New Concepts in Global Tectonics

NEWSLETTER

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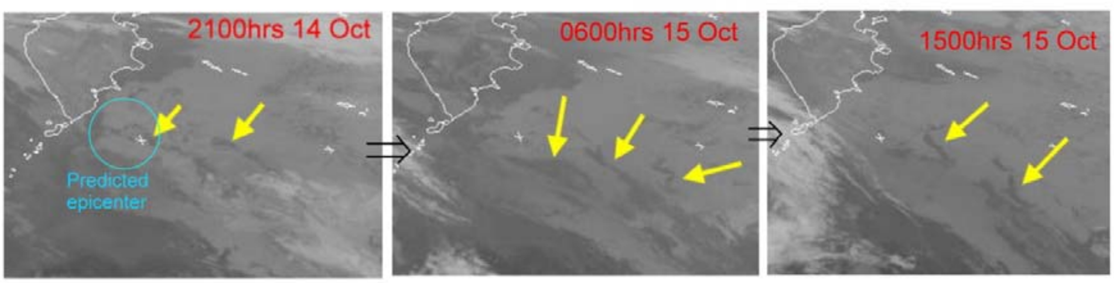
FROM THE EDITOR

The predicted Kamchatka earthquake imminent; spectacular show of nature's force

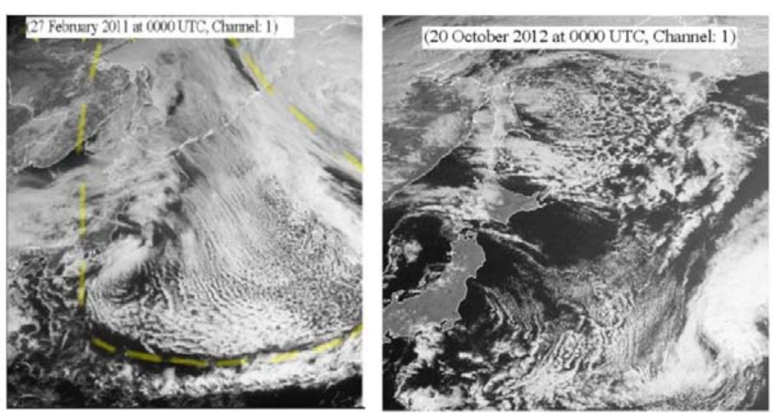
We have at last had a reliable short-term precursory signal; VLF electromagnetic (EM) wave propagation anomaly (ionospheric perturbation) was detected by Masashi Hayakawa on 1 to 3 October between stations in Seattle, USA and Japan. He set the date 10 October with an error margin of few days as a possible day of mainshock and notified to us on 6 October 2012. As the EM signal indicated a flurry of medium magnitude earthquakes (9 quakes with M4.6 to 5.8 by IRIS and EMSC) had occurred between 14 and 18 October along the continental margins of Kamchatka to the central Kuril Islands. All of them were located on three deep-seated fracture systems; ENE-WSW, NWN-SES, and N-S (see page 26 of this NCGT issue). We take them as foreshocks heralding an imminent major shock centered in the offshore southern Kamchatka Peninsula where very active tectonic and thermal activities have been concentrated in the last six months. International Earthquake and Volcano Prediction Center (IEVPC) is closely watching the region today.

Here I am going to show two most outstanding phenomena which we have observed in the last one week; 1) gaping faults as an indicator of the rising crustal high structure, and 2) spectacular clouds appeared from major fracture zones on 20 October 2012 in the northwestern Pacific, which are compared with those appeared 14 days prior to the March 2011 Great East Japan Earthquake.

Other than these we have witnessed many intriguing precursory phenomena. They will be introduced one by one in the future articles. The Choi et al. article in pages 24 to 28 of this NCGT issue focuses on major deep-seated fracture systems which appeared on satellite images and are verified by geological, geophysical and altimetry data.



Gaping cracks seen on 14 and 15 October 2012. They appeared while foreshocks were occurring in the continental slope. Wavy dark lines (with an yellow arrow) are cracks developed in the crust and the mantle. The images are taken by the MTS stationary satellite and are available on http://www.sat.dundee.ac.uk/geobrowse/geobrowse.php. The active region belongs to a NW-SE structural high, where the cracks appeared mainly along the major fracture zones - Mamua Megatrend and its paralleling faults. Orthogonal fracture pattern is recognizable in the crack development.



Spectacular clouds appeared 14 days before the March 2011 Great East Japan Earthquake, left, and similar clouds (but on a smaller scale) appeared on 20 October 2012 in the same region, right. The Kamchatka and Okhotsk Sea area is characterized by concentric cloud pattern with bubbles. These photos prove that a copious amount of energy is discharged before major earthquakes and a wide extent of affected area.

LETTERS TO THE EDITOR

(Note: Paul Burrell sent the following mail to Steven Foster with a copy to the Editor. Paul and Steven agreed to release the letter for NCGT readers)

Dear Dr. Stephen Foster,

I wish to thank you for your rousing letter in *New Concepts in Global Tectonics NEWSLETTER*, no. 63, which I am reading just now.

I agree that the Russians have had the right idea long before many of us in the West caught on (for me, only in the last ten years have the scales fallen from my eyes in terms of global tectonics).

I work in the mineral exploration industry in a management role in Southeast Asia, so am not "hands-on" right now, but I look forward to every issue of NCGT as a gold mine of varying concepts – I agree with you that this is following the true Scientific Method.

Meanwhile, whenever I am mentoring undergraduate or junior geologists, I gently encourage them not to believe everything they are taught and generally the response is surprise; that there is this multitude of perfectly healthy hypotheses and theories being tested and re-tested as observations continue. Very different from an overarching paradigm that smothers the Scientific Method.

Dr. Dong Choi is to be congratulated once again for a delightful newsletter. Dr. Foster, thanks again for your letter.

Best wishes,

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4 August, 2012

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Pressure increases in geothermal plants and the disappearance of bees: Premonitory signals of strong earthquakes? The case of the recent seismic swarm in the Po Valley Plain (Italy)

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The recent earthquakes in the Po Valley Plain (Italy), **Fig. 1**, with a long seismic sequence that began on 20 May 2012 and resulted in seismographs recording 1,000 earthquakes in just 10 days, provided further information on natural and anthropic phenomena that may be associated with seisms of a strong intensity. The most violent tremors occurred on 20 and 29 May, with magnitudes that reached M6, and resulted in considerable damage and a score of deaths. On 18 May 2012, two days before the mainshock, in the city of Ferrara, one of the provinces worst hit by the violent seisms, there had been anomalous values and peaks in the geothermal heating plant values (Bignami, 2012), while countless dead fish had been found in the canals.

Another curious occurrence was the sudden disappearance of the bees (**Fig. 2**) which abandoned their hives just as the seismic swarm began. This phenomenon was observed at San Carlo, a place where a long, metre-wide fracture opened up (**Fig. 3**), with a throw that reached around 50 centimetres locally (**Fig. 4**). Again in San Carlo, the seismic tremors caused the rare phenomenon of the liquefaction of the detrital materials, sand and clays deposited on the riverbeds, which erupted in various places even in and around buildings, fracturing floors, while the pressure of the eruption was sufficient to lift a parked car over a metre from the ground. The phenomenon of these "mud volcanoes" has been observed for over a century in the Emilian plain. Anelli (1915) described the gurgling produced by gases passing through salt water and mud with the following chemical composition: Carbon dioxide (4.25%), Carbon monoxide (0.12%), Oxygen (0.90%), Nitrogen (3.20%), Non-saturated hydrocarbons (0.04%) and Methane (91.40%). The ground under the Emilian plain is rich in hydrocarbons and it is likely that the phenomenon of San Carlo may be associated with this abundance. Instead, the increase in values at geothermal plants is a brand new element in the study of signals preceding a potentially destructive seism. Since a geothermal plant is built as a closed circuit, the increase in pressure observed by the instruments may justifiably be due to an increase in the temperature of the rock below the plant generated by the circulation of fluids through fractures in it. Observation of this event indicates a new avenue and branch of research to be worked on in the future, as part of analyses of seismic precursors.

A further curiosity consists in the sudden disappearance of bees near the large fracture caused by the seism, which ran across nearby farmland and the built up area of San Carlo. Investigations into premonitory signals manifested by animals over the last few years has concentrated on the study of reptiles (Straser, 2012), e.g. for the earthquakes of 23 December 2008 and 27 January 2012, in the area near Parma (North Western Apennines) approximately 100 kilometres from the epicentre areas. If reptiles are sensitive to vibrations in the ground and to temperature, it is known that fish and bees (*apis mellifera*) can perceive magnetic fields thanks to particular protein receptors (Balmori, 2005-2007; Ishay and Gavan, 1999; Walker et al., 1989; Warnke, 2008). Electromagnetic fields, low frequency waves in the ELF range, and radio-interference emissions (**Fig. 5**). We might hypothesize that the production of electromagnetic fields and low frequency waves may have disoriented the animals due to unrecognizable signals with respect to the normal values of the Earth's magnetic field. The electromagnetic alteration generated by strong seisms of a magnitude between M5 and M6 on the Richter Scale alters the frequencies of insects' neuronal receptors dispersing them elsewhere, far from the epicentre area.

References cited

Anelli, M., 1915. Cenni geologici sui dintorni di Traversetolo e Lesignano Bagni. *Bollettino Società Geologica Italiana*, v. XXXIV, Roma.

Balmori, A., 2005 - Possible Effects of Electromagnetic Fields from Phone Masts on a Population of White Stork *(Ciconia ciconia). Electromagnetic Biology and Medicine,* v. 24, p. 109-119

Balmori, A. and Hallberg, O., 2007. The urban decline of the house sparrow *(Passer domesticus):* a possible link with electromagnetic radiation. *Electromagn Biol Med.*, v. 26, no. 2, p.141-151

Bignami, L., 2012. La pianura trema. Focus, n. 237, p. 24-32.

Ishay, J.S., Gavan, J., 1999. "Hypothesis stipulating that a natural radar navigational system guides hornet flight". *Journal Electrom*., v. 13, no. 12, p. 1611-1625.

Straser, V., 2012. "Sensitive Zones", seismic precursors and earthquake. *New Concepts in Global Tectonics Newsletter*, no. 63, p. 4-6

Walker, M.M., Baird, D.L. and Bitterman, M.E., 1989. Failure of stationary but not for flying honeybees (Apis mellifera) to respond to magnetic field stimulate. *Jour. Comp. Physiol.,* v. 103, p. 62-69.

Warnke, U., 2008. Bees, birds and mankind, destroying nature by "electrosmog". www.buergerwelle.de (pdf).
http://www.google.it/imgres/

Fig. 1. Index map of the seismic swarm.


Fig. 2. *Apis mellifera* (http://en.wikipedia.org/wiki/File:Apis_mellifera_carnica_worker_hive_entrance_3.jpg)

Fig. 3. The crack that appeared after the earthquake near San Carlo.

Fig. 4. The difference in level that appeared in the village of San Carlo after the mainshock of 20 May 2012.

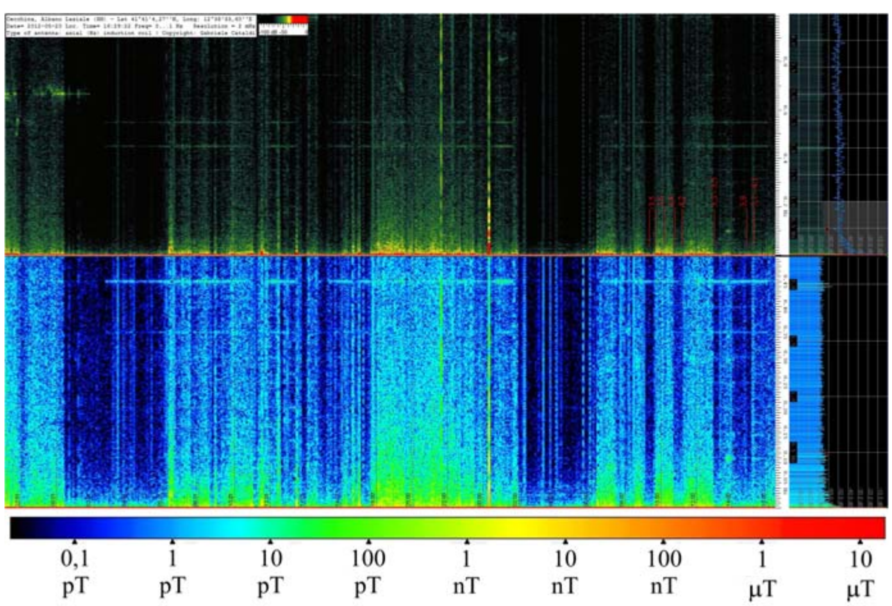

Fig. 5. The radio interference that preceded some of the tremors on 20 May, 2012 (Courtesy Dr. Gabriele Cataldi).

ARTICLES

9/56 YEAR CYCLE: WORLD MEGA VOLCANIC ERUPTIONS

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Abstract: A 9/56 year cycle was found to be applicable in seismic timing for various regions and countries around the world. Additionally, a 9-45 year cycle was established for major world earthquakes (M => 8.5) since 1900. Such cycles were also hypothesised to arise in the timing of mega volcanic eruptions over the past few centuries. A 9/56 year grid was confirmed for more moderate world eruptions (VEI = 4). However, this was not observed for larger events (VEI => 5) and a 9-27/56 year grid was found to be more relevant for these mega events. Strangely, eruptions causing major loss of life could be correlated with a 9/56 year grid, which seemed unusual. It was speculated that patterns based on multiples of 9 and 56 years were caused by Moon-Sun tidal harmonics triggering mega seismic and eruptive events.

Keywords: *9/56 year cycle, earthquakes, volcanoes, eruptions*

Introduction

A 9/56 year cycle was established in the timing of major earthquakes in various countries and regions (McMinn, 2010a, 2010b, 2010c). However, world mega seismic events (M => 8.5) could not be correlated with a 9/56 year cycle, with a 9-45/56 year grid proved to be far more relevant (see Table 12, McMinn 2011b). The latter consisted of a grid repeating intervals of 9, 45, 9, 45, 9...... on the horizontal and 56 years on the vertical. This grid was hypothesised to also apply to mega volcanic eruptions, but no significance could be achieved. Even so, a 9-27/56 year pattern could be firmly established, based on the catalog by the Smithsonian Institute of major eruptions (VEI => 5) since 1600. More moderate events (VEI = 4) appeared selectively in a 9/56 year grid.

Seismic and volcanic catalogs become more unreliable and incomplete the further one goes back in time. Thus, some earlier eruption dates given by the Smithsonian Institute were only guesstimates, for example the 1650 Shiveluch event was given as ± 10 years and the 1660 Long Island event as ± 20 years. These could not be used in the assessment. An unknown major eruption occurred in 1809. Cole-Dai et al (2009) reached this conclusion after ice core analyses revealed large amounts of volcanic sulphur in the 1809 and 1810 layers. The finding applied to samples from both Greenland and Antarctica, indicating that the eruption took place in the tropics. Again from studying ice cores, Crowley et al (2008) viewed mega eruptions as taking place in:

* 1694. Large tropical eruption. Possibly Long Island, offshore New Guinea.
* Mid – late 1804 eruption.
* 1809. Unknown tropical eruption.

Unfortunately, problems arising from the unreliability of the early data cannot be avoided.

The 9/56 year cycle was fundamental in the timing of earthquakes and financial panics and consists of a grid with intervals of 9 years on the horizontal (called sub-cycles) and intervals of 56 years on the vertical (called sequences). The 56 year sequences have been numbered in accordance with McMinn (Appendix 2, 2002), with Sequence 01 being designated as 1817, 1873, 1929, 1985, Sequence 02 as 1818, 1874, 1930, 1986 and so forth. The year of best fit was applied in the various tables presented in the paper. The abbreviation E^o applied to the position of the lunar ascending node on the ecliptical circle and was equivalent to the angle made to the spring equinox point (000 E^o). The term Volcanic Explosivity Index was abbreviated to VEI throughout the text.

9-27/56 Year Grid VEI => 5

A 9/56 year cycle could not be established for the timing of major world eruptions (VEI => 5) since 1600, based on the listing by the Smithsonian Institute (see **Appendix 1**). This was examined in some detail but no significance could be realised. Even so, two grids with repeating intervals of 36 years on the horizontal and 56 years on the vertical were important (see **Table 1**). Grid A in this table was displaced by 9 years in relation to Grid B, thus Grid A plus 9 years gave Grid B. Combining these two grids realised a series with intervals of 9, 27, 9, 27, 9, 27... years on the horizontal and 56 years on the vertical (denoted as a 9-27/56 year cycle). Of the 34 mega eruptions listed by the Smithsonian Institute for the post 1600 epoch, some 18 appeared in **Table 2** (significant $p < .001$). All five events with VEI => 6 prior to 1950 fell in this pattern, but this did not apply to the unknown 1694 and 1809 eruptions or to the more recent 1991 Mt Pinatubo event. The proposed eruption in mid-late 1804 (Crowley et al, 2008) could have taken place in Sequence 44 and within these tables.

Table 1
36/56 YEAR GRIDS AND WORLD MEGA ERUPTIONS SINCE 1600 VEI => 5
Based on a listing by the Smithsonian Institute
Year ending October 20

Grid A

Sq 19		**Sq 55**		**Sq 35**		**Sq 15**		**Sq 51**		**Sq 31**		**Sq 11**
												1603
										1623	+ 36	1659
						1607	+ 36	1643	+ 36	1679	+ 36	1715
				1627	+ 36	**1663 0813**	+ 36	1699	+ 36	1735	+ 36	1771
1611	+ 36	1647	+ 36	1683	+ 36	1719	+ 36	**1755 1017**	+ 36	1791	+ 36	1827
1667 0923	+ 36	1703	+ 36	**1739 0819**	+ 36	1775	+ 36	1811	+ 36	1847	+ 36	**1883 0827**
1725	+ 36	1759	+ 36	1795	+ 36	1831	+ 36	1867	+ 36	1903 **1902 1024**	+ 36	1939
1779	+ 36	**1815 0517**	+ 36	1851	+ 36	1887	+ 36	1923	+ 36	1959	+ 36	1995
1835 0120	+ 36	1871	+ 36	**1907 0328**	+ 36	1943	+ 36	1979	+ 36	2015		
1891	+ 36	1827	+ 36	**1963 0317**	+ 36	1999	+ 36	2035				
1947	+ 36	1983	+ 36	2019								
2003												

Grid B

Sq 48		**Sq 28**		**Sq 08**		**Sq 44**		**Sq 24**		**Sq 04**		**Sq 40**
												1632 **1631 1216**
								1616	+ 36	1652	+ 36	1688
				1600 0219	+ 36	1636	+ 36	1672	+ 36	1708 **1707 1216**	+ 36	1744
		1620	+ 36	1656	+ 36	1692	+ 36	1728	+ 36	1764	+ 36	**1800 0115**
1640 0731	+ 36	1676	+ 36	1712	+ 36	1748	+ 36	1784	+ 36	1820	+ 36	1856

1696	+ 36	1732	+ 36	1768	+ 36	1804	+ 36	1840	+ 36	1876	+ 36	**1912 0606**
1752	+ 36	1788	+ 36	1824	+ 36	1860	+ 36	1896	+ 36	**1932 0510**	+ 36	1968
1808	+ 36	1844	+ 36	1880	+ 36	1916	+ 36	1952	+ 36	1988		
1864	+ 36	1900	+ 36	1936	+ 36	1972	+ 36	2008				
1920	+ 36	**1956 0330**	+ 36	1992	+ 36	2028						
1976	+ 36	2012										

VEI => 6 eruptions presented in **Blue**.
VEI = 5 eruptions presented in **Red**.
Dates denoted as YYYYMMDD.
Abbreviation: VEI - Volcanic Explosivity Index.
Source of Raw Data: Smithsonian Institute. Global Volcanism Program. Large Holocene Eruptions

Table 2
9-27/56 YEAR CYCLE AND WORLD MEGA ERUPTIONS SINCE 1600 VEI => 5
Based on a listing by the Smithsonian Institute
Year ending October 20

Sq 48		**Sq 19**		**Sq 28**		**Sq 55**		**Sq 08**		**Sq 35**		**Sq 44**	
								1600 0219	+27	1627	+9	1636	+27
		1611	+9	1620	+27	1647	+9	1656	+27	1683	+9	1692	+27
1640 0731	+27	**1667 0923**	+9	1676	+27	1703	+9	1712	+27	**1739 0819**	+9	1748	+27
1696	+27	1725	+9	1732	+27	1759	+9	1768	+27	1795	+9	1804	+27
1752	+27	1779	+9	1788	+27	**1815 0517**	+9	1824	+27	1851	+9	1860	+27
1808	+27	**1835 0120**	+9	1844	+27	1871	+9	1880	+27	**1907 0328**	+9	1916	+27
1864	+27	1891	+9	1900	+27	1827	+9	1936	+27	**1963 0317**	+9	1972	+27
1920	+27	1947	+9	**1956 0330**	+27	1983	+9	1992	+27	2019	+9	2028	
1976	+27	2003	+9	2012									

Continued……

Sq 15		**Sq 24**		**Sq 51**		**Sq 04**		**Sq 31**		**Sq 40**		**Sq 11**	
												1603	
								1623	+9	1632 **1631 1216**	+27	1659	
1607	+9	1616	+27	1643	+9	1652	+27	1679	+9	1688	+27	1715	
1663 0813	+9	1672	+27	1699	+9	1708 **1707 1216**	+27	1735	+9	1744	+27	1771	
1719	+9	1728	+27	**1755 1017**	+9	1764	+27	1791	+9	**1800 0115**	+27	1827	
1775	+9	1784	+27	1811	+9	1820	+27	1847	+9	1856	+27	**1883 0827**	
1831	+9	1840	+27	1867	+9	1876	+27	1903	+9	**1912**	+27	1939	

								1902 1024		**0606**			
1887	+9	1896	+27	1923	+9	**1932 0510**	+27	1959	+9	1968	+27	1995	
1943	+9	1952	+27	1979	+9	1988	+27	2015					
1999	+9	2008	+27	2035									

VEI => 6 eruptions presented in **Blue**.
VEI = 5 eruptions presented in **Red**.
Dates denoted as YYYYMDD.
Abbreviation: VEI - Volcanic Explosivity Index.
Source of Raw Data: Smithsonian Institute. Global Volcanism Program.

Seasonality showed up in the 9-27/56 year grid presented in **Table 2**. In Sequences 48 to 15, all eruptions happened either in the four months ending May 20 (6) or in the two months ending September 25 (3). For Sequences 51 to 11, the eruptions were experienced in the month ending June 8 (2) or the 3.7 months ending December 16 (5). The date given for the 1800 Mt St Helens eruption was January 15 ± 120 days and was thus unreliable.

Since 1800, VEI => 5 eruptions usually occurred in clusters every 20 to 30 years, a trend that held up reasonably well apart from the 1822 Galunggung occurrence. The last event in the previous cluster plus 20 years gave the approximate beginning of the next cluster. Given that it has been 21 years since the Mt Pinatubo and Cerro Hudson episodes in 1991, additional mega eruptions will probably take place in the coming decade.

Mega Eruptions VEI => 5	Approximate Duration
1800, 1804*, 1809*, **1815**	15 yrs
1822	Anomalous
1835, 1854	19 yrs
1875, **1883**, 1886	11 yrs
1902, 1907, **1912**, 1913	11 yrs
1932, 1933	2 yrs
1956, 1963	7 yrs
1980, **1991**, 1991	11 yrs

* Mega eruptions according to Crowley et al (2008).
Source of Raw Data: Smithsonian Institute.

9/56 Year Grids VEI => 6
Mega eruptions (VEI => 6) tended to group within 9/56 year patterns. Three happened in only two 56 year sequences (Sqs 08 & 55). From ice core analyses, Crowley et al (2008) believed that a "large tropical eruption" took place in 1694, which showed up in Sequence 46 in the table.

Year ended May 31				
Sq 46		**Sq 55**		**Sq 08**
				1600 0219
1638	+ 9	1647	+ 9	1656
1694 ????	+ 9	1703	+ 9	1712
1750	+ 9	1759	+ 9	1768
1806	+ 9	**1815 0410**	+ 9	1824

1862	+ 9	1871	+ 9	1880
1918	+ 9	1927	+ 9	1936
1974	+ 9	1983	+ 9	1992 **1991** **0615**

The remaining three VEI => 6 eruptions listed by the Smithsonian Institute appeared in the following 9/56 year grid, as did the mysterious 1809 mega eruption.

Year ending August 31								
Sq 31		**Sq 40**		**Sq 49**		**Sq 02**		**Sq 11**
								1603
1623	+ 9	1632	+ 9	1641	+ 9	1650	+ 9	1659
1679	+ 9	1688	+ 9	1697	+ 9	1706	+ 9	1715
1735	+ 9	1744	+ 9	1753	+ 9	1762	+ 9	1771
1791	+ 9	1800	+ 9	**1809** **????**	+ 9	1818	+ 9	1827
1847	+ 9	1856	+ 9	1865	+ 9	1874	+ 9	**1883** **0827**
1903 **1902** **1024**	+ 9	**1912** **0606**	+ 9	1921	+ 9	1930	+ 9	1939
1959	+ 9	1968	+ 9	1977	+ 9	1986	+ 9	1995
2015								

9/56 Year Grid VEI = 4

Historic volcanic eruptions of VEI 4 were also listed by the Smithsonian Institute (see **Appendix 4**). These more moderate events tended to fall within the 9/56 year pattern shown in **Table 3**. Of the 110 episodes during the 1590 – 1940 epoch, some 33 fell in this grid (significant $p < .01$). Post 1940, only 5 eruptions fell in this pattern, which could have been expected by chance.

Table 3 **9/56 YEAR CYCLE: VOLCANIC ERUPTIONS 1590-1940 VEI = 4** **Based on the listing by The Smithsonian Institute** **Calendar years**										
Sq 52	**Sq 05**	**Sq 14**	**Sq 23**	**Sq 32**	**Sq 41**	**Sq 50**	**Sq 03**	**Sq 12**	**Sq 21**	**Sq 30**
							1595 *	1604	1613	**1622** *
	1597 *	**1606** **	1615	1624	1633	1642	1651	**1660** ***	1669	1678
1644	1653	1662	1671	1680	1689	1698	1707	**1716** *	1725	1734
1700	1709	1718	**1727** *	1736	1745	**1754** *	**1763** *	1772	1781	**1790** *
1756	1765	1774	**1783** **	1792	1801	1810	1819	1828	1837	**1846** *
1812 **	1821	1830	1839	1848	**1857** *	1866	1875	1884	**1893** *	**1902** ***
1868	**1877** **	**1886** **	1895	1904	1913	1922	**1931** **	1940		

1924 **	**1933** **									
* Denotes an eruption of VEI = 4.										

Human Fatalities

Blong (1984) presented a listing of post 1600 volcanic eruptions causing over 500 deaths (see **Appendix 2**) and was a commonly quoted reference. Of the 23 volcanic disasters listed, 12 occurred in the 9/56 year grid as presented in **Table 4** (significant p < .01). This particular grid occurred in a similar sector of the complete 9/56 year cycle, which has also been closely linked with:

* the timing of VEI = 4 eruptions for the 1590-1940 period (see **Table 3**).
* the beginnings of Hawaiian volcanic eruptions (see Table 13, McMinn, 2011c).
* the timing of US and Western European financial panics since 1760 (McMinn, 1995).

Table 4
9/56 YEAR CYCLE: DEADLIEST VOLCANIC ERUPTIONS post 1580
Based on the listing by Blong (1984)
Calendar Years

Sq 23	**Sq 32**	**Sq 41**	**Sq 50**	**Sq 03**	**Sq 12**	**Sq 21**	**Sq 30**	**Sq 39**	**Sq 48**	**Sq 01**	**Sq 10**
											1602
					1604	1613	1622	**1631** *	**1640** *	1649	1658
1615	1624	1633	1642	1651	1660	1669	1678	1687	1696	1705	1714
1671	1680	1689	1698	1707	1716	1725	1734	1743	1752	1761	1770
1727	1736	1745	1754	1763	**1772** *	1781	1790	1799	1808	1817	1826
1783 **	**1792** *	1801	1810	1819	1828	1837	1846	1855	1864	1873	1882
1839	1848	1857	1866	1875	1884	1893	**1902** **	**1911** *	1920	1929	1938
1895	1904	1913	1922	1931	1940	1949	1958	1967	1976	**1985** *	1994
1951 **	1960	1969	1978	1987	1996	2005	2014	2023			
2007	2016	2025									
* Denotes a volcanic eruption causing at least 500 deaths.											

The catalog of deadly eruptions by John Seach (see **Appendix 3**) could also be correlated with the 9/56 year grid presented in **Table 4**. A total 36 catastrophes were given, of which 16 occurred in this layout (significant p < .01) (see **Appendix 5**). Interestingly, of the top 12 events causing 4000 or more deaths, 67% showed up in this pattern, while the comparable figure for eruptions with 500 to 3999 fatalities was only 32%.

The database at the National Geophysical Date Center (NGDC) was accessed to produce a listing of world eruptions causing at least 500 deaths since 1600. No correlates (significance p > .05) could be produced with a 9/56 year grid, thus contradicting the findings derived from the compilations of Bong (1984) and John Seach.

Discussion

It seemed unusual that mega earthquakes (M => 8.5) tended to fall in a 9-45 grid since 1900 (see Table 12, McMinn, 2011b), while mega eruptions happened preferentially in a 9-27 pattern over the past 410 years (see **Table 2**). The timing of these two phenomena did not coincide and they seemed to follow different cyclic trends over recent centuries. Less severe eruptions (VEI = 4) mainly took place in a 9/56 year trend, as shown in **Table 3**. By implication, mega eruptions (VEI => 5) may also have a different cyclical timing to less severe episodes (VEI = 4). This was pure speculation and more research is essential before any conclusions can be drawn.

The 9-27 year grid showed up for mega eruptions since 1600 (see **Table 2**) and the beginnings of Hawaiian eruptions from about 1830 (see Table 14, McMinn 2011c). However, only one 56 year sequence (Sq 48) appeared in both patterns and the two phenomena functioned with different cyclic timing.

The correlates between the 9/56 year grid and eruptions causing major loss of life were unexpected and nothing can be offered accounting for this observation. One could expect the biggest eruptions to be the most fatal (eg 1815 Mt Tambora and 1883 Krakatau eruptions), but many of Blong's events do not show up in the Smithsonian Institute's listing of events with a VEI => 5. Much would depend on population densities in the regions surrounding particular active volcanoes.

Cycles based on multiples of 9 and 56 years are found in the timing of eruptions and earthquakes. Presumably they are caused by Moon Sun tidal triggering, as proposed by McMinn (see Appendix 5, 2011a). All events in the 36/56 year Grid A in **Table 1** occurred with the lunar ascending node sited on the ecliptic between 070 and 215 E^{o} (a range of 145 degrees), while for Grid B the ascending node was found between 235 and 035 E^{o} (a range of 160 degrees). There were no exceptions for either sample, which could have been expected from Moon Sun cycles. For any phenomenon clustering in a 9/56 year pattern (eg: world eruptions VEI = 4 in **Table 3**), the lunar ascending node will always be found in two segments approximately opposite in the ecliptic circle, with no exceptions. For events occurring around the same time of year and grouped in the 9/56 year grid, apogee will be sited in three segments 120 degrees apart on the ecliptic circle with no exceptions. For events falling in the same 56 year sequence, the lunar ascending node will be found in a narrow sector of the ecliptical circle with no exceptions.

Cycles clustering in grids of 9-45/56 years (mega quakes) or 9-27/56 years (mega eruptions) may offer clues to help decode worldwide patterns of tectonic events. Overall trends are hypothesised to arise, based on the assumption that Moon – Sun tidal harmonics play a pivotal role in the timing of earthquakes and eruptions. Such forces apply worldwide, but vary according to the particular terrestrial location being assessed.

In the 18.0 year Saros eclipse cycle, the relative angles between the Moon, Sun, ascending node and apogee repeat very closely every 223 lunar months or 6585.32 days. The .32 in the latter figure means that every 223 lunar months a very similar Moon, Sun and ascending node and apogee configuration will be repeated approximately 120 degrees longitude further west, as the Earth has turned an extra one third of a revolution. For a Double Saros of 36 years, the configuration will repeat two thirds further west, while for a triple Saros cycle of 54 years the same alignment will repeat on the same longitude. Every 111.5 lunar months (one 9 year Half Saros), the Moon forms the same angle to the ascending node, with the Sun 180 degrees on the opposite side of the ecliptic circle. 111.5 lunar months equals 3292.66 days and the .66 in the latter figure means that this configuration repeats 240 degrees further west on the Earth's surface. How all this plays out in terms of Moon Sun diurnal cycles at a particular location on the Earth's surface has yet to be considered. Alas, good references on this topic were not readily available to provide vital background information. Obviously the 3rd and 6th tidal harmonics played a key role, but little else can be stated.

Conclusions

Over the past four centuries, mega volcanic eruptions (VEI => 5) have occurred preferentially in a 9-27/56 year layout as given in **Table 2**, while a 9/56 year grid applied to the more moderate eruptions (VEI = 4) (see **Table 3**). The world's deadliest eruptions occurred preferentially in a 9/56 year pattern as shown in **Table 4**, a finding based on the listings by Blong (1984) and John Seach (but not supported by NGDC data). Correlates between the 9/56 year grid and the deadliest volcanic events were puzzling.

The findings presented in this paper are of great interest and contribute to the body of work on the 9/56 year cycle. Much more research is required to confirm or negate this new paradigm. If the Moon Sun-tidal harmonics can ever be deciphered, accurate predictions of future major eruptions and earthquakes may become possible. This has been the Holy Grail in tectonic studies over the past century, but achieving this goal has remained very elusive.

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References

Blong, R J. 1984. Volcanic Hazards: A Sourcebook on the Effects of Eruptions. Academic Press, 1984.

Cole-Dai, J., Ferris, D., Lanciki, A., Savarino, J., Baroni, M. and Thiemens, M.H., 2009, Cold decade (AD 1810–1819) caused by Tambora (1815) and another (1809) stratospheric volcanic eruption, *Geophys. Res. Lett.*, 36, L22703, doi:10.1029/2009GL040882.

Crowley, T.J. et al., 2008. Volcanism and The Little Ice Age. *PAGES News*. Vol 6. No 2. p 22-23. April.

Mason, B.G., Pyle, D.M., Dade, W.B. and Jupp, T., 2004. Seasonality of Volcanic Eruptions. *Journal of Geophysical Research*. Vol 109, B04206, 12 PP. doi:10.1029/2002JB002293

McMinn, D., 1995. Financial Crises & The 56 Year Cycle. Twin Palms Publishing. 103p.

McMinn, D., 2002. 9/56 Year Cycle: Financial Crises. http://www.davidmcminn.com/pages/fcnum56.htm

McMinn, D., 2011a. 9/56 Year Cycle: Californian Earthquakes. *New Concepts In Global Tectonics Newsletter*, no. 58. p. 33-44.

McMinn, D., 2011b. 9/56 Year Cycle: Record Earthquakes. *New Concepts In Global Tectonics Newsletter*, no. 59. p. 88-104.

McMinn, D., 2011c. 9/56 Year Cycle: Earthquakes in Selected Countries. *New Concepts in Global Tectonics Newsletter*, no. 60, p. 9-37.

McMinn, D., 2012a. 9/56 Year Cycle: Earthquakes in Peru, The Philippines and Selected US States. *New Concepts in Global Tectonics Newsletter,* no. 62, p. 23-30.

McMinn, D., 2012b. Financial Cycles: A Key to Deciphering Seismic Cycles? *New Concepts in Global Tectonics Newsletter.* No 63. p 15-36. June.

Seach, J., Volcano Eruption Fatalities.

Smithsonian Institute. Global Volcanism Program. Large Holocene Eruptions. http://www.volcano.si.edu/world/largeeruptions.cfm

Appendix 1
WORLD VOLCANIC MEGA ERUPTIONS SINCE 1600 VEI => 5
Listing by the Smithsonian Institute

VEI	DATE	VOLCANO	COUNTRY
6	**1600 Feb 19**	**Huaynaputina**	**Peru**
5	1625 Sep 02	Katla	Iceland
5?	1630 Sep 03	Furnas	Azores
5	**1631 Dec 16**	**Vesuvius**	**Italy**
5	**1640 Aug 31**	**Komaga-Take**	**Japan**
5?	1641 Jan 04	Parker	Philippines
5	1650 ± 10 yrs*	Shiveluch	Kamchatka Russia
6	1660 ± 20 yrs*	Long Island	Papua New Guinea
5	**1663 Aug 16**	**Usu**	**Japan**
5	**1667 Sep 23**	**Shikotsu**	**Japan**
5?	1673 May 20	Gamkokora	Indonesia
5?	1680 ?? ??	Tongkko	Indonesia
5	**1707 Dec 16**	**Fuji**	**Japan**
5?	1721 May 11	Katla	Iceland
5	**1739 Aug 19**	**Shikotsu**	**Japan**
5?	**1755 Oct 17**	**Katla**	**Iceland**
5	**1800 Jan 15 ± 120 days**	**Mt St Helens**	**Washington USA**
7	**1815 May 10**	**Tombora**	**Indonesia**

5	1822 Oct 08	Galunggung	Indonesia
5	**1835 Jan 20**	**Cosiguina**	**Nicaragua**
5	1854 Feb 18	Shiveluch	Kamchatka
5	1875 Mar 25	Askja	Iceland
6	**1883 Aug 27**	**Krakatau**	**Indonesia**
5	1886 Jan 11	Okataina	New Zealand
6	**1902 Oct 24**	**Santa Maria**	**Guatemala**
5	**1907 Mar 28**	**Ksudach**	**Kamchatka Russia**
6	**1912 Jun 06**	**Novarupta**	**Alaska USA**
5	1913 Jan 20	Colima	Mexico
5	**1932 Apr 10**	**Azul Cerro**	**Chile**
5	1933 Jan 08	Kharimkotan	Kuriles Russia
5	**1956 Mar 30**	**Bezymianny**	**Kamchatka Russia**
5	**1963 Mar 17**	**Agung**	**Lesser Sunda Is**
5	1980 May 18	Mt St Helens	Washington USA
6	1991 Jun 15	Mt Pinatubo	Philippines
5	1991 Aug 12	Cerro Hudson	Chile

* Imprecise date could not be used in the calculations.
Events in **bold** fell within the 9-27/56 year cycle as shown in **Table 2**.
Abbreviation: VEI - Volcanic Explosivity Index
Source: Smithsonian Institute. Global Volcanism Program. Large Holocene Eruptions.

Appendix 2
VOLCANIC ERUPTIONS POST 1600 CAUSING AT LEAST 500 DEATHS
Listing by Blong (1984)

Volcano	**Year**	**1. Deaths**	**Major cause of deaths**
Tambora, Indonesia	1815	92,000	Starvation
Krakatau, Indonesia	1883	36,417	Tsunami
Mount Pelee, Martinique	**1902**	**29,025**	**Ash flows**
Ruiz, Colombia	**1985**	**25,000**	**Mudflows**
Unzen, Japan	**1792**	**14,300**	**Volcano collapse, tsunami**
Laki, Iceland	**1783**	**9,350**	**Starvation**
Kelut, Indonesia	1919	5,110	Mudflows
Galunggung, Indonesia (a)	1822	4,011	Mudflows
1. Vesuvius, Italy	**1631**	3,500	**2. Mudflows, lava flows**
Papandayan, Indonesia	**1772**	**2,957**	**Ash flows**
Lamington, Papua New Guinea	**1951**	**2,942**	**Ash flows**
El Chichon, Mexico	1982	2,000	Ash flows
Soufriere, St. Vincent	**1902**	**1,680**	**Ash flows**
Oshima, Japan	1741	1,475	Tsunami
Asama, Japan	**1783**	**1,377**	**Ash flows, mudflows**
Taal, Philippines	**1911**	**1,335**	**Ash flows**
Mayon, Philippines	1814	1,200	Mudflows
Agung, Indonesia	1963	1,184	Ash flows
Cotopaxi, Ecuador	1877	1,000	Mudflows
Pinatubo, Philippines	1991	800	Disease
Komagatake, Japan	**1640**	**700**	**Tsunami**
Ruiz, Colombia	1845	700	Mudflows
Hibok-Hibok, Philippines	**1951**	**500**	**Ash flows**

Eruptions highlighted in **bold** fall in the 9/56 year grid as presented in **Table 3**.
(a) The 1822 eruption was incorrectly listed by Bong (1984) as occurring in 1882.
The table included "All eruptions with more than 500 known human fatalities."
Source: Blong 1984.

Appendix 3
ERUPTIONS POST 1580 CAUSING AT LEAST 500 DEATHS
Listing by John Seach

Fatalities	Volcano	Location	Year
92 000	Tambora	Indonesia	1815
36 000	Krakatau	Indonesia	1883
29 000	**Mt Pelee**	**Martinique**	**1902**
28 000	**Nevado del Ruiz**	**Colombia**	**1985**
15 000	**Unzen**	**Japan**	**1792**
10,000	**Kelut**	**Indonesia**	**1586**
10 000	**Laki**	**Iceland**	**1783**
6 000	**Santa Maria**	**Guatemala**	**1902**
5100	Kelut	Indonesia	1919
5000	**Santiaguito**	**Guatemala**	**1929**
4000	Galunggung	Indonesia	1822
4000	**Vesuvius**	**Italy**	**1631**
3500	El Chichon	Mexico	1982
3200	Awu	Indonesia	1711
3000	Merapi	Indonesia	1672
2951	**Papandayan**	**Indonesia**	**1772**
2900	**Lamington**	**PNG**	**1951**
2806	Awu	Indonesia	1856
2000	Nyiragongo	DR Congo	1977
1700	Nyos	Cameroon	1986
1500	**La Soufriere**	**Saint Vincent**	**1902**
1500	**La Soufriere**	**Saint Vincent**	**1902**
1500	Awu	Indonesia	1892
1480	Oshima-Oshima	Japan	1741
1330	**Taal**	**Philippines**	**1911**
1300	Merapi	Indonesia	1930
1200	Mayon	Philippines	1814
1200	**Asama**	**Japan**	**1783**
1100	Agung	Indonesia	1963
1000	Raung	Indonesia	1638
1000	Nevado del Ruiz	Colombia	1845
960	Awu	Indonesia	1812
800	Cotopaxi	Ecuador	1742
740	Pinatubo	Philippines	1991
500	Iliwerung	Indonesia	1979
500	**Rabaul**	**PNG**	**1938**
500	**Hibok-Hibok**	**Philippines**	**1951**

Eruptions highlighted in **bold** fall in the 9/56 year grid as presented in **Appendix 5**.
The appendix included all events causing 500 or more fatalities.
Source: John Seach. Volcano Eruption Fatalities.

Appendix 4
WORLD VOLCANIC MEGA ERUPTIONS SINCE 1600 VEI = 4
Listing by the Smithsonian Institute

Vocano Name	**Region**	**Date**	**Volcano Name**	**Region**	**Date**
Merapi	Java Id	2010 Nov 5	Kliuchevskoi	Kamchatka	1829 Sep 9
Eyjafjallajokull	Iceland	2010 Apr 14	Avachinsky	Kamchatka	1827 Jun 27
Sarychev Peak	Kuril Is	2009 Jun 11	Kelut	Java Id	1826 Oct 11
Kasatochi	Aleutian Is	2008 Aug 7	Isanotski	Aleutian Is	1825 Mar 10
Okmok	Aleutian Is	2008 Jul 12	Usu	Hokkaido Jp	1822 Mar 12
Chaiten	Chile	2008 May 2	Colima	México	1818 Feb 15
Rabaul	New Britain	2006 Oct 7	Raung	Java Id	1817 Jan 16
Manam	**New Guinea**	**2005 Jan 27**	Mayon	Luzon Ph	1814 Feb 1
Reventador	Ecuador	2002 Nov 3	Suwanose-Jima	Ryukyu Is Jp	1813
Ruang	Indonesia	2002 Sep 25	**Awu**	**Indonesia**	**1812 Aug 6**
Shiveluch	Kamchatka	2001 May 22	**Soufriere StV**	**West Indies**	**1812 Apr 27**

Ulawun	New Britain	2000 Sep 29	Pago	New Britain	1800 ?
Rabaul	New Britain	1994 Sep 19	Westdahl	Aleutian Is	1795
Lascar	Northern Chile	1993 Apr 19	San Martin	México	1793 Mar 2
Spurr	Alaska	1992 Jun 27	Alaid	Kuril Is	1793 Feb
Kelut	Java Id	1990 Feb 10	**Kilauea**	**Hawaiian Is**	**1790 Nov ?**
Kliuchevskoi	Kamchatka	1990 Jan 30	Etna	Italy	1787 Jul 18
Chikurachki	Kuril Is	1986 Nov 20	Pavlof	Alaska	1786
Augustine	Alaska	1986 Mar 27	**Asama**	**Honshu Jp**	**1783 Aug 3**
Colo	Sulawesi Id	1983 Jul 23	**Grimsvotn**	**Iceland**	**1783 Jun 8**
Galunggung	Java Id	1982 May 17	Sakura-Jima	Kyushu Jp	1779 Nov 8
El Chichon	México	1982 Mar 28	Raikoke	Kuril Is	1778
Pagan	Mariana Is	1981 May 15	Usu	Hokkaido Jp	1769 Jan 23
Alaid	Kuril Is	1981 Apr 30	Cotopaxi	Ecuador	1768 Apr 4
Augustine	**Alaska**	**1976 Jan 22 ?**	Helka	Iceland	1766 Apr 5
Tolbachik	Kamchatka	1975 Jul 6	Michoacan-Guanajuato	México	1764
Fuego	Guatemala	1974 Oct 17	**Miyake-Jima**	**Izu Is Jp**	**1763 Aug 17**
Tiatia	Kuril Is	1973 Jul 14	Planchon-Peteroa	Central Chile	1762 Dec 3
Fernandina	Galápagos Is	1968 Jun 11	Makian	Halmahera Id	1760 Sep 22
Awu	Indonesia	1966 Aug 12	Michoacan-Guanajuato	México	1759 Sep 29
Kelut	Java Id	1966 Apr 26	**Taal**	**Luzon Ph**	**1754 Nov 28**
Taal	Luzon Ph Ph	1965 Sep 28	Ksudach	Kamchatka	1750 ?
Shiveluch	Kamchatka	1964 Nov 12	Taal	Luzon Ph	1749 Aug 11 ?
Agung	Indonesia	1963 May 16	Cotopaxi	Ecuador	1744 Nov 30
Carran–Los Venados	Central Chile	1955 Jul 27	Oshima-Oshima	Hokkaido Jp	1741 Aug 29
Spurr	Alaska	1953 Jul 9	Fuego	Guatemala	1737 Aug 27
Bagana	Bougainville Is	1952 Feb 29	**Oraefajokull**	**Iceland**	**1727 Aug 3**
Kelut	**Java Id**	**1951 Aug 31**	Cerro Bravo	Colombia	1720 ± 150 yrs*
Lamington	**New Guinea**	**1951 Jan 21**	Raoul Island	Kermadec Is	1720 ± 50 yrs*
Ambrym	**Vanuatu**	**1951**	Fuego	Guatemala	1717 Aug 27
Hekla	Iceland	1947 Mar 29	**Taal**	**Luzon Ph**	**1716 Sep 24**
Sarychev Peak	Kuril Is	1946 Nov 9	Chirpoi	Kuril Is	1712 Dec 31 ± 365 days*
Avachinsky	Kamchatka	1945 Feb 25	Komaga Take	Hokkaido Jp	1694 Jul 4
Michoacan-Guanajuato	México	1943 Feb 20	Serua	Banda Sea	1693 Jun 4
Rabaul	New Britain	1937 May 29	Hekla	Iceland	1693 Feb 13
Kuchinoerabu Jima	**Ryukyu Is Jp**	**1933 Dec 24**	Chikurachki	Kuril Is	1690 ± 10 yrs*
Suoh	**Sumatra Id**	**1933 Jul 10**	**Katla**	**Iceland**	**1660 Nov 3**
Fuego	Guatemala	1932 Jan 21	**Guagua Pichincha**	**Ecuador**	**1660 Oct 27**
Aniakchak	**Alaska**	**1931 May 11**	**Teon**	**Banda Sea**	**1660 Feb**
Kliuchevskoi	**Kamchatka**	**1931 Mar 25**	Taranaki	New Zealand	1655 ?
Komaga-Take	Hokkaido Jp	1929 Jun 17	Santorini	Greece	1650 Sep 27
Avachinsky	Kamchatka	1926 Apr 5	Makian	Halmahera Id	1646 Jul 19
Iriomote-Jima	**Ryukyu Is Jp**	**1924 Oct 31**	Kelut	Java Id	1641
Raikoke	**Kuril Is**	**1924 Feb 15**	Komaga-Take	Hokkaido Jp	1640 Jul 31
Manam	New Guinea	1919 Aug 11	Llaima	Central Chile	1640 Feb
Kelut	Java Id	1919 May 19	Raung	Java Id	1638
Katla	Iceland	1918 Oct 12	Raoul Island	Kermadec Is	1630 ± 50 yrs*
Tungurahua	Ecuador	1918 Apr 5	**Colima**	**México**	**1622 Jun 8**
Agrigan	Mariana Is	1917 Apr 9	Katla	Iceland	1612 Oct 12
Sakura-Jima	Kyushu Jp	1914 Jan 12	**Colima**	**México**	**1606 Dec 13**
Lolobau	**New Britain**	**1911**	**Colima**	**México**	**1606 Nov 25**
Vesuvius	Italy	1906 Apr 8	Momotombo	Nicaragua	1605
Lolobau	New Britain	1905	Suwanose-Jima	Ryukyu Is Jp	1600 ?
Grimsvotn	Iceland	1903 May 28	**Hekla**	**Iceland**	**1597 Jan 3**
Pelee	**West Indies**	**1902 May 8**	**Nevado del**	**Colombia**	**1595 Mar 12**

			Ruiz		
Soufriere StV	**West Indies**	**1902 May 6**	Colima	México	1585 Jan 10
Pelee	**West Indies**	**1902 May 2**	Fuego	Guatemala	1582 Jan 14
Dona Juana	Colombia	1899 Nov 13	Fuego	Guatemala	1581 Dec 26
Mayon	Luzon Ph	1897 Jun 25	Katla	Iceland	1580 Aug 11
Calbuco	**Southern Chile**	**1893 Jan 10**	Cayambe	Ecuador	1570 ?
Colima	México	1890 Feb 16	Aniakchak	Alaska	1560 ± 50 yrs*
Suwanose-Jima	Ryukyu Is	1889 Oct 2	Maly Semiachik	Kamchatka	1550 ?
Bandai	Honshu Jp	1888 Jul 15	Pago	New Britain	1550 ?
Niuafo'ou	**Tonga Is**	**1886 Aug 31**	Katla	Iceland	1550 ?
Tungurahua	**Ecuador**	**1886 Jan 11**	Augustine	Alaska	1540 ± 100 yrs*
Augustine	Alaska	1883 Oct 6	Cotopaxi	Ecuador	1534 Jun
Fuego	Guatemala	1880 Jun 28	Cotopaxi	Ecuador	1532 Nov 15
Cotopaxi	**Ecuador**	**1877 Jun 26**	Telica	Nicaragua	1529
Suwanose-Jima	**Ryukyu Is Jp**	**1877**	**Hekla**	**Iceland**	**1510 Jul 25**
Grimsvotn	Iceland	1873 Jan 8	Katla	Iceland	1500 ?
Merapi	Java Id	1872 Apr 15			
Sinarka	Kuril Is	1872			
Makian	Halmahera Id	1861 Dec 28			
Katla	Iceland	1860 May 8			
Fuego	**Guatemala**	**1857 Jan 15**			
Komaga-Take	Hokkaido Jp	1856 Sep 25			
Usu	Hokkaido Jp	1853 Apr 22			
Fonualei	**Tonga Is**	**1846 Jun 11 ?**			
Hekla	Iceland	1845 Sep 2			
Babuyan Claro	Luzon Ph	1831			

* Imprecise date could not be used in the calculations.
Abbreviations: Is – Islands, Jp – Japan, Ph – Philippines, Id – Indonesia. StV – St Vincent.
Source: Smithsonian Institute. Global Volcanism Program. Large Holocene Eruptions.

Appendix 5
9/56 YEAR CYCLE: DEADLIEST VOLCANIC ERUPTIONS post 1580
Based on the listing by John Seach
Calendar Years

Sq 23	**Sq 32**	**Sq 41**	**Sq 50**	**Sq 03**	**Sq 12**	**Sq 21**	**Sq 30**	**Sq 39**	**Sq 48**	**Sq 01**	**Sq 10**
									1584	1593	1602
			1586 *	1595	1604	1613	1622	**1631 ***	1640	1649	1658
1615	1624	1633	1642	1651	1660	1669	1678	1687	1696	1705	1714
1671	1680	1689	1698	1707	1716	1725	1734	1743	1752	1761	1770
1727	1736	1745	1754	1763	**1772 ***	1781	1790	1799	1808	1817	1826
1783 **	**1792 ***	1801	1810	1819	1828	1837	1846	1855	1864	1873	1882
1839	1848	1857	1866	1875	1884	1893	**1902 ********	**1911 ***	1920	**1929 ***	**1938 ***
1895	1904	1913	1922	1931	1940	1949	1958	1967	1976	**1985 ***	1994
1951 **	1960	1969	1978	1987	1996	2005	2014	2023			
2007	2016	2025									

* Denotes a volcanic eruption causing at least 500 deaths.

WHENCE THE CARIBBEAN?

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The Caribbean has long puzzled geologists. In the first half of the 20th century opinion on its crustal origin was divided between ocean becoming continent and continent becoming ocean – but continent was involved.

In 1966, Tuzo Wilson proposed that the Lesser Antilles volcanic arc was the leading edge of a lithospheric raft moving eastwards relative to North and South America, giving rise to the Pacific – and thus, oceanic – origin of the Caribbean. At the same time the "Plate tectonic revolution" was taking shape.
Since then, the most quoted model for the origin of the Caribbean has been that it formed as Jurassic oceanic crust in the Pacific, where it thickened to a 20-kilometer pile of basalt in the Cretaceous. This collided with an intra-oceanic volcanic arc, driving it east to form the Greater and Lesser Antilles.
The least quoted model, held by a (Galilean) minority that includes me, is that the area evolved in place between diverging North and South America.

While Wilson advanced his ideas, Russian oceanographers (e.g. Beloussov, 1970) urged caution until further data were obtained. Today, they, among others, continue to note abundant samples of continental rocks retrieved from deep oceans and highlight Deep Sea Drilling Project (DSDP) samples of mid-Jurassic to Miocene shallow-water deposits and sub-aerially weathered rocks now at depths of one to seven kilometers in the Atlantic, Indian and Pacific (e.g. Ruditch, 1990; Vasiliev and Yano, 2007; Yano et al., 2009 and 2011).

In the West, Mid-Atlantic Ridge beach sands and continental rocks that puzzled Woods Hole scientist Maurice Ewing (1948, 1949) are generally overshadowed (ignored inconveniences) by the plate tectonic paradigm.

Depending on data

Earlier, Alfred Wegener (1912, 1929) had proposed that continents drifted apart. Original continuity suggested by sedimentology, palaeontology and geometrical fit of shorelines in the south Atlantic was reinforced by the famous Bullard (1965) computer fit of continents along their 2,000-meter deep margins. This, however, had problems of overlap in Central America and the Blake-Bahamas-Florida platform – and ignored data for the Caribbean. British geologist Anthony Hallam (1971) wrote, "Of the alternative initial fits of the continents, that along the boundaries of the Quiet Magnetic Zones is preferred" (see later).

Post-Bullard models creatively reconstructed Middle America by placing continental blocks Maya (Yucatán) and Chortís (Honduras-Nicaragua-Jamaica) (**Fig. 1**) in the Gulf of Mexico and alongside southwest Mexico, whence they enthusiastically rotated 135 degrees and 180 degrees anticlockwise into today's positions.

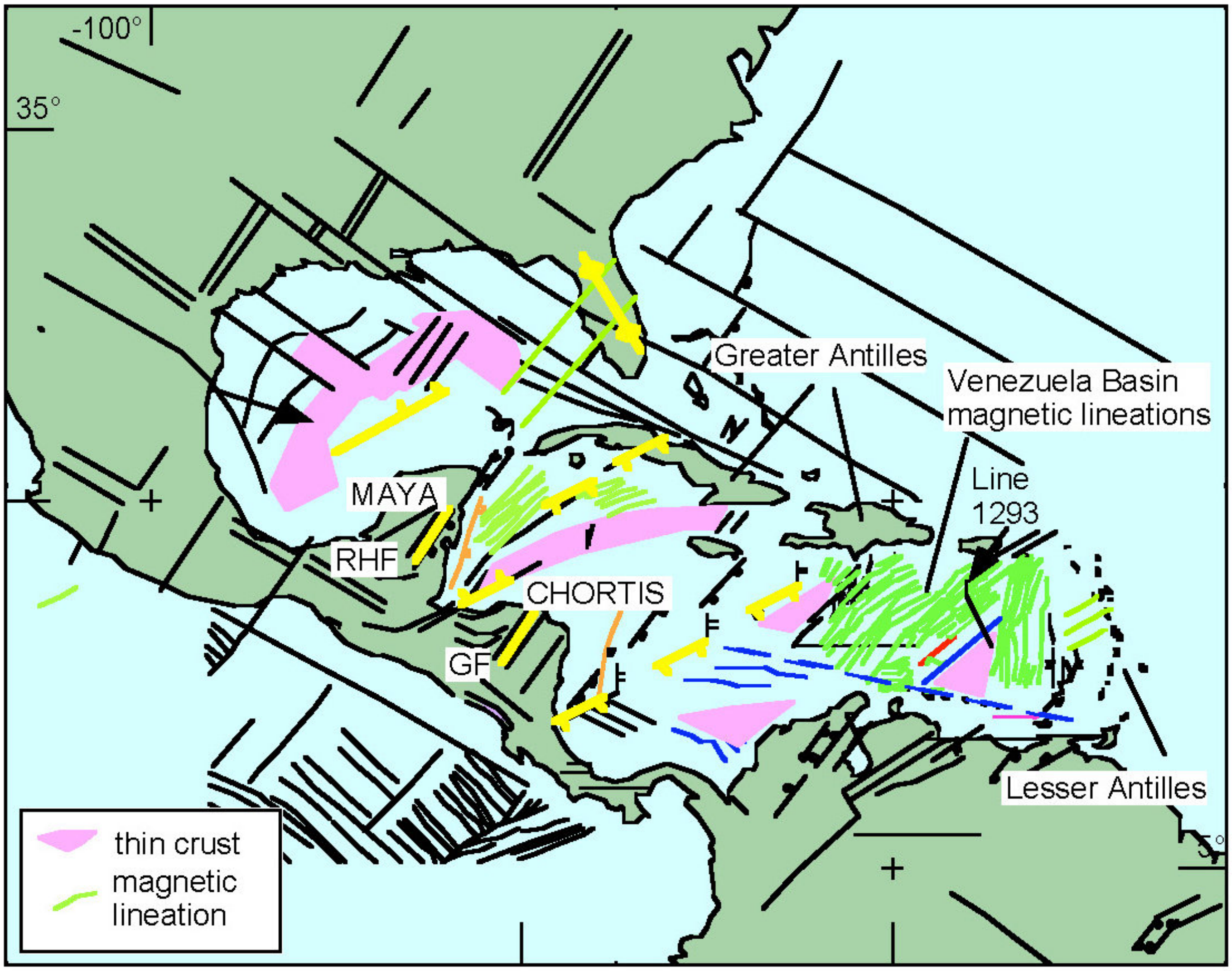

Fig. 1. Tectonic fabric of Middle America. RHF – Rio Hondo Fault, GF – Guayape Fault. James, 2009, Fig. 3.

Or both could have rotated clockwise from the Gulf – there are all sorts of possibilities. Data, however, would have it otherwise.

A northeast trending Jurassic graben (Guayape F.) crosses Chortis, precisely parallel to a similar feature on the Maya (Rio Hondo F., Yucatan). The grabens continue, offset to the east, the trend of Triassic-Jurassic grabens in the Gulf of Mexico, below the Coastal Plain and along eastern North America, where offshore seismic shows seaward-dipping wedges of reflections and drilling has touched salt diapirs. Neither Maya nor Chortis has rotated – Chortis always has been at the western end of the Caribbean and its presence obviates any plate migration from the Pacific.

A few DSDP sites on thick Caribbean crust – the Caribbean "Plateau" – reached upper Cretaceous, shallow marine or sub-aerial basalt. Seismic data show wedges of reflections here as well, below the basalt. "Oceanic" eyes interpret these as volcanic deposits. Peaks, surrounded by moats and rising from the sea floor are seamounts.

These data, however, mimic the north Atlantic Vøring, Møre and Rockall Plateaus, where continental basement lies below sedimentary layers five-10 kilometers thick and basalts. This is the classic signature of submarine extended continent. Thus, in the Caribbean I see continental crust, rifted and extended in the Triassic-Jurassic, Cretaceous carbonates and salt diapirs with rim synclines (**Fig. 2**), continuing the geology of offshore eastern North America but including basalt flows.

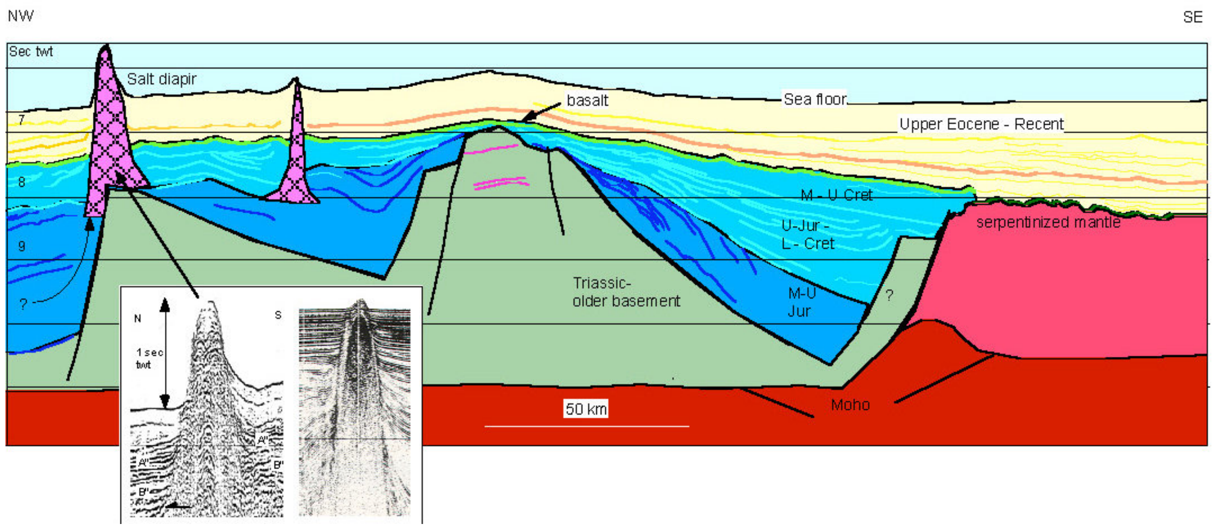

Fig. 2. (Re)Interpretation of seismic line 1293 (location Fig. 1) over the Venezuela Basin. Inset: comparison of "seamount" (left) with drilled, Challenger salt diapir, Gulf of Mexico (right).

Some evidence emerges

Fig. 3 shows magnetic data over the south Atlantic. Magnetic stripes attributed to 84 million years of seafloor spreading appear in the center of the ocean. Between these and land the magnetic signatures of South America and Africa show important continuations offshore. Rather than "Cretaceous Quiet Zone" – oceanic crust formed when the Earth forgot to reverse its magnetic field for 40 million years – these areas are subsided, extended continental crust.

Reconstruction of South America-Africa along the margins of these extensions provides the good "Pangaean" (**Fig. 3 inset**) suggested by Hallam. It shows continental masses significantly larger than currently recognized. Before subsidence, dinosaurs, freshwater fish and snails, mammals and flowering plants migrated merrily along direct, overland routes between Europe, South America, Africa and Madagascar, blissfully unaware of "biodispersal problems."

Drilling in increasingly deep water (current deep rigs rated to four kilometers) is providing evidence of this considerable continental subsidence. Cretaceous shallow marine limestones offshore Brazil now lie at seven kilometers, below thick salt and more than two kilometers of water. The step into deep water and the amazing recent discoveries there (Tupi/Lula) came after new geological concepts and analogs were imported from the North Sea and Gulf of Mexico.

How does this relate to the Caribbean?

If your curiosity is piqued, compare seismic data over the Santos Basin and the Caribbean "plateau" (hints: mobile salt, shelf break carbonate buildups).

Magnetic data over the Caribbean show extended continent signature – classic oceanic magnetic striping is not present. Detailed magnetic data do show lineaments, but these reflect crustal structure. They trend northeast, parallel to the grabens of Maya, Chortís and North America.

What other data support continental origins for the Caribbean? Crustal thicknesses, tectonic fabric, highly silicic volcanic rocks, gravity data, stratigraphy and palaeontology all converge in this direction.

Shallow marine Eocene and Oligocene (on the Bahamas) limestones now kilometers deep show that geologically recent subsidence occurred here also.

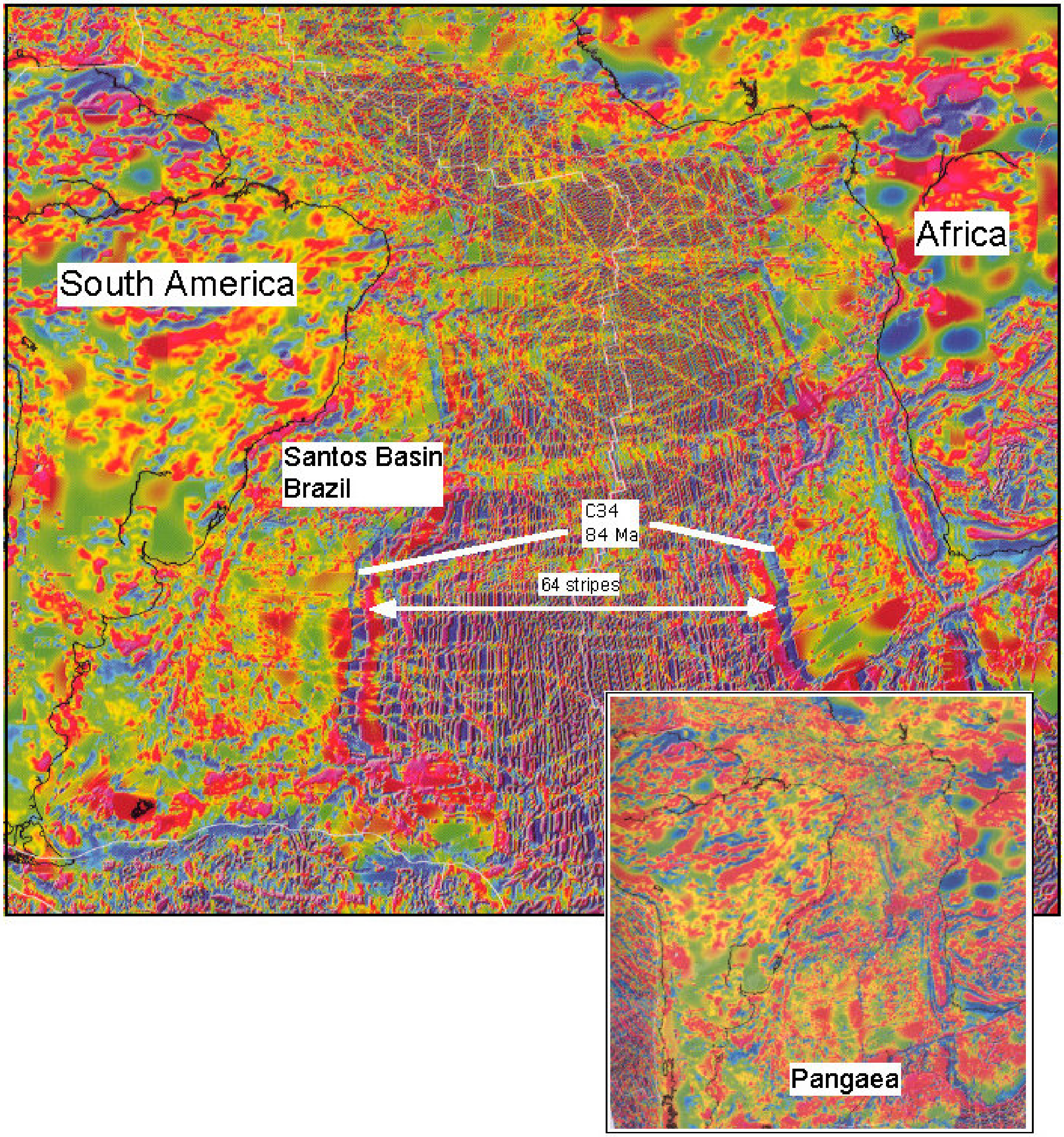

Fig. 3. Magnetic data (from Korhonen et al., 2007, Magnetic Anomaly Map of the World), S Atlantic. Inset: "Pangaean" reconstruction.

The big question

Could hydrocarbons be present in the Caribbean?

The similarity with offshore North America suggests at least a Jurassic system, with associated salt, below the basalts drilled by DSDP.

Basalt is not a problem – Ireland's Corrib Field taps gas from sandstones below basalt and vesicular/fractured basalt hosts oil in Japan's Yurihara Field. Sub-basalt exploration is under way offshore Norway and India.

I'll bet the Caribbean carries significant hydrocarbon resources. I anticipate that changes in vision will lead to these and to paradigm shifts in Caribbean and global plate tectonics.

Whichever model one chooses affects the bottom line for petroleum geology:

- If entirely basaltic and derived from the Pacific, the Caribbean will not carry hydrocarbons.
- If formed in-situ, sharing history with northern South America, the Gulf of Mexico and eastern North America … well, that's another story.

References cited

Beloussov, V.V., 1970. Against the hypothesis of ocean-floor spreading. *Tectonophysics*, v. 9, p. 489 - 511.

Bullard, E.C., Everett, J.E. and Smith, A.G., 1965. The fit of the continents around the Atlantic. *Royal Society of London Philosophical Transactions*, Ser. A., v. 258, p. 41-51.

Ewing, M., Walker, J., Henry, T.R., Llocke, J.N., Watson, D., Culver, W.R., Vosburg, F.G., Stewart, B.A., And Wharton, C.H., 1948, Exploring the Mid Atlantic Ridge. *National Geographic Magazine*, September, v. XCIV, no. 3.

Ewing, M., 1949. New Discoveries on the Mid Atlantic Ridge. *National Geographic Magazine*, September, v. XCVI, no. 5.

Hallam, A., 1971. Mesozoic geology and the opening of the North Atlantic. *Jour. Geology*, v. 79, no. 2, p. 129-157.

James, K.H., 2009. In-situ origin of the Caribbean: discussion of data: In: James, K.H., Lorente, M.A. and Pindell, J. (eds.), Origin and evolution of the Caribbean Plate. Geological Society of London, Special Publications, v. 328, p. 75-124.

Korhonen, J.V., Fairhead, J.D., Hamoudi, M., Hemant, K., Lesus, V., Mandea, M., Maus, S., Purucker, M., Ravat, D., Sazonova, T. and Thebault, E., 2007. Magnetic Anomaly Map of the World Commission for the Geological Map of the World, Paris.

Ruditch, E. M., 1990. The world oceans without spreading, Part I. Shallow-water facies of the World Ocean. In, Barto-Kyriakidis, A., (ed.), Critical Aspects of the Plate Tectonic Theory, 1990. Theophrastus Publications, v. 2, p. 343-395.

Vasiliev, B.I. and T. Yano, 2007. Ancient and continental rocks discovered in the ocean floors. *New Concepts in Global Tectonics Newsletter*, no. 43, p. 3-17.

Wegener, A., 1912. Die Enstehung der Kontinente. *Geologische Rundschau*, v. 3, no. 4, p. 276-292.

Wegener, A., 1929. Die Ehstehung der Kontinente und Ozeane, 4th edition, translation. Biram, J., 1966, The Origin of Continents and Oceans by, Dover Publications, 248p.

Wilson, J.T., 1966. Are the structures of the Caribbean and Scotia arcs analogous to ice rafting? *Earth and Planetary Science Letters,* v. 1, p. 335-338.

Yano, T., Choi, D.R., Gavrilov, A.A., Miyagi, S. and Vasiliev, B.I., 2009. Ancient and continental rocks in the Atlantic Ocean. *New Concepts in Global Tectonics Newsletter*, no. 53, December, p. 4-37.

Yano, T., Vasiliev, B.I., Choi, D.R., Miyagi, S., Gavrilov, A.A. and Adachi, H., 2011. Continental rocks in the Indian Ocean. *New Concepts in Global Tectonics Newsletter*, no. 58, December, p. 9-28.

SHORT NOTE

PLANETARY FRACTURE SYSTEMS AND RECENT SEISMIC ACTIVITIES IN THE NORTHWESTERN PACIFIC OCEAN

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Abstract: Numerous distinctive, very long, linear cloud patterns were noted on satellite images while studying earthquakes in the Kamchatka-Kuril and NW Pacific regions since early 2012. Most of these lines were found coinciding with planetary fracture systems shown in available geological, geophysical and satellite altimetry data. All of the strong seismic events (M6+) have occurred on or near major fracture zones, especially the ENE-WSW fractures, implying that they play a decisive role in localizing earthquakes and constraining their energy transmigration paths in conjunction with major crustal structures. The correct understanding of deep fracture systems and the crustal structures is essential in understanding the process and mechanism of earthquakes, hence for their prediction.

Keywords: *earthquake, prediction, planetary fracture system, crustal structure*

Introduction

During the course of intensive and comprehensive study on the Kamchatka earthquakes in recent months by a team of newly established IEVPC, we have observed numerous phenomena that occur at the preparation stage of major earthquakes. Our study included a wide range of fields; geology and tectonics, clouds, total electron content (TEC), outgoing longwave radiation (OLR), sea surface temperature (SST), VLF electromagnetic wave, interplanetary magnetic field (IMF), planetary alignment, and historic seismicity and volcanic eruptions. Of these, crucial information particularly for medium-term prediction was provided by satellite cloud images which are freely available from NEODAAS (NERC Earth Observation Data Acquisition and Analysis Service) geostationary satellite images (http://www.sat.dundee.ac.uk/geobrowse/geobrowse.php).

The interpretation of the satellite images in particular in comparison with geological and geophysical data allowed us to identify many cardinal fracture systems in the study area, some of which have not been known for us before. It also made it possible to analyze the relationship between the deep fracture systems, seismicity and thermal phenomena. The results gave us valuable information for understanding earthquake formation mechanism and thereby helped forecast future strong earthquakes.

In this article we will describe briefly the recognized relationship between the deep fracture systems and seismic/thermal features observed in the study area. Other findings of our comprehensive study on Kamchatka earthquakes could not be included in this article due to the time constraint; they will be reported in the future papers.

Major fracture systems appeared on satellite cloud images

The cloud images obtained by geostationary satellites, available at every three hours, contain a wealth of information for understanding what is happening under the sea bed or ground surface: Pressured thermal gases, discharged from ground or sea bed through open fractures or faults which are developed in the mantle and the crust, interact with atmosphere and form unique and a variety of clouds or cloud-free zones. For general introduction and features of earthquake clouds and the cloud-based earthquake prediction, readers are asked to refer to Shou (2006 and http://www.gisdevelopment.net/proceedings/tehran/p_session2/bampf.htm).

In his lithosphere-atmosphere-ionosphere (LAI) coupling model, Pulinets (2009) explained earthquake cloud formation from the viewpoint of radon gas emanation and air ionization – ionospheric and thermal anomalies are coupled through the ionization process produced by radon; when positive ions emitted into troposphere increase the cloud formation, while negative ions lead to reduced cloud. The former is called "vapour cloud", and the latter, cloud-free zone, "geothermal eruption or geoeruption" by Shou (2006).

We have noted planetary fracture systems appearing occasionally on satellite images often with a long lateral extension well over 1,000 km. Their appearance is in three forms on satellite images; 1) as linear white clouds (**Fig. 1**), 2) as linear cloud-free zones frequently with small, discontinuous mound of clouds (**Fig. 3**). Other than these, we noted concentric circular features with cloud-free inner circle and a series of small clouds along the outer circle. We consider this circular pattern has some prediction capability, but we will discuss on this interesting feature in the future articles.

The extracted linear cloud or cloud-free zones were compared with available geological and geophysical maps, satellite altimetry data, and other publications for verification and analysis. This process confidently concluded that most of the long, linear features reflect deep Earth structures particularly cardinal planetary fracture systems which are deeply rooted in the mantle.

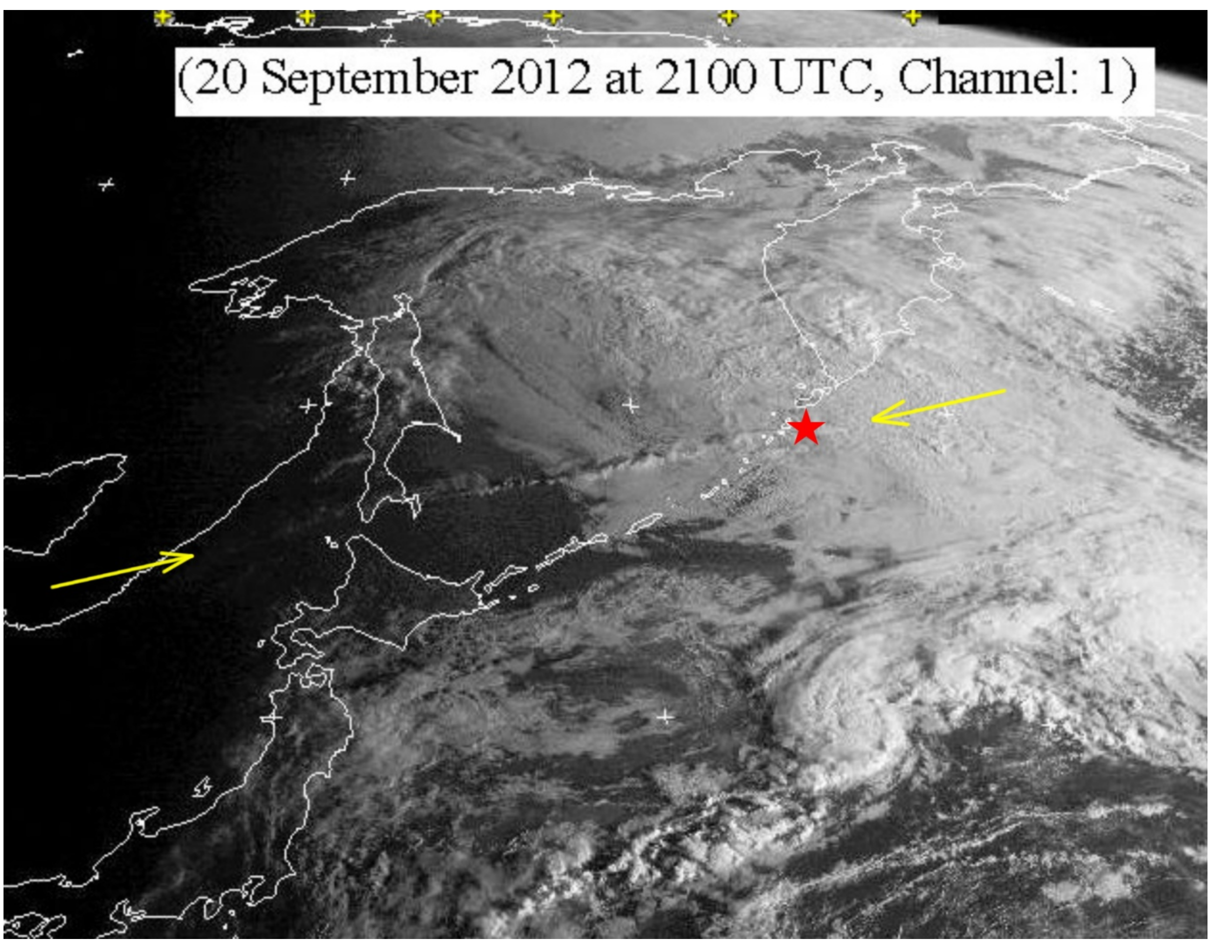

Figure 1. A line of clouds, over 1,000 km long, appeared in Okhotsk Sea on 20 September, 2012 at 2100hrs, UTC. Published geological/geophysical maps and satellite altimetry data prove it is truly a major fracture system which extends into the Asian continent forming one of deep seismic zones. Several earthquakes (including M6.0 on 20 July 2012, red star in the map) occurred at the junction of this fracture and the Kuril arc, or the northern Kuril Islands in the last few months (Fig. 2), indicating the fracture has been active for some time.

Results and discussion

Planetary fracture systems in the NW Pacific and strong seismic activities

The primary fracture systems identified by this and other studies including satellite altimetry data (DeKalb, 1990; Smith and Sandwell, 1997; Jatskevich et al., 2000; Smoot, 2005 and 2012; Choi, 2005; and many others) were superimposed on the world magnetic map (Korhonen et. al., 2007), **Fig. 2**. The map indicates loci of strong earthquakes with magnitude M6.0 or greater which occurred from January to September 2012. In addition, the map shows very strong deep shocks occurred in the last few years and their shallow appearances with energy migration direction in red arrow.

As seen clearly in the seismo-tectonic map (**Fig. 2**) that all major earthquakes with M6.0+ in the study area are located on or near the ENE-WSW fracture systems without exception, and mostly at the intersection with the perpendicular NWN-SES fracture systems. The latest M6.9 quake on 26 September 2012 in Andreanov Islands, Aleutian which occurred after this paper had been completed perfectly fits this rule.

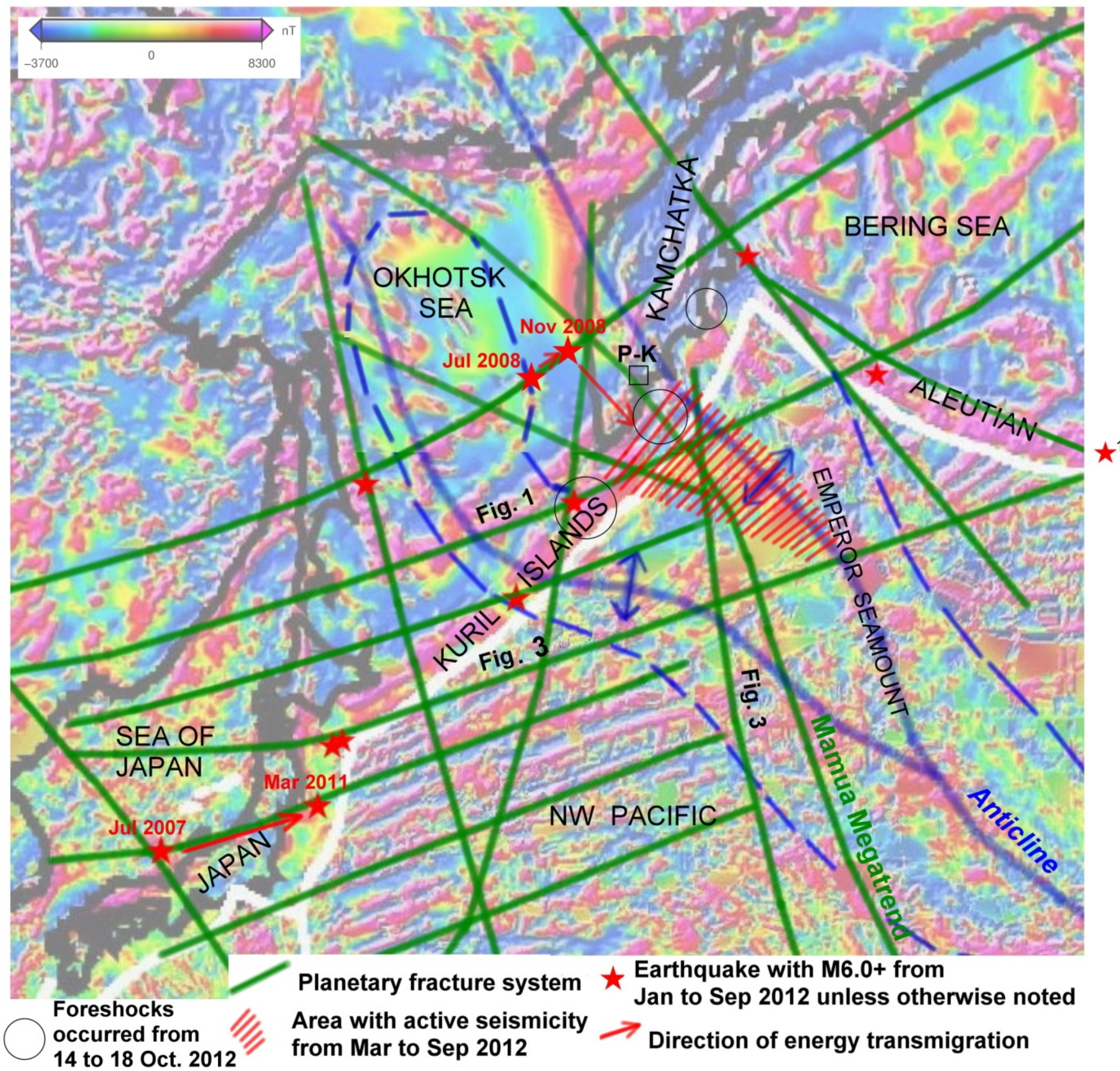

Figure 2. Seismo-tectonic map showing planetary fracture zones and hypocenters of strong earthquakes with magnitude 6 or larger (red star) that occurred in the last nine months (January to September 2012) in the Kuril-Kamchatka-Aleutian region. Other significant quakes are also indicated with annotation. Anticlinal axes are partly speculative due to the paucity of available data. ★ [1] = M6.9 quake, 26 Sep. 2012 (UTC) occurred after this manuscript was completed. P-K = Petropavlovsk-Kamchatky. Many continental rocks have been dredged from sea mounts in the NW Pacific where magnetic stripes are developed (Vasiliyev, 1986; Vasiliyev and Evlanov, 1982, and others), suggesting that the stripe pattern reflects fracture systems.

These facts evidently show that the cardinal deep fracture systems are strongly related to the earthquake formation mechanism – from original thermal energy release at deep Earth, its transmigration paths, to the shallow great earthquakes. It also suggests that the vertical crustal block movement is the primary tectonic style in the study area. The senior author of this article has repeatedly documented this (Blot and Choi, 2007; Choi, 2005, 2007 and 2011, for example). In this scenario there is no room for the plate tectonics model to fit in. Magnetic stripes cannot be related to the ocean floor spreading in any sense (Agocs et al., 1992; Storetvedt, 2010).

Planetary fracture systems affecting thermal regime – sea surface temperature (SST) and outgoing longwave radiation (OLR)

The following figure (**Fig. 3**) shows the monthly SST (bottom) and OLR (middle) anomalies and a cloud image taken at 0300hrs 15 September 2012 (UTC) at the top. Here the cloud image was taken with the mid-infrared wave band 3.5 to 4.0 μm (Channel 2), but a blow up in the inset map is the Channel 1, visual-green to near infrared wave band image for comparison. Both SST and OLR are for the 30 day-average anomaly during August to September with inserted figures for the 15 September one-day anomaly.

As seen in cloud image the perpendicular faults bounds a large crustal block in the NW Pacific characterized by magnetic stripes (**Fig. 2**). The striped block is relatively free from clouds, which is confirmed on Channel 1 image of the same data set. The cloud-free block also coincides with high thermal area as evidenced by very high monthly OLR and SST anomalies. Their daily anomaly on 15 September shown in the inset maps also matches this trend.

Here we can see how strongly the major planetary fracture systems control seismic and thermal regimes of the Earth. Obviously they are deeply rooted in the mantle and affect Earth's geodynamic processes. The earthquake prediction, which we are currently engaged in, cannot be made without in-depth understanding of Earth structures represented by planetary fracture systems together with other geological factors, such as block structure of the crust, and geomagnetic and thermal phenomena as well.

Conclusions

1. This study demonstrated again the important role of geological structures, particularly deep fracture systems in understanding earthquake formation mechanisms.
2. The deep fracture systems also affect many phenomena which appear prior to major shallow earthquakes including precursor shocks, thermal regime in water and atmosphere, and other global and local geophysical and electromagnetic signals.
3. The deep fracture systems continuing from continent to ocean floor negate the application of plate tectonics to the NW Pacific region and beyond.

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References cited

Agocs, W.B., Meyerhoff, A.A. and Kis, K., 1992. Reykjanes Ridge: quantitative determinations from magnetic anomalies. In, Chatterjee, S. and Hotton, N. III, "New Concepts in Global Tectonics". Texas Tech Univ. Press, p. 221-238.

Blot, C. and Choi, D.R., 2007. The great twin earthquakes in late 2006 to early 2007 in the Kuril Arc: Their forerunners and the seismicity-tectonics relationship. *NCGT Newsletter*, o. 43, p. 22-33.

Choi, D.R., 2005. Deep earthquakes and deep-seated tectonic zones: a new interpretation of the Wadati-Benioff zone. *Boll. Soc. Geol. It*., vol. spec. no. 5, p. 79-118.

Choi, D.R., 2011. Geological analysis of the Great East Japan Earthquake in March 2011. *NCGT Newsletter*, no. 59, p. 55-68.

DeKalb, H.F., 1990. The twisted Earth. Lytel Eorthe Press, Hilo Hawaii, USA. 156p.

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

Korhonen, J.V. et al., 2007. Magnetic anomaly map of the world. Commission for the Geological Map of the World, scale 1:50,000,000. 1st edition. Paris.

Pulinets, S., 2009. Lithosphere-atmosphere-ionosphere coupling (LAIC) model. In, Hayakawa, M. (ed.), "Electromagnetic phenomena associated with earthquakes", p. 235-254.

Shou, Z., 2006. Earthquake vapor, a reliable precursor. Mukherjee, S. (ed.), "Earthquake prediction", p. 21-51. Brill Academic Publisher, Leiden-Boston.

Shou, Z., Bam earthquake prediction & space technology. http://www.gisdevelopment.net/proceedings/tehran/p_session2/bampf.htm

Smith, W.H.F. and Sandwell, D.R., 1997. Global sea floor topography from satellite altimetry and ship depth soundings. *Science*, v. 277, p. 1957-1962.

Smoot, N.C., 2005. Seamount chains, fracture zones, and Ocean megatrends. *Boll. Soc. Geol. It.*, vol. spec. no. 5, p. 23-52.

Smoot, N.C., 2012. North-central Pacific basin lineaments and mobilist: really? *NCGT Newsletter*, no. 2, p. 5-21.

Storetvedt, K.M., 2010. World magnetic anomaly map and global tectonics. *NCGT Newsletter*, no. 57, p. 27-53.

Vasiliyev, B.I., 1986. The results of dredging of some submarine mountains in Japan marginal oceanic rampart. *Tikhookeyanskaya Geologiya (Pacific Geology),* no. 5, p. 35-42 (in Russian).

Vasiliyev, B.I. and Evlanov, Y.B., 1982. Geological structure of submarine mountains in the region near Kuril-Kamchatka and Japan Trenches. *Tikhookeyanskaya Geologiya (Pacific Geology),* no. 4, p. 37-44.

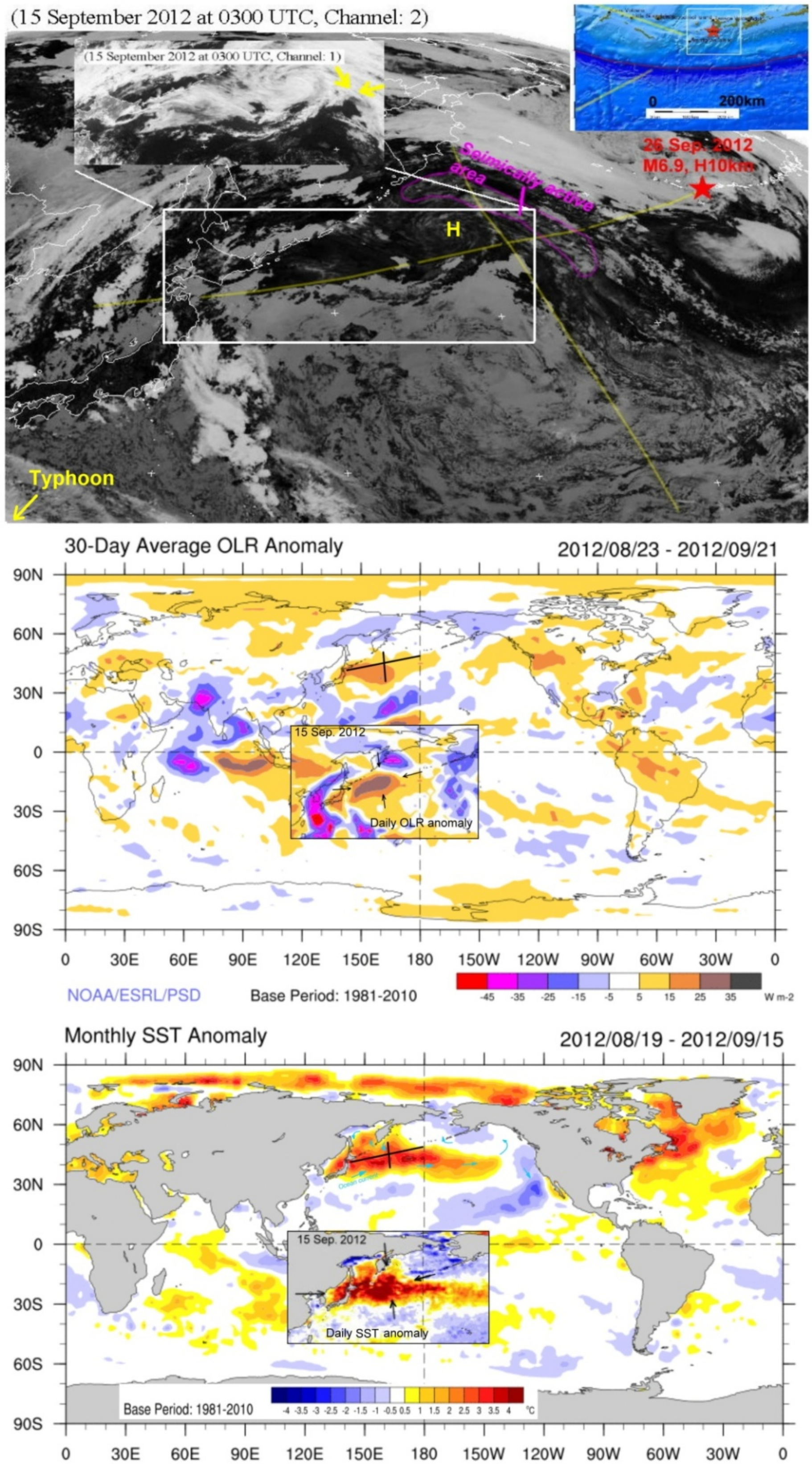

Figure 3. Cloud photo (top, on 15 September, 2012), and monthly outgoing longwave radiation (middle, OLR) and sea surface temperature anomalies (bottom, SST). The right inset map of the top figure is the 26 Sep. 2012, M6.9 quake which is situated on the fracture zone. Inset maps in the bottom two figures are daily anomaly on 15 September, 2012. H in the top figure (in yellow) = high atmospheric pressure.

ESSAY

THE ATLANTIC AND ITS BORDERING CONTINENTS – A WRENCH TECTONIC ANALYSIS: LITHOSPHERIC DEFORMATION, BASIN HISTORIES AND MAJOR HYDROCARBON PROVINCES

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– …we can be blind to the obvious, and we are also blind to our blindness –
Daniel Kahneman, in: *Thinking, fast and slow*

Abstract: Main facets of the Alpine tectonic revolution for the 'continental hemisphere' are evaluated in the context of Global Wrench Tectonics. Particular attention is paid to the pan-global system of rectilinear fractures – presumably implanted in the late Archaean and intensified throughout Proterozoic and post-Precambrian times. The progressive dynamically-enforced mechanical break-up of the lithosphere, along with the development of deep and thin-crusted oceanic basins during the Mesozoic, the late Cretaceous lithosphere was tectonically more deformable than ever before. Hence, the mechanical prerequisite of the Alpine revolution was in place. Increased crustal loss to the mantle during Upper Mesozoic had led to a certain planetary acceleration – in turn giving rise to inertia-driven torsion of the outer brittle layer. In this process, the continental masses stayed with their deep mantle roots. For the Atlantic bordering continents, the azimuthal changes were moderate – resulting only in a minor reshaping of the evolving between-continent oceanic basins, from an original configuration of parallel opposing margins to their present southward fanning-out shapes. The Alpine re-shaping of the Atlantic basins led to considerable shear reactivation of the pre-designed rectilinear fracture system, involving along-fault mineralogical changes – the basis of linear marine magnetic anomalies. In this wrenching process, the present curvilinear shape of many oceanic fracture zones was established. As the larger continental masses were internally deformed, concurrently with the reshaping of adjacent oceanic basins, tectonic discontinuities along the evolving continental margins were either minimal (Pacific) or non-existent (Atlantic). Hence, many on-land tectonic structures will have their natural continuation into the deep sea basins. For example, the Pelusium tectonic system of Central Africa extends across the Equatorial Atlantic and northern South America, before continuing into the adjacent equatorial Pacific. The increasing deformation of the lithosphere in Meso-Caenozoic times apparently led to accelerated alteration of the Earth's crust. Fluid-enforced sub-crustal eclogitization and associated delamination of the original continental surface layer led to basin formation on various scales; this process opened up pathways for mantle fluids and gasses leading to a range of geological, biological and environmental consequences. Using wrench tectonics as an operational and predictive guide, we suggest that all major oil and natural gas provinces in the world are associated with avenues for upward transport of mantle volatiles. It follows that water, high concentration brines, crude oil and natural gas, and occasionally magma, moves towards the surface as planetary degassing products. There are now good reasons for considering that all major petroleum provinces are fed from the deep Earth – probably making many of them capable to produce forever.

Keywords: *fundamental fracture systems, inertia-driven lithospheric deformability, basin histories, mantle-derived hydrocarbons, tectonic pre-condition of major petroleum provinces*

Introduction

In a recent article in this journal we took a critical look at the Alpine age tectonic history of the North Atlantic and Arctic basins (Storetvedt and Longhinos 2011), paying particular attention to their complex tectono-topographic build-up – features that have led to endless non-clarifying plate tectonic (PT) based speculations. Pervasive shear deformation of the oceanic basement, the random distribution of so-called micro-continents and the many puzzling cases of crustal thickness variation are among most pressing issues in global geology today. Taking a bird's eye view of the body of structural facts, we are tempted to consider that Alpine reactivation of the pre-designed and ubiquitous orthogonal fracture network has played a crucial role in the evolution and shaping of the Atlantic basins – and apparently the rest of oceanic and continental physiographic traits come to that.

To judge from the multitude of shear tectonic structures featuring in the basement of the Atlantic and other deep oceans, in association with dynamo-metamorphic and very old rocks sampled along oceanic ridges worldwide, it seems reasonable to conclude that the thin-crusted ocean tracts represent attenuated continental crust having subsequently been turned into a system of broad oceanic tectono-topographic belts. As there is no evidence that deep sea depressions, to any extent, existed prior to the middle-late Cretaceous, the main global deformation phase must date from the Alpine climax; during this Upper Cretaceous to Lower Tertiary tectonic revolution, the oceanic tracts were turned into a type of between-continent fold belts never seen on Earth before (Storetvedt, 1990). According to this view, the dynamical trigger of all global tectonic cataclysms, the Alpine events as well as all preceding revolutionary happenings in Earth history, can be directly linked to changes in Earth's rotation – i. e. to changes in its Moments of Inertia. Thus, it can be inferred that internal planetary degassing and related mass reorganization have given rise to periodic changes of the Earth's spatial orientation (True Polar Wander) as well as to spasmodic variations in the rate of planetary spin. Such changes in rotation would have caused hydrostatic pressure increase in the evolving gas/fluid-rich asthenosphere, setting off 1) surface gas blow-outs (cratering) and 2) volcanic activity, processes that in turn would be liable to cause 3) environmental and 4) biotic catastrophes. In addition, 'jerky' changes in planetary spin would trigger latitude-dependant inertial motions of the global lithosphere, for which the palaeo-equatorial regions would attain maximum tectonic stresses. The inferred lithospheric torsion has given rise to moderate reshaping of the oceanic basins, including minor *in situ* rotations of the main continental masses. In a wider time perspective, the episodic changes of the Earth's rotation are the dynamic trigger mechanisms of the diversity of surface processes defining geological time boundaries. In broad terms, this is the principal basis of a new Earth evolution theory – *Global Wrench Tectonics (*Storetvedt, 1997, 2003, 2010b and 2011).

The role of planetary rotation in global tectonics – explaining the association of 1) the shifting gross palaeoclimate system of the globe, 2) the phenomenon of True Polar Wander, and 3) the changing pattern of fold belts – was substantiated already a century ago by Damian Kreichgauer – in his book *Die Äquatorfrage in der Geologie* (1902). However, due to its drastic break with conventional thinking in geology at that time, Kreichgauer's global tectonic synthesis was practically ignored by his contemporaries. But Kreichgauer's book was one of Alfred Wegener's basic texts in his elaboration of the time-progressive shift of global palaeoclimatic belts (based on fossil and rock evidence) in terms of the dynamical mechanism of Polar Wander – meaning episodic spatial reorientation of the Earth's body. According to Kreichgauer, changes in planetary rotation was a key factor in understanding the Earth's tectonic system; the principal tectonic belts across the Earth had been formed by latitude-dependent inertia forces – such as the Coriolis Effect – producing tectonic belts 1) along corresponding palaeoequatorial regions (e.g. Appalachian, European Hercynian, Alpine) or 2) as rifted provinces breaking away from the respective palaeoequatorial zones (e.g. Grenville Province, Central African Belt, Ural Belt).

In concert with accelerated oceanic basin formation in the upper Cretaceous, the present ocean/continent configuration had basically been installed by the K/T boundary. Triggered by the increase of crustal loss to the upper mantle with associated acceleration in planetary rotation rate, the ensuing geodynamic event – the Alpine climax – pitched the Earth into a tectonic calamity. During the degassing-related crustal oceanization processes, the development of the asthenosphere had got a certain boost, and therefore the lithosphere had become tectonically more unstable than before. Hence, during the Alpine revolution the planetary lithosphere was subjected to westward torsion, with maximum wrenching effects in the palaeoequatorial region: the northern palaeo-lithospheric cap was twisted clockwise, while the southern palaeo-lithosphere was wrenched in the counter-clockwise sense – turning the intervening Alpine tectonic belt into an overall transpressive zone. In this global tectonic scenario, the thin-crusted and mechanically weak oceanic basins underwent latitude-dependent tectonic reactivation and moderate geometrical reshaping.

Within this global deformation scheme, continental-oceanic structural discordances of any significance did not develop. Continental and oceanic lithospheres were subjected to the same general torsion, but the weak and thin-crusted oceanic basement was subjected to stronger internal deformation than the more resistant continental blocks. However, as products of the global wrenching process – and in part due to tectonic interaction – the major continental masses underwent variable but moderate relative rotations *in situ*. However, the resulting tectonic effects were spread over wider tracts of the thin-crusted oceanic regions – triggering reactivation of the predesigned conjugate fracture systems, producing tectonic bending and shearing features such as exposed by the zigzag pattern of the mid-ocean ridges. The mid-oceanic rift zones, which along with continental mountain ranges became subject to topographic elevation during the latest Tertiary, can similarly be seen as products of Alpine age lithospheric torsion. Following the crustal-tectonic development of *Wrench Tectonics,* continental and oceanic basins are surface products of the same internal mass reorganization – differing only in the degree of development. Furthermore, it is important to note that owing to the overall moderate lithospheric mobility pertaining to palaeomagnetic data, prominent continental fault zones are likely to extend across (or deep into) surrounding oceanic basins. It is the intention of the present paper to review main aspects of the tectonic development and basin histories of the Atlantic ‘hemisphere’ in addition to reviewing its tectonics-related hydrocarbon potential.

The rectilinear fracture network

There are good grounds for considering that the pan-global system of near-vertical orthogonal fractures originated in the late Archaean. By then, some outer layering of the Earth had experienced significant cooling, thereby changing the manner by which the crust would respond to tectonic stresses. Thus, the ductile behaviour of Earth’s early incrustation – acquired by heat from radioactive decay, tidal friction and chemical processes (see Storetvedt 2003, 2011 for references and discussion) – had apparently been replaced by more brittle conditions. Thus, well in advance of the Archaean-Proterozoic boundary (ca. 2.5 billion years ago), the evolving greenstone belts basically formed along down warps or fault-bounded troughs, – implying that larger-scale brittle fractures had been implanted by then. In the modern Earth, a ubiquitous orthogonal network of rock breakage is commonly seen cutting the range of lithological complexity and rock ages (cf. **Fig.1a&b**) – including in some cases flat-lying Pleistocene sediments. In fact, for a dynamic Earth any basic system of rock failure will expectedly be inherited by ever younger surface strata. So in the case the variegated oceanic basement is the product of uneven sub-crustal attenuation of an original continental crust, for which there now is ample evidence, younger rocks of the developing oceanic crust would be bound to carry the same orthogonal fracture systems as the continents.

In outcrop scale, the characteristic system of rock discontinuities is commonly represented by a micro-fabric network of near-vertical joints (exemplified by **Fig. 1c & d**). Joints are contiguous rock discontinuities with relatively smooth planar surfaces, the most prevalent of which normally constitute two steeply dipping, near-perpendicular sets, – but in most cases one of the two sets predominates. Despite the fact that joints represent the most common type of brittle fracture in the Earth’s crust, their origin has remained enigmatic and therefore nearly completely ignored. For a review of proposed causes, see Pollard and Aydin (1988). Crustal strain is undoubtedly involved, and several authors have argued that the characteristic near-vertical joint planes, with their sharp intersections and smooth faces, are likely to have formed through crustal shear (Bucher, 1921; Scheidegger, 1982; Hancock, 1985). In this context, it is important to note that in addition to the two vertical sets of joints one generally observes an irregular sub-horizontal rupture system (see **Fig. 1c & d**) suggestive that tectonic wrenching has been in operation at some stage. The presence of flat lying lithospheric break-ups has undoubtedly facilitated the sub-crustal eclogitization-delamination processes during ocean basin formation.

Fig.1 The conjugate orthogonal fracture system is the most common tectonic feature on the Earth – cutting rocks of all ages. Goole Earth photographs are from the Øygarden Gneiss Complex at Goltasund, SW Norway (a) and from the late Tertiary volcanic region of Langavatn, SW Iceland (b) – both displayed with true geographic bearing. In comparison, (c) and (d) show close-up vertical sections of the fracture/joint network – from a coastal exposure in the metamorphic basement of western Norway (c) and from a road cut in the Newfoundland Appalachians (d), photos are by Frank Cleveland and Karsten Storetvedt respectively.

The presence of occasional slickenside features (scratched and smeared surfaces caused by friction) – such as reported from the Langavatn region of western Iceland (Passerini et al., 1991) – clearly demonstrate the involvement of shearing. Authors like Muehlberger (1961) and Segall and Pollard (1983) interpreted these 'polishing-and-striation' features as secondary (superimposed) structures; nevertheless, the predominant sets of joint surfaces in general have bearings parallel to faults or fault zones, towards which the joint frequency may increase. Such observations suggest that there is a causal relationship between faulting and jointing even though the majority of joints are probably younger than the principal age of tectonic deformation. All in all, it seems likely that a micro fabric texture was implanted at a relatively early stage of the crust's brittle history, and that certain elements of this linear fabric have subsequently developed into more prominent structural discontinuities – such as mega scale transcurrent faults.

It is generally observed that the contemporary stress field is oriented in the direction of one of the predominant regional fracture planes (Engelder, 1993). On the assumption that the basic fracture fabric originated in late Archaean time, probably having been intensified throughout Earth's episodic tectonic history, implantation of new fracture sets with diverse orientations would be difficult. This assumption may account for the fact that the same structural trends are commonly repeated in large-scale tectonic belts (e.g. O'Driscoll, 1980). This principle is well demonstrated for eastern North America where linear basins and tectonic belts have had a long history of reactivation. Thus, the Lower-Middle Palaeozoic Appalachian fold belt follows along and in part cutting into the 1-1.3 billion years old Grenville tectono-magmatic province to the west; the combined tectonic zone lines up with the prevalent fracture/joint system of eastern North America (see below). The close correlation between the directions of contemporary horizontal stress and the principal set of characteristic fractures is well demonstrated for North America (Zoback and Zoback, 1980; Engelder, 1982).

At a time when PT has turned Earth history into a system of lithospheric mobility without bounds, with continents floating around as cork on the ocean, it is important to be aware of the systematic orientation and extensive distribution of the rectilinear fracture system. Thus, the prevailing structural lineaments and morphological trends in Newfoundland, displaying NE-SW and NW-SE strike directions respectively (**Fig. 2a&b**), characterize larger parts of the Northern Hemisphere, extending from the north-eastern seaboard of North America, through Baffin Island (Scheidegger, 1998), and western Europe (e.g. Ramberg et al., 1977; Storetvedt and Scheidegger, 1992; Engelder, 1993). According to the compilation of Zoback (1992), the same Northern Hemisphere stress orientation and lineament system apparently extend across Asia as far as the Pacific margin (see also Storetvedt et al. 2003).

The fairly consistent overall joint orientation across the North Atlantic, from Western Europe to Newfoundland, indicates that the two continental masses are unlikely to have undergone significant relative solid block rotation. However, the presence of an extensive margin-parallel belt of transverse fracture zones in the western Central Atlantic, with south-bended arcuate shape, suggests that a certain clockwise inertia-drag has affected North America along with adjacent oceanic tracts (see below). In addition, Upper Cretaceous-Lower Tertiary palaeomagnetic directions for Europe and the United States favour ca. 30 degrees of clockwise rotation of North American sampling locations relative to sites in Western Europe (Storetvedt, 1990, 1992 and 1997). The answer to this apparent contradiction, between joint orientation data and palaeomagnetic directions, may be found in the internal deformation of continental North America. **Fig. 2c** describes the directions of maximum horizontal compressive stress for the north-eastern US, corresponding to average strikes of the prevailing set of regional joints (Engelder, 1982). In comparison with the structural trends of Newfoundland – exemplified in **Fig. 2a&b** – the orthogonal joint/fracture systems of the mid-continent cratonic region seem to have undergone a vertical-axis clockwise rotation increasing southwards – adding up to about 30 degrees.

While PT basically presumes internally rigid continental blocks, the theory of Wrench Tectonics has no such pre-conditions – as the entire lithosphere is subdivided by a network of deep fractures, conditions would pave the way for inertia-driven lithospheric deformation for oceanic regions as well as for continental masses. Thus, as every part of the Earth's outer brittle shell has been subjected to intermittent torsion, it has been susceptible to varying degrees of reshaping, internal tectonic rotation, faulting and stress-related crustal remagnetization (cf. Rother and Storetvedt, 1991). Thus, the southward swing of the combined joint/stress system of North America is consistent with its westward tectonic rotation relative to Europe, as established by palaeomagnetic evidence. Also, space geodetic measurements indicate that within-continent deformation of North America is currently taking place (e. g. Fallon and Dillinger, 1992; Argus and Gordon, 1996). Within the inertia-based wrench system, tectonic discontinuities will be spread over wider oceanic regions. Any continental motion/deformation process will be associated with similar spread-out distortion of the adjacent oceanic basement, implying that prominent marine-tectonic lineaments may have fairly uninterrupted onshore continuations.

As the inertial effect is latitude-dependent – with maximum deformation in the palaeoequatorial zone – the Central Atlantic would be particularly prone to Alpine wrench tectonics (Storetvedt, 2003); the time-equivalent equator cut across the Central Atlantic – running along the southern rim of the Mediterranean and continuing towards southern Central America (see below). In this deformation process, certain sections of the 'E-W' set of fundamental fractures were reactivated and greatly enlarged to form mega scale transverse faults, and basin deformation gave rise to the characteristic zigzag pattern of the subsequently uplifted Mid-Atlantic Ridge. **Fig. 3** shows north-seeking fracture axes for locations of the Atlantic-bordering continents (plus Australia) extracted from case studies of joint orientations by Scheidegger and co-workers (see Storetvedt, 2003 for list of references) – all data being after statistical treatment according to Scheidegger (1965) and Kohlbeck and Scheidegger (1977). Even from this admittedly rough and preliminary survey, one cannot but be struck by the fairly consistent 'N-S' and 'E-W' orientations of the fracture axes. Also, the perpendicular and fault-controlled Ninety-east and Broken ridges of the Indian Ocean have orientations that fit with the pre-Alpine fracture axes delineated in **Fig. 3** – probably representing a setting of the Precambrian fracture network and serving as a 'mould' for the subsequent tectono-topographic evolution of the Earth's surface.

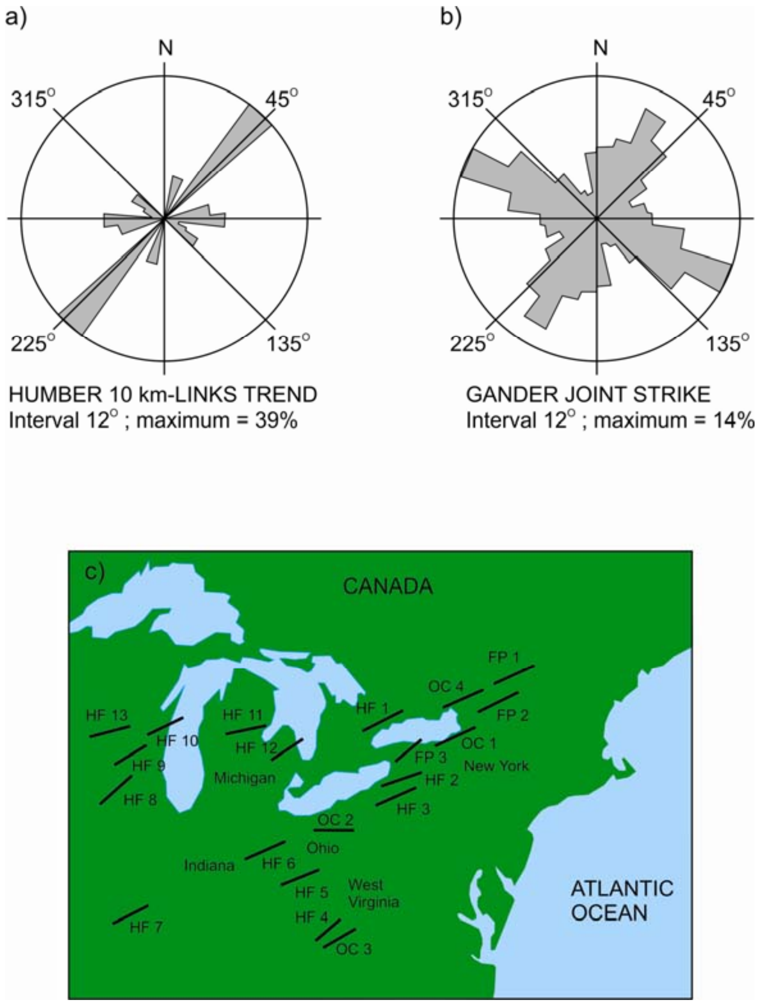

Fig. 2. Rose diagrams of Newfoundland morpho-tectonic features, exemplified by links trends (elements of river courses and embayment directions) in the Humber Zone (**a**) and by joint strikes in the Gander Zone (**b**). For comparison, orientation of the prevailing set of joints in north-eastern US, defining azimuths of the region's maximum horizontal compressive stress, is depicted in (**c**). Note the ca. 30 degrees of clockwise rotation in structural bearings from Newfoundland (ca. N040E) to north-eastern US (ca. N070E). Diagrams (a) and (**b**) are after Miller et al. (2001) while (**c**) is from Engelder (1982).

Fig. 3. Strike directions (solid bars) of north-seeking joint axis plotted in Mercator projection, – after correction for Alpine tectonic rotations but without changing of continental azimuths. When extended across the globe, these joint trends form a simple global pattern with intersections close to the present geographic poles. For data base and other details, see Storetvedt (2003, p. 315-325).

The Alpine Atlantic: A first-order tectonic picture

During the Upper Mesozoic, sub-crustal thinning processes – primarily through hydrous fluid-triggered eclogitization and associated crustal loss to the upper mantle – made a significant advance. The build-up and release of upper mantle hydrostatic pressures, causing repeated uplift and subsidence of the developing oceanic basins, were apparently in phase with the transgression-regression pulses affecting low-lying continental regions (cf. http://www.youtube.com/watch?v=gOC7TgAlhV8&feature=channel). By inference, successive regressive events led to progressively deeper oceanic basins. Until the late Mesozoic, remaining trans-oceanic land connections were still relatively unimpaired. But due to the pre-existing sets of ubiquitous parallel fractures (outlined above), the evolving continental margins became closely parallel; in other words, these margins developed along pre-existing deep fault zones cutting into the mantle, along which fluid-enforced eclogitization became particularly prevalent. The presence of marked gravity anomalies along many continental margins of the world concur with this prediction. Furthermore, accelerated eclogitization/delamination along the bounding ocean-continent fault zones would predictably also have led to bands of enhanced crustal thinning, basin subsidence and anomalously thick sedimentary piles on the seaward side of many continental margins. The thick margin-parallel sedimentary deposits of the Central and South Atlantic are depicted in **Fig. 4**.

The Upper Cretaceous-Lower Tertiary wrenching of the planetary lithosphere brought about relative azimuthal changes of the Atlantic-bordering continents, and the accompanying reshaping of the thin-crusted oceanic tracts led to the present southward fanning-out shapes of both the North and South Atlantic – in addition to cases of mega scale transverse faulting. It can be envisaged that during the Middle Mesozoic deep sea basins were very limited, frequently giving rise to anoxic conditions and black shale deposition within enclosed sub-basins. Inferentially, the developing Central and South Atlantic were characterized by a mosaic of continental and semi-continental remnants – a physiographic situation resembling that of the present North Atlantic (cf. Storetvedt and Longhinos, 2011). Towards the end of the Cretaceous, however, internal degassing had led to the build-up of asthenospheric gas pressures to a level sufficient to instigate widespread buoyant forces, – particularly affecting the thin-crusted oceanic basins. In consequence, major parts of the remaining land masses (including the present Atlantic continents) were flooded by relatively shallow epicontinental seas – the major Cenomanian transgression, serving as an antecedent of the Alpine tectonic revolution.

It can be inferred that during the pre-Alpine Cretaceous the outline of the Atlantic was approximately as depicted in **Fig. 5** (Storetvedt, 1997 and 2003). Continental margins evolved along prominent members of the 'N-S' striking fundamental fracture system (discussed above) along which volatile-driven eclogitization of crustal material was particularly effective. Hence, gravity-driven crustal loss to the upper mantle would have been especially active along the evolving (fault-controlled) margins – giving rise to the combination of anomalously thin crust, unusually thick sedimentary basins and the presence of positive gravity anomalies along many margin segments (often referred to as enigmatic in the PT literature). Triggered by the increased sub-crustal delamination in the late Cretaceous, the inertia-driven global tectonics – dominated by the Coriolis Effect – led to global-extent tectonic processes. For the larger continental masses the inertial azimuthal changes were only of a few tens of degrees at most, but these relatively minor *in situ* continental swings readily account for the observed discrepancies of palaeomagnetic polar paths (Storetvedt, 1990, 1997 and 2003). By now it is appropriate speak of "mobile continents" – for the first time in Earth history.

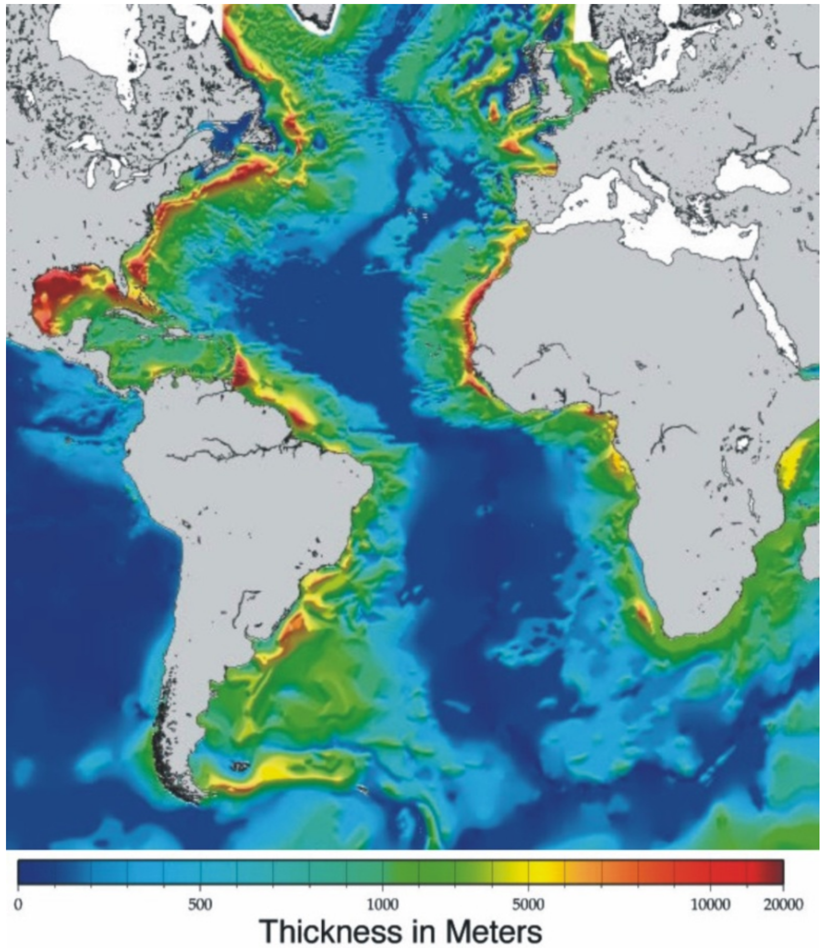

Fig. 4. Digital sediment thickness for Central and South Atlantic as compiled by the National Geophysical Data Center (NGDC), Marine Geology & Geophysics Division. Diagram represents a cut from http://www.ngdc.noaa.gov/mgg/image/sedthick9.jpg

Before the Alpine tectonic revolution, the Walvis Ridge and Rio Grande Rise apparently constituted land connections across the South Atlantic. For example, in a study of morphology and geological structure of the Equatorial Atlantic, Timofeyev et al. (1990) concluded that it once had formed "a kind of intercontinental structural barrier, which for a long time separated the North and South Atlantic." Likewise, in the North Atlantic the surface basalts of both Iceland and the Azorean Archipelago are likely to rest on continental basement, and in the structurally complex Norwegian-Greenland Sea continental remnants abound (see Storetvedt and Longhinos, 2011 for references and discussion). The list of pre-Alpine shallow water or sub-aerial masses may be greatly extended, including ridges such as the Cape Verde Rise, the Bermuda Rise, the New England Seamount Chain, the Madeira-Torre Rise etc. (see Storetvedt, 1985 and 1997).

The many isolated Atlantic sub-basins would naturally have caused stagnant water conditions with deposition of black bituminous mudstone – often referred to as the black shale horizon which during the Upper Mesozoic had widespread distribution in the world oceans (e.g. Fischer and Arthur, 1977; Thiede and van Andel, 1977). For example, from a study of mineralogical composition and fossil content of the organic-rich deposits of the Central Atlantic, Arthur (1979) found that the pelagic sedimentation had taken place under euxinic conditions. These stagnant conditions ended relatively abruptly around early Turonian time, ca. 90 my ago, after which many deep sea cores are characterized by a major sedimentary hiatus in turn followed, in the topmost Cretaceous, by deposits laid down under well-oxygenated conditions. The marked Upper Cretaceous sedimentary hiatus, apparently reflecting oceanic crustal uplift in association with erosion or non-deposition, is in phase with the major eustatic sea level rise at that time – the Senomanian transgression. In addition, the onset of the Upper Cretaceous basement uplift correlates with a widespread magmatic event in the Central Atlantic – such as the volcanism associated with the emergence of the Cape Verde Islands (Storetvedt and Løvlie, 1983; Storetvedt, 1987).

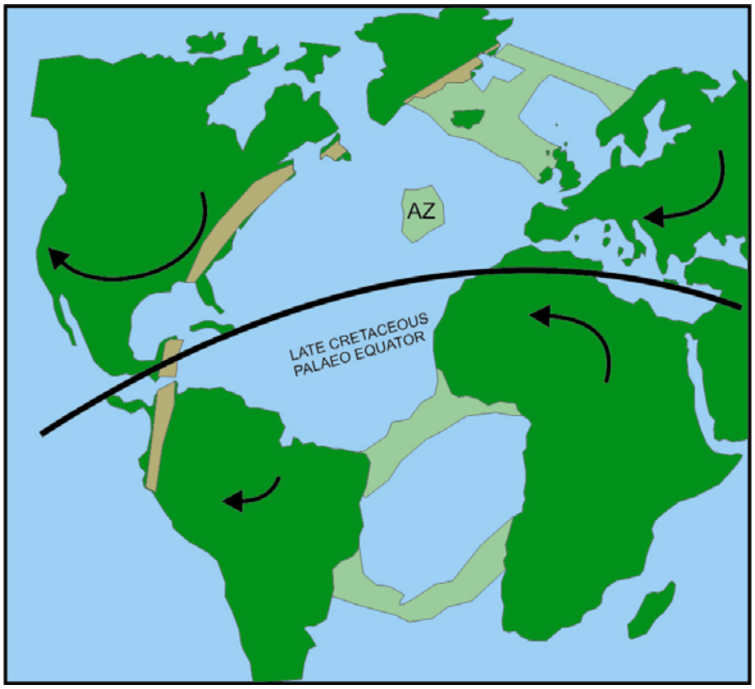

Fig. 5. In the early development stages of the Atlantic, the opposing continental margins were more closely parallel than they are now. Within-basin remains of continental ridges and plateaux (partly exposed) were still abundantly present (indicated by light green colour). During most of Mesozoic time the Atlantic basins had a slow protracted development, but, towards the end of the Cretaceous, accelerated crustal loss to the mantle led to intensified basin subsidence and associated planetary acceleration. Changes in Earth rotation, in combination with the mechanically weakened oceanic lithosphere, led to a variety of wrench tectonic phenomena. By now, the Alpine tectonic revolution was in full force; inertia-driven lithospheric torsion led to variable but moderate changes of azimuths for the major continental masses – giving rise to the present southward fanning-out shapes of the North and South Atlantic. After the Alpine climax, most of the preceding trans-oceanic land 'bridges' and micro-continental masses had largely been absorbed by upper mantle processes, and by the Lower Tertiary only the Europe-Iceland-Greenland land connection was relatively intact. Note that (in the pre-Alpine configuration) the Lower Palaeozoic Appalachian fold belt of North America (light brown colour) attains a natural continuation along the equivalent tectonic zone of the north-western tip of South America. Curved black arrows depict relative *in situ* rotation figures as inferred from palaeomagnetic data. The estimated tectonic swing of South America is only of around 10°, while the rotary motion of North America – for which a substantial part apparently is caused by internal continental deformation, manifested by an increasing clockwise torsion in the southern half of the continent – amounts to some 55° in total. AZ: predicted Azorean micro-continent. See text for further details.

The inferred planetary acceleration during the late Cretaceous brought about a certain degree of lithospheric mobility basically controlled by the Coriolis Effect. Without between-continent mechanical interference, the resulting Alpine tectonic movements would therefore be purely inertial: the northern palaeo-hemispherical cap would be subjected to clockwise wrenching while the corresponding southern palaeo-lithosphere would undergo counter clockwise torsion (with respect to the time-equivalent equator). It is important to note that in a global inertia system, a somewhat broader palaeo-equatorial belt would be particularly vulnerable to shear deformation – as indeed demonstrated for the Alpine North American-Caribbean tectonic boundary and for the Alpine fold belt proper (see Storetvedt, 2003 and 2009). Based on palaeomagnetic data, the smaller and hence more mobile North America rotated about 30 degrees relative to the larger and more sluggish Eurasian land mass – both continents changing their azimuths in the clockwise sense. The Coriolis Effect also dominated the wrenching of the southern palaeo-hemisphere, but due to the relatively narrow equatorial transect, and the tectonic interaction between Africa and South America, this oceanic sector became uplifted and tectonically strained. Even as late as the Upper Miocene, the equatorial oceanic transect was affected by events of shearing and strong vertical movement with repeated emergence of small islands (see discussion in Storetvedt, 1997 and references therein). The widespread Middle Miocene uplift of the oceanic crust led to marine erosion or non-deposition besides causing widespread transgression over some of the continents. **Fig. 6** presents data for the South Atlantic region.

Due to lithospheric interactions, transects of the Atlantic with the narrowest width – the Svalbard-Greenland 'passage' (see Storetvedt and Longhinos, 2011 and references therein) and the equatorial segment – became particularly vulnerable to tectonic straining. For example, off Ivory Coast-Ghana the margin has been subjected to strong folding, faulting and shearing, notably demonstrated within the Cretaceous sedimentary sequence (e.g. Mascle et al., 1995 and 1998). The North Brazilian Ridge, a presently buried topographic lineament that runs along the north coast of Brazil for a distance of 1300 km (Hayes and Ewing, 1970), is probably a product of the inferred transpressive forces across the equatorial transect provided by the counter clockwise rotation of Africa (see below). Consistent with this assumption is the observation of Upper Cretaceous reverse faults and compressional folds on the adjacent North Brazilian margin (Campos et al., 1974).

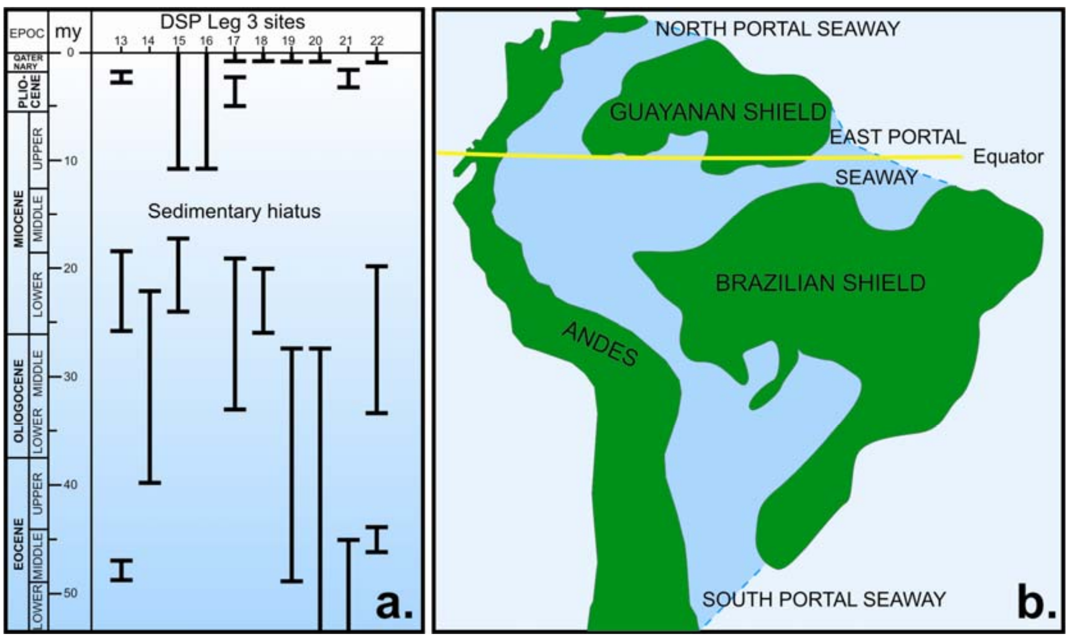

Fig. 6. Diagram **a**) shows the mid-Miocene sedimentary hiatus of DSDP Leg 3 – crossing the South Atlantic at 30˚S. This depositional break apparently corresponds to a major uplift of the oceanic basement; in consequence, low-lying lands were covered by shallow seaways. An example of such flooding, diagram **b**), shows the mid-Miocene transgression of South America – simplified after Webb (1995).

An unusually dense system of transoceanic shear zones characterizes the equatorial Atlantic; it continues across the Amazon tract of northern South America, as well as cutting deep into Central Africa (see also below). The extensive fault system – running in a nonstop manner from Central Africa to deep into the Pacific – undoubtedly represents wrench reactivation of the 'E-W' set of the fundamental fracture network. The relatively small rotation figure estimated for South America (see below) following from palaeomagnetic consideration, gains additional support from studies of joint orientation data for northern South America – depicted in **Fig. 7**. Owing to the insignificant overall rotation of South America, the joint axes orientation corresponds closely to the pre-Alpine global configuration.

Due to the strong Alpine tectonic straining across the Equatorial Atlantic, vertical movements – unexplained by plate tectonic presumptions – are recognized in this transect. Thus, along the Romanche Fracture Zone, topographic heights over a length of 500 km are capped by carbonate banks formed when these summits were close to or even above sea level; sampling on one of these seamounts uncovered 5 my old reef limestone (Bonatti et al., 1977; Bonatti and Chermak, 1981). In fact, episodic crustal oscillation is apparently a characteristic feature of oceanic basin development – running in tandem with the eustatic transgression-regression pulses. For the Atlantic transect in question, DSDP site 355 in the Brazil Basin may serve as a classical demonstration of the history of marine deposition – indeed reflecting the dynamo-tectonic pulse of the Earth. The three depositional breaks depicted in **Fig. 8 –** of late Cretaceous, late Eocene and middle Miocene ages respectively – are periods of erosion/non-deposition presumably related to periods of uplift of the oceanic basement and associated with magmatic events interlayered in the deep sea sediments (see Storetvedt, 1997 for discussion). Principal Alpine magmatic pulses date from around the Cenomanian-Turonian boundary, Maastrichtian, late Eocene, and Lower-Middle Miocene. These tectono-magmatic horizons are also seen in DSDP Leg 3 drilling sites across the South Atlantic (cf. Storetvedt, 1997 and 2003).

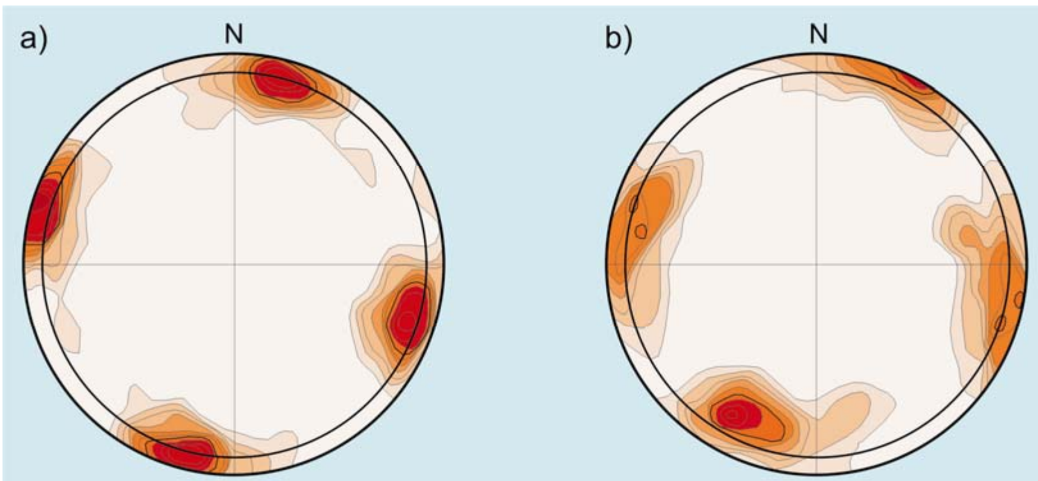

Fig. 7. Presentation of joint pole-density data for the Venezuelan Andes, after Scheidegger, 1982) in which diagram (**a**) shows directions from Presa Jose Antonio Paez district while diagram (**b**) represents joint observations from the Tovar region. The orthogonal joint axes correspond closely to the pre-Alpine global fracture network. Plots are on Lambert projection where the inner circle limits the lower hemisphere whereas the outer circle represents a 10 degrees overlap of the upper hemisphere.

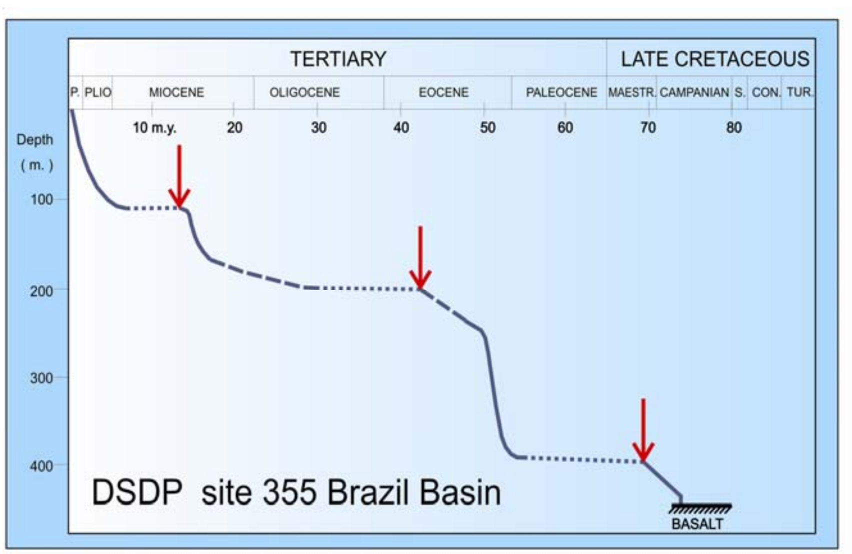

Fig. 8. Sedimentation history at DSDP site 355, Brazil Basin. Red arrows depict magmatic events in association with inferred oceanic basement uplifts. See text for discussion. Diagram is based on Supko et al. (1977).

The American segment

In the pre-Alpine configuration of the American continents, the Appalachian-Caledonian fold belt had a natural continuation along the north-western tip of South America – representing elements of an original palaeo-equator aligned (circum-globe) tectonic zone (Storetvedt, 1997 and 2003). The pre-Alpine palaeo-geographic arrangement of the Americas concurs with the proposition of Wilson (1954) that the circum-Pacific Benioff Zone formed as a great-circle contraction dislocation in the late Archaean. Later, notably during Jurassic and Cretaceous times, this deep fracture zone became a natural detachment structure for the developing Pacific continental margins. **Fig. 9a** portrays the pre-Alpine palaeo-geographic situation, and **Fig. 9b** shows the relative position of the deeper parts of the Benioff Zone after inferred Alpine continental rotations.

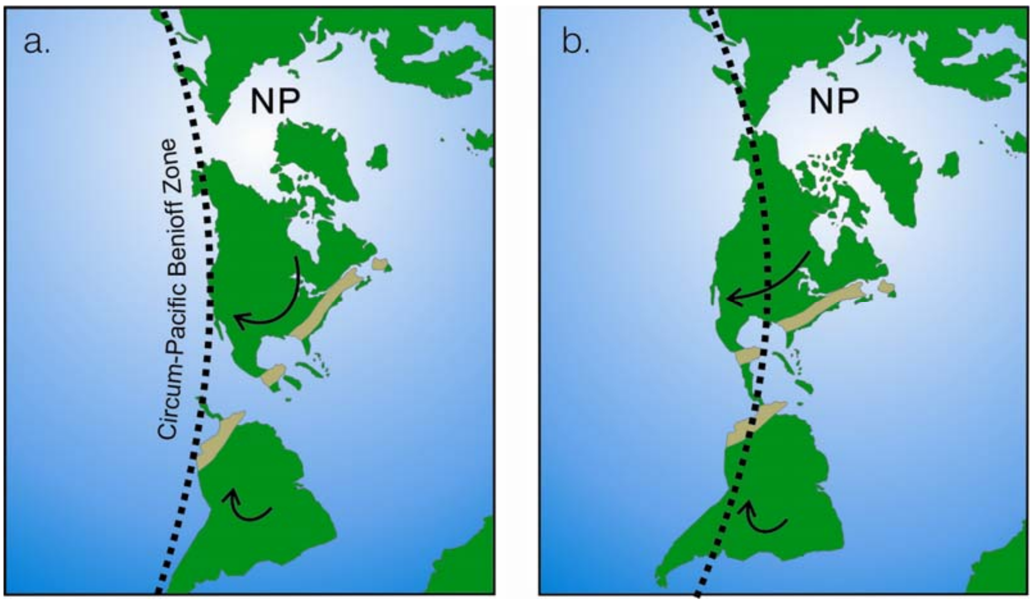

Fig. 9. Diagram (a) shows the fit of the original great circle Pacific Benioff Zone to the pre-Alpine azimuthal setting of the Americas. Continental configuration is in an oblique Mercator projection – after Wilson (1954). Diagram (b) delineates the position of the deeper part of the Benioff zone after Alpine lithospheric rotations. Note how the original Appalachian fold belt (light brown), running as a continuous zone along eastern North America to the north-western tip of South America, has become disrupted by Alpine lithospheric wrenching. NP denotes present North Pole.

As mentioned above, tectonic interaction across the equatorial Atlantic gave rise to considerable tectonic pressure along the developing margin of North Brazil, forcing South America into a certain south-westerly rotation; palaeomagnetic data demonstrate that South America was given an impetus that resulted in a ca. 20° southward latitudinal shift in addition to an overall clockwise rotation of the order of 10° (Storetvedt, 1992 and 1997). The general counter clockwise torsion of the southern palaeo-hemisphere did also affect South America, but its inertial motion was counteracted by a relatively strong transpressive force along the evolving North Brazilian margin – giving the continent an overall minor overall clockwise swing. Resulting from the polygon of inertial and tectonic forces, South America underwent a certain internal deformation with a tectonic hinge line in the region of Bolivia (cf. Storetvedt, 1997 and references therein). As Africa was wrenched counter clockwise while South America was forced into a minor net clockwise motion, the South Atlantic basin was tectonically strained and reshaped – attaining its present southward fanning-out shape, along with reactivation of its orthogonal fracture system, notably affecting the 'E-W' set. The overall minor clockwise rotation of South America, inferred from palaeomagnetic evidence, is illustrated in **Fig. 10a.** With respect to the global reference curve for polar wander, the palaeomagnetic polar paths for Africa and South America are located on opposite sides; this signifies that the two land masses have rotated in opposite senses.

Being located in the southern palaeo-hemisphere, South America would have been affected in part by inertia-triggered counter clockwise lithospheric torsion. This wrenching pattern is well demonstrated by the prevailing fracture system of the SE Pacific; cutting through the East Pacific Rise and the Chile Ridge the dominating set of the orthogonal fault system displays a certain SSW-directed convexity, in addition to having a general bearing being rotated some 20° counter clockwise with respect to its presumed pre-Alpine orientation (discussed above). However, due to the transpressive forcing on the North Brazilian margin the frontal margin of South America must have overridden the shallow-inclined Benioff plane along the Chile margin – producing a certain accretionary wedge in addition to other tectonic effects. For example, in southern Chile, at the junction of the Chile Ridge, the basement along the continental margin consists of metamorphosed Palaeozoic rocks intruded by the late Cretaceous-early Tertiary Patagonian Batholite (Mpodozis and Forsythe, 1983). Coring into Pleistocene sediments of the faulted trench slope of the same general region, ODP site 863 encountered thick and intensely folded sediments (Behrmann et al., 1994), and palaeomagnetic studies of the Taitao igneous complex suggests a deformation history involving at least two rotational events (Veloso et al., 2005).

Along the Peru-Ecuador-Colombia margin, the South American trench is displaying extensive-transtensive features – consistent with the inferred easterly rotation of northern South America. For example, in the Peru Trench numerous faults, running sub-parallel to the trench, are described – commonly forming grabens having widths of 3-5 km over distances as much as 100 km along strike (Warsi et al., 1983). The absence of a regional tectonic wedge along the northern South American Trench is well established. This difference in margin tectonics would expectedly have led to differences in vertical tectonics in turn producing differences in sea-level history. Comparing Cretaceous sea-level variation of the northern sector (Venezuela-Colombia-Ecuador-Peru) with that of Chile-Argentina, Macellari (1988) found a marked difference in the distribution of their marine strata. For the whole northern sector, he found an increasing marine inundation with maximum water depth in Turonian time – an observation that readily fits the average eustatic (global) sea-level variation (Haq et al., 1987). This suggests that any regional tectonic uplift of northern South America must have been insignificant. The situation for southern South America was found to be quite different; as seen from **Fig. 10b;** the global Senomanian-Turonian transgressive event is replaced by a regressive phase. This anomalous southern regression is consistent with the moderate western swing of southern South America, compelling a tectonic upheaval along the east-dipping Benioff Zone of the Chile margin.

The westward rotation of southern South America would naturally have displaced the sub-lithosphere section of the Benioff Zone eastward relative to the continent. Hence, the deeper part of the Benioff Zone, forming a natural supply route/zone for rising volatiles and magmas, would expectedly be expressed by inland volcanism – occurring at increasing distances southward away from the Pacific margin. The general course of the regional late Cretaceous-Recent volcanic zone (Hervé et al., 1987, Munoz and Stern, 1988) extends from just north of Tierra del Fuego on the Atlantic coast to the coastal region of northern Chile (**Fig. 10c**). In fact, the volcanic axis intersects the northern Chile margin at a very shallow angle (10-15°) – an observation that fits with the inferred rotation figure for South America. The sinistral nature of the major Magellanes Fault Zone (**Fig. 10c**), near the southern tip of the continent, is other evidence supporting the wrench tectonic scenario.

For the Atlantic bordering continents, the Alpine inertial rotations were only a few tens of degrees at most. But these relatively modest rotations, being component parts of palaeo-hemispherical torsions, readily account for the observed discrepancies in palaeomagnetic polar wander paths. Due to the relative rotation of the Americas, the Caribbean region – the crust of which, during the late Mesozoic, had been thinned and subdivided into a number of quasi-oceanic basins – was turned into a broad left-lateral shear zone (**Fig. 11**) with repeated activity. The left-lateral nature of the Caribbean-North America tectonic boundary has been corroborated by a variety of geophysical and geological studies (see Weyl, 1980 and references therein). For example, the axis of the Oligocene volcanic arc through Mexico and Central America is offset in a left-lateral sense across the Motagua Fault Zone. In other words, the relative rotation between North and South America was not completed during the Alpine climax. Recent GPS observations in the actual boundary region (Dixon et al., 1998) show that transcurrent motions are still operating.

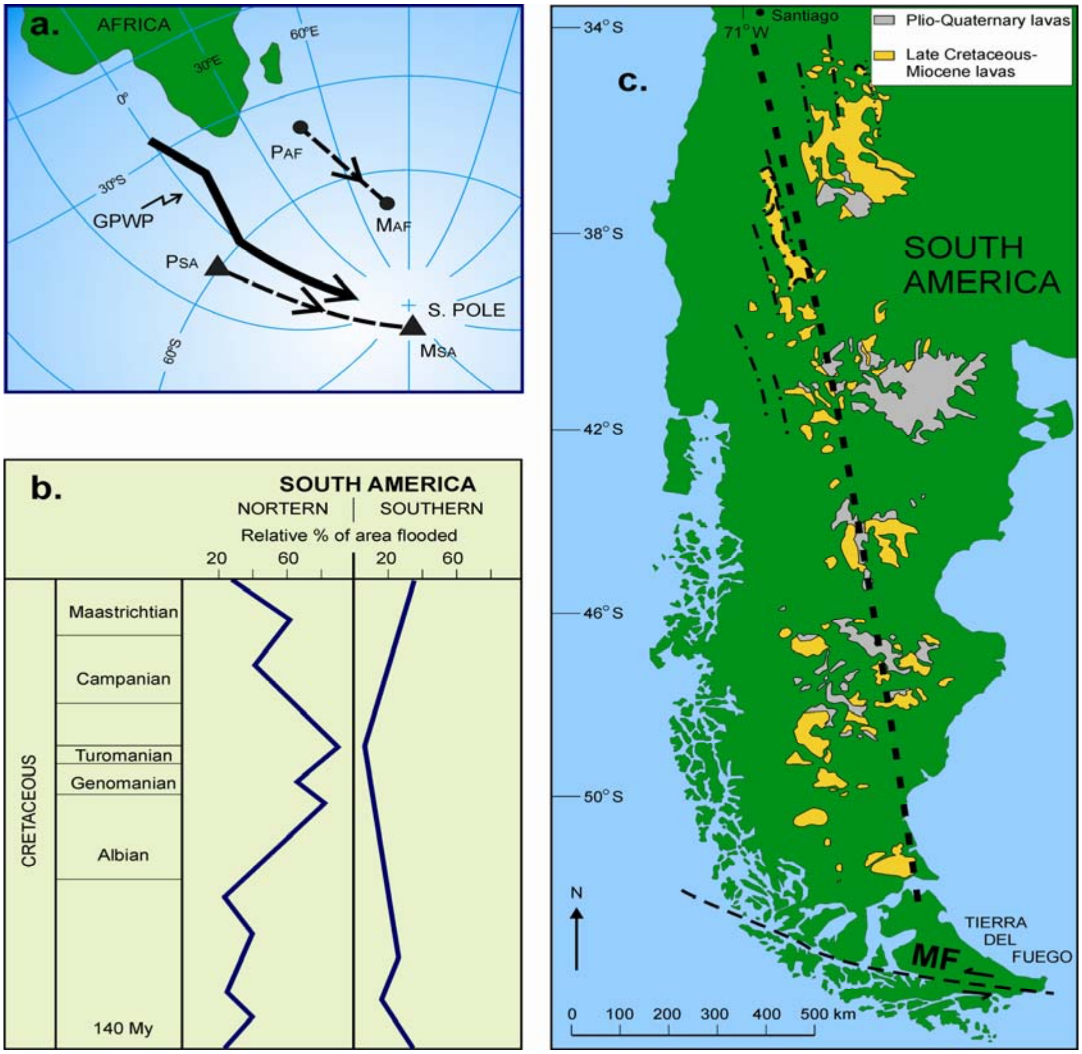

Fig. 10. Diverse observations corroborate the conclusion of a minor clockwise rotation of South America. Diagram a) displays the Permian (P) to late Mesozoic (M) palaeomagnetic polar wander paths for Africa (AF) and South America (SA) in comparison with the global reference curve (GPWP). Note that the polar paths for the two continents are located on opposite sides of the GPWP, suggesting that the two continents have rotated in opposite senses. The much smaller rotation figure for South America (ca. 10°) in comparison with that for Africa (25-30°) is in evidence. The minor clockwise rotation of SA would cause continental overriding of the deeper section of the Chile Benioff plane causing certain land uplift, while such effects did not impinge upon its northern sector. The resulting difference in late Cretaceous sea level variation is depicted in diagram b). Both the inland distribution of late Cretaceous-Recent volcanism and the left-lateral nature of the Magellanes Fault Zone (MF) at the southern tip of the continent (c) are other evidence favouring the wrench tectonic scheme. Diagram sections – a, b, c – are based on Storetvedt (1997), Macellari (1988), and Munoz and Stern (1988) respectively.

A main tectonic boundary formed along the trans-Guatemalan Motagua Fault Zone – a main segment of the palaeo-equatorial break-up zone with further continuation along the northern wing of the Puerto Rico Trench. As a result of this shearing, blueschist belts and other high pressure-low temperature rocks, in addition to occurrences of upper mantle material tectonically emplaced in the solid state, formed along the main fault zones (e.g. Nagle 1974). The overall eastward tectonic swing of northern South America and the Caribbean produced extensive conditions along the Middle America Pacific Trench – accounting for its graben-like structures and the absence of a regional tectonic wedge. The extensional conditions of the Pacific trench, on the South American side of the tectonic boundary, are also demonstrated by deep sea drilling, at IPOD site 67, off southwest Mexico. On the other hand, north of this major tectonic boundary, at IPOD site 66, the westward wrenching of North America has brought about a certain accretionary wedge. In this tectonic scenario, the Caribbean tract is therefore to be considered part of South America which during its moderate clockwise rotation produced a shallow-inclined tectonic arc along the Lesser Antilles. Further discussion is given in Storetvedt (1997, 2003 and 2009).

Southern North America is closer to the relative late Cretaceous-Lower Tertiary equator, and would therefore, during the Alpine climax, have been subjected to stronger inertia-triggered wrenching than more northern parts of the continent. This seems a reasonable explanation of why the characteristic orthogonal fracture axes show clockwise rotation southwards (cf. **Fig. 2**). The increasing southward wrenching processes did not only affect the North American continent, but the northern palaeo-lithosphere led also to notable tectonic deformation of the western Central Atlantic. In this part of the ocean both sets of the ubiquitous orthogonal fracture systems became reactivated; mineral alteration, including variable break-down of the original magnetic oxides, apparently took place along both fracture sets resulting in orthogonal bands of magnetic anomalies – impressed through induction by the ambient geomagnetic field (Storetvedt, 2010b; Storetvedt and Longhinos, 2011).

It is important to note that in the wrench tectonic system it is the palaeo-hemisherical caps that are being subjected to inertia-driven, latitude-dependent motion – during which a somewhat broader palaeo-equatorial region would have been particularly strained. In this process, tectonic breaks between continental and oceanic regions – due to differences in inertial effects between upstanding lands and low-lying oceanic tracts – will normally be insignificant. Therefore, principal marine-tectonic structures usually have their natural continuation onshore. As discussed above, the relatively large clockwise swing of North America, suggested by palaeomagnetic evidence, seems first of all to be a product of internal deformation with an overall westward torsion within the southern part of the continent – rather than representing an in situ rotation of the entire land mass. However, in the westward wrenching of the North American lithosphere, its upper Benioff Zone along the Pacific margin became disassociated from its deeper mantle section. In consequence, the lower section of the regional Benioff Zone attained its present inland position as indicated in **Fig. 9b**. This westward shift of North America, relative to the deeper portions of the Benioff Zone, probably accounts for the fact that the present volcanic activity of western North America occurs at relatively large distances from the Pacific coast.

As can be seen from **Fig.9b**, the Yucátan region of southern Mexico is located at around the intersection of the inferred deep mantle section of the Benioff belt and the Caribbean-North American tectonic boundary. Within the wrench tectonics paradigm, this tectonic junction would form a natural escape route for upper mantle gases and volatiles. Hence, during the Alpine tectonic revolution, when left-lateral displacement along the Motagua-Cayman Trough seems to have been at its peak, the tectonic motions are likely to have generated significant hydrostatic pressure increase in the regional asthenosphere giving rise to gas blow-outs at the intersection of the two major fracture zones. Therefore, the major Chicxulub Crater of northern Yucatan, dating from around the K/T boundary, is likely to represent a kind of pressure valve for release of ‘over-pressured’ mantle gas. It is important to stress that cratering – along with volcanism, tectonism, biological catastrophes etc. – is commonly observed at geological time boundaries. In other words, cratering seems intimately associated with the tectonic pulses building up Earth history (see also below).

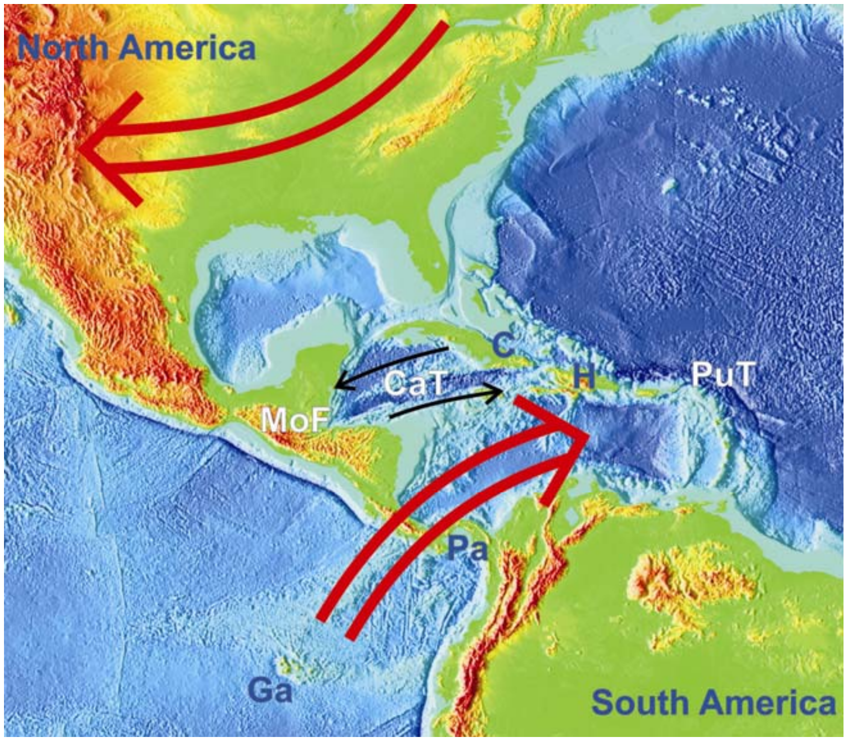

Fig. 11. Extended Middle America for witch superimposed large open arrows (red) depict the relative rotation of North and South America during Alpine time. The resulting main tectonic boundary, represented by the Motagua Fault Zone and the Cayman Trough, is marked by black arrows. The relative rotations of the Americas turned the quasi-oceanic Caribbean region into a broad left-lateral shear zone. To the south of this structural boundary, the Pacific margin – off Central America and northern South America – displays extensional features, while the trench north of the boundary show compressive characteristics including a certain sedimentary wedge (cf. text). Abbreviations are: CaT, Cayman Trough; MoF, Motagua Fault Zone; PuT, Puerto Rico Trench; C, Cuba; H, Hispaniola; Pa, Panama; Ga, Galapagos Islands.

The Africa-Europe tectonic relationship

Owing to the progressive deepening of the oceanic basins during the Mesozoic, it can be expected that an increasingly strong tidal grip led to accelerated planetary slowing. However, concurrently with the oceanic deepening, a substantial amount of former continental crust had been/was lost to the mantle, providing a net planetary acceleration (for data compilation see figs. 5.12b and 5.13b in Storetvedt, 2003). This acceleration (eastward), peaking at around the K/T boundary, led to a westward inertial wrenching of the global palaeo-lithosphere, with the maximum tectonic effect occurring along the time-equivalent equatorial zone – running along the present day Mediterranean region (see **Fig. 5**). However, within the late Cretaceous to Lower Tertiary time span the relative position of the palaeo-equator seems to have varied by some 15˚ of latitude – between the Alpine belt (in the north) and the northern rim of Africa (cf. Storetvedt, 1997 and 2003). In other words, during the Alpine diastrophic stages the palaeo-equators passed the general tracts of one of the two predominant contraction dislocations of early Precambrian age (see Wilson, 1954). The existence of such a deep globe-encircling fracture zone, along which sub-crustal thinning and basin subsidence would readily have occurred, explains the protracted development of the relatively shallow intra-continental *Tethyan Sea* (e. g. Sűss, 1893; Wolfart, 1967).

Long before the tectonic revolution along the Alpine-Himalayan axis, this mega-scale tectono-topographic tract was the site of an extensive east-west running seaway – the *Tethys.* To the south, the relatively narrow Tethys was bounded by the Afro-Indo-Arabian platform, but during the Palaeozoic the Sea repeatedly transgressed deep into the Arabian Peninsula and northern Sahara. To the north, a shallow continental ridge delimited the extensive *Tethyan* waterway from another epi-continental sea: the *Para-Tethys* (cf. Sonnenfeld, 1981 for extensive bibliography). *Para-Tethys* repeatedly covered major parts of Central Europe and

Central/North Asia. According to Sonnenfeld (1981), facies correlation across the Tethys demonstrates that, throughout Palaeozoic and Mesozoic times, while this epicontinental sea was a slowly subsiding basin, its southern and northern shores were in the same climatic belts with the fauna frequently displaying an endemic (geographically enclosed) character. However, the protracted Tethyan depositional history came to a close in Alpine time, but it is an important fact that the present-day Mediterranean basins are not remnants of the former Tethys. For example, according to Pannekoek (1969, and references therein) the West Mediterranean had a Lower-Middle Tertiary topography fundamentally different from that of today; numerous geological observations on the surrounding lands suggest sediment supply and nappe transport from areas now being occupied by West Mediterranean deep sea basins. Furthermore, Nesteroff (1973) observed a Miocene river channel parallel to the French coast, apparently having formed when no deep slope existed at right angles to its course (i.e. in the direction to present Alboran-Ligurian seas) – favouring the traditional (pre-plate tectonics) model that the West Mediterranean deep sea basins formed by vertical subsidence during the late Miocene (see Wezel 1985).

Turning to the Africa/Europe inertia-driven Alpine kinematic system, the two continental masses were located on opposite flanks of the palaeo-equatorial zone, continuing westward across the Central Atlantic towards the Caribbean and Central America. In this global tectonic process, Africa and Europe (Eurasia) moved in opposite senses – the inertia effects providing the dynamic forcing of the intervening Alpine fold belt. The relative rotation brought about a range of geological and geophysical features, including the well-established palaeomagnetic declination discrepancy between Africa and Europe (see **Fig. 12**), eventually leading to the collapse of the longstanding Tethyan Sea. In this process, “the supra-crustal infill was uplifted and deformed, and some of these deposits were thrust out over adjacent blocks. The Alpine thrust faults have a shallow ultimate angle that do not cut through the crust – unlike the earlier high-angle block faults” (Sonnenfeld, 1981, p. 35). The Tethys had had a long history of faunal endemism, but in the late Cretaceous that situation came to an end; due to the major (eustatic) Cenomanian transgression, oceanic faunas entered into the Tethys.

It is implied that, during the relative in situ rotations of Africa and Eurasia the two continental masses must, overall, have experienced similar marginal velocities (Storetvedt, 1990 and 1997). However, depending on variations in their instantaneous velocities, including latitude-dependent internal deformation, both right-lateral and left-lateral displacements would expectedly have taken place on individual faults along Alpine tectonic axis. In consequence, the wrench tectonic system predicts complex rotational behaviour of micro-blocks within the overall transpressive Alpine fold belt; numerous palaeomagnetic studies in the Central Europe-Mediterranean region conform to this prediction. However, the fact that the first-order tectonic boundary appears to have been positioned along the present-day Alpine and Pyrenean axes (Storetvedt, 1990) – not along the present Mediterranean as commonly alleged – profoundly alters the kinematic histories of regional micro-blocks (e.g. Storetvedt et al., 1990 and 1999).

Within the European Alps, blueschists and eclogites are relatively widespread (Droop et al., 1990), and the high pressure/low temperature conditions implied by these rocks are readily compatible with the Wrench Tectonics scenario. As has been shown by numerous authors, high pressure belts with glaucophane-bearing blueschists are principally of Alpine age; of particular importance, Ernst (1972) found that aragonite with jadeitic pyroxene and quartz are confined exclusively to late Cretaceous to Lower Tertiary metamorphic terranes. The observed time-dependent mineralogical variations suggest that the tectonic pressure in metamorphic belts has increased with time – being much stronger during the Alpine event than during preceding geological epochs. In addition, local transtensional regimes, with associated basin formation, basically reactivating elements of the fundamental orthogonal fracture network, would inevitably develop in places. Hence, ductile upper mantle material would easily be subjected to upward tectonic injection (at, say, 500˚C) through deep fractures. The tectonized ultrabasic material (of upper mantle provenance), generally altered to buoyant rocks rich in serpentine, chlorite, epidote and albite and often occurring in association with volcanics and geosynclinal sediments, are termed *ophiolites*. Thus, the general shearing tectonics along the Alpine-Himalayan tectonic axis readily accounts for the disconnected nature of these ‘exotic’ rock bodies. In conformity with the prognosis of Wrench Tectonics, Brookfield (1977) inferred that the ophiolites were located in narrow belts of vertical instability, between more rigid platforms, having been emplaced during high-angle wrench faulting.

Faced with the facts that the Earth's crust is extensively ruptured and that at least a certain portion of the fundamental rectilinear fracture systems cuts below the Moho (see Storetvedt, 2003, p. 176-177), it becomes evident that phases of global wrenching would have caused both reactivation and a certain degree of reshaping of the continental masses – such internal tectonic deformability being particularly expressed in near palaeo-equatorial regions where inertia 'forces' attain their maximum effects. The frequently observed parallelism between continental rifts and the pre-existing structural fabric attest to this principle. For example, during Alpine time the Precambrian rift system of Central Africa (**Fig. 12**) have repeatedly been affected by magmatic and tectonic activity. For example, in the Benue Trough, a 1000 km long and 50-100 km wide NE-SW striking rift depression, late Cretaceous and Lower Tertiary magmatism of varying composition occur at restricted sites along its entire length (e. g. Maluski et al., 1995). The presence, within the Benue Trough, of a 400 km wide positive gravity anomaly has generally been interpreted in terms of thinned continental crust having been replaced by elevated denser mantle. For example, on the basis of a 90 mGal anomaly amplitude Fairhead and Okereke (1990) arrived at ca. 14 km of sub-crustal thinning over a width of some 300 km of the Trough. Results like these are fully consistent with the evidence for crustal oceanization – on which the Wrench Tectonics schema is intimately related.

As outlined above, the pre-Alpine configuration of the South Atlantic, with its transoceanic land connections and their developing intermediate basins came to a close during the Alpine tectonic revolution. The combination of 1) global inertia effects and 2) tectonic interaction across the relatively narrow equatorial Atlantic passage led to moderate in situ oppositely directed motions of the Africa and South America – giving rise to the present-day southward fanning-out shape of the South Atlantic. Due to the minimal rotation of South America, regional segments of the 'E-W' set of fundamental fractures continue relatively unimpeded from the equatorial Pacific across northern South America to the mouth of the Amazon, extending over the Equatorial Atlantic, before going ashore in Africa in the Gulf of Guinea.

The African transcontinental fracture zone – a postulated overall left-lateral shear zone which has been termed the *Pelusium line* – has been studied by Neev (1975 and 1977; Neev and Hall, 1982; Neev et al., 1982). Neev and co-workers extended their tectonic mapping by using mosaics of LANDSAT imagery; they concluded that across Central Africa the fault zone consists of a series of *en echelon* shears. Further, they found that the fault system converge north-eastward – performing a relatively sharp counter clockwise swing in NE Africa. The Pelusium "convergence is most pronounced where the equatorial fracture zones join the African part of the system, close to the Gulf of Guinea, and also where the system approaches the southeast corner of the Mediterranean Sea, where the curvature of the system appreciably increases" (Neev and Hall, 1982, p. 10.689). A sketch map of the inferred *Pelusium Megashear* is shown in **Fig. 13**. The increasing counter clockwise bend towards the Mediterranean region is fully consistent with the Wrench Tectonic schema. As outlined above, the Mediterranean region had a palaeo-equatorial setting during the Alpine revolution along which the Coriolis Effect would have had its maximum significance. Just as we saw in the case of North America, on the opposite side of the time-equivalent equatorial zone, the internal inertia-driven continental deformation (rotation) increases towards the palaeo-equatorial belt.

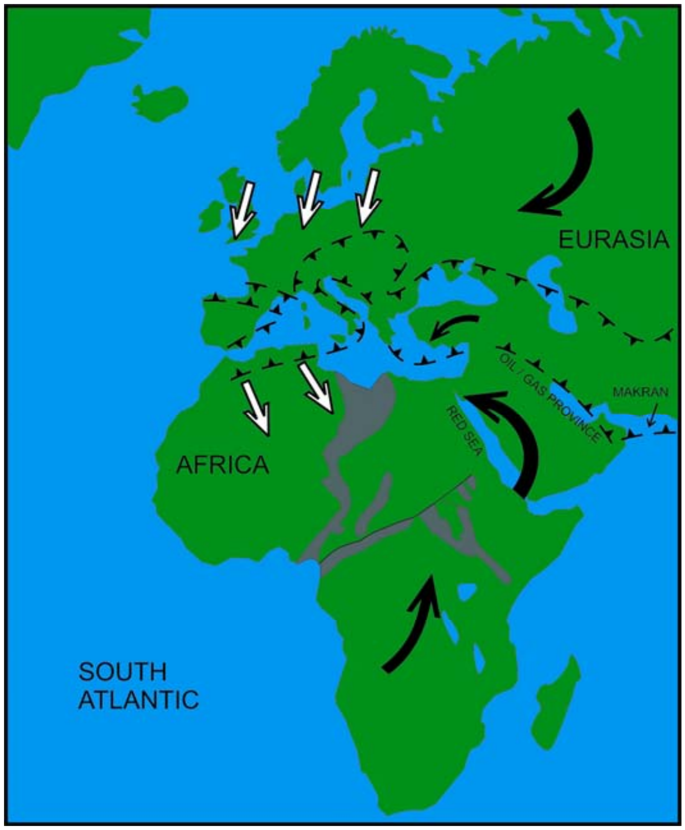

Fig. 12. A schematic diagram illustrating the relative Africa/Eurasia kinematics based on palaeomagnetic data. The common boundary region represents a section of the Alpine age palaeoequatorial zone. The intervening fold belt, which formed an overall transpressive zone, corresponds to the Alpine mobile belt. The continental rotations reactivated the old fundamental fracture systems which paved the way for the formation of continental basins in orthogonal arrangement – demonstrated here for Africa (grey colour). Note how the inertia-driven Alpine age continental rotations have given rise to the present declination discrepancy between pre-Alpine palaeomagnetic directions (white arrows) for Africa and Europe. Diagram is simplified after Storetvedt (2003). The counter clockwise rotation of Middle East is strongly supported by modern GPS-derived site velocity data (see Fig. 13). Note that the super-giant Arabian Gulf petroleum province follows along the southern regional boundary of the Alpine-Himalaya fold belt.

The palaeomagnetically-defined counter clockwise rotation of Africa (Storetvedt, 1990), along with the structural bending of the Pelusium line, is currently supported by a comprehensive continental deformation study based on the pattern of GPS-derived velocities of the north-eastern corner of the 'African' mobile block; the GPS study covers parts of Nubia and Somalia (NE Africa), the Arabian Peninsula, parts of the Zagros and central Iran, Turkey and the Aegean/Peloponnesus regions (McClusky et al., 2000; Reilinger et al., 2006). The overall velocity pattern, relative to the very slowly moving Eurasia, is sketched out in **Fig. 13**. The circulatory velocity pattern displays coherent motion with internal deformations – ending in a tectonic front along the Aegean Arc. Reilinger et al. pay attention to the relatively rapid motions (ca. 20-30 mm/yr) dominated by the large-scale counter-clockwise wrenching that encompasses Arabia, Anatolia (Turkey), and the Aegean region. They emphasize that the entire continental region south of the North Anatolian Fault of northern Turkey, and its south-easterly extension into central and southern Iran, is involved in this well-defined circulatory velocity/tectonic pattern. Reilinger et al. suggest further that the principal forces driving the Anatolia fault system is directly related to the origin of the south convexing Aegean Arc/Hellenic trench. Within the area of investigation, the velocity field shows significant internal variation – varying from a few mm/yr in NE Africa, 20-30 mm/yr across the Arabian Peninsula, and reaching maximum values of around 40 mm/yr in the Aegean region. Owing to the presence of the old rectilinear fracture systems, the superimposition of Alpine lithospheric torsion would be liable to cause smaller-scale curved deformations along principal tectonic boundaries. Thus, structures like the Aegean, Lesser Antilles, Scotia, Indonesian, Aleutian arcs would be predicted within the wrench tectonic scenario.

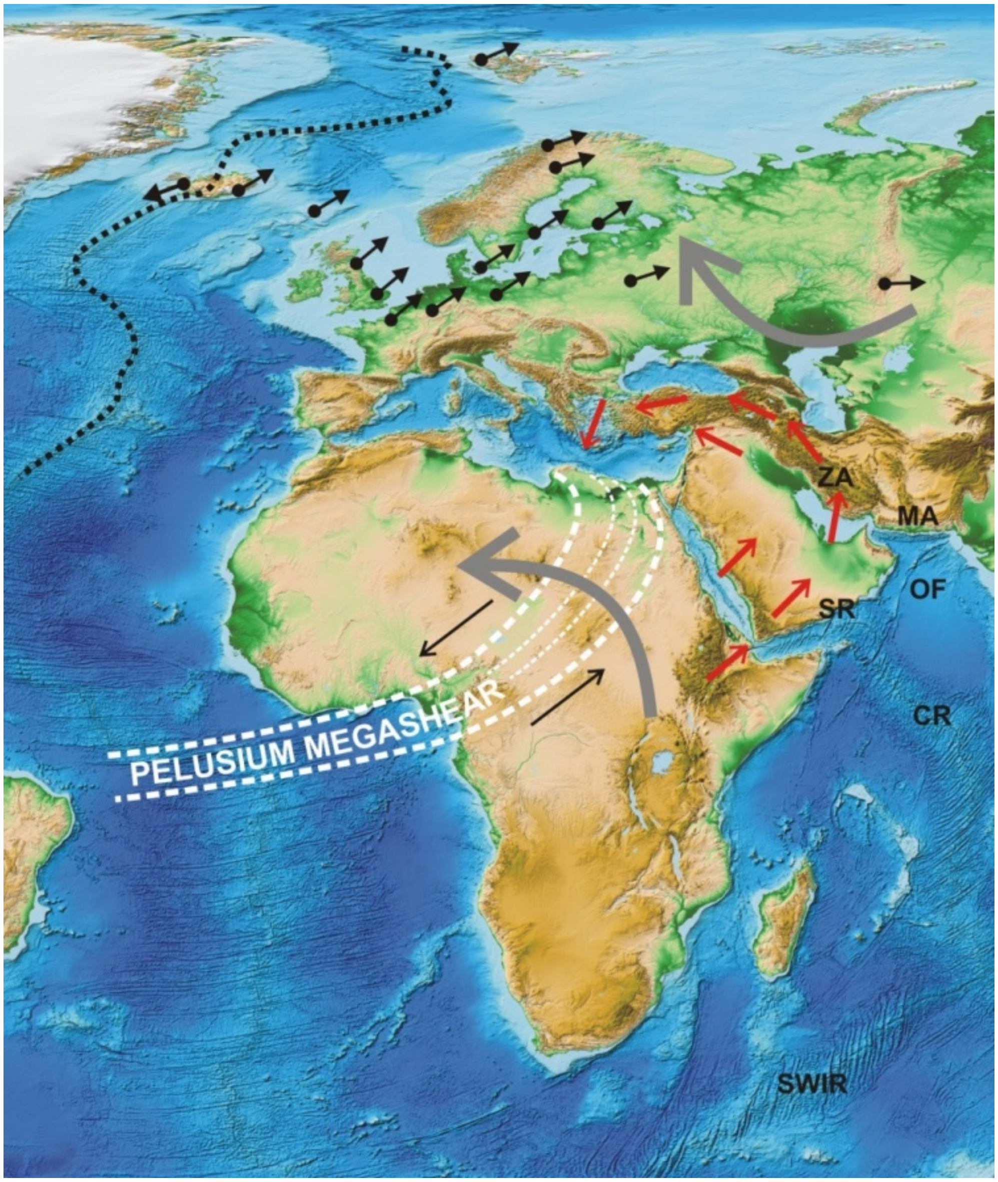

Fig. 13. Sketch map depicting the Alpine-Recent tectonic relationship between Africa and Europe. The large curved arrows (grey) represent *in situ* rotations of the two continental masses (ca. 25°each) for the Alpine climax, as defined by palaeomagnetic data (Storetvedt, 1990). Note that these motions are in opposite senses, which are consistent with 1) the position of the time-equivalent palaeo-equator (running along the southern rim of the Mediterranean) and 2) the inertia principle of hemispherical wrenching. Red arrows give a qualitative presentation of GPS motions within the Arabia-Iran- Aegean region; the marked circular motion defines a marginal tectonic block moving in harmony with the inertial torsion of the southern palaeo-hemisphere (anti-clockwise). For comparison, the suggested Pelusium Megashear across 'Central' Africa (based on Neev and Hall, 1982) is sketched out by hatched white lines; note its increased counter clockwise curvature in the palaeo-equatorial region – consistent with the inertia-based global wrenching principle. Thin black arrows across Central Africa indicate the inferred left lateral shear along the Pelusium Line. Short black arrows present examples of the well-established space geodetic motion system (GPS) for Western Europe – north of the Alpine front. The North Atlantic GPS data contradict the notion of seafloor spreading; instead, they are consistent with a shear origin of the Mid-Atlantic rift zone (cf. Storetvedt and Longhinos 2011). In agreement with the European GPS site motions, the whole of Eurasia appear to be currently undergoing a clockwise rotation (Zemtsov, 2007) – continuing its Alpine age motion devised by palaeomagnetism. Notations are: SWIR, SW Indian Ridge; CR, Carlsberg Ridge; OF, Owen Fracture Zone; MA, Makran compressive front; ZA, Zagros transpressive zone; SR, Sheba Ridge.

The Mediterranean Sector

From late Palaeozoic to Lower Tertiary times, Central and South Europe was crossed by a number of palaeo-equators (see also below); hence, by the time of the Alpine shear deformation across southern Europe a broad continental belt had already been tectonically reactivated and mechanically weakened – probably explaining the complex pattern of the European Alps, including a number of northerly swings deep into Europe. In the western Mediterranean, the first-order tectonic boundary seems to have been positioned along the present-day Alpine and Pyrenean axes – not along the present southern Mediterranean as advocated by plate tectonic presumptions. It follows that during the peak Alpine event the Mediterranean and Alpine regions were located along a northern marginal flank of Africa (which was part of the southern Alpine palaeo-hemisphere undergoing counter clockwise torsion). The westward convexity of the Western Alps is likely to be shaped by the counter clockwise rotation of Africa. In this regard, a GPS survey of the region (Vigny et al., 2002) found a relatively consistent, but small, westerly directed motion which they related to a certain E-W extension. In disharmony with plate tectonics inflicted models, predicting overall N-S compression, the authors state that "the north component of most of the GPS points within the western alpine belt and in the Corsica-Sardinia block is nearly 0 mm/yr with respect to Eurasia" (Vigny et al., 2002, p. 74).

The Alpine belt of the westernmost Mediterranean is bounded by the Pyrenean axis in the north while the southern border follows along the transpressive Atlas zone of North-West Africa (cf. **Fig. 12**). In addition, the major Azores-Gibraltar Fault Zone – splitting the regional Alpine shear belt and probably also being primarily responsible for sharp westward convexity of the Gibraltar Arc, Iberia was destined to significant tectonic instability. Like many other Alpine tracts, the North Pyrenean extensional basins were, in the latest Cretaceous, subjected to compressive/transpressive deformation that led to the development of folding, cleavage and low-temperature/high pressure metamorphism; the compressive phase(s), including a significant transport of imbricated tectonic units away from the basins, continued into the Eocene (Choukroune, 1976; Munoz et al., 1986). An estimated vertical offset of the Moho beneath the North Pyrenean Fault (Daignièrs et al., 1982) can be regarded as a product of juxtaposition of crustal segments of varying thickness during the late Cretaceous-early Tertiary transpression along the fault zone. On the other hand, the Alpine structural evolution of the Pyrenees cannot be happily matched with the alleged opening histories of the adjacent Bay of Biscay – the traditional counter clockwise rotation of Iberia.

In the Pyrenean region the inferred counter clockwise rotation of Iberia provided a transtensional regime which explains both the pull-apart basins and the alkaline magmatic activity occurring at that time (Storetvedt et al., 1999). Then, from about 75 to 60 my ago, Iberia rotated clockwise approximately 70˚. Hence, the net Upper Cretaceous tectonic effect in the Bay of Biscay was 30˚ clockwise, leading to a resultant closure (compression) in the Bay – not extension, as is commonly believed. Indeed, the net compression explains the intensive deformation, compressive margins, and deep marginal trenches of the Bay. **Fig. 14** gives a schematic display of the inferred kinematic history of Iberia in the topmost Cretaceous.

In recent papers, Gutscher and co-workers (Gutscher et al., 2002; Gutscher et al., 2009) have proposed subduction beneath Gibraltar, arguing against the longstanding and widely accepted opinion that the Alboran region was shaped by sub-continental delamination – i .e. a densified and detached lithosphere has sunk vertically to some level of the upper mantle, thereby giving rise to the present deep Alboran basin (e.g. Calvert et al., 2000). The extreme attenuation of the Alboran crust, from 36 km in the bordering Betic and Rif regions to less than 12 km in the eastern part of the Alboran basin (Torne et al., 2000), has given rise to some 8 km of sediments deposited since the Middle Miocene. In support of the attenuation/subsidence model, the results of Ocean Drilling Program Leg 161, at Site 976, of a basement high in the West Alboran Basin, "demonstrate that the basin is floored with metamorphic rocks of continental origin (high-grade schist, migmatitic gneiss, marble, and calc-silicate rock, cross-cut by granitic dikes)" (Comas et al., 1999).

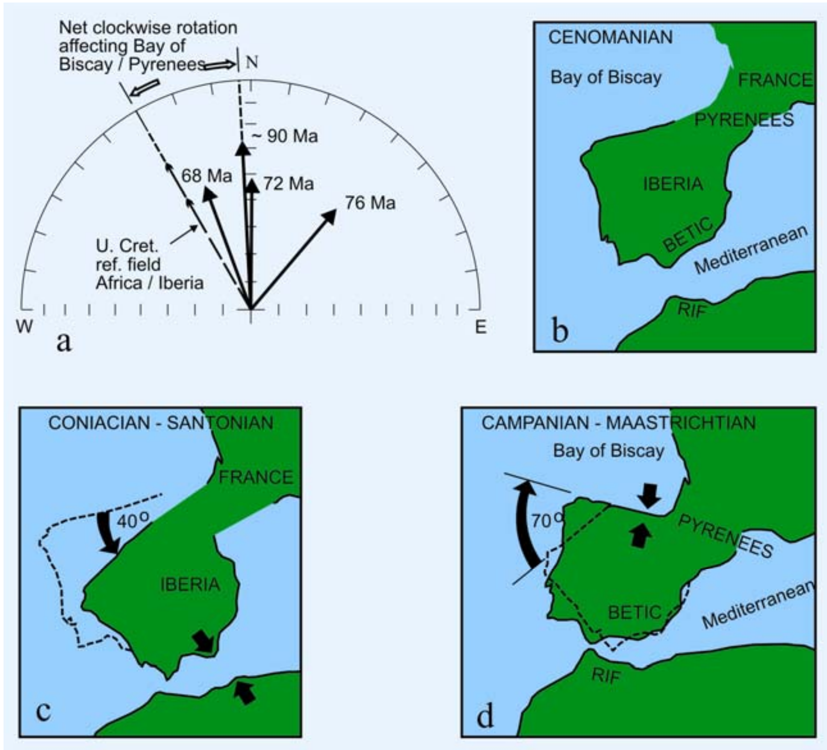

Fig. 14. Late Cretaceous kinematic history of Iberia based on palaeomagnetic and isotopic age studies (Storetvedt et al. 1990). Diagram (a) depicts the time sequence of late Cretaceous palaeomagnetic directions derived from dated alkaline intrusive rocks of Portugal, and diagrams (b)–(d) present the related tectonic evolution of Iberia. The inferred two-phase rotation, a counter clockwise torsion followed by a clockwise one, may account for the early Alpine deformation in the Betic and Rif belts – in addition to imposing metamorphic processes in the crystalline basement of the entire Alboran Sea region (c), as well as for the onset of Alpine tectonics in the Pyrenees. According to this mobile scheme the late Cretaceous alkaline intrusive rocks of the Pyrenean region, as well as in Portugal, were emplaced during the transtensive regime resulting from the anti-clockwise wrenching of the Iberia block. The resultant of the two-phase motion is a 30° rotational shortening of the Bay of Biscay (d) – compressing the pre-Alpine Bay (b), apparently being responsible for its strong basement deformation, compressive margins and bounding trenches. Illustration is from Storetvedt (1990).

Instead of the popular counter clockwise rotation of the Iberian Peninsula, palaeomagnetic and isotopic age studies (Storetvedt et al. 1990, 1999) have arrived at a two-phase rotational history – brought about by its unstable tectonic setting between the North Pyrenean Fault and the Gibraltar Fracture Zone. It was found that a ca. 40˚ of counter clockwise rotation (relative to Europe) had taken place at 100-90 my ago, giving rise to an intensive compressive deformation in the fold and trust belts of the Betic (SE Spain) and Rif (N Morocco) zones; the two tectono-topographic belts constitute the Gibraltar Arc that surrounds the 400 km long and 200 km wide Alboran Sea. Assuming counter clockwise rotations of Iberia and Africa, the Betic region would be prone to transpressive deformation probably including an overall dextral strike-slip; on the basis of recent crustal seismicity and GPS velocity data this sense of motion has in fact recently been suggested (Gutscher, 2012, fig. 1).

The crustal history of the Alboran Sea is likely to be a proper reflection of entire Mediterranean crustal belt. Thus, after the Alpine tectonic climax and prior to the vertical crustal collapse in the Upper Miocene, the whole western Mediterranean was supposedly a relatively high-standing continental area from which rivers were flowing towards the surrounding lands (cf. Pannekoek, 1969). Wezel (1985), for example, argued that, in the late Miocene, the Tyrrhenian region was the site of an upstanding intra-Alpine continental crust that in Plio-Quaternary time was subjected to variable sub-crustal thinning and vertical collapse activated by upper mantle processes; normal faults show throws up to 2000 m, rejuvenating pre-existing tectonic trends (Fabbri and Curzi, 1979). Reviewing the evidence for Plio-Quaternary ages of vertical tectonics of the Mediterranean, Sonnenfeld (1984) referred to studies indicating vertical throws up to 3000 m in post-Messinian times in Sicily, and that the crust of the Ionian, Aegean and Levantine seas probably collapsed in Quaternary time. A crust of intermediate thickness, with a Moho depth of about 20 km, has been arrived at beneath the Levantine Basin – in contrast to normal continental crust thicknesses of 30-40 km for mainland Egypt (Abdel Aal et al., 2000).

In comparison with the horizontal GPS velocities for the Arabia-Iranian-Aegean tectonic sector, the motion of sites for 'stable' Europe (north of the Alpine front) is relatively moderate – of around 10-20 mm/yr. The Alpine age clockwise rotation of Eurasia estimated from palaeomagnetic data (Storetvedt, 1990, 1997 and 2003) and supported by magnetic anomaly consideration (Storetvedt 2010b), is apparently still taking place. Thus, a compilation of GPS motions for Eurasia (Zemtsov, 2007), show that the continent is presently undergoing a slow clockwise rotation. A schematic presentation of Caltech/NASA GPS data north of the Alpine front in Europe, including sites east of the Mid-Atlantic rift zone, is depicted in **Fig. 13**. It is conceded that the continent, along with the north-eastern North Atlantic, is moving north-east – i.e. in a direction perpendicular to that required by the seafloor spreading hypothesis. A shearing origin of the Mid-Atlantic Ridge now appears much more likely – consistent with structural evidence from Iceland and many other segments of the North Atlantic (Storetvedt and Longhinos, 2011). The general northeast directed velocity field of the NE Atlantic includes also a site in NE Iceland. In a GPS study on the western Mid-Atlantic flank in Iceland (Hreinsdóttir et al., 2001), it was shown that when reducing the NUVEL-predicted motion (a plate tectonics-inflicted frame) for the reference station at Reykjavik, the GPS site velocities on the western flank of the Reykjanes rift attain south-westerly motions. It seems likely therefore that Iceland, and the rest of northern North Atlantic rift is being subjected to left-lateral shearing.

Major salt basins and hydrocarbon provinces within the degassing/wrench tectonics Earth

Facts opposing conventional thoughts

Western conventional wisdom holds that crude oil has been produced by biological processes – the fossil fuel theory. Despite the overwhelming support of the biotic view the scientific literature appears completely deficient in experimentally demonstrating any mechanism(s) by which biological substances decay to produce oil, after having been subjected to some kind of postulated 'pressure-cooking' process. Even when a fossil origin is taken for granted, Wilson (2005) – reviewing a number of obstacles surrounding conventional thoughts on the origin, generation, migration and accumulation of petroleum (a complex mixture of hydrocarbons), states that "The expulsion of oil from deeply buried source rock has never been satisfactorily explained and according to geochemists remains an enigma. The failure to decisively explain deep primary migration withdraws an essential foundation stone from the catagenic edifice". Wilson refers to much field evidence contradicting the conventional oil generation and migration hypotheses, arguing that ignorance of crucial facts have led to major misdirection in petroleum geological thinking. Too many aspects have simply been assumed rather than scientifically confirmed. Though the mass opinion holds that hydrocarbons are formed from sedimentary petroliferous beds, mostly shales and carbonates, pinpointing their actual source beds have frequently been an open question (e.g. Mahfoud and Beck, 1995; Mahfoud, 2000). The question of the source of petroleum was raised by Robinson (1966) who concluded that these resources have a duplex origin – being both organic and inorganic.

The perhaps strongest early critics of the fossil fuel theory was the Russian chemist Dmitry Mendeleyev [1837-1907] who suggested that crude oil and natural gas are primordial material – generated by the hydration of iron carbides upwelling from the deep Earth. From these early ideas, Kudryavtsev (1951) first articulated the modern Russian-Ukrainian theory of abiotic petroleum origins, and authors like Porfir'ev (1974) suggested that the bulk of hydrocarbon is generated in the upper mantle and then transported through deep faults to shallow regions of the crust. Around the world, hydrocarbons of undoubted mantle origin are seen being expelled as volcanic gases and as fluids discharged from vents. For example, Welham and Craig (1983) reported concentrations of methane and hydrogen in hydrothermal fluids at 21˚N on the East Pacific Rise, and Lupton and Craig (1981) described a major He-3 source – commonly regarded as a primordial constituent – on the same ridge at 15˚S. Melton and Giardini (1974) found that natural diamonds – having been rapidly transported to the surface in explosive vents (kimberlitic pipes), from their presumed source in the upper mantle – frequently contain inclusions of carbon-bearing fluids such as methane and carbon dioxide. Hunt et al. (1992) regarded these carbon-bearing fluids as reaction products of silicon carbides upwelling from the deep mantle. In harmony with the latter view, a diamondiferous kimberlitic rock from Fuxian, China, Leung at al. (1990) found clusters of silicon carbide co-existing with diamond.

In the solar system, methane is a major component in the atmospheres of the outer planets, and in the northern latitudes of Saturn's moon *Titan* large areal depressions filled with liquid methane and ethane have recently been discovered (e.g. Stofan et al., 2007; Metri et al., 2007). As hydrocarbon ices are common in the solar system (e.g. Kaufmann, 1988), and that much of the carbon material of carboniferous meteorites consists of hydrocarbons, in both solid and liquid forms (e.g. Studier et al., 1965; Gelphy and Oro, 1970; Hodgson and Baker, 1964), it appears likely that the Earth acquired its carbon inventory predominantly in its unoxidized hydridic form (e.g. Gold, 1985, 1999; Gold and Soter, 1982). Gold argues that if the Earth at some early stage had been a hot liquid body, those primordial hydrocarbons would have become oxidized. The fact that unoxidized hydrocarbons are being expelled continuously through the crystalline crust provides *prima facie* evidence that, overall, the Earth's internal temperature has always been relatively low (see also Storetvedt, 2011a). If the Earth is actually undergoing continual degassing, its outer regions would expectedly be subject to high hydrostatic pressure – maintaining an open fracture system below the depth level where the outward-directed hydrostatic pressure outweighs the inward-directed gravitational force. This is in fact what has been observed in the two super deep continental bore holes in Europe – in Kola and S. Germany

According to conventional belief, it is conceded that below a few kilometres the weight of the overburden is so great that fractures within even most resistant rocks are compressed to close all fracture spaces – thereby eliminating the possibility of fluid flow from deeper levels. For a degassing Earth, however, the situation would be quite different. At each depth level, rocks and fluids would be subject to a common pressure – providing a kind of pressure bath situation, with fracture spaces being kept open just as in near-surface rocks at relatively low overburden weight (Gold's pore theory, see Hoyle, 1955). This principle has been well demonstrated in the super deep drilling projects – in Kola (max depth of 12.2 km) and at the KTB near Windischechenbach of S. Germany (max depth of 9.1 km). In both cases it was found, against conventional thinking, that the fracture spacing increased with depth, and at many levels one encountered free flow of hydrous fluids with an assortment of gases – such as hydrogen, carbon dioxide, nitrogen, methane etc. Below 3.4 km of the KTB hole, in continental crystalline basement thought to be bone dry, observations found several fluid inflows with high methane concentrations. Apart from methane and ethane, propane and butane as well as traces of unsaturated hydrocarbons such as ethane and propene could also be detected at many levels of the drill hole (Zimmer and Erzinger, 1995). Based on the ratio of nuclear isotopic weights of the helium gas, which was entrained in the hydrocarbons, the hydrocarbons were identified as having mantle origin.

Petroleum is commonly found to contain fossil fragments. The question arises therefore whether these biological components are remains after some unresolved oil-producing process, or have the spores, pollen and other bio-fragments simply been picked up by upward flow of hydrocarbon-bearing solutions from deeper levels? The Dnieper-Donetsk depression of Ukraine, a major hydrocarbon-rich basin in which the oil contains a considerable quantity of micro-photo-fossil components from a variety of ancient plants, may serve to elucidate this question. Thus, studies have shown that 70-75% of all the ancient spore pollens found in the oil of the Ukrainian basin are of Proterozoic origin, regardless of which reservoir rock and depth from which the oil is recovered (cf. Corsi and Smith, 2005, and references therein). In a 2001-report on hydrocarbon potentials of the Dnieper-Donetsk Basin, surveying all the scientific analyses conducted, gave the following conclusion; "These results, taken either individually or together, confirm the scientific conclusions that the oil and natural gas found both in the Precambrian crystalline basement and in the sedimentary cover of the (…) basin are of deep, and abiotic, origin" – see individual articles in the report on

The Drilling and Development of Oil and Gas Fields in the Dnieper-Donetsk Basin; http://www.gasresources.net/DDBflds2.htm.

As overwhelmingly demonstrated by observation, a steady outward flow of volatiles – water vapour, carbon dioxide and various gaseous hydrocarbons – gives reason to believe that de-volatilization of the interior body has been an on-going process since the dawn of the planet, an internal mass transfer process that seemingly is far from completed (cf. Storetvedt, 2003 and references therein). In this context, Gold (1987 and 1999) regards buoyant fluids the principal agents in the internal mass transfer system – a perpetual process towards thermo-chemical equilibrium; he paid particular attention to the role of hydrocarbons which apparently are widespread in the solar system (and in the universe). Methane effusion through crystalline rocks is a worldwide phenomenon; thus, from a deep sea drilling (ODP Leg 118) site on the SW Indian Ridge, Evans (1996) and Kelley (1996) describe the findings from a 0.5 km core of gabbroic rocks – underlying mid-ocean MORB basalt – in which methane is an abundant volatile component in fluid inclusions throughout the length of the core, in some horizons the only major volatile. The methane concentrations were found to be up to 40 times those of oceanic vent fluids.

Methane occurs in many habitats: it apparently leaks from most of the Earth's surface rocks and oceans, it is found in swamps and in manure of animals, it is found in diamonds of lower/upper mantle provenance, it is commonly associated with oil – but it occurs also in geological domains where oil is relatively rare or absent, such as within tectonic belts (Howell et al., 1992). Gold argued that the continuing stream of upwelling un-oxidized hydrocarbon gases – in volcanic and non-volcanic regions alike, probably being responsible for the major world-wide occurrences of gas hydrates found along many deep continental margins – is *prima facie* evidence for a cold origin of the Earth. If the planet at some stage had had a molten or very hot deep interior, the volatiles would have been driven off while for an originally cold planetary body gradually heating up degassing processes would likely be continuing as long as internal temperatures are increasing in any part of the interior (Gold, 1985). In addition to the common stream of methane, the occurrence of oil along many deep fracture zones, notably in sectors of the circum-Pacific Benioff zones and on 'mid'-oceanic rifts (e.g. Czoshanska et al. 1986, Kenvolden and Simoneit 1990, Bazhenova et al. 1998), has remained puzzling for the biotic theory.

Today, cases of hydrocarbons in reservoirs of the crystalline basement are steadily reported, but such 'unconventional' finds are still on a serendipitous basis (Farooqui et al., 2009). Numerous productive oil and gas fields around the world are producing from reservoirs in the crystalline basement – see www.geoscience.co.uk. Shutter (2003) has presented an extensive, but incomplete, list of hydrocarbon-bearing igneous rocks – including production fields, seeps and shows – showing their worldwide distribution. Since the late 1970s, discoveries of hydrothermal fields along the Mid-Atlantic Ridge have repeatedly been made; their characteristic feature is their location on, or adjacent to, mantle outcrops of peridotites. Serpentinization of peridotites may, in reaction with water, produce a chain of chemical substances for which end products are methane and carbon-dioxide (see Konn et al., 2008) – gases that are prevalent in oceanic vents.

Sugisaki and Mimura (1994) analyzing mantle-derived rocks such as tectonixed peridotites and peridotite xenoliths found that these rocks contained heavier hydrocarbons. From their study, they concluded: "It appears that hydrocarbons may survive high pressures and temperatures in the mantle, but they are decomposed into lighter hydrocarbon gases such as CH4 at lower pressures…". In a subsequent comment to these findings, Kenney (1995) concurred. He summarized earlier results of Mogarovskiy et al. in Russia in which the concentration of dispersed hydrocarbon material had been found to be greatest in rocks of clearly mantle origin, diminishing in granulites and related basic rocks. According to Russian findings, crude petroleum in their investigated rock collection was of inorganic (mantle-derived) origin. In subsequent work, Kenney et al. (2002) described the properties of the hydrogen-carbon system, concluding that in the Earth's mantle methane is unstable; for thermo-chemical reason they inferred that at pressures of the mantle methane will decompose to different types of oil found in natural petroleum. If so, the methane flow through the Earth's crust may be referred to chemical processes in the upper mantle and/or lower crust, consistent with the observations of methane inclusions in diamonds – found in kimberlitic pipes of suggested mantle provenance. However, from recent high-pressure chemical experiments (Kolesnikov et al., 2009) it was concluded that methane is stable under upper mantle conditions and that hydrocarbons heavier than methane can be produced by abiogenic processes in the upper mantle. Adding to this, Hunt et al. (1992) suggested that at reduced pressure levels, in the upper mantle and lower crust, fluid carbides and hydrides (ascending from the deep Earth) in reaction with hydrogen/oxygen may produce other volatiles, such as monosilane ($SiH4$) and methane, both being combustible and endowed with latent heat. Following the latter idea, the irregular asthenosphere, with its assortment of gases and pockets of magma, may be explained. All in all, it seems overwhelmingly demonstrated that crude oil and natural gas can be created in other ways than via biological remains. This means that hydrocarbon reservoirs can be expected to occur in all types of rock – the granitic basement included.

Recently, GEO365.no published an article [in Norwegian] on the first major discovery of oil in the Caledonian basement of the North Sea: the Tellus field – http://www.geo365.no/olje_og_gass/mettet-med-olje/. The article mentioned also that indications of petroleum occurrences in the granitic basement had been available already by the early 1970s, but, as 'nobody' could envision that granitic rocks could contain hydrocarbons at that time, exploration of the basement had been severely delayed. The Tellus field is in highly fractured and weathered granitic-metamorphic rocks – probably of Precambrian age but with strong Caledonian overprinting at ca. 400 my. With respect to the origin of the oil, it was noted that it seems impossible to distinguish between the oil from the basement reservoir and that of the overlying Jurassic sandstones – indicating that the oil in both reservoirs have been surged up from deeper sources. The surprising finding in Norwegian waters is compared with similar occurrences elsewhere, such as the discovery in fractured granites offshore Vietnam (Cue Long Basin), in granites of the Arakan ranges of India – Borhola and Champang fields (www.dghindia.org), and in granites and metasediments of Yemen (Gutmanis, 2009). The present situation is well described by Farooqui et al. (2009, p. 47) who state: "While some operators might stop drilling after encountering 'basement', those with a better understanding of the potential of volcanic rocks may treat them like any other prospective reservoir rock".

The 'enigma' of major salt deposits: evaporates or precipitates?

Palaeozoic the northern continents experienced repeated events of surface salt accumulation. For example, during the Infra and Lower Cambrian the Salt Range Province of Most prolific oil and gas fields have a salt-controlled structure; hence, they are often referred to as salt basins. During the Pakistan, the Arabian Gulf and Central Iran were all sites of salt accumulation in subsiding regional sub-basins of the early Tethys (Husseini and Husseini, 1990). At that time, the Earth had a markedly different spatial orientation than now. Thus, according to palaeomagnetic and palaeoclimatic data the time-equivalent equator ran across present-day Arctic Canada with continuation along the length of the Atlantic, giving Pakistan and environs very high latitudes (cf. Storetvedt, 2003 and 2005); the 'northern' pole was positioned around Afghanistan with the corresponding anti-pole located in the SE Pacific. Despite of their high palaeolatitudes, the regions of western Pakistan, Afghanistan, Iran and Arabian Gulf, have carbonate facies rocks of latest Precambrian-early Cambrian age that grade into layered deposits of chlorides, sulphates and nitrates, reaching a maximum thickness of the order of 1000 metres. This major concentration of salts (with various chemical compositions) is the largest sequence of its kind reported for these early times (cf. Zharkov, 1981 and references therein). Freeze-drying may lead to the production of brines (and eventually to salt deposition in high latitude lakes, such as is observed in present-day Antarctica), but salt evaporation in a polar environment is not likely to precipitate layered salts, and the amount of such desiccations would be negligible compared to that of the great majority of salt basins. As stated by Sonnenfeld (1984), the environmental conditions to be fulfilled for large-scale and voluminous evaporate precipitation to take place are indeed, at any latitude, very specific and therefore unlikely to be met on a continual basis. But even so, major salt deposits occur in nearly all epochs of the Phanerozoic. Therefore, the question arises whether the major Tethyan region salt basins (with ages spanning from Cambrian to late Miocene) primarily are products of precipitates from fault-controlled planetary outgassing of high-concentration brines – rather than having formed as products of surface evaporation.

It is known that the thickest sequences of salt are located to the areas of a basin that have experienced the greatest rate of subsidence – in grabens or fault-controlled basins (cf. Sonnenfeld, 1984 for discussion); layered halite deposits in depressions generally occur where strong linear trends suggest fault control. In Europe the most significant salt basins are found in the Zechstein belt of Central Europe, the North Sea Basin, the Dnieper-Donetsk Basin of Ukraine, the major Kengurian salt sequence in the deep basin at the northern Caspian Sea, and along the Ural Belt. **Fig. 15** shows the distribution of these salt basins, seen in conjunction with the Permian palaeoequator. While the Zechstein and Dnieper-Donetsk salt sequences formed along the equator-aligned fault zone, the Permian salt of the North Sea and Ural depressions originated in rift basins oriented at steep angles to the same palaeoequator; this near-orthogonal arrangement of salt basins is a dynamo-tectonic consequence of global lithospheric wrenching (Storetvedt, 2003 and 2007) driven by planetary degassing and related internal mass reorganization. Considering the degassing Earth proposition, major salt basins would be restricted to regions of transtension – associated with deep lithosphere-cutting faults providing the necessary channels for mantle fluids and gases – including brines, hydrocarbons, water, magma etc.

Sonnenfeld (1984), taking a cursory glance at various suggestions in terms of a non-evaporitic origin of salt accumulations, mentioned non-traditional observations scattered in the literature, such as: a plutonic origin of sedimentary salt sequences, that some basic volcanic eruptions are followed by a relatively thick succession of halite, and that fumarole encrustations around some Central American volcanoes precipitate a range of principal minerals characteristic of salt sequences – predominantly halite, sylvite, gypsum and anhydrite. Furthermore, numerous studies of granulites and deep-seated granitic intrusions have described inclusions of solid halite and high concentrations of saline fluids, carbon dioxide, methane and water (e.g. Bradley et al., 1978; Konnerup-Madsen, 1979; Frezzotti et al., 1994; Lira et al., 2007; Srikantappa et al., 2010). Thus, Lira et al. (2007) described halite and sylvite solid inclusions in igneous quartz and feldspar crystallized under magmatic conditions. In the same thread, Harris (1986) – studying the mineralogical composition of Ascension Island granite intrusion (Equatorial Atlantic) – argued that, because the original magma had been saturated with respect to saline aqueous fluid, the observed mix of silicate melt and saline aqueous had most likely a magmatic origin. In the passing, we should not forget that when the KTB deep continental drill hole reached below 4 kilometres in the old crystalline crust of SE Germany, "more than half a million litres of gas-rich, calcium-sodium-chloride brine twice as concentrated as sea-water poured into the well. Abundant fluids gushed from depths as great as 6 kilometres" (Kerr, 1993).

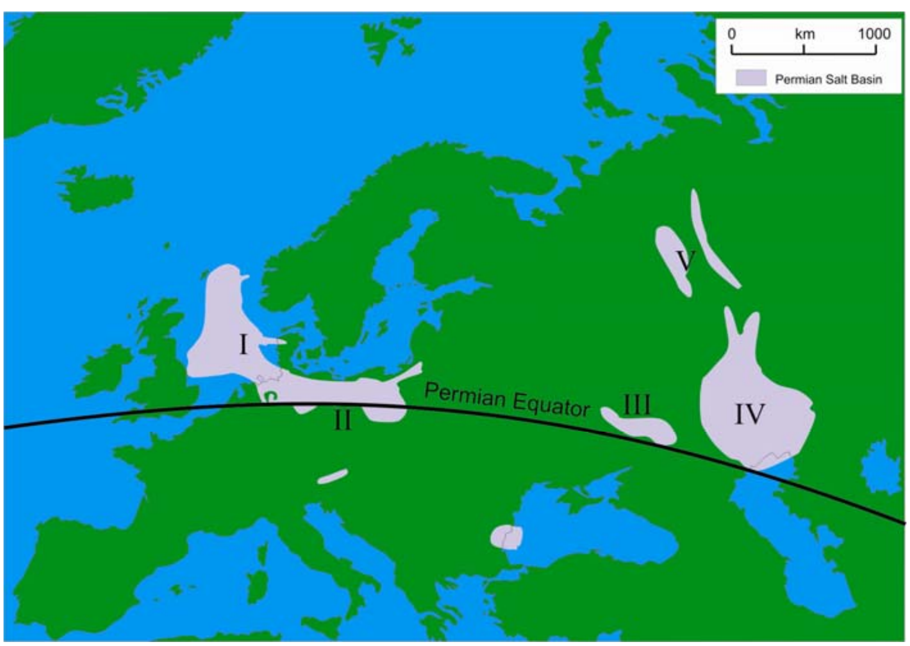

Fig. 15. The Permian palaeo-equator seen in conjunction with contemporary European salt basins: I, North Sea; II, Central European Zechstein; III, Dnieper-Donets; Northern Caspian; IV, Ural, Northern Caspian; V, Ural.

Deep Sea Drilling Project, Leg 13, unravelled a vast salt deposit beneath the deep abyssal floor of the Mediterranean – consisting of successions of dolomite, gypsum, anhydrite and halite. The results spurred off the ‘deep-basin, shallow-water’ desiccation model (Hsü, 1972; Hsü et al., 1973); it was concluded that around 5-6 million years ago (Messinian time) the Mediterranean Basin was cut off from its oceanic contact and subsequent phases of drying-up and periodic flooding (through the Gibraltar channel) of the Mediterranean had gradually accumulated a total of 2-4 km of evaporates. Despite the wide acceptance of the deep-basin origin of the salt layers, a number of their mode of formation has apparently not been properly accounted for (e.g. Hübscher et al., 2007). Wezel (1975), for example, argued that stratigraphic information from DSDP Leg 13 cores contradicted the deep desiccation model for the major Messinian salt deposits. He concluded that seismic reflection profiles in the Western Mediterranean showed progressive pinching-out of the salt sequence, and of its overlying Pliocene unit, toward the margins of the depositional basins. In the interpretation of Wezel, these observations favoured the traditional (pre- plate tectonics) subsidence model for the West Mediterranean deep sea basins. According to Debenedetti (1976), analysis of the salt budget suggests that the Mediterranean salts were precipitated from brine and were not the product of repeated evaporation to total desiccation.

Also, authors like Nesteroff (1973) and Sonnenfeld (1985) argued against a deep-basin, shallow water origin for the Messinian salt deposits and both presenting long lists of counter arguments the evaporate model. Recently, the deep-basin, shallow water formation of the anomalously thick salt accumulation has been challenged by Hardy and Lowenstein (2004) and Manzi et al. (2005). **Fig. 16** shows the distribution of the Messinian halite and gypsum/hydride occurrences, a regional coverage that presently pay little attention to sea floor structure or coastline configuration. In fact, these layered chloride and sulphate accumulations presently are found both in deep water settings as well as at heights of some 3000 metres in surrounding lands (cf. Sonnenfeld, 1984).

According to the Wrench Tectonic theses, the marked mid-late Miocene eustatic regression (e.g. Haq et al., 1987) is intimately related to the youngest major phase of crustal oceanization, transforming particular regions of continental crust into oceanic-type structures. For example, after the Alpine climax the western Mediterranean region seems to have been relatively high-standing draining towards the surrounding lands (Pannekoek, 1969). In conformity with that view, Wezel (1985) argued that, in the late Miocene, the Tyrrhenian Sea – which presently (like the rest of the Mediterranean) is underlain by transitional crust of greatly variable thickness – was the site of an upstanding intra-Alpine continental crust. Then, in Pliocene-Quaternary time the regional crust was subjected to variable attenuation and vertical tectonic collapse activated by upper mantle processes – giving rise to the present configuration of individual circular-to-oval-shaped depressions. The dynamo-tectonic wave that swept the Earth in Miocene-Pliocene time is likely to have functioned like a hydraulic device affecting a wide range of geological processes. Besides its crustal attenuation mechanisms, the assortment of asthenospheric fluids and gasses – brines, carbon dioxide, petroleum, hydrocarbon gasses, etc. – were subjected to upward surge through lithosphere-cutting faults/migration pathways. In this view, it is not surprising that the Levant Basin (inner Mediterranean), with a Messinian salt sequence of up to 2 km, is presently being regarded as having giant oil and natural gas prospects (Peck, 2008).

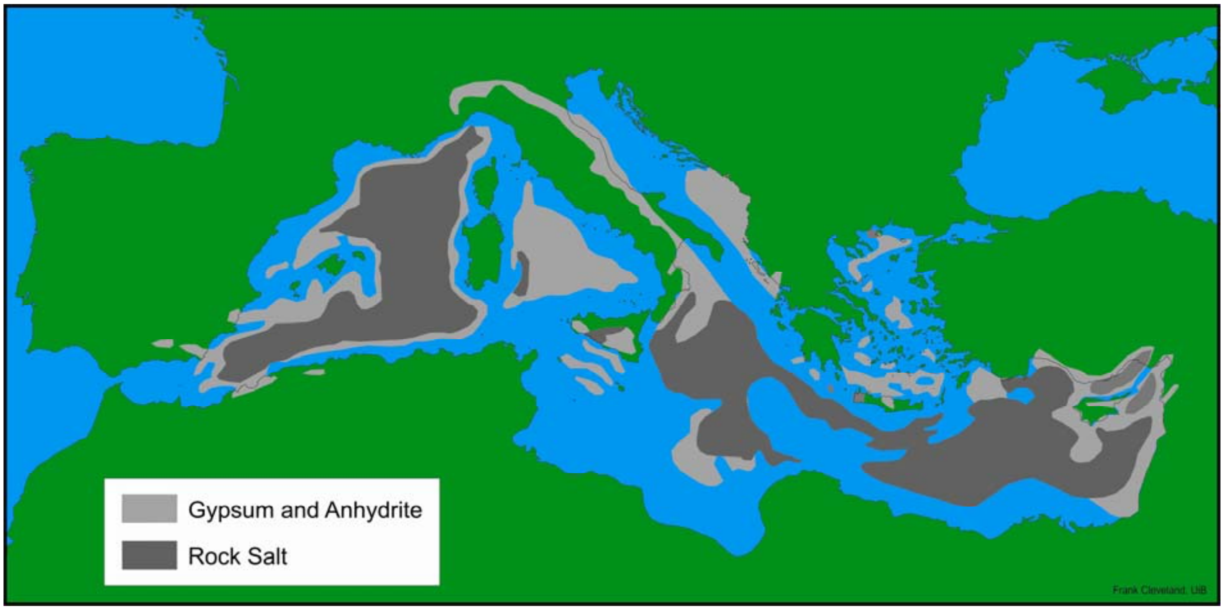

Fig. 16. Simplified distribution of Messinian rock salt (halite) and gypsum/anhydrite layers in the Mediterranean region. After Rouchy (1980).

Major hydrocarbon provinces versus Wrench Tectonic predictions

From the consideration above it seems very likely that at least a major part of hydrocarbons in the crust – in gaseous, liquid, and solid states – stems from chemical processes in the mantle. We are led to believe that high-concentration brine, juvenile water, oil, natural gas, hydrogen sulphide etc. are being expelled from the mantle in the jerky dynamically-powered hydraulic system of the Earth (cf. Storetvedt, 2003). Effective upward surging processes would require deep lithospheric fracture zones, which according to the wrench tectonic thesis is, for example, a required condition for the development of distinct ocean-continent boundaries. In fact, granted the availability of sufficient hydrous fluids, and with hydrostatic pressure conditions being satisfied, the metasomatic reaction to eclogite will proceed rapidly along prominent lithospheric fracture zones, reducing the rock volume by 10-15% (Austrheim et al., 1996) – thereby adding to the transtensive nature of the continental margins arising from sub-crustal attenuation and related isostatic sinking of oceanic territories. The along-fault volume reduction caused by upward progressing eclogitization will increase the fracture spacing of the developing continental margin, allowing enhanced fluid infiltration and related metamorphic reactions as well as providing a more effective fluid pathway towards the surface. Beside hydrocarbons, an important constituent in the transport system of volatiles is water which at temperature conditions expected for the topmost mantle would be in a supercritical state (e.g. Bellissent-Funel, 2001). In general terms, a supercritical fluid has properties between those of a gas and a liquid, and the combined solubility and diffusibility of supercritical water have the ability to entrain solid matter predictably breaking down solid rocks to mud. The Earth is apparently continuously ejecting juvenile volatiles from the mantle. These emissions may be explosive, giving rise to surface cratering, occasionally associated with hot magma, but at numerous locations around the world volatiles reach the surface as constituents of rather sedate mud volcanoes. However, as has been reported by numerous authors, the emitted gases, pervading crystalline terranes, are often flammable, comprising constituents such as alkane hydrocarbons (methane), hydrogen sulphide and hydrogen.

On this background, it is not surprising that an association of gas hydrates and mud volcanos are found in regions of deep lithospheric fracture zones – either along continental margins or within major tectonic zones where methane and hydrous volatiles would have had escape routes to the surface. Solid gas hydrates resemble ice, in which the host molecule is water and the guest molecule is methane or another gas. Natural methane hydrate deposits are found primarily in near-surface sediments in deep margin settings (e.g. Kenvolden and McMenamin, 1980; Milkov, 2000; Buffett and Archer, 2004) – occurring in discrete layers pushing the sediment fabric apart. In addition to the upward flow of an assortment of natural gasses and juvenile water, the margin fracture zone will also be prone to transport a steady stream of mantle-produced oil and brines to surface layers. During the Alpine wrenching of the global lithosphere, many continental margins became hyper-transtensive, accelerating the fluid-enforced eclogitization/delamination processes, and exhumation of mantle rocks in many parts of the thinned and fractured oceanic crust; the process gave rise to many deep margin-parallel sedimentary belts – including gas hydrate formation, accumulation of oil and natural gas, and precipitation of salt from high-concentration brines. According to wrench tectonics, the Atlantic margins are primarily of hyper-extended nature, having provided the tectonic condition for the development of salt basins with their complex salt deformation structures and petroleum resources. Many of the Atlantic border zones have indeed turned out to be prolific hydrocarbon provinces (see **Fig. 17**), but many more discoveries will most likely be made in the future.

The Americas

The westward swing of North America during the Alpine climax (late Cretaceous to early Tertiary) brought the deeper section of the regional peri-Pacific Benioff Zone to an inland position – away from the Pacific coast. At this time, the late Cretaceous eustatic sea level rise – the Cenomanian transgression, gave rise to the relatively shallow Western Interior Seaway extending from the Mexican Gulf to the Canadian Arctic. According to the wrench tectonic scenario, the Cenomanian transgression was the product of a significant increase of volatile pressures in the asthenosphere which in turn lifted the already thin-crusted oceanic basement; additional fluid-enforced attenuation of the oceanic crust led to major subsidence and a marked regression at around the K/T boundary. The accelerated crustal loss to the mantle was the dynamo-inertial driver of the Alpine lithospheric wrenching – including the westward swing of North America. As seen from **Fig. 17** the geographical distribution of the large hydrocarbon province of western North America, along with late Cretaceous-earliest Tertiary craters, correspond to the relative position of the mantle segment of the NE Pacific Benioff Zone. In late Tertiary time, the region of the Western Interior Seaway was uplifted to its present mountainous/high plain situation (uplifts at that time apparently formed mountain chains all over the globe) and which probably gave rise to crustal extension along that belt producing pathways for rising mantle fluids and gasses. Such link-up of diverse observational facts/phenomena is strong *prima facie* evidence favouring mantle origins of surface hydrocarbons; in such coherent understanding, craters are just forceful break-outs of high-pressured interior gases and fluids. The popular impact theory of cratering seems to rest on pretty shaky grounds.

The younger Alpine craters of North America – Houghton, Mistantin, Wanapitei Lake, Montaignais, and Chesapeake Bay – date predominantly from around the Eocene/Oligocene boundary, at circa 37 my ago (after the time scale of van Eysinga, 1975). These younger craters interpreted by us to be volcanic gas blow-out structures, localized along the northern and eastern margins of the continent, suggest that North America had a second mobile phase (clockwise rotation) in mid-Tertiary time – opening up fluid pathways along the Arctic and Atlantic margins. It is anticipated therefore that these continental border zones may hold undiscovered hydrocarbon resources.

At the Eocene/Oligocene boundary, a sharply-delineated event of polar wander took place during which the Earth underwent a 35˚ of angular shift of the equatorial bulge (a turning-over of the globe in the approximate Greenwich meridian plane), bringing the Earth to around its present spatial orientation. Besides producing significant changes of the climatic belts (producing cooling in Europe and overall temperature rise in Africa); this polar wander episode can be seen as the terminal spasm of the main Alpine tectonic processes triggering widespread tectono-magmatic activity, notably in the oceans. In addition to the time-equivalent craters of North America, occurrences like the Popigai crater in Russia and the Ethiopian flood basalt eruption add to the diversity of global geological phenomena at that time. Furthermore, it is an important fact that the volcanic ashes of the Massignano stratigraphic section of Italy, which again dates from around 35 my, contain a distinct iridium peak in association with shocked quartz (Montanari et al., 1993).

Turning to South America, the hyper-transtensive Atlantic margin is likely to comprise many prospective oil and gas provinces – extending the present hydrocarbon prosperity of the Santos and Campos basins southwards to the Falkland Plateau. In the north, the moderate clockwise rotation of the combined Caribbean/South America did not significantly disturb the orientation of the global orthogonal fracture pattern (discussed above). However, resulting from this rotation the Lesser Antilles Arc formed as a curved thrust front, and regional wrenching led to transtensive reactivation of the 'N-S' set of fundamental fractures. The moderate lithospheric break-ups along the northern rim of South America can be regarded the necessary tectonic prerequisite for opening up of gas/fluids pathways from the upper mantle – probably the very reason why northern Venezuela and Colombia represent rich hydrocarbon provinces.

Despite its minor overall Alpine tectonic rotation, South America seems to have been internally deformed. Thus, the distinct change in structural trend of the Central Andes, between 10˚S and 30˚S, led Carey (1955) to speculate about a tectonic bending of the continent, an idea that have later been substantiated by palaeomagnetic data. Thus, Heki et al. (1983) and Kono et al. (1985) arrived at fairly clear declination discordances consistent with the distinct break in the Pacific coastline, and suggested that the oroclinal bending of the order of a few tens of degrees had taken place around a hinge line in North Bolivia. A subsequent palaeomagnetic study (Roperch and Carlier, 1992) added further substance to the concept of the so-called Bolivian Orocline. Roperch and Carlier suggested a significant part of the tectonic bending had taken place prior to the Lower Oligocene. It seems, therefore, that combined tectonic and inertia forces affecting South America in Upper Cretaceous-Lower Tertiary time enforced intra-continental lithospheric deformation – paving the way for upward fluid flow from the mantle and the present-day hydrocarbon boom in Bolivia.

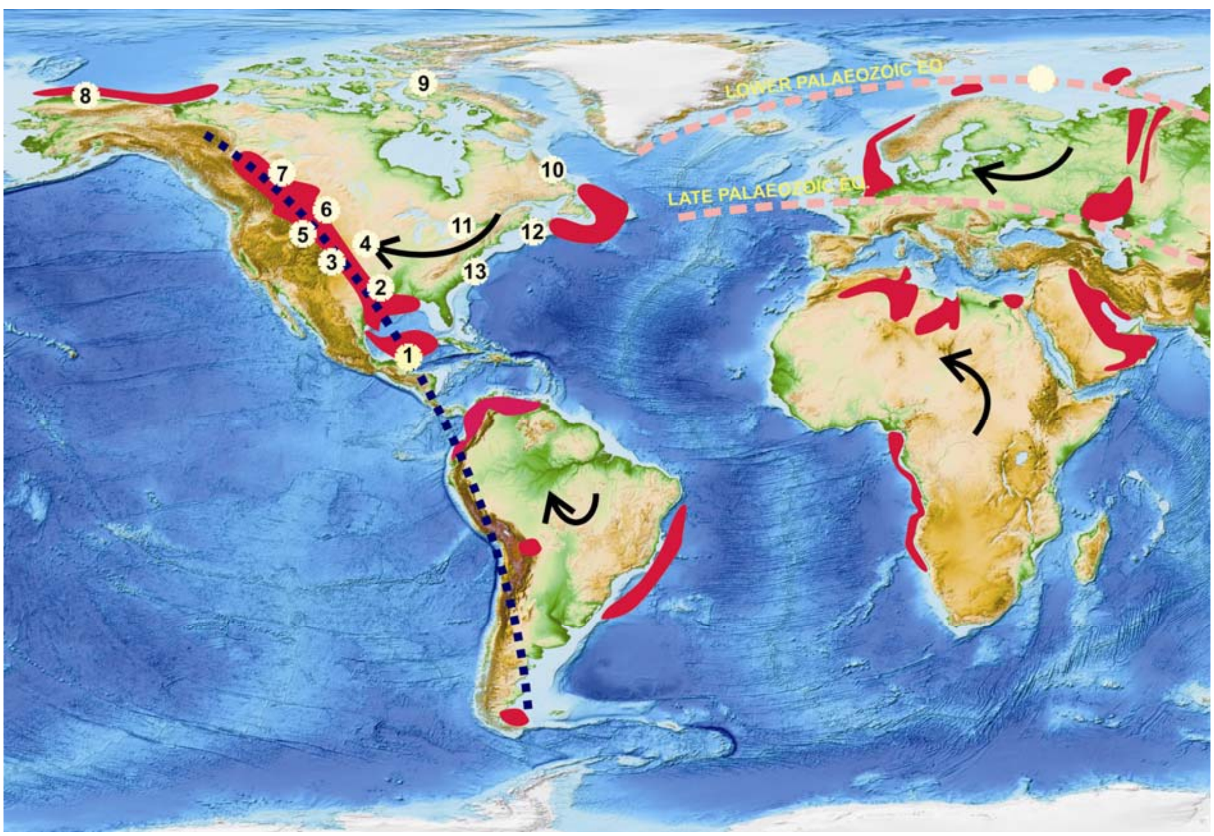

Fig. 17. Diagram shows a schematic presentation of major hydrocarbon provinces in the 'continental hemisphere' – marked in red. Curved black arrows depict inertia-triggered wrench rotations of/within the Atlantic bordering continents inferred from palaeomagnetism – motions which are consequences of Alpine torsion of the global lithosphere. The relatively minor 'crustal' deformations led to the present fanning-out shapes of the North and South Atlantic – changing the original parallelism of the developing pre-Alpine continental margins. This global torsion produced hyper-extended Atlantic margins, opening up effective migration routes for mantle hydrocarbons and brines. Clockwise rotation of North America during the Alpine climax shifted the sub-lithosphere mantle section of the

regional deep circum-pacific Precambrian contraction dislocation – indicated by black stippled line – to an inland position which corresponds to the position of the extensive hydrocarbon province of western North America. Note also that craters (white asterisks) dating from the Alpine climax (c. 100-65 my ago), fall along the western hydrocarbon province indicating that they represent gas blow-out structures (NOT impacts!). Numbered craters (with approximate age in parentheses) are: 1, Chixculub (65 my); 2, Sierra Madre (100 my); 3, Marquez (60 my); 4, Upheaval Dome (65 my); 5, Manson (75 my); 6, Eagle Butte (65 my); 7, Steen River (95 my); 8, Avak (< 95 my); 9, Houghton (38 my); 10, Mistastin Lake (38 my); 11, Vanapitei Lake (37 my); 12, Montaignais (50 my); 13, Chesapeake Bay (35 my). In the European sector, the unnumbered crater is the Barents Sea Mjølnir structure dating from around the Jurassic/Cretaceous boundary (c.142 my). Lower and Late Palaeozoic equators are shown by stippled pink lines. Crater information is based on the Meteorite Impact Crater Map published at http://robslink.com/SAS/democd28/impact.htm

For most of geological history – prior to the development of the thin and mechanically weak oceanic lithosphere, including most of present-day deep sea regions – global tectonics was largely confined to specific fold belts. These pre-Alpine zones constituted either overall transpressively or transtensively deformed palaeoequator-aligned lithosphere-cutting tectonic sectors – often outlined by deep sedimentary basins, or they formed rift zones oriented at steep angles to their corresponding palaeoequators (cf. Storetvedt, 1997 and 2003). Once broken up, these deep fracture zones would be likely to stay forever, undergoing tectonic reactivation during subsequent global dynamo-tectonic events – besides serving as potential transport channels for upward transfer of mantle gasses and fluids. Due to Earth's dynamic instability – in terms of episodic polar wander (changing the equatorial bulge) and/or changes of its rate of spin – the globe has functioned as a kind of hydraulic pump; besides producing superimposed events of inertial tectonic activity, one might envision an intermittent upward flow of juvenile water, brines, and mantle derived hydrocarbons from the mantle.

European region

Examples of the link-up of inertia-triggered rifting (occurring both parallel and at steep angles to the actual palaeoequator), wrench folding and subsequent development of petroleum-rich salt basins, are well demonstrated for the Palaeozoic of Europe. For example, the Arctic sector of the Lower Palaeozoic equator, extending from eastern North America (in the pre-Alpine azimuthal orientation) and further along the margin of E Greenland, cuts across the central Barents Sea (**Fig. 17**). In the North America and E Greenland transects, the Appalachian/Caledonian fold belt follows along the time-equivalent equator, but the Caledonian segments of western Scandinavia and western Spitsbergen apparently formed as near-perpendicular rift basins – with subsequent overprinting by Lower-Middle Palaeozoic phases of lithospheric wrenching (cf. Storetvedt, 2003). The palaeoequator-aligned Caledonian fold belt of E Greenland, characterized by reworked Precambrian basement rocks and affecting an up to 9 km thick Lower Palaeozoic sedimentary succession (Whittaker et al., 2011), is well exposed between 70°N and 81°N – as a 1300 km long and up to 300 km wide coast-parallel deformed geosynclinals belt (www.geus.dk). According to Whittaker et al., an offshore salt basin extends as far north as 80°N.

The eastward continuation of the Lower Palaeozoic equator passes through the intracratonic Barents Sea for which the Moho depth varies from 25 km in the western sector to around 35 km in the eastern province (Neprochnov et al., 2000; Ritzmann et al., 2007). This large Arctic Shelf region contains several depot-centres, separated by structural arches and platforms, and in the south-eastern region the South Barents Sea Basin reaches a depth-to-basement of 20 km (O'Leary et al., 2004; Werner et al., 2012). However, the overall structure of the Barents Sea Shelf Province may be subdivided into a number of north-south striking sub-provinces. From west to east they are: Western Barents Margin, Barents North/South platforms, North/South Barents basins, Novaya Zemlya basins, Novaya Zemlya Island, and Kara Sea Basin. Neprochnov et al. (2000) argued that the "large thickness of the sedimentary cover, and blocky fragmentation of the crust are features of deep graben-rift basins"- a depositional history that apparently had its peak in the Palaeozoic and Triassic, but continued with much reduced vigour throughout the Mesozoic. This conclusion is concordant with the expectation of the wrench tectonic model – as well as being consistent with explaining the NW European Caledonides as a mega scale Lower Palaeozoic rift basin (geosyncline) with transpressive-transtensive overprinting during Lower-Middle Palaeozoic times. Hence, in a global wrench tectonic context it would be impossible to distinguish fold belts that have formed in palaeo-equatorial settings from those having developed from rifting at steep angles versus their time-equivalent equators.

With respect to petroleum resources, assessment of the Barents Sea is only in its infancy. But extending eastward from the Western Barents Margin, the Hammerfest and Nordkapp basins – just off northernmost Norway – have turned out to be productive salt basins, and the enormous Stockman gas field of the South Barents Sea Basin is well established. However, the future hydrocarbon prosperity of the Barents Shelf region is probably signalled by the 40-km-diameter Mjølnir crater dating from around the Jurassic/Cretaceous boundary (c. 141 my) – for location, see un-numbered asterisk in **Fig. 17**. As we have argued throughout this article, craters may be seen as Earth's natural pressure valves – releasing over-pressured gasses (such as water vapour, carbon dioxide, and hydrocarbons) of the asthenosphere. In that interpretation, gas fields may be found outside the perimeter of the Mjølnir crater, in the same way as the South Barrow, East Barrow and Sikulik gas fields are found off the outer boundary of the Avak Crater of northern Alaska (Kirschner et al., 1992). Here it is appropriate to mention that along the Palaeozoic equatorial belt of eastern North America numerous craters, spanning ages from Ordovician to Middle Mesozoic, have been reported (cf. SAS/Graph Meteorite Impact Crater Map).

During Ordovician-Silurian time, the developing South Barents and Kara Sea basins, or rift grabens, broke southwards, away from the corresponding palaeo-equator which continued across Siberia in a south-easterly direction – establishing an embryonic Uralian tectonic zone. Within the well-defined and relatively narrow Uralian crustal belt several kilometres of sediments accumulated during the Palaeozoic. Consistent with this observation, one of the possible crustal models based on seismic refection data is in favour of crustal thinning towards the Main Uralian Fault Zone (cf. Juhlin et al., 1995). This interpretation suggests the presence of a deep lithosphere-penetrating shear zone, paving the way for rising mantle fluids (see also Carlowicz, 1995). In fact, the 'palaeo-meridian' setting of the Ural Fault Zone would make it vulnerable to fluid-enforced sub-crustal delamination, basin subsidence, and shear reactivation – notably during the Palaeozoic. In Hercynian time the palaeo-equatorial belt had shifted south to Central Europe, extending eastward across the northern region of the developing Caspian Basin. Again, the Ural zone had a palaeo-geographic setting favouring additional break-up and shearing – at this time the locus of tectonic fracturing and wrench deformation was from the south. Judging from the thick pile of Ural sediments, a transtensional regime is likely to have been predominant throughout the history of the belt though transpressional conditions may have featured at times, for example during its terminal tectonic event in the late Permian (for wrench tectonic arguments, see Storetvedt, 1997 and 2003).

The cross-cutting of the significant Ural rifting and the inferred Hercynian palaeoequator-aligned fracture zone, may be seen as the tectonic background of the super-giant Peri-Caspian oil province. Such tectonic intersections can be expected to represent effective migration routes for mantle brines and hydrocarbons. According to this principle, the giant Stockman gas field may be seen as a northern equivalent of the Peri-Caspian hydrocarbon province, and the central North Sea rift zone is another case of this category. In the northern North Atlantic, where the Lower Palaeozoic equator cuts across the inferred W Spitsbergen/NW European Caledonian rift belt (a deep lithospheric fracture zone along which the continental-oceanic boundary developed in Meso-Caenozoic time), the Western Barents Margin may become a prosperous petroleum province; the Hammerfest Basin of that region has already demonstrated its hydrocarbon potential. Further, the super-giant Mexican Gulf hydrocarbon province is another example associated with an easy escape route of mantle fluids and gasses – located as it is at around the intersection of the mantle section of the regional Benioff Zone and the lithospheric shear boundary between North and South America – the Motagua Fault/Cayman Trough (cf. **Figs.11 and 17**).

N. Africa and Middle East

During the Alpine climax, the counter clockwise rotation of Africa reactivated the old fracture network paving the way for formation of continental basins in orthogonal settings. In consequence, during the Cenomanian transgression, an intra-continental seaway existed across present-day Sahara – between the

Gulf of Guinea and the Mediterranean region. As the Alpine palaeo-equator passed along the northern rim of Africa (see **Fig. 5**), inertia-triggered southward rifting of the North African basins opened up supply routes for mantle brines and hydrocarbons. Being located within the southern limit of the Alpine shear belt, natural hydrostatic pumping mechanisms are probably re-charging the oil and gas provinces of North Africa on a long term basis.

Turning to the Persian Gulf, the most prolific hydrocarbon province in the world, it is important to note that this region represents the southern boundary of the Middle East Alpine tectonic belt – cutting across the south-eastern tip of the Arabian Peninsula. In the Alpine tectonic process, Africa was a component part of the counter clockwise rotation of the southern palaeo-lithosphere, during which a significant wrenching affected the thin-crusted Indian Ocean. Due to the topographic uplift of mountain ranges (continental as well as oceanic) in late Miocene-Recent times (Storetvedt, 2003), oblique shearing is particularly demonstrated along mid-ocean ridges. And curvilinear patterns of oceanic fracture zones (Friedrich and Leduc 2004) occur throughout deep oceans – forming the tectono-mineralogical basis of linear marine magnetic anomalies (Storetvedt, 2010b). As can be seen from the physiographic image of the SW Indian and Carlsberg ridges (see **Fig. 13**), the overall direction of shear is consistent with the established counter clockwise rotation of Africa. However, at the northern Carlsberg Ridge, the tectonic pattern attains a fan-shaped pattern for which one limb turns into the Gulf of Aden along which the shear intensity diminishes westward. The most important shearing pattern turns into the Owen Basin off Oman where it apparently splits into two branches – one of them takes a north-easterly course, bounded by the curved Owen Fracture Zone, apparently abutting against the compressive/transpressive Makran front, while the second turns counter clockwise, cutting across SE Arabian Peninsula in Oman – forming a sedimentary basin that extends throughout the Persian Gulf/Iraqi oil basin. To the east, this super-prolific petroleum province is bounded by a prominent transpressive zone along Zagros fault system. The en-echelon offsets of the Sheba Ridge (Gulf of Aden) – increasing eastward, the left-lateral motion along the Owen Fracture Zone, and the overall counter clockwise swing of tectonic trends – varying from NE along Gulf of Aden to NW along the Zagros region and Persian Gulf – are consistent with the counter clockwise rotation of the Middle East region as demonstrated by GPS-derived site velocities (Reilinger et al., 2006) – sketched out in **Fig. 13**.

In the quasi-oceanic 250 to 400-km-wide Owen Basin (Whitmarsh, 1979), being bounded to the east by the curved and tectonically active Owen Fracture Zone, relatively weak magnetic anomalies show NE strike directions, and in the tectonically exposed upper mantle mélange of Masirah Island (off the southeast coast of Oman) intersecting dykes are oriented parallel to magnetic lineations of the Owen Basin (see Moseley and Abbotts, 1979). Discussing various emplacement models of the Masirah ophiolite complex, Moseley and Abbotts preferred that of a diapiric upthrust onto the developing Oman continental margin, along near-vertical, NNE-striking deep faults parallel to the Owen Fracture Zone. Northern Oman is characterized by a complex tectonic system – consisting of a wavy shaped syncline/anticline/reverse fault association. It seems likely therefore that also the Semail Ophiolite Complex of North Oman has formed as a diapiric upthrust during the Alpine climax. In the presence of abundant water, upper mantle peridotites would be liable to become serpentinized, – and as serpentine is a relatively low-density and ductile rock it would become buoyant and rise diapirically, notably along transtensive segments of high-angle shear zone. In a section of the Owen Fracture Zone, Bonatti (1978) described the occurrence of large vertical sections of serpentinite – giving rise to negative gravity anomalies. Thus, wrench-powered emplacement of solid serpentinite protrusions may be the likely explanation of the disconnected Owen Ridge topography. Similarly, the Sharbithat Ridge at the southern end of the Owen Basin (cf. **Fig. 13**), extending from the Owen Fracture Zone to a complex intersection with the Arabian continental margin, is also characterized by negative gravity anomalies (cf. Stein and Cochran 1985) and may therefore be another upthrust of serpentinized upper mantle material.

Consistent with the wrench tectonic situation of the Arabian Peninsula and the Persian Gulf Basin, the region is characterized by basement block faulting and, notably along the margin of Iran, of disconnected NE-dipping basement blocks which in turn have given rise to folding of the sedimentary cover (Comby et al., 1977); in this process, numerous large anticlines with abundant diapiric salt and oil have formed. As stated by Edgell (1996), basement extensional and wrench faulting of the Gulf region, which often has been rejuvenated, has played an important role in the formation of salt tectonics. Following the abiotic origins of hydrocarbons adhered to here, intersecting faults and/or strike slip faults may be seen as the avenues for upward movement of brines – precipitating the thick regional salt masses, along with mantle-derived crude oil and natural gas. The counter clockwise rotation of the Middle East lithosphere, demonstrated by the distribution of GPS-velocities (**Fig. 13**), has probably been a continuous process since the onset of the Alpine revolution (Upper Cretaceous). Thus the long term transpressive forces affecting the Zagros belt – producing a major steeply dipping frontal reverse fault zone and imbricating the basement to the SW – is likely to be the cause of the highly asymmetrical Gulf Basin, with sediments thinning from a few hundred metres in the inland of the Arabian Shield to 18000 metres immediately south of the Main Zagros Reverse Fault (Edgell, 1996). In conclusion, the super-giant hydrocarbon province of the Arabian-Persian Gulf is located along a major Alpine tectonic boundary – a relatively broad, but little thinned, lithospheric crush zone having abundant avenues for transport of fluids and gases from the mantle to near-surface reservoirs. In a hydrocarbon perspective, it is a distinct possibility therefore that the Gulf region may produce forever.

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References
Aal, A. et al., 2000. Tectonic evolution of the Eastern Mediterranean Basin and its significance for hydrocarbon prospectivity in the ultradeep water of the Nile Delta. *The Leading Edge,* Oct. 2000, p. 1086-1102.
Argus, D.F. and Gordon, R.G., 1996. Tests of the rigid-plate hypothesis and bounds on intraplate deformation using geodetic data from very long baseline interferometry. *Jour. Geophys. Res.,* v. 101, p. 13555-13572.
Arthur, M.A., 1979. North Atlantic Cretaceous black shales: the record at site 398 and a brief comparison with other occurrences. In: Sibuet et al., *Initial Reports of the Deep Sea Drilling Project,* Leg 47, Washington DC, US Govt. Print. Office, p. 719-752.
Austrheim, H. et al., 1996. Garnets recording deep crustal earthquakes. *Earth Planet. Sci. Lett.,* v. 139, p. 223-238.
Bellissent-Funel, M.-C., 2001. Structure of supercritical water. *Jour. Mol. Liq.,* v. 90, p. 313-322.
Bazhenova, O.K. et al., 1998. Oil of the volcano Uzon caldera, Kamchatka. *Org. Geochem.,* v. 29, p. 421-428.
Behrmann, J.H. et al., 1994. Tectonics and geology of spreading ridge subduction at the Chile Triple Junction: a synthesis of results from Leg 141 of the Ocean Drilling Program. *Geol. Rundsch.,* v. 83, p. 832-852.
Bonatti, E., 1978. Vertical tectonism in oceanic fracture zones. *Earth Planet. Sci. Lett.,* v. 37, p. 369-379.
Bonatti, E. et al., 1977. Neogene crustal emersion and subsidence at the Romanche F.Z., equatorial Atlantic. *Earth Planet. Sci. Lett*., v. 35, p. 369-383.
Bonatti, E. and Chermak, A., 1981. Formerly emerging crustal blocks in the equatorial Atlantic. *Tectonophysics*, v. 72, p. 165-180.
Bradley, W.C. et al., 1978. Role of Salts in Development of Granitic Tafoni, South Australia. *Jour. Geol.,* v. 86, p. 647-654.
Brookfield, M.E., 1977. The emplacement of giant ophiolite nappes; Mesozoic-Cenozoic examples. *Tectonophysics*, v. 37, p. 247-303.
Bucher, W.H., 1921. The mechanical interpretation of joints. *Jour. Geol.,* v. 29, p. 1-28.
Buffett, B. and Archer, D., 2004. Global inventory of methane clathrate: sensitivity to changes in the deep ocean. *Earth Planet. Sci. Lett.,* v. 227, p. 185-199.
Calvert, A. et al., 2000. Geodynamic evolution of the lithosphere and upper mantle beneath the Alboran region of the western Mediterranean: Constraints from travel time tomography. *Jour. Geophys. Res.,* v. 105, p. 10.871-10.898.
Campos, C.W.M et al., 1974. Geology of the Brazilian Continental Margin. In: *The Geology of Continental Margins,* Berlin, Springer-Verlag, p. 447-470.
Carey, S.W., 1955. The orocline concept in geotectonics. *Proc. Roy. Soc. Tasmania,* v. 89, p. 255-288.
Carlowicz, M., 1995. URSEIS Peaks Under Urals for Mountain-Building Clues. *EOS*, v. v. 76, no. 52, p. 533.
Czoshanska, Z. et al., 1986. Organic geochemistry of sediment in New Zealand. 1. A biomarker study of the petroleum seepage at the geothermal region of Waiotapu. *Geochem. and Cosmochem. Acta,* v. 50, p. 507-515.
Choukroune, P., 1976. Strain patterns in the Pyrenean chain. *Phil. Trans. Roy. Astron. Soc.,* v. A 283, p. 271-280.
Comas, M.C. et al., 1999. The Origin and Tectonic History of the Alboran Basin: Insights from Leg 161 Results. In: *Proceedings of the Ocean Drilling Program, Scientific Results,* v. 161, p. 555-580.
Comby, O. et al., 1977. An approach to the structural studies of the Zagros Fold Belt in the EGOCO Agreement Area. *Proc. 2nd Geol. Symp. of Iran*, Teheran, p. 103-159.
Daigniers, M. et al., 1982. Implications of the seismic structure for the orogenic evolution of the Pyrenean range. *Earth Planet. Sci. Lett.,* v. 57, p. 88-100.
Debenedetti, A., 1976. Messinian salt deposits in the Mediterranean: Evaporites or precipitates? *Bull. It. Geol. Soc.,* v. 95, p. 941-950.
Dixon, T.H. et al., 1998. Relative motion between the Caribbean and North American plates and related boundary zone deformation from a decade of GPS observations. *J. Geophys. Res.,* v. 73, p. 2087-2100.
Droop, G.T.R. et al., 1990. Formation and distribution of eclogite facies rocks in the Alps. In: *Eclogite Facies Rocks*, Glasgow, Blackie, p. 225-259.

Edgell, H.S., 1996. Salt tectonism in the Persian Gulf Basin. In: *Salt Tectonics*, Geol. Soc. London Spec. Publ., no. 100, p. 129-151.
Engelder, T., 1982. Is there a genetic relationship between selected regional joints and the contemporary stress within the lithosphere of North America? *Tectonics*, v. 1, p. 161-177.
Engelder, T., 1993. *Stress Regimes in the Lithosphere,* Princeton NJ, Princeton Univ. Press, 475p.
Eppelbaum, L. and Katz, Y., 2011. Tectonic-Geophysical Mapping of Israel and the Eastern Mediterranean: Implications for Hydrocarbon Prospecting. *Positioning*, v. 2, p. 36-54.
Evans W.C., 1996. A gold mine of methane. *Nature*, v. 381, p. 114-115.
Ernst, W.G., 1972. Occurrence and mineralogic evolution of blueschist belts with time. *Am. Jour. Sci.,* v. 272, p. 657-668.
Fabbri, A. and Curzi, P., 1979. The Messinian of the Tyrrhenian Sea: sismic evidence and dynamic implications. *Giorn. Geol.,* v. 43, p. 215-248.
Fairhead, J.D. and Okereke, C.S., 1990. Crustal thinning and extension beneath the Benue Trough based on gravity studies. *J. Afr. Earth Sci.,* v. 11, p. 329-335.
Fallon, F.W. and Dillinger, W.H., 1992. Crustal velocities from geodetic very long baseline interferometry. *Jour. Geophys. Res.,* v. 97, p. 7129-7136.
Farooqui, M.Y. et al., 2009. Evaluating Volcanic Reservoirs. *Oilfield Review*, v. v. 21, p. 36-47.
Fischer, A.G. and Arthur, M.A., 1977. Secular variations in the pelagic realms. In: *Deep water carbonate environments.* SEPM Spec. Publ., v. 25, p. 19-50.
Frezzotti, M.l., et al., 1994. Evidence of magmatic CO2-rich fluids in peraluminous graphite-bearing leucogranites from Deep Freeze Range. *Contrib. Mineral. Petrol.,* v. 117, p. 111-123.
Friedrich, J. and Leduc, G.G., 2004. Curvilinear patterns of oceanic fracture zones. *J. Geodyn.,* v. 37, p. 169-179.
Gelphi, E. and Oro, J., 1970. Organic componds in meteorites – IV. Gas chromatographic-mass spectrometric studies of isophrenoids and other isometric alkanes in carbonaceous xhondrites. *Geochim. Cosmochim. Acta,* v. 34, p. 981-994.
Gold, T., 1985. The origin of natural gas and petroleum, and the prognosis for future supplies. *Ann. Rev. Energy*, v. 10, p. 53-77.
Gold, T., 1987. Power from the Earth: *Deep Earth Gas – Energy for the Future*. London, Dent and Sons, 208p.
Gold, T., 1999. *The Deep Hot Biosphere*. New York, Springer Verlag, 235p.
Gold, T. and Soter, S., 1982. Abiogenic methane and the origin of petroleum, *Energy Exploration and Exploitation*, v. 1, p. 89-104.
Gutmanis, J.C., 2009. Basement Reservoirs – A Review of their Geological and Production Characteristics. Int. Petro. Tech. Conf., IPTC 13156, p. 1-7.
Gutscher, M.-A. et al., 2002. Evidence for active subduction beneath Gibraltar. *Geology,* v. 30, p. 1071-1074.
Gutscher, M.-A. et al., 2009. Tectonic shortening and gravitational spreading in the Gulf of Cadiz accretionary wedge: Observations from multi-beam bathymetry and seismic profiling. *Mar. Petrol. Geol.,* v. 26, p. 647-659.
Gutscher, M.-A., 2012. Subduction Beneath Gibraltar? Recent Studies Provide Answers. *EOS, Trans. Am. Geophys. Un.,* v. 93, no. 13, p. 133-134.
Hancock, P.L., 1985. Brittle microtectonics: principles and practice. *Jour. Struc. Geol.,* v. 7, p. 437-458.
Haq, B.U. et al., 1987. Chronology of fluctuating sea levels since the Triassic. *Science,* v. 235, p. 1156-1167.
Hardie, L.A. and Lowenstein, T.K., 2004. Did the Mediterranean Sea Dry Out During the Miocene? A reassessment of the Evaporite Evidence from DSDP Legs 13 and 42A Cores. *J. Sed. Res.,* v. 74, p. 453-461.
Hayes, D.E. and Ewing, M., 1970. North Brazilian Ridge and adjacent continental margin. *Bull. Am. Assoc. Petrol. Geol.,* v. 54, p. 2120-2150.
Heiki, K. et al., 1983. Rotation of the Peruvian Block from paleomagnetic studies of the Central Andes. *Nature*, v. 305, p. 514-516.
Kenney, J.F. et al., 2002. The evolution of multi-component systems at high pressures: VI. The thermodynamic stability of the hydrogen-carbon system: The genesis of hydrocarbons and the origin of petroleum. *Proc. Nat. Acad. Sci,* v. 99, 10976-10981.
Hervé, F. et al., 1987. Chronology of provenance, deposition and metamorphism in the southern limb of the Scotia arc. In: *Geological evolution of Antarctica,* Cambridge (UK), Cambridge Univ. Press, p. 429-435.
Hodgson, G.W. and Baker, B.L., 1964. Evidence for porphyrins in the Orgueil meteorite. *Nature*, v. 202, p. 125-131.
Hoyle, F., 1955. *Frontiers in Astronomy.* Melbourne, Heinemann, 360p.
Howell, D.G. et al., 1992. Compressional tectonics point to more gas reserves. *World Oil,* v. 213, p. 117-120.
Hreinsdóttir, S. et al., 2001. Crustal deformation at the oblique spreading Reykjanes Peninsula, SW Iceland: GPS measurements from 1993 to 1998. *J. Geophys. Res.*, v. 106, p. 13.803-13.816.
Hsű, K.J., 1972. Origin of saline giants: A critical review after the discovery of the Mediterranean evaporite. *Earth Sci. Rev.,* v. 8, p. 371-396.
Hsű, K.J. et al., 1973. Late Miocene deciccation of the Mediterranean. *Nature,* v. 242, p. 240-244
Hunt, C.W. et al., 1992. *Expanding Geopheres. Energy and Mass Transfers from Earth's Interior*. Calgary, Polar Publishing, 422p.
Husseini, M.I. and Husseini, S.I., 1990. Origin of the Infracambrian Salt Basins of the Middle East. *Geol Soc Lond. Special Publ.,* v. 50, p. 279-292.
Hübscher, Ch. et al., 2007. Global Look at Salt Giants. *EOS*, v. 88, no. 16, p. 177, 179.
Juhlin, C. et al., 1995. Project Conducts Seismic Reflection Profiling in the Ural Mountains. *EOS*, v. 76, no. 19, p. 193.
Kahneman, D., 2011. *Thinking, fast and slow.* London, Allen Lane – Penguin Books, 499p.
Kaufmann, W.J., 1988. *Universe.* New York, Freeman, 634p.
Kelley, D.S., 1996. Methane-rich fluids in the oceanic crust. *Jour. Geophys. Res.,* v. 101, p. 2943-2962.
Kenney, J.F., 1995. Comment on 'Mantle hydrocarbons: Abiotic or biotic?' *Geochim. Cosmochim. Acta,* v. 59, p. 3857-3858.
Kenvolden, K.A. and McMenamin, M.A., 1980. Hydrates of Natural Gas: Their Geologic Occurrence. *U.S. Geological Survey Circular,* no. 825.
Kenvolden, K.A. and Simoneit, B.R.T., 1990. Hydrothermally derived petroleum: example from Guaymas Basin, Gulf of California and Escanaba Trough, northeast Pacific Ocean. *Am. Assoc. Petrol. Geol.,* v. 74, p. 223-237.

Kerr, R., 1993. Looking deeply into the Earth's crust in Europe. *Science*, v. 261, p. 295-296.

Kirschner, C.E. et al., 1992. Impact origin of the Avak Structure, Alaska, and genesis of the Barrow gas fields. *Am. Assoc. Petrol. Geol. Bull.,* v. 76, p. 651-679.

Kohlbeck, F. and Scheidegger, A.E., 1977. On the theory of evaluation of joint measurements. *Rock Mech.,* v. 9, p. 9-25.

Kolesnikov, A. et al., 2009. Methane-derived hydrocarbons produced under upper-mantle conditions. *Nature*, v. 2, p. 566-570.

Konn, C. et al., 2009. Hydrocarbons and oxidized organic compounds in hydrothermal fluids from Rainbow and Lost City ultramafic-hosted vents. *Chemical Geology*, v. 258, p. 299-314.

Konnerup-Madsen, J., 1979. Fluid inclusions in quartz from deep-seated granitic intrusion, southern Norway. *Lithos*, v. 12, p. 13-23.

Kono, M. et al., 1985. Paleomagnetic study of the central Andes: Counterclockwise rotation of the Peruvian block. *Jour. Geodyn.,* v. 2, p. 193-209.

Kreichgauer, P.D., 1902. *Die Äquatorfrage in der Geologie.* Steyl, Missionsdruckerei, 304p.

Kudryavtsev, N.A., 1951. Against the organic hypothesis of the origin of petroleum (in Russian). *Petroleum Economy,* v. 9, p. 17-29.

Leung, I. et al., 1990. Natural occurrences of silicon carbide in a diamondiferous kimberlite from Fuxian. *Nature,* v. 346, p. 352-354.

Lira, R. et al., 2007. Solid inclusions of magmatic halite and sylvite in felsic granitoids, Sierra Norte, Córdoba, Argentina. *Lithos*, v. 99, p. 363-384.

Lupton, J. and Craig, H., 1981. A major helium-3 source at 15°S on the East Pacific Rise. *Science*, v. 214, p. 13-18.

Lyatsky, H.V., Friedman, G. And Lyatsky, V.B., 1999. *Principles of Practical Tectonic Analysis of Cratonic Regions.* New York, Springer-Verlag, 369p.

Macellari, C.E., 1988. Cretaceous palaeogeography and depositional cycles of western South America. *Jour. South Am. Geol.,* v.1, p. 373-418.

Mahfoud, R.F., 2000. Theory links lithospheric rotation to possible abiogenic oil re-charge. *Offshore*, May 2000, p. 102-108.

Mahfoud, R.F. and Beck, J.N., 1995. Why the Middle East fields may produce oil forever. *Offshore,* April 1995, p. 56-62.

Maluski, H. et al., 1995. Argon-40/Argon-39 chronology, petrology and geodynamic setting of Mesozoic to early Cenozoic magmatism from the Benue Trough, Nigeria. *Jour. Geol. Soc. London,* v. 152, p. 311-326.

Manzi, V. et al., 2005. Deep-water clastic evaporates deposition in the Messinian Adriatic foredeep (northern Apennines, Italy): did the Mediterranean ever dry out? *Sedimentology*, v. 52, p. 875-902.

Mascle, J. et al., 1995. The Cote d'Ivoire-Ghana transform margin: an example of an ocean-continent transform boundary. In: *Rifted Ocean-Continent Boundaries*. Dordrecht, Kluwer Academic, p. 327-339.

Mascle, J. et al., 1998. A geological field trip to Cote d'Ivoire-Ghana transform margin. *Oceanologica Acta*, v. 21, p. 1-20.

McClusky, S. et al., 2000. Global Positioning System constraints on plate kinematics and dynamics in the eastern Mediterranean and Caucasus. *Jour. Geophys. Res.,* v. 105, p. 5695-5719.

Melton, C.E. and Giardini, A.A., 1974. The composition and significance of gas released from natural diamonds from Africa and Brazil. *Am. Mineralogist*, v. 59, p. 775-782.

Metri, G. et al., 2007. Hydrocarbon Lakes on Titan. *Icarus*, v. 186, p. 385-394.

Milkov, A.V., 2000. Worldwide distribution of submarine mud volcanoes and associated gas gydrates. *Marine Geology*, v. 167, p. 29-42.

Miller, H.G., Storetvedt, K.M. and Scheidegger, A.E., 2001. The main structural trends of Newfoundland: interpretation within a new dynamo-tectonic framework. *Proc Int. Workshop on Global Wrench Tectonics*, Oslo 9-11 May 2001.

Montanari, A. et al., 1993. Iridium anomalies of Late Eocene age at Massignano (Italy), and ODP Site 689B (Maud Rise, Antarctica). *Palaios*, v. 8, p. 420-437.

Mpodozis, C. and Forsythe, R., 1983. Stratigraphy and geochemistry of accreted fragments of the ancestral Pacific floor in southern South America. *Paleogeogr.,Paleoclimatol., Paleoecol.,* v. 41, p. 103-124.

Moseley, F. and Abbotts, I.L., 1979. The ophiolite mélange of Masirah, Oman. *Jour. Geol. Soc. Lond.,* v. 136, p. 713-724.

Muehlberger, W.R., 1961. Conjugate joint sets of small dihedral angle. *Jour. Geol,* v. 69, p. 211-218.

Munoz, J.A. et al., 1986. Thrust sequences in the eastern Spanish Pyrenees. *Jour. Struc. Geol.,* v. 8, p. 399-405.

Munoz, J.B. and Stern, C.R., 1988. The Quaternary volcanic belt of the southern continental margin of South America: Transverse structural and petrological variations across the segment between 38°S and 39°S. *Jour. South Am. Earth Sci.,* v. 1, p. 147-161.

Nagle, F., 1974. Blueschist, Eclogite, Paired Metamorphic Belts, and the Early Tectonic History of Hispaniola. *Geol. Soc. Am. Bull.,* v. 85, p. 1461-1466.

Neev, D., 1975. Tectonic evolution of the Middle East and the Levantine Basin (easternmost Mediterranean). *Geology*, v. 3, p. 683-686.

Neev, D., 1977. The Pelusium Line: A major transcontinental shear. *Tectonophysics*, v. 38, T1-T8.

Neev, D. et. al, 1982. The Pelusium Megashear System Across Africa And Associated Lineament Swarms. *Jour. Geophys. Res.,* v. 87, No. B2, p. 1015-1030.

Neev, D. and Hall, J.K., 1982. A Global System of Spiralling Geosutures. *J. Geophys. Res.*, v. 87, No. B13, p. 10.689-10.708.

Neprochnov, Y.P. et al., 2000. Comparison of the crustal structures of the Barents Sea and the Baltic Shield from seismic data. *Tectonophysics,* v. 321, p. 429-447.

Nesteroff, W.D., 1973. Un modèle pour les évaporites messiniennes en Méditerranée des bassins peu profonde avec dépôt d'évoporites lagunaires. In: *Messinian Events in the Mediterranean.* Amsterdam, North-Holland, 272p.

O'Driscoll, E.S.T., 1980. The double helix in global tectonics. *Tectonophysics,* v. 63, p. 397-417.

O'Leary, N. et al., 2004. Evolution of the Timan-Pechora and South Barents Sea basins. *Geol. Mag.,* v. 141, p. 141-160.

Pannekoek, A.J., 1969. Uplift and subsidence in and around the western Mediterranean since the Oligocene: a review. *Verhandelingen Kon. Ned. Geol. Mijnbouwk.,*v. 26, p. 53-77.

Passerini, P. et al., 1990. Slickensides in western and southern Iceland: data from Langavatn, Burfell and Vördufell. *Ofioliti,* v. 15, p. 191-196.

Peck, J.M., 2008. Giant oil prospects lie in distal portion of offshore East Mediterranean basin. *Oil & Gas Journal*, 6 Oct. 2008.

Pollard, D.D. and Aydin, A., 1988. Progress in understanding jointing over the past century. *Geol. Soc. Am. Bull.,* v. 100, p. 1181-1204.

Porfir'ev, V.B., 1974. Inorganic origin of petroleum. *Am. Assoc. Petrol. Geol. Bull.*, v. 58, p. 3-33.

Ramberg, I.B., 1977. Analysis of fracture patterns in southern Norway. *Geol. Mijnbouw*, v. 56, p. 295-310.

Reilinger, R. et al., 2006. GPS constraints on continental deformation in the Africa-Arabia-Eurasia continental collision zone and implications for the dynamics of plate interactions. *J. Geophys. Res.,* v. 111, B05411, doi: 10.1029/2005JB004051.

Ritzmann, O. et al., 2007. A three-dimensional geophysical model of the crust in the Barents Sea region: model construction and basement characterization. *Geophys. Jour. Int.,* v. 170, p. 417-435.

Robinson, R., 1966. The Origins of Petroleum. *Nature*, v. 212, p. 1291-1295.

Roperch, P. and Carlier, G., 1992. Paleomagnetism of Mesozoic rocks from the Central Andes of Southern Peru: Importance of rotations in the development of the Bolivian Orocline. *Jour. Geophys. Res*., v. 97, p. 17.233-17.249.

Rother, K. and Storetvedt, K.M., 1991. Polyphase magnetization in Lower Carboniferous rocks of S. Scotland. *Phys. Earth Planet. Inter.,* v. 67, p. 251-267.

Rouchy, J.M., 1980. La génèse des evaporates messiniennes de Méditerrané: un bilan. *Bull. Cent. Rech. Pau,* v. 4, p. 511-545.

Scheidegger, A.E., 1965. On the statistics of the orientation of bedding planes, grain axes and other sedimentological data. *US Geol. Surv. Prof. Paper* 525C, p. 164-167.

Scheidegger, A.E., 1982. *Principles of Geodynamics*, Berlin, Springer-Verlag, 395p.

Scheidegger, A.E., 1998. Morphotectonic indications for the opening of Davis Strait. In: *Mechanics of Jointed and Faulted Rock,* Rotterdam, Balkema, p. 95-100.

Schutter, S.R., 2003. Occurrences of hydrocarbons in and around igneous rocks. *Geological Society of London, Special Publications*, v. 214, p. 35-68.

Segall, P. and Pollard, D.D., 1983. Joint formation in granitic rock of Sierra Nevada. *Geol. Soc. Am. Bull.,* v. 94, p. 563-575.

Sigisaki, R. and Mimura, K., 1994. Mantle hydrocarbons: Abiotic or biotic? *Geochim. Cosmochim. Acta,* v. 58, p. 2527-2542.

Sonnenfeld, P., 1981. The Phanerozoic Tethys Sea. In: *Tethys, The Ancestral Mediterranean*. Stroudsburg (US), Dowden, Hutchinson and Ross, p. 18-53.

Sonnenfeld, P., 1984. *Brines and Evaporites*. New York, Academic Press, 613p.

Srikantappa, C. et al., 2010. CO2-H2O, Highly Saline and Carbonic Fluids from the Mesozoic Mashhad Granitoids, NE Iran. *Iranian Jour. Earth Sci*., v. 2, p. 163-169.

Stein, C.A. and Cochran, J.R., 1985. The transition between the Sheba Ridge and the Owen Basin: rifting of old oceanic lithosphere. *Geophys. Jour. R. Astron. Soc.,* v. 81, p. 47-74.

Stofan, E.R. et al., 2007. The lakes of Titan. *Nature*, v. 445, p. 61-64.

Storetvedt, K.M., 1985. The pre-drift Central Atlantic; a model based on tectono-magmatic and sedimentological evidence. *Jour. Geodyn,* v. 2, p. 275-290.

Storetvedt, K.M., 1987. Evidence for ocean-continent boundary beneath the abyssal plain of the East Central Atlantic. *Phys. Earth Planet. Inter.*, v. 48, p. 115-129.

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.

Storetvedt, K.M., 1992. Rotating plates: new concept of global tectonics. In: *New Concepts in Global Tectonics*. Lubbock, Texas Tech. Univ. Press, p. 203-220.

Storetvedt, K.M., 1997. *Our Evolving Planet*, Bergen, Alma Mater (Fagbokforlaget), 456p.

Storetvedt, K.M., 2003. *Global Wrench Tectonics*, Bergen, Fagbokforlaget, 397p.

Storetvedt, K., 2005. Polar wander and global tectonics. *Boll. Soc. Geol. It, Volume Speciale,* no. 5, p. 177-187.

Storetvedt, K., 2007. Global Wrench Tectonics and Evolution of the Tethys. In: *Proc. Second Int. Conf. on Geol. of the Tethys*, Cairo, Tethys Geol. Soc., p. 1-26.

Storetvedt, K.M., 2009. The Caribbean evolution – a new account. *Geoscientist Online* 2 December 2009; http://www.geolsoc.org.uk/gsl/site/GSL/lang/en/page6816.html.

Storetvedt, K.M., 2010a. Falling Plate Tectonics – Rising New Paradigm: Salient Historical Facts and the Current Situation. *New Concepts in Global Tectonics Newsletter, no*. 55, p. 4-34.

Storetvedt, K.M., 2010b. World Magnetic Anomaly Map and Global Tectonics. *New Concepts in Global Tectonics Newsletter*, no. 57, p. 22-47.

Storetvedt, K.M., 2011. Aspects of Planetary Formation and the Precambrian Earth. *New Concepts in Global Tectonics Newsletter, no*. 59, p. 60-83.

Storetvedt, K.M. and Løvlie, R., 1983. Magnetization properties of intrusive/extrusive rocks of East Maio, (Rep. of Cape Verde) and their geological implications. *Geophys. Jour. Roy. Astron. Soc.,* v. 73, p. 197-212.

Storetvedt, K.M. and Scheidegger, A.E., 1992. Orthogonal joint systems in the Bergen area, southwest Norway, and their regional significance. *Phys. Earth Planet. Inter.,* v. 73, p. 255-263.

Storetvedt, K.M. and Longhinos, B., 2011. Evolution of the North Atlantic: Paradigm Shift in the Offing. *New Concepts in Global Tectonics Newsletter,* no. 59, p. 9-48.

Storetvedt, K.M. et al., 1990. A new kinematic model for Iberia; further palaeomagnetic and isotopic age evidence. *Phys. Earth Planet. Inter.*, v. 62, p. 109-125.

Storetvedt, K.M. et al., 1999. Alpine remagnetization and tectonic rotations in the French Pyrenees. *Geol. Rundsch.,* v. 87, p. 658-674.

Storetvedt, K.M. et al, 2003. New structural framework for SE Asia, and its implications for the tectonic evolution of NW Borneo. *Geol. Soc. Malaysia,* Bull. 47, p. 7-26.

Studier, M.H., 1965. Organic componds in carboniferous chondrites. *Science*, v. 149, p. 1455-1459.
Sugisaki, R. and Mimura, K., 1994. Mantle hydrocarbons: Abiotic or biotic? *Geochimica et Cosmochimica Acta*, v. 58, p. 2527-2542.
Supko, P.R. et al, 1977. *Initial Reports of the Deep Sea Drilling Project*, Leg 39, Washington DC, US Govt. Printing Office.
Süss, E., 1893. Are great ocean depths permanent? *Natural Sci.,* v. 1, p. 180-187.
Timofeyev, P.P. et al., 1990. Equatorial segment of the Mid-Atlantic Ridge as a possible structural barrier between the North and South Atlantic. *Trans. USSR Acad. Sci., Earth*, v. 312, p. 133-135.
Thiede, J. and van Andel, T.H., 1977. The palaeoenvironment of anaerobic sediments in the Mesozoic South Atlantic Ocean. *Earth Planet. Sci. Lett.,* v. 33, p. 301-309.
Torne, M. et al., 2000. Lithospheric Structure Beneath the Alboran Basin: Results from 3D Gravity Modeling and Tectonic Relevance. *Jour. Geophys. Res.,* v. 105, No. B2, p. 3209-3228.
Van Eysinga, F.S.B. (compiler), 1975. Geological Time Table, 3rd Edition. Amsterdam, Elsevier.
Veloso, E.A.E. et al., 2005. Tectonic rotations during the Chile Ridge collision and obduction of the Taitao ophiolite (southern Chile). *The Island Arc*, v. 14, p. 599-615.
Vigny, C. et al., 2002. GPS network monitors the Western Alps' deformation over a five-year period: 1993-1998. *Jour. Geodesy,* v. 76, p. 63-76.
Warsi, W.E.K. et al., 1983. Convergence structures of the Peru Trench between 10° S and 14° S. *Tectonophysics*, v. 99, p. 313-329.
Webb, S.D., 1995. Biological implications of the Middle Miocene Amazon Seaway. *Science,* v. 269, p. 361-362.
Welhan, J.A. and Craig, H., 1983. Methane, hydrogen and helium in hydrothermal fluids at 21°N on the East Pacific Rise. In: *Hydrothermal Processes at Seafloor Spreading Centres*, New York, Plenum Press, 810p.
Werner, S.C. et al., 2012. Structural interpretation of the Barents and Kara Seas from gravity and magnetic data. In: *Arctic Petroleum Geology*, London, Geological Society Memoirs, v. 35, p. 197-208.
Wezel, F.-C., 1975. Critical re-examination of cores from leg 13 cruise of DSDP, *Show and Tell seminar on the evaporate facies of the Messinian*, Erice/Palermo/, Abstract 3p.
Wezel, F.-C., 1985. Structural features of basin tectonics of the Tyrrhenian Sea. In: *Geological Evolution of the Mediterranean Basin.* New York, Springer Verlag, p. 153-194.
Weyl, R., 1980. *Geology of Central America.* Berlin, Gebrűder Bornträger, 371p.
Whitmarsh, R.B., 1979. The Owen Basin off the south-east margin of Arabia and the evolution of the Owen Fracture Zone. *Geophys. Jour. Roy. Astron. Soc.,* v. 58, p. 441-470.
Whittaker, R.C. et al., 2011. The NE Greenland Shelf: Full Crustal Imaging of Salt Tectonics and the Wandel Sea Mobile Belt. *Recovery*. CSPG CSEG CWL5 Convention, p.1-4.
Wilson, J.T., 1954. The development and structure of the crust. In: *The Earth as a Planet*, Chicago, Chicago Univ. Press, p. 138-214.
Wilson, H.H., 2005. A review of geological data that conflict with the paradigm of catagenic generation and migration o foil. *Jour. Petrol. Geol*., v. 28, p. 287-300.
Wolfart, R., 1967. Zur Entwicklung der paläozoischen Tethysin Vorderasien. *Erdöl u. Kohle, Erdgas u. Petrochemie*, v. 20, p. 168-180.
Zemtsov, V.A., 2007. Influence of Earth rotation on continental motions. *Jour. Gondwana Res.,* v. 12, no. 5, p. 242-251.
Zharkov, M.A., 1981. *History of Palaeozoic Salt Accumulation*. Berlin, Springer Verlag, 308p.
Zimmer, M. and Erzinger, J., 1995. On the geochemistry of gases in formation and drilling fluids – results from the KTB. Scientific Drilling, v. 5, p. 101-109.
Zoback, M.L. and Zoback, M.D., 1980. State of stress in the conterminous United States. *Jour. Geophys. Res.,* v. 85, p. 6113-6156.

COMMENTS AND REPLIES

Annulling the "marriage of convenience" between Earth expansion and seafloor spreading. Comment on Stephen Foster paper in *NCGT Newsletter*, no. 63, p. 82-86.

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In an article published in the June 2012 issue of the *NCGT Newsletter*, Stephen Foster (2012) announced that he had changed his mind concerning the expanding Earth hypothesis and now rejects it, offering a *mea culpa* for having previously advocated expansion. Dr. Foster notes that he rejected subduction long ago but until recently accepted seafloor spreading and Earth expansion. However, Dr. Foster now believes that seafloor spreading, like subduction, is a myth, and he provides a valuable review of the data that refute the seafloor spreading hypothesis, recapping several articles previously published in this newsletter that describe the widespread existence of ancient continental rocks on the floors of the world's oceans.

Dr. Foster seems to believe that *if* seafloor spreading *and* subduction are *both* myths, then ocean widening and continental displacement, lacking a plausible mechanism, must also be myths, which renders superfluous any theory that purports to explain them, including, and perhaps especially, Earth expansion. In my opinion, Dr. Foster has drawn the wrong conclusion. He apparently assumes that seafloor spreading is the *only* available mechanism for ocean widening on an expanding Earth. That is not so. However, it is not surprising that he has made that assumption because most expansion advocates following S. Warren Carey have done the same thing.

Carey (1976) characterized plate tectonics as a "shotgun wedding" between subduction on the one hand, dismissed by Carey as a myth that exists "only in the minds of its creators," and seafloor spreading on the other, which Carey endorsed and incorporated into his expansion model. "Plate tectonics and expansion schools agree in respect to sea-floor spreading. They differ mainly in the interpretation of the trenches. This issue then is the crux of the debate." In other words: subduction *bad*, seafloor spreading *good*. Unfortunately, Carey, by endorsing seafloor spreading, essentially sanctioned a "marriage of convenience" between expansion tectonics and seafloor spreading. Given the many problems now facing the seafloor spreading hypothesis, that marriage has not proved happy. But the failings of one partner should not besmirch the other. Expansion and seafloor spreading are *not* joined at the hip, so their fates are not inextricably intertwined. More to the point, and dispensing for the moment with the matrimonial metaphor, the refutation of seafloor spreading should have no bearing on Earth expansion.

Following Carey (1976), most expansion advocates have tacitly or explicitly accepted the "conveyor belt" model of seafloor spreading. Indeed, many expansion chronologies, such as those proposed by Owen (1983) and Maxlow (2005), are based on the Vine and Matthews (V-M) hypothesis (1963) and the associated polarity reversal timetables, such as Hertzler et al. (1968), which treat the marine magnetic anomalies as reliable "isochrons" that are literally *written in stone* on the ocean floor, and which purportedly reveal the history of seafloor spreading from the Early Mesozoic down to the present day. By accepting the gradualism implicit in V-M, these expansion chronologies invariably indicate continuous expansion from the Early Mesozoic onward.

There was, however, one continental-drifter and expansionist who never accepted Vine-Matthews or, for that matter, seafloor spreading (in the generally accepted sense of a convection-driven bilateral "conveyor belt"). Lester C. King, the great South African geologist and geomorphologist, was among the earliest critics of Vine-Matthews and seafloor spreading. Not only did he dispute the emerging plate tectonic dogma, but he also insisted that continental displacement (i.e., expansion) unfolded through a series of discrete tectonic episodes that were largely restricted to the Mesozoic, as opposed to a gradual and continuous process from the Triassic onward, as the V-M-based plate tectonic and expansion theories would have it (Erickson, 1988).

In his 1983 book *Wandering Continents and Spreading Sea Floors on an Expanding Earth* (a book rarely cited in the literature, alas), King challenged the underlying assumptions of the V-M hypothesis and seafloor spreading in general. Although it is impossible to fully describe King's vision here, which I hope to accomplish in a future article in this newsletter, a few quotations from his book should suffice:

- The Vine and Matthews (1963) hypothesis which requires that reversal patterns are frozen into the sea-floor rocks is only assumptive. But the reversal blocks, as drawn [in a figure in Vine and Matthews (1963)] convey a degree of confidence not yet warranted by the original data. (King, 1983, p. 111.)
- [W]hat the [shipborne] magnetometer has measured is a present total magnetic field. While this may have developed by migration laterally away from the zone of origin, there is no proof that the rocks through which the magnetic impulses now pass have themselves moved laterally with time. (96)
- That there is a pattern of polarity reversals is agreed; that these are "frozen" into the rocks is *assumed*, and that the pattern demonstrates the physical transportation of rock masses beneath the sea-floor is also an assumption that will be true only if the magnetism is "frozen" into the sea-floor basalts and other rocks. (96, italics in original)
- Symmetrical injection and outflow of lava from the ridge axis is assumed; but it is not likely to be so in nature. The boundaries for the claimed magnetic polarity reversals are unlikely to coincide with natural outflows of lava. (76)
- [T]he magnetic phenomena generated in relation to the mid-ocean ridges, and in particular the twinned polarity reversal stripes recorded by magnetometer traverses across the oceans, may well be only "signals" the pattern of which passes away to either side from the crestal zone of the ridge *through* the ocean floor, without any necessary displacement of, or addition to, the floor itself. On this viewpoint, sea-floor spreading is an unnecessary and perhaps wrongful assumption. (105, italics in original)
- To this author "sea-floor spreading" expresses the action admirably; but he sees no evidence of the "conveyor-belt" technology. Instead, he comprehends a general enlargement of the mantle body within the Earth. (82)

King also anticipated many articles in this newsletter in noting "the long list of Palaeozoic rocks dredged from certain ridge crests." These are impossible to reconcile with seafloor spreading without recourse to secondary *ad hoc* hypotheses that merely "explain" the specific anomalies after-the-fact but yield no new discoveries or predictions, which is symptomatic of a "degenerative scientific research programme" (Lakatos, 1970).

King's criticism of the Vine-Matthews hypothesis and seafloor spreading both expresses and justifies his rejection of the gradualism implicit in plate tectonics. Instead of continuous post-Paleozoic seafloor spreading and continental displacement down to the present day, as envisioned by plate tectonics (and those expansion chronologies that rely on V-M), King argued that most of the global tectonic "action" in the ocean basins occurred during the Jurassic and Cretaceous periods of the Mesozoic era:

- [T]here were two phases of continental disruption and drift in the mid-Jurassic and late Cretaceous respectively, followed during most of the early Cenozoic by tectonic quiescence and widespread planation – denudational upon lands, sedimentational in the oceans. Only the India-Australia-Antarctica land mass drifted extensively during the early Cenozoic. Tectonic activity resumed on the planetary scale (with only local drift) during the late Oligocene to early Miocene, and has increased (with quiescent intervals of widespread synchroneity) until the Pleistocene at least. (120-121)

- Several authors have drawn attention to the apparent lack of disturbance in the sediments of the ocean basins, and remarked that such horizontality over such vast distances is surely not in conformity with the concept of convectional spreading. The extent of Cretaceous sediments is so vast as to indicate that most of the present oceanic area was already in existence at that time. In other words, the late Mesozoic fragmentation of Gondwanaland was followed by very rapid dispersal of the southern continents, and relatively little drift in Cenozoic time. (80)
- Argument from the study of geomagnetic reversal patterns in rocks have generally led to the conclusion of smoothly continuing, slow spreading of the ocean floors. The geological record, however, is one of "fits and starts" with short tectonic episodes followed by prolonged intermissions of relative quiescence. (79)
- [S]ea-floor spreading and plate tectonics became popular concepts immediately following the acceptance of continental drift, which was already proved by geological data. But, following du Toit [1937], geologists have been careful to relate continental drift to late Mesozoic tectonic activity, which was episodic. The neotectonicists disregarded this point and thought of plate tectonics as a general and continuous process of lateral change. They postulated average rates of horizontal movement in the several oceans – averaged over the past 100 million years. *In geology, time is long and tectonic averages mean little. Tectonic happenings (both vertical and horizontal) are episodic and not infrequently of global extent, with long quiet intermissions during which wide planations developed upon the lands and ample depositions took place in the oceanic basins*. (120) [*Emphasis* added.]

If seafloor spreading *sensu stricto* is not viable, as seems to be the case, then ocean widening must have been caused by other geological processes. King, of course, recognized this requirement, and he invoked processes that should be very familiar to readers of this newsletter.

> Of great importance is the nature of the basaltic lower crust which, during the late Mesozoic when most of the continental break-up and drift occurred, must have been potentially eruptive upon a global scale, as is shown by the wide distribution of plateau basalt synchronous with the motion of the continents. This basaltic, lower crustal type is universal beneath the continents and ocean basins alike. Isotopic and trace element evidence suggests that it is derived as a product of fractional melting of the upper mantle on which it rests, sometimes with an intervening layer of gabbroic complexes and periodotitic rocks. But there is more. This upper mantle is abundantly charged with primitive volatiles at high temperature and low viscosity, which confer upon the melt an extraordinary state of mobility and vitality. (74-75).

Describing the Mesozoic breakup of Gondwanaland, upon which large depositional troughs and basins had previously formed, King wrote:

> As the supercontinent subsided, tensional fissures leading upward would form at the base of the sagging crust. Advantage would be taken of these for the potent magmas of the upper mantle, with their volatiles, to begin a large scale invasion of the overlying supercontinental crust. Widespread dyking (with sill intrusion into suitable rock formations (shales)) then reversed the continental sagging and instead began domings of both the base and the surface of the supercontinent…. *The crust of Gondwanaland became engorged with levitated mantle*, and because of the new doming was placed under a set of centrifugal forces (partly gravitational) with each sector of its periphery tilted outward (or forward) ready to fly apart….
> [A]s the magmas finally reached the surface in the mid-Jurassic, they poured forth the immense floods of plateau basalts covering hundreds of square kilometers in Brazil, in South Africa, in India, and in Antarctica. This was the moment of disruption….
> Henceforth the present southern continents were on their own. Each daughter continent inherited a leading edge of fold mountains that had formed part of the Gondwanaland circumvallation, each was tilted forward in the direction of travel, and each had to supply its own motive power….
>
> *Each continent rode as it were upon a cushion of levitating mantle. The power source might be expected to fail ultimately, but to begin with each continent was powered like a rocket.* Later power surges are indicated by

> further outpourings of plateau basalt in early Cretaceous time (Brazil and southwest Africa) and late Cretaceous to Eocene (India), so that propulsion died down by the end of the Cretaceous…. But from the remaining southern land masses there is, as yet, no compelling geological evidence of Cenozoic drift, only of vertical displacements *in situ*. Certainly there is no orthodox geological evidence of Cenozoic subcrustal convection currents, or of sea-floor spreading.
>
> The phenomena accompanying the disruption of Gondwanaland and the centrifugal dispersion of its fragments, with distinct mid-Jurassic, late Cretaceous and Miocene episodes of drift, and quiet intermissions of stability between, form the prescription which must be fulfilled by tectonicists. *It is a problem immensely grander* than the opening of the North Atlantic, which has received a disproportionate amount of attention. (89-91). [*Emphasis* added.]

King's account of the geological processes that dismembered Gondwanaland has many similarities to the "neo-fixist" tectonic models propounded in this newsletter and elsewhere by Beloussov (1992), Rezanov (2003), Storetvedt (2003, 2010), and others. Expansion and the neo-fixist models agree that the Earth was once entirely enclosed by sialic (continental) crust and that the ocean basins are post-Paleozoic. They also agree that the continents are "fixed" to deep mantle roots and thus have always remained more or less *in situ,* and also that ocean basins are created by the infiltration of volatile-rich mantle material into the base of the continental crust along zones of weakness. However, expansion differs from the neo-fixist models in that the various land masses on an expanding Earth became displaced vertically on the globe (horizontally in plan view) as the mantle expanded beneath them, and thus it also differs with respect to ocean-basin development.

Like plate tectonics, the neo-fixist models assume a constant-sized Earth. But unlike plate tectonics, the neo-fixist models envision "oceanization" of the continental crust as the proximate cause of ocean basin formation (Beloussov, 1992). According to these models, oceanization spreads laterally outward from ancient geosynclines (marginal seas), which eventually transforms the continental crust into oceanic basins through extensional faulting, attenuation, basaltic magmatism (basification), and sub-crustal delamination, in a progressive manner that is similar to seafloor spreading in its horizontal propagation, but also quite different because there is no crustal displacement.

In contrast, an expansion model based on King (1983) envisions that new oceanic crust was formed between the various "levitated" remnants of the ancient supercontinents as the mantle expanded and became exposed at the surface. Thus, the continental land masses for the most part were seemingly unaffected by oceanization, except on their peripheries, where narrow epicontinental seas (zones of weakness) stretched and evolved into wide global oceans. Since the primary tectonic motion of the crust – *all* of the crust – on an expanding globe is radially outward and upward on diverging radii, the "levitated" continents remained fixed to their mantle roots (**Figure 1**). So it should come as no surprise that pieces of old continental crust, where it was torn asunder and oceanized, were also transported radially outward and upward and were therefore intermixed *in situ* with the new oceanic basalt: e.g., Madagascar and the Seychelles in the Indian Ocean, St. Peter-Paul Rocks in the mid-Atlantic (James, 1997), Jan Mayan Ridge in the North Atlantic (Yano et al., 2009), the numerous submarine plateaus worldwide, and the many continental rocks that have been dredged from all of the oceans (Vasiliev and Yano, 2007).

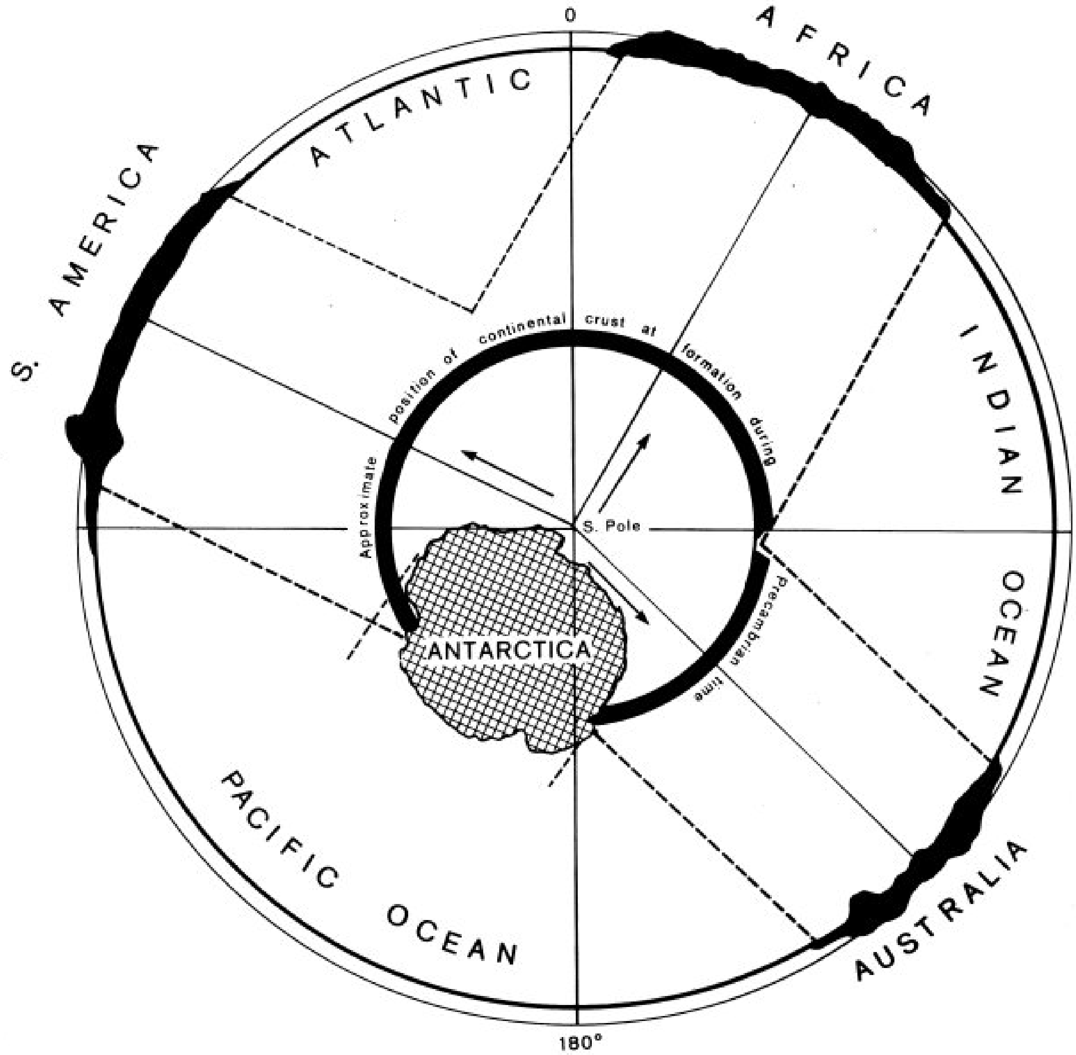

Figure 1. Present southern continents and ocean basins on an expanding Earth. Original size of continental crust in heavily-drawn inner circle. Continental drift is shown by vertical rise of the continents on diverging radii, and growing distance between them on the increasing circumference. As areas of continental crust do not enlarge during global expansion, the increase of the surface is taken up in the oceanic areas which become wedge shaped. Probable order of ocean basin formation is: (1) Pacific Ocean; (2) Indian Ocean; (3) Atlantic Ocean. South America and Africa are drawn from equatorial section, Australia at 15° S latitude. Antarctica is shown in plan near its present position. (Figure and caption from King, 1983, fig. 31).

In this alternate model based on King, expansion tectonics is divorced from seafloor spreading and wed to oceanization, but only on its own terms and in a much narrower sense. Indeed, this expansion model explains how and why oceanization was triggered in the first place. As the Earth expanded – which certainly must have involved mineral phase changes in the mantle on a global scale – the continental crust became attenuated, or "stretched" laterally and perpendicularly to ancient geosynclines, where the new ocean basins originated. This stretching, or lateral extension, of the continental crust initially may have taken many forms: horst-and-grabens, low-angle listric faults, and brittle deformation (fault breccias and gouge) near the surface, as well as ductile deformation (mylonites, schists and gneisses) in the deeper, hotter, and more plastic levels of the continental crust. Attenuation weakened the continental crust, and block faulting provided pathways for volatile-rich mantle materials to intrude along high-angle faults or simply through cracks and joints in the rocks (e.g., sheeted dykes, ophiolites, and basaltic magmatism generally), topped by subaerial "traps" and pillow basalts in submarine environments. Eventually, widespread flood basalts buried most of the remaining continental rocks in the ocean basins whilst leaving isolated chunks, slivers, and debris of the ancient crust here and there – *in situ*.

Southwestern North America provides dramatic evidence of crustal extension, attenuation, and magmatism at what may be a nascent *pre-oceanic* stage: the Basin and Range Province (Dickinson, 2006; **Figure 2**), characterized by numerous extensional features, such as horst-and-grabens, listric and low-angle detachment faults, mylonites (**Figures 3 and 4**), and metamorphic core complexes (Coney, 1980; **Figure 4**); the Rio Grande Rift (Wilson et al. 2005; **Figure 2**), where the continent is "stretched like taffy" (Hill, 2005); the Yellowstone Caldera (Figures 2 & 5) and Snake River Plain (**Figures 2 and 6**) in the heart of the North American Cordillera, where the crust is highly attenuated and the upper mantle is very close to the surface (Christiansen et al., 2002; **Figure 5**); and the Columbia River flood basalts, which are among the largest on Earth (Bryan et al., 2010; **Figure 2**). The total basin-and-range extension is estimated to be between 50% and 300% (Liu and Shen, 1998, and references therein).

According to expansion tectonics, the primary tectonic motion is vertical and radially outward, so these Neogene extensional and magmatic features may simply be the means by which the continental crust accommodates the increased surface area of the globe and they may presage, if expansion continues (or resumes), the development of a large and largely basaltic oceanic basin, or perhaps the eastward enlargement of the Pacific basin through oceanization, with or without expansion. (Cf. Carey, 1976 and Storetvedt, 2003.).

Significantly, the Basin and Range Province falls directly on the line of the East Pacific Rise and thus may be the northward continuation of that feature beneath North America (**Figure 2**). Plate tectonic theory denies this and maintains instead that transform faults, e.g., the San Andreas, have shifted this "spreading center" westward so that it sidesteps North America and continues off the west coast as the Gorda and Juan de Fuca Ridges.

Plate tectonic theorists interpret the Cenozoic geology of southwestern North America generally in a convergent, subduction zone setting (Dickinson, 2006). The basin-and-range topography and other extensional features are thought to have resulted, at least initially, from the collapse of a thick, gravitationally unstable crustal welt that developed in the Late Cretaceous and Paleogene during the Laramide orogeny (Coney, 1987; Cf. Liu and Shen, 1998), which occurred along the entire length of the North American Cordillera. However, plate theorists, invoking subduction, have considerable difficulty explaining how or why Laramide deformation developed approximately 1000 km inland from the nearest active margin. "None of the proposed mechanisms for driving Laramide orogenesis satisfactorily explain the geometry, timing, or extent of this inboard, continental-scale orogeny." (English and Johnston, 2004.) There are striking similarities between the American Basin and Range and the Tyrrhenian Basin southwest of Italy, which is now kilometers deep beneath the Mediterranean. "The extensional basin of the Tyrrhenian formed within thickened continental crust on the former site of a collisional orogeny." (Kastens and Mascle, 1990).

The Colorado Plateau (**Figures 2 and 7**) is surrounded by this tectonic mayhem but seems to have been largely unaffected by it and, moreover, it has risen 2-3 km above sea-level, which is also difficult to explain: "What caused the elevation gain of this previously stable cratonic region in Cenozoic time? Did the source of buoyancy for plateau uplift arise from the crust, lithospheric mantle, or asthenosphere, or through some combination of the three? Why did this low-relief plateau escape significant upper crustal strain during uplift, in contrast to the Cenozoic surface deformation that is so strikingly apparent in the high-relief landscape of the surrounding Rocky Mountain, Rio Grande Rift, and Basin and Range provinces?" (Flowers, 2010). These problems remain unsolved. Southwestern North America has some of the most interesting, enigmatic, and important geology on Earth and therefore deserves close and careful study.

Finally, we should recall that most if not all of the neo-fixist models propounded in this newsletter and elsewhere agree that ocean basin formation was essentially a Mesozoic phenomenon (e.g., Beloussov, 1992;

Rezanov, 2003; Storetvedt, 2003; Choi and Vasiliev, 2008; Storetvedt and Longhinos, 2011). However, this very important *geohistorical fact* remains unexplained by those models, except in a very general way, and is therefore mere happenstance according to them. But if King is right, then the sudden and unprecedented creation of the wide ocean basins was a direct *and necessary* consequence of rapid Earth expansion during the Mesozoic, which ruptured the ancient supercontinents that had formerly covered the smaller Earth and perforce required *something* – i.e., young mantle-derived basalts intermingled with fragments of ancient continental crust – to fill in the voids between the remnant continents as the latter were displaced vertically on the 3-D globe and horizontally on 2-D maps. *Natura abhorret a vacuo.*

In rejecting Earth expansion based solely on the shortcomings of seafloor spreading, Dr. Foster has thrown out the baby with the bathwater. Accordingly, I urge him to reconsider his *mea culpa* and take a fresh look at the expansion hypothesis; i.e., an alternate version of expansion tectonics based on King (1983), a version that eschews Vine-Matthews and seafloor spreading, and one that embraces crustal attenuation and oceanization.

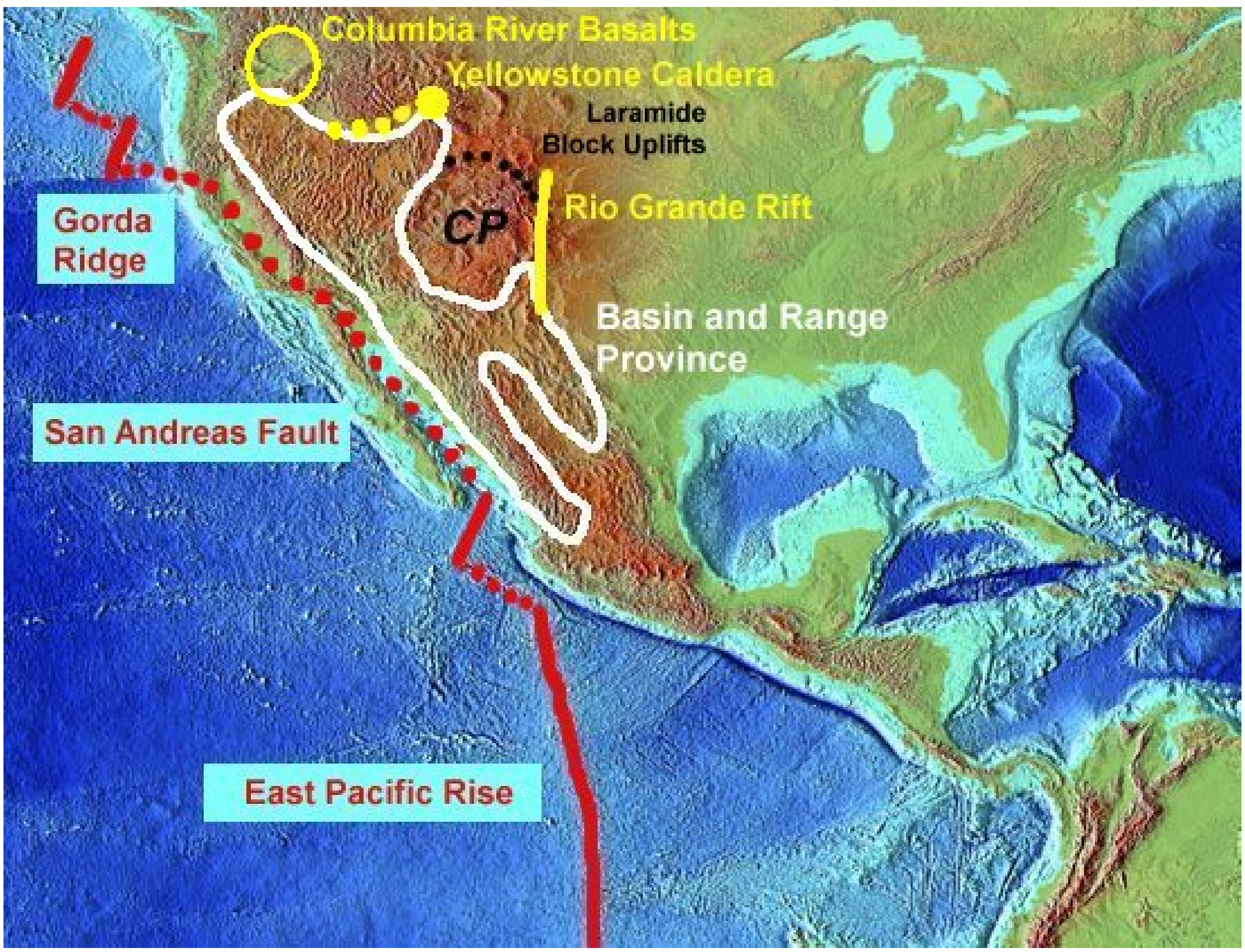

Figure 2. Geographical setting of the Basin and Range Province, outlined in white, and the other Neogene features mentioned in the text shown in yellow, in southwestern North America, north of where the East Pacific Rise approaches the continent. Note the Big Horn Mountains and the Black Hills, barely visible to the left of the word "Laramide" and beneath the letters "ll" and "s," respectively, in the word "Yellowstone, which are reverse-fault-bounded uplifts of Precambrian crystalline basement, as are the Wind River Range and Laramie Mountains further south, along the black stippled line. These block uplifts are associated with the Laramide orogeny, "a profound compressional event" that occurred during the Late Cretaceous and Paleogene and extended from Canada to Mexico. "The entire crust was folded and broken by very deep-seated thrust faults" (Coney, 1978). In the midst of all this tectonic mayhem is the Colorado Plateau (labeled "CP"), the iconic landscape of the American West (e.g., Monument Valley, The Arches, Zion, the Grand Canyon [Figure 7], etc.), which is a veritable island of crustal stability, barely touched by the Cenozoic diastrophism that surrounds it.

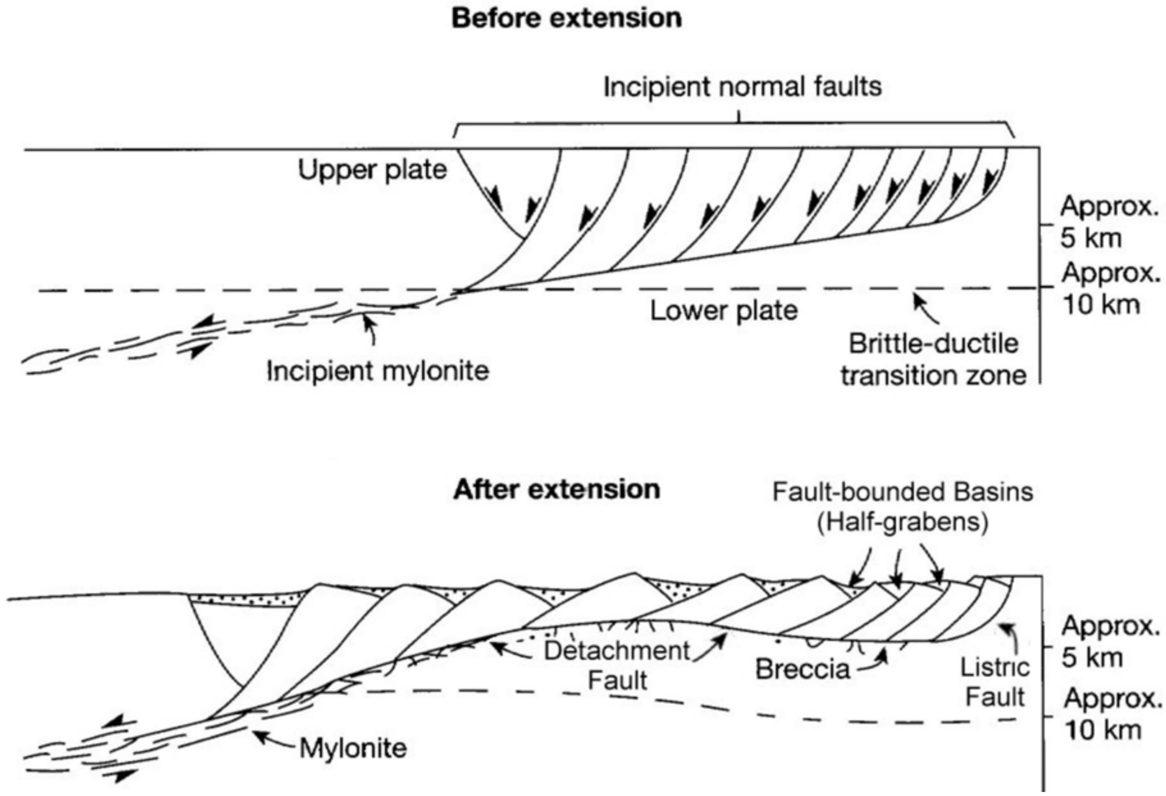

Figure 3. Schematic cross-section of basin-and-range geology before and after crustal extension: normal, listric and low-angle detachment faults, imbricate fault blocks, and mylonites near the brittle-ductile transition zone. Modified after Michaelsen.

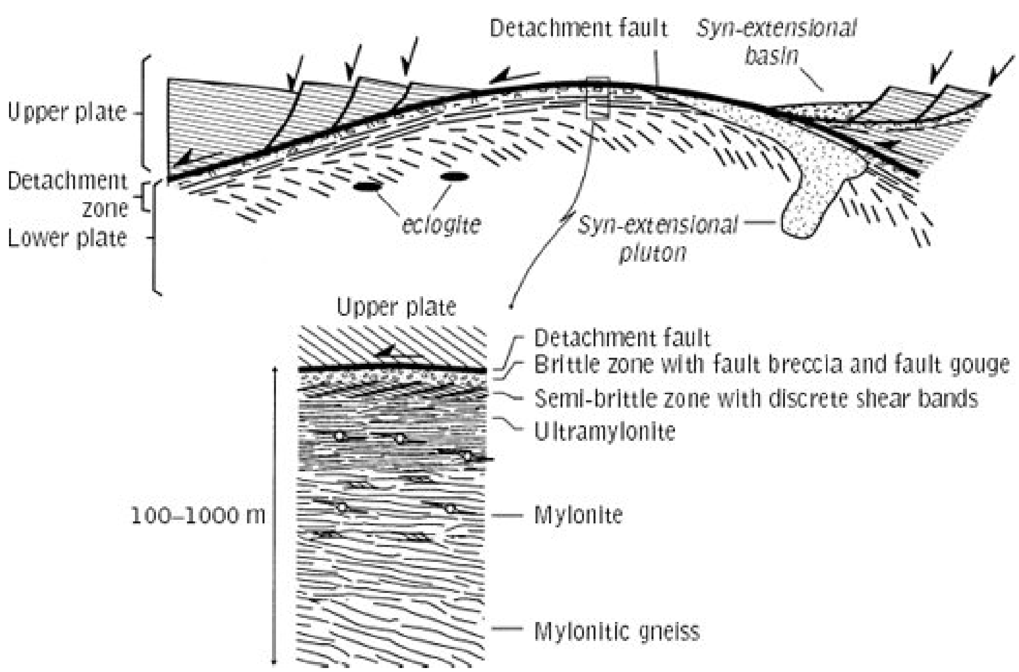

Figure 4. Schematic cross-section of a metamorphic core complex, with detachment fault and metamorphic basement exposed at the surface. This extensional mode of basement exposure differs significantly from the Laramide style, which involved reverse block-faulting indicative of compression. The development of metamorphic core complexes in many places marked the onset of post-Laramide extension (Coney, 1987).

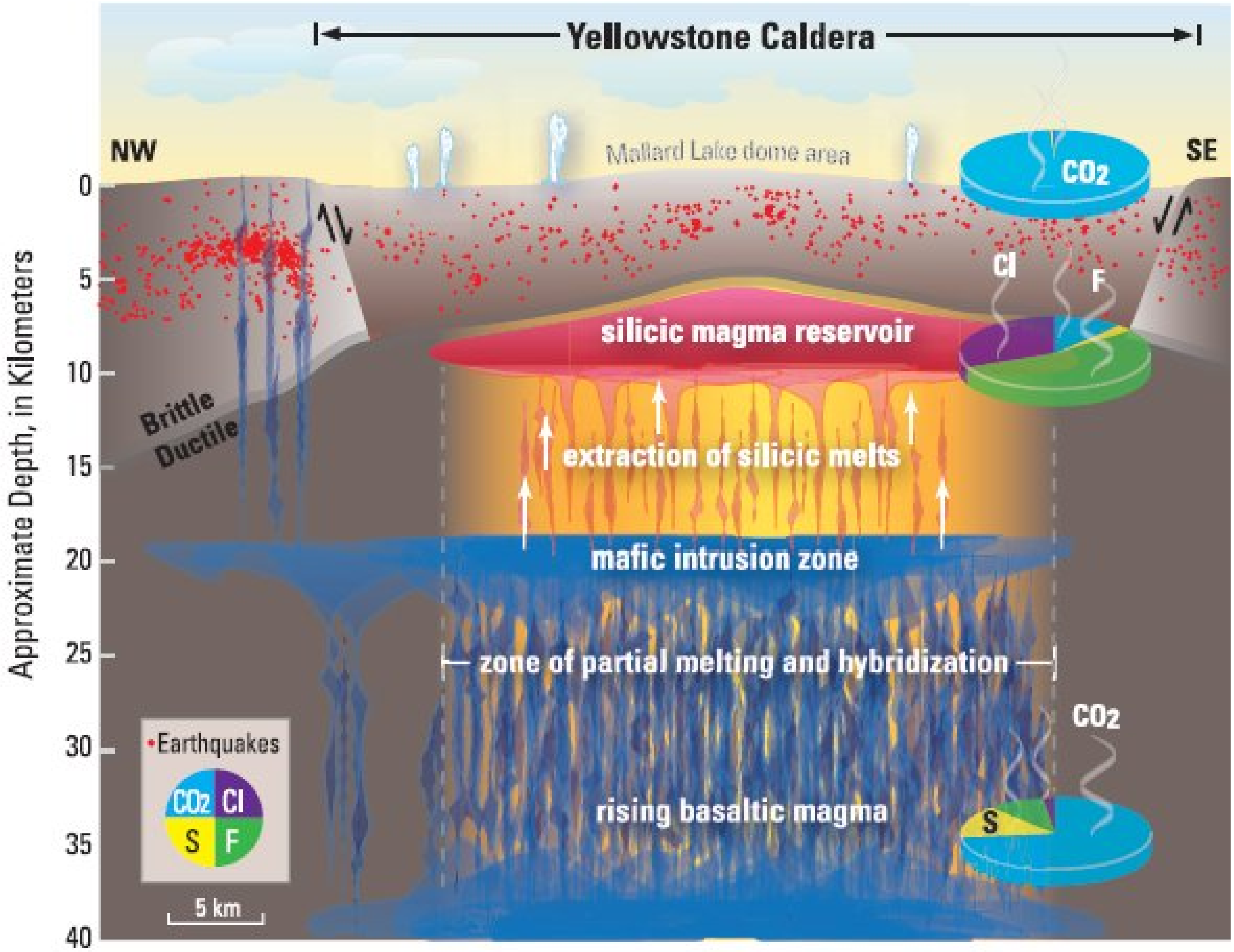

Figure 5. Schematic cross-section of the crust beneath the Yellowstone Caldera [references excluded]. Red dots represent earthquake epicenters. The silicic magma reservoir is responsible for most of the volcanism over the past 2.1 million years and overlies a middle and lower crust invaded by mantle derived basalt. The silicic magma is a hybrid of crustal melts and residual liquid formed as mafic magma cools and crystallizes. Magma rises closest to the surface (5–7 km depth) beneath the resurgent domes. Pie diagrams compare the relative abundances of volatiles emitted from the Yellowstone hydrothermal system (top) with the abundances of volatiles dissolved in Yellowstone rhyolites (middle) and hotspot basalts (bottom). The CO_2-rich hydrothermal system appears to reflect the basalt dominated crust below (Figure and caption from Lowenstern and Herwitz, 2008).

References

Beloussov, V.V., 1992. Endogenic regimes and the evolution of the tectonosphere. In, Chatterjee, S., and Hotton, N., III (eds.), New Concepts in Global Tectonics, Lubbock, Texas Tech University Press, p. 411-420.

Bryan, S.E., Peate, I.U., Deate, D.W., Self, S., Jerram, D.A. and Mayby, M.R., 2010. The largest volcanic eruptions on Earth. *Earth-Science Reviews,* v. 102, p. 207-229.

Carey, S.W., 1976. *The Expanding Earth.* Amsterdam, Elsevier Scientific Publishing Co, 488p.

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.

Christiansen, R.L., Foulger, G.R. and Evans, J.R., 2002. Upper-mantle origin of the Yellowstone hotspot. *Geological Society of America Bulletin, v.* 114, 1245-1256.

Coney, P.J., 1978. The plate tectonic setting of southeastern Arizona. In, New Mexico Geol. Soc. Guidebook, 29th Field Conf., Land of Cochise, p. 285-289.

Coney, P.J, 1980. Cordilleran metamorphic core complexes. *In* Crittenden, M.D., Coney, P.J. and Davis, G.H. (eds.), Cordilleran Metamorphic Core Complexes, Boulder, GSA Memoir 153**,** p. 7–34.

Coney, P.J., 1985. The Grand Staircase. Artwork by Dick Beasley. Wikipedia: *Grand Staircase.*

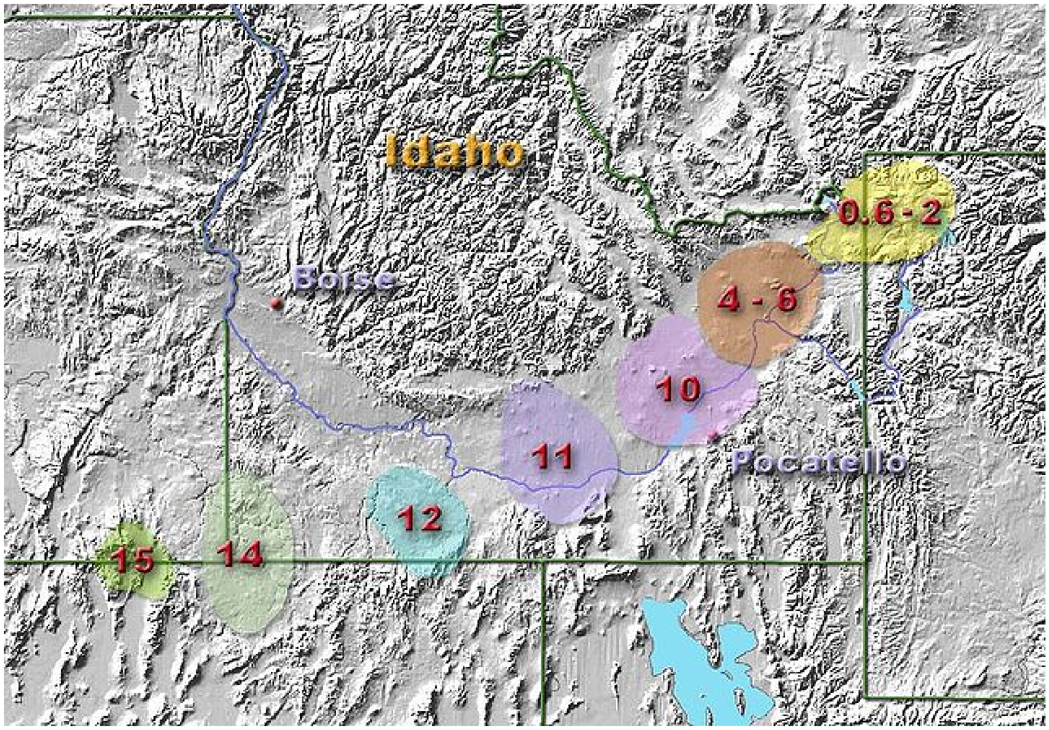

Figure 6. Path of the Yellowstone "hot spot" during the past 15 million years along the Snake River Plain at the northern edge of the Basin and Range Province (Wikipedia: *Yellowstone Caldera*). Note the basin-and-range topography south of the path, but not north of it, suggestive of a northeast trending (and advancing?) tectonic boundary.

Coney, P.J., 1987. The regional tectonic setting and possible causes of Cenozoic extension in the North American Cordillera. In Coward, M.P., Dewey, J.P. and Hancock, P.L. (eds.), Continental extensional tectonics. Geological Society, London, Special Publications, v. 28, p. 177-186.

Dickinson, W.R., 2006. Geotectonic evolution of the Great Basin. *Geosphere*, v. 2, no. 7, p. 353–368.

Du Toit, A.L, 1937. *Our Wandering Continents: An Hypothesis of Continental Drifting*. Westport, Conn., Greenwood Press, 366p.

English, J.M and Johnston, S.T., 2004. The Laramide Orogeny: What were the driving forces? *International Geology Review*, v. 46, p. 833–838.

Erickson, W.C., 1988. Ever since Wegener: A brief history of the expanding Earth hypothesis. *http://www.frontier-knowledge.com/earth/papers/Ever%20since%20Wegener.pdf*.

Flowers, R.M., 2010. The enigmatic rise of the Colorado Plateau, *Geology*, v. 38, 671-672.

Foster, S., 2012. Mea culpa: The Earth is not expanding – but the continents are not moving either. *New Concepts in Global Tectonics Newsletter,* v. 63, p. 82-86.

Heirtzler, J. R., Dickson, G. O., Herron, E. M., Pittman III, W. C. and LePichon, X., 1968, Marine magnetic anomalies, geomagnetic field reversals, and motions of the ocean floor and continents. *Jour. Geophys. Res.*, v. 73, p. 2119-2136.

Hill, K., 2005. The Rio Grande Rift: A Continent "Stretched Like Taffy". *http://www.nmt.edu/news/all-news/96-2005/2787-23feb02g*.

James, P., 1997. A synthesis of major objections to mobile plate tectonics. *New Concepts in Global Tectonics Newsletter,* no. 2, p. 6-12.

Kastens, K. and Mascle, J., 1990. The geological evolution of the Tyrrhenian Sea: An introduction to the scientific results of ODP leg 1071, *Proceedings of the Ocean Drilling Program, Scientific Results, v.17, p.* 3-26.

King, L.C., 1983. *Wandering Continents and Spreading Sea Floors on an Expanding Earth.* Chichester, John Wiley & Sons, 232p.

Lakatos, I., 1970, Falsification and the methodology of scientific research programmes. In, Lakatos, I. and Musgrave, A. (eds), Criticism and the Growth of Knowledge. Cambridge, Cambridge University Press, p. 91-196.

Liu, M. and Shen, Y., 1998. Crustal collapse, mantle upwelling, and Cenozoic extension in the North American Cordillera, *Tectonics*, v. 17, p. 311-321.

Lowenstern, J.B. and Hurwitz, S., 2008. Monitoring a supervolcano in repose: heat and volatile flux at the Yellowstone Caldera, *Elements*, v. 4, p. 35-40.

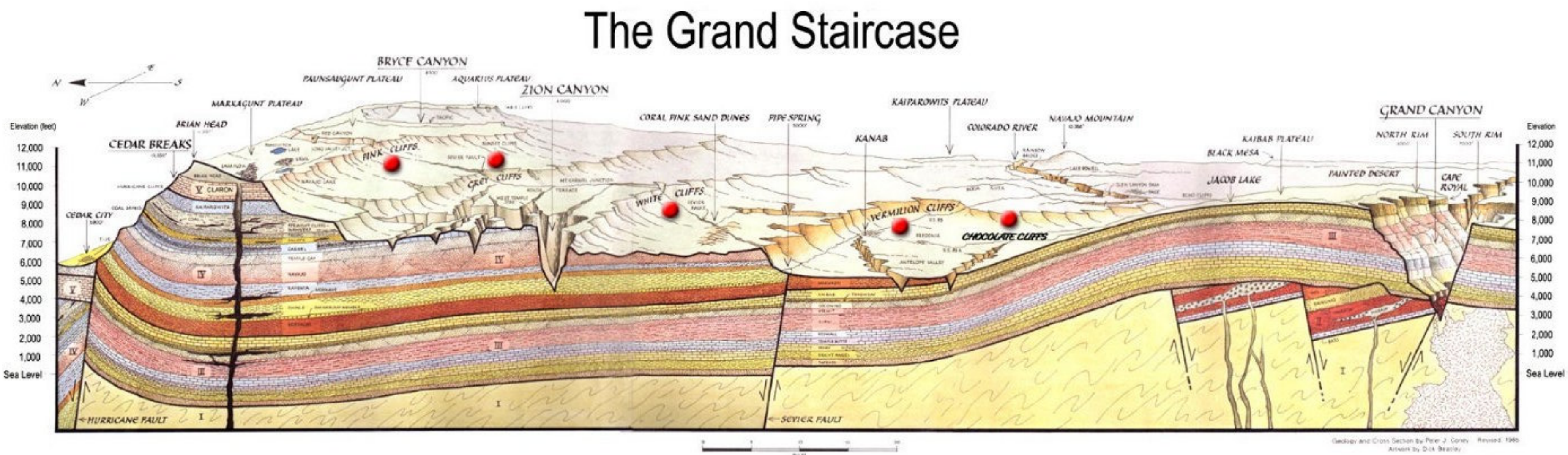

Figure 7. Stylized cross-section of "The Grand Staircase" in the southwestern region of the Colorado Plateau (Coney, 1985). From left-to-right (north-to-south) are Cedar Breaks, Bryce Canyon, Zion Canyon and the Grand Canyon. The strata are Cambrian through Eocene (discontinuous) resting unconformably on Middle Proterozoic basement. Note the almost complete absence of Phanerozoic deformation, despite the Cenozoic diastrophism (Laramide, Basin-and-Range, etc.) that surrounds the Colorado Plateau.

Maxlow, J., 2005. *Terra Non Firma Earth: Plate Tectonics Is a Myth.* Perth, Terrella Press, 156p.
Michaelsen, J., Date unknown. Basin and Range (Transierra) region physical geography. http://www.geog.ucsb.edu/~joel/g148_f09/readings/basin_range/basin_range.html.
Owen, H.G., 1983. *Atlas of Continental Displacement, 200 Million Years to the Present.* Cambridge, Cambridge University Press, 159p.
Rezanov, I.A., 2003. Geologic history of continents and oceans. *New Concepts in Global Tectonics Newsletter,* no. 26, p. 3-8.
Storetvedt, K.M., 2003. *Global Wrench Tectonics*. Bergen, Fagbokforlaget, 397p.
Storetvedt, 2010. Falling plate tectonics – Rising new paradigm: Salient historical facts and the current situation. *New Concepts in Global Tectonics Newsletter*, no. 55, p. 4-33.
Storetvedt, K.M. and Longhinos, B., 2011. Evolution of the North Atlantic: Paradigm shift in the offing. *New Concepts in Global Tectonics Newsletter,* no. 59, p. 9-48.
Vasiliev, B.I. and Yano, T., 2007. Ancient and continental rocks discovered in the ocean floors. *New Concepts in Global Tectonics Newsletter*, no. 43, p. 3-17.
Vine, F.J. and Matthews, D.H., 1963. Magnetic anomalies over ocean ridges. *Nature,* v. 199, p. 947-949.
Wilson, D., Aster, R., West, M., Ni, J., Grand, S.., Gao, W., Baldridge, W.S., Semken, S. and Patel, P., 2005. Lithospheric structure of the Rio Grande rift. *Nature,* v. 433, p. 851-855.
Yano, T., Choi, D.R., Gavrilov, A.A., Miyagi, S. and Vasiliev, B.I., 2009. Ancient and continental rocks in the Atlantic Ocean. *New Concepts in Global Tectonics Newsletter,* no. 53, p. 4-37.

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Reply to the Erickson comment

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You were correct in your reading of my essay but because of the word limit my reasons for changing my mind re-earth expansion could not be explained fully and all of the evidence that I had taken into consideration reviewed. I have therefore attached a copy of a letter which I sent to one of the members of the editorial board of *Geoscientist* in March 2012 in which I describe in more detail the evidence which I consider invalidates sea-floor spreading. You were correct to assume that I consider that this also disproves all theories of earth expansion, including that of the late L. C. King which until now I did not know about but would like to thank the author for his clear and concise explanation of it. While I do *not* think that earth expansion can only be explained by sea-floor spreading, I do have serious doubts about any hypothesised process(es) that attempt to account for expansion, and the evidence which is used to support them. For me this was a major problem with any EE theory and I considered it to be a major weakness, as I regularly told my students.

I think that the flaws in King's hypothesis lie in his attempts to explain ocean widening and mountain building.

Ocean widening

I note that King wrote his book at a time when there was even more limited knowledge of the geology of the ocean floors (not helped by the manipulation of the data as published in the records from the DSDP) than even today, and he seemed to be unaware of or ignored the important criticisms made by Meyerhoff and Meyerhoff of the correlations made between the different geologies of the continents by Wegener, Holmes and du Toit. The important bathymetric maps that were produced by the US Navy were not publicly available at that time either, yet they provide important information about fracture zones/faults which can be traced from ocean floors across continents and back into ocean floors, and which must be incorporated into and explained by any theory of the origin and history of the oceans. I also mentioned the Hayes-Oceanographer FZ in the N Atlantic which also invalidates attempts to join N America to W Africa if reconstructions of Pangaea are to work properly. The existence of thick, tectonically undisturbed sedimentary sequences beneath the Japan, Java and other trenches must also be taken into account, together with the presence of a major Mesozoic sedimentary basin in the S W Pacific which has a continuation into E. Asia. Of course King did not know of these important features because they had not been described when he was writing, but we do have to take account of them today and that is what I am trying to do. No theory of Earth expansion can logically explain these phenomena away. We will not understand the geological history of the ocean floors by studying continental rocks alone: we will require data from the deep ocean floors from a variety of sources including that obtained by systematic deep drilling of the kind that the research vessel *Chikyu* is going to do.

In the meantime it is my considered opinion that Bellousov and his students have provided a more accurate and viable hypothesis to explain the origins of the oceans than either PT theory or earth expansion, namely that the ocean basins and the bulk of the ocean waters are Mesozoic and Tertiary in age. Indeed it seems entirely plausible that the volume of water on the Earth's surface has varied considerably throughout geological time, that the planet has more water on the surface today than at any other time in the past, and it is still being exhaled (outgassed) via "black" and "white smokers" on the ocean floors. Uniformitarianism as widely understood does not apply in this case: there were no Panthalassas because the ocean water was not there to form them.

Mountain building

You quote King's attempt to explain the origin of mountain ranges on the edges of some continents:

> "Henceforth the present southern continents were on their own. Each daughter continent inherited a leading edge of fold mountains that had formed part of the Gondwanaland circumvallation, each was tilted forward in the direction of travel, and each had to supply its own motive power…." (L. C. King)

This idea was not new to King: many others (including Wegener), had suggested similar theories to explain the distribution of fold mountains especially around the Pacific rim, but the weakness of this was and is that it doe not explain the origins of mountain ranges that are not found on the edges of continents, or the existence of older fold mountain ranges on other parts of the Earth, in continental interiors for example. King tried to explain uplift of young fold mountains in terms of lateral displacements (drift) while all the time ignoring the evidence from mountain ranges that were not on the edges of continents which also display plentiful evidence for contemporaneous episodic uplift with ranges that are, and the evidence of tectonic activity in these the Andes of S. America and the Western Cordillera of N. America which pre-dates the Mesozoic and his proposed phase of Earth expansion. It would seem that King was of the school that followed Geike and others in arguing that fold mountains are a product of local crustal shortening and compression, whereas the weight of evidence seems to favour episodic uplift of thick volcano-sedimentary piles by diapiric intrusion. By using Occam's razor (admittedly not an infallible tool but nevertheless a useful one), we are forced to accept a single general theory to account for fold mountains rather than having one for Mesozoic and more recent orogens in restricted parts of the globe, and another for the rest. There is also the problem of the Bengal fan which as far as we can tell from current data started to form in the Cretaceous and has been growing ever since. Crustal expansion would surely have left its mark on this as well as many other large submarine fans around the world. Expansion also does not seem to take into account the clear evidence for rapid uplift and subsidence of the ocean floors, in particular the relatively recent subsidence of extensive areas of ocean floor (i.e. since mid Miocene times) and in particular the ocean trenches.

You argue that the oceanization process which began in the Mesozoic was a "mere happenstance" which remains unexplained by this hypothesis. I would reply that King also fails to offer any explanation as to why Earth expansion should have suddenly occurred in the Mesozoic: Maxlow does argue for a continuously expanding Earth but he too offers no convincing explanation as to why this should be occurring. Carey's attempt to assign a cause to expansion (described in *Theories of the Earth and Universe*), was related to the bigger idea of an expanding universe, a product of Big Bang theory. While I do not want to go off on a tangent in astrophysics I think it will suffice to say that Big Bang theory can be considered to properly belong to mathematical metaphysics, not materialistic science. In reply to your criticism I would argue as others have done that the Earth is a complex, evolving thermo-chemical system that undergoes irreversible changes through time, and that the rates at which these processes operate can also vary in time. Oceanization and the accompanying outgassing of large volumes of water during and since the Mesozoic would be one consequence (among many) of this. Oceanization is a relatively new phenomenon because it represents the current state of change in the evolution of this planet: we can say little more because we barely understand the planet's inner workings, and not too much of its pre-Mesozoic history.

Any attempt to explain the origin of large scale feature of the planet are bound to run against major problems because we do not understand either many of the processes involved or the time scales over which they operate. This means that we are inevitably forced to speculate - as the late S.J. Gould wrote of evolution, we cannot wind back the tape and play it over again, - the same applies to Earth history. However we do need to try to account for as much as possible in any viable and coherent theory of the Earth and not project from local details to the global scale as many proponents of PT theory and others do. I welcome your comments because they stimulate debate and thinking outside the PT framework which was the original purpose of my essay, but was stifled by the editorial board of Geoscientist whose members seem to want to prevent any such debate taking place, or at least reserve it to members of the select few who have entered the hallowed portals of the temple of academe. Unless we can have such debates we are reduced to zombie science and advocacy research where instead of trying to discover new knowledge and gain a better understanding we are reduced to merely confirming what we think we already know and remain unwilling to admit that our understanding is to a greater or lesser degree provisional. Then rational doubt is driven out and replaced by dogma. Whatever the weaknesses of expanding earth theories may be they do at least represent a different way of thinking and seeing, and for that reason I welcome them as part of an informed discussion.

References

Carey, S.W., 1988. *Theories of the Earth and Universe*. Stanford Univ. Press.

Choi, D.R., 1998. Geology of the southeast Pacific, parts 1-3, *New Concepts in Global Tectonics Newsletter,* no. 7, p. 11-15; no. 8, p. 8-13; no. 9, p. 12-14.

Choi, D.R., 1999: Geology of East Pacific: Middle America Trench, *New Concepts in Global Tectonics Newsletter,* no. 12, p. 10-16.

Choi, D.R., 2000: Subduction does not exist - from seismic data interpretation. *New Concepts in Global Tectonics Newsletter,* no. 15, p. 9-14.

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

Meyerhoff, A.A. and Meyerhoff, H.A., 1972. The new global tectonics: major inconsistencies. *Am. Assoc. Petrol.Geol. Bull.,* v. 56, p. 269-336.

Ollier, C. and Pain, C.F., 2000. *The Origin of Mountains.* Psychology Press.

Shepard, F.P. and Dill, R.F., 1966. *Submarine Canyons and other Sea Valleys,* Rand McNally.

Smoot, N.C., 1989. North Atlantic fracture-zone distribution and patterns by multi-beam sonar. *Geology,* v. 17, p. 1119-1122.

Smoot, N.C., 2010. Global tectonics: an ocean floor structure and age reality check. *New Concepts in Global Tectonics Newsletter,* no. 56, p. 9-31.

Comment on Pavlenkova's fluid-rotation model

Pavlenkova, N.I., "The Earth's degassing, rotation and expansion as sources of global tectonics". *NCGT Newsletter*, no. 63, p. 49-71, 2012.

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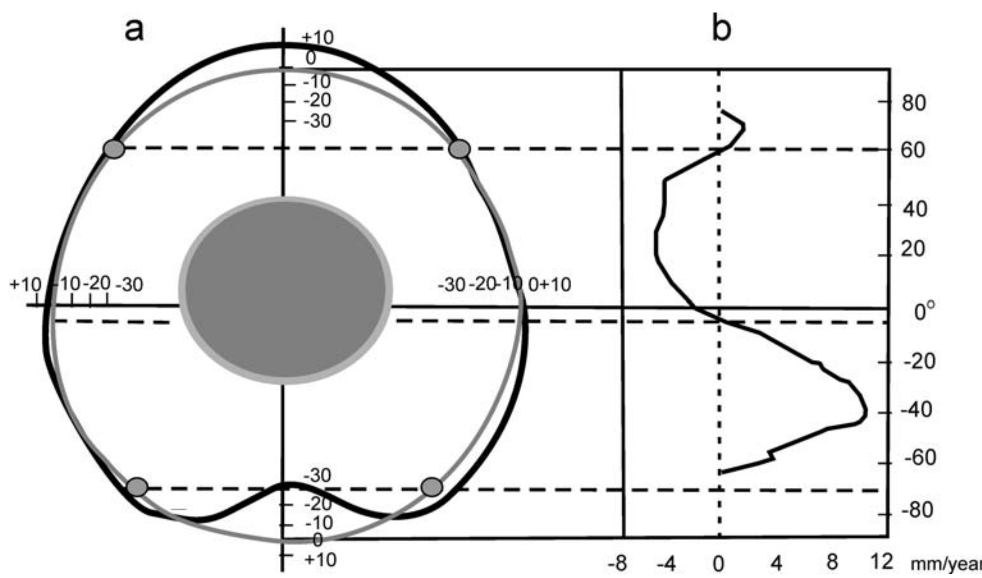
In her article on the fluid-rotation model of geotectonics, Nina Pavlenkova argues that the earth's southern hemisphere began to expand in the Mesozoic. Karsten Storetvedt has already highlighted several objections to this hypothesis (NCGT 63, p. 94-105). A simple way of assessing the expansion claim is to look at the actual dimensions of the earth. Pavlenkova presents her fig. 12 (reproduced below) as evidence that the southern hemisphere 'is expanded relative to the northern hemisphere'. It shows that the earth is very slightly pear-shaped. The excess radius in the southern hemisphere is no more than 10 metres, about 2000 times less than the excess radius of the equatorial bulge. This is equivalent to an increase of just 45 metres in a circle of latitude at 45ºS – hardly sufficient to explain the origin of the midocean ridges.

According to fig. 12, the average current rate of expansion in the southern hemisphere is about 5 mm/yr. If this had continued for 200 million years, a circle of latitude in the southern hemisphere would be 1000 km longer than in the northern hemisphere. This is obviously not the case, which shows that the present expansion in the southern hemisphere and shrinkage in parts of the northern hemisphere is not a secular, one-way process. It is more likely to be an oscillatory process.

I have previously raised this issue with Nina Pavlenkova and her response was as follows (pers. comm., 17 June 2011): 'I think it is impossible to say now anything about the Earth expansion rate and it is impossible to use the Fig. 12 data for such evaluations. The South hemisphere expansion provoked the whole Earth expansion to keep the true Earth form. The rate of the expansion may be evaluated from the midoceanic ridge widths but it is difficult because we don't know the rate of their spreading.'

So here she says that it's not just the southern hemisphere that expands but the entire Earth, driven in some unexplained way by the southern hemisphere. Yet her detailed article on her new model fails to mention this.



Reply to the comments by Storetvedt and Pratt

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In the issue 63 of NCGT Newsletter I presented a new model of the global tectonics in the article "The Earth's degassing, rotation and expansion as sources of global tectonics" (Pavlenkova, 2012). The article has been published together with the critical comments by Storetvedt. These comments are a good occasion to discuss not only my article but the general problems of the main topic of the NCGT.

Karsten Storetvedt (KS) comments may be divided in two groups. The large part describes geological data which were not discussed in my article. They are really important but they were explained by KS or by other researchers and are not necessary to repeat their interpretation. The more important second group of the comments shows "the mass of geological and geophysical evidence which contradict the hypothetical model of Nina Pavlenkova" or which are interpreted by KS in other way. The final conclusion is: "Surprisingly, she regards her paper to be a 'complete version' of a new global theory… but the proposed model does not have the attributes of a true scientific theory".

I agree that my conception (and any other modern conception) cannot be considered as a complete scientific theory. In general, now there are not enough data on the Earth's origin and its composition to create any theory of the tectonosphere evolution. I propose only a possible model of the global tectonic, fluids-rotation model, which explains some global structural features of the Earth in a complete form with the cause-end-effect relationships between the main stages of the tectonic development. It does not mean that it is the only possible model. The main aim of this model presentation is to provoke a discussion of the unsolved problems of global tectonics and to try to find their better solution. KS opens this discussion in the NCGT Newsletter and it is the positive event because the main aim of the NCGT audience is to develop new conceptions of the global tectonics.

Any new global conception has to explain global features of the Earth's structure and do not contradict the geological and geophysical data. The main aim of my model is to answer the following major questions:

(1) How the continents and the oceans were formed?
(2) What is the origin of regular system of the mid-oceanic ridges which is symmetrical above the South Hemisphere?
(3) What is the origin of the Pacific Ocean specific structure: the regular form of the margins and of the earthquake ring?
(4) What is the main energy source of the global tectonics?

Let us consider how the proposed model answers these questions and examine whether it really contradict the geological data mentioned in KS's comment or not.

1. The problem of the continent and ocean formation.

Three most developed conceptions of global tectonics, the plate tectonics, the Earth's expansion and Storetvedt's wrench theory, propose that at first the continental crust formed "a relatively thick pan-global crystalline blanket" and then the oceans were formed by different processes: by the spreading-subduction process (plate tectonics), by spreading without subduction due to the Earth' expansion (Scalera and Jacob, 2003), and by the chemical transformation of the continental crust (Sroretvedt, 2003). The discordance of the plate tectonics with the geological data is already proved and there is not necessary to repeat this statement once more for the NCGT audience. The origin of the all oceans as a result of the Earth's expansion is also doubtful because it suggests too large (twice) increasing of the Earth's radius during the short period of the geological time. Storetvedt (2003 and 2011) develops another process: the oceanic crust "is most effortlessly understood as an attenuated and chemically transformed virgin-state continental crust…The production of sub-crustal eclogite would easily have a density higher than that of the surrounding mantle so that crustal material….sink into some deeper level of the upper mantle. Such detachment/erosion of the lower crust, along with upward migration of eclogitization metasomatism, would lead to rising of the developing Moho, isostatic subsidence of the gradually transforming crust, and basin development".

I thank Storetvedt for such excellent description of the eclogitization process and for the important references, I have known only Russian papers on this topic (Artushkov et al., 1980; Frolova et al., 1992; Perchuk, 1987). I have emphasized in many my articles that the eclogitization of the lower continental crust and basification of the whole crust are very important processes in the continental margin thinning and in the deep sedimentary basin formation. And I do not agree with KS's conclusion that in my conception "the fact that the continental crust often shows progressive thinning towards continental margins – a crustal feature that sometimes can be followed deep into the oceans – is ignored".

For instance, this process was discussed in Pavlenkova (2006). The seismic data show some regular changes in the crustal structure from the inner part of the Eurasia continent to its margins and to the ocean. In **Fig. 1 a & b** four basic crustal types are determined for this area (Beloussov, Pavlenkova, 1984). Three basic layers describe the crustal types: the upper crust or "granitic" layer with velocities 5.8-6.4 km/s, middle crust with velocities 6.5-6.7 km/s and lower ("basic") crust with velocities, 6.8-7.2 km/s. The types differ by the crustal thicknesses and by thickness of the upper crust. These three layers with thickness of 10-15 km are characteristic for the continental type. It is observed in the inner part of all continents. In West Europe the crust is thinner than normal continental crust: the lower crust is wedding out. The thinning of the crust continues and become more intensive in the ocean. The typical oceanic crust (thickness 5-7 km, average velocity ~6.5 km/s) is observed, however, only in deep water depressions. The shallow water areas and the ridges (or microcontinents) are characterized with the thickness of 10-20 km and velocities 6.5-7.0 km/s (suboceanic crust) or by subcontinental crust with the thin "granitic" layer (velocities of 6.0-6.4 km/s). Such crust covers the main parts of the North Atlantic: the wide continental margins, Iceland-Faeroe Ridge, Vöring Plateaus, Rockall Ridge etc. Even beneath Iceland located on the Mid-Atlantic Ridge, the crust is about 25 km thick (Pavlenkova and Zverev, 1981). Deep drilling data in the North Atlantic indicate that large areas of the ocean were previously covered by shallow seas (Rudich, 1990). These data mean that the North Atlantic might have continental crust before the later very rapid subsidence.

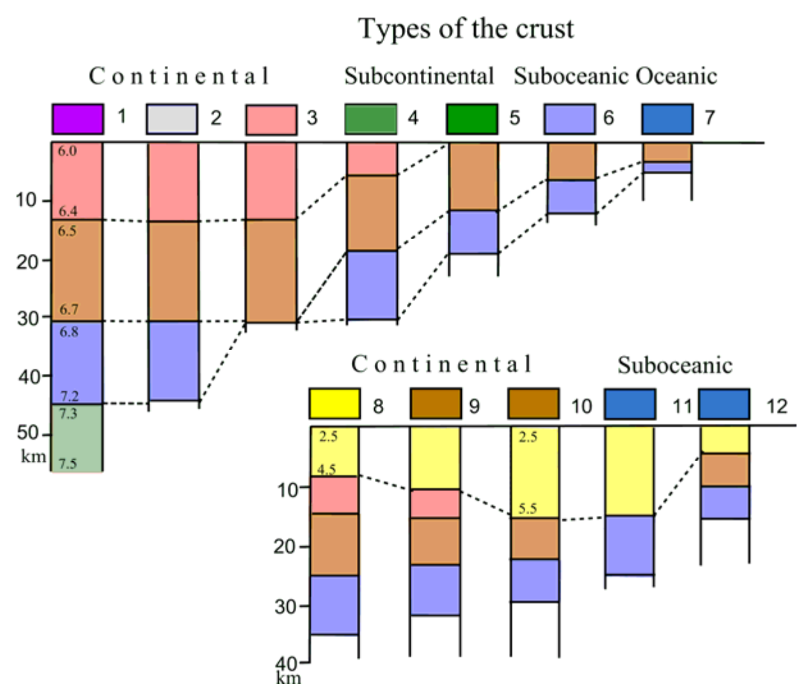

Fig. 1a. The seismic velocity models of the crustal types. The basic parameters which determine the crustal type are the thickness of the crust and of the crustal layers with velocities 5.8-6.4 km/s (upper crust). There are seven crustal types with the sediments thickness not more than 4 km: 1- thick continental crust with crust-mantle transition layer, 2 – normal continental crust, 3 – thin continental crust, 4 – subcontinental crust, 5 – suboceanic crust, 6 – thick oceanic crust , 7 – normal oceanic crust, and five types of deep sedimentary basins: 8 -10 – continental type, 11-12 –suboceanic crust.

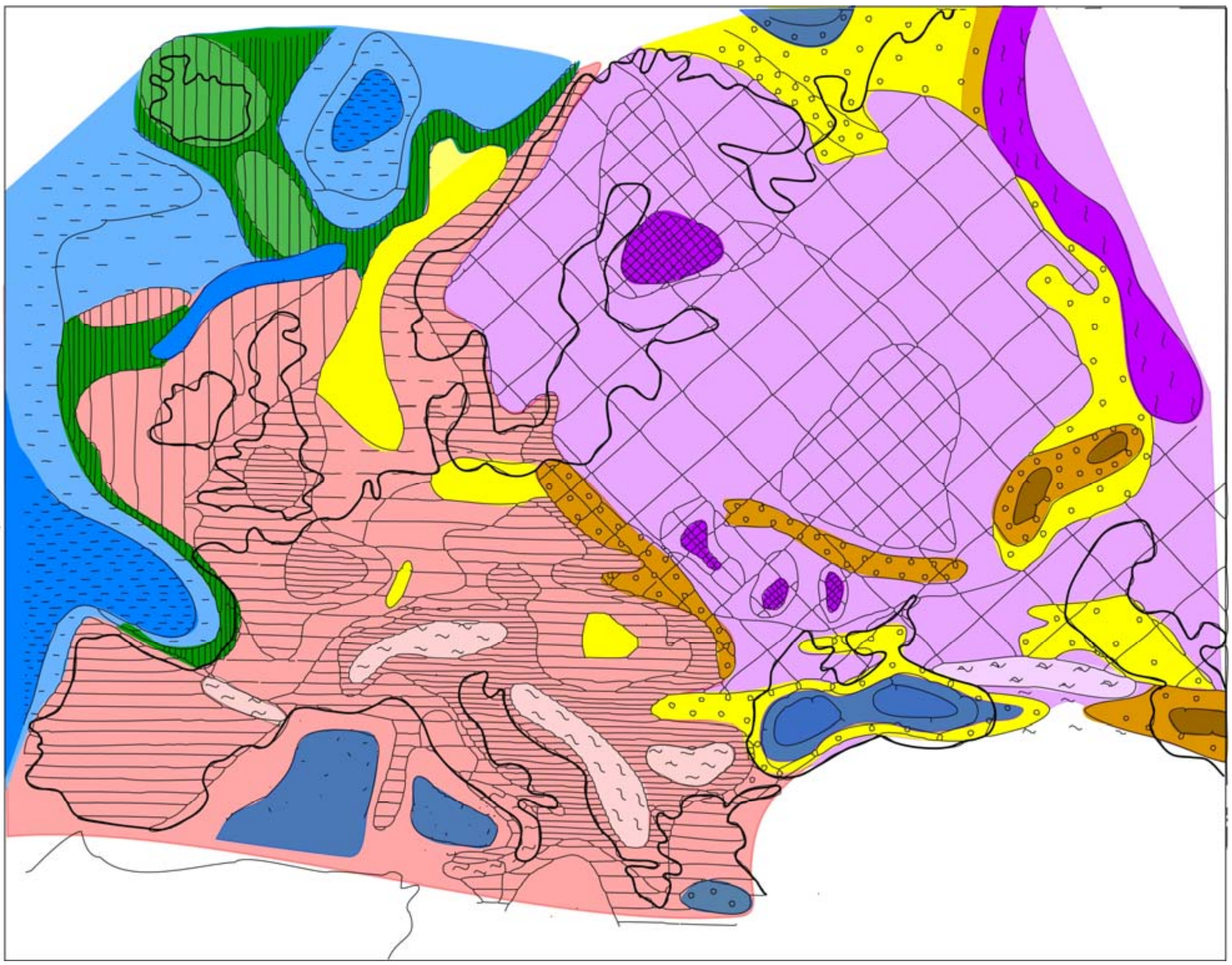

Fig. 1b. Map of the crustal types in the Europe and North Atlantic. For colour symbols see Fig. 1a caption.

The seismic cross-section in the North Sea (**Fig. 2**) also confirms the idea of the West Europe crust thinning: the boundary M1 at the depth of 40 km, which is the characteristic depth of the Moho boundary in the inner parts of the Eurasia continent, may be interpreted as the old Moho.

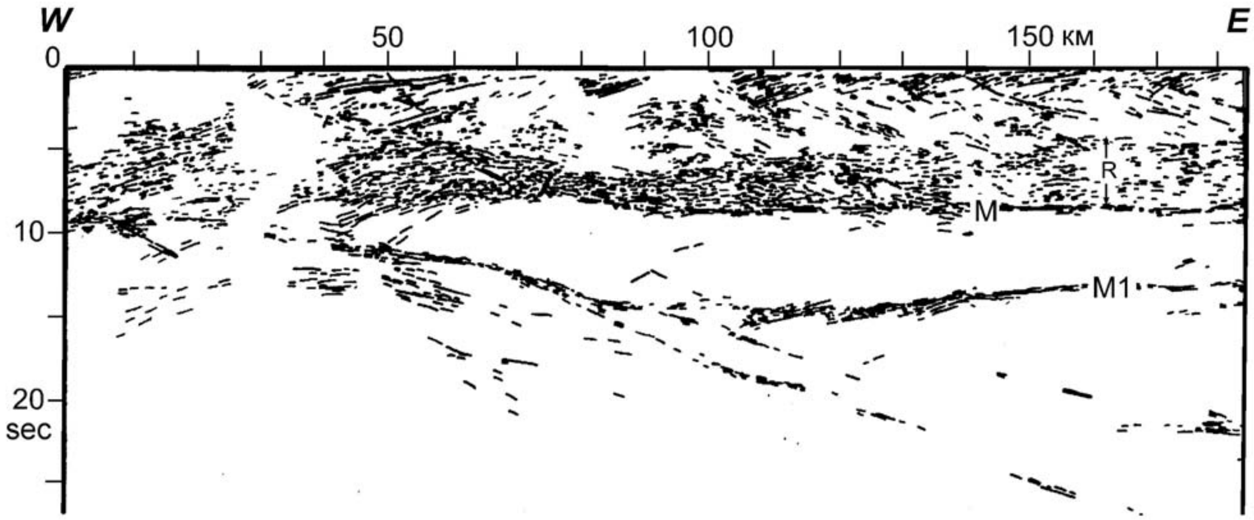

Fig. 2. Seismic CDP time cross-section of the west-northern margin of the European continent (Snyder, 1991). M is the Moho boundary, and M1 is proposed to be the old Moho.

I have often demonstrated the seismic data on the “suboceanic” crust in the South Caspian, South Barents, Kuril basins and in the deep sedimentary basins where the thickness of the crust decreases due to wedging out of the "granitic" layer (suboceanic crust). The Moho relicts (the double Moho) are observed beneath many deep depressions (Pavlenkova, 1995).

The North Atlantic example demonstrates, however, that the process of the oceanic crust formation by the continental crust destruction produces the complicate structure of the oceanic crust with strong variation of the crust thickness. Such structure is also observed in the western Pacific but the main part of the oceans is characterized by the simple thin crust which thickness does not change in the large areas of the oceans.

Fig. 3 (Fig. 7 from my NCGT article) shows a seismic/gravimetric cross-section of the South Atlantic (Pavlenkova et al., 1993). The crust has the same thickness along this profile of thousand km long. How can this simple crust be formed by the complicate transformation of the thick continental crust? Storetvedt found the answer on this question in the presence the low velocity layers (or ‘asthenosphere’ lenses) in the upper mantle of this profile. He considers the mid-oceanic belt as “a lithospheric supply route for accumulated hydrous fluids, which are important for the formation of sub-crustal eclogite” and “the serpentinization of the delaminated sub-crustal masses gives a ready explanation of the low-velocity asthenoliths”. But the velocity cross-section does not confirm this interpretation. The eclogites have the seismic velocities of 8.0-8.1 km/s, but the velocities in the uppermost mantle of the Angola basin and between the asthenolites are 8.5 km/s. Such high velocities are characteristic for the anisotropic mantle with the olivine as the main composition mineral. The velocity anisotropy has been really discovered in the Angola basin by two crossed seismic profiles (Zverev et al., 1996). Thus, there is no reason to propose the eclogite upper mantle in this region. And in general, the low velocity layers are observed only beneath the mid-oceanic ridge. Does it mean that KS’s interpretation proposes the existence of the initial thick continental crust only along the ridges, and in the Angola basin should be another crust? It is a strange proposal.

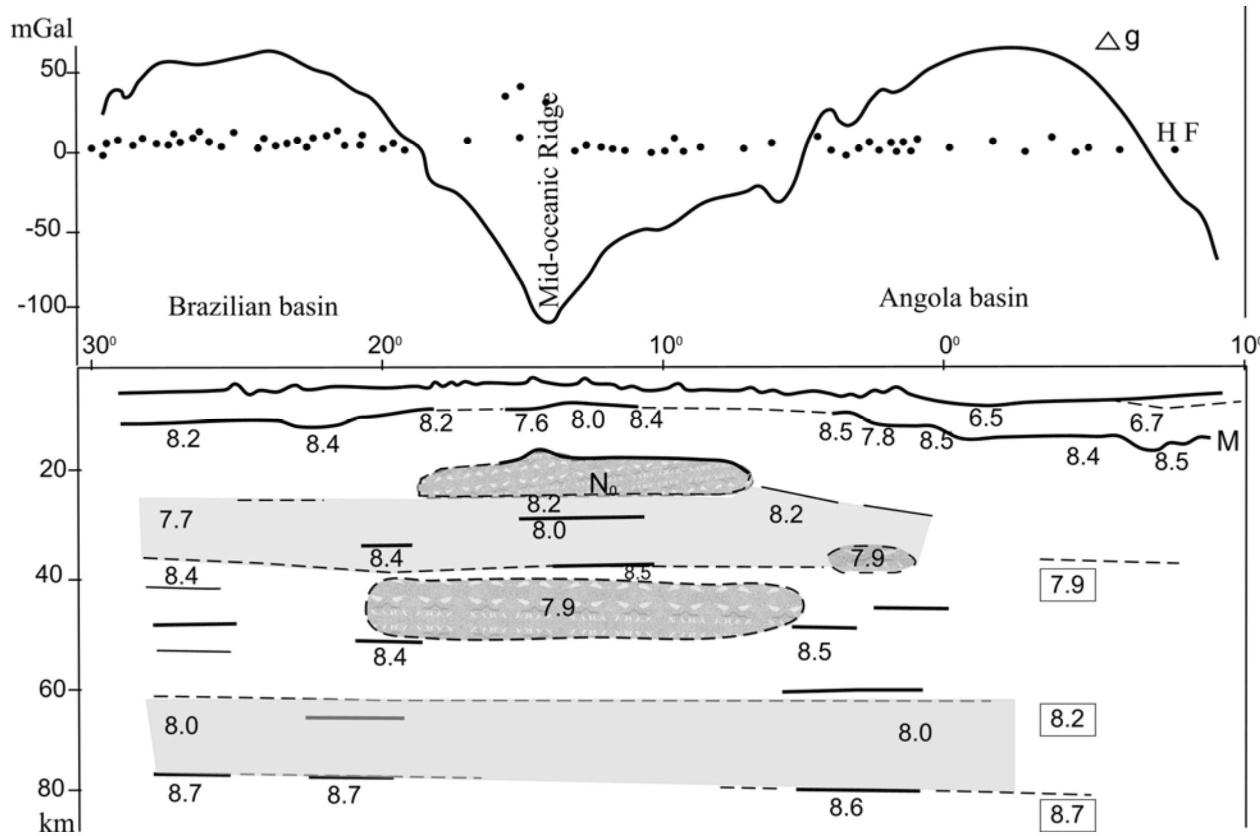

Fig. 3. Seismic cross-section along the Angola-Brazil geotraverse (Pavlenkova et al. 1993). Δg –gravitational anomalies, HF – heat flow. In the cross-section the digits stand for velocities (km/s), the shadows mark the low velocity layers; the thick lines show the seismic boundaries. The data show the several low velocity layers (asthenolites) beneath the Mid-Atlantic ridge which are separated by the anomalous high velocities. Such structure is characteristic for the areas of the deep fluids flows.

Another important point: the eclogitization can transform the basic rock (lower crust) but it is difficult to destroy the acid rocks (upper crust). There are also not enough evidences that this process can completely destroy the mantle continental roots with thickness more than 300 km.

That is why I propose that the continental crust transformation has not been the only way of the ocean formation. The rifting with some spreading of the continental crust was also important process. And I propose that the continental crust has never covered the whole Earth's surface. Acording to Lutz (1980) the continental crust was formed from the mantle matter saturated with fluids in the areas of the intensive deep fluid flows. The most intense areal fluxes saturated by fluid mantle material and generated the greatest volume of continental crust, are related to the Proterozoic (Lutz, 1994). During this period the area of the increased fluid flows is proposed to be the Southern hemisphere, as on the paleomagnetic data all the continents were located at that time in this hemisphere. In the areas of the modern oceans (mainly in the Pacific) the fluid flows are proposed to be weak and only the subcontinental and suboceanic crusts could be formed. KS writes that "The division of the Pacific Ocean in two parts is regional feature of the ocean and not discussed in NP article". It may be explained by the higher fluids flows in western part which creates more continental crust fragments than in the eastern part.

The Dupal Anomalies do not contradict this interpretation too. KS writes "The Dupal Anomaly is not really an anomaly; it should be regarded as a general geochemical feature resulting from chemo-mechanical transformation of an original continental crust towards its present oceanic mode". In my model there were no empty oceanic areas, there were areas with the large and with small continental fragments. These fragments transformation could produce the Dupal Anomalies.

Storetvedt comments that my proposals contradict the experimental tomographic data on the structure of the core-mantle boundary (CMB). He writes: "the CMB depth map (Morelli and Dziewonski, 1987) shows the upstanding CMB regions, which correspond, in outward projection, to the world's oceans". The CMB uplifts are interpreted by him as regions of higher geodynamic activity and higher degassing. With such interpretation "the CMB lows correspond to less reactive regions with correspondingly reduced degassing offshoots; the supposedly little-reactive CMB regions correspond to the land masses". His conclusion is that this map speaks against my degassing model, as much the maximum CMB highs ('degassing segments') correspond to the thin-crusted oceanic basins. However, the observations of the global hydrogen degassing (Syvorotkin, 2002) do not confirm that the uplift areas of the CMB are principal degassing areas. The Earth's degassing is now studied from the ozone sphere structure because the hydrogen flows destroy this sphere. The ozone sphere features indicate that the "principal degassing area" is now (and maybe in past) the southern hemisphere (**Fig. 4**). The large scale CMB uplifts beneath the oceans may be explained in more simple way: by isostatic compensation of the lower oceanic relief.

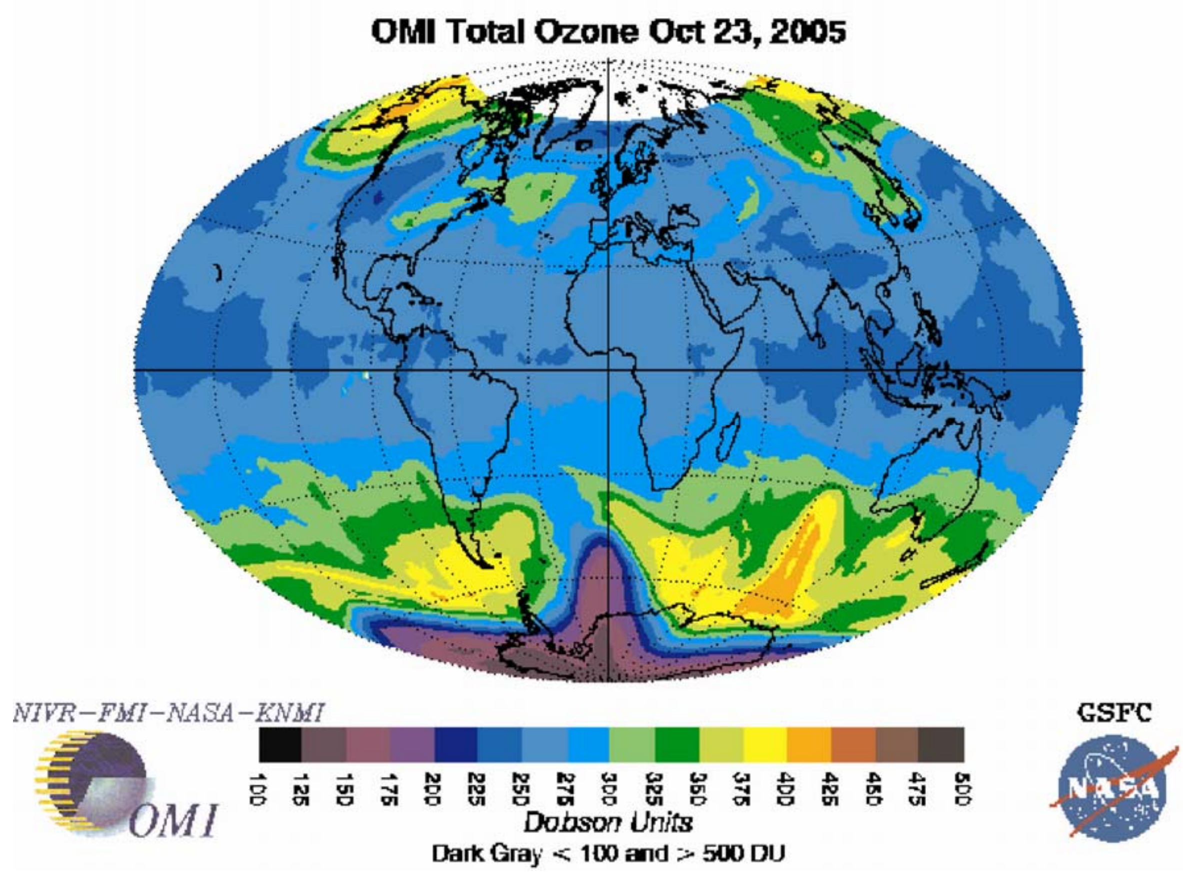

Fig. 4. Typical structure of the ozone sphere which is generated mainly by the hydrogen flows (Syvorotkin, personal communication). The figure shows that the hydrogen flow is most intensive in the Southern Hemisphere.

2. The origin of the regular system of the mid-oceanic ridges and of the Pacific ring.

My model of the global tectonics (fluids-rotation model) proposes that the mid-oceanic ridges were formed as a result of the Earth's expansion with relative larger expansion of the Southern Hemisphere. The KS writes "The speculative Southern Hemisphere expansion is thought to account for the formation of main oceanic ridges and rifts trending northward, away from Antarctica. However, the arguments are disconnected and not well constrained". But the geological data confirm that the Atlantic rifting begins from the south. For instance, **Fig. 6** shows that the ages of the trappean basalts decrease from the southern continental margins of the Atlantic Ocean to the northern ones.

And is the regular form of the ridge system (**Fig. 5**) not the crucial fact which is very difficult to explain in another way? KS prefers to ignore this fact although he writes “Ultimately, a realistic global theory should be able to establish a nested system of well-established surface geological phenomena, and the simplest and most forthright theoretical scheme, without a load of ad-hoc provisions, is normally the better solution”. I agree with this statement and the main aim of my model is to explain the global phenomena like the regular systems of the mid-oceanic ridges and of the earthquake rings. Sorry, these phenomena are not considered by KS as the important ones.

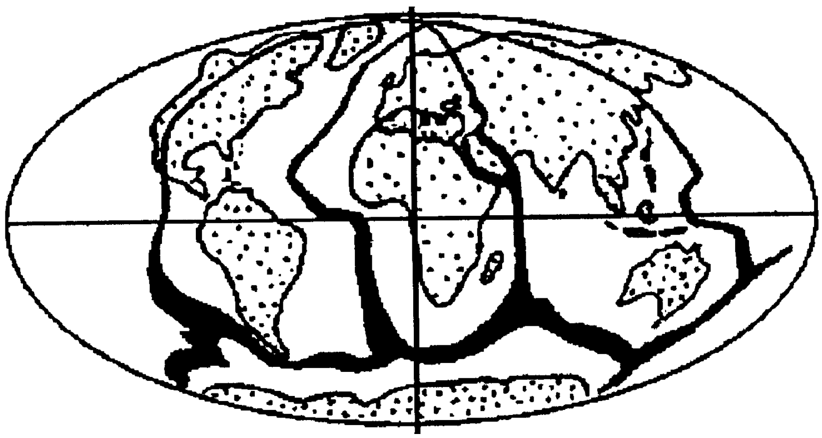

Fig. 5. System of the planetary rifts which are the major channels of the Earth degassing (Syvorotkin, 2002)

The data on the nowadays South Hemisphere expansion (Fig. 12 in my article and the figure in the Pratt’s comments) are also an argument that such expansion was possible. I agree, however, with Pratt’s conclusion that these data cannot be used to value any possible extension in the past because the process is cycle. It is impossible to estimate the expansion rate in any other way too. It was mentioned above that the proposals of the Earth’s expansion conceptions that all oceans are the result of the expansion, is not reliable. The width of the mid-oceanic ridges also cannot be used for the expansion rate valuation because the ridges may be not a result of the large spreading but a result of the local rifts formation. It is not a reason, however, to deny the expansion.

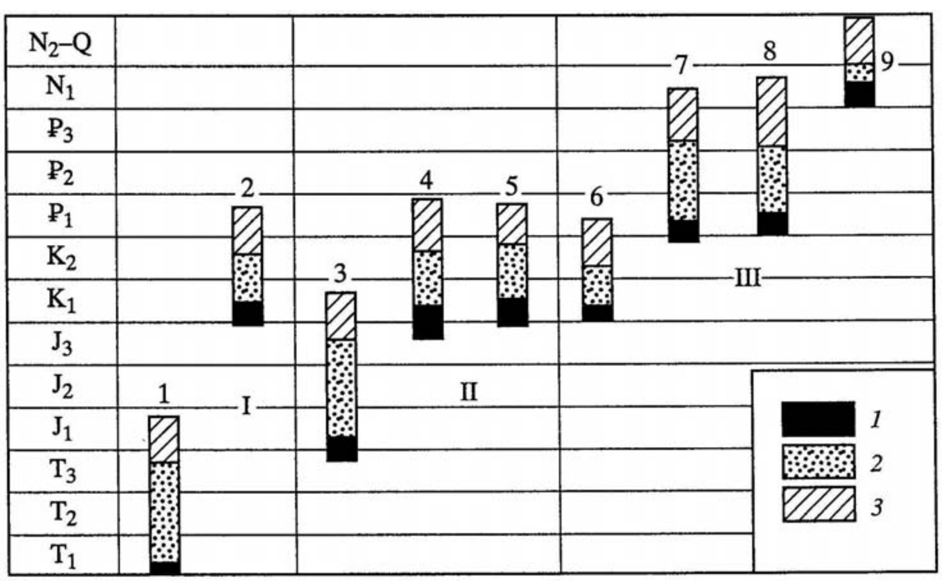

Fig. 6. Ages and geological structure of the trappean formation in the continental margins of the Atlantic Ocean in its central (I), southern (II) and northern (III) parts (Makarenko, 1997). Legend: 1 – tholeiite basalts, 2- sediments with basic intrusion, 3 – alkaline rocks.

Pratt writes that my model does not give the cause of the Southern Hemisphere expansion. It is not correct. Three basic stages of the tectonosphere formation are distinguished by my conception. Judging by the paleomagnetic data in Archean-Proterozoic several continents were formed in the southern hemisphere. The formation of the thick continental lithosphere in the Southern hemisphere led to an imbalance of separate spheres of the Earth. As a result, in the Paleozoic began the second phase: the rotation of the mantle around the core and the movement of the continental hemisphere to the north. This displacement has created a new imbalance of Earth's sphere mass centers, which has led to the third stage of the tectonosphere development - to the expansion of the Southern Hemisphere and to the formation of the mid-ocean ridge system, symmetrical about the South Pole. Thus, the fluids-rotation model shows the cause of the larger expansion of the Southern Hemisphere in the Mesozoic time. And in general, an important advantage of the model is the causal connection between the main stages of the Earth's tectonosphere development

Another global regularity in the Earth structure which is not explained by the other conceptions is the specific structure of the Pacific Ocean. The ocean is outlined by the deep Benioff zone ring. This ring has the regular form and it is crossed by another regular ring, by the Alpine-Himalaya belt (**Fig. 7**). The ring's form is the main reason to consider them as a result of the Earth's expansion. "The structural sub-division of this ring into small-circle tectonic arcs" (KS's remark) is not an argument to deny the ring global significance.

Another reason to consider the Pacific Ocean as a principal global structure is the gravity negative anomalies which surround the ocean (Choi and Pavlenkova, 2009). These anomalies divide the Earth into two hemispheres with different relief: the Pacific hemisphere with the lowered relief and thin oceanic crust, and the continental hemisphere with the raised relief and thick continental crust. These hemispheres had different geological histories.

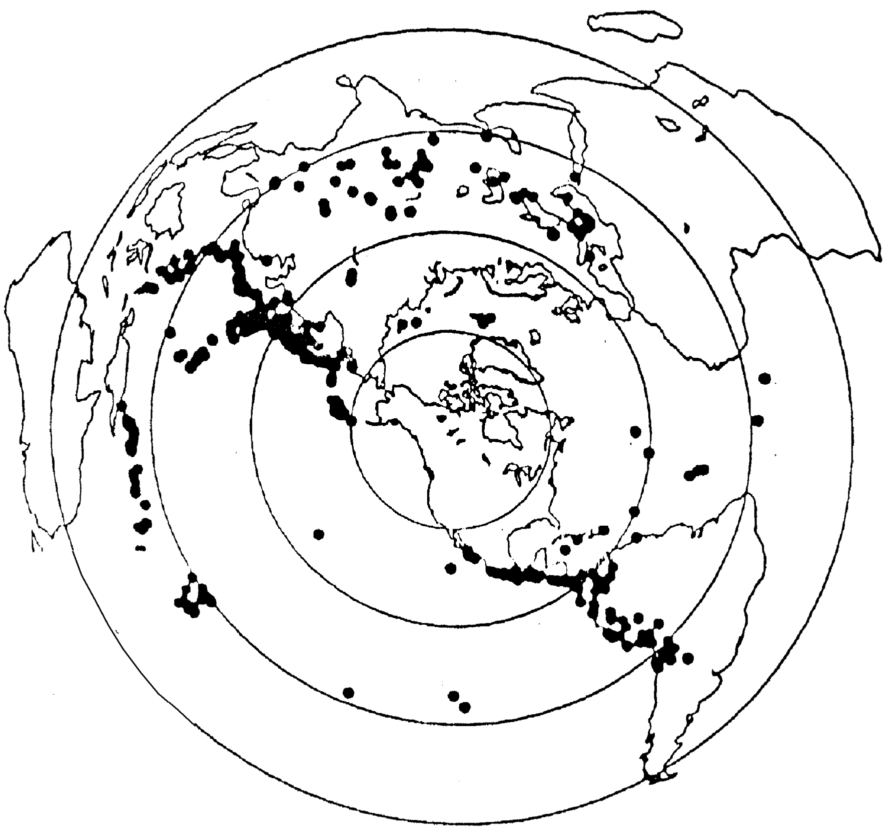

Fig. 7. Two global rings of the earthquake distribution or deep fracture zones, the Pacific and the Alpine-Himalayan belts (Wilson, 1954)

4. The main energy source: Earth’s degassing and rotation

As shown above, the fluids-rotation model considers an important role in global geodynamics of the internal energy sources, associated with the Earth’s degassing and with the deep fluids advection. Storetvedt agrees that the fluids play an important role in the tectogenesis but his presentation of this role is not adequate. He writes “The density deficit of the core is widely accepted – requiring a sizable fraction of light elements such as hydrogen”, but “what evolutionary processes have retained a relatively large fraction of lighter elements in the core, while heavy radioactive elements became concentrated in the outer rim of the evolving planet? This is a critical question unanswered by the conventional view of a hot molten embryonic planet (see Storetvedt, 2011). That is a primitive near surface mechanics interpretation.

The experimental data showed that the hydrogen is not “the lighter elements in the core”, its density is very high at the core PT condition (Larin, 1995). The deep fluids exist in the Earth’s core as the solid and high density H- and He- solutions and compounds with metals. They release from core solutions and incorporating in H-He and other chemical compounds and following gradual decomposition due to decompression are accompanied by intense energy release (Gilat and Vol, 2005). This process is better to describe by the electrochemical or by nuclear physics lows (Krivitsky, 2003) but simple mechanics. From this point of view the large amount of the radioactive elements in the continental crust is not a problem like KS presents: the more high density deep fluids - the more the radioactive elements.

I was glad to find some KS’s remarks which agree with the fluids concept. It is “there are reasons to believe that the Earth has an inverse temperature profile: having retained relatively cold temperatures in the deep interior while it has acquired hot conditions in its outer regions (Storetvedt, 2011)”. The proposition that the Earth may have an inverse temperature profile, can explain the seismic velocity model of the Siberian upper mantle: in the high heat flow areas the seismic velocities are lower only up to 200-300 km depth, in the deeper part they become higher than in the colder areas (Pavlenkova, 2011).

Another important source of the energy besides of the degassing is the external source, caused by Earth's and its individual sphere rotation. Its role in the global tectonics is shown above at the description of the main stages of the tectonosphere development.

I agree that my article don’t consider many important data on the Earth rotation. For instance, KS writes: ‘Regarding NPs hypothesized mantle rotation around the core (an attempt to explain the palaeomagnetic master curve for polar migration), she states that the “rotation of the mantle around the core took place unevenly” but give no natural explanation for, or tectonic implications of this irregular progression’. I will make that in the next articles with more detailed description of the Russian astronomer’s data on this topic.

5. Conclusions

Thus, the proposed fluids-rotation model explains several global elements of the Earth’s outer sphere structure which seldom considered by the other conceptions. I have not found an important argument in Storetvedt’s critics which excludes this model as a possible one. And this model does not contradict the wrench tectonics which explains in details many surface geological phenomena. KS described them in his comments and they are really excellent solutions of many geological problems. I have not considered them because my model has to solve more global problems.

The problem which is really missed in the fluids-rotation model is the cause of the ocean formation during the short period of the Mesozoic time: “In early Cretaceous, the two ‘sides’ of the Earth seem to have been much more similar then than they are now” (KS). It is necessary to study this problem. The only idea which comes to mind: maybe the thick continental blocks were isostatically compensated during their formation in the Southern Hemisphere but after their moving to the Northern Hemisphere this compensation was lost and the light blocks began to rise up.

In general, the critics of the any new hypothesis are useful because they help see the weak points of the new propositions. But the more useful critics are if they give the better solutions of the discussed problems. The main part of KS's critical comments connects with "the second order" of the Earth's structure evolution and he does not give any explanation to the origin of the regular system of the mid-oceanic ridges and to the origin of the Pacific specific structure features. I will be glad if such discussions provoke the development of any new models of the global tectonics which give the better answers on the questions formulated above. Storetvedt critics are hard and sometimes rude but I am glad that he opened this discussion because the main aim of NCGT are the new conceptions and they can be created only by joint work of researches in different branches of the science.

References

Artushkov, E.B., Shlesinger, A.E. and Yanshin, A.L., 1980. The origin of vertical crustal movements within lithospheric plates. In, Bally, A.V. (Ed.), Geodynamics of Plate Interiors. *Am. Geophys. Union., Geodyn*. ser., 1, p. 37-51.

Choi, D.R. and Pavlenkova, N.I., 2009. Geology and tectonic development of the Pacific Ocean. Part 5. Outer low gravity belt of the Great Pacific Ring structure. *NCGT Newsletter*, no. 50, p. 46-54.

Beloussov, V.V. and Pavlenkova, N.I., 1984. Types of the Earths crust of Europe. *Jour. of Geodyn*., v 1, p. 3-14.

Frolova, T.I., Perchuk, L.L. and Burjakova, I.A., 1992. Magmatism and transformation of active areas of the Earth's crust. Oxford & IBH Publishing CO.PVT.LTD., New Delhi, 271p.

Gilat, A. and Vol, A., 2005. Primordial hydrogen-helium degassing, an overlooked major energy source for internal terrestrial processes. *HAIT Journal of Science and Engineering* B, v. 2, Issues 1-2, p. 125-167

Krivitsky, V.A., 2003. Nuclear dissociation of chemical elements in the geochemical history of the Earth's evolution. *Geoinformatika*, no. 1, p. 42-50 (In Russian).

Larin, V.N., 1995. Hypothesis of the original hydride Earth (new global conception). Moscow, Nedra. 101p. (In Russian)

Lutz, B.G., 1994. Magmatic geotectonics and the problems of the Earth's continental and oceanic crust formation. *Regional geology and Metallogeny*, no. 3, p. 5-14.

Makarenko, G.F., 1997. Periodicity of the basalts, biocrisis and structure symmetry of the Earth. *Geoinformmark*, Moscow, 96p. (In Russian)

Pavlenkova, N.I., 1995. Double Moho in the Dnieper-Donets basin. C.R. Acad.Sci. Paris (Academie des Sciences). T. 321. Serie 11a, p. 85-93.

Pavlenkova, N.I., 1996. Crust and upper mantle structure in Northern Eurasia from seismic data. In, Dmowska, R. and Saltzmann, B., eds., Advances in Geophysics, Academic Press, Inc., v. 37, p. 1-134.

Pavlenkova, N.I., 2005. Fluids-rotation conception of global geodynamics. *Bull. Soc. Geol. It*., Volume Speciale, n. 5, p. 9-22

Pavlenkova, N.I. 2011. Seismic structure of the upper mantle along the long-range PNE profiles – rheological implication. *Tectonophysics*, v. 508, p. 85-95.

Pavlenkova, N.I., Pogrebitsky, Yu.E. and Romanjuk, T.V., 1993. Seismic-density model of the crust and upper mantle of the South Athlantic along Angola-Brazil geotraverse. *Physics of the Solid Earth*, v. 10, p. 27-38.

Pavlenkova, N.I. and Zverev, S.M., 1981. Seismic model of Iceland's Crust. *Geologischau Rundschau*, Band 70, p.1-6.

Pavlenkova, N.I., 2012. The Earth's degassing, rotation and expansion as sources of the global tectonics. *NCGT Newsletter*, no. 63, p. 49-71.

Pavlenkova, N.I., 2006. Structure of the Earth's crust and upper mantle from seismic data. In, Morozov, A.F., Mezhelovskii, N.V. and Pavlenkova, N.I., eds., Structure and dynamics of the Eastern Europe. Results of the EUROPROBE studies. Issue 2. Moscow, GEOKART, GEOS. p. 559-599

Perchuk, L.L., 1987. Basification as magmatic replacement. Sketches of Physics-Chemistry Petrology, 14. Moscow, Nauka, p. 39-64

Rudich, E.M., 1990. The world ocean without spreading. In, Barto-Kiriakidis, A., ed., Critical aspects of the plate tectonics theory. v. 2, Theophrastus Publication, S.A., Athens. p. 343-396.

Scalera, G. and Jacob, K-H. (eds), 2003. Why expanding Earth? A book in honour of Ott Christoph Hilgenberg. Instituto Nazionale di Geofisica e Vulcanologia, Roma, 465p.

Snyder, D.B., 1991. A Caledonian age for reflections from a relic Moho in Scotland. *Am. Geophys. Un. Geodyn*. Ser., 22, p. 307-313

Storetvedt, K.M., 2003. Global wrench tectonics. Fagbokforlaget. 397p.

Storetvedt, K.M., 2011. Aspects of planetary formation and the Precambrian Earth. *NCGT Newsletter*, no. 59, p. 113-136.

Syvorotkin, V.M., 2002. Deep degassing of the Earth and global catastrophes. Geoinformcentre, Moscow. 250p. (In Russian)

Wilson, J.T., 1954. The development and structure of the crust. In, Kuiper, G.P., ed., The Earth as a planet. Chicago Univ. Press., Chicago. p. 138-214.

Zverev, S.M., Kosminskaja, I.P. and Tulina, Yu.V., eds., 1996. Deep seismic sounding of the lithosphere along the Angola-Brazil geotraverse. Results of researches on the International geophysical projects. Moscow. Russian Academy of Science. 149p. (In Russian)

PUBLICATIONS

MIGRATION OF SEISMIC AND VOLCANIC ACTIVITY AS DISPLAY OF WAVE GEODYNAMIC PROCESS

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Abstract: Publications about the earthquake foci migration have been reviewed. An important result of such studies is establishment of wave nature of seismic activity migration that is manifested by two types of rotational waves; such waves are responsible for interaction between earthquakes foci and propagate with different velocities. Waves determining long-range interaction of earthquake foci are classified as Type 1; their limiting velocities range from 1 to 10 cm/s. Waves determining short-range interaction of foreshocks and aftershocks of individual earthquakes are classified as Type 2; their velocities range from 1 to 10 km/s. According to the classification described in Bykov (2005), these two types of migration waves correspond to slow and fast tectonic waves. The most complete data on earthquakes (for a period over 4.1 million of years) and volcanic eruptions (for 12 thousand years) of the planet are consolidated in a unified systematic format and analyzed by methods developed by the authors. For the Pacific margin, Alpine-Himalayan belt and the Mid-Atlantic Ridge, which are the three most active zones of the Earth, new patterns of spatial and temporal distribution of seismic and volcanic activity are revealed; they correspond to Type 1 of rotational waves. The wave nature of the migration of seismic and volcanic activity is confirmed. A new approach to solving problems of geodynamics is proposed with application of the data on migration of seismic and volcanic activity, which are consolidated in this study, in combination with data on velocities of movement of tectonic plate boundaries. This approach is based on the concept of integration of seismic, volcanic and tectonic processes that develop in the block geomedium and interact with each other through rotating waves with a symmetric stress tensor. The data obtained in this study give grounds to suggest that a geodynamic value, that is mechanically analogous to an impulse, remains constant in such interactions. It is thus shown that the process of wave migration of geodynamic activity should be described by models with strongly nonlinear equations of motion.

Key words: *migration, waves, rotation, seismicity, volcanism, geodynamics, conservation law, rheidity.*

Introduction

One of the first important specific features of seismicity, which researchers noted much time ago, is periodicity, i.e. repeatability of the strongest earthquakes in one and the same location at specific time intervals (Davison, 1936; Ambraseys, 1970). Development of instrumental seismology, completion of the global network of seismic stations, introduction of the concept of earthquake magnitude, *M* for instrumental seismological observations (Richter, 1935; Gutenberg, 1945), and consolidation of data in global and regional earthquake catalogues on the basis of this concept (Gutenberg, Richter, 1954; Duda, 1965; Rothe, 1969) ensured a fairly complete description of the geography of planetary seismicity. As a result, the concept of seismic belts was introduced (Morgan, 1968; Isaks, 1968); it states that seismic belts are stretching along the entire surface of the planet for many thousands of kilometers. Another important scientific result is the theory of seismic gaps (Fedotov, 1966; Kelleher, 1973; Mogi, 1968b), which is very productive in forecasting of strong earthquakes (Fedotov, 1972; Proceedings, 1978; Sykes, 1971).

Migration as a property of seismicity was revealed in the first seismic activity maps. On a plane with coordinates (Distance along the belt, l / Time, t), earthquake foci are located within a straight line, whose slope ($dl / dt = V$) determines velocity of migration of the earthquake foci, V. The first description of migration of foci of the strongest earthquakes ($M \approx 8$) was published in the late 1950s by Richter (1958] who reviewed the earthquakes that occurred along the Anatolian fault in Turkey. In the late 1960s, Mogi reviewed migration of earthquakes of similar magnitudes along the entire Pacific margin and the eastern termination of the Alpine-Himalayan belt (Mogi, 1968a). In both cases, earthquake migration velocities along the seismic zones were similar and amounted to $V \approx 200$ (170–230) km/year. It was also noted that almost all the foci of the earthquakes of the magnitude range under study were lined up in migration chains. In other words, the phenomenon of earthquake foci migration of the strongest earthquakes was so obvious that it *did not require any proof*.

In the early 1960s, the phenomenon of migration in all regions of the Earth was revealed by Tamrazyan, Duda and many other researchers who reviewed strong ($M \geq 5$) foreshocks and aftershocks in the foci of individual earthquakes (Duda, 1963). Migration velocities V of these events ranged from 10 to 1,000 km/year. In 1961, Tarakanov and Duda (Duda, 1963; Duda and Bath, 1963) revealed oscillations of strong aftershocks at the edges of foci of the Kamchatka (1952, M=9.0) and Chile (1960, M=9.5) earthquakes, both of a length of almost 1 000 km; a term of 'boundary seismicity' was introduced later on to describe this phenomenon. In the early 1970s, with development of electronic earthquake catalogues, Keilis-Borok, Prozorov, Vilkovich, Shnirman and others proved the phenomenon of migration of foci of strong earthquakes ($M \geq 6$) (see also Kasahara, 1979 and Tadocoro, 2000). In 1970, Kanamori recorded migration manifested by elastic impulses in the laboratory studies of rock samples (Kanamori, 1970); similar experiments have been repeated many times by other researchers.

In 1975, Guberman published his concept of the wave nature of earthquakes migration and introduced the notion of effect of *D*-waves. It was then convincingly shown by research results based on numerous actual data that the effect of earthquakes migration is a part of a global phenomenon demonstrating that earthquakes can make clusters in time and space and can be grouped by values of elastic energy released in foci. Relationships between seismic activity and a number of geophysical processes were established. Based on mechanical models (Elsasser, 1969; Savage, 1971; Nikolaevsky, 1996), it became possible to reveal that seismicity is associated with movements of tectonic plates, and thus the tectonic nature of earthquake migration waves became apparent. Now the established earthquake foci patterns are successfully applied for prediction of earthquakes. It seemed that the phenomenon of earthquakes migration took its strong position in the Earth sciences and was uniquely associated with the concept of tectonic waves.

The history of evolution of ideas about earthquakes migration and extensive bibliography are available in detailed reviews (Bykov, 2005; Vikulin, 2003). All the published (by 2003) data on earthquakes migration velocities and slow movements of the Earth's crust are consolidated in (Vikulin, 2003). An important conclusion of the given phase of researches was stated by Bykov (2005): "It has been long accepted that seismic activity is migrating, yet the nature of such migration is still unclear".

Despite the fact that studies of wave earthquake migration, which seemed so promising for both theory and practice, were intensive in the 1960-1970, this field of research failed to gain adequate progress in the 1980-1990's and beyond. Possible causes are described in Vikulin, 2011, p. 376. Firstly, the earthquakes migration is characterized by small velocities that are smaller than velocities of seismic waves by a factor of 3 to 5 (and more); wave motion equations with symmetric stress tensor are not able to provide an explanation of the nature of such waves, even if appropriate non-linearities are included in the equations. Secondly, all the models applied to explain the wave nature of tectonic waves (and earthquake migration as well) (Schallamach, 1971; Comninou, 1977; Elsasser, 1969; Savage, 1971; Gershenzon, 2009) are based on highly nonlinear equations of movement (such as sine-Gordon, Schrodinger and other equations). As a matter of fact, such mathematical equations are based on the concept of asymmetric stress tensor. Even the mathematical rigor of such models and their ability to describe a large number of tectonic and geophysical phenomena do not allow us to recognize these equations as physical models, because neither moment elastic modules included in the models nor velocities corresponding to such modules have been experimentally determined yet. Besides, these models are determined by quite 'vague' values of their constituent parameters of viscosity and elastic moduli of geomedium and sizes of layers of the crust and lithosphere, which are always effective and specified up to several orders of value in the best case.

Under the concept of *block* geomedium, the analysis of seismicity of the Earth's most active Pacific zone highlighted ways to solving the problem of earthquake migration waves and establishing a relationship between earthquake migration, tectonic and seismic waves (Vikulin, 2008 and 2010). Independent studies conducted by different researchers yielded over 50 migration velocities of migration of the Pacific earthquakes with different magnitudes on the plane with the coordinates of 'energy (earthquake magnitude *M*) – velocity (the logarithm of velocity Lg*V*)'; from this database, two types of migration are clearly distinguishable as they are represented by two compact fields of points. Field (*1*) is global; it stretches along the Pacific margin and has lower velocities. Field (*2*) is local; it includes fore-aftershocks in earthquake foci with higher velocities. 'Tilts' of the two fields are different:

$$M_1 \approx 2LgV_1,\ M_2 \approx LgV_2.$$

A margin between the two fields is an extreme value of global migration velocity (Vikulin, 2010):

$$V_{1,\max} = 1 - 10 \text{ sm/s}.$$

In the rotational model with a symmetric stress tensor, this extreme value can be interpreted as velocity:

$$c_0 \approx \left(\Omega R_0 \sqrt{G/\rho}\right)^{1/2} \approx \left(V_R V_S\right)^{1/2} \sim V_{1,\max},$$

where Ω – angular velocity of the Earth's rotation around its axis, ρ; G – density and shear modulus of the Earth; R_0 – typical size of a block of the crust/ lithosphere; V_R and V_S – centrifugal and shear seismic velocities.

The velocity yielded from the above equation is typical of block rotating media, including geomedium, in the same way as elastic longitudinal and transverse waves is typical for 'normal' solids (Vikulin, 2008). The extreme value of local migration velocity of earthquakes foci fore-aftershocks in the rotational model is the speed of elastic seismic waves 1 – 10 km/s (Vikulin, 2010). According to the classification (Bykov, 2005), global and local waves of earthquake foci migration correspond to slow and fast tectonic waves.

Thus, the analysis of earthquakes migration processes within the Pacific margin allowed us to distinguish between two types of rotational velocities controlling interactions between the earthquake foci in conditions of the planet's rotation around its axis (Vikulin, 2008 and 2010). The first type (with the limiting value of velocity, c_0) is responsible for long-range mechanism of interaction between blocks within the entire Pacific margin, and the second type (with the limiting value of seismic velocities) is responsible for the short range of foreshocks and aftershocks within foci of individual earthquakes (Vikulin, 2011). Rheid properties of the geomedium can be explained by rotary-wave mechanism, without involvement of mechanisms of dislocation creep, diffusion creep, structural superfluidity and other mechanism that are well-known in geodynamics (Vikulin, 2011, p. 384-394). This means that superplastic deformation of the geomedium, including the vortex geological structures (Lee, 1928; Xie Xin-sheng, 2004; Vikulin and Tveritinova, 2007), can be viewed as 'the flow of solid media' (Corey, 1954; Leonov, 2008).

Besides the above-described 'longitudinal' earthquake migration *along* the seismic belt, earthquake migration *across* to the belt was revealed in some parts of the Pacific margin (Japan, Kamchatka and others), based on the data available in the earthquake catalogues covering significant time periods (Vilkovich and Shnirman, 1982); it is termed 'lateral' migration (Vikulin, 2011, p. 57-69). It should be noted that upon establishment of numerous geodetic polygons with quite dense networks of measuring gauges, it was convincingly concluded that strain waves propagate both along and between faults (Kuzmin, 2009).

Migration trajectories of foreshocks and aftershocks within foci of strong earthquakes are highly complex (Vikulin, 2011, p. 109-118); they often degenerate into oscillation, i.e. alternating increase of activity at different edges of the foci. In foci of the strongest Aleutian earthquakes of 1957, 1964 and 1965 ($M\approx9$), which stretched along the latitude, migration of aftershocks from east to west is faster than migration from west to east, and the velocity difference is determined by the Doppler effect associated with the Earth's rotation around its axis. In the areas of the strong Chile (1960) and Sumatra (2004) earthquakes ($M>9$), which stretched along the meridian, aftershocks migrate with the same velocity both from north to south and from south to north (Vikulin, 2011, p. 109-118). These data on migration of foreshocks and aftershocks of strong earthquakes provide the direct *physical* evidence of *wave nature of earthquakes migration* and, in particular, explain the Chandler wobble of the planet pole (Vikulin, 2002; Vikulin, 2011, p. 244-258).

The detailed study of regularities of space-time distribution of earthquakes, as exemplified by the most active seismic zone of the planet, allowed interpreting earthquakes migration at the qualitatively new level as a *wave process* and to quantitatively relate it to seismic and tectonic waves (Vikulin et al., 2010).

The available data show that volcanic activity (well as seismic activity) events tends to reoccur (Gushchenko, 1985), i.e. to occur rhythmically (Ehrlich and Melekestsev, 1974; Civetta, 1970; Gilluly, 1973; Schofield, 1970) and to migrate (Leonov, 1991; Sauers, 1986; Berg, 1974; Kenneth, 1986; Lonsdale, 1988), and they can be grouped by locations with respect to latitudes and longitudes (Gushchenko, 1983; Fedorov, 2002) and size (Golitsyn, 2003; Tokarev, 1987; Hedervari, 1963; Tsuya, 1955). Actual data are available which give direct evidence that catastrophic seismic and volcanism events are closely related (Melekestsev, 2005; Bolt, 1977; Khain, 2008). With reference to all the available data, the aim of this research project is to study the processes of 'longitudinal' migration of earthquakes foci and volcanic eruptions along the most active zones of the planet, including the Pacific margin, the Alpine-Himalayan Belt and the Mid-Atlantic Ridge, and to review such processes as interrelated phenomena.

Source Database

Data from the world catalogues of earthquakes and volcanic eruptions are consolidated in the special-purpose database in the unified format briefly described in Vikulin et al. (2010). The database is regularly populated with new data. It includes the following parameters of seismic and volcanic events: date (year, month, day), time (hour, minute, second), coordinates of earthquakes/ volcanoes (longitude and latitude in degree fractions), and depth (it is accepted as zero for volcanic eruptions). The energy characteristics of earthquakes are magnitudes, M, and of eruptions – values W, where $W = 1, 2, ..., 5, ..., 7$ correspond to ejection volumes $10^{-(4-5)}, 10^{-3}, ..., 1, ..., 10^{2}$ km^3. The earthquakes catalogue contains information about 12,725 events that occurred over the last 4.1 thousand years and includes all known data on earthquakes in the period from 2150 BC to 1899, and data on the strongest earthquakes ($M\geq6$) in the period from 1900 to 2010. The catalogue of eruptions includes data on 627 volcanoes of the planet, which cover 6 850 eruptions in total through the past 12 thousand year, i.e. from 9650 BC to 2010.

Table 1. Slope angles of curves showing reoccurrence of earthquakes (b) and volcanic eruptions (B) in geodynamically active regions

Region	Earthquakes				Eruptions			
	$M_{min} \div M_{max}$	ΔT, *years*	N	b	$W_{min} \div W_{max}$	ΔT, *years*	N	B
Worldwide	*6 ÷ 9.5*	4 160	10 495	-0.9±0.3	*2 ÷ 7*	11 658	6 850	0.52±0.05
Margin of the Pacific ocean	*6 ÷ 9.5*	1 362	8 527	-0.8±0.1	*2 ÷ 7*	11 658	5 877	0.53±0.05
Kamchatka Peninsula	*6 ÷ 8.7*	273	464	-0.8±0.2	*2 ÷ 7*	10 058	536	0.48±0.06
Bezymianny volcano, Kamchatka Peninsula					*2 ÷ 5*	2 460	53	0.38±0.13

Alpine-Himalayan region	*7 ÷ 9*	4 160	435	-0.7±0.1	*2 ÷ 7*	10 490	1 600	0.57±0.05
Raung volcano, Java island					*2 ÷ 5*	422	65	0.55±0.09
Etna volcano, Italy					*2 ÷ 5*	3 508	186	0.63±0.15
Mid-Atlantic Ridge	*6 ÷ 7.6*	100	124	-1.2±0.1	*2 ÷ 6*	10 920	311	0.42±0.09
Laki volcano, Iceland					*2 ÷ 6*	10 234	63	0.34±0.12

Legend: $M_{min} – M_{max}$ ($W_{min} – W_{max}$) – minimum/maximum values of M (W); ΔT – timelines in the catalogues; N - number of events in the catalogues.

Based on the data from the catalogues, recurrence curves of earthquakes, LgN=$b·M$+a, and volcanic eruptions, LgN=$B·W$+A, are constructed (**Figure 1**) (N – number of events, value M and W; b and B – slope angles of frequency; a and A – constants, numerically equal to normalized values of seismic and volcanic activity). Slope angles of recurrence curves for different regions of the planet are listed in **Table 1** that shows that seismic processes (events of $M \geq 6$) in areas with different geodynamic settings are characterized by different angles of the recurrence curves. Indeed, for the areas of compression within the margin of the Pacific Ocean and the Alpine-Himalayan belt, the slope angles are similar and amount to b=–(0.7÷0.8)±0.1, while for the areas of “spreading” within the Mid-Atlantic ridge, the slope angle is significantly smaller, b=–1.2±0.1. For the planet, an average slope angle of the earthquake recurrence curve is b=–0.9±0.3.

In the representative range of $W \geq 2$, the slope angles of the curves showing recurrence of volcanic eruptions in different parts of the world differ insignificantly in terms of statistics. In general, for all the regions and individual volcanoes with numerous eruptions (no less than 50), the slope angle can be accepted as B=–0.5±0.1. Considering the curves showing recurrence of volcanic eruptions in all the three zones under study, it seems that the slope angles are constant due to uniformity of geodynamic conditions within the zones that, per se, are the areas of “spreading”.

The data obtained in this study confirm the conclusion (Tokarev, 1991; Golitsyn, 2003; Hedervari, 1963; Tsuya, 1955) about the existence of the volcanic eruptions recurrence law, which actually suggests that volcanic eruptions can be grouped by size, and thus parameter W, as well as earthquake magnitude, M can be considered as energy characteristics of individual eruptions, groups of eruptions, and the volcanic process in general.

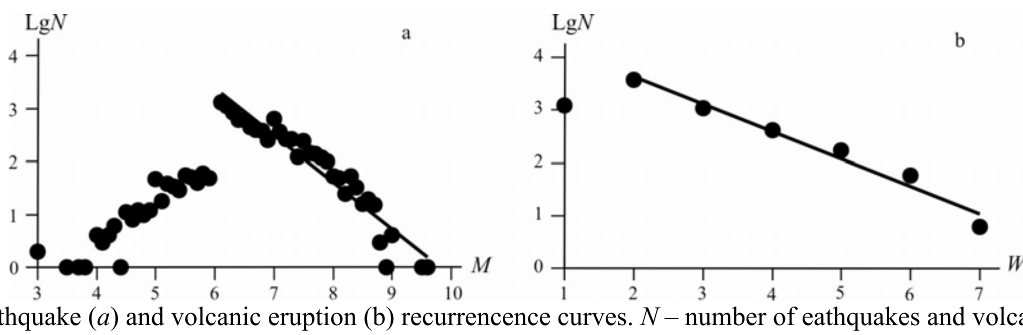

Fig. 1. Earthquake (*a*) and volcanic eruption (b) recurrencence curves. N – number of eathquakes and volcanic eruptions.

Research method

Seismic and volcanic events, considered in the aggregate, have a very distinctive feature - they are scattered along fairly narrow (Λ = 100 – 200 km) long zones (which maximum lengths, L_{max} amount to several dozens of thousands of kilometers); such zones border the entire planet. In studies of spatial and temporal distributions of events, such a configuraion of the zones ($L_{\max} >> \Lambda$) allows using two coordinates instead of three coordinates (latitude, longitude, and time) of the plane with axes ‘distance along the belt length l ($0 \leq l \leq L_{\max}$) – time t ($0 \leq t \leq T_{\max}$)’, where $T_{er,er,\max}$ – maximum duration catalogs of earthquakes (*ea*) and volcanic eruptions (*er*).

In this study, the following method is used for conversion of geographical coordinates of the events to distances along line *l*. The catalogued data on geographical longitudes and latitudes is consolidated into sets of events (with new coordinates, *l*), and the sets of events are referred to when studying migration of the events in 'space ($0 \le l \le L_{max}$) – time ($0 \le t \le T_{max}$)', which is revealed by reconstructing sequential chains of events, i.e. migration chains. The three most active zones of the planet - the Pacific margin, Alpine-Himalayan, and the Mid-Atlantic zones - are studied. Locations of earthquakes epicentres, volcanoes and coordinate lines, *l,* are shown in **Figure 2**.

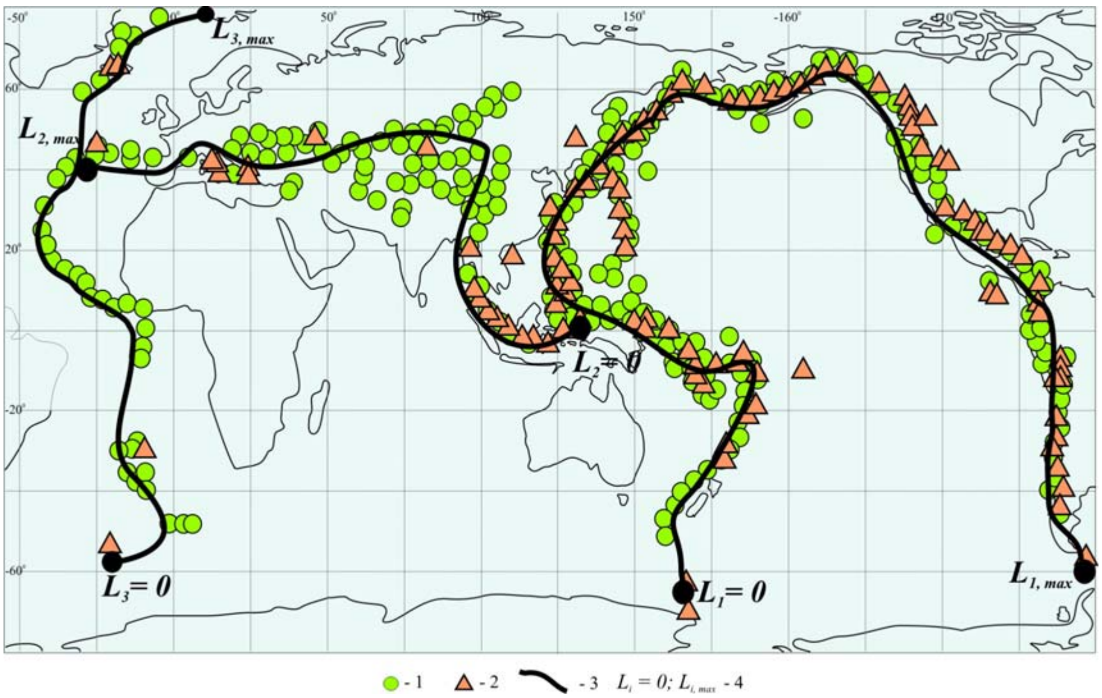

Figure 2. Active zones of the planet. 1 – earthquake foci; 2 – volcanoes with eruptions; 3 – lines along the axes of the belts in reference to which coordinates of earthquakes and volcanoes are calculated; 4 – terminations of zones ($L_i = 0$; $L_{i,\,max}$) (*i* = 1 – Pacific margin; *i* = 2 – Alpine-Himalayan belt; *i* = 3 – Mid-Atlantic ridge).

Coordinate lines, *l*, along which migration of seismic and volcanic activity is studied, are constructed by interpolating the systems of nodal points. Integrated Tsunami Database for the World Ocean (WinITDB) software (Babailov et al., 2008) is applied to produce arrays of nodal point and to represent the areas under study in maps showing earthquake foci and/or volcanoes. Sets of the nodal points are determined for the most active areas (with the largest clusters of events), and thus they typically follow the junction lines of tectonic plates. Geographic coordinates are determined for all the points in the sets.

Coordinate lines, *l* are constructed along the Pacific margin (with reference to 59 points), Alpine-Himalayan Belt (39 points), and the Mid-Atlantic Ridge (33 points). For each line, a parametric equation of the interpolating curve is obtained: $\begin{cases} \theta = \theta(\tau) \\ \lambda = \lambda(\tau) \end{cases} \quad \tau \in [0; N-1]$, where geographic latitude, $\theta(\tau)$ and longitude, $\lambda(\tau)$ are cubic twice differentiable splines; *N* – number of points on the line. Distances along the Earth's surface from initial point ($\tau = 0$) to point with current coordinates of $\theta(\tau)$, $\lambda(\tau)$ are calculated as follows:

$$l = R_{Earth} \int_0^{\tau} \sqrt{\left(\frac{d\theta}{ds}\right)^2 + \cos^2 \theta(s) \left(\frac{d\lambda}{ds}\right)^2} \, ds \,, \qquad (1)$$

where latitude, θ and longitude, λ are given in radians; R_{Earth} – radius of the Earth; $0 \le l \le L_{i,max}$.

Lengths of the three most active belts of the Earth are determined as follows (**Figure 2**): the Pacific margin from Buckle Island Volcano (Antarctica) L_1=0 to Desepson Volcano (South Shetland Islands) – $L_{1,max}$=45 000 km; the Alpine-Himalayan belt from Timor Island (Indonesia) L_2=0 to the Azores – $L_{2,max}$ =20 500 km; the Mid-Atlantic Ridge from South Sandwich Islands (South Atlantic) L_3=0 to Iceland Island (North Atlantic) – $L_{3,max}$ =18 600 km.

The algorithm for selection of migration chains of seismic and volcanic events within each zone is as follows: for each *i*-th event in catalog with time t_i and coordinate l_i , an $i+1$-th event is selected so that its time and coordinate can satisfy the condition: $t_{i+1} \geq t_i$, $l_{i+1} \geq l_i$. Migration chains are constructed for different energy ranges, $M \geq M_0$ and $W \geq W_0$, in which the boundary values are widely variable: $6 \leq M_0 \leq 9$, $1 \leq W_0 \leq 6$. For each migration chain, the following parameters are determined: number of events, duration (time interval between the first and last events), length (difference of *l* coordinates between the first and last events), and migration velocity (calculated from all the events by the least-squares method).

Examples of chains of migrating events

The strongest earthquakes ($M \geq 8$) and volcanic eruptions ($W \geq 6$) are reviewed below. The available catalogues provide long-term coverage of such events, and thus comprehensive information can be obtained about cluster spacing of the chains of migrating events.

Figure 3 shows four consecutive (IX, X, XI and XII) chains of the Pacific earthquakes foci ($M \geq 8$), which occurred in the 18th – 21st centuries within the Pacific Ocean margin ($L_{1,max}$ = 45,000 km) (see **Figure 2**). As shown in **Table 2**, in total 23 chains are determined. Every chain shown in **Figure 5** is sufficiently representative as it contains from 7 to 10 events. Considering average chain parameters: duration ΔT = 150 ± 80 years; length ΔL = 26.5 ± 3.4 (L_{max}=38) thousand miles, and migration velocity V = 260 ± 160 km/year, which are consistent with the overall data (see **Table 2**), it is noted that these chains overlap and almost completely cover the Pacific Ocean margin.

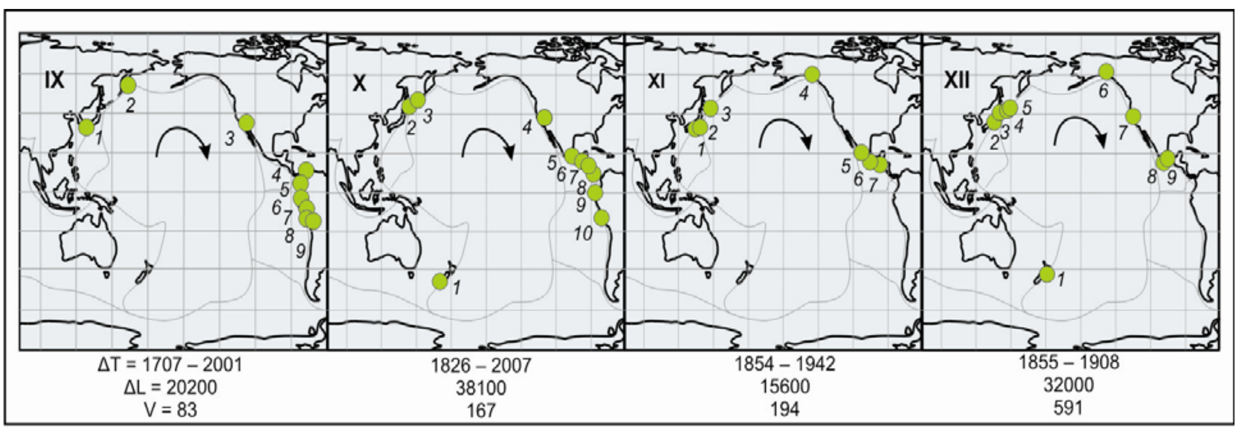

Figure 3. Locations of four sequential chains of foci of the Pacific earthquakes ($M \geq 8$) that occurred in the period from 1707 to 2007. I = IX, X, XI and XII – serial number of a chain; i = 1 – 10 – serial number of events in a chain; ΔT [year] = $t_2 - t_1$ – chain timeline, where t_1 and t_2 – time of the first and the last event in the chain; ΔL [km] = l_2 - l_1 – chain length as a difference between coordinates of the last (l_2) and the first (l_1) events in the chain; arrows show directions of migration in chains of events.

Five chains (I – V) are determined for the mid-Atlantic earthquakes ($M \geq 7$) that occurred in the 20th century (see **Table 2**). All the chains overlap and cover the entire zone too (**Figure 4**). However, the chains themselves tend to ‘migrate’ to L_3 = 0 (see **Figure 2**).

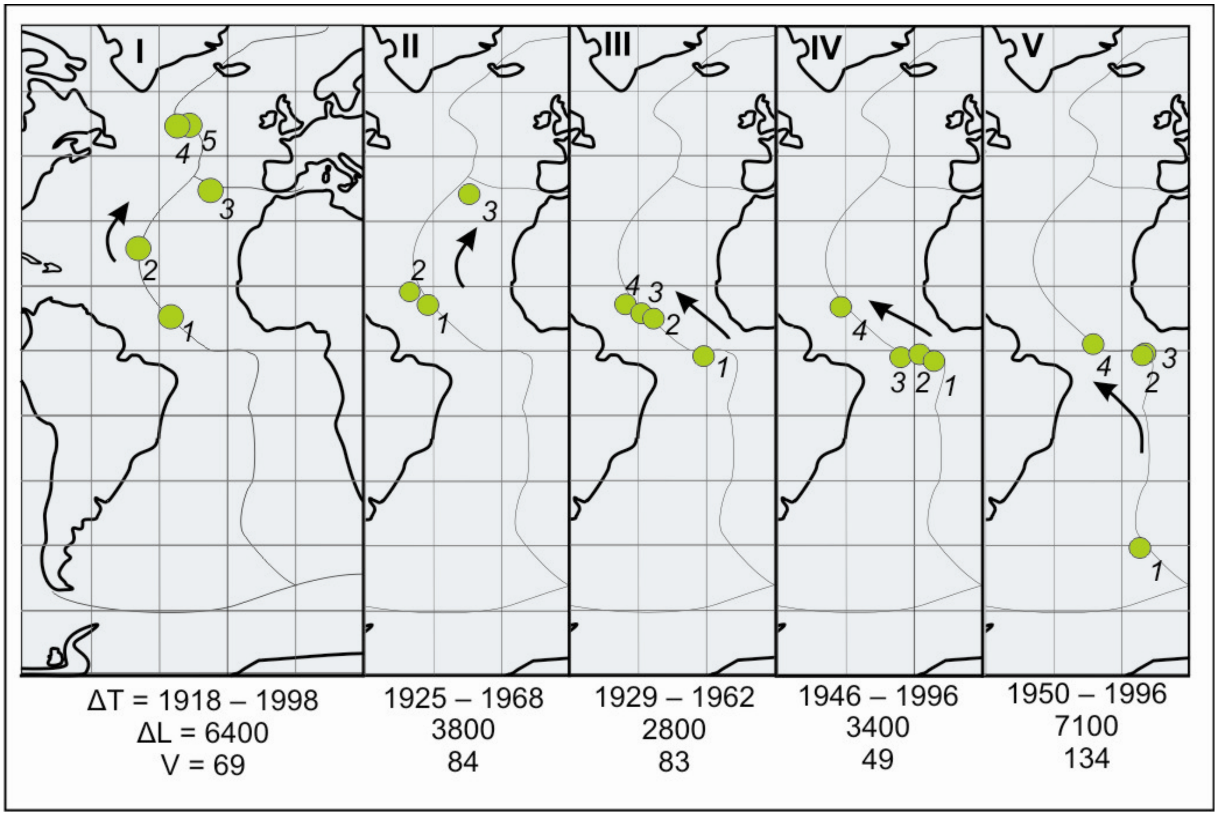

Figure 4. Locations of five chains of foci of the mid-Atlantic earthquakes (M ≥ 7) that occurred in the 20th century. See the legend in Figure 3.

Eight consecutive chains (I - VIII, out of 10 chains determined, see **Table 2**) of sufficiently strong volcanic eruptions (W≥6) are determined within the Pacific margin from the available data covering the past 11 thousand years. The first two chains (I and II) overlap and cover the major part (ΔL = 22 000-25 000 km; ΔT = 5.6-9.4 thousand years; V = 2.3-3.8 km/year) of the Pacific margin. Chains III, IV, V and VI cover mainly the northern parts (ΔL = 7 600-16 000 km; ΔT = 4.8-8.4 thousand years; V = 1.2-2.5 km/year). Chains VII and VIII cover the eastern (VII) and south-eastern (VIII) parts (ΔL = 8,800-14,000 km; ΔT = 3.0-3.4 thousand years; V = 2.4-2.5 km/year).

Figures 3 and 5 show the world's longest belt, the Pacific margin ($L_{3,max}$ = 45,000 km, see **Figure 2**) which database includes information about seismic events for 1 400 years and volcanic eruptions for 11 thousand years. The longest seismic and volcanic chains overlap and cover the major part of the Pacific margin. As shown in **Figure 5**, the shorter-than-maximum volcanic chains tend to be smaller in terms of both length and time. However, no significant changes in migration velocity of volcanic eruptions are revealed. Each event included in the chain is then excluded from any further reconstructions. This may explain changes in lengths and durations of the last chains and also a reason of the trend of 'migration' to $L_{1,3}$ = 0, which can thus be considered as consequences of 'knocking out' of the events by the preceding chains from the catalogue of strong events, as well as longer periods of recurrence and limited lengths of the zones.

Cluster spacing of migration of chains of weaker events has not been studied in detail. Weak seismic (M<8) and volcanic (W<6) events are quite frequent, and weaker events occur more often, as shown by the recurrence curves (see **Figure 1**). With decreasing energy characteristics of the events, the number of migration chains increases, while timelines and lengths of the chains do not change significantly, as described below (**Table 2**). It is assumed that the majority of the chains comprising weak events can compose a quite 'uniformly' dense cover over the entire zone, as they demonstrate a major overlap with each other.

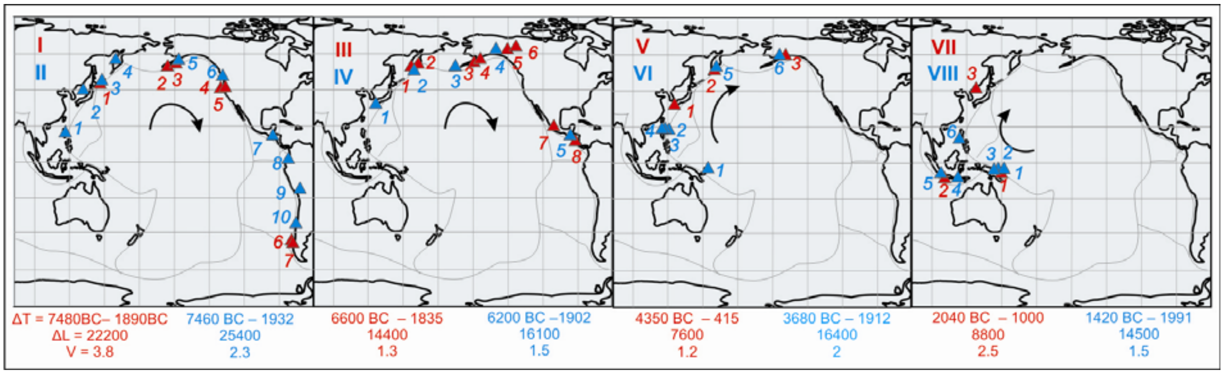

Figure 5. Locations of eight sequential chains of volcanic eruptions ($W \geq 6$) that occurred within the Pacific margin in the period from 7480 BC to 1991. See the legend in Figure 3.

Migration and geodynamic settings

The most typical examples of the migration chains are shown in **Figure 6**, and their parameters of seismic and volcanic activity are given Table 2, which also includes the data from our earlier studies (Akmanova, Osipova, 2007; Vikulin, 2003 and 2010; Vikulin et al., 2010).

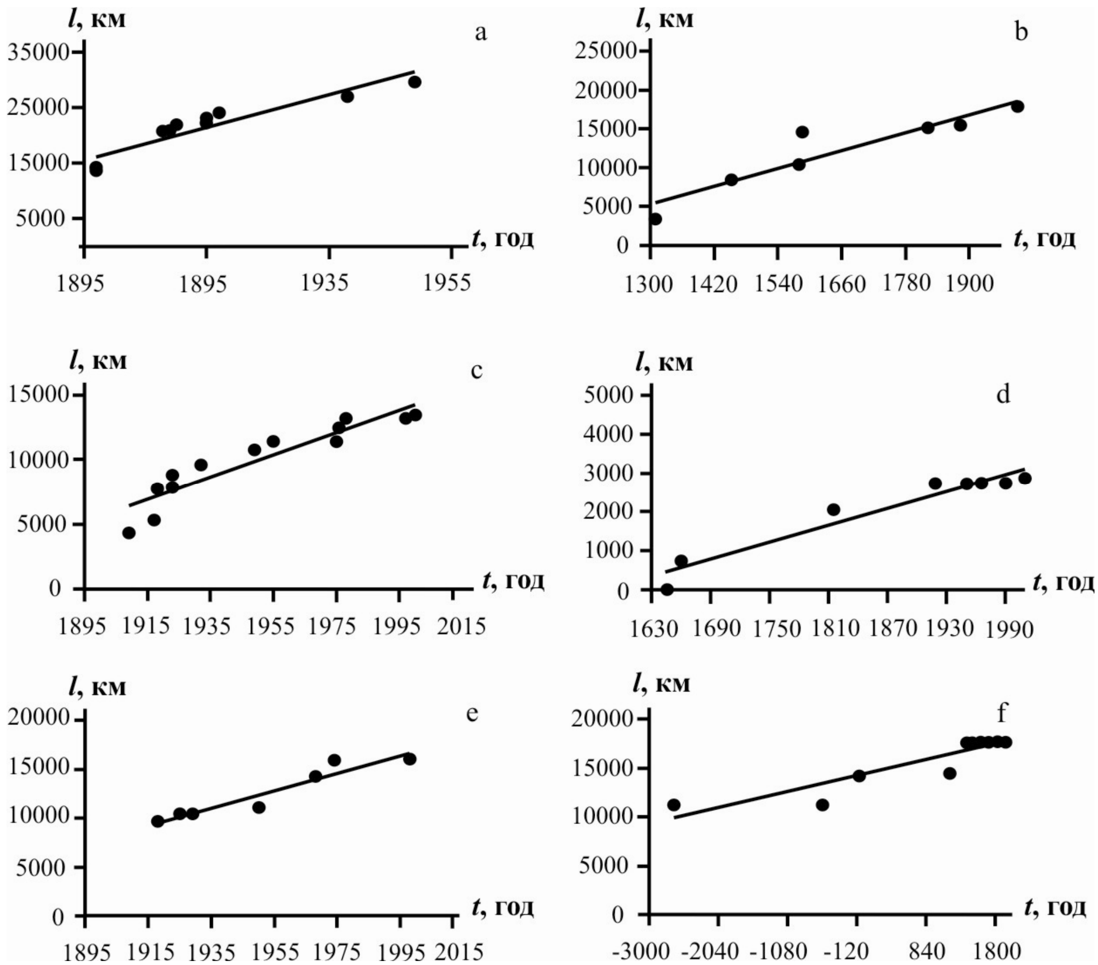

Figure 6. Examples of migration chains. **a** and **b** - migration chains of earthquake foci ($M \geq 8$) and volcanic eruptions ($W \geq 5$) within the Pacific margin; **c** and **d** – migration chains of earthquake foci ($M \geq 7$) and volcanic eruptions ($W \geq 4$) within the Alpine-Himalayan Belt; **e** and **f** – migration chains of earthquake foci ($M \geq 7.2$) and volcanic eruptions ($W \geq 4$) within the Mid-Atlantic Ridge. Migration velocities, V and correlation coefficients of linear chains/regressions R^2 for the chains shown in Figure 6: V = 300; 90; 90; 20; 7; 2 km/year, and R^2 = 0.88; 0.86; 0.86; 0.93; 0.90; 0.84, respectively.

Table 2. Parameters of migration chains of earthquakes and volcanic eruptions revealed in the regions under study

Earthquakes

$M \geq M_0$	k	$N \pm \Delta N$	$T \pm \Delta T$	$L \pm \Delta L$	$V \pm \Delta V$
The Pacific margin					
$M \geq 6$	177	35±11	110±100	18 900±6 600	150±60
$M \geq 6.5$	113	24±8	140±130	18 800±6 500	190±40
$M \geq 7$	85	18±6	170±150	17 200±7 600	190±90
$M \geq 7.5$	52	12±3	190±170	17 700±6 600	240±90
$M \geq 8$	23	8±2	260±240	19 600±4 900	400±230
$M \geq 8.5$	7	4±1	320±370	13 300±7 800	640±500
The Alpine-Himalayan seismic belt					
$M \geq 7$	30	10±3	550±720	6 700±2 300	280±290
$M \geq 7.2$	24	9±2	520±660	7 100±2 100	160±70
$M \geq 7.5$	20	7±2	450±530	7 000±2 400	370±150
$M \geq 7.7$	15	5±1	100±90	6 800±2 100	330±160
$M \geq 8$	4	4±1	110±60	3 800±2 200	590±280
The Mid-Atlantic Ridge					
$M \geq 6$	19	6±2	40±30	5 900±2 500	340±250
$M \geq 6.2$	14	6±2	40±30	5 900±2 500	160±120
$M \geq 6.5$	8	5±1	50±20	5 100±2 600	170±130
$M \geq 6.7$	6	5±1	50±10	6 000±2 100	120±70
$M \geq 7$	5	4±0.3	50±10	4 700±1 600	90±30
$M \geq 7.2$	1	7	80	6 400	90

Volcanic eruptions

$W \geq W_0$	k	$N \pm \Delta N$	$T \pm \Delta T$	$L \pm \Delta L$	$V \pm \Delta V$
The Pacific margin					
$W \geq 1$	110	51±17	2 150±2 790	19 900±8 400	70±50
$W \geq 2$	103	45±16	2 280±2 890	19 400±8 900	60±40
$W \geq 3$	56	23±9	3 490±3 370	20 300±8 300	60±80
$W \geq 4$	34	14±5	4 470±3 390	21 800±7 800	20±20
$W \geq 5$	18	9±3	5 010±3 120	22 700±9 700	13±14
$W \geq 6$	10	6±2	5 050±2 370	15 400±5 200	3±1
The Alpine-Himalayan seismic belt					
$W \geq 1$	43	37±15	1 130±1 420	4 700±3 300	13±7
$W \geq 2$	42	31±14	1 150±1 440	4 700±3 300	11±6
$W \geq 3$	23	13±6	1 890±2 020	4 300±3 400	9±8
$W \geq 4$	10	6±2	2 750±2 860	4 300±3 400	4±3
$W \geq 5$	5	4±1	3 390±2 500	4 900±3 600	3±2
The Mid-Atlantic Ridge					
$W \geq 1$	12	21±12	3 360±2 840	4 200±3 500	2±2
$W \geq 2$	12	20±13	3 110±2 770	3 400±2 900	3±4
$W \geq 3$	7	16±9	4 260±2 450	6 100±3 300	1±0.5
$W \geq 4$	4	14±4	5 620±1 220	6 200±3 100	1±0.7
$W \geq 5$	2	5±1	1 690±1 560	2 700±2 100	0.30±0.01

Legend: M – earthquake magnitude; W – 'energy' of eruption; M_0 and W_0 – the lowest values of M and W in the database under study; k – number of revealed migration chains in cases that one event is included only in one migration chain; in cases when one and the same event occurs in several chains, the value of k for every such chain is increased roughly by a factor of ten; N – average number of earthquakes and/or volcanic eruptions in a migration chain; T – average timeline of a migration chain (year); L – average length of a migration chain (km); V – average migration velocity of earthquakes and volcanic eruptions of various 'energy' ranks (km/year); ΔN, ΔT, ΔL and ΔV – root-mean-square deviation of N, T, L and V, respectively.

Similar to the data on the Pacific margin, the data in **Table 2** and **Figure 6** for the Alpine-Himalayan Belt and the Mid-Atlantic Ridge show that migration of seismic and volcanic activity is a typical process that takes place commonly and has wave nature.

Actually, **Table 2** seems to be the most comprehensive collection of data on migration of seismic and volcanic activity in the three most active zones of the planet. The tabulated data on each seismic and volcanic belt reviewed in this study show that there are specific changes in migration velocities in proportion to end values M_0 and W_0 of the reviewed sets of events. According to **Table 2**, relationships between logarithms of migration velocities of seismic and volcanic events, *LgV* and values *M* and *W* for each zone are determined by the least-squares method as follows:

$M = (3.7 \pm 0.6)LgV - 1.6$; $M = (1.5 \pm 0.7)LgV + 3.7$; $M = (-1.9 \pm 0.4)LgV + 10.7$, (2 a, b, c)
$W = (-2.3 \pm 0.3)LgV + 7.2$; $W = (-3.8 \pm 1.2)LgV + 6.6$; $W = (-2.0 \pm 2.1)LgV + 3.6$. (2 d, e, f)

Each of the three seismic (2a-c) and volcanic (2d-f) correlations corresponds to the edge of the Pacific, the Alpine-Himalayan belt and the Mid-Atlantic Ridge. Correlations (2a-f) are shown in **Figures 4a-f**, respectively. The root-mean-square error in determinations of the slope angles of seismic (2a-c) and volcanic (2d-f) correlations is within the range as follows:

$$\Delta p_{M,W} = 0.3 - 2.1, \; \Delta p \approx 0.9, \quad (3)$$

where Δp is an average deviation.

Correlation (2a) confirms relationship $M(LgV)$ for the Pacific margin, being of wave nature, which we established earlier. It can thus be logically concluded that all other correlations (2b-f) confirm wave nature of migration of seismic and volcanic activity in all the three zones under study.

Slopes of seismic curves $LgV \approx p_{Mi}M$ for the zones located in different geodynamic settings are significantly different. For the Pacific margin (i = 1, (2a)) and the Alpine-Himalayan belt (i = 2, (2b)), which are known as zones of compression, it is established that ratios $p_{M,1,2}>0$ (**Figures 7a, b,** respectively). For the Mid-Atlantic Ridge (which is known as zone of stretching) (i = 3, (2c)), $p_{M,3}<0$ (**Figure 7c**).

Slopes of volcanic curves $LgV \approx p_{Wi}W$, showing specific features of migration of volcanic eruptions, are negative: $p_{W,i}<0$, (i = 1, 2, 3, (2d–f), **Figures 7d–f**) along all the three zones under study. Such a decrease of migration velocity of volcanic eruptions with increasing values of *W* seems to be related to tension stresses within all the volcanic belts; the tension stresses are caused by magma penetration from the depth.

The results of this study show that specific features of spatial and temporal patterns of seismic and volcanic activity (a wave migration process as it is), as well as features of 'energy' distribution (variable values of the slope angles of frequency curves) are fairly 'sensitive' to the character of *geodynamic* (seismic and volcanic) movements – compression ("subduction")/ stretching ("spreading") – in the active zones and their vicinity.

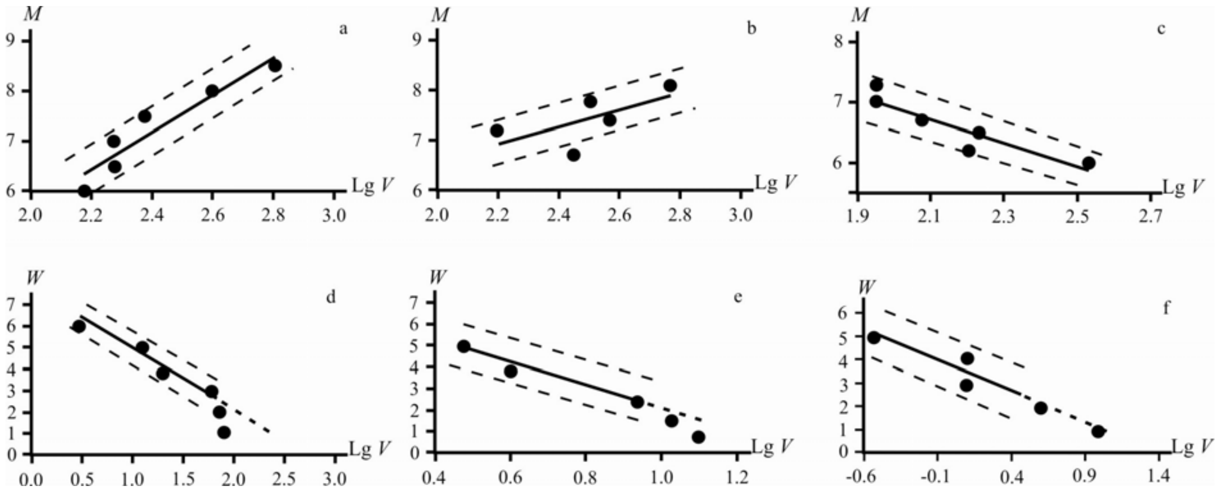

Figure 7. Migration velocity *V* of earthquakes (a, b, c) and volcanic eruptions (d, e, f) versus energy characteristics *M* and *W* of the events. a and d – the Pacific margin; b and e – the Alpine-Himalayan belt; c and f – the Mid-Atlantic Ridge. Correlation coefficients of linear regressions for curves (a to f): R^2 = 0.90; 0.61; 0.88; 0.96(0.87); 0.93; 0.49(0.88).

Discussion of results

For the purpose of this study, the most complete database on earthquakes and volcanic eruptions of the planet for the period of *thousands of years* is systematically consolidated and analysed by the original methods proposed by the authors. It is confirmed that migration of earthquakes and volcanic eruptions along the Pacific, the Alpine-Himalayan and the Mid-Atlantic zones is of wave nature. New regularities of spatial and temporal patterns of seismic and volcanic activity are established as functions of energy characteristics of processes. Being considered *in aggregate*, they clearly suggest a close relationship between seismicity and volcanism, on the one side, and geodynamic settings of the zones, on the other side. On the basis of these data in combination with information about velocities of movements of tectonic plate boundaries (Vikulin, Tveritinova, 2008), a new approach can be developed to solving problems of *geodynamics*, comprising interrelated seismic, volcanic and tectonic processes (Vikulin, 2011). The correlation between migration velocities and energy characteristics of the process (Equation 2) determines the format of laws of motion describing the process of migration as strongly nonlinear equations.

Currently, the problem is addressed with other approaches based on review and analyses of regional-scale source data. In the Institute of the Earth's Crust SB RAS, tectonophysists and geologists have been studying faulting in the lithosphere for many years. They proposed a model of the deep structure of faults in Central Asia (Sherman et al., 1992 and 1994) and completed the following studies:

- Physical modelling of formation of large faults in the lithospheric extension zones, and determination of quantitative characteristics of the deformation process taking place in such zones (Sherman, Cheremnykh, Bornyakov et al., 2001)
- Development of the original geodynamic model of space-time development of rift basins of the Baikal region and Transbaikalia (Lunina et al., 2009)
- Development of a tectonophysical model of a seismic zone (Sherman, 2009), which confirms that faults are activated due to *low deformation waves of excitation* being generated by interplate and interblock movements of the lithosphere (Sherman and Gorbunova, 2008) and also occur in zones of slow migration of seismicity (i.e in zones of earthquake clusters which can be considered as the lithosphere blocks) (Novopashina, 2010; Sherman, 2009; Sherman et al., 2011).

The concept of the above mentioned tectonophysical model of a seismic zone includes the following: fault-block media, real-time activation of faults due to deformation waves, and seismic events that occur sequentially. According to Sherman (2009), development of the comprehensive tectonophysical model of the seismic process and its solutions "will pave the direct way to obtaining the knowledge on spatial and temporal patterns of earthquakes and to prediction of earthquakes". However, our research results suggest that this way being 'battled through' in the regional direction (Sherman et al., 1992, 1994, 2001, 2008 and 2011; Sherman, 2009) may prove to be not so direct.

According to Sherman and Gorbunova (2008), migration velocities V of earthquakes of energy class $K \geq 12$ ($M \geq 4$-5) vary from 1 to 100 km/year, and this conclusion is consistent with the above described correlations (2a, b) for the Pacific margin and Alpine-Himalayan belt, both being "subduction" zones. However, it contradicts with correlation (2c) for the Mid-Atlantic Ridge that is the zone of "spreading". Sherman and his colleagues study the region in Central Asia which is a rift, i.e. the zone of spreading. In view of our research results, there is a contradiction between their data on earthquake migration in Central Asia and our data on the zones of spreading. Otherwise, it has to be admitted that either the subject region of Central Asia is not a rift, or their data on earthquakes migration cover only one side of the rift and thus do not refer to the entire rift zone.

Besides, we cannot accept their tectonophysical interpretation of the results obtained for the above mentioned region of Central Asia region. According to Sherman and Gorbunova (2008), lengths, l of faults activated by deformation waves, and lengths, L of the deformation waves passing through the faults are typically related as $L \geq l$. A question is how can a fault (that does not radiate any waves and only gets activated) 'be aware' of the length of the wave passing through it? The authors answer this question through the statement that the time of fault activation and the earthquake migration velocity are related to the length of the wave passing through the fault.

The studies conducted by Sherman and his colleagues provide a basis for linking two large zones of faulting in the Baikal rift zone and the Amur region; active fractures are identified, and it is shown that fault activation is manifested through seismicity, which is triggered by specific mechanisms, including slow deformation waves that pay a leading role in this process (Sherman et al., 2011). Anyway, the overall picture of the seismic and geodynamic setting of the entire Baikal-Amur zone, considered as a global intraplate boundary, is still quite vague, 'regional' hypothetically cross-linked only for some separate locations.

Thus, the 'regional' approach to the problem does not yield a complete picture. Moreover, while designing a model, the researchers have to introduce relationships between the parameters and thus to considerably restrict interpretations of the model's consequences at the final stage of research which is critical for geodynamical conclusions.

With a reasonably generalized approach to the problem, it is basically possible to apprehend the challenges of the Earth's sciences and refresh definitions of *geodynamic* problems to be resolved. In this respect, the first results of our study offer principally new options of physical interpretation of the geodynamic correlations and regularities.

According to Vikulin and Tveritinova (2008), same as the energy of seismic and volcanic processes, the energy of tectonic plate movements, E_T is proportional to movement velocity:

$$LgE_T \approx p_T LgV, \quad (4)$$

and the factor of proportionality is equal to that in the seismic correlation for the Pacific margin:

$$p_T \approx p_{M1}. \quad (5)$$

The geodynamic activity of the planet is determined by seismic, volcanic and tectonic processes which are considered cumulatively. The three most active zones of the planet release over 98% of the Earth's seismic and volcanic energy and host nearly all the most hazardous earthquakes and volcanic eruptions. Correlations (4) and (5) published in Vikulin and Tveritinova (2007 and 2008) yield from the analyses of velocities of movements estimated for almost all the most active boundaries of the tectonic plates of the planet. We believe that specific features of the energetics of the geodynamic (seismic + volcanic + tectonic) process should be determined from seismic and volcanic relationships (2a-f), supplemented by similar tectonic relation (5), in which p_T is taken equal to the slope angle specified in the correlation for the seismic Pacific margin (2a).

Of special interest is distribution of values of coefficient p in correlations (2a-f) and (5). The sum of slope angles of seismic (2a-c), volcanic (2d-f) and tectonic (5) correlations, taking into account the accuracy of their determinations, is equal to zero:

$$\sum_{i=1}^{3} p_{M,i} + \sum_{i=1}^{3} p_{W,i} + p_T \pm 7\Delta p = -1.1(\pm 6.3) \approx 0\,, \qquad (6)$$

with approximately equal 'positive' and 'negative' values of the slope angles ($p_+=\{p_{M1,2,T}>0\}$; $p_-=\{p_{W1,2,3,M3}<0\}$, respectively) in absolute magnitude:

$$p_+ = +3.0 \pm 0.6\,;\ p_- = -2.5 \pm 1.0\,;\ |p_+| \approx |p_-|\,. \qquad (7)$$

It seems that splitting of coefficient p in two much-the-same sets of values, p_+ and p_- (7), which 'compensate' each other in the sum (6), is non-random.

The set of $p_{M,W,T}$ values describes regularities of *different* processes (M – seismic, W – volcanic, and T – tectonic) taking place in *different* physical and chemical conditions, *different* geodynamic settings, in *separately reviewed* regions and the planet *as a whole*, and timelines of such processes are *quite extensive*. Notwithstanding such a variety of conditions, the geodynamic process (that can be called 'breathing of the Earth') takes place in such a ways that volcanic, seismic and tectonic movements tend to 'compensate/balance out' each other, as shown in Equation (6). In other words, grouping the values of coefficient p in quite simple sets described by Equations (6) and (7) is essentially typical of conservation laws. It can thus be assumed that the total set of values

$$p = \{p_M, p_W, p_T\} = \{p_+, p_-\} \qquad (8)$$

is actually *conserved geodynamic value p*.

Upon one-to-one splitting of the complete set (8) of seismic (M), volcanic (W) and tectonic (T) values $p = \{p_M, p_W, p_T\}$ in two sets $p=\{p_+, p_-\}$, each corresponding to a specific geodynamic situation (p_+ for subduction, and p_- for spreading), it is possible to state a physically limpid assumption: conserved geodynamic value p depends on the direction of the process and is thus *vector variable*.

According to Equation (2), parameter p is determined as follows:

$$p = \frac{dM}{d(LgV)} = \frac{d(LgE)}{d(LgV)} = \frac{V}{E}\frac{dE}{dV}\,, \qquad (9)$$

where earthquake magnitude, M and energy, E released in the earthquake focus are related according to the well-known relation: $M \approx LgE$. According to Landau and Lifshitz (1973), value dE / dV is termed as generalized momentum in mechanics.

The values of velocities and magnitudes/energy are highly uncertain, as shown in **Table 2**. This means that, within the intervals under study, in any sufficiently large neighborhood (ΔM_0, ΔV_0) of the point (V_0, M_0), for example, in the neighborhood of (M_0=7±1, V_0=280±290 km/year), geodynamic value $p{\cdot}E_0 / V_0$ (or value p in case of constant E_0 and V_0) can be interpreted as momentum of the geodynamic system.

In combination with the available data on tectonic plate activity, the new data obtained in this study of regularities of the planetary patterns of earthquake and volcanic eruption provide for determination of a parameter of the geodynamic process, which can be analogous to mechanical momentum. In further research, it may be possible to design *fundamentally new physical models* based on seismic, volcanic and tectonic data in order to describe the geodynamic processes that take place in active zones of the planet.

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References cited

Akmanova, D.R. and Osipova, N.A, 2007. On seismic and volcanic processes relation: case study for the pacific margins. *Bulletin of Kamchatka regional association "Educational-scientific center". Earth sciences*, no. 10, p. 144–155 (in Russian).

Ambraseys, N.N., 1970. Some characteristic feature of the Anatolian fault zone. *Tectonophysics*, v. 9, no. 2-3, p. 143-165.

Babailov, V.V., Beizel, S.A., Gusev, A.A., Gusyakov, V.K., Eletckii, S.V., Zyskin, I.A., Kamaev, D.A., Fedotova, Z.I., Chubarov, L.B. and Shokin, Y.I., 2008. Some aspects of construction of a new generation of the tsunami warning systems. *Computational technologies*, v.13, Special issue no. 2, p. 4–20 (in Russian).

Berg, E. and Sutton, G.H., 1974. Dynamic interaction of seismic and volcanic activity of the Nazca plate edges. *Physics of the Earth and Planetary Inter*., no. 9. p. 45-68.

Bolt, B.A., Horn, W.L., Macdonald, G.A. and Scott, R.F.,1977. Geological hazards. Springer-Verlag Berlin Heidelberg New York. 440p.

Bykov, V.G., 2005. Strain waves in the earth: theory, field data, and models. *Russian geology and geophysics*, v. 46, no. 11, p. 1176–1190 (in Russian).

Civetta, L., Gasparini, P. and Adams, J.A.S., 1970. Geocronology and geochemical trends of volcanic rocks from Campania, South Italy. *Eclogae Geological Helv*., v. 63, no. 1, p. 57-68.

Comninou, M. and Dundurs, J., 1977. Elastic interface waves involving separation. *Journal Applied Mechanics*, v. 44, no. 6, p. 222-226.

Carey, S.W., 1954. The Rheid concept in geotectonics. *Bulletin Geology Society Australia*, v. 1, p. 67-117.

Davison, Ch., 1936. Great earthquakes. Thomas Murby Co. London, 286p.

Duda, S.J., 1963. Strain release in the Circum-Pacific belt, Chile 1960. *Journal Geophysical Research*, v. 68, p. 5531-5544.

Duda, S.J., 1965. Secular seismicity energy release in the circum-Pacific belt. *Tectonophysics*, v. 2 (5), p. 409-452.

Duda, S.J. and Bath, M., 1963. Strain release in the Circum-Pacific belt, Kern County 1952, Desert Hot Springs 1948, San Francisco 1957. *Geophysical Research*, v. 7, p. 554-570.

Elsasser, W.M., 1969. Convection and stress propagation in the upper mantle. *The Application of Modern Physics to the Earth and Planetary Interiors*. Ed. S.K. Runcorn. N.Y. Wiley. p. 223-246.

Erlikh, E.N. and Mekekestsev, I.V., 1974. Problem of rhythm and of synchronic of Kenozoic volcanism. *Geodynamics, magma-forming and volcanism*. Petropavlovsk-Kamchatsky: IV, p. 104–123 (in Russian).

Fedorov, V.M., 2002. The Latitude Distribution of Volcanic Eruptions. *Journal of volcanology and seismology*, no. 4, p. 39–43.

Fedotov, S.A., 1966. On regularities of strong Kuril-Kamchatka earthquakes location and long-term prediction. *The eleventh Pacific science congress, Tokyo. Abstracts of papers related with geophysics. Proceedings,* v. 3. Divisional Meeting Solid Earth Physics I, Seismology, p. 37.

Fedotov, S.A., Gusev, A.A. and Boldyrev, S.A., 1972. Progress of earthquake prediction in Kamchatka. *Tectonophysics*, 14 (3/4) p. 279-286.

Gershenzon, N.I., Bykov, V.G. and Bambakidis, G. 2009. Strain waves, earthquakes, slow earthquakes, and afterslip in the framework of the Frenkel-Kontorova model. *Physical Review*, E 79. 056601. p. 1-13.

Gilluly, F., 1973. Steady plate Motion and episodic Orogeny and magmatism. *Geology Society of America Bulletin*, v. 84, no. 2, p. 499-514.

Golitsyn, G.S., 2003. An explanation of the dependence between frequency and volume of volcanic. *Doklady Earth Sciences*, v. 390, no. 3, p. 394–396. (in Russian).
Guberman, Sh. A., 1975. About some regularities of earthquakes. *Doklady Academy of Sciences USSR*, v. 224, no. 3, p. 573-576.
Gushchenko, I.I., 1983. Patterns of distribution of volcanic activity centers around the globe. *Journal of volcanology and seismology*, no. 6, p. 10–29.
Gushchenko, I.I., 1988. Volcanoes of the world: Eruption Cycles. *Journal of volcanology and seismology*, no. 7, p. 189-218.
Gutenberg, R., 1945. Amplitudes of surface waves and magnitudes of shallow earthquakes. *BSSA*, v. 35, p. 3-12.
Gutenberg, R. and Richter, C. 1954. The seismicity of the Earth 1904-1952. Prinston University Press, 310p.
Hedervari, P., 1963. On the energy and magnitude of volcanic eruptions. *Bulletin volcanism*, v. 25, p. 1-18.
Isaks, B., Oliver, J. and Sykes, L.R., 1968. Seismology and the new global tectonics. *Journal Geophysical Research*, v. 73, no. 18, p. 5855-5900.
Kanamori, K., 1970. Recent developments in earthquake prediction research in Japan. *Tectonophysics*, v. 9, no. 2-3, p. 291-300.
Kasahara, K., 1979. Migration of crustal deformation. *Tectonophysics*, v. 52, no. 1-4, p. 329-341.
Kelleher, J., Sykes, L. and Oliver, J., 1973. Possible criteria for predicting earthquake locations and their application to major plate boundaries of the Pacific and Caribbean. *Journal Geophysical Research*, v. 78, no. 14, p. 2547-2585.
Kenneth, L., Tanaka, E.M., Shoemaker G. et al., 1986. Migration of volcanism in the San Francisco volcanic field, Arizona. *GSA Bulletin*, v. 97, no. 2, p. 129-141.
Khain, V.Y. and Khalilov, E.N., 2008. Space-time regularities of seismic and volcanic activity. Burgas: SWB, 304p.
Kuzmin, Yu. O., 2009. Tectonophysics and Recent Geodynamics. *Izvestiya, Physics of the Solid Earth*, v. 45, no. 11, p. 973-987.
Landau, L.D. and Lifshitz, E.M., 1976. Mechanics. Course of Theoretical Physics. V. 1. Butterworth-Heinemann; Edition 3, 224p.
Lee, J.S., 1928. Some Characteristic Structural Types in Eastern Asia and Their Bearing upon the Problems of Continental Movements. *Geology Magazine*, LXVI, p. 422-430.
Leonov, M.G., 2008. Tectonics of the consolidated crust. Transactions of Geological Institute, v. 575. Moscow: Nauka, 457p. (in Russian).
Leonov, V.L., 1992. Some regularities in the development of hydrothermal and volcanic activity in Kamchatka. *Journal of volcanology and seismology*, v. 13, no. 2, p. 165-180.
Lonsdale, P., 1988. Geography and history of the Louisville hot spot chain in the southwest Pacific. *Journal Geophysical Research*, v. 93, no. 34, p. 3078-3104.
Lunina, O.V., Gladkov, A.S. and Nevedrova N.N., 2009. Rift basins in Pribaikal'e: tectonic structure and development history. Novosibirsk: GEO, 316p. (in Russian).
Melekestsev, I.V., 2005. Natural disaster of 1737-1742 in Kamchatka as a model for future regional disasters in island arcs of Northwest Pacific // Modern and Holocene volcanism in Russia / Ed. by N.P. Laverov. Moscow: Nauka, p. 553–571 (in Russian).
Mogi, K., 1968a. Migration of seismicity activity. *Bulletin of the Earthquake Research Institute*, v. 46, p. 53-74.
Mogi, K., 1968b. Sequential occurrence of recent great earthquakes. *Journal Physics Earth*, v. 16, p. 30-36.
Morgan, W.J., 1968. Rises, trenches, great faults and crustal blocks. *Journal Geophysical Research*, v. 73, no. 6, p. 1958-1982.
Nikolaevsky, V.N., 1996. Geomechanics and Fluidodynamics. Dordecht-Boston-London: Kluwer Academic Publishers, 448p.
Novopashina, A.V., 2010. The analysis of dynamics of seismic structure of the lithosphere in the Baikal region based on GIS technologies. Avtoreferat of dissertation for the degree of PhD. Geology and Minerology Sciences. Irkutsk: Institute of Earth's Crust SB RAS, 22p. (in Russian).
Proceedings of conference VI methodology for identifying seismic gaps and soon-to-break gaps, 1978. California, 924p.
Richter, C.F., 1935. An instrumental earthquake magnitude scale. *BSSA*, v. 25, p. 1-32.
Richter, C.F., 1958. Elementary seismology. San Francisco. W.H. Freeman and Co, 768p.
Rothe, J.P., 1969. The seismicity of the Earth 1953-1965. Unesko, 336p.
Sauers, J., 1986. The westward migration of geophysical events in the Aleutians, Springs, 1986. *Cycles*, 37, no. 9, p. 203–204.
Savage, J.C., 1971. A theory of creep waves propagation along a transform fault. *Journal Geophysical Research*, v. 76, no. 8, p. 1954-1966.
Schallamach, A., 1971. How does rubber slide? *Wear*, v. 17, p. 301-312.

Schofield, J.C., 1970. Correlation between sea level and volcanic periodicities of the last millennium. *New Zealand Journal Geology and Geophysical*, v. 13, no. 3, p. 737-741.
Sherman, S.I., 2009. A Tectonophysical Model of a Seismic Zone: Experience of Development Based on the Example of the Baikal Rift System. *Izvestiya, Physics of the Solid Earth*, v. 45, no. 11, p. 938-952.
Sherman, S.I., Cheremnykh, A.V., Bornyakov, S.A. and Shishkina, L.P., 2001. Modeling of large faults in zones of lithospheric extension and numerical constraints on deformation. *Russian geology and geophysics*, v. 42, no. 7, p. 1052-1057 (in Russian).
Sherman, S.I. and Gorbunova, E.A., 2008. Wave origin of fault activation in the Central Asia on the basis of seismic monitoring. *Fiz. Mezomekh*, v. 11, no.1, p. 115-122 (in Russian).
Sherman, S.I., Seminsky, K.Zh., and Bornyakov, S.A., et al., 1992. Fanlting in the lithosphere. Extensional zones. Novosibirsk: Nauka, Siberian Branch, 228p. (in Russian).
Sherman, S.I., Seminsky, K.Zh., and Bornyakov, S.A., et al., 1994. Fanlting in the lithosphere. Compressional zones. Novosibirsk: Nauka, Siberian Publishing Firm All-Russian Inc., 263p. (in Russian).
Sherman, S.I., Sorokin, A.P., Sorokina, A.T., Gorbunova, E.A. and Bormotov, V.A., 2011. New data on active faults and zones of the recent fracturing of the lithosphere of Amur region. *Doklady of the Academy of Sciences*, v. 439, no. 5, p. 685-691 (in Russian).
Sykes, L.R., 1971. Aftershock zones of great earthquakes, seismicity gaps and earthquake prediction for Alaska and Aleutians. *Journal Geophysical Research*, v. 76, no. 2, p. 8021-8041.
Tadocoro, K., Ando, M. and Nishigami, K., 2000. Induced earthquakes accompanying the water injection experiment at the Nojima fault zone, Japan: seismicity and its migration. *Journal Geophysical Research*, v. 105, NB3, p. 6089-6104.
Tokarev, P.I., 1993. Volcanic activity on Kamchatka and the Kuril Islands in the 20th century and its long-term forecast. *Journal of volcanology and seismology*, v. 13(6), p. 703-710.
Tsuya, H., 1955. Geological and petrological studies of volcano Fuji. Part 5: On the 1707 eruption of volcano, Fuji. *Bulletin Earthquake Research Institute of Tokyo University*, v. 33, p. 341-384.
Vikulin, A.V., 2006. Earth rotation, elasticity and geodynamics: earthquake wave rotary model. *Earthquake source asymmetry, structural media and rotation effects* / Eds. R. Teisyre, M. Takeo, E. Majewski. Springer-Verlag Berlin Heidelberg, p. 273-289.
Vikulin, A.V., 2003. Physics of wave seismic process. Petropavlovsk-Kamchatsky: KGPI, 150p. (in Russian).
Vikulin, A.V., 2008. Energy and moment of the Earth's rotation elastic field. *Russian Geology and Geophysics*, v. 49, p. 559–570.
Vikulin, A.V., 2010. New type of elastic rotational waves in geo-medium and vortex geodynamics. *Geodynamics & Tectonophysics*, v. 1, no. 2, p. 119–141.
Vikulin, A.V., 2011. Seismicity. Volcanism. Geodynamics. Selected Works. Petropavlovsk-Kamchatsky: KamGU, 407p. (in Russian).
Vikulin, A.V., Akmanova, D.R. and Osipova, N.A., 2010. Volcanism as the indicator of geodynamic processes. *Lithosphere*, no. 3, p. 5–11. (in Russian).
Vikulin, A.V., Ivanchin, A.G. and Tveritinova, T.Yu., 2011. Moment vortex geodynamics. *Moscow University Geology Bulletin*, v. 66, no. 1, p. 29–35.
Vikulin, A.V. and Krolevetz, A.N., 2002. Seismotectonic processes and the Chandler oscillation. *Acta Geophysica Polonica*, v. 50, no. 3, p. 395-411.
Vikulin, A.V. and Tveritinova, T.Y., 2007. Energy of tectonic process and vortex geological structures. *Doklady Earth Sciences*, v. 413, no. 3, p. 336-338.
Vikulin, A.V. and Tveritinova, T.Y., 2008. Moment wave nature of geological medium. *Moscow University Geology Bulletin*, no. 6, p. 10–16 (in Russian).
Vilkovich, E.V. and Shnirman, M.G., 1982. Waves of migration of the epicenters (examples and models). *Mathematical model of the Earth and earthquake prediction. Computational Seismology*, no. 14. Moscow: Nauka, p. 27–37 (in Russian).
Xie, Xin-sheng, 2004. Discussion on rotational tectonics stress field and the genesis of circum-Ordos landmass fault system. *Acta Seism Sinica*, v. 17, no. 4, p. 464-472.

Derivation of the Gutenberg-Richter empirical formula from the solution of the generalized logistic equation

Lev A. Maslov and Vladimir M. Anokhin, 2012. *Natural Science*, v. 4, Spec. Issue p. 648-651.

Abstract: We have written a new equation to study the statistics of earthquake distributions. We call this equation "the generalized logistic equation". The Gutenberg-Richter frequency-magnitude formula was derived from the solution of the generalized logistic equation as an asymptotic case for the approximation of large magnitude earthquakes. To illustrate how the solution of the generalized logistic equation works, it was used to approximate the observed cumulative distribution of earthquakes in four different geological provinces: the Central Atlantic (40N – 25N, 5W 35W), Canary Island, Magellan Mountains (20N – 9S, 148E – 170E), and the Sea of Japan. This approximation showed an excellent correlation between the theoretical curves and observed data for earthquakes of magnitudes 1<m<9.

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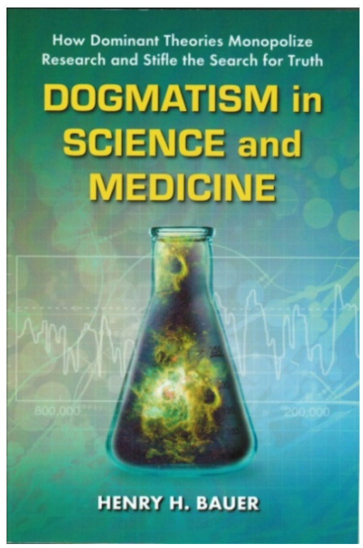
Dogmatism in Science and medicine: How dominant theories monopolize research and stifle the search for truth



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The nature of scientific activity has changed dramatically over the last half century, and objectivity and rigorous search for evidence that once defined it are being abandoned. Increasingly, this text argues, dogma has taken the place of authentic science.

This study examines how conflicts of interest—both institutional and individual—have become pervasive in the science world, and also explores the troubling state of research funding and flaws of the pee-review process. It looks in depth at the dominance of several specific theories, including the Big Bang cosmology, human-caused global warming, HIV as a cause of AIDs, and the efficacy of anti-depressant drugs. In a scientific environment where distinguished experts who hold contrary views are shunned, this book is an important contribution to the examination of scientific heterodoxies.

Contents

Preface

When everyone knows the same thing, that can be called a knowledge monopoly: public knowledge is monopolized by this supposed truth.

Where education is reasonably good and universal, as in most of the developed world, there are many situations where everyone knows (or believes) the same thing: that the Earth is (approximately) spherical rather than flat, say. Of course there are always the odd people who contest what everyone else knows. The term "flat-earther" denigrates a person who rejects what everyone knows to be true, on any issue at all.

Two points about literal flat-earthers: First, it is no secret that there are such people. Second, the evidence that flat-earthers are wrong is plain and easily understandable: ships disappearing over the horizon, satellites circling the Earth and enabling communications, photos of Earth taken by lunar astronauts.

This book is about a different set of knowledge monopolies, those where it remains something of a secret to most of the general public – and, most important, to policy makers – that there is anyone who dissents from the common opinion; and when the very existence of dissent is a secret, it is naturally also a secret that those who dissent may actually have significant evidence on their side.

Ask an educated, informed, intelligent man or woman, or a member of the chattering classes, whether the burning of fossil fuels is causing the Earth to warm at a dangerous rate and to a dangerous extent, and the answer will be "Yes", possibly followed by "of course."

Ask a follow-up: "Is there any doubt about it? Do any scientists disagree?"

The answer will often be "No," but perhaps occasionally something like, "well, may be, there's one in every crowd, I suppose among scientists too"; or perhaps, "Sure, there are some capitalists, libertarians, and right-wing kooks who won't accept it because it's against their ideology."

Similar responses will follow the question, "Does HIV cause AIDS?"

Or the question, "Did the universe begin with a Bing Bang?"

Or, "Are the continents drifting around?"

Or, "Did an asteroid kill off the dinosaurs?"

On each of these subjects, and on others as well (more examples in Chapter 4), only a few people know that in fact there are perfectly competent and well informed scientists who disagree on the basis of good evidence with what everyone else believed, and that this evidence and the arguments offered by these dissenters is simply ignored by their supposed peers, who seek to enforce an orthodoxy instead of assessing all the evidence with an open mind.

It runs counter to what science is thought to be, that competent voices are ignored. The prototypical case of Galileo is commonly taken to be an instance of religious suppression of science, not as the suppression of an unorthodox scientific view by a scientific orthodoxy. There is no popular icon comparable to Galileo to stand for suppression *within science itself by scientists themselves*. So any instance of that seems unbelievable to most people.

It has seemed unbelievable to the competent specialists who found themselves suddenly shut out by their peers because they raised questions about the mainstream consensus. Geologists who recognize problems with the theory of plate tectonics (or, as formerly called, continental drift), and who are frustrated because their mainstream peers ignore those problems, do not usually know that there are similar circumstances with respect to Big Bang theory and global warming theory and HIV/AIDS theory: that in each case, a minority of insiders tries to draw attention to problems unacknowledged by the mainstream.

Because dissenting, ignored, denigrated experts are typically aware only of their own troubles in their own specialty, it has not yet been widely recognized that this has become quite a general phenomenon. Dissenters assume almost everyone else, they believe that science works pretty much the way it is supposed to, and pretty much as it indeed did for several centuries: progressing through critical discussions in which all competent specialists were free to join, reaching conclusions that were increasingly objective because determined ultimately by the available evidence and not by authority or hierarchy of forces external to science.

That traditional view of science no longer holds. Over an increasing range of fields of science and medicine there are knowledge monopolies that have become hegemonic: ideological, dogmatic, *unscientific* in the sense of ignoring competent minority opinion and the significance of undisputed evidence; unscientific in declaring an issue closed even as uncontradicted evidence calls for open-minded reassessment.

A nascent recognition of these circumstances, and much understanding of what has led up to them, exists within the relatively new academic specialty of science & technology studies (STS), an interdisciplinary merging of history of science, philosophy of science, sociology of science, and the like. Scholars in these academic specialties have observed, described, even predicted the slow transformation of something like an open-minded intellectual free market of truth-seeking scientific researchers into a bureaucratic, corporate, monopolistic enterprise that profits tangibly from the *status quo* and defends closed-mindedly a consensus that has morphed into established dogma.

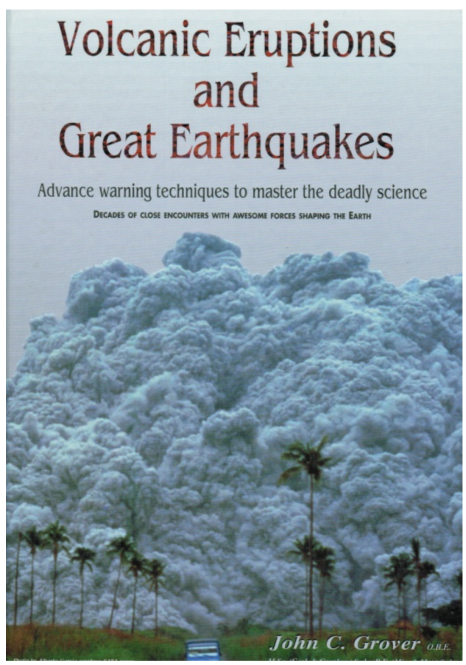
The changes came gradually enough to have escaped general notice, yet their cumulative effect has become sufficiently great that the traditional view of science is now dangerously misleading. Since roughly the middle of the 20th century science has become increasingly a very different animal than the so-called modern science of the two or three earlier centuries, whose successes molded and colored the popular view of what science is and how it works, a popular view that has not changed with the changing times. That traditional belief, that science is disinterested, open-minded, truth-seeking, is still the popular conventional wisdom, largely shared by the media and by the public and by policy makers and by most scientists themselves, and that traditional view continues to be taught to schoolchildren and to college students.

So the general phenomenon of contemporary closed-minded, hegemonic knowledge monopolies remains largely unrecognized. The examples given in this book show, however, that it is indeed quite general. The offered explanation for how and why this has come about (in Chapters 5 and 6) invokes indubitable changes in scientific activity in recent decades: perhaps primarily that scientific activity broadly speaking (often described as "research and development") consumers nowadays as much as several percent of Gross Domestic Product and thereby has become inextricably intertwined with commerce and politics (Grandin, Wormbs and Widmalm, 2004). As a corollary, the culture of science and its ethos have undergone drastic changes, to the extent that cheating and fraud, which were once extraordinarily rare in scientific research, have become sufficiently noticeable as to bring into being centers and journals focused specifically on ethical issues in research and their implications. Unrecognised hegemonic knowledge monopolies are what one can now expect to find in science and medicine under these new circumstances.

Knowledge monopolies are dysfunctional, because they enshrine as true what may not be true at all. Thereby scientific advice and medical practice have become unreliable and fallible to a dangerous degree: science, long regarded as the ultimate authority, has become untrustworthy through censoring or suppressing legitimate differences over interpretation of evidence. It would greatly benefit the public good if the media and the public and policy makers would pay attention to the competent experts and specialists whose views are not to the liking of the majority of their peers, so that independent judgements could be made by those whose responsibility it is to apply the soundest possible knowledge to public purposes.

History teaches that minority views within science and medicine have prevailed in the longer run on some of the most important issues. That is highly likely to be so with some of today's knowledge monopolies. Future historians will look back on our era as the time when science led the whole world astray because, in cahoots with powerful self-interested commercial and ideological forces, science had succumbed to closed-minded dogmatism.

JOHN GROVER BOOK FOR SALE



Copyright Publishing, Brisbane, Australia is offering a warehouse clearance sale of "**Volcanic eruptions and great earthquakes - advanced warning techniques to master the deadly science**", authored by the late John Grover. This is the only book which has an in-depth description of Claude Blot's 'thermal seismic energy transmigration' in English, which has entered the world center stage of earthquake and volcano prediction science today. Discount price AUS$30.00 plus $5 incl pack and post to any postal address in Australia. See web site for price incl pack and post to overseas postal addresses. Only limited number of copies available. Please contact editor@ncgt.org or johnmcrobert@bigpond.com or web site < http://www.copyright.net.au/details.php?id=19> if you are interested in purchasing.

GEOPOLITICAL CORNER

The March 2011 Great East Japan Earthquake: Fukushima and "Forseeability"

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If we could know the future, would we act any differently?

Today we have untapped and largely unrecognized capabilities that can help us to foresee. We have new and powerful computers. There are new potentials in social media, in particular the transformational power of guided "smart" narratives. But do we truly want to see? That is the question. What might be the consequences if our relationship to the future were to shift?

The nuclear catastrophe which resulted from the earthquake and tsunami at Fukushima on March 11, 2011 helps us to explore these issues, because the tragedy continues to unfold, even at this moment, as the radioactive flotsam from Fukushima rolls out across the Pacific toward Hawaii, California, Oregon, Washington, Alaska, and Canadian shores.

Most legal systems recognize the doctrine of negligence, and one of its key elements is the principle of "forseeability." Before a cause of negligence can be recognized, plaintiffs must show a breach of a clear duty of care, that the accident which occurred was "foreseeable," and the negligence was the proximate or "but for" cause of the accident. In plain terms, the accident would not have occurred without it.

There are several potential defendants in the Fukushima catastrophe. They are: the utility, TEPCO; the foreign manufacturer of five of the six Mark 1 reactors; and the local and central governments which approved the installation in an area known to be vulnerable to earthquakes and tsunami. The issue of forseeability in Fukushima can be subdivided into: 1. Was the original accident and its consequent loss of life foreseeable? and 2. Will the ongoing dumping of radioactive waste into the ocean at Fukushima cause long term damage not only in Japan, but also to other human populations, property, and the international environment; and were these harms foreseeable?

On February 1976, three nuclear scientists who helped to design the Mark 1 resigned because of their extreme lack of confidence in the reactor's ability to contain pressure in case of a meltdown, the precise situation that occurred at Fukushima. From a legal perspective it is very difficult to run the clock backward thirty-six years to establish present liability solely upon this evidence. The practical and interesting question is: how might our new oracular tools and methods apply to the present hazards, especially since the daily radioactive discharges from Fukushima are likely to penetrate food chains within the Pacific Ocean and arrive on foreign shores. Should these damages be deemed foreseeable in a legal sense?

Let us consider a specific example and place ourselves in the position of Neil Abercrombie, the Governor of Hawaii. The Japanese Atomic Agency has forecast that the debris is likely to reach Hawaii sometime in 2013-2014. If it does, Hawaiii will have a gigantic clean up problem. Worse, Hawaii's local fishing and tourist industries could be seriously damaged, and it is possible that Hawaii residents will face a serious health hazard from eating fish in 5, 10, or 15 years from now. Should Governor Abercrombie do anything today? Is it possible for him to foresee these future dangers? Is it acceptable for him simply to wait for the injuries to occur? Does the Governor have a legal responsibility to inform himself and to prepare the state? What about the governors of other Pacific coastal states? To answer these questions we must explore several critical issues:

- On what does forseeability depend? Although the future is uncertain, my research suggests that many events can be forecast with high probability, and we can, to a surprising extent, influence these probabilities by our actions. We have a wealth of tools such as scenario planning, risk analysis, discovery engineering, collaborative innovation, collaborative guided automation, and other techniques, which are not being systematically applied to forecasting significant public hazards such as international contamination from Fukushima. Moreover, many psychological studies confirm that what we see is highly influenced by our proclivities and wills: In the end, we see what we want to see.

- If foreseeability is a learnable skill, what is the duty of care of public officials to acquire this skill or at least to locate predictive resources? To gain an edge Governor Abercrombie need not look very far. He has easily available the work of Igor Mezic, a professor of mechanical engineering at the University of California in Santa Barbara, one of the world's leading flow experts. Professor Mezic accurately documented the pathway of the British Petroleum Gulf oil spill, weeks in advance of its impact on the Gulf state coastal areas, when the responsible U.S. government agencies, NOAA, the U.S. Coast Guard, and the Navy, simply got it wrong. (http://engineering.ucsb.edu/news/460/)Unfortunately Dr. Mezic's urgent warnings were ignored and huge preventable damages occurred. I believe Governor Abercrombie has a public duty to inform himself, and if possible, to prepare his state for an intelligent emergency response.

- Who should bear the legal burden of scientific uncertainty? No matter how powerful, our predictive tools will always be imperfect. We are always balancing uncertainties, probabilities, and risks. In developing his strategy Governor Abercrombie can cite an important Japanese legal innovation.

In the Yokkaichi air pollution case decided on July 24, 1973, six petrochemical companies (the same number as the nuclear power plants at Fukushima) were held liable for causing the pulmonary illnesses (asthma, bronchitis, emphysema) of local residents. When addressing the issue of the defendants' liability, the court held that plaintiffs had produced sufficient evidence of forseeability, causation, and the breach of a duty of care to justify shifting the burden of proof to the six companies, which the court held were collectively responsible. By the same reasoning the Yokkaichi case and other precedents suggest that TEPCO and the power plants, which are responsible for daily radioactive discharges, have a duty to foresee, and therefore must bear the burden of proving that these radioactive discharges are **not** the causes of future injuries. It is astonishing what people will be able to foresee when there are legal incentives upon them to do so.

The good news is the same powerful tools that can help us to foresee the future can also be used to devise ingenious ways to help us to avoid or mitigate its highest harms.

Note: Julian Gresser is an international attorney, inventor, and Japan specialist. His first book, *Environmental Law in Japan,* MIT Press, 1976*,* examined the history of Japan's legal innovations in protecting the environment. His forthcoming book, *Piloting Through Chaos-The Explorer's Mind* (Bridge 21 Publishing, November/December 2012) offers an original way to explore and to engage with the world.

NEWS

Earthquake session at the European Geosciences Union, April, 2013

At the General Assembly of the European Geosciences Union (EGU), scheduled to take place in Vienna (Austria) from 07 to 12 April 2013, there will be a session dedicated to the theme of seismic risk, as part of "Natural Hazards". The Session is entitled "Earthquake Precursors and Prediction", and represents a "small revolution" in the scientific thinking of Geosciences.

Geology, long associated with a historical approach to natural themes, is preparing for a change of course to become a forecasting science too. And the EGU Session is going to represent a milestone in this scientific innovation.

The theme, "Earthquake Precursors and Prediction", is of extreme delicacy due to the contents it subtends hitherto always relegated to Science's meanderings. Consequently, the appointment in Vienna represents a rare opportunity for all the world's geoscientists to present their studies, research, results and methods, and to debate, in a concrete way and on a solid scientific basis, one of the most important natural emergencies at a global level.

For more details, please visit, www.egu2012.eu/, or contact the convener, Valentino Straser, vstraser@ievpc.org.

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34th International Geological Congress NCGT session report

Dong Choi and Karsten Storetvedt, Conveners

The NCGT session at the 34th IGC, "Pursuit of a new global geodynamic paradigm" was held on 9 and 10 August, 2012. Out of 37 papers which were originally accepted, 23 papers were actually presented at the NCGT session; 15 oral and 8 poster papers. These papers were presented by 15 attendants from eight countries with Japanese delegates occupying an overwhelming majority, six delegates or 40%. The abstracts of the all papers originally accepted are printed in the following pages.

List of delegates who presented papers:

Australia – Dong Choi and Frank Lee
India – Vinayak Kolvankar and Biju Longhinos
Iran – Soheila Bouzari
Italy – Valentino Straser
Japan – Hisao Adachi, Yo Akamatsu, Kensho Iikawa, Takayuki Kawabe, Yoshihiro Kubota and Takao Yano.
Norway – Karsten Storetvedt
United Kingdom – Dmitriy Gurevich
USA – Bruce Leybourne

We missed several important oral papers, especially Louis Hissink (key note speech), and three Japanese papers - Hanada, Suzuki and Tsunoda - at last minutes. Also missed were many poster presenters who originally registered but later cancelled

Despite some difficulties in the early stage, our session was attended by many enthusiastic listeners throughout the two-day session. The major topics discussed are; tectonics and earthquakes, earthquake prediction, ancient continental rocks in the world oceans, ocean floor structures and magnetic anomalies, electric earth, planetary interaction, and global tectonic models. All papers were well prepared with strong supporting data. Heated exchange was seen occasionally between speakers and audience. Many non-NCGT attendants were overwhelmed by our well-founded argument.

While claimed a great success with a large number of attendants, this IGC Brisbane has revealed many serious problems pertaining to recent large international conferences – which are increasingly becoming overly commercialized and expensive. The registration fee is far beyond the reach of scientists from developing countries with disadvantageous currency exchange rates. Even many delegates from developed countries had to weigh the value of attending the IGC in the light of cost effectiveness; cost vs very short exposure time - only 15 minutes. This was reflected in the cancellation of many oral and poster papers of our session. If financial support was not provided by NCGT we would have missed three delegates from India and Iran, which would have resulted in a lopsided situation – a conference only for developed countries; our session would have been dominated by Japanese occupying 60% of the overseas delegates. International Geological Union will have to give a serious thought on the increasingly overly-commercialized state of the IGC – which is remote from the original IGC mission.

Despite these drawbacks, however, our session has demonstrated publicly that there are alternative ideas and theories to plate tectonics. Already wide ramifications are taking place after the IGC; attention by mass media, joining of numerous new colleagues, and so on. No one can stop this tide today.

Function: A total of 20 people attended the cocktail party held in the evening of 10 August, 2012 at the Greek Club near the convention center. Peter James organized the party. We had an unexpected guest, John Rigby, retired local paleontologist. Pleasant conversation and in-depth discussion were made over drinks and foods. There, next NCGT gatherings were proposed by Straser in Italy and Longhinos in India.

Financial support: For those who have financial difficulties to attend the conference, NCGT invited donation from organizations and individuals. Three participants received the NCGT financial support; Vinayak Kolvanker, Biju Longhinos, and Soheila Bouzari. The fund was provided by Raax Australia Pty Ltd. The partial cost for the function came from the NCGT account.

IGC34 Theme 37.2, "Pursuit of a new global geodynamic paradigm"

ORAL SESSION
9 August, 2012. 1530 – 1730. Chaired by Dong Choi and Karsten Storetvedt

Dong Choi and Karsten Storetvedt	Introduction – NCGT history and fundamental problems and future aims.
Takao Yano (Keynote)	Ancient and continental rocks from the world oceans.
Biju Longhinos	The Shetland-Greenland land ridge contradicting Atlantic seafloor spreading.
Soheila Bouzari	A new scenario of Iranian platform geodynamics based on the global wrench tectonic theory
Yoshihiro Kubota	Block tectonics and seismicity in the Niigata Plain, central Japan - formation of "isolated hills" and active faults by mountain uplifting.
Karsten Storetvedt	Caribbean evolution in a global perspective.

10 August, 2012. 0830 – 1050. Chaired by Dong Choi and Karsten Storetvedt

Karsten Storetvedt (Keynote)	World Magnetic Anomaly Map and Global Tectonic Theories.
Yo Akamatsu	The iso-depth contours of deep earthquakes in the Japanese Islands and surrounding areas.
Takayuki Kawabe	Mechanism of induced earthquakes by the Off the Pacific coast of Tohoku earthquake in 2011 according to the change of geothermal water level and its temperature, aftershock activity and geologic structure in Northeast Japan
Dong Choi	Great earthquakes are predictable: precursory signals and a new geodynamic perspective
Bruce Leybourne	Natural disaster weather and earthquake forecasting with geophysical methods

10 August, 2012. 1300 – 1515. Chaired by Biju Longhinos and Takao Yano

Dong Choi (Keynote)	New global tectonic paradigm: recent new advancements
Valentino Straser	Radio anomalies characteristic configurations of the interplanetary magnetic field and IPDP signals preceding M6+ earthquakes.
Kensho Iikawa	Pulsating crustal movement in central Honshu, Japan.
Dmitriy Gurevich	Vortex geodynamics: Atmospheric cyclones to geocyclones.
Vinayak Kolvankar (Keynote)	Sun moon and earthquakes.

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Lee, T.	A non-subjective method of plotting any single continental plate back in time using published paleomagnetic poles
Lee, T.	Magnetism. The uniaxial transfer of d-electrons between Fe-atoms leading to an
Lee, T.	The appearance of the Universe numbers 1.23, 1.19 and 1.38 in mineral chemical
Lee, T.	The use of basic physics theories to determine the step-by-step development of
Straser, V.	Seismic precursors preceding M6+ earthquakes from 60 days to 2?
Adachi, H.	Cenozoic Tectono?]magmatism in the Fossa Magna, Central Japan
Leybourne, B.	Natural disaster weather and earthquake forecasting with geophysical methods
Leybourne, B.	Florida hurricanes and grounding of global electric circuits

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34th IGC "Pursuit of a new global geodynamic paradigm" abstracts.

Cenozoic Tectono-magmatism in the Fossa Magna, Central Japan

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The Fossa Magna is one of the large tectonic unit of the Japanese islands, bounded by the western Itoigawa-Shizuoka Tectonic Line and the eastern Kashiwazaki-Choshi or Tanakura Tectonic Line. In the central Kanto mountains area of the Fossa Magna, the sedimentary basins took place along the tectonic lines in the early Miocene, and they expanded widely in the middle Miocene. The echelon arrangement and depocenter migration of early to middle Miocene sedimentary basins indicate that the tectono-magmatic development in the Fossa Magna district was controlled consistently the behavior of deep-seated elongated bodies of molten mantle. At the end of middle Miocene age, the sea area changed to the land area. In the late Miocene, intense volcanic activity was associated with the formation of collapse subsiding basins in the axes of the Fossa Magna. Late Cenozoic tectonomagmatism in the southern Fossa Magna is often explained by collision tectonics. However, it seems difficult to explain both the formative mechanism of the hierarchical structure of late Miocene volcanic collapse basins and tectonic framework consistent before and after the proposed collision event.

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The iso-depth contours of Deep Earthquakes in the Japanese Islands and surrounding areas

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Turner (1922) pointed out the occurrence of deep earthquake for the first time in the northwest part of south America. Wadati(1927) showed 12 deep earthquakes occurred along the zone crossing the central part of Honshu, Japan. He drew the iso-depth contours of deep earthquakes dipping away from the trenches toward the Asiatic continent. He insisted an intimate vertical relation between shallow and deep earthquakes. Benioff(1954) showed the paper on the inclined distribution of shallow, intermediate and deep earthquakes in the circum-Pacific region. He attributed the inclined seismicity plane to the thrust fault. Richter (1958) criticized Benioff's thrust fault hypothesis, as the faults accompanied by intermediate and deep earthquakes were not thrust fault but normal fault in the Philippines and Indonesian regions. Utsu (1974) examined the distribution of earthquakes in the Japanese islands and surrounding areas. He drew the general trend of flat planes on deep earthquake foci in each area. The Research Group of Deep Structure of Island Arcs(2009) studied the seismicity of the Japanese island and surrounding areas in relation to topography and tried to draw the iso-depth contours. The contours were not simple, as shown by Wadati and Utsu, but more complicated, suggesting the block-like arrangement related to geology and deep vertical roots of each geologic unit. Such figures suggest the block structure of mantle.

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Transverse structures in the Colombian Andes

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The dominant structural trend along the Colombian Andes follows a NE-SW direction. However, transverse lineaments and faults are also a prominent element in the structural framework of this region. After a multi-scale review of geological and geophysical maps and remote-sensing images, numerous transverse structures of different magnitude were recognized. These transverse structures exert an important control on many different geological and physiographic features such as the gross morphology of mountain ranges, distribution of volcanic centres and seismic foci, and the disposition of ancient sedimentary facies and mineral deposits. Two different types of transverse structures are present in the Colombian Andes. NW -SE features represent a common set of structures which are perpendicular to the NE-SW faults characteristic of the Northern Andes. These two sets of structures could be understood as an example of the primordial orthogonal fractures formed in the very early history of the planet. After the proposed clockwise rotation of the entire South America, hypothesized in the Global Wrench Tectonics model, these sets of fractures would have acquired its current position. The second type of features has a younger history and follows an E-W direction. These structures are more common in the northern part of Colombia where they locally control mineralized zones and

some of the conspicuous areas with mud volcanism. Although local vertical movements have been inferred, these structures mainly show dextral displacement sense. The origin of this second group of transverse structures could be related to the establishment of the Caribbean – South America tectonic boundary.

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From a solar protuberance to volcanic and seismic activity on Earth

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The comprehension of Earth's origin is significant for clarifying its structure and physico-chemical evolution. The problem is treated here based on our concept of the Earth primary plasma development from a solar protuberance. We affirm as chemists that the primary terrestrial body consisted of inorganic compounds and water vapours. Cooling down process produced a core containing substances of high melting points and densities and a mantle of substances of diverse such characteristics. The critical point of water was eventually reached on the surface, where the general metamorphic processes produced the oceanic type of Earth's crust. The oceanic waters penetrating the mantle interacted with carbides and other substances to produce new compounds and the primary hydrocarbons, whose underground ignition generated volcanic sites and melting the rocks to lava. The high pressure siphoned the lava to form reefs, mountains and underground caverns. Landslides and cave collapse caused earthquakes. The schist gas, found deep under the sea floor supports our concept. All physicochemical changes on Earth have developed in conformity with the natural laws under the given conditions. Therefore, the widely spread notion about the hypothetical plates and their imaginary movement is unacceptable.

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A new scenario of Iranian platform geodynamics based on the global wrench tectonic theory

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Based on the geological data, an important tectonic revolution happened in the Iranian plateau during the end of Cretaceous and early Cenozoic. The Neo-Tethys basin closed, between the Arabian plate in the south and the Central Iran in the north. Although most of Iranian and other geologist explained this event using plate tectonic theory many questions have remind without answer. For instance the crust thickness in collision zone along the Zagros main fault must be very thick. There is also a large volume of Eocene magmatic activity, especially near the Zagros fault. The geochemical analysis shows no regular distribution. The big question is why was the continental crust extended in this area? Based on global wrench tectonics the tectonic revolution along the Zagros fault zone and the Neogene basins model can be explained by assuming the Iranian plateau is part of the Alpine belt, and that along this belt two mega continents have connected together. The northern part experienced clockwise rotation but the southern part rotates counter clockwise creating a weak and stressful area. Along the weak zone the Uromieh-Dokhtar magmatic belt and Sanandaj-Sirjan metamorphic belt were formed. Along the main fault zone gas and hydrocarbon emerged. Folded structures in the Zagros area are the main hydrocarbon reservoirs. In the late Cenozoic, the Iranian plateau tectonosedimentary basins were formed. Some of them were formed after strong vertical movement along the fault structures and rapidly subsided micro-blocks. Another basin was formed by rift model. The counter-clockwise wrenching is also noticeable around some of the Neogene basins.

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Vernal Point and Earth Rotation

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On March 21st, 1940 the Vernal Point enters the constellation of Aquarius and is verified on Earth with three natural events: (1) Electromagnetically in South America, (2) The equatorial electrojet,

(3) Climate change in South America. The average stability of the magnetic equator and the greater intensity of the equatorial electrojet is approximately 13 ° south latitude. Where the average declination of the Sun is 13 º south and it happen around two dates annually: February 15 and October 28. The equation of time is the difference between mean solar time (usually measured by a clock) and the apparent solar time (time measured by a sundial).The days of different lengths are expressed in the equation of time and the causes are the Earth's orbital cycles: the precession of the equinoxes, obliquity, and eccentricity. From the sun position at the declination 13 ° S and the equation of time we can see that we have a reference system for studying the behavior of the rotational motion of the Earth. Therefore we propose a start of a reference system for studying the movement of rotation of the earth and its effects.

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New global tectonic paradigm: recent new advancements

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Along with the well-established facts, 1) the continental nature of the oceanic crust, 2) continuation of Proterozoic structures from continents to oceans, 3) paleolands in the present-day oceanic areas until the Mesozoic, and 4) the deep roots of the continents and oceans reaching the lower mantle, what has become increasing clear is that fundamental tectonic processes are related to thermal/electromagnetic energy discharged from the outer core and accumulated in the mantle and crustal highs. This discharge of core-energy and earthquake activity interacts with solar and other planetary forces. Upwelling, dome or anticlinal structures are commonly observed on all scales throughout the mantle and the crust, forming a fractal pattern. Two modes of energy transmigration exist: 1) through broad zones of upwelling from the outer core centered in the Fiji region, SW Pacific, which spread laterally in the middle and upper mantle, and 2) narrow linear deep tectonic zones mainly in the western Pacific margins. While the former (broad zones of upwelling) may be predominately from conventional thermal convection, the latter (narrow linear zones) is suspected to be more electrical in nature, especially in the Western Pacific Rim where a 40-day North to South oscillation of earthquake energy is suspected to be driven by sector boundary changes in polarity tied to sweeping Birkeland currents during solar rotation. Large changes in solar magnetism are suspected of producing "surges" of electrical energy responsible for historical volcanic outpourings and earthquakes and are likely related to abrupt extinctions and hiatuses observed in the geologic record.

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Great earthquakes are predictable; precursory signals and a new geodynamic perspective

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Given the unimaginable devastation caused by catastrophic earthquakes, scientific earthquake prediction is an urgent task for all geoscientists. This is all the more important today because , based on the solar cycle trend, the Earth is considered to have entered a mini-ice age since 2008 probably comparable to the Maunder Little Ice Age in th e late 17th century when unusually strong seismic and volcanic activities had occurred. A spate of catastrophic earthquakes, volcanic eruptions and extreme weather events i n recent years have occurred during the rapidly lowering period of the larger solar cycles, 361-and 206-year cycles, which are related to the Maunder and the Dalton Minimums. Despite the consorted claim by mainstream seismologists that earthquakes cannot be predicted, there are many great earthquakes which have been successfully predicted on sound scientific grounds. All catastrophic earthquakes accompany some kinds of precursory signals; deep strong earthquakes, vapour clouds, electromagnetic phenomena (ionospheric perturbations, etc.), gravity/magnetic anomalies, ground temperature anomalies, ground movement and animal behavior. In addition, our studies clarified relationship between seismicity and geological structure, earthquake generation processes in the light of a new global geodynamic model, and the Sun-Earth-Moon interaction that modulates the triggering process. By combining all available early signals supported by right understanding of geological, geophysical and planetary processes which generate and trigger earthquakes, strong earthquakes especially with magnitude 7.0 or greater can be accurately predicted: improvement in our prediction techniques now allows to detect catastrophic quakes well in advance on the order of weeks, months, and years.

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Ore-concentrating zones of Ukraine

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For territory of Ukraine the new types of ore-bearing structures are selected: inter-block sutural zones and trans-block megazones of activation. The first one are presented by the structures of directional evolutional development; the second are the superimposed trans-block zones of destructive character. The inter-block sutural zones are: Nemyryv-Kocheriv, Golovanivka – Traktemyriv, Ingulets-Kryvyi Rih-Kremenchuk, Orekhiv-Pavlohrad. These structures have meridional direction. To the of trans-block megazones of activation North-; Central – and Sonth-Ukrainian zones belong. Exactly to these structures the productive mineralization and unique and rich deposits of various minerals, foremost rare, noble and coloured metals, uranium, fluorite, and also oil and gas are related. The areas of crossing of sublatitudinal linear zones of activation with the submeridional sutural zones where the alternating-sign special processes of tension and compression flow (vibrating tectonics) are important. The high-gradient tectonic field of tensions sends and focuses mineralized fluidal streams and creates geodynamical, geochemical and geoelectric barriers to ore – and oil-gas concentration. A presence of long-living high-gradient dynamic environment is the necessary conditions of self-organization and sustained functioning of the ore-forming systems.

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Fundamental role of deformations in internal dynamics of the Earth

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Some common geomechanical basis of various problems of internal dynamics of the Earth exist basing on fundamental properties of basic systems of equations of nonlinear mechanics, data, results of Green, Ringwood, Liu's known experimental studies. Distribution instability of medium density is shown depending on deformation changes for different geological medium. General mechanism of compressed medium consolidation that transfers to deconsolidation in different stages of process is given. Instability creates the structures in geological medium composition favorable for formation of zones of deconsolidation and small shear stiffness. Destruction by delaminating can lead to void formation in various scales. Instability can be realized further in vicinity of these free surfaces and voids fill ed with loosened mass, i.e. deconsolidation process occurs in compression conditions. More hard bodies of local scale in form of rod, strip, plate, cylindrical body, void, etc. can exist at different depths of mantle. These bodies can lose stability in compression conditions. Therefore, part of their material and environment is loosened and decompression process occurs again. Partial melting can occur in these zones and dilution mass can generate in them depending on mineral association composition, petrochemical properties, thermobaric conditions, depths. Some of these deconsolidation zones can become focus of dilution mass and give beginning to mass flow on different directions further.

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Vortex geodynamics: Atmospheric cyclones to geocyclones

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Asthenosphere and lithosphere are involved in tectonic flow, driven by multi-scale mantle convection and slab sinking/sucking. Tectonic flow is a nonlinear self-organizing process sensitive to weak secular influences, evolving between certain attractors. Vortex is the most important type of attractor, integrating poloidal and toroidal circulations, horizontal and vertical flows. Vortex structures or parts of them were previously many times delineated by the interpretation of geological, geographical, geophysical and remote sensing data. Active vortexes can be mapped using GPS tracing, analysis of earthquake distribution and mechanism, fault displacements, strain patterns and shear wave splitting. In recent years numerical modelling revealed vortex-type flows below several corner or junction points in the subduction zones (Alaska, Kamchatka, Japan, the Aegean). These structures and processes can be considered as induced vortexes, formed in a long-lasting convergent viscous flow influenced by permanent rotating forces. Convergent horizontal flows in asthenosphere (including oblique and trench-parallel flows) are observed around subduction centres. Flow rotation is induced by the Coriolis force, interaction of parallel (shear stress) or nonparallel (collision) mantle steams. Basing on the analogy with non-tropical atmospheric cyclones, the author proposes to call these systems as geocyclones (GC). Diameters of GC vary from a few hundred to several thousand kilometres, their life time spans 20 to 100 MA. Typical mature GC-produced structure includes orocline surrounded by arc-like sectors of compression (collision, slip-strike and trust faults, sutures) interchanging with zones of stretching (sphenochasms, rifts). The author considers some active GC, GC groups, and examples of structures formed by ancient GC.

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Submersion at the ocean floor from the perspective of DSDP data

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This paper shows that, in deep-sea drilling, the distribution of shallow face materials becomes shallower with each era subsequent to the middle period of the Mesozoic. This is said to be caused by various phenomena including: increase in the amount of seawater in the Mesozoic/Tertiary, conversion of continental crust to oceanic crust, deepening of the ocean floor due to plate cooling, and subsidence of the ocean floor accompanying rifting on the passive continental margin. However, these theories have difficulties in terms of paleobiology, physical chemistry or paleogeography, and a plausible explanation cannot be obtained. We believe that what is happening on the ocean floor deeper than items where the shallow face materials of an older era have a young age, is that in situ shallow face materials are brought to the ocean floor together with the era, due to underplating at the ocean floor of basalt magma of the Mesozoic and Cenozoic. Sea level will rise with increasing ocean floor, the location of the original floating point is brought into deep steadily over time.

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The geoplasma connection

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The Earth is considered a negatively charged body partially encapsulated by a highly electrically conductive surficial film (the oceans) and isolated from the solar plasma by ionospheric and magnetospheric plasma double layer(s). The Earth-atmosphere-ionosphere system acts as a leaky capacitor in the Sun-Earth circuit. The source of the earth's electrical charge is proposed to be primarily solar via the polar Birkeland currents which form complex surficial and/or subsurface electrical circuit/s. A modified Alfven solar electric circuit model is used to explain the Earth's electric field. Electric currents passing through the solid -liquid -gas plasma sequence are interpreted to result in a decreasing thermal but increasing dynamical effect as the currents pass through the different states of matter from solid to plasma. These effects are considered to be the major physical forcing at the earth's surface accompanied by secondary thermal effects. The geomagnetic field is due principally to the rotation of a charged Earth. The majority of the earth's electric current flows via the equatorial atmospheric low pressure systems which develop over the more electrically conductive oceans. Concentrated electrical charge escape also occurs as atmospheric discharges commonly known as tornadoes, cyclones, hurricanes, or typhoons, as well as more common lightning. These atmospheric d is charges are similar to some sunspot phenomena. Other geological phenomena are explained in terms of plasma theory.

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Pulsating Crustal Movement in Central Honshu, Japan

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About 1,000 first-order triangulation stations are set every 40 to50km on the Japanese Islands. The first order bench marks are set every 2km along the main roads. The stations were surveyed around 1880s, 1958 and 1979. Based on the displacements of neighboring three triangulation stations, dilatation, rotation, maximum shear, two principal strains and directions of principal strains are calculated. The levelling surveys showed the correspondence of upheaval and subsidence with expansion and shrinkage. In the early stage the upheaval was predominant in the central part of

Honshu, and the subsidence predominant in the north part. Two principal axes show elongation in the former area, and shrinkage in the later one. Such movement was reversed in the later one. Such movement was reversed in the later stage, so the pulsation was general crustal movement. The destructive earthquakes took place in the area greater than 10^{-5} in maximum shear.

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Mechanizm of induced earthquakes by the Off the Pacific coast of Tohoku Earthquake in 2011 according to change of geothermal groundwater level and its temperature, aftershock activity and geologic structure in northeast Japan

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Level and temperature of geothermal groundwater changed and many induced earthquakes has been occurring in Northeast Honshu Island just after t he Off the Pacific coast of Tohoku Earthquake in 2012. Most of geothermal groundwater is presented in any open spaces of faults and fractures under the ground. Places of decreased groundwater level are situated along the faults of N-S directions. This means that the width of the open space of faults and fractures of N-S direction containing groundwater expanded. According to the GPS survey by GSI, Northeastern Honshu Island extended more than 5 meters to the east. This mean t hat the strain in the upper crust decreased and turned relatively to tensional. This caused the change of geothermal groundwater level and temperature. Such change of strain also generated any kind of fluids in the lower part of the upper crust, and they pushed the upper part of the upper crust and tried to move to upward through the existing faults and fractures. This causes the induced earthquakes in the northeastern Honshu Island.

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Sun moon and earthquakes

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During a study conducted to find the effect of Earth tides on the occurrence of earthquakes, for small areas of high-seismicity regions, it was noticed that the Sun's position in terms of universal time (GMT) shows links to the distance between earthquake location-Moon footprint on earth (EMD) together with Sun-Earth-Moon (SEM) angle. This paper provides the details of this relationship after studying earthquake data for over forty high-seismicity regions of the world. It was found that over 98% of the earthquakes for these different regions, examined for the period 1973-2008, show a direct relationship between the Sun's position and the distance between earthquake location-Moon footprint on earth together with the Sun-Earth-Moon angle. As the time changes from 00-24 hours, the sum of EMD and SEM angle, changes through 360^0, and plotting these two variables for different earthquakes, reveals a simple 45^0 straight-line relationship between them. This study indicates that the vast majority (98%) of worldwide earthquakes are governed by the Sun and Moon. Even the smaller earthquakes in the magnitude range of 2-3 faithfully follow this relationship. It is also seen that numerous aftershocks, which follow any major earthquake, faithfully follow straight-line curves, generated by the plot for (EMD+SEM) Vs GMT timings. This paper illustrates and describe s numerous plots for earthquakes for different areas and periods to support this relationship.

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Block tectonics and seismicity in the Niigata Plain, central Japan -formation of "isolated hills" and active faults by mountain uplifting-

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The Niigata Plain, central Japan is alluvial plain faced on the Sea of Japan and its surrounding areas has been called the "Shinanogawa earthquake zone". Recently big earthquakes occurred in 2004 (M6.8), 2007 (M6.8), and 2011 (M6.7) that was the day after "the M9.0 March 2011 Great East Japan Earthquake". But the northern part of the Niigata Plain

still remains as a blanked area of earthquake.
The Kakuda-Yahiko Mountain, dominated by the Miocene volcanic rocks is situated in the NW margin of the Niigata Plain. At the foot of the mountains, the hilly areas are situated. These hills form "isolated hills" which exist alluvial lowlands between mountains and hills. The active fault zone runs in the direction of NNE-SSW there. The formation of these hills and active fault zone formed with the brock uplifting of the Kakuda-Yahiko Mountains.
It seems to be difficult for the plate model to explain the cause of inland earthquakes as mentioned above far from the subduction zone. Recently the low velocity zone by the tomography was observed under the depth of 30km deeper underneath those areas. It is paid attention to the relationship between block tectonics caused by rising of the low velocity zone and occurrence of earthquakes.

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A non-subjective method of plotting any single continental plate back in time using published palaeomagnetic poles

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Study showed a relationship between Earth *continental plate* wander paths and surface traces of the vertical principal and shear planes caused by a spherical outward pressure from a centre on the N-S line joining the *magnetic* poles, with one of the planes passing through Earth's centre. Assume the palaeomagnetic pole of a continental plate was a *spin* pole that had a *magnetic* pole of identical orientation to the Holocene's two poles. Determine all old *magnetic* pole positions by using a stereographic net. It will be found that when a pole1 is moved to the *magnetic* pole on the Earth's surface, the next oldest pole2 plots on or near one the planes' surface traces. This gives the movement distance and direction of the plate in *degrees*. Next move pole2 to pole1 and repeat for pole3 etc. Eighteen plates have been plotted variously to the Cambrian and many tests applied. All have been supportive. Re. Gondwana, Plotting shows a M. Ordovician Gondwana (less S. America) split into two slightly diverging, west-moving parts as further breakup occurred. A rotating S. America met Africa in L.Devonian and rebounded, and temporarily met Australia/NZ in the M. Jurassic. Move the parts together along their M. Jurassic longitudes and the present-day interpreted Gondwana is obtained.

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Magnetism. The uniaxial transfer of d-electrons between Fe-atoms leading to an explanation of the origin of the Earth's magnetic field

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A unit cell of magnetite is face-centred cubic with 6-Fe atoms and 8-O atoms. The 8-O atoms require 16 electrons to complete their outer L-shells but only 12 circular orbit s-electrons occur in Fe's outer N-shell. This deficiency of 4 must be made up by the maximum-ellipsoidal orbit d-electrons in its M-shell. There are 6 available for filling the 4 O-atom electrons' outer L-shell, leaving 2 d-electrons unattached. I argue it is these which give magnetism, for if energy is uniaxially applied these surplus d-electrons will align parallel to the energy direction, touch, and pass into a neighbouring Fe-atom N-shell. This gives 3 electrons in two orbitals but Pauli's Exclusion Principle says only 2 for atom stability so 1 d-electron is rejected, moving in the direction of applied energy into the adjacent atom. An electron flow develops and the body becomes magnetic. On cessation of the applied energy the O-atoms resist re-orientation and magnetism persists: unlike pure iron. Some years of theoretical research allows the author to confidently state that the solid inner core is not central but offset somewhat north of the centre and towards the Pacific. Result? A uniaxial inclined spiralling coat of the fluid outer core over the inner core (i.e. uniaxial energy applied) to produce an inclined magnetic field that varies under certain conditions explained in the poster.

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The use of basic physics theories to determine the step-by-step development of our solar system

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A rotating spherical mass of gases and minor solids became highly but incompletely differentiated into an onion-like structure: centre to outside Mercury/M-Venus/V-Earth/E-Mars/Ms-"silicate"satellites"icy"satellites-Neptune/N-Uranus/U-Jupiter/J-Saturn/S. (Pluto, Charon, Triton, "Asteroid" ignored here.) It slowly became prolate ellipsoidal and

divided at the Jacobi bifurcation point into protoJ and inert S – ≈78:22 -(4 proofs). ProtoJ internally adjusted as closed force field after division not equal to force before. Core divided into silicate and gaseous spheres touching at centre (N/U-E/V/My = radius 4:1, mass 16:1).
Mild inward collapse of outer gases gave a string of "sil."sats forward (includes Mars) off silicate sphere and of "gas"sats backwards off gaseous sphere These driven out by impulsive force. Mars passed into Sun control, the others orbited J. Further collapse: inner spheres divided into N/U and E/V/My. E/U driven out. E captured Mn (speeds similar); Titan moved out of orbit to balance satellite force sub-system and captured by Saturn. Final collapse: N and V/My driven out: J now in equilibrium. The bodies spiralled out from Jupiter and passed into control of Sun for final System equilibrium: Neptune last. Most of the step-by-step breakup required definite mathematical body relationships, eg densities, radii, orbit speeds, tilts, rotations, isotopes, meteorites. Over 40 have been determined, most in formula form.

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Climate connection to time varying nuclear decay rates

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The process of radioactive decay still remains a mystery, and new evidence of time-varying nuclear decay rates indicate solar influence at several periodicities altering nuclear decay rates on the order of 10^{-3}. This variation is split somewhat evenly between β-Beta decay (neutron conversion to proton emits electrons) typically converting a H3 isotope to He3 common in Earth's mantle and hypothesized to excite "electric earthquakes", and λ-Gamma decay (high energy nucleus emits photons), likely creating "earthquake lights". Correlation with neutrino flux remains largely unexplored. For example, "The swings [in decay rate] seemed to be in synch with the Earth's elliptical orbit, with the decay rates oscillating as the Earth came closer to the sun (where it would be exposed to more neutrinos) and then moving away." Interestingly, a north-south pendulum swing in Western Pacific Rim seismic activity which is hypothesized to be driven by sector boundaries of solar polarity emanating from meridian sweeping Birkeland currents during solar rotation appears to have direct climate control on the Madden-Julian Oscillation's power spectrum. These ideas also converge with the concept of the Pacific Decadal Oscillation 30/60 year global temperature cycles that trend with solar magnetism controlling a doubling of lightning in the Gulf of Mexico as a precursor to hurricane inundation in 2004/2005, and precursor earthquakes to El Niño's Southern Oscillation linked to Hale cycles.

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Natural disaster weather and earthquake forecasting with geophysical methods

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Geophysical modeling for forecasting earthquakes and extreme weather outbreaks associated with changes in solar magnetism are possible. Tele-dynamic relationship between barometric pressure change and force of gravity is ~ 0.30 *u*gal/*m*bar combined with understanding magnetic switching parameters of solar coupling to telluric currents, subtle changes in thermal/pressure coupling of the ocean/atmosphere may be modeled. Lightning and earthquake teleconnections to atmospheric oscillation patterns contribute to numerical modeling based on gravity, electromagnetic, and tele-dynamic functions that modulate atmospheric circulation's potential vorticity. Geographic switching is based on Earth endogenous energy models, where slope of the magnetic dipole moment % decay trend of solar magnetism provides switching components related to power and momentum of Core-Mantle-Boundary events which correlate to changes in ocean/atmospheric temperature and circulation. Outputs may be computed for inputs to conventional atmospheric circulation models. Based on observations, it appears the trigger mechanism for such events is tied to orbital physics and variations in the electromagnetic/gravitational coupling between the earth, sun, moon and interplanetary system. Earth's internal electrical discharges modulated by variation of nuclear decay and precipitated by changes in solar magnetic field strength increase seismicity which is documented as precursors to shifts in global atmospheric oscillations.

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Florida hurricanes and grounding of global electric circuits

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Multiple hurricane tracks across Florida in 2004 may be linked to grounding of the global electric circuit and increased lightning strikes along ancient conductive Triassic Rift anomalies which could attract hurricanes electromagnetically. The Tampa Bay-Lakeland region has more lightning strikes than anywhere in the USA and overlies a conductive anomaly which 3 hurricanes passed directly over during the 2004 hurricane season. In 2003 and 2004 lightning strikes approximately doubled from a previous yearly mean under 600,000 to over 1,000,000 within a 1 x 2 degree swath including the Tampa Bay and Lakeland region. The majority of strikes over the North-northeast Tampa Bay Region define the most conductive grounding area. During activation periods in the global electric circuit the rift area in Central Florida may switch "on", attracting more lightning affecting hurricane tracks and intensity along these ancient conductive rift anomalies. Another lightning anomaly over geomagnetic structural anomaly of the Wiggins Arch in Southern Mississippi lies directly within the most destructive zone of hurricane Katrina's landfall where an especially intense tornado outbreak occurred near Wiggins, MS during Katrina. Lightning increases in the spring before Katrina struck in August 2005 were reported on the Mississippi Gulf Coast. Lightning precursors occur in 2004 and 2005hurricane/tornado outbreaks events and likely related to changes in momentum of global magnetic decay cycles.

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Fundamentals and applications of Earth system dynamics

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Fluid flow Keep the Earth energetic. Earth's inner core is unstable and easily deviate the Earth's center under the circumstance of fluid outer core, which triggers outer core laminar flow. The huge incremental fluid under the core-mantle boundary results in platy mantle flow which makes up hot line and forms mid-ocean ridge; and columnar mantle flow make up hot spot and forms volcanic island. Platy mantle flow causes upper mantle partially melting and forms asthenosphere. A lot of asthenosphere fluid flows laminarly from the mid-ocean ridge into continent, driving ocean plate movement and triggering vertical accretion of continent. Locally concentrated asthenosphere in continent upwells as platy or columnar pattern, leading to laminar flow of continental lower crust and accordingly forming continental rifts and basins, synchronously forming orogens because of increasing lower crust fluid from peripheral basins, therefore crustal circulation in basin-orogen system. While platy deep mantle flow weakens, ocean-continent interaction results in subduction of ocean plate and forms basin-mountain system on continental margin. While platy deep mantle flow vanishes, continent movement controls ocean contraction. Finally continents collide, and the continental accretion is epeirogenic movement rather than orogeny. Earth system dynamics could widely apply to resource, energy, environment, natural disasters and others fields. For example, exploiting geothermal energy could not only improve energy structure, but also reduce disasters and greenhouse gas emissions.

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Dynamic mechanisms and models of tectonic reactivation in North China

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Based on the existing results and data from the study of dynamic reactivation mechanisms in North China Craton, two kinds of lithospheric thinning mechanisms, namely the thermal erosion mechanism and the delamination mechanism, are briefly discussed in this paper. These two mechanisms are closely based on the following two scientific theories: the Rayleigh-Benard instability theory and the Rayleigh-Taylor instability theory. Due to the limitations of these two theories, the porosity-wave induced heat-transfer and mass-transport model needs to be used to investigate the energy accumulation process associated with the dynamic mechanism of North China Craton destruction. With the further modification of the existing Rayleigh-Benard instability theory and Rayleigh-Taylor instability theory, it is possible to create necessary conditions for reproducing the dynamic reactivation process of North China Craton through numerical simulations.

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The Shetland -Greenland land bridge contradicting Atlantic seafloor spreading

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The Shetland-Faeroes-Iceland-Greenland Ridge is a broad, aseismic, flat-topped, NW-trending transoceanic mountain range at water depths of about 400 m. Traditionally it has been regarded as a biogeographic land connection between Europe and N America, to account for the strong pre-late Tertiary fauna and flora relationship between the two continents. In support of that hypothesis, deep sea drilling on the northern flank of the Faeroe-Iceland Ridge cored a 10 m thick subaerial weathering profile of Middle-Upper Eocene age and sedimentological evidence suggests that the Ridge has subsided in the order of 1 km since the laterite layer formed. Thus, in an attempt to fit the high standing Faeroe-Iceland plateau into the popular crustal spreading mould, ad hoc proposals in terms of shallow water or subaerial seafloor spreading has been proposed. However, numerous geophysical studies have arrived at an unusually thick crust, in the order of 35km, for this trans -oceanic ridge suggesting that it constitutes a moderately attenuated continental basement. In addition, t he irregular magnetic anomalies of the ridge display typical continental characteristics. The Shetland-Greenland Ridge is cut by two shallow and relatively narrow NNE-NE trending troughs, at the Greenland and W European margins respectively. These tectonic cuts into the thick-crusted trans-oceanic ridge are consistent with GPS velocities for Western Europe and for the adjoining North Atlantic – adding to other evidence which indicate that Iceland is an in situ continental fragment affected by the same North Atlantic shear system. Crustal spreading – as invoked by plate tectonics and Earth expansion models – are not in evidence.

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Earth Crust Deforming Force and the Earth Crust Deformation

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The vertical gravity force of Newton and the lateral attraction force of Newton-Cavendish appearing on the shape of Pascal principle force is the main driving force for the earth crust deformation. The primitive earth is a ssumed to be center symmetry. The perpendicular gravity force (masses of ice at poles) is the only agent that creates 1/ Pascal principal force that causes the plastic, viscose and melted matters squeeze laterally through its gravity horizon(auto-balance zone) to balance the gravity force of earth body. 2/ Stress distribution on lithosphere (elastic skin) creates two circular stress concentrated rings almost coincides the periphery of ice mass at poles and one tensional ring at equator. At once the constant compression Pascal force inside a major plastic zone, probably Moho zone overcomes to the strength of the lithosphere. The earth crust ruptures on northern hemisphere. From now the continents float in upper mantle. The simultaneous volcanism favored the glaciations. The mountain of ice starts to move while carrying the rotation axe mounting on huge ice mountain. While the ice gradually melts the axe changes its location and wanders but, it is compelled to follow always the point of minimum force of moment for rotation that is under control of ice mass or volcanic relives. The second earth crust rupture well noticed and defined by Wagener, 1924. The continents (density ~ 2.8) are under lateral press by surrounding ocean crust (density 2.9-3.3). This lateral force contracted the continents consequently caused the oceans spreading and let the magma squeeze out of mid-ocean ridges.

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World Magnetic Anomaly Map and Global Tectonic Theories

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The recently published candidates for the World Magnetic Anomaly Maps display many features of essential importance for global tectonic theorizing. It is currently taken for granted that the ‘striped’ anomaly pattern of the deep oceans is a product of periodic changes of geomagnetic polarity superposed on a laterally spreading seafloor – a model which however has failed all critical tests. A wide variety of deep marine evidence – such as 1) the near-absence of volcanism along mid-ocean ridges and 2) the generally low heat flux, 3) a multitude of dynamo-metamorphic rocks, 4) numerous submerged continental masses, and 5) marked shearing deformation –leads to the conclusion that the oceanic basement represent thinned continental crust (a process mostly of Upper Mesozoic age) with superimposed inertia-driven Alpine-age wrenching. This Alpine tectonic torsion and related magneto-mineralogical alteration, having developed primarily along one of the fundamental (pan-global) sets of rectilinear fractures, seem to be the general mechanism of marine and continental magnetic anomalies (the susceptibility-contrast model). The World Magnetic

Anomaly Map favours a global tectonic system directly aligned with changes in Earth rotation. Plate Tectonics, Earth Expansion and Surge Tectonics seem untenable.

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Caribbean Evolution in a Global Perspective

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The structural development of Caribbean region is intimately linked to Earth's dynamo-tectonic system within which variably distributed internal degassing has thinned major parts of the initial thick pan-global continental crust – resulting in a diversity of thin-crusted oceanic sub-basins. Worldwide loss of crustal material to the upper mantle, accelerating in Late Cretaceous to early Tertiary, led to changes in Earth's moment of inertia instigating jerky changes of planetary rotation: the driver of the Alpine tectonic revolution. The latitude-dependent inertia forces led to relatively modest *in situ* rotations of the major land masses, deforming the mechanically weak oceanic lithosphere. During the relative rotation of the Americas the Caribbean region formed part of South America, and the principal tectonic boundary followed along the Polochic-Motagua fault system; in this process basaltic and granitic magmatism occurred in numerous locations of the relatively thin-crusted Caribbean basins. The eastward tectonic swing of the Caribbean led to significant shear tectonics along its margins and internally – ending in the shallow, westward-inclined thrust front seaward of the Lesser Antilles Arc. The Caribbean history is directly linked with principal tectonic features of the bordering Americas and their adjacent oceanic tracts.

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Radio anomalies, characteristic configurations of the Interplanetary Magnetic Field and IPDP signals preceding M6+ earthquakes

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Major earthquakes with a magnitude of M6+ are preceded globally by the appearance of three characteristic elements which are interdependent:

- Variation in the Interplanetary Magnetic Field (IMF)
- Appearance of radio anomalies
- Frequency of occurrence of Intervals of Pulsation of Diminishing Periods (IPDP).

The characteristic pattern on an IMF graph before a strong earthquake as recorded by GOES satellites is a backwards "S", associated with a variation in the magnetic field from 2 to 8nT.
This variation in IMF is followed by radio anomalies in a frequency range from 0 to 3Hz, and IDPD in an interval between 0.1 to 0.6Hz.
The temporal interval between the peak of the backward "S" and M6+ earthquakes ranges from 60' to 8', while the time elapsed between the radio anomaly and the seism varies from 60' to 2'.
From 2009 the repetitiveness of these phenomena has been confirmed both in historical analysis and predictive phases.
Both IMF and IDPD are dependent on the Sun's Dynamo Effect. This, in turn, is related to variations in the Solar System's centre of mass.

Transmission of energy from the Sun in areas subject to tectonic stress is of a gravitational type; variations in IMF and IDPD reflect rotational variations of the Sun, while stress produced on the Earth manifests through the appearance of low frequency electromagnetic waves and radio anomalies.

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Seismic precursors preceding M6+ earthquakes from 60 days to 2'. Proposal for an Interdisciplinary Study Method.

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To produce specific, statistical models for zones prone to seisms, one way to verify the simultaneity of seismic precursors and the validity of the methods and analysis used would be to combine interdisciplinary investigations.
These could start with:

□ the appearance of Earth Lights about 50 days before the seism; □ the formation of earthquake clouds and geo-eruptions in the future epicentre area about one month before the mainshock.
Further confirmation of the progression of tectonic forces prior to a seism can come from: □ thermal anomalies about 10 days before the earthquake; □ an increase in radio interference a week earlier; □ emission of radon gas in the three days preceding the seismic event; □ an increase in magnetic background among the low frequencies; □ variations in IMF and IDPD; □ radio anomalies manifesting anywhere from 8' to 2' before the actual earthquake.
The magnitude has been related to the type of vapour clouds emitted plus an atypical increase in the number of radio anomalies in the run-up to an earthquake, as was the case in Japan in March 2011. Application of geodynamic models combined with seismic data would greatly increase the overall quality of predictions, while the setting up of an international workgroup that brought together various disciplines would undoubtedly lead to a more calibrated definition of seismic risk on a global scale.

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Recent successive occurrence of destructive earthquakes in Japan

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The southwest part of Honshu in the Japanese islands have been activated in seismicity since the occurrence of the Hyogoken-nanbu earthquake(M7.2) of 1995, followed by the Tottoriken-seibu earthquake(M7.3) of 2000, the Geiyo earthquake(M6.7) of 2001 and the Fukuokaken-seihou-oki earthquake(M7.0) of 2005. The Chuetsu earthquake(M6.8) of 2004 was the forerunner of the seismic activity in northeast Honshu, followed by the Miyagiken-oki earthquake (M7.2) of 2005, the Noto-hanto-oki earthquake(M6.8) of 2007, the Iwate-Miyagi inland earthquake(M7.2) of 2008, the Sanriku-Joban-oki earthquake(M9.0) of 2011 and the North Nagano earthquake(M6.7) of 2011.
Those seismic areas are encircled by two rows of ring-like arrangements of faults accompanied by shallow and deep earthquakes in Honshu but two rows of half circles are put under the south end. Ring-like arrangement in off-shore areas of northeast Honshu is of shallow earthquakes. The arrangement of faults of shallow and deep earthquakes in northeast Honshu run parallel each other. The parallel arrangements of faults accompanied by shallow and deep earthquakes and the synchronous activity of shallow and deep ones might be due to the vertical extension of ring-like structure of faults. These structures contradict to the supposed subduction of plate along the deep earthquake zone, as the plate can be traced on the tomography under the coastal and central part of Honshu, but cannot be found under the area of the Sea of Japan.

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Variation of volcano-seismic energy of the Super-hot-Plume in the South Pacific

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Super-hot-plume developed in the South Pacific is a huge thermal transfer channel connected with the Earth's outer core. It is a greatest thermal energy source of the Earth. Thermal energy that is the origin of a volcanic activity can transform to kinetic energy which generates earthquakes. The area of investigation is the South Pacific bounded by the latitude 0°~40°S and the longitude 150°E to 140°W. A quantitative analysis of the total volcanic eruption energy based on their magnitude shows that volcanic energy release from the South Pacific region peaked in the years 1978, 1980, 1985, 1988, 1994, 1998, 2000, 2004 and 2006. However, the peaks of volcanic activity in the world occurred few years after these peak years. On the other hand, the most outstanding seismic energy release from the South Pacific occurred in 1975, 1980, 1995, 1997, 2000, 2002 and 2007. Like the volcanism peak years, the worldwide seismicity peaks lag by few years. These results lead to the following conclusions: First the volcanic and seismic activities start with the rise of temperature in the outer core of the Earth. This is followed by the temperature rise in the super-hot plume situated above the heated outer core. The energy spreads ubiquitously throughout the globe and generates earthquakes and volcanic eruptions one after another along their passages of transmigration.

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The universality of crustal-wave mosaic structure theory

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Since the authors published "The oil/gas boiling inclusion and its geological significance" in the 33rd IGC, we have found 3 core samples with fractures, in which all contain oil/gas boiling inclusions group, so that it rules out this geological phenomenon being only a rare event, it also enriched the substantial geological model of the Earthquake Pump. Through the analysis of more petroleum samples, we confirmed that the oil/gas decompression boiling is a universal reversible geological phenomenon. Accordingly, the authors propose a concept of "Decompression Boiling Zone" that links the Block Waves Movement and the hydraulic press principle. In that we think the decompression boiling is the dominate mechanism for the crust differentiation and fusion, and tectonic active belt s are belts of the decompression boiling zone, which are belts with frequent magma, earthquake, and volcano activities also. Thinking along the same lines, the authors analyzed the distribution of the deep source zone and Japan 311 earthquake at the circum pacific tectonic belt, ex plained that the circum pacific volcano-seismic belt was triggered by the waves movement of the pacific block, that it is the most active decompression boiling zone in recent period and the fusion belt of oceanic and continental crust. Therefore, the authors believe that the crust wave mosaic structure theory could become the most universal tectonic theory.

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Ancient and continental rocks from the world oceans

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Little known to the current community of Earth Science is the fact that ancient and continental rocks have been discovered in localities > 100 of the world oceans. Grouping them into four types, we investigate their implication to ocean genesis. Type A rocks (*continental rocks* located in continent-ocean transition deeper than the ocean-floor depth) prove that part of continent has submerged and turned to ocean floor. Type B and C rocks (*continental rocks* and *rocks with continental geochemical signatures*, located in mid-oceanic ridge and ocean basin) inherit the original continental nature of ocean. Type D rocks (*ancient rocks and fossils* significantly older than predicted oceanic plate ages) indicate the longevity of oceanic lithosphere back to 1.9 Ga and Ordovician. Widespread occurrence of the four-types of rocks thus suggests that ancient continental lithosphere has been destroyed under the world oceans, in association with Meso-Cenozoic vigorous magmatism and deepening. Since marine geological surveys are still extremely sparse, future drilling and dredging may clarify the systematic heritage of ancient continental lithosphere under the world oceans, as well as the destruction process.

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On the Energy Causing Earthquakes, Demonstrated with 2008 Wenchuan Earthquake

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At present, many people believe that earthquakes are caused by sudden rupture of active geological faults. Based on this hypothesis, the energy causing earthquake is the elastic stress and strain energy stored in deformed crust rocks along the faults in association with the plate tectonics hypothesis. The speaker has presented a different type of energy causing earthquakes. The new type of energy causing earthquake is the physical expansion energy of highly compressed and dense natural (methane) gas escaped from fault zones in the deep crust. Therefore, the process of an earthquake can be described as an adiabatic process that is associated with the instantaneous & flashing interaction between the upward flying and expanding of huge highly pressurized natural gas escaped from its traps in deep fault zone of the crest and the surrounding lateral and upper rocks under the confinements of down-ward gravity, in-situ tectonic stresses and rock rigidness & strengths. The gas expansion power is the active force while the ground faulting is a passive consequence during earthquakes. The speaker discovered this gas energy from his intensive and compressive investigations of the devastating Wenchuan Earthquake of May 12, 2008 in Sichuan, China. The speaker has actively investigated the nature of the earthquakes. He has found many quake-related phenomena that happened before, during and after the quaking. These phenomena cannot be consistently and logically explained with the existing energy hypothesis of rock elastic rebounding. But, they can be consistently explained, well linked, and logically predicted with his gas energy hypothesis.

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The Cenozoic Destructive Concenters – a new category of the Earth's ring structures

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The term "Cenozoic Destructive Concenters" (CDC) proposed by the author for new category of centrally symmetric (ring) structures. CDC are the regular sets of the youngest breaks of the Earth's surface: major rivers, abrupt sea shores, sea floor scarps. Focused research showed that most of it are an arcs of the ideal circles whose radii vary up to many thousands of kilometers, the spatial distribution is concentric, the centers are confined to the lows where basaltic volcanism is manifested frequently. CDC are numerous and overlap each other on the principle of superposition. Atypical example is the Bering CDC, which center is located in the eponymous Strait. The cone of destruction of the solid body under the action of shock wave from below serves as an adequate model of a single CDC in the section. In addition, the Bering CDC is divided by two diameters into opposing quadrants of compression (Chukchi and Seward Peninsula) and tension (Bering and Chukchi Seas). I assume that the system of ring breaks was generated by impulse-wave (seismic) energy flow that originated at the mantle-core boundary, and the alternation of the quadrants of compression and expansion is a consequence of the rotation (horizontal) forces.

ABOUT THE NCGT NEWSLETTER

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

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