress state and its arc is in active outward spreading. This regular and parallel distribution of the three lineaments is at odds with the origin of the westward drift of Anatolia, namely the hypothesized collision of the Arabian peninsula against Eurasia.

The general distribution of volcanic rocks and ophiolites seems in favor of a progressive detachment of Africa from Laurasia along a NNE-SSW direction.

This can be linked to a more general idea of a huge lineament of tensional state of stress that pass through the Mediterranean starting from the Indian triple point and stopping on the Atlantic triple point. The associated rate of strain should be considered very low

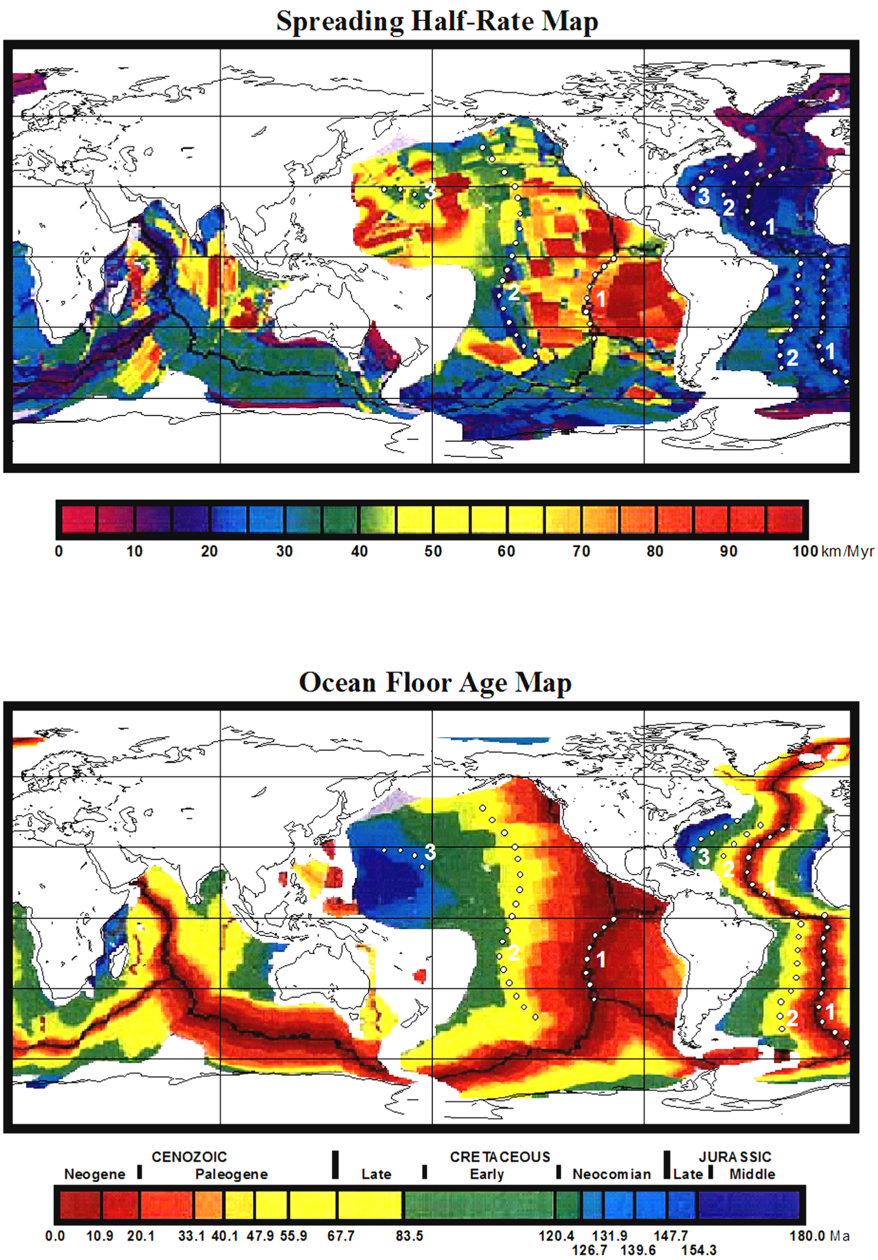


Fig. 17. A tectono-cartographic experiment: finding the possible ages of the old "Neotectonic Periods". The three periods of minimum spreading rate (white dots curves 1, 2, 3) in the upper map have been overimposed to the lower map of the Ocean Floor Age. While we are sure of the existence of the present Neotectonic Period, the existence of analogous periods of coordinated fold belts building in the past is still not ascertained. See the text for a discussion.

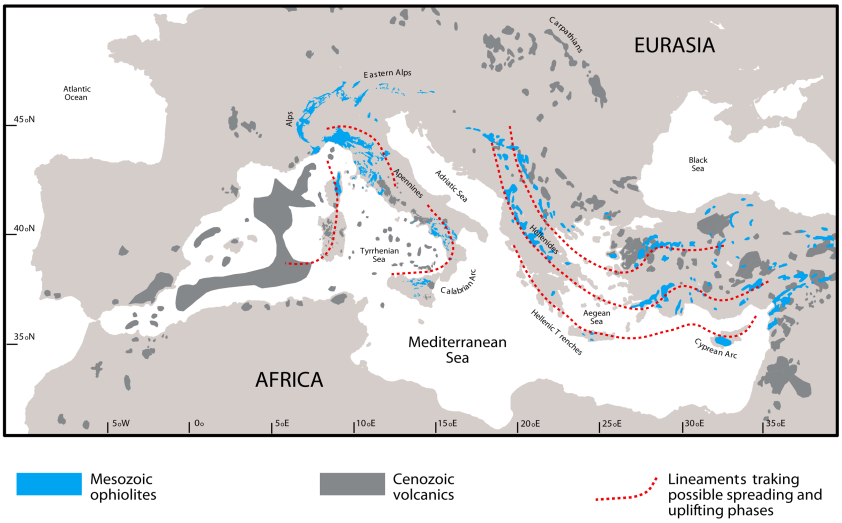


Fig. 18. All the Mesozoic ophiolites (blue) and the Cenozoic volcanics (dark grey) are represented. The data are taken from a figure in Scalera (1997) (based on the CNR's Map of Kinematic Model of Italy, by Bigi et al., 1991), from the maps in Smith & Woodcock (1982), from Serri et al. (2001), and from Lustrino & Wilson (2007). The pattern of the Dinaric and Anatolian Mesozoic ophiolites can be connected in large arched lineaments – see the red dashed lines. These large lineaments are indicative of a succession of phases of the tectonic activity that may be can have some synchronicity with the periods of low spreading rate – probably also low global expansion rate – individuated on the preceding Fig. 17.

(if compared to the Pacific hemisphere rates) because the antipodal position of Mediterranean with respect to the region of Nazca triple point, where the maximum sea-floor expansion rate exists.

This problem has not still a final assessment, but should be studied in connection with the possible neglected systematic errors in the geochronology methods. While it is fully accepted an enlargement of the errors bar going from the Recent toward the deep Geological Time (see Fig. 4 in Scalera et al., 1996), possible still unrecognized collateral sources of over-estimation of the geological ages should be considered (Dalrymple, 1969; Berthault, 2002; De Pontcharra, 2012).

Albeit the exaggerated time shrinking propagandated by creationists cannot be accepted – creationism cannot be part of science – some specific criticisms about the unreliability of geochronological methods should be carefully scrutinized (Dalrymple, 1969; Berthault, 2002; De Pontcharra, 2012).

The solution of this problem has a strong link with the problem of the still geodetically unrevealed Earth's expansion. Beside the possibility of a vicious circle in the geodetic methods – like the possible spurious effect proposed in this volume (Scalera, 2012) –, the stasis of the expansion (a rate of radius increase near to zero) with an enhancement of the foldbelts building (with the favoring mechanism described in this paper) is a second possibility of undetectability of expansion, and the two causes can be superimposed.

13. Conclusions: a mega-dykes dominated reality

A non exaustive overview of the modern expanding Earth conceptions and of the new data on which these ideas are founded, is provided in this paper.

Initially scrutinizing the Mediterranean region – site of the "slowly ever nascent ocean" – , the new detailed 3D distributions of relocated hypocenters laying under orogenic belts has been plotted and discussed. The similarity of the hypocentral patterns under the Tethyan orogenic belts, and under the South American Pacific orogenic margin has been considered a main clue on which to build a more realistic global geodynamic model. The recognizable clusters and filaments of hypocenters taper downwards, leading to the natural interpretation of a deep origin in narrow regions of the disturbance

Other important facts witness in favour of a slow surfaceward movements of deep material along what can be called "mega-dykes". Isostatic rising – but not diapirism – and changes of phase of deep mantle materials along these surfaceward trips are individuated as the cause of the outpouring of the material on the surface, that we observe as orogenic processes. This extrusion of deep materials produces gravitational nappes and their overthrust on the sediments of the pre-existing trough, forcing them on a burial path which emulate the subduction process, but without reaching depths greater than 50-70 km. Only the large scale subduction (undreds or thousand of km) can be excluded.

Phenomenons like metamorphism, mixing, migmization, upward transport of fragments of the buried lithosphere etc. are possible at the boundary between uplifting material and down-pushed crust and lithosphere. The HP as well the UHP metamorphism are possible thanks not to subduction and exhumation of materials along a "two-way path" – as proposed in the plate tectonics – but more symply thanks to tectonic non-lithostatic overpressures due to deviatoric stresses at the interface between mechanically interacting materials.

Additional clues of a main global uplifting of materials are provided by the astrogeodetical indications of a coseismic displacement of the instantaneous Earth's rotation axis in the occasion of the great Sumatra (M_w=9.3) and Honshu (M_w=9.0) earthquakes. These polhody displacements are very significant because in complete disagreement with the plate tectonics modelled axis shift and in agreement with the shift expected in the new expanding Earth conception. Because of analogous opposite predictions of the length of day (LOD) variations following the extreme magnitude earthquakes ($\Delta LOD<0$ vs $\Delta LOD>0$), also future improvements of the time measurement techniques could be of help for a final choice between rival geodynamical models.

The data collected by the satellite GRACE have alredy confirmed (Han et al., 2006) the proposed model of extrusion of materials in a distensional environment. The comparison of the GRACE data before and after the seismic event of Sumatra and Honshu can be explained only by a sudden uplift of mantle material under horizontal tensional conditions (Han et al., 2006) – practically a mega-dyke confirming a serious insubstantiality in the plate tectonics.

Albeit we cannot still know the origin of the mass emplacement – cosmic (Blinov, 2012; Cahill, 2012; Edwards, 2012; among others) and/or from phase transformation of deep Earth' layers (Pickford, 2003; Owen, 1983, 1992, 2012) –, The Nazca region as a whole seems to be the site that with its more intense rate of mass emplacement is able to drive also astrogeodetic phenomenons like Polar Motion and its prolongation into the deep geological time. Not only the PM and TPM find a common unified explanation in the evolution of the Pacific region paleogeography, but also the ages of the Pacific volcanism (in particular of the volcanic chains) can be firmly linked to this explanation. Paleogeography, PM, TPW, ages of the volcanism, volcanoseismic phenomenons, effects of quakes on PM and global tectonic asymmetries find a new nice and simple common cause that should no more be neglected by geosciences community.

The model of fold-belts evolution has been built taking into account all the clues described in this paper, but also the better accord of it with the HCs generation should be considered a supporting important clue. The model overcome the difficulties of the diapirism-based conceptions and give new value to the conclusion of Polyak (2005) based on isotopic and heat flow data – of the necessity of deep hot silicate mantle intrusion under the rifts, mid oceanic ridges and island arcs. While in plate tectonics the cold slab travels in contact with the lithosphere of the continental side, oxidizing materials faced to oxidizing materials, in my framework a high-temperature reducing environment of undepleted mantle rises up and come in contact with the relatively cold oxidizing lithospheric environment. A number of chemical reaction are then favoured in this sort of tectonic oxidizing-reducing pile, leading to a multiple origin of hydrocarbons and to selforganizing phenomenons of mineral accumulation (Jacob et al., 1996; Jacob & Dietrich, 2012).

This review could eventually reach a greater generality. Indeed, the isostatic mechanism of uprising of changing phase undercrustal material, is more efficient if the "room" is not enlarging and the only "escape-way" is toward the surface. As matter of fact, the map of the oceanfloors expansion rate shows some minima – one of them in the Recent – and the "Neotectonic Period" is in the first minimum. From this follows that other neotectonic periods should be expected in synchronism with the other geologic periods of low expansion rate. The possibility of the existence of this great geologic-clock with periodic enhancement of mountain building (and obviously of "mid-oceanic ridges building") in the occasion of a low rate of ocean floor emplacement, repose on the possibility to better distinguish between rocks age and uplifts age, adopting a more open attitude and possibility of manoeuvre considering some isolate critical voices about the neglected sources of systematic errors in geochronology.

I do not consider the ideas expressed in this paper as final word about the building of a new geodynamics view. We are still very far from the – however unreachable but more and more near – goal, but definitely on the good track.

Acknowledgements. All the expanding Earth community that has participated to the meeting in Erice, with his vitality and creativity, has been of great inspiration in writing this paper.

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Author's Biographical Notes: *Giancarlo Scalera was born in Barletta, Italy, on 4 April 1949. He get the University degree in Physics at the University of Bari (1975) discussing a Doctoral Thesis on foundation of Physics. Immediately after, he proposed a mechanical and local model that is able to violate the Bell's inequality. On 1976 Scalera was Assistant lecturer at the Geodesy Institute of the University of Bari and he collaborated to the maintenance of the seismic network of the University of Calabria. On 1979 he was at work in the INGV in Rome. The map of the Maximum Intensity Felt in Italy was drawn by Scalera and co-authors and he found correlations between the Felt Intensities and a number of geological and geophysical characteristics of the Italian region. Research was made in global tectonics, paleogeography and geodynamics, adopting the expanding Earth model. He performed historical researches about shape and movements of the Earth, and biographical researches on scientists involved in the expanding Earth. Presently is proposer of a new mechanism of mountain building based on isostasy. Giancarlo married on 1980 and has a daughter. He loves painting and sculpturing, and – ever more rarely – use the bicycle for excursions.*