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FROM THE EDITOR

New Madrid Seismic Zone, central USA: a new battle front

The Space and Science Research Corporation, based in Florida, USA, issued a press release on 8 June 2015 announcing the arrival of a prolonged solar low cycle (or hibernation) and the possible repeat of the great 1811-12, M8.0+ class earthquakes in the New Madrid area, central USA, between 2017 and 2031. You can download this press release for free from www.spaceandscience.net. A detailed scientific account of the New Madrid earthquakes can be found in a paper by Choi and Casey in the Global Climate Status Report, Edition 1-2015, available on the same website for a small fee. You can also obtain a free pdf copy of this paper by sending a request to the present Editor. The summary of the paper and relevant general information are introduced in this NCGT issue on pages244-245 and 251-252.

The New Madrid seismic study which resulted in a long-term warning is based on five solid grounds: 1) the long-term solar cycle has entered a major inactive cycle or hibernation period for the coming 30 years or so, comparable to the Dalton Minimum (1793-1830), or even worse, to the Maunder Minimum (1645-1715); 2) the well-established anti-correlation between seismic/volcanic activities and solar cycles; 3) the fact that all of the last four strong earthquakes in the New Madrid seismic zone in 1450, 1699, 1811-12 and 1895AD occurred during the major solar low periods – the Spörer, Maunder, Dalton and Centennial Solar Minimums, respectively; 4) the structural position of the New Madrid and lower-middle Mississippi Valley, situated on a Precambrian anticlinal axis which became an energy transmigration channel or a surge channel; and 5) a newly emerging earthquake model developed by the NCGT geologist/seismologist group – energy origin, transmigration, trapping structures, triggers, and electro-magnetic and planetary influences.

The study is a substantial, synergetic work. Now we can easily and intuitively understand why all of the last four historic earthquakes occurred in the solar low periods and specifically in the New Madrid area. The study further endorses the decisive role of the Sun in controlling global climate and the arrival of a major, long-term solar low period.

However, both the geological and climate models adopted for the study and the results conflict with the official view and policy of the US government authorities – plate tectonics and man-made global warming. Confronted by indisputable evidence and the implications of a possible seismic event, which would have a serious impact on human lives and social stability, the establishments are in a serious dilemma: They have no one who can objectively evaluate the paper. If they accept the paper, they will have to accept the demise of both plate tectonics and global warming. But if they reject it, they are likely to face opposition and accusations for many years to come. I believe our New Madrid study can help open up a new era of creative science, free from dogmatic ideas and orthodoxies.

Apart from the above seismic alert, the New Madrid work demonstrated the importance of a multi-disciplinary approach; it was made possible by close cooperation between geologists, geophysicists, seismologists, astrophysicists, and solar scientists. In the same vein, a timely paper on 'Geonomy' by Lidia Ioganson appears in this NCGT issue. It has been proposed as an integrated science of the Earth, uniting Geology, Geochemistry and Geophysics. The New Madrid earthquake work was an expanded version of geonomy. I believe that the future of geology lies in a geonomical direction, as Beloussov, Van Bemmelen and Shadechzky-Kardoss envisaged. However, whatever happens in the future, we geologists must keep sharpening our own tools through meticulous field observations. Our geological acumen does not come from computers, but from the real Earth.

LETTERS TO THE EDITOR

To the Editor:

SIMPLIFICATION OF EARTHQUAKE PREDICTIONS AND OTHER QUANTITATIVE MATTERS

A great benefit of the NCGT Journal is that it is open to the publication of papers of all persuasions, without the imperious dismissals that so often greet papers questioning current paradigms - as when submitted to mainstream journals in the Earth sciences. The NCGT approach does not imply that any published submission necessarily reflects editorial beliefs; the submission is put forward to be read and, when the occasion arises, to be assessed and commented on by the author's peers. This is how science is supposed to work.

Let us look at the matter of earthquake prediction. In the 1960s, the French geophysicist Claude Blot discovered, in the S.W. Pacific, that upward migration of earthquakes, from the mantle to the surface, took place at repeatable rates in the one region. He termed this "transmigration of seismic energy" and, by it, he was able to provide some outstanding predictions of both shallow earthquakes and volcanic occurrence. His reward? Not a Nobel nomination, as one might have expected, but a transference by the French Government to a part of West Africa where there were no earthquakes, no volcanoes. Fortunately, his work has been followed up over the years by publications in these pages, eg. Blot, Choi & Grover (2003), among others.

What is important about the Blot model is that it does outline a mechanism for earthquake activity, although the quantitative analysis of how the mechanism worked was not then made. This matter is being brought up because, in recent editions of NCGT, there have been proposals of earthquake patterns/predictions so regular that they appear almost too good to be true. In Vol 3 #1, there are three papers in this mould, taken in turn, below:-

David McMinn (p 11-20) provides additional data on his 9/56 year cycles of (large) earthquakes. This time in South East Asia. Presumably these would initially have been shallow (devastating) events, at least up until the second half of last century, since most if not all would have come from historical information.

The author develops a rather obtuse way of presenting his data, but in Appendix 2 of this most recent paper he provides a list of the earthquakes in Indonesia from 1797 to 2012. Out of interest, these were plotted by the present writer on a simple event per year basis. The first impression gained was a fairly random spread of events. One active-earthquake gap of 9 years (1852-1861) was, however, recorded with a subsequent 10 year gap (1889-1899). After 1900 the number of events increased substantially, so that it would conceivably be a relatively straightforward procedure to identify 9 year spacings, using a degree of selectivity.

In 1973, when global events began to be recorded at Denver, a plethora of data resulted and, again, it would not be impossible to select 9 year patterns in this – even if one wanted to. However, the duration of this plethora of accurate data is nowhere near long enough to tell us anything about a 54 or 56 year cycle.

In the **Giovanni Gregori** paper (p 21-28), a claim is made, backed by the outstandingly regular findings of the Kolvankar analyses of over 5000 events, Kolvankar (2011, 2011a).. The author chooses, for confirmation of the Kolvankar proposals, earthquakes on the Tonga Trench zone (Lat.25-35ºS), over three eleven year periods from 1973 to 2008. The findings were that earthquakes tend to happen in two time intervals, one close to 06.00 and the other close to 18.00 hours (Local Lunar Time).

For interest's sake – again - the present writer plotted earthquake activity on the Tonga Trench, just above the Gregori area: Lat 15-25º S with the same Longitude values. Using earthquake events, M 2.5 – 5 and depths 10 – 350 km, these were plotted for the year 2000 as events occurring during each hour of each day, local time. Over the year, there turned out to be a relatively consistent count of between 6 and 9 events for each hour of the day. There were, however, two minor peaks: one of 10 events between 6 – 7 am and one of 13 events between 8 – 9 pm. By contrast, in the hour preceding both minor "peaks" there was a hiatus in activity: only two events for 5 – 6am and only two for 7- 8pm, which would more or less cancel out the minor peaks, taken over a two hour period. This regularity surely raises questions about the Gregori interpretation?

A passing comment on the **Michail and S. Kovalyov** piece (p 98-100):- The four earthquakes, stretching from the eastern Mediterranean through South East Asia, across the Pacific to the South Atlantic, are shown to be collinear on a Mercator Projection. The significance of this is questionable. The four earthquake locations are anything but collinear when plotted on a globe. Neither do they lie on a Great Circle - which might have been of significance if they did.

Finally, the submissions of **Professor Storetvedt** have always been interesting and informative, especially with regard to the early days of the development of plate tectonics. However, it would be of benefit if the author were able to provide some guide to the forces/mechanisms he sees to be involved in the rotation of large elements of crust, such as the rotation of Australia et al. (p 43 -62). A first impression (again a personal one) of wrench tectonics is that the forces required would well in excess of those proposed in the mobilist model of subduction of crustal units – and a simple analysis of these subduction forces demonstrates them to be hopelessly inadequate to cause any subduction. This last (anti-subduction) view is, by the way, supported by numerous papers analysing seismological records in Indonesia, N.W America, and elsewhere, Smoot et al (2001), Choi (2006), and others. So?

REFERENCES

Blot, C., Choi, D., and Grover, J., 2003. Energy transmission from deep to shallow earthquakes: a phenomenon applied to Japan. *NCGT Newsletter*, no. 29, p. 3-16.

Choi, D., 2006. Where is the subduction under the Indonesian arc? *NCGT*, no. 39, p. 2-11.

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

Kolvankar, V.G., 2011a. Methodology to check correlation between Earth tide and earthquakes. *NCGT Newsletter*, no. 61, p. 108-111.

Smoot, N.C. et al., 2001. *Active Margin Geomorphology.* Xlibris Corp. USA.

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Dear Editor,

THE OCEANIZATION DEBATE REVISITED

The recent discussion in this journal regarding the continent-deep sea basement transformation, by way of basification, began with the assertions of Lidia Ioganson that this crustal alteration model was invented by the renowned Russian geologist Vladimir Beloussov. When I was a young geophysicist, in the early 1960s, it was indeed Professor Beloussov who promulgated the idea that the basement of the world oceans was attenuated and chemically converted continental crust; the present continental blocks were *in situ* remnants of an original – presumably felsic, pan-global incrustation. At a time when the ideas of continental drift and seafloor spreading were in the forefront of discussion, notably within geophysical circles, it is safe to say that Beloussov's anti-mobilistic crusade was regarded reactionary and met with dumbfounding reactions. By the late 1970s, when plate tectonics had become the dominant paradigm in global tectonics, the uncertainty which the oceanization model originally had caused had more or less gone into oblivion.

During the 1990s, when I was pre-occupied with getting an overview of past time global tectonic theories, I fairly soon discovered that the crustal oceanization model was in fact put forward already in 1919 by another prominent geologist – Joseph Barrell. In my recent letter (NCGT, v. 3, no. 1, 2015), I outlined Barrell's crustal development scheme which was basically the same as that proclaimed by Beloussov in the 1960s. **I argued therefore that Barrell should be credited for this proposal**. I also gave glimpses from behind the scenes in the late 1960-70s when it had become evident that Beloussov was unable to account for the rapidly growing marine geophysical facts; his forceful promotion of oceanization had come in dire straits. Judging from the reply of Lidia Ioganson (NCGT, v. 3, no. 1, 2015), my outline of Joseph Barrell's work on crustal oceanization has apparently come as a shock. She admits that Barrell's model of basification largely coincides with that advocated by Beloussov, and presumes that Beloussov must have been unaware of Barrell's work (see below). However, most of her reply is an attack on me personally. This 'hitting-the-man-instead-of-the-ball' tactic is a well-known maneuver when one has run out of arguments.

Lidia Ioganson opens her reply by referring to my extensive discussions in this journal which in her opinion "*denigrates his opponents, while positioning himself as a victim of the conformist majority of the scientific community and as the author of the most overarching geotectonic hypothesis*". She continues by saying that any discussion "*is only an opportunity for Storetvedt to emphasize once more the value of his 'wrench tectonic' hypothesis*". *It is curious that such self-promotion is accompanied by multiple citations of sources, familiarity with which ought to teach Storetvedt to adopt a more appropriate approach to scientific disputes, to avoid a disdainful tone and soberly assess his own scientific achievements".*

This vexed opening passage tells me first of all that my arguments may have touched some sore-points and perhaps some bad feelings regarding 'science in the making'. Lidia Ioganson says she is astonished of my ignorance of Beloussov's work, but in fact I have never had any basis, nor intension, for discussing Beloussov's major geological work notably on the tectonics of Eurasia! My only concern is his strong advocacy of the simple oceanization model and the problems it met versus modern marine geophysical data. In the western geoscience world, Beloussov was considered a geological heavyweighter having much broader knowledge in regional/global tectonics than most, but it was generally agreed that with regard to his fixism based global tectonics he had gone astray. Beloussov's interest in my first global tectonic synthesis (Storetvedt 1990) – which gave a sketchy outline of my much less mobilistic system than that of plate tectonics, in addition to being able to explain marine structural and geophysical aspects, was communicated to me in 1998 by Beloussov's colleague Victor Sholpo. In the eyes of Lidia Ioganson, publicity of such information would be unacceptable self-promotion.

She should read again what I wrote about my only scientific discussion with Beloussov (NCGT, v. 1, no. 3, 2013) – at the 1975 IUGG General Assembly in Grenoble. After he realized that I was Norwegian, our friendly conversation ended abruptly. As I understood it, he had shortly before been on a scientific visit to Norway but without having got the opportunity to meet the key figures in Norwegian geology. He was obviously hurt and very upset by having been ignored, and I – a young geophysicist who knew nothing about his visit in Norway – had to stand up and take the blame for the weak performance of my compatriots. This brings to the close link-up between science and human nature – which is very important in order to understand science in action.

In many letters and essays in this journal, **I have described science as it is**: A web of observations, established views and procedures, blind faith, professional barriers and resistance to innovation. Adding to this mix, we have the natural complexity of human factors such as competition, envy, false play, convenient omissions, national pride and sociopolitical maneuvers – along with the common burden of wishful thinking. In particular, when it comes to pushing at the frontiers of knowledge, science philosopher Paul Feyerabend (1975) could only see one rule: "*Anything goes*". History of science is indeed filled with embarrassing backstage activities.

In addition, it is no secret that most scientists shy away from the disorderly mixture revealed by *science in action* and prefer the established pattern of methodology and learned rationality – being too busy to study *science in the making* (cf. Latour, 1987). It is not difficult to understand, therefore, that major advances in knowledge always were turbulent affairs. In general, new basic thoughts were invented and forced through by relatively few individuals who had sufficient will power and courage – while the mass of scientists were sitting on the fence, some of them heavily protesting.

For an established research community, unfolding the secret anarchy of science has always been provocative; researchers like to posture themselves as belonging to a noble, dispassionate and rational tradition and that openness about the secret content of Pandora's Black Box merely denigrates the honest endeavours. In his book on the humanity of famous scientists in the 20th Century, Michael Brooks (2012) describes the often proclaimed assertion of their humbleness as outright humbug. As a proper example, he writes that "*Newton was hardly humble, and it would be* […] *true to say that he achieved greatness by stamping on the shoulders of* [other] *giants. When others, such as Robert Hook and Gottfried Leibniz, made breakthroughs in fields he was also researching, Newton fought ferociously to deny them credit for their work".*

Though Beloussov, unlike Barrell, had the benefits of modern geophysical studies of the oceanic crust and upper mantle, it is hard to find that his work took the oceanization concept a step further – with regard to its physico-chemical mechanisms. **I conclude therefore that the credit for this invention must go to Joseph Barrell**. But then comes the controversial point: Why did not Beloussov refer to the work of Barrell? Dr. Ioganson suggests that the simplest reason why Beloussov did not mention Barrell's work must have been that he was uninformed about it. This is not a trustworthy explanation.

Like Beloussov, Barrell had a keen interest in oscillatory movements of the crust, the planet's interior driving mechanisms, and the resulting geotectonic consequences. Barrell suggested that due to upward infiltration of volatiles from the *asthenosphere* – a term he invented for the inferred 'plastic' zone beneath the rigid lithosphere – was unlikely to be sharply defined and, therefore, the depth of isostatic compensation was not uniform as was the prerequisite in the Hayford-Bowie (1912) computations which built on the Pratt model. Barrell argued that vertical oscillations of the crust were products of vertical mass transfer beneath the zone of isostatic compensation, and that surface phenomena like erosion, sedimentation, earthquakes and other tectonic actions, such as crustal subsidence to produce both continental basins and deep oceans, were just passive responses to the internal processes. Barrell was a prominent North American geodynamicist in the early decades of the 20th Century – before his untimely death in 1919, working on fundamental problems in tectonics. Beloussov was clearly aware of his work, because in his 1962 book – *Basic Problems in Geotectonics* – he refers to a 50-page article by Barrell entitled "*Rhythms and the Measurement of Geologic Time*" (Barrell 1917). In the same book, Beloussov is referring to many western scientists, so why is Barrell passed over in nearly complete silence when his work so closely matched Beloussov's own research interests?

Since the early 1960s, my research activity had been limited to the narrow field of European palaeomagnetism, and even as late as the early 1990s my knowledge of global geology was minimal. But my new tectonic theory (based on a reconsideration of global palaeomagnetic data) and my planned books on Earth evolution demanded a proper overview of important global theories – proposed through the ages. However, this search did not turn out to be a particularly difficult and time-consuming task; in global geology (as well as all other branches of science) the number of workers preoccupied with fundamental issues has always been relatively small, and by using the reference lists in books and review articles I worked my way backwards in time. In this process, I readily discovered the work of people like Joseph Barrell and Damian Kreichgauer – whom I had never heard of before. I fairly soon discovered that Joseph Barrell – geology professor at Yale and a prolific writer, was a truly global theoretician and geological historian (see for example Barrell 1914, 1917, 1918a & b, 1919).

Thus, I acquired the needed information without reading everything published; anyway, most papers in Earth science have traditionally been descriptive and mapping-related and therefore of marginal significance for global dynamo-tectonic theorizing. Therefore, when I (a geophysicist) was able to obtain the information I needed without too much effort, it would certainly have been much easier for Beloussov whose primary research interest, for most of his academic career, was indeed large-scale regional and global geology. As an 'easy way out' of the dilemma why Beloussov ignored the work of Barrell, Lidia Ioganson argues that 'it is physically impossible to read all scientific literature'. With reference to my own experience, I do not buy such attempted rationalization.

Creative science has never been a Sunday school affair. As major paradigmatic steps forward come from the untraditional thinking or new findings of relatively few individuals, it follows that the rise of a few creative scientists leads to the fall of many others. Michael Brooks (2012) has given the following fitting description of the battle in the forefront of science: "*You don't give in to the belittling by your peers or even your superiors* […]. *You find ways to beat the system. That's why science is not for the meek and mild. It is red in tooth and claw; its very ideas and breakthroughs are subject to the law of the survival of the fittest. Good scientists must strive to overthrow, undermine and destroy their colleagues' reputation*". In paradigmatic science, life is not a bed of roses.

References

Barrell, J., 1914. The status of hypotheses of polar wanderings. *Science,* v. 40, p. 333-340.
Barrell, J., 1917. Rhythms and the measurements of geological time. *Bull. Geol. Soc. Am.,* v. 28, p. 745-904.
Barrell, J., 1918a. A century of geology – The growth of knowledge of Earth structure. In: *A Century of Science in America, with Special Reference to the American Journal of Science, 1818-1918*. New Haven, Yale Univ. Press, p. 153-192.
Barrell, J., 1918b. The growth of knowledge of Earth structure. *Am. J. Sci.,* v. 196, p. 133-170.
Barrell, J., 1919. The status of the theory of isostasy. *Am. J. Sci.,* v. 198, p. 291-338.

Brooks, M., 2012. *The Secret Anarchy of Science*. London, Profile Books, 311p.
Feyerabend, P., 1975. *Against Method*. London, Verso, 296p.
Latour, B., 1987. *Science in Action*. Cambridge (MA), Harvard Univ. Press, 274p.
Storetvedt, K.M., 1990. The Tethys Sea and the Alpine-Himalayan orogenic belt; mega-elements in a new global tectonic system. *Phys. Earth Planet. Inter.,* v. 62, p. 141-184.
Wegener, A., 1966 (1924 & 1929). *The Origin of Continents and Oceans* (reprinted). London, Methuen & Co, 248p.

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THE GLACIAL ISOSTATIC REBOUND THEORY QUESTIONED

I would like enlist the aid of all thinking geologists to take a serious investigative look at the Isostatic Rebound Theory and the Ice age hypothesis

It is my confirmed opinion that Darwin's observation of "Raised Beaches" was wrong. Darwin thought that the land had risen from the sea. He assumed that the sea level was a constant level: never varied. The concept of a stable sea level was the belief of thinkers in Darwin's time and has persisted, regrettably, in the conventional wisdom till today. Based on this mindset it was natural for Darwin to have assumed that it must be the land that is rising: it was certainly not the sea level that was receding. Again based on the existing mindset the sea level was not an issue in Darwin's observation it was just naturally assumed to be eternally fixed. Darwin's deduction was therefore wrong.

Darwin can be forgiven for making his acceptable observation, but it was his deduction that was wrong. The problem is that the deduction was accepted by other thinkers and men of science at that time and eventually gave birth to the theory of Isostatic Rebound.

Jameison, an agriculturalist who dabbled in Geology and Agassiz, a Glacierologist who also dabbled in everything included fishes, accepted Darwin's deduction hook line and sinker and stated their theory which simply is as follows, *"The reason that the land is rising from the sea is because it was depressed by ice and glaciers in the past ice age and now that the Ice and glaciers have melted away the land is rebounding."*

I am asking the fraternity of Geological scholars to take a serious look at the entire theory and examine Darwin's deduction and most importantly research sea levels throughout history and prehistory up to the present time and do the research which I have done for the last forty years into the mysterious receding seas. Please look at my 17 part video series on www.YouTube.com entitled "The Mysterious Receding Seas" by Richard Guy. WebPage: https://xbraille.wix.com/receding-seas

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ARTICLES

THE REQUIRED SCIENCE FOR A READY TERM - GEONOMY

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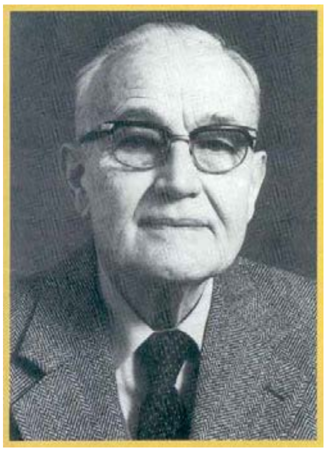
Abstract: History of term "geonomy" as a denomination of integrated science of the Earth, uniting Geology, Geochemistry and Geophysics, is reviewed. Despite many supporters, the term "geonomy" has not received overall acceptance. On the other hand the implied integrated Earth science is increasingly required to solve not only geological but also environmental problems.

Key words: *integrated science, Geology, Geophysics, Geochemistry, Earth science, geonomic approach, integrated methods, science of 21st century*



R.W. Van Bemmelen (1904-1983) **V.V. Beloussov (1907-1990)** **E. Shadechzky-Kardoss (1903-1984)**

In the middle of the 20th century in the international geological community there was a special discussion not associated with certain scientific concepts but with introducing a special term to denote a new integrated Earth science – geonomy. In fact the term "geonomy" has been known in the scientific discourse since the 18th century. According to Van Bemmelen (1969) for the first time it was used by Fuchsel in 1761 for combining geology, mineralogy and knowledge of ore deposits. Verner used this term instead of Gebirdkunde (knowledge about mountains) in 1780 (Van Bemmelen, 1969). In 19th century came into use the term Geology. In 1884 the Russian philosopher Grot (1904) designated the term "geonomy" for the third stage of the development of Earth science, proposing that its first stage is geography as a descriptive discipline and second stage is geology as discipline with historical aspect. He also believed that geonomy is the geoscience of 20th century which established the laws of the Earth's evolution (Lapo, 2006; Poka, 2005).

In the first half of 20th century the term "geonomy" was occasionally used in different meaning, it is mentioned in the number of special dictionaries. For example, Van Bemmelen (1969) referred to: Britannia Dictionary "Standard" says that geonomy is used for study of the Earth in all its geological, physical, chemical and mechanical aspects… The *Glossary of Geology and Related Sciences*, published by the American Geological Institute (1957), says that geonomy is the science of the physical laws of the Earth" (Van Bemmelen, 1969).

In the mid-twentieth century an interest to this term has been revived. The main supporters of "geonomy" were three prominent geologist – Dutch geologist Van Bemmelen, Russian – Beloussov, and Hungarian – Shadeczky-Kardoss, while each of them put the term "geonomy" rather in different content.

Vladimir Beloussov, in 1950s and 60s, repeatedly wrote about geonomy in his articles relating to general and actual problems of geotectonics and general geology. The prerequisite for the problem was quite clear: geology was limited in their methods by studying only surface phenomena, while the deep horizons of the Earth from the point of view of physical properties and chemical composition were the subjects of Geophysics and Geochemistry. Thus, Geology remained a science only on the external manifestations of deep-seated processes, but not on these processes.

Beloussov also argued the necessity of integrating Earth Sciences in general geonomy and gave to this some obvious practical recommendations: “geophysicists, physicists, physical chemists, mathematicians should be interesting in geological issues and should take in this work a direct part. They must work together with geologists on the solution of problems of structure and development of the Earth's crust and the globe in general. Introducing to geological material, the representatives of physics-mathematical and chemical disciplines will learn an entirely new phenomena and processes, therefore, it will expand their scientific horizons, new challenges may arise, the resolution of which will serve to the development not only of geological theory but other sciences too. The combined efforts of a number of sciences will contribute to creating the new geology with extensive observational and experimental base and real theory” (Beloussov, 1953, p. 22).

In other work Beloussov noted that for the convergence of the Earth Sciences methodological changes in the Geology had to happen, in particular “the introduction of quantitative methods in classical Geology”. Then geological ideas can be more accurately characterized by numbers and measures, which facilitates physical and physico-chemical analysis and can be jointly examined by geologists, physicists and chemists” (Beloussov, 1963, p. 21).

In the 1960s an international Project “The upper mantle" was initiated by Beloussov, aimed at the study of deep parts of the Earth's crust to determine the causes of processes that affect the entire spectrum of endogenous manifestations. To understand them, in Beloussov’s opinion, “Geology *must unite* with other Earth Sciences… It is not only for the representatives of various Earth Sciences to work together (which, however, is an absolutely necessary step), but also for the creation of a new United Earth Sciences, in which the geological, geophysical and geochemical methods are merged together… It would be advisable to find a new name for the combined science about the Earth, and this title could be "geonomy" similar to terms such as astronomy or aeronomy, which already exist” (Beloussov, 1963, p. 21).

The same ideas were expressed at 23rd General Assembly of IUGG in 1963 and 22nd IGC in 1964, relating to the study of the causes and mechanism of deep processes. Beloussov said that “in this area a considerable success can be achieved only if all of the Earth Sciences will come together and merge into a single geological-geophysical and geodetic science about endogenous processes. For brevity we will call this science “Geonomy” (Beloussov, 1964, p. 4). It should be noted that Beloussov determined the tasks of geonomy mainly with the study of the crust and upper mantle, the interaction of which governs the tectonic activity and endogenous manifestation. In other words, it is not learning only one crust or the entire globe. The less categorical formulation of Beloussov was implying just integrated geonomical approach to the study of deep processes.

In this sense, ironically, a Beloussov’s ally was one of the founders of plate tectonics and the forthcoming main opponent T.J. Wilson, who, after analyzing the state of Geology and noting the decrease of its prestige, explained this by lack of use of physics, chemistry and mathematics (Wilson, 1968).

In his turn Van Bemmelen argued that there was a need for a brief and rational term for a more general rank for knowledge, uniting Earth sciences, and in this sense the term "geonomy" seemed to be optimal. Initially he meant it as science studying geodynamics on the global level (Van Bemmelen, 1967). Later Van Bemmelen proposed to expand the content of geonomy and its tasks including in its scope the deep spheres of the Earth and atmosphere and our planet should be considered as the Earth-Moon system. Besides, last but not least consideration by Van Bemmelen was the consonance "geonomy", as uniting science about the Earth, to the long legalized "astronomy", which would unite science about the Earth, to be equivalent with the “astronomy”. Thus he believed that “geonomic observations furnish the fundamental data (diagnostic facts) on which our concepts of the character and evolution of our planet are based. Geonomy is the general science which provides man with knowledge about his natural niche of existence” (Van Bemmelen, 1969).

Thus, Van Bemmelen understood geonomy as integrated science about the Earth as a cosmic body while Beloussov – as an integrated science including geology, geophysics and geochemistry for understanding the regularity of tectogenesis. Just in this point there were contradictions between them. Van Bemmelen emphasized: "It seems to be somewhat arbitrary to apply geonomy only to those Earth sciences used for the study of terrestrial conditions and processes at greater depth (e.g. the upper mantle). What should be the natural boundary to geology? 10 km depth, 100 km depth, the Mohorovicic discontinuity? It seems recommendable to widen Beloussov's suggestion for the use of the term geonomy by including not only the study of the deeper Earth spheres but also the disciplines studying the shallower ones, inclusive of the atmosphere. Even the study of the system Earth-Moon might be considered as belonging to the group of Earth sciences, called "geonomy" (Van Bemmelen, 1969).

Obviously, on Van Bemmelen's initiative between the 22nd IGC in Delhi 1964 and the following 23rd IGC 1968 in Prague, a special Symposium, "The geologist and his world" was planned to discuss the meaning, value and usefulness of the term "geonomy" and "whether or not it is desirable to replace the name "geo-sciences or Earth-science" by "geonomy" (Manten, 1969). Before the 23rd IGC a corresponding questionnaire has been distributed through twelve Elsevier journals to find out the attitudes of the international geological community to legitimizing the term "geonomy". The authors of this questionnaire were Van Bemmelen, Krupichka and Manten. In 1969 Manten in "Earth Science Review/Atlas" published an article «Geonomy, Geology or Geo-sciences?» in which the results of inquiry "geo-science or geonomy" among the international geological community were elucidated. It was also proposed to include in the geonomy, in addition to geology, geophysics and geochemistry, the study of the atmosphere and hydrosphere (Manten, 1969).

According to the results of questioning, the majority of participants were in favour of the introduction of the term "geonomy", but this majority was not overwhelming. If the large number of Czechoslovakians participants were excluded, the overall ratio was as follows: 56% – for it, and 42% – against. Most votes for "geonomy" were submitted by Scandinavian and Eastern European countries. The positive attitude to geonomy prevailed in the Netherlands and the countries of southern Europe and South America (Italy, Spain, and Latin America). The negative attitude to geonomy was revealed in English-speaking countries – England, USA and Canada, and to a lesser extent in Australia. It is of some interest to know the motivations behind the opponents of "geonomy". Perhaps the most important arguments were presented mainly by English-speaking professionals who suggested that the term "geology" has long been used in a broader sense than its classic narrow meaning. Moreover, there is also the term "geological Sciences". So "geonomy" can only become a synonym.

There were also objections against introducing the name "geonomy" because etymologically "geonomy" stems from the Greek "nomos", which means "law"; the Earth science has not, however, reached the stage where they are able to formulate laws comparable to those in astronomy, physics, or chemistry, for example, and thus cannot yet claim a justified use of the term "nomos" (Manten, 1969). Some opponents thought that the change of the term "Earth science" to "geonomy" makes sense only when geonomy will get a clear definition and will be approved by researchers around the world. Others felt that "geonomy" reminds the antiquated term "geognosy". The pessimists were against "geonomy", suggesting that it is too late to introduce the new term which does not have a chance to be accepted. Nevertheless in conclusion Manten proposed to continue the discussion on the adoption of the name "geonomy" "to denote collectively all the sciences which deal with the solid Earth, the atmosphere and the hydrosphere" (Manten, 1969).

Independently from this discussion the outstanding Hungarian geologist Shadeczky-Kardoss developed his own concept of "geonomy". Its essence is contained in his book «Geonomia» (1974). This work was published in Hungarian language and therefore did not become known to the international geological community. Meanwhile this researcher understood most widely the contents of geonomy, including the aspects, which have acquired recently a special importance in connection with the aggravated environmental problems.

Shadeczky-Kardoss considered Geonomy as all-embracing synthesis of the Earth sciences: "the main task of Geonomy is to systematize the interrelations of scientific phenomena detected by various disciplines using different methods… ". Besides, he argued that "the Earth differs from the other planets mainly in that respect that in its development beside the initial inorganic factors later an ever increasing role has been played by the organic, (palaeo) biological factors. Accordingly, Geonomy is not only geoscience seeking causes, but it embraces inseparably the basically biological themes of the origins and inorganic background of life too." (cited after "Geonomy. The synthesizing Geoscience for the 21st century", 2005). It should be added that Shadeczky-Kardoss attempted to describe the Universe as a whole by means of "Universal Cycle Relation" plotting in a double logarithmic Time versus Space diagram by the various cyclic motions (electromagnetic, mechanical, chemical and biological and subatomic motions) (Geonomy, 2005).

Thus, Shadeczky-Kardoss' concept combined partly the views of Van Bemmelen in the coverage of the subject "geonomy" and of Beloussov on the necessity of combining all the disciplines in the Earth Sciences, but surpassed them by the scale of its task.

While further discussion about "geonomy" practically had stopped, simultaneously studies of the structure of the Earth have increasingly been applied for various geological, geophysical and geochemical methods. According to Beloussov, it seems to testify to the emergence of geonomy: "In recent years in Earth Sciences there were extraordinary changes. They are mainly due to three factors: 1) advances in geophysical and geochemical methods of studying the Earth's interior; 2) advances in the study of the sea floor structure; 3) a new contingent of researchers, without much geological training, but with mostly physic-mathematical training… All-embracing Earth science – geonomy emerged" (Beloussov, 1975. p. 3).

In 1980s Beloussov in his own researches had widely employed geophysical and geochemical data for the analysis of the Earth crust and its development. As a result the selection of different types of crust and their mutual transitions were determined, while ideas about the interaction of the Earth's crust and mantle were advanced (Beloussov, 1989 and 1991; Beloussov and Pavlenkova, 1986 and 1988). However, it is important that he didn't call his works as geonomic, although they can be qualified as such, and since then the term "geonomy" has disappeared from his publications. This could be best explained by Beloussov's frustration with the stalemate over the creation of the new science of geonomy.

It is quite possible that the main reason was the strong resentment in his eyes of geophysical data for the solution of geological problems, which had led to the emergence of plate tectonics. At this stage some undesirable, mainly pyschological aspects appeared that he could not forsee at the time when he proposed the unification of the various disparate 'geological' disciplines into a single geonomy. These motives are repeatedly found in the works of Beloussov in 1980s. In a situation where the striking new data were obtained by mainly non-geological methods, these new materials were used to justify their geotectonic generalizations, while neglecting all the geological factual base accumulated for centuries. Beloussov had to admit that the solution of geological problems involves a large number of completely new people with other methods (physic and mathematical) and other attitudes to the investigated issues, and this inevitably determines the result of geological generalization.

Beloussov expressed his thoughts on the problem as follows: "I will now speak on the other side of the problem – somewhat philosophical. This is justified by the fact that plate tectonics brought in Earth science the particular philosophy, previously unusual to these sciences. Geology is the natural-historical science. She studies the history of the Earth. And those regularities which it sets also have a historical character… Plate tectonics arose from the study of the oceans, where geophysical methods were strongly dominated. As a rule the latter are not adapted to the study of the historical process: they determined the recent structure of the Earth interior and occurring modern processes. This "quickness" of geophysical methods has received the corresponding reflection in the substantive provisions of the "plate tectonics"… And now we are witnessing how this immediacy penetrates into modern Geology (Beloussov, 1984, p. 57).

In recent decades it has become evident that the term "geonomy" has not been established, despite the fact that it is still used by some researchers. Instead of "geonomy", the name "geodynamics" spread, which rather adequately reflect the results of the study of tectonic mobility of the Earth. Still the term "Earth science" is widely used, covering a wide range of disciplines. On the other hand the Earth Sciences firmly established a comprehensive approach using the combined data of geology, geophysics, geochemistry, geodesy, physics, mathematics and astronomy, in fact, geonomical approach, about which Beloussov wrote.

Obviously, any appeals and logical justifications do not create a new science. Only integrated use of data from several adjacent (or even not quite related) disciplines for their occurrence, as can be seen, is also not enough for its establishing, there is need for some additional conditions. In case of "geonomy", most likely the new specific methods of processing the heterogeneous data from different disciplines are required.

Nevertheless there are separate attempts to revive geonomy. In this respect the publication of the book «Geonomy: the synthesizing Geoscience for the 21st Century» (2005) by the Hungarian Academy of Sciences appears to be indicative. In particular, Dudich (2005) declares in the Introduction to the named book: "After several centuries of highly successful analytical science, from the mid-20th century, the need for integration has been growing in the world scientific community. With the boom of space and planetary science, the approach of considering the Earth as a holistic unit, a peculiar planet, became more and more widely accepted. One must not be a prophet, not even a professional futurologist, to predict that the 21st century will bring forth a fundamentally new, all-embracing synthesis of human knowledge, simultaneously anthropocentric and universal, objective and humane, – indispensable to save humankind from self-made nuclear or ecological apocalypse, to have "doomsday cancelled" (Geonomy…, 2005. p. 4).

The book is dedicated to the 100th anniversary of Shadeczky-Kardoss and comprises a set of papers on his scientific heritage and developing his ideas. However, despite such a promising name, the work is essentially a collection of articles on various issues in the Earth Sciences. Apart from the analysis of the ideas of Shadeczky-Kardoss, perhaps directly relates to the subject on enhanced definition of geonomy is found in Poka (2005, p. 8): «Geonomy is a theoretical discipline which processes and transmits information obtained by other geosciences. Its aim is to discover structural and functional interrelations characterizing the Earth as a relatively closed system and as bearer of life". Geonomy has "to study and interpret the dynamism and evolution history of the system Earth, to forecast its short-, medium- and long-term changes, to transform this knowledge for the use by other sciences, and, finally, to establish a humanistic scientific concept of the world".

Thus, it is possible to talk about a certain paradox which consists in the fact that more than two centuries, there is a term for science that has not yet formed, but the necessity of which is increasingly recognized in the geological community. Moreover, the term has undergone its own evolution; it is improving all the time and now reflects the content of wanted science and its objectives. Obviously, in order to exist not only as the term and to be understood not simply as the integrated interpretation of various data, "geonomy" is necessary to develop special methods of its interpretation. Or else – a necessity of emergence of the scientists with Suess' scale who will be able to summarize all the available information about Earth at the global level.

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References

Beloussov, V.V., 1953. About the current state of theoretical Geology. *Priroda (Nature)*, no. 2, p.15–22. (in Russian)
Beloussov, V.V., 1963. On the ways of development of geological science. *Sovetskaya geology (Soviet Geology)*, no. 1, p. 11–28. (in Russian)
Beloussov, V.V., 1975. The basic geotectonics. *M.: Nedra (Earth's Interior).* 262p. (in Russian)
Beloussov, V.V., 1964. The upper mantle and its influence on the development of the Earth crust (the Project "Upper mantle"). *Sovetskaya geology (Soviet Geology)*, no. 1, p. 3–9 (in Russian)
Beloussov, V.V., 1984. Speech at the meeting of the department of Geology, Geophysics and Geochemistry on March 13, 1984. *Izvestiya Ac.Sci. USSR. (News of Ac.Sci. USSR.) Ser. Geol.*, no 12, p.57–58. (in Russian)
Beloussov, V.V. and Pavlenkova, N.I., 1986. The relationship of the Earth's crust and upper mantle. *Geotectonics*, no. 6, p.8–20. (in Russian)
Beloussov, V.V. and Pavlenkova, N.I., 1989. The types of the Earth's crust of Europe and Northern Atlantic. *Geotectonics*, no. 3, p. 3–14. (in Russian)
Beloussov, V.V., 1989. The basic geotectonics. *M.: Nedra (Earth's Interior).* 382p. (in Russian).
Beloussov, V.V., 1991b. Tectonosphere of the Earth: the relationship of upper mantle and crust. M.: *Interdepartmental Geophysical Committee of Presidium Ac. Science of Soviet Union*. 72p. (in Russian)
Dudich, E., 2005. Introduction. In *"Geonomy: the synthesizing Geoscience for the 21st Century»*, p. 4.
Geonomy: the synthesizing Geoscience for the 21st Century, 2005. *Hungarian Academy of Sciences.* Budapest. 82p.

Grot, N.Yak., 1904. Philosophy and its general objectives. *St. Peterburg*.
Lapo, A.V., 2006. Reversion of Geonomy. *INHIGEO. NEWSLETTER*, no, 38, p.52–54.
Manten A.A., 1969. Geonomy, Geology or Geo-sciences. Results of an international inquiry. *Earth Sci. Rev./Atlas, 5. Elsevier Publishing Company,* p. A88–A93.
Poka T. 2005. Geonomy – past and present. A historical approach. I*n: Geonomy: the synthesizing Geoscience for the 21st Century»*, p.7–9.
Shadeczky-Kardoss, E., 1974. Geonomie. *Budapest.* 458p. (in Hungarian)
Van Bemmelen, R.W., 1967. The importance of the geonomic dimensions for geodynamic concepts. *Earth Sci. Rev.,* v. 3, no. 2, p. 79–110.
Van Bemmelen, R.W., 1969. Notes on the history and future use of the term GEONOMY. *Earth Sci. Rev./Atlas, 5. Elsevier Publishing Company,* p. A85–A88.
Wilson, J.T., 1968. A revolution in Earth science. *Geotimes,* v. 13, no. 10, p. 21, December.

ESSENTIAL POINTS OF THE ADVECTION-POLYMORPHISM HYPOTHESIS

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Abstract: The mechanism of the tectonosphere's "heat engine" is analyzed on the basis of evidence of solid-state physics. This hypothetical mechanism quantitatively accounts for major events in geological history within the framework of the energy conservation law. Considered in the paper are requirements for the tectogene hypothesis, energy balance in the tectonosphere, advective heat and mass transfer, dimensions of asthenoliths, depth and temperature of magma chambers in the mantle, as well as comparison of the calculated and experimentally determined parameters of the processes in the Earth's interior.

***Keywords**: tectonosphere, deep-seated processes, crust and upper mantle, endogenous conditions, continents, oceans, transition zones*

INTRODUCTION

This author in 1975 submitted to Vladimir V. Beloussov's judgment his book entitled "Thermal Anomalies in Geosynclines" (Gordienko, 1975) in which the hypothesis of a deep-seated process in the Earth's crust and upper mantle was analyzed (solely for this specific type of endogenous conditions). The book also discussed the concept of correlation between tectonics and magmatism, on the one hand, and advection in the mantle (Beloussov, 1972) and polymorphic transformation of rocks, on the other (Goguel, 1965; Subbotin et al., 1968; and others). The presentation of the book was largely a success, yet at that time as well as during our later conversations (not too many of them – just three or four), Beloussov urged me to pay more attention to manifestations of recent events that impede examination of traces of earlier processes. He also warned me against devising a detailed pattern of heat and mass transfer in the tectonosphere because, in his opinion, not enough empirical evidence has been amassed for continents, let alone for oceans. After a while, the significance of the first remark made sense to me, although I was still reluctant to go along with the second one (Beloussov in 1991 found it necessary to share his latter observation with all geologists in an article that was also his last will and testament). The work on the hypothesis was a long process, and insufficient information for continents hampered it less than the lack of consistency or errors made by this author in the evaluation of manifestations of certain deep-seated processes responsible for the observed geological phenomena. Over the past 20 years, hardly any additional data for oceans that might throw light on their "pre-oceanic" history have been acquired. It may, however, be claimed that an intrinsically consistent (perhaps not yet exhaustive) chart illustrating the effect of the tectonosphere's "heat-flow engine" has been created based on solid evidence and quantitatively accounting for major events in geological history within the framework of the energy conservation law. We are talking about the advection-polymorphism hypothesis (APH) (Gordienko, 1998, 2007, 2012, etc.). A hypothesis claiming to be a solution to this problem should satisfy a number of requirements, and it might be a good idea to consider them before proceeding to the subject matter.

REQUIREMENTS FOR THE TECTOGENE HYPOTHESIS

Reconstruction of the deep-seated processes in the Earth's crust and upper mantle proceeding from known geological episodes in the near-surface zone and physical fields and models is a tricky challenge, as is the case with any inverse modeling. However, differences between versions of deep-seated processes explaining the same observed phenomena go far beyond the limits of equivalent solutions. This scatter is largely the result of resorting to physically unlikely processes in the upper mantle and/or taking into account for control purposes far from all geological phenomena being studied.

The latter complication can be precluded by applying the concept of endogenous conditions each of which is characterized by a series of consecutive "elementary phenomena" in the region's geological history (Beloussov, 1978, 1982; and others). Such materials sum up the huge experience amassed by geological science in the past.

In this author's opinion, the method for the elaboration and implementation of the tectogene hypothesis should satisfy the following criteria:

1. Enable the formulation of concepts of a physically plausible mechanism for the deep-seated process in line with up-to-date knowledge on the composition, structure, and energy capacity of the Earth's tectonosphere.
2. Bring the process design up to a level that would enable sufficiently accurate evaluations of the distribution of physical properties of the material making up the tectonosphere for any moment of the region's history (including the geologically significant period of time following the completion of the active phase).
3. Demonstrate quantitative consistency between estimated and observed geophysical data for the region. Velocity and geoelectric models for the region as estimated on the basis of the hypothetical process are compared to those derived from experimental evidence. Estimated gravitational and magnetic fields and the distribution of heat flow (HF) are directly compared against observed ones. No massaging of stats is an essential requirement. The parameters coincide within the limits of reference accuracy adopted in advance for estimated and experimental data. If the limits turn out to be excessively wide (i.e., if they permit correlation between fields and models for fundamentally dissimilar mechanisms of the process), then comparison employing this method for deep geophysical studies is considered to be inconclusive and must be excluded from the list of control criteria. In the event that an unfinished recent active process is analyzed, when there is no clear picture regarding the type of endogenous conditions and, accordingly, when the type of a deep-seated process cannot be selected with certainty, such comparison can be performed with the help of certain parameters derived from observed data. In this particular case, determining the type of endogenous conditions is precisely the goal of the study.
4. Show that it is possible to reconstruct the geological history of regions with dissimilar types of endogenous conditions. A hypothetical mechanism of the process must enable calculation of rates and amplitudes of uplifting and subsidence, sedimentation, the time of emergence and the depth of magma chambers for various stages of the region's evolution, the distribution of zones of lithogenesis and metamorphism in crustal rocks, etc.

It goes without saying that relevance of different methods for hypothesis control can vary with the type of endogenous conditions and age of the process.

The use of geophysical data is only possible when the impacts of the processes give rise to significant anomalies in the physical properties of crustal or mantle material, anomalies that the hypothesis could predict with sufficient accuracy. Those impacts are caused by changes in the rock composition and abyssal temperatures (T). Changes in composition can be studied in terms of geophysical data provided that, within a considerable depth interval, the contemporary composition has been determined and the composition that had existed prior to the onset of the process is known. It is certainly far from always that such a problem can be solved at a quantitative level. In some cases, the data on the structure and thickness of the Earth's crust and its individual layers as supplied by deep seismic probing constitute an exception. Temperature anomalies that took shape in the Earth's interior during the onset of the process and that have somewhat abated by now can be quite accurately described in terms of the APH. The resulting disturbances in the physical properties (and physical fields) can be recorded, provided that they are large enough, but their magnitudes are maintained solely for Alpine and post-Alpine processes.

The composition of magmatic and sedimentary rocks presently lying at the surface, as well the extent of their lithogenic variations and other geological data have changed much less than temperature anomalies, and therefore, in many cases, the use of the former in the analysis of pre-Alpine processes is to be preferred.

Let us examine the validity of this statement on an example of the Donets Basin Hercynian geosyncline, which has been well covered by geological and geophysical studies and which was also involved in active Cimmerian processes. We will use the results of a thermal model constructed for the region's tectonosphere in terms of APH concepts.

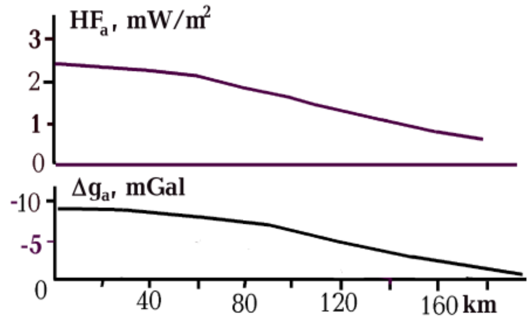

Fig. 1. Graphs illustrating distribution of anomalous heat flow values and anomalous gravitational effect consistent with Hercynian and Cimmerian processes in the mantle of the Donets Basin.

The present temperatures in the Earth's interior of the region that are associated with the Hercynian geosynclinal process (which culminated in folding and final magmatism 250-230 million years ago) and active Cimmerian processes (180-170 million years ago) are not markedly different from those that existed prior to the onset of the geosynclinal cycle of development about 380 million years ago. The strong temperature anomalies that prevailed during the active period have smoothed out almost completely.

A portion of the model associated with Hercynian and Cimmerian heat and mass transfer events displays a positive temperature anomaly not exceeding 50^{o}C within the depth range of 45-180 km. Further down, a negative anomaly of commensurable intensity (about 70^{o}C) was recorded. The solidus temperature is exceeded at the depth of about 300-350 km. In the upper 300-km mantle and crust strata, there are no partial melting layers that might be responsible for appreciable conductivity anomalies associated with melts and fluids arising during thermal dehydration of rocks. The decrease in P-wave velocities under the effect of high temperatures within the depth interval of 40 to 200 km is about 0.02-0.03 km/sec, which is clearly lower than the margin of error. Thus, geoelectric and velocity models of the region's mantle cannot detect traces of the Hercynian and Cimmerian processes in the Donets Basin. The change in mantle rocks density under the effect of positive and negative anomalous temperatures in the central part of the region will average -0.007 g/cm^3 in the depth range of 45-180 km and +0.004 g/cm^3 at the depths between 180 and 450 km. Temperature and, accordingly, density anomalies occur within an area which is at least twice that occupied by the geosyncline. A gravity anomaly in the mantle matching density anomalies along the profile from the center of the region to its periphery is shown in **Fig. 1**. At the center of the Donets Basin, it does not reach 10 mGal, which is lower than this type of disturbance actually recorded there. This anomaly cannot be registered also for the reason that there exists in the region a more significant anomaly associated with recent active processes (up to 30-35 mGal). The estimated anomalous deep-seated heat flow along the profile from the center of the Donets Basin to its periphery which is associated with Hercynian and Cimmerian processes is lower than 3 mW/m^2. This is below the margin of error in heat flow determinations in the Donets Basin (**Fig. 1**). Apart from that, strong thermal field disturbances, associated with effects of recent processes, are common there.

The difference between contemporary crustal temperatures due to the deep-seated processes in question and those that prevailed prior to their onset does not exceed a few dozen degrees. Nor should one expect a substantial change in the depth of the magnetite Curie isotherm or try to attribute it to variations in the thickness of magnetic features or, accordingly, in the magnetic field.

Thus, no appreciable traces of Hercynian or Cimmerian processes should be included in contemporary geophysical data (with the exception of the crust velocity profile), and the relevant information should not be applied for verifying the tectogene hypothesis regarding events of that age. At the same time, the heat-flow model for the Donets Basin constructed in accordance with the APH exhibits a number of specific elements that can be geologically validated.

In terms of the said model, the temperature distribution at the depth of a few kilometers at the time of completion of the Hercynian process must conform to the heat flow amounting to about 70-75 mW/m^2 at the center of the region with a noticeable attenuation toward its periphery. In areas involved in Cimmerian processes the temperatures right after the cessation of those processes are much higher and their distribution with depth is nonlinear. The temperature increase is due to the effect of hydrothermal fluids rising above magma intrusions along fault zones up to the depth of the lower surface of Permian rocks (about 2 km at the onset of Cimmerian processes). Estimated temperatures can be correlated with the data on paleo-temperatures in the corresponding parts of the Donets Basin that have been established according to the extent of coal metamorphism and lithogenic alteration of sedimentary rocks. **Fig. 2** illustrates results of the comparison.

The estimated and experimentally derived temperatures for both periods of geological history match completely.

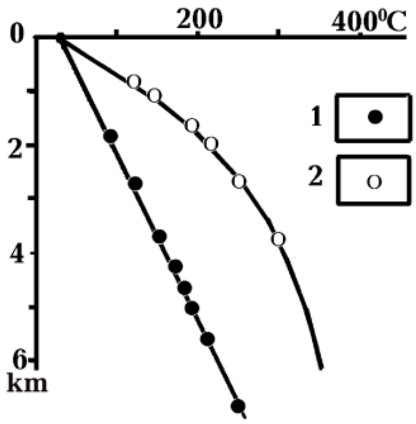

Fig. 2. Comparison between estimated heat-flow models (lines) and experimental data on paleo-temperatures dating back to Hercynian (1) and Cimmerian (2) periods.

A heat-flow model was used to estimate the depths of the top of the asthenosphere in the Donets Basin's mantle for the time of formation of magmatic rocks of mantle origin. They can be correlated with depths of magma chambers derived from the composition of igneous rocks. The available evaluations of the error margin in determining the depth of the upper asthenosphere from geological data come up to about 10 to 15 km. The chemical composition of some rocks testifies to the involvement of crustal material in the formation of the magma's composition. For example, the Southern Donets Basin complex, which is virtually synchronous to inversion, includes trachyandesites and trachyliparites in addition to other rocks.

Table. Comparison of parameters of magma sources in the Donets Basin mantle 380-170 million years ago.

Age, mln. years	Depth of the top of the asthenosphere in km; temperatures in ºC	
	Based on heat-flow model	Based on rock composition
380	255; 1,800	190; 1,650
320	157; 1,550	150; 1,500
320	97; 1,400	90; 1,300
240	60; 1,250	50; 1,200
170	50; 1,200	50; 1,200

Obviously, this type of control was also successful. If we add to the above results a detailed picture of reconstruction of the rate of sedimentation at all stages of geosynclinal evolution (see below) and the size of the erosion zone, it can be concluded that the absence of anomalies of physical fields does not render the pattern of the deep-seated process unverifiable. This pattern can be verified with confidence at a quantitative level in terms of geological evidence. Of course, a high degree of geologic certainty is required for that. Unfortunately, today it can only be achieved for continents and some parts of transition zones. It has to be admitted that the irrefutable change in the Donets Basin's crustal composition as compared to the crust of the adjacent Ukrainian Shield (basification) cannot be accurately interpreted since it may be associated with events of Riphean, Hercynian, or Cimmerian age. The said change can, however, be reliably identified with the help of contemporary anomalies of physical fields in a section of the basin located in the zone of recent active processes. There, at shallow depths, temperature distributions close to those shown in **Fig. 1** (a Cimmerian model) were recorded. Estimated and experimentally obtained anomalies of heat-flow, electrical conductivity, seismic wave velocities, and mantle gravity -- all anomalies predicted by the APH as a result of heat and mass transfer – were found to be quantitatively matching.

Naturally, to tackle the aforementioned problems, we had to substantiate and adopt parameters of the environment (chemical and mineral composition of crustal and mantle rocks, their density, seismic wave velocities in them, thermal and temperature conductivities, electrical conductivity, viscosity, energy capacity, etc.) and the effect of temperature on them (to the extent of a small degree of partial melting), pressure and polymorphous transformations (Gordienko, 2012; and others). A procedure was also adopted for constructing models by way of calculation of background properties for the platform-type tectonosphere material (remaining quiescent for a long period of time) with subsequent computation of corrections taking into account temperature variations and polymorphous transformations due to heat and mass transfer during active processes.

ENERGY BALANCE

Identification of the energy source responsible for deep-seated processes in the tectonosphere is one of the major goals of modern geological science. In this author's opinion, presently available information is perfectly sufficient for a quantitative description of parameters of such a source and for proving the conformity of the released energy to all known energy-intensive phenomena throughout all documented geological history. We are talking about radiogenic heat generation (HG) within the Earth's crust and upper mantle that is used in the APH in this capacity (Gordienko, 2012; and others). The aforementioned problem is not solvable in terms of any other available hypotheses.

Energy balance is the sum of heat generation in the crust and mantle, on the one hand, and energy spent on maintaining the heat flow through the surface, on the other. The latter parameter comprises three components: associated with 1) cooling of the motionless medium; 2) heat generation in the motionless medium; 3) heat and mass transfer in the tectonosphere during active processes. Energy requirements for other manifestations of active processes (magmatism, uplifting, folding, and so on) are insignificant compared to heat-flow anomalies accompanying active processes (Gordienko, 2012 and 2014a; and others). Differences in composition between mantle rocks in platform ("cratonic") and oceanic regions were revealed earlier in studies published by Pronin (1973), Boyd (1989), and others. In Boyd's opinion, cratonic rocks could not in any way have been formed through "clustering" of oceanic rocks. Continental regions outside platforms occupy an intermediate position (Boyd, 1989). Hence, it makes sense to separately analyze the distribution of HG in the tectonospheres of Precambrian platforms, Phanerozoic geosynclinal zones, and oceans.

There are numerous data on the content of uranium, thorium, and potassium (and**,** accordingly, on the contemporary HG) in crustal rocks. For the same rocks, longitudinal seismic wave velocity (V_p) values have been determined, as well as their dependence on temperature and pressure. This enabled us to establish correlation between parameters for rocks in the consolidated crust: HG =1.28exp1.54 (6-V_p) in the case of platform-type temperature distribution (V_p in km/sec, HG in $\mu W/m^3$). Heat generation in weakly lithified rocks (V_p = 2 km/sec) in the upper portion of the sedimentary layer is quite stable (1.2 $\mu W/m^3$). Toward the lower portion of the thick layer, where lithification increases considerably (V_p = 5 km/sec), HG has been found to decrease to approximately 0.8 $\mu W/m^3$ and to 0.5 $\mu W/m^3$ -- at the lithification temperature of 400 ^oC and V_p = 6 km/sec.

Heat flow variations on platforms, including zones of appreciably reduced heat flows, are in fairly good agreement. This kind of monitoring shows absence of any considerable errors in the data used. Heat generation in crustal rocks has apparently been studied much better than in mantle rocks.
Variation of crustal HG with time has been determined according to half-life times. The heat flow, generated over 0-3.6 billion years by the crust of platform type with a typical velocity profile, varies widely and averages 28mW/m^2. Integral heat generation (31.5.10^{14} J/m^2) was determined for the period of 0-3.6 billion years. This time range was selected because it enables us to relatively accurately reconstruct the geological history and assess energy requirements for active processes on platforms (shields). In the Earth's Phanerozoic geosynclinal zones, crustal thickness generally matches that on platforms. In the upper portion of the layer, velocity profiles are similar too (the differences do not exceed natural variations; velocities are somewhat lower down to 10 km; further down they are higher than on platforms; at greater depths, the situation is different, the velocities are higher, especially if one takes into account corrections for temperatures). Heat generation for the entire crust has been estimated, on the average, as being 0.13$\mu W/m^3$ lower than for platforms (it would be preposterous in the given case to talk about precise results). Total contemporary radiogenic heat generation in the crust beneath the platform ($W_{crust} = HG \cdot H$, where H stands for the layer's thickness) amounts to 23 mW/m^2, and under geosynclinal zones, to 17.5 mW/m^2. Beneath oceans with a crustal thickness of about 6 km (about 0.5 km is represented by sedimentary rocks, and 5.5 km – by basic rocks), the average heat generation within the crust amounts to about 0.5 $\mu W/m^3$ and total energy generation is 3 mW/m^2.

There is quite a wide range of opinions regarding the value of HG in the upper mantle. One frequently hears claims to the effect that uranium and thorium there are sparse and that their occasional higher contents are the result of xenoliths being contaminated with the magma material transporting them upwards. Recent evidence makes it possible to reject that point of view and support Ringwood's opinion that "…there is every reason to suggest that the association of peridotite and eclogite xenoliths and xenocrysts encountered in kimberlites is an average 'specimen' of the mantle" (Ringwood, 1981, p. 104) and that the composition of pyrolite is actually "…a mixture in which Alpine peridotites account for three parts of the volume and Hawaiian tholeiites for one part" (Ringwood, 1981, p. 174-175). When applying this model for the evaluation of HG (and not of the chemical or mineral composition of pyrolite), one should certainly keep in mind that basic rocks in the mantle are represented by eclogites, in which uranium and thorium contents are much lower than in basalts (HG shrinks from about 0.5 to 0.1-0.2 $\mu W/m^3$ (Gordienko, 2014a).

HG values for three types of regions, as shown in **Fig. 3**, are clearly different as also are the numbers of analyses used. It can be assumed that the result for platforms will hardly change if we introduce new data (it was the same even with half the amount of data), and in the case of geosynclines this is also quite likely; information for oceans is so far insufficient, and it is necessary to continue amassing it for a reliable evaluation of HG.

In calculating the total HG for the entire upper mantle, the depth of its bottom was assumed to match the beginning of olivine-α to olivine-β transformation at present temperatures beneath quiescent Precambrian platforms. It does not necessarily correspond precisely to a less intensive heat generation in the transition zone (down to 670 km) and in the lower mantle. Yet, it is noteworthy that the total number of radiogenic heat sources in the crust and upper mantle of all the three varieties of regions turns out to be virtually the same: 42 ± 0.5 mW/m^2. In other words, today, at any point of the Earth, the same amount of heat is generated beneath a unit surface, but its sources are distributed in dissimilar ways due to the formation of the crust of one type or another. On continents, the crust of approximately contemporary thickness has been in existence for billions of years. With regard to oceans, the situation is not clear. In all likelihood, the crust there, as it is now (more specifically, with the *Mohorovičić* discontinuity lying at the depth of about 10 km, which is not necessarily an accurate figure), is young, and tens or a few hundreds of millions of years ago its thickness was approximately the same as that of the continental crust, and it was probably more basic in composition. This exhausts all the more or less reliable information on the history of the oceanic crust.

Thus, HG bears information on differences between mantle rocks as established by Boyd. Other parameters (density, seismic wave velocities, and electrical conductivity), given the same depth, temperature, and mineralogy, do not reflect known variations in the chemical composition (Gordienko, 2010, and others).

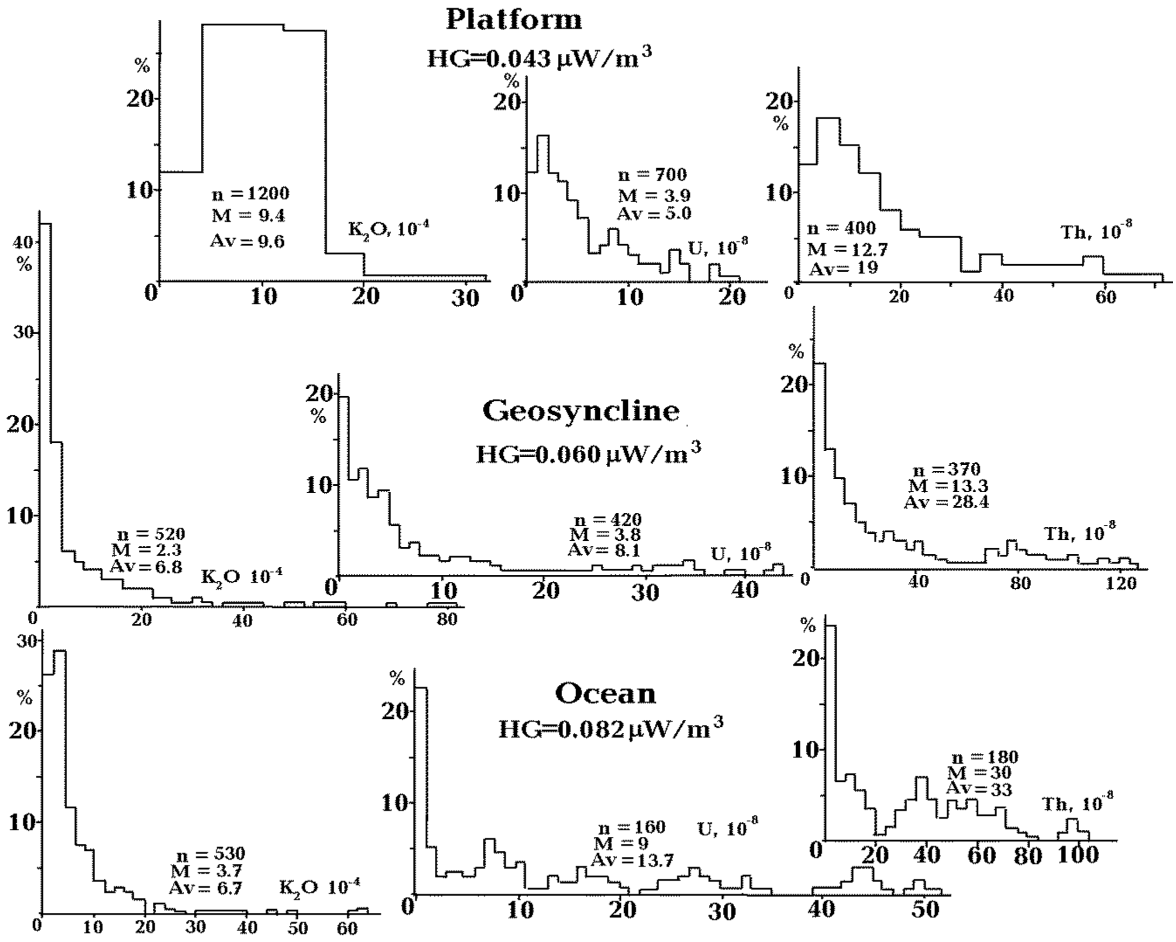

Fig 3. Histograms of K_2O, U, and Th content distribution in mantle rocks of platforms, geosynclines, and oceans, as well as values of contemporary HGs. n is the number of analyses used, M is the median value, and Av is the average value.

The composite value of HF (heat flow) is determined not only as a result of heat generation in the crust and mantle, but also as a consequence of the still ongoing process of cooling in the tectonosphere that started, according to the APH, 4.2 billion years ago with the solidus temperature. For mantle rocks it amounts to T_{sol} =1,013+3.914H - 0.0037H^2, where H is the depth in km (Gordienko, 2012) down to the transition zone at the bottom of the upper mantle. The sum of the two estimated components for the present time – the HG in the mantle and cooling -- is 20.5mW/m^2. This corresponds with a high degree of accuracy to the value of the heat flow in the mantle on platforms (i.e., in the situation of a long-term absence of heat and mass transfer) determined as the difference between experimental HF and estimated radiogenic HF in the crust (Gordienko, 2012; and others). Such a coincidence would have been impossible if the HG, temperature conductivity in the upper mantle, and parameters of its cooling had been selected at random. The sum of all the three components of conductive heat flow presently constitutes 40 mW/m^2, which is very close to the HF observed on the platform outside areas of anomalies associated with deep-seated heat and mass transfer. As a rule, the observed heat flow is higher than estimated by approximately 2 mW/m^2, which, in a number of regions, might be due to a relatively high HG in the sedimentary layer, and to the occurrence of granitoids on the shield.

Integral heat generation in the crust and upper mantle of platforms, over recent 3.6 billion years, amounts to $73.5 \cdot 10^{14}$ J/m^2. Over the said period of time, the conductive heat flow has carried off $59.5 \cdot 10^{14}$J/m^2. The difference, $14 \cdot 10^{14}$ J/m^2, must be supplied by heat and mass transfer during active deep-seated processes.

ADVECTIVE HEAT AND MASS TRANSFER

The thermal evolution model for the mantle is based on the concept of the initial temperature distribution that prevailed about 4.2 billion years ago. If we disregard aspects of the process that are not essential for our purpose, it was due to the antecedent accretion (that led to the planet's heating by 1,500-2,500 ^{o}C, on the average, depending on the process scheme used), to the Earth's differentiation into the core and outer shells (which was responsible for the average rise in temperature by 1,200 ^{0}C) over several hundreds of millions of years (The Early History of the World, 1980; Ringwood, 1981; and others), and to the formation of a "magma ocean" with a depth of about 1,000 km. "The magma ocean is becoming enriched with volatile and incoherent elements by contrast with solid magma, which is becoming very dry and devoid of volatile elements" (The Early History of the World, 1980, p. 28), with crustal material being removed from it. The process is accompanied by intensive heat and mass transfer (in all likelihood, through continuous convection) and by a cooling of the tectonosphere to the level of rock solidus temperature. Once this temperature is reached, the viscosity of the mantle material increases significantly and continuous convection at the rate required for enabling heat and mass transfer during actual active processes becomes unlikely. Subsequent temperature variations are linked to conductive cooling through the surface, emission of radiogenic heat (with an intensity varying with time and, in the absence of heat losses, capable of heating the upper mantle of a future platform by 2,000-2,500 ^{o}C), and to heat efflux through advection during active processes. Additional sources of heat (its generation or absorption) can emerge during displacement of the top of the polymorphic transformation zone in the upper mantle's lower portion. It is precisely the period of the past 0-4.2 billion years, encompassing the greater part of the Earth's history, that is analyzed below. Preference is given to the tectonosphere of platforms because for them results of calculations can be correlated with available evidence.

For the adopted temperatures (T), heat generation HG), and thermal properties of the medium we can obtain the following temperature distribution in the upper 500 km of the Earth's shell (**Fig. 4**).

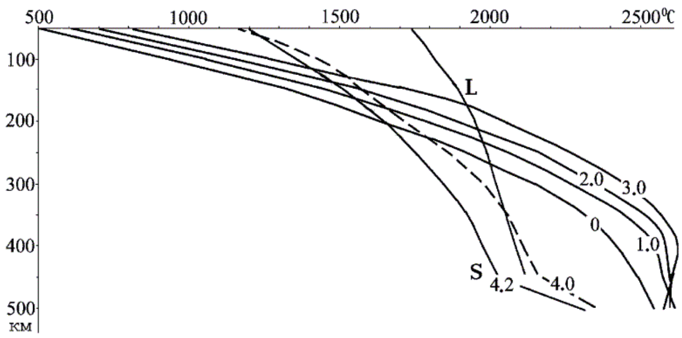

Fig. 4. Estimated temperature distribution pattern without taking into account heat and mass transfer in the tectonosphere of dissimilar ages (the numbers on the curves - billions of years old) and heat generation level within the mantle of the platform. S stands for solidus; L stands for liquidus.

It goes without saying that a structure, in which not just solidus, but also liquidus of mantle rocks within the depth range of hundreds of kilometers are excessively high, cannot be stable. Heat and mass transfer diverting excess heat toward the surface is inevitable.

From the viewpoint of the least action principle commonly applied in mechanics (preference given to a process providing the sought result given the minimal product of mass, velocity, and path length), the transfer of overheated material toward the surface will be through advection, rather than with the help of closed-circuit convection with a long horizontal axis. That was exactly the way in which the Earth's core became separated and all phenomena of magma transfer occurred.

When calculating thermal variation models reflecting the effects of heat and mass transfer, we superposed results of displacement of the material in each active episode of the region's history on the initial model (distribution of solidus temperature down to 1,000-1,100 km depths 4.2 billion years ago) and results of its evolution under the effect of heat generation and heat release through the surface. Studies of the composition of magmatic rocks in the Ukrainian and other shields (Gordienko, 2014b; Gordienko et al. 2005; and others) have shown that, in the course of active Precambrian processes, depths of the top of the asthenosphere varied in the same manner as they did in Phanerozoic geosynclines and rifts. For precisely that reason designations such as "geosyncline" and "rift" were attributed to ancient processes, although tectonic effects there might have been different from Phanerozoic ones.

The choice of endogenous conditions was tied to the type of the preceding thermal variation model. If the temperatures exceeded solidus within a broad range of depths greater than 200 km, the situation was assumed to be suitable for the emergence of convection and of a geosynclinal process within the asthenosphere. Also taken into account was the presence of a gradient exceeding adiabatic in the asthenosphere or in a portion thereof. It was precisely such a segment of the asthenosphere that was considered suitable for a convective interfusion of the material and for shaping of an asthenolith that floated upwards. If the asthenosphere was thinner, conditions were considered to be suitable for rifting or for a single activation episode (during which the material moved like at the initial stage of rifting). In that case, as a rule, the material was removed from the asthenosphere or its portion about 100 km thick, less frequently 50 km thick. In the absence of the asthenosphere or its insignificant thickness (less than 50 km), the evaluation (implying just the evolution of the background and smoothing of previous temperature anomalies) was continued until required conditions were obtained. To simplify calculations, the diameter of a single quantum of tectonic action (QTA – a minimum volume of material capable of changing position, see below) was in all cases considered to amount to 50 km. Every geosynclinal or rifting event was matched by the transfer of three QTAs. When necessary, restriction of emerging heat sources in length and width was taken into account.

Of course, the modelling that was carried out does not reflect one and the only plausible version of the sequence of active processes in the shield's tectonosphere. When the heat model did not make it possible to conclusively opt for a type of endogenous conditions, we considered several varieties of the process with different thermal properties of the medium and different types of the process, so that active process could start or the time-span of the "tectonic quiescence" could be extended to enable a more complete "maturation" of conditions for subsequent heat and mass transfer. In all cases we observed largely the same pattern. There is nothing that could be added to or removed from the estimated heat and mass transfer episodes.

Computations performed for the depths beneath the zone under study have revealed a peculiar situation. Within a depth range of about 700-1,000 km, a layer with insignificant partial melting left by the "magma ocean" has remained intact throughout the entire geological history. This global asthenosphere is commensurable in volume with the outer core and is larger than the inner core. Presently available velocity models of the mantle do not detect it. There only exist indirect indications of changes in the elastic parameters, but geoelectric studies clearly identify it (Gordienko, 1998; Gordienko et al., 2011b; Semenov, 1998). From the depths of 200-250 km, the density of the liquid is higher than that of the crystalline material with the same composition, and for that reason no supernatant asthenoliths take shape in the global asthenosphere. Low viscosity causes seismicity to cease in the upper part of the asthenosphere at an approximate depth of 700 km.

Let us assess the contribution of active processes to energy transport. The anomalous heat flow in the geosyncline removes $0.68 \cdot 10^{14}$ J/m^2, and if we take into account energy output on nonthermal processes in the near-surface zone (primarily, the uplifting of the crustal block and upper mantle layers), then energy spent on a single geosynclinal cycle increases to $0.8 \cdot 10^{14}$ J/m^2. This value turns out to be somewhat lower in the case of rifting: about $0.6 \cdot 10^{14}$ J/m^2. Approximately the same amount of energy ($0.55 \cdot 10^{14}$ J/m^2) is required for a single-episode active process. In the latter case, it is impossible to plot an experimental heat-flow anomaly, and therefore an estimated amount of energy obtained with the help of the APH was used for the evaluation of the energy output. Judging by the intensity of perturbations in areas where heat-flow anomalies in the zone of recent active processes are presumably associated not just with geothermal activity alone, the maximum heat flow reaches approximately the same values as in the rift: about 20 mW/m^2 (Gordienko, 2014a; and others).

A detailed analysis of model construction and comparison between the estimated age of periods of active processes and that established experimentally for shield rocks of all continents were published in (Gordienko, 2009a & b; Gordienko et al., 2005). The comparison was encumbered by the fact that, starting from the Late Archean and Proterozoic, active processes never spread simultaneously over the entire territory. Insignificant differences in mantle rocks' heat generation have caused a certain shift in the estimated age of active processes within different shield blocks, whereas evaluations were performed for just a single block. It is nevertheless possible to reliably identify dating results suitable for comparison with those determined with the help of models on the Canadian, Baltic, Ukrainian, and Indian shields, as well as on the Siberian, Sino-Korean, African, South American, Australian, and Antarctic platforms.

A small number (four out of 51) of "skipped" experimental dating results by comparison with those based on models could be due to the insufficient level of knowledge about the shields (in many cases recent studies have filled in those gaps) and insufficient information available to this author. Cases of "skipped" results are much more numerous for the Antarctics, a continent which is poorly studied as the greater part of its surface is covered by ice. On the whole, the agreement between estimated and experimental data is beyond doubt, and it would be preposterous to suggest that it was a random coincidence.

In areas of the world's shields and platforms, where traces of active processes that have occurred over 3.6 billion years can be observed, 23 active events have taken place. They include three geosynclinal processes, 11 cases of rifting, and nine active processes (recent active processes are not listed here because they have not yet occurred on the greater part of platforms). The evaluations that have been conducted are in fact about a physical substantiation of Stille's canon (Stille, 1924). The result (energy expenditure of about $14{\cdot}10^{14}$ J/m^2) corresponds to the difference between radiogenic heat generation in the crust and upper mantle, on the one hand, and conductive flow from the tectonosphere, on the other. Therefore, if we compare the derived $14{\cdot}10^{14}$J/m^2 with the entire energy discharged, it accounts for 20 percent of the total energy, whereas if the comparison is with radiogenic energy alone, the corresponding value will amount to 30 percent. Radiogenic heat generation in the tectonosphere is perfectly sufficient for explaining deep-seated processes, and there is no sense in resorting to other data, especially regarding deep-seated processes for which there is no information (the core/mantle interface, and so on).

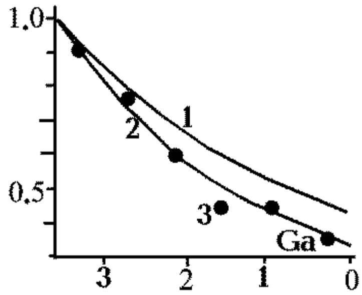

Fig. 5. Relative variations of heat generation in the crust (1) and mantle (2) of platforms and average energy requirements for active processes within stretches of time of 0.6 billion years (3).

Fig. 5 illustrates variation in heat generation in the crust and upper mantle of platforms versus energy spent on active processes over recent 3.6 billion years. Evolution of the activity versus time matches heat generation variations in the mantle better than in the crust. This is natural since crustal energy is largely spent on maintaining the heat flow. **Fig. 5** shows that the drop in the tectonomagmatic activity is due solely to a lower concentration of radioactive elements in the course of their decay. There is no such depletion in mantle rocks in terms of heat generation, or otherwise experimental dots would have been plotted below the curve based on estimated data.

The data of geothermometry reflecting pressure and temperature (PT) conditions under which rock formation or transformation took place during the Early Precambrian through our time also corroborate the adopted level of heat generation in the crust and mantle. This information is supplied by xenoliths transported through kimberlites and alkaline basalts in platform regions. The greater part of crustal data was derived from near-surface rocks making up units with dissimilar sizes of erosional truncation. Mineralogical characteristics of those formations and xenoliths from the greater part of the crust retain traces of maximum temperatures. In the mantle, under the effect of extreme PT conditions, rocks largely "managed to adjust" to platform conditions, but there too estimated and experimentally obtained temperatures match fairly well.

In geosynclinal zones and oceans, during the period following "all-encompassing" active processes (less than 2.5 billion years ago) heat-and-mass transfer events in the mantle must have occurred more frequently than on platforms. Calculations and some experimental evidence indicate that the minimal gap between heat and mass transfer episodes amounts to 20-30 million years. This can also be observed in the Hadean, 4 to 4.5 billion years ago (Balashov, 2009).

In the Archean and Early Proterozoic, experimental ages of active processes in geosynclinal zones correspond to those estimated for platforms. After two billion years, the number of observed data are much more numerous, that is to say, the assumption on a higher activity in connection with more intensive heat generation is justified.

The geological history of oceans is only known for a very short stretch of time. Just for a portion of the Mid-Atlantic Ridge (MAR), the quantity of dating results points to a much more intensive energy generation in the tectonosphere, including in the Precambrian, than what was used in computations of the platform model. In a geologically recent past, active events with minimal age differences have been recorded on relatively small blocks of oceanic regions (Gordienko et al., 2013a & b).

One gets the impression that there also exist regions with intermediate heat generation values between platforms and geocynclinal zones of the Phanerozoic (Baikalides, which are not involved into geosynclinal processes of Caledonian or younger age) and between geosynclines and oceans. In the latter case, we are talking about backarc and intercontinental basins, as well as median massifs with a sharply thinned-out and often basified crust. There is also information on the existence of such incompletely reworked crust-mantle blocks in all oceans (Gordienko et al., 2013a &b). A smooth variation in heat generation can be used as a substantiation of the Eardley principle (Eardley, 1951), but its applicability is clearly limited. For example, the Eardley principle does not work for the southern edge of the Tethys.

On the whole, the available information is sufficient for corroboration of the hypothesis on the elevated heat generation in the mantle beneath oceans and, consequently, on their high tectono-magmatic activity. This issue should, however, be dealt with based on a larger amount of factual evidence.

QUANTUM OF TECTONIC ACTION (QTA)

The QTAs mentioned earlier in the article ascend more or less synchronously toward the upper part of the tectonosphere and aggregate together to form large asthenoliths beneath the entire territory of regions experiencing active processes. Let us analyze the feasibility of existence of such bodies using, to begin with, information on the geometry of regions with synchronous activity of the same type, even though it may only indirectly reflect the size of the sought QTA. In view of the fact that the length of such areas is usually much larger than width, it might be a good idea to concentrate on the latter parameter (width). The collected data refer to structures with rather distinct boundaries. The generalization is not intended to qualify for complete integrity or statistical validity. Its results were only required for answering the following questions: 1) Is there a minimum width of structures that would be typical for manifestations of the same type of endogenous conditions?, 2) Does it vary with age during the Phanerozoic?, and 3) Does it coincide in the case for dissimilar conditions?

For the Tethys, the width of folded zones ranges from 60 to 150 km. Mainly Alpine structures were analyzed (here and hereafter large bodies, such as Carpathian-Dinarides “ovals,” which are known to have been formed by numerous QTAs, were not included in the analysis). In the Pacific Ocean zone, Alpides and Cimmerides were examined. About the same range of widths of structures as in the Tethys was observed there, although a small number of folded structures were either narrower or wider. In the case of Paleozoids (primarily Hercynides) in Western Europe and the Appalachians, the prevalent width is 50-60 km, and narrower structures were virtually not encountered. The same applies to small folded Paleozoid zones of Eastern Australia. Caledonides and Hercynides of Taimyr and of the basement of the Western Siberian Plate and Altay-Sayan-Mongolian region are largely represented by zones 60 ±20 km in width. Essentially the same values of width have been recorded in the youngest folded Paleozoid zones of island arcs at the periphery of the Pacific Ocean and in the Caribbean Basin. The data on Cenozoic rift troughs in the East African system and in the Baikalian and Moma rift zones have also been used. Cenozoic troughs of continental Western Europe were analyzed alongside somewhat older (partly Mesozoic) ones in the North Sea. Materials on the Meso-Paleozoic rift system of the Western Siberian Plate and Paleozoic rifts of the Eastern European Platform have been generalized. In all cases narrow structures were found to prevail, but troughs narrower than 40 km have hardly been found. The widths of deep-water trenches in the Pacific Ocean and adjacent aquatic areas of the Atlantic and Indian oceans are fairly stable. They generally average 50-100 km, and the greater part of the dataset is represented by minimum values from that range.

When it comes to mid-ocean ridges (MOR), it is difficult to mark out boundaries of structures widths. The widths are most certainly not limited by the narrow central rift valleys (some ridges don’t even have them). Those very young (at any rate in terms of recent manifestations of active processes) formations can be used for determining the QTA’s length. If we assume that the QTA’s length is the size of a structure connected with it along the strike, it is impossible in the majority of the aforementioned bodies to determine it: Without a detailed analysis, they seem to be uniform along the strike or fragmented as a result of superposed active perturbations. It is only in the youngest formations, such as MOR, where the crust is thin and friable, that results of action of each individual QTA displacing the axis of the ridge can be detected. As a consequence, the ridge must be broken into a series of blocks separated by young faults.

This is precisely the kind of structure that was detected in well studied areas of the worldwide MOR system. In particular, for the Mid-Atlantic Ridge, typical sizes of blocks along the strike amount to 50±30 km, and for the Californian segment of the East Pacific Ridge, to 60±20 km. Close (or stack-fold) to those sizes are Paleozoic segments of the Dnieper-Donets Depression (DDD) rift that were identified along the strike of the structure.

In connection with recent active processes on the territory of Ukraine, a network of faults experienced synchronous "revival" that also encompassed faults outside active zones proper. Studies of those faults (which have been mobile over recent three million years or so) have made it possible to trace their split arising during a single process. The existence of two networks of faults is obvious. Histograms of the distributions of cell sizes in each of them clearly reflect a mixed arrangement of datasets with predominant sizes of 60 and 120 km, i.e. they correspond to the sizes of 1 and 2 QTAs. Thus, near-surface manifestations of various types of active processes are characterized by fairly stable minimal sizes of bodies that remained unchanged during the Phanerozoic. The sizes in question are close to 50-70 km.

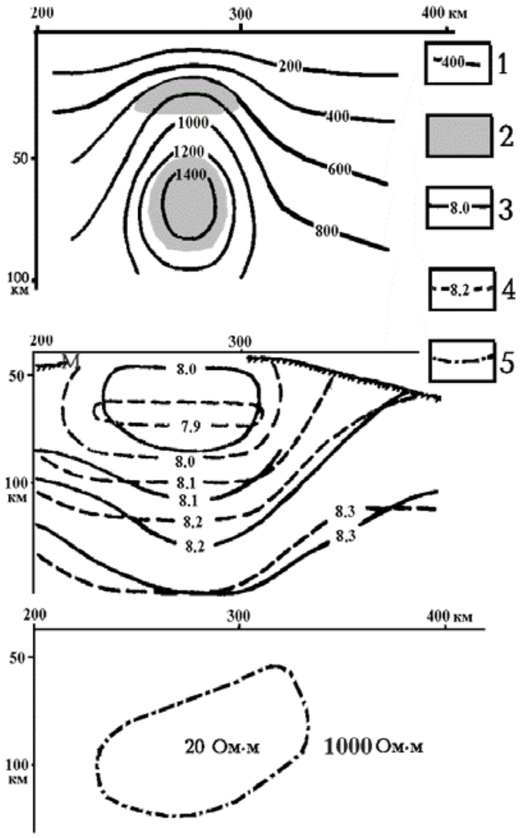

Fig. 6. Anomalous bodies identified in the tectonosphere of the Beltsy zone of recent active processes on the Moldavian Plate. 1—isotherms (oC); 2 – partial melting zones; 3, 4 – seismic wave velocity contours (km/sec): 3 – experimental, 4 – estimated; 5 – boundary of the zone of low electrical resistivity in the mantle.

Direct studies of mantle bodies with anomalous properties beneath zones of young active processes of dissimilar type on continents and in zones of transition to oceans register approximately the same minimum widths: 50-60 km. To identify such formations, we used results of interpreting heat-flow disturbances, geoelectric, and seismological data. The width of anomalous features beneath activated Alpides of the Greater and Lesser Caucasus is 40-60 km; beneath the zones of the Pamirs, Tien-Shan, and the Turanian Plate, 50-100 km; beneath Southern Kazakhstan, 50-70 km; beneath the Kurile Island Arc, 60-80 km; beneath the Tatar Strait rift, 30-70 km; and beneath activated Alpides of the North American Cordilleras Coast Range, 40-60 km.

The QTA thickness can be determined in zones of young active processes where strong anomalies of physical properties of the upper mantle material, corresponding to single features, are encountered. One such example is shown in **Fig. 6**. Anomalous features whose properties match those of partial melting zones and whose thickness is close to the QTA width and length have been identified.

Thus, the feature in question turns out to be isometric in shape and measuring approximately between 50x50x50 and 70x70x70 km. The absence in an individual QTA of "roots" reaching down deep into the mantle, testifies to the advective nature of the heat and mass transfer that produced it.

A seismic wave velocities distribution in regions of recent active processes also points to the prevalent character of the heat and mass transfer. Corresponding sufficiently reliable data (throwing light on the upper mantle within a considerable depth range) are not plentiful so far. Some of them are shown in **Fig. 7** generalizing velocity profiles from publications of Gontovaya et al. (2006); Buryanov et al. (1987); Sobolev et al.; and others.

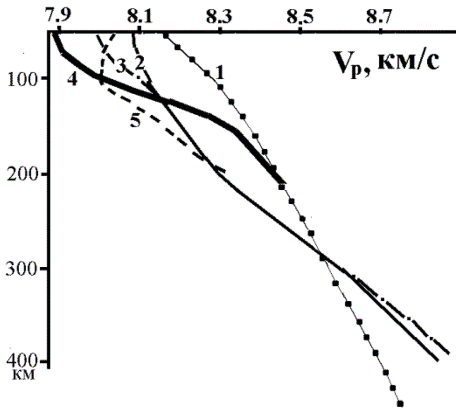

Fig. 7. Velocity models for the upper mantle of various regions. 1-- Platform, 2 -- Alps, 3 – Caucasus, 4 – Kamchatka, 5 – Massif Central, France

It is difficult to provide a full-scale analysis of the physical mechanism of QTA formation, primarily due to shortage of reliable information on properties of the medium and their variations. A possible option for resolving the problem may be provided by results of Khazan's studies (1999a & b) suggesting that a partial melting layer may have existed for a very long time with the top lying at the depth of 200-250 km and the bottom at 400-450 km. In the upper portion of the layer, unstable volumes of material with the diameter of 50-100 km can take shape. They are capable of rising up to 50-150 km, so that they can reach the depth immediately beneath the M. discontinuity. The present author's constructions based on a somewhat different concept of properties of the medium have produced approximately the same parameters (Gordienko, 1998; and others).

PARAMETERS OF MAGMA CHAMBERS

It follows from the chart that the QTAs occur at the same depths under all endogenous conditions. They differ in the sequence of rising to the top position. In order to explain the composition of magmas being melted out and heat flows at different stages of the process, it is necessary to assume that, prior to the emergence of the QTA, there appear magma chambers with depths of the top portions ranging from 220 to 250 km that later decrease to 160, 100, and 40 km beneath the geosynclines. In rifts, the sequence of depth variations is reversed. In zones of single-episode activation with a small initial reservoir of partial melting in the lower part of the upper mantle, the initial rise is likely to have been to a depth of 200-250 km and then -- to beneath the crust.

During active processes in the area of a recently completed geosynclinal or rifling process, a relict asthenosphere with a shallow (about 100 km) depth of its top portion is used for the formation of a QTA. Once the mantle asthenolith reaches depths right beneath the crust, the molten basic material breaks into the lower and median parts of the continental crust, while consolidated eclogitized crustal rocks sink into the mantle. This is possible during real time when the eclogitization reaction gets a boost as a result of heating and under the effect of fluids. The total volume of the crust-mantle exchange is very large: Over the period of crustal history, about half of the contemporary mantle volume (on the average for the Earth) has intermittently been part of its composition. Therefore, the common perception on the upper mantle depletion is groundless.

Crustal chambers are predicted to occur at depths greater than 20 km with individual intrusions of secondary magmas reaching depths of 6 to 10 km.

To verify this hypothetical pattern, we used information on the location of interfaces in the upper mantle that formed above the chambers as zones of repeatedly metasomatically altered rocks, the data on depths from which xenoliths were transported upwards by kimberlites and alkaline basalts, and depths of chambers in terms of the composition of igneous rocks. A small amount of data on the depths of chambers within and beneath the crust was used in terms of the Curie temperature of titanomagnetites in young igneous rocks. The information was collected for all continents and oceans and for all types of endogenous conditions (Gordienko, 2014b; and others). There was one exception: seismological data for Northern Eurasia (Pavlenkova et al., 2006; and others). The relevant data for all continents and oceans are shown in **Fig. 8.**

The data on magma chambers, predicted by the hypothesis and obtained with the help of independent geological and geophysical techniques are in essentially perfect agreement. It can be assumed that quantitative verification based on this parameter has been accomplished.

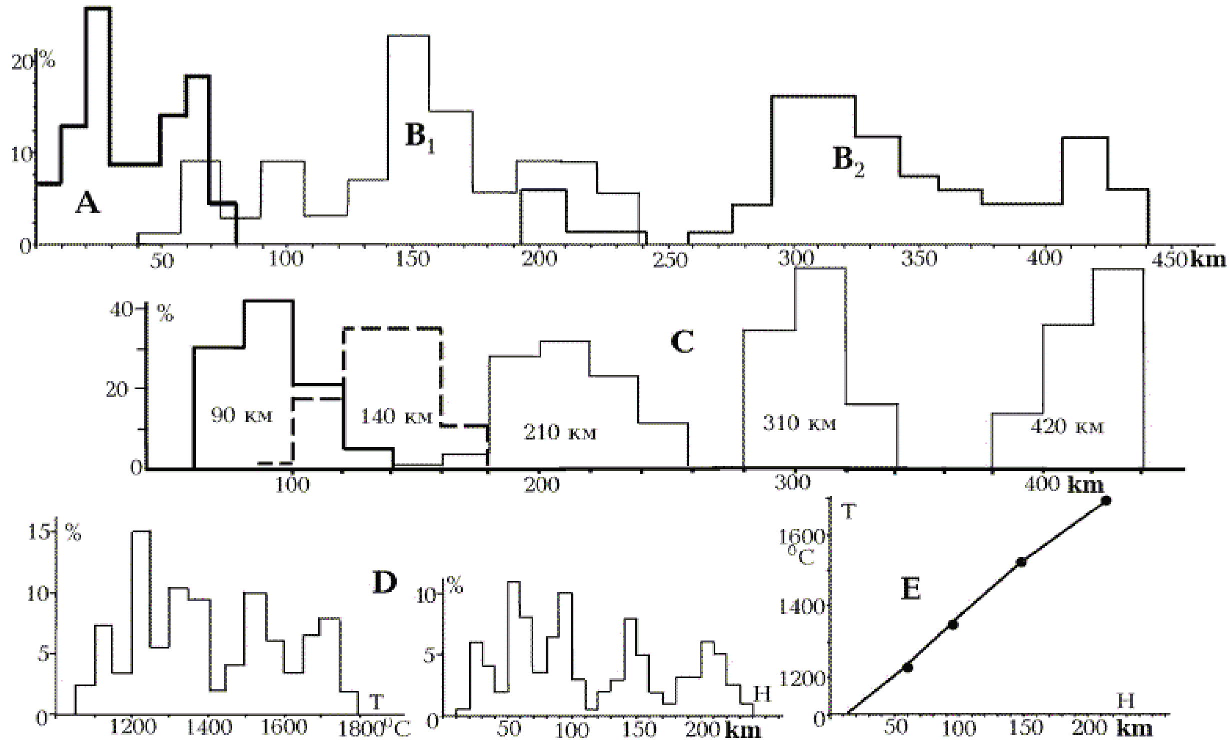

Fig. 8. Histograms showing distribution of parameters for magma chambers.
A-C – depths of the top portions of magma chambers: A – for the Transcarpathian Trough according to Curie temperatures of titanomagnetites in young volcanic rocks; B – according to xenoliths carried upwards by kimberlite and alkaline-basic magmas (B1); according to majorite inclusions in diamonds (B2); C – according to velocity profiles for the upper mantle; D – temperatures and depths of top portions of magma chambers in the mantle in terms of the composition of igneous rocks from most comprehensively studied areas of continents and oceans; E – comparison of solidus temperatures (line) adopted in the APH and temperatures at the top of melting foci (dots).

CORRELATION BETWEEN ESTIMATED AND EXPERIMENTALLY DERIVED PARAMETERS. APPLICATIONS.

In the course of work on the hypothesis, it was continuously verified through examination of the geological history of various regions that featured young and relatively old (Phanerozoic) endogenous conditions of continents, oceans, and transition zones. It would be unrealistic to review this whole study in a single article. Given below are examples of correlations between thicknesses of the sedimentary layer (and its changes with time), gravity field, velocity profiles in the upper mantle, and temperatures within it. Before starting the study of each individual region, we constructed a heat model based on the region's earlier history. A probability of activation in the region in one form or another was determined (see above). Naturally, whenever data on the age of initial active events were available, the onset of a simulated heat and mass transfer was timed precisely to that period. In geosynclines and rifts, the times of second and third QTAs emergence at top positions were also determined taking into account known facts of geological history, even though, of course, the process would not start unless there is a certain reserve of overheated material. The size of the region drawn into active processes was also taken into consideration.

A thickening of the sedimentary layer was viewed as equivalent to its subsidence. This assumption was tested on an example of the Ukrainian Shield and surrounding depressions. The volume of rocks supplied into them fairly well matches the size of the erosional truncation on the shield over the period from the Riphean to present time.

Subsidence (and upheaval) were assumed to be associated with temperature anomalies, polymorphic transformations, and changes in crustal composition and thickness. The latter factor, for example, played a major role in the formation of the Black Sea's western trench. It is located within an extended strip – from the Mesian Plate to the Turanian Plate – an abnormally basified ancient crust (Gordienko et al., 1990; and others). The process of transformation of basaltoids into eclogites during young active processes, imparted an oceanized appearance to the trench.

In the majority of cases **Fig. 9** shows average thicknesses of the sedimentary layer for different basins. The agreement is fairly good, and it is only in Atlantic-type troughs of the transition zone that the differences grow significantly. The deep-seated process for this type of zone has not been studied as reliably as for continents. An analysis of events in intercontinental and backarc seas suggests that the area underwent oceanization. Matching it is the heat and mass transfer in the mantle, similar to that in rifts, but more intensive. It has to be admitted that the triad approach suggested by Cloos (1939) must also be applied to cases of rifting on a basic crust. A syneclise with a thick layer of sedimentary rocks took shape in the Carboniferous-Permian above the rift structure of the Dnieper-Donets Depression whose crust had been basified by Riphean processes. In the Black Sea rift that emerged on a basic crust block, a suboceanic structure formed during the Cretaceous-Cenozoic. In many cases, this kind of structure on the vast expanses of contemporary oceans is not filled with thick sediments simply because provenance areas are too distant from there.

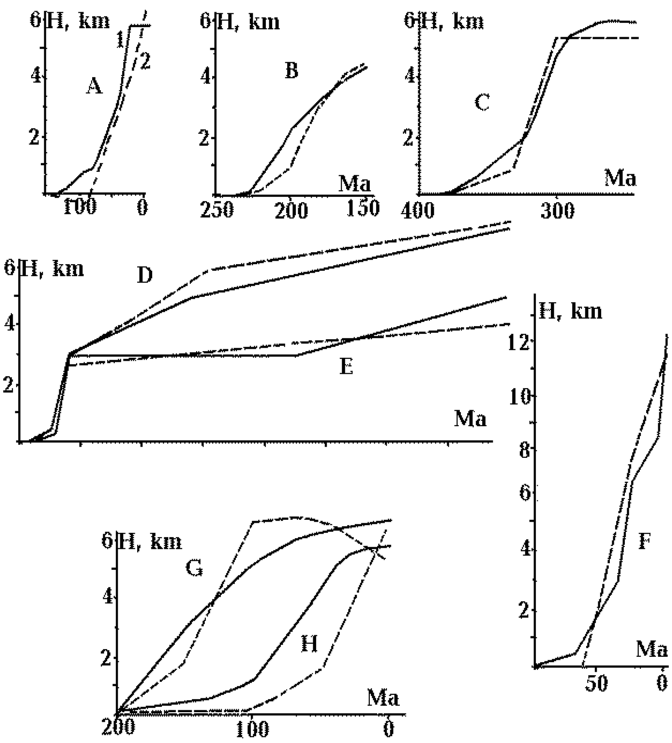

Fig. 9. Experimental (1) and estimated (2) variations of the sedimentary layer thickness in Folded Carpathians (A), on the Scythian Plate (B), in the Donets Basin (C), in the Dnieper-Donets Depression (D), in the Pripyat trough (E), in the Western Black Sea trench (F), in the inner (G) and outer (H) depressions of the North American cis-Atlantic trough.

The notion of a major feature of geosynclinal conditions – holomorphic folding – does not play an essential role in the APH (probably, not yet). Energy spent on it is insignificant, and it is presumed that folding may have resulted from gravitational slide (Aubouin, 1965; Cosgrove, 2005; Frostick, 2005; Guterman, 1987; and others) plus a large contribution of seismic tremors (and displacement toward the outer boundary of the basement's relative uplift), and/or advection during crustal rocks' transformation in the process of plunging and heating (Gerya, 2004; Gordienko et al., 2011a). Substantiation of the "Aubouin wave" thesis can be seen in the earlier onset of conditions for heat and mass transfer in the tectonosphere's central more overheated regions involved in active processes.

Values of the mantle gravity anomaly are estimated as the difference between the observed field and crustal effect. The latter is derived from the density profile established on the basis of the velocity profile. Used in practice are densities anomalous with regard to those in the upper mantle (3.32 g/cm^3). On parts of the platform, where no active processes are known to have taken place over a very long period of time (and the mantle density is normal and close to background values), the crustal effect minus 870 mGal corresponds to a zero observed field (the Bouguer anomaly). The crustal effect is distributed in reference to this norm. Its deviation from the observed field is used to assess the mantle anomaly. Even with high-quality velocity profiles, the error is at least 10 mGal. An anomaly of 20 mGal which in many cases corresponds to recent active processes on the platform was viewed as significant. In Alpine geosynclines and rifts (including those on the territory on which contemporary active processes are taking place in addition to the main process), anomalies are much greater (**Fig. 10**). The data on anomalous temperatures in the mantle and density variations during polymorphic transformations were used to evaluate the anomaly in accordance with the model of the process. Results of the comparison are shown in **Fig. 10**. In most cases the difference between the estimated and observed fields, with an account of the mantle's anomalous effect, cannot be attributed to errors.

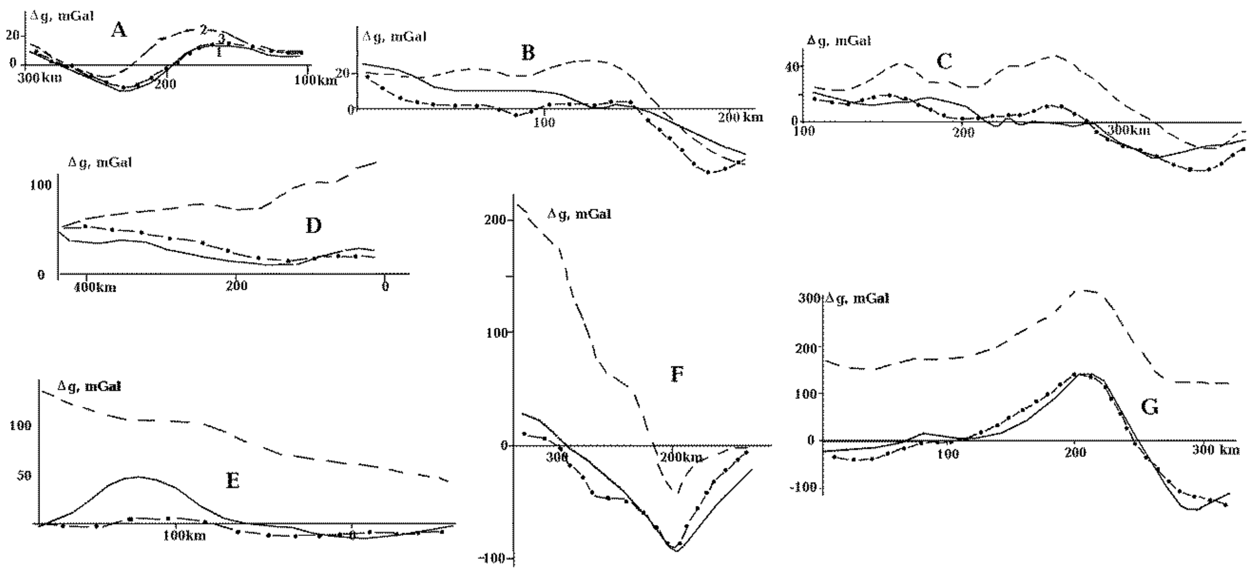

Fig. 10. Mantle gravity anomaly in some areas of active processes that have been covered by studies.
1 -- observed field (the Bouguer anomaly), 2 -- estimated effects of the crust and normal mantle, 3 – estimated effect with an account for the mantle's anomalous density according to the APH. Zones of recent active processes: A – in the center of the Ukrainian Shield; B – in the Dnieper-Donets Depression; C – in the Donets Trough; D – on the Scythian Plate; E – in the marginal part of the area of recent rifting and crust basification in the Western Black Sea Depression; F – in Eastern Carpathians, G – in Eastern Kamchatka, Kurile-Kamchatka Trench, and in the North-Western plate of the Pacific Ocean.

The approach used in the evaluation of the mantle gravity anomaly can be applied not just to continental, but also to some oceanic regions. It should be noted that, in terms of the APH, island arcs are not viewed as pertaining to oceans. Processes in them do not differ from those in other Alpine geosynclines.

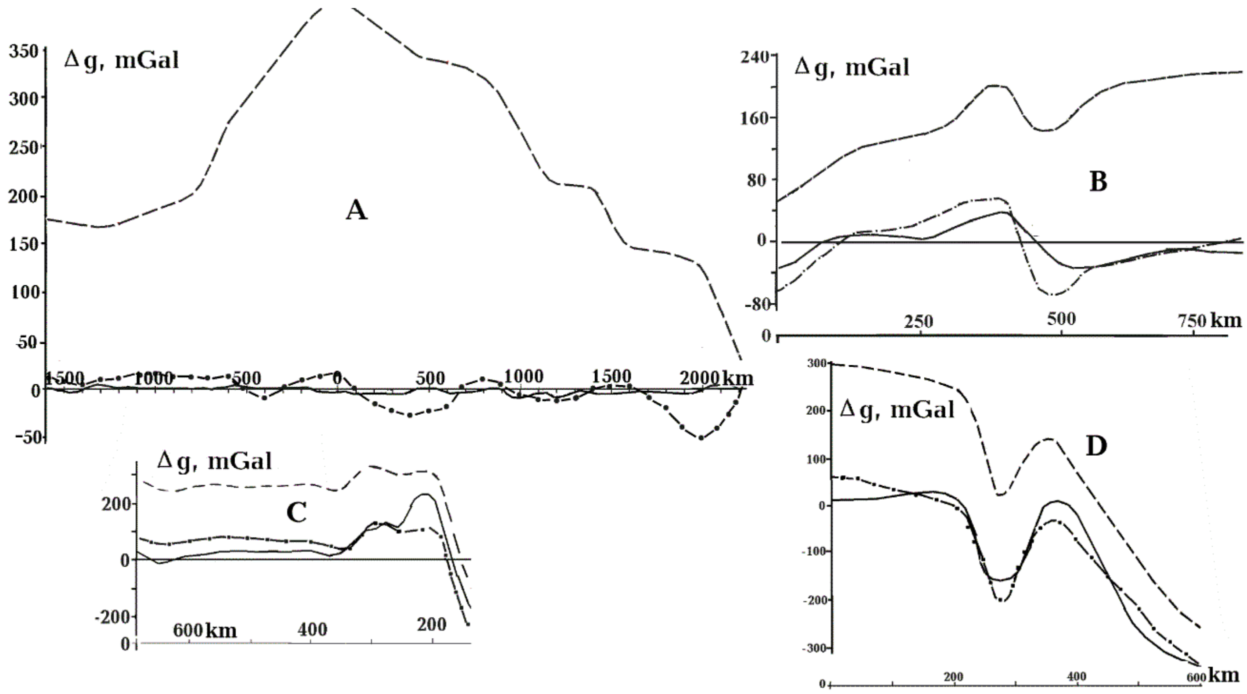

Fig. 11. Gravity anomaly in the mantle beneath some active oceanic and transition zones covered by studies (See Fig. 10 for symbols).
A – Angola-Brazil geotraverse (Pavlenkova et al., 1993) running across the Mid-Atlantic Ridge (MAR) and adjoining basins; B – Inner and Outer depressions of the North American Cis-Atlantic trough and adjacent part of North America with the Appalachian zone of active processes; C – South Okhotsk backarc trough; D -- Transition zone from the Andes to the Nazca Plate.

Fig. 11 shows a collection of data on mantle gravity anomalies in oceans and transition zones. Some of the relevant models of deep-seated processes presented in the study and based on the APH are so far less accurately validated than in the case of continents. The model relating to the transition zone from North America to the Atlantic Ocean is complicated by the need to take into account active processes in the area of the Appalachians and the adjoining part of the platform. The anomaly calculation error grows appreciably (to 20 mGal) in oceans, but the magnitude of the disturbance there is also much greater.

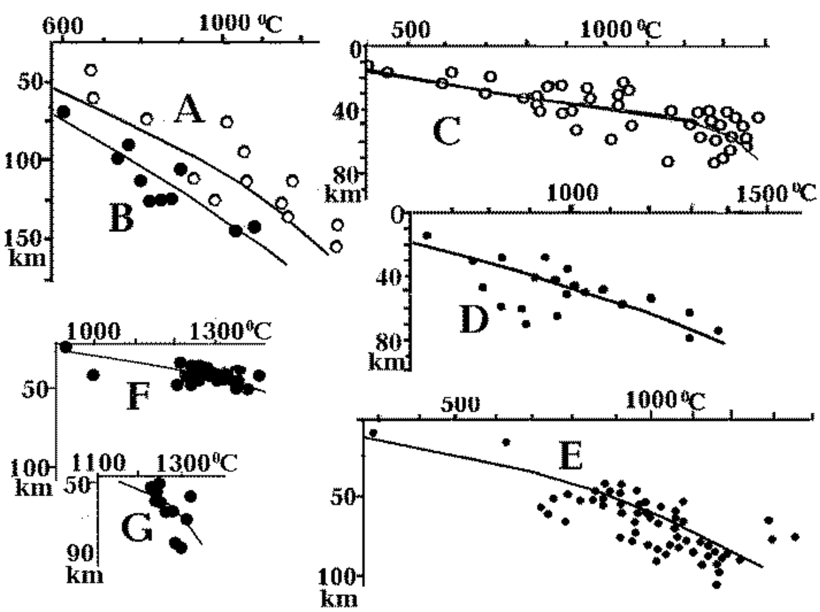

Fig. 12. Temperatures estimated according to the APH (lines) and measured by geothermometers (dots). Ukrainian shield; B – Pripyat arch (platform territory with lower heat generation values in the Earth's crust); C – geosynclines of the Kuriles, Kamchatka, and Apennines; D – rifts of the French Central Massif, Rio Grande, and Kenya; E -- zones of recent active processes in the Aldan Shield, Vitim escarpment, and Bohemian massif; F – Somali, Mariana, and Philippines trenches and the area of the Yap trough; G – Japan basin.

Mentioned above was agreement between temperatures of the crust and upper mantle on platforms as estimated with the help of the APH, on the one hand, and experimental data, on the other. Results of a similar correlation could also be provided for Phanerozoic geosynclines, rifts, and zones of single-episode active processes on continents and in oceans (**Fig. 12**).

It appears that estimated and experimental data are in fairly good agreement. Numerical characteristics of the degree of their correlation are represented by two parameters: differences between estimated and experimental temperatures and differences between temperatures of magmas measured at the same depth. Modal values of both divergences amount to about 50 ^{o}C, i.e. the dissimilarity between experimental and estimated data could be due to an error in the experiment.

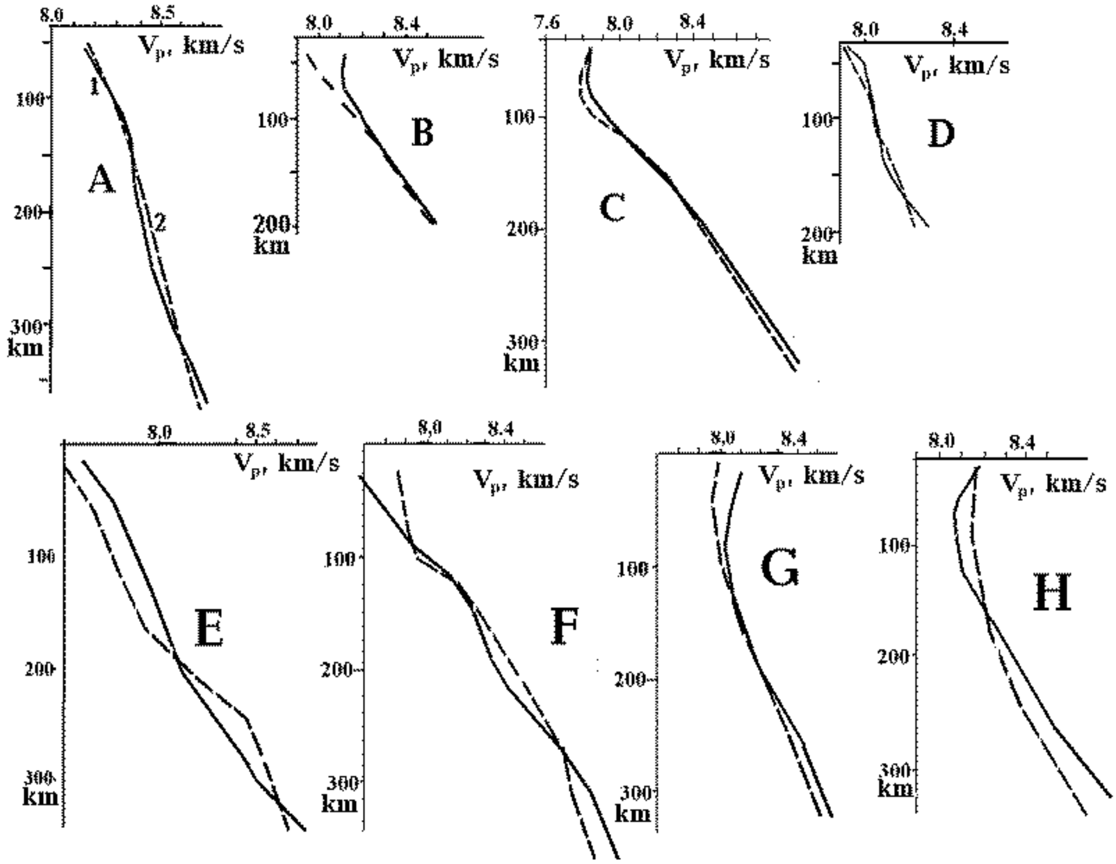

Fig. 13. Comparison between experimental (1) and estimated (2) compressional (P) wave velocity distributions in the upper mantle beneath regions with dissimilar endogenous conditions (Gontovaya et al. 2006; Gordienko et al., 2014; Pavlenkova et al., 2006; and others).
A – Precambrian platform, B – zone of active processes on the platform, C – Alpine geosyncline, D – Alpine rift, E – Mid-Ocean ridge, F – island arcs and offshore ridges at the North and South America Pacific coast, G – Zenkevich swell at the margin of the Pacific North-West plate, H – Kurile-Kamchatka trench.

Yet another parameter that can be used to verify models of deep-seated processes based on the APH is the distribution of seismic P-waves in the upper mantle. Selection of material for comparison is no simple task. Some of the relevant approaches are discussed by Gordienko (2010) and others. Data available for areas beneath vast regions of the Carpathian-Dinarides “oval” and others were used to characterize Alpine geosynclines. Abnormal velocities are considerably less common beneath relatively narrow structures (the Greater Caucasus and the Alps). Data for such zones of North Eurasian Precambrian platforms were used to exemplify recent active processes, since there one has a chance to observe the corresponding anomaly without distortion. This goal has not, however, been achieved (Gordienko, 2010) – see **Fig. 13B**. In the upper part of the profile, observed velocities are appreciably higher than estimated ones, which could be accounted for by eclogitized basic crustal rocks sinking to a small depth in the mantle as a result of the fact that the process was too young. With regard to young rifts, this author does not have at his disposal sufficient information on velocity profiles there. When it comes to oceans, experimental data are meaningful for island arcs (and similar structures – coastal ridges of both Americas) and the Mid-Ocean

Ridge. In the former case, the result is virtually the same as that obtained for geosynclines (with which they are actually identified in terms of the APH). Profiles recorded beneath trenches and oceanic depressions are so far poorly substantiated. Apart from the data listed in **Figs. 13G & H**, a small amount of information is available in publications, but its reliability has yet to be examined.

The list of procedures for verifying the constructed models could be continued, although the rest of the approaches would hardly add more credibility to the result. On the whole, it is good enough. No other hypothesis would make it possible, without selecting parameters of the model, to obtain such quantitative agreement, the divergences being within acceptable limits of error.

Several applications of the APH to studies of seismicity problems and to prospecting for mineral deposits (hydrocarbons, hydrothermal sulphide ores, diamonds, and geothermal energy resources) have been considered. They contribute, with various degrees of significance, to the available knowledge for each of the aforementioned areas of interest. The main value of such applications is perhaps the fact that tried and tested methods for analyzing geological and geophysical information can be applied to new targets. But there also are important new features that may well prove useful as additional tools in the arsenal at the disposal of experts researching the processes listed above. By way of example, let me refer to the possibility of applying the APH in studies of the nature of earthquakes and hydrocarbon deposits.

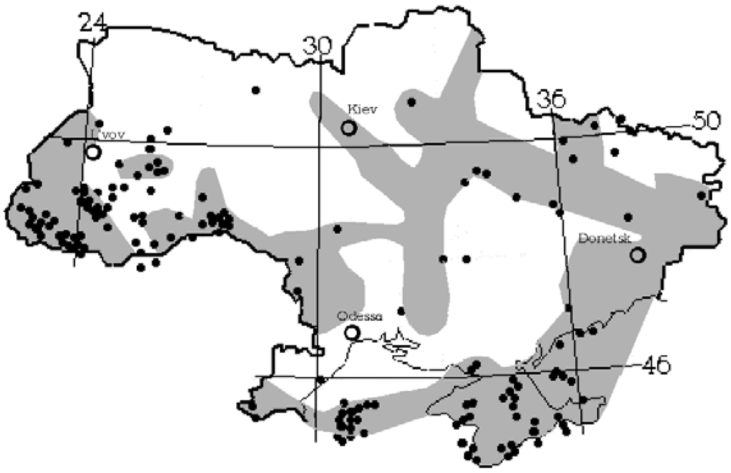

Fig. 14. Distribution of zones of recent active processes (shaded) and earthquake foci (dots) on the territory of Ukraine.

As far as seismicity is concerned, of particular interest is the use of thermal models for studying energy absorption and variations in tremor rate, as well as correlation between the earthquake moment, energy capacity, and the hypothetical volume of the earthquake focus. Still more compelling is the connection between outlines of zones of recent active processes and earthquake epicenters independently determined with the help of geological and geophysical data (Gordienko, 2001; Gordienko et al, 2005; and others). That this connection exists is beyond doubt, even though the picture is not complete due to the lack of relevant knowledge. In Ukraine, a seismic recording system picks up events in the west and south. Information on weak earthquakes in the center and in the east has only been obtained recently owing to observations in Russia. A continuation of such observations will probably lead to spotting new foci.

According to the APH, hydrocarbon deposits have been forming during recent active processes over last hundreds (or probably dozens) of thousands of years. Over that period of time, basic mantle smelts carrying dissolved fluids broke into the lower and middle portions of the Earth's crust. Basic and ultrabasic rocks that had earlier been metamorphically altered to granulite facies underwent serpentinization. Hydrogen and relatively small amounts of hydrocarbons were released. Partial melting in the middle crust encompassed some rocks in the stage of amphibolite facies. The fluid flows rose largely through permeable zones of faults (whose permeability increased by orders of magnitude under the effect of seismicity) and transported hydrogen into the middle and upper portions of the crust. The presence within the crust of appreciable concentrations of carbon (graphite, schungite, or less metamorphically altered, probably primary, sedimentary formations) caused the emergence of hydrocarbons. Calculations suggest that this could be the process resulting in the formation of several "generations" of deposits at the same location. Such a model makes obvious the connection (provided that the aforementioned events occur on the platform without any influence of other types of active endogenous conditions) between clusters of deposits and a number of geological characteristics (helium isotope anomalies, high pore pressure, hydrochemical inversion, appearance within reservoirs of microand nanoparticles from metamorphosed lower crust rocks, and so on), as well as anomalies of physical fields. The entire region of recent active processes is demarcated by a gravity anomaly in the mantle and by a zone of reduced velocities in the upper mantle. Additional anomalies are recorded in the gravity field over permeable (decompressed) faults; the same features are also identified by electric conductivity anomalies. Association of heat-flow anomalies with clusters of deposits is less certain. Over the aforementioned period of time, measurements of heat anomalies from the middle and lower crust have not reached the depths of temperature measurements in boreholes. Elevated temperatures (and helium isotope anomalies) are confined exclusively to areas in the vicinity of local faults through which abyssal fluids are injected into deposits.

The presence of oil and gas in certain parts of the Dnieper-Donets Depression is confirmed by all geological criteria. **Fig. 15** shows that hydrocarbon deposits are confined to areas of the mantle gravity anomaly.

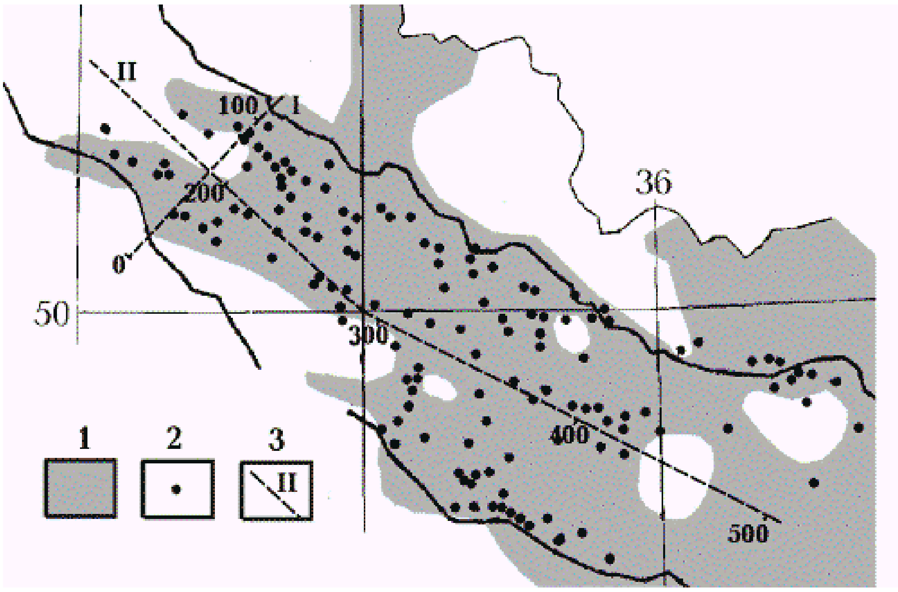

Fig. 15. Oil- and gas bearing capacity in the Dnieper-Donets depression versus mantle gravity anomaly greater than minus 20 mGal.
1 -- anomaly outlines, 2 – oil and gas deposits, 3 – profiles along which variations of oil- and gas bearing capacity and anomalies of physical fields were correlated (see Fig. 16).

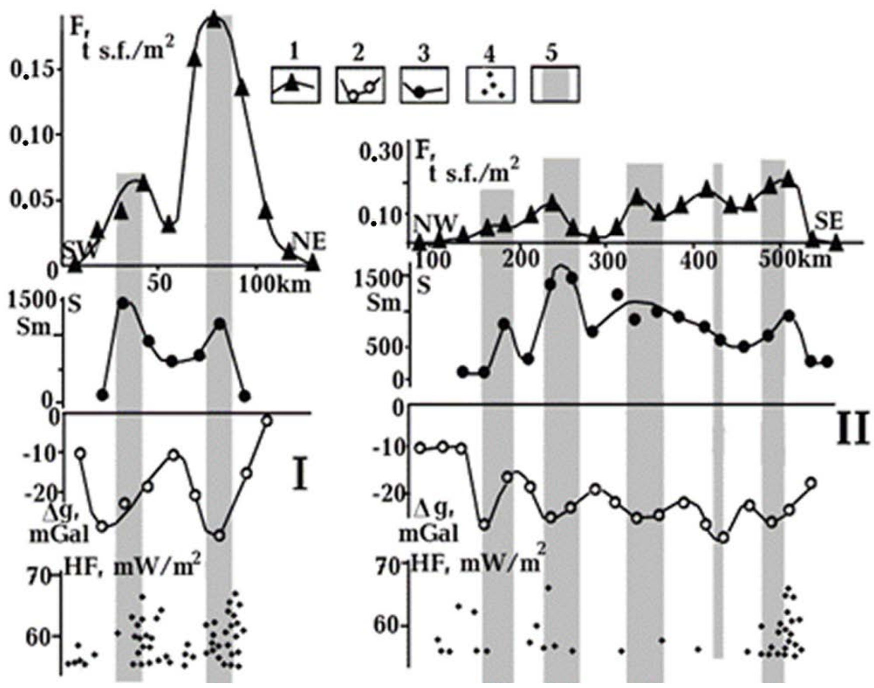

Fig. 16. Comparison of variations in the oil- and gas bearing capacity (1) of the Dnieper-Donets depression with the mantle gravity anomaly (2); with composite longitudinal conductivity in the middle crust (3); and with elevated heat flow values (the background heat flow amounts to 43 mW/m^2) (4); longitudinal and transverse deep-seated faults that have experienced active processes in recent three million years or so (5). t s.f./m^2 - tons of standard fuel to unit area in m^2.

Further south-east, in the Donets Basin, the anomaly remains intact, whereas oil and gas deposits are only located within a narrow zone near the northern marginal fault. In boreholes at the center of the region, in addition to a small amount of "coalbed" methane, a flow of hydrogen from abyssal depths has also been recorded (Murych et al., 1975). It so happens that there was no carbon available at the relevant depth to enable the formation of hydrocarbons within the crust.

For comparison with anomalies of physical fields, the data on the deposits in the depression have been processed in the following way: The territory of the depression was divided into longitudinal and transverse bands with respective widths of 12.5 km and 25 km. Within those bands, reserves of the deposits were added up in tons of standard fuel and assigned to a unit area (t s.f./m^2) . Average values were determined for the mantle gravity anomaly and composite longitudinal conductivity in the middle crust within the same bands. Variations of both parameters are in fairly good agreement with variations in the oil- and gas bearing capacity. Correlation between heat flow anomalies and clusters of deposits is not so perfect (see above). Yet, occasional heat flow escalations have been recorded in the same deposits (**Fig. 16**) against the background values amounting to approximately 43mW/m^2 in the region.

On the whole, predictions based on the APH are being proved true and the resulting data may well prove to be a useful addition to multidiscipline prospecting for oil and gas.

CONCLUSIONS

Information presented in this paper shows that the tectogene hypothesis complying with formulated requirements is realistic. The scope of the paper does not make it possible to further expand the arguments, and this may render it less convincing. All the more so that some of its components do need to be further studied and amended. In recent years, this author has already introduced certain changes into the subject matter of the hypothesis as broached in earlier publications (Gordienko, 1998, 2007 and 2012; and others). This applies even more to earlier studies dealing with the application of the hypothesis to the evolution of the tectonosphere in regions with dissimilar endogenous conditions in northern Eurasia (Buryanov et al., 1987; Gordienko et al. 1990, 1992, 2005, 2006, 2011; and others). At the same time, this author found it appropriate to discuss a full version of the hypothesis for the first time in English. It might therefore be useful to complement this paper with several new publications in which the author could expound in more detail and with greater validity the concepts of the energy source, Precambrian history of the world's platforms, depths of magma chambers in the mantle, evolution of Phanerozoic geosynclines, rifts, regions experiencing recent active processes, oceans and various types of transition zones, seismicity, and origin of mineral deposits.

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References

Aubouin, J., 1965. Geosynclines. *Elsevier Ltd.* 305p.
Balashov, Yu.A., 2009. Development of a heterogeneity in the lithosphere: geochemical evidence. *Petrology.* v. 17, no. 1, p. 90-107.
Beloussov, V.V., 1972. Relationship between the Earth's crust and upper mantle. Earth's crust and upper mantle. Moscow. *Mir*. p. 610-629. (in Russian)
Beloussov, V.V., 1978. Endogenous conditions on continents. Moscow: *Nedra,* 232. (in Russian)
Beloussov, V.V., 1982. Transition Zones Between Continents and Oceans. Moscow: *Nedra*. 152p. (in Russian)
Beloussov, V.V., 1991. Plate tectonics and tectonic generalizations. *Geotectonics.* 2. p. 3-12. (in Russian)
Boyd, F., 1989. Compositional distinction between oceanic and cratonic lithosphere. *Earth and Planetary Sc. Lett*., v. 96, nos. 1/2, p. 16-26.
Buryanov, V. B., Gordienko, V.V., Zavgorodnyaya, O.V. et al., 1987. Geophysical model of European tectonosphere. Kiev: *Naukova Dumka*. 184p. (in Russian)
Cloos, H., 1939. Hebung - Spaltung - Vulkanismus. *Geol. Rundschau*. v. 30. p. 401-519.
Cosgrove, J., 2005. Folding. Encyclopedia of Geology. Eds. Selley, R., Cocks, L. and Plimer. I., *Elsevier Ltd.*, v. 5, p. 339-351.
Eardley, A., 1951. Structural geology of North America. *Salt Lake City*. 357p
Frostick, L., 2005. Rift Valley. Encyclopedia of Geology. Eds. Selley, R., Cocks, L., and Plimer, I., *Elsevier Ltd.,* v. 1, p. 34-43.
Gerya, T. and Maresch, W., 2004. Metapelites of the Kanskiy Granulite Complex (Eastern Siberia): Kinked

P–T paths and geodynamic model 210. *J. of Petrology,* v. 45, no. 7, p. 1393–1412.
Goguel, J., 1965.Traité de Tectonique. Paris: *Masson*. 424p.
Gontovaya, L.I. and Gordienko, V.V., 2006. Deep-seated processes and geophysical model of the mantle of Eastern Kamchatka and Kronotskiy Bay. *Geology and Mineral Resources of the World Ocean*, no. 2, p. 107-121 (in Russian).
Gordienko, V.V., 1975. Thermal Anomalies in Geosynclines. Kiev: *Naukova Dumka*. 142 p. (in Russian).
Gordienko, V.V., 1998. Deep-seated processes in the Earth's tectonosphere. Kiev: *IGP NASU*. 85p. (in Russian).
Gordienko, V.V., 2001. Geological criteria and integrated analysis of a zone of recent activity in Fennoscandia. *Proceedings of the Institute of Fundamental Studies*. p. 10-15.
Gordienko, V.V., 2009a. On the deep-seated processes in the tectonosphere of the Baltic Shield in the Early Precambrian. *Geophys. J.*. v. 3, p. 3-17. (in Russian)
Gordienko, V.V., 2009b. On Precambrian deep-seated processes in the tectonosphere of continents. *Geophys. J.,* v. 5, p. 85-102. (in Russian)
Gordienko, V.V., 2010. On the nature of velocity anomalies of longitudinal seismic waves in the upper mantle. *Geophys. J.,* v. 3. p. 43-63. (in Russian)
Gordienko, V.V., 2012. Processes in the Earth's tectonosphere (advection-polymorphic hypothesis). – Saarbrücken*: LAP*. 256p. (in Russian)
Gordienko, V.V., 2014a. Energy of deep-seated processes on the continents and in oceans. *Geology and Mineral Resources of the World Ocean,* no. 4, p. 48-72. (in Russian)
Gordienko, V.V., 2014b. On PT conditions of magma chambers in the Earth's mantle. *Geophysical J.*. v. 6, p. 28-57. (in Russian)
Gordienko, V.V., Andreyev A.A., Bikkenina K.S., et al., 1992. Tectonosphere of the Asia Pacific margin. Vladivostok: *FEB RAS.* 238p. (in Russian)
Gordienko, V.V., Zunnunov, F. Kh., Tal-Virsky B.B. et al., 1990. Tectonosphere of Middle Asia and South Khazahstan. Kiev: *Naukova Dumka*. 232p. (in Russian)
Gordienko, V.V., Gordienko I.V., Zavgorodnyaya O.V. et al., 2005. Ukrainian Shield (geophysics, deep-seated processes). Kiev: *Corwin press*. 210p. (in Russian)
Gordienko, V.V.., Gordienko, I.V., Zavgorodnyaya, O.V., et al., 2006. Dnieper-Donets Basin (geophysics, deep-seated processes). Kiev: *Corwin press.* 142 p. (in Russian)
Gordienko, V.V., Gordienko I.V., Zavgorodnyaya O.V. et al., 2011. Ukrainian Carpathians (geophysics, deep-seated processes). Kiev: *Logos*. 128p. (in Russian)
Gordienko, V.V. and Gordienko, L.Ya., 2013a. PT conditions in the mantle magma chambers beneath the Pacific Ocean. *Geology and Mineral Resources of the World Ocean,* no. 2, p. 47-63. (in Russian)
Gordienko, V.V. and Gordienko, L.Ya., 2013b. PT conditions in the mantle magma chambers beneath the Atlantic Ocean. *Geology and Mineral Resources of the World Ocean*, no. 4, p. 63 - 78. (in Russian)
Gordienko, V.V. and Gordienko L.Ya., 2014. Velocity model of the upper mantle beneath oil & gas bearing regions of Pacific margins. *Proceedings of the Third Kudryavtsev readings,* Moscow: *CGE.* (in Russian)
Gordienko, V.V. and Logvinov I.M., 2011. On global asthenosphere. *Physics of the Earth*, v. 2, p. 35-42. (in Russian)
Guterman, V.G., 1987. Mechanisms of tectogenesis. Kiev: *Naukova Dumka*. 172p. (in Russian)
Khazan, Ja.M., 1999a. Thermal instability near the level of density inversion of the melt and the solid phase: model based on Rayleigh-Taylor approximation. *Geophysical J.*, v. 3. p. 91-99. (in Russian)
Khazan, Ya.M., 1999b. Rayleigh-Taylor heat instability model near the level of density inversion of the melt and solid phases: numerical evaluation and comparison with observations. *Geophysical J.*, v. 6, p. 40-50. (in Russian)
Murych, A.T., Reznikov A.I., Abrazhevich E.V. et al., 1975. Results of deep drilling in central part of Donbas. *Soviet Geology,* v. 8, p. 125-131. (in Russian)
Pavlenkova, G.A. and Pavlenkova, N.I., 2006. Upper mantle structure of Northern Eurasia from peaceful nuclear explosion data. *Tectonophysics.* V. 416. p. 33-52.
Pavlenkova, N.I., Pogrebitsky, Yu.E. and Romanyuk, T.V., 1993. Seismic-density model of crust and upper mantle in South Atlantic area along the Angola-Brazilian Geotraverse. *Physics of the Earth*, v. 10. p. 27-38. (in Russian)
Pronin, A.A., 1973. Alpine tectonic cycle of the Earth's history. Mesozoic. Cenozoic. Leningrad: *Science.* 224p. and 318p. (In Russian)
Ringwood, A.E., 1981. Structure and petrology of the Earth's mantle. Moscow: *Nedra*. 584 p. (In Russian).
Semenov, V.Yu., 1998. Regional conductivity structures of the Earth's mantle. *Publish. Inst. Geophys. Pol. Acad. Sc.* 65 (302). 122p.
Sobolev, S., Zeyen, H., Stoll, G. et al., 1996. Upper mantle temperatures from teleseismic tomography of French Massif Central. *Earth Planet. Sci. Lett.,* v. 139, p. 147-163.
Stille, H., 1924. Grundfragen der vergleichenden tektonik. Berlin: *Gebrüder Borntraeger*, 443p.
Subbotin, S., Naumchik, G. and Rakhimova, I., 1968. Earth's mantle and tectogenesis. Kiev: *Naukova Dumka.* 173p. (in Russian)
Windley, B. (ed.), 1980. Early History of the Earth. Moscow*: Mir.* 622p. (in Russian)

TECTONIC HISTORY OF JEJU ISLAND, KOREA

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Abstract: The geology of Jeju Island is generally divided into Basement, Paleo-Jeju Volcanics, Seogwipo Formation, Pyoseolly Basalt Group, Tamna Formation, Basalt dyke complex, Hallasan Basalt Group, Baengnokdam Trachyte Group, Volcanic debris-avalanche deposits, Sinyangni Formation and Paleobeach-embayment sand deposits in ascending order. Tectonic history of the island reveals that Mt. Halla is a dome-like uplifted volcanic edifice formed by uprising magma, and that the island is neither a volcanic island nor a shield volcano.

Keywords: *Jeju Island, Mt. Halla, Baengnokdam, Tamna Formation, dome-like uplifted volcanic edifice*

INTRODUCTION

Jeju Island is located at the southwestern entrance to the Korea Strait which is connected with the East Sea (Japan Sea). The island is oval in shape in plan view. The long axis trending in ENE-SWS direction is about 74 km long, and the short axis trending in a NNW-SSE direction is about 32 km long (**Fig. 1**). Jeju Island is known as a volcanic island, because Mt. Halla (Hallasan in Korean language), being 1950 m high, and the main body of the island is known as a stratovolcano. But Yoon et al. (2005 and 2006) stated that Mt. Halla is not a stratovolcano but a dome-like uplifted volcanic edifice formed by uprising magma. This article is to state the tectonic history of Jeju Island in the light of our new studies.

VOLCANIC FORMATIONS AND STRATIGRAPHY

The **basement** is distributed about 210-312 m below sea and comprises of Jurassic and Late Paleocene granites and Cretaceous volcanic rocks such as volcanic sandstones and mudstones, welded tuffs and lapilli tuffs. The **PaleoJeju Volcanics** is only recognized by the basaltic and trachytic gravels in the gravelly sediments of the Seogwipo Formation.

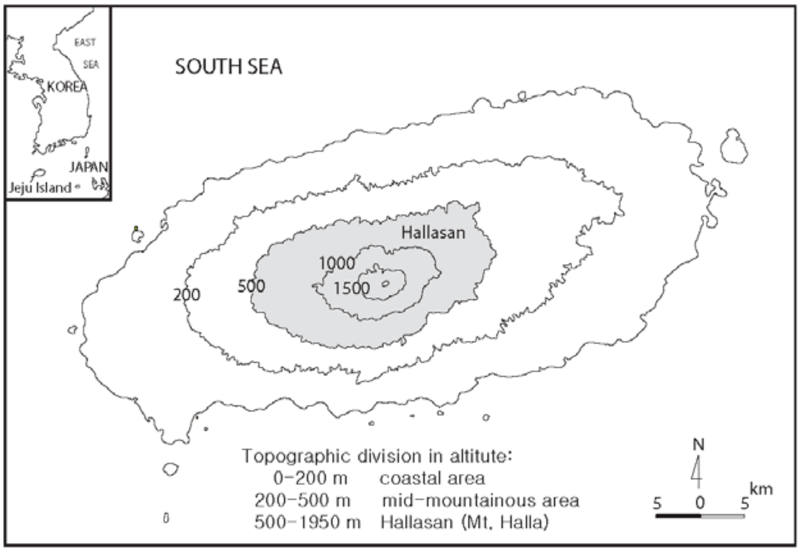

Fig. 1. Index map of Jeju Island with its topographic division.

The **Seogwipo Formation** directly covers the basement and is exposed in small exposures along the western coast. The formation is 371 m in thickness, but only 65 m of the upper part of the formation is exposed at the surface of the central coast. The formation consists of marine gravelly sandstones, fine-grained sandstones, sandy mudstones and mudstones. The upper part of the formation is intercalated with hyaloclastites and hydrovolcaniclastic deposits. Marine organisms such molluscs and foraminifers are abundantly yielded. The geologic age of the formation is from the Late Pliocene to the Early Pleistocene.

The **Pyoseolly Basalt Group** covers the Seogwipo Formation and consists of basalt pahoehoe lavas, and distributes in the eastern and the western parts of Jeju Island. The lavas are characterized by well-developed vesicles, acicular feldspars and olivine phenocrysts about 1 mm in diameter. It is divided into two texture groups: One group is characterized by containing acicular feldspar phenocrysts, and another without acicular feldspar phenocrysts. The K-Ar ages of the Pyoseolly Basalt Group are about 0.63 Ma in the southeastern coast and about 0.60 Ma in the western coast.

The **Tamna Formation** unconformably covers the Pyoseolly Basalt Group, and consists of conglomerates, gravelly sandstones, sandstones, gravelly sandy mudstones, sandy mudstones and mudstones. The formation is the fluvial sediments of laharic origin, and covers the surface of Jeju Island from the coastal area up to the summit of Mt. Halla. The thickness of the formation is about several meters to several tens of meters near the coastal area but exceeds 200 m near the summit of Mt. Halla.

The Tamna Formation is covered by the **Baengnokdam Basalt Lava** (Hallasan Basalt Group), the K-Ar age of which is about 0.47 Ma. It is presumed to be about 0.5-0.6 Ma which is the Middle Pleistocene in geologic age. Vein quartz and quartzite granules and pebbles contained in the gravelly sandstones suggest that a large land existed between Jeju Island and the southwestern corner of the Korean Peninsula; rivers flowed from the peninsula through the island when the Tamna Formation was deposited.

Numerous dykes are found and comprehensively called the **Basalt dyke complex**. The dykes of the complex are divided into two groups: One is sheet-like solitary dykes, and another dykes forming swarms. The solitary dykes intruded at low angle or nearly horizontally with about several meters to a little more than ten meters in thickness, whereas the dyke swarms intruded at high angle or vertically with 0.5-1.5 m in thickness.

The **Hallasan Basalt Group** is the basaltic lavas that cover unconformably the Tamna Formation. The lavas of the group are divided into pahoehoe lavas, aa lavas and transitional facies from pahoehoe lava to block lava, and block lava.

The **Baengnokdam Trachyte Group** is distributed mainly near the summit area of Mt. Halla. Baengnokdam Lava dome Trachyte forming the west wall of the summit crater of Mt. Halla is about 0.07 Ma in K-Ar age.

The Volcanic debris-avalanche deposits were formed by sector collapses of cinder cones. The cinder cones are divided into the older ones before the Tamna Formation and the younger after the Tamna Formation.

The **Sinyangni Formation** of the southeastern corner of Jeju Island consists of beach and nearbeach sediments of the alternation of granule to pebble conglomerates and coarse-grained sandstones. Its thickness is more than 10 m.

The **Paleobeach-embayment sand deposits** are distributed in the northeastern and northwestern corners of Jeju Island, and consist mainly of pulverized mollusc sand (**Fig. 2**).

The formation of Mt. Halla

The high edifice from 500 m to1950 m in altitude in the central part of Jeju Island is defined as Mt. Halla. Mt. Halla had been known as a sratovolcano, but Yoon et al. (2005) reported that Mt. Halla is not a stratovolcano but a dome-like uplifted edifice, and the summit crater is not an explosive crater but a pit crater.

TECTONIC HISTORY OF JEJU ISLAND

Stage I. Basin formation and marine transgression: Seogwipo Formation time.
A basin was formed in the Jeju Island area and marine transgression occurred into the basin. The geologic age is from the Late Pliocene to the Early Pleistocene.

Stage II. Basaltic volcanic activity-I: Pyoseolly Basalt Group time.
The Jeju Island area became a land, and pahoehoe lavas covered the eastern and the western parts of the area. The age is about 0.6 Ma, which is the time when the older cinder cones were formed.

Stage III. Fluvial environment: Tamna Formation time.
After the volcanic activity of the Pyoseolly Basalt Group, the area was under fluvial environment, and the laharic sediments of the Tamna Formation were deposited. The age is presumed to be about 0.5-0.6 Ma, or the Middle Pleistocene.

Stage IV. Basaltic volcanic activity-II: Hallasan Basalt Group time.
Pahoehoe and aa lavas extruded and covered the Tamna Formation. The younger cinder cones were formed.

Stage V. Intrusion of trachytic magma: Dome-like uplift of Mt. Halla time.
Trachytic magma intruded into the central part of the Jeju Island area, forming an uplifted dome, which made the present Mt. Halla edifice. The summit of the edifice collapsed and formed a round pit crater. The age is about 0.07 Ma, the Late Pleistocene.

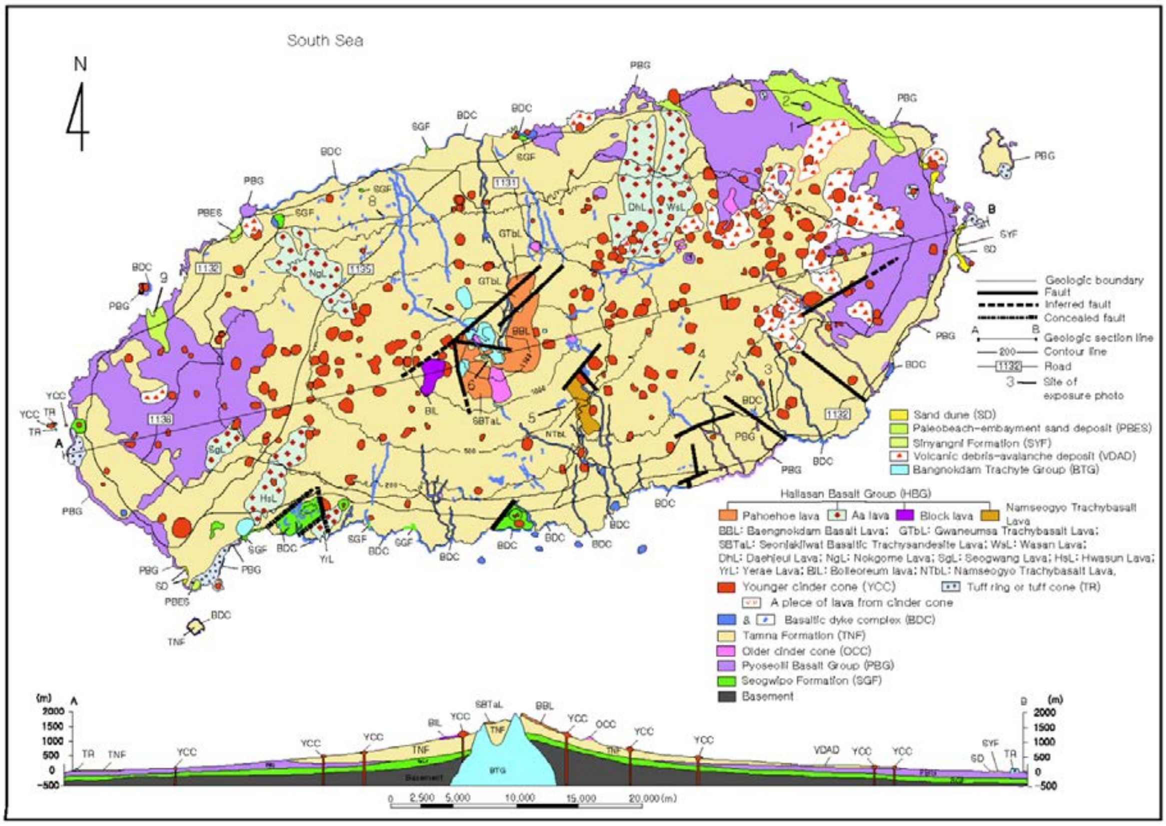

Fig. 2. Geologic map of Jeju Island. Modified from Yoon et al. 2006.

CONCLUSIONS

Jeju Island, having such a tectonic history, is neither a volcanic island nor a shield volcano. It is a submerged volcano, and its shape resembles to a composite volcano.

References

Yoon, S., Hyun, W.H. and Jung, C.Y., 2005. Geology of Hallasan (Mt. Halla), Jeju Island. *Jour. Geol. Soc. Korea*, v. 41, no. 4, p. 481-497 (in Korean with English abstract).

Yoon, S., Jung, C.Y. Song, S.T. and Hyun, W.H., 2006. Geology of Jeju Island. Jeju Provincial Office, Korea Rural Community and Agriculture Corporation (KRC), 73p., 1 map(1: 150,000) (in Korean with English Summary).

SOLAR WIND IONIC VARIATION ASSOCIATED WITH EARTHQUAKES GREATER THAN MAGNITUDE 6.0

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ABSTRACT: The causes of earthquakes can be multiple and diverse, including those related with human activity. Various types of energy should then be evaluated besides the ones of tectonic origin, in order to build a specific modeling system of the data, which may support a probabilistic earthquake prediction in the short term. Among them, there are gravitational, inertial, electric and electromagnetic energies. The scientific question which the authors have tried to answer in the present study, is whether the global M6+ seismic activity is preceded by an increase in the solar activity, and in particular in the ionic variation of the solar wind. For this purpose, an analysis was performed on 428 earthquakes with greater than or equal to M6+ magnitude, which occurred on a global scale between 2012 and 2014. The data on seismicity have been compared with those provided by the geomagnetic observatories and those on the solar modulation transmitted by the ACE satellite orbiting the L1 point at 1.5 million kilometers from Earth. As the results reveal, the analyzed earthquakes with magnitude greater than M6+ have shown a remarkably higher occurrence during the phases of increase and decrease of the proton density of the solar wind.

***Keywords**: Solar wind ionic variation, earthquake prediction, proton density*

INTRODUCTION

Background

The association between solar activity and strong earthquakes on a global scale has been hypothesized since the second half of the last Century and, on and off, resumed over the years by several authors (Simpson, 1967; Zhang, 1998; Han et al., 2004; Choi and Maslov, 2010). The electrically charged particles emitted from the Sun propagate through the heliosphere along the interplanetary magnetic field (IMF) reaching the planets of the solar system. When the solar wind reaches the Earth, it determines geomagnetic disruptions which interact with the Earth's magnetic field and with the ionosphere. The geomagnetic disruptions, which determine variations measurable with the use of electromagnetic sensors placed on the Earth's surface, have been associated with seismic events of high intensity ($Mw \geq 6$) since the 1930's (Yanben et al., 2004).

In 1990, Takayama and Suzuki (1990) associated the Wolf number, i.e. the sunspot number, with destructive earthquakes occurred in Japan, while in 1967 Simpson suggested as a possible seismogenic mechanism the faradic current which is present in the Earth crust and produced by the solar activity. A few years later, in 2004, Han et al. found that large earthquakes were related to variations in the magnetic cycle of the solar activity. Mazzarella et al. (1988) concluded that the seismicity is related to solar activity and geomagnetic anomalies: they suggested that these two phenomena were capable of generating high intensity seismic events. A similar concept contemplating the effect of solar flares and magnetic storms was reasserted by Balasis et al. (2010). In 2011, Tavares and Azevedo suggested that an increase in solar activity coincides with an intensification of seismic events, while a study by the Space Environment Research Center of Kyushu University (Jusoh and Yumoto, 2011) revealed that 70% of great earthquakes (Mw 6-9) occurred within ±4 days, i.e. 4 days before or 4 days after, the arrival of the high-speed solar wind (HSSW). Variations in the solar electromagnetic radiation have been observed preceding great earthquakes, such as the one in Tohoku (He et al., 2012). A possible connection between solar and geomagnetic activity on a century-scale and an interaction mechanism between the two phenomena were proposed by Odintsov et al. (2006), while Straser and Cataldi (2014) recently suggested an interface mechanism of the solar and the geomagnetic activity as a triggering mechanism of strong earthquakes.

Geomagnetic activity and solar wind ionic variation

The variation in the Earth's geomagnetic activity is modulated by variations in ionic density, consisting of protons and electrons and present in the interplanetary medium that interacts with the Earth's magnetosphere. The cause and effect relation between solar and geomagnetic activity affects the natural electromagnetic field in the SELF/ELF band. Such interference has been associated with potentially destructive earthquakes; variations were observed before five >M6.0 magnitude earthquakes in Mexico from 1999 to 2001 (Kotsarenko et al., 2004). Other variations of the geomagnetic field with frequency <3Hz were detected before earthquakes in: Armenia, Spitak (December 8, 1988, M=6.9); Loma Pietra, California, USA (October 18, 1989, M=7.1); Guam (August 8, 1993, M=8) (Hayakawa et al., 2007); and Izu Peninsula, Japan (July 1, 2000, M=6.4) (Ismaguilov et al., 2003). In 1964, a strong disturbance in the natural magnetic field with ≤10Hz frequency was recorded preceding the M9.2 earthquake that occurred in Kodiak, Alaska (Fraser-Smith, 2008). Radio emissions with <3Hz frequency were detected preceding the ML7.1 earthquake that occurred at Hotan of Xinjiang, China, October 19, 1996 (Du et al., 2004). Electromagnetic disturbance with frequency in the range of Pc3 geomagnetic pulsation (10-40s) were detected preceding the strong M6.4 earthquake that occurred on the island of Taiwan, China, December 19, 2009 (Takla et al., 2011). A study carried out from April 1997 to March 2002 by the RIKEN/UEC-NASDA scientific group reported electromagnetic anomalies in the SELF band preceding M6+ earthquakes (Hattori et al., 2004).

Strong radio emissions in the ELF band with 3-10 Hz frequency were detected preceding the strong MS8.0 earthquake that occurred in the Wenchuan County, China, May 12, 2008 (Li et al., 2013). Electromagnetic variations in the 0-15 Hz band preceded the M9.0 earthquake that occurred in Samoa, September 29, 2009 (Akhoondzadeh et al., 2013). Electromagnetic emissions in the 0-20 Hz band preceded the M7.0 earthquake that occurred in Haiti, January 12, 2010 (Athanasiou et al., 2011). Variations in the electromagnetic field between 0.25 and 0.5 Hz were detected preceding seismic events in Central Mexico from 2007 and 2009 (Chavez et al., 2010). Radio emissions in the SELF/ELF band were detected preceding the M5.5 earthquake that occurred in Bovec, Slovenia, July 12, 2004 (Prattes et al., 2008). In addition, strong variations in the geomagnetic field (included the presence of geomagnetic micropulsations) preceded the volcanic activity of Popocatepetl, Mexico, in the period March–July, 2005 (Kotsarenko et al., 2007). And radio emissions within 10.2 to 11.1 mHz and within 13.6 to 14.5 mHz frequency in the SELF band preceded the seismic activity in Central Mexico from 1999 to 2001 (Kotsarenko et al., 2005).

METHODS

The method adopted is deductive and based on an instrumental detection system. The data relating to the solar, seismic and geomagnetic activities, and to the radio emissions, were compared with each other to test any interconnection of electromagnetic type. The data on solar activity and seismic activity were real-time retrieved from the websites.

DATA

The data on the solar activity concern the variation in the ionic density of the solar wind detected by the ACE (Advanced Composition Explorer) satellite orbiting the L1 point (Lagrange point) at 1.5 million kilometers from Earth; Solar Wind Density (ENLIL Heliosphere Ecliptic Plane), variations in interplanetary magnetic field or IMF (GOES); X-ray flux (GOES), temporal monitoring of CMEs events or Solar Coronal Mass Ejections (ISWA); monitoring of the coronal holes position on the Sun's surface (NSO/SOLIS-VSM Coronal Hole); Solar Wind Velocity (ENLIL Helisphere Ecliptic Plane); Electron flux (NOAA/SWPC); Magnetopause Standoff Distance (CCMC/RT).

The data on geomagnetic activity were retrieved from: AL-Index (WINDMI and Kyoto WDC); DST-Index (WINDMI and Kyoto WDC); Driving Input Voltage VSW (WINDMI); Hemispheric Power (NOAA/POES); Total Electron Content (TEC SWACI map); Electron Density (Electron Density map JRO); variations in the geomagnetic field (provided by geomagnetic observatories: Tromso, Sodankyla, Kiruna, Licksele, Cobenzel, USGS, INGV, Canberra, Scoresbysund, Denmark, Narsarsuaq, Kullorsuaq); Estimated Kp-Index (NOAA/SWPC) A-Index (Tromso Geomagnetic Observatory); variations in polar electromagnetic emission (GOES/METP). The data relating to the pre-seismic radio emissions were provided by the SELF/ELF induction magnetometer of the Radio emissions Project (Lat: 41°41'4 .27"N, Long: 12°38'33,60"E, Albano Laziale, Rome, Italy), which reads the intensity and frequency of the Earth's magnetic field every 60 seconds on the Z magnetic component.

The data on the global seismic activity on the M6+ scale were real-time retrieved from USGS (United States Geological Survey), CSEM or EMSC (Centre Sismologique Euro-Méditerranéen or European-Mediterranean Seismological Centre) and GFZ (Deutsches GeoForchungs Zentrum or German Research Centre for Geosciences), and used within 48 hours from publication.

RESULTS

The analysis of the ionic variation of the solar wind in the interplanetary medium has allowed to determine that the earthquakes had occurred after a gradual variation, i.e. lasting more than 24 hours, in the proton density with energy subdivided into five groups: 1060-1900 keV, 795-1193 keV, 310-580 keV, 115-195 keV, 47-68 keV.

The flux of ions from the Sun that reaches the Earth is mainly due to explosions that occur in the solar flare. Fluxes of ions are also originated from coronal holes (50) and are high-density fluxes.
In some cases, the increase of the electron density was superimposed on the increase of the proton density, with energy distributed into two groups: 175-315 keV e 38-53 keV (**Fig. 1**). The final point of the first wave and the starting point of the following one has been defined as "Start Point", i.e. the starting point of what is considered a candidate to interplanetary seismic precursor. It corresponds to the relative basic level that separates the proton increments.

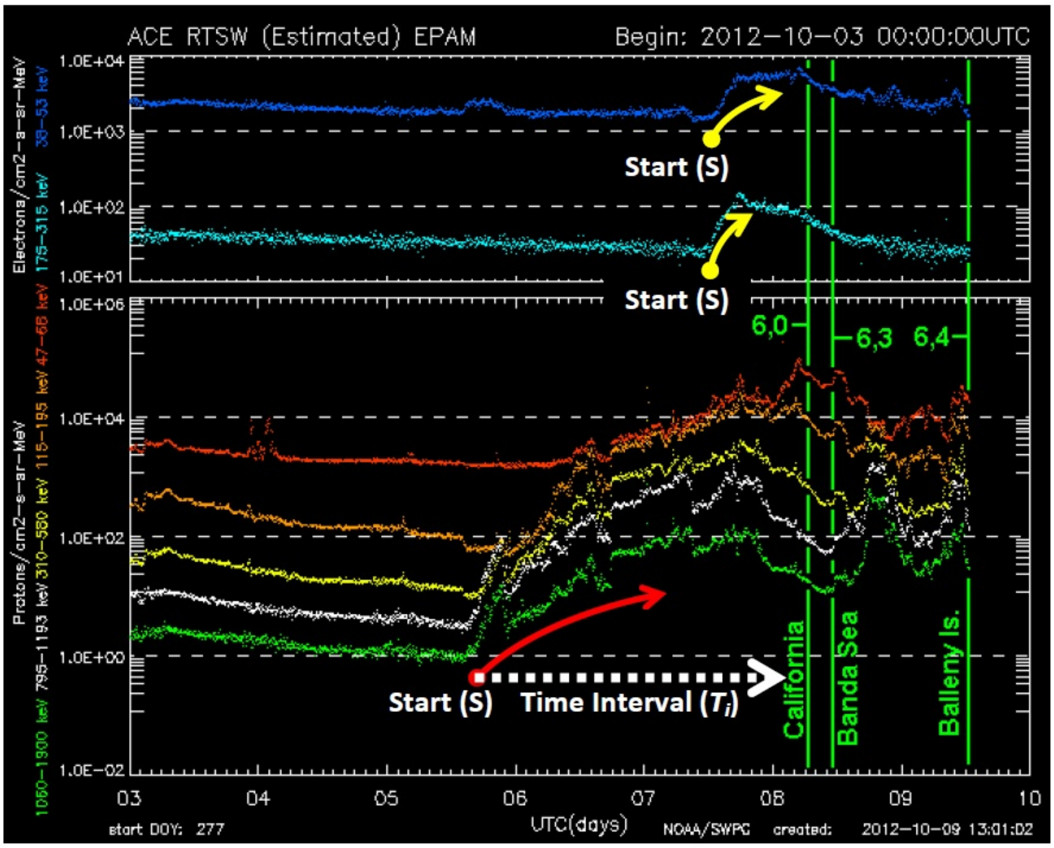

Figure 1. Densitogram of the ions in the interplanetary medium at L1 Lagrange point. Data recorded by ACE (Advanced Composition Explorer) Satellite, October 3-9, 2012. The vertical green lines indicate the time markers for M6+ earthquakes occurred on a global scale, October 8-9, 2012; the green numbers indicate the magnitude (Mw). The red arrow indicates the start (S) and direction of the "gradual" proton increase recorded preceding the M6+ earthquakes. The two yellow arrows indicate the start of the "gradual" electronic increase that preceded the earthquakes examined. The horizontal white arrow indicates the time interval (T*i*) which separates the start of the increase in the proton density and the associated seismic event.

A problem arises when measuring the basic level between two proton increments because of one increment superimposing on the other. The phenomenon, which happens frequently, of a proton increment being superimposed on another one is due to the Sun's dynamics and therefore to the various causes that can produce an ion ejection. When two proton increments overlap leading to the formation of a longer wave, the two waves are simply added together, and the observation of the decrease of ionic density in the following days will identify the basic level.

Referring to **Fig. 2**, which outlines the curve of the proton density variation observed preceding potentially destructive earthquakes in the years 2012, 2013 and 2014, four time intervals were analyzed as follows:
A) during the increase phase of the proton density;
B) at the maximum value recorded of the proton density;
C) during the decrease phase of the proton density;
D) after the complete decrease of the proton density which restored to the basic level.

Basic level in this study refers to the proton density whose energy is included within 1220 and 761 keV (values derived from the ISWA charts) and within 1900 and 1060 keV (EPAM charts). The basic level of protons that have this type of energy corresponds exactly to 0.1-0.5 particles / cm^2/s.

From the experimental observations on M6+ earthquakes occurred in the period between 2012 and 2014 as listed in **Table 1**, the frequencies resulted as follows in the Discussion section.

Tab. 1 Number of M6+ earthquakes that occurred on a global scale in the years 2012, 2013, 2014, compared with the total 428 of the three years considered, in the intervals A, B, C, D (Fig. 2).

	2012	**2013**	**2014**
Interval A 145/428 (33,96%)	42/133	46/142	57/153
Interval B 32/428 (7,49%)	14/133	11/142	7/153
Interval C 214/428 (50,12%)	70/133	70/142	74/153
Interval D 36/428 (8,43%)	7/133	15/142	14/153
Number of M6+ earthquakes	133	142	153

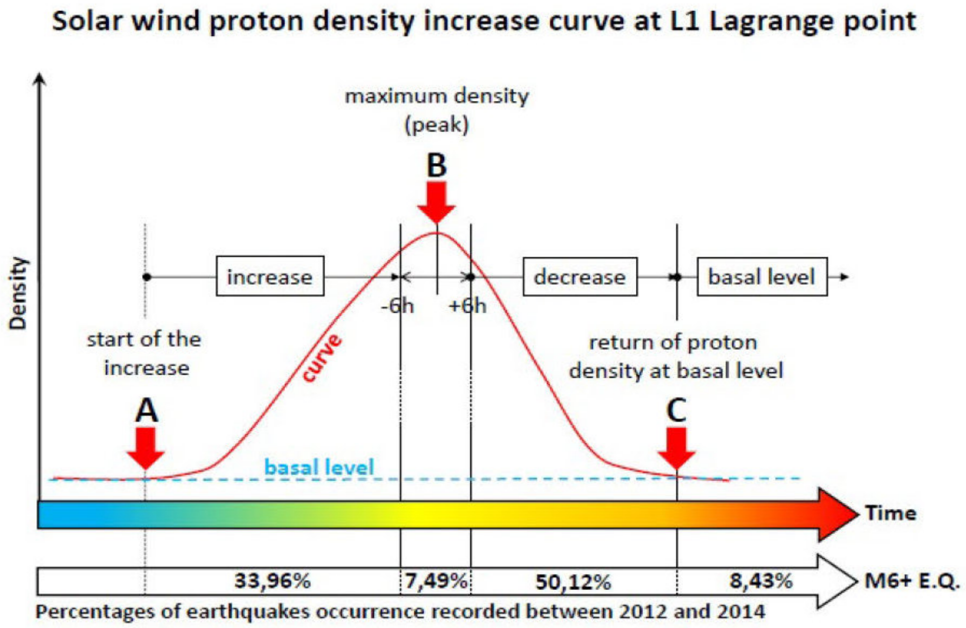

Figure 2. Increase in the proton density of the solar wind as represented in Figure 1, which precedes the earthquakes examined. A refers to the increase phase of the proton density; B refers to the maximum value recorded of the proton density (±6 from the max.); C refers to the decrease phase of the proton density; D refers to the complete decrease of the proton density which restored to the basic level. Where A+B+C+D= 428/428 earthquakes (100%).

DISCUSSION

Between 2012 and 2014, the global seismicity began to increase (**Table 1)** while the solar activity was subject to fluctuations, as reported in the NOAA data (http://services.swpc.noaa.gov/images/solar-cycle-planetary-a-index.gif), after its rise culminated in 2012. In the time interval considered, the solar activity began to weaken and fluctuate because of the absence of spot groups, gathered in extended solar regions.

As illustrated in **Figure 3**, the distribution of earthquakes along the curve of the proton density variation is repeated every year approximately at the same percentage, regardless of the number of M6+ earthquakes. This indicates that the observed phenomenon is objective and recurring.

Table 2. M6+ earthquakes frequency (%) in the intervals A, B, C, D (Fig. 2) in the years 2012, 2013, 2014.

	2012	2013	2014	Average 2012-2014
P_A	31.58%	32.39%	37.50%	33.88%
P_B	10.53%	7.75%	4.61%	7.48%
P_C	52.63%	49.30%	48.68%	5.23%
P_D	5.26%	10.56%	9.21%	8.41%

Assuming that the M6+ seismic events were completely unrelated to the occurrence of solar events, the probability that a seismic event occurred in a definite phase would be equal to the average relative duration of that phase. Considering that the average duration of the complete cycle is T_{Tot}=11.21 days (100%), each phase has a duration: T_A=1.01 days, T_B=1.68 days, T_C=3.1 days, T_D=5.42 days, it follows that:

$$P_{unrelated\ A} = T_A / T_{Tot} = 9\%$$
$$P_{unrelated\ B} = T_B / T_{Tot} = 14.89\%$$
$$P_{unrelated\ C} = T_C / T_{Tot} = 27.65\%$$
$$P_{unrelated\ D} = T_D / T_{Tot} = 48.34\%$$

Thus, the values are consistent within the three years analyzed and considerably different from those deriving from the hypothesis that the two phenomena are unrelated.

The following calculation does not compare $P_{unrelated}$ with single years but with an average value over the complete period, since the durations of A, B, C and D, wherefrom $P_{unrelated\ A}$, $P_{unrelated\ B}$, $P_{unrelated\ C}$, $P_{unrelated\ D}$ derive, are average durations over the whole period and not per single year; comparing homogeneous data seems therefore legitimate.

The odds ratio of occurrence may be understood more correctly as the ratio of observed frequency and expected frequency on the assumption of independent phenomena. Rather than the data reliability, this value denotes more appropriately what indications emerge from the data, and whether they are solid and consistent. When the values are all close to 1, there is no link between the two phenomena, whereas if some of the values are remarkably far from 1, a link is assumed to be present.

The data cannot be evaluated singularly but as a whole since it is obvious that if one is greater than 1, the other data will be less than 1 due to a compensation effect. In particular, determining the odd ratio between two occurrence probabilities, it follows that:

$$P_{A\ mean} / P_{unrelated\ A} = 3.76$$
$$P_{B\ mean} / P_{unrelated\ B} = 0.49$$
$$P_{C\ mean} / P_{unrelated\ C} = 1.81$$
$$P_{D\ mean} / P_{unrelated\ D} = 0.17$$

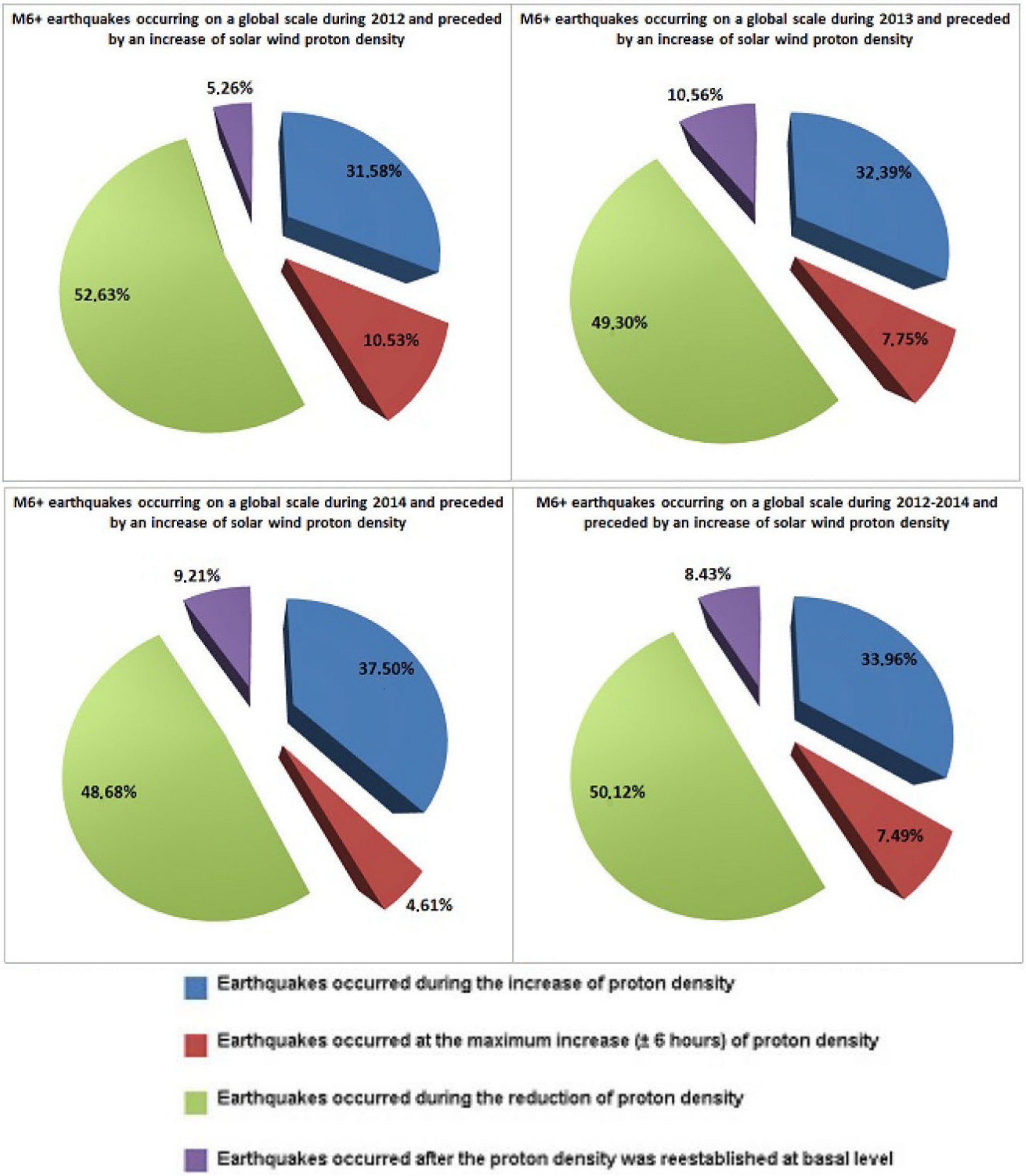

Figure 3. M6+ earthquakes occurring on a global scale during 2012-2014 and preceded by an increase of solar wind proton density in the intervals A+B+C+D represented in Fig. 2.

Observing the data, it results that there is a much greater frequency of M6+ seismic events in the (A) increase and (C) decrease phases compared with the hypothesis of unrelated phenomena, whereas in the peak phase (B) and the basic level (D) the detected frequency is much lower.

Rather than establishing a connection with the intensity of the solar phenomenon, this behavior suggests a link with the variation in its intensity and the global seismic activity with magnitude greater than >M6 on the Richter Scale. If an ionic variation is in progress, earthquakes occur more frequently, while if the proton density levels off avoiding any further increase or decrease, the earthquakes occur less frequently. Thus, the disturbances in the geomagnetic field happen irrespective of its absolute value, i.e. the maximum or minimum value reached at a given time, but only considering the oscillations that occur over a time period.

However, if we consider the data aiming at short-term prediction, we see that the average time interval (T*i*) recorded between the start (S) of the “gradual” increase in the proton density and the M6+ earthquakes occurred on a global scale, was 146 hours. The maximum time interval, 784 hours, was recorded preceding the M7.0 earthquake that occurred in Indonesia, April 6, 2013. The minimum time interval, 1 hour, was recorded during the M6.0 earthquake that occurred in Mariana Islands, November 19, 2013, the M6.5 earthquake in Barbados, February 18, 2014 and the M6.0 earthquake in Papua New Guinea, M6.0, May 10, 2014.

CONCLUSION

The analysis of the data shows a connection between the earthquakes examined in this study and the gradual increase of ionic density of the interplanetary medium (**Fig. 1**) caused by a solar flare or by the presence of a coronal hole. Since the ionic increase of the interplanetary medium is derived from an increase in the solar activity and since the M6+ earthquakes occurred on a global scale in the time period from 2012 and 2014 were preceded by an ionic increase in the solar wind, this approach could be tested to promptly predict a resumption of M6+ seismic activity on a global scale.

In conclusion, we believe that it would be worth investigating in further studies and projects, and in an interdisciplinary context, the possible link between the ionic increase of the interplanetary medium with potentially destructive earthquakes of magnitude greater than or equal to M6.

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REFERENCES CITED

Akhoondzadeh, M., 2013. Novelty detection in time series of ULF magnetic and electric components obtained from DEMETER satellite experiments above Samoa (29 September 2009) earthquake region. *NHSS (Natural Hazards and Earth System Sciences)*, v. 13, p. 15–25.

Abdussamatov, H.I., 2012. Bicentennial Decrease of the Total Solar Irradiance Leads to Unbalanced Thermal Budget of the Earth and the Little Ice Age. *Applied Physics Research*, v. 4, no. 1; February 178 ISSN 1916–9639 E-ISSN 1916–9647.

Athanasiou, M.A., Anagnostopoulos, G.C., Iliopoulos, A.C., Pavlos, G. P. and David, C.N., 2011. Enhanced ULF radiation observed by DEMETER two months around the strong 2010 Haiti earthquake. *NHSS (Natural Hazards and Earth System Sciences)*, v. 11, p. 1091–1098.

Balasis, G., Daglis, I.A., Anastasiadis, A., Papadimitriou, C., Mandea, M. and Eftaxias, K., 2011. Universality in solar flare, magnetic storm and earthquake dynamics using Tsallis statistical mechanics. *Physica A*, no. 390, p. 341–346.

Chavez, O., Millan-Almaraz, J.R., Perez-Enriquez, R., Arzate-Flores, J.A., Kotsarenko, A., Cruz-Abeyro, J.A. and Rojas, E., 2010. Detection of ULF geomagnetic signals associated with seismic events in Central Mexico using Discrete Wavelet Transform. *NHSS (Natural Hazards and Earth System Sciences)*, v. 10, p. 2557–2564.

Choi, D. R. and Maslov, L., 2010. Earthquakes and solar activity cycles. *New Concepts in Global Tectonics Newsletter*, no. 57, p. 85–97.

Du, A., Zhou, Z., Xu W. and Yang, S. 2004. Generation Mechanism of ULF electromagnetic emissions before the ML = 7.1 earthquake at Hotan. *Chinese Journal of Geophysics*, v. 47, no. 5, p. 939–945.

Fraser-Smith, A. C., 2008., Ultralow-Frequency Magnetic Fields Preceding Large Earthquakes, Departments of Electrical Engineering and Geophysics, Stanford University, Stanford, Calif. *FORUM, EOS*, v. 89, no. 23, p. 211.

Hattori, K., Takahashi, I., Yoshino, C., Isezaki, N., Iwasaki, H., Harada, M., Kawabata, K., Kopytenko, E., Kopytenko, Y., Maltsev, P., Korepanov, V., Molchanov, O., Hayakawa, M., Noda, Y., Nagao, T. and Uyeda, S., 2004. ULF geomagnetic field measurements in Japan and some recent results associated with Iwateken Nairiku Hokubu Earthquake in 1998. *Phys. Chem. Earth*, v. 29, p. 481–494.

Hayakawa, M., Hattori, K. and Ohta, K., 2007. Monitoring of ULF (ultra-low-frequency) Geomagnetic Variations Associated with Earthquakes. *Sensor*, v. *7*, n.o 7, p. 1108–1122.

He, L., Wu, L., Pulinets, S., Liu, S. and Yang. F., 2012. A nonlinear background removal method for seismo-ionospheric anomaly analysis under a complex solar activity scenario: A case study of the M9.0 Tohoku earthquake. *Advances in Space Research*, v. 50, p. 211–220.

Jusoh, M.H. and Yumoto, K., 2011. Possible correlation between solar activity and global seismicity. Space Environment Research Center of Kyushu University, ISW/MAGDAS School, Lagos, Nigeria. Proceedings.

Kotsarenko, A., Perez Enriquez, R., Lopez Cruz-Abeyro, J.A., Koshevaya, S., Grimalsky, V. and Zuniga, F.R., 2004. Analysis of the ULF electromagnetic emission related to seismic activity, Teoloyucan geomagnetic station, 1998–2001. *NHSS (Natural Hazards and Earth System Sciences),* v. 4, p. 679–684, SRef-ID: 1684–9981/nhess/2004-4-679, European Geosciences Union.

Kotsarenko, A., Molchanov, O., Perez Enriquez, R., Lopez Cruz-Abeyro, J. A., Koshevaya, S., Grimalsky, V. and Kremenetsky, I., 2005.Possible seismogenic origin of changes in the ULF EM resonant structure observed at Teoloyucan geomagnetic station, Mexico, 1999–2001. *NHSS (Natural Hazards and Earth System Sciences)*, v. 5, p. 711–715.

Kotsarenko, A., Grimalsky, V., Perez Enriquez, R., Valdez-Gonzalez, C., Oshevaya, S., Lopez Cruz-Abeyro, J. A. and Yutsis , V., 2007. Volcano Popocatepetl, Mexico: ULF geomagnetic anomalies observed at Tlamacas station during March-July, 2005. *NHSS (Natural Hazards and Earth System Sciences),* v. 7, p. 103–107.

Ismaguilov, V.S., Kopytenko, Yu.A., Hattori, K. and Hayakawa, M., *2003.* Variations of phase velocity and gradient values of ULF geomagnetic disturbances connected with the Izu strong earthquakes. European Geosciences Union 2003, *NHSS (Natural Hazards and Earth System Sciences),* v. 3, p. 211–215.

Li, M., Lu, J., Parrot, M., Tan, H., Chang, Y., Zhang, X. and Wang, Y., 2013. Review of unprecedented ULF electromagnetic anomalous emissions possibly related to the Wenchian Ms = 8,0 earthquake, on 12 May 2008, *NHSS (Natural Hazards and Earth System Sciences),* v. 13, p. 279–286.

Mazzarella, A. and Palumbo, A., 1988. Solar, geomagnetic and seismic activity. *Nuovo Cimento C*, Serie 1, v. 11c, p. 353–364.

Odintsov, S., Boyarchuk, K., Georgieva, K., Kirov, B. and Atanasov, D., 2006. Long-period trends in global seismic and geomagnetic activity and their relation to solar activity. *Physics and Chemistry of the Earth*, v. 31, p. 88–93.

Prattes, G., Schwingenschh, K., Eichelberger H.U., Magnes, W.M., Boudjada, M., Stachel, M., Vellante, M., Wesztergom, V. and Nenovski, P., 2008. Multi-point ground-based ULF magnetic field observations in Europe during seismic active periods in 2004 and 2005. *NHSS (Natural Hazards and Earth System Sciences)*, v. 8, p. 501–507.

Simpson, J.F., 1967. Solar activity as a triggering mechanism for earthquakes. *Earth and Planetary Science Letters*, v. 3, p. 417–425.

Straser, V. and Cataldi, G., 2014. Solar wind proton density increase and geomagnetic background anomalies before strong m6+ earthquakes, p. 280-286. Proceedings of MSS–14, Space Research Institute, Moscow.

Takayama, T. and Suzuki, T., 1990. On the relation between the sunspot number and the destructive earthquakes in Japan. *Bull. Earthquake Research Institute of Tokyo Imperial University*, v. 8, no. 3, p. 373–374.

Takla, E. M., Yumoto, K., Liu, J. Y., Kakinami, Y., Uozumi, T., Abe, S. and Ikeda, A., 2011. Anomalous geomagnetic variations possibly linked with the Taiwan earthquake (Mw = 6.4) on 19 December 2009. *International Journal of Geophysics*, vol. 2001, Article ID 848467, p. 10.

Tavares, M. and Azevedo, A., 2011. Influences of solar cycles on earthquakes. *Natural Science 3*, v. 3, no. 6, p. 436–443.

Yanben, H., Zengjian, G., Jibing, W. and Lihua, M., 2004. Possible triggering of solar activity to big earthquakes (Ms ≥ 8) in faults with near west-east strike in China. *Science in China Ser. G. Physics, Mechanics and Astronomy*. v. 47, no. 2, p. 173–181.

Zhang, G-Q., 1998. Relationship between global seismicity and solar activities. A*cta Seismologica Sinica*, v. 11, p. 495–500.

Websites cited

E.M.S.C. – European-Mediterranean Seismological Centre – http://www.emsc-csem.org/
Harvard-Smithsonian Center for Astrophysics – https://www.cfa.harvard.edu/
I.N.G.V. – Istituto Nazionale di Geofisica e Vulcanologia – http://cnt.rm.ingv.it/
I.S.W.A. – Integrated Space Weather Analysis System – http://iswa.ccmc.gsfc.nasa.gov/IswaSystemWebApp /
N.A.S.A. – National Aeronautics and Space Administration – http://www.nasa.gov/
N.O.A.A. – National Oceanic and Atmospheric Administration – http:// www.noaa.gov/
S.A.O./N.A.S.A. Astrophysics Data System – http://adswww.harvard.edu/
U.S.G.S. – United States Geological Survey – http://earthquake.usgs.gov/

APPENDIX

Study of relationship between solar wind proton density variation and M6+ global seismic activity.

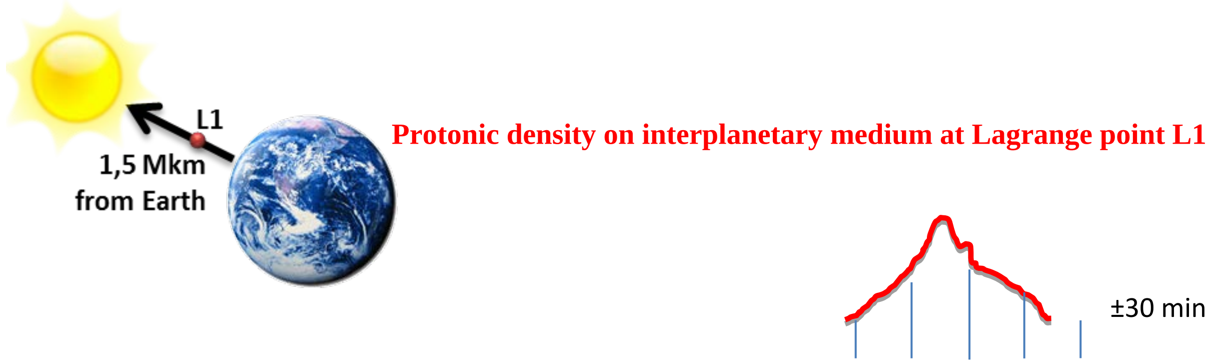
Total: 428 earthquakes, of which:

133 occurred in 2012

142 occurred in 2013

153 occurred in 2014

*Time lag recorded between the **ISP Start** and the **earthquake**
A: during the phase of increasing.
B: at the maximum level of proton density recorded (± 6 hours from the maximum).
C: during the phase of reduction of the proton density.
D: after complete reduction of proton density that has been reestablished to baseline.



Location Earthquake	Magnitude Mw	Data M/D/Y	HH:MM (UTC)	A	B	C	D		*Time Lag (hours)
Izu Idlands	6.2	Jan. 01,2012	05:27			X			183
Santa Cruz Islands	6.4	Jan. 09,2012	04:07				X		374
Northern Sumatra	7.2	Jan. 10,2012	18:36				X		384
South Shetland Islands	6	Jan. 15,2012	13:40	X					43
South Shetland Islands	6	Jan. 15,2012	14:41	X					44
Offshore Chiapas, Mexico	6.2	Jan. 20,2012	18:47	X					168
Sandwich Islands Region	6	Jan. 22,2012	05:53		X				203
Offshore Bio-Bio Chile	6.1	Jan. 23,2012	16:04	X					238
Fiji Islands	6.3	Jan. 24,2012	00:52	X					254
Near the coast of central Peru	6.4	Jan. 30,2012	05:11			X			403
Vanuatu	7.1	Feb. 02,2012	13:34			X			483
Vanuatu	6.1	Feb. 03,2012	03:46			X			497
Vanuatu	6.1	Feb. 05,2012	00:15			X			541
Vanuatu	6.1	Feb. 05,2012	16:40			X			557
Negros	6.7	Feb. 06,2012	03:49			X			568
Negros	6	Feb. 06,2012	10:10			X			574
Solomon Islands	6.4	Feb. 14,2012	08:19		X				75
Fiji Islands	6	Feb. 26,2012	05:21	X					91
Siberia, Russia	6.7	Feb. 26,2012	06:17	X					90
Loyalty Islands	6.6	Mar.03,2012	12:19			X			242
Santiago Del Estero	6.1	Mar.05,2012	07:46	X					25
Vanuatu	6.7	Mar.09,2012	07:09			X			121
Honshu, Japan	6.9	Mar.14,2012	09:08			X			243
Honshu, Japan	6.1	Mar.14,2012	10:49			X			244
Honshu, Japan	6	Mar.14,2012	12:05			X			246
Papua New Guinea	6.2	Mar.14,2012	21:13			X			255
Papua, Indonesia	6.1	Mar.20,2012	17:56			X			275
Oaxaca, Mexico	7.4	Mar.20,2012	18:02			X			276
Papua New Guinea	6.6	Mar.21,2012	22:15			X			300
Maule, Chile	7.1	Mar.25,2012	22:37	X					51
East Pacific Rise	6	Mar.26,2012	18:12	X					71
Honshu, Japan	6.1	Mar.27,2012	11:00	X					88
Oaxaca, Mexico	6	Apr.02,2012	17:36			X			238
Papua New Guinea	6.1	Apr.06,2012	16:15	X					42
Northern Sumatra	8.6	Apr.11,2012	08:38		X				53
North Indian Ocean	6	Apr.11,2012	09:27		X				54
Northern Sumatra	8.2	Apr.11,2012	10:43		X				55
Coast of Oregon	6	Apr.11,2012	22:41			X			57

Michiacan, Mexico	6.5	Apr.11,2012	22:55			X			57
Baja California, Mexico	6.5	Apr.12,2012	07:06			X			66
Baja California, Mexico	7	Apr.12,2012	07:15			X			66
Drake Passage	6.2	Apr.14,2012	10:56			X			117
Vanuatu	6.2	Apr.14,2012	22:05				X		129
Northern Sumatra	6.2	Apr.15,2012	05:57				X		136
Valparaiso, Chile	6.7	Apr.17,2012	03:50	X					16
Papua New Guinea	6.8	Apr.17,2012	07:13	X					19
Sandwich Islands	6.2	Apr.17,2012	19:03	X					32
Papua, Indonesia	6.7	Apr.21,2012	01:16	X					110
Papua, Indonesia	6	Apr.21,2012	01:25	X					110
Kermadec Islands	6	Apr.23,2012	17:36			X			174
Tonga	6.6	Apr.28,2012	10:08				X		49
Chiapas, Mexico	6	May 01,2012	22:43			X			55
Tarapaca	6.2	May 14,2012	10:00	X					73
Coast of Aisen, Chile	6.3	May 18,2012	02:00		X				27
Northern Italy	6	May 18,2012	02:03		X				27
Honshu, Japan	6.3	May 18,2012	07:20		X				32
Indian-Antarctic Ridge	6	May 23,2012	22:59			X			167
Norvegian Sea	6.1	May 24,2012	22:47			X			191
Bonin Islands	6	May 26,2012	21:48	X					27
Santiago Del Estero	6.7	May 28,2012	05:07		X				58
South of Panama	6.3	June 03,2012	00:45			X			31
South of Panama	6.3	June 04,2012	03:15			X			60
Honshu, Japan	6.1	June 05,2012	19:31			X			97
Maule, Chile	6	June 07,2012	04:05			X			130
Southern Peru	6.1	June 08,2012	16:03			X			142
Dodecanese Islands, Greece	6.3	June 12,2012	12:44	X					258
Honshu, Japan	6.3	June 17,2012	20:32			X			74
Aleutian Islands, Alaska	6	June 19,2012	15:56			X			117
Northern Sumatra	6.1	June 23,2012	04:34			X			202
Kamchatka Peninsula, Russia	6	June 24,2012	03:15			X			225
Northern Xinjiang, China	6.3	June 29,2012	21:07	X					26
Cook Strait, New Zealand	6.3	July 03,2012	10:36			X			111
Vanuatu	6.3	July 06,2012	02:28	X					27
Kuril Islands	6	July 08,2012	11:32	X					84
Kuril Islands	6	July 20,2012	06:10			X			189
Simeulue, Indonesia	6.4	July 25,2012	00:27			X			303
Solomon Islands	6.4	July 25,2012	11:20			X			314
Mauritius, Reunion Region	6.7	July 26,2012	05:33			X			332
Papua New Guinea	6,5	July 28,2012	20:03			X			395
Central Perù	6.1	Aug. 02,2012	09:38	X					106
Papua New Guinea	6.1	Aug. 02,2012	09:56	X					106
Fox Islands, Alaska	6.2	Aug. 10,2012	18:37			X			139
Northwestern Iran	6.4	Aug. 11,2012	12:23			X			157
Northwestern Iran	6.2	Aug. 11,2012	12:34			X			157
Xinjiang-Xizang border region	6.2	Aug. 12,2012	10:37			X			179
Sea of Okhotsk	7.7	Aug. 14,2012	02:59			X			219
Sulawesi, Indonesia	6.3	Aug. 18,2012	09:41	X					13
Papua New Guinea	6.2	Aug. 19,2012	22:41	X					50
Molucca sea	6.6	Aug. 26,2012	15:05			X			211
El Salvador	7.3	Aug. 27,2012	04:37			X			224
Jan Mayen Island	6.8	Aug. 30,2012	13:43			X			305
Philippine Islands region	7.6	Aug. 31,2012	12:47			X			329
Java, Indonesia	6.1	Sept. 03,2012	18:23		X				62
Santa Cruz Islands	6	Sept. 05,2012	13:09			X			107
Costa Rica	7.6	Sept. 05,2012	14:42			X			108
Papua, Indonesia	6.1	Sept. 08,2012	10:51			X			177
Kepulauan Mentawai region	6.2	Sept. 13,2012	23:59			X			309
Baja California, Mexico	6.3	Sept. 25,2012	23:45	X					94
Aleutian Islands, Alaska	6.4	Sept. 26,2012	23:59	X					109
Colombia	7.3	Sept. 30,2012	16:31		X				207
Honshu, Japan	6.1	Oct. 01,2012	22:31			X			237
Banda Sea	6.1	Oct. 08,2012	11:43			X			69
Macquarie Island	6.6	Oct. 09,2012	12:32			X			95
Papua, Indonesia	6.6	Oct. 12,2012	00:31			X			155
Celebes Sea	6	Oct. 17,2012	04:42	X					8
Vanuatu	6.2	Oct. 20,2012	23:00			X			99
Costa Rica	6.5	Oct. 24,2012	00:45			X			173
Canada	7.8	Oct. 28,2012	03:04	X					9
Canada	6.3	Oct. 28,2012	18:54	X					25
Canada	6.2	Oct. 30,2012	02:49	X					56

Mindanao	6.1	Nov. 02,2012	18:17				X		144
Guatemala	7.4	Nov. 07,2012	16:36	X					88
Vancouver Island	6.1	Nov. 08,2012	02:01	X					98
Central Perù	6	Nov. 10,2012	14:57	X					53
Myanmar	6.8	Nov. 11,2012	01:12	X					64
Guatemala	6,5	Nov. 11,2012	22:14	X					85
Gulf of Alaska	6.3	Nov. 12,2012	20:42		X				107
Aisen, Chile	6.1	Nov. 13,2012	04:31		X				115
Coquimbo, Chile	6.1	Nov. 14,2012	19:02			X			154
Guerrero, Mexico	6.1	Nov. 15,2012	09:20			X			168
Kuril Islands	6.5	Nov. 16,2012	18:12			X			199
Papua New Guinea	6	Nov. 19,2012	09:44			X			30
Vanuatu	6.1	Dec. 02,2012	00:54			X			310
Honshu, Japan	7.3	Dec. 07,2012	08:18	X					27
Honshu, Japan	6.2	Dec. 07,2012	08:31	X					27
North Island of New Zealand	6.3	Dec. 07,2012	18:19	X					37
Banda Sea	7.1	Dec. 10,2012	16:53			X			107
Molucca sea	6.6	Dec. 11,2012	06:18			X			145
California	6.3	Dec. 14,2012	10:36	X					18
Aleutian Islands, Alaska	6	Dec. 15,2012	04:49		X				36
Papua New Guinea	6.1	Dec. 15,2012	19:30			X			51
Sulawesi, Indonesia	6.1	Dec. 17,2012	09:16			X			91
Vanuatu	6.7	Dec. 21,2012	22:28				X		198
									133 Earthquakes
Alaska	7.5	Jan. 05,2013	08:58				X		180
Pacific-Antarctic Ridge	6.1	Jan. 15,2013	16:09	X					76
Indonesia	6.1	Jan. 21,2013	22:22			X			121
Kazakhstan	6.1	Jan. 28,2013	16:38			X			57
Chile	6.8	Jan. 30,2013	20:15			X			108
Solomon Islands	6.1	Jan. 30,2013	23:03			X			111
Solomon Islands	6.1	Jan. 31,2013	03:33			X			115
Solomon Islands	6	Feb. 01,2013	05:36	X					3
Solomon Islands	6.4	Feb. 01,2013	18:33	X					15
Solomon Islands	6.3	Feb. 01,2013	22:16	X					19
Japan	6.9	Feb. 02,2013	14:17	X					35
Solomon Islands	6	Feb. 02,2013	18:58	X					39
Solomon Islands	6	Feb. 06,2013	00:07			X			117
Solomon Islands	8	Feb. 06,2013	01:12			X			118
Solomon Islands	7.1	Feb. 06,2013	01:23			X			118
Solomon Islands	7	Feb. 06,2013	01:54			X			119
Solomon Islands	6	Feb. 06,2013	10:33			X			127
Solomon Islands	6	Feb. 06,2013	11:53			X			129
Solomon Islands	6	Feb. 07,2013	00:30			X			141
Solomon Islands	6.7	Feb. 07,2013	18:59	X					159
Solomon Islands	6.8	Feb. 08,2013	11:12		X				15
Solomon Islands	7.1	Feb. 08,2013	15:26		X				19
Colombia	6.9	Feb. 09,2013	14:16			X			42
Solomon Islands	6.6	Feb. 09,2013	21:02			X			49
Solomon Islands	6	Feb. 09,2013	18:39			X			166
Russia	6.6	Feb. 14,2013	13:13	X					28
Philippines	6.1	Feb. 16,2013	04:37			X			67
Argentina	6.1	Feb. 22,2013	12:01			X			219
Russia	6.9	Feb. 28,2013	14:05			X			110
Russia	6.4	Mar. 01,2013	12:53			X			133
Russia	6.5	Mar. 01,2013	13:20			X			133
Papua New Guinea	6.5	Mar. 10,2013	22:51	X					154
Fiji	6.1	Mar. 24,2013	08:13			X			476
Guatemala	6.2	Mar. 25,2013	23:02			X			515
Japan	6	Apr. 01,2013	18:53		X				678
Russia	6.3	Apr. 05,2013	13:00				X		769
Indoneia	7	Apr. 06,2013	04:42				X		784
Iran	6.4	Apr. 09,2013	11:52	X					28
Vanuatu	6	Apr. 13,2013	22:49		X				104
Papua New Guinea	6.6	Apr. 14,2013	01:32		X				138
Iran	7.7	Apr. 16,2013	10:44			X			195
Papua New Guinea	6.6	Apr. 17,2013	23:55			X			232
Russia	7.2	Apr. 19,2013	03:05	X					9
Russia	6.1	Apr. 19,2013	19:58	X					25
China	6.6	Apr. 20,2013	00:02	X					30
Russia	6.1	Apr. 20,2013	13:12	X					43
Izu Islands, Japan	6.1	Apr. 21,2013	03:22	X					57
Papua New Guinea	6.5	Apr. 23,2013	23:14			X			125

New Zealand	6.1	Apr. 26,2013	06:53		X				25
New Zealand	6.2	Apr. 26,2013	06:53		X				25
Solomon Islands	6	May 06,2013	10:33			X			127
Ceva-i-Ra, Fiji	6	May 07,2013	10:10			X			118
Iran	6.1	May 11,2013	02:08	X					40
Tonga	6.4	May 11,2013	20:46	X					58
Mariana Islands	6.8	May 14,2013	00:32	X					110
Japan	6	May 18,2013	05:47		X				211
Chile	6.4	May 20,2013	09:49			X			264
Russia	6	May 21,2013	01:55			X			279
Russia	6.1	May 21,2013	05:43			X			253
Tonga	7.4	May 23,2013	17:19	X					28
Tonga	6.3	May 23,2013	21:07	X					32
Sea of Okhotsk	8.3	May 24,2013	05:44	X					40
Sea of Okhtsk	6.7	May 24,2013	14:46	X					49
Taiwan	6.2	June 02,2013	05:43		X				67
Solomon Islands	6,1	June 05,2013	04:47			X			138
Christmas Island	6.7	June 13,2013	16:47				X		342
Kermadec Islands	6	June 15,2013	11:20				X		385
Greece	6.2	June 15,2013	16:11				X		390
Nicaragua	6.5	June 15,2013	17:34				X		391
Greece	6	June 16,2013	21:39				X		10
Northern Mid-Stlantic Ridge	6.6	June 24,2013	22:04			X			202
Indonesia	6.1	July 02,2013	07:37			X			98
Papua New Guinea	6.1	July 04,2013	17:16			X			156
Indonesia	6	July 06,2013	05:05	X					18
Papua New Guinea	7.3	July 07,2013	18:35	X					55
Papua New Guinea	6.6	July 07,2013	20:30	X					57
Sandwich Islands	7.3	July 15,2013	14:03	X					50
Papua New Guinea	6	July 16,2013	09:35	X					69
Peru	6	July 17,2013	02:37	X					86
New Zealand	6.5	July 21,2013	05:09			X			185
Prince Edward Islands	6.1	July 22,2013	07:01			X			211
Vanuatu	6.1	July 26,2013	07:07			X			307
Sandwich Islands	6,2	July 26,2013	21:32			X			321
Tonga	6	Aug. 01,2013	20:01				X		464
Indonesia	6	Aug. 12,2013	00:53				X		708
New Zealand	6.1	Aug. 12,2013	04:16				X		712
Peru	6.2	Aug. 12,2013	09:49				X		717
Colombia	6.7	Aug. 13,2013	15:43				X		9
New Sealand	6.5	Aug. 16,2013	02:31	X					68
Indian Ridge	6.1	Aug. 17,2013	16:32	X					106
Mexico	6.2	Aug. 21,2013	12:38		X				19
New Zealand	6.2	Aug. 28,2013	02:54			X			62
Alaska	7	Aug. 30,2013	16:25	X					19
Alaska	6	Aug. 31,2013	06:38	X					33
Indonesia	6.5	Sep. 01,2013	11:52	X					109
Canada	6.1	Sep. 03,2013	20:19			X			119
Izu Islands, Japan	6.5	Sep. 04,2013	00:18			X			123
Canada	6	Sep. 04,2013	00:23			X			123
Alaska M	6.5	Sep. 04,2013	02:32			X			125
Alaska	6	Sep. 04,2013	06:27			X			129
Northern Mid-Atlantic Ridge	6	Sep. 05,2013	04:01			X			151
Guatemala	6.4	Sep. 08,2013	00:13			X			219
Central East Pacific Rise	6.1	Sep. 11,2013	12:44				X		303
Alaska	6.1	Sep. 15,2013	16:21				X		392
Indonesia	6.1	Sep. 21,2013	01:39			X			61
Pakistan	7.7	Sep. 24,2013	11:29			X			143
Southern East Pacific Rise	6,1	Sep. 25,2013	06:51	X					13
Peru	7.1	Sep. 25,2013	16:42	X					23
Pakistan	6.8	Sep. 28,2013	07:34	X					85
New Zealand	6.5	Sep. 30,2013	05:55	X					130
Sea of Okhotsk	6.7	Oct.01-ott-13	03:38	X					152
Amsterdam Island	6.4	Oct.04,2013	17:26			X			240
Mariana Islands region	6	Oct.06,2013	16:38			X			287
West Chile Rise	6.2	Oct.06,2013	21:33			X			291
New Zealand	6.2	Oct.11,2013	21:25			X			84
Veneziela	6	Oct.12,2013	02:10			X			89
Greece	6.6	Oct.12,2013	13:11			X			100
Philippines	7.1	Oct.15,2013	00:12	X					28
Papua New Guinea	6.8	Oct.16,2013	10:30	X					69
Mexico	6.6	Oct.19,2013	17:54			X			141

Tonga	6	Oct.23,2013	08:23	X					66
Sandwich Islands	6.7	Oct.24,2013	19:25			X			101
Honshu, Japan	7.1	Oct.25,2013	17:10			X			123
Chile	6.2	Oct.30,2013	02:51	X					94
Taiwan	6.3	Oct.31,2013	12:02			X			128
Chile	6.6	Oct.31,2013	23:03			X			139
Easter Island region	6	Nov. 02,2013	15:52			X			179
Tonga	6.2	Nov. 02,2013	18:53			X			183
Russia	6.4	Nov. 12,2013	07:03	X					173
Scotia Sea	6.1	Nov. 13,2013	23:45			X			213
Scotia Sea	6.9	Nov. 16,2013	03:34			X			265
Scotia Sea	7.7	Nov. 17,2013	09:04			X			295
Indonesia	6	Nov. 19,2013	13:32	X					1
Mariana Islands	6	Nov. 19,2013	17:00	X					5
Fiji	6.5	Nov. 23,2013	07:48			X			91
Russia	6	Nov. 25,2013	05:56			X			137
Falkland Islands region	7	Nov. 25,2013	06:27			X			138
South Atlantic Ocean	6	Nov. 25,2013	07:21			X			139
Indonesia	6.4	Dec. 01,2013	01:24	X					29
Indonesia	6	Dec. 01,2013	06:29		X				34
Russia	6	Dec. 08,2013	17:24			X			53
Mariana Islands	6.2	Dec. 17,2013	23:38			X			134
									142 Earthquakes
Vanuatu	6.5	Jan. 01,2014	16:03			X			243
Puerto Rico	6.4	Jan. 13,2014	04:01			X			197
New Zealand	6.1	Jan. 20,2014	02:52			X			363
Tonga	6.1	Jan. 21,2014	01:29	X					9
Indonesia	6.1	Jan. 25,2014	05:14			X			110
Greece	6.1	Jan. 26,2014	13:55			X			141
Visokoi Islands	6.1	Feb. 01,2014	03:58	X					2
New Zealand	6.5	Feb. 02,2014	09:26	X					32
Greece	6	Feb. 03,2014	03:08	X					50
Vanuatu	6.5	Feb. 07,2014	08:40			X			153
Papua New Guinea	6	Feb. 09,2014	14:56			X			205
China	6.9	Feb. 12,2014	09:19	X					35
Barbados	6.5	Feb. 18,2014	09:27	X					1
Alaska	6.1	Feb. 26,2014	21:13	X					42
Nicaragua	6.3	Marc. 02,2014	09:37			X			100
Japan	6.5	Marc. 02,2014	20:11			X			111
Mexico	6	Marc. 02,2014	22:17			X			113
Vanuatu	6.3	Marc. 05,2014	09:56			X			198
California	6.8	Marc. 10,2014	05:18			X			314
Sandwich Islands	6.4	Marc. 11,2014	02:44			X			335
Papua New Guinea M6,1	6.1	Marc. 11,2014	22:03			X			355
Japan	6.3	Marc. 13,2014	17:06	X					39
Peru	6.1	Marc. 15,2014	08:59			X			78
Peru	6.3	Marc. 15,2014	23:51			X			93
Chile	6.7	Marc. 16,2014	21:16			X			115
Chile	6.4	Marc. 17,2014	05:11			X			123
India	6.4	Marc. 21,2014	13:41	X					8
Chile	6.2	Marc. 22,2014	12:59	X					30
Chile	6.2	Marc. 23,2014	18:20	X					60
Fiji	6.3	Marc. 26,2014	03:29			X			117
Solomon Islands	6	Marc. 27,2014	03:49			X			141
Chile	8.2	Apr. 01,2014	23:46			X			281
Chile	6.9	Apr. 01,2014	23:57			X			282
Panama	6	Apr. 02,2014	16:13	X					8
Chile	6.5	Apr. 03,2014	01:48	X					18
Chile	7.7	Apr. 03,2014	02:43	X					19
Chile	6.4	Apr. 03,2014	05:26	X					22
Chile	6.3	Apr. 04,2014	01:37	X					42
Solomon Islands	6	Apr. 04,2014	11:40	X					52
Nicaragua	6.1	Apr. 10,2014	23:27			X			209
Chile	6.2	Apr. 11,2014	00:01			X			210
Papua New Guinea	7.1	Apr. 11,2014	07:07			X			217
Papua New Guinea	6.5	Apr. 11,2014	08:16			X			218
Nicaragua	6.6	Apr. 11,2014	20:29			X			230
Papua New Guinea	6.1	Apr. 12,2014	05:24			X			237
Solomon Islands	7.6	Apr. 12,2014	20:14			X			252
Solomon Islands	7.4	Apr. 13,2014	12:36			X			268
Solomon Islands	6.6	Apr. 13,2014	13:24			X			269
Bouvet Island region	6.8	Apr. 15,2014	03:53			X			307

Balleny Islands region	6.2	Apr. 17,2014	15:06	X					16
Solomon Islands	6.1	Apr. 18,2014	04:13	X					27
Mexico	7.2	Apr. 18,2014	14:27	X					37
Papua New Guinea	6.6	Apr. 19,2014	01:04	X					48
Papua New Guinea	7.5	Apr. 19,2014	13:"8	X					60
Papua New Guinea	6.2	Apr. 20,2014	01:15	X					72
Canada	6.5	Apr. 24,2014	03:10			X			170
Tonga	6.1	Apr. 26,2014	06:02			X			221
New Caledonia	6.6	May 01,2014	06:36	X					4
Fiji	6.6	May 04,2014	09:15			X			78
Fiji	6.3	May 04,2014	09:25			X			78
Japan	6	May 04,2014	20:18			X			79
Thailand	6.1	May 05,2014	11:08			X			104
Chile	6.3	May 06,2014	20:52			X			137
Papua New Guinea	6	May 07,2014	04:20	X					1
Mexico	6.4	May 08,2014	17:00	X					36
Mexico	6	May 10,2014	07:36			X			76
East Pacific Rise	6.6	May 12,2014	18:35			X			135
Panama	6.5	May 13,2014	06:35			X			148
Micronesia	6.1	May 14,2014	20:46			X			185
Micronesia	6.3	May 15,2014	08:16	X					7
Philippines	6.3	May 15,2014	10:16	X					9
Sumatra	6	May 18,2014	01:02			X			72
India	6	May 21,2014	16:21	X					18
Greece	6.9	May 24,2014	09:25			X			82
Mexico	6.2	May 31,2014	11:35			X			126
South Indian Ocean	6.5	June 14,2014	11:10		X				30
Vanuatu	6.2	June 19,2014	10:17			X			23
New Zealand	6.9	June 23,2014	19:19	X					13
New Zealand	6.5	June 23,2014	19:21	X					13
New Zealand	6.7	June 23,2014	20:06	X					14
Alaska	7.9	June 23,2014	20:53	X					15
Alaska	6	June 23,2014	21:11	X					16
Alaska	6	June 23,2014	21:30	X					16
Alaska	6	June 23,2014	22:29	X					17
Alaska	6.3	June 24,2014	03:15	X					21
Japan	6.2	June 29,2014	05:56				X		144
Visokoi Island	6.9	June 29,2014	07:52				X		146
Visokoi Island	6	June 29,2014	14:32				X		153
Wallis & Fortuna	6.4	June 29,2014	15:52				X		154
Wallis & Fortuna	6.7	June 29,2014	17:15				X		156
Japan	6.2	June 30,2014	19:55				X		159
Balleny Islands	6	July 02,2014	06:53				X		241
New Zealand	6.3	July 03,2014	20:50	X					14
Papua New Guinea	6.5	July 04,2014	16:00	X					34
Indonesia	6	July 05,2014	10:39	X					52
Mexico	6.9	July 07,2014	11:23	X					101
Vanuatu	6.2	July 08,2014	12:56	X					126
Japan	6.5	July 11,2014	19:22	X					18
Philippines	6.3	July 14,2014	09:59		X				80
Alaska	6	July 15,2014	11:49			X			106
Tonga	6.2	July 19,2014	12:27			X			203
Owen Fracture Zone region	6	July 19,2014	14:14			X			205
Russia	6.2	July 20,2014	18:32			X			234
Fiji	6.9	July 21,2014	14:54				X		253
Alaska	6.1	July 25,2014	10:54				X		345
Northern Mid-Atlantic Ridge	6	July 27,2014	01:28	X					13
Northern Mid-Atlantic Ridge	6.6	July 27,2014	01:28	X					13
Mexico	6.3	July 29,2014	10:46	X					70
Papua New Guinea	6	July 29,2014	13:27	X					73
Microneria region	6.9	Aug. 03,2014	00:22			X			122
China	6.2	Aug. 03,2014	08:30			X			130
Japan	6.1	Aug. 10,2014	03:43			X			125
Iran	6.2	Aug. 18,2014	02:32		X				63
Iran	6	Aug. 18,2014	18:08			X			79
Chile	6.4	Aug. 23,2014	22:32	X					29
California	6	Aug. 24,2014	10:20	X					79
Peru	6.8	Aug. 24,2014	23:21		X				92
Tonga	6	Sept.04,2014	05:33	X					338
Easter Island region	6.1	Sept.06,2014	06:53		X				387
Mexico	6.2	Sept.06,2014	19:22			X			400
Indonesia	6.2	Sept.10,2014	02:46			X			456

Guam	6.7	Sept.17,2014	06:14			X			460
Argentina	6.2	Sept.24,2014	11:16			X			60
Solomon Islands	6.1	Sept.25,2014	09:13			X			82
Alaska	6.2	Sept.25,2014	17:51			X			90
China	6	Oct. 07,2014	13:49			X			374
Mexico	6	Oct. 08,2014	02:40			X			387
Southern East Pacific Rise	7.1	Oct. 09,2014	02:14			X			411
Southern East Pacific Rise	6.6	Oct. 09,2014	02:32			X			412
Japan	6.3	Oct. 11,2014	02:35	X					5
El Salvador	7.3	Oct. 14,2014	03:51			X			78
Kermadec Islands	6.3	Oct. 14,2014	04:12			X			79
Tonga	6.1	Oct. 25,2014	03:15			X			342
Easter Island region	6	Nov. 01,2014	10:59	X					24
Fiji	7.1	Nov. 01,2014	18:57	X					32
Papua New Guinea	6.6	Nov. 07,2014	03:33			X			160
New Caledonia	6.1	Nov. 10,2014	10:04			X			41
Inodonesia	7.1	Nov. 15,2014	02:31			X			154
New Zealand	6.7	Nov. 16,2014	22:33				X		198
Solomon Islands	6.1	Nov. 17,2014	01:06				X		201
Prince Edward Islands region	6.2	Nov. 17,2014	16:52				X		216
Indonesia	6.5	Nov. 21,2014	10:10				X		306
Japan	6.2	Nov. 22,2014	13:08				X		333
Indonesia	6.8	Nov. 26,2014	14:33	X					20
Philippines	6.3	Dec. 02,2014	05:11			X			131
Panama	6	Dec. 06,2014	17:21	X					31
Indonesia	6	Dec. 06,2014	22:05	X					35
Papua New Guinea	6.8	Dec. 07,2014	01:22		X				39
Panama	6.6	Dec. 08,2014	08:54			X			71
Taiwan	6.1	Dec. 10,2014	21:03			X			131
Indonesia	6.6	Dec. 21,2014	11:34	X					96
Philippineas	6.1	Dec. 29,2014	09:29			X			288
Fiji	6.1	Dec. 30,2014	21:17		X				15
									153 Earthquakes

CELESTIAL BODIES: RELATION BETWEEN UBIQUITOUS TECTONIC DICHOTOMY AND UNIVERSAL ROTATION

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Abstract: The first theorem of the wave planetology states: “cosmic bodies are dichotomous”. This happens due to a warping action of the fundamental wave 1 arising in bodies as a result of their movements in keplerian non-circular orbits with periodically changing accelerations. Wave 1 deforms a body by bulging up one hemispheric segment and pressing in the opposite one. This deforming action requires, according to the Le Chatelier principle, an opposing action trying to remedy this distortion. For this purpose there is only one universal means; to redistribute mass and rotate it for leveling angular momenta of the halves. Thus, rotation is called to repair this natural damage and bring a body to best possible equilibrium (balance).

Keywords: *Tectonic dichotomy, rotation, equilibrium, Saturnian satellites, Ceres, Earth, Moon, Mars*

Introduction

Two universal properties of cosmic bodies, tectonic dichotomy (Kochemasov, 1998-1999) and rotation, are coincided not by chance. Tectonic and its related chemical dichotomy is due to bodies moving in keplerian non-circular orbits with periodically changing accelerations. With time though, as it is known in astronomy, orbits are inclined to round off but their ellipticity still remains. Rotation is also a common feature. Thus, keplerian orbits inevitably deform bodies making one hemispheric segment of them bulging up and the opposite one pressing in. This natural “ugliness” requires, according to the Le Chatelier principle, an opposing action trying repair the damage. The external deformity can be compensated by internal redistribution of mass, multiplied by necessary rotation, to produce the most balanced angular momenta. That is why, the most habitual two-face appearance is Earth with the eastern continental and the western antipodean oceanic hemispheres. The mantle beneath the crust is chemically different: more Fe-rich under Pacific Ocean and relatively Mg-rich (thus lighter) under Africa, Mars and Moon (Basaltic Volcanism…, 1981; Cox, 1985).

Observations and results

Global color mosaics of Saturn’s moons (**Figs. 1-6**) were produced from images taken by NASA’s Cassini spacecraft during the first ten years exploring the Saturn system (Images credit: NASA/JPL-Caltech/Space Science Institute/Lunar and Planetary Institute). The most obvious feature on the maps is the difference in color and brightness between the two hemispheres. According to authors of the images, the darker colors on the trailing hemispheres (on the left side of the images) are thought to be due to alteration by magnetospheric particles and radiation striking those surfaces. The lighter-colored leading hemispheres are coated with icy dust from Saturn’s E-ring formed of tiny particles ejected from Enceladus’ South Pole. These satellites are all, supposedly, being painted by material erupted by neighboring Enceladus.

Some corrections are however necessary for these explanations. The first theorem of the wave planetology (Kochemasov, 1998, 1999 and 2015a & b) states: “Cosmic bodies are dichotomous”. This is due to warping action of the fundamental wave warping moving in keplerian orbits with periodically changing acceleration of celestial bodies. All cosmic explorations of numerous bodies show that a two-face appearance or dichotomy really is their typical trait. Normally, the subsided relatively smoothed hemisphere opposes the uplifted rugged one. The best-studied examples are Earth, Mars, Moon, and Ceres (**Figs. 7 and 8**). Thus, the painting action of Enceladus is an additional action superimposed on already existing tectonic dichotomy - a ubiquitous morphologic feature. It is true that the source of tiny icy particles is Enceladus; that is why it is less color dichotomous (whitened) than other icy satellites (**Figs. 1-6**). Uplifted cracked and fissured (rugged) hemispheres often are darker because some lighter (but darker under decomposition) substance is coming up. This is not the case for Iapetus and probably for Enceladus degassing light toned material.

Uplifted hemispheres are more rugged, cracked, and cratered than the opposite pressed-in hemispheres. Normally pressing – diminishing radius is a reason for forming denser formations in these tectonic blocks (preserving angular momentum considerations; look at Earth and Mars). In the saturnian satellites cases darker substance could be less dense than water ice or presents very thin dark veneers originating from decomposition of material extracted from satellite depths due to very deep cracks (Diona and Rhea). In much more wave warped Iapetus (Thomas et al., 2006) the darker and presumably denser material already fills hemispheric depression.

Although the bright leading hemisphere explanation can be acceptable for the bodies nearest to Enceladus (Mimas, Tethys), it is not properly understood for the distant ones (Diona, Rhea and Iapetus) where the brightness is even stronger. Soot covering the uplifted hemispheres is a possible explanation for the observations. The soot originates under decomposition of light C-containing chemicals. The pressed-in hemispheres could be filled with relatively dense salted water.

Thus, tectonic (geomorphologic) dichotomy is basically more regular, stable and universal than color and brightness dichotomy (look at Ceres and the Moon with tectonically different halves) (**Figs. 7 and 8**). The latter characteristics only underline the universal tectonic expression. Two-face tectonics "spoils" perfect spherical and thus equilibrated globes (**Figs. 1-9**). This "ugliness" awakens opposing actions (Le Chatelier principle): a mass redistribution, rotation and distance to the rotation axis produce an angular momentum that tends to be even in distorted halves. Thus, the tectonic dichotomy and rotation are fundamentally related each other.

Color maps of:	**Radius, km:**	**Orbital period, days**
1 – Mimas, PIA18437	197	0.94
2 – Enceladus, PIA18435	251	1.37
3 – Tethys, PIA18439	524	1.89
4 – Diona, PIA18434	559	2.74
5 – Rhea, PIA18438	765	4.52
6 – Iapetus, PIA18436	718	79.33

Fig. 1 Mimas

Fig. 2 Enceladus

Fig. 3 Tethys

Fig. 4 Diona

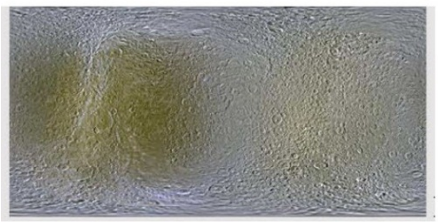

Fig. 5 Rhea

Fig. 6 Iapetus

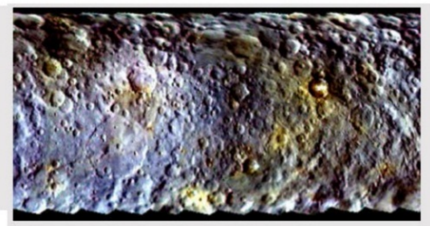

Fig. 7 Cere's elevations, pia 19063_main.png

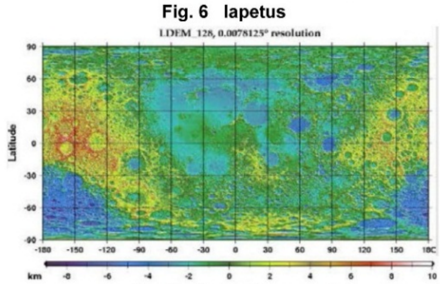

Fig. 8 Lunar topography

Figs. 3 – 8. Images credit: NASA/JPL-Caltech/Space Science Institute/Lunar and Planetary Institute.

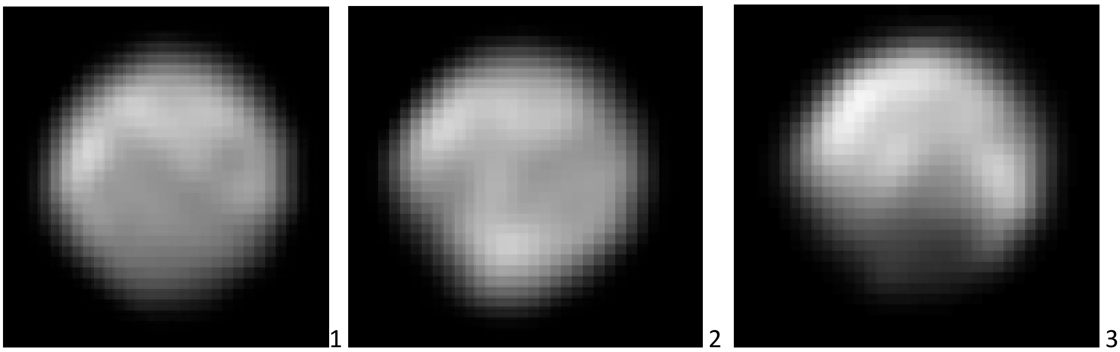

Fig. 9. Latest images of Pluto taken by the New Horizons cosmic probe (LORRI experiment) from distances of 80 (1), 77 (2), 75 (3) millions of kilometers. Pluto' radius is ~1184 km. The axis of rotation in images is vertical. Pluto central longitude is 350˚(1), 238˚(2), 125˚(3). Credit: NASA. Two-faced nature of the rotating planet is developing.

Conclusion

The key question of planetology (in a wider aspect, astronomy) – rotations of celestial bodies is resolved in connection to this property with their ubiquitous characteristics - tectonic dichotomy. Tectonic dichotomy (first theorem of the wave planetology) is a consequence of distorting bodies. Keplerian ellipticity of orbits requires, according to the Le Chatelier principle, its opposing neutralizing action. Thus, mass redistribution and rotation are called to create and level angular momenta of distorted hemispheric segments.

References

Kochemasov, G.G., 1998. Tectonic dichotomy, sectoring and granulation of Earth and other celestial bodies. *Proceedings of the International Symposium on New Concepts in Global Tectonics*, "NCGT-98 TSUKUBA", Geological Survey of Japan, Tsukuba, Nov 20-23, 1998, p. 144-147.

Kochemasov, G.G., 1999. Theorems of wave planetary tectonics. *Geophys. Res. Abstr.*, v.1, no. 3, p. 700.

Kochemasov, G.G., 2015a. A lunar "mould" of the Earth's tectonics: four terrestrial oceans and four lunar basins are derivatives of one wave tectonic process. *NCGT Journal*, v. 3, no. 1, p. 29-33.

Kochemasov, G.G., 2015b. Ceres' two-face nature: expressive success of the wave planetology. *NCGT Journal*, v. 3, no. 1, p. 63-64.

Thomas, P.C., Veverka, J., Helfenstein, P., Porco, C. et al., 2006. Shapes of the saturnian icy satellites. *Lunar and planetary Science Conference XXXVII,* Houston, USA, Abstract 1639 pdf. CD-ROM.

POLYGONAL CRATER FORMATION BY ELECTRICAL DISCHARGES

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Abstract: Polygonal craters in the form of regular hexagons, as seen on planetary surfaces e.g. Mars, Venus and Mercury, and also on Earth's moon and other planetary satellites, are considered to be the result of impacts by meteoritic bodies (meteorites or asteroids). Other large craters on Earth, usually described as 'roughly circular' or 'lozenge shaped' are also considered to be the result of such impacts. This paper will show that many of these craters are in fact polygonal in the form of octagons and that, by assembling a conceptual model of a lightning bolt, will demonstrate that both the underlying formation processes of a lightning bolt and its internal dynamic relationships are directly reflected in the resultant morphologies of these two specific and distinct types of polygonal crater; thus proving that they are the direct result of single lightning strikes. Diatremes and kimberlite are considered to be formed by volcanic processes but, by applying the lightning bolt model to the Kimberley Big Hole, the model provides a more complete and satisfactory explanation of diatreme and kimberlite formation than current theories and models do. The model will also be used to show that lightning bolts are responsible not only for the formation of all meteorites, regardless of their origin, but also for the high levels of iridium found in meteorites and at the K-T boundary; thus refuting impact theory in general and the Alvarez Hypothesis in particular.

Keywords: *Polygonal craters, electrical discharges, Alvarez Hypothesis, kimberlite diatreme formation, meteorite formation, Iridium at K-T boundary*

1. Terminology

The focus of this work is a specific type of electrical arc discharge through a plasma medium, to avoid any confusion I shall make the following distinction.

Maintained Arc - An electrical arc discharge where prolonged surface contact, over a period of seconds or minutes, is maintained by a steady or controlled current level; as seen in laboratory plasma experiments or arc welding.

Lightning Bolt - An electrical arc discharge initiated by a Z-Pinch, which strikes the surface momentarily for a period of microseconds; as seen in cloud to ground lightning strikes.

2. Theory

2.1. Ionised pathway

Following charge separation within a thundercloud, the negative charges will gather together at the base of the cloud. If the excess charge is to be transferred to the ground it requires an ionised pathway along which to travel, as air is a very poor electrical conductor. This pathway is created when charged particles in the atmosphere respond to the presence of a large amount of electrical charge by forming Birkeland currents. This process begins nearest to the charge i.e. at the base of the cloud and appears as a 'stepped leader' descending from the cloud and seeking out the best path to earth. As the stepped leader nears the surface, positive charges in the earth respond by migrating towards the surface. This increase in surface charge causes charged particles close to the ground to respond by again forming Birkeland currents near the ground, which are seen as 'positive leaders' rising from the ground. When a descending stepped leader makes contact with a rising positive leader then the ionised pathway is complete and the process of charge transfer begins. What happens in the next 3-5 milliseconds is relatively unknown due to the extreme difficulties involved in monitoring a process which occurs over such a short time interval. I propose to explain this by assembling a conceptual model of a lightning bolt from initiation, through contact with the surface, to the resulting mechanism of discharge.

2.2. Lightning Bolt

2.2.1. Formation and external structure

Electrical arc discharges through a plasma medium are known to undergo filamentation, producing a number of filamentary Birkeland Currents in the form of cylinders of equal diameter. When a surge in current levels leads to a Z-Pinch, the cluster of current filaments will be compressed by their radial magnetic fields towards their volumetric center (**Figure 1**).

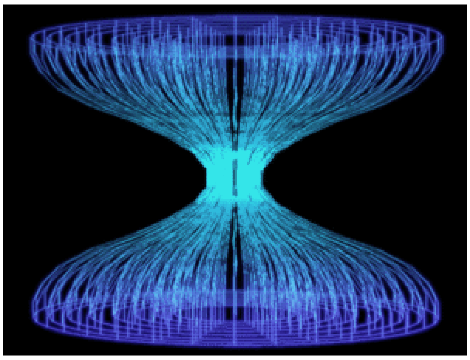


Figure 1. Z- Pinch.

A Z-Pinch occurs across a single plane of action, perpendicular to the longitudinal axes of the current filaments. As the filaments have only one degree of freedom within that plane of action i.e. lateral movement, then they can be reduced to their two dimensional counterparts - circles of equal diameter. Whatever spatial geometries apply to the circles, will also apply to the current filaments. Taking a horizontal cross section (**Figure 2**) of the filaments produces a cluster of circles of equal diameter.

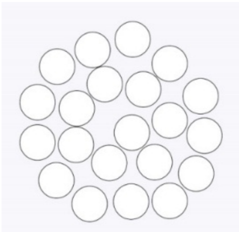


Figure 2. Horizontal cross section of current filaments.

Under a Z-pinch, the current filaments will be quickly constricted by their radial magnetic fields, forcing them into a close packing arrangement. Circles (and by extension the current filaments) of equal diameter have only two possible close packing arrangements – hexagonal close packing (HCP) and cubic close packing (CCP) (**Figures 3 and 4**).

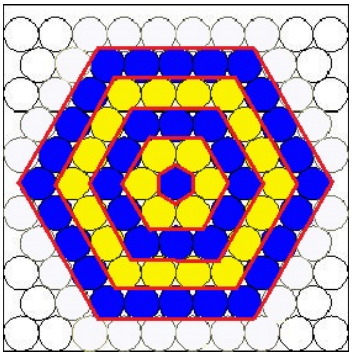


Figure 3. Hexagonal close packing.

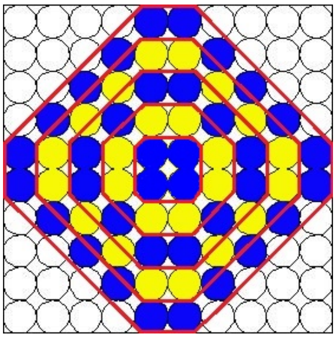


Figure 4. Cubic close packing.

As these two close packing arrangements are the only ones available to the current filaments, then I submit that a lightning bolt can have only two possible cross sections, a regular hexagon (**Figure 3**) or an isogonal octagon (**Figure 4**), which has alternate long and short sides.

Both close packing arrangements produce an infinite series of concentric polygonal layers of current filaments, indicating that the underlying formation process of a lightning bolt is infinitely scalable. Therefore I submit that this establishes the possibility of lightning bolts on a colossal scale which, though not witnessed in recent recorded history, may have occurred in the distant past.

The mechanism by which a hexagonal and not an octagonal lightning bolt is produced, is unclear at this point, but I tentatively suggest that it may be due to fluctuating current levels. If the current is high then the consequent higher strength of the radial magnetic fields will lead to a stronger Z-pinch, forcing a HCP arrangement. If the current is at a lower level then the resulting lower strength of the radial magnetic fields will lead to a weaker Z-pinch and the current cylinders will adopt a CCP arrangement. Under laboratory conditions where current levels can be controlled, it may be that HCP will be the more prevalent arrangement, and CCP will be more common in the natural world where current levels are not controlled. Perhaps close study of electrically machined metal surfaces might provide further information on this.

2.2.2. Internal structure.
From established work on Birkeland currents we know that they exhibit both long range attraction via their axial component, and short range repulsion due to their radial component. Their short range repulsion will cause the current filaments to space themselves out (**Figure 5**), but still be restrained by their limited spatial geometries into an arrangement of concentric polygonal layers.

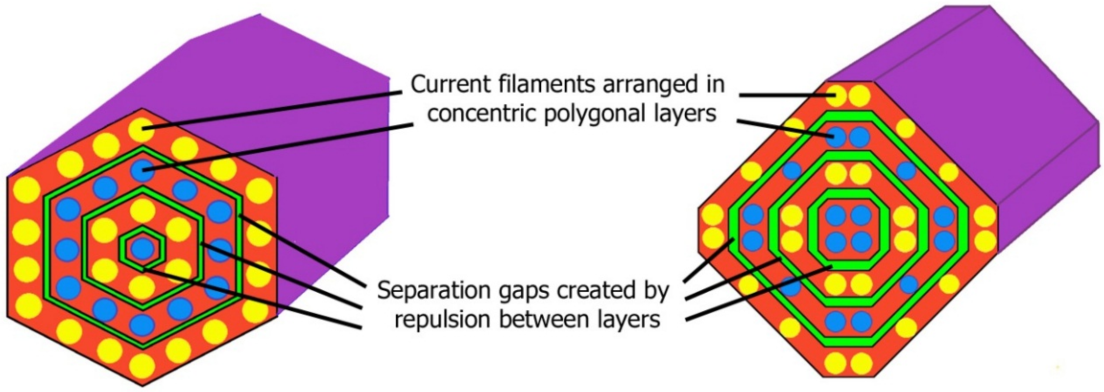


Figure 5. Extended cross sections of hexagonal and octagonal lightning bolts showing the arrangement of current filaments after separation by repulsion.

By separating into concentric layers, the current filaments gain a degree of freedom in that they can rotate as a unit. This enables the filaments shown in white (**Figure 6**) to repel each other in the only way possible i.e. by spinning in opposite directions. This automatically creates the counter-rotational effect (**Figure 7**) predicted by Scott (2015).

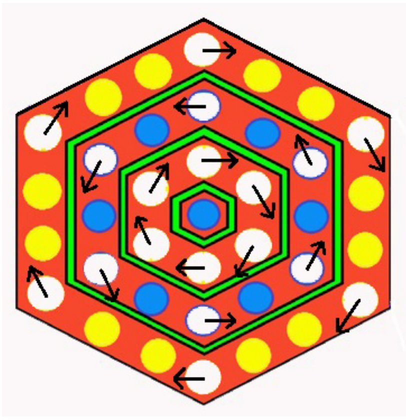


Figure 6. Repulsion between layers.

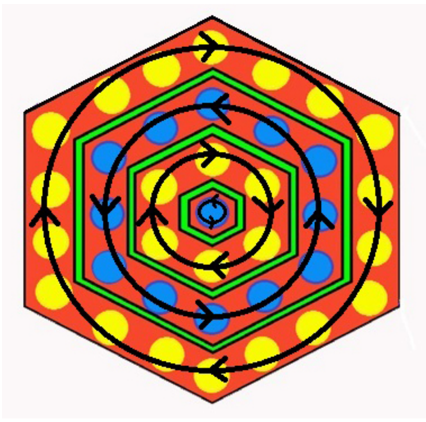


Figure 7. Counter-rotation of layers.

To put this all into an easy to visualise, three dimensional form, we can use the schematic representation of the lightning bolt model shown in **Figure 8**. Each layer has been extended to emphasise its freedom of movement within the bolt due to repulsion between layers; the repulsion gaps are shown in yellow and the white arrows indicate direction of rotation.

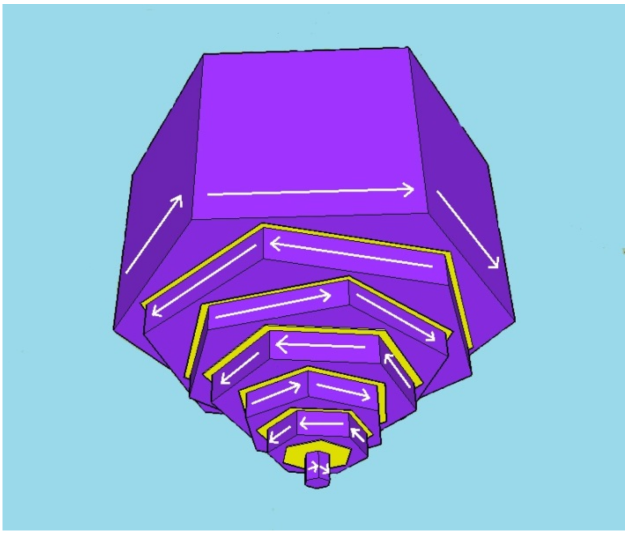


Figure 8. Lightning bolt model.

For ease of illustration and to avoid duplication, all further diagrams will show a hexagonal bolt, any relevant differences between this form and the octagonal one will be mentioned where necessary.

2.2.3. Contact with surface

The strong radial magnetic fields induced by the high current levels surging through the lightning bolt will maintain its structural integrity for the entire length of the bolt. This is in agreement with the common observation that the width of a lightning bolt appears to be constant for the whole of its length.
Just before contact with the surface, the high current levels surging towards the bolt's tip will induce a Z-pinch. As the current density decreases from the center to the outer edge of the bolt, then each successive layer, moving from the center of the bolt to its outer edge, will be progressively less constricted by their radial magnetic fields, which decrease in strength as current density falls. The effect this has on the profile of the bolt's tip (**Figure 9)** indicates there will be a succession of contacts with the surface.

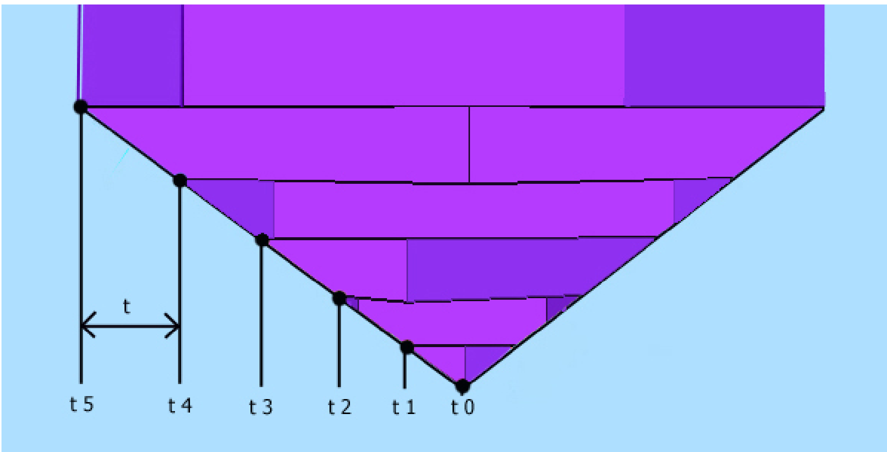


Figure 9. Time intervals between contacts of successive layers.

The central current filament will make contact with the surface and discharge at t 0, with each successive layer making contact and discharging at intervals of t microseconds, until the outside layer makes contact and discharges at t 5.

This process is illustrated in **Figure 10**, where each layer has a different colour with a matching discharge pattern.

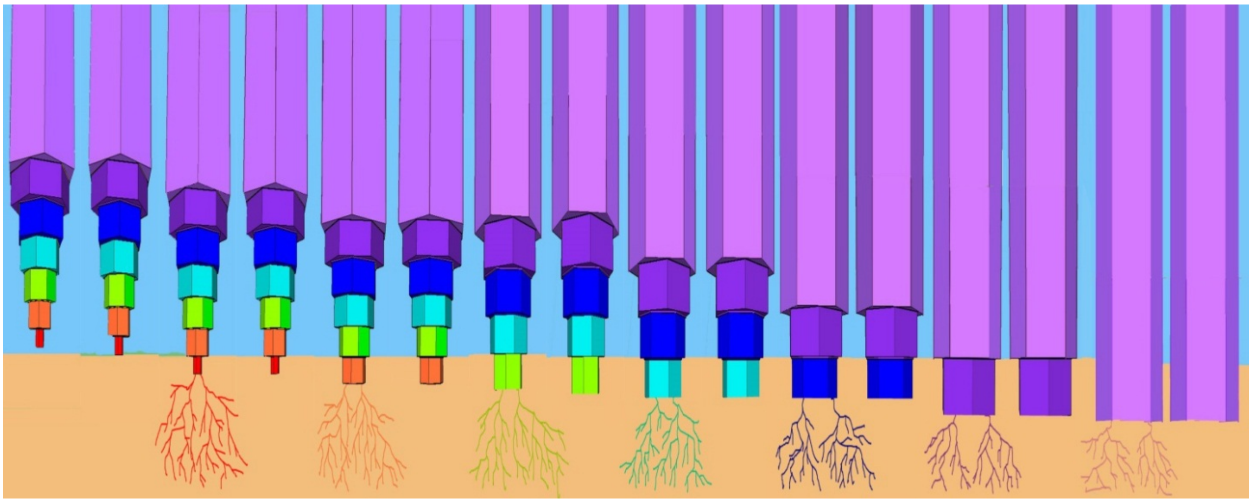


Figure 10. Contact and resulting discharge of successive layers of filaments.

As shown, each layer will make contact and discharge, before the next layer makes contact. The discharge patterns have been simplified to illustrate the principle of successive discharges separated by the time interval between successive layers making contact. The tip profile has also been exaggerated for the same purpose.

2.2.4. Discharge mechanism

Taking into account that each layer is rotating in a counter direction to adjacent layers, the resulting pattern of discharges will more closely resemble those in **Figures 11 and 12**. Here, all the layers and their relative discharges are shown simultaneously to give a better idea of how the system works to produce an extremely efficient method of charge delivery and dispersal.

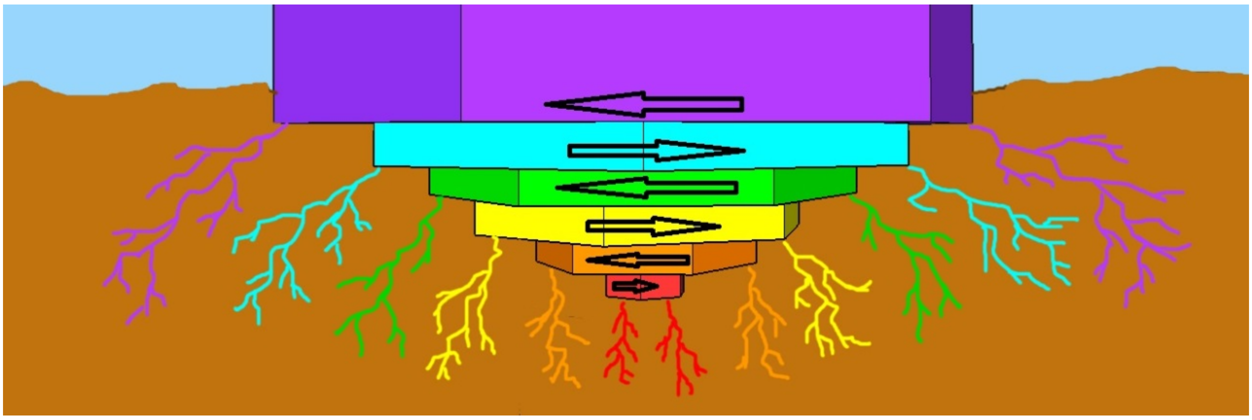


Figure 11. Cross sectional view of counter-rotating layers and their discharges.

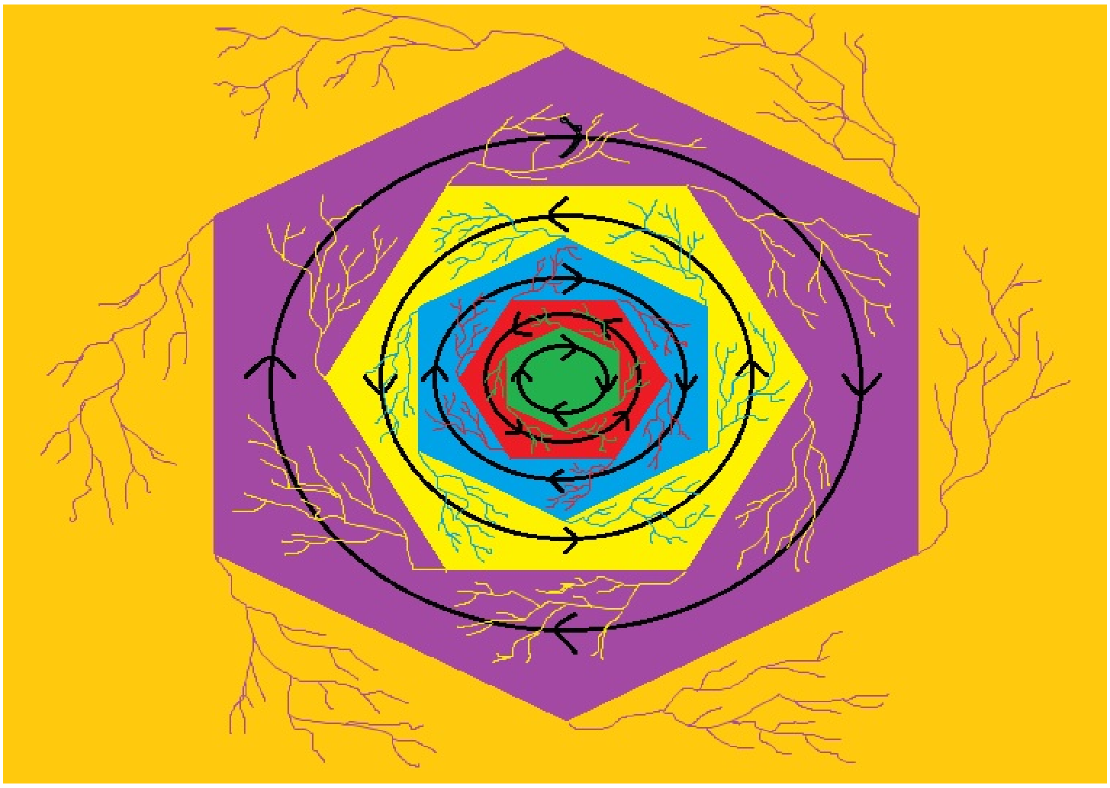


Figure 12. Underside view of counter-rotating layers and their discharges.

When a lightning bolt makes contact with a surface, its function is to deliver and disperse a large amount of electrical charge as quickly and efficiently as possible. By using this system of counter-rotating layers of filaments, discharging in succession, the currents are prevented from discharging all at the same time, which I suggest would be far from efficient. Instead, the total amount of charge is delivered in increments, which are spun out in opposite directions in a series of ever increasing circles. Thus the discharges avoid each other as much as possible, ensuring an even and efficient dispersal of the total charge.

I submit that the lightning bolt model outlined here is a complete and accurate model of the lightning bolt process, and that every aspect of it will be justified by directly linking it to clearly observable features in the respective morphologies of the two polygonal craters discussed in this paper.

3. Evidence

3.1. Crater outlines

3.1.1. Mars

Hexagonal craters, like those below, have been observed on the surface of Mars and elsewhere in the solar system and are well documented.

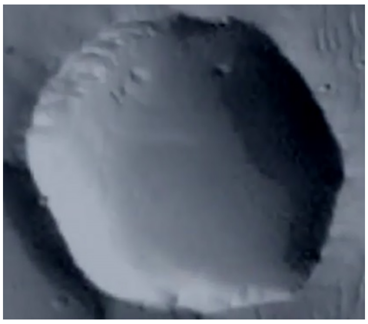


Figure 13. Hexagonal craters on Mars. Images: screenshots(1).

However, despite being more numerous, there appears to be no mention of octagonal craters; but they can be harder to identify than hexagonal craters. The main reason for this is the difference in packing density between the HCP and CCP arrangements (**Figure 14**).

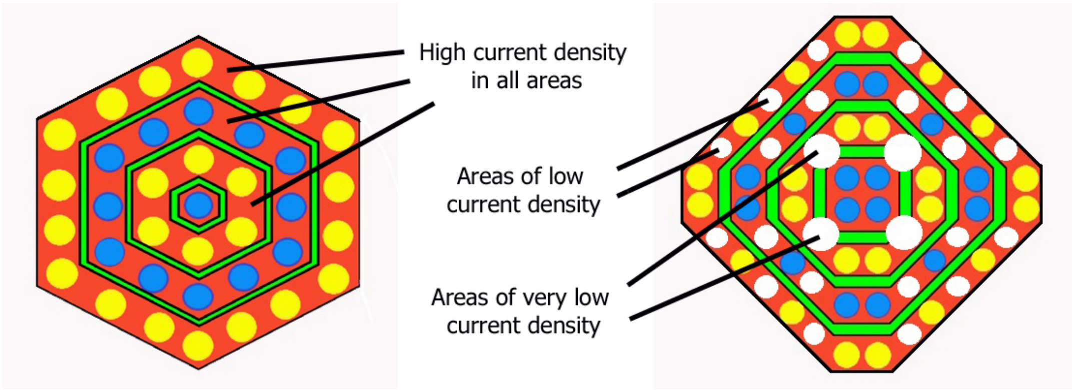


Figure 14. Cross sections of hexagonal and octagonal lightning bolts, illustrating the differences in current density produced by HCP and CCP arrangements.

The hexagonal bolt has a high current density in all areas and would be expected to have a higher degree of ‘cutting power’ than an octagonal bolt, which has areas of low current density and so will have less ‘cutting power’.

On smooth, rocky surfaces like that of Mars, this will result in hexagonal craters having clean cut, well defined edges, with smooth faces on the inner walls and crater floor (**Figure 13**); whereas octagonal craters will have less well defined edges with rough crater walls. They will be more susceptible to erosion, making their outlines harder to see, especially their angular vertices, leaving a ‘roughly circular’ outline. The GE screenshots of craters in **Figure 15** are examples of this and are shown with and without a polygonal outline as a guide. More examples of octagonal craters on Mars are included in Appendix A.

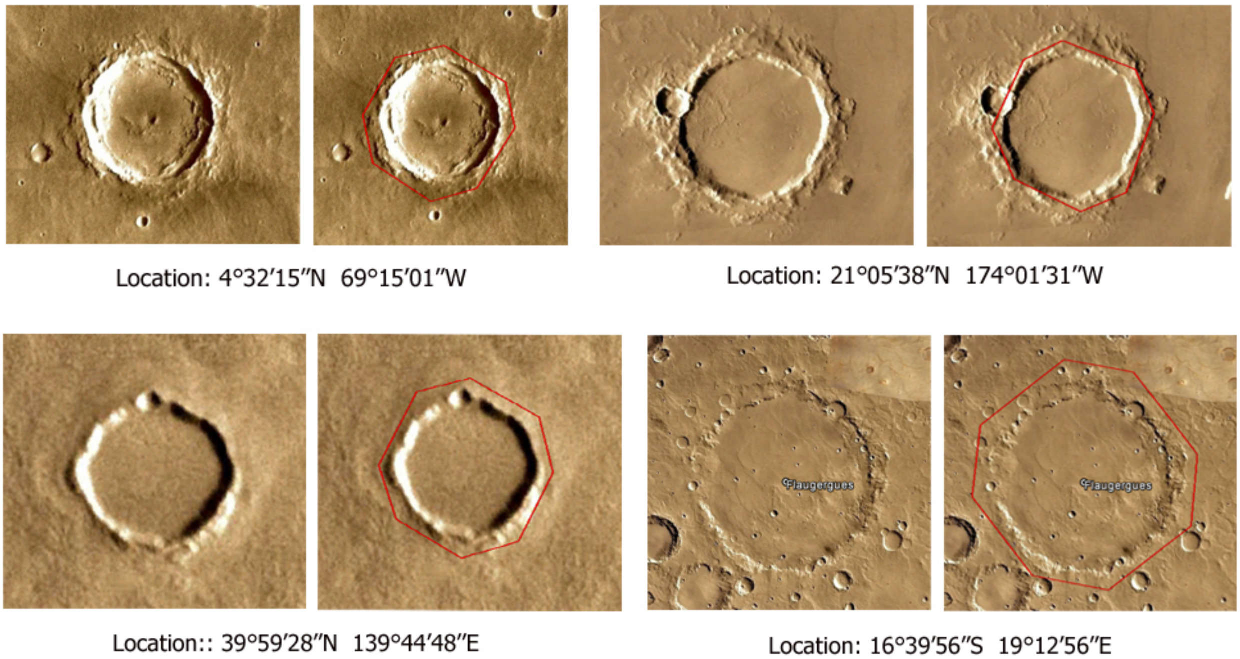


Figure 15. Series of craters on Mars, illustrating the difficulty of identifying octagonal outlines.

3.1.2. Earth

Unlike Mars, Earth has an ample supply of water for erosion and an extensive cover of vegetation to further hide and obscure eroded crater outlines. Urbanisation and agricultural land use add to the problem, making crater identification by visual means more difficult on Earth.

a) High angle shot sourced from the net | b) Low angle shot Image by Dave Smith | c) Aerial view Google Earth | d) Octagonal grid acetate overlay | e) Polygonal outline Google Earth

Figure 16. Crater identification using aerial views and Google Earth.

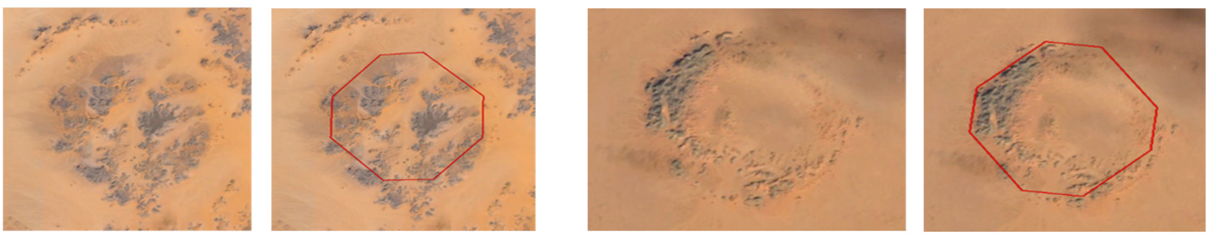
Overhead views from the air may seem to be the best way of identifying craters but even they can be deceptive. Image a) in **Figure 16** is of Te Whekau Lagoon in New Zealand and shows a roughly circular depression but not much more. A better view is presented by a low angle shot b) which emphasises the vertices and gives an initial impression of a hexagonal outline. Taking an overhead view c) on Google Earth (GE), we can see that most of the outline has been eroded but there are three distinct edges to the north-east, in shadow, which show two internal angles of approximately 135°. All internal angles of the isogonal octagon produced by a CCP arrangement are 135°, which suggests that Te Whekau Lagoon may be an octagonal crater formation. The center of the three walls shows a vertical rock face, as do the adjacent edges of the other walls, before erosion obscures the outline, indicating that they are the least eroded parts of the crater. Applying a grid overlay d) and using these three edges as a baseline, the crater can be centered in the grid and a guide outline applied e) with GE's polygon tool.

To show that many craters regarded as impact craters with a 'roughly circular' shape are actually polygonal, in the form of either regular hexagons or isogonal octagons, I applied the above method to a sample of crater formations from around the world. Most of these were confirmed impact craters[(2)(3)], with other examples being sourced via internet articles and images, or GE searches. Some of these are shown in **Figure 17**, with more examples in **Appendix A**.

Odessa, Texas 31°45′21″ N 102°28′44″ W | **Odessa, Texas 31°45′44″ N 102°31′54″ W**

Lonar Lake, India 19°58′39″ N 76°30′30″ E | **Patomsky crater, Russia 59°17′05″ N 116°35′22″ E**

Figure 17. See next page for caption.



Kebira Crater, Libya 24°40′53″ N 24°57′55″ E | **Oasis Crater, Libya 24°34′36″ N 24°24′28″ E**

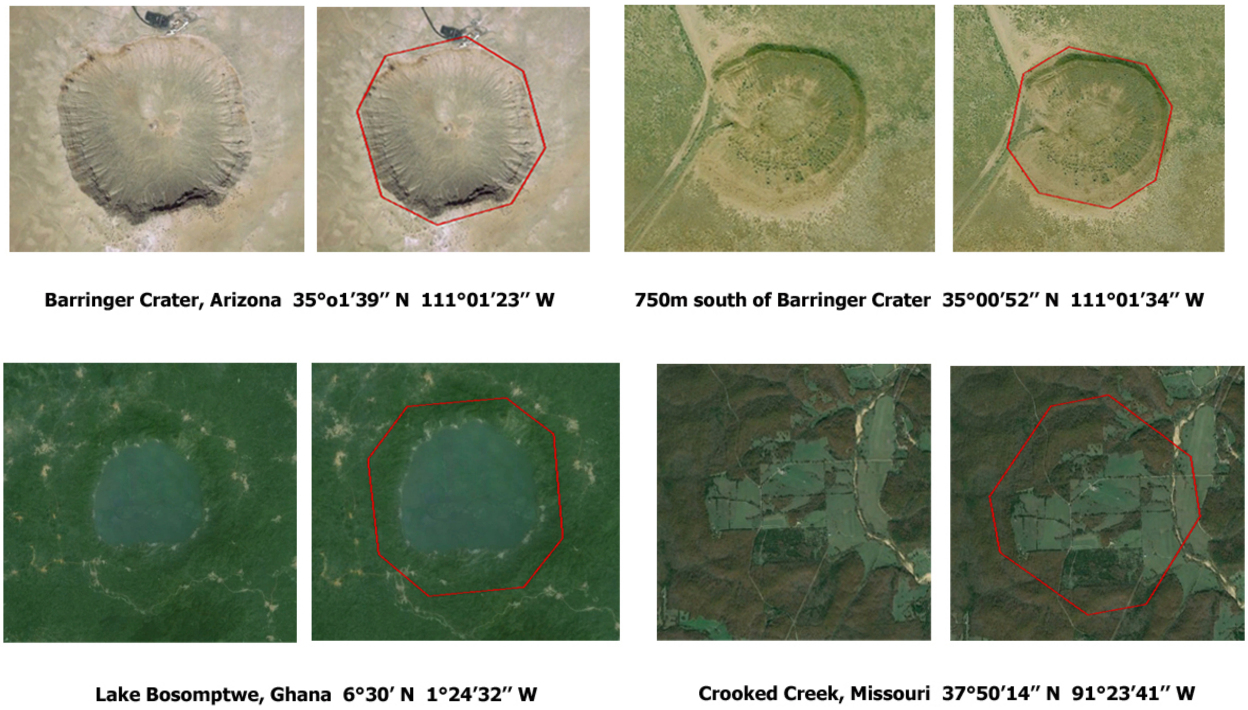


Figure 17 (continued). Confirmed and unconfirmed impact craters showing clear evidence of polygonal outlines in the form of regular hexagons and isogonal octagons. All images, with the exception of Patomsky crater (internet), are sourced from GE screenshots.

On the basis that: 1) All of the craters in **Figure 17**, Appendix A, and those used to illustrate various points throughout this paper, have either regular hexagonal or isogonal octagonal outlines. 2) These distinct and specific polygonal outlines are a direct match for the only two possible cross sections a lightning bolt can have. 3) There is no current theory or model which can satisfactorily explain why random impacts by meteoritic bodies on planets and their satellites consistently leave craters in the shape of perfect regular hexagons and isogonal octagons. I submit that all the craters examined in the course of this work, and others with the same two matching polygonal outlines are formed by lightning strikes, not meteoritic impacts and should be re-named ‘lightning craters’.

3.2. Concentric ring structures

Concentric ring structures have often been observed on the floor of impact craters but there does not appear to be a satisfactory explanation of them.

3.2.1. Aorounga Crater, Borkou, Chad

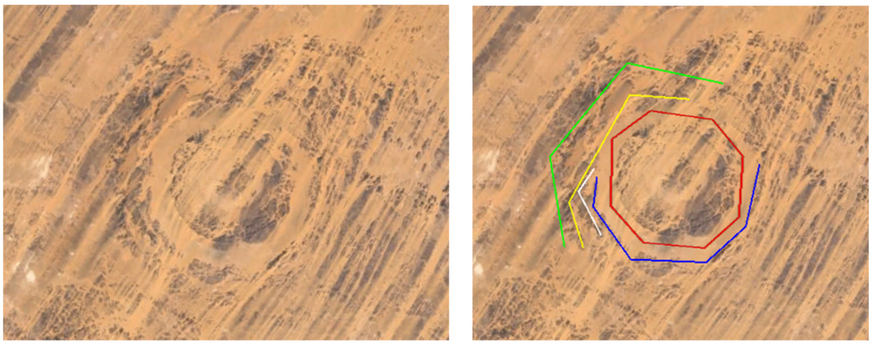


Figure 18. Aorounga crater (19°05’30’’ N, 19°14’34’’ E) showing isogonal octagon around the raised central area and a series of concentric polygonal outlines (CPO’s) with angles of approximately 135°. (GE screenshots)

Looking closer at the CPO’s we can see they are in the form of raised ridges with a clear line of scorched rock running along the top of some of the ridges.

Figure 19. Close up shots of CPO’s showing scorched rock on the raised ridges. (GE screenshots)

The CPO’s seen in **Figures 18 and 19** mark the outlines of concentric, polygonal layers of current filaments; the line of scorched rock being where the currents made contact with the surface and discharged. These outlines, in the form of raised ridges, suggest an electrical discharge on a positively charged surface. This is supported by the fact that the central feature of the crater is a raised dome, indicating that Aorounga crater is an example of a lightning strike on a positively charged surface.

3.2.2. Olympus Mons

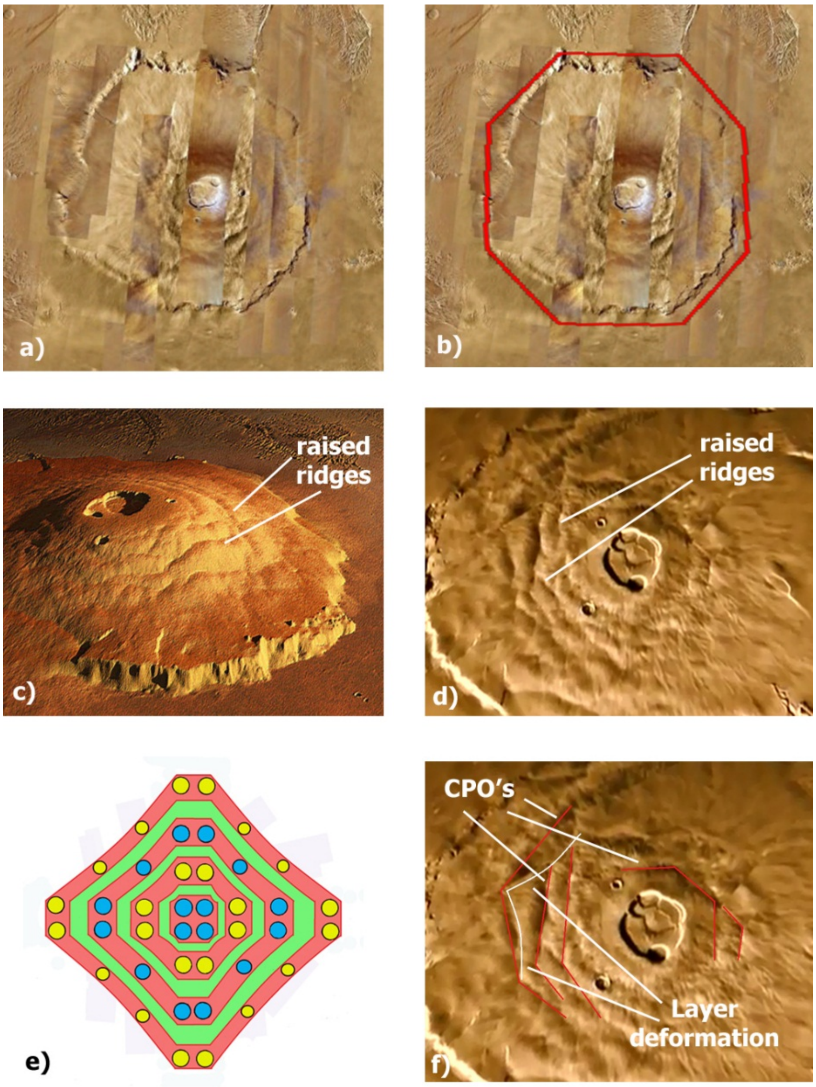


Figure 20. a) Olympus Mons, b) outline guide, c) profile view, d) overhead view, e) deformation of layers, f) CPO's and inward bowing of layers. Image sources: a), b) – GE screenshots; c) internet; d), f) screenshots[(2)].

Olympus Mons is another example of a lightning strike on a positively charged surface. It has an isogonal octagonal outline (b); a central dome with wineglass profile (c); and a series of CPO's in the form of raised ridges (c, d, f). The areas of low current density (**Figure 14**) in an octagonal bolt increase as the bolt increases in size. Olympus Mons is over 350 miles in diameter and an octagonal bolt this large may be expected to show some deformation in its polygonal layers (e), as the radial magnetic fields will be at their strongest in the plasma pinch which occurs just before contact with the surface. This effect can be seen in **Fig. 20f**) where two edges are seen to bow inwards.

3.2.3. Martian crater

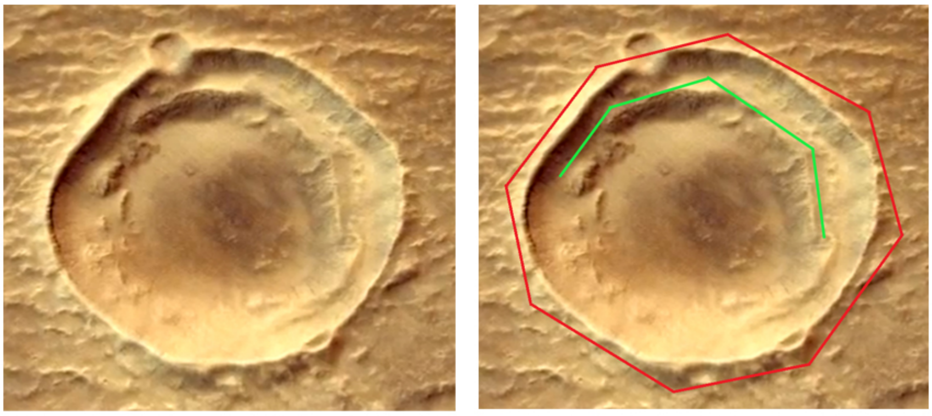


Figure 21. Martian crater showing isogonal octagonal outline and a CPO. Images: Screenshots[(1)].

The CPO shown in **Figure 21** is formed differently as this example is one of a strike on a negative surface. In this case, the outlined ridge and other raised areas on the crater floor have not been carved as much as the rest of the crater. This is because the polygonal layers produced by CCP have areas of low current density (**Figure 14**) with the current density being lowest at the edges of the layers i.e. where the separation gaps between layers are. The ridge thus marks the edge of a polygonal layer of current filaments. Note the top of the ridge, unlike those at Aorounga, is not scorched but its inside face is, indicating that the currents discharged inside the line of the ridge.

As the concentric ring structures at Aorounga crater, Olympus Mons and the octagonal crater on Mars have been shown to be polygonal with internal angles of approximately 135^o (including the line of scorched rock at Aorounga) and match the polygonal outline of their respective craters, I submit that this is firm evidence for the system of concentric polygonal layers of current filaments, separated by short range repulsion proposed earlier (**Figure 5**).

3.2.4. Random pattern of CPO's

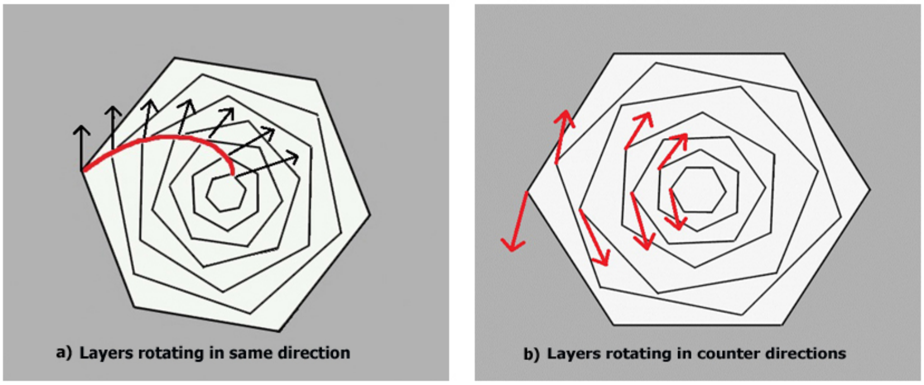


Figure 22. Possible rotational patterns of polygonal layers.

If the concentric polygonal layers identified at Aorounga crater had been rotating in the same direction (**Figure 22a**), then, even allowing for a time interval between successive layers making contact with the surface, we would have expected an easily trackable pattern such as the one shown by the red arc connecting the vertices of successive layers rotating in the same direction.

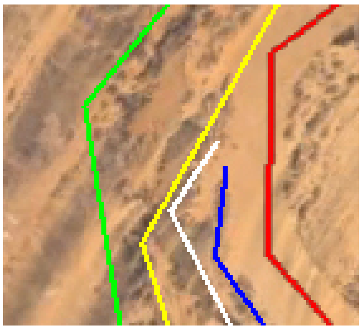


Figure 23. Close up of CPO's at Aorounga. GE screenshot crater.

The pattern of CPO's at Aorounga (**Figure 23**) more closely resembles that shown in **Figure 22b**), which indicates the concentric layers are rotating in counter directions. I submit that this is firm evidence for the counter-rotation proposed earlier (**Figure 7**).

3.3. Central feature

An octagonal lightning bolt has several areas of low current density (**Figure 14**) due to the relatively lower packing density of a CCP arrangement compared to a HCP arrangement. There are four areas in particular where the current density is at its lowest – the corners of the square formed by the four central current filaments. This results in a square central feature (**Figure 24**) with distinct 'corner posts' marking the areas of lowest current density. The same feature can be seen in the Serra de Cangalha crater (**Figure 25**) in Brazil.

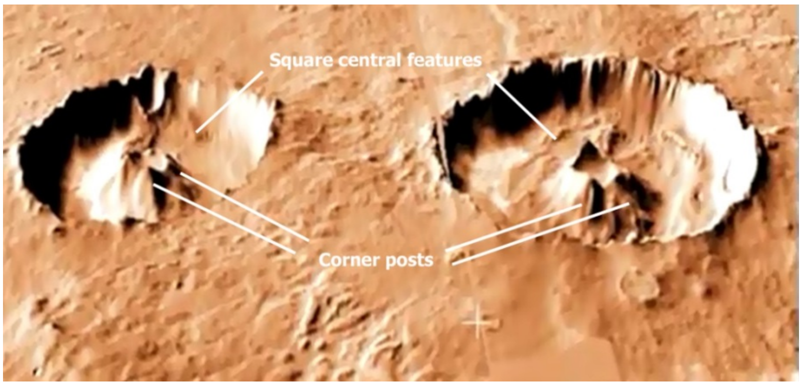


Figure 24. Two 'bullseye' craters showing square central features with 'corner posts'. Image: Screenshot(1).

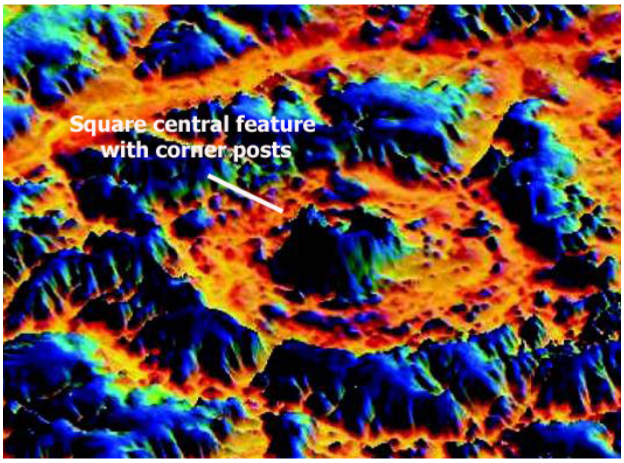


Figure 25. Serra da Cangalha crater, Brazil. Image: Reimold, W.U. et al. (2006).

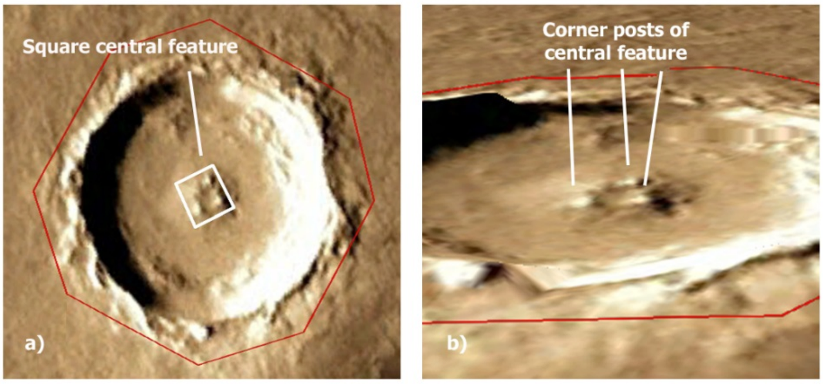


Figure 26. Octagonal crater with eroded central feature. Images: GE screenshots.

The corner posts, where the current density is at its lowest, will be the most robust parts of the central feature and less susceptible to erosion. This can be seen in a more heavily eroded crater (**Figure 26**) where only the stubs of three posts remain, with a faint trace of the fourth. I submit this is further evidence for a system of polygonal layers, separated on the basis of short range repulsion.

3.4. Successive discharges within a single strike

By filming lightning in super slow motion[(4)], M. Geoff McHarg (Director, USAF Space Physics and Atmospheric Research Centre) has shown that a single lightning strike actually consists of a succession of discharges, separated by short intervals. I submit that this is clear evidence for the system of successive contacts (**Figures 9 and 10**) resulting from the plasma pinch just before contact with the surface.

3.5. Shatter cones

Shatter cones have long been regarded as morphological indicators of impact events and several methods of formation have been proposed (Baratoux and Melosh, 2003; Sagy et al., 2004), all revolving around interference in shock wave propagation. None of these theories however have given a satisfactory explanation for three distinct features of shatter cones: 1) the frequency with which they are found in counter orientation to each other, which would appear to contradict the general theory that they are formed in a radial blast and should therefore be oriented in the same direction. 2) Their surface patterns of striations often referred to as horsetails. 3) Their oblate or 'spoon shaped' surface profile.

These three key features of shatter cones are easily explained by the system of counter-rotating layers of current filaments discharging in succession (**Fig. 12**) as proposed by the lightning bolt model.

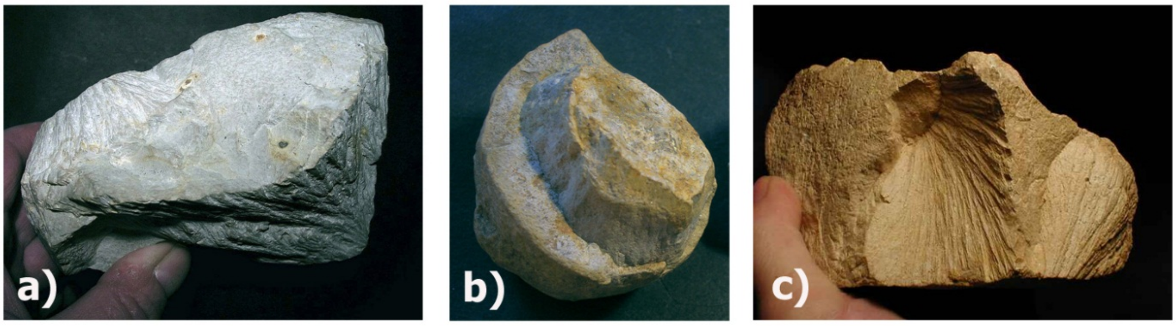


Figure 27. Shatter cones showing counter orientation a) Kentland impact crater, b) Tüttensee crater, Chiemgau impact c) Steinheim impact structure. Images: impact-structures.com.

As shown earlier in **Fig. 11** the system of counter-rotating layers of current filaments will automatically produce discharges which are in counter orientation to those from adjacent layers, like the example from Steinheim (**Figure 27c**). With the layers discharging in succession, one layer will have discharged and formed shatter cones before the next layer discharges, producing situations like **Figure 27b**) where the bottom cone was formed before the top cone in an adjacent layer was formed. The same applies to the Kentland example (**Figure 27a**) where the small cone on the upper left was formed before the larger cone, which has discharged around the smaller one.

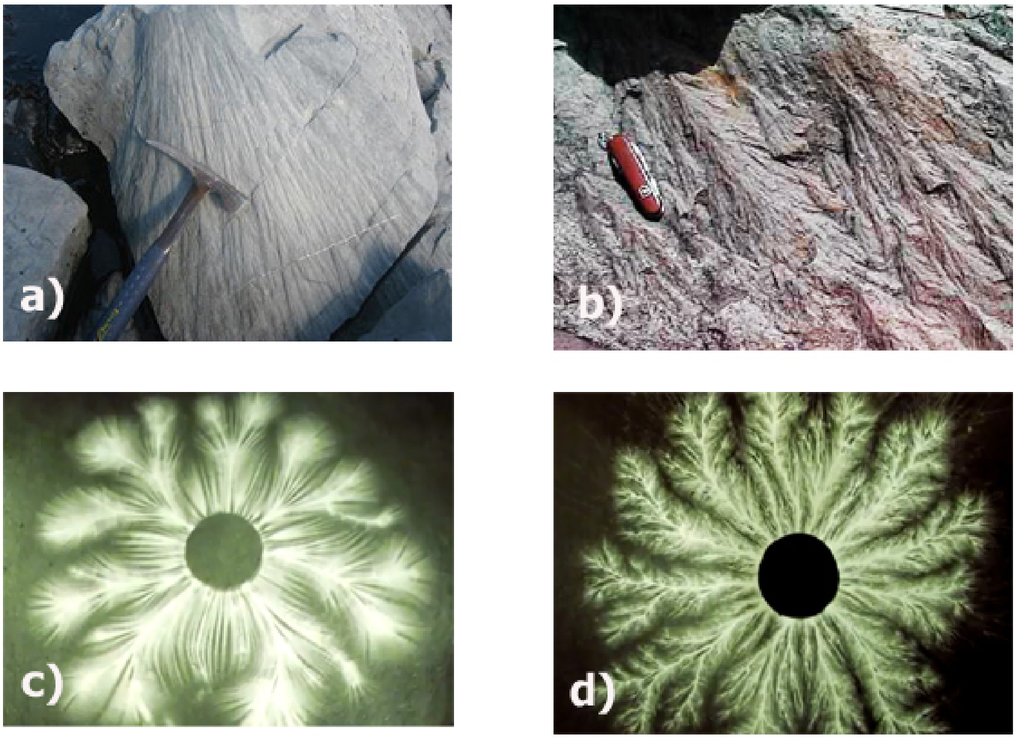


Figure 28. Shatter cone surface patterns compared with electrical discharges. a) Charlevoix crater, Canada b) Vredefort dome, SA c) discharge onto a negatively charged surface d) discharge onto a positively charged surface. Images: a) and b) sourced from the internet. c) and d) are screenshots[(1)].

I submit that shatter cones are the result of electrical discharges through the rock and that their surface patterns are in fact Lichtenberg figures (**Figure 28c & d**). I also suggest that there may be two distinct forms, as shown in figure 28. The Charlevoix cone a) shows a filamentary, feathery pattern, resembling the pattern of discharge onto a negative surface in c), while the cones at Vredefort are more dendritic in nature with frequent branching like the discharge onto a positive surface in d). This would appear to match up with the respective sites where the cones were found, Charlevoix being a crater (negative surface) and Vredefort a dome (positive surface), but more detailed examinations of cones from different sites would be needed to provide further evidence for this suggestion.

The oblate surface profile of examples like those from Steinheim (**Figure 27c**) and Charlevoix (**Figure 28a**) is the result of the discharges being made not only at a high velocity, which would sweep patterns like those in **Figure 28c**) and d) into cone shapes, but also because of their rotational movement, coupled with the spiralling motion of Birkeland currents due to the spiral nature of their wrap around radial component. This will tend to swirl the discharges in a downward spiral as suggested by the cone in **Figure 29**.

Figure 29. Shatter cone of unknown origin showing possible spiralling grooves. Image: internet.

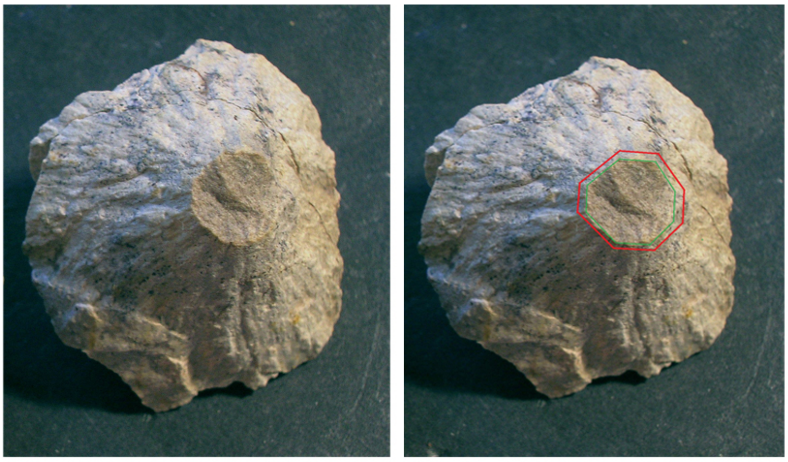


Figure 30. Truncated shatter cone from Crooked Creek, showing isogonal octagonal outline of cross section. Image: impact-structures.com.

Further evidence that shatter cones are the result of electrical discharges from Birkeland currents is the truncated shatter cone from Crooked Creek in **Figure 30**. The outline guide applied to the cross section clearly shows an isogonal octagon, the same polygonal outline as the crater from which it was sourced (see **Figure 17**) and the lightning bolt which ultimately created it.

As I have been able to explain three defining characteristic features of shatter cones and also their formation process (none of which has yet been satisfactorily explained) in terms of my lightning bolt model, then I submit that shatter cones provide firm evidence for the system of counter-rotating, successively discharging, layers of current filaments which my lightning bolt model utilises. In light of this I submit that these structures be re-named 'discharge cones' and treated as indicators of a lightning strike.

Summarising the evidence presented in sections 3.1., 3.2., 3.3. and 3.5.; I submit that the four key morphologies discussed have all been more than adequately explained in terms of the lightning bolt model, while the current impact model has been found to be lacking in all areas. On this basis I suggest that these key morphologies be regarded as reliable indicators of craters formed by lightning strikes.

3.6. Submarine craters

These craters can be difficult to identify because of their location, but modern imaging techniques are very helpful in identifying certain morphological features.

3.6.1. Silverpit crater

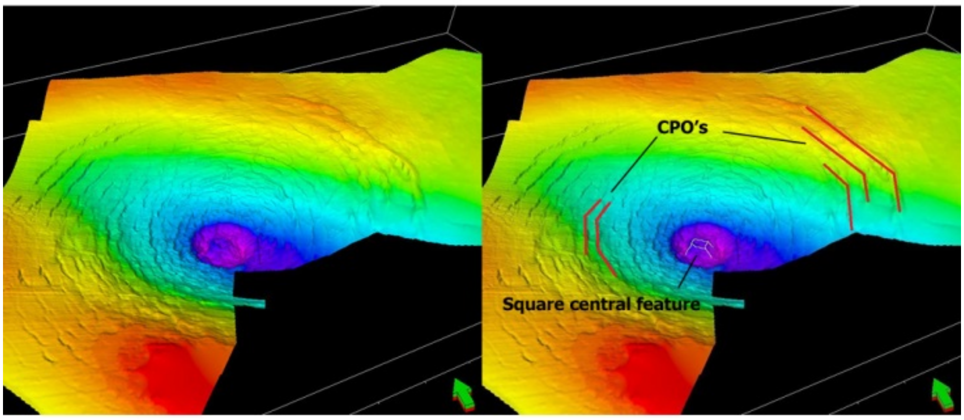


Figure 31. Silverpit crater showing CPO's with 135° angles and a square central feature. Image: internet.

Silverpit crater was initially proposed as a 'multi-ringed impact structure' by Stewart and Allen (2002) with an alternative theory of salt withdrawal proposed by Underhill (2004). Neither theory can explain both the square central feature and the concentric polygonal outlines. As I have explained both of these morphological features (sections 3.2. and 3.3.) within the overall context of my lightning bolt model, I submit that Silverpit crater was formed by a lightning bolt, not a meteorite.

3.6.2. Chicxhulub crater

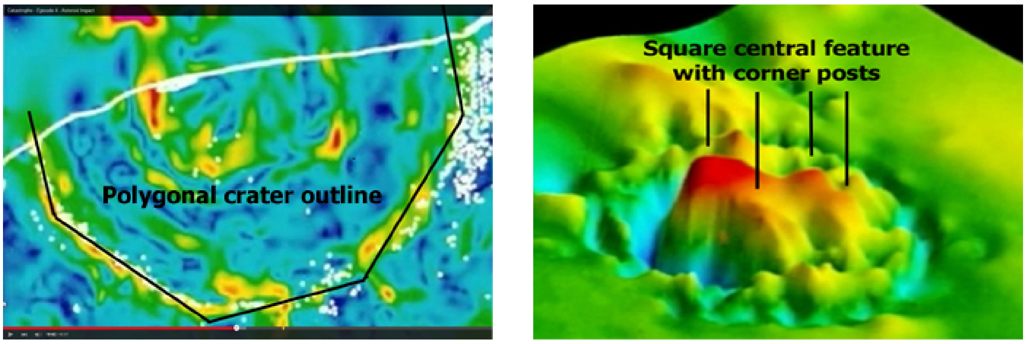


Figure 32. Isogonal octagonal crater outline and square central feature with corner posts. Images: Screenshots[5].

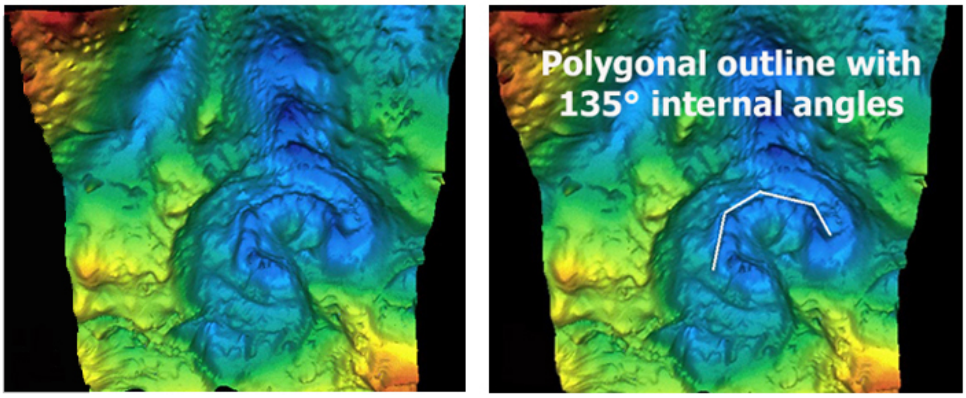


Figure 33. Concentric structure with polygonal outline. Images: Screenshots[5].

The Alvarez Hypothesis (Alvarez et al., 1980) considers Chicxulub crater to be the site of a massive asteroid impact which triggered a series of catastrophic events, culminating in the mass extinction of the dinosaurs and many other species at the end of the Cretaceous period. However, it shows clear signs of having been formed by a lightning bolt. The crater outline, as marked by the cenotes which follow its southern edge, is polygonal in the form of an isogonal octagon, with a matching internal CPO. There is also a square central feature with corner posts. Further evidence for a lightning strike comes from the analysis of seismic and gravity data by Dan Bridges (2004). His schematic lithologic cross section east of the crater center (Dan Bridges 2004, figure 4) shows that, moving from the crater center to the outer edge, the depth of the ring faults becomes progressively shallower and the layer of carbonate breccia near the top of the Cretaceous becomes progressively thinner. This is consistent with a lightning strike. The temperature and impact pressure of a lightning bolt are dependent upon the current density which follows a profile as shown in **Figure 36**. Current density is highest at the center of the bolt and decreases exponentially towards the outer edge. Thus the differing depths of the ring faults reflect the bolt's impact pressure profile and the differing thicknesses of the breccia layer reflect the bolt's temperature profile. The breccia layer itself is formed during the lightning strike as a result of processes covered in greater detail in sections 3.8. and 3.9. I submit this is enough to indicate that Chicxulub crater was formed by a huge lightning bolt.

The cenotes are considered to be the result of a shock wave from the asteroid thought to have formed the crater. I suggest the polygonal outline rules out any theory of a radial shock wave, which would have produced a circular outline. I propose that they were formed by current filaments in the outer polygonal layer which punched through the surface crust of the limestone platform, in areas where groundwater had dissolved the limestone below the surface. If so, then I suggest that the cenotes may show signs of downward spiraling radial grooves caused by Birkeland currents. They may also show signs of a polygonal outline, if not too heavily eroded.

3.7. Siberian craters

The following images (**Figure 34**) are of odd crater formations observed in the Yamal Peninsular, Siberia. To my knowledge at least three of these strange craters have been observed, the most recent being in July

2014. The craters have appeared in an area with methane pockets just below the surface. Scientists have put forward various explanations, but the main consensus appears to be the thawing of permafrost which weakens the surface crust and releases the methane[6].

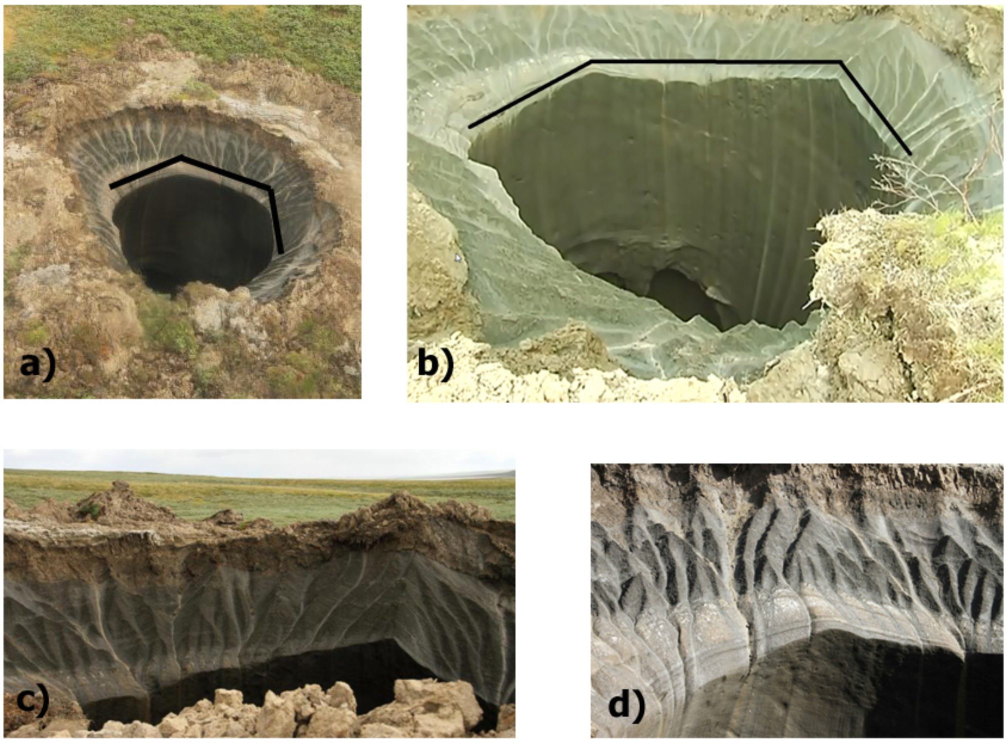


Figure 34. Siberian craters, Yamal. a) overhead view with polygonal outline b) close- up of polygonal outline c) dendritic channels d) dendritic channels close up. Images sourced from internet.

I offer the following explanation. These odd craters show the effect of lightning strikes which have punched through thin crust and ignited the methane pockets just below the surface. Thus I submit that the isogonal octagonal hole a), b) is the outline of an octagonal lightning bolt. Images b) and c) support this by showing perfectly cut 135^o angular vertices of an isogonal octagon. All four images show signs of dendritic ridges/channels around the crater rim, made by streamers from the lightning bolt. I also predict that further evidence of a lightning strike e.g. a fulgarite may be found in the chamber which held the methane pocket.

3.8. Kimberley Big Hole

The Kimberley Big Hole (KBH) is a mined out kimberlite pipe, or diatreme, considered to have been formed by a multi-stage volcanic process; yet it shows signs of being the result of a lightning strike **(Figure 35**). It has an isogonal octagonal crater outline with a matching CPO around the edge of the diatreme opening. The outer crater floor has a wineglass profile with steep sided inner walls at its outer edge. Radial scoring, with indications of a downward spiraling motion, is clearly seen around the diatreme walls.

Figure 35. Kimberley Big Hole. a) Kimberley Big Hole b) Polygonal outline and matching CPO c) Close up of CPO d) Outer crater floor profile e) Measurements of height from rim at five points of a radial score, using an arbitrary scale to show downward spiraling. Images a) – d) from GE screenshots; e) Internet sourced.

None of these features, or other anomalies associated with diatreme and kimberlite formation, are satisfactorily explained by current models of diatreme and kimberlite formation (Kazanovitch-Wulff, 2011). I aim to address all of these anomalies by offering the following explanation.

As noted by Kazanovitch-Wulff (2011), recent developments in geophysics indicate cratonic layers of high electrical conductivity at depths of only 10 km below the surface. The presence of such a large area of electrical charge would easily form the point of focus for a lightning bolt as it seeks the shortest path to earth.

Estimates of impact force at crater sites are independent of the nature of the causal agent and are directly applicable to other possible causal agents e.g. lightning bolts. The presence of shock metamorphic effects e.g. shocked quartz indicate pressures of 8 GPa, while the finding of reidite at Rock Elm crater in Wisconsin[7] indicates pressures of 30 – 80 GPa, giving a range of impact force of 8 – 80 GPa.

Cloud to ground lightning heats up the air around it to over 30,000°C (30x10^3K), which is six times higher than temperatures at the core/mantle boundary. This figure is for bolts perhaps 1m or less in diameter and is a conservative estimate as the temperature at the center of a lightning bolt will be much higher. The temperatures generated by bolts whose diameter is measured in kilometres can only be speculated upon, but an extrapolation of two orders of magnitude for a 100m diameter bolt would give temperatures of 3x10^5K. KBH is 460m in diameter, so a bolt that size would produce temperatures of approximately (4.6 x 3) x 10^5K = 1.38 x 10^6K.

With extremely high temperatures and pressures such as these, a large lightning bolt the size of KBH presents a set of conditions, with regard to temperature and pressure, which are not reproducible elsewhere on Earth, not even at the core/mantle boundary. The temperature and pressure of a lightning bolt depend on current density, which follows a profile like that shown in figure 36, where the highest temperatures/pressures are at the center of the bolt and decrease exponentially towards the outer edge.

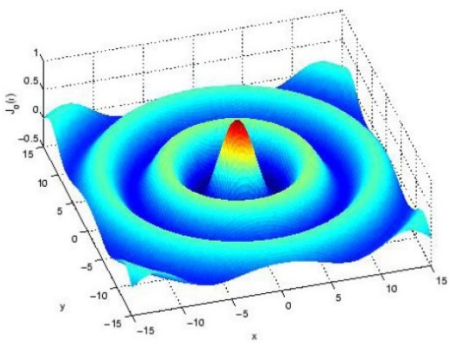


Figure 36. Current density profile of a Birkeland current. Image courtesy of Donald E Scott.

When each current layer makes contact with the surface, the target rock will be subjected to an impact cycle (IC) consisting of 1) fragmentation; 2) flash heating, flash cooling (FHFC); 3) expulsion outwards in a radial direction. I submit that it is this unique set of conditions that is responsible for the formation of kimberlite diatremes and the strike which created KBH would have proceeded as shown in **Figure 37**.

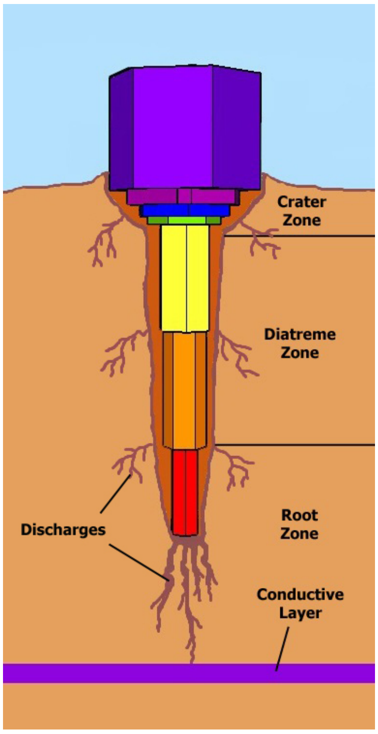


Figure 37. Diatreme and kimberlite formation by lightning bolt.

The central currents will spiral downwards; fragmenting, compressing and melting the rock, as they seek to connect with the conductive layer and discharge. Following their discharge, the rock in the root zone which has probably only experienced one IC will be left to cool slowly, appearing as the igneous intrusion, hypabyssal kimberlite. The root zone itself is an area of complex, irregular structures with ”discrete columns and pillars as well as blind appendages” (Field, Scott-Smith, 1999). I suggest this is an apt description of structures created by electrical discharges as shown in **Figure 37**.

Successive current layers will follow, leaving the radial scoring around the diatreme opening, descending as far as their ‘cutting power’ allows before discharging, until the exponential decrease in current density takes effect and outer layers lack the power to penetrate deep into the crust and will instead excavate the surface, leaving a wineglass profile outer crater with sharply defined, vertical inner walls, cut by the outer edge of the lightning bolt.

The rock in the diatreme zone will be subjected to multiple IC’s but, following the initial fragmentation by the central currents, it’s confinement within the diatreme will restrict further fragmentation. The diatreme rock will be subjected to impact pressure and the shockwave will travel through the semi-molten rock fragments with some of the energy being reflected back by the diatreme walls. This process results in an indeterminate number of high pressure ‘pulses’ being applied to the semi-molten rock in the diatreme zone. I submit that this process generates much higher pressures than those at the sites of excavated craters - where much of the impact energy is dissipated by radial shockwaves - and is responsible for the formation of diamond, garnet and peridot xenocrysts associated with kimberlite.

It is impossible to predict how many IC’s have taken place in the diatreme zone, but pelletal lapilli provide a very good indicator of this.

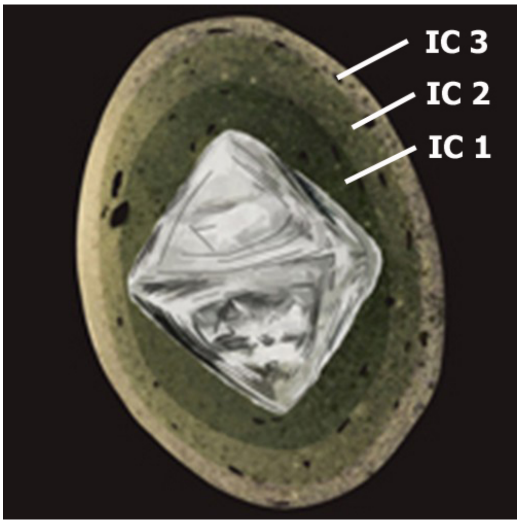


Figure 38. Pelletal lapilli formed around a diamond crystal ‘seed’, indicating three impact cycles. Image source: southampton.ac.uk(7).

The example in **Figure 38** would have been formed in the first impact cycle when a molten clump of fine grained material rapidly condensed around the diamond crystal. Successive IC’s will have progressively lower temperatures, and will not be high enough to melt the rock formed in the previous IC, producing a series of accreted layers around the rim, each one representing a melt produced at progressively lower temperatures and pressures. The exponential decrease in formation conditions is reflected in the decreasing thickness of the IC layers moving from the center to the rim.

These processes will result in the diatreme rock resembling an igneous breccia containing country rock xenoliths from the first fragmentation, irregular fragments and the xenocrysts mentioned earlier. This, I submit, is tuffistic kimberlite breccia. The diatreme walls will also show signs of melting as they were in contact with the current layers.

In the crater zone the IC’s will be more explosive and will include fragmentation stages now that the country rock is no longer contained by the diatreme walls. The rock here will resemble an extrusive igneous rock like volcaniclastic kimberlite. Finer particles will be blown outwards and form a lining of tuff on the crater inner walls.

There has never been a reason for anyone to look for shatter cones within a diatreme crater but I predict that they will be found as indicated by the discharges in **Figure 37**. Supporting evidence, in the form of shatter cones, for a link between lightning strikes and kimberlite are the three kimberlite pipes found within the Luizi impact crater in the Democratic Republic of Congo (Ferrière et al 2014), where shatter cones have been found over the inner 6 km of the crater. The same link is seen in the Mongolian ‘astropipes’ documented by Dorjnamjaa et al. (2011). These are small ‘impact structures’ where kimberlite and gold have been found along with shatter cones.

By subjecting surface crust to temperatures and pressures exceeding those of the deep mantle, the lightning bolt model explains all of the anomalies associated with kimberlite. As kimberlite is formed in situ under conditions of FHFC, there is no need to account for the rapid ascent of deep melt and the subsequent rapid cooling needed to form diamond crystals rather than graphite. Kimberlite’s origin from surface crust also accounts for its high volatile content and the similarities in chemical composition to sedimentary and metamorphic rocks of the Earth’s crust, as noted by many researchers (Kazanovitch-Wulff, 2011). Lightning bolts are driven by one thing – the need to find the shortest path to Earth; so the location of diatremes formed by lightning bolts will be determined by the presence of large amounts of sub-surface electrical charge e.g. the cratonic layers of high electrical conductivity mentioned earlier and not by any other factor. This easily explains the location of diatremes far from zones of tectonic activity, their lack of association with other lithologies or basement structures and their random spatial distribution. As the morphological anomalies (**Figure 35**) associated with the outer crater have also been accounted for, along with a complete and satisfactory explanation of the formation of pelletal lapilli; then I submit that the lightning bolt model of formation for kimberlite diatremes and kimberlite provides a more than credible alternative to current theories and models of diatreme and kimberlite formation.

3.9. Meteorites

If the polygonal craters discussed in this paper were formed by lightning strikes, how do we account for the meteorite fragments associated with them e.g. the Canyon Diablo meteorite found in and around Barringer crater? If a crater was formed by a lightning strike then I submit that any associated meteorite fragments were also formed in the strike event. I offer the following explanation.

The temperature and pressure of a lightning bolt are dependent on the current density, which has a profile like that shown on the left in **Figure 39**. Based on the same estimates used to calculate the temperature of a 460m diameter lightning bolt at KBH, a bolt the size of Barringer crater would be approximately 1km in diameter, generating a temperature of $30x10^6$K. On the right is a diagram of the strike area mapped out in concentric circles, representing the counter-rotating layers of current filaments. Superimposed on this is a series of zones of temperatures and pressures roughly corresponding to the current density profile, which is at its highest in the center of the strike area and decreases exponentially towards the outer edge.

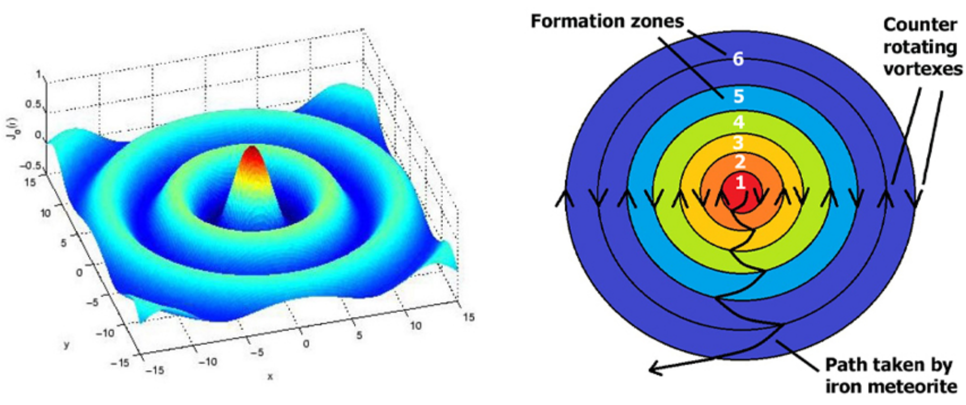


Figure 39. Meteorite formation zones within a lightning strike. Image on left courtesy of Donald E. Scott.

The strike will start when the central currents impact the surface, and progress with a succession of impact cycles (as outlined earlier in section 3.8.) until the outer layer of current filaments makes contact and discharges. Each zone will produce rock fragments whose composition is determined by the temperature and pressure at which they were formed. By applying the zonal formation model to the main groups of current meteorite classification systems, we can build up a complete picture of the various rock types produced by a single lightning strike. Each type can be assigned to its respective formation zone according to composition and appearance.

Zone 1

At an estimated temperature of 30x10^{6}K, almost all the minerals will be vapourised and the only metals left would be iron and nickel with traces of other members of the iron peak series (IPS) Cr, Mn, Co, V, if present in the target rock. The (IPS) metals are regarded as end products of stellar nucleosynthesis, believed to take place at approximately 15x10^{6}K, and stable up to the much higher temperatures required for the formation of heavier elements, a process thought to take place in supernovae. Iron and nickel are the most prominent of the IPS because they have the highest nuclear bonding energies, making them the most stable. As the higher temperatures required for supernovae nucleosynthesis are not reached then the iron and nickel will remain behind to form the iron-nickel alloy taenite under flash heating. Other IPS metals present will be incorporated into the iron-nickel based minerals associated with meteoric iron e.g. chromite ($FeCr_2O_4$) and cohenite ($[Fe,Ni,Co]_3C$). The resulting molten chunks of taenite will then undergo flash cooling.

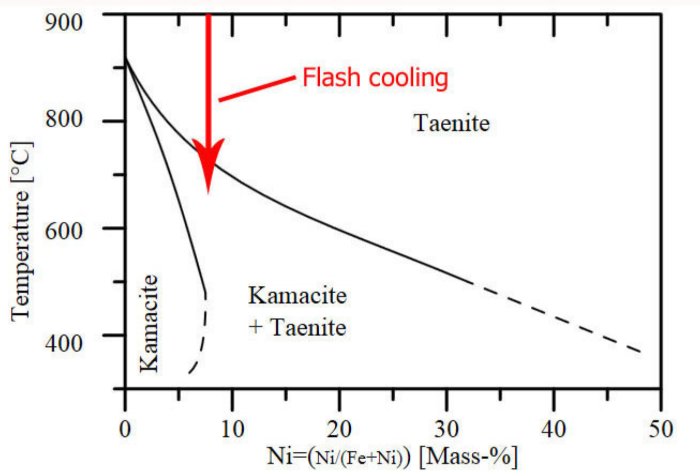


Figure 40. "Meteoric iron phase diagram taenite kamacite" by Tobias1984 - Own work. Licensed under CC BY-SA 3.0 via Wikimedia Commons[8].

Flash cooling will promote a rapid descent down the phase diagram in **Figure 40** resulting in the almost simultaneous crystallisation of kamacite and taenite. This I suggest may be responsible for the Widmanstatten patterns (**Figure 41b**) characteristic of iron meteorites. Following this extremely rapid FHFC cycle, the metal fragments are thrown out into zone 2 where they will continue on the path shown in **Figure 39**. This will take them through a series of counter-rotating vortexes, where they will be battered by rock fragments, some solid, some molten; while possibly undergoing brief periods of FHFC before being ejected from the strike area. This results in a final appearance like the sample of the Canyon Diablo meteorite (**Figure 41a**), covered in indentations or regmaglypts.

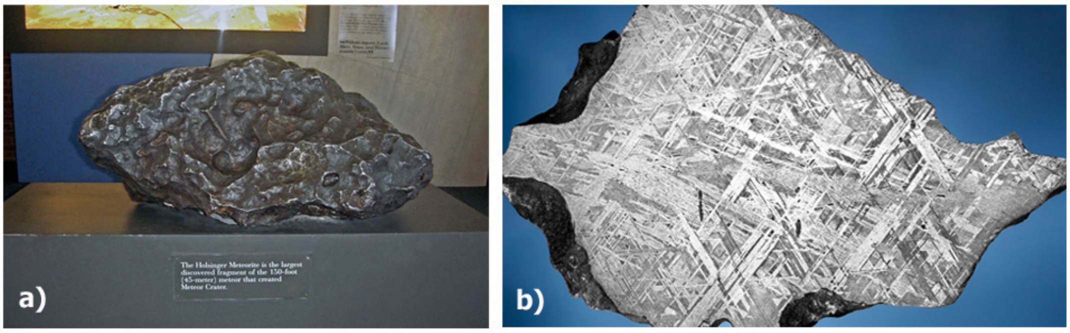


Figure 41. Iron meteorites: a) Holsinger meteorite (Canyon Diablo fragment) b) Gibeon meteorite, Namibia, showing Widmanstatten patterns.

Zone 2

With slightly lower temperature and pressure more minerals will remain. Zone 2 is where we find the pallasites. These stony-iron meteorites are mainly iron-nickel alloy with a small amount of minerals and will appear as olivine clasts in an iron-nickel matrix. Like the iron meteorites, they too will travel through zones of exploding rock fragments and will have a battered appearance with lots of indentations.

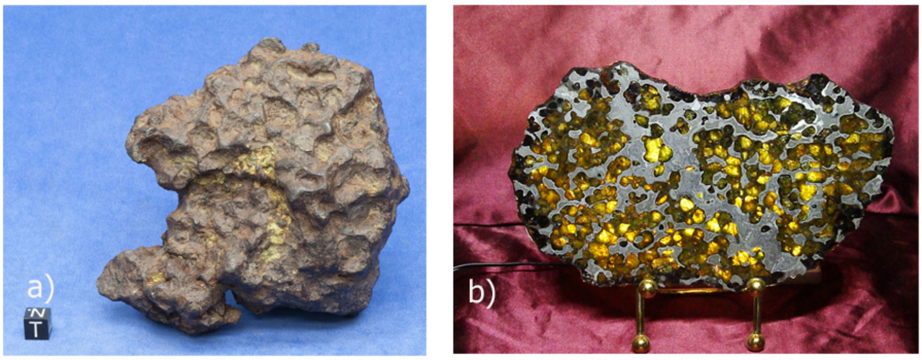


Figure 42. a) Sterley Pallasite, meteorites.wust.edu, image by Laurence Garvie b) Brenham pallasite, kdmeteorites.com.

Zone 3

In zone 3 the exponential decrease in current density takes effect and the temperature falls significantly.

This is where the mesosiderites are found. These brecciated stony-iron meteorites containing roughly equal amounts of metal and silicates are formed when fragments of metal and minerals are fused and melted together with neither component being dominant, before being expelled from the strike area.

Their final appearance results from their lack of a contiguous metal surface which would suffer indentations from collisions. Instead, their irregular, partly stony surface of fused lumps of metal and chunks of rock will be chipped and fragmented as they travel outwards to the edge of the strike area, like the Vaca Meurta example in **Figure 43a**.

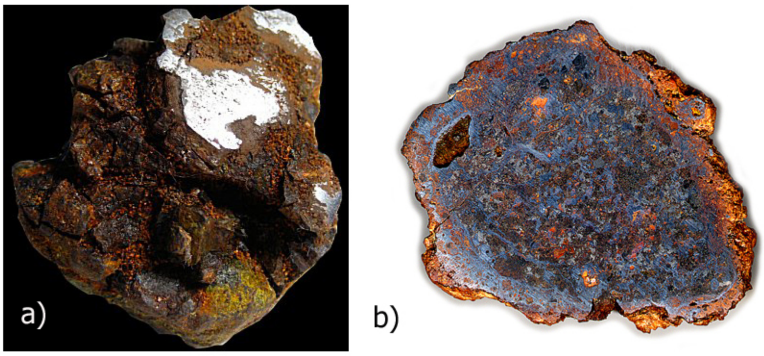


Figure 43 a) Vaca Meurta mesosiderite, spacerocksuk.com b) Dalgaranga mesosiderite, astro.washington.edu.

Zone 4

Zone 4 sees another significant drop in temperature and pressure with the appearance of the first of the stony meteorites, the achondrites. They appear as igneous breccias, showing signs of melting and recrystallisation. The main members of this series are the HED achondrites – howardites, eucrites and diogenites. Diogenites have the largest particle size and would be found closest to the center while eucrites, which have a smaller particle size, would be placed further from the center on the grounds that smaller particles would be blown further outwards. The howardites are a mix of diogenites and eucrites, indicating that they are formed from eucrite and diogenite fragments blown out and fused at the outer edge of zone 4.

Having a contiguous stony surface, the achondrites will form a surface crust following FHFC. As they will experience fewer collisions before being expelled from the strike area, they will have a more regular surface appearance like the Milbillillie eucrite in **Figure 44a**.

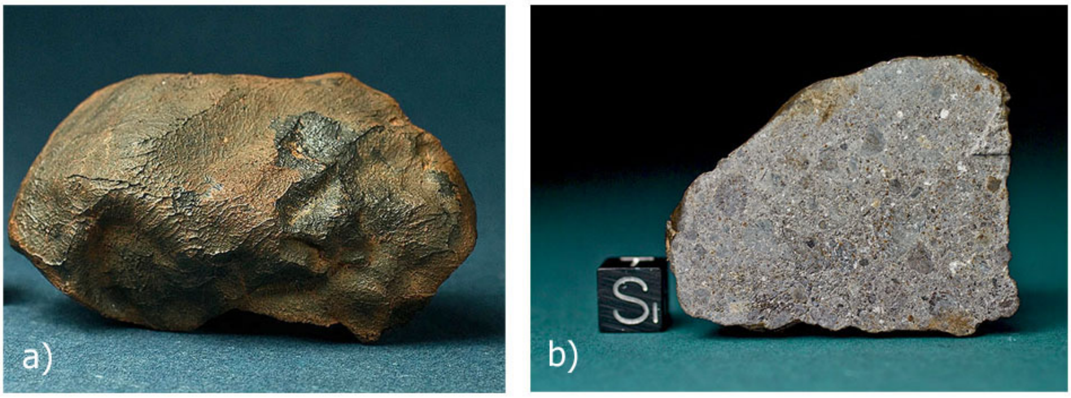


Figure 44. a) Millbillillie eucrite b) NWA 2482 eucrite Images: meteorite-recon.com

Zone 5

In zone 5 are the primitive achondrites which have an igneous texture, indicating melting processes. Unlike achondrites though, they have a chemical composition similar to chondrites and they also contain chondrules. Chondrules appear in zone 5 but their formation process begins earlier in zone 3, or even zone 2. As discussed in the case of diogenites and eucrites, fine particles will be expelled at a higher velocity than large fragments, increasing the probability that they will pass through several stages of FHFC; large fragments will probably only undergo one stage of FHFC when they are first formed and will not be expelled quickly enough to be caught up in the FHFC stages of successive impact cycles.

I suggest that the formation process of a chondrule is as follows. A dust sized particle of metallic iron or silicate mineral is melted and condensed under FHFC in zone 3 before being rapidly expelled into zone 4. The lower temperatures in zone 4 will be insufficient to melt the particle and instead it will become encased in a layer of condensing melt rich in olivine and pyroxene, and then expelled into zone 5. At even lower temperatures and pressures the particle will again be encased in a layer of condensing melt, but this melt will be rich in feldspathic material and provide the chondrule with its final layer of condensed melt. This process, whereby a 'seed' particle provides the nucleation site for the successive accretion of discrete layers of material differing in composition and/or appearance, is the same as that which produces pelletal lappili in kimberlite. Like pelletal lapilli, chondrules are indicative of several stages of FHFC resulting from successive impact cycles. In this respect, these two similar expressions of the same unique process, operating in two widely differing environments, not only infer a link between the formation processes of kimberlite and meteorites but are also suggestive of a common causal agent such as the lightning bolt model which predicts successive FHFC cycles.

Some chondrules will be trapped in larger amounts of condensing melt and appear in primitive achondrites while others will be expelled into zone 6. Primitive achondrites will have a surface texture much like the achondrite in **Figure 44a**.

Zone 6

Out here the temperatures are not high enough to melt rock and the chondrules expelled from zone 5 will be fused with the fragmented rock of zone 6 to form chondrites. Like the other stony meteorites the chondrites will develop a fused crust but they will be smoother than the achondrites as they don't pass through any impact zones other than where they were formed and are therefore subject to fewer collisions (**Figure 45**).

Figure 45. Chondrites arizonaskiesmeteorites.com.

Outside of zone 6, the surrounding area will be overlain with ejected meteorite fragments and tektites, which are examples of the fulgarites produced by the action of lightning on loose sand or soil; their darker, blackened colouration indicative of the higher temperatures involved in their formation. They are formed from the pedolith overlying the country rock. They are the first products to be formed and the lightest so they will be expelled from the crater first and will be found over a wide area and at great distances from the crater.

I submit that all meteorites, regardless of their origin, are the products of a lightning strike on country rock. Their respective compositions and appearances are a result of where, based on the zonal formation model (**Figure 39**), they were formed within the strike area.

All meteorites, whether associated with impact craters on Earth or from witnessed falls, have high concentrations of iridium. If, as I believe I have shown, the polygonal craters discussed in this paper were formed by lightning strikes, then so were their associated meteorites, and the high levels of iridium found can only be the result of the lightning bolt process. I offer the following explanation. Iridium, being siderophilic, has a high affinity for iron. I submit that in the highly reducing atmosphere of a lightning strike, the high temperatures and pressures will provide a unique set of conditions under which any iridium present in the target rock will form metallic bonds with the metallic iron produced in zone 1 and perhaps zones 2 and 3 (if temperatures and pressures are high enough in these zones). The meteorites formed in these inner zones will then be subject to collisions and FHFC cycles, distributing the iridium throughout the strike area where it will be incorporated into the other meteorites at each FHFC cycle, before they exit the strike area. The crater itself will also show high iridium levels from all the finer particles expelled by the strike.

Earth has received meteorites from the moon, Mars and possibly, as in the case of the Murchison meteorite, outside of our solar system, so we know that meteorites can be ejected from a planetary surface into space. Considering the numerous polygonal craters scattered throughout the solar system, which must have been excavated by lightning bolts; and the abundance of meteoritic bodies in areas such as the asteroid belt, I suggest that the excavation of planetary surfaces by huge lightning bolts is a process which has occurred many times in the history of our solar system.

4. Conclusions

On the basis of all the evidence presented in Section 3. I make the following conclusions.

1. The lightning bolt model presented here is the most complete and accurate model of the lightning bolt process to date and may prove useful in furthering our understanding of both cloud to ground lightning and above cloud phenomena e.g. sprites, elves and blue jets. As these above cloud phenomena appear to occur at the same time as cloud to ground lightning, I suggest they may all be part of a single regulatory system which the natural world uses to address localised imbalances of electric potential, by the transfer of electrical charge via the lightning bolt process. If cloud to ground lightning transfers the negative charges at the bottom of a thundercloud to the ground, then I suggest that sprites, elves and blue jets may be involved in transferring the positive charges at the top of the cloud to the ionosphere.
2. All examples of the two polygonal craters discussed in this paper are the result of lightning strikes; their key morphologies i.e. polygonal outline, concentric polygonal structures, central feature and discharge cones being definitive indicators of a crater formed by a lightning bolt.

3. By accounting for the anomalies associated with diatremes and kimberlite, including a previously lacking satisfactory explanation of pelletal lapilli, the lightning bolt model offers a more than credible alternative to current theories and models of diatreme and kimberlite formation.
4. All meteorites are formed by large lightning strikes, their composition and appearance being a direct result of their respective positions within the area of the lightning strike, as delineated by the zonal formation model presented here.
5. The lightning bolt formation process has been shown to be infinitely scalable and therefore the possibility of colossal lightning bolts has been firmly established. One possible origin of such huge electrical discharges could have been close encounters at some time in Earth's history with large planetary bodies whose electrical potential was much higher than Earth's, resulting in the transfer of huge amounts of electrical charge via colossal lightning bolts. The only difference between this and the cloud to ground lightning we see today is that a planetary body has been substituted for the thundercloud; the principle and the process are the same. As currently accepted theories and models of solar system formation and the behaviour of planetary bodies within solar systems do not allow for this, then they should be reconsidered and re-examined within the context of the Electric Universe model, as this is the only model which predicts close inter-planetary encounters and resultant colossal electrical discharges.
6. The high levels of iridium found at the K-T boundary have formed the basis of several theories concerning mass extinction events linked to meteorite/asteroid impacts, most notably the Alvarez hypothesis. As Chicxulub and other impact craters discussed here have been shown to be caused by lightning strikes, and that lightning is responsible for the presence of high levels of iridium, then any mass extinction events linked to high levels of iridium and meteoritic impacts, should also be reconsidered and re-examined within the context of the Electric Universe model for the same reasons given above in 5.

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References

1) "Symbols of an Alien Sky part 2 – The Lightning Scarred Planet, Mars"
2) List of impact craters on Earth: http://en.wikipedia.org/wiki/List_of_impact_craters_on_Earth
3) Impact structures of the world: http://www.somerikko.net/impacts/database.php?show=all
4) Lightning in super slow motion: https://www.youtube.com/watch?v=RLWIBrweSU8
5) Channel 4 Documentary series "Catastrophe – episode 4 – Asteroid Impact", 2008
6) http://www.sott.net/article/283249-Earth-is-opening-up-Mysterious-Siberian-crater-attributed-to-methane
7) "Rare Mineral Discovered in Ancient Meteorite Impact Crater." http://www.livescience.com/48584-reidite-discovered-rock-elm-wisconsin.html
8)http://www.southampton.ac.uk/oes/news/2012/05/16_chocolate_and_diamonds_why_volcanoes_could_be_a_girls_best_friend.page?
9) "Meteoric iron phase diagram taenite kamacite" by Tobias1984 - Own work. Licensed under CC BY-SA 3.0 via Wikimedia Commons - http://commons.wikimedia.org/wiki/File:Meteoric_iron_phase_diagram_taenite_kamacite.svg#/media/File:Meteoric_iron_phase_diagram_taenite_kamacite.svg
Alvarez, L.W., Alvarez, W., Asaro, F. and Michel, H.V., 1980. Extraterrestrial cause for the Cretaceous-Tertiary extinction. *Science*, v. 208, p. 1095-1108.
Baratoux, D. and Melosh, H.J., 2003. The formation of shatter cones by shock wave interference during impacting. *Earth and Planetary Science Letters*, v. 216, p. 43-54.
Dan Bridges, L.W., 2004. The volcanic interpretation of Chicxulub, Mexico. *New Concepts in Global Tectonics Newseltter*, no. 28, p. 9-15.
Dorjnamjaa, D., Voinkov, D.M., Kondratov, L.S., Selenge, D., Altanshagai, G. and Enkhbaatar, B., 2011. Concerning diamond and gold-bearing astropipes of Mongolia. *International Journal of Astronomy and Astrophysics*, v. 1, p. 98-104.
Ferrière, L., Kaseti, P.K., Lubala F.R.T., Akwerali, J. and Djuma, A., 2014. New finds of impactites at the Luizi impact structure (Democratic Republic of Congo). 77th Annual Meteoritical Society Meeting.
Field, M. and Scott-Smith, B.H., 1999. Contrasting geology and near-surface emplacement of kimberlite pipes in Southern Africa and Canada, Proceedings of the VIIth International Kimberlite Conference, vol. 1.
Khazanovitch-Wulff, K.K., 2011. Some problems and questions of kimberlite geology and electric discharge hypotheses. *New Concepts in Global Tectonics Newsletter*, no. 61, December.
Reimold, W.U. et al., 2006. Investigation of Shuttle Radar Topography Mission data of the possible impact structure at Serra da Cangalha, Brazil. *Meteoritics & Planetary Science*, v. 41, no. 2, p. 237–246.
Sagy, A., Fineberg, J. and Reches, Z., 2004. Shatter cones: Branched, rapid fractures formed by shock impact. *Jour. Geophys. Research*, v. 109, B10209, doi:10.1029/2004JB003016.
Scott, D.E., 2015. Birkeland Currents: A Force-Free Field-Aligned Model. *Progress in Physics*, v. 11, Issue 2.

Stewart, S.A. and Allen P.J., 2002. A 20-km-diameter multi-ringed impact structure in the North Sea. *Nature*, v. 418, no. 6897, p. 520–523.
Underhill, J.R., 2004. Earth science: an alternative origin for the 'Silverpit crater'. *Nature*, v. 428, no. 6980.

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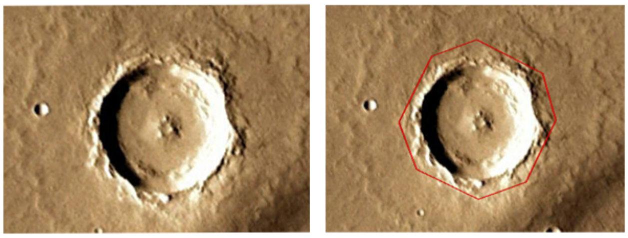
Appendix A

Mars



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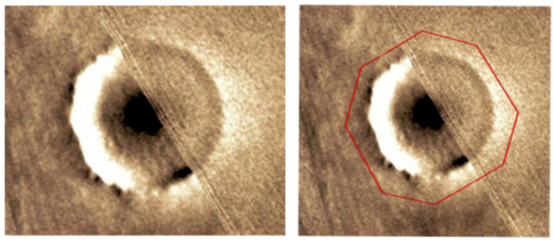

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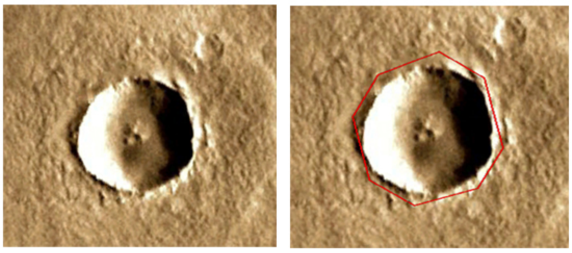
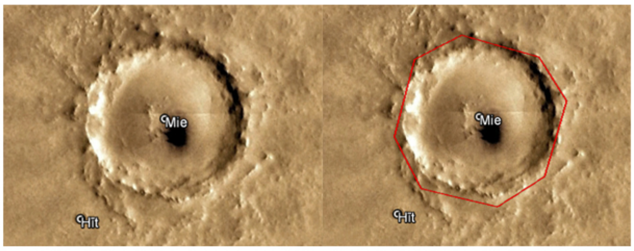


Location: 38°35′30″N 137°13′52″E

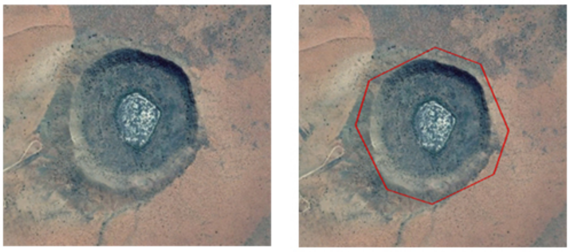


Location: 48°05′54″N 139°38′08″E

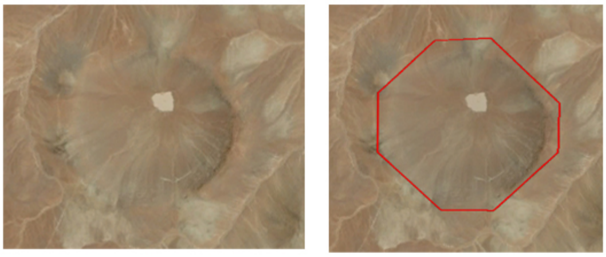
Earth

Bni Hadifa, Morocco 35°00′25″N 407′40″W

Puchezh-Katunki crater, Russia 56°58′01″N 4156′48E



Wolfe Creek crater, Australia 19°10′18″S 127°47′43″E

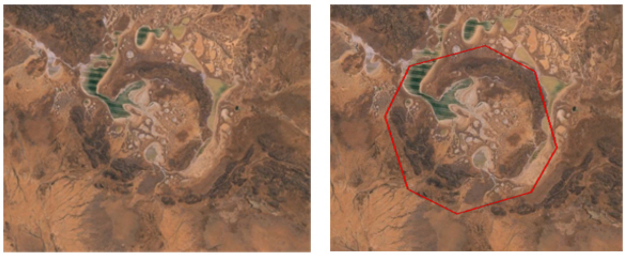


Monturaqui crater, Chile 23°55′41″S 68°15′42″W

Manicouagan crater, Canada 51°24′23″N 68°39′59″

Ramargh crater Rajhastan 25°19′57″N 76°37′31E

Serra da Cangalha, Brazil 80°4′50″S 46°51′28″



Shoemaker crater, Australia 25°50′41S 120°52′40″E

EVOLUTION OF THE TECTONO-MAGMATIC PULSATIONS IN THE EARTH'S HISTORY

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Abstract: The article presents the consideration on the geological history and some tectonic-magmatic paradoxes of the Earth' development. It is shown that in two early periods, from Hadean to Riphean, predominant endogenous processes were initially associated with the formation of protosial, then with the generation of ultramafic-basaltic (sima) shells. Protomantle lost huge amount of heat which accompanied by its layering and compacting. The light and melting material migrated into the crust. Consolidation of the crust in the Paleoproterozoic was associated with the phenomena of inversion of sial, subsidence of sima, and subsequent cooling of the tectonosphere. Starting from the Riphean in condition of the relatively cold lithosphere the water-sedimentary cover was formed. Since Riphean to present the intensity of sedimentation has increased exponentially. Predominance of subsidence in the Neogeic indicates a consistent decline of the geoid surface and the continuing effects of compacting and pulsating contraction of the Earth. The average thickness of the platform crust, not distorted by its subsequent transformation, is probably the criterion value of reducing the Earth's radius (≈40 km).

Keywords: *evolution of the Earth, tectonomagmatic processes, protosial, basaltic layer, sedimentary cover, water of the oceans, Earth's fluctuating contraction hypothesis*

Introduction

Recently our understanding of the early history of the Earth has significantly changed. Geosynclinal theory, which proposed a universal mechanism of the growth and evolution of the Earth's crust, from its inception to consolidation in the form of platforms, has undergone a dramatic ostracism. Because of this theory is based on the process of subsidence and powerful sedimentation, its application to the early stages of the Earth development has become to be questionable. On the contrary, more and more data testify that early history of the Earth is essentially associated with magmatic processes. Due to this new value assume the basic results on the sedimentary cover of the Earth in Neogeic[1] obtained earlier (Ronov, 1980; Ronov, 1990). The success of "zirconium" geochronology and isotopic geochemistry led to discovery of minerals with age more than 4 billion years, close to the beginning of the planet formation (Hanchar and Hoskin, 2003). According to isotopic Geochemistry (Caro et al., 2003) the first differentiation of the primary matter of the Earth with the appearance of highly enriched derivatives took place approximately 100 million years after accretion: 4460+/-115 million years. The stabilization of the Earth's atmosphere occurred 4.45+/-0.02 billion years (Zhang, 1998).

Generation of protosial

According to the isotopy of the noble gases, later, in Hadean, protomantle had undergone 8-time recycling, while after Hadean for all the rest of time there was only one recycling (Yokochi and Marty, 2005; Marty et al., 2007). Values of Nd isotopes in the rocks of the Labrador and Western Greenland with age of 3.7-3.8 billion years indicate that by this time more than 40% of modern granite crust was formed (Collerson and Kamber, 1999). These data testify to the formation of the oldest rocks of the crust during the period of 4.4–3.9 billion years, in the first 500 million years (Hamilton, 1998, 2003; Zahnle, 2003*;* Mojzsis et al., 2007). In the most ancient zoned zircons (4.4 billion years) the micro-inclusions of intergrowths of quartz and kalium, feldspar, albite, magnetite, pyrite, were found, indicating its association with granitic melt. Zones of this zircon have δ^{18}O‰=5.0 and 7.4 while the mantle value is ≤ 5.3. A recent review of this problem (Kuzmin, 2014) showed that formation of the continental crust (protosial) within almost all well-studied cratons refers to the interval of 4.5-4.0 billion years with a peak in the period of 4.2 billion years (**Fig. 1**). The temperature of the magmatic ocean crystallization is estimated as 700–800˚C. The study of oxygen isotopic and Cs contents in zircons indicate the formation of the crust under hydrous conditions.

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[1]. The term was proposed by a German geologist, H. Stille in 1964 in contradistinction to Protogeic. In Russian literature Neogeic implies Riphean and Phanerozoic beginning from 1.6 b.y. The Neogeic is characterized by large stable blocks of ancient platforms and the geosynclinal belts and oceans dividing the blocks.

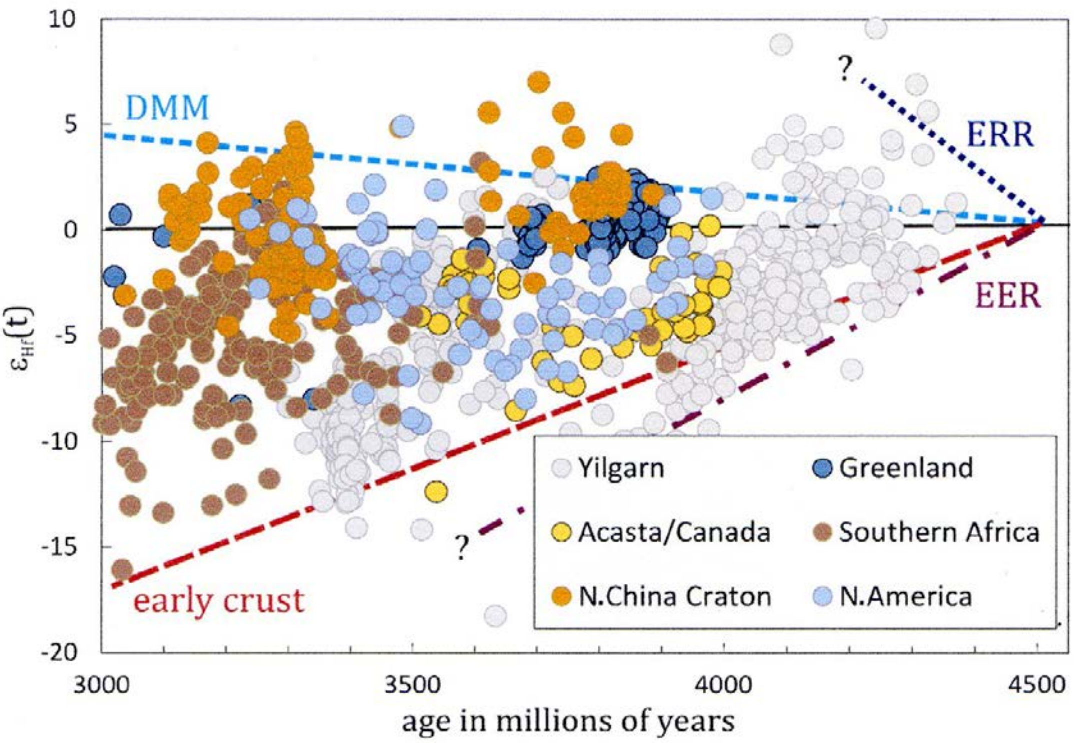

Fig. 1. The composition of the zircon-debris (on the value) detected in the sediment and rock in the disintegrated grey gneisses of the cratons within Australia, Canada, North China, Greenland, South Africa and North America (after Nebel et al., 2014). Derived from Kuzmin, 2014. ERR – the early residual reservoir; EER - the early enriched reservoir; DMM – depleted mantle.

Thus, there is growing evidence about important role of granitoids in the earliest period of Earth's development, in Hadean; on the contrary, the idea of primary gabbro-anorthositic or lunar phase of the early Earth loses its justification (Ermakov, 2002 and 2004). It does not mean that such rocks were absent on the Earth, however they occupy a higher position in the stratigraphic age sequence. The protosial rocks were likely close to the grey gneisses or tonalite-trondhjemite-granodiorite (TTG) series**,** the specific characteristic of which is their reduced kalium. These rocks have the low relation $^{87}Sr/^{86}Sr$ (0.699-0.701), which testifies to their mantle nature.

Our model of the formation of sialic crust is connected with the processes of convective separation of protomantle in the Benard cells (Garagash and Ermakov, 2004). The convection occurs in the conditions of the magmatic ocean and high primary water saturated proto-mantle in layer of ~400 km thick. Just the high water contents with a small percentage of melting contributes to the emergence of low kalium melts in experiments with rock of the chondrite-type[2] (Mysen and Boettcher, 1976); the composition of these melts is close to the granodiorites. In fact, the formation of Benard cells reflects the tendency of a system to dump the excess heat. Release of the heat leads to the disintegration of cells, then its accumulation generates the new cells and new convection. As noted, such recycling could occur repeatedly (up to 8 times) in the entire volume of the upper shell of protomantle. After separation of the fluid-melt protomantle turns into depleted mantle. Thus, we found a probabilistic decision of the primary formation of the proto in Hadean, immediately followed after the period of accretion (Ermakov, 2011).

Generation of sima and inversion of protosial

The main volume of water and atmosphere was formed simultaneously with sialic crust already in Hadean, not later than Archean, however, the first reservoirs were very far from the modern oceans. During this period, there were no contrasting tectonic forms at the surface and so the oceans were not structured; it is possible that the first water-contained forms were astroblemes. Basalt-ultrabasalts rock in the form of greenstone belts (GB) or Granite-greenstone areas (GSA)**,** are mostly younger than complexes TTG or

[2] It should be noted, that recently a more complex composition of primary substances is assumed, with a significant proportion of carbonaceous chondrites. With the latter the presence of water is connected.

grey gneisses and belong to the Archean – Proterozoic. Assumptions about the primary (pregranitic) mafic or basaltic and even alkali-basaltic crust until seem to be a priori**.** The processes of differentiation and fractionation of the ultramafic magma can explain the formation of no more than 5-7% of protosial that is considerably smaller than the observed quantities of the early granitoids. It is also established that the most ancient alkaline rocks (basalts and granites) are of the early Proterozoic age, less than 2.7-2.5 billion years. This fact contradicts to the hypothesis of early crust of alkali-basaltic composition. The observed cross-sections of rocks of basic or ultrabasic composition were forming within almost the entire Archean and Proterozoic, up to Riphean; the total thickness makes up to 15-20 km, sometimes the larger values are known. The specificity of the volcanism of this period is the formation of komatiite, the share of which in certain cross-section are up to 10-15%.

Analysis of the vast literary sources shows that during the Archean-Proterozoic, mainly due to the volcanic processes, the "basaltic" layer of the Earth's crust (sima) was formed (Salop, 1982, and others). The role of another mechanism - magmatic underplating in general formation of the crust in this time, apparently, was not significant.

Investigation in the middle of 20th century showed that in the Earth's crust the volcanic facies of basic rocks (basalts) predominant over the intrusive facies (gabbro-like rock). Such character of Earth’s crust content is associated with the peculiarities of thermodynamics and rheological properties of magmas. The role of gabbro intrusions in the crust essentially lesser comparing to their surface volcanic analogues. This conclusion is directly related to the small scale of underplating. Nevertheless the manifestations of mafic magmatism is considerable, it can be assumed that it covered the entire Earth's shell. Many researchers associated the sima formation with the penetration of the plumes from the lower mantle (Mantle plumes…, 2002).

The sedimentary rocks of the Archean-Proterozoic are presented by shallow-water, terrestrial, and probably eolian formations: breccias, conglomerates, gravelite, shales, siliceous rocks, jaspilite; the total thickness is up to 3-5 km. Rare, but indicative species are leptite and halleflita**,** jaspilite, the accumulation of which is probably due to the hurricane-wind circulation in conditions of active volcanism. The quartzite strata is characterized by their homogeneity and large thickness, up to ≥ 1 km (Salop, 1982). Jaspilite are marked with signs indicating to their relationship both with the volcanic basaltic eruptions and the destruction of protosial rock. Part of sedimentary rocks in the sections does not exceed 15%.

Two- or three-layered geophysical model of the crust with lower basalt layer turned out to be vulnerable from result of deep drilling. In some cases the low position of granitoids (under the basalt layer) was found. Paradox of the basalt layer is that, despite this layer is younger than the oldest TTG-series, in the modern structure of shields basalts are distributed episodically and usually associated with granitoids. The granitoids often make up 75-85% of the total area of GB protosial within the shield. Where is the younger basaltic layer? The issue is solved under the assumption that the layer of sima as it accumulates exchanged by place with protosial. This was due not only to differences in density between protosial and sima, but also due to the high temperature of the penetrated basalt plumes, which caused heating and mobilization of the protosial. Mechanisms of this kind are considered in the works of many researches. The thermal excitation of early TTG-series leads to the rheomorphism and granitization, resulted in the various forms of advection and floating rocks with a less dense to the surface (Ermakov, 2011 and 2011a). Due to the rheomorphism the primary composition of plagiogranites-tonalites to a great extent was lost, and converted to enderbites, charnockites, normal pegmatite and alkaline granites. Bimodality of granitoids and mafics or basaltics GB is the result of their paragenetic, but not genetic connection.

Rising basalt plumes caused the transformation and movement of protosial with the formation of the observed domes or reons[3] (Escola, 1949; Salop, 1982). Thus, during the first two periods of the Earth's crust evolution, i.e. the period of magma-tectonics with the formation of sial and plumetectonics with the formation of the sima were in fact formed the main volumes of the Earth's crust. To the end of this stage (4.4-1.6 billion years) 80-95% of the crust had formed; Armstrong (1981) gave the maximal estimates. Two-layer crust of the magmatic origin is a clear evidence of a huge loss of heat, volatile and low-melting component of protomantle; the mantle has become stratified. The separation of the layers of the upper and lower mantle can be assumed to due to the interpreted heat loss. The first proto-mantle layering was

[3] Salop (1982, p. 69) proposed for granite-metamorphic domes term "reon". Reons rise to the surface during rheomorphism and due to heating. Their dimensions can be up to 800 km.

associated with its depletion and multiple recycling during the Hadean and second, with the loss of low-melting and volatile components from the rising basalt-komatiite plumes from the lower mantle during the Archean and early Proterozoic.

Mixing of the materials, their gravitational arrangement and, finally, cooling, caused a consolidation of the crust. Early formation of protosial predetermined a whole complex of subsequent tectonic events in the Archean-Proterozoic: inversion of protosial and plunge of sima, the accompanying capture of skialites, forming the dome-like structures of GSA or GB**,** metamorphic paradoxes and the domination of granitoids on the surface of the shields. The absence of or presence of thin marine sediments constrain the geosynclinal structure or extended dips, resulting in an absence of reliable evidence of orogeny as well. Many petrologists suggest that the main mechanism of formation of the primary endogenous Earth were the palaeoisland arcs, however, the long-term study of these structures by the author showed that they are structures of oceanization (Ermakov, 2005 and 2006) but not the analogous of not quite understandable tectonic processes in the deep Precambrian. Special volcanological and paleogeographic studies indicate a flat character accumulation of volcanic cover in the Archean and Proterozoic (Svetov and Sviridenko, 2005). Analysis of the dyke fields allows to reconstruct in some cases the shield volcanoes of the considerable height (up to 10 km and more).

The table below lists the most important events of the three main periods of development of the Earth, and the following list highlights the key not recurring events its tectonic-magmatic history (Ermakov, 2011 and 2011a)

Table 1. The most important events of the three main periods of development of the Earth

The main events	Age	Peculiarities of the rock and processes	Peculiarities of the heat processes	Notes
I. Period of magmatectonics. Fluid-molten melting of the protomantle. Formation of the protosial.	Hadean (Prearchean) 4.4 – 3.8 billion years	The tonalites, trondhjemites, and Grano-diorites. Terrestrial magmatism of the ignimbrite type. The high role of the aeolian transfer in the formation of sediments. The primary water and atmosphere. Rare deposits.	Magmatic ocean. The fluid convection of the protomantle in the Bernar cell. Dissipation of the upper layer of the Protomantle to a depth of 400 km	Simultaneous forming of protosial and depleted upper mantle. 8-fold recycling
II. Period of the plumetectonics Expansion of the plumes from the lower mantle sources. Formation of sima, **GB, GSA**. Wide-scale granitization. Shallow-water sedimentation.	Archean-Early Proterozoic 3.8-1.6 b.y.	Ultramafic-basalt magmatism. Komatiite, basalts, autonomic and stratiform intrusions, anorthosites. Enderbite- charnokite formation. Reomorphic and anatectoid granitoide in the core of **GSA**. The main mass of the siderophile deposits	Localization of the Earth's core. Accompanying heating the mantle. The main heat transfer agent – magma of the rising plumes. Convective and conductive heat removal.	Komatiite – an indicator of the undepleted lower mantle. Formation of the sima due to magmatism and underplating. Inversion of the protosial, bordered domes, or reones.
III. Period of the block tectonics Consolidation of the early crust. Formation of the platform (plate) and mobile belt. Contrast tectonic processes. Dominating processes of the transformation and destruction of the crust	Riphean and Phanerozoic <1.6 b.y.	Accumulation of the main volume of the sedimentary rock with small part of the mantle magmatism. Reomorphism, anatexis of granitoide. Increasing variety of the tectonic structures and composition of igneous rocks. The maim mass of the lithophile and chalcophile deposits.	Mainly conductive heat transfer. The mobile belts – the main places of the heat flow on the plate boundaries. Cyclic pulsation of the heating and cooling the platform. The cooling lithosphere of the platform (emergence of the heat deficit)	Splits of the consolidated crust: its dividing into platform and mobile belts. Three cycles of the water regression with deepening ocean floor in Phanerozoic.

The key nonrecurring events in the tectonic-magmatic history of the Earth (after great amount of the works of the Russian researchers).

Magmatic processes

1. The protosial rocks (TTG-series) do not contain much kalium and have essentially natric specifics. With time, from Hadean to Early Archean the role of the TTG-series diminished but the role of the normal calc-alkaline granites increased. The most drastic reversal is connected with Saamian diastrophism (~3600 b.y.).
2. The most old enderbite are known in Early Archean (3.8-3.6 b.y.), i.e. the geological evidence of the reomorphism and recycling the protosial. At the turn of Archean and Early Proterozoic the rocks were subjected to the metamorphism and granitization, the most powerful in the history of the Earth. The maximal mafic magmatism occurred in this time.
3. High-Mg komatiites (22-33% Mgo) are typical for Archean while the less magnesial komatiites – for Proterozoic- Phanerozoic. The typical ophiolite, blueshist metamorphism appear only since Later Proterozoic and Fe-Ti-picrite – not early than 2.2 – 2.0 b.y. Since Riphean disappear such rocks as anorthosite, cordierite granulite and charnokite.
4. Alkaline (kalium) igneous rocks appear 2.7-2.5 b.y. ago although their main volume and variety increased in the end of Proterozoic, especially in Phanerozoic. To this time the sediments with high kalium content are dated. Alkaline natric rocks (foidites) appear later, phonolite are known only since Triassic. Kimberlite appear only since Riphean with maximum about 0.4 b.y.; xenolite of eclogites in these rocks are of 2.7-3.5 b.y., and the oldest diamond of zonal structure – 3.2-3.4 b.y. These data testifies to the crust influence on the alkaline melt as well as kimberlite formation.
5. There is regular distribution of the ore formation in the history of the Earth. The ore fields are rare in Archean. The main mass of the siderophile deposits and platinum group are connected with Early Proterozoic while with Phanerozoic – several maximum of deposits of the lithophylic and chalcophile element. The largest fields of the ore elements were formed in Later Phanerozoic and Cenozoic what suggests that concentration of these elements are directly related to the evolution of the continental crust.

The sedimentary processes

1. The initial sediment of the early Earth were essentially chemogenic and later – lithogenic. Only since Riphean the areas and thickness of sedimentary rock become a significant factor of tectonic subsidence. The subsidence were likely connected with gradual increasing eclogitization about ≤3.5-2.7 b.y. what caused the anomalous weighting the crust.
2. The main volume of jaspilite was formed in the early Proterozoic, in association with rocks of GB**;** further, since the middle Paleozoic their formation stopped. In Riphean the biogenic rock appeared, including the carbon and graphite schists, but greywackes are rare. On the contrary, maximum accumulation of the carbonates and evaporates accounted for the Paleozoic-Mesozoic; in late Proterozoic and Paleozoic among carbonates dominated the dolomites, and in Meso-Cenozoic **-** limestone.
3. In the Early Precambrian the role of the orogenic clastic formation was small. In the end of Meso-Proterozoic the first red formation appeared what testifies to the appearance of the free oxygen. The molasses of the noticeable thickness (about 4 km) appear only in the late Riphean, this is 2-4 time lesser comparing to the thickness of the Phanerozoic molasses. Since Riphean hitherto the relative rate of sedimentary rocks accumulation within the continents has increased 7 times. Over time, sedimentary processes on the continents become more differentiated, localized and intense. It is directly connected with multiple recycling the sediment, but also with an increasing intensity of mountain building.

Neogeic – period of the sedimentary shell formation

In Riphean-Phanerozoic, or Neogeic**,** the third period in the Earth' evolution, the sedimentary and various tectonic processes dominated. Boundary between Early and Late Proterozoic (Riphean) was the most significant in the history of the outer shells of the Earth. It is associated with the increased oxidative conditions in the atmosphere and the wide development of red-colored formations, the first evaporites, strengthening processes of biogenic deposition (Ronov, 1980). The main volume of the sedimentary shell (about 70%) is located on the continents, including more than 2/3 in the mobile belts and less than 1/3 – on platforms. In spite of the huge dimension of the oceans, they contain only 17% of the all the world sedimentary cover. The thickness of sedimentary cover on the Siberia and East-European platforms are up to 9-13 km; the total thickness of sedimentary cover in the mobile belts in two or more times higher than on platforms. In the mobile belts the processes of the recycling, the repeated accumulation and erosion of the sedimentary rocks occurred. The average thickness of the Neogeic sedimentary rocks on the continents is about 4-5.1 km, within the continental margins – 3.9 km, on the platform – 2.5 km. In the oceans the thickness of sedimentary cover is about 0.4 km (Ronov, 1980; Ronov et al., 1990). This means that statistically average modern depth of the conventional consolidated basement is 1.7 km under sea level. The area of the shields, the median massifs, i.e. the area of the permanent and intensive erosion makes only 17-20% of the continental land, and considering only the shields – 6% (Ronov, 1980). The rest of continental areas are covered by the sedimentary rocks.

This data are evidence that the consolidated crust, which, apparently, before the Riphean reached a maximum area of spatial distribution and was the predominant area of erosion, to date, is largely submerged beneath the sedimentary cover. This submergence is mosaic and in the places of the local maximal submerge the basement surface is at the depth of 20 km (South Caspian). The evidence of the mosaic submerge of the Atlantic, Pacific and other oceans and corresponding tectonic schemes are presented by Beloussov (1989), Rudich (1984), Orlyonok (1985), Vasiliev and Choi (2001), Blyuman (2011) and other researchers.

During the Neogeic the tendency of subsequent submerge and mosaic deepening the consolidated crust and increasing intensity of the sedimentary process was continuing. The water – a geological layer, the light crust. The water and the sediment perform in tectonics the same function, it is embodied sagging, with the only difference that the water is more mobile than the sediment. Given that 2/3 of the Earth' surface are occupied by oceans, which since Mesozoic are the huge basin of the accumulation of the water and sediment, the main tendency of the tectonic submerge of the Earth surface are evident. It is established that water regression on the platform and mobile belts were synchronous; that is why they were not caused by water regression on the platform and mobile belts were synchronous; that is why they were not caused by water flow from one area to other. There were four stage of sharp displacement of hydrosphere on the continents in Phanerozoic: 1. Whole Cambrian; 2. Late Silurian – Early Devonian; 3. Permian – Triassic; 4 – from Paleogene up till now (Ronov, 1980). These impulses indicate the time of the world's oceanic deepening and essential change of the sedimentary mechanisms. The volume of the World' ocean after the middle Jurassic increased on 260 mil. km^3 with deepening sea floor to 4 km (Rudich, 1984).

The probability of the pulsating contraction hypothesis of the Earth' evolution

The global character of these changes testifies to that named regressions with increasing the areas of continental land show the subsequent lowering of the geoid's surface. The effect of the consecutive sagging the ocean with detected periodicity of the transgression and regression on the continents prove that consolidated platforms are the residual uplifts. The known graph of the alternation of epochs of the global regressions and transgressions points to the lowering surface of the geoid on the areas of the continents and oceans in anti-phase. The descending movement of the platforms caused the transgression and sedimentary cover accumulation and following submerge of the sea floor and increasing the oceanic water volume resulted in the regression on the platform. The diversity of the structure of the platform cover and water-sedimentary filling the oceans indicates the different character of the tectonic movement of these global structures: the submergence on the platform occur relatively evenly while in the oceans the signs of catastrophic subsidence are detected. Actually this explains the phenomenal voidness (term of the Author) of the oceans in relation to the sediment accumulation.

It may be proposed that the subsidence of the main structure of the Earth on the lower level of the Earth's perimeter is connected with compression (and transitions from light to a denser phases); this leads to the new compression stress. These alternations, and especially the periodical submerges of the platform are directly related to the great Phanerozoic extinctions in Earth's history.

The average height of the old platform not distorted by local tectonic uplift, may reflect a previous level of geoid comparable to modern oceans. The older and higher surface of geoid, complicated by isostatic floating, **-** the surface of the shields. The combination of these surfaces reflects the lowering of the geoid' level during the 1.6 b.y. in Neogeic. Relating to the first two periods (see **Tab. l**) the Neogeic is the period of regressive development, of erosion and tectonic destruction and transformation of the early crust. **Fig. 2** shows the hypothetical qualitative assessment by Author of distribution of the continental crust comparing to the known estimates by other researchers. This graph is based on the isotopic data (Hawkesworth and Kemp, 2006). A, B, C, F – curves of the growth of the crust according to the geosynclinal theory and plate tectonics, G – our line from idea of basification of the oceanic crust. The numbers on the line G correspond to the three main periods in **Tab. l**.

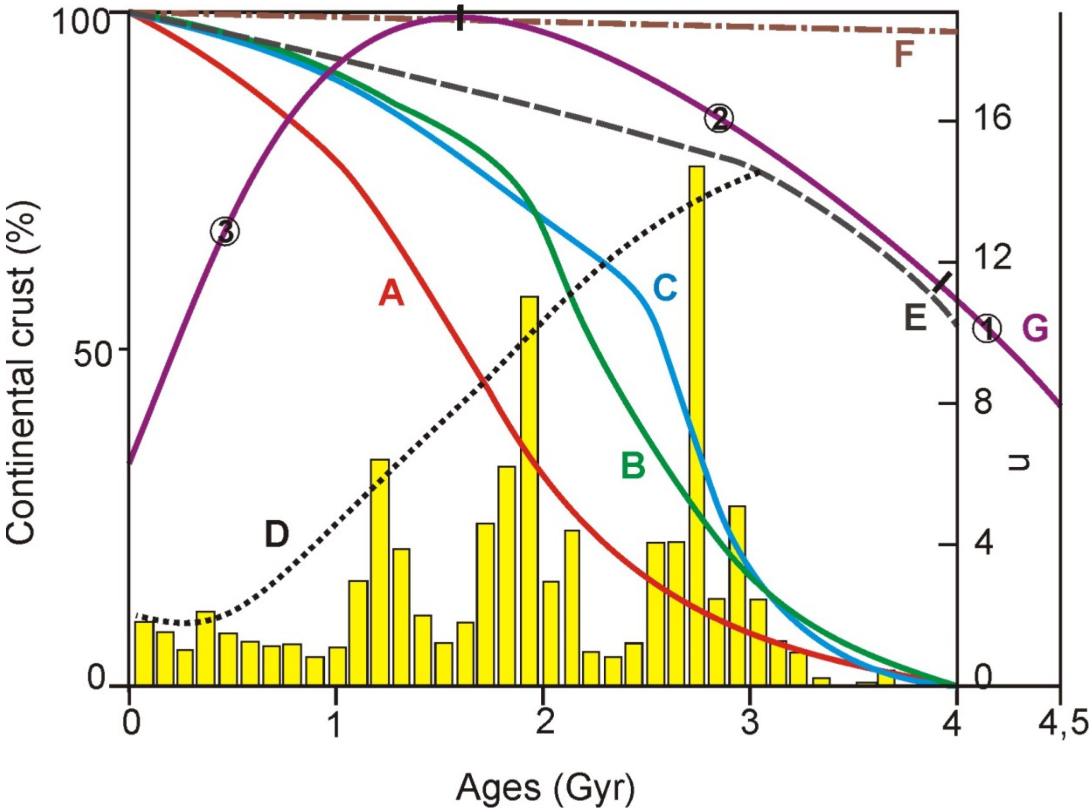

Fig. 2. The curves of the growth of the continental crust. The histogram of the generation of the continental crust is shown (after Hawkesworth and Kemp, 2006) with compliment of the Author. The histogram shows the distribution of the juvenile crust age (based on the U-Pb dating on 2006). The number on the right scale – the amount of the determination. The curves A, B, C – data of the various Authors according to isotopes Nd (A) and Pb (B and C) in the schists. E – a curve after Reymer and Schubert (1984); F –after Armstrong (1981). D – curve summarizes the peak ages of the histogram (by the author of this article). G – is calculated by the Author with use of data in this article supposing the oceanization of the continental crust in Neogeic. 1, 2, 3 on G-curve – the age intervals of the growth and transformation of the crust, described in Table 1. The estimate for modern time reflects the part of the ocean area on the modern Earth surface. The beginning the oceanization dates back to the Riphean.

The change of the heat flow during the geological history, having the form of a descending almost exponential curve, show that accumulation of the sediment in Neogeic took place in condition of strong cooling as compared to the Hadean and Archean. Before Riphean and especially before Phanerozoic (in Vendian?) on the Earth there was first deficit of the endogenous heat, the platform lithosphere was cooling and possessed the properties of rigidity (term of the Author – overcooling, local compacting, finally - consolidation). The internal energy sources of the Earth since then localized and migrated in a linear structure of the mobile belts and mid-ocean ridges.

The positive fluctuation of the heat flow in Phanerozoic with high maximum in the middle Cretaceous is needed in special explanation; recently it is almost exhausted and reached the lowest level in the Late Riphean. In the course of geological time there is a simultaneous heat and density differentiation of the Earth's matter: light-melting and volatile parts of protomatter are transported into the crust and in the atmosphere.

The maximal extension of the Earth falls on the earliest period of the existence of a magmatic ocean and the maximum compacting is yet to come; between these two states operates a lowering harmonic of both processes, reflecting the accumulation, discharge and heat loss. Thus we find the causes of manifestation and alternation of the various deformation or pulsation in the history of the Earth. The future of Earth – the water' planet and then – the ice' planet.

The thickness of the crust or lithosphere (?) is just the criteria of the shortening the initial radius of the Earth. Indeed, the initial Moho surface is the surface of the depleted mantle, released in Hadean from light components (similar idea proposed by Hoshino, 2014). Thus, the value of the total shortening corresponds to an average crustal thickness (~36-40 km). It is not excluded that in the future, with better understanding of the nature of the mantle lithosphere (under the platform) this value will increase. In cases where the Moho has a complex and layered structure one can think of its secondary and repeated renewal at the expense of phase transitions and other recurring tectonic and magmatic processes. The proposed ideas are qualitative close to the contraction' hypothesis which put forward Kropotkin (1992), Orlyonok (1985) and other researchers. However our estimates differ from their calculations by small values of the shortening radius.

The proposed hypothesis of the pulsating contraction raises a lot of the new questions. What is the cause of the origin of the magmatic ocean in Hadean? What about the widely accepted ideas on mantle convection or asthenospheric flows? How the world ocean developed? The part of these questions is considered in the paper, the others were discussed earlier (see references). The originality of the proposed hypothesis is assured by its new empirical base. Recently the set of the interesting work is suppressed, including the raised questions with problem of the contraction and oceanization (Beloussov, 1989; Rudich, 1984; Orlyonok, 1985; Meyerhoff et al. 1996; Milanovsky[5]1996, 1998; Storetvedt, 1999; Vassiliev and Choi, 2001; Blyuman, 2011 et. al.). The contraction mechanism was very thoroughly considered by Meyerhoff (Meyerhoff et al., 1996), who connects it with surge channels in asthenosphere. In this respect it is close to the mechanism proposed by Kropotkin and implied the displacement and extrusion of the excess asthenosphere to the surface (Kropotkin and Efremov, 1992). The proposed hypothesis at some parts is close to evolution model of Storetvedt (1999), which is based on the mechanism of the oceanization of the crust and includes the proposition on the ancient granite-granulite crust. As follows from our ideas both these presumptions get the more objective arguments.

Here it is important to note the productivity of the very idea, which gives hope for convergence of the controversial approaches based on the ideas of contraction, as well as for obtaining better results in the future.

References

Armstrong, R.L., 1981. Radiogenic isotopes: the case for crustal recycling. *Phil. Trans. R. Soc. Lond.*, v. A-301, p. 443-472.

Beloussov, V.V., 1989. The basic geotectonics. *M.: Nedra (Earth's Interior).* 382p. (in Russian)

Blyuman, B.A., 2011. The Earth's oceanic crust. *St.-Peterburg.* 344p. (in Russian)

Caro, G., Bourdon, B., Birck J.-L. and Moorbath, S., 2003. ^{146}Sm-^{142}Nd evidence from Isua metamorphosed sediments for early differentiation of the Earth's mantle. *Nature*, v. 423, p. 428-431.

Collerson, K.D. and Kamber B.S., 1999. Evolution of the Continents and the Atmosphere inferred from Th-U-Nb systematics of the depleted mantle. *Science,* v. 283, p. 1519 – 1522.

Ermakov, V.A., 2002. The qualitative model of the origin of the Earth' protocrust. *The tectonics and geophysics of lithosphere,* v. 1, p. 192-196. Moscow. (in Russian)

Ermakov, V.A., 2005. The island arches and their role in the evolution of the continental margin. *Volcanology and seismology.* No. 5. P. 3-18. (in Russian)

Ermakov, V.A., 2006. Tectonics of the island arches and the continental crust formation. *Bulletin of Moscow Society of Earth's investigators.* v. 81, no. 5. *Geol. Department,* p. 21-34. (in Russian)

Ermakov, V.A., 2008. Nonrecurring history of the Earth. General and regional problem of Tectonics and Geodynamics. *Moscow: GEOS*, v. 1, p. 287-293. (in Russian)

Ermakov, V.A., 2011. The tectonic-magmatic evidence of the oscillate contraction. Part 1. *Geophysical research,* v. 12, no. 2, p. 57-82. (in Russian)

Ermakov, V.A., 2011. The tectonic-magmatic evidence of the oscillate contraction. Part 2. *Geophysical Research,* v. 12, no. 3, p. 66-91. (in Russian)

Eskola, P.E., 1949. The problem of mantled gneiss domes. *Quart. Journ. Geol. Soc. London,* v. CIV, pt.4.

Frolov, V.T. and Frolova T.I., 2011. On the Pacific Ocean origin. *Moscow: Max Press.* 52 p. (in Russian)

Garagash, I.A. and Ermakov, V.A., 2004. A probable geodynamic model of the early Earth. *Reports of Earth Sciences,* no. 1, p. 73-77.

Hamilton, W.B., 1998. Archean magmatism end deformation were not products of plate tectonics. *Precambrian Research,* v. 91, nos. 1-2, p. 143-179.

Hamilton, W.B., 2003. An alternative EARTH. *GSA Today*. November. p. 4–12.

Hanchar, J.M, Hoskin, PWO (eds.), 2003. Zircon. *Mineralogical Society of America Reviews in*

Mineralogy & Geochemistry, v. 53. 500p.
Hawkesworth, C.J. and Kemp, A.S., 2006. Evolution of the continental crust. 2006. *Nature,* v. 443, p. 811–817.
Kropotkin, P.N. and Efremov, V.N., 1992. Change of the Earth' radius in the geological past. *Geotectonics,* no. 4, p. 3-14. (in Russian)
Kuzmin, M.I., 2014. The early stages of the Earth' formation. *The science in Russia,* no. 6(203), p. 13-24. (in Russian).
Marty, B., Coltice, N. and Meibom, A., 2007. Noble gas sources and fluxes in the Hadean. *Presentation on 9th International Conference on Gas Geochemistry*, October 1-8,
Mojzsis, S.J. and Cates, N.L., 2007. Geochemical evolution of the atmosphere and ocean at the Hadean-Archean transition. *XVIII symposia on the isotope geochemistry*. Moscow, 14-16 November.
p. 17–18.
Mysen, B.O. and Boettcher, A.L., 1979. Melting in a hydrous mantle (in Russian). Mir Press, 123p.
Nebel, O., Rapp, R.P. and Yaxley, G.M., 2014. The role of detrital zircons in Hadean crustal research. *Lithos 190–191*, p. 313–327.
Orlyonok, V.V., 1985. Physics and dynamics of the outer geospheres. *M.: Nedra (Earth's Interior).*184p. (in Russian)
Reymer, A. and Schubert, G., 1984. Phanerozoic addition rates to the continental crust and crustal growth. *Tectonics,* v. 3, no. 1, p. 63-77.
Ronov, A.B., 1980. The sedimentary shell of the Earth. *Moscow: Science.* 80p. (in Russian)
Ronov, A.B., Yaroshevsky, A.A. and Migdasov, A.A., 1990. *Moscow: Science.* 183p. (in Russian)
Rudich, E.M., 1984. The spreading oceans: facts and hypothesis. *M.: Nedra (Earth's Interior).* 252 p. (in Russian)
Salop, L.I., 1982. The geological evolution of the Earth in Precambrian. *Leningrad: Nedra (Earth's Interior).* 343p. (in Russian).
Svetov, A.P. and Sviridenko, L.P., 2005. Centres of endogenous magmatic activity and ore-formation in the Fennoscandian shield (Karelian region). Karelian Research Centre RaN. Inct. Geology. Petrozavodsk, 358p. (in Russian).
The Mantle plumes and metallogeny. 2002. Editor in chief A.F. Grachev. *Petrozavodsk-Moscow.* 515p. (in Russian).
Vassiliev, B.I. and Choi, D.R., 2001. Geology of the deep-water trenches and island arcs of the Pacific. *Vladivostok, Dalnauka*. 184p. (in Russian).
Yokochi, R. and Marty, B., 2005. Geochemical constraints on mantle dynamics in the Hadean. Earth *Planet. Sci. Lett.*, v. 238, nos. ½, p.7–30.
Zahnle, R., 2003. Hadean Earth. *Geochim. et Cosmochim. Acta.* Sp. Suppl. to no. 18, p. 574.
Zhang, Y., 1998. The young age of Earth – Constraints on atmosphere and mantle evolution. *Geochimica et Cosmochimica Acta,* v. 62, no. 18, p. 3185–3189.

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THE DARWIN RISE AND GEOMORPHOLOGICAL-GEOLOGICAL INDICATIONS OF FOCAL SYSTEMS ON THE PACIFIC OCEAN FLOOR

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ABSTRACT: Some questions about the Darwin Rise and ring morphostructures are discussed by reviewing the studies of sea floor relief and other data. The relics of underwater mega arch-blocks and arch rises as plume and mantle diapirs are recognized by geomorphologic and geological data from the Pacific Ocean floor. They are raised areas with anomalous high concentration of magmatic centers and their connected volcanic buildups. All major focal systems are characterized by: 1) radial-concentric morphostructural patterns (ridges, rises, basins, blocks, faults, volcanoes and guyots); 2) hypsometric and geological zonal structure of the central type; 3) existence of three major types of their internal elements disposition (nuclear, nuclear-satellite and satellite); 4) intimate relation with deep faults. The focal structures and faults are basic energy bearing objects in the Earth's crust; therefore they represent the most useful tectonic criteria for mineralogenic forecast and division of ore districts not only in land but also in oceanic floor. The disputed idea about the Darwin Rise existence has no sufficient factual grounds.

Keywords: *Darwin Rise, ring structure, geomorphology, plume, arch-block rise*

Introduction

In several recent NCGT issues an active debate on the Darwin Rise, which was previously published by Menard (1964) in the northwestern Pacific has been published in the NCGT Journal (*NCGT Journal*, 2014, v. 2, no 3, p. 41, p. 42-54, p. 54-60; 2014, v. 2, no 4, p. 94-98, p. 98-105). Various points of view on the problems of the Rise's origin and development were represented by Yano (2014 a, b), Smoot (2014a, b) and Choi (2014).

The main questions and contradictions discussed are connected with criteria of the proposed Darwin Rise and different notions about its nature. Smoot emphasizes the basic meaning of bathymetric data and considers that Yano's model conflicts with bathymetric pattern and altimetry information provided by the GEOSAT satellite system, as well as gravity anomalies in the sector 72°N to 72°S. He argues specifically the data about double ridges in Mendocino Fracture Zone; some structural trends on ocean floor and other morphotectonic regional features demand explanations. "No bathymetry, no swell", as Smoot asserts for the Darwin Rise (*NCGT Jour.*, 2014, v. 2, no. 3, p. 41).

Yano gave a priority to geological data and concludes that available drilling and dredging materials justify the Darwin Rise's existence. Considering Late Mesozoic volcanic rock distribution in the western Pacific he reconstructed the Darwin Rise on the basis of the regional multiphase volcanic activity analysis and offered the appropriate paleobathymetric model. For that he puts the alternative question "Did the Darwin Rise demised or revived?" and draws conclusion that Darwin Rise hypothesis enables to explain the End-Aptian regional uplifting, the contemporaneous Late Mesozoic regional volcanism and some another features of the West Pacific region development.

Choi joined this discussion and rightly underscored the necessity of the Darwin Rise uniform structural basis identification and its regional and global position. He suggests that there was the Jurassic-Early Cretaceous volcanic belt as tectonic framework of NW Pacific bottom. It was developed along a global system of depressions and intratelluric fracture zones. But the so-called Darwin Rise does not exist in the tectonic and bathymetric senses.

The present author examines these notions and offers another model of the Pacific NW sector development.

Open questions

To understand morphostructural elements developed in land or water, a multitude of signs including geomorphologic, geological and geophysical data are used. Only neotectonic patterns are mapped usually based on the bathymetric information. More ancient morphostructures can be detected on the Earth's surface if during neotectonic stage (Late Cenozoic) they keep up the trend of their development and have not undergone essential transformation. Rises which have undergone a scale denudation or tectonic destruction are expressed, as a rule, on topographical or bathymetric maps only by way of residual relief shapes. Therefore they cannot be identified only on a basis the bathymetric data. When Smoot writes "No bathymetry, no swell", it excludes from morphostructure and the paleogeomorphologic analysis of a whole class of relic objects which are reflected in the pattern of small or only partially conserved rises.

The geological data have priority significance by geomorphologic and tectonic reconstructions. Such approach is fully represented in Yano's papers. However, the geological information application without hypsometric or bathymetric position doesn't allow us to distinguish the active and passive, inherited and superimposed elements of morphostructure pattern. For comprehensive (geologic- geomorphologic) analysis of ancient relief shapes it is necessary to investigate possible floor projection transformation in the Late Cenozoic stages. If the Late Mesozoic period is the time for the Darwin Rise origin and their active evolution, then Paleogene and Miocene magmatism in the West Pacific should have been able to form as inherited and superimposed elements of morphostructural plan. For example, the Marshall Island Rise was a field of active magmatic events during Paleogene period but it inherited from Cretaceous.

Experience which the author has obtained during the continental margins mountain research shows that the alternative target setting by the geodynamic analysis of the regional rises, "demise or revive" as Yano coined in *NCGT Jour.* v. 2, n. 3, is hardly verified because they are developed as a rule in pulsating conditions. The period of a constructive tendency alternates with a destructive one, and vice versa. At the same time a phenomena of the tectonic and magmatic activation are usually realized discretely in space and time, affecting seldom on all regional rises. Exactly such disposition and morphostructural element relations are represented on bathymetric and geological maps of the West Pacific (International …, 2003; Jatskevich, 2000 and others).

According to McNutt's (1998) opinion, the Darwin Rise proposed by Menard consists of two different segments. The northwest segment relates to Mid Pacific underwater mountains and adjoining broad areas of uplifted seafloor, the southeast one is considered as the South Pacific Superswell. In an article (McNutt and Fisher, 1987) some data are cited about the model by Gordon and Henderson (1985) in which the Darwin Rise is examined as tracks of South Pacific hot spots projection by plate movement towards northwest.

The geophysical information about the Earth crust capacities (seismic, gravimetry modes and others) and volcanic rocks distribution under loose rock deposits (magnetic modes) is a necessary component of morphostructural investigations too. Therefore the author agrees with Yano that only multifactor application and synthesis of geomorphological, geological and geophysical data allow us to obtain rather adequate tectonic and morphotectonic models of the NW Pacific region. It is also necessary to understand the parametrical and hierarchical elements of morphostructure pattern, and to define dominating tectogenesis factors as well as main rocks deformation (strain) types. With these positions the question about the Darwin Rise and its tectonic basement remains open as we do not have the compatible interdisciplinary data file. We can take only some geological data that Yano used, but the geomorphological and geophysical vindications are lacking. It is necessary to recognize this situation and agree to Smoot's and Choi's conclusions that at present the Darwin Rise does not exist in nature. But did it exist in geological past?

The regional NW Pacific tectonic model by Choi, which is mainly based on Jatkevich et al. (2000) geological map, postulates the Jurassic-Early Cretaceous volcanogenic constructions belt can be substantiated by tectonic framework of rising areas correlative with the Darwin Rise only under two main conditions:

1 – existence of regional chains of the paleomagmatic large focus structures, volcanoes and their grouping with corresponding age and with relatively similar parameters of magmatic rocks areas.

2 – inherited elevation of the rise or the most of its parts during tectonic evolution in Mesozoic and Cenozoic that provides similar bathymetric characteristics, the correlated erosion levels within guyots and the similar Late Mesozoic complexes.

However there is another picture of a much different geologic and morphological fabric of the seafloor. We can see everywhere discrete and irregular distributions of island archipelagos, underwater mountain massifs, swells and volcanic ridges, which are separated from each other for many hundreds to thousands kilometers. The same regularities are marked for the Jurassic, Early and Late Cretaceous magmatic rocks areas (Jatskevich, 2000). But for all that the most part (70-80%) of guyots, paleovolcanic constructions and volcanic deposits of the Late Mesozoic age concentrate within the Northwest Pacific (NWP) relic mega-arch (Gavrilov, 2005, 2013). The Late Mesozoic rocks are developed in other domain (beyond the mega-arch) only restrictedly in a form of separate elevated blocks in fracture zones and in some rises' apical parts. The NWP mega-arch has no direct expression on the bathymetric map, including ETOPO 1 data (**Fig. 1**) as it represents the Late Mesozoic rise which has undergone destruction and been sinking in the Late Cenozoic. But the radial-concentric features of this rise are expressed distinctly due to geomorphologic and gravimetric determination of sea surface heights variation (**Fig. 2**). This phenomenon can be connected only with the existence of gravity anomalies in the rise core. It is one of the examples of ancient focal systems influencing on modern oceanic processes.

The present morph-structural elements of the NW Pacific region include two main types: 1) one is represented by the linear systems of volcanoes, located within magma controlling faults, and 2) ring clusters of volcanoes, which are connected with deep focal systems and fracture zones junction. The first type form mountain ridges on the Pacific floor. Tectono-magmatic rises with the radial-concentric allocation of volcanic constructions with the corresponding hypsometric zoning belong to the second type.

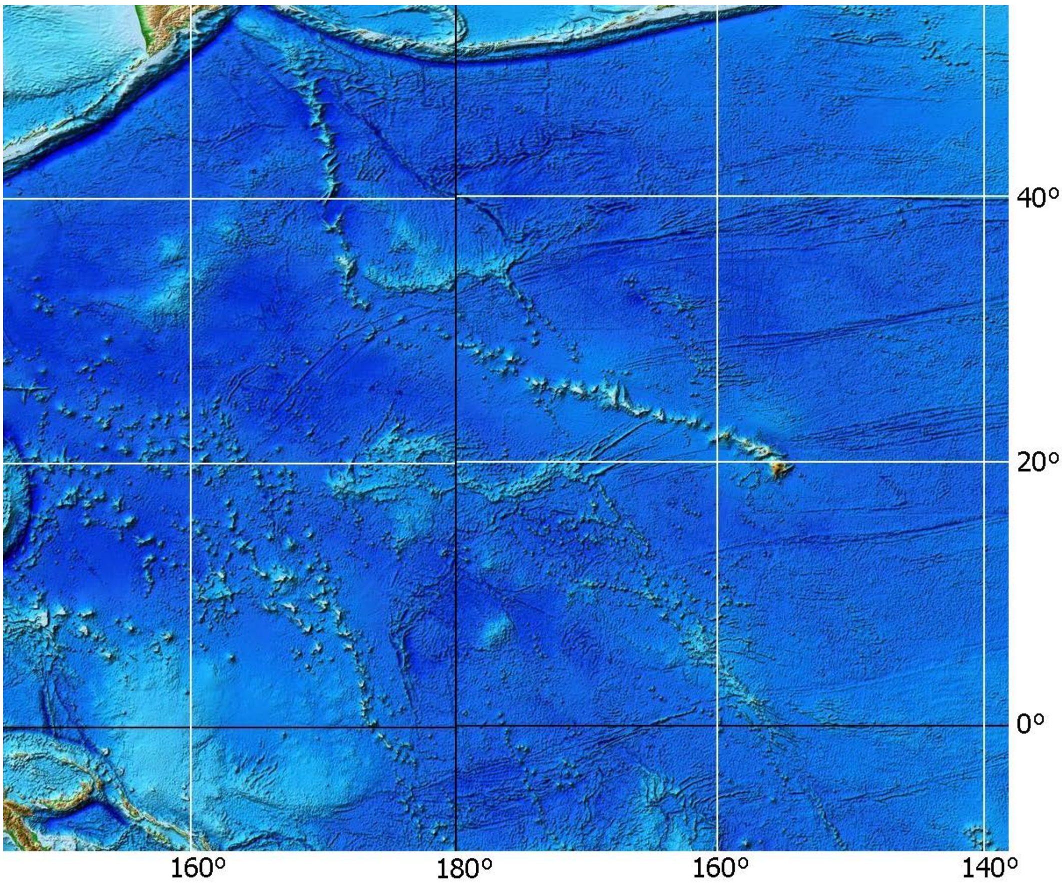

Fig. 1. The Northwest Pacific floor relief adopted from ETOPO 1.

In spite of the fact that Late Mesozoic magmatism had a regional character (Choi and Vasiliev, 2008; Yano, 1914a & b, and others), it was localized in separate magmatic centers connected with fracture zones (mountain ridges) or with deep-seated focal systems, which were reflected in relief as large orogenic arches or swells. The highest concentration of Late Mesozoic and Cenozoic magmatic areas and volcanic buildups within such ring rises on the oceanic bottom allows us to consider them as projections of long-life energy centers (hot spots, mantle diapirs and others) of different depths and ages of the formation. There are all bases to assume that similar structural regularities of magmatic events existed during all geological evolution of the Pacific seafloor.

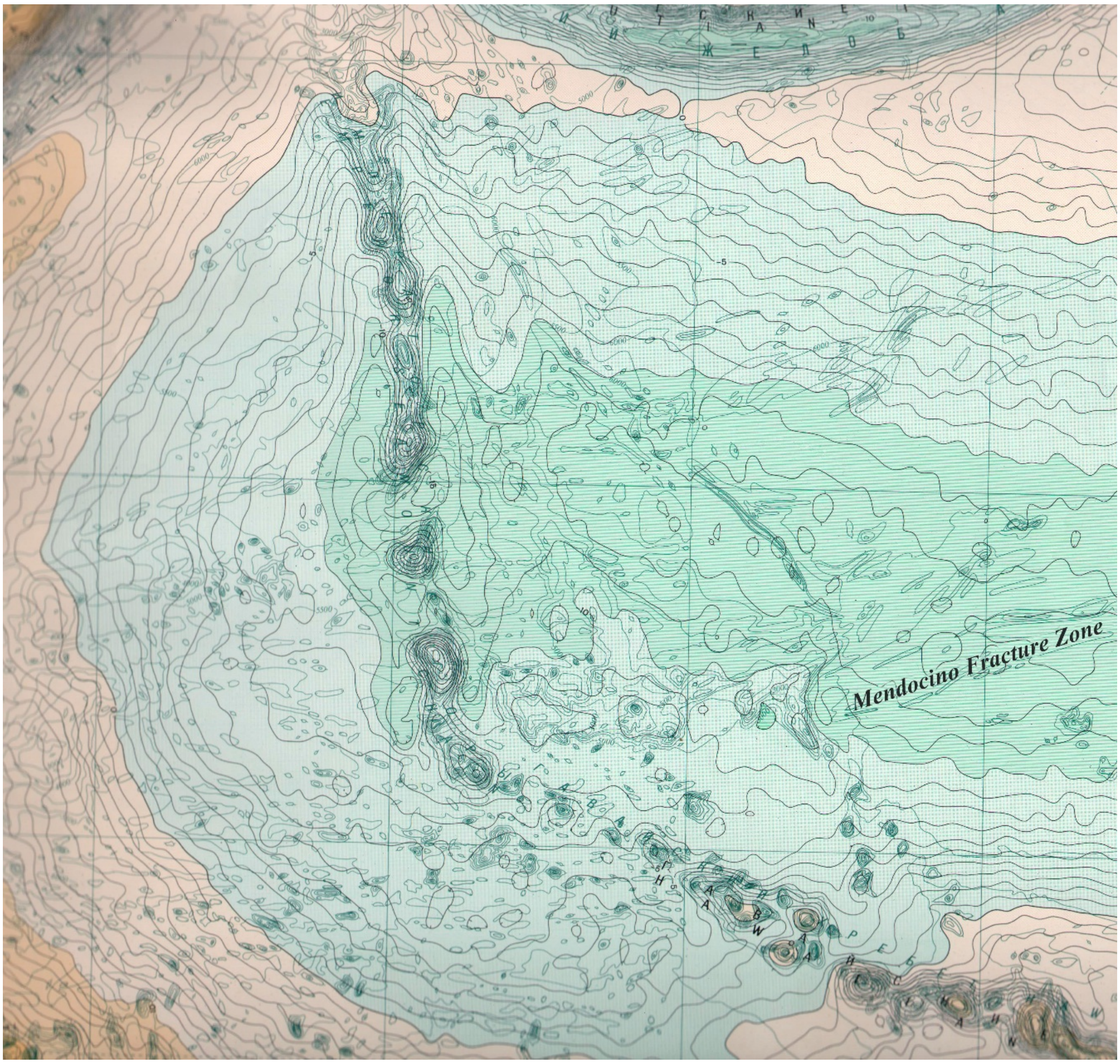

Fig. 2. Sea surface heights variation within NWP mega-arch. Heights scale in meters: from -20 (blue) to + 50 (yellow). Zero line is the border between blue and yellow areas (International …, 2003).

Only by this way we can explain the huge scale of magmatic phenomena, long existence, pulsating development, morphology and intimate structure of tectonic-magmatic rises. They have all features of **morphostructures of central type (MCT)** which are well examined on land.

The geophysical materials about increased Earth crust capacities in the ring island rises, underwater mountain massifs and swells indicate that scale of volcanic material accumulation exceeds (overbalances) the tectonic foundering. In this case the positive relief shapes in stretching (tensile) and sinking conditions are formed. It is overcompensation or redundant character of the volcanic domains development. Negative gravitational anomalies are in conformity to reduced density domains under such rises and to their deep “roots”.

Thus all observed geomorphologic and geological facts reveal that principal factors of endogenous morphogenesis within oceanic bottom are connected with magmatism and focal geodynamics. The fault-block tectonics assumes the secondary role. Therefore the volcanic constructions, their ring and linear groups as well as large focal morphostructure are considered by the author as typical and major structural elements of the Pacific floor, whose investigation is prerequisite for solution of a number fundamental and applied problems such as mineralogeny, seismic, volcanic hazards and others.

Some questions of MCT investigations
The increasing advanced researches on the mantle and crust interaction fundamental problem compels to connect together the concept of plume tectonics and ideas about the existence of planetary, regional and local systems of MCT as projections of deep endogenous activity centers as well as the views about the role of Earth degassing, defluidization and magmatic, metamorphic factors in focal tectonic processes during the planet's geological evolution.

There are certain geological and geomorphologic characteristics of the MCT. These are the radial-concentric zonation of the relief hypsometry (bathymetry), structural elements and substantial complexes, the presence of fault systems that are radial, arc or ring in the plan and conic fractures in the section as well as energetic centers or diapirs. They are by their own nature injective dislocations (intrusive, protrusive, explosion and others) of different parameters, age and localization depths. The MCTs are in many respects unique because in the processes of focal tecto-genesis; magmatic, metamorphic petrogenesis, fluids, hydrotherms and ore deposit formation simultaneously have taken place.

For describing such structures, various terms (concentric complexes, ring structures, focus systems, ring fractures, structures of central type) have been used. The distinction between them is subtle, defined only by an emphasis either on morphological, structural, or genetic features of the natural objects. Although the existence of local ring forms (volcanic, intrusive and others), as a rule, doesn't raise doubts, the recognition of such global and regional-scale ring morphostructures leads to the opposition to neomobilism. As above, it is obvious that the deep heat-mass transfer flows connected with plumes and mantle diapirs have to be imprinted in the geological structure and relief of the Earth (Gavrilov, 2005, 2013 and others).

Grachev (2000) considers that specific geological signs of mantle plumes are; 1) arch rises with a radius (R) up to 1000 km, 2) structures of large faults and rifts triple joints, 3) basalt magmatism of the fissure type, 4) high heat flow, 5) increased crust capacities, and 6) specific geochemical and isotope characteristics of magmatic rocks. Geomorphologic methods and all sets of procedures and criteria used by investigation of the continental MCT can be applied for identifying plume and other focal systems in the seas and oceanic floors. The geomorphologic analysis of the bottom surface includes the search of anomalous relief shapes (or shapes groups) with radial and concentric hypsometric zonation, the orographic elements pattern (ridges, basins, blocks and others) mapping, the intimate structure of focal systems standardized description and others. Geological approach uses the information about radial-concentric distribution of magmatic rock areas, volcanoes and others focal structures (intrusives, protrusions, extrusion massifs, explosion craters), the date of radial, arc, ring fault systems, dikes, and so on. Among geophysical materials, gravimetric data, magnetic anomalies, radial-concentric arrangement are important.

During the development of deep strong energy generation in the lithosphere in layered geological environment, not only a frame network of radial and concentric faults, but also well-ordered systems of satellite magmatic focuses are formed. They are localized at junctions of faults and geologic-geophysical partition crossings (Ezhov and Nikonova, 2003), where the spasmodic change of lithostatic pressure occurs (decompression mechanism of magma formation). There, three universal types of the intimate MCT pattern of MCT: nuclear (without satellite centers), nuclear-satellite and satellite (without nuclear) infrastructures. The conducted researches have shown that these regularities are typical for all MCT categories. The similarity of internal elements pattern schemes indicates the structural homology phenomenon of focal systems. That opens up possibilities for formalized description of their infrastructures on the basis of symmetry formulas.

The obtained data allow formulating a thesis about homology of focal systems: **During their development within relatively isotropic geological environment independent of mechanism of origin, location depth, parametrical characteristics, age and genetic types, all injective dislocations (focal systems) tend to create homologous forms and intimate patterns with symmetry of the central type.** On the basis of invariance of MCT development, the following number of factors are present: 1) the existence of energy, gas, fluid or magma generative focuses (centers), 2) layered structure of the Earth bowels, 3) the presence of thermodynamic mechanisms of focal systems formation, and 4) similarity in phase states, forms, ways and conditions of endogenous material migration by heat-and-mass transfer processes in a geological environment (Gavrilov, 1993 and 2002).

From the above thesis, the models of local focal structures established on the basis of representative geomorphologic and geologic-geophysical data are applicable in principle for explanation of large deep intrusive bodies (mantle diapirs and plumes) and their formation mechanism as well. The existence of the homology between planetary, regional and local MCTs is an important sign of the reliability of mega objects (Gavrilov, 1993, 2002 and 2013).

Some MCTs of the Pacific Ocean bottom

In contrast to these notions some plume projections revealed by geologists in the Pacific Ocean floor have often geometry far from figures of the central type. For example in the paper by Vikulin and Melekestsev (1997) the Darwin Rise has a shape of the irregular triangle which is considered as an indicator of a huge super plume. The length of its one side comes near to 10 thousand km, two others make 5 and 7 thousand km. Some researchers such as Maruyama et al. (1994) compare a projection of the Southern Pacific super plume with the East Pacific Rise (length - 7600 km, width – 850 km).

The North-West-Pacific (NWP) over plume mega arch-block rise (R = 2000-2500 km) is the key element of the West Pacific morphostructural pattern. This mega arch-block MCT includes the largest Islands Archipelagos, underwater ridges, guyots, rises of the Northwestern and Central Pacific (Mapmakers, Emperor, Mid-Pacific, Marcus, Hawaiian Seamounts, Shatsky and Hess Rises) as well as arch-block morphostructure. Mapmakers, Emperor, and Hawaiian Ridges traverse radial trends through areas with densely populated guyots and volcanic buildups of various sizes and ages (**Fig. 3**).

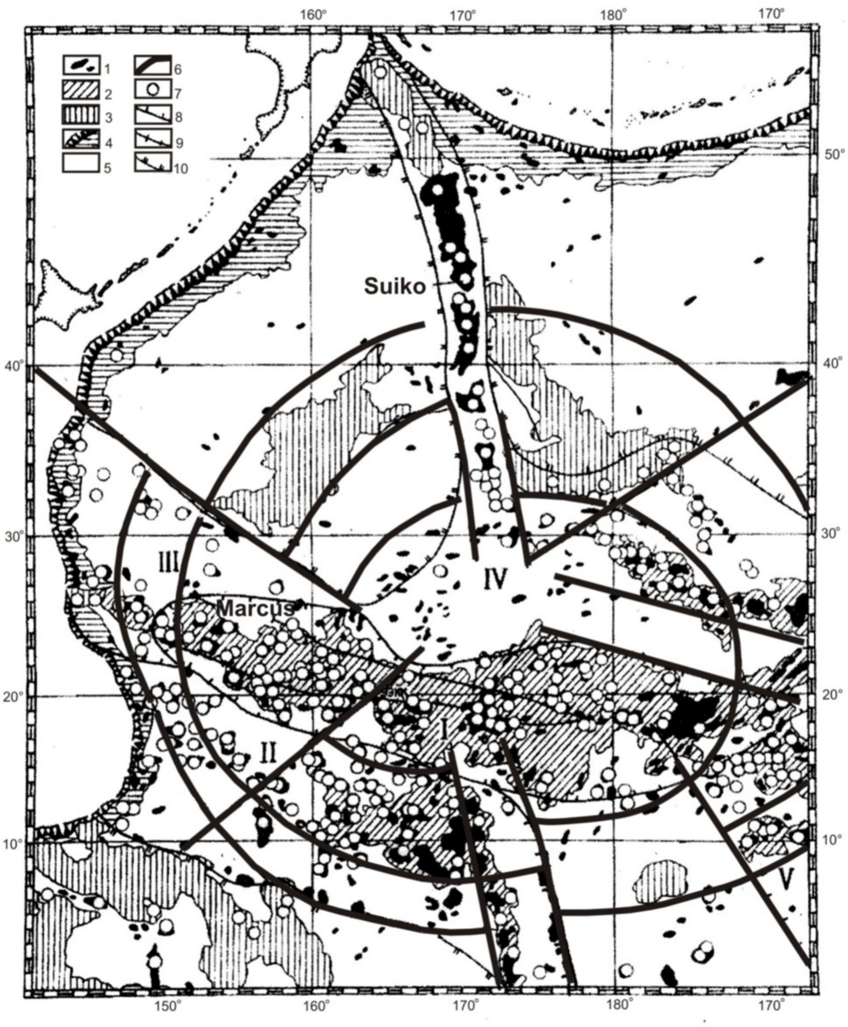

Fig. 3. The scheme of underwater mountains and ore-bearing guyots distribution within northwest part of the Pacific Ocean by (Schkolnik et al., 1996), with additions and new interpretation of the author (Gavrilov, 2013).
1 – underwater mountains and ridges; 2 – swell-like raisings in basement of volcanic mountains; 3 – underwater rises (Shatsky, Hess and others); 4 – marginal slopes of deep-water trenches; 5 – oceanic basins; 6 – radial and arc framework lineaments of the West Pacific over plume mega-arch; 7 – underwater mountains and guyots with bathymetric depth marks no more than 2000 m; 8 – borders of ore-bearing provinces: I – Mid-Pacific, II – East-Mariana, III – Ogasawara, IV – Emperor-Hawaiian, V – Line; 9 – distribution outlines of phosphate containing basalts in carbonate and the brecciated phosphorite areas of the Mid-Pacific province; 10 – areas of practical absence of ore-bearing guyots.

Unlike the North Pacific mega-MCT (R = 3400 km) distinguished by some authors (Ezhov and Nikonova, 2003), the considered mega arch-block Rise differs in size (smaller), external border arrangement and the position of geometrical center. This rise has a concentration of main volcanic buildups, many of which contain the mixture of ferromanganese concretions, cobalt-manganese crusts and a phosphorite mineralization (of carbonate and silicate types) (Schkolnik et al., 1996). The distinctly expressed various concentration of ore-bearing guyots within southwest and northeast diametrical blocks of the NWP mega arch illustrates the phenomenon of mineralogenic asymmetry of MCT (Gavrilov, 1999).

In Cretaceous period the volcanic activity had an areal character while the Cenozoic magmatism was concentrated within regional fracture zones. However, the NWP mega arch-block rise kept skeletal elements of radial-concentric infrastructure and inherited features of the development. The most ancient Jurassic - Early Cretaceous volcanic and volcanic-sedimentary complexes occupied the NWP MCT central parts - that testifies to a removal of thick layer by erosion and denudation of their nuclear and centrifugal tendencies of the effusive magmatism distribution. The satellite magnetic anomaly maps at the 400 km altitude from Magsat and POGO satellite reflect the radial-concentric structure of this mega arch-block rise too (**Fig. 4**). There is a large positive anomaly in the nuclear of this mega-MCT that indicates possible existence of the mantle diapir swell here.

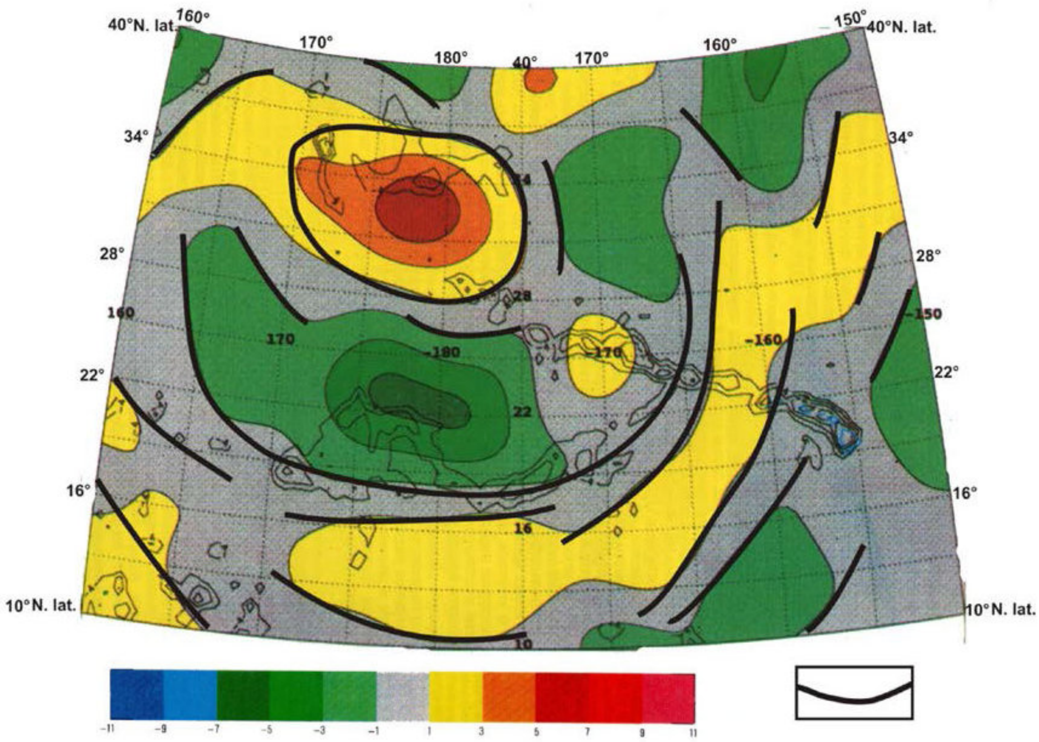

Fig. 4. The satellite magnetic anomaly pattern (International…, 2003) within West Pacific mega arch-block Rise. Units are nT. The black arc and curve lines are borders of magnetic anomaly zones.

The Pacific mantle inhomogeneity for the depth 2850 km (Su et al., 1994) stands out in the seismo-tomographic model **(Fig. 5)** in the position of the West Pacific, the Polynesian and the Galapagos MCTs. The global ring and arc pattern of density and heat anomalies is conformable, in author's opinion, to the Indo-Pacific planetary ring system of interconnected largest oceanic and continental ridges (Gavrilov, 2002).

On the analogy of the NWP mega arch-block rise it is possible to consider some rises of the Pacific floor as projections of deep intrusives and magmatic arches. There are the East Pacific ring arch-block rise (R = 1100-1300 km), the Polynesian (Tuamotu) arch-block rise (R = 1000-1200 km), the Marshall-Ontong-Java arch-block rise (R = 900-950 km), the Marshall arch rise (R = 500-550 km) (**Fig. 6**), the North Line (R = 450 km) arch rise and others. Earlier, the Magellan underwater mountain MCT system

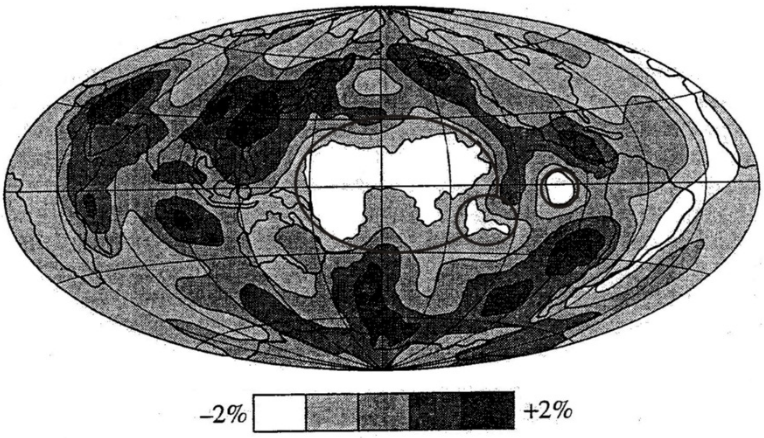

Fig. 5. Seismo-tomographic model for the 2850 km depth of the Pacific mantle showing inhomogeneity (Su et all., 1994), with author's interpretation (circles).

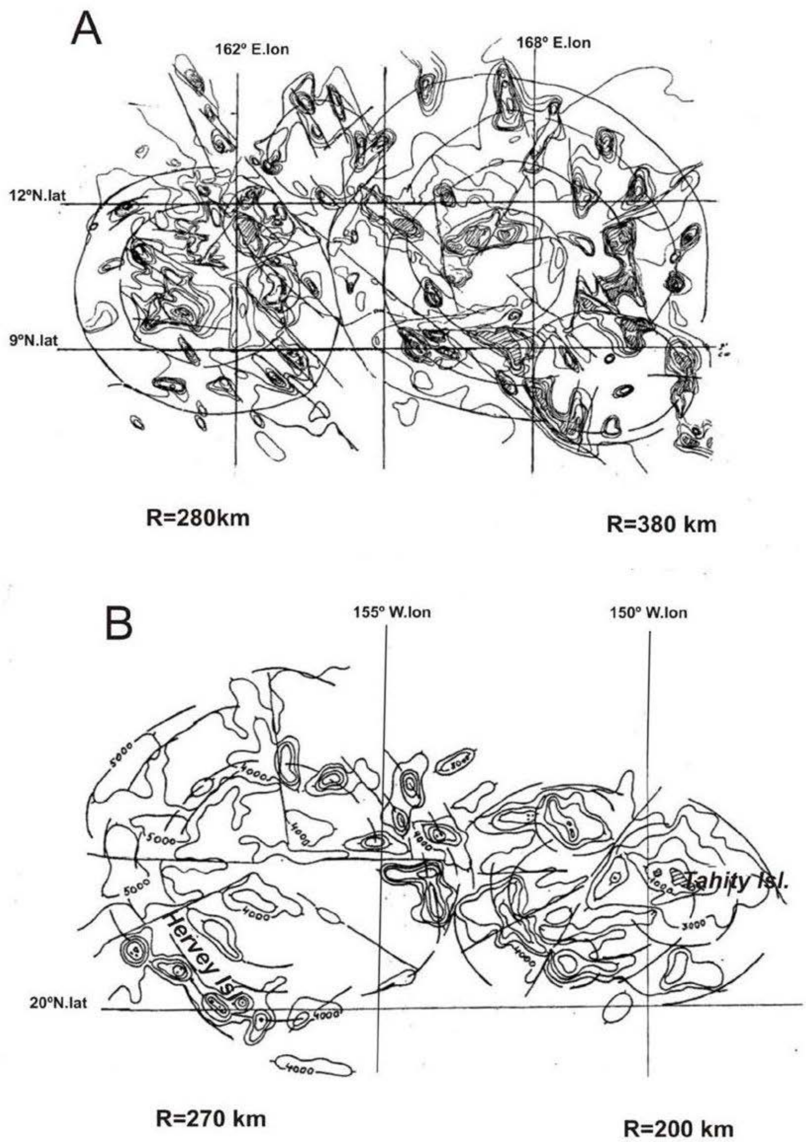

Fig. 6. Some examples of Island archipelagoes ring magmatic arches. Morphostructural imagines are based on bathymetric maps of the scale 1: 2 000 000. The thin lines on schemes are isobathic curves. The thick lines are arc and radial fracture elements. **A** – MCT of the Marshall Islands arch with nuclear-satellite internal pattern are elements of the Marshall-Ontong-Java mega arch-block Rise, **B** – MCT with satellite internal pattern of the Society and the Hervey Islands located within limits of the Polynesian (Tuamotu) mega arch-block Rise.

(Kulakov et al., 1987) was described. Some parallel large chains of islands (Marques, Tuamotu, Tubuai and others archipelagos) and underwater ridge patterns are morphotectonic framework of the Polynesian mega-arch which was revealed in some tectonic schemes (Golovinsky, 1985).

Numerous underwater mountains of the Marshall Island arch consist of guyots and various other volcanic buildups. Within this domain four phases of the magmatism are distributed. In Late Jurassic the gabbro-dolerite-basalt complex was formed. The effusions of alkaline basaltoids occurred from the Barremian to Santonian. The third phase of regional magmatism was followed by accumulation of volcanites in basalt-trachyte composition. In the final Paleogene stage magmatic arches and volcanic ridges developed, which continued to Oligocene when the processes of riftogenic destruction and large-scale sinking of the territory started to dominate. The general numerical ages of magmatic rocks ranges from 16 to 90 million years (Vasiliev, 2009).

According to geological data there are two volcanic constructions in Tahiti which are composed of Pliocene-Pleistocene alkaline basalts, andesites and trachytes. Some xenoliths of basalts with absolute age from 44 to 74.9 million years and also ancient metamorphic rocks with 833 million years were discovered in volcanic rocks. In the island also the massif of the late Jurassic nepheline gabbros and syenites (150 million years of age) is known. The formation time of volcanogenic rocks of Society and Hervey archipelagoes varies in the interval 0.38-28.6 million years (Vasiliev, 2009), reflecting long (Oligocene- Pleistocene) and a discrete nature of magmatism events in time and space.

The Sala-y-Gomez Ridge, Chile Rise, some islands, underwater mountains and the segment of the East Pacific Ridge form the next large ring morphostructure system (R = 1000 km) of the Pacific bottom east domain. The crossing of such large underwater ridges is connected with their nuclear part.

The so-called Juan Fernandez Microplate has all features of the MCT which are correlated with East Pacific magmatic mega arch (**Fig. 7**). The East Pacific Rise has developed actively since the Cretaceous, according to Vasiliev (2009).

In addition to the areal volcanism, effusions of large stratovolcanoes occurred. Together with basalts the rocks of middle and acid composition (pumices and tuffs of the Easter Island for example) accumulated. The high values of the heat flow (International.., 2003) at present time and seismic tomography data indicate the protrusion of a hot mantle at depths of 200 km within nuclear part of the East Pacific mega-MCT.

It is possible to examine some another raised areas as MCTs whose development is determined by mantle diapirs or hot spot projections: Galapagos Island magmatic arch-block Rise (R = 250 km) (**Fig. 8**), Bismarck MCT (R = 200-400 km), Fiji Island magmatic arch rise (R = 900 km), South Hawaiian magmatic arch MCT (**Fig. 9**), (R = 250-320 km), Stokman MCT (R = 200 km) located within Sala-y-Gomez, Nazca Ridges crossing, and others. The typical instance of the nuclear internal pattern is the structure of the Fiji magmatic-arch rise. It has a complicated infrastructure in which central part the archipelago of the same name is located. The specific highest values of the heat flow (International…, 2003) within this domain indicate an existence of a hot mantle protrusion here. The same high heat flow meanings are typical and for Galapagos magmatic arch too.

It is possible to surmise that all considered MCTs are the projections of long lasting focal systems of the Late Mesozoic – Early Cenozoic or Early Cenozoic age. The majority of arch rises have undergone significant destruction and submergence in Late Oligocene-Miocene. This destruction was caused by the activation of riftogenic processes and by the phenomena of mantle diapirs in a prevailing tensile field against of the large-scale basalt volcanism manifestation in the Pacific Ocean bottom. The chains of islands within arches represent the top parts of undersea ridges which are formed of modern or relic (guyots) rows of volcanic constructions connected with rings and radial magmas controlled by fault systems. One of the possible formation mechanisms of MCT rows and volcanic ridges is caused by an effect of gaping and ring faults origin within the shear-fault zones (**Fig. 10**).

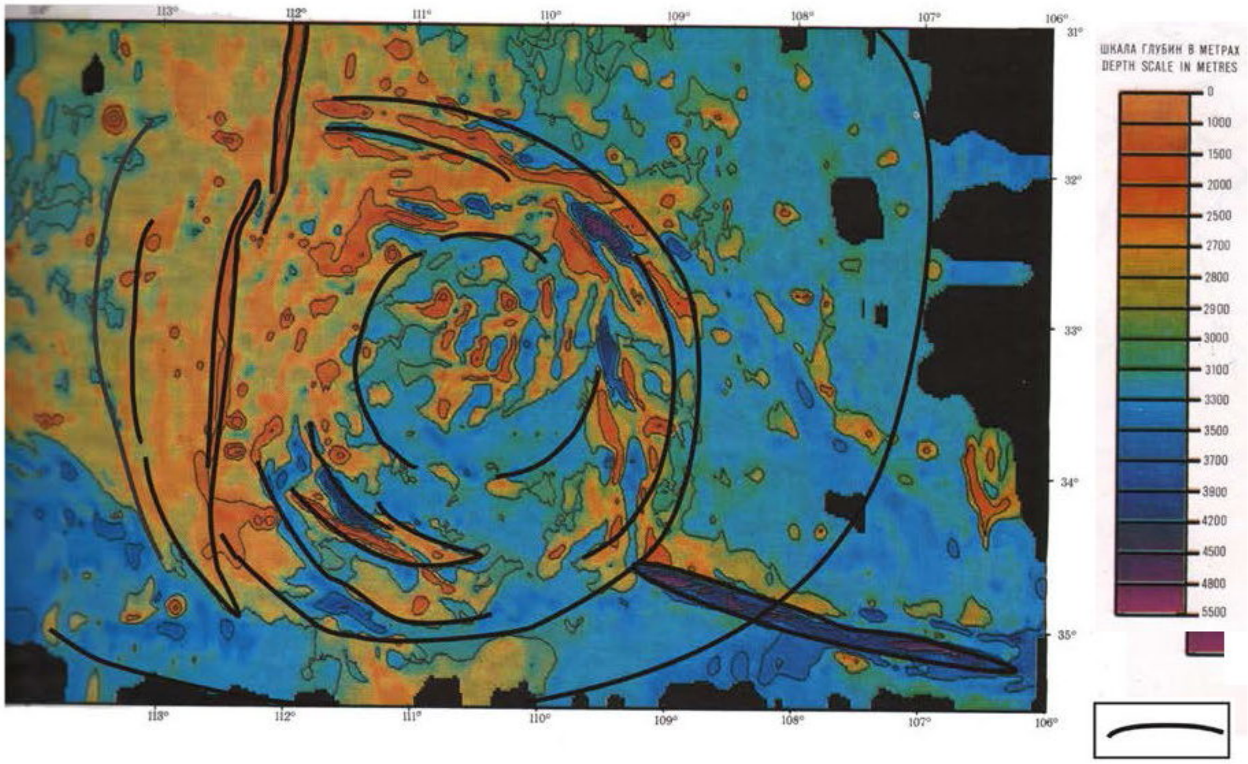

Fig. 7. The East Pacific mega arch-block Rise. It is charted on the basis of bathymetric map (International …, 2003). The black lines are zones of highest bathymetric gradients.

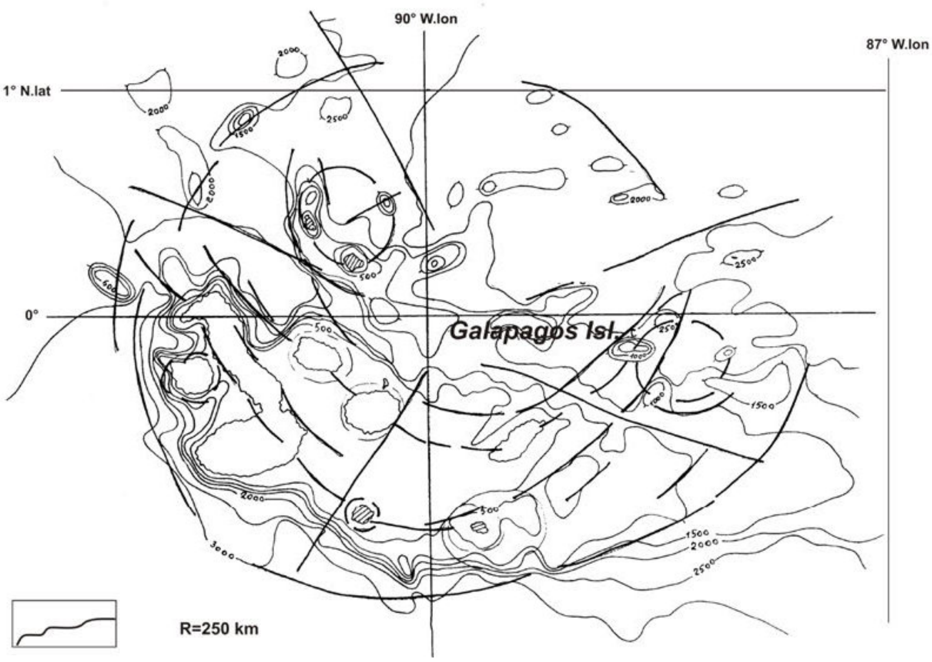

Fig. 8. The Galapagos magmatic arch-block rise with satellite internal pattern. Morphostructural imaging is on the basis of bathymetric maps of the scale 1: 2 000 000. The legend same as Fig. 4

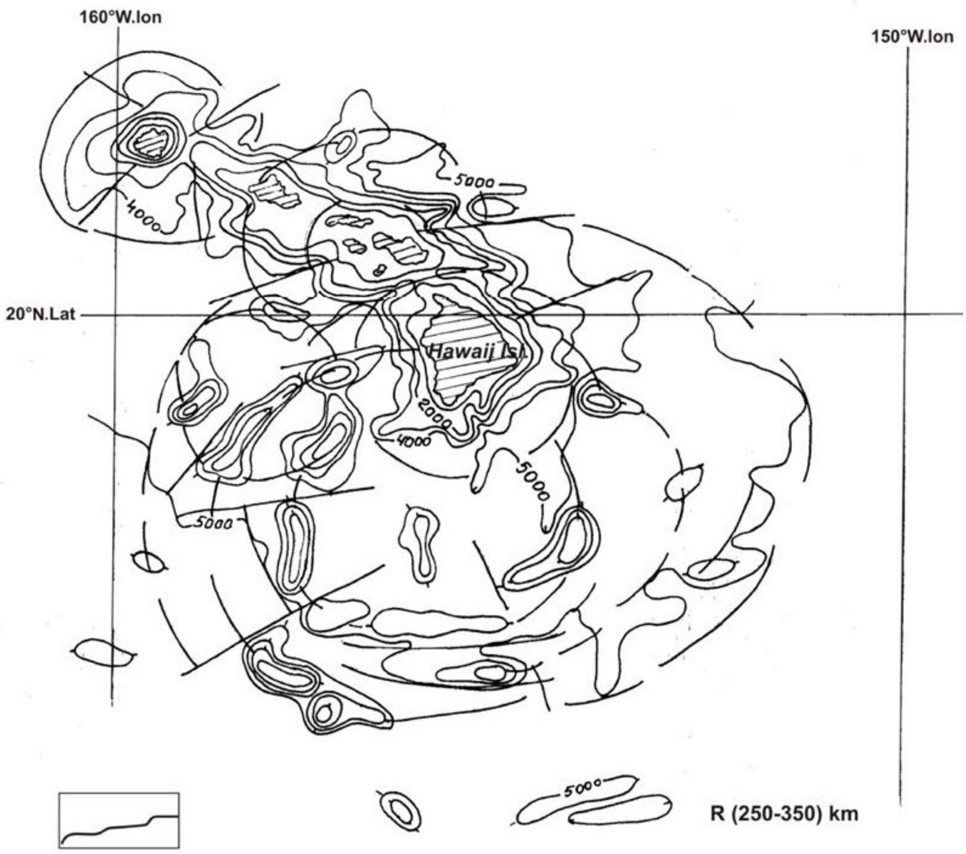

Fig. 9. South-Hawaiian magmatic arch-block rise with satellite internal pattern. Morphostructural imaging is on the basis of bathymetric maps of the scale 1: 2 000 000. Lines on schemes are isobathic curves

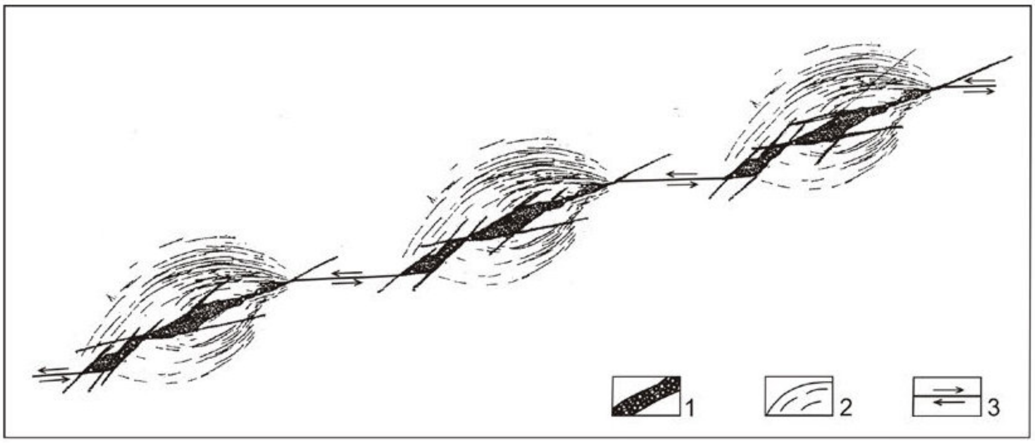

Fig. 10. The mechanism of ring structures formation within the shear-fault zones. 1 – gaping faults zones; 2 – ring faults; 3 – vectors of displacements

There are some large ring morphostructures with basins in central parts and island archipelagos on periphery whose morphology reflects probably both primary central type symmetry of arch rises or mantle diapirs. The Marshall-Ontong-Java arch-block rise (R = 900-950 km) and East Carolinian arch (R = 400-500 km) have undergone an inversion as a result of the rise of their central parts the Melanesian and East Carolinian isometric basins. In contrast to magmatic arches they are characterized only by satellite type of the infrastructure by the peripheral disposition of volcanic centers and zones. It is obviously that they are developed in conditions of the tectonic stretching. The origin of graben and trough systems at apical parts of arches is well vindicated by numerous tectonic-physical experiments (Gsovsky, 1975; Ramberg, 1985 and others).

Conclusions

1. The Darwin Rise has no unified tectonic basis and morphological features, therefore it does not exist in nature, but exists only in literature.
2. MCT with various sizes are typical and important elements of morphostructural fabric of the Pacific Ocean floor.
3. The long lasting deep focal systems have developed in pulsating and inherited regime during Late Mesozoic- Early Cenozoic. They form the tectonic basis of large rises of the Pacific Ocean bottom. Each plume arch-block rises consists in hierarchical groups of multitude of volcanoes.
4. The focal and fault systems are connected with deep and crustal energy centers and channels ensuring a delivery of magma, gases, fluids and hydrothermal migration. Therefore they represent the most adequate tectonic basis for mineralogenic forecast and division of ore districts of oceanic bottom

Acknowledgements: The author sincerely thanks Dong R. Choi and an anonymous reviewer for editorial and critical comments that helped improve the manuscript.

REFERENCES

Choi, D.R. and Vasiliev, B.I., 2008. Geology and tectonic development of the Pacific Ocean. Part 1. Mesozoic basins and deep-seated tectonic zones. *New Concepts in Global Tectonics Newsletter*, no. 46, p. 28-34.

Choi, D.R., 2014. Tectonic framework of the “Darwin Rise”. *NCGT Journal*, v. 2, no. 4, p. 94-98.

Ezhov, B.V. and Nikonova, R.I., 2003-2004. Morphostructure of the North Pacific region oceanic floor from positions of the focal geodynamics. Proceedings of the Profes. Club. Fascicle. 8-9. Vladivostok, p. 54-64. (in Russian)

ETOPO 1. http://www.ngdc.noaa.gov/mgg/global/global.html

Gavrilov, A.A., 1993. Problems in morphostructural-metallogenic analysis. Parts 1 and 2. Dal’nauka, Vladivostok. 322p. (in Russian)

Gavrilov, A.A., 1999. Mineralogenic asymmetry and dissymmetry of endogene SCT. Article 1. P. Kyuri principle and metal ore, diamondiferous kimberlites allocation within focal systems. *Pacific Geology*, v. 18, no. 1, p. 103-114 (in Russian)

Gavrilov, A.A., 2002. Classification of the Earth ring structures (RS). Article 1. Planetary model, RS of the constructional trend of the tectogenesis. Electronic magazine, “(in Russian). It is investigated in Russia". v. 180, p. 1990-2010. http://zhurnal.ape.relarn.ru/aricles/2002/180.pdf

Gavrilov, A.A., 2005. Ring morphostructures of the Pacific Ocean. Regularities of the Structure and Evolution of Geospheres – VII. Proceedings of VII Internat. Interdiscip. Symposium and Intern. Geoscience Programme (IGCP-476). Vladivostok, p. 73-75.

Gavrilov, A.A., 2013. Geomorphologic indication of plumes and other focal systems of the Pacific Ocean bottom. Geology of seas and oceans. Internat. Scient. Conference (School) of marine geology. Moscow, M.: GEOS. T. V., p. 51-55. (in Russian)

Golovinsky, V.I., 1985. Tectonics of the Pacific Ocean. M. Nedra. 196p. (in Russian)

Gordon, R.G. and Henderson, L.J., 1985. Pacific plate hot spot tracks, unpublished reprint.

Grachev, A.F., 2000. Mantle plumes and problems of geodynamics. *Physics of Earth*, no. 4, p. 3-37. (in Russian)

Gsovsky, M.V., 1975. Principles of tectonophysics. M. Nedra, 536p. (in Russian)

International Geological-Geophysical Atlas of the Pacific Ocean, 2003. Moscow–Sankt-Petersburg, 19p.

Jatskevich, B.A. [ed.], 2000. Geological Map of the World. 1:15,000,000. Ministry of Natural Resources of Russian Federation, RAS.

Kulakov, A.P., Ermoshin, V.V., Ishchenko, A.A. and Nikonova, R.I., 1987. New morphostructure data of the Pacific Ocean southwest part. Preprint. PGI FEB of the USSR Academy of Sciences. Vladivostok, 60p. (in Russian)

Maruyama, S., Kumazava, M. and Kawakami, S., 1994. Towards a new paradigm of the Earth’s dynamics. *Jour. of the Geol. Soc. Japan*, v. 100, no. 1, p. 1-3.

Menard, H.W., 1964. *Marine Geology of Pacific*. McGraw-Hill, New York, 255p.

McNutt, M.K and Fischer, K.M., 1987. The South Pacific Superswell. Geophysical monograph Series V. 43. Seamounts, islands, atolls. p. 25-34.

McNutt, M.K., 1998. "Superswells". *Reviews of Geophysics*, v. 36, no. 2, p. 211-244.

Ramberg, H., 1985. Gravity, deformation and the Earth crust. M.: Nedra. 309p. (in Russian)

Schkolnik, E.L., Govorov, I.N., Hershberg, L.B., Zadornov, M.M., Mel’nikov, M.E. and Volokhin, Yu.G., 1996. Ore provinces of the western and central parts of the Pacific Ocean – scales of a phosphatogenes and cobalt - manganese mineralization. *Pacific Geology*, v. 15, no. 6, p. 120-128. (in Russian)

Smoot, N.C., 2014a. Darwin Rise– Sisyphus and oceanography. *New Concepts in Global Tectonics Journal*, v. 2, no. 3, p. 41.

Smoot, N.C., 2014b. Sisyphus and the Darwin Rise. *New Concepts in Global Tectonics Journal*, v. 2, n. 3, p. 54-60.

Su, W.J., Woodward, R.L. and Dsienwonski, A.M., 1994. Degree 12 model of shear velocity heterogeneity in the mantle. *Jour. Geophys. Res*., n. B4, p. 6945-6980.

Vasiliev, B.I., 2009. Geological structure and origin of the Pacific Ocean. Vladivostok, Dalnauka, 560p.

Vikulin, A.V. and Melekestsev, I.V., 1997. Seismicity, volcanism of the Pacific Ocean and rotation of the planet. *Bulgarian Geophysical Jour*., T. XXIII, n. 1, p. 62-68. (in Russian)

Yano, T., 2014a. Late Mesozoic tectono-magmatism in the west Pacific Ocean – Did the Darwin rise demise or revise? *NCGT Journal*, v. 2, no. 3, p. 42-54.

Yano, T., 2014b. Late Mesozoic tectono-magmatism in the West Pacific Ocean – in a linear depression or on a domal uplift? *NCGT Journal*, v. 2, n. 4, p. 98-105.

DISCUSSIONS

Re: Giovanni P. Gregori, Comment on Stephen Hurrell: A new method to calculate paleogravity using fossil feathers

NCGT Journal, v. 3, no. 1, p 68-70

Robert J. TUTTLE
rjtuttle@earthlink.net

Dr. Gregori points out the complicated respiratory system of birds. I consider the fact that birds, in some form, survived the end of the Cretaceous, but all the other dinosaurs were extinguished. I use that to define true dinosaurs: "all and only those dinosaurs that were extinguished by the end of the Cretaceous", rather than "non-avian" dinosaurs. I think the true dinosaurs had ineffective active respiratory systems, but absorbed oxygen through their skin. In our modern world, humans absorb 4% of our metabolic oxygen directly through our skin; some new-born joeys (baby kangaroos in the mother's pouch) absorb 50% of theirs, and a certain frog absorbs 100% through wet skin.

Peter Ward (University of Washington, "Out of Thin Air – Dinosaurs, Birds, and Earth's Ancient Atmosphere", Joseph Henry Press, Washington, DC 2006) proposes instead that the (true) dinosaurs had the same efficient flow-through respiration as modern (true) birds, and that let them thrive in an atmosphere that was deficient (thin) in oxygen. This is based on the assumption that the mass, density, and pressure of the ancient atmosphere were essentially the same as now, and no consideration of the greatly different world envisioned by Earth Expansion. His presentation is weakened by his confusion over thin air (less density where birds fly over the Himalayas) and thin air (low oxygen content, as has been measured at the beginning of the dinosaur era). He is also guided by the idea that modern birds are direct descendants of the dinosaurs; I think they descended, quite differently, from common ancestors that were prior to the dinosaurs. Those differences killed the (true) dinosaurs but let some (true) birds survive. He doesn't explain how the dinosaurs were extinguished, other than blaming "a large asteroid", and that avoids the need to explain how respirably similar birds survived.

I suggest that dinosaurs absorbed most of their metabolic oxygen through their skin, and through special anatomical features, such as fins, frills, crests, and plates, that are otherwise explained as species identifiers or sexual indicators. I speculate that the active respiratory system (lungs) might have served primarily to discharge carbon dioxide. The high density (high pressure) air proposed here to provide buoyancy would have made skin absorption of oxygen very effective.

One of the clear problems with thick air is the speed at which animals such as *Tyrannosaurus rex* and other presumed predators could run. (If *Tyrannosaurus rex* and the other carnivores were scavengers, such a concern becomes moot.) It is difficult to construct accurate analogies for such an extreme world. A common comparison offers wading in deep water as an analogy for moving through thick air at a density of 65% that of water. If your speed while walking in deep water is limited by viscous drag, as I think is the case, and if the same were true for thick air, it is important to recognize that water is a liquid and air is a gas, and the viscosities differ greatly because of that. The dynamic viscosity of water (at 15C and 1 atmosphere pressure) is 1136 micropascal-seconds, while for air at a density of 649 kg/m^3 (65% the density of water), which I use to support *Tyrannosaurus*, the dynamic viscosity is only 62 micropascal-seconds. Since viscous drag varies as the square of the speed, if you could walk at 2 mph in deep water, *T. rex* could walk (run) at somewhat more than 8 mph in thick air, with the same amount of viscous drag. If we consider the pterodactyls to be dynamically similar to a manta ray, swimming at up to 25 mph in water, the air density I use to support the pterodactyl *Quetzalcoatlus northrupi*, about 800 kg/m^3, provides a dynamic viscosity of 150 micropascal-seconds, which is a factor of 7.6 less than that of water. That would allow *Quetzalcoatlus* to fly at a similar speed of 69 mph in thick air, for the same amount of viscous drag as the manta ray.

If, as someone proposed (reference lost), the atmosphere of the early Earth was 2,100 times as massive as at present, some mechanism must have depleted it over time. Impacts (from space) disperse some of the atmospheric material away from Earth. The solar wind can erode the atmosphere during the time of geomagnetic field reversals. Radiation from nearby supernovas and gamma-ray bursts can blow away some of the atmosphere. These are all theoretical effects and, fortunately, we have no observational data, as the effects might have been disastrous.

It is also difficult to find a modern animal that is geometrically and dynamically similar to *T. rex*. The early reconstructions in a tripodal stance have been given up, and I think the true case is likely to be like a shark on two legs, with a definitely straight and horizontal spine. Similarly, ancient dinobirds with feathered hindlegs as well as forelegs, have no obvious analog in the modern world, other than, perhaps, four-finned fish. It will take some creative anatomy to match some of the ancient animals.

I think it is important in this discussion to keep in mind that I am not trying to save giant dinosaurs from the fate of a beached blue whale. There are some studies (R. M. Alexander, "*Dynamics of Dinosaurs and Other Extinct Giants*", Columbia University Press, New York (1989), J. E. I. Hokkanen, The Size of the Largest Land Animal. *Journal of Theoretical Biology* **118**, 491-499 (1986)) that support giants living on the present Earth, so the blue whale may be a red herring. The beached whale may expire more from not being designed to survive on land as from its great weight out of water. However, those studies do not recognize the possible effects of different surface gravity, and avoid the question raised by the decline in maximum animal size from the Mesozoic through the megafauna to the present; something must have been changing. Rather than showing that recreating dinosaurs for Jurassic Park is possible (or not), I am trying to save the Expanding Earth theory from extinction because it appears that it can't support the dinosaurs and their friends.

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Re: Robert J. TUTTLE Earth Expansion and Thick Air for Ancient Birds NCGT Journal, V. 3, No. 1, March 2015.

James Maxlow
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Dear Robert,

I have read your recent discussion "Earth Expansion and Thick Air for Ancient Birds" which was in response to the article of Stephen W. Hurrell: "A new method to calculate paleogravity using fossil feathers", and replies. (Robert Arthur Beatty and Stephen Hurrell, NCGT Journal, v. 2, no. 4, December 2014). As you make mention of my research into Expansion Tectonics on a number of occasions in your discussion I feel compelled to respond in order to clarify a number of misconceptions.

Firstly, may I make expressly clear that Expansion Tectonics (formerly Expanding Earth theory) does not support a constant Earth mass scenario, hence your comparative ancient surface density factors are not relevant? Expansion Tectonic research is based on the published Geological Map of the World (CGMW & UNESCO, 1990). This geological map formed the basis for empirical small Earth modelling studies, extending from the present-day back to the early Archaean. This research, along with the research of Carey and others during the 1980s and 1990s, concluded that Earth radius increases exponentially in response to an exponential increase in mass over time. This is discussed at length in my book: On the Origin of Continents and Oceans, 2014, available from Amazon.com.

Where did the additional mass come from? The causal mechanism for increase in Earth mass has always been a contentious issue, and one that has continually been used to deny expansion. It is interesting to note that in 2000, four identical Cluster II satellites were launched to study the impact of the Sun's activity on the Earth's space environment by flying in formation around Earth. For the first time in space history, this mission was able to collect three-dimensional information on how the solar wind interacts with the magnetosphere and how it affects near-Earth space and its atmosphere, including auroras. This study was undertaken by the European Space Agency and results showed that it is much easier for the solar wind to penetrate the magnetosphere than had previously been thought.

A group of these scientists directly observed the existence of certain waves in the solar wind that were not expected. These waves enable incoming charged solar wind particles to breach the magnetopause, suggesting that the magnetosphere responds more as a filter rather than a continuous barrier. These discoveries were considered by the European Space Agency's project scientists to be of great importance because it showed how the Earth's magnetosphere can be penetrated by solar particles under specific interplanetary magnetic field circumstances. The study also suggested that these waves may be a lot more common and possibly represents a means for the constant penetration of solar particles into terrestrial magnetospheres.

From an Expansion Tectonic perspective, it is envisaged that these charged solar particles, comprising electrons and protons, enter the Earth at the poles and recombine within the 200 to 300 kilometres thick D" region, located at the base of the mantle directly above the core-mantle boundary. Kremp concluded in 1992 that, *"...this thermal increase in the outer core may be a fairly recent process forcing a rapid expansion of the Earth."* New matter formation requires not only pure energy but the presence of both electrons and protons and science now knows that these are plentiful from the Sun. The recombination of charged electrons and protons within this D" region then provides a mechanism to form new matter. This matter, in turn, becomes the building blocks of all elements and mineral species present on and in the Earth, including the new lava, water and gases now being expelled from the mid-ocean-ridge spreading centers in all of the ocean basins.

On an Expansion Tectonic Earth this increase in new matter results in an increase in Earth mass and volume which manifests itself as a swelling of the mantle. This increase in Earth volume and associated mantle swell is then transferred to the outer crust where it results in crustal extension, which is currently occurring as extension along the full length of the mid-ocean-rift zones. Extension within the mid-ocean-rift zones is accompanied by intrusion of new basaltic mantle-derived lava, along with expulsion of new water and gases. These, in turn, increase the surface area of all of the modern oceans in strict accordance with the seafloor mapping as shown in the Geological Map of the World (CGMW& UNESCO, 1990).

The second point I wish to make is the subtle implication in your discussion that the volume of atmospheric gases, and by inference volume of the ocean waters, has remained relatively constant over time. I again make it expressly clear that Expansion Tectonics does not assume, nor support, a constant volume for the atmosphere or hydrosphere.

Fundamental to the concept of Expansion Tectonics is the premise that the ocean waters and atmospheric gases have been accumulating throughout much of geologic time in sympathy with the formation of ancient supercontinental crusts and new seafloor volcanic crusts. It was considered by Bailey and Stewart (1983) that *"...for an Earth undergoing expansion with time, the bulk of the oceans would have to be outgassed since the Palaeozoic, requiring fundamental changes in atmosphere, climate, biology, sedimentology and volcanology."* It was also considered by Carey (1988) that, *"as the generation of the ocean floors depends fundamentally on the out gassing of juvenile water, it would therefore be expected that the volume of seawater* [and atmospheric gases] *and capacity of the ocean basins both increased, but not necessarily precisely in phase, in a related way."*

The primitive atmosphere and hydrosphere was considered by Lambert (1982) to have been formed largely from elements and molecules degassed from the Earth's interior and subsequently modified by physical, chemical, and biological processes. Rubey proposed as early as 1975 that degassing—the removal of dissolved gases from liquids [inclusive of molten magma]—has been a continuous or recurrent process, which is still occurring today. Rubey further suggested that "*the whole of the waters of the oceans have been exhaled from the interior of the Earth, not as a primordial process, but slowly, progressively and continuously throughout geological time."*

Studies of melted igneous rocks carried out since the 1980s have shown that the solubility of water in melted rocks increases with increasing pressure and temperature until a maximum value is reached in the mantle. Quoted examples range from 14 to 21 percent by weight of water dissolved in volcanic rocks at temperatures varying between 1,000 to 1,200 degrees Celsius and high pressures. For silica-rich magmas, carbon dioxide was also shown to be readily dissolved, in particular under high pressures. It was concluded from these studies that if water and carbon dioxide were available, they would both be highly soluble in the magmas normally generated in the upper mantle.

Before making speculative proposals and disagreement between my own empirical research, may I suggest that you, and the readers, at least study what Expansion Tectonics has to offer. It is no mere coincidence that seafloor crustal plates, when modelled on smaller radius Earth models, neatly fit together with an estimated plate-fit in excess of 99% fit for each period and epoch back to the early Triassic. It is also no mere coincidence that, by progressively reducing the surface areas of Phanerozoic and Proterozoic sedimentary basins, the remaining ancient Archaean cratonic crusts also neatly fit together with a similar high degree of precision to form a primitive Archaean Earth containing relatively shallow continental seas and a much reduced atmosphere at 1,700 kilometres radius.

These phenomena are discussed at length on my website at: www.expansiontectonics.com and in my hardcopy book and eBook: On the Origin of Continents and Oceans, 2014, available from Amazon.com.

References

Bailey, D.K. and Stewart, A.D., 1983. Problems of Ocean Water Accumulation on a Rapidly Expanding Earth. 67-69 in Carey S.W. (ed.): Expanding Earth Symposium, Sydney 1981, University of Tasmania.

Carey, S.W., 1988. Theories of the Earth and Universe: A History of Dogma in the Earth Sciences. Stanford University press, Stanford, California.

CGMW and UNESCO, 1990. Geological Map of the World. Commission for the Geological Map of the World, Paris.

Kremp, G.O.W., 1992. Earth Expansion Theory Versus Statical Earth Assumption. In: Chatterjee S. & Hotton N (III) eds. New Concepts in Global Tectonics. Texas Tech Univ. Press, USA, p. 297-307.

Lambert, I. B., 1982. Early geobiochemical evolution of the Earth. Revista Brasileira de Geociências 12, 32-38.

Rubey, W.W., 1975. Geologic history of sea water; an attempt to state the problem. In: Kitano Y. ed. Geochemistry of Water. Dowden, Hutchinson & Ross Inc., Stroudsburg, Pennsylvania.

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Re: Robert J. TUTTLE: Earth Expansion and Thick Air for Ancient Birds. *NCGT Journal*, v. 3, no. 1, p. 65-68.

Comments on some publications most people seem to have missed

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I have just been reading the interesting Discussion by Robert J. TUTTLE: Earth Expansion and Thick Air for Ancient Birds. *NCGT Journal*, v. 3, no. 1, p. 65-68. This has prompted me to share some of my thoughts and ideas with our readers. The publications thought not to have been seen by most people are listed as Review References along with details of how to get copies. These are Carey (1996) and Adams (2010).

My ideas favouring Earth Expansion (EE) did not germinate until somewhere in the 1970s, but 1 need to go back even further. My undergraduate studies in Geology were during the early 1950s when no one had any acceptable scientific concept concerning the past distribution of continents and oceans through geological time, the most popular seemed to be that the continents occupied the same positions on the geoid now as they had during previous geological time. Other ideas were often less realistic in hindsight. Even then the various ideas differed according to the background of the speaker, for example, I was a student of palaeontology studying in the Southern Hemisphere where the ideas of Wegener and du Toit seemed to fit better with fossil distribution data than most of the other proposals. Although not a student of the University of Tasmania I had been influenced to some extent by the early work of Professor S. W. Carey. This was reinforced after I had read Carey's 1958 Symposium. I have noticed that modern authors, whenever they cite Carey's works, always quote Carey, 1988. Readers would have noticed in the period 1958 to 1988 his books and monographic papers showed an evolutionary development in his concepts, so it is unfortunate that no one, possibly excepting myself ever seem to cite his last work of 1993. This book is a continuing refinement and extension from his earlier views. It is very easy to read, A4 format, illustrated with 127 figures, and well indexed.

My research interests in the 1960s were in fossil floras of the Late Palaeozoic in Gondwanaland as they still are now, although my time range has extended. Carey very generously gave me a copy of his 1993, fig. 44, on p. 66, to use as a base map, on which to plot the occurrences of two Cathaysian genera from the Permian of Western Papua in an otherwise totally Gondwanan terrestrial flora of largely seed plants incapable of dispersion over a marine seaway, the Tethys Sea, At that time was supposed to have an opening of an arc of about 30° spherically, origin at the center of the Earth, according to Plate Tectonics (PT).

The ascendency of Plate Tectonics (PT) appears to have been 'set in some non-yielding medium such as stone' by two short papers in 1965; by Wilson (1965) who described magnetic banding in lavas extruded in a parallel alignment from fault zones along a boundary between two tectonically inactive continental plates off-shore from Vancouver Island, British Columbia (read first) and by Vine and Wilson (1965) who interpreted Wilson's observations that the ages of the bands were from oldest furthest from the fault, and youngest along the tectonically active zone which could be interpreted as upwelling of lava pushing the two plates apart. Neither they nor any of their successors seem to have considered the possibility so evident in wound healing in multicellular animals and plants where the body 'overwhelms' the wound with new cell growth causing a swelling along the injury forming a sliver of new tissue. Transferring this behavioural observation to the inorganic world, the stable plates were being pulled apart exposing a 'wound' that is repaired with a band of new lava and thus a philosophical rather than a scientific observation. This might be repeated many times, resulting in many bands, which is what we see now. The motive force is (Earth Expansion) EE. I attempted to explain this (Rigby, 1999) by suggesting that the extra mass as needed was derived from neutrino transmutation from the high energy form to the high mass form deep within the earth.

Subsequently a leading international nuclear physicist patiently explained to me how this was not a practical suggestion. I appreciated this conversation which I cannot acknowledge. In the same paper, I suggested that for flight to have been successful for animals other than birds, a much denser atmosphere was needed. This goes against one of the sacred tenets of PT, that the atn1ospheric pressure throughout the Phanerozoic remained almost constant. Changes in its composition, e.g. in $C0_2$ without change in pressure, could easily have brought about changes in global mean temperature, but not have assisted flight in the four-winged, toothed 'birds' which needed extra buoyancy to fly. These were the dinosaur derivatives that came into prominence during the Jurassic about the same time as the modern birds evolved. An approximate doubling of the atmospheric pressure at sea level would have provided adequate buoyancy.

Adams (2010) has suggested that parts of continental Zealandia had migrated to along the coast of West Antarctica to South America. West Antarctica does not have a continental base, but if the ice were to melt it would be replaced by some islands some separated by deep oceanic trenches. To me this see1ns like a hard ask for a leading PT. First what/where was Zealandia. Sutherland (1999) had mapped a large area of the southwest Pacific as a former continent that now is exposed to a small extent as New Zealand and some small oceanic islands. Adams (2008) used the name Zealandia for this former continent, but I have been unable to find whether this is the first use of the name. This paper was expanded later to include a map suggesting a part of Zealandia occupied an area along the oceanic coast of Chile (Adams, 2010, fig. 3).

This would have been obvious to EE as the position would have been at the southern end of the area before where the future Pacific Ocean would expand into (Carey, 1996, fig. 44). Carey very generously gave me a copy of this figure on which to plot the distribution of some of the Permian floras at a time when he thought the Tethys Ocean was a narrow sea-way (Rigby, 1998). interestingly, the editors of this paper allowed me to include a distribution map based on EE as long as I also included a similar map on approximately the same scale based on PT, map kindly supplied by Professor I. Metcalfe, University of New England, Armidale, New South Wales. I think history of the Pacific area clearly demonstrates that PT has some significant flaws, particularly in relation to biological distribution. PT appears to have been promulgated without any consideration of biological constraints. A number of palaeontologists support PT as they study shallow water faunas where constraints to distribution differ to those pertaining to large terrestrial animals and large plants.

Review References

Adams, C.J., 20 I 0. Lost terranes of Zealandia: possible development of late Paleozoic and early Mesozoic sedimentary basins at the southwest Pacific margin of Gondwanaland, and their destination as terranes in southern South America. *Andean Geology*, v. 37, pt. 2, p. 442-454.

This journal is available as a free download by Googling Andean Geology Journal, and choosing the Archive button. The download may be very slow to start up, patience!

Carey, S.W., 1996. *Earth, Universe, Casinos.* Geology Department, University of Tasmania, Hobart. Pp. xiv + 232.

This book is not available on the web or booksellers. It can be bought only at the address below for $45.00 Australian: http:www.utas.edu.au/codes/publications/publications-for-sale.

Postage is extra, so contact the above address before you try to buy, a range of credit cards are accepted. Anyone interested in Carey's works should consider buying this book.

Other References

Adams, C.J., 2008. Geochronology of Paleozoic terranes at the Pacific Ocean margin of Zealandia. *Gondwana Research* v. 13, p. 250-258.

Carey, S.W., 1988. *Theories of the Earth and Universe.* Stanford University Press. 413p.

Rigby, J.P., 1998. Upper Palaeozoic floras of SE Asia. P. 73-82. in Hall, R. and Holloway, J.D. (eds.). *Biogeography and Geological Evolution of SE Asia.* Backhuys Publishers, Leiden, The Netherlands.

Rigby, J.P., 1999. Permian floras and palaeogeography with particular reference on Gondwanaland and the Tethyan margin. *International Symposium Shallow Tethys (ST)* 5, p. 185-196. Available on Researchgate.

Sutherland, R., 1999. Base1nent geology and tectonic develop111ent of the greater New Zealand region: an interpretation from regional magnetic data. *Tectonophysics* v. 308, p. 341-362.

Vine, F.J. and Wilson, J.T., 1965. Magnetic anomalies over a young granite ridge off Vancouver Island. *Science* v. 150, p. 485-489.

Wilson, J.T., 1965. Transform faults, oceanic ridges, and magnetic anomalies southwest of Vancouver Island. *Science* v. 150, p. 482-485.

ESSAYS

NATURAL SEISMICITY

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ABSTRACT: Natural earthquakes are analysed in terms of localised shear failures, with horizontal stresses restricted to the maximum geoid stress value and shear strengths restricted to the values of pertinent discontinuities in the substrata. With increase in depth down to the Benioff Zones the role of high volatile (pore) pressures becomes increasingly significant. Deep earthquakes, below the Benioff Zones, are taken to be the result of a hydraulic fracture mechanism, induced by the release of high temperature/high pressure volatiles from the Lower Mantle. These deep events reveal the presence of structure in the Upper Mantle. Between the deep earthquakes and the lower Benioff Zone is often an aseismic zone of obscure origin.

Keywords: *earthquake patterns, in situ shear stress/shear strength, geoid stress, hydraulic fracture, volatile migration, Mantle structure*

Author's Note: Some short sections of the following essay have been published in the NCGT pages previously, as referenced. The sections are included herein for the purposes of completeness and for reader convenience.

1 Introduction

Earthquakes have been estimated to occur at a rate of about a million a year, most of which are recorded on hundreds of thousands of seismograph stations, globally installed. Apart from the normal scientific pursuit of knowledge in the realm of natural phenomena, such recordings have another major aim: to develop a reliable means of predicting earthquakes, in particular events likely to present a threat to life and property.

The vast majority of the natural events are pretty harmless. Earthquakes of magnitudes M2 to M3 may be readily felt by humans - and no doubt other sensitive fauna – but do not normally cause structural damage, except perhaps in susceptible environmental situations such as recent sediments. Structural damage usually begins around magnitude M5, particularly in areas of susceptible environments and/or areas of poor quality construction. The 1963 devastating earthquake at Skopje, Yugoslavia, was of borderline magnitude, but it was shallow, the epicenter was close to Skopje, and the event revealed a plethora of poorly constructed buildings. By magnitude M6, however, even well-built structures may suffer; landslides may be generated and, under certain circumstances, tsunamis. Destruction goes up almost exponentially thereafter.

A.E. Wallace, of the *Wallace Line* fame, travelled extensively in the Indonesian Archipelago during the mid-19th Century and claimed the region had recognisable earthquake events every week, with a severe shock every year. (In fact, these were probably understatements.) He named some ill-famed eruptions of the past:- an earthquake in 1646 that rent open Maluka Island, leaving a huge chasm on one side which, after 215 years, burst forth again to take with it twelve Malay villages; Papandayang in Java, in 1772, when a whole mountain blew up; Tomboro, on Sumbawa Island in 1815, spreading ash for 500 km out to sea and causing a known death toll of twelve thousand. Krakatoa, which came after Wallace (in 1883), produced an eruption that was heard in Sri Lanka and Western Australia. Its wave generation and tsunami destroyed villages and 30,000 - 40,000 people, while its air waves passed several times around the world.

Population decimation has obviously increased in the more populous modern world and well over a million people are estimated to have been killed (with probably as many severely injured) in some fifteen large earthquakes during the first half of the Twentieth Century. The rate of earthquake occurrence continues and, although improvements in earthquake design have greatly reduced casualty statistics in many countries, there has been little reduction in the trauma aspects of ground shaking. Thus, prediction of significant earthquakes remains high on the priority list.

Numerous precursors have been identified over time, including phenomena such as "earthquake lights" which were identified as far back as Roman times; tidal effects; lunar phases; vapour clouds; radiation of heat; abnormal behaviour of animals... The majority of these are, however, typically suggestive rather than specific. By that is meant they might well herald an event but they are unable to give repeated success regarding specified location, depth, magnitude and timing of the event - which, of course, is what human societies require in order to survive.

A personal view on the matter of prediction is that we first need to identify and understand the mechanisms of earthquake generation before we can set up reliable monitoring systems for prediction. Without this knowledge of mechanisms, we are often doing little more than searching in the dark and hoping to get lucky. This is particularly so when we seek to link earthquake activity with regular phenomena like tidal or astronomical effects. Natural events that happen with regularity often allow such a nexus to be inferred, particularly in hindsight, but the problem remains: which specific item of a regular occurring natural phenomenon is to be chosen in advance, as a precursor?

Early in 2012, an International Earthquake and Volcanic Prediction Centre (IEVPC) was set up in Florida, with this journal's editor leading the research. The IEVPC has recently been able to claim several successful predictions that were made well in advance, these being based on the Claude Blot hypothesis of upwardly migrating of seismic energy: a promising start. However, the long history of disappointments in the prediction field will obviously require a substantial portfolio of successes from the IEVPC, together with the resolution of some form of scientifically based monitoring program, before confidence in the public domain can be established. We look forward to this taking place.

Referring back to the above mentioned understanding of the mechanisms of earthquakes, it has to be said that the lack of critical assessment in the mobile plate tectonics model – at least in mainstream geosciences publications - has been no help in the matter of prediction. In the following discussions, no reliance is placed on any of the inferences of the mobilist model. Instead, analyses of the mechanisms of earthquakes will be based on the relationship between insitu stress conditions and insitu shear strengths, as introduced by the author with regard to artificially induced seismicity in a previous issue of the NCGT journal. It will be established that this approach should also be effective in analyzing natural seismicity, at least down to the base of the Benioff Zones. Below this level, the patterns of earthquakes in the Upper Mantle (say, 500 to 700 km depth) indicate quite a different mechanism. Some questions are also raised on the nature of an aseismic zone that is frequently encountered between the deep earthquake zone and the lower Benioff zone.

2 Variable Insitu Shear Stresses at Depth

Insitu stress measurements in the upper levels of the Earth's Crust reveal that, while the vertical (total) stress is typically given by depth times density, horizontal (total) stresses can range from less than half the vertical value[4] up to seven or eight times this. The former case represents tensile conditions, the latter represents conditions of compression. For any analyses based on these values it is necessary to work in terms of effective stress, which takes into account the effects of the pore, or volatile, pressures acting at the subject level.

The existence of high horizontal stresses at depth has been explained in many textbooks as the result of erosion during the geological history of the stratum. The argument is as follows. In a sediment undergoing deposition, the vertical stress (σ_v) would be given by depth times density. In an argillaceous sediment, the corresponding horizontal stress at any depth is given theoretically by the relationship:

$$\sigma_h = \sigma_v \, . \; \nu/(1-\nu)$$

where ν = Poisson's Ratio, perhaps around 0.2 to 0.3 for a compressible material

That is, horizontal stresses would increase at the rate of maybe a quarter the rate of increase in the vertical stress and this would go on until the end of the sedimentation process. At the conclusion of a sedimentary cycle, most deposits sooner or later become subject to erosion. In simple terms, this means that a sediment originally squashed down by vertical loadings in the past, then has some – or quite a lot - of that vertical loading removed by erosion. During the process of load removal, the vertical stress at any point within the sediment reduces in proportion to the amount of load removed. However, since the vast majority of sediments can be taken as semi-infinite in the horizontal direction, this means that the original, or maximum, horizontal stress developed by the end of the deposition cycle tends to remain locked in, despite the erosion.

[4] In former days, such values were often disregarded as instrument error.

If enough superincumbent material is removed by erosion, the situation can arise where the vertical stresses are reduced to a level below the in situ horizontal stresses. The process is illustrated by **Figure 1**.

The Eocene London Clay typically exhibits horizontal stresses two to three times the vertical. For this to have been produced by erosion alone would mean that something like ten to fifteen times the present vertical loading on the sediment had been removed. Thus, if the in situ stress measurement was taken at 20m depth, then one would assume that at least 200m of sediment had been removed from above the present land surface of the London basin. If the measurement was taken at 40m depth, the depth of sediment removal comes out as around 400 m. This poses something of a quandary, except for the fact that the geology of the London basin has been relatively stable since Jurassic times and overlying sequences from below the London Clay to the deposits of the last ice age are still partially intact in some areas, making it fairly clear that there has never been an additional 400m, or even 200m, of sediments removed from above the present land surface of the London Basin. Thus, one would have to conclude that the high horizontal stresses are the product of tectonic activity. Which is not unexpected. On the Isle of Wight, to the south of the London basin, there is a large monoclinal structure in beds slightly younger than the London Clay: a fairly clear indication that there have been compressive N –S tectonic forces in the region.

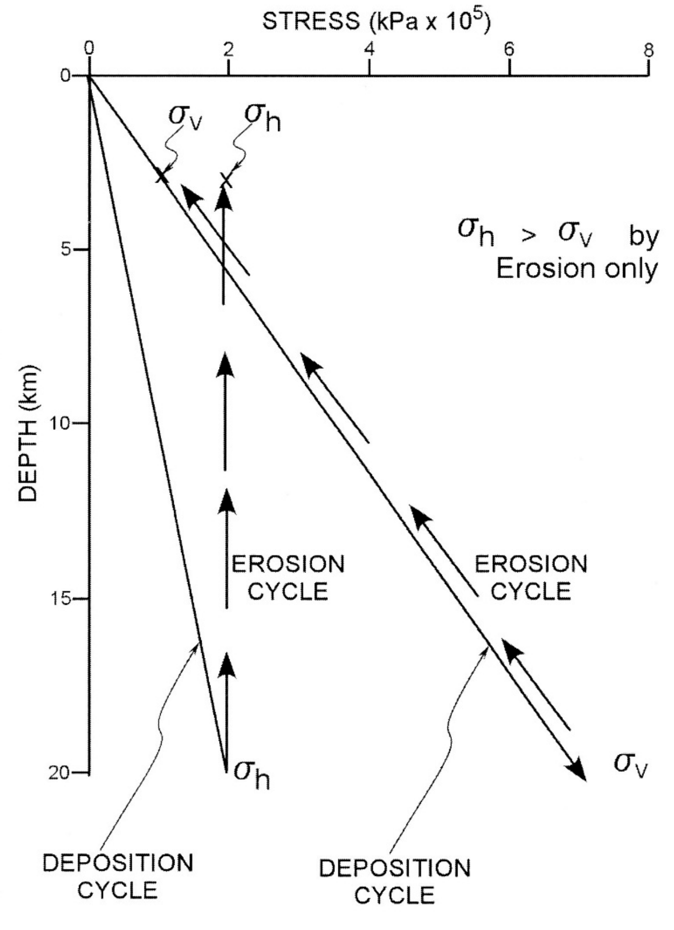

Figure 1. Stress changes during the deposition and erosion cycles, leading to a horizontal stress exceeding the vertical.

A similar sum can be done for the flat lying sandstone /shale beds of the Sydney Basin, based on the in situ stress measurements of Enever and Lee (2000) and briefly treated in NCGT, two issues ago, on artificially induced seismicity. Here, an erosion cycle of some 5,000 m would be required to produce the recorded high horizontal stresses. Again, there are no geological indications of anything like this amount of superincumbent strata ever having been present in the Sydney Basin's geological past. The conclusion is thus again that tectonic compressive forces have been at work.

In previous submissions to NCGT and in James (1994), the writer has introduced the concept of strain-imposed stresses resulting from elements of the near surface layers of the Earth being obliged to adjust to geoid changes as a result of polar wander. Heiskanen and Meinesz (1958) were probably the first to look at this problem and calculated that an element of crust "moving" from an area of polar flattening to an area of equatorial "stretching" would be subject to a tensile stress of 1.5 x 10^5 kPa. And vice versa. Incidentally, a value of the same order can also be obtained by a simple Hooke's Law approach, using a reasonable deformation modulus for hard rock.

Heiskanen and Meinesz obtained their value on the basis of the Earth being composed of concentric shells, like an onion. In fact, the often bimodal nature of the Earth's crust makes the stress changes at the interface of, say, a shield and the ocean crust increase by 50%. It has been demonstrated by the writer that these orders of stress magnitude are adequate to produce geosynclines when palaeoequatorial alignments lie along such crustal interfaces. In addition, the compressive stresses imposed when the geosynclines move away to higher latitudes are adequate to produce deformation, folding and thrust faulting of the geosynclinal sediments, and hence fold mountains. This is incidental to the main theme of this submission, but is introduced here since maximum geoid stresses of the order of 1.5 x 10^5 kPa will be used below in the analysis of earthquake failures. Incidentally, again, the same strain-induced horizontal stresses outlined above would also be imposed on any lithospheric plate travelling across major geoid changes. To date, however, it appears that no cognizance of this factor has been taken by mobile plate tectonics advocates.

3 Earthquake Patterns

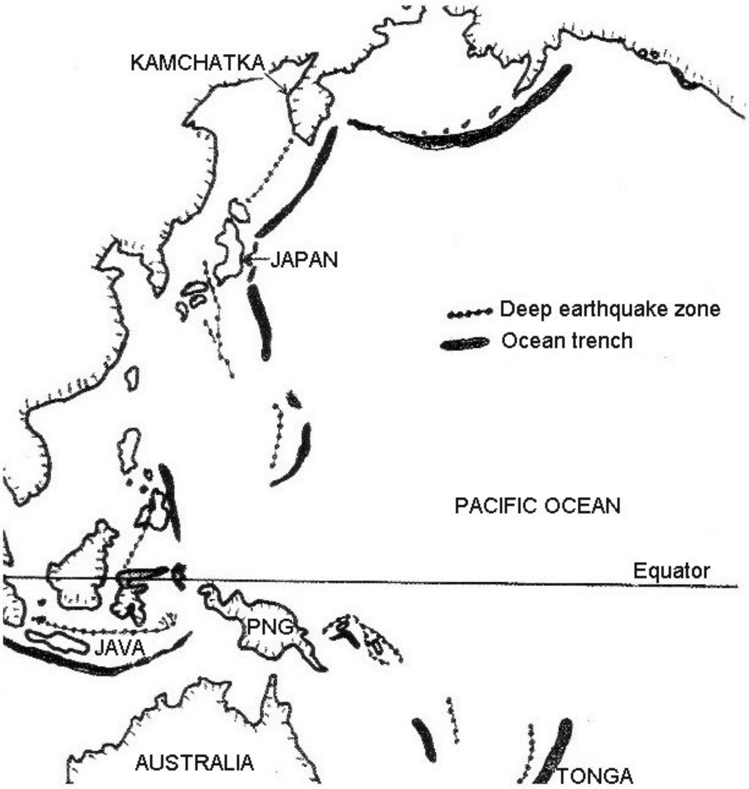

Figure 2. Deep earthquake zones and oceanic rifts, west Pacific.

Earthquakes first appear at what is labelled the Lower Mantle/Upper Mantle boundary, a boundary related to laboratory-observed phase changes in certain minerals such as peridotite. This boundary is specified at depths of around 670 km but the earthquake events are a little less specific, first occurring anywhere within the Upper Mantle between, say, 700 and 550 km depth. An immediately obvious pattern shown by these deep earthquake zones is a salient intimacy with the fringes of the Pacific Ocean: from Kamchatka to Java and then sporadically across the south-west Pacific to Tonga, **Figure 2**. In these regions, the deep earthquake zones form (on the Mercator Projection) long curvi-linear traces of vertically aligned earthquakes. All are associated with overlying Benioff (Benioff-Wadati) Zones and, at the surface, with sub-parallel oceanic trenches. Between these two major alignments, it is normal to find parallel "strings" of volcanoes and/or volcanic islands.

A similar pattern is to be found on the other side of the Pacific, in South America. Here, however, the deep earthquake alignment occurs beneath the continent itself, on the eastern side of the Andes, **Figure 3**.

Nonetheless, there is the same sub-parallelism with the oceanic trench, just off the Pacific coastline and also with the masses of volcanoes along the Andes cordillera. Incidentally, the deep earthquake alignment here runs very close to the boundary of the South American Shield.

Figure 3. Deep earthquake zone, South America

It is also worth mentioning at this stage that there are other regions presenting similar patterns of oceanic trenches and affiliated volcanic alignments, except for the fact that a deep earthquake segment is missing. Sumatra, for instance, has a deep oceanic trench that extends up from the southern side of Java; it has the strings of volcanoes and Benioff zones dipping beneath the island. But it is without any events deeper than 200-300 km. The Aleutian arc, in the far north of the Pacific, has the same curvi-linear oceanic trench, the same sub-parallel string of volcanic islands, the same – if rather more dispersed - upper level Benioff zones. But, again, there are no earthquakes below some 200 km depth. Similar patterns are also to be found in Central America. Some further words on this are given later.

A typical deep earthquake to surface elevation profile is illustrated by **Figure 4**. The deep earthquakes form vertical arrays in the Upper Mantle and, when plotted against a time scale, it becomes apparent that the earthquakes migrate upwards, a fact that was first recognised by the French geophysicist, Claude Blot, in the 1960s. In many locations, however, there is an overlying aseismic zone between 500 and 350 km depth, but the time factor can be picked up again at the lower levels of the Benioff Zones. Each of the two zones comprising the Benioff complex has a distinct inclination – a feature that led Benioff to conclude the zones probably had different origins. Indeed, the shallower zone, inclined at 27 - 30º, fits the pattern of failure under original conditions of compression. The inclination of around 60º for the deeper zone fits failures under original tensile conditions and explanations for the geometry have been discussed elsewhere by the writer, e.g. James (2009). Above the upper Benioff Zone activity becomes less structured or, rather, more hectic - particularly in the Earth's crust.

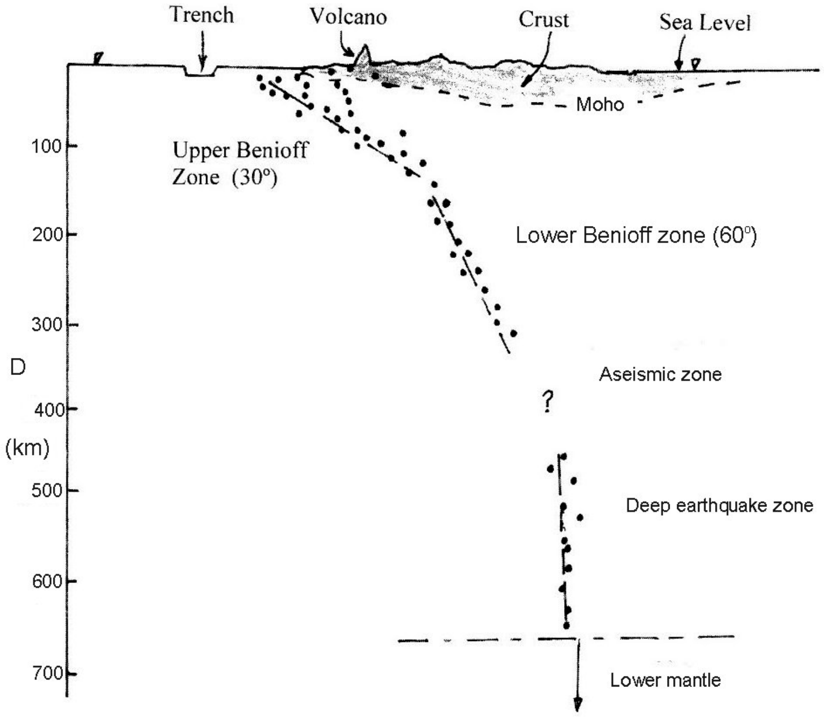

Figure 4. Idealised earthquake-event distribution in deep earthquake environments

Around the middle of the 20th Century, the idealized earthquake pattern of **Figure 4** became the basis for a process labelled subduction, a boon to the then developing mobile plate tectonics model. It appeared as a logical and relevant interpretation, allied to sea floor spreading. Nonetheless, a number of mismatches had to be explained away or, at least, ignored. Firstly, continuation between an oceanic trench and the deep earthquake zone is not always present, as might be expected if subduction is taking place. Large gaps often occur a) between the ocean trench and the shallow Benioff zone; b) between the shallower and the lower Benioff Zone where the gap is occasionally a couple of hundred kilometers wide; and c) a further gap often occurs between the lower Benioff Zone and the deep earthquakes, referred to herein as the aseismic zone.

In addition to these gaps, the ocean trenches themselves typically show no evidence of subduction, being rift-type structures diagnostic of tensile failure. Moreover, a substantial number of the trenches in the Pacific contain horizontally bedded sediments on the basement, dating back to the Tertiary or earlier, Bogdanov (1973). In other words, these trenches indicate a long term static situation, not a dynamic condition.

Other evidence refuting the postulated subduction mechanism has been presented by the author in the form of a) quantitative analysis of the forces involved in such a mechanism and b) the effects of a moving basement (e.g. the Juan de Fuca "plate") on an overlying abyssal sedimentary fan. In the former case, the forces attributed to the subduction mechanism are demonstrated to be quite inadequate for the job they are alleged to carry out. In the latter case, a moving basement would have no option other than to cause deformation, folding and thrust faulting of an overlying sedimentary fan. But abyssal sedimentary fans, world-wide, are generally horizontally bedded and, apart from occasional gentle folding, undeformed.

In their book on "Active Margin Geomorphology", Smoot et al (2001) found no seismic evidence of subduction anywhere around the Pacific. Choi (2005) and (2006) asks the same question of subduction: "Where is the evidence?" in relation to the Indonesian arc and the Juan de Fuca Plate. As long ago as 1972, Meyerhoff A.A. & A.H., listed instances of geological sequences carrying right across boundaries that were classed as subduction zones. All these criticisms have been to no avail in the growing enthusiasm for the isomorphic approach to global tectonics.

A final point might be made that there is no (seismic) evidence of any horizontal deformation in the fracture zones of the sea floor that are alleged, from the sea floor patterns, to be moving. **Figure 5** provides one example of what is meant.

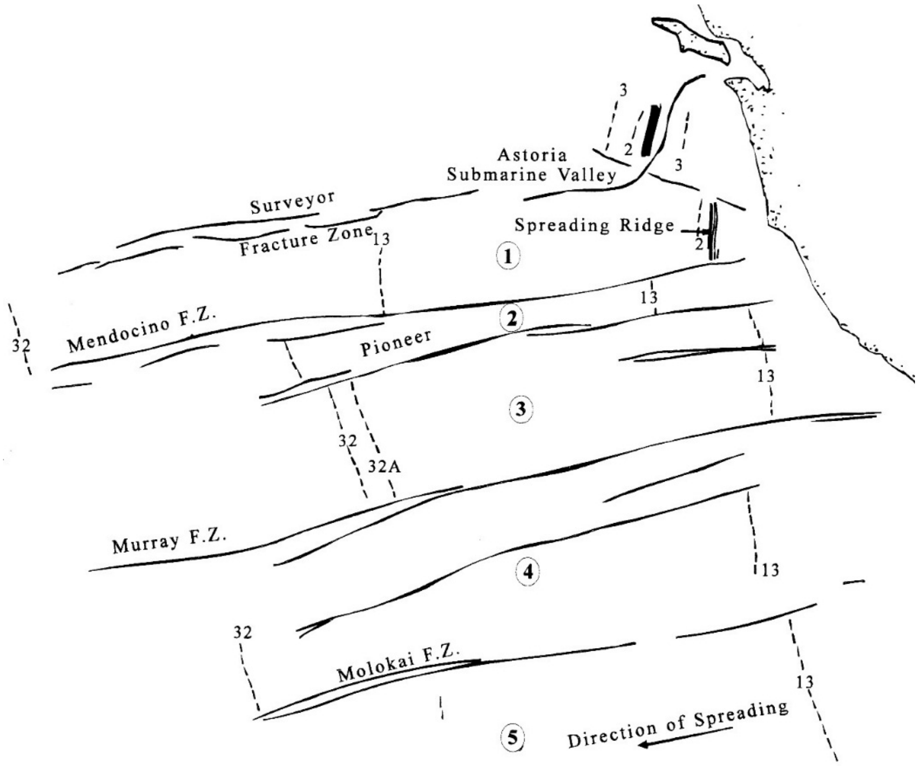

Figure 5. Fracture zones in the north east Pacific, taken to indicate differential spreading rates, are aseismic.

Here, in the north east Pacific, the interpreted spreading rates of the sea floor, based on the ages of the magnetic stripes, are:

Zone	Spreading Rate
1	4 cm/yr
2	4.3 "
3	4.7 "
4	6.7 "
5	4.8 "

The zone between the Murray and the Molokai Fractures is allegedly spreading at some 2 cm/yr faster than the zones on either side. That is a differential rate of movement equal to what is measured on the San Andreas Fault. Yet the two fractures bounding either side of this zone of alleged relative movement are aseismic. Aseismic deformation of this order is a difficult one to explain when the whole of the mobile plate tectonics model is based on seismic patterns. Incidentally, the situation in the north east Pacific is not unique but can also be seen in patterns in the Southern Ocean, below Australia.

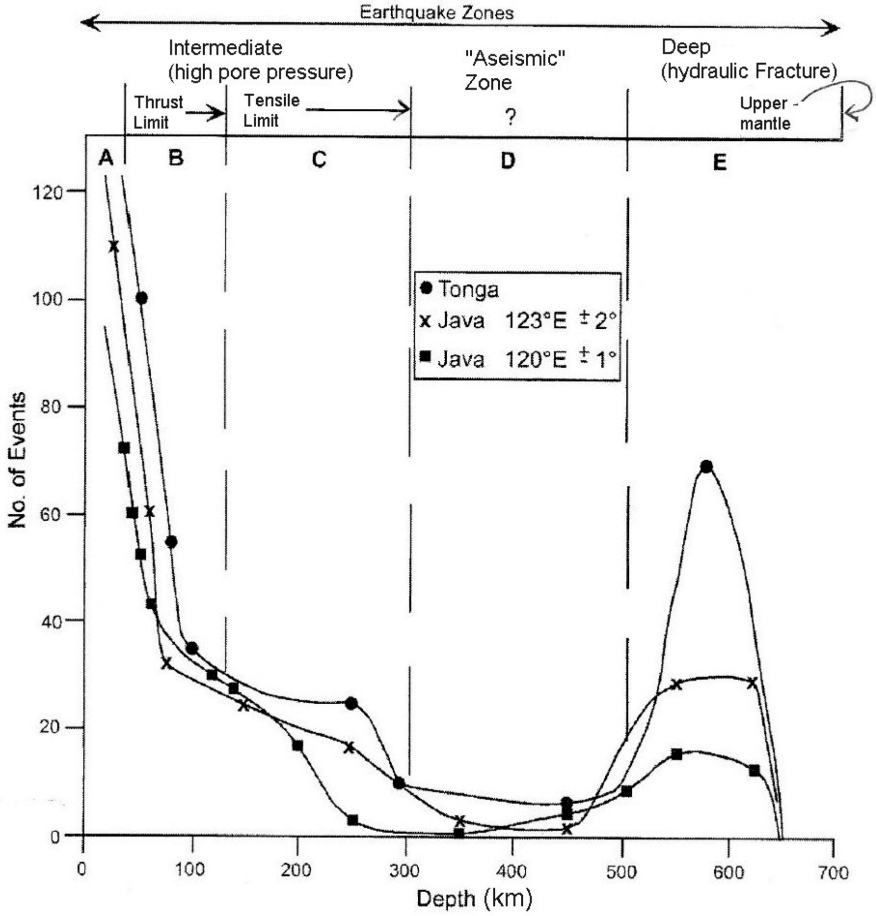

Figure 6. Earthquake frequency with depth, Tonga and Java, since 1973

The patterns of earthquakes shown above in **Figure 4** may be looked at from the point of view of frequency. **Figure 6** shows an example of the changing frequency of the earthquake intensity with depth in the Pacific Ocean environment. The categories in the figure are as follows:-

- Zone A: shallow, partly crustal zone of very high activity. It will be demonstrated below that, within the upper parts of this zone, earthquakes can occur through geoid stresses, often with no more than a hydrostatic pore pressure regime.
- Zone B and Zone C: earthquakes on the Benioff zones. Here, it will be demonstrated that elevated pore pressures are required for earthquake activity, based on the geoid stress model. Failures under compressive conditions (thrust faults) occur only in Zone B and not in Zone C, which is the province of failures under tensile conditions. (Obviously, there is no reason to prevent tensile failures occurring at the levels of Zone B, as well, and this could account for the higher number of events in this Zone.)
- Zone D is largely an aseismic zone, presently of unknown origin.
- Zone E: earthquakes in the Upper Mantle. Here, the earthquakes will be presented not as shear stress failures but as the result of hydraulic fracture caused by the emission of high temperature, high pressure, volatiles from the Lower Mantle.

Justification for these statements will now be provided, taking the earthquake zones in turn.

4 Shallow Earthquakes

In this sub-section, the conditions analysed will be those presented in a previous NCGT issue on artificially induced seismicity: that is, earthquakes will be taken as localised failures generated when the effective shear stresses exceed the shear strength at any particular level. The three parameters controlling this situation are thus the insitu shear stress, the in situ shear strength - typically along discontinuities in the rock mass - and the pore pressure regime. In the upper crustal levels, the first two conditions can be taken as reasonably static, at least on a human time scale. One principal stress in this equation is the total vertical loading, σ_v, given by depth times density, less uplift for effective stress conditions, σ_v'. Horizontal stresses provide the other two principal stresses. These are unlikely to be equal but it will be the larger horizontal stress (in the case of compressive conditions) and the lesser (in the case of tensile conditions) that dictate the failure conditions. This allows an analysis to be made in two dimensions, with shear stress in the form of $(\sigma_h' - \sigma_v')/2$ for conditions of compression and $(\sigma_v' - \sigma_h')/2$ for tensile conditions. As mentioned earlier, on a geoid tectonics basis, the maximum shear stress available in either case would be approximately 1.5 x 10^5 kPa, but this is probably unlikely to exist in most environments.

As indicated above, shallow earthquakes in the Earth's crust occur most readily in the presence of pre-existing discontinuities, particularly when these are favourably orientated with respect to the principal stress. As anyone who has mapped deep tunnels would know, most rock masses have a plethora of discontinuity sets, so this orientation requirement will not normally be a great problem. Parameters along such planes of weakness are proposed as an angle of shearing resistance (friction) with a value not greatly exceeding 20º and a cohesion that would be small to negligible. In relatively stable regions of the Earth's crust, a hydrostatic water pressure distribution might be expected at shallow crustal levels and this condition will be incorporated in the initial analyses. Normal, thrust, and strike-slip faults are treated separately.

Normal Faults

Normal faults occur under tensile conditions, where possible on steeply dipping discontinuities. A two-dimensional Mohr Circle analysis of the situation is given in **Figure 7** for the case of a hydrostatic increase in pore pressure with depth. The two Mohr Circles shown on the figure illustrate the role of different geoid stresses would have on the depth to which earthquakes might take place under a hydrostatic pore pressure regime. In the figure, the circles have been hypothetically adjusted for the relevant hydrostatic pore pressure conditions at each depth, so that they represent conditions in terms of effective stress. For the shallower case in the figure, it can be seen that the Mohr Circle cuts the failure envelope when only a part of the full potential geoid stress is applied.

The circle on the right utilises the maximum value of the geoid stress. From this, it can be inferred that, beyond depths of around14 -15 km, the Mohr Circles for the maximum geoid stress will begin to fall beneath the failure envelope, at least when combined with hydrostatic pore pressures. This indicates a depth limit for normal faulting, at least under these specific conditions.

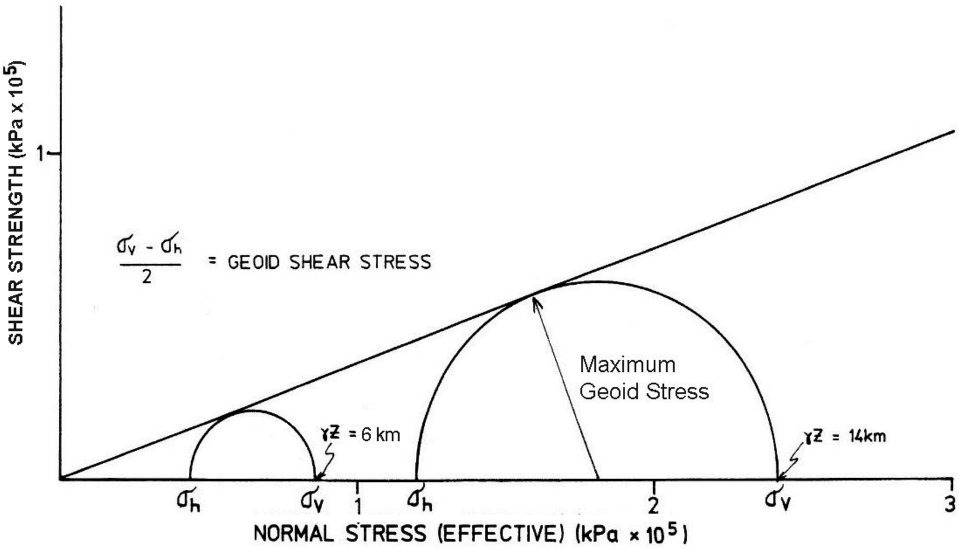

Figure 7. Mohr Circle relationships for tensile conditions (normal faulting) at two depths.

Thrust Faults

A similar approach for thrust faulting, is shown on **Figure 8**, with failure along discontinuities inclined between, say, 20 - 35º. Again, two depths are arbitrarily chosen to provide an example of the requirements of faulting under these specific conditions. At moderate depths, say to 4 km, thrust faulting can be initiated by horizontal stresses smaller than the maximum geoid stress value. Somewhere about 7 - 8 km depth, however, the full geoid stress would be required to bring the Mohr Circle to the failure criterion, under hydrostatic pore pressure conditions. This then defines the depth limitation for thrust faulting, under these specific conditions.

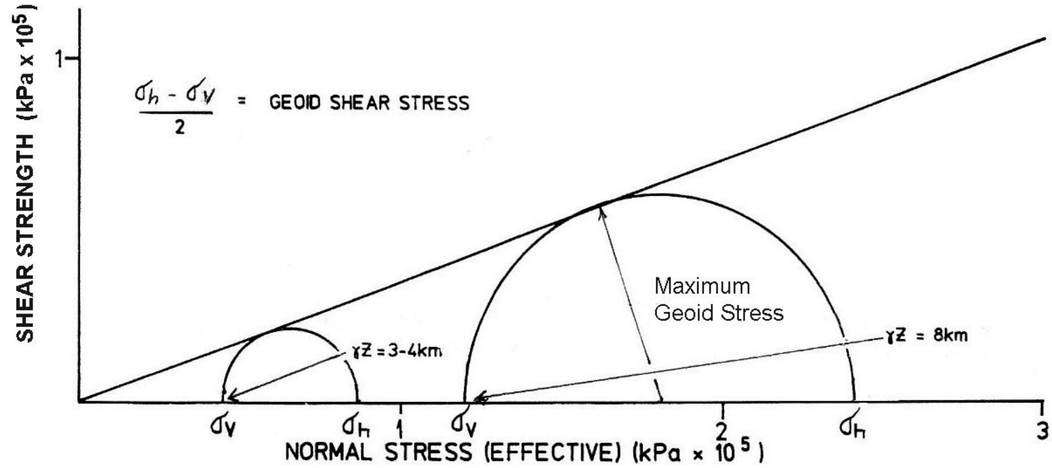

Figure 8. Mohr Circle relationships for conditions of compression (thrust faulting) at two depths.

A general relationship between geoid stress, hydrostatic pore pressure and probable earthquake depths on favourable discontinuities is illustrated in **Figure 9.**

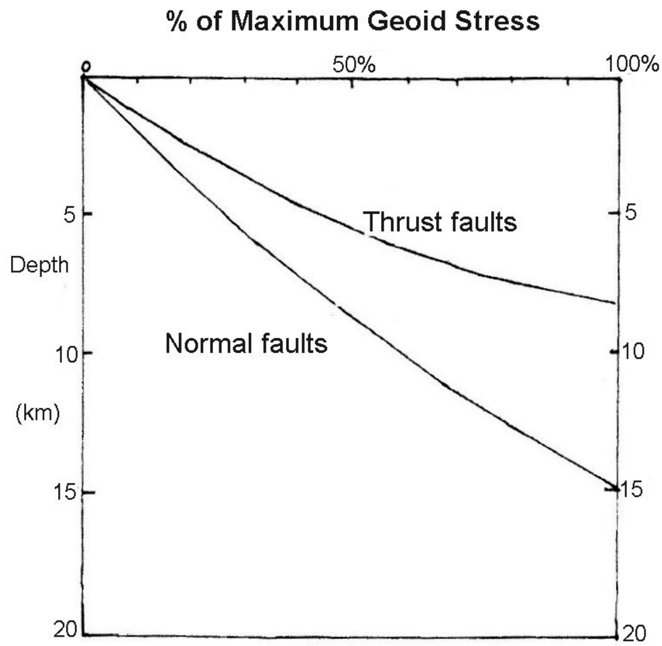

Figure 9. Estimated depths of faulting for shear stress as a percentage of maximum geoid stress, in a hydrostatic pore pressure regime

Obviously, earthquakes occur at much greater depths than shown in **Figure 9**, so what might be the logical explanation for this?

In stable geological regions, there is not a great deal of opportunity for changes in two of the (rock) parameters used above. Shear strengths along a discontinuity in the crust, for instance, are unlikely to change without some outside factor. In situ shear stresses should also be relatively static in stable geological regions – although long term recordings of horizontal movements of the Earth's crust, now available on a global scale, may be causing small ongoing strain-induced stresses. However, it would be drawing a long bow to try to guess the effect of this on any local deterministic analyses.

This leaves only one parameter susceptible to change: pore (or volatile) pressure. Large changes in pore pressure are, in fact, quite commonly found in deep boreholes and are assumed herein to be associated with the migration of high pressure/high temperature volatiles from the upper mantle, Gold and Sofer (1980). This factor will be seen to play a decisive role in the capacity for earthquake generation at depths greater than those given just above and further words on this matter will be left until the subsection on Benioff Zone earthquakes. Before moving on to that, a short digression on strike-slip faulting is in order.

Strike-Slip Faults

Strike-slip (wrench or transform) faults, such as the San Andreas Fault, are typically shown in the literature as the result of "push" on one side of the fault line acting in the opposite direction to the push on the other side: in other words, a complete reversal of regional stress directions across a singular major discontinuity. How such a situation might arise is difficult to explain since one would normally expect that a regional stress field would exhibit much the same level of stress on either side of a single, linear, fault line.

One possible answer to this problem is to allow that a singular uni-directional stress field is in operation, but it is operating on two different crustal units. If a strike-slip fault line is actually the marker of a crustal boundary (or relic crustal boundary) such as oceanic crust abutting against a shield or continental crust, each crustal unit will respond differently to the same stress. (Indeed, strike-slip lineations are common along the zones of past geosynclines, which features themselves have been demonstrated to form under equatorial "stretching" along an oceanic/shield interface, James (ibid). These strike-slip features are now to be seen clinging to the edge of the fold mountains that developed from geosynclines.)

It has been demonstrated in a previous NCGT publication, and also in James (1994), that a thin oceanic crust is vulnerable to being "pushed" or "pulled" by geoid stresses and that they undergoes finite deformations in response. A shield or thick continental crust, on the other hand, is able to resist the maximum geoid tectonic stresses with no more than a quasi-elastic response. Thus, where a fault line marks the trace of a crustal interface, the same "push" on both sides of the line produces a marked difference in response, **Figure 10**.
A very approximate estimate of the way the forces act in a strike-slip situation can be given. Firstly, if the σ_3 stress is compressive, then so is the σ_2 stress likely to be. This would produce a high frictional resistance along the fault line itself, making any strike-slip deformation very difficult – unless, of course, high volatile pressures are involved, reducing this friction.

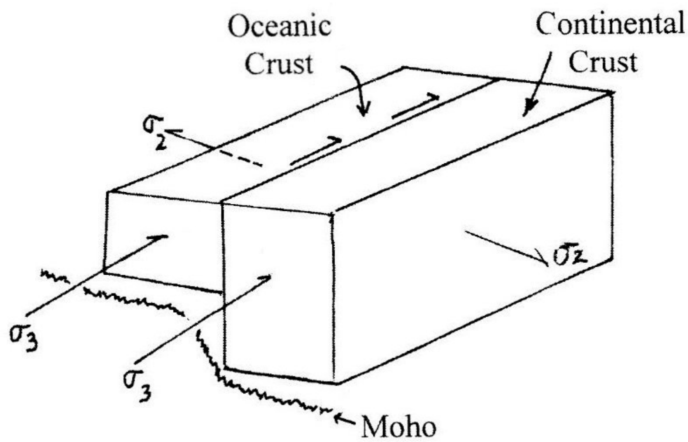

Figure 10. An insitu geoid stress, σ_3, acting as a uni-directional horizontal "push" on a crustal boundary, sets up differential strain conditions across the boundary, producing deformations on an existing a strike-slip fault lineation.

If σ_3/σ_2 stress field were to be tensile situation, however, as in equatorial stretching or as in a relic of such a condition, then the value of σ_2 would be low or negative, making frictional resistance to deformation along the fault line minimal. Thus, one would need either the development of high volatile pressures invading the fault line, or the presence of in situ low or tensile stresses normal to the fault line, before any deformation along the strike-slip faultline – that is, an earthquake – would be able to take place. It is of interest to note that work by Bruce Martin (1964) and (1992) showed evidence of tensile failure (normal faulting) on the Pacific side of the San Andreas Fault.

Taking cognizance of this constraint might be of assistance in setting up monitoring programs for predicting major failures along features like the San Andreas Fault. For instance, a rise in the volatile pressures, particularly in areas that were not exhibiting steady deformations at the surface, could represent a precursor. Alternatively, any decrease in the stress normal along the fault line (which might be seen as small deformations) would also be ominous.

5 Intermediate Earthquakes (Benioff Zones)

Barton (1976) has suggested that a base line value of φ = 30º might be reasonable for hard rocks at high stress levels: that is, in the ductile range. Support for this view comes from the inclination of Benioff Zones. As already mentioned these occur, with some exceptions, at two preferred inclinations to the horizontal: a shallower set at around 27 - 30º, extending to some 100 - 125 km depth; a deeper set inclined at around 60º, extending sometimes to 300 - 350 km depth. These inclinations are explained by a simple sand box experiment, where these same inclinations are obtained in compression and tension, respectively, for sand that has a value of φ = 30º.

Benioff zones are invariably located above the curvi-linear traces of the deep earthquake zones. Events along the Benioff Zones are therefore taken to be influenced by the migration of high pore/volatile pressures emanating from the deeper zones. Indeed, on the model of maximum geoid stresses expounded in these pages, normal (tensile) shear failure first becomes a possibility on the Benioff zones. Initial analysis is again made by utilizing the Mohr Circle approach.

Before embarking on this course, however, it is worth a glimpse at the long term fate of upwardly migrating volatiles. Earthquakes, or what has been termed seismic energy transmigration, would be likely to have volatile pressures and temperatures reduced during the upward migration from the deep levels. It would be in keeping with most natural processes that any reduction would probably be no more than the minimum necessary to deal with the conditions at the particular depth involved. By that is meant the upwardly migrating volatiles could be expected to retain a substantial part of their original pressures and temperatures on each step of the journey upwards from the deep levels. In this way, relatively high volatile pressures and temperatures would be able to reach the Earth's crust. Here, these volatiles would assist in the production of shallow earthquakes but full pressure relief might not be achieved until the surface of the Earth is reached, when phenomena such as the injection of dykes and sills, or the extrusion of lavas, or volcanic eruptions, would represent the final stage of the migration.

With regard to the magnitude of these volatile pressures during their upward migration, one could propose a hypothetical upper limit to the pressure at any depth and a limit not exceeding the total super-incumbent loading at that depth is proposed as a logical choice. This is partly an arbitrary limitation but is also based on the reasoning that, if the pressures of upwardly migrating volatiles were in a general state of excess above this value, the crust or crust/lithosphere of the Earth would tend to lose its integrity though the uplift factor and would probably undergo hydraulic fracture, rather than shear failure, to relieve the excess pressures. Such a process would disrupt the pattern of the Benioff Zones – of which disruption there does not appear to be any obvious evidence. Thus, on the Benioff Zones, we could put the maximum volatile pressure "u" as close to the overburden loading at any specific depth.

$$u \quad < \quad \gamma \,.\, D$$

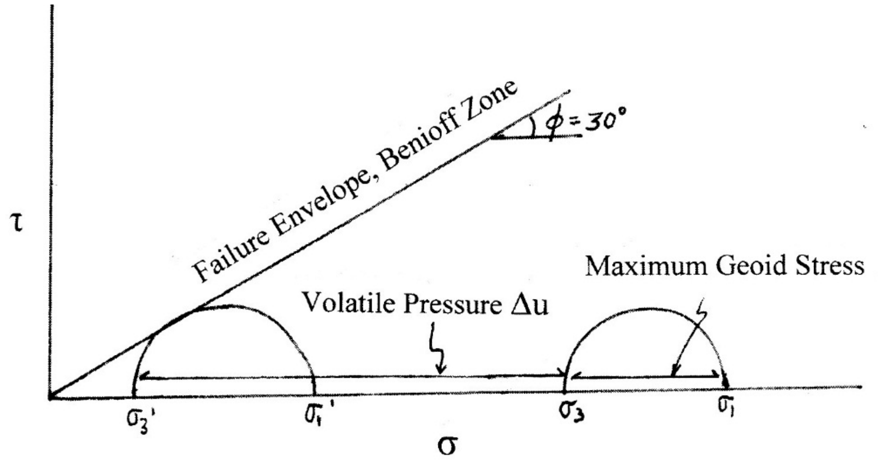

Figure 11. Effect of high volatile pressures on displacement of Mohr Circle (not to scale)

With specific gravity of the crust ranging from around 2.7 to 3, and that of the lithosphere and asthenosphere much higher, this would provide pore pressures up to three times the hydrostatic values used in Section 3, for shallow earthquakes. This higher volatile pressure parameter, when put into the Mohr Circle equation, as before, displaces the Mohr Circles a much greater distance to the left than in the hydrostatic case, as illustrated on **Figure 11**.

It is now apparent that, even though the maximum geoid stress can be quite insignificant in comparison to the vertical stress at intermediate earthquake levels, the raised volatile pressure is capable of displacing the Mohr Circle far enough to the left to have it intersect the failure envelope. Both thrust faults (Upper Benioff Zone) and normal faults (Lower Benioff Zone) can be analysed as carried out in the preceding sub-section, using a variation in volatile pressures up to the proscribed maximum.

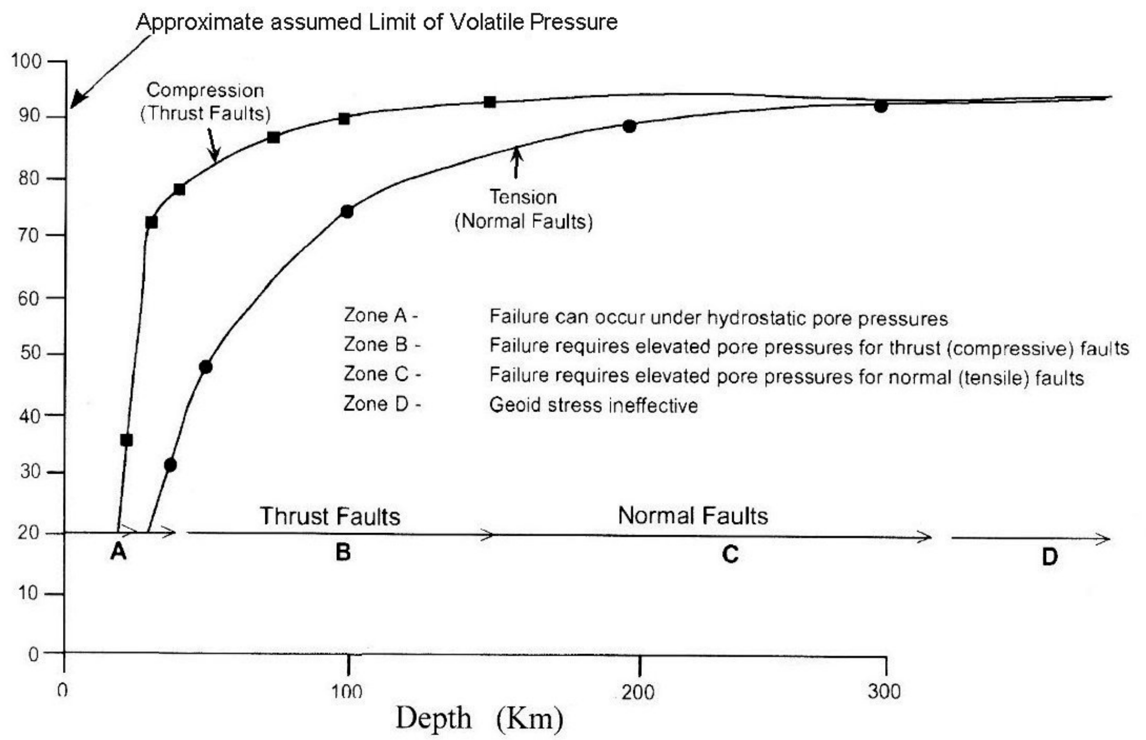

Figure 12. Influence of volatile pressures on the capability of the maximum geoid stress to cause earthquake failure on the Benioff Zones.

Figure 12 illustrates the approximate depth limits obtained for intermediate earthquake events along the Benioff zones, taking a value of the shear strength along the discontinuities to be φ = 20º. Both tensile and compressive conditions, under the conditions of high pore pressure are illustrated.

In the Figure, volatile pressures are given on the Y-axis, in the form of their percentage of the full overburden pressure. Earthquake depths are given on the X-axis. The curves on the figure predict the depth limits for earthquakes at any specific volatile pressure to overburden ratio. The curves were originally obtained algebraically and redone graphically, resulting in some minor changes to the curves, but giving essentially the same pattern.

The critical or maximum depths of earthquakes, at the above-defined maximum volatile pressures, can be read from the figure as:

- For compressive conditions (the upper Benioff Zone), approaching 125 km depth
- For tensile conditions (the lower Benioff Zone), approximately 300 km depth.

These predicted depths correspond reasonably well with the actual depth limits for both types of failure along the Benioff Zones. However, this all sounds a bit too simplistic for what might be the full story. If, however, we return to **Figure 6**, we can now find a partial explanation for the frequency pattern of earthquakes with depth. The highest frequency of events occurs in the crust, or shallow zone, Zone A, since earthquakes of all origins – compression, tension, strike-slip type failure - can occur under both a hydrostatic pore pressure regime (combined with maximum geoid stresses) or under moderate excess pore pressure regimes. In Zone B, the shallow Benioff Zone, excess volatile pressure is required. This brings failure under compression to a maximum depth of a little more than 100 km. As already mentioned, there is no reason why failures would not occur in this zone under conditions of tension, as well. In other words, failures under both compressive and tensile conditions in Zone B would explain the greater numbers in this zone. Whereas, in Zone C, earthquakes no longer occur under conditions of compression even at maximum volatile pore pressures. This leaves only failures under tensile conditions and hence fewer events.

Zone D of **Figure 6** is the aseismic zone, where earthquake activity is missing, or otherwise scarce and/or of low magnitude, but it might be useful to leave any discussion of this zone until after the deep earthquake zone is treated.

6 Deep Earthquakes

In addition to the deep earthquake zones, already mentioned above, should be added a limited number of moderately deep events in the Mediterranean, located to the north of Sicily, but there is no obvious curvi-linear geometry involved with these particular events although they do indicate an association with volcanoes in the region.

Having specified the deep earthquake locations, it also needs to be stated that our knowledge of deep earthquake patterns is based on a relatively short study period. It would be no (personal) surprise to learn of other deep earthquake zones on the globe, presently quiescent. For instance, examples of zones around the Pacific that resemble the surface manifestations of the deep earthquake zones, but are missing the deep earthquakes themselves, were mentioned above. Were there deep earthquakes in these regions at some former time - phenomena that have since "dried up"? Or are we likely to see new eras of volatile migration? Earthquakes at this deep level are not the result of simple shear failure, as described for the above shallower patterns, but would appear to require some form of hydraulic fracture. This would occur initially when the upwardly migrating high temperature/high pressure volatiles first emerge from the Lower Mantle/Upper Mantle Boundary. The patterns in the Upper Mantle then indicate evidence of vertical structure, which would suggest a less plastic medium than traditionally assumed. This view is also in contrast to the view of the Earth as a celestial onion. If it were like an onion, then one might expect the upward migration of volatiles to reveal a tendency to spread horizontally at the Lower Mantle/Upper Mantle boundary and at the boundaries of other major zones. There is no evidence of this sort of behavior and a vertical structure is often revealed. For instance, the very large earthquake event (M 8.2) that took place below Bolivia in 1994, in the vicinity of 13º S and 68º W, is shown in **Figure 13**.

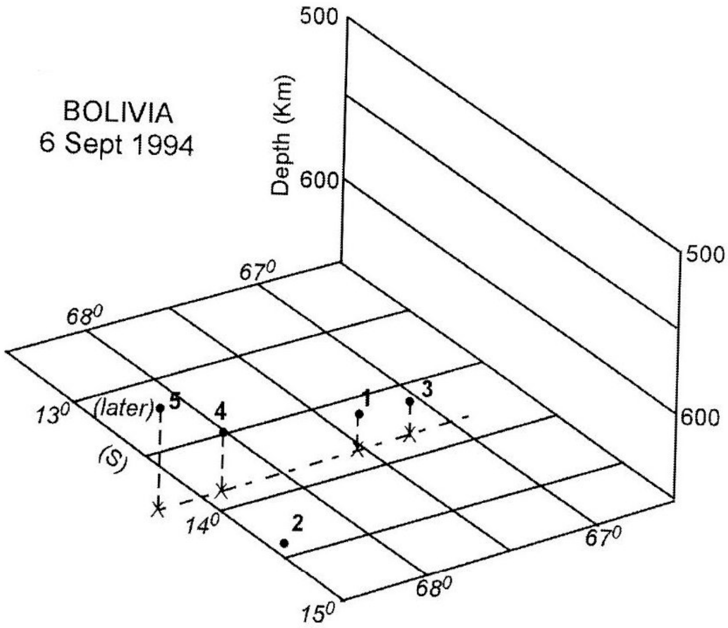

Figure 13. Bolivia. Alignment of deep earthquakes of 6/9/1994, approximately normal to the deep earthquake alignment shown in Figure 3.

This was not a single event but one accompanied by quasi-contemporaneous events at similar depths and located up to 100 km distance, horizontally, from the original earthquake. In three dimensions, the events plot with an east-west trend, a trend that is at cross purposes with the curvilinear alignment of the deep earthquake zone beneath South America.

Tonga

The ordered arrangement of deep earthquake zone(s), shallow earthquake alignments, volcanoes, and an oceanic trench, in the Tonga region, was one of the early examples used for the alleged mechanism of subduction. A plan of the region is given in **Figure 14**.

The first impression of this complex is that there is not the parallelism one might expect if the real purpose of this arrangement was subduction. While there is reasonably good parallelism between the deep and the shallow earthquake alignments, the ocean trench does not fit this. Nor do the anomalies in the deep earthquake alignment, at a couple of locations, fit a pattern of ordered subduction over the whole section, as a plot of deep earthquakes for the years 1973 to 1982, centered on 18º S latitude and between 177 and179º W longitude shows. This is illustrated in **Figure 15**, where two trends are obvious.

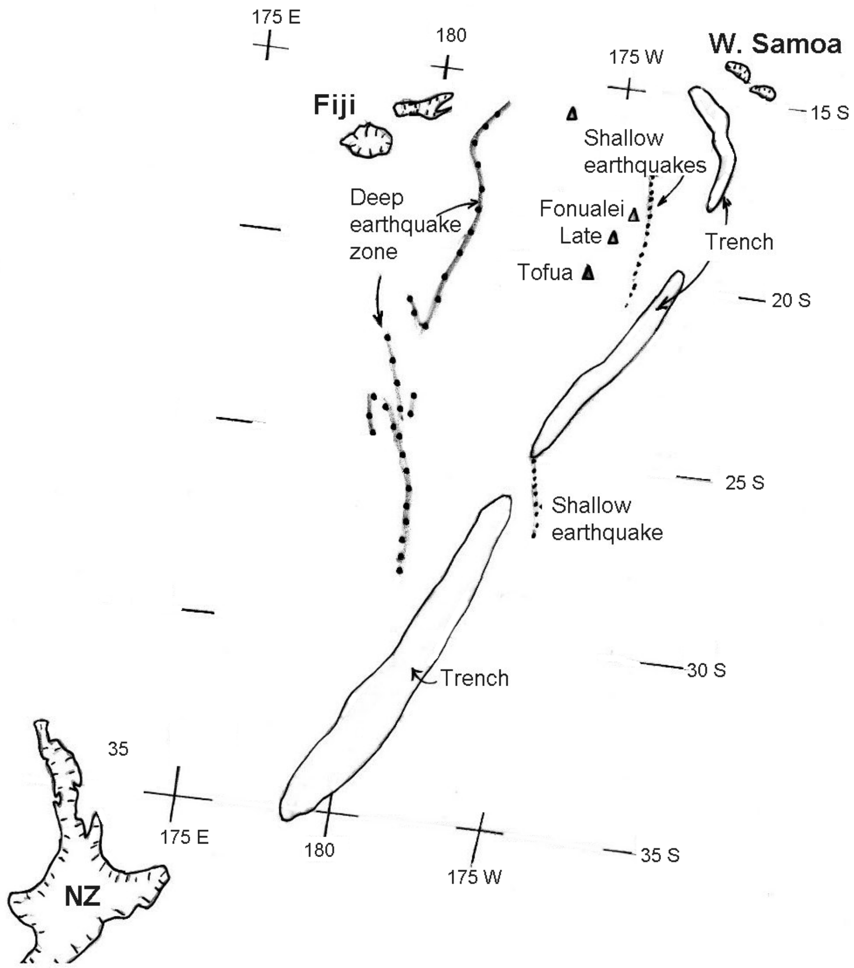

Figure 14 Earthquake and associated activities related to the Tongan Trench.

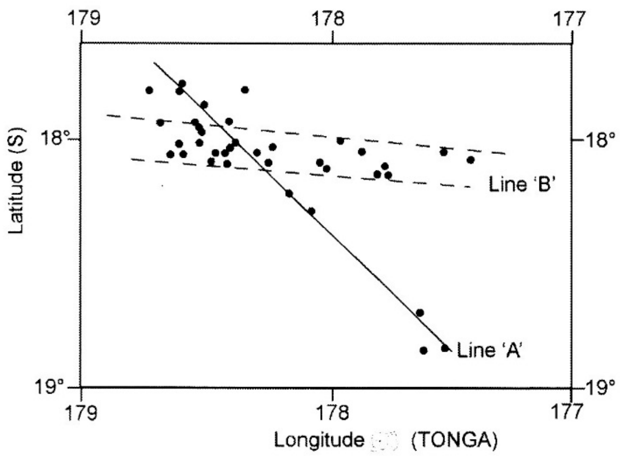

Figure 15. Deep (600km) earthquakes, Tonga, showing apparent structure: (Line B) not aligned with the alleged subduction zone (Line A).

Line A is the general alignment of the deep earthquake zone as shown on the **Figure 14**. Of more interest at this juncture is the more active Line B, a zone running across the extended deep-earthquake trend. Line B incidentally passes well beneath the super-incumbent Benioff zone that descends from the east towards Line A. Within the Line B zone, there are a number of small quasi-contemporaneous swarms that have occurred during the years 1973 to 2001, many having taken place over a time frame of a day or several days.

Two examples of these swarms are plotted in **Figures 16 a** and **b**, to provide a three dimensional view. Again, the strong impression is that the events are controlled by some form of vertical structure, or vertical planar discontinuity. Secondly, it appears reasonable to ask the question: does this subvertical planar structure extend down below the presumed phase change at upper/lower mantle boundary? If so, would volatiles be able to utilise such a continuation to make crossing the boundary from deeper Mantle levels a more practical proposition? Some seismic interpretations by Choi (2005) indicate that structure sometimes extends deep into the earth, passing well below this upper/lower mantle boundary. Indeed, seismic tomography, Choi (2003), suggests that the upper 1000 km of the Earth appears to be anything but a series of relatively homogeneous and isotropic "shells", particularly in regions near the interface of what might be termed as continental (or shield) and oceanic domains.

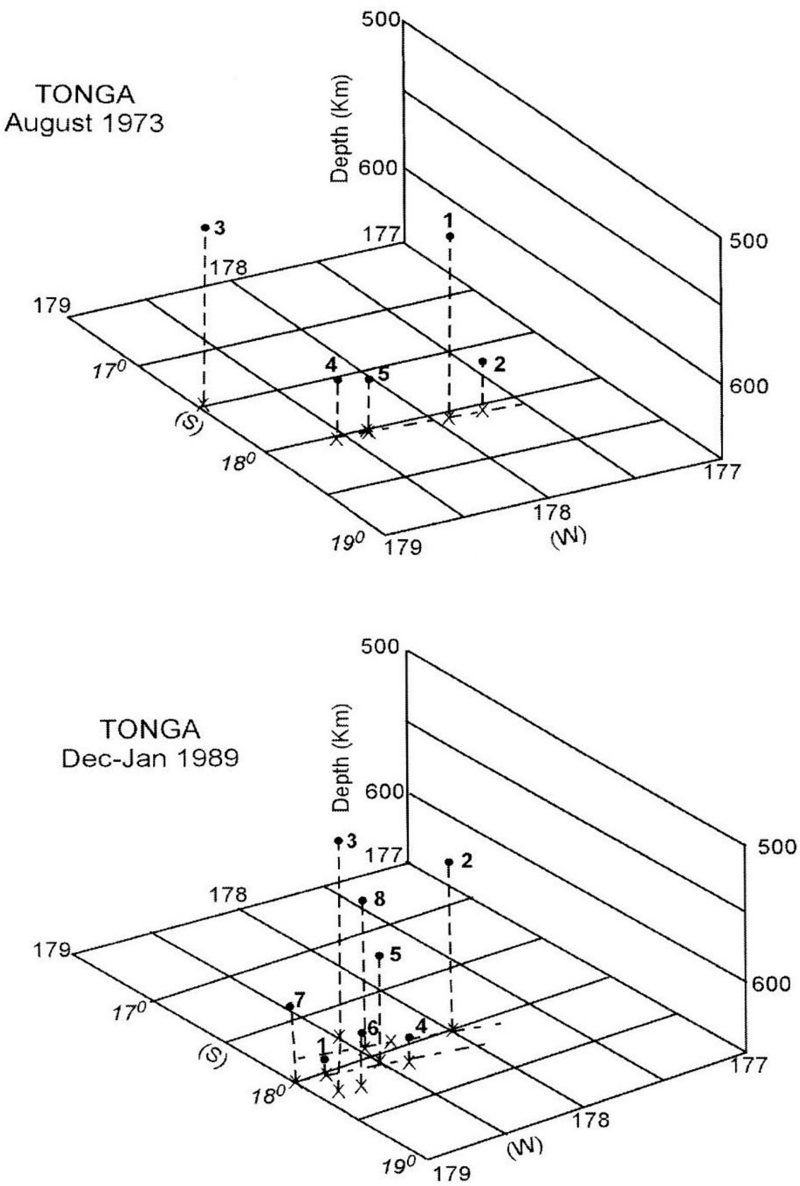

Figure 16 a and b. Evidence from quasi-simultaneous swarms of deep of sub-vertical structures aligned with Line B of Figure 15.

New Hebrides

A plan of the deep earthquake locations in the New Hebrides region, 1973 to 2001, is given in **Figure 17**. These events, all at 600km depth or greater, suggest two trends that present a geometry redolent of conjugate shears in relatively brittle materials.

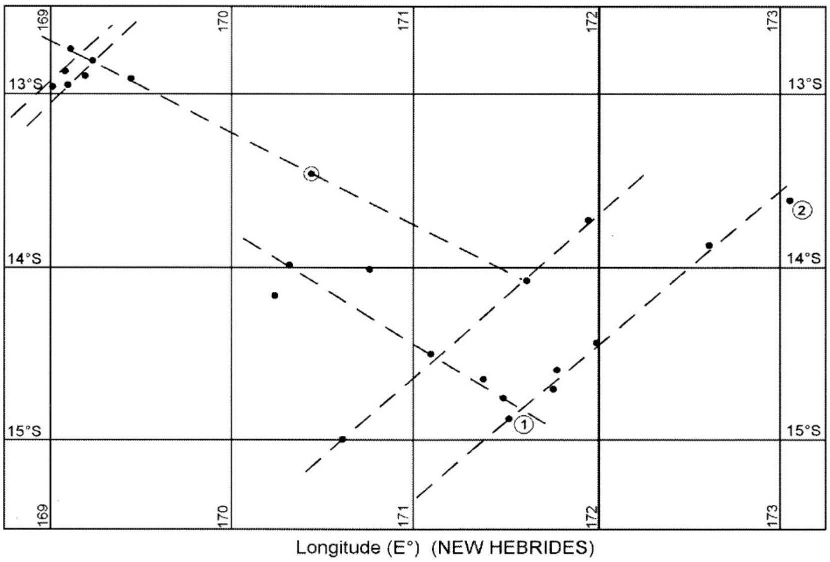

Figure 17. New Hebrides. Deep earthquakes, M>5, 1973-2000.

An array of events much the same as these was also recorded in the years 1955 to 1974 by the French geophysicist, Claude Blot and can be found on figure 68, page 129, of Grover (1998). The New Hebrides is where Blot began his first excursions into detailed and surprisingly successful long range predictions of earthquakes/volcanoes, based on the rates of upward migration of "seismic energy" from the deep levels. It might have been fortunate that the earthquake sequences in this particular environment were particularly uncomplicated: a paucity of deep events generally around 650 km depth; then an aseismic zone with virtually no activity until above 300 km depth. This meant a more straightforward exercise to identify a deep event and its next stage event on the Benioff Zone. In many other parts of the world, the conditions are more complicated and upward migration of volatiles is more variable – as, indeed, Blot himself pointed out.

7 The Aseismic Zone

No direct continuity between the deep earthquake zone and the lower Benioff Zone is recorded in a substantial number of cases around the Pacific. This gap is termed, herein, as an aseismic zone and a listing of locations where the gap occurs is given below in **Table A**. It can be noted that the aseismic gap often extends for distances of two or three hundred kilometres vertically. It should be mentioned, however, that although quite devoid of major earthquake activity in most cases, there is the occasional event to be found in some locations. Moreover, this zone has not been investigated by the author for minor magnitude events.

TABLE A
ASEISMIC ZONES

Location or Island Arc	Aseismic Levels (km)	Max. E'q Depth (km)	Remarks
Indonesia	300 – 500	650	Zone undulates along deep trace
S Philippines	390 – 520	610	Curvilinear trace
Marianas	250 – 400	610	“
Japan, Bonin	250 – 350	500 – 540	Zone varies in depth
Kamchatka	200 – 400	680	Deep earthquakes common from 500-600 km
New Hebrides	300 – 600	660	
Tonga	320 – 520	650	
S. America	200 – 550	600 – 680	Occasional event at 680 km

The origin of such a gap presents something of a riddle and, to date, there does not appear to have been a great deal of interest in the matter nor any close look taken at the mechanisms that might cause such a nadir in earthquake activity. The surprising feature is the rapid rate of upward migration of volatiles recorded through this zone. If one takes liberty with a D'Arcy's Law view of the situation, using a simple hydraulic head between 600 and 300 km depth, we can arrive at a sort of mass permeability for the zone. This turns out to be of the order of 3 to 5 x10^{-1} cm/sec, the sort of permeability associated with a loose or coarse sand and fine gravel. Naturally, one would tend to think that the pressures obtaining at the depths of the aseismic zone would hardly allow for the presence an open, granular-like, structure. Secondly, migration upward through a porous medium would make it difficult to explain how a diffuse, migrating, plume of volatiles – after leaving the "structure" of the deep earthquake zone - would be able to travel upwards from the deep zone and locate the base of the Benioff Zones so efficiently.

An alternative might then be to suggest that something like a series of direct connections occur between the deep earthquake zone and the lower Benioff Zone, something like residual migration "pipes" that developed over geological time. Again, justifying this sort of explanation would be tricky and it seems unlikely that any earth scientist would hang his hat on any such explanation. But, if such "pipes" were able to exist, it would suggest that the aseismic zone is, or has been in its history, affected by tensile conditions. This again raises the question of "How?". Perhaps such ducts were formed during an early cooling process in the planet? If so, why is the aseismic zone not present everywhere? Unless whatever has produced the zone is still undergoing development and some areas are lagging behind? Or perhaps the areas without the aseismic zones are advanced stages, with constricted "pipes"? If so, what is happening to the rising volatiles? Unfortunately, one can do little more than speculate at this stage.

REFERENCES

Barton, N.R., 1976.The shear strength of rocks and rock joints. *Internat. Jnl. Rock Mech. & Min. Sci.*, v. 13, p. 255-279

Benioff, H., 1949. Seismic origin for the fault origin of oceanic deeps. *GSA Bulletin*, v. 60, p. 1837-1856.

Benioff, H., 1954. Orogenesis and deep crustal structures. *GSA Bulletin*, v. 65, p. 385-400.

Blot C., Choi D. and Grover J., 2003. Energy transmission from deep to shallow earthquakes: a phenomenon applied to Japan. *New Concepts in Global Tectonics Newsletter*, no. 29, p. 3-16.

Blot C. and Choi D.R., 2004. Recent devastating earthquakes in Japan and Indonesia viewed from the seismic energy transmigration concept. *New Concepts in Global Tectonics Newsletter*, no. 33, p. 3-12.

Bogdanov, N.A., 1973. Paper in *The Western Pacific*, 12th Pacific Science Conf., Ed. P.J. Coleman. Univ. of W.A. Press.

Bolt, B.A., 2003. *Earthquakes*. W. H. Freeman & Co, NY.

Choi, D.R., 1987. Continental crust under the Pacific Ocean. *Jnl Pet. Geol.*, v. 7, no. 4, p. 437.

Choi, D.R., 2003. Deep earthquakes and deep seated tectonic zones (E. Asia). *New Concepts in Global Tectonics Newsletter*, no. 27, p. 8-25.

Choi, D.R., 2003. Deep tectonic zones and structure of the Earth's interior as revealed by seismic tomography. *New Concepts in Global Tectonics Newsletter*, no. 30, p. 7-14.

Choi, D.R., 2005. Plate subduction is not the cause of the great Indonesian earthquake, Dec. 26, 2004. *New Concepts in Global Tectonics Newsletter*, no. 34, p. 21-26.

Choi, D.R., 2006. Where is the subduction under the Indonesian arc? *New Concepts in Global Tectonics Newsletter*, no. 39, p. 2-11.

Enever, J.R. and Lee, M.F., 2000. On the prediction of rock stress. *GeoEng* 2000, IEA, Melbourne.

Gold, T. and Sofer, S., 1980. The deep earth gas hypothesis. *Scientific American*, June, p. 154-161.

Grover, J.C., 1998. *Volcanic Eruptions and Great Earthquakes*. Copyright Publ., Brisbane, Australia.

Heiskanen, W.A. and Meinesz, V., 1958. *The Earth and its Gravity Field*. McGraw Hill.

James, P.M., 1994. *The Tectonics of Geoid Change*. Polar Publ., Calgary.

James, P.M., 2000. On the state of stress in the Earth's crust: inferences from RIS. *New Concepts in Global Tectonics Newsletter*, no. 17, p. 9-10.

James, P.M., 2003. An analysis of earthquake patterns. *New Concepts in Global Tectonics Newsletter*, # 26, p8-15

James, P.M., 2005. Further inferences on structure in the mantle from deep earthquake patterns. *New Concepts in Global Tectonics Newsletter*, # 37, p. 20-27.

James, P.M., 2007. On the origin and implications of high horizontal stress variations in the Earth's crust. AAPG Conf., Athens (Nov.).

Martin, B.D., 1964. *Geology of the Monterey Canyon.* PhD Thesis, Univ. of S. Calif., L.A.

Martin, B.D., 1992. Constraints to right-lateral movements, San Andreas fault system, central and northern California. *New Concepts in Global Tectonics* (Ed. Chatterjee S. and Hotton), Texas Univ. Press.

Meyerhoff, A.A. and Meyerhoff, A.H., 1972. Major inconsistencies in global tectonics. *Bull. Amer. Soc. Petrol. Geol.*, v. 56, no. 2, p. 269-336.

Smoot, N.C., Choi, D.R. and Bhat, M., 2001. *Active Margin Geomorphology*. Xlibris Corp., USA.

Walker, D.A., 1988. Seismicity of the eastern Pacific. *EOS Trans*. AGU, v. 69, p. 857.

MIGRATION OF FORESHOCKS AND/OR VOLCANIC ERUPTIONS THE *"BLOT'S MIGRATION LAW"*

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Abstract: According to observational evidence formerly envisaged by the late Claude Blot, under suitable circumstances, some earthquakes appear to be precursors either of a subsequent violent earthquake, or of volcanic eruptions. The same conclusion was later supported by other investigations. This evidence, however, was sometimes contended by other authors, as it did not fit with the generally agreed paradigms. But, no reason requests that all case histories are the same. In addition, every observation is never a matter of a coincidence, and we must understand whether the known physical laws are consistent or not with every proposed interpretation. The present paper is a discussion of the physical explanation of two "laws" envisaged by Blot. It is shown that they can be explained in a realistic and simple way. They are therefore to be taken into account in order to understand the primary mechanisms of several case histories of natural catastrophes. The explanation of some large fraction of occurrences is fundamental in order to understand the different mechanisms that are to be eventually appealed to, also in order to explain eventual observation that sometimes could not fit with the Blot model.

Keywords: *migration – endogenous heat – foreshocks – island arcs – serpentinization – superswells - overthrust – volcanic eruptions*

Earthquakes and volcanic eruptions are a manifestation of planetary processes that occur according to a calorimetric criterion. That is, whenever some suitable energy reservoir attains a threshold, it can accumulate no additional energy, and it has therefore to release its content through an almost step-like (or in any case short-duration) event.

Planetary scale phenomena have a long-range trend. Therefore it is reasonable to guess that the spatial and temporal correlation between seismic and volcanic events can be a reliable and realistic indicator of geodynamic evolution and of its processes.

Different kinds of physical mechanisms can be involved, which are operative in different case histories. Neither all events can be compared with one another, and therefore no statistical analysis can be carried out in terms of the classical Gaussian analysis (which requires the assumptions of the central limit theorem). Therefore, any formal mathematical data handling, in general, can result of little help unless a physical mechanism is guessed, to be eventually confirmed or denied by observations.

Therefore, in general we can expect to deal with no "general law". No "universal" thumb-rule can be envisaged. Rather, a list of attempts can be carried out. But, we should refrain from the temptation to consider every case history only as a matter of a coincidence: our deontological obligation is to try to understand phenomena.

From a mere methodological perspective, these attempts focus on a concrete assessment of some long- and wide-range teleconnection between different events. This is the prerequisite in order to understand, sometimes in the future, the planetary scale behavior of the Earth, before the occurrence of a so-called natural catastrophe.

The feasibility of every local forecast will probably wait for a second step. Indeed, when the planetary evolution of the Earth system will be monitored and suitably understood in terms of drivers and response etc., it will be possible to concentrate the concern on a regional or local perspective. This methodological approach is substantially new - and also prudential and understating - compared to the previous general feeling that is characterized by a dichotomy between "enthusiast believers" and "skeptics" about the existence of some "magic" precursor that can provide with a fully reliable "forecast". A realistic concreteness is a constructive approach to understanding, by avoiding any nonsense competition between pro and con any kind of suggestion.

Four kinds of physical processes can be envisaged.

The *first* process applies to volcanic eruptions, at least for volcanoes that are supplied by a sea-urchin spike

(Gregori, 2002, 2006 and 2009). An eruption occurs on the occasion of a comparably larger amount of local heat supply to the sea-urchin spike. The upward propagation of the spike causes – through local thermal expansion - progressively shallower earthquakes, until it reaches the depth where the reduced lithostatic pressure permits melt and formation of magma. The subsequent hydraulic process is finally concluded through magma effusion.

Instead, the 2nd, 3rd and 4th processes apply to tectonics and geodynamics.

The *second* mechanism is through serpentinization (Judd and Hovland, 2007). Crustal fracturing favors water penetration through de-hydrated rocks. Serpentinization explosively originates other crustal cracks. The final result is propagation of seismic activity along preferential directions, characterized by a comparatively larger crustal fracturing. Note that, according to plate tectonics, the regions of greater crustal fracturing are interpreted like plate borders. This process can be investigated by means of the "pole position area" (*ppa*) algorithm (to be discussed elsewhere, in preparation). It should be stressed that the *ppa* algorithm is a rigorous mathematical tool applied to an objective data series of observations. It is not important whether the explanation of its evidence agrees or disagrees with the serpentinization or any other preconceived rationale. Rather, its inferred evidence must be explained in some way. In the past, no analysis of this kind was carried out, as this appeared in contrast with the *a priori* arbitrary choice of the paradigm of plate tectonics.

The *third* mechanism occurs when, following an increase of endogenous heat production, a comparatively more rapid uplift occurs of a geotumor or of a superswell. According to warm-mud tectonics (*WMT*) the consequent increased speed of the lithosphere - that slides on the slopes of a geotumor or superswell - determines an increase of crustal overthrust inside the surrounding mega-synclines (Gregori, 2002, 2006, and 2009). A first lesser geodynamic activity ought to occur on the top of the geotumor or superswell where lithospheric thinning occurs, to be followed by some later and more violent events associated with the surrounding overthrust.

The *fourth* mechanism can be associated with island arc formation, according to a model that can be briefly summarized as follows. Typically, let us refer, e.g., to the Pacific border of Eurasia. The loading tide, which is associated with the water mass of the Pacific Ocean, pushes on the Eurasian continental shelf, originating a large crustal stress that is observed synchronously until central Italy and the Ionian Islands (Poscolieri et al., 2006). But, a westward drift of Eurasia, relative to the Pacific Ocean-floor lithosphere, causes a sinking of the oceanic lithospheric slab, due to lack of support by the endogenous pressure, which is associated with volcanism and formation of the island arc islands. This model can be quantitatively tested (in preparation) as the location and the age of islands, and the relative drift speed of continent and ocean floor, must satisfy a uniquely defined relationship. In this respect, even the timing of the formation of islands, at some regularly spaced locations, is thus a phenomenon of migration of geodynamic activity.

As far as the mere seismic activity is concerned, it is reasonable to expect that hypocenters involve first the deeper section of the Wadati-Benioff plane (*WBP*) zone, and display a subsequent migration towards shallower depth.

An almost endless amount of literature ought to be scanned and re-interpreted according to this whole rationale. Owing to brevity purpose, only very few papers can be here mentioned, while several papers can be found on NCGT with several related references.

In general, it appears surprising the way these several remarkable observational evidences have been apparently "forgotten" by the official "generally agreed" feeling only because they are not expected according to plate tectonics. Science is not a matter of "believes". One should always refrain from emphasizing all what is pro his expectation, and from blaming what is contrary to it. One should blame his blindness in front of the objective observational evidence. This blindness is irresponsible if one considers the huge amount of causalities and great sufferance associated with natural catastrophes.

In addition, natural phenomena cannot be expected to satisfy to any “simple” rule. We can eventually observe a relation, but we should never expect that *every* case history satisfies to an *identical* “law”. The job of an Earth scientist is not to “believe” that some law is correct or not. His job is rather to assess how many case histories satisfy to a given relation, while others behave according to a different rationale. Then, the physical interpretation of different case histories can be investigated. The competition is not between "believers" and "skeptics", rather it is a challenge and contest between Earth scientists and natural phenomena.

Let us refer e.g. to Blot et al. (2003), who review previous investigations on the energy transmigration (*ET*) phenomenon. In particular they recall the "migration law" (Blot, 1964 and 1971). The time delays between deeper precursor shocks and shallow events (both earthquakes and volcanic eruptions) are of the order of a few months and years. According to Blot (1976) the following relationship holds, that will be here briefly called "*Blot's migration law*"

(1)
$$t = k \cdot log_{10}\left(\frac{h_0}{h}\right) \cdot \left(\frac{1}{\cos\ a}\right)$$

where t = time delay from the precursor shock (in *days*), k = constant unique to every region, h_0 = depth of the precursor deep shock, h=depth of the shallower shock, a= dip-angle of earthquake zone with the vertical in degrees (**figure 1**).

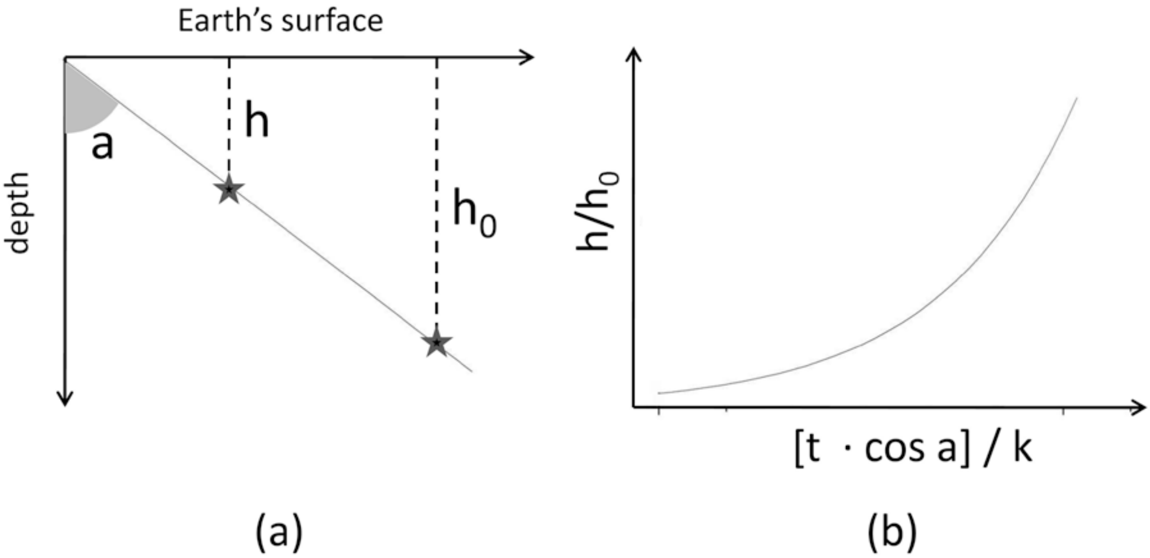

Figure 1. Blot's migration law. See text.

It is not important whether this law is satisfied in every case history, or not. Even if it is satisfied only on very few occasions and under particular circumstances, we have to explain it. It is ethically irresponsible to require that natural phenomena strictly always behave according to our will and to any "simple" or "universal" law or paradigm. In the case of a natural catastrophe, this is equivalent to be guilty of manslaughter.

Blot et al. (2003) claim that "*Blot applied his concept to many of the historic earthquakes which had occurred in Japan including the 1933 Sanriku-Oki earthquake, the 1944 Tonankai earthquake, and the 1952 Tokachi-Oki earthquake (Blot, 1976), as well as the 1993 Hokkaido-Nansei-Oki earthquake (Grover, 1998); all of these events proved to be exactly in accordance with the time-depth relationship formula*."

Several other papers confirmed this relationship in different subsequent case histories. Several papers can be found in NCGT with several references. The purpose of the present paper is to discuss the physical interpretation of this "*Blot's migration law*", with no concern about reviewing how many times it was confirmed by observations.

A physical interpretation of (1) is as follows. For simplicity, let us forget about units and consider natural logarithms etc. Refer to the sketch of **Figure 1**.

The deep shock occurs at depth h_0, and it is the precursor of a subsequent shockat depth h. Hence h/h_0 is the depth, expressed in units h_0, of the shock that we want to "forecast". The time delay between precursor and final shock seems to be proportional to the propagation time of the stress along the crustal slab, which is inclined at a deep angle a reckoned with respect to the vertical direction. According to observations, this propagation time results to be maximum when $a = 90°$, and proportional tocos a. Equivalently, one can state that the physical relevant condition is related to the *vertical* component of the linear extension of the crustal slab, while a perfectly horizontal slab has no shock, nor precursor and no final event.

Therefore, the law (1) can be re-written as (**Figure 1b**)

(2)
$$\frac{h}{h_0} = \exp\left(\frac{t\ \cdot \cos\ a}{k}\right)$$

When the units are used that are proposed by Blot et al. (2003), (2) implies that when $h/h_0 = 10$ it is $k = t\ \cdot \cos\ a$, which gives a physical meaning for k.

A suitable rationale, which appears consistent with observations, can be in terms of a tension applied to the crustal slab, where the tension is proportional to the weight of the slab, hence to its deep. In this respect, refer e.g. to figure 1 of Blot et al. (2003), which was drawn on the basis of geological evidence alone.

Call L the length of the slab. If a tension dF is applied to it, its length increment is $dL = L\ \cdot EdF$, where E is the elastic (or Young's) modulus. When the tension isintegrated along the whole slab of original length L_0, its length becomes therefore$L = L_0 e^E$. Whenever L gets above some given threshold the crustal slab finally yields and a shock occurs.

According to Blot et al. (2003), the mean propagation speed of the effect along the crustal slab varies with the depth of the precursor, i.e. *2.6 km day^{-1}* for h_0*= 600 km, 0.9 km day^{-1}* for h_0 *= 200 km, 0.5 km day^{-1}* for h_0 *= 100 km*, and *0.15 km day^{-1}* for h_0 *= 33 km*. This means that the resistance to traction of the crustal slab is fainter at larger depth, maybe due to the comparatively higher temperature and pressure.

A quantitative analysis can be carried out on these *4* data. Call $v_m(h)$ the *mean* propagation speed evaluated for a precursor shock occurring at depth h (which was called above h_0), call $v(h)$ the *local* propagation speed at depth h, and define $u(h)$ as follows. It is

(3)
$$v_m(h) = \frac{1}{h}\int_0^h v(x)dx$$

(4)
$$u(h) = h\ \cdot\ v_m(h) = \int_0^h v(x)dx$$

(5)
$$v(h) = \frac{du(h)}{dh}$$

Figure 2 shows the plots of $v_m(h)$, $u(h)$ and $v(h)$. The numerical values for$v(h)$ are *3.45, 2.375, 0.98619* and *0.67239*, respectively at depth *600, 200, 100* and *33* (units are *km day^{-1}* and *km*, respectively). These values are to be considered as being only indicative, as it makes nonsense to be concerned about error bars based on only *4* observational data that probably reflect an average of very different tectonic settings and primary endogenous energy input.

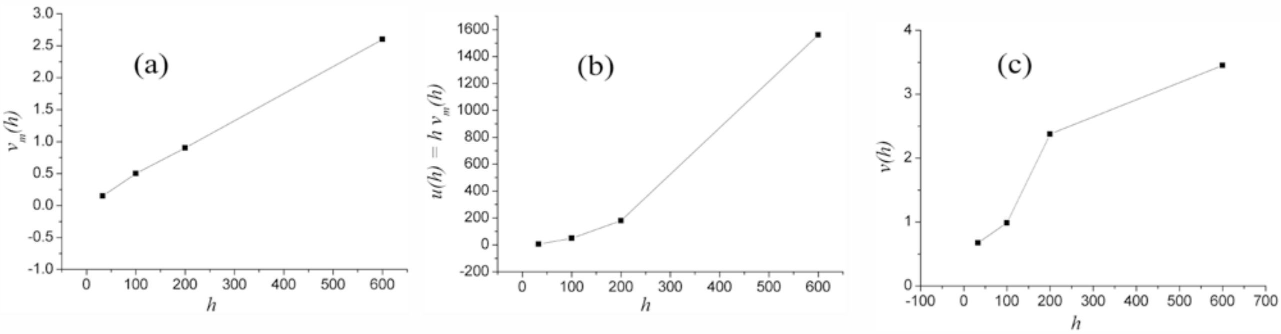

Figure 2. Mean propagation speed *vs.* depth, and local propagation speed *vs.* depth, of the precursor crustal stress through the crustal slab, based on *4* observational data after Blot et al. (2003).Units are *km* for depth, and *km day^{-1}* for speeds.

This analysis, however, is a formal mathematical treatment that *per se* cannot explain the real physics of phenomena. A better understanding, although on a qualitative ground, can be achieved, maybe, as follows.

Consider that the Young's modulus *E* is not the same along the whole lithospheric slab. The relevant varying parameter is likely to be mainly the local temperature, as a warmed material is less rigid and more prone to yield, compared to the same, although cooler, material.

Refer to the sketch of **Figure 3a**. Suppose that owing to some reason (i.e. either due to the loading-tide-island-arc formation mechanism, or as mentioned below due to "surge tectonics") some decrease of internal pressure occurs, by which the lithospheric slab is no more sustained underneath, and its weight pulls it down. Thus, sometimes it yields, at some comparatively large depth (**Figure 3b**): this is the deep precursor shock.

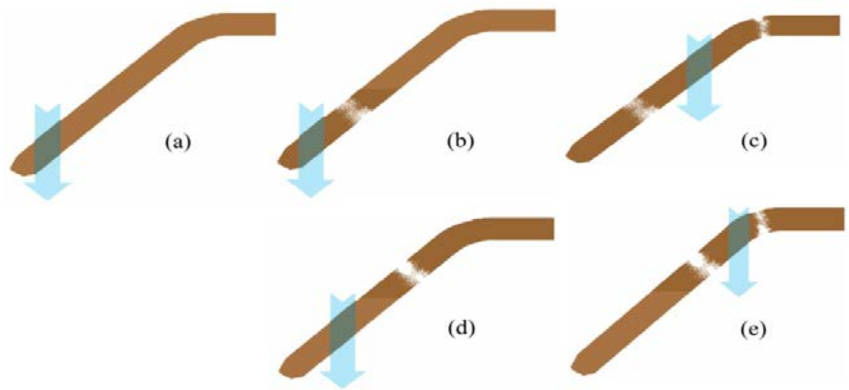

Figure 3. Qualitative tentative mechanism aimed to explain the larger apparent "propagation speed" between precursor and main shock.

Therefore, the remaining slab segment, which is located above the rupture region, pulls it down, until it eventually yields anew at some shallow depth (**Figure 3c**): this is the main shock, which is the really destructive event, as the crust is more rigid, hence fragile, and thus capable to store a comparative greater amount of elastic energy.

Suppose that - depending on temperature or any other reason - the Young's modulus *E* has a different value at different depth. Hence, the first rupture eventually occurs (as in **Figure 3d**) at some shallower depth compared to the case history of **Figure 3b**. In this case also the weight is comparatively smaller of the remaining upper segment of lithospheric slab.

Suppose therefore that a rupture is going to occur as in **Figure 3e**.

Hence, it appears reasonable to guess that the process, which causes the main final shock, ought to appear to "move" comparatively faster in the case of **Figure 3c** compared to the case of **Figure 3e**. This should explain why, in the case of a deeper precursor, the apparent propagation speed of the "signal" that causes the main shock appears faster, compared to the case history of a shallower precursor.

In any case, all these mean speeds are much smaller compared to the propagation speed of the "domino effect" (Gregori, 2013), which is $8.64\ km\ day^{-1}$. Indeed, both phenomena are physically substantially different, and cannot be compared with each other.

Summarizing, in any case the "*Blot's migration law*" appears to be consistent with a simple model that also reminds about the aforementioned island arc formation model, although also other models can be envisaged.[5] Indeed, Blot et al. (2003) refer to a different rationale (i.e. surge tectonics) that, however, is not in contradiction with the island arc model here considered, as the identical observational evidence can be interpreted according to different schemes. The eventual difference (Gregori, 2002, 2006 and 2009) is to be highlighted upon considering suitable "crucial" observational tests capable to discriminate between different possibilities. *WMT* and "surge tectonics" rely on a basically almost identical observational support. "Surge tectonics", however, appeals to a conspicuous flow of matter underground, aimed to close the fluid circuit of

[5] A review and critical discussion of a sound full analysis of the island arc phenomenon ought to require a set of papers (in preparation together with some authoritative colleagues) and cannot be here even briefly mentioned.

matter inside the Earth. In contrast, *WMT* requires no flow of matter, rather only a flow of electrons, Joule heat, and thermal expansion. The "crucial" test, therefore, would be the capability to monitor matter-flow underground.

Blot et al. (2003) state: "*recent regional study by Choi (2003) on deep tectonic zones and deep quakes unequivocally demonstrated that the deep shocks are directly related to the deep activities along the major tectonic zones particularly in the area of subsidence. He supported surge tectonic interpretation of the* WBP *zones (Meyerhoff* et al.*, 1992); it regards the zones as an Earth's cooling crack in relation to the minor contraction of the Earth's surface ... Contrary to the public belief, the* WBP *zone does not indicate the plane of oceanic plate subduction...*"

In either case, the evidence is clearly stressed in favor of a tensile pattern, rather than according to the standard plate tectonics compressive assumption inside the so-called subduction zones.

Blot and Choi (2004) claim that the "*devastating earthquakes in the Indonesia - Nicobar - Andaman Island arc as well as Japanese earthquakes in 2004 are well explained by the* ET *concept… Numerous cases of successful application of this concept to the worldwide earthquakes and volcanic eruptions … have proved the validity of this relatively little appreciated concept. The concept allows predicting catastrophic earthquakes and volcanic eruptions on a scientific ground. However, because the concept is based on upward movement of energy which is contrary to the downward moving plate slabs, the Blot concept has been suppressed and neglected by the powerful, dominant plate tectonics establishments since the initial proposal of the concept in 1960s (Blot, 1964 and 1965) …*"

A substantially different law is envisaged by Blot (2004) referring to Stromboli. "*The inventory of all the shocks occurred since 1950 at the deep root of this volcano… and the noteworthy eruptions ensure the correlation equation (Blot, 1995)*

(6) $$T = \frac{D}{0.075 \cdot m + 0.216}$$

(T in days; D in km*; m is the magnitude)*

Since 1994 with the use of this formula, most of the big explosions and lava discharges at Stromboli were anticipated several months to over one year before the events with only a few days of inaccuracy …

Further support for the ET *formula comes from the older records of seismicity and volcanicity of Mt. Stromboli between 1983 and 1993 …*"

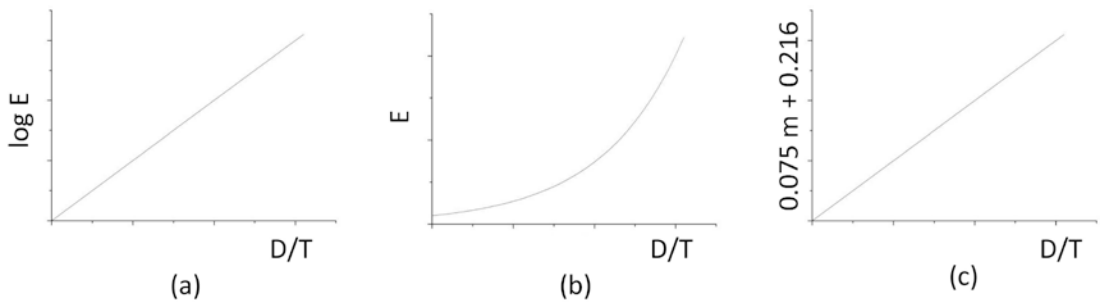

Figure 4. Timing of Stromboli's precursors. *(a) log E vs. D/T; (b) E vs. D/T; (c) 0.075 m + 0.216 vs. D/T.*

A physical interpretation of (6) can be approximately given as follows, in terms of physical dimension. Since, apart constants etc., the magnitude is proportional to the logarithm of the energy E, let us state that $[0.075 \cdot m + 0.216] \propto E$. Hence (6) is equivalent to $\log E \propto D/T$ or $E \propto e^{D/T}$. See **Figures 4a** and **b** where, however, with no approximation, **Figure 4a** is just **Figure 4c**. That is, given a shock of magnitude m, we know D/T and when we know D we can forecast T.

But D/T is just the apparent mean speed of propagation of the primary driver,i.e. of the penetration of hot fluids through the volcanic edifice. Hence, (6) or equivalently **Figures 4** mean that the stronger is the precursor shock, the faster is the propagation speed.

The magnitude of the shock is proportional to the logarithm of the energy of the primary driver. But this energy is linearly related to the temperature of the endogenous hot fluids or also to their pressure (when we refer to a given and the same initial volume of the pores inside the rocks of the volcanic edifice). Hot fluids break the chemical bonds of the boundaries of the pores, and trigger a progressive coalescence of smaller pores into larger ones. The speed of propagation of this rupture process is evidently found to be linearly related to the logarithm of either the energy, or the temperature, or the initial pressure of the endogenous fluids.

Therefore, justice must be given to these Bolt's relations. The concern is not about whether they are correct or not, whether being pro or con them etc. Rather it is about the range of their applicability and the way they can be practically used for issuing some kind of "reasonable" alert, and on what occasion etc. But this is a concern for every Civil Protection, not for Earth scientists alone.

We must refrain from any "dream" to be sometimes capable to issue any kind of "absolutely" certain "forecast". Only a realistic and understating approach - in terms of a sincere "humility" in front of Nature - can lead us to prevent sometimes in the future a huge number of causalities and great sufferance. Every other presumptuous approach on our side would just be criminal.

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References

Blot, C., 1964. Origine profonde des séismes superficiels et des éruptions volcaniques. *Bureau Central Séismologique International. Sér. A, Travaux Scient*., no. 23, p. 103-121.

Blot, C., 1965. Relations entre les séismes profonds et les éruptions volcanique au Japon. *Bull. Volcanol*., v. 28, p. 1-39.

Blot, C., 1971. Séismes du manteau supérieur, précurseurs des séismes superficiels violents (abstract). *Communiqué a la XVIe Assemblée Generale de l'U.G.G.I.*, Moscou, Aout 1971.

Blot, C., 1976. Volcanisme et sismicité dans les arcs insulaires. Prévision de ces phénomenes. *Geophysique, Cahiers ORSTOM,* **13**, 206p., Paris.

Blot, C., 1995. Stromboli. *L'Association Volcanologique Européenne (L.A.V.E.*), no. 54, p. 19-23.

Blot, C., 2004. Volcanic eruptions predicted by the energy transmigration phenomenon - A case of Mt. Stromboli Volcano, Italy, *New Conc. Global Tect., Newlett*., no. 31, p. 10-14.

Blot, C., and Choi, D.R., 2004. Recent devastating earthquakes in Japan and Indonesia viewed from seismic energy transmigration concept. *New Concepts Global Tect. Newslett*., no. 33, p. 3-12.

Blot, C., Choi, D.R. and Grover, J.C., 2003. Energy transmigration from deep to shallow earthquakes: a phenomenon applied to Japan - Toward scientific earthquake prediction, *New Conc. Global Tect., Newlett*., no. 29, 3-16.

Choi, D.R., 2003. Deep earthquakes and deep seated tectonic zones. Part 5, Discussion. *New Conc. Global Tect. Newlett*., no. 27, p. 8-25.

Gregori, G.P., 2002. Galaxy – Sun – Earth relations. The origin of the magnetic field and of the endogenous energy of the Earth, with implications for volcanism, geodynamics and climate control, and related items of concern for stars, planets, satellites, and other planetary objects. A discussion in a prologue and two parts. *Beiträge zur Geschichte der Geophysik und Kosmischen Physik*, Band 3, Heft 3, 471p.

Gregori, G.P., 2006. Galaxy-Sun-Earth relations: the origin of the magnetic field and of the endogenous energy of the Earth, with implications for volcanism, geodynamics and climate control and related items of concern for stars, planets, satellites, and other planetary objects. *Newslett. New Concepts Global Tect. Newslett*., no. 38, p. 34-36.

Gregori, G.P., 2009. The Earth's interior – Myth and science, *New Concepts Global Tect. Newslett*., no. 53, p. 57-75.

Gregori, G.P., 2013. Space-time constraints on earthquake predictability-A 10 cm/sec "domino effect" typical of every fracture phenomenon, *New Concepts in Global Tect. Jour.*, vol. 1, no. 2, p. 23-39.

Grover, J.C., 1998. *Volcanic eruptions and great earthquakes - Advanced warning techniques to master the deadly science*. 272p., Copyright Publishing Co., Pty Ltd., Brisbane.

Judd, A.G., and Hovland, M., 2007. *Submarine fluid flow, the impact on geology, biology, and the marine environment*. 47p., Cambridge University Press.

Meyerhoff, A.A., Taner, I., Morris, A.E.L., Martin, B.D., Agocs, W.B. and Meyerhoff, H.A., 1992. Surge tectonics: a new hypothesis of Earth dynamics. In Chatterjee, S., and N. Hotton III (eds.), *New concepts on global tectonics*. Texas Tech. University Press, Lubbock, TX, p. 309-409.

Poscolieri, M., Lagios, E., Gregori, G.P., Paparo, G., Sakkas, V.A., Parcharidis, I., Marson, I., Soukis, K., Vassilakis, E., Angelucci, F. and Vassilopoulou, S., 2006. Crustal stress and seismic activity in the Ionian archipelago as inferred by combined satellite and ground based observations on the Kefallinìa Island (Greece). In, Cello, G., and Malamud, B.D. (eds.), 2006. Fractal analysis for natural hazards. *Geol. Soc. Lond., Spec. Publ.*, v. 261, p. 63-78.

PUBLICATIONS

Relationship between major geophysical events and the planetary magnetic Ap index, from 1844 to the present

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Summary
In this study, for the first time, we compared the annual magnetic Ap index, taken from original sources, from 1844 to the present day *[Svalgaard, 2014]*, with:

i) sixteen large volcanic eruptions of index VEI5 + recorded by, Smithsonian Institute (Global Volcanism Program),
ii) three sets of the volcanic aerosols data (Ammann et.al, 2003; Gao, Robock and Ammann, 2008; Traufetter et.al., 2004).
iii) eight major earthquakes of a magnitude between 8.7<M<9.5, which occurred from 1900 to the present.

We observe that the twenty four major geophysical events which occurred were in proximity to two specific thresholds, or limits, of the annual planetary Ap index. Specifically, in the downward phase of the planetary Ap index, under the annual value of 7 or, in the phase when the annual value exceeded 22. We identified a total of 14 transitions (eight in the solar minimum and six in the solar maxima) each with a period of about two and a half years making a total of almost 35 years of activity during the 169 years under review. During the 14 transitions 18 of the 24 major historical geophysical events occurred from 1844 to the present. Analysis of data shows a clear link between the electromagnetic (EM) dynamics recorded in large historical solar minima (Maunder, Dalton or solar minimum 1880-1920), the large solar maxima (solar cycles 19, 21 & 22) and the energy released during large geophysical events (Casati, 2014). The physical process of solar-terrestrial interaction, also reveal a deep and intrinsic relationship between the EM dynamics of the inner solar system and the temporal occurrence of major geophysical events. The references in scientific literature, in support of this work, are numerous: from empirical evidence, that we find in the late nineteenth century - early twentieth century, to more recent references. Some of which are: Casey (2010 and 2011), Charvátová (2010), Choi (2010), Duma and Vilardo (1998), Khachikyan et al, (2014), Kolvankar (2008), Kovalyov (2014), Mazzarella and Palumbo (1989), Stothers (1989), Streštik (2003), Sytinsky (1987, 1989 and 1998).

Results and Discussion

The fourteen transitions identified in this study (each with a period of approximately two and half years), cover a total period of 35 years, of the 169 years studied. The fourteen transitions occurred during the minimum /maximum of the solar cycle, or very close to the ascent or descent phase (Chart A).

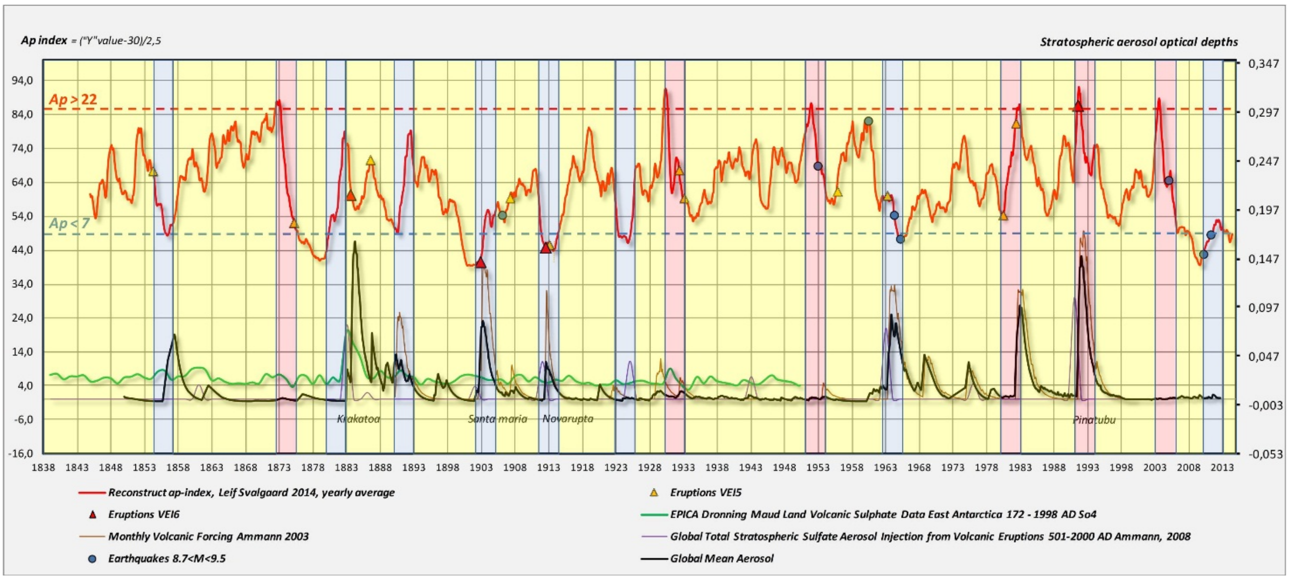

Chart "A"1844-2014 - The 14 transitions (eight in the solar minimum and six in the solar maxima) each with a period of about two and a half years making a total of almost 35 years of activity during the 169 years under review.

The solar cycles involved are:

Solar minimums and solar maximums (Chart B):

i. four solar minima: SC9-SC10; SC15-SC16; SC19-SC20; SC23-SC24
ii. four solar maxima: SC11; SC16; SC18; SC23

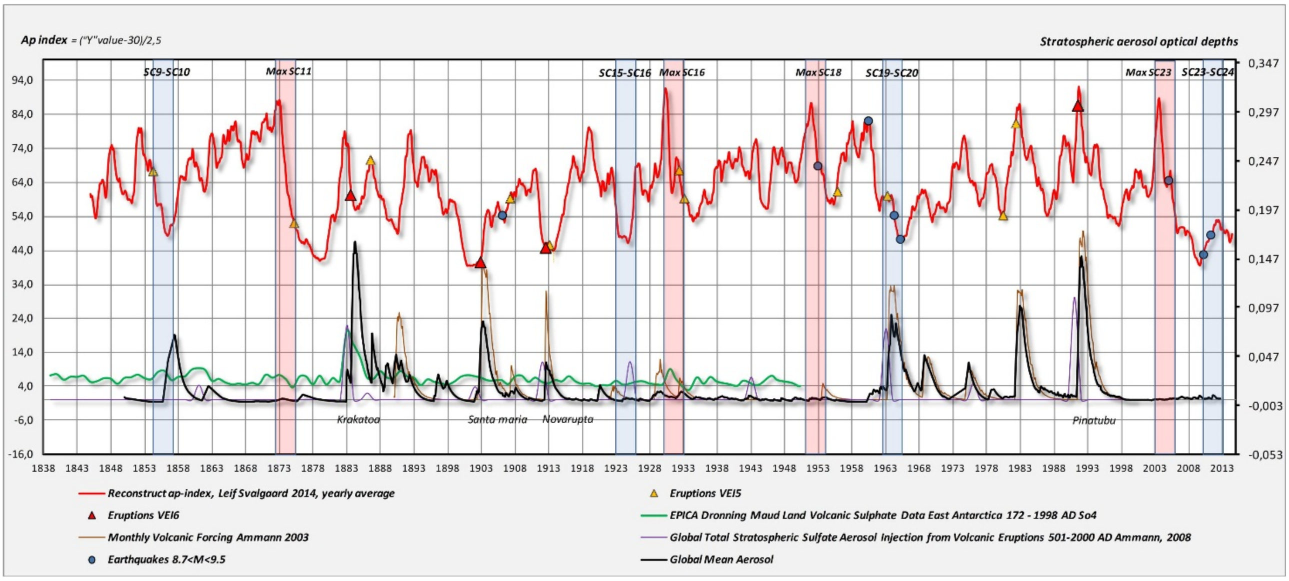

***Chart "B"** Four solar minimums and four solar maximums*

Deep solar minimum and large solar maximum (Chart C):

i. four historical deep solar minima occurred between 1880 and 1920. Solar cycles from SC12 to SC15
ii. two major solar cycles (bicentennial), SC21 (1976-1986) & SC22 (1986-1996)

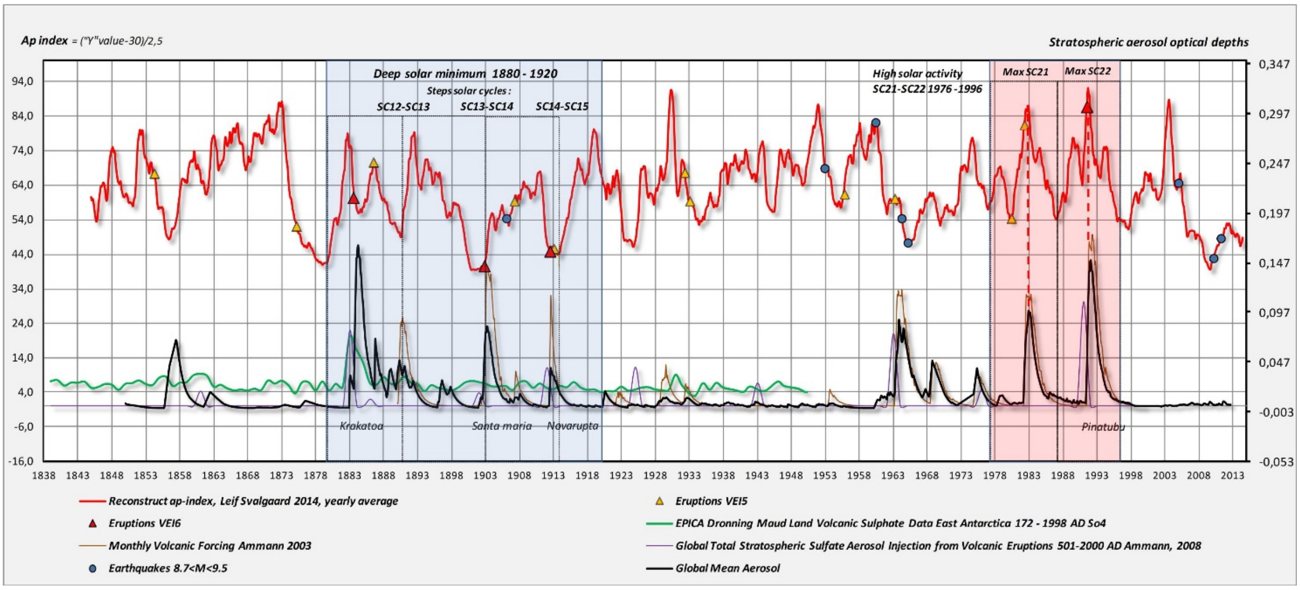

***Chart "C"** Deep solar minimum and large solar maximum*

During the other 134 years (yellow areas – chart A), with the annual Ap index between 7<Ap<22, we find the remaining six geophysical events (in blue, table A) that occurred during the moderate solar activity oscillations. Phases characterized by moderate fluctuations of the planetary index Ap (weak EM variations of the interplanetary magnetic field, in intensity and speed of the transient). Four of the six major geophysical events, including the great eruption of Krakatoa in August of 1883 and three other major geophysical events, are outside of the fourteen transitions of about two and half years (Chart A). However the four events, are found within the well-known historical period, 1880-1920, called the Gleissberg minimum, when there was extreme low solar activity. The forty years of weak and irregular EM activities are shown for example, in the register of the count of the sunspot cycle SC14, 1902-1913 (Chart D).

Major geophysical event	Date (*tge*)	VEI or Magnitude	Solar cycle phase	Lower or upper thresholds "Index Ap"	Date (*tap*)	(*tge*)-(*tap*) [Years]
Honshu, Japan	2011.21	M9.0	Rising SC24	3.8	2009.71	1.50
Chile	2010.13	M8.8	Transistion SC23 - SC24	3.8	2009.71	0.42
Sumatra	2004.96	M9.1	Declining SC23	23.4	2003.62	1.34
Hudson Cerro	1991.63	VEI5+	Maximum SC22	24.8	1991.70	-0.08
Pinatubu	1991.46	VEI6	Maximum SC22	24.8	1991.70	-0.24
El chichon	1982.29	VEI5	Declining SC21	22.3	1982.54	-0.25
St.helen	1980.38	VEI5	Maximum SC21	22.3	1982.54	-2.16
Rat Islands, Alaska	1965.13	M8.7	Transistion SC19 - SC20	6.8	1965.38	-0.25
Alaska	1964.21	M9.2	Transistion SC19 - SC20	6.8	1965.38	-1.17
Agung	1963.21	VEI5	Declining SC19	6.8	1965.38	-2.17
Chile	1960.38	M9.5	Declining SC19	6.8	1965.38	-5.00
Benzymianny	1955.80	VEI5	Rising SC19	22.9	1951.96	3.84
Kamchatka	1952.88	M9.0	Declining SC18	22.9	1951.96	0.92
Kharimkotan	1933.04	VEI5	Transistion SC16 - SC17	24.6	1930.29	2.75
Cerro azul	1932.29	VEI5+	Declining SC16	24.6	1930.29	2.00
Colima	1913.04	VEI5	Transistion SC13 - SC14	5.5	1913.71	-0.67
Novarupta	1912.46	VEI6	Transistion SC13 - SC14	5.5	1913.71	-1.25
Ksudach	1907.21	VEI5	Maximum SC14	3.8	1900.88	6.33
Off the Coast of Ecuador	1906.04	M8.8	Maximum SC14	3.8	1900.88	5.17
Santa maria	1902.79	VEI6	Transistion SC12 - SC13	3.8	1900.88	1.92
Mount tarawera	1886.46	VEI5	Declining SC12	4.4	1879.29	7.17
Krakatoa	1883.63	VEI6	Maximum SC12	4.4	1879.29	4.34
Askja	1875.21	VEI5	Declining SC11	23.2	1873.04	2.17
Shiveluch	1854.13	VEI5	Declining SC9	7.3	1856.38	-2.25

Table "A". From left to right, list of twenty four major geophysical events that occurred from 1844 to the present, geophysical event date "tge", volcanic explosivity index or magnitude, the phase of the solar cycle (rising, declining, maximum, minimum), maximum (ap> 22) or minimum (ap <7) thresholds of the Ap index, annual Ap planatery index date "tap" used for comparison with geophysical events date, and time lag (number of years late or early) (tge) - (tap).

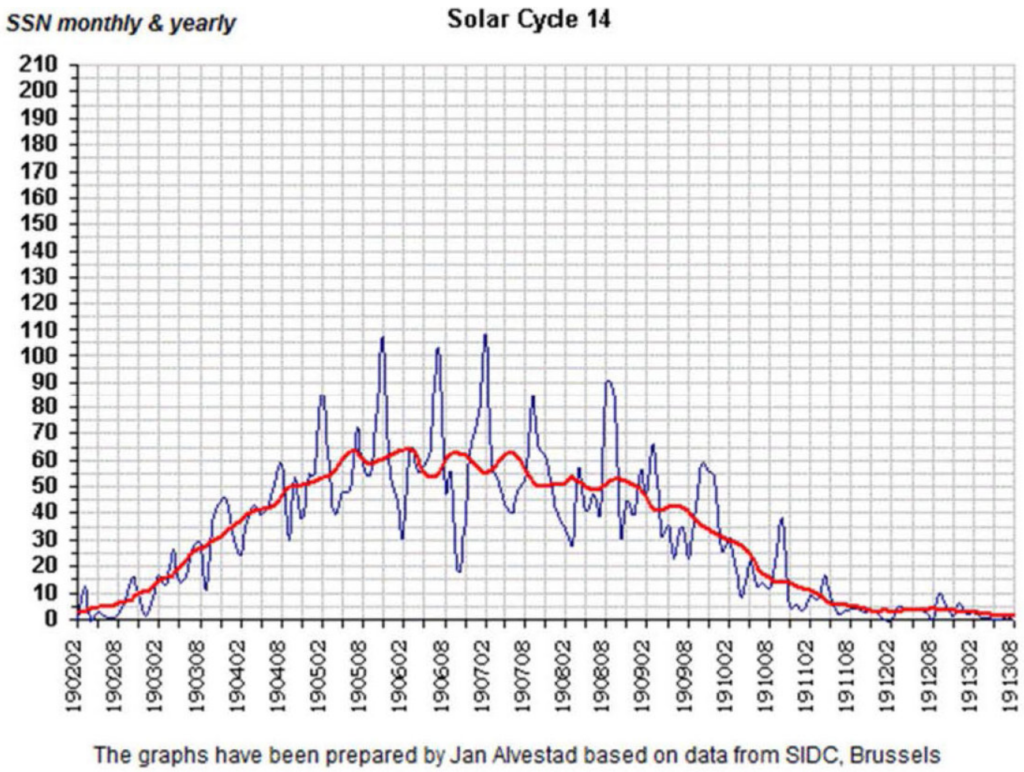

Chart "D" Solar Cycle SC14. Cycle 14 began in February 1902 with a smoothed sunspot number of 2.7 and ended in August 1913**.**

We hypothesize that:

i. atypical electrical impulsive phenomena (EM solar-terrestrial interactions) occurred during the solar minimum, with an enormous amount of energy released during the geophysical event. Phenomena not yet fully understood from a physical point of view (hypothesis of the global electrical circuit, GEC),

ii. the change in the genesis of the major geophysical events (occurring between 1970 and 1995, solar cycles 21 and 22, with the annual Ap index > 22) is to be linked to the major solar activity. Solar activity that did not have such high EM characteristics during the previous 200 years (Steinhilber, Abreu, Beer and McCracken, 2010) or possibly even the last 3000 years (Usoskin, 2014).

The significant trace, of the three main sets of the volcanic aerosols data (see the black line in all graphs), further validates the observations described above.

Conclusions

i. Solar activity has returned to low levels of late 18th century - early 19th century, in terms of magnetic activity (annual Ap index).
ii. Probable entry into a long deep solar minimum, during the transition to the next solar cycle SC25. Assertion made by many solar physicists: Casey (2011), Ahluwalia, (2013), Goelzer, Smith, Schwadron and McCracken (2013), (Livingston, Penn and Svalgaard (2012), Steinhilber and Beer (2013),
iii. European Space Agency has recently confirmed the general trend of the weakening of the Earth's magnetic field (European Space Agency, Third Swarm Science Meeting 'in Copenhagen, Denmark., 2014).
iv. Hypothesis of a possible and imminent geomagnetic reversal or excursion in the near future (2034 ± 3 years) (De Santis, 2013).
v. Possible relationship between the major volcanic eruptions, the general increase of volcanism, the weakening of Earth's magnetic field, the geomagnetic excursions or magnetic reversals: Kennett and Watkins (1970), Schnepp and Hradetzky (1994), Cassidy (2006), and Nowaczyk (2012).

We consider it is possible that an intense heliosphere EM oscillation (destabilization of the Earth's magnetosphere during the years of minimum solar or early ascent of the solar cycle), may trigger a major geophysical event (for a example a large volcanic eruption with index VEI5+) during the transition to the next solar cycle SC25 and/or successive SC26. Major geophysical events that would not be completely unexpected, as we concluded in our earlier study (Casati and Straser, 2013).

Acknowledgements: We are also thankful to Dr. Leif Svalgaard -Stanford University- for his kind help in database management and plotting the annual magnetic Ap index.

References

Ahluwalia, H.S., 2013. An empirical approach to predicting the key parameters for a sunspot number cycle. University of New Mexico, Department of Physics & Astronomy, MSC07 4220, Albuquerque, NM 87131, USA. doi:10.1016/j.asr.2013.11.044.

Ammann, C.M., Meehl, G.A., Washington, W.M. and Zender, C.S., 2003. A monthly and latitudinally varying volcanic forcing dataset in simulations of 20th century climate. *Geophysical Research Letters*, v. 30, no. 12, p. 1657. doi:10.1029/2003GL016875.

Casati, M., 2014. Significant statistically relationship between the great volcanic eruptions and the count of sunspots from 1610 to the present, EGU General Assembly 2014, 27April - 02May, in Vienna, Austria id. EGU2014-1385-2.

Casati, M. and Straser, V., 2013. Possible relationship between changes in IMF, M7+ earthquakes and VEI index, during the transition between the solar minimum cycle 23 and the rise of solar cycle 24. EGU General Assembly 2013, 7April -12 April, in Vienna, Austria. id.EGU2013-1405.

Casey, J.L., 2010. Correlation of Solar Activity Minimums and Large Magnitude Geophysical Events. *Space and Science Research Center*, *Research Report* 1-2010 (Preliminary), p. 1-5.

Casey, J.L., 2011. Cold Sun. Trafford Publishing. www.trafford.com. 167p.

Cassidy, J., 2006. Geomagnetic excursion captured by multiple volcanoes in a monogenetic field. G*eophys. Res. Lett.*, v. 33, L21310. doi:10.1029/2006GL027284.

Charvátová, I., 2010. Long-term relations between the solar inertial motion (SIM) and solar, geomagnetic, volcanic activities and climate. AGU Foz do Iguaçu Brazil 2010.

Choi, D.R. and Maslov, L., 2010. Earthquakes and solar activity cycles. *NCGT Newsletter*, no. 57, p. 85-97.

De Santis, A., Qamili, E. and Wu, L., 2013. Toward a possible next geomagnetic transition? *Nat. Hazards Earth Syst. Sci.*, v. 13, p. 3395-3403. doi:10.5194/nhess-13-3395-2013.

Duma, G. and Vilardo, G., 1998. Seismicity cycles in the Mt.Vesuvius area and their relation to solar flux and the variations of the Earth's magnetic field. *Phys. Chem. Earth*, v. 23, nos. 9-10, p. 927-931. doi:10.1016/S0079-1946(98)00121-9.

Gao, C., Robock, A. and Ammann, C., 2008. Volcanic forcing of climate over the past 1500 years: An improved ice-core-based index for climate models. *Jour. Geophys. Res.*, v. 113, D23111. doi:10.1029/2008JD010239.

Kennett, J.P. and Watkins, N.D., 1970. Geomagnetic polarity change, volcanic maxima and faunal extinction in the South Pacific. *Nature*, 227, 930 - 934. doi:10.1038/227930a0.

Khachikyan, G., Breusov, N. and Zhantayev, N., 2014. On dependence of seismic activity on the 11 year variations in solar activity and/or cosmic rays European Geosciences Union, EGU General Assembly 2014, 27April - 02May, in Vienna, Austria id. EGU2014-5253.

Kolvankar, V.G., 2008. Sun induced semi-diurnal stresses on Earth's surface, which trigger earthquakes and volcanic eruptions. *NCGT Newsletter*, no. 47, p. 12-23.

Kovalyov, M. and Kovalyov, S., 2014. On the relationship between cosmic rays, solar activity and powerful earthquakes arXiv:1403.5728.

Livingston, W., Penn, M.J. and Svalgaard, L. 2012. Decreasing Sunspot Magnetic Fields Explain Unique 10.7 cm Radio Flux. *The Astrophysical Journal Letters*, v. 757, Issue 1, article id. L8, 4p. doi:10.1088/2041-8205/757/1/L8.

Mazzarella, A., 1989. Palumbo, A. Does the solar cycle modulate seismic and volcanic activity? *Jour. Volcanol. Geotherm. Res.*, v. 39, no. 1, p. 89–93. doi :10.1016/0377-0273(89)90023-1.

Molly, L.G., Smith, C.W., Schwadron, A.A. and McCracken, K., 2013. An analysis of heliospheric magnetic field flux based on sunspot number from 1749 to today and prediction for the coming solar minimum. *Journal of geophysical Research: Space Physics*, v. 118, p. 7525–7531. doi:10.1002/2013ja019404.

Nowaczyk, N., Arz, H.W., Frank, U., Kind, J. and Plessen, B., 2012. Dynamics of the Laschamp geomagnetic excursion from Black Sea sediments. *Earth and Planetary Science Letters*, v. 351-352, p. 54-69. http://doi.org/10.1016/j.epsl.2012.06.050.

Traufetter, F., Oerter, H., Fischer, H., Weller, R. and Miller, H., 2004. Spatio-temporal variability in volcanic sulphate deposition over the past 2 kyr in snow pits and firn cores from Amundsenisen. *Antarctica.Journal of Glaciology*, v. 50, no. 168, p. 137-146.

Schnepp, E. and Hradetzky, H., 1994. Combined paleointensity and $^{40}Ar/^{39}Ar$ age spectrum data from volcanic rocks of the West Eifel field (Germany): Evidence for an early Brunhes geomagnetic excursion. *Jour. Geophys. Res.*, v. 99(B5), 9061–9076,doi:10.1029/93JB03365.

Stothers, R.B., 1989. Volcanic eruptions and solar activity. *Journal of Geophysical Research, Solid Earth (1978–2012)*, v. 94, Issue B12, pages 17371–17381, doi: 10.1029/JB094iB12p17371.

Steinhilber, F. and Beer, J., 2013. Prediction of solar activity for the next 500 years. *Journal of Geophysical Research, Space Physics*, v. 118, Issue 5, pages 1861–1867, doi:10.1002/jgra.50210.

Steinhilber, F., Abreu, J.A., Beer, J. and McCracken, K.G., 2010. Interplanetary magnetic field during the past 9300 years inferred from cosmogenic radionuclides. *Jour. Geophys. Res.*, v. 115(A1), A01104. doi:10.1029/2009JA014193.

Střeštik, J., 2003. Possible correlation between solar and volcanic activity in a long-term scale solar variability as an input to the Earth's environment. International Solar Cycle Studies (ISCS) Symposium, 23 - 28 June 2003, Tatranská Lomnica, Slovak Republic. Ed.: A. Wilson. ESA.

Svalgaard, L., 2014. Stanford University - Reconstructed Ap-Index yearly averages. http://www.leif.org/research/.

Usoskin, I.G., Hulot, G., Gallet, Y., Roth, R., Licht, A., Joos, F., Kovaltsov, G.A., Thebault, E. and Khokhlov, A., 2014. Evidence for distinct modes of solar activity. *Astronomy and Astrophysics*, v. 562: L10, doi: 10.1051/0004-6361/201423391.

Sytinsky, A.D., 1987. Connection of seismicity of the Earth with solar activity and atmospheric processes. Leningrad. Hydrometeoizdat, p. 99,

Sytinsky, A.D., 1989. On the relation between earthquakes and solar activity. *Fizika Zemli*, no. 2, p. 13–30.
http://meetingorganizer.copernicus.org/EGU2015/EGU2015-2501-2.pdf

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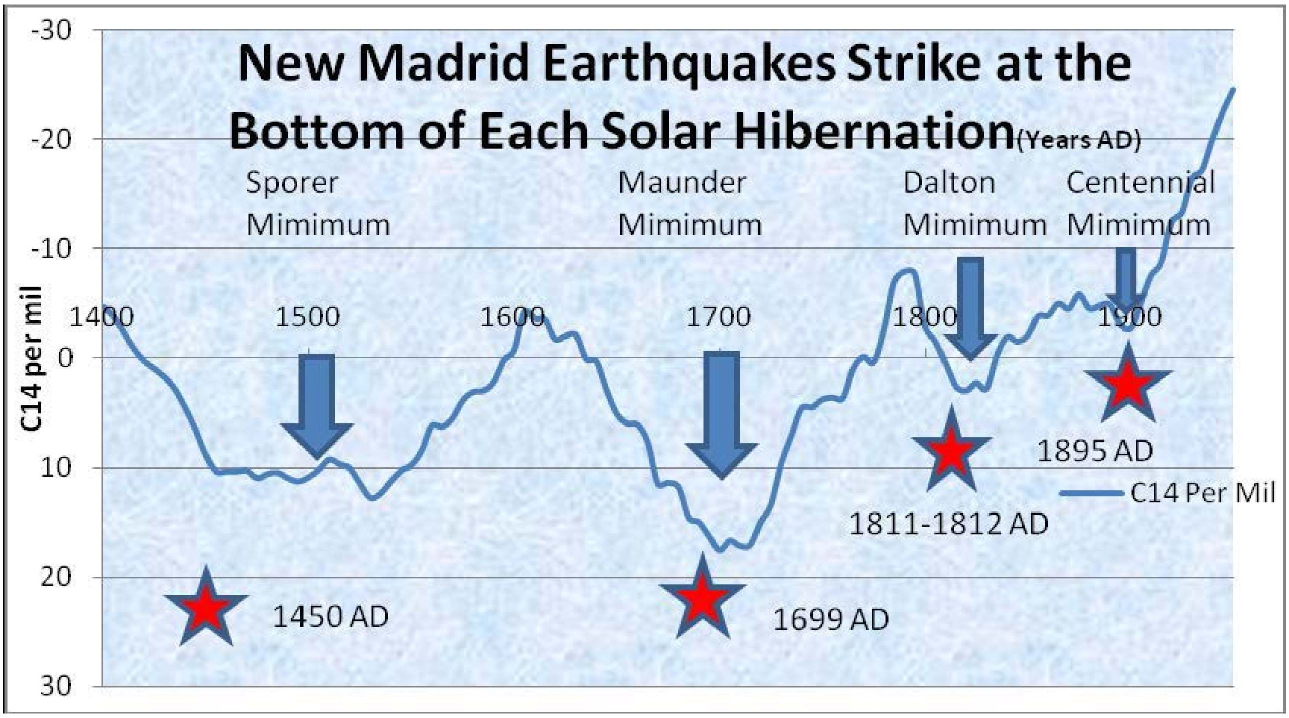
New Madrid Seismic Zone, Central USA: The great 1811-12 earthquakes, their relationship to solar cycles, and tectonic settings

Dong R. Choi and John L. Casey

Global Climate Status Report, Edition 1-2015, June, p. 16-29. www.spaceandscience.net

Abstract: The 1811-1812 New Madrid series of earthquakes were the largest in magnitude (estimated to be M8.0 or greater) in the continental North America in the history. The quakes occurred in the midst of Dalton Solar Minimum (1793-1830). Other major historic earthquakes in the same region also occurred during major solar minimums, or "solar hibernations." From a tectonic viewpoint, the New Madrid Seismic Zone (NMSZ) is situated on the axis of the N-S American Geanticline or Super Anticline which is Archean in origin. It has been subject to repeated magmatic and tectonic activities in Proterozoic and Phanerozoic – the Caribbean dome (now oceanized to form the Caribbean Sea and the Gulf of Mexico) has been the site for rising thermal energy from the outer core since the Mesozoic. Energy transmigrates northward along the anticlinal axis (or surge channel) and is trapped at the embayment bounded by less permeable Precambrian-Paleozoic basement highs in the north of the New Madrid area. The arrival of a major, prolonged solar low

period or "hibernation" in the coming 30 years, which are considered comparable to the Dalton or even Maunder Minimum (1645-1715), increases the likelihood of repeating the 1811-12 class seismic events. Heightened awareness, monitoring of precursory signals, and disaster mitigation planning are required.



History of New Madrid earthquakes compared to solar minimums or "solar hibernations" from 1400-1950 AD. Solar activity deduced from C14 proxy variation. The years of major New Madrid earthquakes are shown in red stars with dates. Source: Casey, Data: Reimar et al., INTCAL04.

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The Earth's crust and upper mantle structure of the Northern Eurasia from the seismic profiling with nuclear explosions

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Series of analytical reviews; "Essays for Regional Geology of Russia". Issue 10, Moscow. International Center for Geological Cartography. GEOKART: GEOS. 2014, 191p.

This manuscript is a reduced English version of the book — "The Earth's crust and upper mantle structure of the Northern Eurasia from the seismic profiling with nuclear explosions" published in Russian by the Federal Subsoil Resources Management Agency (ROSNEDRA) and Institute of Physics of the Earth of the Russian Academy of Sciences (IPE RAS).

The long-range seismic profiles with large chemical and with Peaceful Nuclear Explosions (PNEs) were carried out in Russia during the last decades of the 20th century. Three-component analogue seismic stations equipped by short period seismometers (1-2 Hz) were deployed along the profiles with interval of 10 km. The length of the profiles varies from 1500 to 3200 km. The chemical explosions provided recordings up to 300-600 km offsets, the PNEs – up to 3200 km offsets. The profiles cross several large tectonic structures: the East European Craton, the Urals, the young Timan-Pechora and West-Siberian plates and the Siberian Craton. They differ in age, in geological history and geophysical fields.

2-D crust and upper mantle velocity models up to depth of 700 km were constrained for all these profiles using a common method for the wave analysis and velocity modelling. As a result, 3-D velocity model of the upper mantle was compiled for this large area. The models show that the old and cold East-European and Siberian Cratons have higher velocities in the thick (about 300 km) lithosphere than the young Timan-

Pechora and West Siberian platforms with higher heat flows. Mostly horizontal inhomogeneity is observed in the uppermost mantle: the velocities change from the average 8.0-8.1 km/s to 8.3-8.4 km/s in some blocks of the Urals and in the Siberian Craton.

Analyses of the seismograms from all the profiles indicate prominent velocity boundaries N1 and N2 at a depth around 100 km, L boundary at a depth of 180-240 km and H boundary at 300-330 km. Analyses of the waves from the mantle transition zone indicate prominent velocity discontinuities at 420, 510 and 660 km depths. All the boundaries are not simple discontinuities, they are heterogeneous (thin layering) zones which generate multiphase reflections. It is difficult to determine the lithosphere-asthenosphere boundary in traditional form because the 'thermal' asthenosphere at depths of 250-300 km was not traced as a lower velocity zone. The rheological stratification follows, however, from the regular change of horizontal heterogeneity which determines three layers of different plasticity. The layers are divided by the seismic boundaries N1 and L. The block structure typical of the upper brittle part of the lithosphere disappears beneath the N1 boundary and the thin low velocity layer is observed. These structural features propose that the depth of 100-120 km is a bottom of a brittle part of the lithosphere. At the L boundary the Q factor decreases and the upper mantle structure also changes which marks this boundary as a bottom of the whole lithosphere.

The velocity-density modelling, performed along the PNE profiles revealed significant distinctions in the upper mantle composition in the Northern Eurasia. The Siberian Craton of the same age and of the same heat flow as the East-European Craton is characterized by the higher upper mantle velocities and by the lower densities. That proposes the depleted upper mantle beneath the Siberian Craton, which is characterized by negative gravity anomaly.

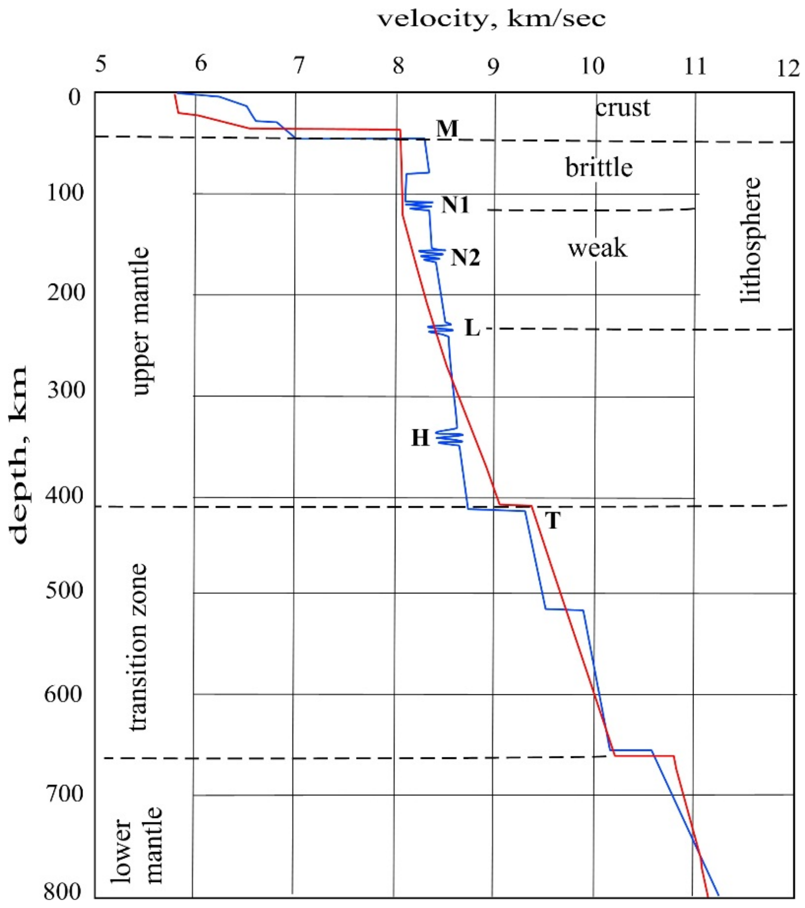

Fig. 1. General 1D velocity model of the Eurasian cratonic upper mantle and transition zone (blue line) in comparison with the IASPS-91 model (red line).

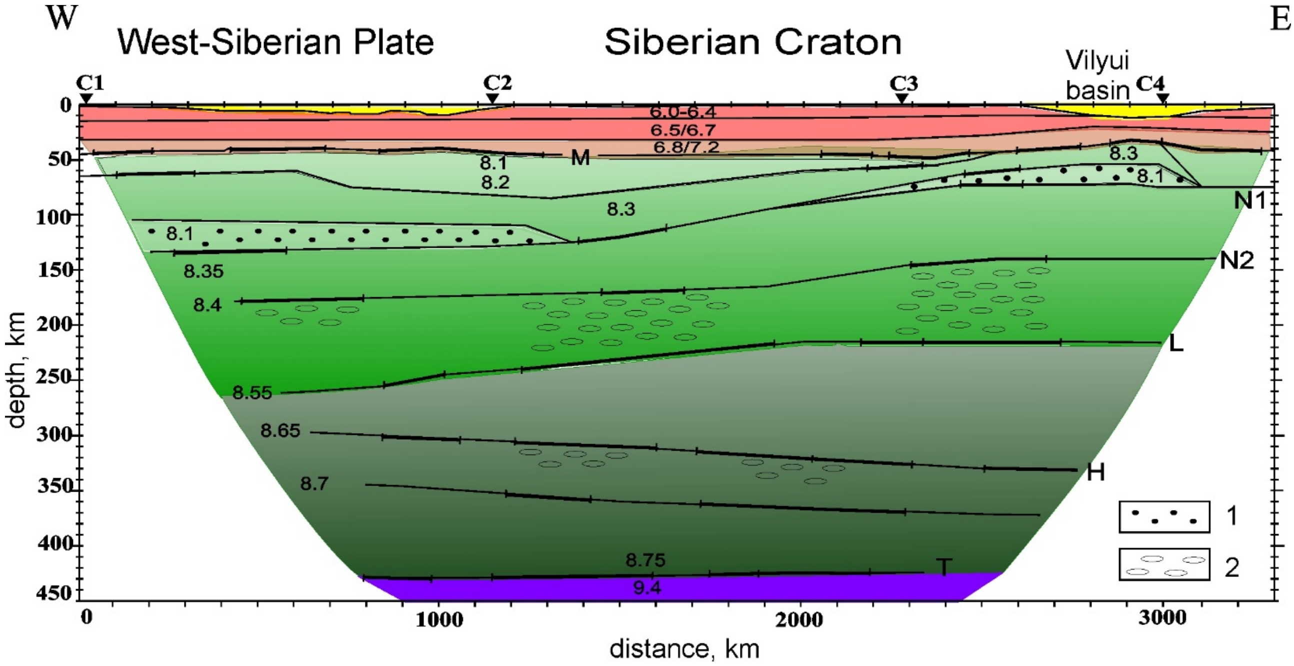

Fig. 2. Velocity cross section across the Siberian Craton in E-W direction. C1-C4 are the nuclear explosion points. The reflection boundaries are shown by the thick lines. Legend: 1- low velocity layer, 2 – high heterogeneity zone

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Some reflections on science and discovery

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Observations, ideas, and discoveries are the substance of science. We are, in a very real sense, creatures of the mind, building science on the tenuous fabric of human thought so that it becomes its own evolving tapestry, a tapestry that must be passed down from generation to generation without unravelling.

Only a few months after receiving my PhD in nuclear chemistry in 1974, I presented a seminar at the University of California, San Diego. There were two men in the audience whom I only knew by reputation: Nobel laureate Harold C. Urey (1893–1981), who discovered deuterium and conceived the idea of oxygen isotope paleothermometry, and Hans E. Suess (1909–1993), co-discoverer of the shell structure of the atomic nucleus, which earned codiscoverer J. Hans D. Jensen a share of the Nobel Prize in physics in 1963. Both Urey and Suess were recipients of knowledge passed down from masters. Urey had served a postdoctoral apprenticeship with Niels Bohr in Copenhagen; Suess had learned from his father Franz Eduard Suess, a famous geologist, who had learned from his father, Eduard Suess, an even more famous geologist and author of *Das Antlitz der Erde* (1892). Something I said during that seminar led to my being invited by these two giants of science to serve as a postdoctoral apprentice to them.

Suess and Urey were well schooled in the principles, methods, and ethics of pre-World War II science, a time when science received little government funding. After the war came the Cold War and government became the primary funding source for most scientific research. The US National Science Foundation was established in 1951 and wrote the new rules for the government administration of scientific research funding, including anonymous peer review. Secret reviews by one’s competitors encourage deceit, human nature and the logic of competition for limited resources being what they are. Further, the requirements for funding proposals trivialize science by insinuating non-scientific or political ends into the process of rationalization. How can one specify beforehand what will be discovered that has never before been discovered, or what one will do to make that discovery? By 1974, the tapestry of science was already frayed. Now, 41 years later, I wish to pass along some of the insights I learned from Urey and Suess, as well as during my own life of making scientific discoveries.

The purpose of science is to determine the true nature of the Universe and all it contains. The word 'true' is paramount. Science is about truth and integrity. But in many other human activities, politics for example, truth does not have the same necessity as it does in science. (Although as acknowledged by Mahatma Gandhi, 'Truth never damages a cause that is just'.)

Science is the ever-evolving activity of replacing less precise understanding with more precise understanding. But how does one know whether a new idea represents an advance or not? How does one determine the truth? In mathematics one can offer proofs that are true, without doubt, but such absolute certainty is generally not achievable in science. So, when a new idea comes along there should be discussion and debate. Efforts should be made to refute the new idea, to show that it is not true. If the scientific community is unable to refute the idea, ideally in the same journal where it was first published, then the idea should be acknowledged and cited in the relevant scientific literature that appears afterwards.

The criterion for truth in science is different than for truth in other fields. Jurisprudence, for example, filters evidence as to whether it is admissible or inadmissible and allows a jury of ordinary citizens untrained in the law to determine truth, i.e. guilt or innocence. In matters of political governance, for example, consensus is the criterion for truth, but in science consensus is nonsense. Science is a strictly logical process, not a democratic process; with every new discovery, consensus is overthrown.

Fundamental new ideas typically meet with resistance. I have observed there is a human analogue to Lenz's law in physics and Le Chatelier's principle in chemistry, the tendency of a system to oppose change. Once, after a pleasant dinner, I began to explain my recent discoveries to a friend, a visiting scientist whom I had not seen for several years. As I described how Earth's interior differed from what he had been taught, his demeanour changed, his face became ashen, and he hardly spoke the remainder of his visit. I have encountered similar experiences with other scientists. When I am exposed to a fundamentally new concept, I ask myself, 'Suppose the new concept is correct, what does it mean? What advances might follow from it?' I try to allow a new idea the benefit of doubt before discarding it abruptly.

Good science, properly executed and securely anchored to the known properties of matter and radiation, transcends opinion. Ideally, one seeks to discover fundamental quantitative relationships in nature. In my view the making of models, based upon arbitrary assumptions, on the other hand, is not science. Furthermore, models are computer programs that generally begin with an assumed end result which is then attained by selecting variables and assumptions that yield the sought end result. Some models can prove useful, but they do not lead to scientific discoveries.

Six months into my postdoctoral apprenticeship, Suess asked me directly one afternoon if I knew why he had chosen me. I confessed I did not. Then he reminded me of my seminar and the questions that followed and one specific question in particular I had long since forgotten. He reminded me that I had answered by saying I could not answer that question, that the information was simply not known. Suess told me that not one young scientist in a thousand would have answered the way I had; most would have tried to answer the question. He then explained it is much more important to know what is not known, than to know what is known.

There is a technique, a method, one can use to begin to know what is not known: quite simply, go back in time. Travel through time, through a historical review and understanding of the events and ideas that led to the present state of understanding of a specific scientific idea. The changing movement and development of ideas is documented in the scientific literature. Logically ordering historical observations and ideas into a sequential progression of understanding, while being keenly aware of later changes and discoveries, helps one to see gaps in the sequence, to begin to know what is not known, and, in the light of later data, perhaps to find mistakes that were made and not corrected.

Science is a logical progression of causally related events, analogous to a really good movie where all the actions are logically and causally related; the pieces – the characters, their actions, and the sequences of events – all fit together. Now, if something about nature does not make sense and seems like a really bad movie – unrelated pieces just stuck together – ask the question, 'What is wrong with this picture?' That can be the first step towards making an important discovery.

There is a more fundamental way to make discoveries than the variants of the scientific method taught in schools: An individual ponders and through tedious efforts arranges seemingly unrelated observations into a logical sequence in his or her mind so that causal relationships become manifestly evident and a new understanding emerges, showing a path on which to make new observations, new experiments, new discoveries, and new theoretical considerations (Herndon, 2010).

Science should not simply be an academic discipline without reference to the human community or Earth's biota, but should aim to improve the well-being of life on our planet. The content of *Current Science*, for example, is wholly consistent with that aim. Although the infusion of politics into funding and oversight by government agencies sometimes make it difficult, scientists should maintain the integrity that should be an intrinsic part of their profession. By virtue of their abilities and advanced training, scientists have an implicit responsibility toward humanity. That is especially the case in India and elsewhere where resources are limited and small advances and innovations can make significant improvements in the quality of human life.

References

Herndon, J.M., 2010. *Hist. Geo. Space Sci*., v. 1, p. 25–41.
http://www.nuclearplanet.com/hgss-1-25-2010.pdf

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Some YouTubes for your interest

1. Global climate – John Casey: Coming cold crisis
   https://www.youtube.com/watch?v=XQanWtkSDHE
2. Natural Philosophy Alliance Conference, 20 Nov., 2014. Giovanni Gregori and Bruce Leybourne Presentation: Climate anomalies, their drivers and tectonic connection.
   https://www.youtube.com/watch?v=WJjVgfUk91I
3. Bio-gravitics, Hutchinson effect and acoustic levitation
   https://www.youtube.com/watch?v=OqpPi8wNed8
4. Nassim Haramein's Natural Philosophy
   https://malagabay.wordpress.com/2015/06/18/as-above-so-below-nassim-haramein/

GLOBAL CLIMATE CORNER

CLIMATE CHANGE WITH A DIFFERENCE

A New Little Ice Age Has Started: How to survive and prosper during the next 50 difficult years. L.E. Pierce. 2015. Published by Lawrence E. Pierce, Box 82, Hornby Island BC, Canada V0R 1Z0. Available from Amazon. Kindle U$3.15. Paperback U$12.95.

This small book is something new in the Climate Change debate. In the past decades we have been overwhelmed by books on Global Warming and its successor Climate Change, and a large (though much smaller) number of books that take a sceptical view of these issues.

This book goes beyond global warming and the usual arguments against. It does not deal with the details of carbon dioxide as a greenhouse gas, simply noting that its amount has gone up in the past 60 years from about 350 to 400 ppm, while temperatures have not risen for the past 18 years. Clearly there is no correlation. Instead the arguments are assembled to show that a new ice is upon us.

On the scientific side he gets into the role of alignment of planets affecting gravity, cosmic rays (the link between solar flares and climate), and the relationship between volcanoes and climate (big eruptions cause cooling). But this book is for the layman, so he does not use masses of facts and statistics, but rather anecdotal evidence. Instead of using satellite measurements to show the growing Greenland ice cap he recounts that a plane lost in World War II was discovered in 1989 under 87m of ice.

He goes on to show the fallacious science that has been used to blind the public to the reality, with discussion of the role of Climategate where climate scientists exchanged cynical e-mails discussing their fraud and manipulation very openly. He describes the work of the IPCC (Intergovernmental Panel on Climate Change) who publish their political Executive Summaries for politicians months before the actual Scientific Reports. They claim to use first class data but in fact use all kinds of non-refereed reports from green agencies such as Greenpeace instead of scientific evidence. Pierce has a few words to say on the disgraced ex-chairman of the IPCC, Dr. Pachauri, Al Gore's misleading propaganda film, and Michael Mann's infamous hockey-stick.

Why does he do this? It turns out that the author is an ex lawyer who retired to grow grapes in British Colombia. But the weather didn't warm as he had been promised and the business failed. So he started his own investigation.

Of course he found the pause in global warming. But more than this he found a completely different story. Carbon dioxide was barely a player, and the thing that has the best correlation with climate is the sunspot cycle. He describes the cycle using good diagrams and tables, and recounts the climatic history of the past few hundred years, with the Mediaeval Warm Period and the subsequent Little Ice Age. As an aside he gives an account of Mann's famous 'hockey stick' graph showing ever accelerating temperature increase (a one-time logo for the alarmists), the construction of which required the elimination of both the Medieval Warming and the Little Ice Age – which are incontrovertible facts.

He describes the cold periods in the past starting roughly as follows: – the Oort 1000, Wolf 1250, Sporer 1400, Maunder 1645, Dalton 1780 - all related to sun spot minima. And then comes the shocking discovery – we have already started our descent into the next Little Ice Age. Solar Cycle 24 has started, and could be the Solar Cycle with the lowest recorded sunspot activity since accurate records began in 1750, so we are likely to have very cold weather for the next fifty to eighty years. He points out that the minima are not times of permanent cold, but have great variation, with short hot spells and many storms.

In general life is good in the warm spells between little ice ages – the Roman, Medieval and Twentieth century warm periods, but harsh in the cold periods. He ties historical events to his narrative, such as Bonaparte's attack on Moscow in one the very cold winters, the collapse of the Nordic settlement in Greenland, the Irish potato famine and many others. We have come to accept the twentieth century warm as the norm, but the time of abundance is over.

He sees the oncoming Ice Age as a real cause for alarm, and he asks why has it been kept from us? Why are our governments spending trillions to 'avoid' global warming when the real peril is just the reverse, and we have no plans to meet it. He feels cheated that the governments, scientists and journalists who he trusted have in fact completely misled him.

Finally he writes about what to do about the coming cold. Unfortunately this is a very parochial view and really tells people in Canada what to do. 35 out of 125 pages of the main text are devoted to this topic. But he pointed out that during the cold periods of previous little ice ages wiped out hundreds of thousands of people outside Canada by famine and associated war and disease. At present there are many countries, especially in the Middle East, who have booming population growth but are entirely dependent on buying food from elsewhere. If the boundary of the wheat belt in the northern hemisphere moves 300 miles km to the south, they are in jeopardy. Guess what they will do. So if you believe his text you must make your own strategy to survive the hard times that are coming.

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Global Climate Status Report (GCSR)

Edition 1-2015, June. 57p. Space and Science Research Corporation (SSRC), Orlando, USA.
Editors; John L. Casey and Ole Humlum. www.spaceandscience.net

(The following is an excerpt from "Note from the Editor" with permission of SSRC)

In addition to providing the most accurate, independent and un-biased status of the Earth's climate that we can, in this edition we have added an important set of papers covering earthquakes and to a lesser extent, volcanic eruptions.

First a few comments about this edition of the GCSR regarding changes in the 24 climate parameters.

As expected, the intense secondary peak of solar activity observed during solar cycle 24 has caused global temperature increases in certain oceanic and atmospheric parameters which are documented herein. As promised with the first GCSR, we will continue to report climate status as the facts dictate, unaffected by politics or other biased influences.

This rare phenomenon of the secondary peak being more powerful than the first of the two standard peaks at the top of the normal 11 year solar cycle was examined in detail in the December 10, 2014 edition of the GCSR. It was noted then that rather than being a sign of renewed global warming, this amazing event is instead the final sign from the Sun that it gives us before a sustained decline in global temperatures begins. This decline, which will be obvious by the end of 2016, will not end until the bottom of the next global cold era (solar hibernation) is reached. The latter is estimated to be in the year 2031and may last during the entire solar cycle 25 and 26, a period of roughly 22 years. Also previously noted, many of the ill effects of the ongoing new cold climate have already begun. The full range of new global cold is at least a 30 year period. More record cold and snow records should be expected between now and 2031. The first instances of major crop damage from cold effects and the end of the bumper crop era are included in this assessment and were documented in the SSRC Press Release 2-2015. It was titled, "New Cold Climate to Devastate Global Agriculture within Ten Years."

This forecast of solar activity appears to be spot on as the latest solar activity data in this report shows the peak of the solar cycle 24 has now passed and rapid declines in solar parameters are ongoing. This indicates that the predicted dramatic temperature drop is just around the corner.

The SSRC was the first to report the secondary solar cycle peak to the main stream media and our government. Sadly, because this historic climate signal does not follow the false climate science of the current US administration, it has been completely ignored by the US government, the scientific establishment, and both major US political parties. US scientific integrity continues to sink lower with every year we get closer to the bottom of the new cold climate. Enough said of that.

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While past GCSR's have mostly focused on solar, atmospheric and oceanic features of the Earth's climate, this edition, in addition to climate status, is devoted to geophysical events that transpire around the same time we have major declines in solar activity. This means we will address earthquakes and volcanic eruptions that take place during the solar hibernations brought on by the 206 year Bi-Centennial (deVries, Suess) cycle, and the 90-100 year Centennial (Gleissberg) cycle. These cycles are key components of the RC Theory formulated in 2007.

Later in 2010 a preliminary paper was published by me that noted the strong correlation of our worst earthquakes and volcanic eruptions during the bottom or coldest years of solar hibernations. As a result of the latter, leading earthquake theorists and geologists asked me to pull them together into a US based organization to pursue earthquake prediction using the latest state-of-the-art technologies and research in this field. The result was the International Earthquake and Volcano Prediction Center (IEVPC), which became official in February 2012.

Since that time, through two separate test programs, the IEVPC has shown that it can in fact predict some major earthquakes (>M6.0) well in advance. The word “some” is important here. The IEVPC, essentially like its sister company the SSRC, has no ongoing permanent source of funding and accordingly does what it can, when it can, and where it can. Yet, with use of only a few of the many earthquake precursors available in the IEVPC prediction system, it has nonetheless had meaningful success. We believe with full funding where all precursors, personnel, and equipment can be employed, we can achieve never-before-attained levels of major earthquake prediction.

However, what is in great part prompting this special edition of the GCSR, is work completed by Dr. Dong Choi, Director of Research of the IEVPC and myself that examines the history of and future for major earthquakes across the US and the globe during the coming solar hibernation but especially in the well-known New Madrid seismic zone (NMSZ). This zone, that lies roughly between St. Louis, Missouri, and Memphis, Tennessee was the site of the largest set of earthquakes in recorded US history which struck between December 1811 and February 1812. Fortunately, the area back then was sparsely settled and relatively few deaths were reported. This same central US region is now heavily populated with millions of people in major towns and cities, extensive infrastructure including bridges across the Mississippi River and a power grid that includes over a dozen nuclear reactors. Are they rated for M8.0+ earthquakes?

Significantly, in our paper included in this GCSR edition, we show that the threat level for another catastrophic New Madrid quake as bad as the 1811-1812 event, is now at its highest in the past 200 years.

This comes as the Sun enters yet another “solar hibernation,’ where solar energy output declines dramatically bringing a record cold climate to the Earth, just as happened in the 1811-1812 series of New Madrid M7.0 to M8.0 earthquakes. In our paper we reveal that all major NMSZ earthquakes since the year 1400 have happened at the bottom of a solar hibernation. While the mechanism behind these massive temblors striking at the same time the Sun is at lowest ebb and the Earth is coldest is still not understood, the undeniably strong correlation, speaks for itself.

As indicated in the Conclusions section of the paper, we believe every possible precaution should now be taken for what we at the SSRC and the IEVPC believe is a likely event. Four times in a row a major New Madrid quake has struck at the bottom of a solar hibernation. We should take this natural cycle seriously and get ready for number five. If the earth skips this high risk period for the next one, there will still be many benefits to the large scale preparation required. The most likely window for another catastrophe in the NMSZ has already opened with the highest risk period between 2017 and 2038.

Also in this edition are commentaries from other researchers at the IEVPC, each with unique backgrounds and experiences in the field of earthquake research and prediction. It has been my great pleasure to be associated with these selfless and amazingly gifted people for the past three years.

John L. Casey
Editor, Global Climate Status Report
President, Space and Science Research Corporation

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OBITUARY

James Nelson Murdock

James N. Murdock. 1930 – 2015.

James Nelson Murdock passed away on January 10, 2015, after a long illness. Jim was a native of Statesville, North Carolina. After graduating from high school, Jim went into the US Army. When his military service was completed, he attended the University of North Carolina (NC), Chapel Hill. He graduated with a BS degree in Geology in 1959, specializing in geophysics. He continued studying geophysics in graduate school and accepted a job in private industry doing seismological research under contract to the US Air Force. After 4 years he took a position as seismologist with the US Geological Survey in Albuquerque, New Mexico, and spent the rest of his career at the Albuquerque Seismological Laboratory. One of his major accomplishments while with the USGS was the development of an automatic signal detector/picker that successfully emulated a human analyst. It is still in use today. He retired in 1996.

Jim was a good Tarheel fan and contributed heavily to the UNC Geology Dept as well as to several scientific societies of which he was a member.

In his retirement, Jim studied the Aleutian Islands subduction zone and wrote several papers critical of the general thinking on the subject. Some of his papers were published in the New Concepts in Global Tectonics journal.

Jim had various hobbies and interests which occupied his time when not studying subduction zones. He was particularly proud of his roses of which he won awards at the New Mexico State Fair. He also enjoyed training the geese in the pond in his back yard, which were the talk of the neighborhood. Other interests included ballroom dancing (which he took up in his retirement), watching horse racing, and kayaking.

Jim will be sorely missed by his friends and colleagues.

Dale Glover, Banner Elk, NC, and Charles Hutt, huttalbq@aol.com, Albuquerque, NM, USA

List of papers published in *NCGT Newsletter*.

1997. Importance of critically testing the megathrust, Aleutians. No. 4, p. 7-10.

1998. Production of great arcuate troughs and their subsequent deformation: a case study, the Aleutian Island Arc, Part 1. No. 9, p. 23-28.

1999. Deformation of the giant trough of the forearc: the Kodiak Islands region of the eastern Aleutians, Alaska, Part II. No. 10, p. 6-14.

1999. Oceanward propagation of the blind decollement beneath the Kodiak shelf, offshore of Kodiak Island, Alaska, Part III. No. 11, p. 9-19.

1999. Unrecognized failure of a critical test of strict plate tectonics, the trench region offshore of Guatemala, and a comparison with the Aleutians: Part IV. No. 12, p. 2-9.

2002. Overview of two websites hat present interpretations different from strict plate tectonics. No. 24, p. 20-21.

2003. Overview of differences of interpretations of thrust faulting at the Guatemala convergent margin. No. 28, p. 6-7.

Editor's note: James Murdock bequeathed U$3,136 to NCGT, which largely helped improve our financial situation.

CORRIGENDUM

Re: The Tsunoda et al. paper in the last issue, v. 3, no. 1 of *NCGT Journal*, March 2015, p. 34-42.

“These data” in the second line of Acknowledgements (page 42) should read, “Figs. 2, 3, 4, 5 and 6”.

FINANCIAL SUPPORT

The *NCGT Journal* is an open online journal available freely to all individuals and organizations. This means **we have to rely on voluntary donations from readers** as well as commercial advertisements to cover the increasing running costs of the journal. **We welcome your generous financial support.**

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ABOUT THE NCGT JOURNAL
The New Concepts in Global Tectonics Newsletter, the predecessor of the current NCGT Journal, 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 at Smithsonian Institution, Washington, in association with the 28th International Geological Congress in Washington, D. C. in 1989. The NCGT Newsletter changed its name to NCGT Journal in 2013.

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 and prediction of earthquakes, 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.