THE EMPIRICAL SCHEME OF SHORT-TERM PREDICTION OF EARTHQUAKES AND THE CRITICAL PARALLELS OF THE EARTH

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ABSTRACT

Until recently, short-term prediction of earthquakes with answers to the main triad of questions (When ?Where ? What magnitude ?)was considered an unsolvable problem. And if for the forecast of place and energy (or magnitude) a number of empirical regularities confirmed with theoretical models was set, the principal possibility of short-term forecast of the time (a period from several days to months) of the beginning of earthquakes was denied by most professionals. To answer the first question of the main triad of forecast there were not reliable empirical regularities and model approaches. This was due to a flashing character in time and mosaic manifestation in the space of many types of earthquake precursors of different geophysical nature and ambiguity of their interpretations. However, the development of Internet technologies and means of terrestrial and space monitoring of different environmental parameters have allowed in real-time to obtain, compare and analyze various anomalies in the Geosphere shells of the Earth: the magnetosphere, the ionosphere, atmosphere, lithosphere and deep layers of the Earth. This has led to a breakthrough in solving the main problems of Geophysics-short-term prediction of strong earthquakes.

KEYWORDS

Short-term earthquake prediction, seismomagnetic meridian, seismotectonic cloud indicator, critical parallel, explosions of gas in mines.

SHORT-TERM EARTHQUAKE PREDICTION

According to the empirical scheme of Scientific Center of Operative Monitoring of the Earth (SCOME) of short-term forecast [1,2] Earthquake with a magnitude of M>=6 usually occur along the boundaries of lithospheric plates at the intersection with the zones of action of seismomagnetic meridians (SMM). The topological type of SMM with ±3º zones of their actions and earthquakes with M>=4.5 happened during the period of June 07-21, 2011 is presented in Fig.1, which is one of the many examples of retrospective validation of main geophysical empirical regularities of forecast schemes [1,2]. In Fig.1 potential forecast zones in areas where SMM intersect with the boundaries of lithospheric plates are shown with dashed circles, and their radii only visually increases from the equator to the poles due to distortions in the Mercator projection.

Let us notice that only two of four SMM in Fig. 1 occurred seismoactive for earthquakes M6+, in the zone of action of which there were three strong seism activities: along SMM-23/157 (blue) in New Zealand, Papua New Guinea and Santa Cruz; along SMM 112/-68 (green) In Peru, Chile (Antofagasta) and the Moluccan sea. All other earthquakes were with M<6 and they are explained by the induced seismicity and aftershocks from the previous strong seism activities or earthquakes, when the SCOME scheme does not always work.

The algorithm of calculation of SMM with the help of instrumental fixed geomagnetic disturbances from geoeffective phenomena on the Sun is described in details in [1], where there are data on forecasts by the SCOME scheme of more than thirty earthquakes for the period from January 2007 to January 2010. And in [2] the implementation details are described on the SCOME scheme of forecast experiment on Taiwan: 7 realized forecasts with M6+ for the period of 7 months.

Until recently, most seismologists and geophysicists denied the possibility of short-term forecast of the time of seismoactivities, prepared in deep layers of the Earth. However, according to the SCOME scheme the most likely dates d_* of the possible sequences of earthquakes in zones SMM are determined by the formula

$$d_* = d_s + \left[\left(7 \vee 14 \ \vee \ 21 \right) \pm 2 \right], \qquad (1)$$

where d_s is date of geoeffective events on the Sun such as flashes or coronal mass ejections.

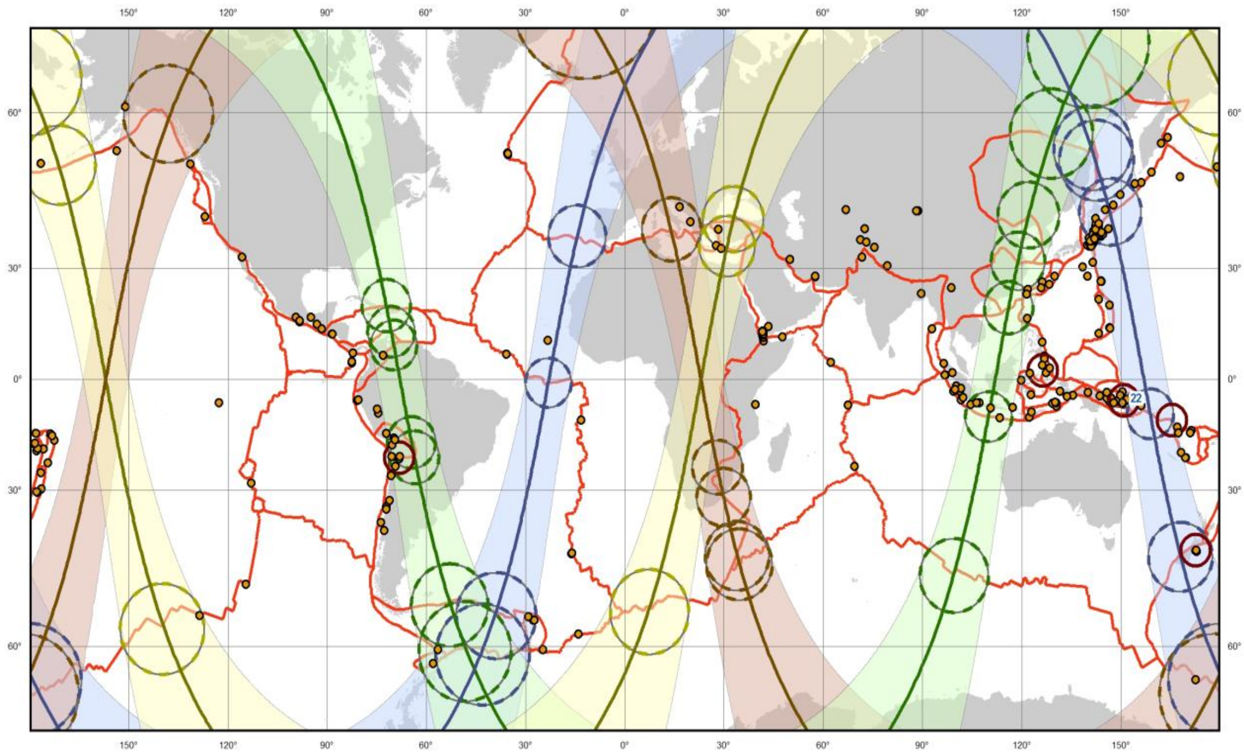

Fig. 1.Seismomagnetic meridians and chains of earthquakes in June 2011

In the methodology of short-term SCOME forecast seismotectonic cloud indicators (STCI) play an important role. It is new and the most informative type of earthquake precursors. STCI do not only provide additional localization of places of possible earthquakes in zones of intersection of SMM with the boundaries of lithospheric plates, but also they allow to estimate the potential value of magnitude M with accuracy of ±0.2 of future earthquakes with simple formula [1,2]

$$L/L_0 = \exp M \Leftrightarrow M = \ln L/L_0 , \quad L_0 = 1km \qquad (2)$$

where L is the maximum linear size of STCI.

In formula (1) compared to [1,2] weak dependence from the number Carrington turns of the Sun in 27 days is omitted, but here are added: the possibility to run earthquakes in one week, and not only after two or three weeks. Seismoeffectivity of geomagnetic perturbations for seven days in deep layers of the Earth after recent (1-2 years) strong earthquakes or in coal mines with potential explosions of gas was first reported in [3].

The most characteristic example of this kind is a powerful earthquake on May 9, 2010 with M=7.2 on Sumatra, which occurred in the area of the two close SMM from May 02, 2010. This double SIM went through Kuzbass (Russia), where exactly in 7 days May 09, 2010 occured the tragedy known in Russia with the explosion of gas and human losses in mine “Raspadskaja”, and on May19, 2010 in mine “Alexievskaya” the accident occurred with the collapse of the roof. The retrospective analysis also revealed other cases of 7 day seismoactivity of geomagnetic perturbations in the areas of the SMM. In particular, the strong earthquake on Sumatra on December 22, 2007 with M=7.4 ([1], table 1, case №8, where in line 5 the icon “R” means that the forecast is officially registered in the Russian Expert Council on earthquake prediction - REC). Later there were fixed other cases of 7 day seismoactivity in the areas of SMM in different seismic regions of the planet: July 18, 2011 in the sea of Okhotsk and Krysa Islands with M=5.2 and 5.6, and in the next three months in Italy, Japan and Taiwan with a magnitude range M=5.8±0.2.

However, from mid-November 2012 the solar activity increased, to make predictions in accordance to the SCOME scheme and moreover to distinct clearly the 7 day seismoactivity became problematic because of the abundance of SMM. If for each month (up to August 2013) we draw all SMM on the map as in Fig. 1, even without the allocation of zones of actions of ±3º degrees, SMM will actually cover the entire surface of the Earth and in this “web” it is extremely difficult to analyze. However, we note several important cases of accidents and explosions of gas in mines that deserves special attention: January 28, 2013 (Pakistan), February 11, 2013 (Vorkuta, Russia), May 10, 2013 (China) and, especially, May 13, 2014 (Turkey) that occurred on the date of the new or full moon ±1 day. The latest tragedy will be analyzed separately.

The analysis of specificity of 7 days seismoactivity of geomagnetic perturbations for weak seismoactivities with M<5 (including mountain strikes with accidents and gas explosions in mines) and strong earthquakes with M>6 is not finished because of the low statistics. However, the consideration in formula (1) the term of one week from mid-2012 have already increased the efficiency of the empirical scheme of short-term forecast [1].

Morphological classification of STCI is presented in the thesis [4], where the five main types are highlighted, and in [5,6], the analysis of fast change of types STCI was done in the period February 18-20, 2011 in the area of future mega-earthquakes Tohoky, March 11, 2011 with M= 9. In cases where the rapidly changing of types of STCI occur the potential magnitude is calculated by formula (2) with the maximum linear size of all types of STCI.

Despite the mentioned difficulties of short-term forecast since November 2012 according to the SCOME scheme during from July 21, 2011-March 13, 2014 and Japan more than 30 forecasts of earthquakes with M6+ was realized, including nine forecasts with M6.5+ officially registered in REC and eight of them was realized with magnitudes M=6.7/6.9/6.8/6.9/7.3/6.5/7.1/6.3 and only one missed on February 02, 2013 with M=6.9 on Hokkaido.

When developing forecasts for Japan and other seism dangerous regions of the world in addition to formulas (1) - (2) and algorithm of calculation of SMM and searching and identification of STCI there applied system analysis of a wide range of often interdependent litosphere-atmospheric-ionospheric (LAI) signs [1] of the preparation and beginning of earthquakes. The example of usually analyzed LAI characteristics is presented in the work [2] in Fig. 1, and the method of their analysis and forecasting scheme of SCOME are described in details in [6].
Although initially the empirical scheme [1,2] have been developed for the prediction of crustal earthquakes with M6+ along the boundaries of lithospheric plates, but the main geophysical regularities of this scheme has proved effective for prediction of deep-focus earthquakes off the coast Kamchatka. Since 2002 there were realized all registered in REC forecasts for earthquakes with M7+ on Kamchatka seismic zone, the data presented in table 1.

In [1] there were noted general situations, when the empirical scheme of forecast can give some failures on the time, place, or the magnitude: 1) if in the zone of the SMM there are active volcanoes; 2) if in the area of future epicenter there are powerful typhoons; 3) when there is the effect of “failure date” of initial forecast in the area of intersections or small distance between various SMM when that replaces a single strong earthquakes in a series of weaker ones.

Table 1

№	Real event/Prediction			Recording method, date documenting
	date / period	place (latitude; longitude), [degrees] – depth, [km] / prediction zone	Magnitude, M	
1.	Nov. 17, 2002	(48.1; 146.0) – 500 – Sea of Okhotsk	7.3	REC, Nov.11,2002
	until Dec.12, 2002	Kamchatka	7.3+	
2.	Apr. 20, 2006	(61.1; 167.1) – Koruakia, Russia	7.7	REC, Apr.12,2006
	until Apr.19, 2006	Kamchatka or Kuril Isl.	6.0+	
3.	July 05, 2008	(53.9; 152.9) – 632 – Sea of Okhotsk	7.7	SCOME website, Jun. 06,2008
	until July 07, 2008	Kamchatka	7.0+	
4.	Nov. 24, 2008	(54.2; 154.3) – 600 – Sea of Okhotsk	7.3	REC, Nov.12,2008
	until Dec.01, 2008	Kuril Isl. or Kamchatka	7.1+	
5.	Aug. 14, 2012	(49.8; 145.2) – 625 – Sea of Okhotsk	7.7.	REC, Jul. 31, 2012
	until Aug. 17, 2012	Kuril Isl. or Kamchatka	7.0+	
6.	May 24, 2013	(54.9; 153.2) – 605 – Sea of Okhotsk	8.3	REC, May 20,2013
	until June 16, 2013	Kamchatka	7.4+	

An illustration of the latter two situations is the analysis of seismomagnetic and cloud conditions for June 2009 in Central America (Fig. 2). Then the forecast area was covered with six different SMM from June 04, 2009 till June 24, 2009. Therefore, according to formula (1) and taking into account the two - and three-week harmonics in this area there could be earthquakes in the period of June 16 - July 18, 2009 (Fig. 2 the probable date is specified along each SMM). It's no accident that the official forecast in REC ([1], table 1, №№ 16, 17) was registered on three SMM on June 14, 2009 with the latest date July 05, 2009 ±2 days. Notably, two earthquakes M6.0 occurred within the specified period; and three serial Typhoon in the area (A) of the first STCI off the coast of California reduced the potential magnitude of M 6.7 by formula (2) to the real 6.0, and in the zone of the second (B) STCI type with a potential value of M=7.4±0.2 there were a series of four earthquakes with M<5.

Some cases of replacement of predictable by the SCOME scheme seismic activities on the volcanic activities were noted on Kamchatka ([1], table 1, nos 14, 26), and later were recorded in Italy, Iceland and Japan. However the authors consider that the most impressive case of this replacement is a sudden awakening of the volcano Flat Tolbachik (November 27, 2012) on the Kamchatka Peninsula after the 36-year-old “sleeping” and of the considered long extinct volcano

Puyehue (June 06, 2011) in Chile, because of the eruption and emission of ashes which in the southern hemisphere many airports were closed, and the total damage exceeded 2.5 billion dollars.

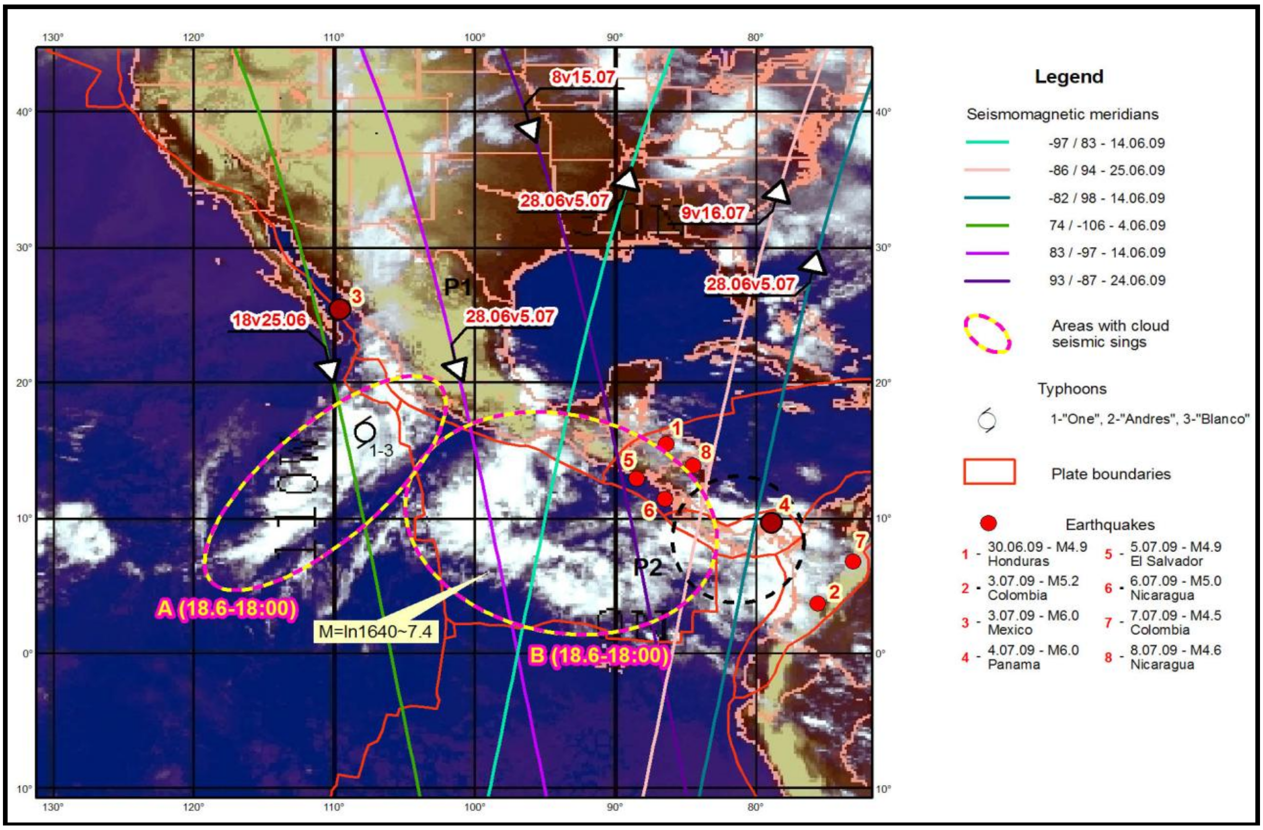

Fig.2. Seismomagnetic and cloud conditions in Central America in June 2009

The retrospective validation of empirical scheme of forecast according to archival data of the British Geological service about three-hour AA-index of geomagnetic activity for June 1908 led to the unequivocal conclusion that the time and place of the famous Tunguska catastrophe (June 30, 1908) fully comply with the SCOME scheme (Fig. 3). And system analysis of complex of other LAI signs and famous paradox of this mysterious phenomenon of nature allowed to develop geophysical scenario of Tunguska as volcanic earthquakes with developed gas phase and detonation of hydrogen-methane degasification jets from the crater of Kulikovskii paleovolcano that was the epicenter (60º53N, 101º53E) of the Tunguska catastrophe [7].

The analysis of other SMM (Fig. 3) allowed to explain and other phenomena related with Tunguska: 1) powerful geomagnetic storm June 03, 1908 exactly two weeks after strong intensification of the volcano mount Erebus in Antarctica ; 2) SMM on June 24,1908 covered the sea of Azov and provoked a powerful gas explosion at Makariev mine in the Taganrog district exactly one week after that;3) SMM on June 26, 1908 went through Italy and Sicily, where Etna activated; 4) powerful geomagnetic perturbations on June 29, 1908 caused a bright glow of the night like polar lights not only in the North, but also in Antarctica seven hours before Tunguska, and on the morning of June 30, 1908 a giant protuberance was registered on the Sun. In the framework of geophysical scenario in the review paper by N.V. Vasilyev [7] the known paradoxes of Tunguska received a mutually agreed explanation that could not be done within the framework of traditional (meteor or comet) versions.

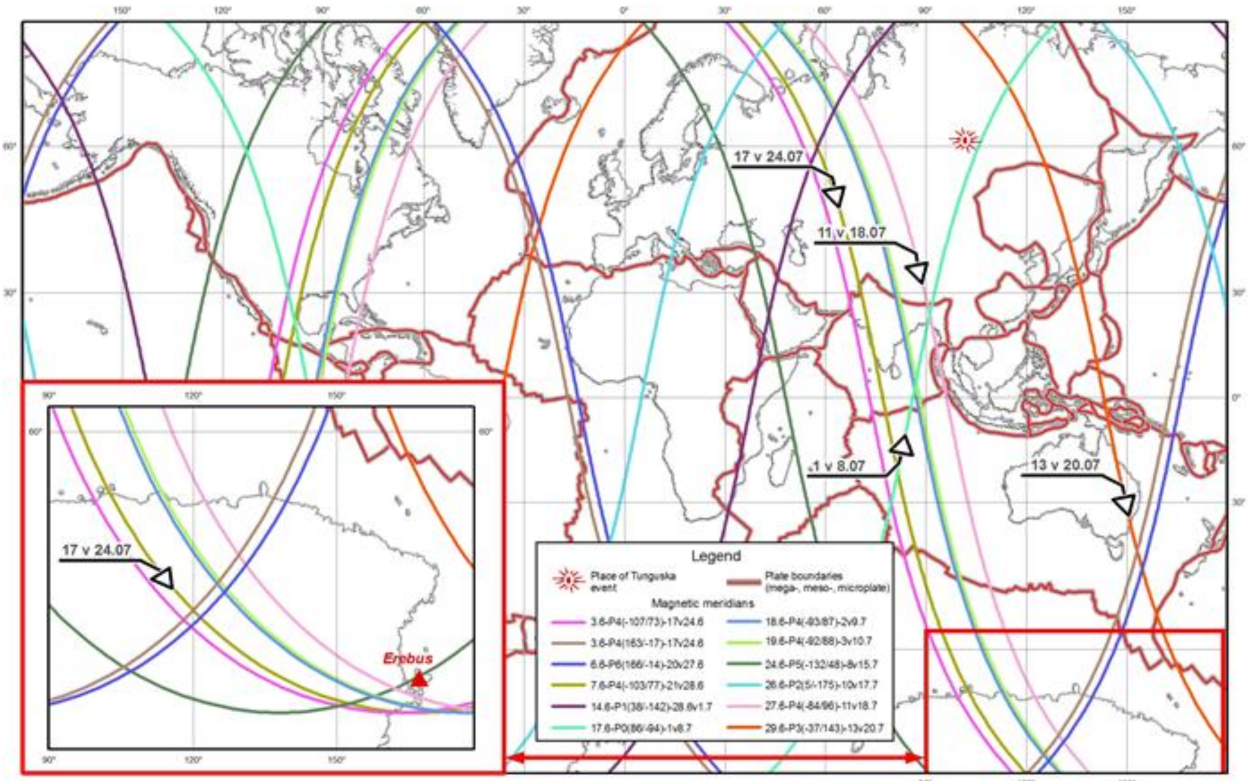

Fig. 3.Seqsmomagnetic situation in June 30, 1908

THE CRITICAL PARALLELS OF THE PLANET AND NATURAL DISASTERS

In the late 1960s the old hypothesis of mobility of the continents by A.Vegener received a powerful impulse and development, first in the form of kinematic scheme of movement of lithospheric plates on the underlying mantle. Since then this scheme became a dominant concept of global tectonics. Many supporters of this concept connect activation of tectonic forces, which manifests itself in seismic and volcanic activity, with the processes inside the Earth. In this concept, which many researchers call a theory, in fact there is no place to account rotational forces at the expense of own rotation of the planet, as well as external influences of the Moon, the Sun and other planets on the Earth that moves in complex way in space.

At the beginning of XX century the alternative approach was recognized based on the laws of Newtonian mechanics and taking into account rotational force from the own rotation of the Earth and the gravitational influence of the Moon and the Sun. This approach allowed to receive theoretical justification of the so-called critical parallels that were originally partially revealed by geographical topography of the planet. Significant contribution to the study of critical parallels made Liebenson (Russia, 1910), A. Veronnet (France, 1912), P. Appell(France, 1932), F. Krasovsky (USSR, 1941), B. Lichkov (USSR, 1944), M. Stovas (USSR, 1959-1975) and other. The last author was one of the representatives of the Leningrad school of planetary geophysics (astrogeology) and he investigated almost the entire set of critical parallels or latitudes of the globe in the works [8]: 0º the equator, ±19º, ±35º, ±48º, ±62º, ±90 – the poles. Some authors distinguish two critical latitudes (±45º and ±65º), and two major critical meridians: the belt of 100º - 105º E and 70º - 75º W, 15ºE and 165ºW.

The critical parallels have been theoretically obtained by Stovas in the studies of extreme values of different characteristics at deformation of elastic ellipsoid (with its volume constant) as a model the geoid. The important result by Stovas is the solution of the problem of the mechanisms of formation of planetary deep breaks in the earth's plates along the latitudes of ±35º. The model of complex loading of thick elastic spherical shell (layer) was researched with calculation of distribution of principal stresses (Fig. 4) in depth with changing of polar compression of the order of 10^{-7}. Maintensions $\sigma_{1,2,3}$ werecalculatedbytheformulas [8]:

$$\sigma_{1,2} = \frac{\sigma_r - \sigma_\theta}{2} \pm \tau_m, \quad \sigma_2 = \sigma_\varphi, \quad \tau_m = \sqrt{\frac{(\sigma_r - \sigma_\theta)^2}{4} + \tau_{r\theta}^2} \qquad (3)$$

where $\sigma_{r,\theta,\varphi}$ are the tensions in spherical coordinates; compressing and stretching tensions σ_1 (Fig. 4b) are directing along the surface tangent in the meridional direction from the equator and the poles to 35º parallel; the tension along latitudes σ_2 (Fig. 4a) acts perpendicular to the meridional planes and compresses spherical layer from the poles to parallel 35º, but stretches the layer from latitude 35º to the equator; the main tension σ_3 (Fig. 4b) acts on the external surface of spherical shell along radius-vector r and it is defines vertical movement because of volume expansion. Let us note that the distribution of σ_3 to the depth near latitude 35º is similar to distribution of σ_1 (which follows from formulas (3) and should be understandable to specialists in the field of elasticity), but outside of this zone lines of σ_3 have another topological view: when approaching the poles and the equator they seem to be spread and become similar to the spherical layers $r = const$.

It should be emphasized that with the depth the directions of σ_1 и σ_3 change, and the angle between the systems of coordinates r,θ and σ_1, σ_3 varies from 0° degrees on the outer surface of the shell and reaches a maximum of 45° on the inner surface of the shell in the zone of 35° latitude. The shortly described picture of stresses is correct under an overall increase of polar compression of spherical shell, and with decrease of polar compression the direction of main stresses are changed to the opposite.

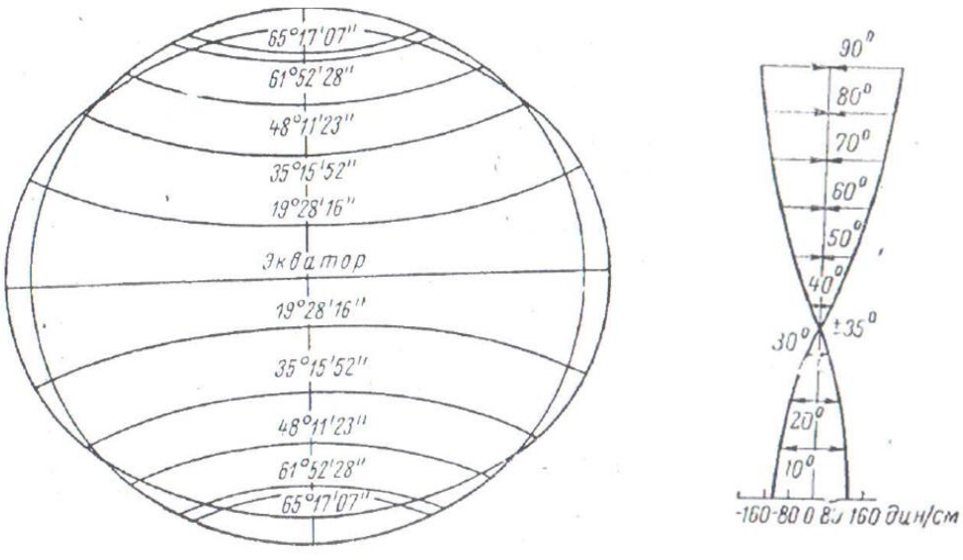

Fig.4a. The critical parallels of the geoid and the tension along latitudes σ_2

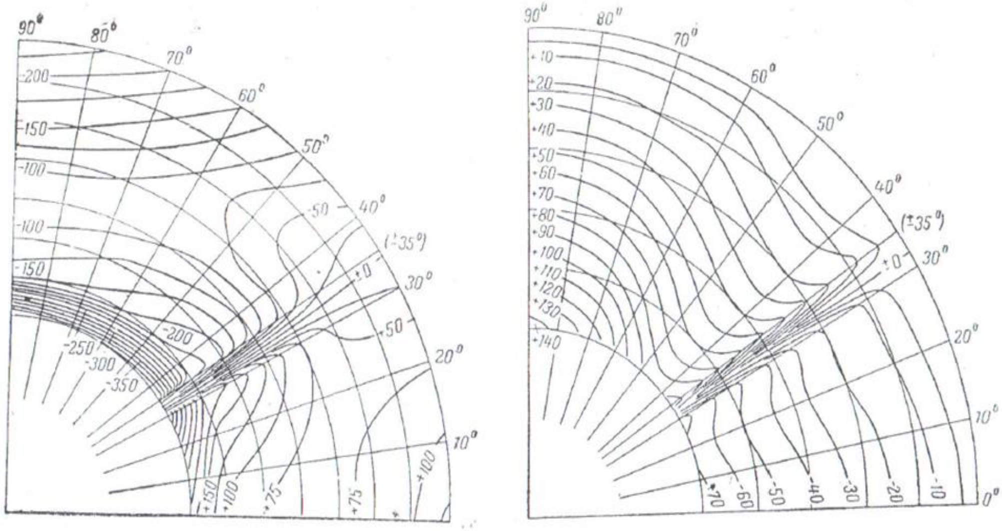

Fig. 4b. Meridional σ_1 and normal σ_3 tensions of the geoid

From these theoretical calculations it follows that the magnitude and direction of the principal stresses in the earth is continuously changing as the result of continuous variation of the rotational motion of the Earth in the system of the Earth-Moon-Sun, and therefore the accumulation of deformations occurs in the areas of critical parallels ±35º. This will evidently affects high seismicity of regions adjacent to latitudes ±35º. This conclusion of the theoretical calculations were confirmed by Stovas and other astrogeologists with sample statistics of strong earthquakes, latitude coordinates of which are grouped near the equator and give a noticeable peak in the area of ±35º latitudes. As examples are historically known earthquake: Lisbon (1755t; 38º), California (1872, 1906; 38º), Messina (1908t; 38º), China (1920, 1927; 35º-37º), Tokyo(1923t; 35º), Japan (1933t - 1953; six earthquakes M7.5+; 33-38º), Chile (1835t, 1939, 1960t; -36º), Ashgabat (1948; 37º) and others. The letter "t" in dates means that the earthquake was accompanied by strong enough tsunami.

In addition to these empirical data on seismic activity in the area of the main critical parallels ±35º let us notice a unique case of almost simultaneous acting of twenty five volcanoes located from Santiago along the critical meridian 70W to Concepcion over 800 km in range along critical parallel 35S on April 18, 1932 in Chile.

But by the mid 70-ies of the XX century the fashionable concept of global tectonics of lithospheric plates already began to dominate among geophysicists and the theoretical results and empirical generalizations of astrogeology was forgotten quickly even in Russia. However, in recently there appeared some works where in statistical surveys on the distribution of earthquakes [9] and volcanism [10] considered the gravitational and rotary factors and the importance of critical parallels was demonstrated again clearly.

For the Northern hemisphere the results of work [9] proved the conclusions of astrogeology as for earthquakes with M>=5 (from 1900 till 1993, 1574 events), so for the cases when we take into account weak seismic activities with M>=4 (1973-1993, 109087 events) from catalog of NEIC. The maximum number of earthquakes was clearly observed in the area of 35N; for M>5 this maximum is almost two times exceeded the number of events in the region of the equator, for M>=4 max of 35N (16391 events) was almost equal to max of (0-9)S (16798 events). Local maxima in the range 10-19N (10964) and 10-19S (10705) was almost equal to each other that corresponds to the critical parallels ±19º. Other critical parallels in histograms with step of 10º are not explicitly revealed, but there is a certain asymmetry in the number of earthquakes with M>=4 and their energy for the Eastern and Western hemispheres, and the distribution of the total energy of earthquakes for the whole planet at the latitudes 30-39N, 10-19N, 0-9, 10-19Sи 20-29S were almost equal.

A similar analysis of the distribution of volcano eruptions in the catalog for the period 1900-1977 has shown [10] that relatively narrow 5-degree latitudinal zones of volcanic activity are separated with broader 15-degree zones of relative calmness. From the histograms there clearly stand out the most active volcanic zones with latitudes: 0-N (27%), 19+N (17%), 35+N (15%), 48+N (4%), 62-N (10%) in the Northern hemisphere and 19+S (6%), 35+S (4%), 48+S (2%) in the Southern hemisphere. Signs"+" or"-" means a shift with increases or decreases in degrees from absolute values: in particular, volcanic activity on the equator is slightly tilted to the side of the southern hemisphere, and in areas ±35º it is shifted to the poles.

The growing interest to the problems of planetary Geophysics in the light of the important role of astronomical factors is evidenced by the papers [11], where in a number of reviews they do not only remind the merits of astrogeology, but also provide modern data confirming the researches by Stovas.

In conclusion of the paragraph on the relationship of critical Parallels and meridians of the planet with the distribution of strong earthquakes and volcanism here are well-known examples of these natural disasters that have been predicted or retrospectively analyzed on the basis of short-term forecast by SCOME. Let us say about some catastrophic earthquakes: December 26, 2004 Sumatra (0 ,100E), January 12, 2012 Haiti (19N, 75W), March 11, 2011 Japan (38N), November 17, 2002 (48N) and August 14, 2012 (50N) in the sea of Okhotsk, Kamchatka. Mega earthquakes on Sumatra and Haiti with numerous human victims ([1], table 1, № 25) did not only happen at the intersection of critical parallels and meridians, but there also occurred anomalous cases of sudden awakening of long extinct volcanoes: June 06, 2011 Puyehue in Chile (35S, 70W) and June 30, 1908 the paleovolcano Kulikovsky (61N 102E) that was the epicenter of the Tunguska [7].

ACCIDENTS WITH GAS EXPLOSIONS IN MINES

A natural question arises: is there a link between accidents with possible gas explosions in coal mines and critical parallels or some special dates? Despite the absence of directories on these natural and man-made disasters it is possible to give an affirmative answer to the given question. In particular, for the period 1947-1963 it was proved by the explosions of gas and emissions of coal in mines of Donbass (Ukraine, 48N) statistically and it was found that such accidents occurred 15 times more often on the days close to the dates of the new moons and full moons [3,12]. For the period 1951-1996, statistical analysis on 8000 cases in mines of Donbass has already shown that when the moon was at perihelion or at aphelion 54% and 24 % accordingly of such accidents took place [3]. Less complete data on mines of Karaganda (Kazakhstan,48N) show that near the date of the new and full moon abnormally high number of accidents happen. Data available for 1970-2010 give that from seventeen accidents with gas explosions and victims in mines in USA (33-39N) nine cases happened after the full moon with delay of 2-4 days and 5 cases were near the new moon + / - 3 days. Three similar cases in New Scotia coal mines (Canada, 45°-46°N) occurred after the new moons in 2.2 and 7 days.

It is interesting that in some cases of accidents in mines of Donbass and Karaganda located near the critical parallel 48N were synchronized in date. The most striking example is September 22, 2006 (the new moon and the day of the autumnal equinox). Two days before this date there happened two explosions in mines of Donbass and oneexplosion in the mine near Karaganda, and in one day there took place the third explosion in Donbass.

In [3,12] such accidents are associated with deep hydrogen degassing, which increases rapidly near the dates of the new and full moon because of the solid lithosphere tides with an amplitude of about 10 sm. In all countries accidents in mines with gas explosions are traditionally associated with methane and they install sensors for this gas. However, the concentration of hydrogen from 4 to 72% in the air forms a very explosive mixture (explosive gas), and to initiate combustion or explosion one spark is often enough! While for starting combustion of methane it is open fire or a short circuit that is required with the formation of an electric arc in places of bad contacts in electrical equipment

It is known since 1956 that there is high concentration of hydrogen in mines in the Kuzbass coal basin. However there are not sensors for hydrogen in mines of Russia. Although the very necessity of these measures has been discussed for a long time [12].

In conclusion, let us recall about the tragedy of May 13, 2014 in Turkey in the mine near the town of Soma (39N), which has claimed more than 300 lives and happened a day before the full moon. Earlier of the date, this area was covered by three SMM (Fig. 5.) And in accordance with two-week harmonics the date of May 13, 2014 got in the forecast interval from each of these SMM. So the place and time of the incident in Turkey tragedy actually confirm geophysical regularities of the SCOME scheme and the facts of the special role of the new and full moon.

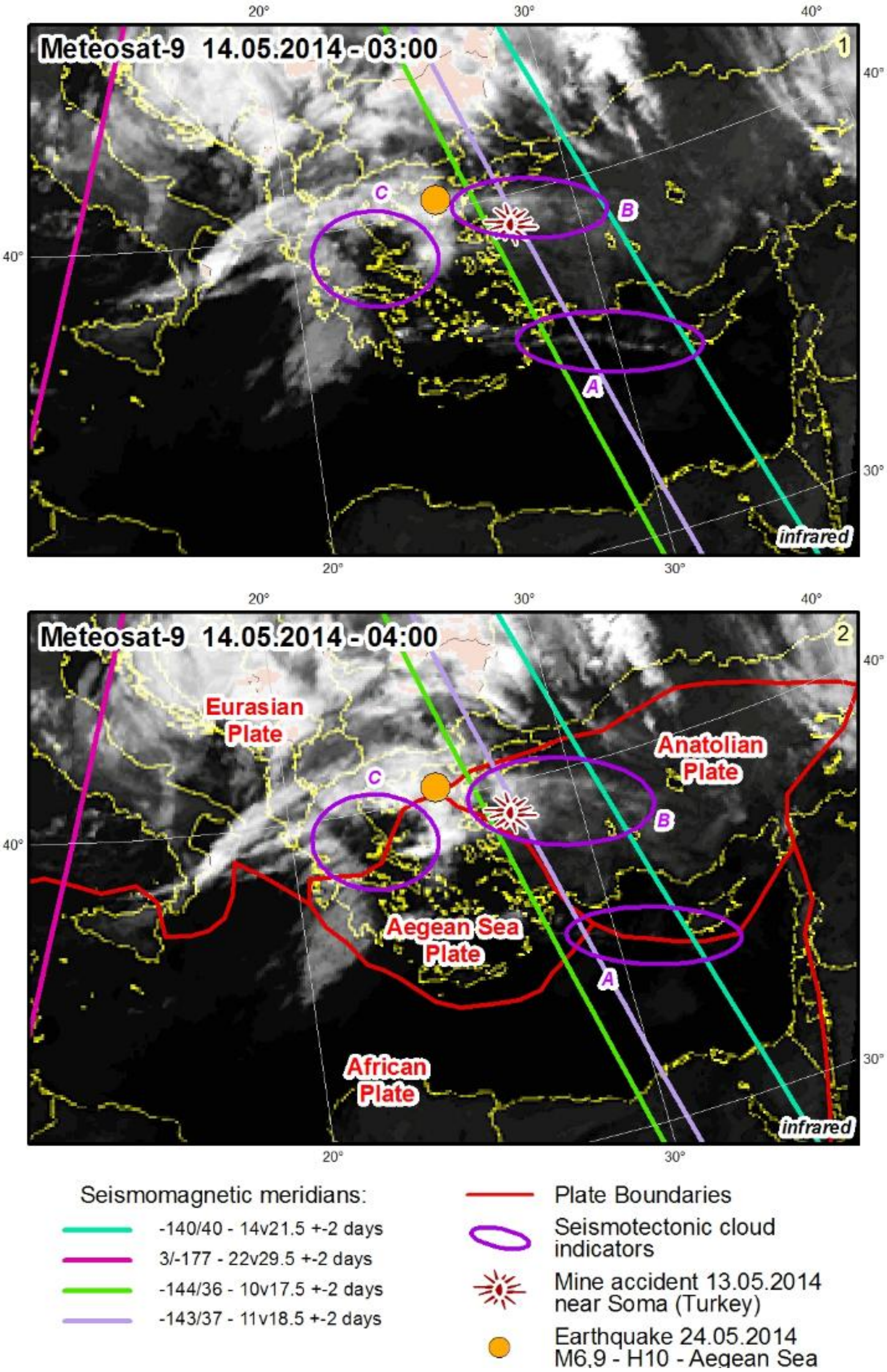

Fig. 5.Seismotectonic Cloud Indicators in Anatolia plate zone.

To prevent such tragedies in the future and to improve safety on mines it is necessary: 1) to install the sensors not only for methane, but also for more explosive hydrogen; 2) to take into account not only the specific phases of the moon and celestial configurations at spring and autumn equinoxes, but also potentially dangerous dates according to formula (1) in cases when the territorial area is covered with SMM from geoeffective events on the Sun.

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