New Concepts in Global Tectonics NEWSLETTER

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20TH-ANNIVERSARY SYMPOSIUM, COLLOQUIUM FOR STRUCTURAL GEOLOGY, JAPAN

The colloquium for structural geology was established in 1991. Since then we have organized meetings regularly twice a year to promote original studies based on thoroughgoing field work. To commemorate the 20th anniversary, a special symposium entitled “New global tectonics and megaquakes” was held in Tokyo on 18th December 2011. Dr. Dong Choi was invited from Australia to deliver a lecture, “Great East Japan Earthquake viewed from a new global tectonic perspective” for two hours. Seven other Japanese scientists lectured at the symposium too. It was attended by more than 50 enthusiastic scientists who over-filled the lecture hall. Their abstracts are introduced in the following pages. The symposium was timely as the Japanese people are fearful of the next big earthquakes, and it was eye-opening. All attendants strongly felt that the plate tectonic era has finished and great earthquakes are surely predictable. The long hot day was closed with a watchword, “we will meet again at the 34th IGC in Brisbane!!

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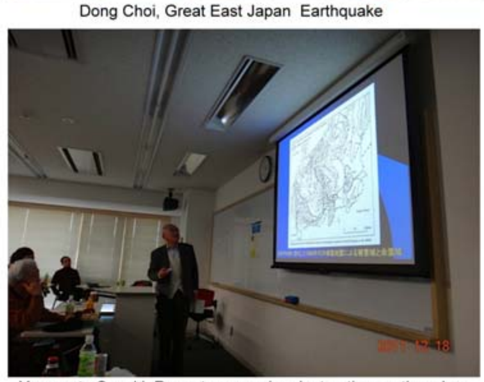
Masashi Hayakawa, Short-term earthquake prediction

Fumio Tsunoda, VE process of gigantic earthquakes

Audience and a film crew

Dong Choi, Great East Japan Earthquake

Michihei Hoshino (standing) presented a paper "Earthquakes and waters (sedimentary basin)"



Yasumoto Suzuki, Recent successive destructive earthquakes

ABSTRACTS OF THE PRESENTED PAPERS

Great East Japan Earthquake viewed from a new global tectonic perspective

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Available geological and geophysical data indicate that epicenters of the fore-, main- and aftershocks of the M9.0 March 2011 Great East Japan Earthquake (GEJE) are situated in the coastal and offshore area of northern Honshu bounded by the two prominent NW-SE trending structural highs; Offshore Hidaka Uplifted Belt in the north and the Sado-Chosi Anticline (new name) in the south. The region is a broad crustal high block characterized by the N-S trending Paleozoic ridges. This crustal high structure was formed in relation to the process of the Pacific Ocean formation (subsiding) and the rise of the island arcs since the Mesozoic.

The mainshock occurred at the junction of a Paleozoic basement ridge and an ENE-WSW trending planetary fracture system that runs from the southern part of the Sea of Japan, through Noto Peninsula, to the northwestern Pacific. The strong foreshocks on 9 to 10 March 2011 also occurred in the same tectonic setting. This interpretation is in harmony with the moment tensor solution which implies a NE-SW high-angle fault movement and energy distribution pattern. All of the strong aftershocks (M6.0+) are situated on the basement ridges, along their margins, or along the major WNW-ESE tectonic lines.

This unusually strong magnitude earthquake is the result of convergence of deep earthquake energy originated in the western part of the Sea of Japan/coastal area of the Russian Far East and the on- and offshore central Japan along the Susongchon-Lake Biwa Tectonic Zone (M5.5 to 6.8; depth – 350 to 640 km, occurred from 2005 to 2008). Additional thermal energy was supplied through the MJ (Mariana-Japan) route in accordance with the Tsunoda's VE process. The converged powerful thermal energy was trapped in the upper mantle under a broad crustal high block. The thermally-bulged mantle uplifted the overlying crust, which finally ruptured along the basement ridges and fault zones. A powerful trigger was provided by the force exerted by the Sun and the Moon; the Sun discharged strong flares (coronal mass ejection) several days before the disaster and the Moon was closest to the Earth at that time.

The deep forerunners appeared in 2005 to 2008. These years also roughly correspond to the rapidly declining period of the 361-year solar cycle – which is comparable to the early stage of the Maunder Minimum or Little Ice Age. The unusually strong natural disasters in recent years including earthquakes, volcanic eruptions and extreme weathers can be attributed to the combined effects primarily originating from the enhanced discharge of the Earth-core energy during a major solar cycle trough triggered by a planetary force.

The GEJE was preceded by a vapor cloud or geoeruption 16 days prior to the mainshock. Global Network for the Forecasting of Earthquakes, based on strongest gravitational anomaly registered at their monitoring stations from 7 March 2011, informed their clients on 9 March 2011, two days prior to the main event, with pin-point accuracy in time, magnitude and locality. The electromagnetic precursory signals were also detected by Hayakawa. These facts show that major earthquakes are predictable on a firm scientific ground today.

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Short-term earthquake prediction by means of electromagnetic effects

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The conventional seismic measurements have been carried out for many years in short-term earthquake prediction, but it is concluded that earthquake prediction is impossible with such mechanical measurements. During the last two decades we had an enormous progress in earthquake prediction by means of a new way of using electromagnetic effects (such as the anomalies in the electric and/or magnetic field, electromagnetic radiation, ionospheric perturbations and so on). Especially, the ionospheric perturbation on the basis of subionospheric VLF/LF propagation, is found to be statistically correlated with earthquakes (with magnitude greater than 6.0 and shallow depth – 40km), by using the long-term data. Recently we have established a venture company providing the public with earthquake prediction information, and such information will be released on mobile phones in the middle January of 2012.

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VE process of ultra gigantic earthquakes in Sumatra Island and in Eastern Japan

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The earthquakes occurring in a hopping manner were recognized as harbingers of two ultra-gigantic earthquakes in Sumatra Island and in the eastern Japan. This seismic romping becomes visible when a platy rock massif overlying the thermal expansional layer starts to bend upward.

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Geology of Thingvellir Area, Southwest Iceland -Negative concept on plate tectonics-

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It has been suggested that the Mid-Atlantic Ridge, Reykjanes Peninsula and Lake Thinvallavatn of southwest Iceland are situated on the axis of crustal spreading and about 200 gjas resulted from by the movement around Thingvellir. The present writer mapped the geology around Thingvellir. The stratum in this area are volcanic rocks of Matuyama Reverse Polarity Chron (1.8Ma~1.2Ma), lava flows and hyaloclastites (1.1Ma~0.7Ma), table mountains (0.5Ma~0.2Ma?), Thingvallahraun (9ka) in ascending order. At the east of Hrafnabjorg, magma reservoir ascended to the surface and volcanic activity began on the top of the uplifted zone. About one hundred sheets of Thingvallahraun came from the fissure vents, mainly from Eldborgir. Another magma reservoir under the Thingvellir area moved off towards the uplifted zone and entered the former. As the result of the movement, the Thingvellir area subsided down to a depth of about 20 meters and formed a great many gjas (gaping, dilation fissures). Therefore, the origin of gjas is not crustal spreading, but subsidence of the ground.

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Recent successive occurrence of destructive earthquakes in Japan

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The southwestern part of Honshu in the Japanese islands have been activated in seismicity since the occurrence of the Hyogoken-nanbu earthquake (M7.2) of January 15, 1995, followed by the Tottoriken- seibu earthquake (M7.3) of October 6, 2000, the Geiyo earthquake (M6.7) of March 24, 2001 and the Fukuokaken-seihou-oki earthquake (M7.0) of March 20, 2005. The area is encircled by several rows of elliptical arrangement of faults deduced from P-wave radiation pattern of shallow earthquakes. The Chuetsu earthquake (M6.8) of October 23, 2004 was the forerunner of the seismic activity in northeast Honshu in the 21th century, followed by the Miyagi-oki earthquake (M7.2) of August 16, 2005, the Noto-hanto-oki earthquake(M6.8) of March 25, 2007, the Iwate-Miyagi inland earthquake(M7.2) of June 14, 2008, the Sanriku-Joban-oki earthquake (M9.0) of March 11, 2011 and the North Nagano earthquake (M6.7) of March 12, 2011. Those seismic areas are encircled by two rows of ring-like arrangements of faults accompanied by shallow and deep earthquakes in Honshu but two rows of half circles are put under the south end. Ring-like arrangement in off-shore areas of northeast

Honshu is of shallow earthquakes. The arrangement of faults of shallow and deep earthquakes in northeast Honshu runs parallel each other. The parallel arrangements of faults accompanied by shallow and deep earthquakes might be due to the vertical extension of ring-like structure of faults. The synchronous activity is recognized between the shallow and the deep earthquake groups. These structures contradict the subduction of a plate along the deep earthquake zone, and the mantle tomography does not always show the plate under the Japanese islands, as the plate can be traced under the coastal area and the central part of Honshu, but cannot be found under the coastal area of the Sea of Japan.

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Earthquakes and waters -sedimentary basins-

Michihei Hoshino

(The following paragraphs were cited by Kubota from "Crustal development and SEA LEVEL", Hoshino, 2007, ISBN 978-4-9903950-0-1, E.G.SERVICE, Sapporo, Japan)

On that day, Dr. Hoshino emphasized, "Earthquakes are completely geological phenomena, not geophysical phenomena". Outlines of his theory are as follows: The micro-expansion of the Earth, due to the formation of the surface layers of the Earth, controlled various geological phenomena through crustal uplift and sea level rise. The crustal uplift (expansion) preceded the formation of the sedimentary basin. The expansion of the earth is a basic phenomenon in the development of the Earth. In the past, geologist urged that crustal subsidence was necessary for the formation of sedimentary sequences, however, the supply of clastic materials from uplifted land blocks is the principal factor for sedimentation. There can be no sedimentary basin without the supply of clastic materials, and in the case of no supply of clasts, the basin remains empty, i.e., a lepto-basin. Among the sedimentary basins, the geosynclinals basin is most important. The primitive geosynclinal basins were created as remnant depressions between uplifted platforms in the early Proterozoic. The peaks of igneous activity in the Basaltic Stage (Hoshino, 1981) are the times of the Late Cretaceous to Early Paleogene, and the Neotectonic Period. In the case of former, marked anatexis acidic magmas were produced due to the water from transgression and heat from the basic magma which rose along deep faults. In the Neotectonic Period, underplating of the basic magma formed global high mountains and plateaus. This contemporaneous global high uplift cannot be explained by plate theory, and the magmatic quiet zone of the oceanic basins, the origin of the Moho discontinuity, and the difference between the trench with and without accretional bodies plus the distribution of variety of rock types in the oceanic basin create difficult problems for the plate theory.

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Seismicity in relation to geodetic crustal movement of northeast and central Honshu, Japan

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1st order triangulation stations are set every 40 to 50 km all over the Japanese islands and they were measured about 1898, 1962 and 1979. The author applied the strain analysis to the displacement of neighboring three stations in northeast and central Honshu. The dilatation was positive to the north of the line between Akita and Sendai and negative to the south in the former period in general. The dilatation was reversed in the later period, though the boundary was not changed. The bench marks of leveling survey of first order are set every 2 or 1 km along the national roads and re-leveling have been conducted every several to ten years. The upheaval and subsidence of bench marks in each period accord with the expansion and shrinkage of triangulation. Maximum compression axes deduced from the P-wave radiation pattern of earthquakes run parallel to the maximum shrinkage axes of strain ellipse. These geodetic crustal movements suggest the block structure of the crust and upper mantle, and contradict the idea of an external force causing geotectonic movement.

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Tectonics of The northeast Japan Arc according from the 2011 off the Pacific coast of Tohoku Earthquake, its aftershocks, upper mantle tomography and crustal movement by GPS measurements

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The 2011 earthquake off the Pacific coast of Tohoku Earthquake of March 11, 2011 occurred at offshore of Miyagi Prefecture, Tohoku Province, Japan, and strong motion and tsunami attacked the coast area of the Tohoku to Kanto Provinces. But seismic vibration of the areas situated west of the Ouu Backbone Mountains is not so strong because its *S*-wave is not absolutely strong. The *S*-wave seems to have been weakened during passing under the Ouu Backbone Mountains where the low *S*-wave velocity zone exists. Northeast Japan arc extended several tens meters to the east, and central part of the arc sunk slightly by the quake. Areal aftershock swarms appeared and illuminated the geologic structures around the swarms. These mean that the pressure in the crust decreased by extension of the arc and the upper crust melted partially. Several caldera volcanisms occurred around these areas in geologic past, but they did not occur at this time. Tectonics of the Japan Arc is controlled by a thermal plume from the mantle to the arc which is drawn by the tomography. The thermal plume seems to be not strong in the recent period and the surface of the arc is not tensional but compressional, while activities of the thermal plume were strong and the surficial crust was tensional during the past geologic period when the caldera volcanic activities occurred.

LETTERS TO THE EDITOR

Dear Editor,

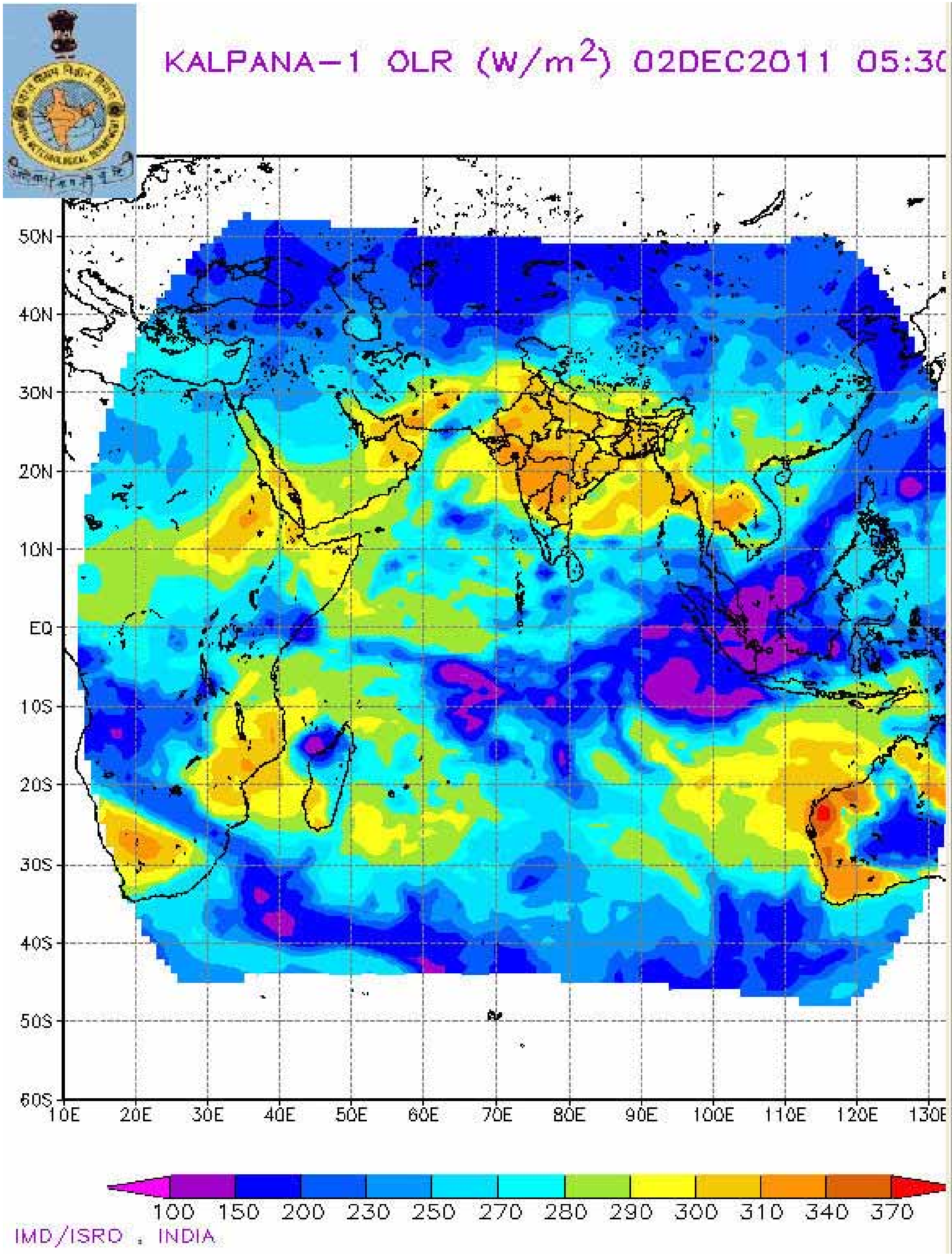
I happened to see some interesting features in the Outgoing Long Wave Radiation (OLR) at a particular location in NNW Australia on 02 Dec. 2011. I informed an Australian friend of mine Mr. Phil Hollis-Watts (p.hollis-watts@bigpond.com) about the possibility of occurrence of an earthquake. To my surprise an earthquake occurred on 05 Dec 2011. The mail sent to Hollis-Watts is as follows:

> I am attaching an unusual feature satellite photo of Outgoing Long Wave Radiation (OLR). It is showing very high temperature in western coast of Australia. Such a pattern I have not seen. Please check this happening for earthquake occurrence. You would find a small area of high temperature on the western coast of Australia in the vicinity of 23 S and 115 E. This is indicated by red spot in NNW Australia. Please inform whether you could record any precursory signal and whether the temperature high is seismic or non-seismic.

Arun Bapat
arun_bapat@vsnl.com

The seismic event has occurred on 05 Dec 2011. The details as per USGS are as follows.

Magnitude	**5.1**
Date-Time	• **Monday, December 05, 2011 at 19:10:03 UTC** • Tuesday, December 06, 2011 at 04:10:03 AM at epicenter • Time of Earthquake in other Time Zones
Location	21.660°S, 114.650°E
Depth	9.8 km (6.1 miles)
Region	WESTERN AUSTRALIA
Distances	370 km (229 miles) NNE of **Carnarvon, Western Australia, Australia** 433 km (269 miles) WSW of **Port Hedland, Western Aust., Australia** 556 km (345 miles) WNW of **Newman, Western Australia, Australia** 1144 km (710 miles) N of **PERTH, Western Australia, Australia**
Location Uncertainty	horizontal +/- 20.6 km (12.8 miles); depth +/- 5.9 km (3.7 miles



India Meteorological Department

ARTICLES

RECENT SEISMIC ACTIVITY IN THE JAPANESE ISLANDS FROM THE VIEWPOINT OF SEISMOTECTONICS

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Abstract: Initial motion of P-waves of an earthquake is divided into four quadrants by two nodal planes in general and either of them corresponds to fault. Two nodal planes run often parallel each other, and the strike of fault is positively defined. The fault is normal or reverse fault without strike-slip component. When one nodal plane is steep and another gentle, the former runs parallel to the plane of dip-slip type in general, so it might correspond to the fault. The fault is obliquely slipping normal or reverse.

The faults deduced from the P-wave radiation pattern of shallow and deep earthquakes show ring-like arrangement with width about 200 to 400 km. The arrangement of faults accompanied by shallow earthquake run parallel to those accompanied by deep ones, so the ring-like structure spreads its root vertically and the subduction along the deep earthquake zone is impossible.

The strain analysis of re-triangulation data of first-order stations shows pulsation in each unit with the ring-like arrangement.

Keywords: *earthquake, initial motion, nodal plane, pulsation, quadrant, divergence*

Introduction

The initial motion of P-waves of the earthquake is divided into 4 quadrants by two planes running perpendicularly in general (Honda, 1940). The Kita-tango earthquake (M7.8) occurred in 1927 in central Honshu was the quadrant type in P-wave radiation pattern. It was accompanied by the Gomura fault running in NW-SE direction and by the Yamada fault in a NE-SW direction parallel to the two nodal planes.

The Kita-Izu earthquake (M7.3) took place in central Honshu in 1930, showing also the quadrant type in P-wave radiation pattern and the nodal planes running in N-S and E-W directions. The Tanna Fault occurred parallel to the former nodal plane.

Thus the fault accompanied by the earthquake is thought to be caused by a shear parallel to one of two nodal planes.

Though the earthquake is accompanied by two nodal planes, we can determine the direction of fault, when two nodal planes run parallel each other (**Figs. 1 and 2**). The fault is normal or reverse without strike-slip component. When one nodal plane is steep and the other gentle, the former must be the fault plane, as it runs parallel to nodal plane of dip-slip type in the neighborhood. In the following figures, normal fault in dip-slip type is shown as a white spindle, and reverse fault in dip-slip type as a black spindle. Diagonally slipping normal fault is shown as a comb, and diagonally slipping reverse fault as a comb with an arrow.

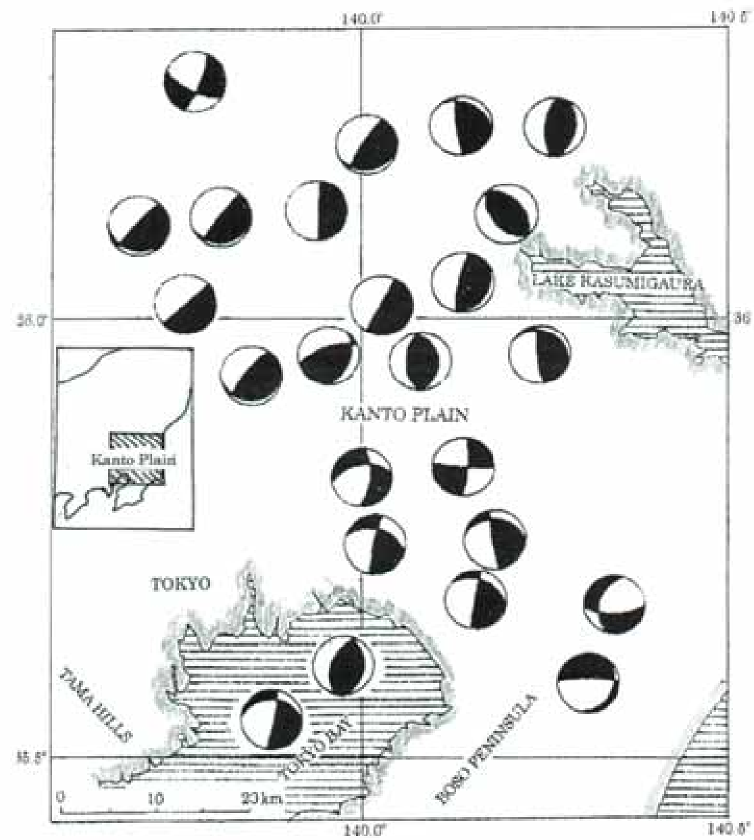

Figure 1. Upper hemisphere stereo-net projection of P-waves accompanied by the earthquakes occurred in Kanto plain.

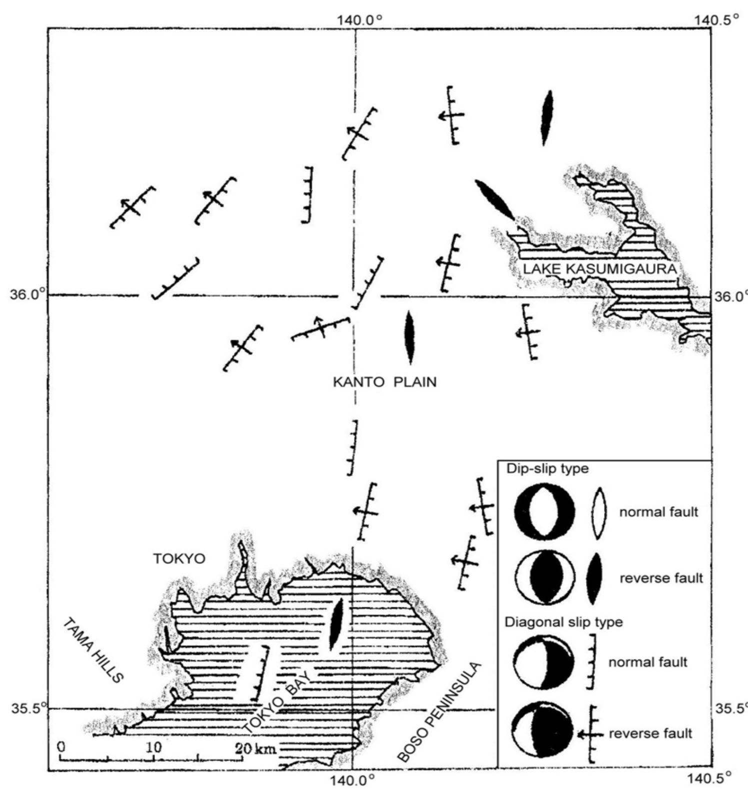

Figure 2. Faults accompanied by the earthquakes deduced from P-wave radiation pattern occurred in Kanto plain.

The figures of P-wave radiation pattern in the Japanese islands and adjacent areas have been published by the Meteorological Agency of Japan. The authors draw the faults accompanied by the earthquakes from the figures, following the nodal plane analysis stated above.

Arrangement of faults

Suzuki and Kobayashi (2005) and Suzuki et al. (2009) applied the nodal plane analysis to the earthquakes occurred in the central part of Honshu, and showed that the general trend of faults accompanied by deep earthquakes and shallow ones ran parallel circularly.

We applied the nodal plane analysis to the earthquakes occurred in the Japanese islands and surrounding areas (**Fig. 3**). Faults accompanied by shallow earthquakes along the Japanese islands and their adjacent seas run circularly. The faults accompanied by deep earthquakes distributed under the Japanese islands and their inner zones except the southwest part of Honshu show the circular arrangements parallel to those of shallow earthquakes. The authors think that it might be due to vertical extension of ring-like arrangement of faults just like the grain of wood.

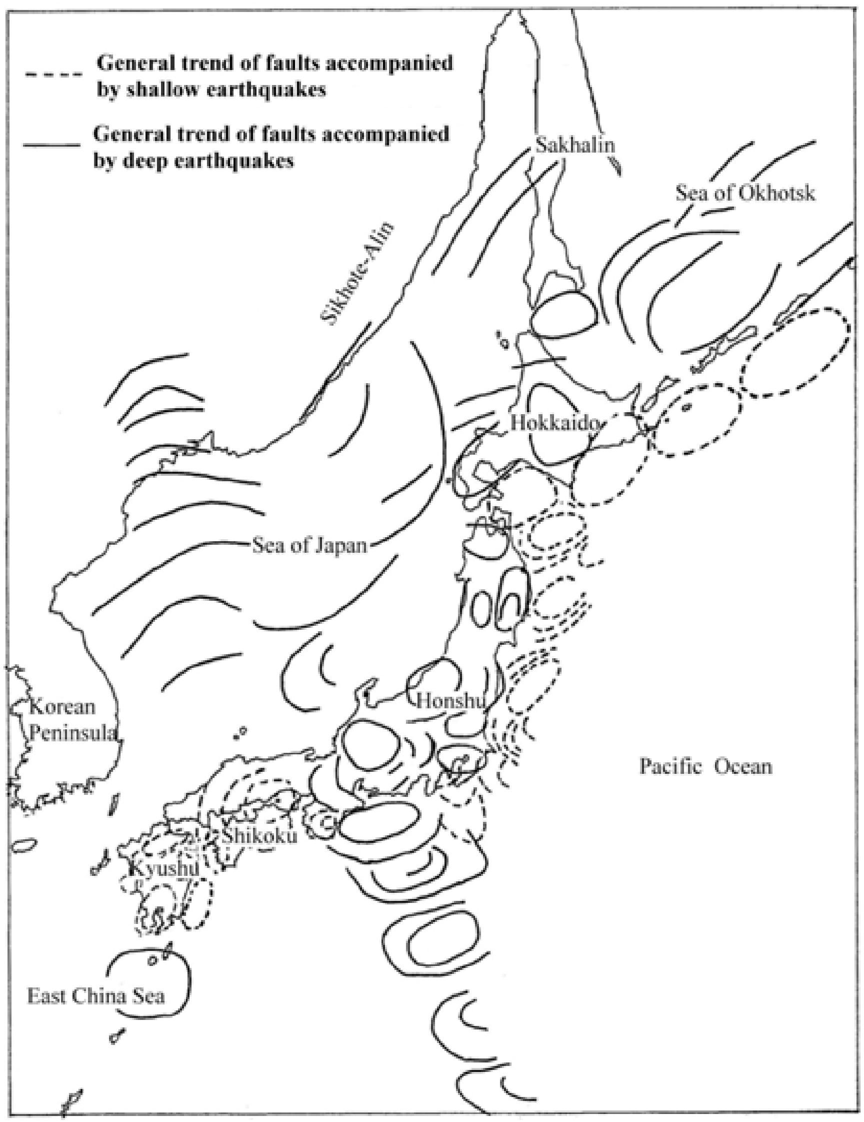

Figure 3. General trend of faults accompanied by shallow and deep earthquakes in the Japanese islands and adjacent areas.

The circular arrangements of faults accompanied by deep earthquakes are found in Okhotsk Sea basin, the northeast part of Japan Sea basin and Yamato basin, following the outer rims of the basins (**Fig. 3**). In the southwestern part of Japan Sea, arched arrangement of faults is found. Circular arrangements of faults accompanied by the deep earthquakes are found along the Nanpo-shoto (or Izu-Ogasawara islands*)* too.

Faults in relation to granitic rocks

The ring-like arrangements of faults accompanied by shallow earthquakes are shown in relation to the distribution of the Mesozoic and Cenozoic granitic rocks and the Mesozoic and Paleogene intermediate and felsic effusive rocks in Honshu in **Fig. 4**. The faults seem to circumscribe the granitic rocks in northeast Honshu, and the parallel arrangement of faults with the granitic rocks in central and west Honshu are observed. The thick ring-like arrangement of granitic rocks is observed in central Honshu, which is nearly 200 km in width. The ring-like arrangement of granitic rocks is dual in west Honshu, which is about 300 km horizontally and about 150 km vertically. It seems to suggest the granitic rocks were derived from the depth of several tens to 200 km or so.

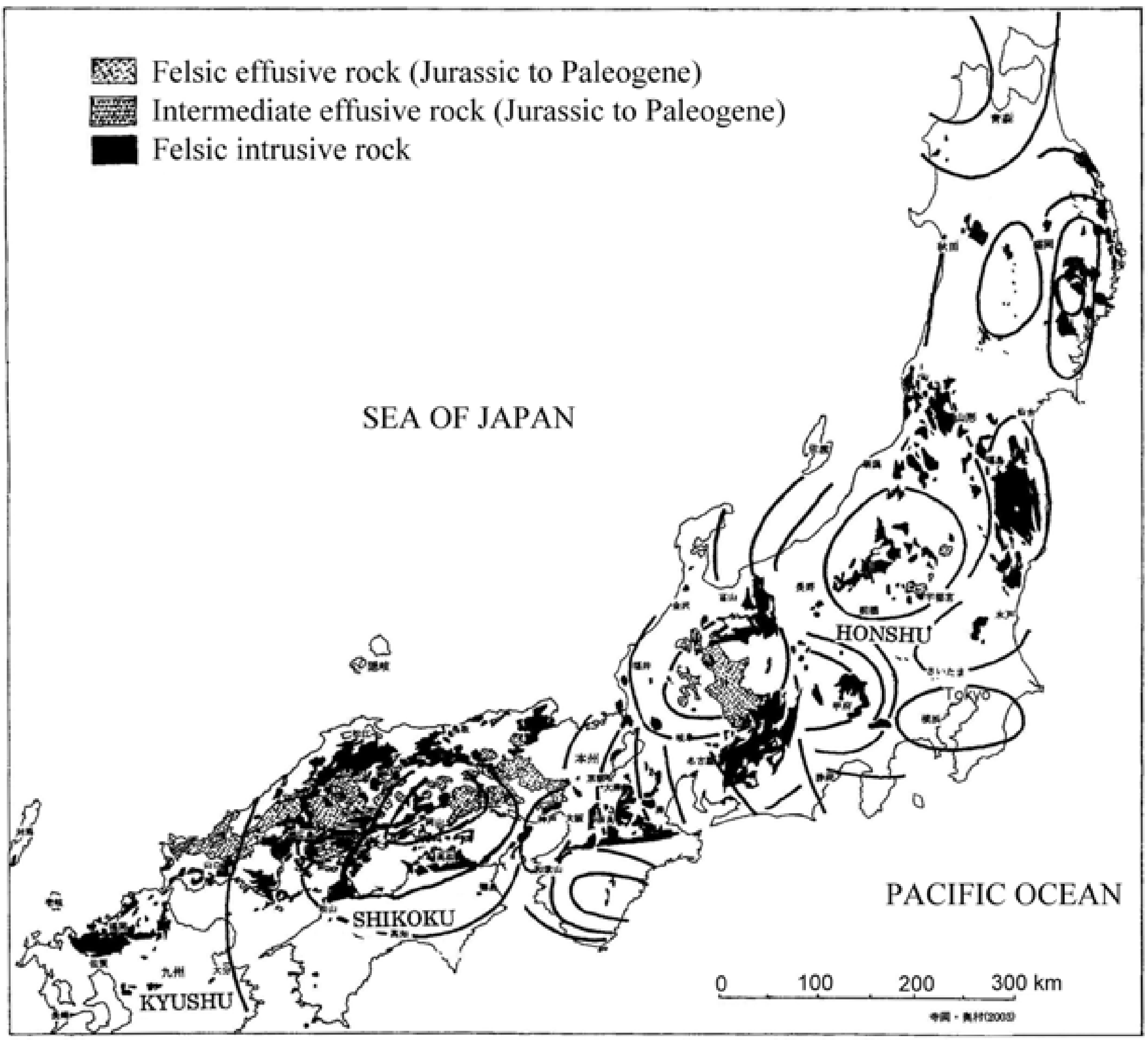

Figure 4. General trend of faults accompanied by shallow earthquakes in relation to the distribution of igneous rocks in Honshu and Shikoku.

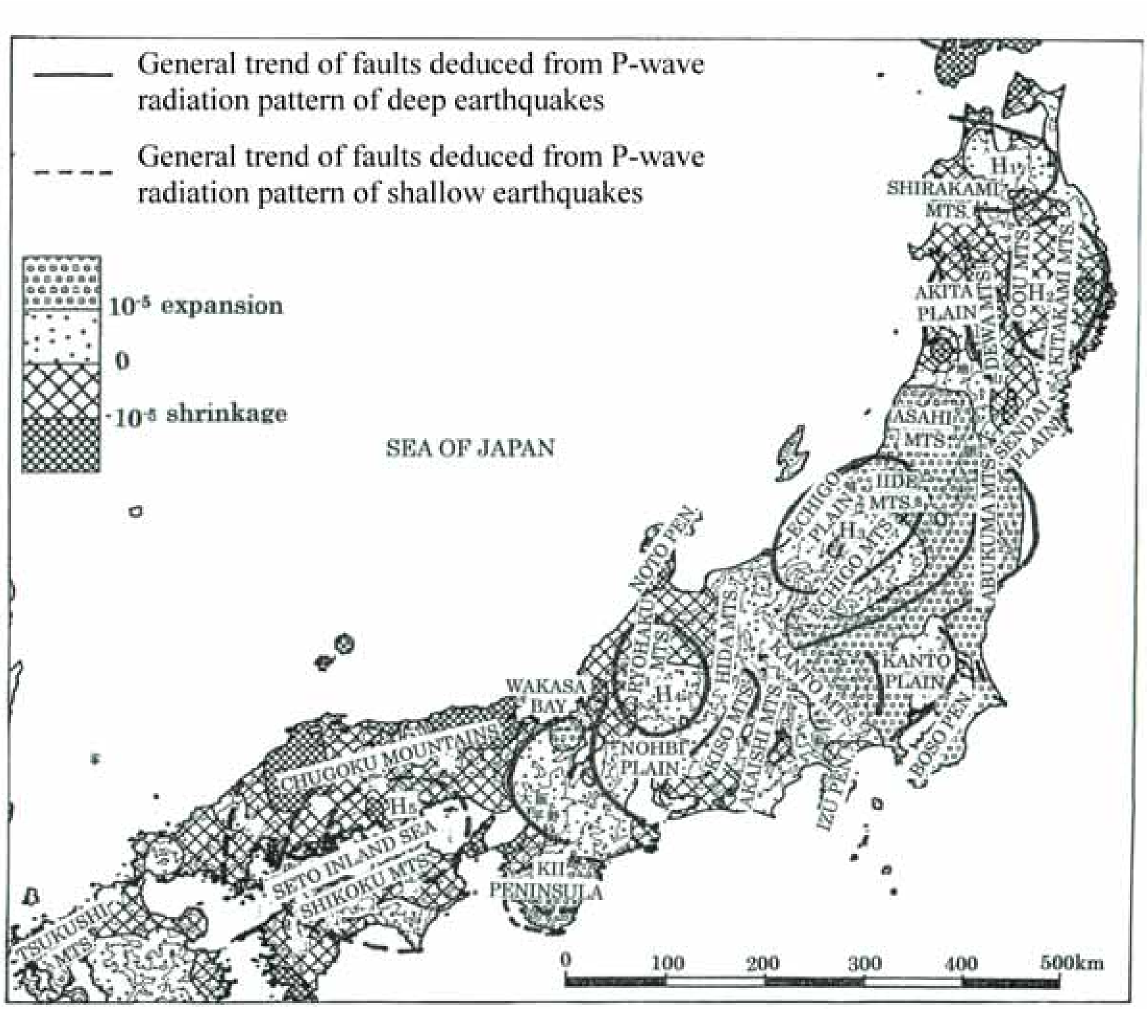

Figure 5. Distribution of divergence calculated from the displacement of 1st order triangulation stations in Honshu from roughly 1895 to 1958 in west Honshu in relation to the general trend of faults deduced from P-wave radiation pattern.

Pulsation

First order triangulation stations are set every 40 to 50 km on the Japanese islands and their displacements were measured about 1895, 1958 and 1979 or so by the Geospacial Information Authority (formerly the Geographical Survey Institute). Kobayashi (2006) analyzed the strain distribution based on the displacements of those stations.

The analysis showed that the area was divided into the expanding and shrinking areas, where most of two principal axes were expanded or shrank in general. But these movements were reversed in the next stage (**Figs. 5 and 6**). In the former period most of the Honshu Island expanded except for the northern and southwestern ends, but the movement was reversed except for the southwestern part of the Honshu. Thus the Honshu Island has been pulsating with each pulsating unit being 200 or 400 km in width.

The pulsation unit corresponds roughly to the circular unit defined by the faults accompanied by shallow and deep earthquakes. The boundary of expansion, contraction, and their orders are defined at each stage. The nature of movements is reversed at the next stage, but their boundaries have not changed much. Such movement seems to suggest the block structure of crust and mantle.

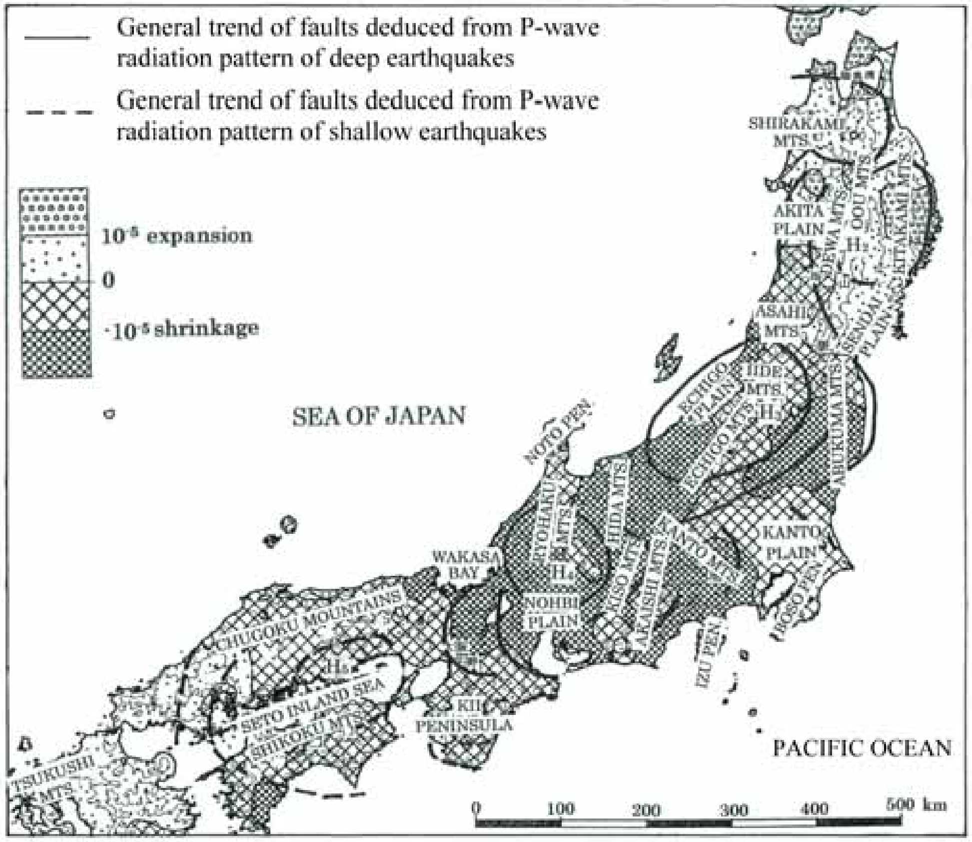

Figure 6. Distribution of divergence calculated from the displacement of the 1st order triangulation stations in Honshu from roughly 1958 to 1979 in relation to the general trend of faults deduced from P-wave radiation pattern of earthquakes.

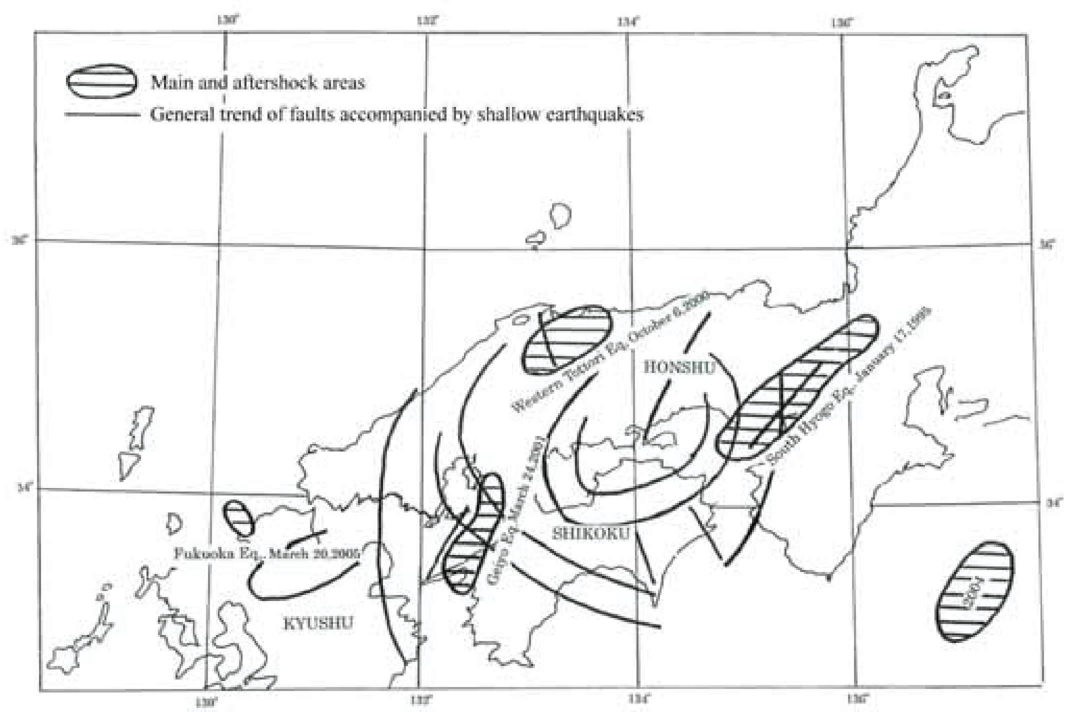

Figure 7. Successive occurrence of destructive earthquakes in west Honshu, Shikoku and Kyushu since 1995.

Recent seismicity

The Japanese islands have become seismically active since 1995, when the destructive earthquake occurred on January 17, 1995 in South Hyogo (M7.3) (**Fig. 7**). This was followed by the Tottori-ken-seibu earthquake (M7.3) in 2000, the Geiyo earthquake (M6.7) in 2001 and Fukuoka-ken-seiho-oki earthquake (M7.0) in 2005. Those earthquakes were situated in the area of ring-like arrangement of faults accompanied by shallow earthquakes.

Imamura (1947a) summarized the seismicity in Chugoku and Shikoku, and showed similar mode of occurrence of destructive earthquakes in recent years and historic times.

The occurrence of destructive earthquakes in the Japanese islands was shifted from Chugoku, Shikoku and Kyushu to northeast Honshu. The first one was the Chuetsu earthquake (M6.8) in 2004, followed by the earthquakes in northeast Honshu (**Fig. 8**).

Sanriku-Joban-oki earthquake (M9.0) was brought up in the front region of northeast Honshu, which was followed by the earthquake in the northern part of Nagano (M6.7, **Fig. 8**).

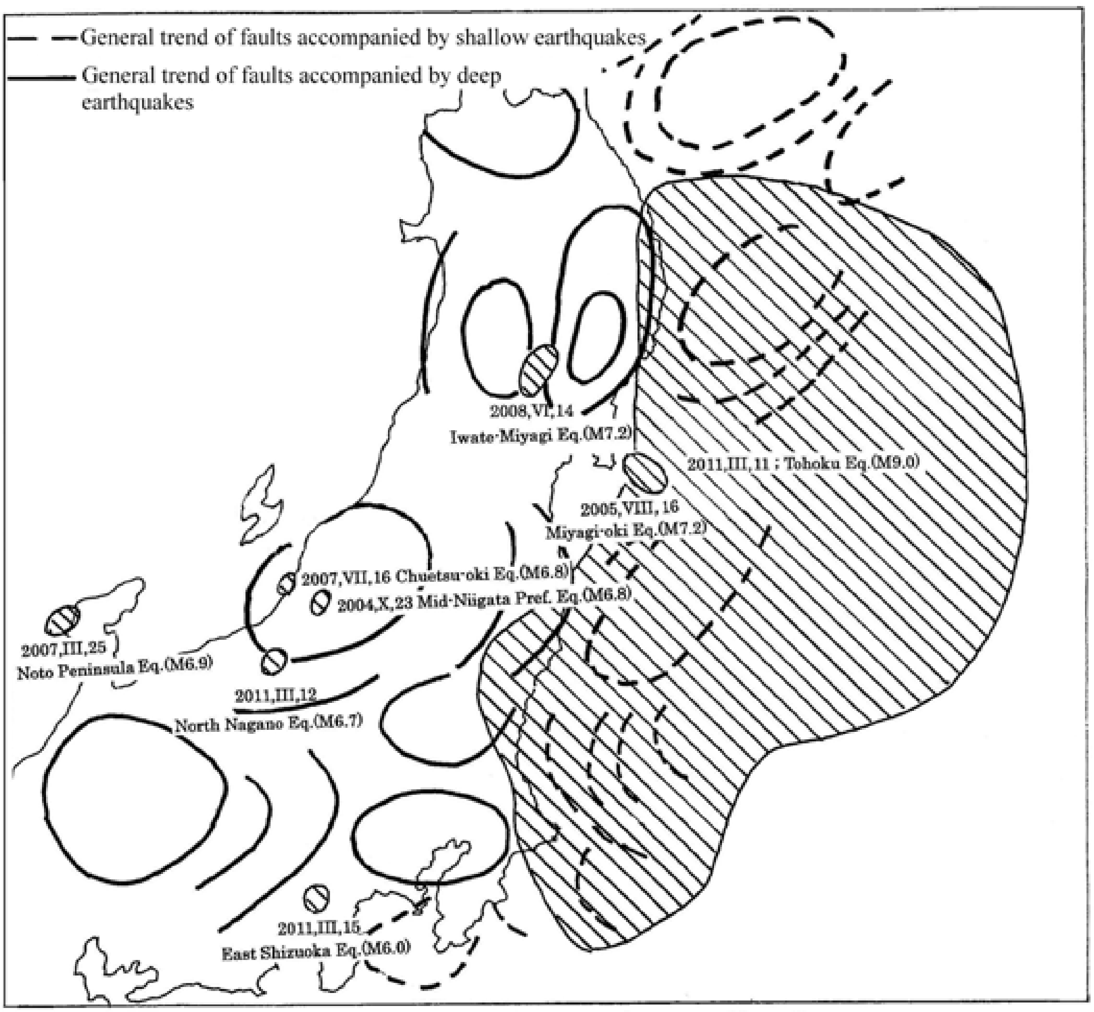

Figure 8. Distribution of recent destructive earthquakes occurred in northeast Honshu and surrounding areas in relation to general trend of faults accompanied by shallow and deep earthquakes.

Imamura (1947b) summarized the seismicity in northeast Honshu and pointed out the synchronous occurrence of destructive earthquakes on both sides of the Honshu. It might be due to the ring-like arrangement of faults accompanied by shallow and deep earthquakes.

Conclusions

The fault accompanied by earthquakes is determined from the initial motion of P-waves, when two nodal planes run parallel each other and the steeper nodal plane run parallel to the former one.

The general trends of faults are drawn for shallow and deep earthquakes in the Japanese islands and surrounding areas. They run parallel circularly with a 200 to 400 km width. Such arrangements seem to suggest the unit surrounded by circularly vertical deep faults

Each circular area of faults accompanied by earthquakes follows the boundary of expansion and contraction or the difference of order of contraction or expansion. It suggests the block structures of crust and mantle.

Each circular area or several circular ones has its own seismicity. It suggests each area is controlled by its own internal process of the Earth.

Each circular unit circumscribed by the faults accompanied by shallow and deep earthquakes expands and contracts.

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TECTONICS OF THE WEST MEDITERRANEAN AND CARPATHIAN ARCS SINCE THE LATE CRETACEOUS

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Abstract: The West Mediterranean and the Carpathians are both almost complete arcs, yet current tectonic interpretations are those of a one-sided eastward pull. This study argues that the accepted eastward slab retreat/pull model ignores synchronous thrusting to the west in both arcs, hence missing the crucial point of symmetry. The radial outside thrusting around both arcs apparently fits a mantle plume structure and this study suggests reconsideration of this tectonic agent as a viable explanation. Seismic tomography interpretation of slab directions at present and in past disprove the mechanical pull power of slab retreat. Features as uplift, subsidence, extensions, high heat flow and metamorphism inside the two arcs may indicate a mechanism of vertical magma circulation, whereas paleomagnetism, paleostress and volcanism interpretations show ambiguous results. The paper further claims that the two mantle plumes of Miocene age grew over relics of an utterly different Late Cretaceous, NE and NW tectonic pattern of collision between the European plate and Africa-Arabia, triggered by north indenting triangular Adria. The distinction between NE- and NW- directed structures may help discriminate Late Cretaceous from Miocene orogenesis around the western Mediterranean.

Keywords: *mantle plumes, west Mediterranean, Carpathian, Late Cretaceous, structural geology, seismic tomography*

1. Introduction

The recent tectonic structure of the western and central Mediterranean is currently explained as the complicated result of N-S convergence between the Africa-Adria-Arabia (AF-AD-AR) and European (EU) plates. Most directions of the resultant mountain belts south of the Alpine E-W front collision strike either NE-SW or NW-SE or are curved (**Fig. 1**), and a satisfactory explanation has not been forthcoming during the last 150 years of geological research. The directions are routinely explained by post Oligocene slab retreat (Alvarez et al., 1974; Malinverno and Ryan, 1986; Royden, 1993), locally followed by slab tear (Wortel and Spakman, 2000), which started after the demise of northward drift of the AF-AR plate (35-26 Ma ago; Jolivet and Faccenna, 2000). It was suggested that eastward slab retreat of the lower plate was driven by thrusting of the upper plate across the Western Mediterranean (WMED) (**Fig. 1**). Later, slab retreat shifted to the south, bending the central and southern Apennines and the Maghreb by east-southeast-southward thrusting. Similarly, eastward slab retreat in the Carpathians apparently shifted to the south, bending the east-southeast rim of the Carpathian Mountains. However, eastward slab retreat and rotation to the south can neither explain the Betics' western flank of the WMED nor the northwestern Slovakian and southwestern Slovenian flanks of the Carpathians. Both structures show westward thrusting.

Adria (Apulia) was an "adjunct" microplate north of the AF AR plate that supposedly drove Early-Late Cretaceous (ECT-LCT) thrusting (Channell, 1996). In the north, it was most affective in curving the western Alpine arc. Toward the east it curved the NW directed Dinarides-Hellenides. Western Adria's flanks (Apennines, Betics) are controversial in the role of LCT east or west slab and thrust directions (see two contrasting versions in **Fig. 2**). The problem lies in explaining the Middle Mediterranean Terrane (MT; **Fig. 3**) as thrusting westward on the Iberian Betic flank or eastward over Calabria. I would argue that NE was the trend of LCT structures, both in the Betics and the Apennines, but the Miocene orogen was curved. Thus, two different tectonic regimes drove the LCT and Miocene orogens. Invoking Miocene eastward and westward slab retreat to explain the curved WMED (Lonergan and White, 1997) is not adequate.

Some earlier studies interpreted the tectonic origin of west central Tethys (central and southern Europe and the northern Maghreb) using a mantle plume (MP) model (e.g. Stegena et al., 1975; Weijermars, 1991; Wezel, 2005). This was later replaced by horizontal motion through slab retreat in many numerical and laboratory models (e.g. Göğüş et al., 2011). More recently consideration of the composition and strength of the lithosphere and upper mantle combined with vertical magma circulation and horizontal far field stress Burov and Cloetingh, 2010; Faccenna et al., 2010).

A mantle plume is just one of three models explaining the origin of the Ligurian, Provençal and Tyrrhennian basins (Lustrino et al., 2009). Other models are lateral extrusion of a crustal wedge (Mantovani et al., 2009) and variants of slab pull (Royden, 1993), eastward mantle drag (Doglioni et al., 2007).

This study compares slab retreat with plume-driven slab advance models. Comparison of LCT and Miocene tectonic patterns helps distinguish between these and suggests two curved WMED and Carpathian plumes drove Miocene orogenesis around central Tethys (western Tethys is the extension toward the Caribbean). Late Cretaceous NE-SW structures are not discussed and are still considered enigmatic.

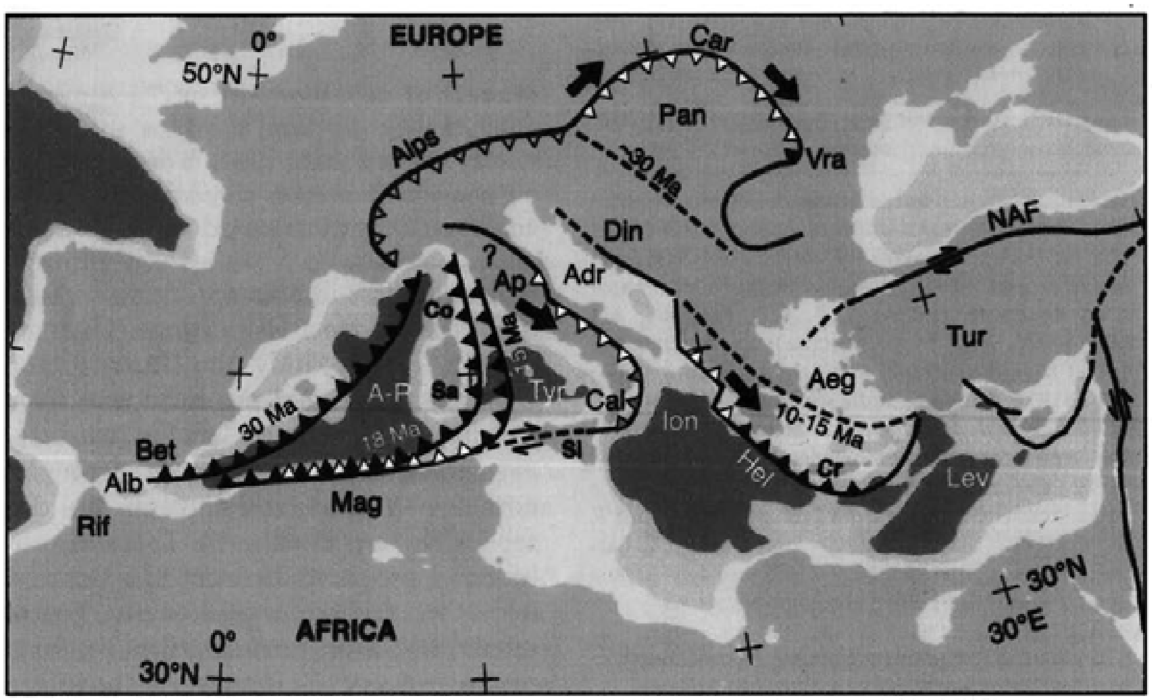

Fig 1. Migration of subduction zones in the Alpine-Mediterranean-Carpathian region and evolution of plate boundaries during Tertiary-Quaternary times (after Wortel and Spakman, 2000). Adr-Adria. Aeg-Aegean. A-P - Alboran-Provence. Ap-Apennines. Bet-Betics. Cal-Calabria. Car-Carpathians. Co-Corsica. Cr-Crete. Din-Dinarides. Hel-Hellenides. Ion-Ionian. Lev-Levant. Mag-Maghreb. NAF- North Anatolian Fault. Pan-Pannonian. Sa-Sardinia. Si-Sicily. Tur-Turkey. Tyr-Tyrrhenian. Vra-Vrancea.

2. Geological background

Complications in studying tectonics of the west-central Tethys stem from superposition of three orogens: Variscan-Hercynian (Carbonifereous-Triassic), Eo-Alpine (ECT-LCT) and Late Alpine (Miocene).

Structures of the Hercynian orogen are partly parallel to the LCT NE directions in central Europe and the Maghreb in north Africa (Corsini and Rolland, 2009; **Fig. 4**). Reconstruction of the Early Carboniferous (340 Ma) suggests a wide Paleotethys ocean between Gondwana and Euroasia. Stampfli and Borel (2004) suggested one long and narrow land "ribbon" (Hun superterrane) between Gondwana and Avalonia-Laurentia during Early Paleozoic and another ribbon (Cimmerian terrane) during its Late

Paleozoic north-drifting journey. These are supposed to have moved northward, narrowing the distance between the two major plates and driving south European Paleozoic metamorphism.

Triassic-ECT rifting of central Tethys occurred during southeastward drift of Africa (Handy et al., 2010). From ECT-LCT time (84 Ma - Dewey et al., 1989), Africa and Arabia started their journey to the north, closing a gap of some 2000-3000 km (e.g. Dewey et al., 1989; Dercourt et al., 2000). Piromallo et al. (2008) posed the question: How could the LCT orogen act through that wide gap? Adria is the consensual answer, illustrated as a north –directed triangle indenting the Alpine E-W striking, emerging mountain belt from the Early Mesozoic. The NW and NE flanks of Adria, very different in detail (Schmid et al., 2008; Schettino and Turco, 2011; **Fig. 2**), confront the Penninic-Ligurian-Piemonte Ocean in the west and the Vardar-Pindos-SBA Ocean in the east.

Miocene deformation partly overlaps LCT directions (Betics, Dinarides-Hellenides) but differs from it by curving the southeastern flank of the WMED and beginning to curve the Carpathian arc (30 Ma: **Fig. 1**). Two other developments were curvature of the western Alps and slab retreat of the Cyclades, both as the result of west-southwestwards extrusion.

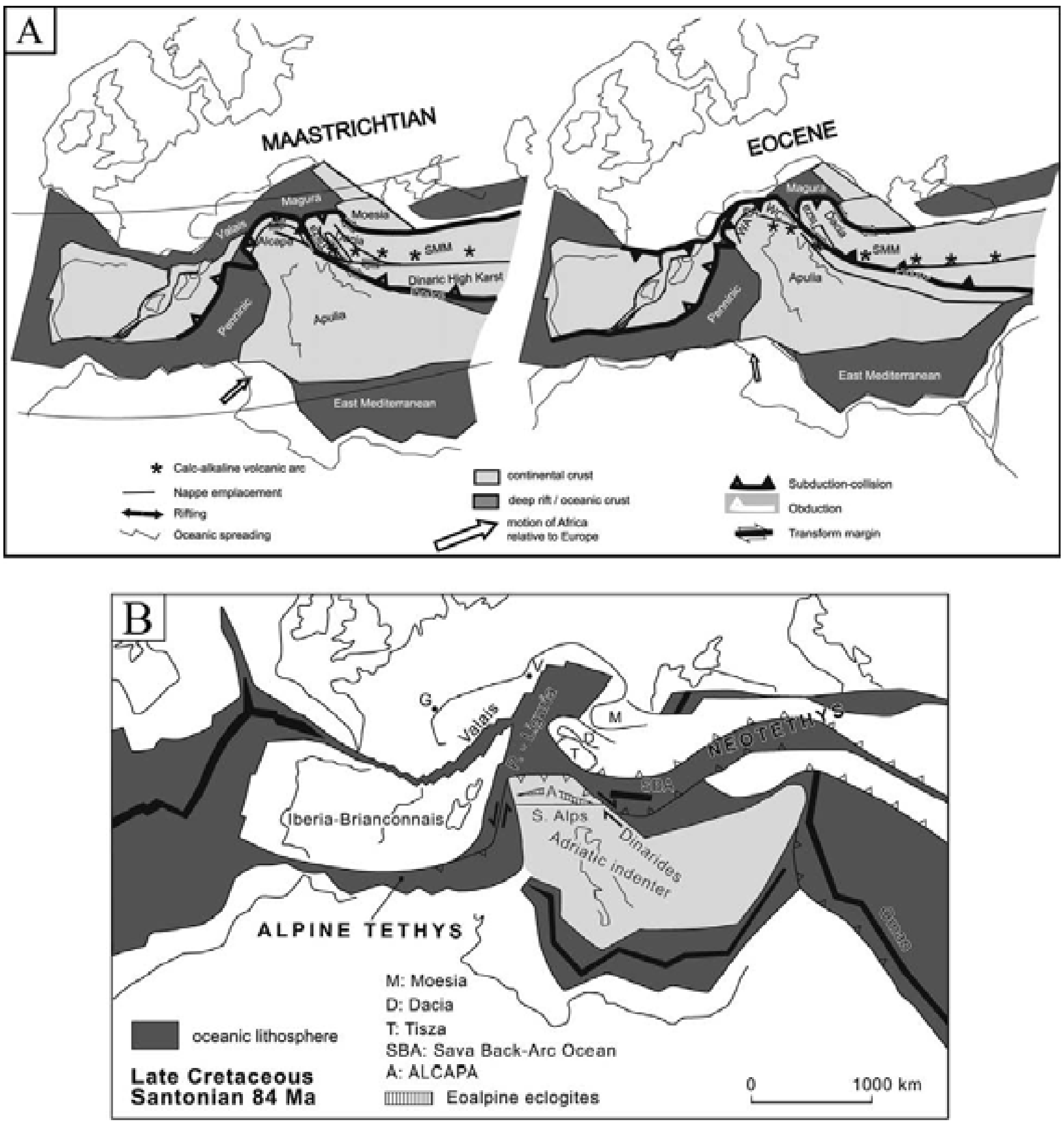

Fig 2. LCT layout of the western Mediterranean after Csontos and Vörös, (2004) (A) and Schmid et al. (2008) (B). SMM-Serbo Macedonian. WA-West Alpine. EA-East Alpine. WC-West Carpathians.

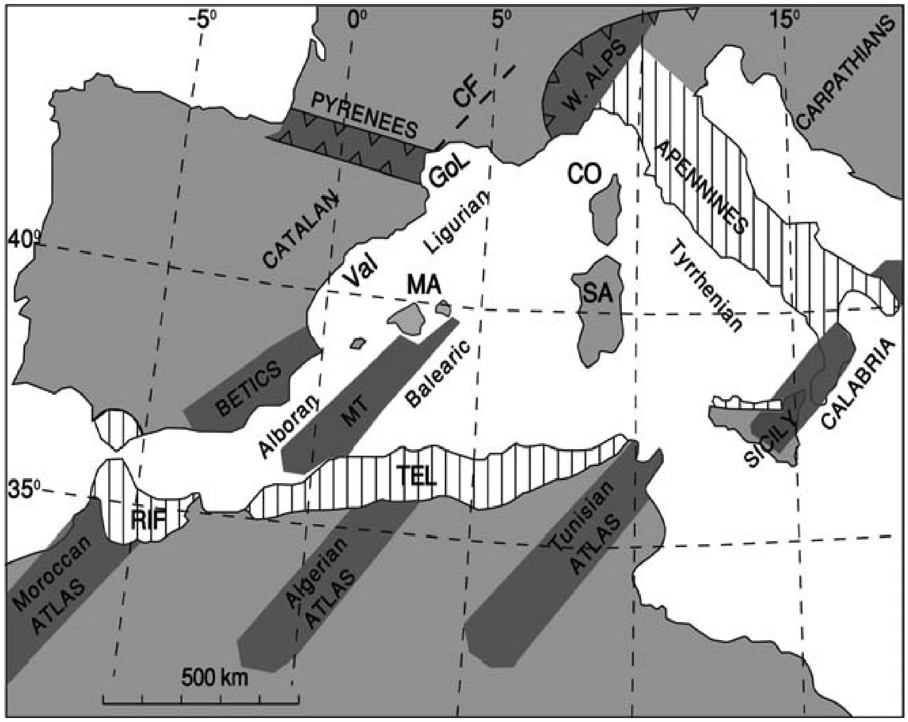

Fig 3. NE-SW structural trends in the WMED. CF-Cevenes Fault. Co-Corsica. GoL-Gulf of Lion. MA-Majorca. MT-Mediterranean (Middle) Terrane. SA-Sardinia. Val-Valencia.

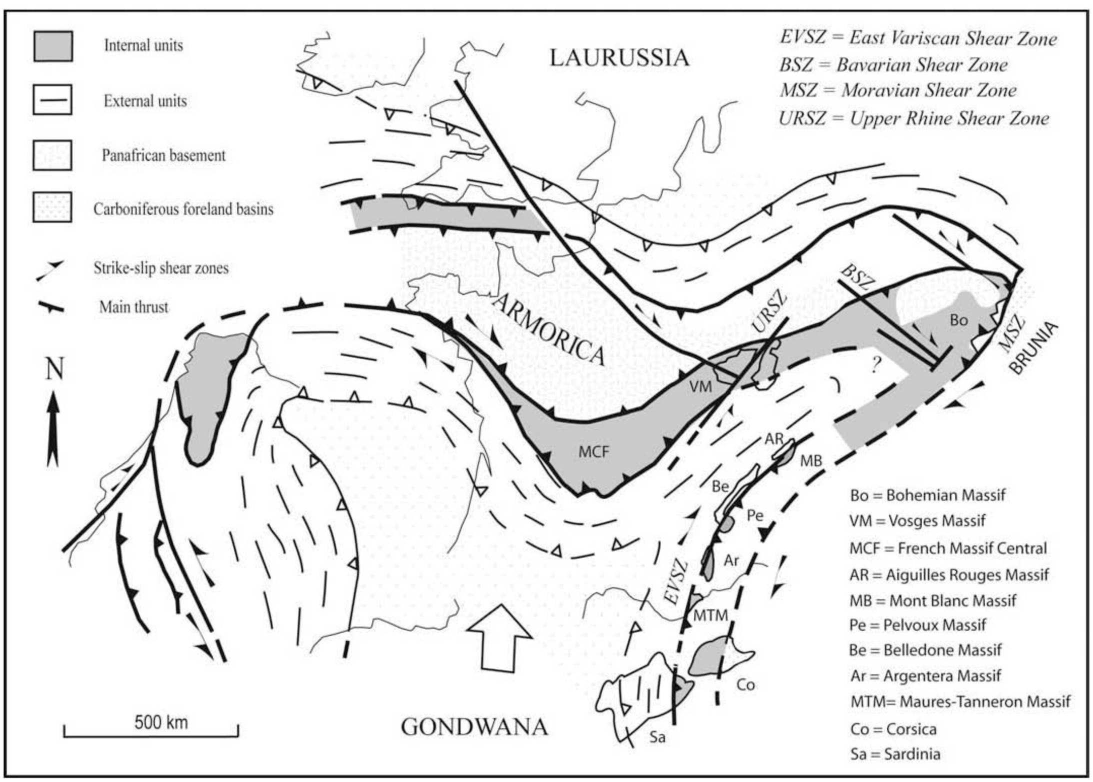

Fig 4. Structural sketch map of the Southern European Variscan belt after Corsini and Rolland (2009).

3. Radial outward thrusting and slab directions

Radial outward thrusts are typical in both WMED and Carpathian arcs. This section details their regional occurrences, contemporaneous inner extension, uplift, collapse, and metamorphism.

Seismic tomography records inward slab inclinations between 20 and 200 km. Deeper, the slabs become almost vertical. The current tectonic paradigm interprets outward thrusting as a result of convergence between different upper plates. As slabs respond to drift of plates on a scale of millions of years (Garfunkel et al., 1986), projections to past drift directions are subjective and rely on the eye of the interpreter. Here, I attempt to report all models, including contradicting opinions.

3.1) The Apennines

The present structure of the Apennines is arcuate, open to the west, from NW Italy to SW Sicily (**Fig. 1**). All thrusts are directed outward, parallel to topography. Eastern "Adriatic" compression and western "Tyrrhenian" extension characterize the length of Italy (Pauselli et al., 2010). Shallow seismic tomography (100-200 km) shows westward slab inclinations. Down through the upper mantle to 660 km depth (MTZ-mantle transition zone) the slab appears almost vertical (Chiarabba et al. 2009) but there is debate as to whether it is continuous (Lucenta and Margheriti, 2008) or torn apart (Wortel et al., 2009). There is no doubt that a relatively cold body overlies the MTZ (Chang et al., 2010; see **4.3.6**).

Development of the slab through time is also debated. Some describe a continuous westward (Adriatic) slab since LCT times (Jolivet et al., 2008). Others claim an eastward (Alpine) slab direction to explain LCT metamorphism in the northern and southern Apennines, followed by Eocene or Miocene flip to the west (Molli, 2008). Yet another version shows a clear, recent eastward slab direction down to the upper mantle (Finetti, 2006).

The current model for the WMED locates the start of eastward slab retreat along the eastern coast of Iberia and SE France, behind terranes such as the Rif, Grand Kabylia, Petit Kabylia, Galite block, Corsica, Sardinia and Calabria-Peloritan (**Fig. 5**). During retreat, the terranes jumped over the slab trench (see **4.4**) to remain as islands or accrete the coasts of southern Italy and the Maghreb (Thomas et al., 2010). The Apennine west-directed slab is seen to become younger from north to south, beginning at ca. 28 Ma at the Tertiary Piemont Basin (TPB) to 4 Ma off Sicily (Mazzoli and Helman, 1994). However, this does not account for late Oligocene-early Miocene seismic horizon B3.3, offshore Sicily, which rests directly on basement (Sartori et al., 2004). The difference between the age of sediments and the age of thrusting casts doubt on the contention that the slab becomes younger to the south.

3.1.1 Western Alps - Northern Apennines

The Alps are one of the most geologically-complicated regions on Earth. Almost 150 years study have led to understanding in the context of the modern Plate Tectonics (PT) (Laubscher, 2010). The curved, east-facing west Alpine arc contradicts the concept of European-Adria N-S collision. Instead, the accepted solution concentrates on Miocene westward extrusion and counter clockwise (CCW) rotation of an Alpine median wedge (Sue et al., 2010). However, all three slabs that possibly acted around the arc, - the west Alpine slab dipping SE, the Adriatic slab dipping NW and the Apennines dipping SW - are not easily interpreted. West Alpine subduction to the SE (Jura-LCT-Eocene times) was followed by Apenninic NE slab retreat, Oligocene-Miocene eastward migration of extensional shear and finally SE retreat (**Fig. 1**).

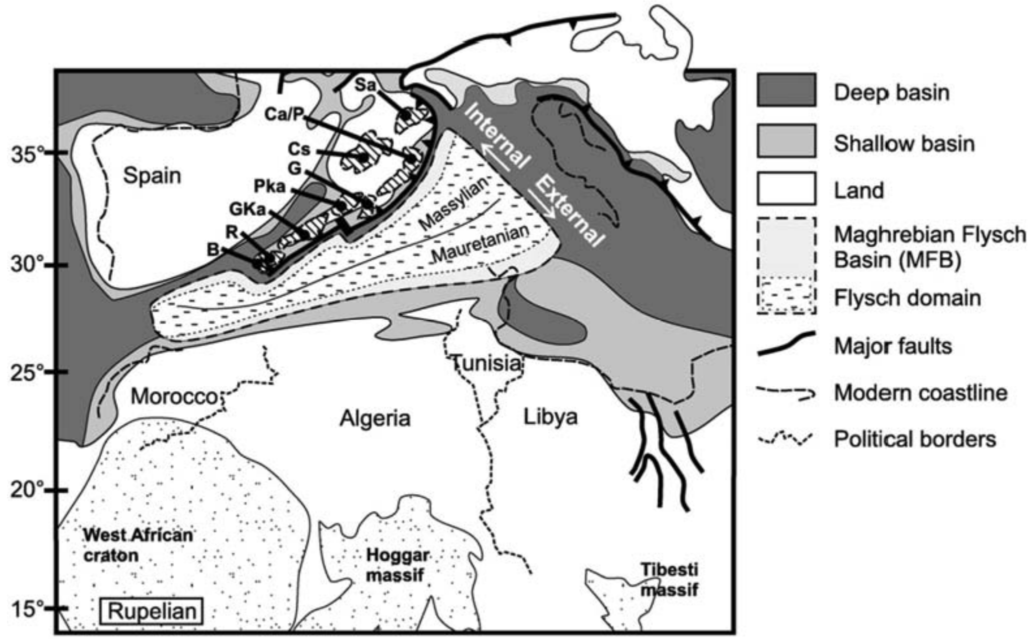

Fig 5. Oligocene paleogeographic map of the WMED highlighting the location of some flysch basins, after Thomas et al., (2010). *B-Betic, R-Rif, GKa-Grand Kabylie, Pka-Petit Kabylie, G-Galite block, Cs-Corsica, Ca/P-Cal*abria *and Peloritan*, *Sa-Sardinia.*

Maffione et al. (2008) illustrated three steps of switching around the Alpine and Apennine slabs in a "helicoidal shape" since the Oligocene. Retreat of both Alpine and Apennine slabs enabled final extension of the central Alpine arc following metamorphism. A few crystalline and metamorphic core complexes (MCC) massifs are indicated within external and internal zones along the arc. One of these, the Voltri massif, is the subject of recent debate between deformation by extension or compression (Capponi et al., 2009). All solutions invoke Apennine NE to SE outward thrusts. The relevance of this in later discussion is whether by slab pull or push.

3.1.2 Central Apennines

Large parts of Mesozoic oceanic lithosphere were thrust eastward and subducted westward during the Eo-Alpine orogenic phase. External Ligurides (EL) are the eastern foreland fold and thrust belt, partly low-grade metamorphosed (Tuscan unit) or unmetamorphosed Sicilide and Liguride units. Internal Ligurides (IL) are the western sedimentary and ophiolite suites of thin-skin imbricate structures (Moli, 2008; Marroni et al., 2010 [north]; Bonardi et al., 2009 [south]). Thrusting migrated eastward and extension is indicated by slight metamorphism effecting western sectors since the late Miocene (Brogi, 2008). This study interprets the phase of outward thrusting and inner extension to result from MP activity.

The northernmost sector of the Apennines restores a slab with northeastward inclination. It corresponds to Alpine southeastward inclination in a complicated manner of opposite directions (Maffione et al., 2008). A low velocity (Vp) anomaly from the surface down to about 200 km under the Po Plain is interpreted to result from hydration and delamination, as further discussed in the broader context of the Alpine and Adria collision (see **4.3.6**).

3.1.3 Calabria-Peloritani Arc (CaP)

The CaP (CAL in **Fig. 1**) is located at the southern tip of the Apennines and continues with tight curvature to the E-W northern Maghreb thrust front. It is a complicated structure with various thrust directions, metamorphism and kinds of volcanism. Some points of discussion follow.
1) In contrast to all reports on NW inclination of the CaP slab, Schellart (2010, fig 1d) and Faccenna et al., (2010, figs 4 and 7a) show the slab as almost vertical down to 660 km.

2) A change in tectonic transport from NE in LCT Eo-Alpine times to SE in Miocene times (Heymes et al., 2010). Others interpret these directions acting simultaneously.
3) The CaP was a separate microplate moving to the SE via E-W or NW-SE directed strike slip faults according to Cavazza and Barone, 2010 (Sangineto and Taormina sutures). This solution was contested by others.
4) The width of the slab is only some 200 km. Shortening, underplating and retreat are estimated by Minelli and Faccenna (2010) to amount to 380 km. However, their attached cross sections do not support these high figures.
5) Calc-alkaline (orogenic) and alkaline (anorogenic) volcanism are spatially very close in the southern Apennines and the CaP. Some of the latest solutions concentrate on roll-back, toroidal circulation and decompression melting of the upper mantle around the Ionian NW directed slab (Schellart, 2010; Faccenna et al., 2010). However, proximity of the two retreating slabs prompts caution.
6) Coexisting tectonic compression and extension is the latest suggestion by Cuffaro et al. (2011) in response to shortening due to NNW motion of Africa relative to Eurasia and E-W back-arc spreading of the hanging wall of the Apennines. The three slabs, African, Adriatic-Apennines and the Ionian, are responsible for complications when approaching each other around the CaP.

3.2) E-W Maghreb front

All along the Maghrebian, 2000 km long coast of North Africa, the slab dips to the north and external flysch material thrusts to the south, building a 200 km wide strip (Sami et al., 2010). Turbidite material is almost identical in age and composition at both ends (Puglisi, 2008), indicating a simultaneous orogenisis since late Oligocene-middle Miocene (Thomas et al., 2010). This south directed thrusting was lately revised by adding a new Quaternary offshore north verging reverse fault, heralding a new style of subduction (Yelles et al., 2009).

3.3) Betics – Ligure - Provençe

3.3.1 Gibraltar Arc

Researchers do not agree on the direction of slab dip in the Betic part of the Gibraltar arc. Some claim it dips eastward. Others suggest it dips NE, SE or NW. Platt (2007) suggested a gravitational sink and vertical shortening of the thickened crust, creating a bulb of cold material under the Alboran Sea. Lithospheric delamination and convective removal are other processes suggested to cause thinning of the lithosphere.

Models are further complicated by recent geophysical findings. SKS splitting measurements show that the fast polarization direction curves around the arc but diverts to the south under northern Morocco (Diaz et al., 2010). A stress map based on microtectonics indicates that most slab retreat has already stopped, except for a narrow section directed N20º-30ºE (Pedrera et al., 2011). A new NNE-SSW fault zone is developing at the Atlantic-Mediterranean transition zone west of the Alboran arc (Fullea et al., 2011). Rosell et al. (2011) interpreted magnetotelluric data to indicate Ligurian eastward slab break-off and fill by hot asthenospheric intrusion to explain an area of low velocities without earthquake hypocenters.

3.3.2 The Betics

The structure of the Betics mirrors that of the Apennines, with westward outward thrusting and a shallow slab inclined to the east. Down to 150 - 600 km seismic records are difficult to interpret. According to Buforn et al. (2004) intermediate depth earthquakes in the Alboran Sea display vertical records with the main plane trending E-W. Solutions of very deep shocks correspond to vertical dip slip along N-S trends. Here, as in the Apennines, there is no agreement as to whether the slab is continuous (Valera et al., 2008) or detached. Lonergan and White (1997) suggested Miocene split of the west-directed Apenninic slab to one segment retreating to the east and southern segment retreating to the west. Michard et al. (2006) and Martín-Algarra et al. (2009) presented evidence of Hercynian eastward thrusting in contrast to Alpine westward thrusting and that a flip from east to west slab dip occurred 50 to 30 Ma ago. The MT terrane (ALKAPECA) under the Alboran Sea was the original location of internal, on-shore metamorphosed rocks after long distance westward thrusting. Two opposite versions for slab direction under the MT are illustrated by Puga et al., (2011), showing a continuous eastward direction vs the opposite NW slab direction (Schettino and Turco, 2011).

3.3.3 Ligurian-Provençal Basin (LPB)

The Betics and Catalan structures are part of the NW flank of the WMED. Further to the NE the margins of the LPB apparently preserve the former location of Corsica-Sardinia (CoSa) islands (**Fig. 1**) that drifted apart. Some features on the CoSa islands are parallel to Betics-Catalan NE tectonic directions (Oudet et al., 2010). Sedimentation in the intervening LPB started in the Oligocene-early Miocene. Continental Provençe was under the influence of three structural directions: E-W in the Pyrenees and the Southern Alps (Le Pichon et al., 2010), NE-SW in the LPB (Andreani et al., 2010) and NW-SE structures in the TPB. An attempt to relate structures to one of the three typical directions and estimation of the timing of deformation are debated. Bache et al. (2010) suggested a new interpretation of a narrow instead of wide rift along a NE-SW fault inside the Gulf of Lion.

3.4) The Carpathian Arc

In contrast to the oceanic cover of the central WMED, the center of the Carpathian arc is continental and much more accessible for geological research. The arc is built of almost radial outward thrusts. Shallow seismic activity shows inward inclinations (Alasonati-Tašárová et al., 2009). Deep tomography images are interpreted to show almost vertical dips (Sperner et al., 2004). Since the early 1970's, Carpathian geologists shifted their understanding from a geosyncline and mantle plume diapir (Stegena et al., 1975 and earlier Hungarian studies) toward the plate tectonic model. This better explained changes in sedimentary facies of deposition, block rotations, strike-slip and nappe thrusting. This involves four tectonic processes:

1) North indentation and CCW rotation of Adria (Channell, 1996).
2) CCW rotation of Alcapa and clockwise (CW) rotation of Tisza-Dacia blocks (Csontos and Voros, 2004: note opposite directions of Tisza-Dacia in **Fig. 2**).
3) Eastward slab retreat (roll back) and CW rotation of the main stress and thrust direction (Jirićek, 1979).
4) CW rotation of Moesia followed by a "corner effect" and "wrapping" of the south Carpathians (Ratschbacher et al., 1993).
The problem with these four processes is that they overlap in space and time and are even contradictory.

Csontos and Vörös (2004) suggested five steps to bend the two major (NW and SE) oroclines into one complete arc: Triassic-Jurassic rifting, Mid Cretaceous nappe emplacement, LCT oroclinal bending (shearing, thrusting and normal faulting), Palaeogene strike slip and rotation to amalgamate the two composite terranes and Middle Miocene large-scale internal back-arc extension.

The following mechanisms explain how curving a single arc is complicated by horizontal translations in the frame of two separate, LCT and Miocene, orogens. Five reservations are:

1) The basement of the west Carpathians apparently is in-situ and not extruded. Extrusion as suggested by Oszczypko and Slaczka (1985) apparently meant the flysch and molasse accumulated in retreating basins due to "migration of a compression wave." They did not mean retreat of the whole crust.
2) Counter block rotations of Alcapa and Tisza cannot produce continuous concentric rims like those resulting from radial outward thrusting.
3) The strike slip, "corner effect" and "wrapping" between Danubia (SW Romania) and Moesia could not be produced by the almost non rotating Moesia block (13°; van Hinsbergen et al., 2008; see also positioning of Moesia in Golonka et al., 2009).
4) The LCT starting position of Alcapa, Tisza and Dacia blocks is controversial: either along the NE directed margins of the Ligurian-Piemonte basin (Schmid et al., 2008; **Fig. 2b**) or along the NW directed margins of Adria (Csontos and Vörös, 2004; **Fig 2a**). In each case, rotations are different.
5) Oblique collision and out-of-sequence tectonics (e.g. Matenco et al., 2010) are interesting solutions, but are here regarded as a last option.

These five reservations form the basis for discussion of extrusion, slab retreat and block rotation as tectonic mechanisms causing curvature of the Carpathian Arc.

The direction of slab inclination deserves more attention. Grad et al. (2006) argued for NE outward inclination of the lithosphere along a NE section from the Pannonian Basin to the East European Craton. Others accepted this concept down to 200 km depth but then argued for slab detachment. Janik et al. (2011) repeated the common concept of inward SE and SW inclinations on sections across the NW and NE Carpathians, respectively, but all are seen to discontinue under the Moho, so the controversy is unresolved.

A shallow crust (~20 km) typifies the Pannonian basin and the contact with the Adriatic plate is sharp. Śumanovac (2010) seismically interpreted a wider strip and showed a shallow (~50 km) high-density body and sharp fall in gravity above the Southern Margin Fault (SMF) of the Pannonian basin. This comprises East Dinarides and West Pannonian thrusts, explained either by east-directed Dinaric or west-directed Pannonian slab activity.

4. Discussion

The summary of section 3 is that slabs down to 200-600 km are mostly imaged as vertical, apart from the SE and SW segments of the WMED and SE Carpathian Arc (Vrancea: Neagoa et al., 2010). However, past inclination of slabs and even the direction of plate motions are a matter of interpretation. The following details two possible tectonic mechanisms that could curve the two arcs, namely extrusion and horizontal translation or vertical outward magma circulation. The latter compares contrasting styles of LCT and Miocene orogens around the central Tethys.

4.1) Slab Retreat is a long discussed issue. Although many laboratory experiments confirm it on a box scale, it is still not clear how it works in the real world. What drives a slab to retreat further then its own length after it reaches the top of the lower mantle at 660 km depth (1200-1400 km of the Apennines in Faccenna et al., 2004)? How can the Tyrrhenian slab double itself in width after the split of the Betic-Alboran slab to the west (Lonergan and White, 1997) but still produce the CaP and the Maghreb? Why did both slabs, WMED and Carpathian, curve to the south?

Curvature and oroclinal bending are always illustrated as hanging on their two tips, with counter block rotations (Yonkee and Weil, 2010). Here, the slabs themselves curve and this is quite another story (see details of subduction vs delamination in Göğüş et al., 2011). There is no published attempt to reproduce that kind of retreat in the laboratory or retreat simultaneously in opposite directions and on top of it a kind of horizontal rotation.

Artyushkov et al. (1996) did not accept slab retreat as the cause of lithosphere deflection, but preferred density changes in the crust and mantle ("vertical crustal movement"). Doglioni et al. (2007) are old opponents of slab retreat. They raised 22 arguments against it and instead suggested mantle drag on Earth rotation. Some of the arguments question the relation of slab dip to the age of the oceanic plate, the real composition of the upper mantle, buoyancy of continental and oceanic slabs, depth of eclogitization and the cause of lithospheric subduction. Alvarez (2010) suggested "basal traction" or "continental undertow" down to the asthenosphere to explain protracted continental collision along Tethys and elsewhere.

Three additional reservations concerning slab retreat follow.
1) Jolivet et al. (2008), in their Apennine slab retreat model rely on displacement trajectories of Africa and Apulia with respect to stable Eurasia as drawn by Dewey et al. (1989) and many others. However, the “swerve” to NW convergence in the last 9 Ma cannot and did not intend to explain the Betic Mountains since the LCT (Viti et al., 2010). On the other hand, obliquity of transport and shear direction across the Betics and Gibraltar is not mentioned (Platt et al., 1989).
2) Eastward slab retreat of the Apennines and rotation to the south is substantiated by extensional thrusting and evidence that synrift sediments become younger to the SE. However, older synrift sediments (Jolivet and Faccenna, 2000) and older extensional faulting are reported as well.
3) The eastward slab retreat and southward rotation model of the Carpathians was further refined to passive rifting followed by active rifting (Huismans et al., 2001). However, the ENE-WSW direction of

the Pannonian Basin and N-S direction of the Transylvanian Basin (Sanders et al., 2002) do not match the reported first rifting shear and slab directions. Furthermore, Dombrádi et al., (2010) analyzed the last Pliocene-Recent inversion from extension to compression by laboratory, numeric and analogue modeling and showed a large-scale (300-400 km) wavelength folds. These folds (Styrian, Transdanubian, Great Hungarian Plain, Apuseni and Transylvanian) were inherited from earlier orogenic phases and this should have been expressed in those analyses. Note that the folds strike NE and not SE as may be deduced from the presented cross sections.

4.2) Rifting related to asthenospheric uprise was considered to precede MP activity (passive rifts/active rifts: Bada and Horváth, 2001). Rifts were supposed to open the crust by far field extension. The role of MPs was to later impinge upon, heat and weaken the lithosphere and supply volcanic material (Cloetingh and Ziegler, 2007). It was the first stage model for the Carpathians as suggested by Huismans et al., (2001) as well as the model for the Ligurian-Provençal Basin. However, an MP may start without any preliminary rifting. Uyeda et al. (2008) discuss several analogue and numerical modeling attempts to explain oceanic and continental subduction. They found that retreat is numerically possible but wondered how to explain horizontal wide slabs with round plume heads. "Baby plumes" were explored by Burov and Cloetingh (2010). They concentrated on linear vs radial symmetry, the proximity to the Africa-Europe plate boundary, the thermo-mechanical age of the lithosphere and other parameters to help them distinguish rifting, folding and MP activity (elongated vs round). Hence, mantle plumes may act independently from preconditioned rifts (Huismans and Beaumont, 2011). The tectonic history of the rifts plays, of course, a crucial role in the process (Armitage et al., 2010).

4.3) Mantle Plumes are here suggested as the driver of Cenozoic tectonics in the WMED and Carpathian arcs. There is a "general consensus on the first order kinematic evolution of the WMED" (Wortel et al., 2009) and the Carpathians. Nevertheless, few geoscientists believe in MP dynamics in the WMED (Bell et al., 2006; Lavecchia and Creati, 2006; Shahar, 2000) and in general (Puchkov, 2009). This great debate is discussed at length by Foulger (2010). Outside radial thrusts, inside lithosphere thinning and hotter temperatures and some MCC occurrences inside the WMED and Carpathian arcs have been widely explored in the last two decades and here are taken to support tectonic vertical circulation. The shape of an MP in the upper mantle, including its possible vertical walls may be found in Kogiso (2007). The following paragraphs consider further details.

4.3.1. The Carpathians. Eastward slab retreat could not work on a rift that runs in the same ENE-WSW direction. The Alcapa and Tisza-Dacia counter rotated blocks cannot explain the round outer rim of the Carpathians. The SW Carpathians (Hrvatsko-Zagorje zones) were suggested to have rotated CW 130º during the Paleogene-Oligocene and to back CCW 35º after the Miocene (Tomljenović et al., 2008). The configuration of the rotated block is apparently vague (Źumberak vs Medvednica blocks). It is here suggested that regional remagnetization of all LCT - Oligocene PM data occurred, similar to northern Spain (Osete et al., 2011 and references therein), since arguments there are quite similar (see also **4.5**). The contact between the west Carpathians and the NW Dinarides is not clear. Only a few kilometres of the proposed 300-600 km strike-slip are known (Placer et al., 2010; see also **4.7**). South of this strip complicated Dinaride tectonism prevailed (Robertson, 2011), with clear convergence of two plates: Apulia from the west and SMM, Rhodope and Eurasia from the northeast.

4.3.2. NW WMED. The area from Provençe to the TPB is a junction of three different slabs and three structural directions (**3.1.1**). Are there any indications of the CoSa rifting advancing along a strike to the NE or SW? Sage et al. (2011) examined onshore and offshore NW-SE seismic sections and concluded that rift-related extension tectonics lasted until the late Miocene, followed by south Alpine N-S compression and uplift. Activity of the curved, rotated southern edge of the Alpine arc terminated the NE extension of the LPB. The SW extension of the Ligurian Basin was also limited by the North Balearic fracture zone. Hence, rifting of the LPB is therefore local and had no regional implications on the entire WMED.

4.3.3. SE WMED (CaP). This area underwent HP-LT metamorphism during continental subduction and exhumation during the last 10 Ma. The slab along the arc is continuous and all laboratory experiments that consider a tearing of western (Atlas) and eastern (Apennines) wings are irrelevant. The jump from wide to narrow slab is artificial and it is doubtful that it imitates Nature. A transient opening of the Vavilov and Marsili rifts is not supported by a new set of magnetic lineations (Florio et al., 2011) and therefore the function of upper plate thrusting and the opposite lower plate slab pull and slab tear solutions need further study.

4.3.4. **Toroidal circulation** has always been an unsolved problem. Bercovici (2003) estimated the ratio between poloidal (vertical) and toroidal (horizontal) magma circulations to be about 50%. All new suggestions for local horizontal magma circulation around edges of subducting slabs as in Jadamec and Billen (2010) and the STEP solution by Wortel et al. (2009) still do not completely resolve this 50% figure. Radial, time-dependent outward thrusting around the eastern arcs of the Apennines and Carpathians ("vertical vorticity" and "gravitational instability": Lorinczi and Houseman, 2010) may be the result of a horizontal CW component of vertical magma circulation. This mechanism could explain southward rotation following the slab retreat.

4.3.5. Volcanism. Alkali basalts have lost their credibility as indicators of plume material and contamination is the new name of the game. What only a few years ago were surface indicators of mantle diapirs are now small degrees of partial melting due to decompression (Faccenna and Backer, 2010), passive upwelling in a heterogeneous asthenospheric mantle (Seghedi and Downes, 2011) or diapir instabilities (Beccaluva et al., 2011). Diapir uprise in the Carpathians was considered as the reason for a late stage volcanism that resulted in gravitational instability or detachment and slab tear. However, relying on the type of volcanism to prove retreat of subduction or even a "new type of mantle plumes" (Faccenna et al., 2010) instead of "heterogeneity caused by plate tectonics" (Foulger, 2010) is still a matter of hot debate.

4.3.6. Cold slab above deep mantle. Seismic tomography in western Europe is constantly improving as stations are added and upper mantle structure is seen more clearly (Koulakov et al., 2009: small resolutions of relatively shallow hot magma under the Rhine, Eifel, and Eger rifts are out of the scope of this study). Above the WMED and Carpathian MTZ (660 km depth) a relatively cold layer is interpreted as a relic of the retreating slabs. In the Carpathians, Dando et al. (2011) confirmed this layer, but found no connection with slab retreat, suggesting instead "down welling mantle" (note that their doughnut round structure fits that of an MP, including the reported vertical walls). In the WMED, Chang et al. (2010) related the 1000 km length of the cold layer above the MTZ to a retreating slab. Nevertheless, physical and mineralogical investigations on olivine (peridotite) behavior under high pressure, temperature and partial melting show jumps in phase transition and lattice preferred orientations (Karato et al., 2008), partly due to change in water content (dehydration). Thus, the cold layer above the MTZ and the hot layer above it (top MTZ: 410 km depth) are not yet fully understood. However, the cold layer above the MTZ may result from both slab retreat and slab advance tectonic drive.

4.3.7. Radial slab advance is here offered as an alternative to the slab retreat mechanism. In addition to the well-recognized criteria of deep, cylindrical, near vertical plume-like structures as in Yellowstone and Hawaii, another two criteria may be added: 1) Horizontal component of the outside radial advance (spreading out), caused by the vertical magma circulation. 2) Toroidal component of the vertical magma circulation. Although not further substantiated, both mechanisms are apparently equal alternatives based on seismic tomography records.

4.4) Trench retreat / advance. Many studies invoke retreat of both WMED and Carpathian slabs from west to east, but no evidence of any trace is supplied to discern between retreat and advance. Some elements for discrimination are subducting plate velocity, viscosity, thickness, stiffness, width, age and its response to the mantle below and the upper plate above (e.g. Lallemand et al., 2008). Trench migration is a surface expression of subduction (Jolivet et al., 2008) and the history of subduction involves paleoreconstruction. Advances or retreats are the derivatives of this general concept, but lack direct evidence. GPS data confirm the direction of recent drift, but projection from this to past directions of subductions is uncertain. Lister and Forster (2009) detailed switches of stress regimes in space and time to show that possible alternatives. Hence, rifting in the WMED (Betics, LPB) did not prove advance from west to east. Extrusion in the northern Carpathians (if any) was limited only to the upper lithosphere.

Regarding the retreat mechanism of the Aegean slab (Royden and Papanikolau, 2011), proof of retreat relies on the ages of deformation. However, even in this accepted case of a retreat, questions remain**:** 1) Why is the Aegean arc E-W symmetric (van Hinsbergen et al., 2010) if stress acted in the NE-SW direction? 2) How do we explain the junction of two orthogonal retreating slabs (the Aegean and Calabrian slabs) on both flanks of the same confined or even overlapping block (Del Ben et al., 2010)?

4.5) Eastward extrusion and block rotation is the routine explanation for the Carpathian Arc, based on paleomagnetic analyses showing NW declinations for the Alcapa block and NE declinations for the Tisza-Dacia block. All diversions from these expected declinations were excluded as disintegration, strike-slip, detachment or simply "soft collision" (Brückl et al., 2010; Márton et al., 2011). Maybe it is about time to consider strain load remagnetization as the prime cause for the observed directions of the magnetic fabric (Borradaile, 1997) and to be more cautious in interpreting PM results as indicators for past block rotations.

4.6) Horizontal push is one of the alternative models suggested by Lustrino et al. (2009), also called belt-parallel indentation-extrusion. Mantovani et al. (2009) suggested NW-N-NE directed compression by the Hyblean Adventure Promontory during Pliocene-Quaternary times, in aiming to explain the whole Apenninic arc (for Miocene times see earlier paper in 2007). If vergence direction does not fit structures, they suggest oblique divergence between the Adria and the CoSa blocks. The "sound" question of bending is answered by eastward extrusion along Calabrian faults and horizontal escape to the Carpatho-Pannonian region. The model fails to resolve Miocene bending of the north Apennines or to explain curvature of the whole WMED. Fault plane solutions are often used for learning about past strains, yet Sperner and Zweigel (2010) recommended caution in drawing far-fetched conclusions.

4.7) Adria indenter. Adria (Apulia) was a kind of amorphic terrane during Triassic- LCT times (**Fig. 2**). Multiple ophiolites and metamorphic ribbon-like exposures along Adria suggest different marginal NW directed basins (Severin, Meliata, Vardar, and Pindos) that opened and closed during that time (Csontos and Vörös, 2004; Rosenbaum and Lister, 2004). On the western side, Adria fronted the NE directed Ligurian ocean. At present, the N-S elongated core of Adria is covered by the Adriatic Sea and plunges eastward under the Dinarides-Hellenides, westward under the Apennines and partly northward under the Alps. GPS measurements indicate its differential motion to the N-NNE (Pinter et al., 2006).

The NW drift of Adria during the Triassic-Jurassic rifting stage is not accurately constrained. Eastward thrusting onto the future Apennines and westward thrusting onto the future Dinarides (Robertson, 2011) assume the Iberian plate pushing from the west with Moesia, Serbo-Macedonian (SMM), Rhodope and Eurasia as counter plates. Most analyses of N-S closing of the wide Tethys are based upon ophiolite occurrences but embayment positions are quite flexible (very large "transit" ocean; large N-S "Vardar" strike slips). The start of the northward "hair pin turn" of African drift should have been followed by hundreds of kilometers of strike slip. Although this is mentioned (600 km; Karamata, 2006) solid evidence for the large scale orogen-parallel separations is still missing. Handy et al. (2010) described Adria in its Alpine context (SE subduction) since the Triassic until recent times. They started with a NE directed Ligurian-Piemonte ocean basin that later bent into a sigmoid structure during Iberian pull and oblique shortening (131-84 Ma), followed by apparent push (84-35 Ma) and then (35-0 Ma) N-S convergence. The problem with this reconstruction is that the western Dinaric-Hellenic flank of Adria is partly ignored, so that the reader may have an impression of one sided tectonic activity around Adria since Triassic times.

4.8) Late Cretaceous reconstruction. The LCT is widely recognized as an orogenic period but many misunderstandings still remain. My intent here is to inquire what structural trends occur inside the metamorphic and nonmetamorphic basements on both the WMED and Carpathian arcs. There is clear dominance of NE-SW trends in both arcs and they also occur all around the west central Tethys. Some geoscientists understate the importance of LCT orogeny: NW Europe (Dèzes et al., 2004); the Maghreb

(Frizon de Lammote et al., 2009) and emphasize instead the Eocene-Oligocene-Miocene "Alpine" orogeny. However, most authors are aware of it (e.g. Guiraud et al., 2005). LCT thrusting and metamorphism in Alboran, Liguria, Provençe, Corsica, Sardinia and the mid-Hungarian zone converged across NE strikes and this direction functioned as a suture at the start of Oligocene-Miocene orogeny (Apennines: Ortona-Roccamonfina line, Livorno-Salerno line; Carpathians: Ceahlau-Severin, Getic and Supergetic (Ciulavu et al., 2008). Reconstructions in Fig 3 show the Carpathian arc starting to develop only after LCT orogeny. On the other hand, part of the NE directed structures in central Europe (Eger rift) are inherited from the Variscan orogeny (**Fig. 4**) with Cenozoic rejuvenation.

5. Conclusions

Both the WMED and Carpathian arcs look like MPs, behave like MPs and therefore are MPs. This study attempts to put the mantle plume tectonic engine on a same probability level as the slab retreat mechanism. The supporting arguments for MP structures are radial outward thrusting and inner high heat flow and extensional shear. Problems with the slab retreat mechanism include lack of explanation for the beginning of retreat and the later separation to counter retreats of the WMED slab. Furthermore, there is no slab left to rotate in the south Carpathian arc. My solution simply changes the tectonic engine from slab retreat to radial slab advance by outwardly enlarging the circle of activity. Note that the study concentrates only on structural geology, without taking into account the great debate on mantle heterogeneity (Don Anderson). The WMED and Carpathian arcs are two Miocene orogenic features developed on both sides of Adria indenter, in complete variance from the earlier LCT NE and NW striking orogen. Accordingly, there was no EU-AF convergence around those two arcs during Miocene times. The two complete round arcs do not preserve directions of the Alpine E-W striking orogen, but developed their own radial/concentric features. MP as a tectonic engine renders superfluous split and counter retreats of the Tyrrhenian vs Alboran slabs. From the south Carpathian perspective radial outward push nullifies oroclinal bending, block rotations, extrusion, oblique collision and "Moesian wrapping". MP activity declined since the Late Miocene while back building of almost N-S compression as is expected from the European-African convergence.

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FUNDAMENTAL ROLE OF DEFORMATIONS IN INTERNAL DYNAMICS OF THE EARTH

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Abstract: The question of distribution of medium density depending on changes of deformations is studied and shown that this dependence for various geological media is instable. Distinguishing the various forms of instability is shown, that depending on geometric forms of bodies and structures of medium these processes contribute to emergence of structures, which are favorable for formation of deconsolidation zones. Comparing the received theoretical results with results of known experimental researches is shown that the processes of loss of stability of elastic equilibrium state on geometric shape change and on "internal" instability precedes to the processes of phase transitions of various mineral systems. These questions are studied using non classical linearized approach within framework of theory of small and large initial deformations involving various elastic potentials.

Keywords: *dynamics of the Earth, deformation, consolidation, deconsolidation, stability, phase transition*

1. Introduction and brief review

The problems of distribution of medium density, zones of small shear resistances, material and energetic mass flow in the internal structures of the Earth belong to fundamental ones and have importance in studying of various practical geological and geophysical tasks. These problems raise the issues of mineralogy, petrology, geothermal, tectonics, petrophysics and other basics of geology and geophysics in varying degrees. They are closely related to the tasks of distribution the pressure and temperature in the internal structures of the Earth. Almost all processes of internal dynamics of the Earth are based by these processes or accompanied by them, or they are the major elements of natural mechanism of their control in evolution where the deformations play significant role.

Without going into details of different publications, we note that enough large number of scientific publications have been published in this direction so far. Various practical tasks are considered in them along with fundamental issues. In particular, we can point to recent works of Anderson (2010); Belyakov et al. (2000); Campbell and Kerr (2007); Dean and Gudmundur (2011); Foulger and Jurdy (2007); Green et al. (2010); Holtzman et al. (2010); Korchin (2010); Nettles and Dziewonski (2008); Lee et al. (2009); Pavlenkova (2002); Rusinov (2005); Sokolovsky et al. (2007); Timurziev (2009), et al., where the references to other works are also given.

Based on fundamental properties of basic systems of equations of mechanics of deformable solid bodies, it is shown in this report that there are some common geomechanical basis of these phenomena. The question of distribution the density of medium depending on the change of deformation is studied. It is shown that this dependence for different geological environments is unstable. Various forms of instability are distinguished.

This theoretical result suggests that there is a general mechanism of consolidation of compressible medium, which transits to deconsolidation in different stages of the process. Depending on the realized forms of instability, geometric forms of bodies, and structure of the medium, these processes have their own specifics. On the other hand, the instability of deformation process contributes to appearance of the structures, which are favorable for the formation of deconsolidation zones. In further evolution, some of these deconsolidation zones can become a focus of compressed mass and give the beginning of mass flow on different directions. Conducting the comparison of received theoretical results of the given work with results of known experimental researches, it is shown that the processes of loss of stability of elastic state of equilibrium on geometric formability and on "internal" instability are preceded by processes of phase transitions of various mineral systems in determined mine-geological conditions.

The proposed approach is realized using the known data and results of experimental studies of Green, Ringwood, Akimoto, Liu and Jarkov. These data are considered reliable and useful to analyze their results together with the results obtained from theoretical positions and to conduct the testing of a new approach. In case of a success, this approach can be applied to the solution of similar regional tasks.

1. Distribution of density, Debayev's temperature, Grewnayzen's parameter, grating part of the heat conductivity coefficient, earth specific entropy, adiabatic temperature, melting temperature and their gradients, contrast entropy and heating effect during the cycle skip, dip of the curved phase equilibrium and the thermal crystallization for mantle and core are the main Earth inner structure parameters in parametrical models (Jarkov, 1983). While the determination, it's necessary to know preliminarily the move out density on entrails depth. Therefore, it's important to determine this parameter in real conditions more exactly. Using the known ratio of nonlinear theory of deformable solid bodies, (Guliyev and Asgerov, 2007) obtained the following ratios to determine the changes of density depending on changes of deformation

$$\frac{\Delta\rho}{\rho} = \frac{1}{\sqrt{I_3}} - 1,\ \Delta\rho = \rho_* - \rho;$$

$$\frac{dV^*}{dV} = \sqrt{I_3}; \qquad (1)$$

$$I_3 = 1 + 2A_1 + 2(A_1^2 - A_2) + \frac{4}{3}(2A_3 - 3A_2A_1 + A_1^3).$$

$$A_1 = \varepsilon_1 + \varepsilon_2 + \varepsilon_3;\ A_2 = \varepsilon_1^2 + \varepsilon_2^2 + \varepsilon_3^2;\ A_3 = \varepsilon_1^3 + \varepsilon_2^3 + \varepsilon_3^3,$$

ε_i - basic value of Tensor of Green's deformations; ρ, ρ_* - medium density in natural and actual states, accordingly; V, V^* - the volumes of medium in natural and actual states, accordingly.

Adams-Williamson' (Jarkov, 1983) equation is applied in recent models to determine the increment of density

$$\Delta\rho = \frac{\rho g}{\Phi}\Delta\ell,$$

where, ρ – structure density in examined depth, g – gravitational acceleration corresponding to given depth, $\Delta\rho$ – move out density, $\Delta\ell$ – move out depth, $\Phi = \frac{K_0}{\rho}$ – seismic parameter, $K_0 = \lambda + \frac{2}{3}\mu$ – bulk modulus; λ, μ – elastic module of the second order.

In case of linearized theory (in coordinates of initial state) within the framework of theory of large initial deformations (Guz, 1989)

$$\frac{dV_*}{dV} = \lambda_1\lambda_2\lambda_3,$$

where λ_i - coefficients of lengthening (shortening). Using these formulae, it is possible to obtain the formula for determining the density and for small deformations within the frameworks of non-classical linearized theory, Guliyev and Asgerov (2006).

It is indicated in the scientific literature that the change of density of depths of the Earth by Adams-Williamson's formula is well described for depths greater than 670 km. The main disadvantages of this formula are:

- unrecordness of phase transitions in it;
- unevenness of deformed states (which is more characteristic to structures to depth of 670 km).

The formulae (1), which are free from these shortcomings and is accurate and the most common within the frameworks of mechanics of continuum media are applied in this paper.

It is necessary to point out the universal nature of this dependence. The nature of deformations (it can be caused by tectonic, gravity, geochemical, hydromechanical, thermal, radiation, etc.) is arbitrary here and the parameters of the stressed state, physical-mechanical, chemical, temperature and other fields in obvious form are not the components of it. Deformations can be small and large (final), linear and non-linear, elastic, elastic-plastic, plastic, viscous, etc. and be corresponded to isotropic, anisotropic, homogeneous and inhomogeneous (heterogeneous) media. These factors have very significant meanings to specify and perform the experimental studies as well as for interpretation procedures and other geophysical data from inaccessible (for direct observation and measuring) Earth depths.

In particular, the results reflected in **Fig. 1** from Guliyev (2010) show that uneveness of deformations makes significant influence on growth of density.

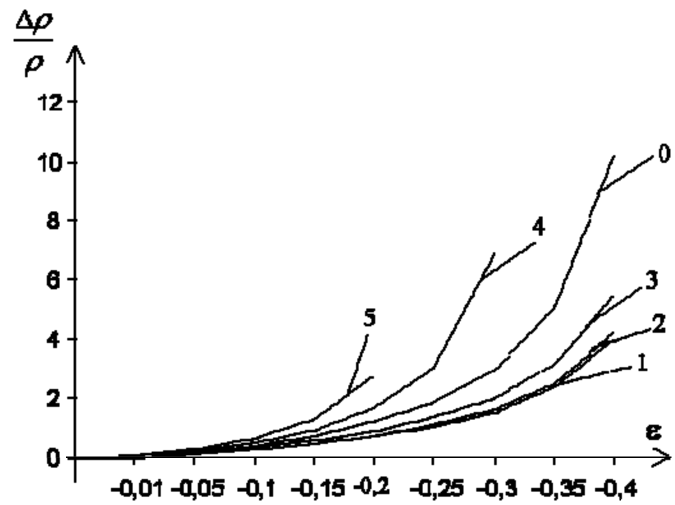


Figure 1. Graphs of the accretion of density in case of 3D uneven deformation. (Guliyev, 2010): line 0 - $\alpha = \beta = \gamma = 1$;line 1 - $\alpha = \beta = 1,\ \gamma = 0{,}01$; line 2 - $\alpha = \beta = 1,\ \gamma = 0{,}1$; line 3 - $\alpha = \beta = 1,\ \gamma = 0{,}5$; line 4 - $\alpha = \beta = 1,\ \gamma = 1{,}5$; line 5 - $\alpha = \beta = 1,\ \gamma = 2$; $\varepsilon_1 = \alpha\varepsilon_0,\ \varepsilon_2 = \beta\varepsilon_0,\ \varepsilon_3 = \gamma\varepsilon_0$.

2. The following results on relative decrease of volume in phase transitions, referred to normal conditions are given in Jarkov's book (1983): for composition 90% MgSiO3 · 1-% Al_2O_3 phase transitions (author Lin-gun Liu, **Figs.7 and 8**) orthopyroxene→ garnets, garnet→ ilmenite, ilmenite → perovskite occur at a relative change of volume, respectively at - 7.8%; - 8.0% and - 6.9%.

The data on physical properties for Pyroxenes are available in Jarkov (1983), Ringwood (1982). In particular, for Enstatite and Garnet (**Table 1**).

Table 1.

Enstatite	**$MgSiO_3$**	**ρ, g/cm^3**	**K, 10^{12} dyn/cm^2**	**V_p, km/s**	**V_s, km/s**	**λ, Kbar**	**μ, Kbar**
		3,2	1,212	8,36	4,99	$0{,}662 \cdot 10^3$	$0{,}796 \cdot 10^3$
Garnet	**(Ca, Mg, Fe^{+2}, Mn)$_3$**	3,47	1,65	8,7	4,8	$1{,}02 \cdot 10^3$	$0{,}8 \cdot 10^3$

Using these data and formulae

$$\frac{\Delta\rho}{\rho} = \frac{1}{\sqrt{I_3}} - 1 \text{ and } \frac{dV^*}{dV} = \sqrt{I_3},$$

we obtained, that corresponding changes of density $\frac{\rho_*}{\rho}$ have the following values in below given relative changes of volume.

Enstatite in normal conditions – $3{,}2 g^2/cm^3$ } to 8,45%
Garnet – $3{,}47\ g^2/cm^3$ } to 8,7%
Ilmenite – $3{,}77\ g^2/cm^3$ } to 7,4%
Perovskite – $4{,}05\ g^2/cm^3$

We obtain from the formula (1) for determining the density:

$$\frac{\rho_*}{\rho} = \left(1 + A\varepsilon_0 + B\varepsilon_0^3 + C\varepsilon_0^3\right)^{-\frac{1}{2}},\ \varepsilon_1 = \alpha\varepsilon_0; \varepsilon_2 = \beta\varepsilon_0; \varepsilon_3 = \gamma\varepsilon_0;$$

$$A = 2(\alpha + \beta + \gamma);\ B = 4(\alpha\beta + \alpha\gamma + \beta\gamma);\ C = 8\alpha\beta\gamma. \tag{2}$$

Using the formula (2) we clarified that in which deformation conditions such density changes can occur. In these formulae ε_0 - is a parameter of comprehensive deformation, α, β, γ - are real numbers; ρ, ρ_*, V, V_* - are the densities and volumes of media in normal conditions and in actual state. The numerical values $\frac{\rho_*}{\rho}$ calculated in various non-uniform homogeneous deformation states are given in **Fig. 2**.

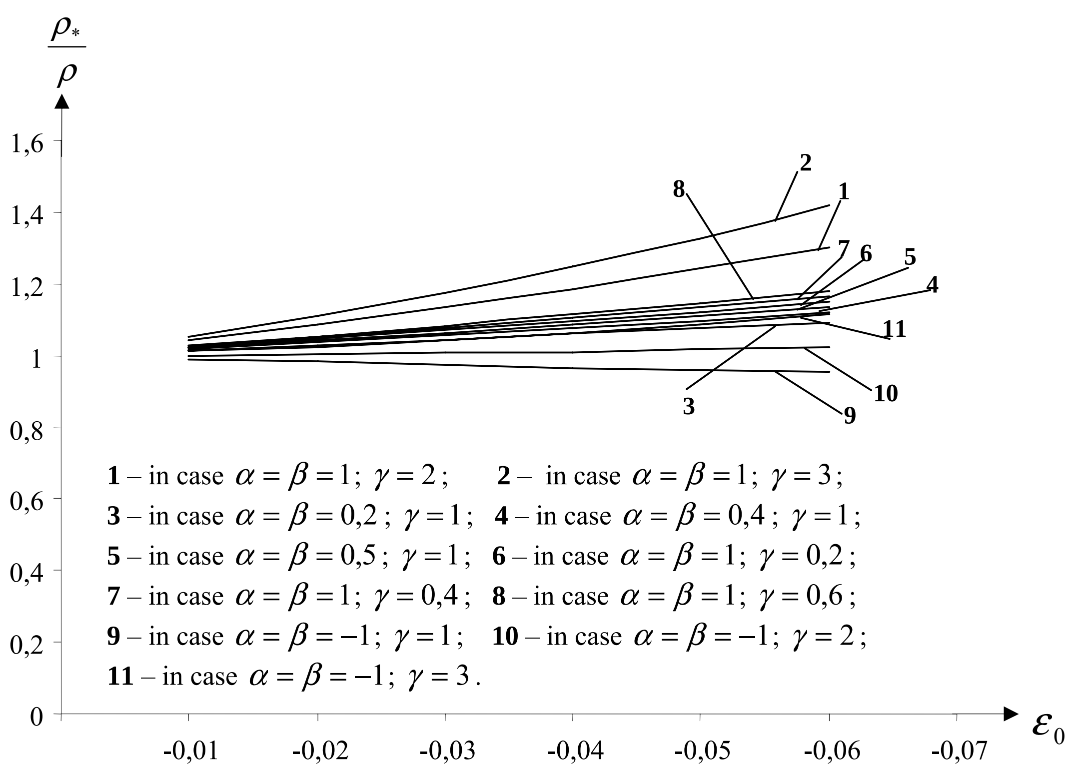


Figure 2. Growth dependence on values of deformations

The results of **Fig. 2** show that the transition of enstatite with a density of 3.22 g/cm^3 in the garnet with a density of 3.47 g/cm^3 can occur in relative change of density to 8.45%. The following cases of inhomogenous deformation correspond to this process in this example:
$\varepsilon_0 = -0{,}02, \alpha = \beta = 1, \ \gamma = 2$; $\varepsilon_0 = -0{,}055, \alpha = \beta = 0{,}2, \gamma = 1$; $\varepsilon_0 = -0{,}045, \ \alpha = \beta = 0{,}4, \gamma = 1$; $\varepsilon_0 = -0{,}04, \alpha = \beta = 0{,}5, \gamma = 1$; $\varepsilon_0 = -0{,}03, \alpha = \beta = 1, \gamma = 0{,}6$.

The other variants could also be available basing on **Fig. 2**.

Similarly, it is possible to determine under what deformation conditions are occurred the transitions of garnet→ ilmenite and ilmenite→perovskite.

We clarified under what deformation conditions the garnet with 3.47 g/cm^3 of density may be transferred to the ilmenite from 3.77 g/cm^3 of density, i.e. the relative density change occurs to 8.7%. It is seen from the results of **Fig.2** that such changes can occur in:
$\varepsilon_0 = -0{,}021, \alpha = \beta = 1, \ \gamma = 2$; $\varepsilon_0 = -0{,}01, \alpha = \beta = 1, \gamma = 3{,}5$; $\varepsilon_0 = -0{,}05, \ \alpha = \beta = 0{,}25, \gamma = 1$; $\varepsilon_0 = -0{,}04, \alpha = \beta = 0{,}5, \gamma = 1$; $\varepsilon_0 = -0{,}03, \alpha = \beta = 1, \gamma = 0{,}7$

It is assumed, that the materials of rocks are subject to the model of an isotropic elastic body with small deformations. In principle, such assumption is justified. This follows from the numerical results. They show that the considered phase transitions can be realized at 1 - 5.5% deformations.

Further, we will define the quantitative characteristics of the stress of considered deformed states.

To do this, we start from the known relations of the theory of elasticity
$$\sigma_{ij} = \lambda \delta_{ij} \varepsilon_{nn} + 2\mu \varepsilon_{11}$$
and use the data of **Fig. 2.** Here $\sigma_{i,j}$ $(i, j = 1,2,3)$ - are the components of stress tensor and
$\varepsilon_{nn} = (\alpha + \beta + \gamma)\varepsilon_0$; $\varepsilon_{11} = \alpha \varepsilon_0$.

Then
$$\sigma_{11} = [\lambda(\alpha + \beta + \gamma) + 2\alpha\mu]\varepsilon_0;$$
$$\sigma_{22} = [\lambda(\alpha + \beta + \gamma) + 2\beta\mu]\varepsilon_0; \qquad (3)$$
$$\sigma_{33} = [\lambda(\alpha + \beta + \gamma) + 2\gamma\mu]\varepsilon_0,$$
where λ, μ - are Lame's moduli of elasticity.

I. Calculations for transition of Enstatite → Garnet. Let's consider the following concrete variants:

a) In case of $\varepsilon_0 = -0{,}02, \alpha = \beta = 1, \ \gamma = 2$; $\alpha + \beta + \gamma = 4$ from the formulae (3) we receive that, the deformed state $\varepsilon_{11} = \varepsilon_{22} \sim 2\%$ and $\varepsilon_{33} \sim 4\%$ is occurred by tensions $\sigma_{11} = \sigma_{22} = -84{,}8\, Kbar$, $\sigma_{33} = -116{,}64\, Kbar$.

b) In case of $\varepsilon_0 = -0{,}055, \alpha = \beta = 0{,}2, \gamma = 1$; $\alpha + \beta + \gamma = 1{,}4$ from the formulae (2) we find that the deformed state $\varepsilon_{11} = \varepsilon_{22} \sim 1{,}1\%$ and $\varepsilon_{33} \sim 5{,}5\%$ is happened by tensions $\sigma_{11} = \sigma_{22} = -68{,}75\, Kbar$, $\sigma_{33} = -138{,}6\, Kbar$.

c) In case of $\varepsilon_0 = -0,03, \alpha = \beta = 1, \gamma = 0,6$; $\alpha + \beta + \gamma = 2,6$ from the formulae (3) we find that the deformed state $\varepsilon_{11} = \varepsilon_{22} \sim 3\%$ and $\varepsilon_{33} \sim 1,8\%$ is happened by tensions $\sigma_{11} = \sigma_{22} = -99,4\,Kbar$, $\sigma_{33} = -80,31\,Kbar$.

Similar calculations can be made for the phase transitions garnet → ilmenite and ilmenite → perovskite.

It should be noted that the data of **Fig. 2** were obtained taking into account the temperature. At the same time, this factor is not taken into account in formulae (3). Their account could lead to some clarifications of the values of stresses.

In case of small elastic comprehensive deformations depending on changes of density from the pressure on the base of formula (1), it is possible to determine on the following formula

$$\frac{\rho_*}{\rho} = \left(1 - 3x + 3x^2 - x^3\right)^{-\frac{1}{2}}; \; x = \frac{1-2\nu}{\mu(1+\nu)}P \qquad (4)$$

The numerical values $\frac{\rho_*}{\rho}$ and ε_0 for different rocks depending on the growth of comprehensive pressure calculated on formulae (3) and (4) are given in **Fig. 3**.

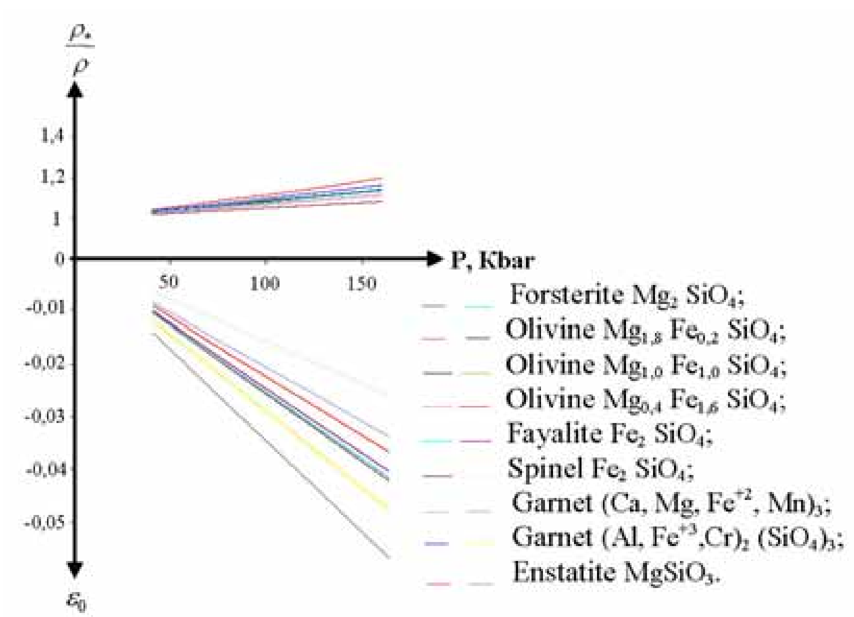


Figure 3. Dependence of density growth and deformation on values of pressure

It follows from the **Fig. 3** that the value of growth $\frac{\rho_*}{\rho}$ outpaces the value of growth of deformation. Moreover, this tendency is kept for all considered rocks in interval of pressure (0-160) Kbar.

The results of calculations corresponding to the phase transitions: 1. Enstatite-Garnet; 2. Garnet-Ilmenite 3. Ilmenite - Perovskite assuming comprehensive deformation is given in **Table 2**. Here $S_{\beta\beta}$ - is the physical component of stress tensor (which is measured in unit of area in undeformed (natural) state). These stresses are calculated using the formula (Guz, 1989) in case of applying the quadratic potential within the framework of the theory of large initial deformations:

$$S_{\beta\beta} = \frac{\lambda}{2}\left(\lambda_1^2 + \lambda_2^2 + \lambda_3^2 - 3\right) + \mu\left(\lambda_\beta^3 - 1\right). \quad (5)$$

Table 2

Numbers of transitions	λ	μ	ε_0	λ_1	S_{11}^0	σ_{11}
1	662	796	-0.0264	0.9732	-114.634	-94.4592
2	1020	800	-0.027	0.9726	-146.537	-125.82
3	1512.35	815.29	-0.0235	0.9762	-163.418	-144.939

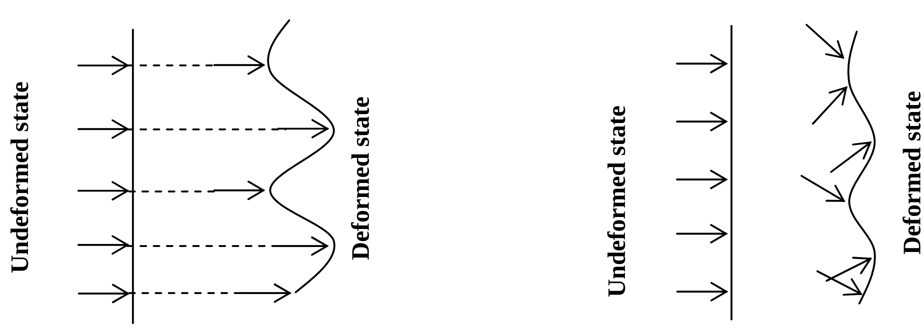
The data on physical mechanical parameters of range of rocks are given in **Table 3**.

Table 3

Name of rock	**Chemical formulae**	**ρ, g/cm³**	**μ, Kbar**	**λ, Kbar**	**ν**	**V_p, km/s**	**V_s, km/s**
Forsterite	$Mg_2 SiO_4$	3,214	808,33	743,3082	0,2395	8,569	5,015
$Olivine_1$	$Mg_{1,8} Fe_{0,2} SiO_4$	3,34	838,34	708,1635	0,2289	8,45	5,01
$Olivine_2$	$Mg_{1,0} Fe_{1,0} SiO_4$	3,82	726,17	789,0679	0,2604	7,66	4,36
$Olivine_3$	$Mg_{0,4} Fe_{1,6} SiO_4$	4,17	558,60	1080,707	0,3296	7,26	3,66
Fayalite	$Fe_2 SiO_4$	4,39	510,47	979,2538	0,3287	6,75	3,41
Spinel	$Fe_2 SiO_4$	4,85	815,28	1512,361	0,3249	8,05	4,1
$Garnet_1$	$(Ca, Mg, Fe^{+2}, Mn)_3$	3,5	806,40	1036,35	0,2812	8,7	4,8
$Garnet_2$	$(Al, Fe^{+3}, Cr)_2 (SiO_4)_3$	3,3	638,88	694,0857	0,2603	7,73	4,4
Enstatite	$MgSiO_3$	3,2	796,80	642,8672	0,2232	8,36	4,99

3. Earlier in Guliyev and Asgerov (2007), basing on the solution of tasks of mechanics, showed that the dependence of change $\frac{\rho_*}{\rho}$ on the growth of deformation is not continuous, i.e. the loss of stability of equilibrium states of different geometric forms of deformed bodies under compression can be realized in certain values of deformation on different forms. The values of these critical deformations depend on the nature of impacts.

We use compressible or incompressible models of elastic media in small and large linear and nonlinear deformations in tasks of sustainability as a model of deformation. The action of weight of the overlying layers and corresponding reactions of the underlying layers, depending on their actual physical composition and the ability to transfer efforts are modeled as external conservative - "dead" or non-conservative - "follower" loads, **Fig. 4.**



a) Model of “dead” load b) Model of “follower” load

Figure 4. Character of action of external surface loads.

Experience shows that, the values of critical deformations significantly differ on conservative, non-conservative and combined (conservative forces act on one side of the body of surface and non-conservative forces act on the rest of the surface) external loads. The values of critical deformations also differ substantially and on different forms of bodies: half-space, cavity, cylindrical and other forms of bounded (on geometric scales) bodies.

There are also differences related to the forms of loss of stability of equilibrium states. Two different classes are distinguished. In the first class, geometric changes in the shape of a deformable body are realized in the process of instability. In the second - the "internal" instability occurs and it corresponds to a loss of continuity of medium and tracts as the beginning of process of destruction. Moreover, the second case may be preceded by the first class of process (it is not needed condition).

Study of the stressed-deformed state takes a central place among the issues of mechanics of rocks, related to the mining, wells, caves, tunnels, heterogeneities, etc. These objects disturb the medium continuity and the stress concentrators. The term "working stability" is used in the rocks mechanics. Under this term they mainly consider the definition of the stressed-deformed state near the concentrators with its further assessment from viewpoint of theory of strength, theory of plastic flows, theory of destruction mechanics, etc.

Under the stability one intuitively consider the property of system to keep its state at external influences. If the system has no such a property, then it is instable one. In real states there are always some reasons due to which the inclinations from initial equilibrium state can take place. However, the stable system always returns to the initial state. So, under definite situations the possibility of transition to a new state in the unstable system always realizes. In this case they say that the stability loss had occurred. The local character of stability loss of equilibrium state near the concentrators follows from the local character of concentration of the compressing stresses. In this case the stability loss in individual places near concentrators can be considered as one of the possible reasons of appearance of destructions, displacements, flows, etc. It is known that when stability loss the great motions and deformations take place; their values are much greater than deformations and motions in the pre-critical state. It brings to that contours of concentrators (mining workings, wells) can acquire such forms which can not be determined by solving the tasks on the stressed-deformed state in the linear statement. Such situation makes unpredictable the directions of destruction cracks, directions of plastic flows, directions of remolding, etc.

The following results are known (Guz, 1989; Guliyev, 1987; Guliyev, 1988):
1) the state of elastic equilibrium of an arbitrary geometrical shape of isotropic bodies is stable (with respect to shape changes), if pressure is applied in the form of "follower" load over the entire surface;

2) the state of equilibrium is unstable if the pressure is applied in the form of "dead" in one part of the body surface, while in other part – in the form of "follower" loads; the presence in one part of the surfaces of "follower" load has a stabilizing effect on equilibrium state.

Further, for simplicity and clarity, we present the concrete results for isotropic models of elastic media. Similar results are also obtained for different models of elastic and elastic-plastic composite media.

In particular, the task of stability for the band (within plane deformation) is formulated as follows. Stability of the band $(0 \le x_1 \le \ell; -h \le x_2 \le h)$ is considered which rubs with a friction-free with absolutely rigid walls or hinged in $x_1 = 0, \ell$. Uniform pressure of weight of overlying layers $\sigma_{22} = -kP$ as “dead” is applied to the top surface $x_2 = h$, uniform pressure in the form of "follower" (the intensity of the "dead" and "follower" loads are equal and their locations may be interchangeable) load is applied to the bottom surface $x_2 = -h$. The compressive stresses $\sigma_{11} = -P$ are given in $x_1 = 0, \ell$ along axis ox_1.

It is received, that in case of rigid fixing the ends and $h << \ell$ at

$$(-\sigma_{11})^{fl.}_{cr.} \approx \frac{P_{el.}}{1-\kappa}\left\{1-\frac{\chi^2}{15}\left\{\frac{2(6-\nu)}{1-\nu}+\frac{5}{1-\kappa}\left[1+\kappa\frac{2-\nu}{(1-\nu)^2}\nu\right]\right\}\right\};$$

$$(-\sigma_{11})^{d.}_{cr.} \approx \frac{P_{el.}}{1+\kappa}\left\{1-\frac{\chi^2}{15}\left\{\frac{2+3\nu}{1-\nu}+\frac{5}{1+\kappa}\left[\frac{1-2\nu}{1-\nu}-\kappa\frac{\nu(1-2\nu)}{(1-\nu)^2}+\frac{1}{1+\kappa}\frac{2}{1-\nu}\right]\right\}\right\}; \qquad (6)$$

$$P_{el.} = \frac{\chi^2}{3}\frac{E}{1-\nu^2},\ \chi = \frac{\pi m}{\ell}h$$

a loss of stability of equilibrium state of initial flat shape of isotropic band on bending shape, or on form with necking is happened and it transits to a more sustainable curved form of equilibrium concerning the level and type of operating system of forces.

Here $(\sigma_{11})^{fl.}_{cr.}$ - is critical value of stresses, corresponding to the loss of stability in case, when the "follower" loads are given to $x_2 = \pm h$; $(\sigma_{11})^{d.}_{cr.}$ - when "dead" loads are given to $x_2 = \pm h$; E - elasticity module; ν - is Poisson's coefficient of medium; m - is number of halfwaves of curvature; $P_{el.}$ - is value of critical load of loss of stability in unaxial compression of band along ox_1, determined within the applied theory with involving the hypothesis of Kirchhoff-Love. In case of giving to $x_2 = h$ and $x_2 = -h$ of external loads differed with characters, the values of critical forces of loss of stability are computed from corresponding characteristic equation (Guliyev, 1988).

In case of hinge support of isotropic bands to $x_1 = 0, \ell$, the values of critical stresses are determined from:

$$(\sigma_{11})_{cr.} = -2\nu\frac{\sqrt{3}\sqrt{1-2\nu+4\nu}-3\nu}{(1-\nu)^2}P_{el.}\left\{1-\frac{2\chi^2}{3\nu}\left[1+4\nu+\frac{1-3\nu}{\nu(1-\nu)^2}\left(\sqrt{3}\sqrt{1-2\nu+4\nu}-3\nu\right)\right]\right\}; \qquad (7)$$

$$P_{el.} = \frac{E}{3}\frac{\chi^2}{1-\nu^2};\ \chi = \frac{\pi mh}{\ell}.$$

Thus common form (which consists of a combination of bending and necking forms of changes) of loss of stability of the equilibrium state of initial flat shape of the band happens and it passes to more sustainable form of curved equilibrium.

In the theory of linear mechanics of destructions there are also the cases when its method doesn't describe the real process of destruction. In these cases, proceeding from linear mechanics of destruction it is impossible to assess the stresses state. The linear mechanics of destruction provides three types of cracks development in solids. The achievement of coefficient of stresses concentration in cracks ends to the extreme values for specific material is considered as the destruction criterion. Let's suppose that the infinite elastic space is in triaxial compressing homogeneous stressed-deformed state and the flat crack locates in direction of main planes of compressive stress (**Fig. 5**).

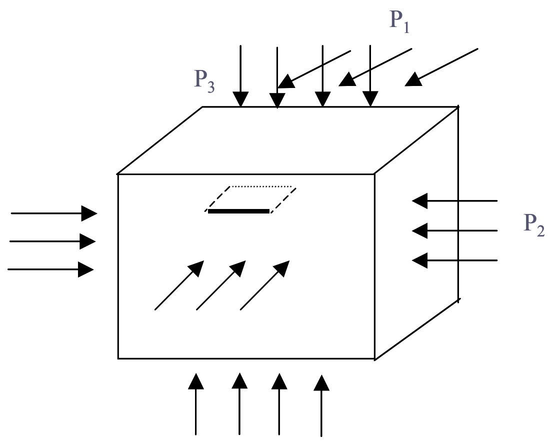


Figure 5. Scheme of the triaxial compression of solid with cracks.

All three types of criteria don't work here in considered cases, as the coefficients of concentration are equal to zero. But in the real cases the destruction takes place when achieving the intensity of compressible stresses of definite values. Such process of destruction can be explained with application of stability theory near the cracks. At the same time the different forms of deformation of the cracks surfaces at stability loss are possible (a. Surfaces are similarly deformed with different numbers of wave-forming; b. Surfaces are deformed in opposite directions in the same plane; c. As the same but in different planes), that can bring to different processes of destruction. Theory of destruction of bodies with fractures in conditions of compression had been developed by Guz (1983). The development of the given theory in relation to the tasks of mining mechanics, seismology and structural geology had been received by Guliyev (1983, 1995, 2001 and 2010).

Surface instability

Process of stability loss of the equilibrium state on geometric formability in vicinities of the free and loaded surfaces can precede the processes of the plastic deformation, destruction and phase transitions.

Analytical formulas for calculation of values of critical loads of loss of stability of equilibrium state on near-surface form of half-space (tasks had been solved within the frameworks of plane deformation) are shown in Guliyev (2010):

Local loss of stability in vicinities of cylindrical cavities

Tasks of three-dimensional instability in vicinities of cylindrical surfaces in various homogenous and inhomogeneous stressed states had been studied by Guliyev (1988).

Elastic and elastic plastic tasks of stability are solved with application of variational methods by Guliyev (1983 and 1988) in inhomogeneous stressed state in vicinities of cylindrical cavities in isotropic and anisotropic media.

The homogeneous stresses states can realize near the cylindrical cavity at definite ratios of the external influences. It is possible to obtain the solution in analytical state (critical values of efforts – at small initial deformations and critical values of extension – at great initial deformations) in these cases.

Theory of the final subcritical deformations. Harmonic potential (Guliyev, 1988; Guliyev and Jabbarov, 2010)

$$2\varepsilon_{ij}^{0} = 2\delta_{ij}\varepsilon_{0};\ 2\varepsilon_{0} = \lambda_1^2 - 1$$

$$\lambda_1^* < (\lambda_1)_* < 1;\ \lambda_1^* = 1 - \frac{1-2\nu}{2-\nu}$$

$$(\lambda_1)_* = -\frac{(1+\nu)(1+2\nu)}{2(2+\nu-4\nu^2)}\left\{1-\left[1+\frac{8(2+\nu-4\nu^2)}{(1+2\nu)^2}\right]^{\frac{1}{2}}\right\} \quad (8)$$

Here ε_{ij}^0 – components of Green strain tensor in the initial state; λ_1 – coefficient of shortening along the axe ox; $(\lambda_1)_*$, λ_1^* - critical values λ_1, corresponding to the loss of sustainability on geometric form change and "internal" loss of sustainability (Guliyev, 2010; Guz, 1989); ν – Poisson coefficient.

The numerical results calculated on formulae (2) and (8) for different coefficients of Poisson are given in **Table 4**.

Table 4.

ν	:	0,1	0,2	0,3	0,4
$(\lambda_1)_*$	:	0,82	0,84	0,89	0,94
$(\varepsilon_0)_*$	:	-0.1638	-0.1472	-0.10395	-0.0582
$\left(\frac{\rho_*}{\rho}\right)_*$	:	1.8136	1.6871	1.4185	1.2039
λ_1^*	:	0,58	0,67	0,77	0,87
$(\varepsilon_0)^*$	:	-0.3318	-0.27555	-0.20355	-0.12155
$\left(\frac{\rho_*}{\rho}\right)^*$	:	5.1252	3.3248	2.1904	1.5186

Using the data of **Table 3**, the critical values of deformation $(\varepsilon_0)_*$ and critical values $\left(\frac{\rho_*}{\rho}\right)_*$ corresponding to the loss of stability of equilibrium state in the shape of transition from cylindrical form of equilibrium with rectilinear axis to the form of curved axis for concrete rocks are also calculated. $(\varepsilon_0)^*$ and $\left(\frac{\rho_*}{\rho}\right)^*$ - corresponding to "internal" instability, i.e. loss of continuity of medium are also calculated and their value for range of rocks are given (**Table 5**).

Table 5

Name of rock	ν	λ_1^*	$(\lambda_1)_*$	$(\varepsilon_0)^*$	$(\varepsilon_0)_*$	$\left(\frac{\rho_*}{\rho}\right)^*$	$\left(\frac{\rho_*}{\rho}\right)_*$
Forsterite	0,2395	0,704061	0,861797	-0,25215	-0,12865	2,865289	1,562377
Olivine$_1$	0,2289	0,693863	0,85738	-0,25928	-0,13245	2,993502	1,586646
Olivine$_2$	0,2604	0,724534	0,870741	-0,23752	-0,12091	2,629196	1,514723
Olivine$_3$	0,3296	0,795977	0,902706	-0,18321	-0,09256	1,982889	1,359444
Fayalite	0,3287	0,79501	0,902266	-0,18398	-0,09296	1,990135	1,361435
Spinel	0,3249	0,790938	0,900415	-0,18721	-0,09463	2,021031	1,369847
Garnet$_1$	0,2812	0,745404	0,879961	-0,22219	-0,11283	2,414489	1,467608
Garnet$_2$	0,2603	0,724435	0,870697	-0,2376	-0,12094	2,630276	1,51495
Enstatite	0,2232	0,688429	0,855038	-0,26303	-0,13446	3,064949	1,59972

Theory of large initial deformations. Quadratic potential

$$\lambda_1^* < (\lambda_1)_* < 1;\ \lambda_1^* = \left(\frac{1+\nu}{2-\nu}\right)^{\frac{1}{2}};\ (\lambda_1)_* = \sqrt{\frac{3}{3-2x}}$$

$$x = -\frac{3\lambda+5\mu}{8\left(\lambda+\frac{2}{3}\mu\right)}\left\{1-\left[1-\frac{16\mu(\lambda+\mu)}{(3\lambda+5\mu)^2}\right]^{\frac{1}{2}}\right\} = -\frac{3(5-4\nu)}{16(1+\nu)}\left\{1-\left[1-\frac{16(1-2\nu)}{(5-4\nu)^2}\right]^{\frac{1}{2}}\right\} \quad (9)$$

Results calculated on formulae (2) and (9) are given in **Tables 6** and **7**.

Table 6

ν	:	0,1	0,2	0,3	0,4
$(\lambda_1)_*$	:	0,91	0,94	0,95	0,98
$(\varepsilon_0)_*$	:	-0,08595	-0.0582	-0.04875	-0,0198
$\left(\frac{\rho_*}{\rho}\right)_*$	:	1,3270	1,2040	1,1663	1,0625
λ_1^*	:	0,76	0,82	0,87	0,94
$(\varepsilon_0)^*$	:	-0,2112	-0,1638	-0,12155	-0,0582
$\left(\frac{\rho_*}{\rho}\right)^*$	:	2,2780	1,8137	1,5186	1,2040

Table 7

Name of rock	λ_1^*	$(\lambda_1)_*$	ε_0^*	$(\varepsilon_0)_*$	$\left(\frac{\rho_*}{\rho}\right)^*$	$\left(\frac{\rho_*}{\rho}\right)_*$	$(S_{11}^0)^*$, Kbar	$(S_{11}^0)_*$, Kbar
Forsterite	0.839084	0.94392	-0.14797	-0.05451	1.692717	1.189035	-660.755	-250.057
$Olivine_1$	0.832984	0.941711	-0.15307	-0.05659	1.730174	1.197423	-678,993	-258,444
$Olivine_2$	0.851196	0.948289	-0.13773	-0.05037	1.62148	1.172674	-604,367	-226,173
$Olivine_3$	0.892175	0.962906	-0.10201	-0.03641	1.408151	1.120078	-492,645	-177,917
Fayalite	0.891633	0.962714	-0.1025	-0.03659	1.410721	1.120747	-449,727	-162,493
Spinel	0.889347	0.961905	-0.10453	-0.03737	1.42163	1.123577	-716,063	-259,218
$Garnet_1$	0.863368	0.952658	-0.1273	-0.04622	1.553863	1.156617	-683,21	-252,898
$Garnet_2$	0.851138	0.948268	-0.13778	-0.05039	1.621812	1.172752	-531,847	-199,044
Enstatite	0.829716	0.940525	-0.15579	-0.05771	1.7507	1.201958	-642,116	-245,174

The numerical values for the physical component of the stress tensor are also given in **Table 7**. These stresses are calculated using the formula (5) within the framework of the theory of large initial deformations in case of applying the quadratic potential. The results correspond to the case of uniform compression, i.e. $\lambda_1 = \lambda_2 = \lambda_3$.

Second variant of theory of the small initial deformations. Potential of the linear elastic isotropic solid

$$P_* = P_2 = \frac{3\lambda + 5\mu}{4}\left\{1 - \left[1 - \frac{16\mu(\lambda+\mu)}{(3\lambda+5\mu)^2}\right]^{\frac{1}{2}}\right\} = \frac{5-4\nu}{8(1+\nu)(1-2\nu)}\left\{1 - \left[1 - \frac{16(1-2\nu)}{(5-4\nu)^2}\right]^{\frac{1}{2}}\right\} \qquad (10)$$

Results calculated on formulas (10) are shown in **Table 8**.

Table 8

ν	:	0,1	0,2	0,3	0,4
$\frac{P_*}{E}$	:	0,245	0,236	0,233	0,227
$\left(\frac{\rho_*}{\rho}\right)_*$	:	2.1093	1.6478	1.3626	1.1535
$(\varepsilon_0)_*$	:	-0.196	-0.1416	-0.0932	-0.0454
$\frac{P^*}{E}$	:	0,454	0,416	0,384	0,357
$\left(\frac{\rho_*}{\rho}\right)^*$	:	6.9876	2.8216	1.7342	1.2600
$(\varepsilon_0)^*$	:	-0.3632	-0.2496	-0.1536	-0.0714

Here P^* - is a critical value of parameter of the external medium corresponds to the inner instability.

Instability of inclusions in shape of solid cylindrical bodies in geological medium

Interesting and more visible results are obtained in case when there is an inclusion in the medium in the shape of a solid cylinder. Critical values of strength of stability loss of the trilaterally compressed cylindrical solids are defined using the formulae, given in Guliyev (1987) and Guliyev (2010).

The results of calculations received on formulas of Guliyev (1987) works for some rocks in modeling of the process of deformation of solid cylindrical inclusions in the shape of linear elastic isotropic media are given in **Fig. 6.**

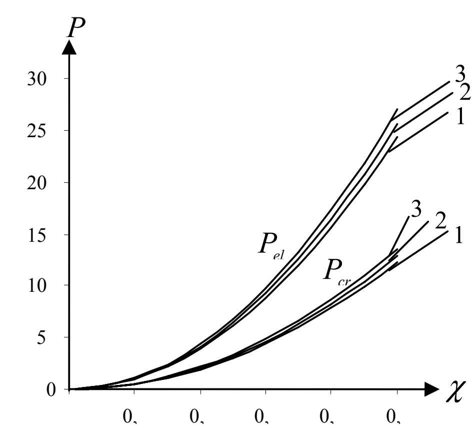


Figure 6. Dependence of critical pressures on parameter of thinness. $P_{el.}$ - Euler critical load (uniaxial compression along axis of the cylinder); $P_{cr.}$ - critical load under uniform compression, when internal impact on cylindrical surfaces is given as conservative loads.

Numbers 1 – 3 in graphs correspond to the numbers of phase transitions indicated in **Table 2**.

Parameter of thinness χ is determined on formula

$$\chi = m\frac{\pi}{l}R .$$

m - number of halfwaves; R - radius of cylinder; l - length of cylinder.

Discussion of results

1. It is possible to discuss about influence of uneveness of deformations on distribution of density with growth values of deformations on results given in **Fig. 1**. For example, growth value of density $\frac{\Delta\rho}{\rho} = 1,8$ in confining pressure ($\alpha = \beta = \gamma = 1$ - line 0) reaches under deformation $\varepsilon_0 = -0,21$. The same value of growth of density under decrease of value of vertical component of deformation ε_3 (under keeping constant values of horizontal components of deformations ε_1, ε_2) is obtained in too growth of value ε_0 (lines 1-3). All is on the contrary (lines 4-5) under increase of values of vertical component of deformation ε_3 (in keeping constant values of horizontal components of deformations ε_1, ε_2). Thus, unevenness of deformation influences too much (perhaps several times) on distribution of density of medium with growth of depth. Depending on change of configuration of unevenness of deformation of growth values of deformations could lead both to increase and slowdown of consolidation process.

2. Experimental results of Ringwood, Mezera, Akimito and Lin-gun Liu on interrelation of values of pressures, temperatures, depths of phase transitions for various mineral systems depending on their molar composition (Jarkov, 1983) are well known. They had been received in assumption of continuous deformation of tested homogenous samples. There is no opportunity to verify this assumption in natural conditions of depth of mantle. Therefore direct transfer of these experimental results to natural conditions of mantle and conducting in this base the interpretation related with depths and pressures of phase transitions could lead to incorrect results. The above results (**Table 4-8** and **Fig. 6**) show that under presence of various kinds of inclusions, free and contacting surfaces and cavities in geological structure the process of deformation occurs otherwise than assumed in experiments. Occurred stress-deformed states and distribution of density with growth of depth are changed in these conditions and may have significant influence on further processes of deformation, phase transitions and on their interrelation. Experimental results obtained for olivine $(Mg, Fe)_2 SiO_4$ and pyroxine system (Mg, Fe) SiO_3 with results shown in **Fig. 3** had been compared for clarification of these questions. They are shown in **Fig. 7-9**.

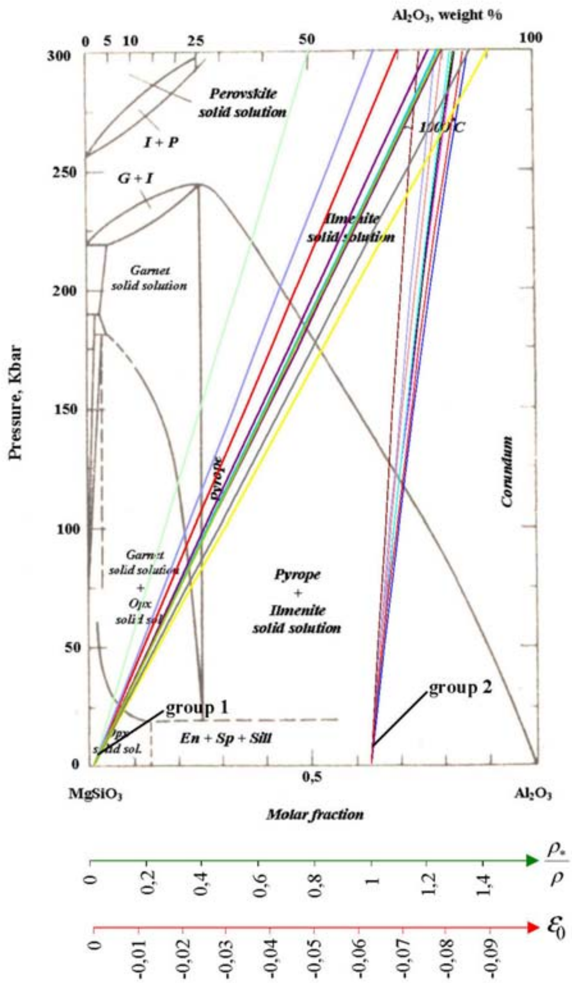


Figure 7. Isothermal section (T ~ 1000ºC) of phase diagram MgSiO3 –Al2O3. Notation: Opx-orthopyroxene, En-enstatite, Sill- sillimanite, G-garnet, I-ilmenite, P-perovskite, Sp-spinel (author Lin-gun Liu in Jarkov, 1983). The results of **Fig. 3** are shown by colored lines. Group 1 – dependencies between pressures and deformations; group 2 – dependencies of growth of density on pressure.

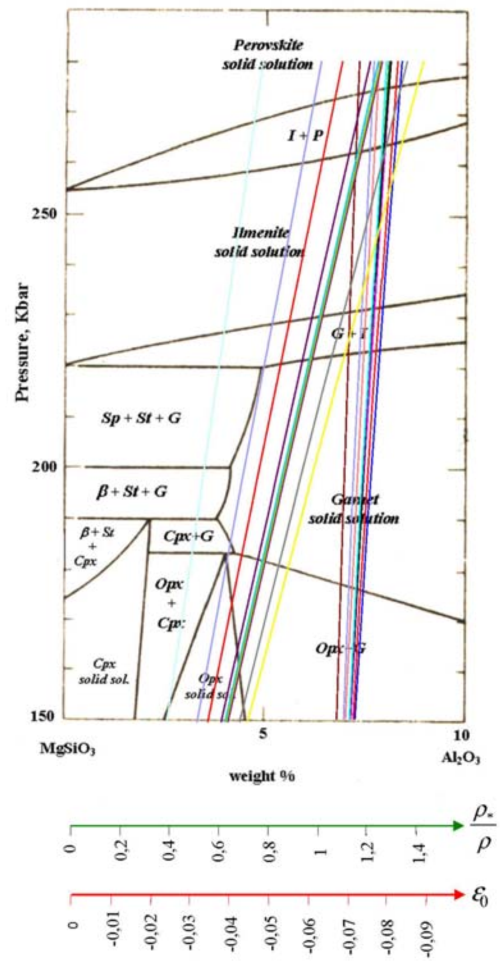


Figure 8. Isothermal section (T~1000º) of area of phase diagra**m MgSiO3-90% MgSiO3 ·10% Al2O3 in enlarged form** in the area of pressures 150-290 Kbar. β and Sp-β and γ-phases of olivine, St-stishovite, Cpx - clinopyroxene (author Lin-gun Liu in Jarkov, 1983). The results of **Fig. 3** are shown by colored lines.

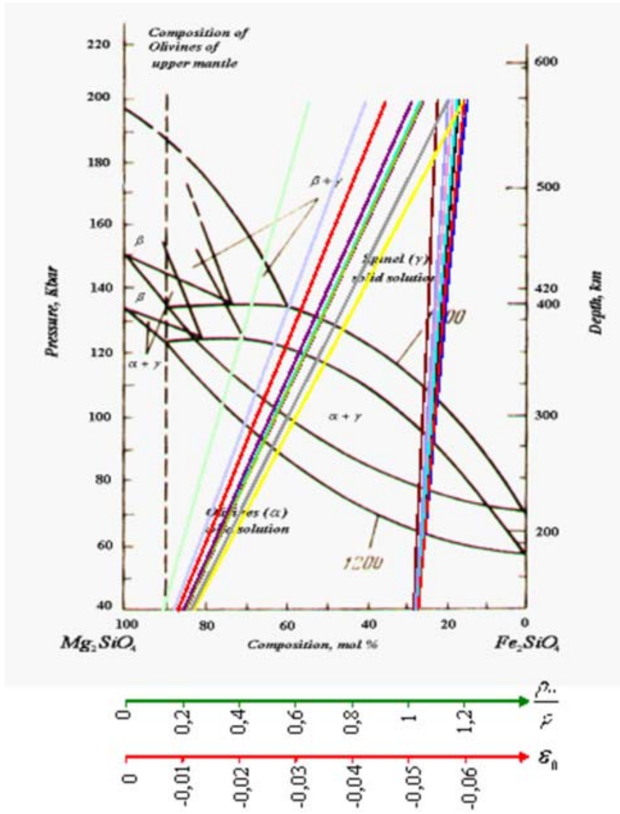


Figure 9. Phase diagram of system $Mg_2SiO_4 – Fe_2SiO_4$. Two combined isothermal sections at 1200 and 1600°C are shown. Section at 1600°C had been constructed by extrapolating of experimentally received sections at 800, 1000 and 1200° C. The composition indicated in molar percentages on axis of abscissa , on axis of ordinates – pressure in kilobars (left) and corresponding depths in the Earth (right), α - olivine phase, γ - spinel phase, β - phase of modified spinel (Author Akimito in Jarkov, 1983). The results of **Fig. 3** are shown by colored lines.

Values of pressures (on vertical axis), deformations (on horizontal axis – red axis), density (on horizontal axis – green axis) and molar fraction of composition on x-axis correspond to each points in given lines. Comparison of these results with the results shown in **Table 4-8** and in **Fig. 6** allows to discuss the influence of growth of pressure P on the process of deformation, distinguish the stability state and instability of olivine and pyroxene system in various molar compositions. In particular, it follows from the results of **Fig. 6** that the inclusion of elastic equilibrium state in enough small values of pressures and deformations is instable in presence of straight linear cylindrical (complete) form in geological medium. Values of critical pressures and deformations with growth of parameter of thinness increase nonlinearly. Consequently, the process of loss of stability of elastic equilibrium state on geometric shape change may quietly precede the process of phase transition. This may radically change the interpretation of experimental results. As a result of loss of stability of equilibrium state, the structure of medium can be curved at stresses which (stress corresponding to $(\varepsilon_0)_*$) is considerably smaller in size than stresses of phase transitions. Internal balanced stresses (Guliyev, 2010) are additionally happened due to curvatures in the structure of the samples. The sum of external and internal (arising due to curvature of the structures) stresses may be sufficient for phase transitions. Consequently, it is possible the phase transition not reaching the proposed depths. In another variant, these self-equilibrated stresses in local zone may have a different sign than the lithostatic pressure. The value of total pressure will be less in this case. If the value of lithostatic pressure was close to the pressures of phase transition, due to indicated mechanism, phase transition will not be realized at a given depth. It is necessary to go deeply into further for this reason. It is possible to interpret the results of comparison of data of **Table 4-8** with experimental results in presence of cylindrical cavities, free and contacting surfaces analogically. Herewith, there is opportunity to study the influence of values (small and large) of deformations on considered processes within the framework of various theories of initial deformations.

3. It follows from these results the possibility of realization of process of deconsolidation through the way of shooting the walls of cylindrical cavity at much lower stresses $\left(S_{11}^{0}\right)_{*}$, (stresses corresponding to $\left(\varepsilon_{0}\right)_{*}$), than stress $\left(S_{11}^{0}\right)^{*}$ corresponding to the limited strength (stress corresponding to $(\varepsilon_{0})^{*}$) of rocks.

This mechanism is related with the fact that the loss of stability of equilibrium elastic state is happened and the structure is curved long before the achievements of theoretical limits of strength $(\varepsilon_{0})^{*}$ of medium. As a result of this process the surface of a cylindrical cavity is "shot" (the mechanism of destruction through "shooting" is well known in mining mechanics; many accidents in coal mines are precisely happened on this mechanism) and the destruction is happened and the cavity is filled with loosened rock. Similarly, we can show that such mechanisms of destruction and deconsolidation can also be realized in the vicinities of flat surfaces, and other forms of inclusions and cavities. In particular, it is seen from the results of **Fig. 8** that the critical force of stability is growing with growth of values $\frac{R}{\ell}$.

Corresponding ratio $\frac{R}{\ell}$ is decreased with increasing number of half-waves of loss of stability m.

Consequently, the thinner cylindrical bodies transit to the curved (with many harmonics) form of the equilibrium as a result of loss of stability of rectilinear form of equilibrium in minor compressions. Herewith, the realization of process of destruction caused by additional stresses of curvatures and loosening of rocks are more likely. The presence of "dead" impact on the cylindrical surface leads to the decrease $P_{cr.}$ in comparison $P_{el.}$. The comparison of these results with the results of **Fig. 7-9** shows that the process of loss of stability of equilibrium elastic state is preceded to the processes of phase transition for considered values of χ in the considered case. For small values χ, value $P_{кр.}$ is an order and less, than value of pressure of phase transition.

4. Comparison of results of **Fig. 8** with results of **Fig. 1** shows that, the growth of density with growth of values of deformations is instable. As a result of this instability, the process of growth of density could transfer to the process of deconsolidation. As a result, deconsolidation zones (zones of small shear resistances, waveguides) are formed in determined mining-geological conditions in various depths of mantle (and also in the crust) on various mechanisms (one of possible mechanisms is given in item 3 of the given discussion).

5. According to instability conception it is considered that when approaching the values λ_1^{*} and P^{*} near the cylindrical cavity a brittle fracture takes place under great and small initial deformations accordingly. From results given in **Table 4-8** it is seen that as at small and great initial deformations in case of realization in vicinity of cylindrical cavity of homogenous stressed states, the process of loss of stability of elastic state of equilibrium precedes the process of destruction. The most reliable results from these results are given in **Tables 6** and **7**. It is related with the fact that all the same the scales of deformations refer to the class of large deformations and quadratic elastic potential is more adequate model of process of deformation for the considered rocks. Seen that, linear elastic model of isotropic medium is very crude and its use leads to curved results, although they correctly reflect the observed tendencies of deformation and process of consolidation as a whole, and can quietly be applied in case of small deformations.

The abovementioned results show that there is a possibility of precedence of process of the stability loss of the elastic state of equilibrium to the processes of the plastic deformation, phase transitions and brittle fracture. Thus, when assessing the stressed state in every specific case it is also necessary to check the possibilities of realization of these processes' subsequence. The pressure of phase transition, the magnitude of destructive forces, and character (types of destruction) of process of destruction will change in case of precedence of the process of loss of stability of elastic state of equilibrium to these processes. At the same time the above mentioned simple analytical expressions can be used for critical forces and shortening coefficient.

The obtained numerical results decisively show that the specific processes of consolidation and deconsolidation are realized in different depths of bowels of the Earth as a result of deformed processes. These processes promote the formation of foci of the compressed mass together with the relevant structural changes.

These masses begin to move and form various mass flows in the process of further evolution of internal structures on different mechanisms.

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RADIO ANOMALIES AND VARIATIONS IN THE INTERPLANETARY MAGNETIC FIELD USED AS SEISMIC PRECURSOR ON A GLOBAL SCALE

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Abstract: The monitoring of radio anomalies, which has been going on constantly since 2009 at the LPTA station near Rome, Italy and a comparison of these results with variations in the Interplanetary Magnetic Field, have allowed not only a study of these two physical phenomena but also their relationship with the occurrence of earthquakes on a global scale at a magnitude that is generally greater than 6. From experience gained in the field, it has been found that strong seisms are normally preceded by the appearance of radio anomalies anywhere between a few minutes to some hours earlier. The association of radio anomalies with seismic precursors is not universally recognised and for this reason has not yet been properly classified. Consequently, this study proposes to call "Global Seismic Precursors", that category of antecedents identified by instrument readings which correlates radio anomalies with "characteristic variations" in the Interplanetary Magnetic Field. Both of these values, compared and related to one another, indicate the approach of a potentially destructive seism at a global scale. Unfortunately, this method as it stands, despite positive results in applying it, does not yet allow us to pinpoint the location of the epicentre. For this category of Electromagnetic Seismic Precursors, it is also possible to compare the results on a temporal scale – in order to validate them – with magnetic anomalies recorded by other stations located around the Earth, even where these are far apart.

Keywords: *radio anomalies, interplanetary magnetic field, global seismic precursors, seismic markers, electromagnetic seismic precursors*

INTRODUCTION

The aim of this work is to propose a new category of precursors, here names "Global Seismic Precursors", which represent certain signals that normally precede, by anywhere from a few minutes to some hours, potentially destructive earthquakes, which, in the main, have a magnitude of more than 6.

The investigation procedure is based on the appearance of radio anomalies along with characteristic variations in the Interplanetary Magnetic Field (IMF) which frequently manifest before an earthquake. The data are collected continuously, 24/7, by the LPTA station, Rome, Italy (www.**ltpa**observer**project**) (**Fig. 1**).

Global Seismic Precursors differ from traditional ones because they do not necessarily manifest in the future epicentre zone via physical, chemical or other types of signal, but merely indicate, that "before long" a potentially destructive earthquake is going to occur. However, if on the one hand the method has proved useful on a temporal scale producing encouraging results, on the other, it provides no indications on the actual location of the epicentre. Instead the latter objective may be achieved by using several investigation methods simultaneously such as, for example: satellite detection of infrared precursors (Saraf and Choudhury, 2005), Geoeruptions and Vapour Clouds (Shou, 2007 and 2011), earth lights (Straser, 2007), thermal anomalies (Leybourne et al., 2006), energy transmigration (Blot et al., 2007; Choi and Maslov, 2010), or radon gas emission (Chyi et al., 2005; Singh et al., 2010).

In instrument terms, the radio anomaly manifests on the monitor as a small horizontal line coloured according to the magnetic intensity, in a range of the lowest frequencies and associated with background "noise", as can be seen in the spectrogram in **Fig. 2**.

To analyse spectrograms of radio anomalies we also need a colorimetric scale to estimate the value of the magnetic field associated with it (Straser, 2011). A radio anomaly may be defined as an unknown radio emission that has no characteristics (duration, extension, intensity, etc.) compatible with:

- IAGA classification (International Association of Geomagnetism and Aeronomy) of geomagnetic pulsations;
- Emissions of an anthropic type
- Known natural emissions (Whistler, Chorus, lightning strikes, electrophonic meteor sounds, plasma, etc.). The association of radio anomalies with seismic precursors is not universally recognised and for this reason has not yet been properly classified.

Figure 1. Index map. The blue circle indicates the LPTA Project monitoring zone, near Rome – Italy, 41°41'4.27" N; 12°38'33.60" E

The majority of radio anomalies are observed below 32 Hz (generally between 0.1 and 20 Hz). The only known emissions in the ELF and SLF bands are of a magnetospheric or Alfven type. To be precise, between 0.1 and 10 Hz, it is possible to observe emissions linked to the Alfven cavity, and this type of emission falls within the range of frequencies where radio interference appears.

The frequencies of Electromagnetic Seismic Precursors (ESPs), including radio anomalies, cover a vast waveband. At the epicentre of the seism an emission may be observed that has a wide waveband ranging from 0.001 Hz to hundreds of MHz. With increasing distance, however, the higher frequency emissions gradually wane until they disappear entirely while ELF emissions from 0.001 to 3 Hz remain visible. This phenomenon is linked to attenuation by the materials the waves encounter. For this type of investigation it is only possible to listen to emissions lower than 1000 Hz since these are subject to virtually zero attenuation, and as a result permeate tens of thousands of km of rock without waning.

The background "noise", observable between 0 and 20 Hz (**Fig. 2a**) consists of both natural and anthropic emissions. Anthropic emissions come from electromagnetic "noise" generated by long-distance, high-voltage powerlines for the railway which have a frequency of 16 Hz with concurrent 8Hz and 32 Hz harmonics (not always visible). Below this frequency there are random occurrences of a 3 Hz source, once again generated by trains, however no objective examinations have been made of this. Apart from these

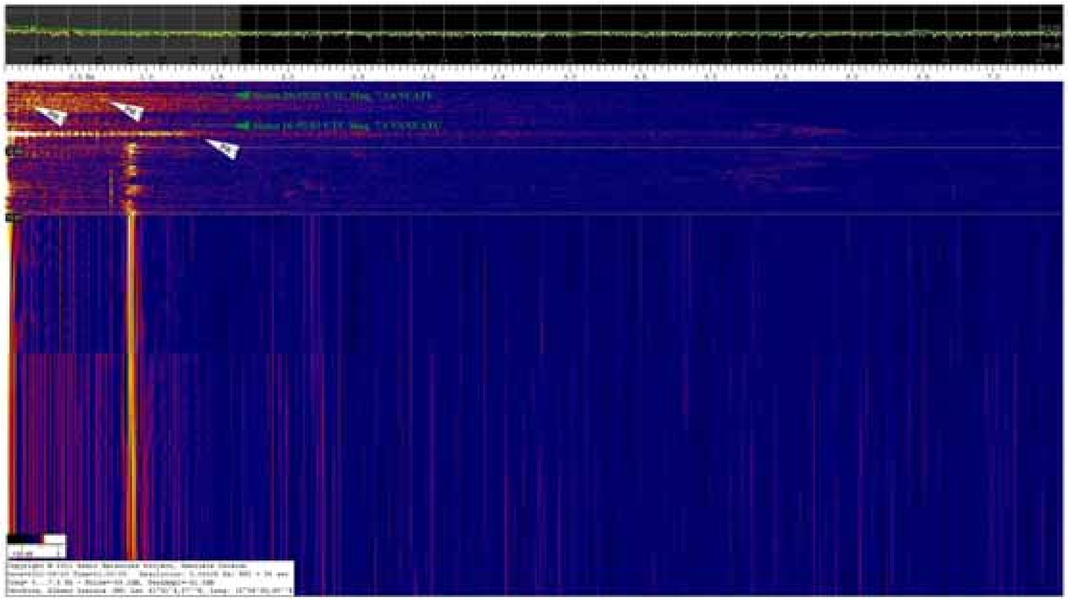

Figure 2. The radio anomaly can be seen on the left of the spectrogram, indicated by the initials ESP (ESP – Electromagnetic Seismic Precursor) and a white arrow. The perturbation appears in the range of low frequencies and is distinguished from the others by its elongated horizontal shape. The spectrogram also indicates the seisms associated with radio anomalies, shown by the green arrows (courtesy of Gabriele Cataldi).

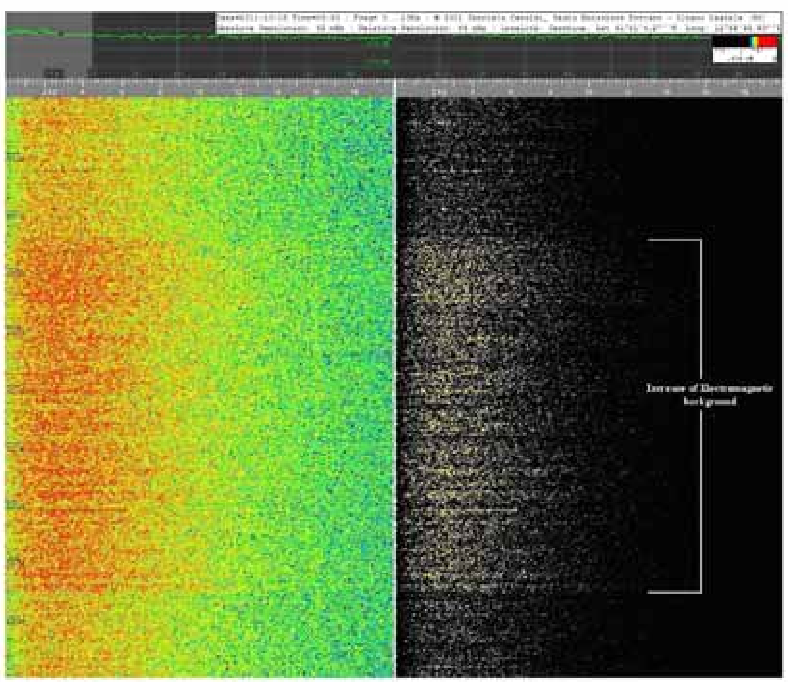

Figure 2a. Increase in background noise highlighted on the left of the spectrogram, and indicated by red shading (courtesy of Gabriele Cataldi).

anthropic sources there are no other similar emissions, save for resonance harmonics from the 50 Hz domestic mains supply. These harmonics are easily recognised, however, since being harmonics, they feature mirror-like “sister” emissions at the same distance, starting from 50 Hz. Except for these signals, the remaining background noise is generated by natural sources. By "natural sources" are meant: The Sun (solar wind which produces geomagnetic pulsations, interacting with the magnetosphere), electrical phenomena in the atmosphere lightning and storms), longitudinal and transverse resonance emissions from the Earth/ionosphere cavities (including Schumann's resonance), emissions from the Earth/magnetosphere resonance cavities, and the Alfven cavity (magnetohydrodynamic waves, magnetospheric resonance), natural pre/peri-seismic emissions.

In addition, the ESPs can be observed at every point of the Earth's surface at frequencies from 0.1 to 5 Hz, i.e. the same frequency range where PC1-type geomagnetic pulsations may be detected. For this reason, ESPs are observed as part of the radiation produced by the Earth's magnetosphere cavity. Furthermore, this cavity can be subject to alterations from the irradiation of such natural sources as ESP, and cause alterations in the intensity of geomagnetic pulsations.

ESPs and Geomagnetic Pulsations are not the same thing however, and should not be confused. Both are detected in the same frequency band seeing that: geomagnetic pulsations are the result of solar activity interacting with the magnetosphere, and these interactions generate emissions with a very low frequency. ESPs, on the other hand, are emissions which can have a very wide spectrum, but only emissions which fall below 5 Hz have a sufficiently high intensity and frequency as to be able to permeate the body of the planet and be detected everywhere. Furthermore, some of these emissions can create perturbations of the Alfven cavity and cause alterations in the geomagnetic pulsations, which can likewise be observed using bobbin antennas.

From a chronological point of view, the first instruments use for detection of ESP were receivers that used different types of antenna at the same time since the exact wavelength of this type of signal was unknown, hence it was considered indispensable to use different antennas to cover a vast range of frequencies.

Currently, use is made of radio receivers tuned to VLF, SLF, ELF and ULF bands. The antennas used are of the Loop or Bobbin type, and, in recent years, also Flux-Gate magnetometers have been used.

In this study, radio anomalies were compared both with data supplied by other monitoring stations (some even situated a considerable distance from Rome), and with characteristic variations in the Interplanetary Magnetic Field, monitored by the GOES 13 and 15 satellites (http://www.swpc.noaa.gov/Data/goes.html), whose data may be consulted online 24/7.

From in-depth analysis of the data starting from 2009, it has been noted that shortly before seisms of a magnitude of M>6, the IMF graph undergoes a slight deformation, drawing a characteristic "S" shape, denominated henceforth in this study by the Greek letter *sigma* "σ".

The figure shows the appearance of "σ" in the IMF trace during the Honshu earthquake on the 31st March 2011, where the characteristic variation known as 2 nT can be seen, a marker present in most of the cases studied (**Fig. 3**). In certain cases, the pattern of the IMF graph offers interesting analogies, bona fide seismic markers, that precede strong earthquakes, as can be noted, for example, in the sequence which occurred from the 22nd to the 24th of August 2011 (**Fig. 4**).

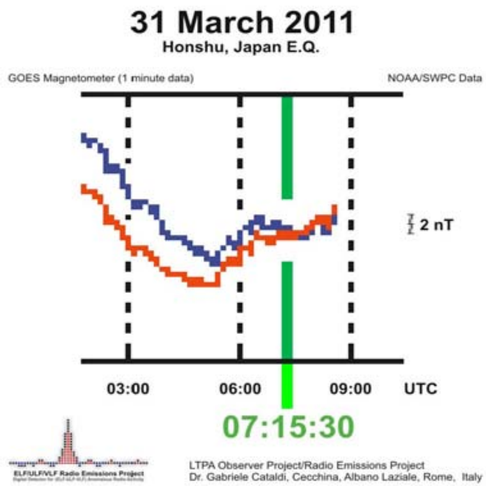

Figure 3. The figure shows the traces from the GOES 13 and 15 satellites, distinguished by their respective colours, blue and red. The vertical green line indicates the occurrence of a seism, in this case at Honshu (Japan) on the 31st of March 2011. The two graphs, corresponding to the Japanese earthquake, are superimposed along with their corresponding electromagnetic value of 2nT. In the figure can be noted the relationship between the "sigma" form of the curve and the earthquake.

In the three cases shown in **Fig. 4**, we can see the recurrence of the troughs indicated with the letter "A" which manifest when the IMF values are at a minimum. These peaks are followed, in the ascendant phase of the graph by a "hook", highlighted with the letter "B" which normally precedes by around 5 hours the appearance of the "σ" just a few minutes before the main shock.

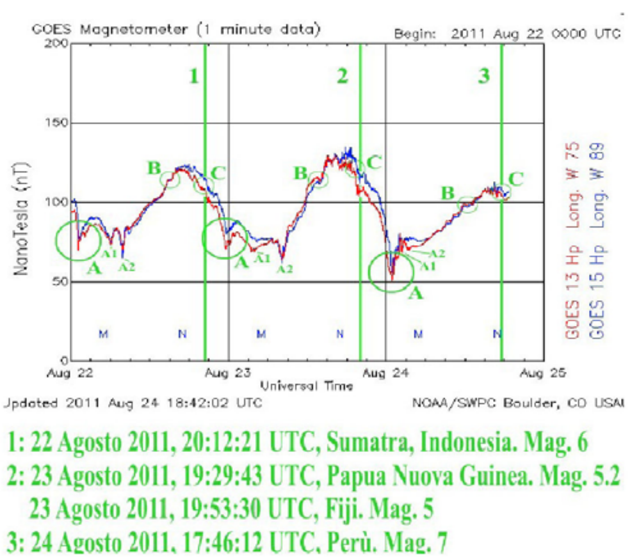

Figure 4. The figure shows the repetitiveness of particular shapes in the trace in relation to the occurrence of earthquakes. Among the minimum values appear three related values, indicated respectively by the letters A, A1 and A2. In the ascendant phase, after about 6 hours a ripple appears, indicated by the letter B, while the letter C indicates the seism, in relation to the sigma shape. This latter interval recurs about 5 hours after the letter B.

Both the variations in IMF and the radio anomalies, as discussed in this study, seem to be associated with one another, seeing that, habitually, the radio anomaly precedes, on a temporal scale, the appearance of "σ" in the IMF graph, from a few minutes to some hours before the earthquake. By way of explanation, see the example in **Fig. 5**, where the seismic marker is indicated in red, and where the occurrence of the earthquake corresponds to the "σ".

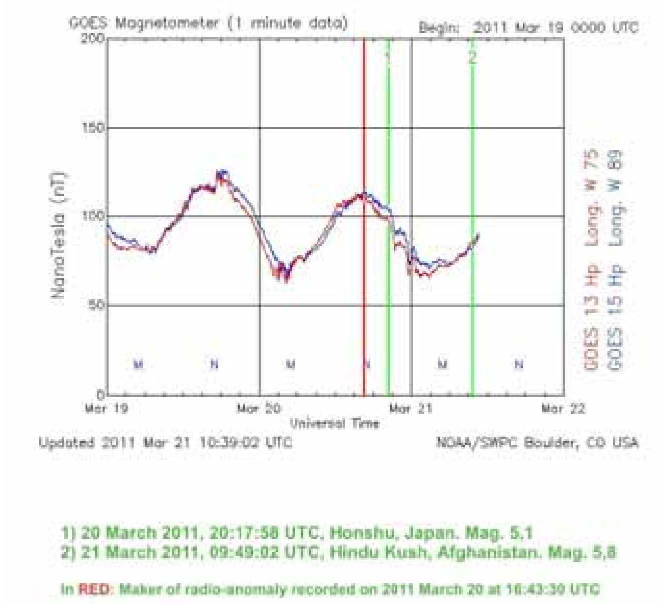

Figure 5. The graph shows the relationship between the appearance of the radio anomaly and the occurrence of two seisms, preceded by the sigma shape in the IMF curve.

Instrumental checks

As mentioned above, ESPs can be observed by several monitoring stations and compared with one another also on a temporal scale. In many cases, but not all, the same alterations in the natural magnetic background have been recorded at the same time, as in the case of the magnetometers of the HAARP Programme (http://137.229.36.30/cgi-bin/magnetometer/gak-mag.cgi) and the Kiruna Project (*www.lund.irf.se/helioshome/***magnetometer***data.html)*, some hours prior to strong seisms. This recurrence was repeated over the previous three years and also in 2011, in the cases of the earthquakes analysed in this study.

For our Method, comparison of data was feasible at a global scale, since the mechanism that gives birth to ESPs can be monitored even at great distances from the area of tectonic stress. In fact, some scientific studies have pointed out that crystals and rocks in general emit electromagnetic radiation just before shattering under mechanical pressure and also while breaking up (http://www.vlf.it/mognaschi/TERREM3.html). For example it has been calculated that energy emissions of 50 MegaW which occur underground at tens of km of depth, are able to prevail over electromagnetic background noise at 3 Hz (1mVm) and, consequently, this type of emission can easily be recorded by a number of monitoring stations.

Methods and data

The method used in this study consists in comparing data, recorded 24/7, on variations in IMF and, in particular, in identifying "σ" shapes in the trace close to the 2 nT value, with the appearance of radio interference as recorded by LPTA instruments at a monitoring station near Rome.

The LPTA station is equipped with a NASA INSPIRE VLF3 frequency data collector and a tri-axial magnetometer which are interfaced with a computer that records data 24/7 (**Fig. 6**). The IMF trace is recorded by the GOES 13 and 15 satellites which may be consulted online 24/7, in order to make a continuous comparison of radio anomaly data with other magnetometers such as, for example, those of the HAARP Programme and the Kiruna Project.

Figure 6. NASA INSPIRE VLF3 frequency data collector issued to the LPTA Project station near Rome.

Instruments used

a) Spectrograms

The spectrograms obtained by the station were recorded every 10 minutes; i.e. 1 horizontal line every 1,600 milliseconds. The data of the Spectrum Lab setting are as follows:
Effect of FFT settings with fs = 44.1000 kHz:
Width of one FFT-bin: 21.0285 mHz
Equiv. noise bandwidth: 28.5988 mHz
Max freq range: 0.00000 Hz to1.37813 kHz
FFT window time: 47.554s
Overlap from scroll interval: 96.6%

b) Colorimetric Scale

Using a colorimetric scale created by Gabriele Cataldi, the spectrogram colours represent specific values in relation to the type of signal produced. Normally, the so-called electromagnetic seismic precursors (ESP or ESS) reach on average 60 nT at 10 MHz (Fraser-Smith et al., 1990), however it is possible to study ESP at frequencies as low as 15 Hz (ELF and SLF bands), even if in practical terms, it is easier to study these signals at 30 Hz, without looking for "MHz". The colorimetric scale shows signals that reach 30 nT in red and in white those that reach 100 nT. In this way, all signals lower than 20 nT appear BLUE and can be easily distinguished from the others. Between 20 to 30 nT the blue changes to red. A deviation of only 10 nT between blue and red efficiently displays all those values of any significance on the one spectrogram. To make a comparison, it is worthwhile recalling that 30nT is equal to three times the magnetic field produced by an electric toaster measured from one metre away, which means that the value is undeniably significant in studying ESPs. Radio wave anomalies in spectrograms are shown in yellow (all the shades of yellow until becoming white), and surrounded by red. In this way we can be certain that we have before us a signal of intensity no lower than 65 nT (the first shade of yellow, which corresponds to intensity greater than that produced by a fluorescent tube 1 metre away).

c) Satellites

Data from satellite tracking system (Orbitron) are as follows:
(http://www.swpc.noaa.gov/Data/goes.html)
GOES 13 (Primary): orbiting at 35,809km; Long 74.5403° W; Lat 0.3317° S; Azim 272.3°; Elev -10.7°; RA 12 h 26 m 24 s; Decl. -7° 07' 04".

GOES 15 (Secondary): orbiting at 35,782 km; Long 88.9147° W; Lat 0.0344° N, Azim 284.2°; Elev -18.6°; RA 11 h 29 m 43 s; Decl. -6° 37' 18".

Discussion
The appearance of radio anomalies and corresponding variations in IMF have demonstrated instrumental analogies with data from other monitoring stations scattered across the Earth during the run-up to earthquakes with a magnitude greater than or equal to 5.5, and more frequently M>6. For each earthquake studied in this work a common pattern has emerged, i.e. an increase in background noise prior to the seism, a reduction in this closer to the shock and a subsequent rise in background noise and radio anomalies after the earthquake.

As an example, see the cases of the two earthquakes which occurred in the Vanuatu Islands on the 20th of August 2011.

First seism (see: www.usgs.gov/):
Magnitude 7.1
Date-Time Saturday: August 20, 2011 at 16:55:02 UTC
Location: 18.260° S, 168.069° E
Depth: 40.6 km (25.2 miles)
Region: Vanuatu

Second seism (see: www.usgs.gov/):
Magnitude 7.0
Date-Time Saturday: August 20, 2011 at 18:19:24 UTC
Location: 18.287° S, 168.132° E
Depth: 28.5 km (17.7 miles)
Region: Vanuatu

Both seisms were preceded by:
- the appearance of "σ" in the IMF trace (**Fig. 7a**);
- radio anomalies which preceded the seism by a few minutes (**Fig. 7b**);
- peaks in the magnetic background (between 0 to 20Hz), comparable on the temporal scale with the ESP recorded by the monitoring station near Rome (**Fig. 7c**);
- anomalies recorded by the HAARP induction magnetometer, comparable on the temporal scale with the LPTA trace **(Fig. 7d);**
- the Kiruna magnetometer, which displays an analogous temporal correspondence (**Fig. 7e**);
- the appearance of interference in the 400 – 5000Hz range, this too recorded by the LPTA station near Rome (**Fig. 7f**).

From experience in the field from 2009 onwards, it has been noted that *the greater the amount of radio interference, associable with the appearance of "σ" in the IMF trace, the greater is the magnitude of the earthquake* (Straser, 2011).

The mechanism hypothesised in this study is a stress produced underground that is able to emit electromagnetic waves, measurable instrumentally on the Earth's surface. Then to the possibility of detecting electromagnetic emissions not linked solely to variations in the magnetospheric background must be added propagation phenomena of Electromagnetic Waves from inside the Earth, similarly to seismic waves (Palangio, 1993; Palangio et al., 2007). Practically speaking, it is conceivable that the electromagnetic fields produced by a seism are able to propagate within the terrestrial crust and bounce off the innermost layers of the planet exactly as happens to a light ray when it crosses through transparent materials with refraction factors that differ due to varying density. All electromagnetic emissions with frequencies lying between 0 and 1000Hz can pass right through the planet without undergoing a reduction in intensity (Palangio, 1993; Palangio et al., 2007). This range also includes low-pressure plasma emissions, of the kind we can observe in our atmosphere. Consequently, it is hypothesised that the emission of electromagnetic waves produced during the run-up to seisms may create sufficient interference in the range of radio waves as to distort the IMF values and cause the appearance of "σ" in the trace recorded by satellite.

Furthermore, electromagnetic waves propagate differently depending on whether they travel through the atmosphere or underground. Electromagnetic waves travel more slowly underground than through the air. Instead, underground they can propagate by bouncing off the various layers and levels of density in the rocks. It is therefore clear that a data collector on the planet's surface can detect different signal at different times, but generated in the same areal zone, near the epicentre. Consequently, from what has been shown, the greater the radio anomalies, the greater the intensity of the stress produced underground.

The cases analysed in this study, which relate radio anomalies to variations in the magnetic field and distortion in the IMF curve (formation of "σ"), can be grouped into at least three classes, i.e. relating to earthquakes with a magnitude of M5 to 6, M>6 and M>7. In each case certain characteristic elements tend to recur, even though not always.

1) For this case we might consider the magnitude 5.1 earthquake which occurred in Spain on the 11th of May 2011. This type of seism has certain common features:

- Radio anomalies less frequent in run-up to main seism
- Temporal gap with absence of radio anomalies of around one hour before and after the earthquake.
- Radio anomalies following the earthquake
- Variations in IMF with the appearance of σ = 2nT
- Weak anomalies recorded by other magnetometers.

Seism: Magnitude: 5.1
Date-Time: Wednesday, May 11, 2011 at 16:47:25 UTC
Location: 37.699° N, 1.673° W
Depth: 1 km (~0.6 mile) set by location programme
Region: Spain

2) Instead, for this case we might consider the magnitude 6.7 earthquake which occurred in the Fiji Islands on the 29th July 2011. This type of seism has the following common features:

- Radio anomalies.
- Variations in IMF with the appearance of σ = 2 nT
- Abundant signals between 400 and 5000 Hz.
- Precursory radio signal between 0 and 20 Hz (up to 1' before seism).

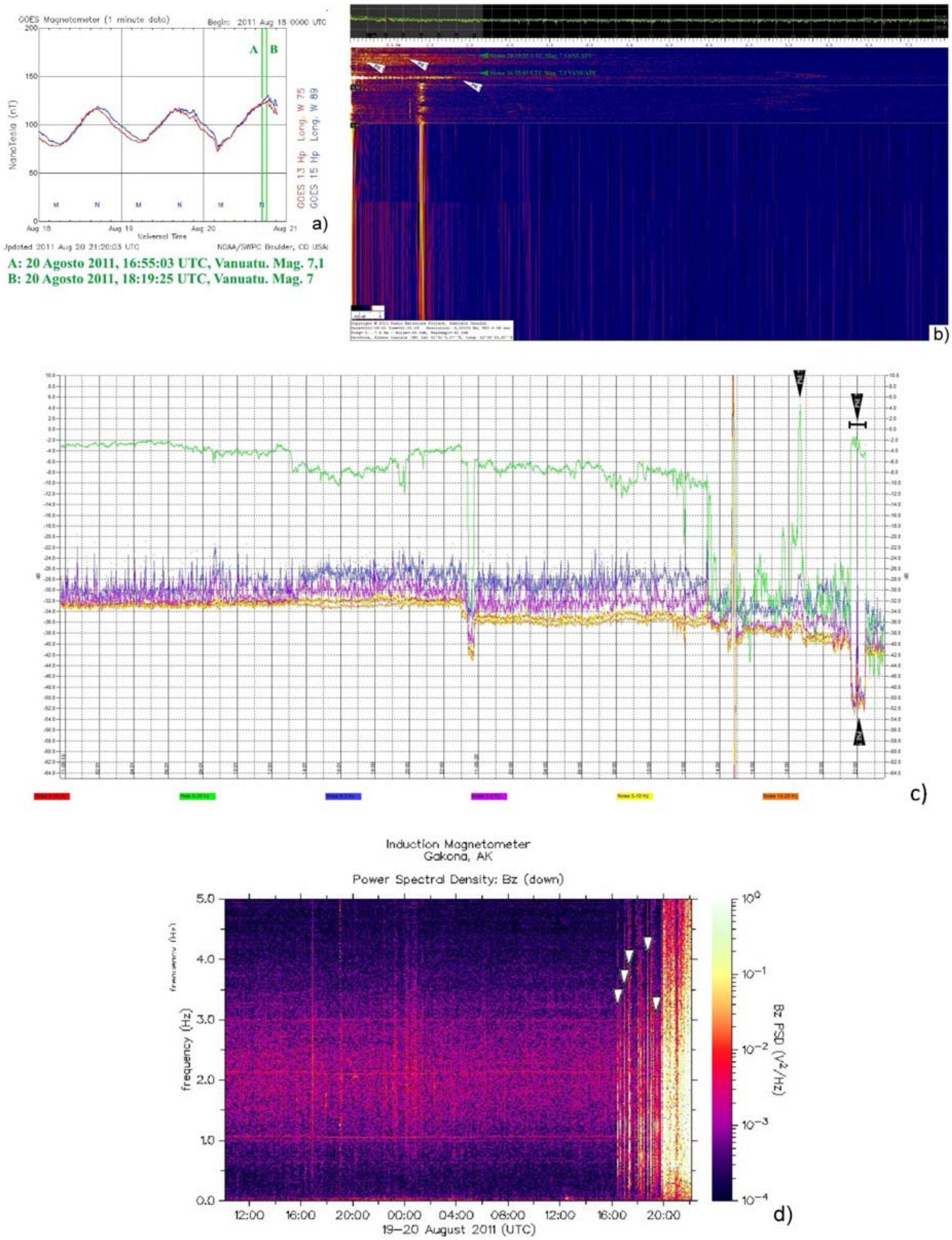

Figure 7. See next page for caption.

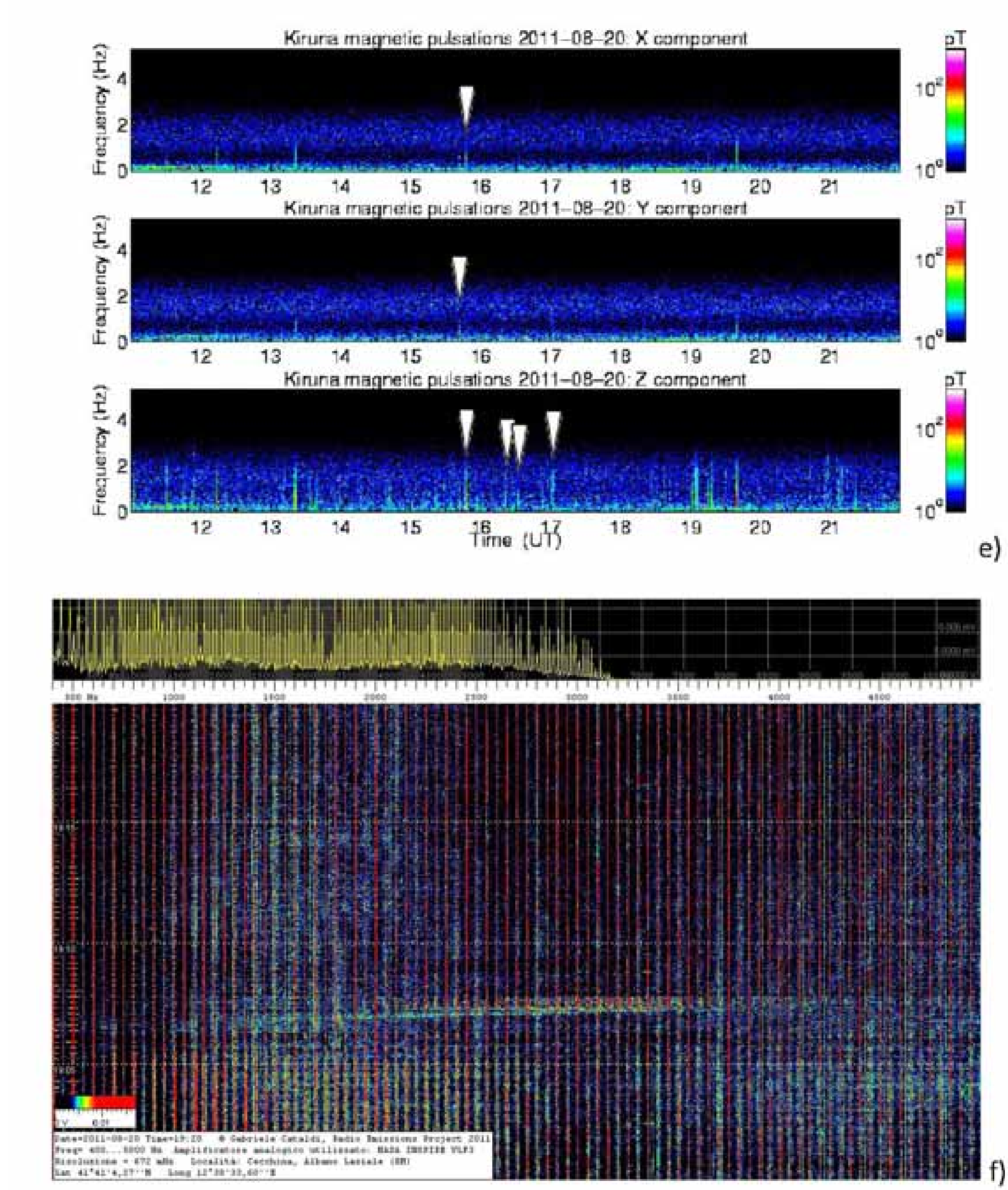

Figure 7. Earthquake data associated with anomalies. a) GOES satellites 13 – 15; b) Radio anomalies; c) Precursory signal between 0 and 20Hz; d) Induction Magnetometer – Gakona (AK) and Kiruna (e) magnetic pulsation; f) LPTA Project trace from 400 to 5000Hz.

Frequent absence of anomalies recorded by other magnetometers (e.g., HAARP, and Kiruna).

Seism: Magnitude: 6.7
Date-Time: Friday, July 29, 2011 at 07:42:23 UTC
Location: 23.651° S, 179.822° E
Depth: 521.7 km (324.2 miles)
Region: South of the Fiji Islands

3) Lastly, for this case we might consider the magnitude 9.0 earthquake which occurred in Japan on the 11th of March 2011. This type of seism has the following common features:

- Significant increase in the number of radio anomalies 10 days before the main shock, with a sharp fall in the total number of radio anomalies on the day of the main shock and a rapid renewal of anomalies the following day (Straser, 2011).
- Increase in geomagnetic field anomalies.
- Increase in the geomagnetic activity index.
- Variations in IMF with the appearance of σ = 2nT
- This shows the radio anomaly that preceded the Japanese seism.
- In this case the appearance of σ in the GOES curve is more accentuated.

From what has been discussed so far, and on the basis of the three types of case analysed, the following interpretative model may be hypothesised, here summarised in three distinct phases.

First phase: As a result of the stress the rocks undergo, electromagnetic signals are produced, which manifest as interference of various kinds recorded by ground and satellite instruments (**Fig. 8**).

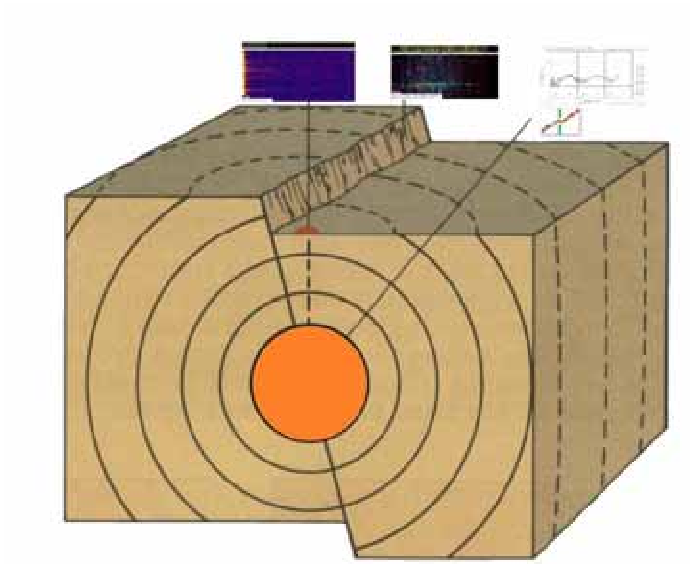

Figure 8. As a result of the stress the rocks undergo, electromagnetic signals are produced, which manifest as interference of various kinds.

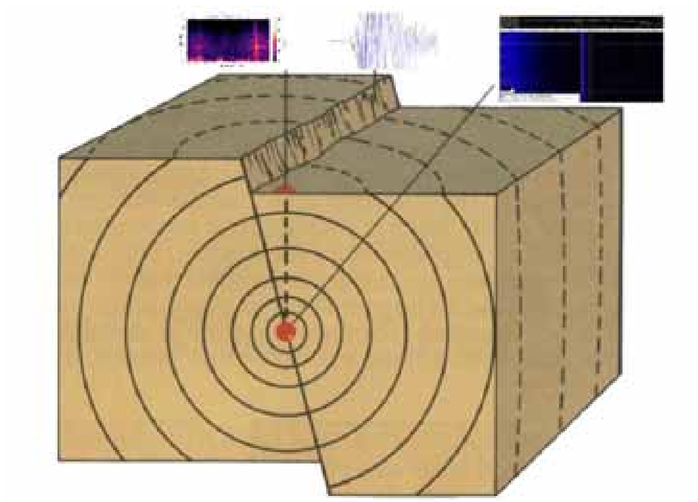

Figure 9. As the stress gradually dissipates, also the electromagnetic signals produced by the rocks diminish to eventually cases for a while (from a few minutes to an hour) before a seism.

Second phase: As the stress gradually dissipates, also the electromagnetic signals produced by the rocks diminish to eventually cease for a while (from a few minutes to an hour) before a seism (**Fig. 9**).

Third phase: The new equilibrium the rock finds determines the appearance of new stress with the emission of fresh electromagnetic signals (**Fig. 10**).

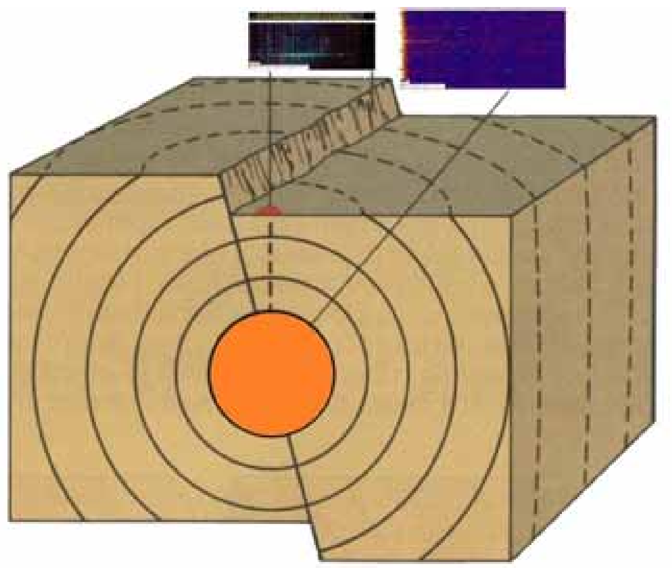

Figure 10. The new equilibrium the rock finds determines the appearance of new stress with the emission of electromagnetic signals.

Conclusions and Suggestions

From experience gained in the field, we can say that since crust stress is proportional to the number of radio anomalies produced, this Method, which is proposed as a way to identify seismic triggers, may be applied at a global scale for particularly violent seisms that are potentially destructive for mankind. One of the limits in applying this Method consists in the difficulty of identifying the location of the epicentre, however it does provide encouraging data on the amount of energy of the seism and the time of occurrence, with a temporal interval that varies from a few minutes to some hours before the earthquake. The location of the epicentre can be estimated using other methods of investigation. Because of this characteristic, this study can be applied in synergy with other methods used to investigate seismic precursors. In fact, by now the mass of data is such that we might attempt a leap in quality by organising a research group which brings together various disciplinary skills useful in arranging the data available into a specific model that could lead to a more calibrated definition of seismic risk at a global scale.

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A POTENTIAL RELATIONSHIP BETWEEN THE CLIMATE, EARTHQUAKES AND SOLAR CYCLICITY IN THE NORTHWEST APENNINES (ITALY)

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Abstract: An association between meteorological phenomena and earthquakes, solar cyclicity and seismicity on the Earth has been passed down orally in many cultures around the world. The province of Parma (North Eastern Apennines – Italy) offers many elements of coincidence between three phenomena; physical, geophysical and astronomical. In this study also local historic landslides in the area under investigation have been considered, because if we admit that the Sun and other celestial bodies can influence the equilibrium underground, this is all the more reason to believe that their influence produces perturbations among subaerial gravitational phenomena too. Analysis of the data has shown that gravitational movements do not reactivate randomly but, instead, seem to be synchronised with solar activity. Analysis of the data in conjunction with an investigation into the past has permitted forecasts for the current year too. The recent tragic events in October and November 2011, only confirmed the fact that the recurrence of floods in Northern Italy manifest more and more frequently in close proximity to the solar maximum. Similarly, also the major earthquakes and seismic swarms in the area under investigation, proved to be dependent upon solar cyclicity.

Keywords: *Solar cycles, earthquakes, climatic variations, historic landslides, angular momentum of Jupiter*

INTRODUCTION

One of the objectives which the natural sciences set themselves is the forecasting of natural phenomena in the short, medium or long term. Science's contribution in supporting anthropic activities and in ensuring the safety of mankind is therefore a priority, for example when it comes to dealing with exceptionally intense atmospheric phenomena, hydro-geological instability, or earthquakes.

This study presents a potential relationship between solar cyclicity, atmospheric conditions and earthquakes, variation in solar energy over time, and the influence exercised by changes in the centre of mass (CM) of the Solar System, as well as variations in the Orbital Angular Momentum (OAM) of the Sun, dependent upon the distribution in space of the masses of the major planets: Jupiter, Saturn, Uranus and Neptune.
The area under investigation lies in the North Western Apennine, in the province of Parma, and stretches around the 45th latitude of the Boreal Hemisphere **(Fig. 1)**.

For the analysis in this study various factors were examined: the first concerns the occurrence of earthquakes with an intensity greater than 6 and a magnitude greater than 4, in the period from 1831 to 2008 inclusive. Neither the intensity nor the magnitude of the seisms considered were particularly significant on an absolute scale, but were important at a local level (Petrucci et al., 1996) since they took place at recurring intervals of time, in an environment where seisms manifest a dozen or so times a year, but do not normally exceed a Magnitude of 3. For this reason, the earthquakes considered in this study do represent important events from a seismic point of view at a local level.

A second element of analysis consisted of a comparison of the flow of a watercourse, the Baganza Stream, which may be considered "median" with respect to the area under investigation. The value of the average annual flow, even though impacted by contributions from its tributaries and works of hydro-geological mitigation, may be considered a function of the precipitations over a determined period of time **(Table 1)**.

A further element considered in this study is the tendency to landslides, since this depends upon precipitations and, therefore, at the end of the day, on water. Moreover, if we admit that the action of the

Sun and particular planetary configurations can influence the equilibrium of rocks underground, then there is all the more reason to believe that these stresses can also manifest on the surface, above all with regard to major hydro-geological instability. The province of Parma, with more than 7,000 landslides, 5 of which are amongst the most extensive in the European continent, is particularly well suited to this type of investigation. Two examples: the territory of Bardi, with a perimeter of around 100 km contains 1,656 areas of instability, that of Neviano, at just over 60 km, has 1,055 landslides (www.regione.emilia-romagna.it/).

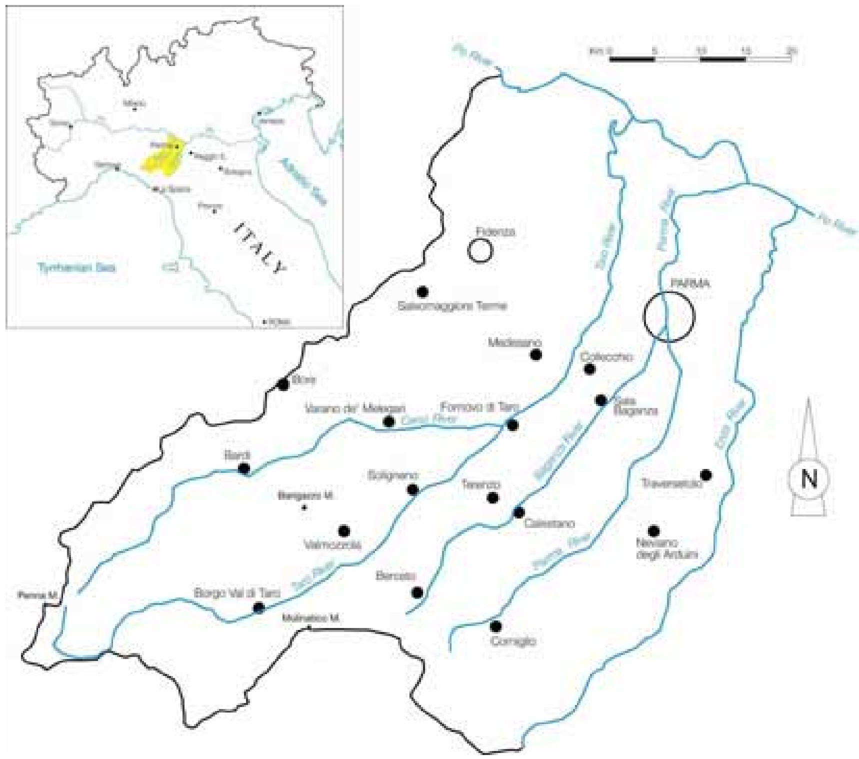

Figure 1. Index Map. The area under investigation is situated in the Province of Parma (Italy) in the North Eastern Apennine Mountain Range.

Table 1. Main earthquakes in the province of Parma from 1831 to 2008.

No.	Year	Intensity or Magnitude	Epicentre
1	1831	I=7	Parmense
2	1834	I=7	Parmense Ap.
3	1835	I=6-7	Cisa Pass
4	1849	I=6-7	Val di Taro
5	1857	I=6-7	Parmense
6	1886	I=7	Parma East
7	1897	I=7-8	Langhirano
8	1898	I=7	Calestano
9	1906	I=6	Compiano
10	1927	I=7	Bedonia
11	1934	I=6	Borgo Val di Taro
12	1934	I=6	Corniglio
13	1937	I=6	Parma West
14	1946	I=6	Pione (Bardi)
15	1958	I=6	Collecchio
16	1959	I=5-6	Santa Maria del Taro
17	1965	I=6	Corniglio

18	1971	I=8	Parma West
19	1972	I=6-7	Calestano
20	1983	I=7	Parma South-west
21	1995	M=4,2	Parmense
22	1996	M=4,1	Parmense
23	2007	M=4,2	Parma-Piacenza
24	2008	M=5,1	Parma- Reggio Emilia

DISCUSSION

SEISMICITY

Let's begin from a general pattern. In the graph (**Fig. 2**), which matches global earthquakes to sunspots albeit with some temporal lag, we can see a correspondence between solar cyclicity and the number of earthquakes which occurred between 1973 and 2010, revealing that, at the solar minimums and maximums, there was a corresponding increase in the overall seismicity of the Earth (Straser, 2011). Other relationships between global seismicity and solar activity have been suggested by Zangh (1988) and Gousheva et al. (2003). If, instead, we consider sunspot activity in relation to earthquakes with a magnitude greater than 6.5, we can see that, while fitting the previous pattern, seismicity tends to sharp increases that correspond to the solar maximums, as shown by the cusps in the earthquake graph (Choi and Maslov, 2010; Straser, 2011).

If we pass from the global to the local scale (i.e. to the area under investigation), we can see that amongst the "strong" earthquakes in the Parma region that occurred between 1831 and 2008, 10 earthquakes manifested in correspondence with the solar minimum, 5 in correspondence with the maximum, and 9 in the waning phase of solar activity, i.e. in the seven years that pass between the solar maximum and the ensuing minimum. The data, if related to this context, reflect the global pattern described by Choi and Maslov (2010).

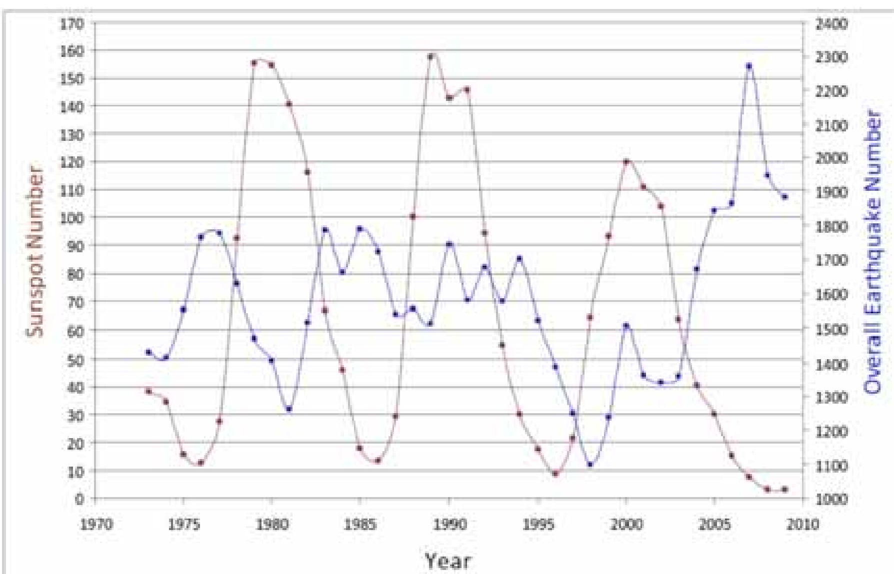

Figure 2. Sunspot number vs. total number of earthquakes from 1973 to 2009.

PRECIPITATION

As regards precipitation, also in this case the overall pattern for Italy was considered first, and was then compared with the local situation. If we compare the maximum values of the average precipitation levels in Italy from 1861 to 2001 (**Fig. 3a**), we can observe a regular pattern of events, occurring every 10 years. Exceptions, during the period under consideration, are the years 1891 and 1941, due to the absence of abundant precipitations. The cyclicity of particularly intense atmospheric phenomena follows (ignoring certain lags) the rhythm of the solar cycles, with a preponderance of maximums compared to minimums (1901, 1911 and 1936). In particular, over the last four decades, if we are considering 2011, the precipitation maximums to all intents and purposes coincided with the solar maximums. Instead, the remaining ones, i.e. those of 1861, 1871, 1021, 1931, 1951, 1961 and 1971, are about 1-2 years out of phase with the solar maximums (**Fig. 3b**).

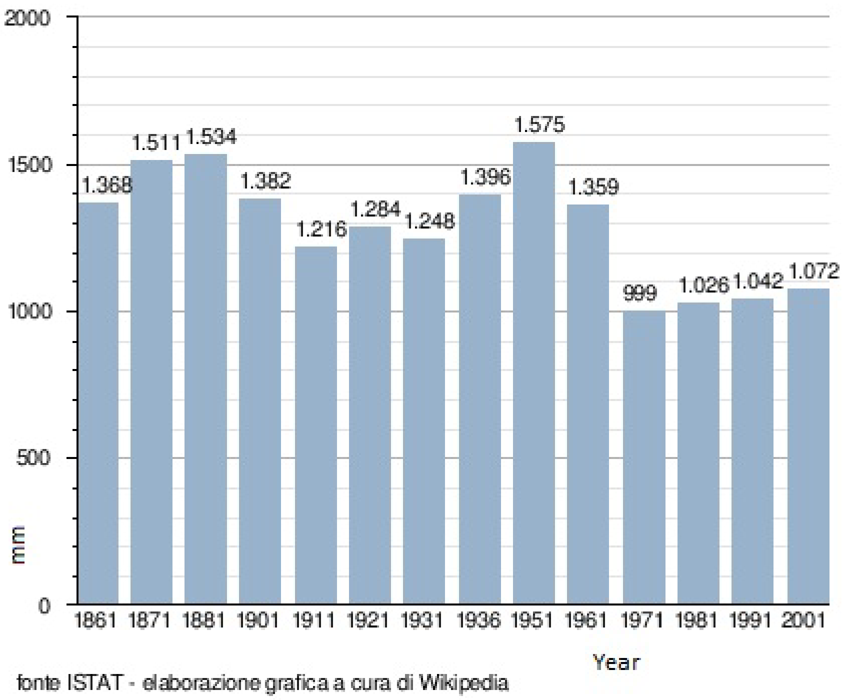

Figure 3a. Average Precipitation in Italy from 1861 to 2001.

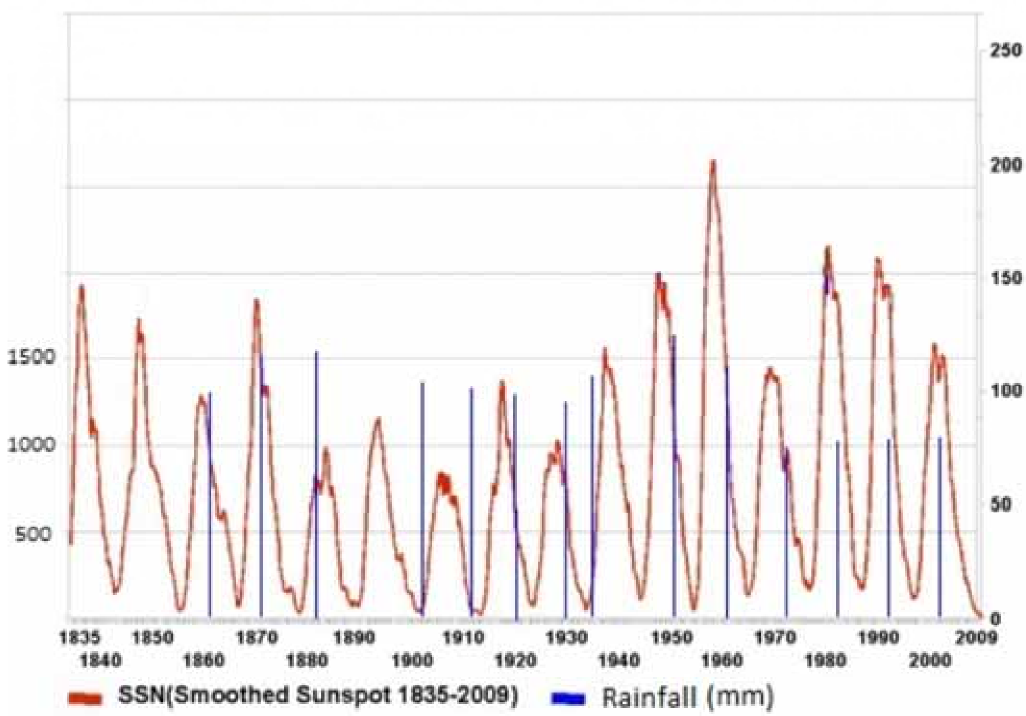

Figure 3b. Sunspot number vs. rainfall in Italy from 1861 to 2001.

If we compare the annual flows of the Baganza Stream (Alifraco, 2008), we can see that, with the sole exception of 1991, the maximum values coincide with the maximum values of solar activity. And, in general, this pattern follows the average one throughout Italy **(Fig. 4).**

At a general level, instead, a link between precipitations and the number of sunspots had already been proposed by Stager et al. (2005, 2007), with regard to the level of Lake Victoria in East Africa. In the case studied by Stager, the correlation between solar cyclicity and the level of Lake Victoria proved to be wholly reliable. In a further study, this time concerning the area under investigation, Tomasino and Dalla Valle (2000) suggested a relationship between the regime of the River Po and variations in the centre of mass of the Solar System (**Fig. 5**), while Landscheidt (1990) proposed a relationship between the intensity of precipitations in the boreal hemisphere with variations in the Angular Momentum of the Sun.

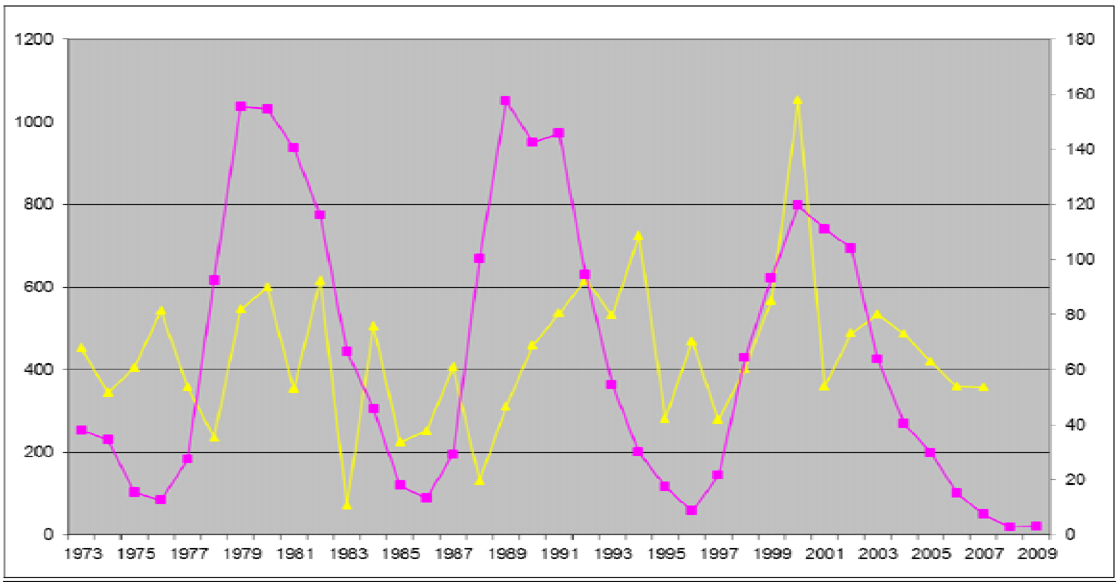

Figure 4. Flow of the Baganza stream Vs Sunspot from 1973 to 2010.

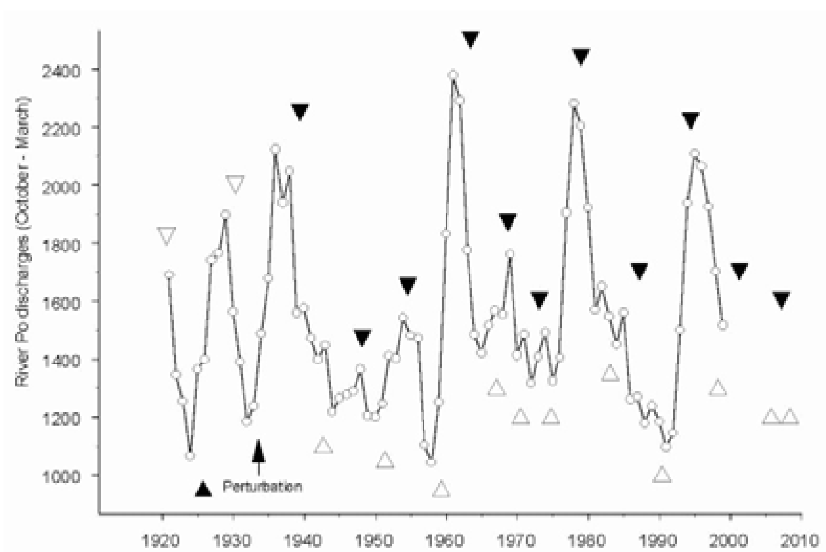

Figure 5. Correlation between River Po discharges and a cycle of the Sun's motion about the centre of mass of the solar system formed by the absolute rate of change in the Sun's orbital angular momentum.

LANDSLIDES
Historic landslides, in the area under investigation, reactivate after varying periods of quiescence – some long, some short. In the province of Parma alone, there are at least a dozen large areas of instability (**Fig. 6**). By way of example; the Corniglio landslide, 3 km long and over 1,100 m in width.

Main morphometric parameters of the landslide:
Height of crown 1160 m;
Height of foot 550 m;
Difference in Level: 600 m;
Average slope in emptying area: 23°;
Average slope of accumulation area: 8°;
Length: 3150 m;
Width: 600 m.

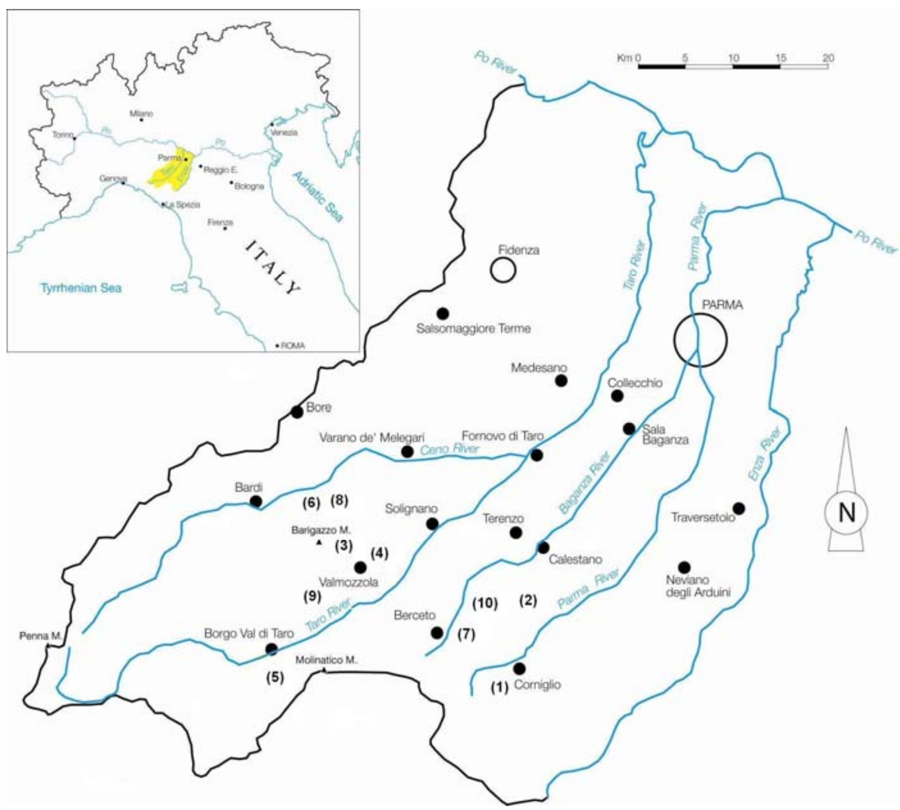

Figure 6. Major historic landslides around Parma. Corniglio (1), Signatico (2), Rovere (3), Valmozzola (4), Borgotaro (5), Tosca (6), Monte Cervellino (7), Pessola (8), Monte Gallo (9), Casaselvatica (10).

Below is a summary of the years of reactivation for some of the main, historic areas of instability, from the XVI century until today: 1547, 1612, 1740, 1836, 1879, 1896, 1902, 1906, 1945, 1957, 1960, 1978, 1994, 2000 and 2010.

The landslides reactivated periodically, from two to seven at a time, but never consecutively, in other words respecting shorter or longer spells of quiescence. If we match the years when the landslides reactivated with solar cyclicity over the last century, we can observe a certain synchronicity with the solar maximums and minimums.

Similarly, also earthquakes with maximum energy reported in the area under investigation follow recurrent intervals of time, i.e. do not manifest with the same frequency from year to year. Therefore, the tendency to both landslides and earthquakes may share a common cause.

We might surmise, for example, that the flares produced during solar maximums can interact with the Earth's magnetic field, causing a variation in the angular momentum (inertia?) of the Earth, which, in turn, can transfer energy to particular zones under tectonic stress, to produce earthquakes or, more superficially, in zones prone to hydro-geological instability, activate landslides.

However, this mechanism is not always obeyed. In fact, solar eruptions and magnetic storms do not appear to have an immediate effect on the Earth.

Certain data confirm this, as in the case of the magnetic storm of 5 and 6 August 2011, and the flares of 9 March 2011 which preceded, by two days, the violent seism in Japan. The magnetic storm of 5 and 6 August was recorded by various monitoring stations around the globe, underscored in the graphs by clear anomalies which were temporally correlated (www.usgs.gov/earthquakes/).

However, on 5 and 6 August (**Table 2**), despite the magnetic storm, the Earth's seismicity, instead of increasing, seems to have waned, as confirmed by the number of earthquakes with a magnitude greater than 5 which occurred in those days: 3 earthquakes on 5 August and 4 on 6 August (**Table 3**).

MAG	**UTC DATE-TIME y/m/d h:m:s**	**LAT deg**	**LONG deg**	**DEPTH km**	**Region**
5.3	2011/08/05 16:08:49	-30.044	-176.762	24.0	**KERMADEC ISLANDS REGION**
5.0	2011/08/05 08:04:21	-6.611	147.917	67.5	**EASTERN NEW GUINEA REG, PAPUA NEW GUINEA**
5.3	2011/08/05 01:13:27	-10.751	165.054	42.3	**SANTA CRUZ ISLANDS**

MAG	**UTC DATE-TIME y/m/d h:m:s**	**LAT deg**	**LONG deg**	**DEPTH km**	**Region**
5.1	2011/08/06 17:17:22	-4.365	152.941	38.9	**NEW BRITAIN REGION, PAPUA NEW GUINEA**
5.1	2011/08/06 13:22:36	-35.856	-73.027	22.4	**OFFSHORE MAULE, CHILE**
5.3	2011/08/06 07:14:57	35.242	141.005	42.0	**NEAR THE EAST COAST OF HONSHU, JAPAN**
5.7	2011/08/06 02:45:55	-2.860	101.174	30.9	**SOUTHERN SUMATRA, INDONESIA**

Table 2. List of M5+ earthquakes at a global scale on 5 and 6 August 2011 (www.usgs.gov/earthquakes/).

Meanwhile, also on the days preceding and following the magnetic storm, the global seismicity of the Earth does not seem to have been affected, as shown by the 2 earthquakes which occurred on 4 August and the 5 on 7 August 2011 (www.usgs.gov/earthquakes/).

MAG	**UTC DATE-TIME y/m/d h:m:s**	**LAT deg**	**LONG deg**	**DEPTH km**	**Region**
6.3	2011/08/04 13:51:36	48.784	154.835	49.0	**KURIL ISLANDS**
5.8	2011/08/04	-2.755	101.187	37.8	**SOUTHERN**

	00:16:08				**SUMATRA, INDONESIA**

MAG	**UTC DATE-TIME y/m/d h:m:s**	**LAT deg**	**LON deg**	**DEPTH km**	**Region**
5.0	2011/08/07 23:05:11	-5.378	133.899	9.2	**KEPULAUAN KAI, INDONESIA**
5.0	2011/08/07 14:35:35	38.440	21.844	13.1	**GREECE**
5.4	2011/08/07 07:01:47	-20.132	179.725	41.7	**SOUTH OF THE**
5.6	2011/08/07 06:22:35	-11.795	168.385	411.9	**SANTA CRUZ ISLANDS REGION**
5.0	2011/08/07 04:01:11	13.843	-60.309	38.0	**SAINT LUCIA REGION, WINDWARD ISLANDS**

Table 3. List of M5+ earthquakes at a global scale on 4 and 7 August 2011 (www.usgs.gov/earthquakes/).

Even the flares of 9 March 2011 (www.space.com) do not seem closely related to the strong Japanese seism. In fact, the stress situation in the future epicentre zone had been discovered two weeks earlier by Shou (2011), in a photograph taken by satellite which shows geoeruption near the epicentre and the appearance of vapour clouds.

If they had depended on the flares, the premonitory signals of the violent seism would not have manifested several days before its occurrence. Instead, the solar eruption itself may have triggered the earthquake. Conceivably, the flares may have added sufficient energy to set the earthquake off early – an earthquake which would have occurred in any case.

Hence, in view of these incoherencies, we might wonder what other phenomena may be associated with solar cyclicity that are not directly influenced by the flow of elementary particles coming from outer space.

In this regard we might reflect on the interaction between celestial bodies and variations in the Solar System's centre of mass. Most of the time, the centre of mass (CM), is to be found outside the body of the Sun. Ample oscillations with distances greater than 2.2 solar rays between the two centres (of the Sun and the masses of the Solar System) observe strict orbits which sometimes give rise to close encounters between the two centres (**Fig. 7**). Variation in the Sun's centre of mass could, in a context of global equilibrium, also affect the movements of the Earth.

The notion that the Angular Momentum of the Sun may condition the movements of the Earth has been around for some time (Bendandi, 1931; Landsheidt, 1998 and 1999).

Solar perturbations and the cyclicity of sunspots would, in turn, according to Bendandi, be due to the combined cyclic action of the positions assumed by the planets Jupiter, Venus and the Earth in their orbit around the Sun.

Jupiter is the celestial body that most perturbs the Sun, with a mass 300 times greater than that of the Earth. Coming a close second is Venus, whose mass is less than that of the Earth, but whose greater proximity to the Sun creates larger perturbations. The action of these two planets is followed by those of Mercury and the Earth, whose influence, while far from negligible, is undoubtedly secondary in creating solar tides, as can be seen in Bendandi's calculations, based on the mass of the respective celestial bodies of the Solar System (**Table 4**).

Table 4. Tidal coefficients of the planets as calculated by Raffaele Bendandi (1931).

Planet	Distance (Km)	Distance (U. A.)	Volume	Tidal coefficient
Mercury	58 million	0.38709	0.05	1040
Venus	108 million	0.72330	0.87	2090
Earth	150 million	1.00000	1.00	1000
Mars	228 million	1.52360	0.16	0030
Jupiter	780 million	5.20250	1230.00	2200
Saturn	1,433 million	9.55474	675.00	0106
Uranus	2,882	19.21814	55.00	0019
Neptune	4,516	30.10957	60.00	0002

"*The average duration of the synodic revolutions of Venus of* **583.92** *days and of Jupiter at* **389.98 days**, *attain on average a ten-year cycle equal to* **11.070** years".

"*With the numerical relationship that exists between the various revolutions of the three bodies – Venus, Earth, Jupiter – we have different degrees of intensity in the various maximums whether ten-year or a longer period, such as those which are more precise of* ***77.442*** *and* ***885*** *years.*" Therefore, according to Bendandi, the eleven-year fluctuation of the Sun (the sunspot cycle) is none other than a periodic reaction to impulses from the celestial bodies, above all the combined effect of Jupiter, Venus and the Earth.

A second element of debate consists of the variation in the Sun's orbital momentum. Indeed, according to Landscheidt, the contribution to the Orbital angular momentum of the Sun with respect to its total angular momentum is far from negligible, and can reach as much as **25%** of the momentum of rotation. The orbital angular momentum varies from **0.1 x 10^{47}** to **4.3 x 10^{47}** g cm^2 sec^{-1} or vice versa, which represents an increase or reduction that is **40** times greater (Landscheidt, 1988).

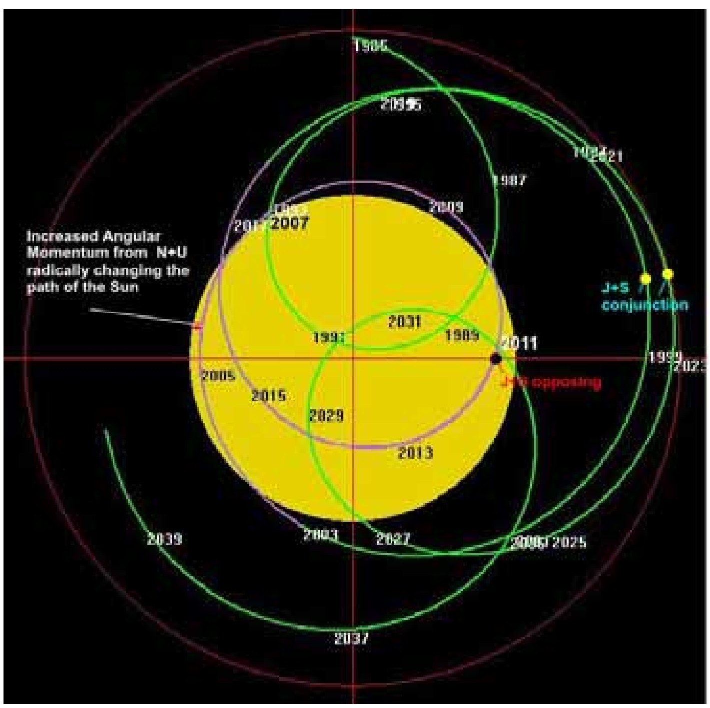

Figure 7. Variation in the solar system's centre of mass (www.landscheidt.info). The figure shows the discrepancy between the barycentre (or centre of mass) of the Solar System, and the Sun's Centre of Mass, caused by the arrangement of the planets in the Solar System.

Landscheidt considered the influence of the two major planets, Jupiter and Venus, amongst the main candidates that can determine these variations on the Sun, in addition to their influence when they are in conjunction, or in opposition.

In 2009 (www.landscheidt.wordpress.com) Sharp calculated the angular momentum with respect to the positions of Saturn (conjunction in aphelion and in perihelion; semi-conjunction, squaring and opposition). The result is startling. The pattern on the graph matches the progress and average duration of sunspot cyclicity. The minimums always correspond to a squaring between Jupiter and Saturn, while the maximums tally with the conjunctions and oppositions between the two largest planets of the Solar System (**Fig. 8**).

Also the variation in the angular momentum of the Sun is cyclic, with intervals between the maximum and minimum values of around 80 years, which express the mean value of the Wolf-Gleissberg cycle that relates climate change to the progression of this cycle. Indeed, there are strong links between the minimums and maximums in the Wolf-Glessiberg cycle and cold and hot spells of weather (www.landscheidt.info).

VOLCANIC ACTIVITY

As for the transmission of energy and the stresses produced by the Sun on the Earth related to the sunspot cycle, reference should be made to the study by Stothers (1989). Stothers focussed on historical data regarding the great volcanic eruptions between 1500 and 1980. Through a painstaking retrospective analysis of these data he discovered two statistically significant periodicities in the pattern of volcanic eruptions that could be correlated respectively to both the 11-year solar cycle, and Wolf-Gleissberg's longer solar cycle of 80 years.

In these periodicities of specific volcanic activity, he observed that there was a notable correspondence between an *increase in volcanic activity* and *solar minimums*, while there was a conspicuous *reduction in volcanic activity* during the *solar maximums*. The historical models were confirmed by searching for acids present in the air produced during volcanic eruptions and trapped in precipitations of snow, later becoming ice in Greenland (**Fig. 9**).

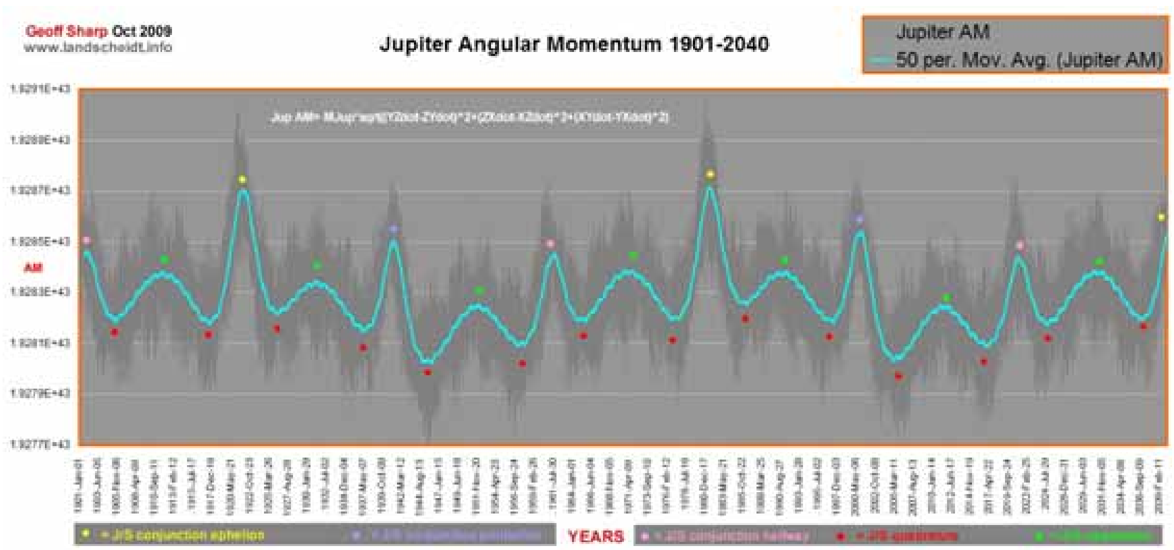

Figure 8. Jupiter's angular momentum 1901 – 2040 (www.landscheidt.info).

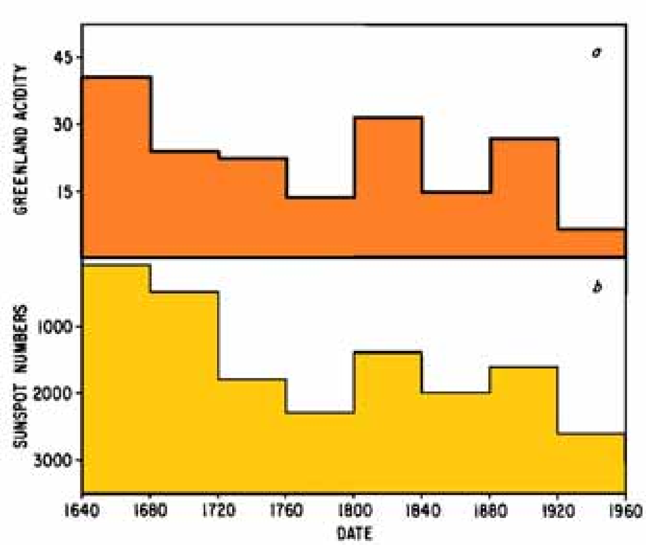

Figure 9. Sunspots Vs. Greenland acidity from 1640 to 1960 (Stothers, 1989).

In this author's opinion, solar flares present during the solar maxima can change the models of atmospheric circulation, even influencing terrestrial rotation. This kind of shock in the dynamics of the movements of the terrestrial crust, according to Stothers, can provoke micro-earthquakes which limit volcanism since they lessen the pressure on faults.

Conclusions

The dynamics of the Earth are heavily influenced by both solar activity and the configurations of the major gassy planets of the Solar System. The area under investigation by this study has demonstrated that there are correspondences between solar cyclicity, atmospheric circulation, the occurrence of earthquakes, and the periodic reactivation of powerful gravitational movements. Analysis of data from the last two centuries leads to the following conclusions.

Conclusion 1

Solar cyclicity demonstrates relationships with the intensity of precipitations, the reactivation of historic landslides and the occurrence of strong earthquakes, with reference, naturally, to the area investigated by this study.

An interpretation of the mechanism might read as follows: Atmospheric circulation, which produces evaporation processes and the weather, is conditioned by solar energy. Variations in evaporation induce precipitations which, in turn, reactivate landslides.

Solar flux > Atmospheric circulation > Evaporation > Precipitation > Reactivation of historic instability

Conclusion 2

The cyclic appearance of sunspots is synchronous with the Angular Momentum of Jupiter. The rhythmic positioning of the large gassy planets may also influence the form of the geoid and affect both seismic cyclicity and the Earth's tectonic evolution.

Solar cycles > Deformation of the Geoid > Global Seismic Cyclicity > Tectonic Evolution

Finally, in this author's opinion, only by means of interdisciplinary studies can we reach a solution to this fascinating problem, which, in the future, may provide vital indications on the climate, seismic cyclicity, and the reactivation times of significant gravitational instabilities, to lessen alarming repercussions on human activity.

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VOLCANIC AND SEISMIC ACTIVITIES DURING THE SOLAR HIBERNATION PERIODS

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Abstract: A massive number of strong earthquakes and volcanic eruptions occurred during the Maunder Minimum or Little Ice Age (1645 to 1715) worldwide. Both magmatic and seismic activities dwindled dramatically after the end of the Maunder Minimum. The Dalton Minimum shows some regional variations; seismically still quiet in Japan and Turkey, whereas in some other regions including India, Indonesia, continental North America and northern South America very strong earthquakes occurred. Indonesia's Tambora volcano erupted in this solar low period.

Magmatic and seismic events became active worldwide after the closure of the Dalton; this trend has continued until today with a conspicuous rise since 2000 when the 206- and 361-year solar cycles started to decline sharply. The recent spate of unusually strong natural disasters (earthquakes, volcanic eruptions, and extreme weather events) has occurred during the rapidly declining period of this longer solar cycle – probably comparable to the earliest stage of the Maunder Minimum.

This paper confirms the remarkably heightened magmatic and seismic events during the major solar hibernation periods in the past. This fact prompts us to prepare for more severe catastrophic natural disasters in the coming two to three decades or even longer as the solar hibernation deepens further.

Keywords: *earthquakes, volcanic eruptions, solar hibernation, Maunder Minimum, Dalton Minimum*

Introduction

On 14 June 2011 the National Science Foundation's National Solar Observatory sent a shock wave round the world by announcing that the Sun would be heading into a more dormant period with activity during the next 11-year solar cycle (cycle 25) greatly reduced or even eliminated (http://www.boulder.swri.edu/~deforest/SPD-sunspot-release/SPD_solar_cycle_release.txt). Should this forecast be correct, this means the Earth has entered a solar hibernation period similar to the Maunder Minimum from 1645 to 1715 (Eddy, 1976).

The arrival of a major solar cycle low period (cycles 24 and 25) has been predicted and strongly advocated by John Casey (2008) along with many other earlier researchers including Komitov and Kaftan (2003), Schatten and Tobiska (2003), Landscheidt (2003) and Archibald (2006). Against the global warming alarmists, Casey warned that the arrival of a solar hibernation period in the coming 20 to 30 years comparable to the Maunder or Dalton Minimums, which would result in prolonged deeply cold weather. Some of the coldest years will destroy crops and produce catastrophic food shortages. He later warned (2010) of the increase in large volcanic and seismic events in the solar cycle trough periods comparable with the Dalton Minimum, their ill-effects on global climate and food production, and social disruption.

His advocacy was supported by Choi and Maslov (2010). Based on an exhaustive study of earthquakes and comparison with solar cycle, they showed an inverse or anti-correlation between seismic activity and the solar cycle; when the Sun is active (rising and peak phases of the cycle) seismicity becomes low, but when the Sun becomes inactive (trough and declining period), more of the largest earthquakes occur.

The above underlying understanding prompted the authors to examine global tectonic activity during the major solar low periods – Maunder and Dalton Minimums. The first area chosen was in the Molucca Sea, Indonesia, because the region is expected to have a major shallow earthquake sometime around late 2012 (Choi, 2010). The study was expanded to other regions where historical archival data are available. This paper briefly describes our main findings to stimulate discussion on the intriguing tectonics and related planetary interaction.

Volcanism in the Indonesian region since 1960

Molucca Sea

Volcanoes in the Molucca Sea region form the chains of islands on both sides of the Sea: the Sulawesi-Sangihe islands in the west and the Halmahera chain in the east. **Fig. 1** was compiled from the Smithsonian Institution's Global Volcanism Program website (http://www.volcano.si.edu/world/) for each chain, and compares the results with the published solar cycle taken from the NASA website with emphasis on major solar cycle trough periods (highlighted in blue).

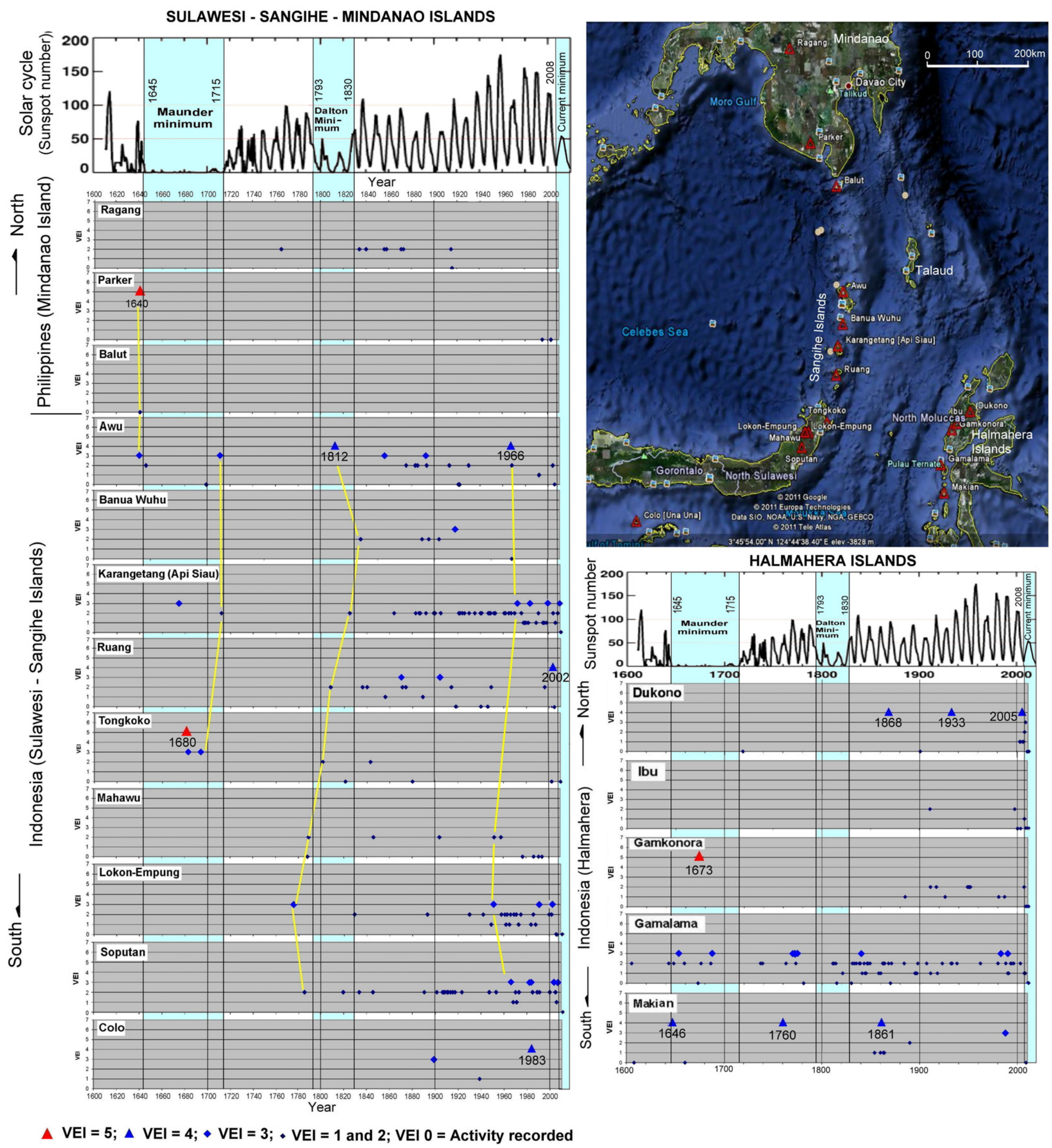

Figure 1. Volcanic eruption history in the Sulawesi-Sangihe Island chain and Halmahera Islands around the Molucca Sea.

The above figure shows that large volcanic eruptions took place during the Maunder and Dalton Minimums in the Molucca Sea region: The strongest volcanism in the region (VEI 5) occurred during the Maunder Minimum (Tongkoko and Gamkonora). The Dalton Minimum period roughly coincides with the starting period of magmatic reactivation which has continued until today in many volcanoes. In the Sulawesi-Sangihe chain, volcanoes south of Karangetan are active, but its northern volcanoes, Banua Wuhu and Awu, are inactive at this moment. In the Halmahera islands all volcanoes except for the southernmost one (Makian) are currently active at the end of 2011.

Lesser Sunda, Java and Sumatra Islands

For comparison with the above Molucca Sea region, the volcanic history of Lesser Sunda, Java and Sumatra Islands was studied (**Figs. 2-4**). In all regions some volcanoes were active during the Maunder Minimum, such as Merapi in Java and Krakatau. Merapi, Raung and Tengger Caldera in Java were active during the Dalton Minimum, and so were Tambora (1815, VEI 7), Sangeang Api, Agung, and Bartur in Lesser Sunda, whereas there was no recorded activity in volcanoes in Sumatra during both the Maunder and Dalton troughs. Interestingly in all regions of Indonesia volcanoes became active after the end of the Dalton Minimum.

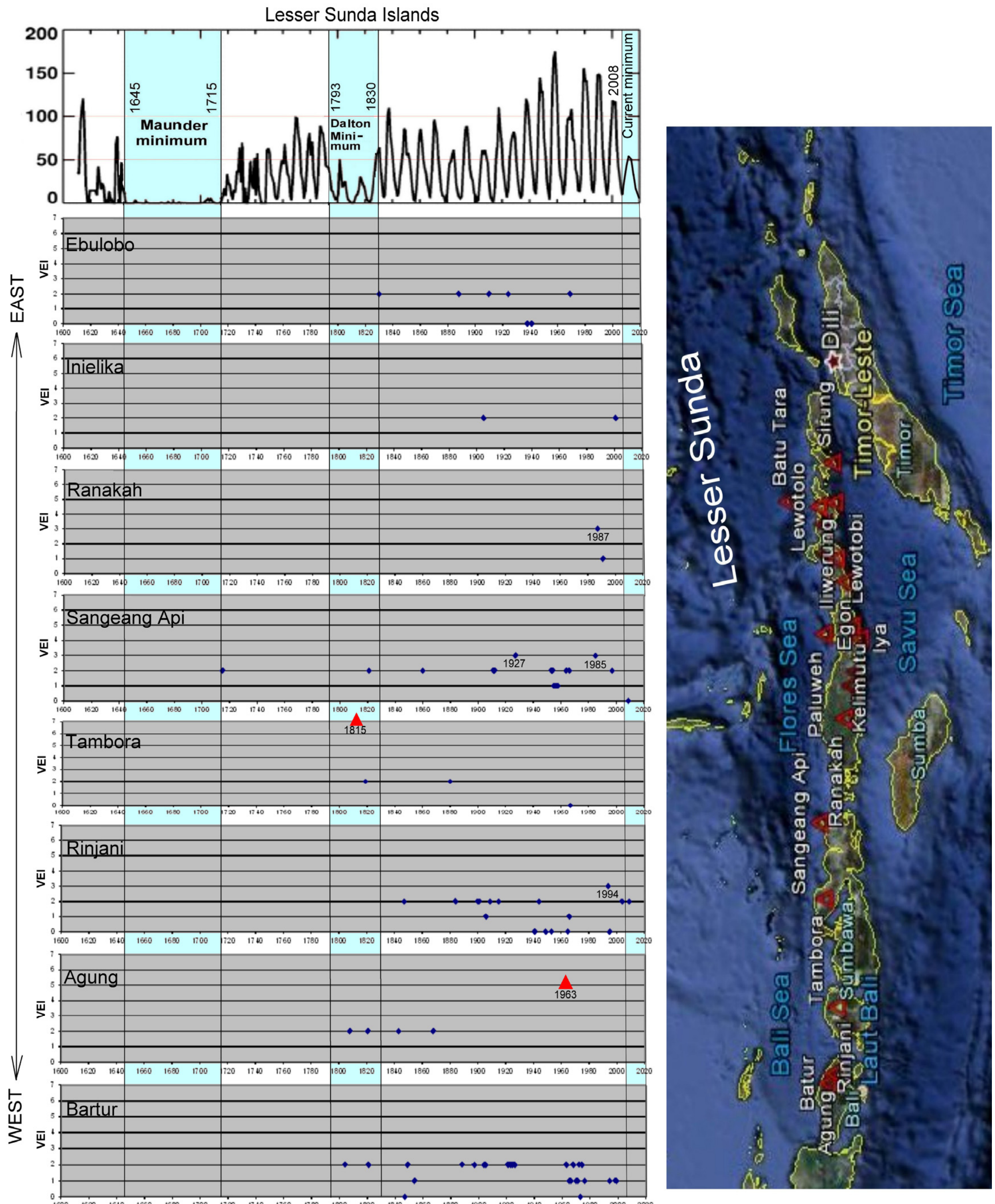

Figure 2. Volcanoes in the Lesser Sunda Islands. Note the eruption of Tambora in 1815 (VEI 7 – strongest in world history) in the middle of Dalton and Agung in 1963 (VEI 4) which also occurred in the declining period of the solar cycle 19 (see Fig. 6).

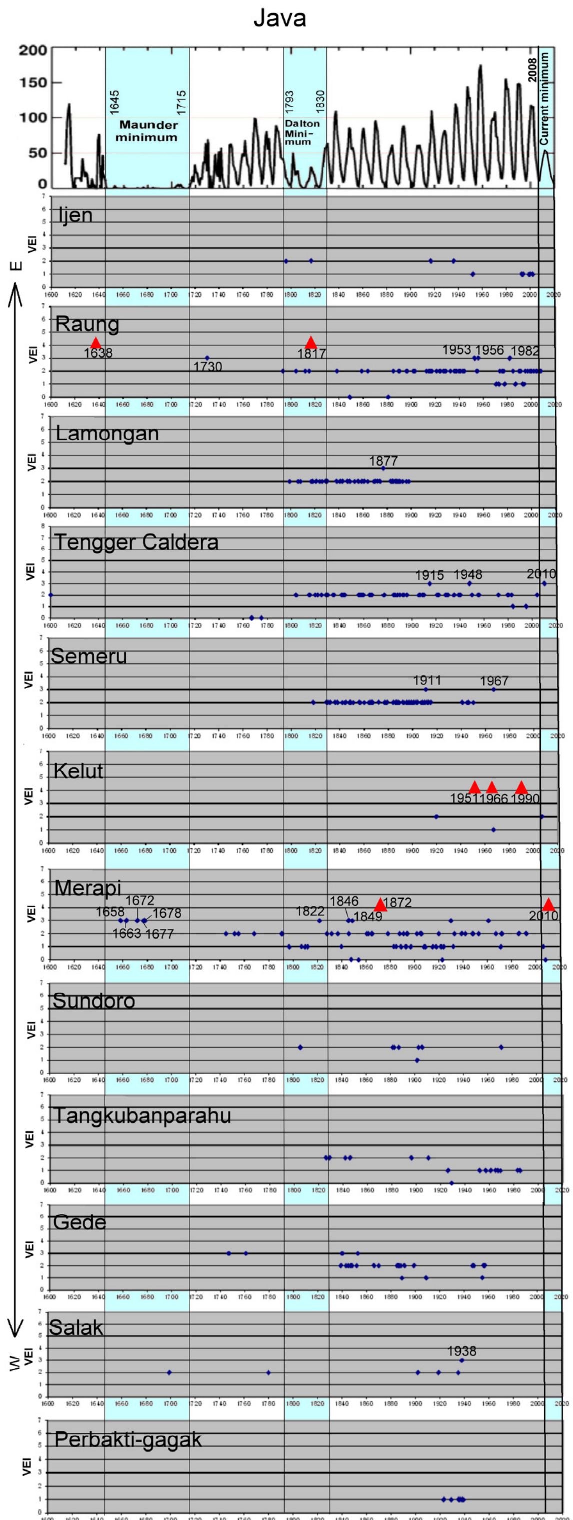

Figure 3. Volcanoes in Java Island. Note periodic, intensive eruptions of Merapi during the early half of the Maunder Minimum, and a series of eruptions starting from the Dalton Minimum period in the eastern half of Java.

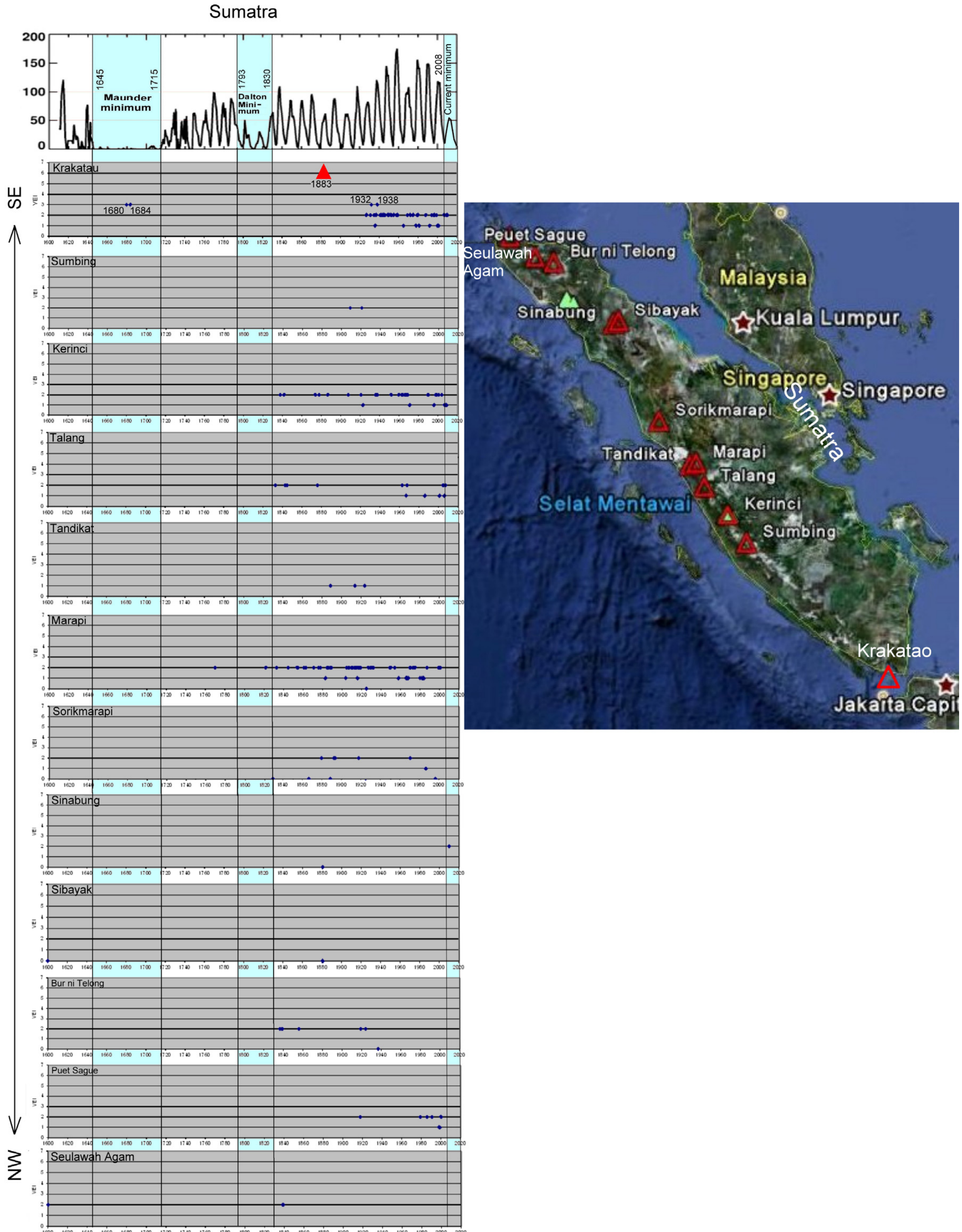

Figure 4. Volcanoes in Sumatra. No strong eruptions above VEI 3 have been recorded in Sumatra except for Krakatao, which also erupted during the Maunder Minimum. Another interesting trend is the start of small eruptions after the Dalton Minimum.

Quantitative analysis of volcanic and seismic activities in the Celebes-Molucca Sea region

To analyze the available data in a quantitative way, **Fig. 5** was produced. It represents the energy level of volcanic and seismic activities in the Celebes-Molucca Sea region, an area bounded by latitudes 0.00

and 10.00N and longitudes 120.00 and 130.00E – roughly covering the area shown in **Fig. 1**. The energy level is expressed in the form of volcanic and earthquake points; the calculation methods are shown in the figure caption. It is clearly seen that volcanoes were very active during the Maunder Minimum – represented by Tongkoko and Gamkonora volcanoes in the middle of the low period. A most outstanding event during the Dalton Minimum was the Awu volcano eruption in 1812 – also in the middle of the low period. Otherwise the activity level remained relatively low throughout the Dalton. Volcanic activities gradually increased after the Dalton low period, notably after 1980s in the region.

Historical earthquakes in the region are archived on the Utsu-WEQ website (http://iisee.kenken.go.jp/cgi-bin/utsu/result.cgi). However, compared to the volcanoes, relatively few reliable historical earthquake records are available, particularly for the period before1840. Yet the limited data show that the total energy level of earthquakes for each five-year interval was quantitatively expressed in the form of the total number of M6.0 quakes at the bottom of **Fig. 5**. It is interesting to note that there is a distinctive peak between 1890 and 1930. The period coincides with a minor but notable peak in volcanic activity too, suggesting heightened activity in the Earth's outer core during this period. However, after 1970 there is no clear correlation between earthquake and volcanism; the study area needs to be expanded for meaningful analysis.

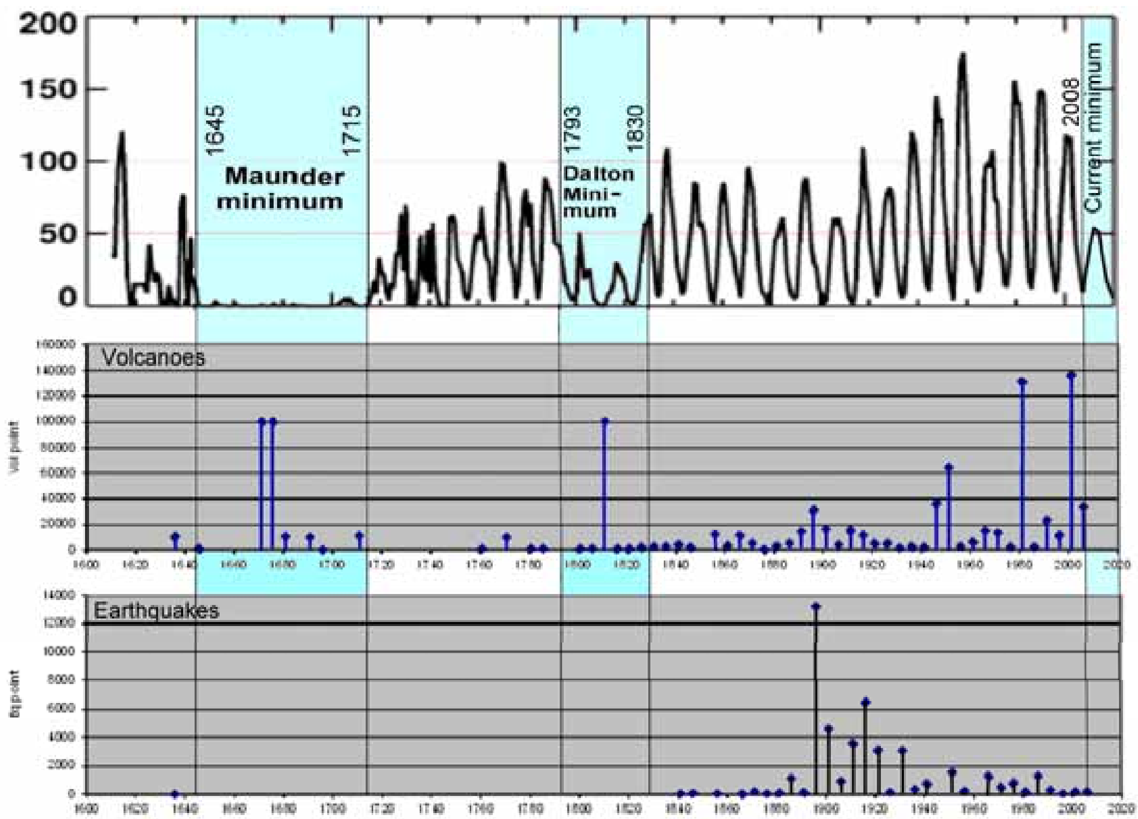

Figure 5. Volcanic and seismic activities in the Indonesian region in comparison with the solar cycle in the Celebes-Molucca Sea region. Calculation method of **volcanic points**: Each eruption was given the following points: Level 0 (VEI 0) = 1 point, Level 1 = 100 points, Level 2 = 1,000 points, Level 3 = 10,000 points, Level 4 or greater = 100,000 points. Five-year total points are indicated in the figure. Data source: Smithsonian National Museum of Natural History, http://www.volcano.si.edu/world/find_regions.cfm,2011, and Volcanic Alert Level (WOV) (http://www.wovo.org/). Note extreme highs in the middle of the two solar minima. **Earthquake points**: Based on magnitude (which is on a logarithmic scale), all earthquakes with magnitude 6.0 or greater were converted to the number of M6.0 earthquakes and the total number of M6.0 was counted; for example, an M7.0 quake = 32 M6.0 quakes, an M8.0 quake = 32 x 32 (= 1024) M6.0 quakes, and an M8.7 quake = 12 x 32 x 32 (= 12,288) M6.0 quakes.

As seen above, the following trends in volcanic and seismic events are observed in the Indonesian region: 1) very strong and intensive activities during the Maunder Minimum, 2) much subdued but still marked activities during the Dalton Minimum, 3) renewed, continuous activities after the end of Dalton, and 4) very high level of activity after 2000. It is also of note that the observed spike in earthquake activity in the first decade of the 1900's correlates strongly with the "Centennial Cycle" solar minimum described by Casey (2008) and his subsequent forecast of increased seismic activity during major solar minima or 'solar hibernations'.

Historic seismicity and volcanism, and their relation to the solar cycles of the world
To see global trends in the solar cycles and seismicity/volcanism we searched for references for some selected regions: Japan, India and Turkey, where historical records are available. The results are displayed in **Fig. 6**.

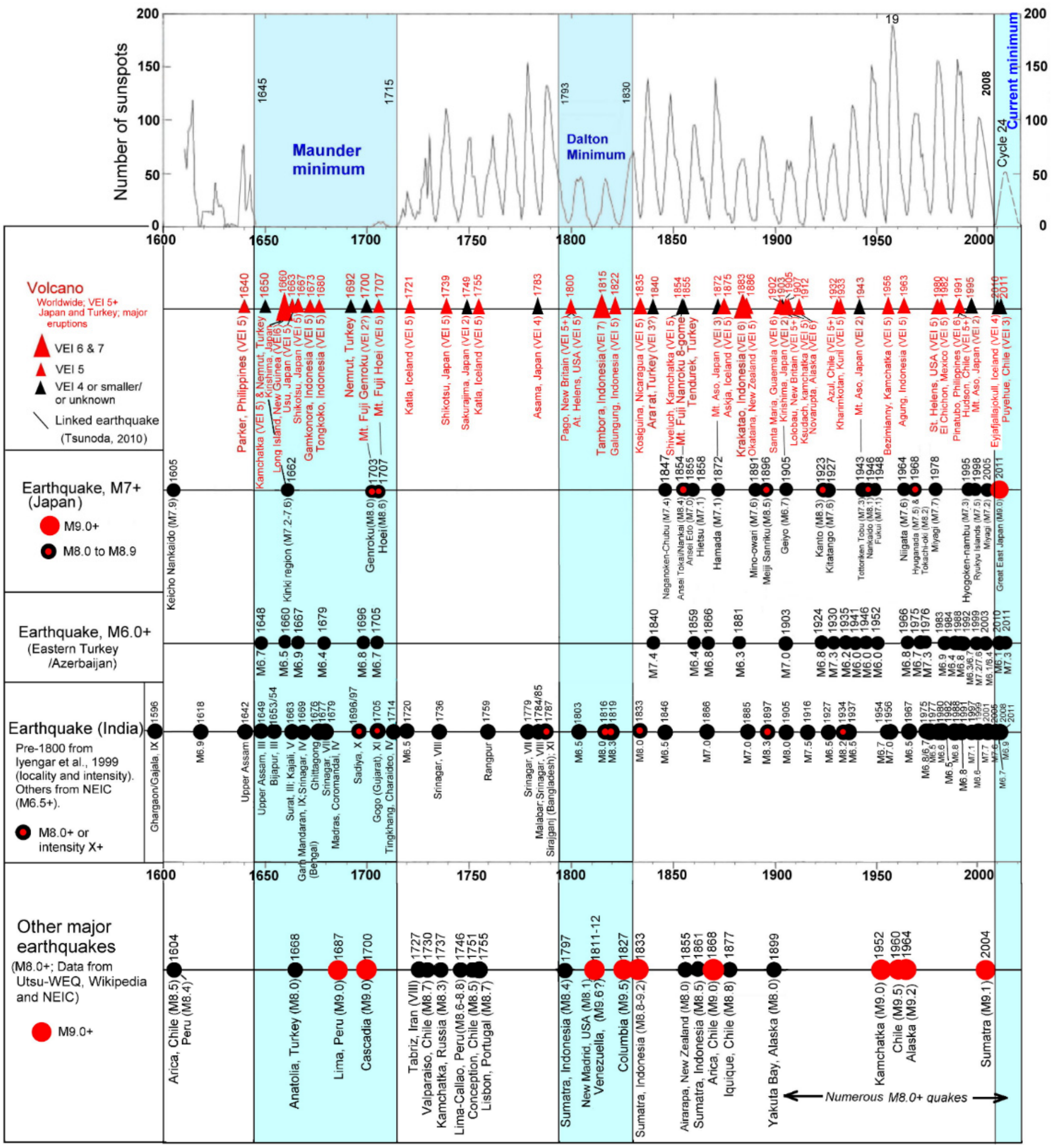

Figure 6. Composite figure showing major volcanic and earthquake events since about 1600 in some selected regions.

As clearly shown in the above figure, the most intensive activities are recorded during the Maunder Minimum throughout the world. After the end of the Maunder, many regions entered a quiescent period until the start of the Dalton low, but in South America in particular strong earthquakes continued. In general the Dalton period saw renewed activity in both seismicity and volcanism, though showing local variance - some areas such as Japan and Turkey remained seismically quiet. In the post-Dalton era, seismicity was renewed in Japan and Turkey. In all regions the heightened activity trend has continued until today. These trends are harmonious with those of volcanoes in Indonesia as discussed earlier.

Worldwide earthquake energy level fluctuation during the Maunder and Dalton Minimums

Maunder Minimum

To see global seismicity trends during the solar hibernation periods we retrieved historical quakes recorded on the Utsu-WEQ site. The results for the Maunder period are shown below (**Fig. 7**). To show them in a quantitative manner, as done in the Celebes-Molucca Sea region, all M6.0+ earthquakes were converted to the total number of M6.0 quakes.

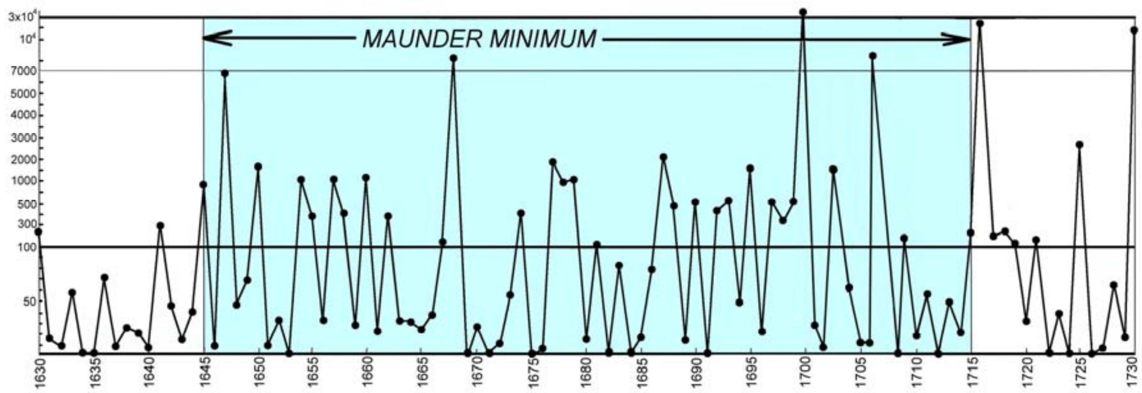

Figure 7. Frequency of earthquakes during the Maunder Minimum. Data source: Utsu-WEQ website, http://iisee.kenken.go.jp/cgi-bin/utsu/result.cgi. See the caption to Fig. 6 for conversion method.

If we set the major earthquake frequency peaks at around 7,000 (**Figs. 7 and 8**), the years 1647, 1668, 1700, 1716, and 1730 become the peak years, separated by intervals of 21, 32, 16 and 14 years. Among them exceptionally high energy years are 1700 and 1716, which are equivalent to over 25,000 M6.0 quakes.

The start of the Maunder Minimum is 1645 (Eddy, 1976). However, it seems more reasonable to take 1646 as the starting year, as the very strong energy release occurred in 1647. On the other hand, the end of the Maunder is generally taken to be 1715; but because 1716 is one of the highest energy peaks during the Maunder, it appears more natural to place the end of the Maunder in 1716.

Dalton Minimum

The Dalton low period's energy level fluctuation is shown below (**Fig. 8**). The Dalton's starting year cannot be clearly defined by the earthquake energy level. But one possible year is 1795, before the curve started to rise in 1796. Regarding the end year of the Dalton, we consider 1828 is a better choice than 1830 based on the rapid energy drop seen in 1828. This year also corresponds to the rising period of solar activity (**Fig. 6**).

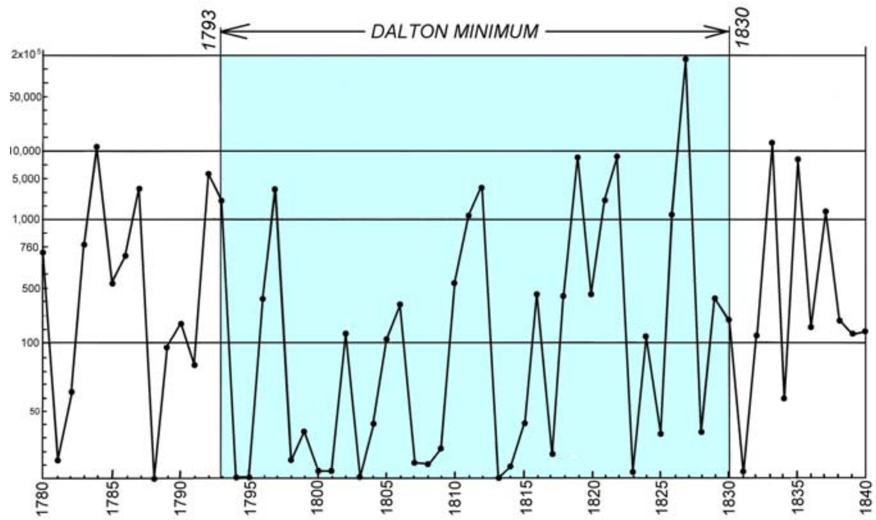

Figure 8. Earthquake frequency during the Dalton Minimum. Data source same as Fig. 7.

Discussion

Stothers (1989) extensively studied volcanic catalogs complied by Simkin et al. (1981) and Newhall and Self (1982). He ably summarized many preceding studies on volcanic eruption and solar cycles. Based on statistical analysis, he detected two weak eruption cycles - 11 and 80 years; the incidence of volcanic eruptions is slightly greater around the time of solar minimum than at any other phase. Both Stothers (1989) and Fairbridge (1980) noted the abnormally high volcanic eruption numbers during the Maunder Minimum; this is supported by elevated acidity in Greenland deep ice cores covering the years from 533 to 1972 AD (Hammer et al., 1980) during this protracted solar minimum.

In his well-researched book, Casey (2011) summarized the effect of cold climate on humans and society especially during the Dalton Minimum, and warned of the imminent arrival of a cold climate in the coming 20 to 30 years. Our current study strongly supports his conclusions; the prolonged Maunder-type cold period if it occurs, will surely be accompanied by remarkably heightened volcanic and earthquake activities in the coming several decades.

The heightened tectonic and magmatic events during the solar low period as documented here are harmonious with the earthquake-solar cycle anti-correlation proposed by Choi and Maslov (2010). A reasonable explanation for this fact must be addressed urgently. One of the hints comes from Gregori (2002), who considers the Earth to be a leaky capacitor or a battery which is charged when solar activity is strong, but discharges energy when solar activity declines. However, further studies of various facets including cosmic ray effects, microwave background radiation, etc. are needed to get a clearer picture of this intriguing phenomenon.

Relationship between the solar minima and earthquake energy cycle

In general, very strong seismicity peaks with over 10,000 M6.0 quakes (including worldwide trends, **Fig. 6,** and other published data) have a cycle of about 40 years, and other minor peaks 10 to 20 years (Tsunoda, 2010). These trends are maintained regardless of the solar cycle fluctuation pattern. However, if examined more closely, during the low cycles the number of peaks increases, which is especially well observed during the Maunder Minimum (**Fig. 7**). Therefore, the Earth's energy level during the solar low periods is undoubtedly higher than during the solar high periods. Also it is worth noting that, when viewed in terms of the total energy level fluctuation or the VE process (Tsunoda, 2010), while the start and the end of the Maunder are clearly defined, those of the Dalton are unclear.

All available data presented here seem to suggest that the recent unusually strong volcanic and earthquake activities especially after 2000 are comparable with those which occurred during the early stage of the Maunder Minimum. This is the time when the longer solar cycles, both 206- (Casey, 2008) and 361-year cycles (Sonnett and Finney, 1990), have started to sharply decline. We tentatively set the year 2008 (lowest trough before the rise of the solar cycle 24) to be the starting year of the Current Minimum. It well matches the 206-year cycle after the start of Dalton and the 361-year cycle after the start of the Maunder.

Conclusions

This preliminary study shows heightened volcanic and seismic activities during the major solar hibernation periods since 1600. Because the Earth is likely to have a Maunder-type inactive solar cycle period in the coming decades, we will have more numerous catastrophic magmatic and seismic disasters coupled with unusually severe weather events.

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SOME PROBLEMS AND QUESTIONS OF KIMBERLITE GEOLOGY AND ELECTRIC DISCHARGE HYPOTHESES

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Abstract: Invasion of cosmic bodies of asteroidal size in Earth's atmosphere is incomparable with anything electrical disturbance, which interact with electric fields in zones of high electrical conductivity in the bowels of the planet and promote occurrence of electric breakdown of the upper crust. And just to achieve this "mission" asteroids is falling to the Earth, burst and create impact craters. The melt is formed by the electric discharge in the channel of the tube, has the characteristics of the P-T close to the mantle, what has caused the formation of a pseudomantle mineral associations at depths of several kilometers. The model agrees well with the characteristics of kimberlite geology and answers many questions (traces of melting in the tube walls, the structural independence of the placement, the group nature of the kimberlite pipes in the fields, lack in evidence of magmatic melt, and the presence of anachronistic xenoliths of mantle lithologies, etc.).

Keywords: *kimberlite, asteroids, electrical discharges, zones of electrical conductivity, pseudomantle minerals*

INTRODUCTION

The author's hypothesis is that over geological time asteroid sized meteoric bodies (MB) intruded into and through the earth's atmosphere causing perturbations of the earth's electric field that initiated deep seated geological processes which subsequently generated the formation of kimberlites and related igneous extrusions.

During the Phanerozoic epoch the earth was repeatedly exposed to asteroid bombardment confirmed by the recently discovered remnants of huge astroblemes (up to 200 km diameter). This ancient bombardment of the Earth was invariably accompanied by impact explosions, the formation of craters and the emission of a large quantity of exploded ejecta into the atmosphere, overloading the atmosphere leading to a climate cold snap and mass biotic extinctions. Such extinction events are well studied at the boundary between the upper Devonian Frasnian and Famennian (367 million years ago), and at the boundaries of the Permian and Triassic (251million years) and Mesozoic and Cenozoic (65 million years). These data form a well understood and accepted body of geological theory. However, while current explanations for meteoric impacts are considered sufficient to explain observed surface phenomena as the result of direct impact, little if any, consideration is turned to the possible subsurface effects generated prior to impact by non impacting cosmic bodies.

ELECTRONIC FIELD GENERATED BY BOLIDE AT THE EARTH SURFACE

The author's analysis of the well-known bolides of the 21th and 21st centuries (Tunguska, Sikhote-Alin, Chulym and Vitim) shows that they were all generators of induced electric fields at the Earth's surface. Electrophonic sounds, electromagnetic excitation of the terrestrial subsurface and associated seismicity effects were shown to be connected to the electrical currents generated by the bolide before impact. These effects have since received additional support during the second half of 20th and beginning of 21st centuries:

a) A telephone operator received an electric shock from the disconnected telephone line during the flight of the Sikhote-Alin body, 1947.
b) The Chulym bolide of 1984 caused burnout of lightbulbs, the failure of the automatic runway illumination at the airport, etc.;
c) The Vitim bolide of 2002 affected two settlements (Mama and Lugovskoye), producing fire in half of the heated light bulbs in the disconnected electric system and the occurrence of St Elmo's fire on airport fencing in the Mama settlement.

Thus the electrical nature and surface effects of some bolides have been well established from experience and observation, but this has not been generally appreciated by mainstream science.

These electrical effects can be logically extended to bodies of asteroid size with diameters more than 1 km and which can lead to high voltage electric currents of more than 10^4 V/cm leading to electric discharges from zones of higher conductivity in the Earth's crust. Thus, as stated at the beginning of the 1970's the idea of kimberlite pipes looking like electric discharges at the Earth's crust (geologists K.M. Alekseevsky and T.T. Nikolaeva, and electrophysicist A.A. Vorob'ev), has received additional support; in addition, it is the author's view that the passage of asteroid bodies through the Earth's atmosphere could cause a significant increase in atmospheric electricity and the Earth's electric field leading to the subsequent initiation of electrical discharges within earth's crust (Khazanovitch-Wulff, 1991, 2007a and 2011).

GEOLOGICAL FEATURES OF DIATREMES

This hypothesis correlates with the geological features of diatremes that have had no unequivocal genetic origin until now or whose genesis remains highly controversial. First of all, the interpretation of kimberlite fields as "trains" of astroblemes, for which the author can cite more than 25 examples (varying degrees of reliability) of such spatial–temporal correlation on different continents. Some examples are listed below:

(Abbreviations - a) KZ - kimberlite zone b) KF - kimberlite field, c) KP - kimberlite pipes, d) DF - diatreme field, q) AB – astroblemes. → - vector direction to next body in the "train" of bodies for a particular example.)

NORTH AMERICA:

1. "38th Parallel" (0 - 275 km): KF Avon, USA, Missouri, 79 diatreme, age <377 Ma → 125 km to the W → AB Crooked Creek, diam. 7 km, geol. age 320+-80 Ma →100 km W → AB Decaturville, diam. 6 km, geol. age <300 Ma → 50 km W → AB Weaubleau-Osceola, diam. 19 km, geol. age 310-330 Ma.

2. KF Norris Lake, USA, Kentucky, 2 K-body, geol. age <286 Ma → 35 km NE →AB Middlesboro, USA, Kentucky, diam. 6 km, geol. age <300 Ma.

3. KF Elliott County, USA, Kentucky, 3 KP, abs. age 88 Ma→ 135 km to the W → AB Versailles, USA, Kentucky, diam. 1,5 km, geol. age. ~ 90 Ma → 30 km W → AB Jeptha Knob, USA States, Kentucky, diam. 5 km, geol. age ~ 90 Ma.

4. KZ Central Saskatchewan (KF Fort a la Corne, Prince Albert, Candle Lake, Snowden, etc.), Canada, a few tens KP, abs. age 95-105 Ma→ 270 km to the NE→AB Deep Bay, diam. 12km, abs. age 99±5 Ma.

5. KF Riley County, USA, Kansas, 13 KP, abs. age .64-67 Ma → 320 km to the NE → AB Manson, USA, Iowa, diam. 38 km, abs. age 61.9 -73.8 Ma.

BRAZIL:

6. KF Redondao, Fazenda Largo and Bom Jesus, Brazil, geol. age <250 Ma → ~100 km NE → AB Santa Marta (Gilbues), diam. 10-12,5 km, geol. age <65 Ma (from other sources <250 Ma).

7. KP Picos, Brazil, 16 KP, geol. age <250Ma → ~ 80 km NE→ AB Sao Miguel de Tapuyi (SMT), diam. 20-25 km, geol. age <$D_3 - C_1$.

EUROPE:

8. DF Urach, Germany, Swabian Alb, diam.40 km, 250 diatremes, abs. age – 14.7 Ma → 60 km NE → AB Steinheim, ibid, diam. 3.8 km, abs. age14.8 +-0.7Ma → 40 km NE → AB Riss, ibid, diam. 24 km, abs. age 14.8 +-0.7 Ma.

9. KF Kuopio and Kaavi, Eastern Finland, 24 KP, abs. age - 759 ± 15 Ma and 756.8 + -2.1 Ma → 150 km to the SE → AB Janisjarvi, Karelia, North. Ladoga, diam.14 km, abs. age 725 ± 5 Ma.

10. Nenokskoe DF, Arhangel'sk region, Russia, geol age - D_3-C_1 → 60 km NE → KF Izhmozero → 50 km NE →KF Zimneberezhnoe, ~ 30 KP, abs. age ~ 367 Ma → 270 km to NE → AB? Choshskaya Guba, Arch. reg., diam. 125 km, age geol. – D_3?

ASIA:
11. KZ Marho-Olenek, 130 KP, 7 KF (SW to NE): Alakit, Daldyn, Upper-Muna, Chomurdah, West Ukukit, East Ukukit, Upper Motorchun, Merchimdem located in a linear zone of NE-trending, abs. age. ~ 367 Ma → 50-70 km to the NE→ AB? Olenek Uplift, diam. ~ 200 km, geol. age D_3-C_1 ?
AFRICA:

12.DF in the eastern part of Libya, near the border with Egypt, more than 100 DP ranging in size from a few tens of meters to 1 km, age - KZ? → 20 km→ AB Kebira on the border of Libya and Egypt, diam. 31 km, geol. age - KZ?

13. DF in the eastern part of Libya→ almost close→crater British Petroleum diam. 2,8 km, geol. age – KZ→ 80 km to the NE→ crater Oasis, diam. 11.5 km, geol. age - the same (?).

AUSTRALIA:
14. KF Leonora, east. part of the craton Dzhilgarn, West Australia, a few tens of KP, $Є_1$? → 200 km NE→ AB Shoemaker (Teague Ring), diam. 31 km, abs. age 568+-20 Ma.

15. DF West Kimberley, Western. Australia, 150 pipes, abs. age >17.5 Ma→ 50 km in E → AB Goat Peddok, diam. 5,1 km, geol. age <50 Ma.

16. KF West Kimberley, NW Australia, about 10 pipes, dikes and bodies of unknown shape, abs. age - 568 or 752-819 or 804-826 Ma → 150 km W → AB Spider, diam. 13 km, geol. age > 570 Ma.

From this list, it is clear that most of these examples are not based on reliable radiometric dates but are based primarily on interpretations of the inferred geological age of the causative meteorite objects (except for the number of examples 4, 5, 8). However, in the author's view, these data suggest that the hypothesis of the spatially, quasi, linear eruption of the various surface kimberlite structures as the meteoritic object enters into and travels through the Earth's atmosphere, passing over the Earth's surface before impact, producing a quasi-linear trail of erupting kimberlites in its wake as a historical record of its impact, as the direct result of an electrical interaction between the Earth and the impacting meteorite objects as they pass over the Earth's surface, should be taken seriously as a primary cause of kimberlite genesis. In support of this deduction it is proposed that chains of two or more astroblemes and diatreme fields, interpreted as forming the proposed tail, are especially valuable in understanding the general model proposed here (examples 1, 3 and 8)

STRUCTURAL POSITION OF FIELDS AND ZONES.
It has been established that:
a) Areas of kimberlite (K-) fields are not related to cover and basement structures,
b) Location of K-fields are not connected with intersections of regional faults, and
c) K-zones have an independent structural position and also are not connected with zones of faults.

These data allowed the author to form a number of conclusions:

a) Zones of high fracturing are the CONSEQUENCE of the formation of K-pipes, but not the REASON of their localization,
b) Formation of K-pipes and associated dome structures is the typical process connected with intruding force of K-melt,

c) The corresponding K-field dome-shaped structures were formed as a result of simultaneous, spatially associated intrusions of kimberlite magmatic melts. Thus the generally practiced interpretation that K-fields and zones are structurally controlled contradicts with the absence of any universal spatial connection with the more ancient structures of the Earth's crust. The K-fields and zones are actually independently positioned relative to ancient structures. The ultrmafic alkaline ring massifs in particular in Kola Peninsula, Russia, have a similar random structural setting.

DISCUSSION

In spite of the fact that many geologists and geophysicists continue to try to find deep-seated faults, rifts or aulacogens under the K- fields and zones, the independent character of their structural setting from more ancient structures of the Earth crust are well described in the literature by researchers of kimberlites (Khazanovitch-Wulff, 2007). These data support the author's hypothesis for an extraterrestrial origin for kimberlitic fields.

Thus, the assumption of placing kimberlites and their spatial–temporal connection with, spatially, initially, unconnected astroblemes might confirm the author's bolide hypothesis. It is suggested that the known kimberlite structures and diatreme morphology could also be explained in terms of the electrical discharge hypothesis.

A plausible explanation of a kimberlite diatreme's formation mechanism has the first stage; when the structural cavity is formed, has not been possible though it is known that kimberlite diatremes formation involves a downward excavating vortex mechanism, and the hypothesis of electric discharge of Earth crust can explain this mechanism well. The resulting violent discharge plasma escapes to the surface with a great speed, and producing a downward, vortex-like matching mechanism (Hissink, 2010), thus forming the typical crater facies diatremes. The author assumes that the small portion of anatexis melt (forming local melt) is a result of the electric discharge or vortex. It rises upwards but does not fill the diatreme to the surface. The characteristic deficiency of kimberlite magmatic melt in the crater facies testifies to a non-mantle source; otherwise each diatreme would exhibit volcanic structures and lavas and would be surrounded with products effusive outpourings. Nothing similar is observed in kimberlite geology.

The necessary conditions for kimberlite melts (T = 1200-1300^{o}C, P = 30-40 Kbar), the inferred environment of static loading at depths of 200-250 km, could also be achieved by electrical discharge and anatexis in the near surface of Earth crust as the result of a cosmic bolide interaction . Thus, kimberlites, as well as all other similar diatreme interactions, most likely are better described as anatexites. The zone of anatexis in the limits of each individual pipe may also represent analogs of intermediate magmatic centers, presently used to explain the wide variation of composition of kimberlites in a specific field. It is thought that the position of these individual diatremes correlates with zones of highest electrical conductivity, and could possibly explain the structural features of kimberlites and related rocks. However, the mechanism of this process remains in mystery.

One of the lines of evidence for a crustal origin model of kimberlites is the chemical composition of kimberlites, undoubtedly testifying that these rocks were formed from sedimentary or former sedimentary metamorphic rocks of the Earth's crust, as repeatedly described by many Russian researchers (for example – Mikheenko, 1977; Sorokhtin et al., 2004; etc.). According to them, carbon, phosphorus, nitrogen, most lithophile elements, carbonates, water and other fluids in diamond formations are not derived from the mantle, but from a primary sedimentary origin. This is evidenced by the same high concentrations of rare earth elements, the relationship potassium /sodium, thorium/uranium, isotopes of oxygen, hydrogen, sulfur and strontium in kimberlites, as well as gas-liquid inclusions in diamonds: $H_2 O$, H_2, CH_4, CO_2, CO, N_2, Ar, C_2, H_4, and C_2H_5OH. The same applies to the isotope ratios of carbon in diamond crystals.

The proposed kimberlite crustal model here is considered to be most plausible, and with fewer contradictions, capable of explaining many features of kimberlite geology. But, Sorokhtin and his colleagues (2004), for example, believe that the sedimentary rocks, which some kimberlites were formed from, were subsequently lowered to a depth of 200-250 km as a result of ancient subduction. This and other models of kimberlite genesis suffer from implausible contradictory explanations for the source of kimberlite melt. The hypothesis of electrical discharge, however, eliminates this and puts kimberlite genesis on a new footing.

The author assumed earlier that the level for electric interaction was at the crust-mantle boundary, 30-40 km in depth. However, recent developments of modern geophysics have delineated cratonic layers with sharply lowered resistance (=high electrical conductivities) at depth only about 10 km, including the Brazilian and Baltic shields and the Siberian platform. These data introduce essential corrective amendments to the earlier proposed model of the electrical discharge of Kemerovo physicist V.Ju. Kaznev, and thus reduces the depth of electrical discharge interactions from 30-40 km to 10 km. However, the physical-mathematical substantiation of this model remains problematical. In particular the following question needs to be considered: can the powerful electric field induced by a bolide on the surface of the Earth concentrate electric currents in the nearest zone of high electrical conductivities at depth and cause an electrical discharge to the surface?

The mantle-origin model for kimberlites has a considerable number of contradictions and questions. The main problems are:

a) Under the conditions that tectonic control of the kimberlite fields and zones is absent, the mechanism of lifting and the subsequent intrusion of magmatic melt from depths of 200-250 km to a surface of the Earth has no plausible explanation. Mantle melts need an extremely short time from origin to the surface to allow preservation of mantle phases, particularly diamond, on solidification at the surface. The slightest delay to the uprising, often diamondiferous, kimberlite melt along its path to the surface (for example - by thick obstructing dolerite sills hundreds of metres thick such as the flood basalts in Siberia or the Karoo basalts in South Africa) will result in magma pooling causing a reduction in the cooling rate that results in a transition of carbon from the diamond phase to the graphite phase, either as a complete phase transformation or partially as graphitised diamonds of varying quality. However, the process of a fast rising melt is presently considered absolutely unreal. Researchers are forced to admit huge speeds of the melt from the upper mantle: from a depth of 200-220 km - 180 km/h (Sorokhtin et al., 2004); from a depth of 400 km, the lower mantle (Kaminsky et al., 2009), the rate should increase by two times - up to 360 km/h or 100 m/sec!

b) The same concerns also to a strict quantity of melt, or the lack of other mantle-sourced volcanic rocks. The absence of kimberlite flows and other surface volcanic facies such as lava flows etc., characteristic of mantle sources of magma, which should form on a surface of a planet and form integumentary outpourings and volcanic forms of relief, is another problem.

c) Presence of mantle minerals and rocks in diatremes isn't an unambiguous indication of the mantle nature of kimberlite. Former mantle rocks form parts of Earth's crust where they have intruded in and on some hundred million years before kimberlites and which have been sampled as the kimberlite passed through in the form of xenoliths during formation of pipes as it, for example, is undoubtedly proved by a geological situation in the Krushne Gory, Czech area (Kopecky, 1971).

d) The various dates of authigenic minerals in kimberlites formation, on the one hand, and xenogenic inclusions in them of mantle rocks and minerals, on the other, proves the long time spans (sometimes to 1 billions years and more!) of their formation. This circumstance is another serious argument against the mantle-origin hypotheses.

The usefulness of the "kimberlite mantle model" in diamond geology becomes quite problematical with such a number of inexplicable contradictions.

MODEL OF KIMBERLITE FORMATION

Given all the above characteristics of the conditions of kimberlite pipe formation and their associated geological features, the following model of kimberlite pipe formation is proposed:

a) Traveling through the solar system among the plasma of "solar wind", meteoritic bodies (MB) of asteroid sizes acquire an electrical charge, which increases with their entry into the magnetosphere and the various conductive layers of the Earth's atmosphere.

b) As these MB pass close to the Earth they start to induce an electrical charge on the Earth's surface at so-called "tension spots" (which lag behind the MB as it transits through the Earth's atmosphere), forming strong and intense focused electric fields (greater than 10^4 V/cm).

c) This surficially induced charge then starts to interact with a zone of high electrical conductivity in the upper crust (up to the depths of approximately 10 km), resulting in a breakdown between the plates of this natural capacitor. The consequence of this process is the formation of diatremes and, in particular, kimberlite pipes (**Figs. 1 and 2**).

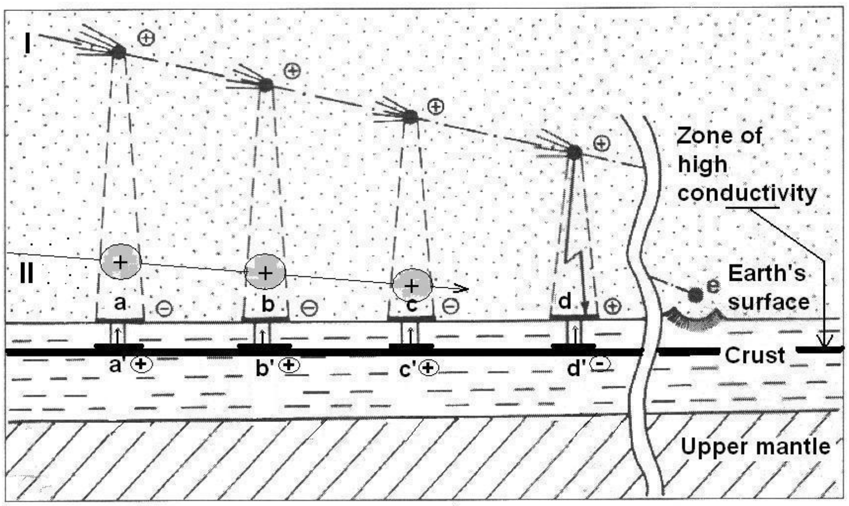

Figure 1. Model of V.Y. Kaznev, 1991 (Khazanovitch-Wulff, 2011) revised by the author. Instead of interacting with the deep located (30-40 km) "crust-mantle" boundary (or Moho), the presence of the zone of high electrical conductivity (HEC) at a depth of about 10 km is assumed under the Baltic shield, Brazilian and Siberian platforms (black bar in the upper part of the crust) – the fireballs induce a charge at the Earth's surface. The size of the meteor body – 2 km (position I) and 10 km (position II)); in the latter the height of the meteor body over the Earth's surface, the depth of the HEC and the length of the electrical discharge are commensurate to the diameter of the body, and the model becomes more plausible.

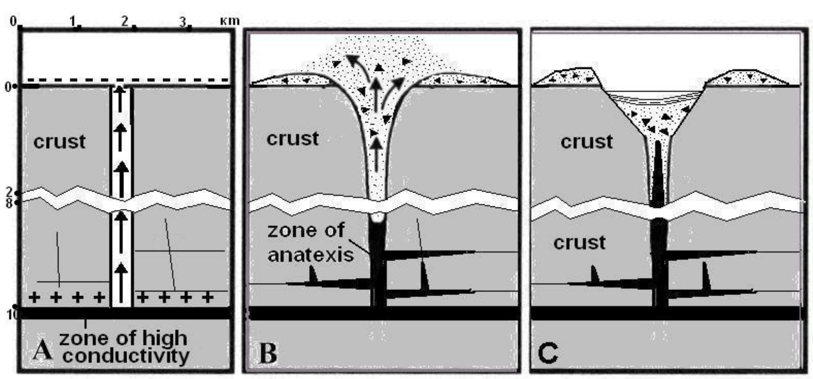

Figure 2. The consequences of electrical discharge between the Earth's surface and the zone of high electrical conductivity (HEC) at a depth of 10 km. The figure shows only the lowest and the uppermost part of diatremes length of about 2 km. Break in the section is about 6 km. The horizontal scale of the image is largely exaggerated. A – electrical discharge of the upper part of the Earth's crust, the formation of a cavity with fused walls filled with plasma; B – moments after, a melt is produced at the bottom part (zone of anatexis), which starts to climb up the column and fills in loose horizontal (sills) and vertical (dikes) zones; plasma formed during a high speed burst outwards, producing a fracture of the channel walls, expanding them and throwing explosive material and xenoliths of country rocks around the mouth of the tube. C - final form of the tube and its mouth; column of the molten rocks rose almost to the mouth, but the amount of the melt is not enough to fill and outpour to the surface.

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CATASTROPHES IN THE FIRST HALF OF HOLOCENE AND THEIR POSSIBLE DYNAMIC CAUSES

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Abstract: Studying ancient megalithic complexes in the Urals, and their orientations, we have uncovered traces of strong earthquakes and climatic changes. We formulated a hypothesis that all the various observations were provoked by a combination of changes of the axial tilt of the Earth and by true polar wander (drift). Hence, we are talking about global processes for which traces are found in locations spread around the world. Thus, it is inferred that glacial cycles were caused by changes of Earth's orbital eccentricity, its axial tilt to the plane of the ecliptic, and to the well-established phenomenon of true polar wander. Judging from orientations of megalithic constructions, the astronomical-dynamic processes seem to have been relatively abrupt rather than gradual. It is hypothesized that at least some of the explanation is to be found within the framework of an Expanding Earth.

Keywords**:** megaliths and their orientation, Polar Wander, axial tilt, amphi-Atlantic climatic oscillation, Holocene, earthquakes

Introduction

Generally, the humanities are very far from natural sciences, but many of them, especially archaeology, use methods and results from the natural sciences. An inverse connection is rarely seen. However, studies of ancient megaliths raise problems relevant to fields such as geophysics and astronomy. One of the pressing issues is the cause of cycles of ice ages and their interglacial periods. And although the megaliths were erected much later in Holocene, they keep in their architecture information about the mechanism of the process.

Fig. 1 Map of the Urals with localization of the Vera Island archeological site.

Ancient earthquakes and climatic changes

For several years we have studied a unique archaeological complex situated on Vera Island in Lake Turgoyak (Southern Urals) (**Fig. 1**). The complex includes many ancient megalithic structures and settlements (Grigoriev and Vasina, 2010). The excavations have revealed traces of a strong earthquake that happened after the mid 4th millennium BC – corresponding to the first stage of the Copper Age in the Urals. The archeological remains are most visible in the center of the island. Ancient people lived here under the shelter of a stony roof; but the roof collapsed, which is well marked by a collapse of large granite plates and blocks covering a level with Neolithic and Copper Age ceramics (**Fig. 2**).

Fig. 2. Photo depicting the collapsed roof of a Neolithic stone shelter. The caved-in roof has fallen into a cultural layer with artifacts of Neolithic and Copper ages.

The building of megalith 3 on the Vera Island had not been completed. Its walls were made of massive boulders, but their base is presently strongly declined from its presumably horizontal position and, as a result of a strong pressure, large blocks had been broken off from their outer sides (**Fig. 3**).

Fig. 3. Megalith 3 location (upper diagram) and a profile (lower diagram) showing inclined (rotated) boulders at the site. Red arrows indicate shattered pieces of rock broken off as a result of forceful pressure. The blocks have broken off in places where they should break off – corresponding to their original locations in the sharply inclined boulders. The two pieces of broken rocks are probably physically connected, being indicative of an earthquake.

Stone tools and ceramics have been found in tectonic cracks in underlying granite plates on another Copper Age settlement – Vera Island 7. If the cracks had preceded the ancient occupation, they would have been filled by soil and the ceramics couldn't have been placed into them. Hence, it is concluded that the tectonic cracks were formed after the Neolithic occupation.

Most interesting results have been obtained from excavations of settlement Vera Island 4 – located on the shore of the lake, constituting a beach ridge of sand and stones. Beach ridges are a typical geomorphological feature of many Ural lakes; they are usually formed as a result of ice activity (as usually thought), but their development is modified by surf.

Virgin soil on an outer flank of the ridge is presented by laminated beach sediments suggesting that this location was flooded a long time. The upper part of this floodplain is saturated with hydroxides of iron, minerals that usually occur in warm conditions without storms. These deposits probably formed long before the local settlement. Unfortunately, full studies of the lake are lacking, but coring in the southern part of the lake has revealed floodplain soil of Boreal age at a depth of 9.5 meters (Deryagin, 2009). In the Post-Pleistocene period, gradual rise of the water level of the lake and associated floodplain sedimentation occurred. Rising water exceeded present-day Vera Island shore level – being possibly, at least in part, a result of space requirement of the depositing laminated sediments.

It is inferred that significant oscillations of the lake's water table occurred during the Atlantic period. Thus, underwater investigations[1] have demonstrated that at one time the water-level was three meters lower than the modern level, because we have found a megalith at a depth of two meters and a quarry at a depth of three meters. At this time of water lowering, an ashy cultural layer with Neolithic ceramics was deposited at this place, soon to be followed by a Copper Age settlement. Subsequently, but still of Copper Age, the water level rose again, and masses of ice pushed the first beach ridge (**Fig. 4**) which consists of coarse-grained sand with streaks of iron hydroxides and inclusions of large stones. The outer part of the ridge – facing to the south and lake ward, and therefore receiving more solar heat – is saturated with iron hydroxides. The observations seems difficult to interpret without the action of a relatively thick ice layer having formed as a result of intense cooling, followed by a sharp increase of temperature. It is thought that a thick ice mass pushed the first beach ridge, but this explanation is not without problems in that a linear expansion of each 1km of ice is only ¾m if temperature increases to 15˚C; therefore a simple expansion model seems insufficient to account for the formation of such a ridge.

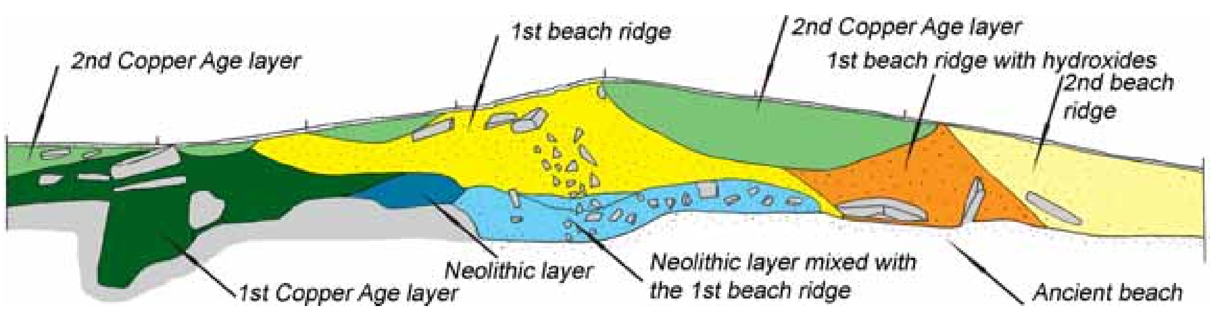

Fig. 4. Diagram shows the stratigraphy of the Vera Island 4 settlement. The local deposition of the Neolithic layers begins after fall of the water-level, upon which follows the first layer of Copper Age settlement. Then the first beach ridge is formed, covering and partially displacing the archeological layers. At last, the beach ridge is cut by the second layer of Copper Age, but the stratigraphical correlation of this layer with the second beach ridge has not been elucidated. However, the first beach ridge is of Copper Age.

[1] This work was organized by director of diving-club "Argonaut" I.A. Fomin. Underwater objects were studied by archaeologists V.G. Kotov and S.A. Grigoriev.

The power acting on the ridge was so strong that a granite block of 10-15 tons was displaced. The outer border of the rocky bed, which had been crushed, consists of small splintered pieces indicating that a strong mechanical force has been at play.

In the next development stage, a second ridge – consisting of fine white beach sand – covered the outer part of the first ridge. This means that after the rising of the lake's water table and formation of the first ridge, wave motions produced the white beach sand in front of the first ridge. But the formation of this second ridge was also the result of ice movement because some large stones have been found here too. All in all, we arrive at two significant cooling events intercalated by a sharp increase of temperature. But the climatic effect was probably accompanied by additional factors such as earthquakes. Within the ridge and beneath it, Neolithic and Copper Age artifacts have been found, but the ridge was covered by another Copper Age layer.

Very interesting climatic evidence has been uncovered from palynological data from eight probes in the upper part of the ridge[2]. Three of the probes, from the layer beneath the ridge and from its lowermost part, have shown warm and dry climatic conditions of the first half of the Atlantic period (8000 – 6000 BP). Three higher level probes define warm and moist conditions of the second half of the Atlantic period (6000 – 4500 BP). At last two of the uppermost probes indicate climatic conditions similar to that of present-day or Sub-Boreal times. It is to be understood that probes from the ridge will have to contain pollen deposited in the previous period. In other words, the formation of the ridge took place within the transitional period between the Atlantic and Sub-Boreal periods. The climatic changes which are found also in other Ural lakes, associated with the variation of water level of the lakes, are likely to have global causes.

A sterile sedimentary layer some 15-40 cm thick, consisting of sand and rock pebbles and located between the levels of the Neolithic and Copper ages, was found on the settlement of Korablik along Lake Great Miassovo. On the shores of Lake Chebarkul, the same sterile horizon of either sand or clay is found in the ancient settlements of Chebarkul IV, and in Shatanov I on Lake Irtyash (Krizhevskaya, 1977, p. 21, 23 and 43-45).

Plotnikov (1978, p.15-34) discussed evidence of a major earthquake in this area some 7000 years ago, arising from the fact that the bottom of the ancient Ilmen lake peat bog occurs 6 meters higher than the bottom of the lake today. Traces of an ancient earthquake have been reported by Deryagin and Zakharov (Deryagin, personal communication 2009) on the closely located lakes of Great Terenkul and Chebarkul.

The major increase of water level was not limited by the regions discussed above. Thus, on the settlement of Berezki (Bannoe Lake near Magnitogorsk, Southern Urals) a Neolithic layer is covered by a major beach ridge – cut by dwellings of Copper Age (Matyushin, 1982, p. 55-61). Adding to the evidence of tectonic disturbances discussed above, beach ridges of the Ufimskoe Lake (Southern Urals) are faulted and displaced several meters (Deryagin, 2009).

The evidence described above demonstrates that during the 4th millennium BC significant seismic activity took place in the Urals; it was accompanied by major increase of water level (and oscillation prior to this), formation of beach ridges and climatic changes. But if the heavy blocks of megalith 3 of Vera Island had been disturbed by strong earthquakes, how could then the remains of megaliths 1 and 2 – constructions that were built of similar stone blocks and covered by platy granite slabs – have continued relatively intact? Most probably the latter constructions were built after the tectonic event.

Megalithic structures and archaeo-astronomy

It is an old-established fact that many megaliths in different parts of the world were connected with some celestial objects, mainly sun and moon. Their orientations were directed to some particular events:

[2] For palynological analyses and conclusions readers are referred to N.K. Panova and T.G. Antipina, Institute of ecology of plants and animals (Ekaterinburg).

sunrise and sunset in autumnal and vernal equinoxes, winter and summer solstices, particular moon phases, etc. Thus, the abovementioned megaliths 1 and 2 (**Fig. 5**) of Vera Island are oriented in such a way that the equinox rays of the setting sun penetrated under a capstone in the west and illuminated niches in the eastern wall. Such examples were found in megalith 1 of Copper Age, but not in its early stage.

In the cultic place of Vera Island 9 there were several menhirs – tall upright monumental stones – indicating directions to sunrise in equinoxes and solstices. But deviations from the modern points of sunrise are about 13° clockwise in equinox and 9° clockwise in winter solstice (**Fig. 6**).

Fig. 5. Megalith 2 – with its opening facing the sun.

Fig. 6. Orientations of menhirs on the cultic place of Vera Island 9. Red arrows indicate directions between menhirs; yellow arrows indicate directions to the point of sunrise at equinoxes and winter solstice. The lines between menhirs are deviated from the modern points of sunrise – about 13° clockwise in equinox and 9° clockwise in winter solstice.

It is remarkable that materials corresponding to the transitional period from the Neolithic to Copper ages predate the formation of the beach ridge on the settlement of Vera Island 4. Thus, based on the situation of the island we may conclude that there were mighty natural catastrophes, including climatic changes and replacement of points of sunset and sunrise. The matter concerns, consequently, the change of the Polar point relative to the Earth's surface. But if so, this must have been a global dynamic process for which evidence should be found in widespread locations around the Earth. In fact, in Neolithic and Copper Age times many natural catastrophes took place around the globe; for listing of events, see Stanford University website - (www.stanford.edu/~meehan/donnellyr/3000bc.html). In Russian Karelia, excavators of some Copper Age settlements have revealed traces of strong earthquakes dated to the 6th and 3rd millennia BC (non-calibrated) (Zhuravlev 1993). During significant ground shaking, Le Grand menhir at Carnac (Brittani, France) – a construction 21 m long and weighing over 300 tons – collapsed and now lies broken in four pieces (Thom and Thom, 1978, p. 5-6). The evidence of strong tectonic disturbances is revealing.

Some megaliths in Brittany are today on islands though originally they had a continental coastal setting (Daniel, 1960, p. 73). There are also megaliths located at shallow coastal level or under water. Archeologists explain such observations to indicate that after the end of ice age the sea level has risen (Joussaume, 1985, p. 85). But megaliths have appeared in this area in the second half of the 5th millennium cal. BC (Scarre et al., 2003, p. 80). We have seen that on Vera Island the rise of water level was contemporary with seismic events. Most probably then, also the observations from Brittany can be connected with the tectonic activity too – implying either regional or global regression of sea level.

As mentioned above, orientations of ancient cultic objects to points of sunset and sunrise at equinoxes and solstices have been reported by many investigators – megalithic buildings being clear manifestations of these cultic phenomena. In this field of study, the works by Alexander Thom and his associates are most impressive. But the question arises whether 1) these ancient 'observatories' allow exact observations to the extent that ancient lunar eclipses can be estimated, as indeed Thom has supposed, or whether 2) they are marking only solar and lunar cycles serving sacral purposes. But many scientists seem to have no doubt in associating megalithic structures with solar cycles, pointing out that all of Thom's solar objects are close to solar azimuths of the British islands with deviations of no more then 10˚ (Schlosser and Cierny, 1996, p. 59; Patrick, 1981, p. 215). Though there seems to have been a strong tradition in orientating the ancient megalithic structures, even within local areas deviations of the rule are quite common – builders simply ignored the tradition. This deviation from the common practice cannot be explained by processes of precession as these effects are insignificant; today the azimuth of the sunset at summer solstice in Munster is 23˚44´, and in 3000 BC it has been estimated to 24˚02´ (Hänel, 2008, p. 32).

Already by 4600 BC, it is a common opinion that the ring-shaped ditches of Central Europe (so-called rondels) were connected with solar and lunar orientations – corresponding to present-day bearings. These are enormous structures extending sometimes over several hundreds meters and up to five meters in depth; in some cases excavations reveal that their orientations had been corrected – for unclear reasons. It has been supposed that ancient builders had missed the actual astronomical bearing, and after completion of the work it became clear that the sun, unfortunately, rose in another point in the horizon. Another explanation has been that in hundreds of years the holidays changed, whereby adjustment of the constructions became necessary (Schlosser and Cierny, 1996, p. 77). But taking into account the quite simple initial determination of points of sunset and sunrise, as well as the continuance of the building of these huge constructions, the inadvertence in benchmarking is doubtful. Neither are changes of dates of holidays, which in antiquity mainly followed the solar calendar, to be regarded a good explanation. Therefore, the most probable explanation seems to be in terms of changing points of sunset and sunrise.

An example of deviation from true azimuth on an early site is a famous rondel Těšetice-Kyovice of the mid-5th millennium BC (**Fig. 7**). Deviations of gates of this construction are about 10˚ counterclockwise (Weber, 1986, p. 317). If we actually turn all the structures 10˚ clockwise – which is contrary to deviations of the ancient constructions in the Urals – gates will accurately correspond to the cardinal points.

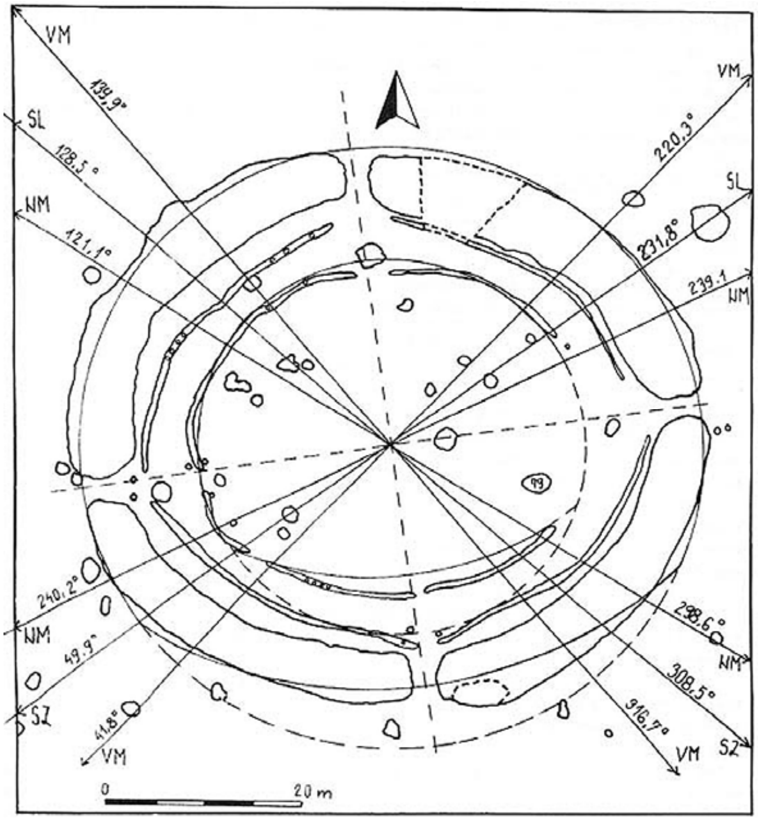

Fig. 7. Orientation of the rondell Těšetice-Kyovice (Weber, 1986, Abb. 5). Deviations of gate orientation would be better in line with the modern cardinal points if we turn the construction approximately 10˚ clockwise.

There are also similar problems with orientations of megalithic tombs in Netherlands and Northern Germany. Usually entrances to these constructions are directed to the south, but deviations about 14-19˚ to the east of due south are very typical. Such a similarity can not be explained by particular landscapes, all the more as all these countries are flat. Ancient people apparently did not direct their cultic building to any hypothetical line – obtained by vector addition of a line directed to the sun to a line borrowed from a distant area. This explanation is of course very speculative. However, it is remarkable that also the megalithic structures of North Germany and the Netherlands have orientations in a counterclockwise deviation from true azimuth.

There is the same tendency in Britain. Thus, Alexander Thom demonstrated that the orientations of many megaliths were neither connected with sun nor moon and; perhaps, they were directed to some star? From his extensive work on hundreds of megaliths and their declinations, Thom has shown that statistically the declinations fall in separate groups. In addition to the groups connected with either equinoxes or solstices, there are statistically well-defined groups apparently without any astronomical significance. But questions regarding stellar orientations have been raised, because it has been assumed that they might have been needed to determine time at night.

In an attempt to clarify this problem, Thom has suggested that the additional orientations were necessary to divide a year into 16 parts (so called "megalithic months") in addition to the four periods between equinoxes and solstices (Thom, 1967, p. 103-113). However, some of the groups of megalith orientation correspond to Celtic holidays, which are slightly different from solar calendar holidays typical of ancient societies. Whatever the explanation might be, radiocarbon dating of some ancient constructions with doubtful stellar orientation suggested they were older than those having solar or lunar connections (Thom and Thom, 1978, p. 179).

Some authors believe that astronomical orientations of megaliths appeared only in the second half of the 3rd millennium BC (Startnin and Bradley, 1981, p. 332) while others suppose that the earliest orientations are dated from the early 2nd millennium BC (Thom and Thom, 1978, p. 178). But there are early megaliths with solar orientations – such as Stonehenge (at c. 3100 BC) and Newgrange (at c. 3250 BC)[3]. This might indicate that a change of the relative position of the rotation pole could have taken place in the 4th-3rd millennia BC – implying an event(s) of True Polar Wander. Such an instability of Earth's axis of rotation – which is understood as periodic changes of the Earth's spatial orientation (cf. Gold, 1955) would be consistent with the evidence from Vera Island. Alternatively, changes of the axial tilt of the Earth cannot be entirely excluded.

During the last Ice Age the average global temperature was 5˚ lower, and over the ice shield 12-14˚ lower, than now. In the tropics, however, the temperatures seem to have been either similar or higher than now. Surprisingly, in oceans of the equatorial belt temperatures in different areas were the same or higher and lower than now (Burroughs, 2005, p. 41). An explanation is very simple. At 1) either another angle of the Earth's axis, or 2) another location of the pole most parts of the equatorial belt will be in the tropics, but a part of the tropical area will be near the Equator (**Fig. 8**).

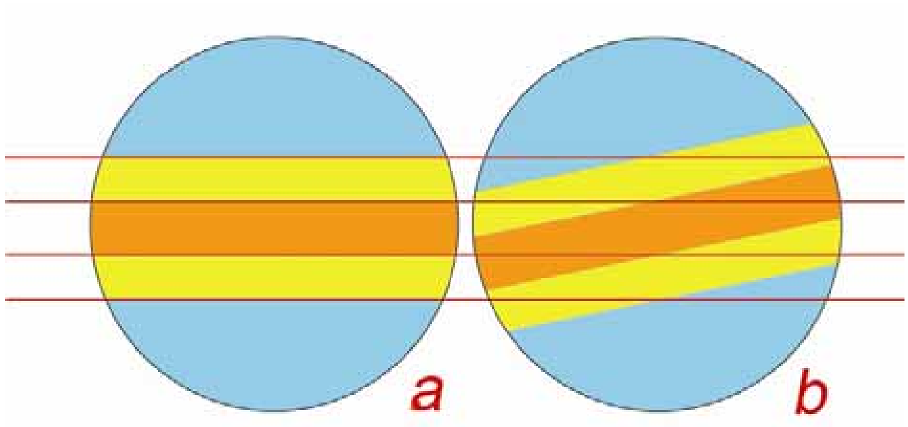

Fig. 8. Suggested post-Pleistocene change of geographic zonation: a – present situation, b – Pleistocene. In response to relative changes of the geographical pole (Polar Wander), or changes in inclination of the earth's axis of rotation, the boundaries of the geographic/climatic zones essentially change.

In the period of maximum late Pleistocene glaciation in the Eastern Hemisphere, ice shields were limited only to Scandinavia, the Baltic area and Northern England, while in the Western Hemisphere the Laurentian ice shield was extending much further south – to latitude 40º N. Thus, the Northern Hemisphere ice shields were very asymmetrical in their distribution. If we place the geographic North Pole in north-western Greenland or Arctic Canada, the ice shields will attain a more 'normal' distribution (**Fig. 9**). It is also notable that melting of the Laurentian ice shield in North America was later than melting of ice shield in Europe (Lamb 1982, p. 106-108). Many years ago Ch. Hapgood, who collected a material accessible at that time, paid attention to this situation and suggested, for the last glacial period, a relative geographic pole in the central part of Hudson Bay (Hapgood, 1970, p. 124). According to Hapgood the pole was located around Yukon some 80,000 years ago and to the east of Greenland some 55,000 years ago. Our location of the pole in northwest Greenland does not contradict Hapgood's proposals. In the present article we discuss the end of the glacial period and Holocene, and a time-progressive northward shift of the pole from the Hudson Bay region would naturally pass through Arctic Canada/NW Greenland. It is important to emphasize that there are also other evidence about the polar track suggested by Hapgood (ibid.).

[3] In the case of New Grange it may be a situation of counter-clockwise deviation too, because re-examination of this famous fact has demonstrated that sun rays penetrated the megalith a week before and a week after the winter solstice (Kaelas, 1994, p. 609).

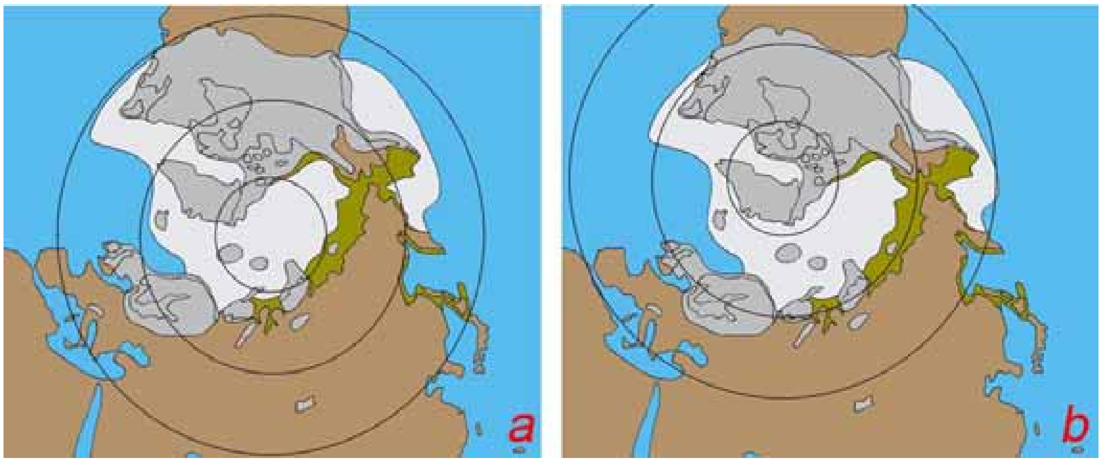

Fig. 9. a – Maximum late Pleistocene ice shields in present geographic coordinates. Note that continental ice cover and pack-ice in North America occur considerably further to the south than for Eurasia (Butzer 1964, fig. 9). b – Distribution of ice shields and geographic latitudes with respect to a pole in NW Greenland – for which the Northern Hemisphere ice shields attain a more comprehensible distribution.

In late Pliocene-Quaternary time, glaciations took place in repeated events; traces of the earliest episodes, Huronian, happened around 2.3 Ma ago. Investigations of the ice shield in Antarctica have revealed eight glaciations for the last 736,000 years. According to conventional interpretation of palaeomagnetic data (Irving, 1956; Wesson, 1970; Tarling, 1978), secular movements of the palaeogeographic pole, for Pre-Cambrian, Miocene, Pleistocene and Quaternary times, have been proposed. But according the same authors the pole has not only shifted its position with respect to certain land-masses, but also that these land-masses have moved relative to one another. The causes of such movements can be of both physical and astronomical nature. On the face of it, what we see in the Holocene is likely to be only minor jerky occurrences of such dynamo-astronomical processes. The fluctuation of glacial periods and changes of axial tilt – i.e. variation of the ecliptic – and events of True Polar Wander naturally result in climatic changes. For example, the axial tilt varies between 22.1° and 24.5°, and cases of its decrease the difference between summer and winter temperatures decreases it can be presumed that glaciation starts gradually (Gribbin, 1978, p. 140); during the reverse process, ice shields can be expected to have melted rapidly. All in all, even modest changes in dynamo-astronomical processes may have provoked geological catastrophes.

Because the Earth's ellipsoidal shape, changes of the axial tilt and/or variation of the Earth's spatial orientation (True Polar Wander), resetting the equatorial bulge, will naturally result in strong tectonic stresses in the Earth's crust as well as hydrostatic pressure increase of the asthenosphere. The result will be many local natural catastrophes spread across the globe – for example in transitional periods between ice ages and interglacials. The eruption of the supervolcano Toba on Sumatra coincides with the sharp global cooling that happened 71.000 years ago. During that event, average global temperature decreased by 5˚ C, but the summer temperatures in high latitudes may have decreased by as much as 15˚ C (Burroughs, 2005). It is necessary to emphasize that causes and effects of this process had this sequence, instead of a reverse one (the eruption of the supervolcano causing cooling, leading to glaciations and change of the earth's axis relative to the Earth). Cooling effect of a strong volcanic event is of short-term duration (1-3 years); major emissions of volcanic dust may lead to temperature decrease over larger areas of the Earth. However, volcanic emission of the carbon dioxide, methane and water vapor would expectedly form a more long-lasting greenhouse effect. Thus, volcanic activity is not likely to be the causation of glaciations (Tarling, 1978). In addition to this, glaciations on the Earth have a cyclic variation that forces us to search for other mechanisms. Similarly it is difficult to imagine that an eruption of a supervolcano could displace the pole significant or change the ecliptic. However, the volcanic effect in the form of the sharp short-term cooling replaced by warmer conditions is interesting. It is not unlikely that the two-phase formation of the ridge on the Vera Island had been provoked by a cooling of similar nature.

Conclusions

Milankovitch (1930) formulated a hypothesis that glacial cycles were caused by the orbital eccentricity and the axial tilt to the plane of the ecliptic. Though this is the most accepted view today, the Milankovitch theory can hardly explain the very rare occurrences of ice ages; for example, there is no evidence of polar ice between latest Tertiary and Hercynian time (c.270 Ma). In fact, other theories suggest that a cause of glaciations is associated with the passing of the Earth through galactic dust clouds (McCrea, 1975). The evidence presented above is consistent with the Milankovitch hypothesis – to the extent that the archeological observations can be related to changes of Earth's axial tilt. But these changes were obviously in terms of a series of relatively small and energetic movements. Presumably, future studies of orientations of ancient megaliths will allow dynamics of this process for the early and middle Holocene to be understood. But even now we may draw some conclusions.

A paradox is that there seems to be a definite discontinuity in polar drift after the Ice Age – as is indicated in Thom's statistical groups of megalith orientations. Also, as we know from natural catastrophes such as the Toba eruption, this process can not be described as a simple change of the orbital eccentricity – other more forceful mechanisms, such as spatial resetting of the globe and True Polar Wander, is likely to have been at play.

During changes of geographic pole location many areas changed their latitude, as can be demonstrated, for example, in the astronomic characteristics between the erections of the various megaliths; thus, menhirs of the cultic place of Vera Island 9 and the area of the Turgoyak Lake seem to have attained more northerly positions. The initial latitude was 48.5°N, but after the latitudinal shift it became 55°N – judging from the difference of angles of directions to sunrise at equinox and winter solstice. As it has been argued above, the deviations of menhirs' orientations on the earlier cultic place, relative to the modern points of sunrise, are about 13° clockwise in equinox and 9° clockwise in winter solstice. The orientation of megalith 2 corresponds to the present situation. This difference (4°) is very remarkable, because it is larger in higher latitudes. Before the change of latitude the area was situated more than 400 km further to the south[4] and this northward latitudinal shift of the area is reflected in transition from warm condition of the Atlantic period to Sub-Boreal states. Very simple calculations[5] demonstrate that the pole in the mid-4th millennium BC (Vera Island 9) was somewhere closer to the Chukchi Peninsula. This point can be achieved by a line set by menhirs of the Vera Island 9. The distance to the pole increases, taking into account the more southern localization of this place. Somewhere between this point of the 4th millennium BC and the pole during the last glaciations was the pole corresponding to the European Neolith and the start of megalithic building. This explains the deviation of many megaliths in Northern Europe – having another orientation and being built under the warm climatic conditions of the Atlantic period in western Eurasia. Hydrostatic pressure increase in the gas/fluid-rich asthenosphere triggered volatile-driven volcanic activity (Storetvedt, 2011) and the effect of long-term increase of temperatures (discussed above) resulted in greenhouse conditions. Such explanation was indeed suggested by Hapgood (1970).The final relative polar shift of the period (to its present location) led to the cooler conditions of the Sub-Boreal period (**Fig. 10**).

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[4] The change of latitude can be calculated by means of a simple formula:
Cos A = Sin B / Cos C,
where **A** – azimuth to a point of sunrise (the modern azimuth to sunrise at winter solstice because of high horizon is 130˚, and azimuth to the menhir is 139˚), **B** – sun declination for a given date at a given latitude (at winter solstice declination is -23°.5), **C** – latitude.
From the formula above we can calculate latitude:
C = ArcCos (Sin B / Cos A)
Hence, we receive the change of latitude:
$C_1 - C_2$ = ArcCos (Sin B / Cos A_1) - ArcCos (Sin B / Cos A_2) =
ArcCos (Sin -23°.5 / Cos 139˚) - ArcCos (Sin -23°.5 / Cos 130˚) = 6.4473344735˚ = 6.5˚
Accordingly, at the moment of creating the complex of Vera Island 9 geographical latitude of Turgojak Lake was 48.5˚ (instead of 55˚ now). Proceeding from it, it is possible to calculate this northward drift in kilometers:
6.5×Cos 55×40000 / 360 = 414,25 km
[5] Angle of 13˚ clockwise and additional 400 km.

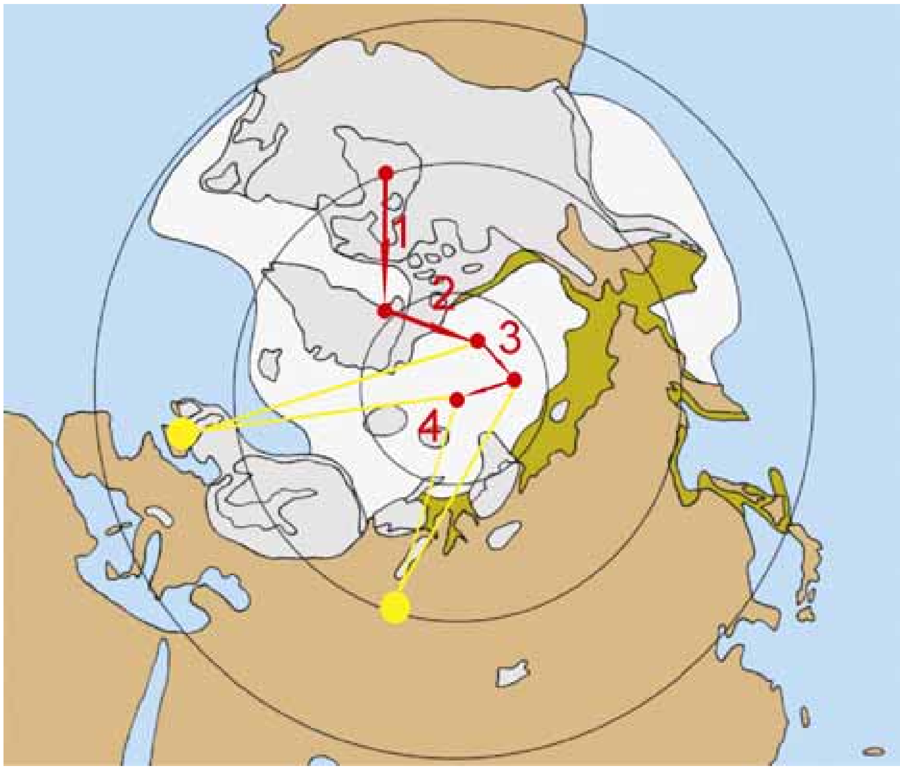

Fig. 10. Progression of North Pole (arrows connecting red points) during the late Pleistocene to first half of Holocene – relative to the Earth's surface. Yellow points denote areas of megaliths in England and the Urals respectively, and yellow lines mark directions and distances to the various poles. Numbers represent segments of polar change for time periods as follows: 1 – Younger Drias (this explains the sharp cooling in Europe and North Atlantic, which was not so expressed in North America), Preboreal periods, 3 – Boreal, early Atlantic periods, 4 – the late Atlantic period. However, the actual polar pattern could well be more complex than indicated in this diagram.

Problems for discussion

The polar drift demonstrated here does not correspond to a deviation of 2.4˚ as suggested by the Milankovitch hypothesis. This means that the considered polar change is likely to have had some other causation. It is necessary to understand that the changing axial tilt and the polar drift are different processes, although in particular periods they could be connected to one another. In the opinion of the present author, the hypothesis of Milankovitch may describe the mechanism of these processes more adequately than what follows from the facts discussed in this article. However, the coincidence of the end of the glacial age with the intensive polar drift allows us to assume that these processes were somehow connected. The following question arises: What mechanism caused the axis change described by Milankovich? But according to the latter author there is statistically a connection with solar cycles. Taking into account the colossal inertia of the Earth, we must search for its reasons not in the space, but inside our planet even if the trigger mechanisms are in space.

Concerning the dynamical causes of the polar drift, perhaps the problem can be viewed within the hypothesis of an Expanding Earth (e. g. Scalera, 2003) – for which a possible mechanism has been suggested by Larin's hydridic Earth (Larin, 1993). According to this model, in the primary hydridic Earth a metallospere was formed after decomposition of hydrides, and related hydrogen degasification. This led to essential decompression of substances and, accordingly, to subsequent expansion of the Earth. On the other hand, the seemingly "irregular degassing and the associated internal reorganization of planetary mass would naturally have caused changes of spin rate as well as episodic changes of spatial orientation of the body of the Earth – thereby repositioning the equatorial bulge" (Storetvedt and Longhinos, 2011). This gives a ready explanation of the classical phenomenon of True Polar Wander –

a dynamical process substantiated more than a century ago on the basis of rock and fossil evidence for palaeoclimate (Kreichgauer, 1902; Köppen and Wegener, 1924). But in case of an irregular expansion of the Earth's body, Polar Wander might have been the dynamical consequence. However, most expansion alternatives suggest uniform enlargement of the globe. Furthermore, expansion hypotheses takes for granted that seafloor spreading is a reality, but this idea is counteracted by a multitude of marine geophysical and geological facts (see Storetvedt, 2010 for summary).

Considering the presumed contemporary oscillation of sea/lake level in Brittani and in the Urals, Storetvedt and Longhinos (2011) submit that "sea-level variation is a direct consequence of ongoing Earth degassing with the attendant build-up of hydrostatic pressure in the upper mantle – causing oceanic crustal elevation and related transgression over lower-standing continental regions – intermittently punctuated by outbursts of pressurized asthenospheric gasses and gas-driven magma". Therefore, each particular event of Polar Wander was/is triggered by interplay of different primary and secondary processes. Planetary degassing is likely to be the consequence of chemical instability in core and mantle; the relatively hot topmost mantle (asthenosphere) is thought to be a product of degassing-related chemical reactions, rather than radiogenic heating (Storetvedt, 2011). But when it comes to unraveling Earth's internal state and processes, we are certainly not at the end of the road.

We note the relatively small (dynamical) shifts connected with cycles of glaciations, and above we discussed their possible connection with Milankovitch cycles. Streams of neutrino passing through the Earth may expectedly be capable of increasing internal temperature triggering both degassing and possible expansion. Both processes are liable to displace the Earth's center, and its axes of inertia – giving rise to the dynamical processes of polar wander (polar drift) causing climatic changes across the globe. Furthermore, it should be remembered that solar cycles have also a direct influence on climate (Perry and Hsu, 2000).

Thus, processes of glaciation and de-glaciation were very complex. Possibly, we are faced with a series of interconnected processes – such as oscillation of solar radiation, Milankovitch cycles, degassing of the Earth's interior – resulting in a range of surface tectonic processes. Thanks to the orientation of megaliths, described in this article, they seem to provide a certain data bank that enable us to study the complex interconnection of global processes as recent as the 5th-3rd millennia BC.

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METHODOLOGY TO CHECK CORRELATION BETWEEN EARTH TIDE AND EARTHQUAKES AND FOR PLOTTING [EMD+SEM] VS GMT TIMINGS

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*(**Editor's note**: This article is a supplement to the Kolvankar paper which appeared in NCGT Newsletter, no. 60, p. 50-66, "Sun, moon and earthquakes".)*

To plot earthquake counts from new moon [NM] to full moon [FM] with respect to the lunar position within 360^0 degrees.

Earth rotates around itself within 24 hours. However within the same interval Moon moves to east by about 12.12^0 degree and Earth needs to rotate this extra angle so that moon comes to the same longitude which takes about 0.842 hour approximately. So in short Moon takes about 24.842 hours to come to the same earth longitude.

The period NM to NM is about 29.5 days = 708 hours [29.5 X 24 hours], so within this time moon makes total 708/24.842 = 28.500 rounds approx.

For paper "Earth tide and Earthquake" (NCGT no. 57, p. 54-75) the horizontal scale [-180^0 to $+180^0$] for the moon rotation around earth [NM-FM-NM] was normalized to 96 columns. The vertical scale was the EQ counts. [For convenience the number of columns was reduced by factor of 4.]

This horizontal axis represents three different procedures hence three different ranges.
1. By marking NM-FM-NM it is possible to get the SEM angle on this for any specific earthquake between two new moon's timings.
2. It also represents longitudes of the earth from -180 degrees to +180 degrees and clearly shows the onset of the plots [for 00 hours GMT] for different regions with different longitudes.
3. Finally it also represents 00-360 degrees [readjusted for -180^0 to $+180^0$] for final calculated values of the X axis.

For the paper "Sun moon and Earthquakes" (NCGT no. 60, p. 50-66), the horizontal axis is the same but no columns are used.

For all NM and FM [The timings of all NM and FM can be found from the program new moon, full moon, Apogee, Perigee calculator program available on the net] from 1973-2008, the positions of moon [long] on earth to be calculated. This can be done using the same program [POSONLONG-developed by us] used to find the position moon for each earthquake of the catalog. [Only replacing the event time with time of NM and FM]. *Alternately this data can be found from programs Alcyone Ephemeris OR Home planet.*

The Moon longitude for each earthquake [LE] can be found considering following two parameters.
1. As the Lunar position changes from NM1 to NM2, an additional phase [Tm] corresponding to the travel of Moon towards east @12.12^0 /24 hours. This also represents as SEM [Sun earth moon angle]. When Moon moves towards east [clock wise] its position changes with increasing longitude values and hence this term is treated as +ve.
2. Due to the rotation of the Earth the position of the Moon changes at 15^0/hour. As the earth rotates clockwise the position of the Moon [so also for Sun] changes from higher longitudes to the lower longitude values [from $+180^0$ to 0^0 and to -180^0] and therefore this term is negative @ -15^0 /hour.

The overall calculation involves four parts.

Part A.

In this part the phase travel by moon for each earthquake is calculated as follows:
Phase travel by Moon Tm = 360^0 *(LE-NM1)/(NM2-NM1) where NM1 and NM2 are provided in format NM1.F1 and NM2.F2.

As the Moon travels to East with respect to Earth by about 360 degrees / 29.5 = 12 degrees/day approx. The term Tm is considered as +ve in the calculation and the term Tm expressed in degrees is taken as +ve [Nm to Nm period is equal to NM2-NM1].

THIS CALCULATION IS THE SAME FOR SEM [SUN EARTH-MOON ANGLE] WHICH IS ADDED AS TERM TO EMD EARTH-MOON DISTANCE IN THE RECENT PAPER.

Part B Considering self-rotation of the Earth of 360^0

The NM1, NM2 and LE are expressed in fraction such as for NM1 it is NM1.F1, NM2 it is NM2.F2 and for earthquake at given time can be Eq.F0.
The fraction calculation is FC = [F0 – F1]* [360] in degrees.

Part C

Moon position is given by Moon pos = [-(longitude of Moon at NM1)- (FC) + Tm].
[Tm calculation is given in part A]

Part D

The plot is given by [(earthquake long) – (Moon pos) + Tm]. **This is same as [EMD + SEM].**

If [EQL-(Le -LNM)] is less than -180^0 then [EQL-(Le -LNM)] = [EQL-(Le -LNM)] $+360^0$
[LNM is the longitude of Moon at New Moon].
If [EQL-(Le -LNM)] is greater $+180^0$ then [EQL-(Le -LNM)] = [EQL-(Le -LNM)] – 360^0.

The procedure is repeated for all earthquakes for NM-NM cycle and for all earthquakes within the cycle. For new NM-NM cycle the procedure is repeated from point2-7.

For a specific earthquake location EQ, [EMD + SEM] angle bears a direct relation with the position of Sun [OR GMT timings] as illustrated in paper "Sun Moon and Earthquakes"

Table 1 [Sun Moon and earthquakes] provides the starting plot counts for 42 different high seismicity regions of the world. The area chosen for each region is typically 10^0X10^0. As seen from this table, the start for the earthquake plot vary with different longitude ranges since these regions at different local time see the different Sun positions. So for different longitude ranges the starting plot counts shifts by about 4 [15^0] per hour shift in the local time. The starting of the earth quake plot is `at the mean` of the longitude range.

Illustration of examples to calculate the moon position and earthquake-lunar distance, SEM angles etc.

Example 1.
Date = 17.01.2000 Time = 19:24:51 = 16.8083, NM1 = 5.7604 NM2-NM1= 29.7841 Elong = -124.64, LNM=-92.50
Moon travel [SEM] = (16.8083- 5.7604 = 11.04789/29.7841 = 0.3709 * 360 = 133.52^0
Fraction Cal. = 0.8033-0.7604 = 0.0429 * 360 = 15.444^0
Moon pos. = (-92.50 – 15.44 +133.52) = 25.58
Plot value = (-124.64 +133.52 -25.58) = **-16.7^0= 343.3^0** and 343.3/3.75 =91.54 Correct.

Example 2.
Date 24.01.2000, Time = 23:33:56 = 23.9813 NM1 = 5.7604 NM2-NM1= 29.7841 Elong = -125.88, LNM= -92.50
Moon travel = (23.9813 – 5.7604) = 18.2209/29.7841 = 0.0.6116 * 360 = 220.23^0
Fraction Cal. = (0.9813 – 0.7604) = 0.2209 * 360 = 79.53

Moon pos. = (-92.50 – 79.52 +223.23) = 48.21.
Plot value = -125.88 -48.21 +220.23 =**46.14^0** and 46.14/3.75 = 12.304 Correct.

Example 3.
Date = 27.01.2000 Time = 18:04:41 = 26.7528 NM1 = 5.7604 NM2-NM1= 29.7841 Elong = -124.4, LNM= -92.50
Moon travel = (26.7528 – 5.7604) = 20.9924/29.7841= 0.7048 *360 = 253.73^0
Fraction Cal. = (0.7528 - 0.7604) = -0.0076 *360 = -2.736^0
Moon Pos. = (-92.5 +2.736 +253.73) = 163.96^0
Plot value = -124.33 -163.96 +253.73 = **-36.11^0 =323^0** and 323/3.75 = 86.37 Correct

Example 4.
Date = 30.01.200 Time = 20:52:28 = 29.98694 NM1 = 5.7604 NM2-NM1= 29.7841 Elong = -120.13, LNM= -92.50
Moon travel = (29.8694 – 5.7604) = 24.109/29.7841 = 0.8094 *360 = 291.40^0
Fraction Cal. = (0.8694 – 0.7604) = 0.109 *360 = 39.24^0
Moon pos = (-92.5 -39.24 +291.4) = 159.66
Plot value = (- 120.13 -159.66+291.40) =**11.61^0** and 11.61/ 3.75 = 2.97 Correct.

Example 5
Date = 24.01.2000 Time = 09:58:01 = 23.4153. NM1 = 5.7604 NM2-NM1= 29.7841 Elong = -127, LNM= -92.50
Moon travel = (23.4153 – 5.7606) = 17.6549/29.7841 = 0.592 * 360 = 213.12
Fraction cal. = (0.4153- 0.7606) = -0.3453 *360 = -124.30
Moon Pos = (-92.5 +124.3 +213.12) = 244.92 = -115.08
Plot value = (-124.3 + 115.08 +209.83) = **201.2^0** and 201.2 /3.75 = 53.65 Correct.
[Moon travel is same as SEM angle]

Table1: Sample data providing the details of calculations values: Data as per the event list

EDate	Original_ Time	dETime	NT1d	NT2d	Latitude	Longitude	Depth	Magn	Plot	Fract. Calcul	Moon travel [SEM] B	Moon Pos Cal.	Moon PO HP	EQ-MOON DIST A	A+B	X axis [A+B-180]	[A+B]/ 3.75
1/7/2000	21552	6.0938	5.7604	35.5451	40.48	-125.42	16	3.2	24	-239.97	4.029	151.49	+151.20	83.09	87.12	-92.88	23.23
1/7/2000	64929	6.284	5.7604	35.5451	43.23	-126.56	10	2.7	41	-171.50	13.18	92.18	+85.04	141.26	154.44	-25.56	41.184
1/7/2000	13118	6.0632	5.7604	35.5451	40.68	-124.73	15	3.5	20	-250.99	3.65	162.14	+161.98	73.13	76.78	-103.22	20.47
1/8/2000	21731	7.0951	5.7604	35.5451	40.5	-126.5	25	5.4	24	-239.5	16.13	163.13	+162.54	70.37	86.5	-93.5	23.066
1/9/2000	42147	8.1813	5.7604	35.5451	47.87	-128.99	10	3.1	31	-208.47	29.26	145.23	+144.15	85.78	115.04	-64.96	30.67
1/10/2000	232639	9.9764	5.7604	35.5451	40.52	-124.01	22	2.9	13	77.76	50.95	-119.31	-121.67	355.3	46.25	-133.75	12.33
1/10/2000	123316	9.5229	5.7604	35.5451	43.45	-126.56	10	2.7	65	-85.5	45.47	38.47	+33.68	194.97	240.44	60.44	64.117
1/13/2000	112354	12.4743	5.7604	35.5451	44.13	-128.82	10	3.8	93	-102.99	81.44	91.93	+86.97	139.25	220.69	40.69	58.85*
1/16/2000	150758	15.6299	5.7604	35.5451	47.82	-122.77	17	3	75	-46.98	119.29	73.77	+69.13	163.46	282.75	102.75	75.4
1/16/2000	15132	15.0771	5.7604	35.5451	40.46	-125.71	2	4.3	22	-245.98	112.6	-93.92	-98.92	328.21	80.75	-99.25	21.53
1/17/2000	194245	16.8208	5.7604	35.5451	41.02	-125.09	1	3.3	93	21.74	134.17	19.93	+16.73	214.98	349.15	169.15	93.10
1/17/2000	100001	16.4167	5.7604	35.5451	42.47	-126.51	10	3.8	54	-123.76	128.80	160.06	+156.74	73.43	202.23	42.23	53.928
1/17/2000	192451	16.8083	5.7604	35.5451	40.42	-124.64	15	3.3	92	17.24	133.53	23.79	+21.02	211.57	345.1	165.1	92.02
1/17/2000	175754	16.7479	5.7604	35.5451	44.19	-128.94	10	4	85	-4.5	132.8	44.8	+41.91	186.26	319.06	139.06	85.08
1/18/2000	4047	17.0278	5.7604	35.5451	43.92	-120.86	6	2.8	18	-263.73	136.18	-52.59	-54.83	291.73	67.91	-112.09	18.10
1/19/2000	23652	18.1083	5.7604	35.5451	44.36	-128.71	10	4	23	-234.75	149.24	-68.51	-67.98	299.8	89.04	-90.96	23.744
1/19/2000	202320	18.8493	5.7604	35.5451	43.9	-128.29	10	4.4	95	32.00	158.2	33.7	+36.59	198.01	356.21	176.21	94.98
1/20/2000	94147	19.4035	5.7604	35.5451	43.65	-127.26	10	6.1	52	-128.48	164.9	-159.12	-154.60	31.86	196.76	16.76	52.46
1/20/2000	233313	19.9813	5.7604	35.5451	40.17	-124.4	0	3	12	79.52	171.88	-0.14	+06.21	235.74	47.62	-132.38	12.69
1/22/2000	31332	21.134	5.7604	35.5451	43.59	-127.78	10	2.8	26	-225.5	185.82	-41.18	-32.07	273.4	99.22	-80.78	26.458
1/24/2000	95801	23.4153	5.7604	35.5451	43.72	-127	10	2.6	53	-124.23	213.39	-114.88	-103.20	347.88	201.27	21.27	53.67
1/24/2000	233356	23.9813	5.7604	35.5451	40.54	-125.88	1	3.4	12	79.52	220.23	48.21	+59.61	185.91	46.16	-133.84	12.30
1/26/2000	82720	25.3521	5.7604	35.5451	43.31	-126.69	10	2.9	48	-146.98	236.80	-68.72	-58.12	302.03	178.83	-1.17	47.68
1/26/2000	82008	25.3472	5.7604	35.5451	43.34	-126.62	10	3	47	-148.72	236.37	-67.4	-56.28	300.78	177.15	-2.85	47.21
1/27/2000	180441	26.7528	5.7604	35.5451	40.78	-124.33	23	2.8	86	-3.04	253.73	164.27	+172.78	71.4	325.13	145.13	86.70
1/27/2000	61636	26.2611	5.7604	35.5451	40.46	-125.43	2	3.8	39	-179.74	247.79	-24.97	-15.50	259.54	147.33	-32.67	39.28
1/30/2000	205228	29.8694	5.7604	35.5451	45.18	-120.11	1	2.8	2	39.24	291.40	159.66	+164.65	80.24	11.64	-168.36	3.104
1/30/2000	43451	29.1903	5.7604	35.5451	43.68	-127.35	10	2.9	32	-205.23	283.19	35.92	+41.55	196.73	119.92	-60.08	31.97
1/30/2000	204607	29.8653	5.7604	35.5451	45.19	-120.1	8	3.4	2	37.76	291.35	161.09	+166.18	78.81	10.16	-169.84	02.70
1/30/2000	191023	29.7986	5.7604	35.5451	45.2	-120.12	0	4.1	92	2.292	290.54	-164.25	-170.62	44.13	334.67	154.67	89.25*

Moon position at NM1 [5.7604] = -92.5 degrees. Moon position at NM2 [34.5451] = -29.29 degrees.

The data in red color for which examples for calculation of Moon position and SEM and EMD are provided

Details of the fields:

1. eDate : Date of the event [Source NEIC USGS earthquake catalog]
2. original time : time of the event in GMT
3. dEtime : Date + Time of the event in decimal format with respect to 01.01.2000 00-00 hrs GMT
4. NT1d : New moon 1 Date + Time in decimal format [Source : Program for Apogee, Perigee, New Moon, Full Moon timings]
5. NT2d : New moon 2 Date + Time in decimal format
6. Latitude : Latitude of the event
7. Longitude : Longitude of the event
8. Depth : Depth of the event in km.
9. Magnitude : Magnitude of the event
10. Plot : Plot value calculated by program
11. Fract. calculation: Fractal calculation used for obtaining moon position
12. Moon travel [B] : [SEM]Moon travel from towards east from NT1d till event date and time [dEtime]
13. Moon pos cal. : Moon position calculated for event date and time
14. Moon pos HP : Moon position provided by Home planet program for event date and time
15. EQ- Moon dist [A] : The distance provided along longitude between earthquake longitude and moon longitude [on Earth] [MEASURED IN ONE DIRECTION]
16. [A] +[B] : EQ- Moon dist + Moon travel [SEM angle]
17. [[A] +[B]]/3.75 : Plot Value calculated manually. [USED IN PROGIRAM FOR EARTHTIDES AND EARTHQUAKES]. In this program the number of columns was reduced to 96 [360/3.75] for convenience.
18. X axis [A+B-180] : The X axis values are adjusted for range of -180^0 to $+180^0$

ESSAY

FACTS, THEORIES, BLIND COMMITMENTS AND SOCIO-DYNAMICS

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– Every man, wherever he goes, is encompassed by a cloud of comforting convictions which move with him like flies on a summer day –

Bertrand Russell, in: *Sceptical Essays*

Summary: The history of the natural sciences is a narrative filled with an anarchic mix of facts, fictions, emotions and the struggle for prestige – including non-technical professional alienation, false play, bandwagonism, socio-political group pressure, national pride, immediate incentives, and the rest of non-relevant human peculiarities. Thus, one shouldn't be too surprised that even the worst of accepted theories have had nine lives. This essay takes a quick look at the history of global tectonics – exemplifying its theoretical undecidedness and confusion that have progressed along with the flow of unexpected observational complexity. The essay pays particular attention to the resurrection of the old idea of continental drift, and its subsequent plate tectonics version, which in the late 1960s was heralded as a major break-through for understanding the structural evolution of the Earth's crust. Nonetheless, guided by these once promising mobile concepts the alleged understanding of the Earth's geological development is much more chaotic today than it ever was before. The geological sciences have apparently got stuck in a non-productive deadlock. Necessary requirements for a next generation theoretical platform are suggested.

Social uniformity pressure favouring popular views

– Communication in the groups tended to be directed at the deviants…in an attempt to bring them back into line –

John C.Turner, in: *Social Influence*

It was interesting to read the book review by M. Hoshino (*NCGT* issue #57) – how the American influence and financial muscle after World War II changed traditional academic values in Japan. Of particular concern here is how US trained young geoscientists, from Japan and many western countries, in the late 1960s and 70s became staunch believers in plate tectonics (PT), – after having been emotionally overwhelmed by its purported simplicity and alleged explanatory power. With the benefit of hindsight, it is important to be alert to the fact that when the more massive conversion to the new global tectonics sat in, vital tests of the model had already begun to send alarming counter-messages; an increasing number of critical observations did not match PT predictions. Already by the early 1970s, the hypothesis had lost some of its original glossy paint, but to compensate for the unexpected development, erection of a daisy chain of ad hoc modifications was in full force – a fruitless game, just inventing an artificial protective belt around the model to avoid its falsification. And not to forget, for the rapidly growing crowd of PT adherents careerism was undoubtedly too strong to be impeded by ugly facts.

In the late 1970s, the rot had more than set in, but despite repeated refutations by critical experiments, notably through deep sea drilling tests (cf. Storetvedt, 1997, 2003 and 2010), the model is still being promulgated as one of the greatest intellectual revelations of the 20th Century. Nonetheless, the basic assumptions of the then 'new global tectonics', and its initial promise to unify the phenomenological diversity of the Earth, have gradually been forgotten. Sustained by funding agencies and vested interests, plate tectonics has been made impervious to disproof, and young researchers are kept in line by career prospects. The situation today can best be described as a mix of authoritarian dogma and social construction; the PT paradigm has become a self-sustained delusion.

As a young geophysicist in the early 1960s, with the commonplace narrow scientific platform and extremely fragmentary knowledge of global tectonics, I readily slipped in among the crowd of PT enthusiasts – driven by oversized self-confidence, and bursting with pride and opportunistic attitudes. But my overly enthusiasm didn't last for long; already by 1970 I had become a growing sceptic to the popular Vine-Matthews model of seafloor evolution. By then, it was taken for granted that the striped pattern of the marine magnetic field anomalies represents a kind of tape recorder of polarity changes of the geomagnetic field which, in connection with the seafloor spreading hypothesis of Hess (1962), was thought to serve as a dating tool of ocean floor development. Having lost faith in this central PT credo, I was never back to the cheering gang of supporters. A ceaseless enquiry had begun, but for the following 20 years my theoretical house of cards was still staggering along in my teaching of global geophysics. In early 1989, this process ended abruptly; my complete dismissal of plate tectonics took place along with erecting a first version replacement theory of the Earth – eventually leading to my *Global Wrench Tectonics*. In the aftermath, pondering over my own scientific development, I have often recalled a statement by science philosopher Thomas Kuhn (1970, p. 80) which says:

> "Given the slightest reason for doing so, the man who reads a science text can easily take the applications to be the evidence for the theory, the reason why it ought to believed. But science students accept theories on the authority of teacher and text, not because of evidence [my underlining]. What alternatives have they, or what competence?"

Such professional alienation with respect to fundamental thinking is obviously not limited to students and young researchers – unfortunately it is a distinctive characteristic of the science community at large! Reminding us about another fact, Thomas Kuhn submits (Kuhn, 1970, p. 47):

> "Though many scientists talk easily and well about the particular individual hypotheses that underlie a concrete piece of current research, they are little better than laymen at characterizing the established bases of their field [my underlining], its legitimate problems and methods".

Knowing human nature, it is no secret that when a once well-established research paradigm has reached a stage of increasing professional insecurity, signalling that time is ripe for fundamental rethinking, a new promising theory eventually catches on for other reason but rationality and professional insight – a change of 'thought' fairly similar to what we observe in the world of fashion. A major reason for the overwhelming current support of PT is undoubtedly that it is *the only legitimate game in town*; the model has become entrenched dogma with its associated pressures towards social and professional uniformity (**Fig. 1**). Within the plate tectonic 'imprisonment', subversive facts apparently place no burden on the mind of the majority; what first of all concern scientists is loyalty to the system – the prime necessity for academic 'success', including funding and other professional benefits. In addition, floating along with the stream is a necessity for social acceptance within ones academic community. Therefore, the individual worker simply takes the ruling paradigm for granted and resist any major change of fundamental thought (Barber 1961). But if all scientists were stuck in the conventional 'league', a particular field would become entrapped in a single paradigm and would never progress beyond it. Or as Thomas Kuhn (1970, p. 24) puts it:

> "No part of the aim of normal science is to call forth new sorts of phenomena; indeed those that will not fit the box are often not seen at all. Nor do scientists normally aim to invent new theories, and they are often intolerant of those invented by others".

In order to understand science, it is essential to understand it as a historically evolving body of knowledge, and that a hypothesis or theory can only be adequately appraised if due attention is paid to its historical-sociological context. In fact, people with some academic life experience would not need to be well-read into the history of science to have sensed that in general researchers are so deeply committed to their own professional hang-ups that scientific progress becomes inhibited, or at least markedly delayed. Today, this reality is of course one of the sore spots in the conscience of the geosciences. Therefore, from time to time authoritative assertions of the opposite have to be tactically proclaimed. Thus, probably triggered by the current turbulence and scientific uncertainty around the global warming issues – including accusation on climate data manipulations – the American Meteorological Society recently found it necessary to issue a statement on the need of free and open communication in science. This position statement has been adopted by AGU, and in *EOS* 92, no. 37, 2011 the declaration included the following announcements (the portion in italics being added by AGU):

AGU Supports Free and Open Communication of Scientific Findings
"Scientists, policy makers, and supporting institutions should guard and promote unfettered communication of scientific data, debates, and findings as a component of scientific expression".

Advances in science and the benefits of science to policy, technological progress, and society as a whole depend upon the free exchange of scientific data and information as well as open debate. The ability of scientists to present their findings to the scientific community, policy makers, the media, and the public without censorship, intimidation, or political interference is imperative…It is incumbent upon scientists to communicate their findings in ways that portray their results and the results of others, objectively, professionally, and without sensationalizing or politicizing the associated impacts…Thus, scientists, policy makers, and their supporting institutions share a special responsibility at this time for guarding and promoting freedom of responsible scientific expression".

It is pleasing to see such common-sense views of science being so clearly expressed – aims that, despite their elementary nature, have always proved difficult to follow in practise. In my own university, for example, scientists who openly argue against plate tectonics automatically ask for trouble. Likewise, Norwegian scientists within climate-related fields who are sceptical to the ingrained anthropogenic cause of predicted global warming run the risk of being sidelined and without economic support (**Fig. 1**).

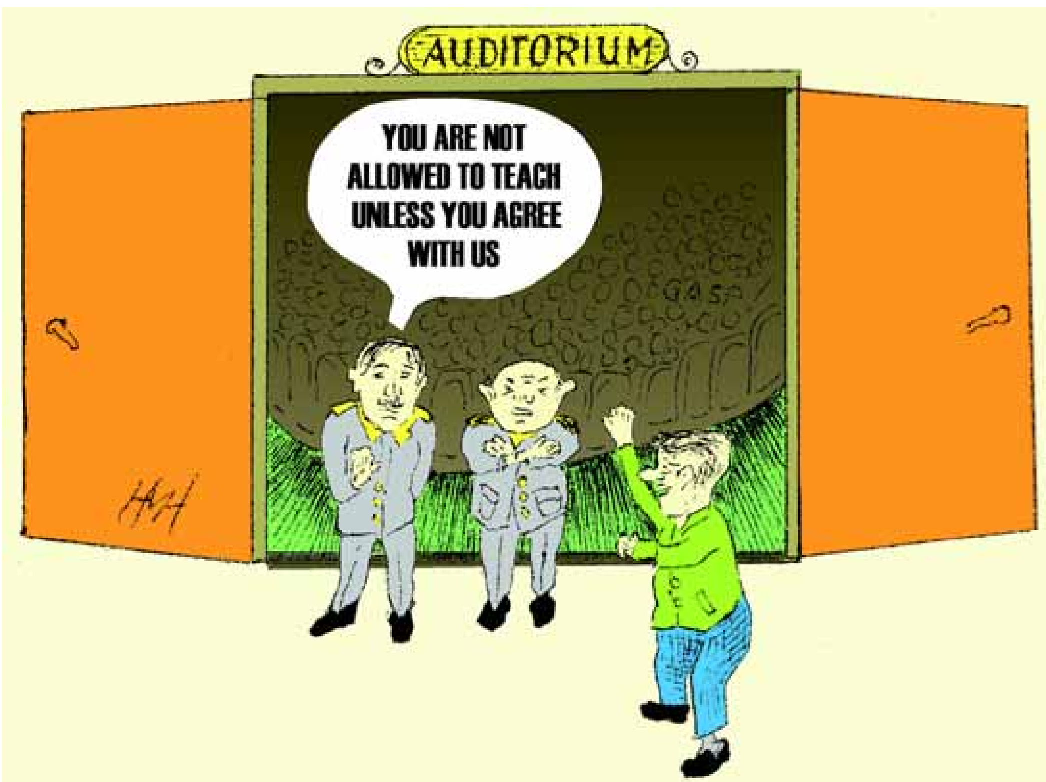

Fig. 1. A ruling scientific paradigm represents the professional identity, pride and binding emotional agent of its community. Professional insecurity, arising from chattering received opinions of the Establishment, is counteracted with whatever actions are at hand – attempting to force contrarians back into conformity with the majority view.

In 1963 the Norwegian novelist and essayist Jens Bjørneboe [1920-1976] published a Manifesto in the form of a poem, which in English translation (http://arneogtullen.blogspot.com/2010_09_archive) is entitled *Ten Commandments for a Young Man with Ambitions*. The poem, which should serve as a safeguard against unethical behaviour and a reminder to every honest seeker of truth – to be profitably included as an *aide-mémoire* in the opening passages of every college text book, reads:

Ten Commandments for a Young Man with Ambitions

I
Commandment One is clear and straight,
The majority is always right.
II
Predict what people will confide,
And take the stronger party's side.
III
When in doubt, deign to pause,
Until you see who gets applause.
IV
Choose your statements when you talk.
Count the costs from group to walk.
V
Don't put forward too free rein,
But stick to what will bring you gain.
VI
Give everyone what they adore,
Go quiet through your boss's door.
(For truth brings sorrow, need and dread,
While daily lies bring daily bread).
VII
Curl your back, creep along,
In every home you will belong.
VIII
A man is never praised too much.
Do all to get him in your clutch.
(And in the shield of brotherhood,
Your future will be long and good).
IX
Store every gossip word you hear.
It can be used when you are there.
(But no discrete and tactful guy
Will talk to him that curse apply).
X
If these commandments are your Lead,
Your future life is guaranteed.
Boldness always gains temptation,
But with prudent moderation!
Stride bravely to your chosen Quest,
One step ahead of all the rest.

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Facts, hypotheses and theories

– Science is built up of facts, as a house is built of stones, but an accumulation of facts is no more a science than a heap of stones is a house –

Henri Poincaré, in: *Science and Hypothesis*

It is a well-established opinion among scientists that science is a rational activity operating according to some special intellectual faculty – that their work consists of the collection of 'facts' by means of careful observation and experiment; subsequent derivation of broader theoretical frames then follows as a kind of logical procedure by what is called an *induction* process. In other words, it is widely held that scientific progress rests on a secure foundation provided by observation; personal opinion or preferences and speculative imaginations have no place in science. However, all honest and experienced practitioners of science know too well that such ideals are completely out of touch with the reality. For example, Thomas Kuhn (1962), in his portrayal of the history of the physical sciences, points out that a field of inquiry is not established as a science until the participants agree on a basic body of facts, associated with a range of theoretical assumptions and techniques (collectively called a *paradigm*) setting the standards for legitimate work within the study area. Within the environment of what he calls 'normal science', real understanding of the paradigm's overall structure and limitations are not on the agenda. Thus, the mass of scientists works confidently within an area dictated by the relevant paradigm, such as the contemporary twin-hypotheses of mantle convection and plate tectonics. A researcher who blames the paradigm for failure to solve a problem will be open to the same charges as a carpenter who blames his tools. Thomas Kuhn rightly describes science as being comparable with any other human activity, bound up with strong psychological and sociological factors, in which the rules of the established paradigm are given superior importance. Puzzling observations that resist solution within the current paradigm are therefore regarded as mere anomalies, 'clearly' to be solved someday, rather than representing falsifications of the paradigm itself.

Paul Feyerabend (1975), who was even more anarchistic in his sociological analysis of knowledge (than Thomas Kuhn), submitted that as a human activity the scientific enterprise has no special features that renders it intrinsically superior to other branches of inquiry. For example, the visual familiarity an observer has when viewing a geological feature will to a varying degree depend on his/her experience, knowledge and expectations. Alan Chalmers (1990, p. 27) puts these facts into perspective when he writes:

> "As far as perception is concerned, the only thing with which an observer has direct and immediate contact is his or her experiences. These experiences are not uniquely given and unchanging but vary with the expectations and knowledge of the observer. What is uniquely given by the physical situation is the image on the retina of an observer, but an observer does not have direct perceptual contact with that image…I am certainly not claiming that the physical causes of the images on our retinas have nothing to do with what we see. We cannot see just what we like. However, while the images on our retinas form part of the cause of what we see, another very important part of the cause is constituted by the inner state of our minds or brains, which will clearly depend on our cultural upbringing, our knowledge, our expectations, etc. and will not be determined solely by the physical properties of our eyes and the scene observed".

Though observers have no identical perceptual experiences, incorrect observation statements have repeatedly been rectified through the test of time – building up a mass of unquestionable facts and true natural phenomena. In a shorter time perspective however a science guided by a false, but well-excepted, maxi-theory may result in flawed interpretations and irrelevant experiments that are useless in the real search for truth. In such cases, the defective precepts contribute continuously to an ever larger archive of artefacts mixed up with true and unsullied data (**Fig. 2**); hence, the research environment would be influenced by growing confusion, and information stress becomes inevitable. Many readers of this journal have long realized that this is a precise description of contemporary Earth sciences – to the extent they are ruled by plate tectonics-laden formalism – which to a large extent has fallen to the level of monistic propaganda. The currently pressing task for the geological community is therefore to allow an open debate on the inadequacy of that model – to identify current enigmas, and formulating basic prerequisites of a next generation global hypothesis.

It is a truism but worth restating that neither science nor scientific knowledge grows by the simple accumulation of uncoordinated observational facts (see **Fig. 3**, left) because amassing facts does not tell us why things behave as they do; some invented 'higher order' thought construction (see **Fig. 3**, right) is always needed to make observations meaningful. Without such an overarching framework – a theory – based on well-founded and independently validated physical principles, data drift about aimlessly on a boundless sea. In all the sciences, the archives normally constitute a compound of true facts and theory-infiltrated artefacts (**Fig. 2**). This chaotic mix will remain useless, for a realistic view of Nature, until some well-founded organizing principle – a *theory* – manages to clean up the messy situation, turning the association of true, but unrelated, observations into a comprehensible pattern. However, erecting such an extensive and intelligible thought pattern is very rare in science. When successful, the basic precepts of a comprehensive global theory lie hidden in the root system of the *Theoretical Tree*, where the processes responsible for the surface phenomena are operating, from which a stem grows up and splits into an ever more diversified system of outward-spreading and progressively finer branches – representing natural phenomena resulting from interconnected physical processes. In a truly prosperous science an extensive range of phenomenological interconnections, building up a sequential order of facts, are established. But in the construction/invention of such a physical frame, it is of paramount importance to avoid a string of ad hoc 'fixes'. In this context Larry Laudan (1977, p. 116) reiterates the common opinion that …

> "…there is something suspicious about any change in a theory which is motivated by the desire to remove an anomaly. We cannot really trust such cosmetic surgery because, once we know what the anomaly is, it is little more than child's play to produce some face-saving change in the theory which turns the anomaly into a positive instance".

Fig. 2. A flawed maxi-hypothesis, frequently having gained popularity primarily through the re-iteration principle and socio-political mechanisms, will provide a confusing research environment; in general, observations do not fit crucial predictions of the model and in an attempt to keep the faulty thesis in circulation ad hoc adjustments/interpretations will flourish. In such cases the research archives will be filled with a bewildered mix of true facts and model-infested artefacts – making the scientific endeavours a troublesome task.

In order to fulfil its aim the intelligible invention of a functional theory must foreswear adjustable parameters – repair actions that have had to be invoked to explain away grave conflicts between theory and true facts. However, it has to be admitted that a scientific community can become so indoctrinated by and committed to its ruling paradigm that the critical faculties and imaginative powers of its members are inhibited. On the other hand, it is important to remember that even a crisis-ridden scientific worldview – dominated by wishful thinking and socio-political forces – may not bring a science to a complete standstill. Even when working within a faulty paradigm, the scientific endeavours will accumulate a mass of true, but puzzling, facts. But the flow of unexpected observations will add to the growing sense that the ruling paradigm has ceased to function adequately in the exploration of nature.

During the history of science many 'well-received' theoretical canons have fallen to the junkyard of failed ideas; after a long-lasting crisis state, the once popular Theoretical Tree (**Fig. 3**, right) has gradually lost its proclaimed explanatory power – and its reputation has slowly deteriorated. However, since no experiment can be conceived without some sort of theory, a scientific community approaching a critical situation will constantly conjure up speculative modifications of existing paradigmatic 'rules' and views. Therefore, reconstructing a field from new fundamentals means changing some of its basic generalizations and methods, a situation which Thomas Kuhn (Kuhn 1970, p. 85) has described as follows:

> "Just because the emergence of a new theory breaks with one tradition of scientific practice and introduces a new one conducted under different rules and within a different universe of discourse, it is likely to occur only when the first tradition is felt to have gone badly astray".

Fig. 3. Without a theory based on validated physical principles a scientific field is without real understanding; no prediction can be made, or the predictions cannot be verified – we have just an un-coordinated heap of true and false observations (left figure). However, a Theoretical Tree (right figure) can be seen as the metaphor of a true and diversified scientific theory putting nature into a conceptually coherent order. Often, however, the theoretical tree has a faulty basement and/or construction – consisting of endless ad hoc provisions, so its eventual collapse is inevitable. In such cases the alleged phenomenological system – the association of leaves, branches and stem – fall to the ground. The collapsed structure is then to be brushed back to the heap of uncoordinated observations and phenomena (left figure).

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Snapshots from the history of global geology

– In their place came accounts…radically at odds with their predecessors –

Larry Laudan, in: *Science and Values*

Contraction models, geosynclines and permanent continents

In global geology, the theoretical tree of the past always had temporary popularity – the ruling theories were either established on meagre factual grounds or it ran into trouble with the growing data bank for which they were unable to account. On this basis, one can only be stunned by the vigour with which many of the old ideas were defended. Around the middle of the 19th Century, the axiomatic idea of a thermally contracting planet, undergoing tangential compression of its outer layers, became the new fashion in geological thinking. Triggered by the development in the field of thermodynamics, and with the incentive to explain not only the formation of mountains but also the broader range of geological phenomena, thought to be associated with it, the contraction hypothesis was elaborated in scientific terms by Elie de Beaumont (1852) and G.H. Darwin (1887). According to the then prevailing view, some outer shell of the Earth had cooled as much as possible while the interior was still in the process of loosing heat. As a consequence of the hypothesized cooling and related volume reduction of the interior, the surface layer, already cooled and solidified, would undergo crumpling and fracturing. There was no agreement, however, on how the presumed contraction had affected geological processes, and no one could offer more than circumstantial evidence that the globe actually had been, or was, subjected to shrinking of its circumference. It is not surprising therefore that, over time, various conflicting theoretical propositions were conjured. However, two main schools of thought, articulated by James Dana [1813-1895] and Eduard Süss [1831-1914] respectively, almost completely dominated geological thought in the second half of the 19th Century and continued to be debated, albeit with strongly declining vigour, up to the middle of the 20th Century.

Dana (1873 and 1881) held that the major configuration of continents and deep ocean basins were primeval features, having been implanted at an early stage of differentiation and solidification of the planetary shell. The end product was relatively thick buoyant blocks of sialic continents interspersed within a mosaic of thinner and denser oceanic crust. This model was consistent with the then new view of isostasy, but in contradiction to the still popular view of Charles Lyell (1830-33) that continents and oceans were interchangeable. During consolidation, nuclei of sialic masses had segregated from a 'primeval' basaltic magma ocean; these incipient continental masses had then continued to grow slowly by episodic accretion around a few siliceous cores. It was thought, however, that the overall physical state of the Earth had not changed significantly during most of its history, implying that the post-Precambrian configuration of continents and oceans had undergone no more than superficial modifications. Hence, the Earth was assumed to be static; the major crustal features would stay in place perforce. Dana's view of the Earth led to the slogan "once a continent, always a continent" – commonly referred to as *permanentism* or *fixism*.

The contraction variant of Eduard Süss (1885-1901) formed a European school of tectonics that was in sharp contradiction to the American fixism. Producing the first critical and comprehensive analysis of the Earth's structural history, he proposed that upward floatation of lighter constituents had formed a relatively uniform pan-global surface shell consisting of two layers, an upper *sial* underlain by a denser *sima*. Sea water was regarded as a natural product having been exhaled during early planetary degassing and spread across a relatively featureless planetary surface. Progressive cooling and contraction had then produced warping and fracturing of the cooled and consolidated crust. In this process, large surface regions had collapsed to become oceanic depressions into which the surface water had drained. Furthermore, he submitted that major sea level rises – transgressions – were interrupted by a fewer number of distinct falls of sea level – regressions. This rhythmic advance and retreat of the sea over low-lying lands Süss attributed to global causes – a kind of Earth pulsation he termed *eustatic*. In the Süssian global system, the oceans grew at the expense of the continents, thereby accounting for the well-established fact that the continents had been subjected to an overall progressive draining at least since Lower Palaeozoic time. However, the crust of continents and oceans was compositionally similar and interchangeable (just as Lyell had predicted); former oceans could now be dry land and *vice versa.* But the long-term effect of contraction would be the growth of oceanic area at the expense of continental surface – he proclaimed.

Süss' global thesis was thought to account for the origin of fold belts – often referred to as *mountain building* – but the fact that tectonic belts had a very inhomogeneous distribution across the globe prompted ad hoc assumptions in terms of rigid and plastic crustal divisions (Süss, 1875). This was clearly one of the weakest spots of his theory. Within the European contraction paradigm, it was emphasized that the grand scale orientation of the principal mountain belts tended to define approximate great circle girdles – a fact that led Bertrand (1887) to conclude that the successive mega-tectonic belts across Europe, with decreasing ages southward, had their westward continuation in eastern North/Central America. This conclusion coincided with earlier suggestions by Elie de Beaumont and supported Süss' argument that a former North Atlantic continent had subsided to become an oceanic basin. But the pre-eminent fact that the fold belts across Europe were progressively younger southwards had no explanation within the contraction paradigm. However, Süss' global geology was much wider in scope than the contemporary North American school.

The observed similarity of fossil assemblages between the present continents, as well as the development of biological differences due to genetic isolation, was readily explained by the Süssian thesis. Thus, the original pan-global crust had contracted and broken up, during which parts of it had subsided to oceanic depths – and the products were both oceanic basins and temporary land bridges between the continents. To account for bio-geographic peculiarities around the present Indian Ocean, he postulated the palaeo-continent of *Gondwana* having originally united all southern lands. When a major part of this continent subsided – through the forces of contraction – the previous biological migration routes were broken. **Fig. 4** depicts the global distribution of land and sea in the late Palaeozoic – according to Süss.

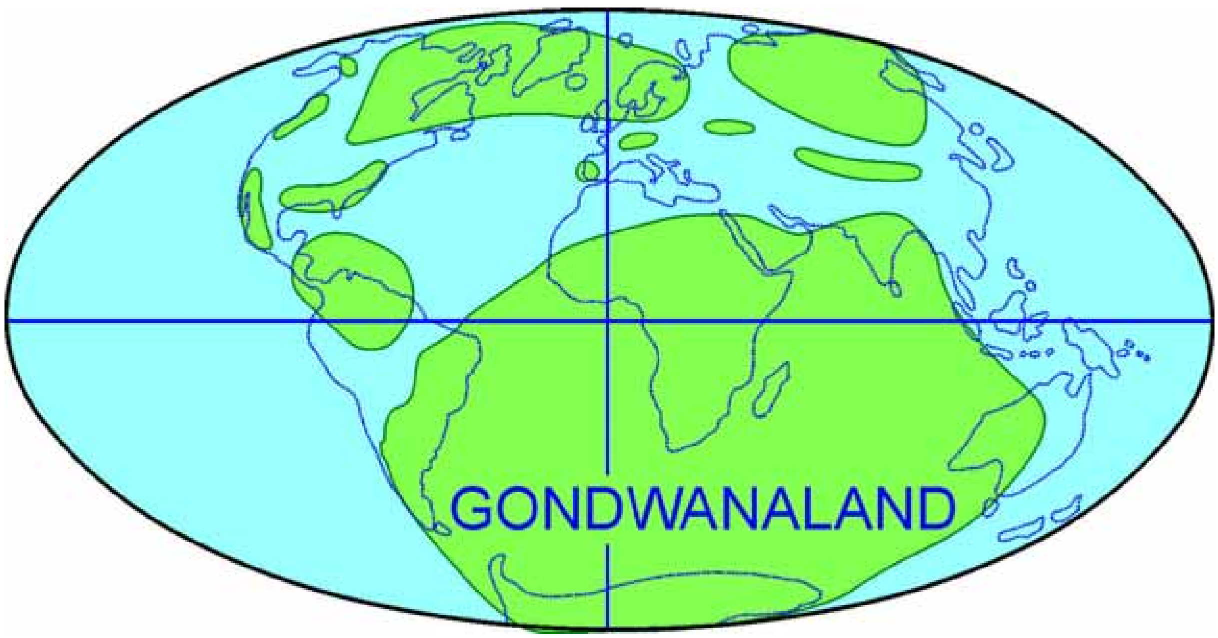

Fig. 4. The distribution of land (green) and sea (blue) in the Upper Palaeozoic, according to the global synthesis of Eduard Süss.

Dana's tectonic scheme did not include an acceptable general justification of the global distribution of fold belts and mountain chains, but Süss' model was only marginally better in that respect. Bertrand (1887) had classified folded zones across the globe according to age – as Huronian, Caledonian, Hercynian and Alpine. But for the two contraction-based Earth models, the overall pattern of fold belts and their interrelationships remained enigmatic. While the Süssian system could give an explanation for the biological similarities between continents now widely separated by deep oceans, the competing model of Dana offered no solution at all for the prominent bio-geographic problems. All in all, Dana's scheme was overall a poorer problem solver than the Süssian one. Nevertheless, both versions of the contraction theory met stumbling blocks in studies of the very problem they were designed to solve: the origin and evolution of fold belts. Equally problematic was the pressing palaeo-climate issues – the cause of the profound changes of palaeo-climatic belts evidenced from fossil and rock data, implying that present Polar Regions had formerly been tropical-subtropical, and *vice versa*. The contraction-based theories had no explanation of these pivotal problems.

One of Dana's American adversaries, James Hall (1882), had developed the *Geosynclinal Theory* which held that the major mountain ranges of the world had originated in thick, narrow and long sedimentary troughs which had formed along slowly subsiding margins of the continents and subsequently elevated into mountain ranges. For example, it was stressed that the Palaeozoic strata of the Appalachians had been laid down in shallow water; the subsequent uplift of the thick sedimentary pile was thought to come from the expansive action of heat to which the deposited sediments had become subjected as they sank (by their increased weight) into the deeper parts of the crust. While Dana and Hall disagreed on a number of details as to how these elongated sedimentary troughs had been turned into mountain ranges, there was mutual understanding that the deformation and overthrusting observed along the Appalachians was concordant overall with Dana's contraction scheme. Thus, the ultimate product of the American version of the contraction theory was a very slow and periodic progressive growth of continents through accretion along their margins.

At first sight the Dana-Hall model seemed to account satisfactorily for the structure of the Appalachians, but what about the field observations that the sediments became coarser towards the Atlantic, and with deltaic deposits spreading out in westerly directions? Clearly, the inferred river system had transported rock material from an extensive upland to the east now occupied by the Atlantic, a palaeogeographic situation that ran counter to the Dana-Hall proposition. Adding to this problem, Joseph Barrell (1914) later demonstrated that the Appalachians included extensive and thick Devonian deltaic deposits the structure of which fitted earlier suggestions that the material had come from the east (the Atlantic side). Other difficulties facing the Dana-Hall model was the puzzle why the Rocky Mountains of Western US were located so far inland, not along the coast as their model required, and how had the intra-continental Alpine-Himalaya belt been formed? The contraction model implied that secular cooling necessarily must have been at its peak in early geological times, but this was inconsistent with the fact that major ranges like the Rocky Mountains had come into existence as late as the Upper Tertiary (Russell 1884). Hence, the lack of explanatory power suggested that there was something fundamentally wrong with the idea that Earth contraction was the driver of tectonic phenomena. On various grounds, the prominent geophysicist O. Fisher (1881 and 1882) had dismissed the contraction hypothesis, and the discovery of radioactivity in 1896 was a most serious blow to the models of a contracting Earth.

Towards the end of the 19th Century, the concept of *Isostasy,* Archimedes' principle applied to the surface structure of the Earth, had been developed into a theory of mountain making, and in the early half of the 20th Century it became one of the larger fields of geological theory (see below). In many ways, isostasy stood in contradiction to the two ruling theories based on secular cooling and contraction which however had been weakened by the discovery of radioactivity. Fundamental questions were raised regarding the cooling history of the Earth, and there was considerable confusion and indecision in explaining even the most predominant topographic and geological phenomena. The arena was open for fundamental re-thinking.

Crustal processes powered by isostasy?

It was generally accepted that certain mountain regions were matched in their elevations by a deficiency in density at some relatively shallow depth, as originally conceived by Pratt and Airy in the early 1850s. It was believed that mountains floated, as it were, in a medium of higher density. The inferred relations of relief to underground density had been given the name of isostasy (Dutton, 1889), meaning equal pressure at some particular depth, but exactly how the pressure compensation was accomplished remained unclarified – explained by either variations of density (Pratt) or thickness (Airy). The model of Pratt assumed a constant level of isostatic compensation, while Airy proposed that the low density surface shell was thickened under high mountains and thinned beneath lower surface regions. Fisher (1881) argued that of the two competing isostatic models the Airy explanation was the only one which accorded with geological observations. He submitted that lateral compressions had shortened and thickened the crust in elongated belts giving rise to both mountains and their associated roots. To attain the suggested compensation of an outer buoyant shell of variable thickness, the existence of a higher density fluid or plastic substrate was evidently required.

Dutton (1889), accepting the Airy principle, perceived the geological bearing of isostasy. He argued that the denudation process, impoverishing uplifted land regions and depositing the eroded sediments along continental margins, would enforce a continuous disturbance of isostasy. He suggested that, due to the mass increase of sediment accumulations, crustal subsidence would ensure lateral displacement of plastic material at depth, producing mass underflow towards continental border zones which, in turn, would undergo enhanced uplift and erosion as well as displaying occasional igneous activity. In Dutton's model, disturbance of an underlying plastic layer – and related mass displacement – in the direction that would regain isostatic equilibrium, was the motive force behind geological change. Thus, coast-parallel mountain ranges were regarded natural products of inferred landward-directed viscous flow in the substrate, producing systematic crustal shortening and folding. However, like Dana's contraction model, the explanatory power of Dutton's operating system was too limited to become a general theory, and confusion arose even with regard to the principal questions it was supposed to tackle.

Against Dutton's explanation of 'fold mountains', Russell (1884) had pointed out that extensional conditions appeared to have played a fundamental role in the formation of the Basin and Range mountains, stating that "The tilted blocks occupy more horizontal space than they did before the faulting took place" and therefore, "The suggestion presents itself that the faulting in the Great Basin is associated with lateral extension". Russell also noticed that the Basin and Range faulting and block rotation was a late Tertiary phenomenon – having occurred after the region had been covered by volcanics. Adding to these 'complications', it had also been acknowledged that the Colorado Plateau had undergone uplift in association with extension. Such observations ran counter to the Airy model of isostasy – on which both Fisher and Dutton had based their work. Furthermore, Le Conte (1889) presented a generalized model of the Basin and Range Province arguing that it had been formed by crustal arching and distensional fragmentation, noting specifically that "The arch was not formed by lateral pressure but by tension of lifting, caused by intumescences of the sub-crust liquid". The conclusions of Le Conte concurred with the views of later Joseph Barrell (see below).

Density differences between continental and oceanic crustal regions were a fact, so it followed that, at least for sufficiently broad surface regions; any isostatic mechanism had to be driven by some kind of Pratt model. If the Earth was able to flex under broader loads, how closely balanced were the more detailed topography and suggested density differences? Gilbert (1889) had rejected isostasy as an explanation of more detailed topographic features within the continents. Like the contraction models, the question of isostasy – as a driver of geological phenomena – was clearly an undecided issue. However, in the early 1900s, Hayford and Bowie (e.g. Hayford, 1911, Hayford and Bowie, 1912; Bowie, 1917) reopened the issue, analysing a significant number of new geodetic and gravity observations mainly in the United States, putting isostasy on a firmer qualitative basis and interpreting the data according to the Pratt model. On the other hand, Barrell (1914a-f and 1919) interpreted the Hayford/Bowie observations quite differently.

The Hayford-Bowie-Barrell reconsiderations

Working within the framework of the Pratt model, and placing isostatic response within the crustal columns (with their presumed individual differences of density), geodesists Hayford and Bowie calculated the isostatic adjustment and surface gravitational anomalies. According to them, compensation is complete, even locally – i.e. every mountain, valley and island is isostatically balanced, regardless of its size. It was taken for granted that depression in response to load, and uplift upon its removal, was a deductive consequence of the isostatic principle. After having worked out formulae and tables for the topographic isostatic correction of the deflexion of the vertical and gravity anomalies corresponding to different values of the depth of compensation, they inferred a hydrostatic equilibrium depth for the Earth (the level of isostatic compensation) at ca. 110 km. It is important to note that according to the Hayford-Bowie model, the Earth was a dynamically passive body, responding, at the depth of compensation, primarily in an elastic manner caused by redistribution of surface masses through erosion and re-deposition.

Though isostatic forces and isostatic equilibrium could be considered as a general operating system of Nature, the underlying assumptions and some of the Hayford-Bowie conclusions were at variance with geological facts. Thus, in a series of papers, Barrell (1914a-f and 1919) set out to discuss what he saw as flaws in the Hayford-Bowie reasoning. Barrell stressed that, 1) the crust was strong, not weak as the geodesists had presumed, and could therefore accommodate significant stresses, and 2) the weakness required to account for the isostatic principle was to be found not within but below the crust – in a soft layer he termed *asthenosphere.* In the Hayford-Bowie database, there were indeed areas displaying significant deviations from isostatic equilibrium; such regions, Barrell argued, were of major interest to tectonics. The geodesists had paid major attention to the shifting of surface loads: erosion caused unloading and uplift, sedimentation caused loading and subsidence, and earthquakes were the product of isostatic adjustment to mass transfer in areas of erosion and sedimentation. This was all wrong, Barrell argued.

Sharply contradicting the Hayford/Bowie conclusions, Barrel held that the relationship between surface phenomena and related vertical movements was just the reverse: uplifts and subsidences of the crust were products of vertical mass transfer beneath a zone of presumed isostatic compensation, and therefore surface phenomena like erosion, sedimentation, earthquakes and other tectonic actions were responses from more deep-seated processes. Hence, Barrell argued that vertical re-distribution of internal mass was the principal motive force behind geodetic, geophysical and geological processes. Indeed, the Hayford-Bowie data showed regional departures from isostatic equilibrium indicating that the crust was able to sustain stresses. And more, their data displayed "a common disregard of physiographic provinces, structural provinces, and geologic formations" (Barrell, 1914c).

The facts highlighted by Barrell were indeed consistent with well-known cases of vertical tectonics in the United States – such as the Basin and Range Province and the Colorado Plateau. These examples suggested irregular up-welling of fluids from deeper levels into a zone of compensation, with further invasion of the overlying *lithosphere* – giving rise to disturbances in isostatic equilibrium. The buoyant hot material would then be the cause of regional igneous activity leading to changes in density and related vertical movements of the regional lithosphere (Barrell, 1914d). A close inspection of the Hayford/Bowie gravity data (**Fig. 5**) reveals that isostatic anomalies are not randomly oriented but rather tend to define a certain orthogonal pattern, the preferred orientations trending NE-ENE and NW-WNW, consistent with regional joint-orientation of eastern United States (cf. Engelder 1993, figs. 2-15). Barrell reasoned that due to vertical fluid infiltration of Earth's outer 'shells' the soft or plastic zone beneath the crust (asthenosphere) was unlikely to be sharply defined and, hence, the suggested depth of compensation was not uniform – as had been the pre-requisites in the Hayford/Bowie computations. An irregular asthenosphere, as advised by Barrell, is indeed supported by modern geophysical studies.

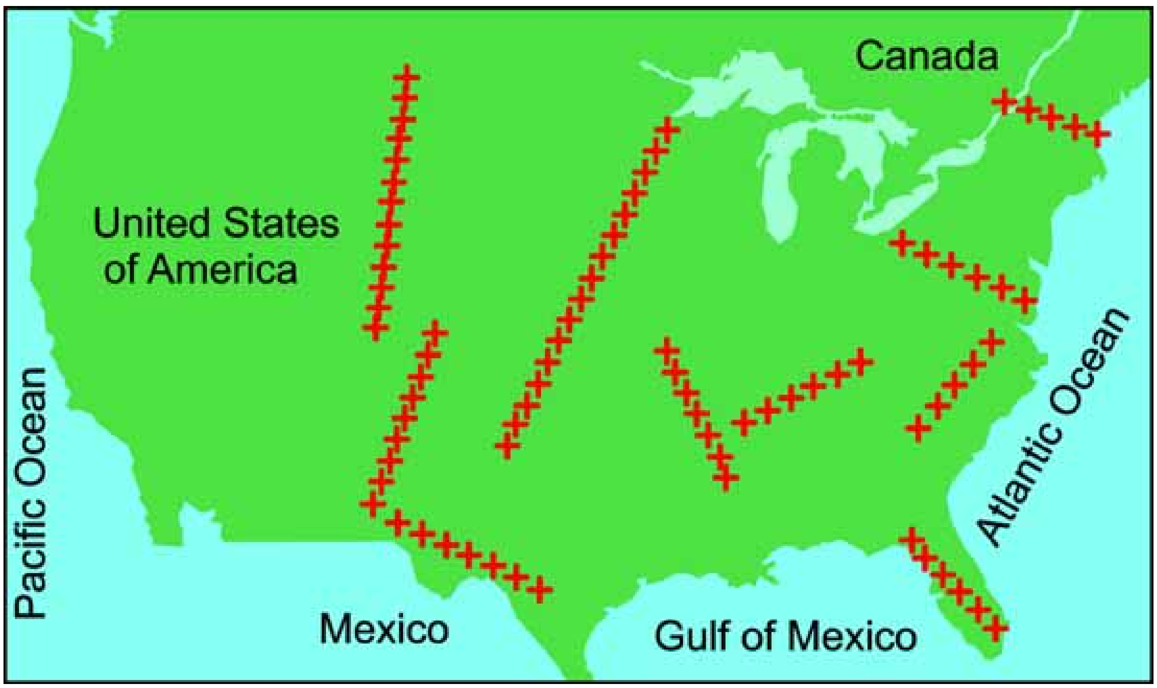

Fig. 5. Axes of positive gravity residuals compiled by William Bowie, as presented by Barrell (1914b). The gravity map was re-interpreted by Barrell (1914b) to argue that the anomalies had no coherent connection to surface topography and therefore had to be caused either by mass heterogeneities at depth or forces internal to the Earth.

Barrell argued that massive intrusions of basaltic material into the lower crust could be expected to have sufficiently increased crustal density, both locally and regionally, to cause them to subside. In this process, the continental crust – presumably having originally had pan-global extent – would be fragmented, and ocean basins would have formed where upstanding lands once had existed. Subsidence would be evidenced by normal marginal faulting, eventually leading to continental margins and deep oceanic basins. To my knowledge, Barrell was the first geoscientist pondering over the possibility that a once all-embracing continental crust had been turned into the present mosaic of continents and deep sea basins, refuting Dana's conception of permanent continents and oceans.

Barrell's re-consideration of isostasy gave this concept a much more realistic basis than it had had before, inasmuch as the revised model could be associated with a number of important geological facts. However, even Barrell's revision was unable to account for the most crucial problems of tectonics – such as the global distribution and age pattern of fold belts, the surprisingly recent elevation of the principal mountain chains of the world (regardless of the age of deformation within these uplifted ranges), and the progressively shifting palaeo-climate zones. Archimedes' principle was a physical fact, but its application to explain physiographic features and geological processes was not prevalent; at best the isostasy principle could only serve as a subsidiary mechanism. The geological sciences were still waiting for a real Theory to explain the variegated facets of Earth history.

Linking global tectonics to changes in planetary rotation

Towards the end of the 19th Century, owing to the confusing situation facing the contraction and isostatic models, German and Austrian geoscientists opened up new directions in global geology. By integrating palaeoclimatology and geophysics, the old notion of *polar wander* was substantiated, and arguments in favour of the old speculations on continental mobility were expounded. Wettstein (1880, cf. Wegener, 1929), for example, maintained that the continents had undergone significant relative displacements while being slowly forced westwards owing to tidal actions, while Löffelholz von Colberg (1895, cf. Wegener, 1929) and Kreichgauer (1902) argued for westward rotation of the whole crust without altering the relative positions of the land masses. Notwithstanding their different mobilistic views, these authors were clearly influenced by Süss' global synthesis, and Wettstein, in particular, held that ocean basins were sunken continents. It appears that it was the Austrian geologist A. Damian Kreichgauer (1902) who first suggested a dynamic link between tectonics and the Earth's rotation. Later, Wegener (1912, 1922 and 1929) gave Kreichgauer the credit for having discovered the *pole-fleeing force* – the combined effect of the dynamics of Earth rotation and the principle of isostasy, later named the *Eötvös force* (Eötvös, 1913), though he chose to ignore Kreichgauer's corroboration of the polar wander – a physical concept Wegener strongly adhered to.

In his 1902 book Kreichgauer submitted that the equator-ward force of crustal motion, directed away from the poles (Polflucht), would have produced fold belts aligned along time-equivalent equators, while a second set of tectono-magmatic belts would have evolved in corresponding meridional settings (i.e. at steep angles to their corresponding palaeo-equators) owing to the westward directed tidal drag from the Sun and Moon. Based on a straight forward interpretation of ancient climates derived from rocks and fossils (defining the time varying position of palaeo-equatorial belts), polar wander seemed to be a reality. For dynamical reasons, the rotational axis had to be aligned along, or to maintain in the vicinity of, the principal axis of inertia – which inferentially, due to redistribution of planetary mass, had changed through geological time. In other words, the apparent displacement of the polar axis over the surface was a result of the Earth's body having intermittently turned over relative to space.

In the Kreichgauer dynamic model, the required changes in the Earth's axes of inertia were brought about by the equator ward and westward movements of the entire crust, without relative continental motion, and the associated changes in the relative position of the palaeo-equator would then have given rise to tectonic belts in variable orientations across the globe. Thus, by combining palaeo-climate observations with his global tectonic system, for different geological epochs, Kreichgauer was able to draw a global polar wander curve (**Fig. 6**) which, apart from its Middle Palaeozoic section, show remarkable similarity to that derived from palaeomagnetic evidence (Storetvedt, 1997 and 2003).

Fig. 6. Tentative path of post-Precambrian geographic poles relative to the Earth's surface – according to Kreichgauer (1902). However, more modern palaeomagnetic and palaeoclimatic studies define the Palaeozoic polar track along the eastern rim of the South Atlantic, in agreement with the by now well-established polar climate in Central-South Africa during the middle-late Palaeozoic. The Lower Tertiary pole is consistent with available facts placing Europe in sub-tropical to warm intermediate-latitude climates, while the present geographical setting was not reached before the late Tertiary. Kreichgauer's tentative polar wander curve suggested that since the Middle Palaeozoic the Earth's body has shifted its spatial orientation by some 70 degrees of latitude – a conclusion which is surprisingly consistent with palaeomagnetic evidence (e.g. Storetvedt, 1990).

In the Kreichgauer dynamo-tectonic scheme, the meridional 'mountain belts' had formed along the rifted zones trending at approximately right angles to their corresponding down-faulted and compressed equatorial seating constituting an elongate crustal depression around the globe. In this way, the elongate sedimentary troughs (geosynclines) of Hall, predating the tectonic deformation phase of many fold belts, were given a dynamical explanation without recourse to global contraction which by then had lost much of its former status. With his tectonic system, Kreichgauer was the first to give a dynamic explanation for the shifting distribution of tectono-magmatic belts around the globe, a problem to which other theories of the Earth had no answer. On the other hand, in the Kreichgauer explanation the transgression-regression cycles had regional phase shifts, a result that stood in striking contradiction to the worldwide simultaneous change of sea level (eustasy) that had been 'demonstrated' by Süss and commonly accepted today.

If isostasy and westward lithospheric shift, so why not continental drift?

In the early decades of the 20th Century, it was widely accepted that a soft/ductile layer existed beneath the outer crystalline shell (lithosphere) – providing both the seat of vertical isostatic adjustment as well as the kinematical explanation of a minor degree of surficial horizontal dislocations. Continents were no longer viewed as rigid, fixed bodies, but rather representing major rafts with strongly limited mobility. According the Hayford, Bowie and others horizontal motions were a side effect of vertical isostatic motions, a view with which Alfred Wegener (e.g. 1912, 1915 and 1929) strongly disagreed. Wegener built on Kreichgauer's evidence for polar wander, and extended the palaeoclimatic basis of this geodynamic concept (Köppen and Wegener 1924). In Wegener's own words "this enormous climatic shift – in Europe from tropical to temperate, in Spitsbergen from subtropical to polar – immediately suggests a shift in position of the pole and the equator, and thus the whole zonal system of climates. In fact this suggestion is inescapably confirmed by the equally large, but exactly reversed climatic change experienced by South Africa…in the same period"

(Wegener, 1929). He further added that "If the meridian through Spitsbergen and South Africa passed through the greatest climatic change, then the simultaneous climatic change in two meridians 90º E and 90º W of this [the meridian of greatest climatic change] must have been nil or quite insignificant; and this is in fact the case". Wegener's climatically based palaeoequatorial system, updating Kreichgauer's early version of polar wander (**Fig. 6**), is depicted in **Fig. 7**.

While Kreichgauer's inertial drag on some planetary surface layer represented a westward shift without relative lateral displacement of continents, Wegener accused him of having based his tectonic work "on an insufficiently substantiated dogma about the configuration of the mountains, alongside the real evidence for climate". On the other hand, with respect to Wegener's own global synthesis it can be argued appropriately that he tried to force his highly hypothetical drift scenario into conformity with selected Permo-Carboniferous palaeoclimate data, disregarding fossil observations that did not fit his scheme (see below). From comparative studies of present and ancient fauna and flora in different continents, palaeontologists had traditionally invoked former existence of trans-oceanic land bridges, in order to account for observed biological similarities. It was widely held that these former land connections had subsided and disappeared in late Cretaceous-early Tertiary time. Indeed, subsidence of oceanic ridges is now an empirical reality, having been repeatedly demonstrated by deep sea drilling since the late 1960s. But Wegener, who leaned strongly on the principle of isostasy, concurred with the long-held opinion that the granitic crust represented a top layer of inert sialic scum which allegedly was unable to sink into the heavier substratum. Nevertheless, he dispensed with this strict view when counter evidence demanded it. For example, with respect to the relatively large Azorean Archipelago/'Plateau' he concluded (Wegener, 1929) that the available rock evidence from these islands, accumulated since the 1860s, indicated that beneath a top layer of younger volcanic rocks there was a continental substratum. In other words, a former continental region had broken up and subsided. So how could he then regard drowned land bridges a geophysical impossibility, when he actually had 'drowned' a former Azorean continental mass? Regardless of this serious inconsistency, Wegener saw isostasy as being fully consistent with his hypothesis of drifting continents: a former physical unification of the present land masses was the clue to understanding the inferred former intercontinental biological links.

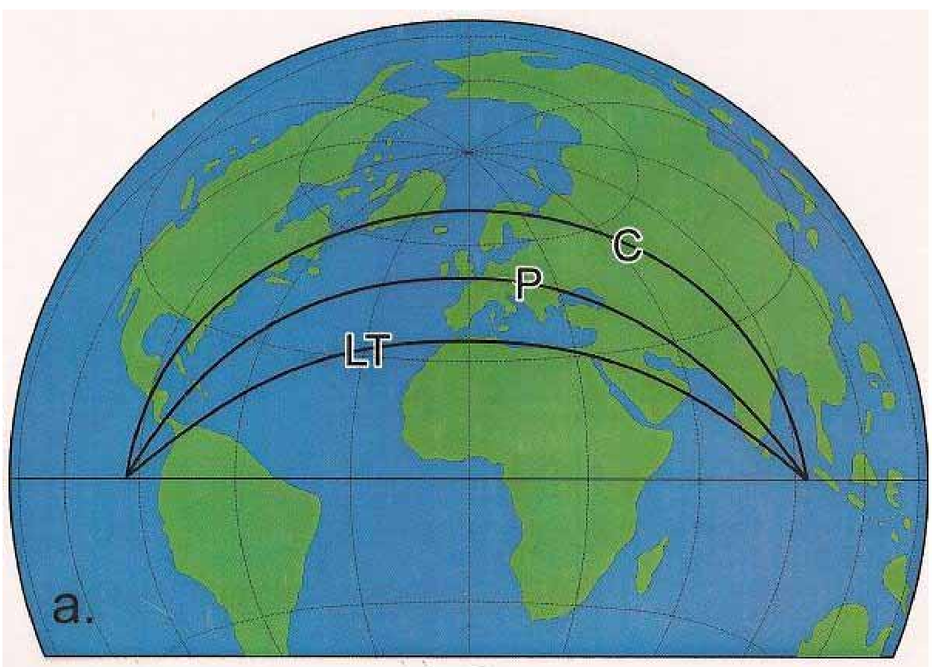

Fig. 7. The shifting of Earth's palaeo-equatorial position since the Middle Palaeozoic based on rock and fossil evidence for palaeoclimate: Carboniferous (C), Permian (P) and Lower Tertiary (LT). Based on description by Wegener (1929). The final relative shift of the equator to approximately its present position took place in the Upper Tertiary – at around the Eocene-Oligocene boundary. The episodic polar wander phenomenon seems to be the most important trigger of Earth's pulsating geological history – giving rise to the dynamo-tectonic heart beats represented by geological time boundaries (Storetvedt 2003).

Wegener (1929) hypothesized that "there were at one time two undisturbed primeval levels, and it seems an inevitable deduction that we are dealing with two different levels in the crust when we refer to the continents and the oceans". Consistent with traditional thinking, Wegener presumed that the primordial Earth had had a thin pan-global surface layer of lighter granitic composition (sial) which, during the Palaeozoic, had been reorganized into a much thicker-crusted continental assembly – Pangaea – through tidal friction and other inertial mechanisms. He argued that if all crustal structures were smoothed out, the granitic top layer would thinly cover the whole planetary surface. However, his hypothesized Pangaea super-continent had subsequently fragmented and drifted towards the modern global geography. This latter drift scheme, covering post-Palaeozoic epochs, was again attributed to inertial forces, but exactly how the same dynamic effects could have had two radically different consequences – first assembling the granitic layer to a single mega-continent and then splitting/drifting it apart – was left unexplained. As I have discussed in more detail elsewhere (Storetvedt, 1997 and 2003), Wegener's continental reconfiguration, and its subsequent drifting apart, was imbued with a multitude of physical, geological and palaeo-climatical problems.

Besides the clear evidence for glacial activity in southern Africa, traces of late Palaeozoic glaciations had, by the early decades of the 20th Century, also been reported from South America, Australia, India, NW Siberia, Central Asia and North America. The latter occurrences of inferred Permo-Carboniferous glacial activity were seemingly of much smaller scale than the main ice centre in southern South Africa. However, it became one of Wegener's great pre-occupations that all glaciated regions of the Southern Hemisphere, plus India, had been in close physical contact – with a common south polar ice cap located around southern Africa. **Fig. 8** gives a sketch map of a modified late Palaeozoic continental arrangement, based on du Toit (1937). The weak spots in Wegener's continental matching efforts were that evidence of Northern Hemisphere glacial activity were ignored, and that the growing fossil record from Antarctica told strongly against his model. As it had turned out, rock and fossil evidence from Antarctica gave witness to protracted tropical-warm temperate conditions – not the polar conditions his *Pangaea* configuration invoked, a fact he apparently chose to ignore (for summary and discussion see Storetvedt, 2003). Wishful thinking had overruled bothersome facts! If Wegener had avoided the distorted scientific vision his preconceived drift hypothesis undoubtedly inflicted upon him, he would have observed that both the Arctic and Antarctic regions had experienced closely similar climate trends since the Lower Palaeozoic – concurrently changing from tropical to polar conditions.

Contrary to most of his contemporaries, Wegener himself did not put the question of mechanism in the forefront of the debate. He realized that settling issues on the internal dynamics of the globe would be an arduous task, and that 'confirmations' of drift and polar wander first of all had to be settled by rock evidence and geophysical surface observations. Therefore, much credit was given to du Toit's extensive pattern-matching work along the Atlantic margins of Africa and South America. However, du Toit did not follow Wegener on some critical details. For example, he hypothesized two mega-continents – Gondwana and Laurasia – separated by an intervening Tethys Ocean, which has constrained global tectonic thinking during the last four decades. In addition, he invoked an intervening pre-drift gap of at least 400-800 km between Africa and South America. This separation was his solution to account for the observed differences in metamorphic facies of the presumed geological link-ups of the opposing Atlantic margins. This meant of course that the geological resemblance, allegedly arguing in favour of a former unification of the two continents, was not that clear-cut after all. In fact, if one had to allow for an initial continental separation in the order of several hundred kilometres, to obtain a 'sensible' geological pattern matching between adjacent margins, how could one then really set an upper limit to the required continental separation?

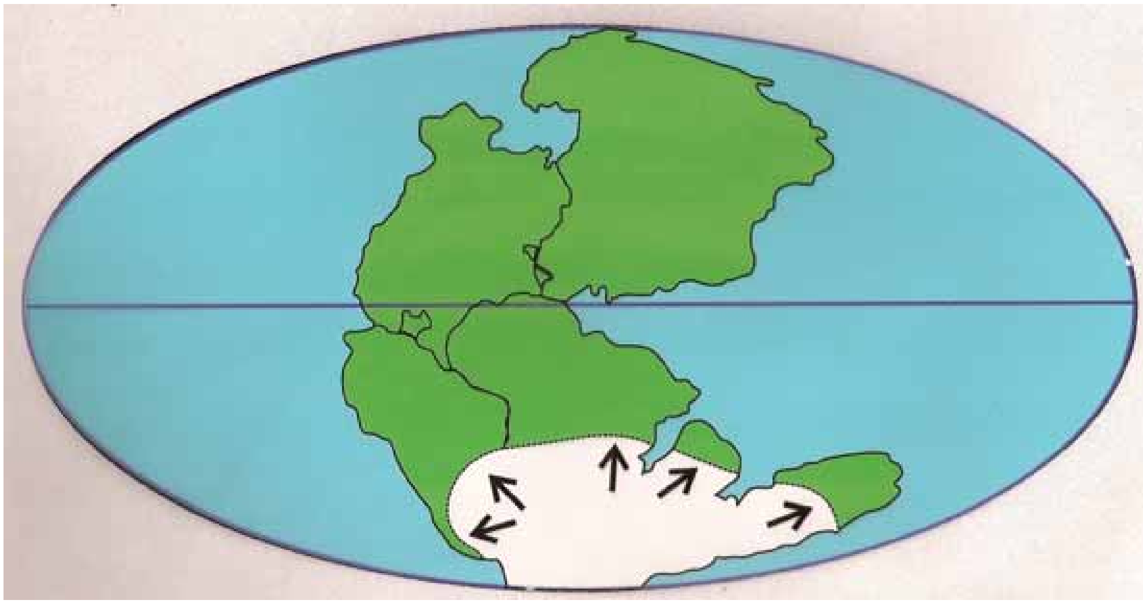

Fig. 8. The late Palaeozoic continental configuration presently in vogue. Du Toit (1937) had split Wegener's *Pangaea* into two loosely connected mega-continents: *Gondwana* in the south and *Laurasia* in the north. However, both Wegener and du Toit had presented arguments against a complete pre-drift closing of the Atlantic bordering continents – reservations that subsequent workers have ignored. In addition, a most serious mistake in this continental arrangement was/is that Antarctica is covered by a south polar ice field, for which there was/is no evidence; already a century ago fossil evidence was revealing that during the whole Palaeozoic and most of younger geological history Antarctica had experienced tropical-subtropical conditions. For most of post-Precambrian time Antarctica had not had that south polar location as proclaimed. Wishful thinking had taken the lead.

For about 4 decades, following Wegener's first presentation of his hypothesis, proselytes who publicly defended drift were very few – the most significant geologists supporting drift in a general way were Daly (1923 and 1926), Holmes (1928, 1929 and1944) and du Toit (1927 and 1937). Both Daly and Holmes had turned to drift due to their problems with the classical concepts – such as thermal contraction, fixed continents and permanent ocean basins, and the isostasy models. Aspects of particular concern for them seem to have been the Earth's thermal budget in association with formation of the Alpine fold belt. But the basic problems facing Wegener's pre-drift configuration of the continents – notably the apparently unsolvable crux posed by the palaeoclimatic record of Antarctica – seem to have been completely ignored. It is strange indeed that geologists pre-occupied with details of observations was so hooked up on driving mechanisms for drift that they paid no attention to surface observation of crucial importance – details they should have been much ready to discuss.

Daly's mechanism for moving continents was gravity: the land masses were first 'piled up' due to crustal distortion caused by thermal contraction or by sub-crustal convection, and from such topographically elevated positions they would be prone to slide 'downhill' over the suggested glassy, low viscosity sub-crustal layer. For Holmes, the building-up of heat through radioactive processes in Earth's interior, and the subsequent release of this accumulated energy, gave rise to a pulsating globe – a cyclical system of expansion and contraction, but without a general shrinkage of the planet – in which mantle convection was of paramount importance. Thus, Holmes regarded hypothetical mantle convection the principal driving force for continental drift and its related tectonic effects, a mechanism invoked earlier by Bull (1921 and 1927) to account for mountain ranges.

To the knowledge of the present author, the paradoxical palaeoclimate problem posed by Antarctica seems not to have been discussed at all by the opponents of drift. For example, Arthur Holmes (1928, 1929 and 1944), one of Wegener's few faithful supporters, either ignored or explained away Northern Hemisphere Permo-Carboniferous traces of glacial activity and though he admitted that "the position to be allotted to Antarctica is necessarily uncertain", he did not mention the growing fossil evidence from this continent contradicting the ancient polar location which was a first order assumption in the drift hypothesis. As a fan of drift, Holmes reiterated contemporary ideas on convective solid state flow in the mantle (Bull, 1921 and 1927) – as an adequate causal mechanism of drift and its supposedly related driver of mountain formation. It was suggested that anomalously hot buoyant mantle material rises to Moho level, then spreads sideways and, when cooled, returns back to some deeper level of the mantle. Indeed, gravity observations at sea, commencing in the early 1920s, seemed to concur with that proposition.

Marine gravity anomalies; a nuisance to traditional thinking
Marine gravity exploration by the Netherlands Geodetic Commission (Vening Meinesz, 1929 and 1932) showed that many oceanic areas departed markedly from presumed isostatic equilibrium. According to the Pratt-Hayford-Bowie model, positive gravity anomalies were to be found in coastal regions with major sedimentary deposits, and not over the deep oceans which were thought to be fully equilibrated. But gravity measurements told otherwise. Thus, along the Java Trench, bounding an extensive onshore belt of significant earthquake and volcanic activity, strong negative gravity anomalies were observed, suggestive of ongoing compression and crustal down warping – strengthening the possibility of mantle convection as a tectonic driver (e.g. Molengraaf, 1921; Holmes 1928; Pekeris, 1935). The results were completely unexpected, giving the isostatic principle in geology a shot across the bows.

According to the prevailing view, coastal regions with high rates of deposition were expected to show a time lag in their isostatic adjustment, and hence strong positive gravity anomalies (after topographic-isostatic reductions) were expected. Furthermore, neither the Nile Delta nor the Mississippi Delta exhibited such anomalies. According to conventional thinking, deeper oceanic regions were expected to be fully isostatically equilibrated, but, as with the Java Trench, large deficiencies of gravity were found both over the Bartlett Deep (NW Caribbean Sea) and in the Nares Deep of the western Atlantic. Adding to the list of surprises, the Gulf of Mexico displayed a relatively large positive gravity anomaly over nearly its whole extent, and positive anomalies were also reported south of Puerto Rico and throughout the full extent of the Caribbean Sea (cf. discussion by Vening Meinesz, 1929). The new observations ran counter to, 1) the popular principle of isostasy, to 2) expectations consequent upon Wegener's drift model, as well as 3) disagreeing with the long-held North American view of a static ocean basin.

Wegener's lateral continental drift would expectedly have induced positive gravity anomalies along the leading edges of moving continents – due to increasing pressure on the oceanic crust – while negative anomalies were to be expected in the space behind them. Hence, Wegener's westward drift of North America would imply positive anomalies along the western side of the continent, while the eastern side should have negative gravity anomalies. However, along both eastern and western margins positive anomalies were found – as if the continent was moving east and west at the same time. To the small camp of drift adherents, marine gravity adjacent to North America inflicted a significant blow to the idea of lateral continental motion and, within the school of isostasy at least, the Pratt-Hayford-Bowie system seemed to have lost its credibility. Seismological studies, in continental as well as oceanic regions, were beginning to show greatly variable crustal thicknesses, but how had this great variability in crustal structure and composition come about in the first place? Was crustal subsidence really a product of surface accumulations of sediments, or was it rather that some unclarified upper mantle process had caused sub-crustal thinning, isostatic subsidence and the associated development of sedimentary basins?

Marine expeditions in the mid-1930s corroborated the original findings that regionally the oceanic crust could be markedly out of isostatic equilibrium. In this respect, Field et al. (1933) and Hess (1937) suggested that the belt of negative gravity anomalies associated with the Lesser Antilles Arc was the product of compression caused by an overall eastward translation of the Caribbean block – forming a down warping of the crust at the region of regional compression. Hess interpreted the band of negative anomalies as associated with intrusion of serpentinized peridotite. The linear band of negative anomalies associated with the Bartlett Deep, NW Caribbean Sea, was ascribed to an uncompensated left-lateral pull-apart structure resulting from the moving Caribbean block. Their tectonic interpretation is depicted in **Fig. 9**. Thus, from the shifting winds of evidence, the discussion of crustal mobility had once more been brought to the surface. The lack of isostatic compensation posed by the large negative gravity anomalies over the Nares (western

Atlantic) and Bartlett deeps suggested that these surface depressions were youthful features. And since the anomalies of the WNW-trending Nares Deep extended beyond its actual length, it was pertinent to think that they were not caused by mass deficit of the Deep, but rather that both its gravity anomaly and surface depression were the combined product of something else. In other words, existing theories were unable to account for the diversity of growing facts; a unifying geological theory seemed to be as remote as ever.

Fig. 9. The movement of the Caribbean block (arrow) as inferred from the Bartlett and West Indies gravity anomaly belts. Diagram adapted after Field et al. (1933). Hess (1933) proposed that the negative anomaly belts bounding the Caribbean had resulted from an overall eastward tectonic translation. The thick arrow represents the suggested direction of maximum compression.

No unifying theory in sight

During the 1920s, when all classical hypotheses of the Earth were in decline, Stille (1924) gave what may be considered the last comprehensive synthesis within the framework of a cooling contracting globe; oscillatory vertical crustal movements, with associated changes of sea-level, was the product of warping caused by planetary shrinking, the same forces that allegedly produced tectonic and volcanic processes. But as had traditionally been the case, Stille was unable to account for many prominent facets of the Earth – such as the youth of the topographic uplift of mountain ranges, the geographic orientation and relative position of tectonic belts, the intermittent shifts of the zonal system of ancient climates, and the marked differences in the pattern of transgressive and regressive changes of sea level. It had become evident that the variety of observations pertaining to evolution of the Earth was more diverse than previously supposed, and cases of tensional and oscillatory movements were incompatible with the schemes of mainstream models. Theory-wise the geological sciences were bungling in the dark – a bewildered state of affairs that continued to well after World War II. There had been no shortage of proposals dealing with limited facets of global geology, and even most fundamental assumptions regarding Earth's origin had been questioned. For example, Chamberlin (1897) had taken a major step 'backward' when arguing against Laplace's *Nebular Hypothesis* and the common view that the Earth at some early stage had been a hot molten body. He submitted that the globe most likely had started life as a cold mass – formed by aggregation of rocky dust particles, and then, due to the presence of radioactive material, it had gradually heated up. From this reasoning it seemed likely that at least part of its initial heterogeneity had been maintained. Thence, some internal chemical imbalance might still exist and therefore associated planetary degassing might be in action even today.

In line with Chamberlin's reasoning, Hixon (1920), noting the inadequacy of the mainstream hypotheses, proposed that tectonic processes were diapiric phenomena caused by the release of internal gas. And subsequent marine gravity observations gave impetus to the possibility of hitherto unsuspected mass irregularities at sub-crustal levels, even opening up for the prospects of mantle convection. Despite the problems facing the contraction and isostasy models, these simplistic ingrained views were still limping along. In Europe the prevailing orthodoxy was the contraction model of Süss, involving a minor degree of crustal mobility, while in North America it was Dana's fixism and the isostasy model that prevailed; despite their inability to account for the system of geological phenomena, there existed a typical 'frozen frame' situation well beyond the middle of the 20th Century. The traditional standards of practice in the geological sciences seemed much more important than the growing evidence contradicting these habits. As an alternative to the old schools, Wegener's continental drift had been discussed and rejected.

Oreskes (1999) writes that the discussion over drift had basically ended by 1935, and Runcorn (1981) submitted that around 1950 it was generally agreed that drift hypothesis was false and best forgotten altogether. But even if the drift hypothesis was sidelined in the first decade following World War II, this was clearly not because evidence told more strongly in favour of the conventional theories. Despite all their ailments, innate traditions were still limping around. For example, the old idea of sunken land bridges was still discussed (Mayr, 1952), the hypothesis of crustal growth around the margins of ancient cratons, through the filling and subsequent uplift of bordering geosynclines, still held sway (Kay 1951). Stille's pulse-like tectonic behaviour of the Earth (Stille, 1924) – worldwide and synchronous events of disturbance in alternation with long periods of tranquillity – was basically reiterated by Umbgrove (1947). On the global distribution of alleged contraction-imposed mountain belts, it was re-emphasized that the Earth's young mountain chains are distributed along two approximate great circles intersecting each other at steep angles, one circumscribing the Pacific and the other following along the Alpine tectono-topographic axis (Wilson, 1954). Regardless of its inadequacy and growing observational obstacles, several authors still adhered to contraction models (Scheidegger and Wilson, 1950; Landes, 1952; Lees, 1953; Wilson, 1959). But the rapidly increasing knowledge of rocks and crustal structure of the deep oceans clearly needed some fundamental re-thinking accommodating the new facts; to the marine geophysical community at least, the long-time search for a functional theory of the Earth seemed to have entered a new promising track. The growing evidence that the oceanic basement had been subjected to faulting and tectonic deformation signified a final farewell to the image of the deep oceanic basins being tectonically stable structures.

As always in science, when new basic views provoke traditional thinking, the sceptics or opponents to drift were in great majority relative to those having sympathy with the hypothesis. In fact, as seems to be the general rule in science, only a very small fraction of the geological community actually took part in theoretical discussions (see, for example, Le Grand, 1988). Within a particular science new basic ideas have never been the prerogative of the mass of researchers – who spend their life investment by observation and mapping, within the theoretical framework of the day. Therefore, emotional resistance to threatening re-thinking will always be strong. But when the tides eventually turn the professional community in question generally invents some rescue hypothesis, trying to give rational explanations why the shift of basic opinion didn't happen before. Thus, in retrospect, after the drift model and its updated version of plate tectonics eventually won out in the late 1960s, there has been a marked tendency to celebrate and dramatize the 'victory', to regard the few early proponents of drift as foresighted idealists and to contempt the many antagonists for prejudice and for having prevented scientific progress. However, most of the global tectonic problems that prevailed in the late 19th Century are as topical today as they were then.

View from a Norwegian platform – late 1950s to mid 1970s

When I was an undergraduate student at the Bergen Geology Department, in the late 1950s, global geology was nearly non-existent in our curriculum. It was understood that the Earth was a 'pulsating' globe: long periods of tectono-magmatic quiescence had been interrupted by relatively short-lived geological upheavals defining geological time boundaries. Due to the common view of the Earth as a full-fledged body in thermal equilibrium, internal driving mechanisms were hard to envisage; to explain the West Norwegian branch of the Caledonian fold belt one just referred to 'tectonic pressures' from the northwest. The common view was that the Earth, sometime in its early history, had been a hot molten planet having attained nearly complete chemical differentiation. On the whole, continents and ocean basins were considered static features, but isostasy and geosynclines were popular concepts allowing for a certain degree of contraction-based horizontal compression, giving rise to crustal thickening and subsequent buoyant uplift – referred to as *Mountain building*.

Although Norwegian geology had been strongly associated with the German/Central European tradition, some of our teachers were markedly influenced by North American thinking – after having had been on exchange programs at US universities after World War II. Thus, Harry Hess' down-buckled geosyncline concept (Hess 1938), Philip Kuenen's tectogene model (Kuenen, 1936), David Grigg's experimental display of hypothesized subterranean convection as the driving force in crustal tectonics (Griggs, 1939), and Joseph Barrell's popular mechanism of "magmatic stooping" were part of our curriculum. But against the more modern views, Charles Lyell's old phrase "the present is the key to the past" and T.C. Chamberlin's "multiple working hypotheses" were repeatedly set forth as superior guidelines in the field. The vagueness of the importance of global theories was prevalent – as if clear "rules of the game" were not needed. For the undergraduate course in geology, we read Arthur Holmes *Principles of Physical Geology* (1944); the final pages of that book included a sketchy account of Wegener's continental drift, for which mantle convection was considered the likely driving mechanism. However, one of our professors, Anders Kvale, expressed strong reactions against drift; the enormous forces that were required to move continents were simply not present, he declared. Nevertheless, global theories of any kind were simply regarded unimportant for the teaching of geology and were therefore treated leniently.

As a graduate student in sold Earth physics [1960-1962] my emphasis was shifted from local and descriptive aspects of geology to more global-scale geophysical phenomena, such as Earth's internal constitution, marine gravity anomalies, principal earthquake zones and main volcanic belts. But the question of their internal dynamo-tectonic machinery remained obscure. The notions of isostasy and mountain building were bumping along, but factual counter-evidence was of some concern. Thus, at a lunch-time discussion in 1961 the local seismologists were pondering over the fact that the seaboard of western Norway had a fairly flat Moho and there was no evidence of the anticipated crustal root beneath the coastal mountain belt. On the other hand, it was well known that the uplift of the coastal range was only a few million years old, much younger than the tectonic deformation of the underlying Palaeozoic fold belt which was some 400-500 million years old. As shallow marine conditions had been widespread in the northern continents at that time, including Norway, the question of whether the tectonic deformation cycle really had given rise to an elevated mountain chain was inevitable (cf. **Fig. 10**). The isostatic principle in geology was perhaps not that important after all. Furthermore, what mechanism had caused the recent uplift of the Scandinavian mountain range? Professional disorientation was unavoidable.

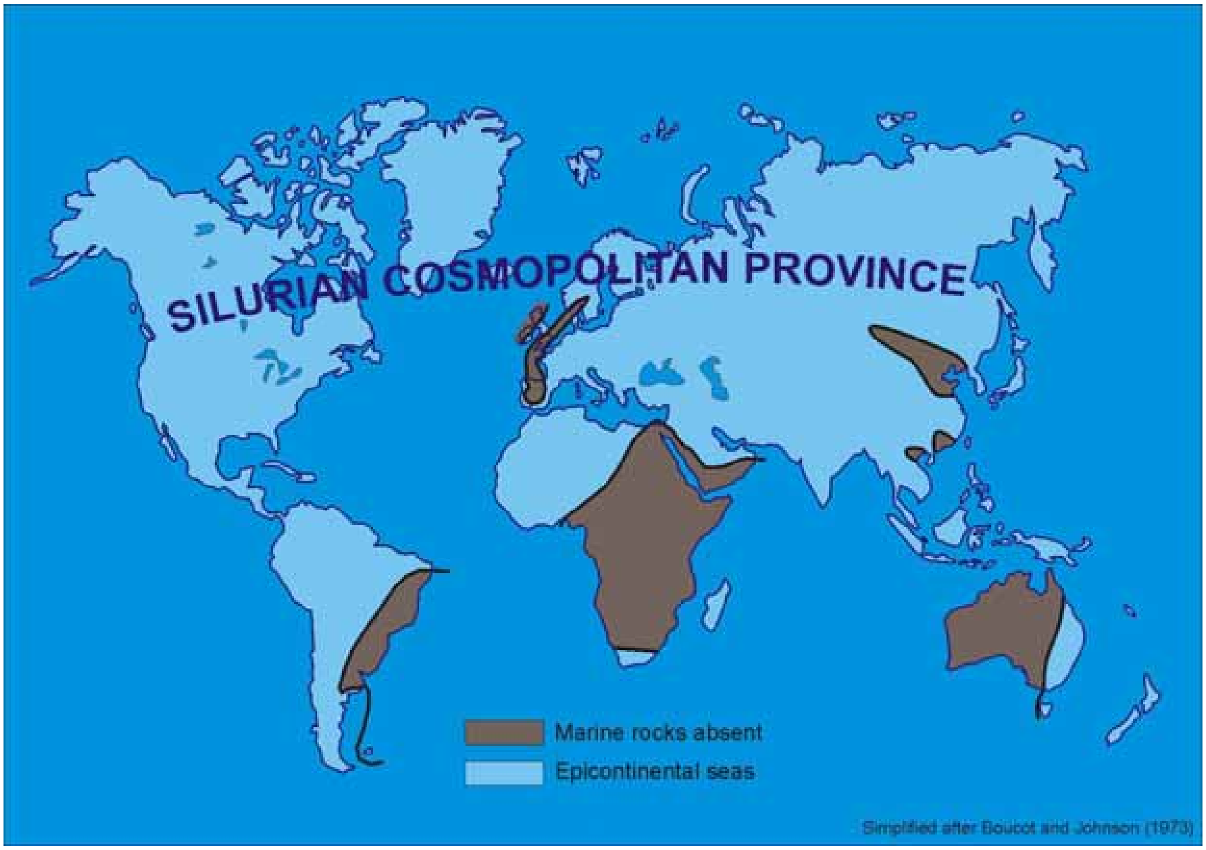

Fig. 10. The fact that epicontinental seas were extensively flooding the continents for greater parts of post-Precambrian time has been common knowledge since the 19th Century. Diagram depicts the distribution of the Silurian shallow seas on the continents, simplified after Boucot and Johnson (1973). The ingrained opinion that the Northern Hemisphere Appalachian/Caledonian fold belt formed uplifted topography, similar to modern mountain ranges, is problematic.

In the late 1950s magnetic field mapping in the NE Pacific had discovered a pattern of alternating bands of positive and negative field anomalies (Mason, 1958; Mason and Raff, 1961; Raff and Mason, 1961). The relatively narrow 'N-S' trending magnetic anomalies, with amplitudes of the order of 500 nano-Tesla, were found to be a general feature of the substantially flat and heavily sedimented abyssal plain off western North America. The striped pattern was however markedly disrupted and apparently tectonically twisted, sometimes displaying shear zones across the 'N-S' striking magnetic anomaly bands (**Fig. 11**). The major discontinuities along with the evidence of tectonic torsion indicated that the NE Pacific crust had been subjected to relatively strong structural deformation. From the form and intensity of these two-dimensional magnetic features, it was calculated that their magnetic sources were located at relatively shallow depths in the crystalline basement. On the regional implications of the inferred deformation, Mason (1958) suggested that the marine features and the displacement along the San Andreas Fault Zone were likely to be interrelated phenomena – possibly brought about by a westward rotation of North America. If true, this might indicate that North America had overridden the NW Pacific Benioff Zone, in addition to having inflicted a relatively strong tectonic force on the adjacent thin-crusted Pacific. Furthermore, interpreting magnetic field anomalies by geomagnetic field induction and variation in magnetic susceptibility had had a long tradition in geophysical exploration on land. So perhaps the observed pattern of marine positive and negative anomaly bands was a magneto-mineralogical product brought about by the suggested motion of North America?

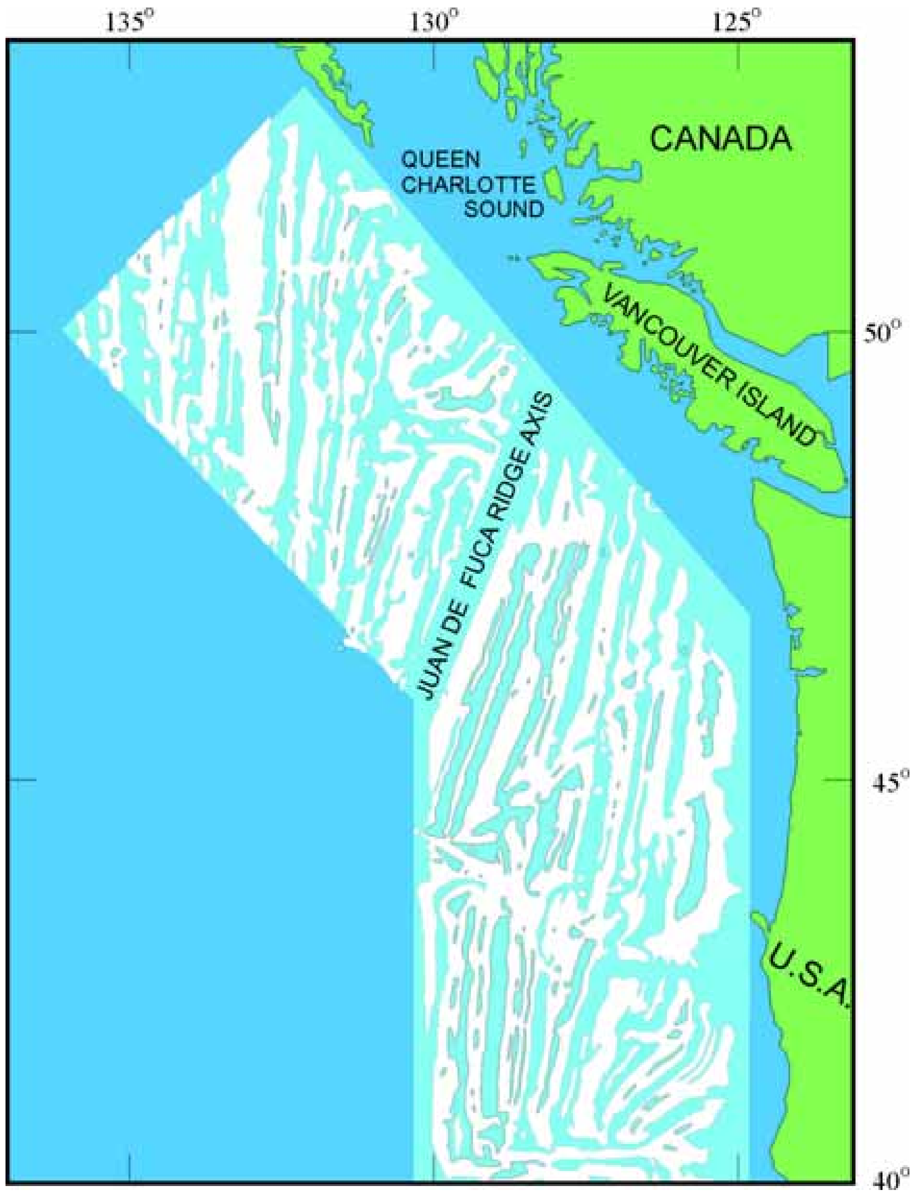

Fig. 11. The first systematic marine magnetic survey, located off western North America, uncovered a new type of marine geophysical information. Bands of magnetic field anomalies – with amplitudes either above (white) or below (light blue) the regional reference field – characterized the whole study area. Anomaly irregularities, with cross-cutting offsets and wavy structures, demonstrated that significant tectonic deformation (wrenching) had taken place. Diagram is based on Raff and Mason (1961).

In March 1961, the journal of the Norwegian Geological Society published an article which in the Bergen geo-science community had a mind-boggling effect. The author was the well-known Norwegian palaeontologist and bio-stratigrapher Nils Spjeldnæs; on the basis of Siluro-Ordovician fossil assemblages – principally from Europe, North America and North-West Africa – he concluded that from the various fauna provinces it was possible to establish zones of Lower Palaeozoic climate. Spjeldnæs (1961) reconfirmed what palaeontologists and palaeoclimatologists long had asserted: at the time in question, the palaeo-equator passed across mid-continent North America in a NE-SW trend, extending along eastern Greenland and the Barents Sea region, and with its continuation through Siberia – in a NW-SE direction. According to Spjeldnæs' fauna provinces one of the palaeo-geographic poles had been located in western Central Africa and the other pole in equatorial western Pacific – conclusions that were consistent with palaeomagnetic polar estimates available at that time. In order to obtain an optimal zoo-geographic fit he stressed that a complete closing of the North Atlantic was incompatible with his palaeoclimatic evidence; a complete closing of the ocean, bringing the tropical Ordovician belt of North America in close contact with the time-equivalent cold polar conditions in NW Africa, would be inconceivable. In his tentative reconfiguration of the continents, Spjeldnæs was clearly influenced by the rapidly growing palaeomagnetic data base, referring in particular to a paper by Runcorn (1959). Spjeldnæs' fauna provinces and his reconfiguration of the Atlantic continents are depicted in **Fig. 12**. Disregarding his partly closed Atlantic, the data told that since the Lower Palaeozoic the Earth's surface had undergone some 70-90 degrees shift of latitude relative to the polar (rotation) axis. In other words, the globe had been subjected to a major spatial reorientation since the Lower Palaeozoic; the old dynamical process of Polar Wander, which by now was amply demonstrated also by palaeomagnetism, had been substantiated. The traditional static Earth had come under debate.

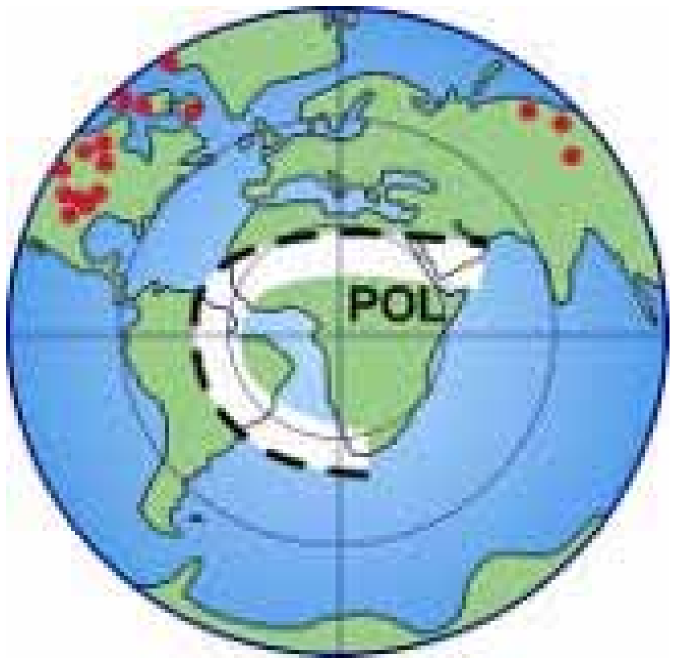

Fig. 12. Spjeldnæs' palaeoclimate zones based on ca. 470 million years old fauna provinces. Simplified after Spjeldnæs (1961). Filled red circles: tropical fauna. Note that, when extended around the globe, the palaeo-equatorial belt passed through present Arctic and Antarctic regions, while the relative time-equivalent geographic poles were located in Western Africa and Central Pacific respectively. A long-term turning-over of the Earth's body was in evidence – reconfirming the Kreichgauer/Wegener/Köppen elaboration of Polar Wander.

In 1962 I moved to the Geophysical Institute where I was destined to build up a palaeomagnetic laboratory – the first of its kind in Scandinavia. After one year of basic palaeomagnetic training at the Physics Department, King's College, Newcastle, I returned to Bergen full of enthusiasm over the new research field. Impressed by the strong international atmosphere in the Newcastle department, and the unavoidable daily dose of excitement about the mobile view of the Earth rapidly gaining ground, I had become a loyal supporter of Wegener's continental drift. The new theory of the Earth, in 1966-68 breaking through as Plate Tectonics, seemed able to lift the Earth sciences out of its protracted theoretical deadlock. In my lectures, lithospheric units in relative motion were proclaimed as facts of the day. In the Norwegian geology departments, however, teaching and research continued along the traditional tracks, and geologists who graduated around 1972 later told that they by then never had heard about plate tectonics. For my own part, I had eventually understood that, having marginal insight in global geology and geophysics in the early 1960s, my original embracing of lateral continental drift had basically been a socio-psychological process. Adding to that, since 1969 I had come to see that my once beloved model was undergoing continuous ad hoc modifications, critical tests did not come out with the expected results; the once glossy paint had begun to peel off.

The change of attitude in the country, towards plate tectonics formalism, seems to have been triggered by two papers dealing with global tectonics and mountain formation (Dewey and Bird 1970; Dewey et al., 1973). In a fairly abrupt and quiet transition, everybody began to speak favourably about plate tectonics as if they had been borne and bred with that paradigm. The notions of crustal mobility had captured the imagination of the Norwegian geologists, and all of a sudden the Earth geosciences community had taken on a new pair of tectonic glasses. At around 1975, the geological museums in Bergen and Oslo put together simplistic plate tectonic displays, and high school textbooks in physical geography soon became increasingly plate tectonics-oriented. This transition, however, was something much less than science – it was largely a social process with strong emotional overtones, a kind of fashion change or trendy contraption, just like my own conversion in the early 60s. An increasing number of geoscientists had clearly felt uncomfortable with the theoretical confusion and uncertainty regarding most prominent geological facts, and in the hope of a future professional delight they jumped on the train to the Promised Land.

At around 1970, the "new global tectonics" was promulgated as having unsurpassed qualities of precision and testability as well as pre-eminent explanatory powers. But in the mid-1970s these high hopes had only become empty words that stood in striking contrast to the reality. However, by now it was too late to openly speak out about the possibility that the plate tectonics paradigm could be flawed. One could only hope that eventually everything would turn out to the best; for the sake of human factors – careerism, projects, funding and prestige – the play had to go on. Today, one pretends that a revolution in understanding Earth processes has taken place, and at all levels of the educational system plate tectonics is being marketed as something like a God's gift to mankind. Through colourful and entertainment 'documentaries', often close to science fiction in content, the stories are dramatized by mass media in most cunning ways.

To me, the gravity of the situation was openly exposed when I began to point out the model's completely flawed predictions, versus the growing facts, along with the perpetual flow of auxiliary hypotheses – invented or the purpose to keep things going. When faced with the many conceptual problems, even high profiled Earth scientists became either silent or tried to talk their way out of it by humorous remarks. In contrast to the plethora of false plays regarding the state-of-the-art in global tectonics, van Andel (1985, p. 138 & 139) speaks his mind when he states:

> "Attempts to reconstruct the plate configurations of the past 100 million years by strict geometric methods have run into serious difficulties that demand the invention of undocumented plates, or abandonment of the rule that plates are not deformed internally…Finally, we have had to call repeatedly for special events and ad hoc assumptions to deal with the episodic intensifications of orogenies that do not follow from the stately progress of crustal creation and destruction".

A lecture and its subsequent commotion

In summer 1920, Wilhelm Bjerknes, the leader of the famous *Bergen School of Meteorology*, arranged two international meetings in the hope of convincing foreign meteorologists that ideas and methods that had been developed in Bergen, during the preceding two years, was the beginning of a revolution in weather prediction. As a meteorologist, Alfred Wegener participated in the second of these meetings. During his stay in Bergen, Wilhelm Bjerknes, who in the years 1912-1917 had been professor at the Geophysical Institute in Leipzig, invited Wegener to give an evening talk on his drift theory. While the German group was in Bergen, Bjerknes got an unexpected visit by Sidney Chapman, newly appointed professor of applied mathematics at the University of Manchester; he was on a bicycle tour in Norway. Chapman was then invited to be present at Wegener's evening talk which is thought to have been Wegener's first presentation of his theory outside of the German speaking Europe. The reaction of the Bergen audience is not known, but back in Manchester Sidney Chapman told his colleague William L. Bragg – Nobel laureate for physics in 1915 – about the evening talk in Bergen.

Bragg became interested, and on behalf of *Manchester Literary and Philosophical Society* Wegener was invited to Manchester to give a lecture on his theory. Wegener was unable to take up the invitation, but to the actual meeting he submitted a summary which was read by William Bragg. The hostile reactions from the geologists present shall have come as a great surprise to the audience. Many years later he told Keith Runcorn (who gave me the story) that even though he was aware of the expression *frothing at the mouth* he had not witnessed the phenomenon before this meeting. The audience feared that the professor of geology was about to have a fit. To Bragg the episode had been most embarrassing, and he thought for a while he had made a fool of himself in front of the learned audience. In his old age, he admitted (to Keith Runcorn) that the incident had been so painful that it had been suppressed.

On behalf of science, this little anecdote from Manchester can only make us ashamed. But it tells us that science is far from the rational activity commonly alleged. The history of science repeatedly reminds us how new basic ideas easily become a nightmare for the discipline(s) concerned. What really strikes us about the resulting controversies is their emotional character and scientific superficiality. The shallow knowledge of fundamental issues among the mass of scientists easily triggers temper and special pleading – false play to conceal the lack of real insight. For example, my dismissal of plate tectonics some 25 years ago led to sustained turmoil in the Norwegian geosciences community, and far beyond – a stir that was nearly completely stripped of real scientific debate. The falsity of the resistance activity was well exposed in 2006, by a member of the local geosciences institute, who phoned me after having read my scientific autobiography (Storetvedt, 2005b). During our conversation he remarked: "*Your colleagues here have no deeper insight into plate tectonics than the simple version that can be found in elementary college text books, nor have they ever taken the bother to try and understand your alternative view. So, when it comes to theories you cannot really expect them to perform in a rational way"!*

It is a well-known fact, notably in Europe, that Keith Runcorn's extensive lecture touring of Europe and North America from the late 1950s onwards, along with his yearly Newcastle conferences in the 1960s, managed to swing the climate of opinion in favour of drift-related geophysics. In fact, it was Keith's visit to Bergen in 1961 that made me hastily jump at palaeomagnetic research and its association with drifting continents – without having anything but casual knowledge of global geophysics. Realizing this strong psycho-social component in science, notably in the context of paradigm shifts, it would be vital for the sound progress of a science that the mass of scientists have been led along a prosperous and scientifically sound path; if so, a large number of scientists in relevant fields will be contributing to the progress. On the contrary, if new paradigmatic rules and views eventually turn out to be wrong, a scientific stagnation will be the natural consequence; in the latter case, the involved sciences will move around in an intellectual deadlock – without the stagnation being seen or openly admitted. To end the story about Keith Runcorn's vital role in promoting Wegener's continental drift, it is no longer a secret that he in his older age took issue with that hypothesis – while he was ceaselessly exploring other ways of lithospheric mobility able to account for between-continent palaeomagnetic discrepancies. In a Runcorn memorial volume, I published the last two personal notes Keith sent me (cf. Storetvedt 1998) in which he gave some 'kicks' to plate tectonics orthodoxy. In return, I received a few sarcastic comments from fellow scientists.

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The past and the present – a perspective

– It is all too easy to derive endless strings of interesting-looking but untrue or irrelevant formulae instead of checking the validity of he initial premises –

John Ziman, in: *Reliable Knowledge*

Looking back on the history of global geology, one cannot but be struck by the relatively few individuals who advanced ideas that dominated global geological thinking for decades – despite the inability of these concepts to account for the global situation and the gradual accumulation of new facts. In hindsight we recognize how very limited in both scope and precision the various theories have been – concentrating only on a few problems that geoscientists had come to identify as particularly acute. However, many observations were found to be at variance with the predictions, and in attempts to keep things 'straight' adjustable parameters were unceasingly added – an *ad hoc* state which however did not disturb the peace of mind of the great majority of geoscientists. After all, their work was basically concerned with local or regional mapping – various forms of fact gathering and description. The real understanding of the amassing facts did not seem to have bothered the geosciences community to any extent. To the great majority of geologists, Chamberlin's notion of *multiple working hypotheses* seems to have served as a kind of ideal well into the 1960s. In my own student days, around 1960, global geology – meaning a comprehension of geological observations in terms of some 'higher-order' axiom – never went beyond the stage of lunch time chatting.

Albeit this lack of interest in overarching theoretical frames, the contraction thesis as well as the isostatic principle ruled supreme; these two concepts formed kind of background truths in the teaching of tectonics. It is to be admitted that a scientific community can become so deeply attached to ingrained views that the critical faculties and truly imaginative powers of its members are inhibited.

Neither the contraction thesis nor the isostasy model were able to give satisfactory accounts of the formation of tectono-magmatic belts and their shifting global arrangements versus geological time – even if such aspects really ought to have been among the primary goals of any global tectonic theory. For example, the North American version of Earth contraction was advanced as a global theory despite the fact that it hardly could be applied to regions outside North America – perhaps a good example of the role of national pride in science. Nevertheless, talking about the longstanding unsolved problems regarding formation and the time-shifting global distribution of tectono-magmatic belts, one would have thought that when a solution to such pressing matters was advanced the geosciences community would automatically be genuinely interested and giving it serious consideration. Alas, in a chauvinistic science brotherhood this cannot really be expected. Thus, when Damian Kreichgauer in 1902 presented his theory in which fold belt formation was intimately associated with changes of Earth rotation (these belts being primarily aligned along, and in part perpendicular to, time-equivalent equators), his work was nearly completely silenced. Kreichgauer's proposal was a major break with conventional thinking in geology, and probably for that reason alone he was ignored. Even in Scandinavia, where historically Central European thinking had deep roots, Kreichgauer's work was seemingly given a cold shoulder. Thus, when I in the 1990s became interested in Kreichgauer's 1902-book (reprinted in 1926), I had to go to the Innsbruck University Library to obtain a copy.

It is safe to say that prior to World War II global geology made very little progress. A real awakening had come with the marine gravity measurements in the 1920s and 30s which gave a shot across the bows to the isostasy principle as well as to the ingrained North American school of continental/oceanic 'permanence'. Also, to some extent the new gravity observations ran counter to predictions following from the hypothesis of lateral continental drift. Further development came from marine exploration during World War II – unfolding unexpected topographic details of the sea floor – in addition to the breakthrough of the palaeomagnetic method in the 1950s. Ever since new evidence from palaeomagnetism provided justification for some kind of continental mobility, Wegener's system of lateral drift has been expounded as one of the greatest scientific revelations of the 20th Century. However, even a cursory glance at the history behind this basic shift of explanatory hypothesis soon uncovers a mass of speculative scientific arguments topped up by strong socio-political factors. Today it is not difficult to see that if the British palaeomagnetists in the late 1950s had opted for inertia-driven directional changes of the continental lithosphere – i.e. moderate *in situ* rotations of the larger land masses (to account for the observed discrepant locations of their polar wander paths) – instead of unreservedly jumping on Wegener's lateral drift, the Earth sciences are likely to have taken an utterly different intellectual path; hence, observations would have been looked at with new eyes and given new meanings.

In the 1960s, new pressure groups rapidly entered the scene and, within a decade or so the Earth sciences had become the victim of a trendy theoretical edifice running impulsively in favour of lateral drift and plate tectonic principles – soon to become the supermobilistic orthodox opinion in fashion today (e. g. Storetvedt, 1997, 2003 and 2010b). However, to the well-informed geoscientist, it has gradually become evident that things have gone terribly astray; in the event, the new conceptual suit fits neither the body of classical facts nor the panoply of newer observations – but, of course, that is quite hard to admit. In other words, the plate tectonic revolution has not been a revolution of enlightenment – a real understanding of the mass of classical geological phenomena is still as open as ever. This is of course the very reason why this journal – *New Concepts in Global Tectonic Newsletter* – exists. On the bright side of it, however, the technological development and the ceaseless search of the plate tectonics community, to establish observational facts in compliance with predictions of that paradigm, has resulted in an extensive mass of new and more detailed observations. Today, the data base for the building of a next generation global theory is therefore much stronger and more varied than what it was when plate tectonics took ground in the 1960s.

Around the mid-1960s, the possibility of Earth expansion, as an alternative model of explaining the intercontinental discrepancies of polar wander paths, was much debated (e.g. Carey, 1958; Fairbridge, 1964, Holmes, 1965; Creer, 1965; Jordan, 1966). If the oceanic basins were the surface manifestation of a global swelling, compositional differences between continental and oceanic mantles would most likely ensue, and, hence, this version of crustal separation could be expected to be compatible with the evidence of MacDonald (1964) that the mantle is bound to the crust at least to depths of a few hundred kilometres. Eclipse observations indicated that the Earth was slowing (Munk and MacDonald, 1964). This was problematic for lateral drift and plate tectonics, but not for expansion – provided there was no significant disturbance from reorganization of internal mass. Results from growth rings in corals (Wells, 1963; Scrutton, 1965) did in fact suggest that deceleration of the Earth's spin had, on average, been an ongoing process at least since Devonian time. On the other hand, later studies revealed that the long-term deceleration had been interrupted by periods of acceleration, and these break-points in the length-of-day (LOD) corresponded to major geological time boundaries (for data summaries see Creer, 1975; Storetvedt, 2003). Neither the expansion model nor plate tectonics were able to explain such observations; therefore, the LOD data were conveniently ignored.

If the Earth was in a process of swelling, newly added crust would be expected to occur as ridge-parallel sheeted intrusives. However, subsequent deep sea drilling revealed that such dyke-in-dyke complexes, required both by the expansion model as well as the seafloor spreading hypothesis, are practically non-existent in the deep sea crust (e.g. Storetvedt, 1997 and 2003). Measuring changes in Earth's size has not been an easy matter, but a recent study of the Terrestrial Reference Frame origin versus the hypothesis of Earth expansion, Wu et al. (2011) concluded that the mean radius of the solid Earth is not changing to within the current measurement uncertainties of 0.2 mm per year. And looking at this aspect in a geological perspective, the *NCGT* journal has repeatedly reported that the deep oceanic crust, even along mid-ocean ridges, is packed with old continental and altered rocks, in a range of metamorphic grades; hence, the favoured continental reconfigurations, hypothesized by expansion/spreading models, seem physically impossible.

The old view that all oceanic regions were originally continental – having subsequently been subjected to sub-crustal delamination and isostatic foundering, notably since the Cretaceous – is steadily being strengthened. Adding to the numerous cases of crustal oceanization already described in the literature, the University of Sydney recently reported new findings of submerged former continental masses (*News and Events*, Univ. of Sydney) in the abyssal plain off Western Australia, in water depths of more than 1.5 km, the CSIRO research vessel *Southern Surveyor* found two flat topped seamounts, covering an area the size of Tasmania and described as 'micro-continents'. Instead of expected oceanic basalts, the researchers recovered a variety of continental rocks – including granite, gneiss and fossiliferous sediments.

In the mid-1960s when uprooting of traditional ideas was in full force, Tuzo Wilson (1963), whose theoretical inclination switched from contraction, via expansion, to convection/seafloor spreading in less than 5 years, argued that "the farther an ocean island is from a mid-ocean ridge, the older it is likely to be". Wilson's paper, which got an enormous impact and was widely cited at the time, was obviously more of a socio-political contribution than a scientific one in that it contained quite a bit of wishful thinking. Menard (1986), discussing Wilson's paper, wrote that "he [Wilson] … made a number of refutable errors, …[but] I was later unprofitably distracted into publishing a refutation of the significance of his data". On the question of Wilson's presumption that oceanic islands are being formed at the crest of mid-ocean ridges, Menard wrote: "This assumption was manifestly incorrect. With the exception of Iceland there are hardly any islands at ridge crests, and active volcanoes show that they can grow anywhere in the ocean basins".

In order to account for the unexpectedly low heat flux along mid-ocean ridges a number of hypotheses have been invoked – including the frequently favoured hydrothermal circulation proposal leading to artificially constructed oceanic heat fluxes according to alleged spreading rates (e.g. Jaupart, 2010). However, in a recent study of Earth's heat flux (Hofmeister and Criss, 2005) the authors conclude that "Hydrothermal circulation cannot cause the huge discrepancy [between the observed observations and plate tectonic expectations] because the…magmatic system is too small and because hydrothermal systems are too weak movers of heat". They further submit that the planet's heat balance currently approximates a steady-state condition. In this context it is important to note that the heat flow problem of mid-ocean ridges is nothing but an artificial theory-laden problem: the near-absence of active volcanism and the irregular and generally low values of heat flux along these ridges is only Nature's way of telling us that seafloor spreading and expansion models are wrong.

Taking a perspective look at the history of global geology, it is obvious that the Earth sciences are still without an adequate universal theory – encompassing a well-founded Theoretical Tree (**Fig. 3b**). A satisfactory theory should ideally put all of its major manifestations – including dynamic, tectonic, magmatic, palaeoclimatic, space geodetic, and biogeographic phenomena – into a coherent system. And it must be so precisely defined that it can generate specific predictions – a requirement that neither plate tectonics nor previous tectonic hypotheses have been able to fulfil. These prognoses must be in compliance with existing hard facts, initially and principally as revealed by surface observations. Only when we are able to pursue a lengthy prediction-confirmation chain, embracing an ever more diversified range of natural phenomena, can we be reasonably confident that we are on the right track towards erecting a substantive theory – a true understanding, resembling the metaphor of a solidly grounded *Theoretical Tree*. In the past, the Earth sciences have had many 'working hypotheses', generally erected to account for a limited number of phenomena, but after decades of muddling along with awkward observations – requiring continuous *ad hoc* repairs of basic mechanisms – they have eventually been replaced by new theoretical constructs. The dual-hypothesis of plate tectonic and mantle convection is apparently the next thought pattern waiting to be engulfed by the waves of model-inflicted mockeries.

Any global geological theory will always involve some physico-chemical workings in the deep – providing dynamic driving mechanisms related to planetary formation and the development of Earth's internal constitution. In recent decades the traditional idea of a layered, differentiated interior has been difficult to reconcile with modern tomographic images. For example, the current view of a convecting mantle – slow creep motions required to drive plate tectonic processes – is hard to harmonize with the relatively chaotic state of the interior presently unveiled. Instead of the predicted layered structure, the construction of the mantle rather looks like a chocolate cake or a plum pudding (e.g. Tackley, 2008), apparently being cut by rising material from the core or core-mantle boundary (CMB) region. We are then back to the frequent proposal (in recent decades) that the core is not in equilibrium with the mantle and that the strongly irregular CMB region is somehow the seat of energetic exchanges and couplings between core and mantle (Poirier, 2000). To account for the compositionally and structurally complex mantle, diversified *ad hoc* proposals abound. Hence, in an attempt to keep plate tectonics afloat, it is now hypothesized that down-welling cold slabs of lithosphere extend all the way to the core-mantle boundary where they form slab graveyards (e.g. Kellogg et al., 1999; Tackley, 2008). A fundamental problem is, however, whether any lithospheric mass would be able to penetrate the high viscosity mantle. It seems a much more likely possibility that the chaotic internal state is a consequence of the planet's incomplete degassing – implying that the globe has not differentiated from a hot molten state. Perhaps the deep interior has much lower temperatures than what have been traditionally conceived, and that the Earth, throughout its lifetime, has struggled to attain internal thermo-chemical stability (Storetvedt, 2011).

It has become overwhelmingly clear that plate tectonic is a bogus theory, and that the geological sciences therefore need a new intellectual foundation. But history tells us that the transition towards a new system of thought will for a long time be counteracted by the range of non-scientific operations – including self-interest, idiosyncratic taste and disciplinary prejudices – until the load of inconsistencies and ad hoc changes make it to suddenly collapse. According to Bornholdt et al. (2011), for example, "scientific paradigms have a tendency to rise fast and decline slowly. This asymmetry reflects the difficulty in developing a truly original idea, compared to the ease at which a concept can be eroded by numerous modifications". Going against the tide in science is normally an arduous task; innovators are often penalized if they go too far in breaking conventional boundaries, even if by doing so they may re-define conventions and pave way for future scientific revolutions.

In an attempt to get out of the present deadlock in global geology and solid Earth physics, a multitude of prominent tectonic aspects has, during the last 15 years, been reinterpreted by applying the theory of *Global Wrench Tectonics* – GWT (Storetvedt, 1997, 2003, 2005a, 2007, 2009, 2010a, 2010b and 2011; Storetvedt et al., 1999; Storetvedt et al., 2001; Storetvedt and Longhinos, 2011). In the GWT frame, it is the slow continual reorganization of internal mass, giving rise to episodic changes of the planet's moment of inertia and hence of its rotation characteristic, which triggers the pulse-like dynamo-tectonic behaviour of the Earth. Whatever the future course of events will be, it is first of all the ability to conceptualize the infinite quantity of well-established surface observations that will bring the Earth sciences forward – not the incessant pumping of funds in the ceaseless run for ever more details, many of them being subjected to PT-laden manipulations before finally being placed in the dusty shelves of the storage bank.

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COMMENTS AND REPLIES

TIDES & EARTHQUAKES

Kolvankar, V., 2011. Sun, moon and earthquakes. *NCGT Newsletter*, no. 60, p. 50-66.

Comment by Peter James
Reply by Vinayak Kolvankar (in italic)

The plots in Figure 3 – 6 et al, in the paper by Vinayak Kovankar, "*Sun, Moon and Earthquakes"* (NCGT # 60), present an almost absolute adherence of low magnitude earthquake behaviour to tidal effects, down to depths of 5 – 10 km.

An analogy might be drawn between this view and the phenomenon of reservoir induced seismicity (RIS). In RIS, an increasing depth of water impounded behind a dam is known to initiate earthquakes down to the 5 – 10 km depth range. This activity can be logically explained as a result of the reduction in effective stress across discontinuities in the underlying rock mass. But two conditions appear to be necessary. The first is that the depth of impounded water typically exceeds some 30 – 50 m before RIS is triggered. (Even so, the changes in effective stress beneath a 50 m are small, less than 1% at depths of 5 km.) The second condition is the implication that the underlying rock mass needs to be highly stressed and in a state of incipient failure before this relatively minor change is able to bring about an earthquake. (P. James)

In the paper "Sun moon and earthquakes" general seismic data of the world, is discussed. However as Dr. James pointed out it would be interesting to see whether these phenomena can be applied to the RIS induced earthquakes. If the RIS induced earthquakes data from any location does appear in the NEIC USGS catalogs [1973-2008] then the same can be examined for [EMD+SEM] Vs GMT Timings. (V. Kolvankar)

Where tidal effects are cited as a cause for earthquake activity, the same condition of high in-situ rock stresses would appear to be even more important prerequisite and this condition should be largely satisfied by the paper's focus on very active areas of the Earth. Tidal effects are, however, fairly minor. Sea level variations of the order of 2 m occur, which would represent a change of only 0.04% in the effective stresses at 5 km depth. One could, of course, postulate that the daily tidal effects do help facilitate upward migration of high pressure volatiles from greater depths, but that puts us in a different ball game.

Before giving the tide/earthquake nexus the proverbial "housewife's seal of approval", it would be useful to have some further information from the author:-

- Firstly, a more detailed explanation on how the SEM + ADM parameter (the X-axis of the plots) was arrived at. The same goes for the Y--axis. (P. James)

As explained in the body of the paper [Sun Moon and earthquakes] the X axis is composed of [EMD +SEM]. For our earlier paper "Earth tides and earthquakes" (Kolvankar et al., 2010, NCGT no. 57, p. 54-75), the x axis is the same but the y axis is for number of earthquakes. For each earthquake we took the cursor [on x axis] to the values SEM [Sun Earth moon angle] and then plot earthquake [or increment corresponding column] with respect to the lunar position [EMD]. This is simple plain thinking and I suppose all other researchers have used similar concept for finding out the Earth tide effect. In earlier paper [Earth tides and earthquakes] large earthquake counts were observed close to Full Moon [FM] for all earthquakes up to magnitude 5.0 and small and shallow focus earthquakes were observed in large number close to New moon [NM]. The quantity [EMD + SEM] is plotted from the origin of the plot for each earthquake.

The difference in the plots drawn for this paper and for our earlier paper [Earth tides and earthquakes] is in the change of parameters in Y axis. [X axis is same for both set of plots]. We found serial change in the quantity [EMD + SEM] when the earthquakes are lined up for timings from 00-24 hours GMT. This was found to be very consistent for any high seismicity region of the earth. Of course the physics behind this phenomenon need to be investigated. *(V. Kolvankar)*

- Secondly, with such a close adherence of earthquake activity to tidal effects, shown by Figures 3 – 6 et al., one might expect corresponding patterns to show up in other, more simple, formats: the day to day activity in any one region, for example. To this end, the data in the fourth figure of Figure 5, for the Tonga Trench in the year 2000, was plotted up by this writer as number of events per day in the magnitude ranges M 2.5 – 5 and also the M ≥ 5 range.

On the plot were also noted the new moons and full moons. No obvious nexus between earthquake activity and these two phases of the moon emerged, with only a couple of exceptions: a slight increase in earthquake numbers on January10 and December 11 (New Moon) and on September 2 and mid-July (full moon). This is a correspondence of only about 15%. Perhaps some form of delay camouflages the proposed association? If so, how would such a delay show up on Figures 3 – 6 of the paper? (P. James)

All the plots are plotted for the entire magnitude range from M 2.5 and above. The quantity of earthquakes provided on top of each plot provided is for the period which is also explicitly mentioned.

Fig. 11 of this paper provides a typical earthquake plot for (EMD+SEM) Vs GMT timings, for latitude range 30^0 to 50^0, longitude range 20^0 - 40^0, for a lower magnitude range of 2-3 and for the year 1993. Hollow triangles are used here to indicate high densities of earthquake on the edges (indicated by arrows) close to the new Moon phase. The Earth tide plot for the same parameters is also provided, which illustrates high earthquake counts in the new Moon phase.

The high density of earthquakes at the edges [of this figure] are possibly caused by the direct triggering by possible pull from Sun and Moon together close to NM period. This effect is over 300-400% as compared to nearly 10-20% seen for earthquakes [Please refer to our paper Earth tides and earthquakes]. These plots also show small delays as you have anticipated. *(V. Kolvankar)*

Earthquake prediction is now the *cause célèbre* of the Earth sciences and here the Kovankar paper would appear to be of great promise. Unfortunately, if the initiating condition for any earthquake is the maximum tidal effect, such an effect occurs a couple of times per month (New moon & Full Moon) - and globally, as well. We are left with the problem of which new/full moon is going to do the trick? Perhaps the problem could be resolved by combining the tidal patterns with other earthquake precursors that have been discussed in recent NCGT issues? Notwithstanding these approaches, we surely still need to know the conditions of in-situ stress at any location/depth: that is, whether the crust at any given location is in a condition of incipient failure and therefore vulnerable to these minor stimuli. Establishment of a micro-seismic network appears to be one way to monitor this matter, at least on a localised basis. And could not, one wonders, a start be made with records of past micro-seismic networks associated, say, with dam projects? – that is, if some enthusiastic research institution could be persuaded to volunteer for the job.

Peter JAMES
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5 December, 2011

NEWS

34th INTERNATIONAL GEOLOGICAL CONGRESS
BRISBANE, AUSTRALIA. 5 – 10 AUGUST, 2012
www.34igc.org

Important dates to remember:

17 February 2012	**Abstract submissions close. Submit abstracts here**
31 March 2012	Field trip bookings close
30 April 2012	**Early Bird registrations close (Standard registration rate commences) Presenters registration deadline.**
5 June 2012	Accommodation reservations to be made by this date
1 July 2012	Standard Congress registrations close (Late registration rate commences)
July 2012	Fifth Circular - Final Program

NCGT session: Theme 37, Alternative Concepts, *Pursuit of a new geodynamic paradigm*
Conveners:
Ismail Bhat, India. bhatmi@hotmail.com
Karsten Storetvedt, Norway. Karsten@gfi.uib.no
Dong Choi, Australia. raax@ozemail.com.au

Major topics:
Critical tests of plate tectonics, alternative dynamo-tectonic replacement theories, Earth evolution, climate and its variation through geological time, natural hazards and outlook for prediction, planetary interaction, origin of hydrocarbons and distributions of major oil/gas fields.

Keynote speakers:
Boris Vasiliyev – Ancient and continental crust from the world oceans (1)
Takao Yano – Ancient and continental crust from the world oceans (2)
Karsten Storetvedt – World magnetic anomaly map and related theories
Ismail Bhat – Global climate and new global geodynamics
Dong Choi – Earthquake prediction from a new tectonic perspective
Louis Hissink – Geoplasma connection (Electric Earth)

Those who wish to present papers at the NCGT session, please contact one of the session conveners. Both oral and poster sessions are planned.

We are planning some small group meetings for specific topics as well as a function during the conference. They will be announced in the next NCGT issue. Please let us know if you have any proposals, requests or opinions.

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FINANCIAL SUPPORT

Following suggestions from many readers, NCGT Newsletter has become an open journal. Now anyone can access all issues without log in. This will increase the number of readers dramatically. This means we have to rely on good-will, voluntary donations from readers as well as commercial advertisements to defray the journal's running costs. We welcome your generous financial contributions. Hard copy subscription fee for 2012; US$140/year (or equivalent euros) plus postage (air mail). Advertisement fee structure: ***Premium positions.*** Page 3 (after the Editorial), full page – U$400/issue, U$1460/year. **Back cover**, full page – U$200/issue, U$720/year (or equivalent euros). Half page – 80% of the full-page price; ***Other positions***. 10% discount from the back-cover price. For more information, please contact editor@ncgt.org.

If you have a PayPal account, please send the payment to the following account (*PayPal accepts payment by credit cards; Visa and MasterCard* – we encourage everyone to use this method; http://www.paypal.com/cgi-bin/):
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Name of bank: Commonwealth Bank (Swift Code: CTBAAU2S), Belconnen Mall ACT Branch (BSB 06 2913).
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ABOUT THE NCGT NEWSLETTER

This newsletter was initiated on the basis of discussion at the symposium "Alternative Theories to Plate Tectonics" held at the 30th International Geological Congress in Beijing in August 1996. The name is taken from an earlier symposium held in association with 28th International Geological Congress in Washington, D. C. in 1989.

Aims include:
1. Forming an organizational focus for creative ideas not fitting readily within the scope of Plate Tectonics.
2. Forming the basis for the reproduction and publication of such work, especially where there has been censorship or discrimination.
3. Forum for discussion of such ideas and work which has been inhibited in existing channels. This should cover a very wide scope from such aspects as the effect of the rotation of the earth and planetary and galactic effects, major theories of development of the Earth, lineaments, interpretation of earthquake data, major times of tectonic and biological change, and so on.
4. Organization of symposia, meetings and conferences.
5. Tabulation and support in case of censorship, discrimination or victimization.

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Geophysical Forecasting and Modeling with G-MagTeleDyn
Climate Stat develops gravity/magnetic teleconnection dynamics climate models to account for short-term (hourly to monthly and seasonal) and long-term (decadal and inter-decadal) geophysical variations affecting electromagnetic, gravitational, and thermal coupling parameters to atmospheric forcing.

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Preliminary research suggests a moderate likelihood that significant improvements to hurricane and weather prediction models can be made. Geophysical modeling outputs are tested in historical atmospheric circulation models to improve conventional models.

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To improve accuracy in global weather forecasting, commodity trading, and insurance actuary support.

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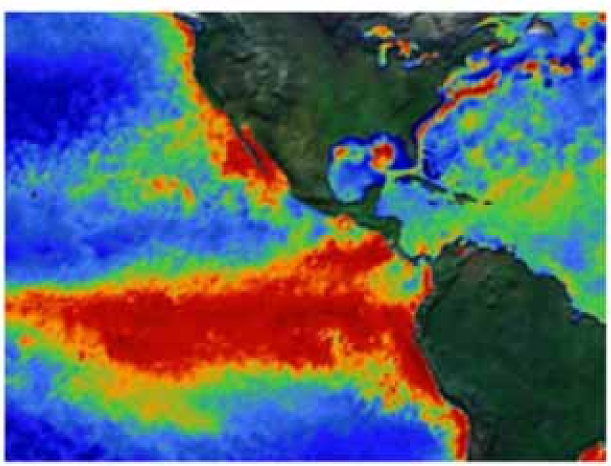

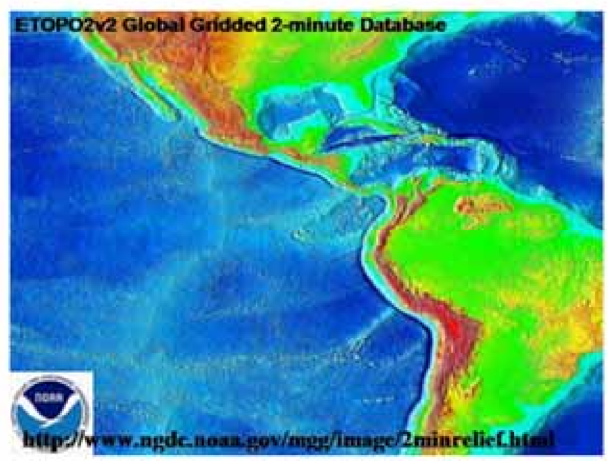

Left figure: Full Blown El Nino Feb. 1998 Sea Surface Temperature Signal.
Right figure: The Y structure in the Sea Surface Temperature Anomaly above as reflected in the sea floor ridge geomorphology below.

Bruce Leybourne - CEO / Geophysicist
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