American Continent Lithospheric Earthquakes after Nuclear Tests of France in November 1990

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***Abstract*—** *The correlation between lithospheric earthquakes on the American continent and tropical cyclones that arose after the French nuclear tests is considered. The transfer of the local impact of TC on the lithospheric plates of the other hemisphere is proposed to be assessed by the effect of "Fantom" TC symmetric with respect to the center of the Earth. It is shown that the localization of earthquakes shifts in accordance with the movement of the "Fantom" TC and its intensity. This indicates that TCs are a trigger for earthquakes in the most intense seismic areas.*

***Keywords*— nuclear test, typhoon, earthquake, american continent.**

I. INTRODUCTION

Earlier it was shown that in separate seismically active areas earthquakes correlate with the energy of TCs and their localization [1-6]. Moreover, the energy of lithospheric earthquakes released at all major faults during the day has maxima at the phases of a sharp increase and decrease in TC intensity, which was shown for the strongest typhoon Gay-92 in 35 years [4].

Several mechanisms have been proposed for the TC effect on earthquakes:

1. The first one is associated with oscillations of long waves excited by TC in the coastal zone. This mechanism has been studied using special seismic sensors at ~ 2800 US stations for more than 10 years [1].
2. The second one is associated with the lithospheric mechanism of the transfer of the moment of forces from the rarefaction area under the TC when it is located near the edge of the large lithospheric plate adjacent to the small one. This mechanism was considered in the analysis of small lithospheric plate earthquakes with magnitude M> 4.5 without foreshocks of [2-3].
3. The third one is that vertical displacements of the Earth's surface in the zones of action of a cyclone and anticyclone can cause a stress release in seismically active regions, as shown by the example of Kamchatka in [5].
4. Fourthly, it is shown that the impact of the Harry-89 TC during the passage of the New Caledonia Island can be considered as a lever that “lifted” the northeastern edge of the Australian plate, which caused a series of earthquakes [6]. By the example of the Vanuatu fault closest to the Harry TC, the change in the depth of earthquakes from deep focus h ~ 100 km to the upper boundary of the lithosphere h ~ 30 km is explained.

It seems important to return to the observations of the transfer of the Pacific Plate influence to the area of the Mid-American Trench and Peru-Chile Trench due to the French nuclear tests in November 90 [3], to explain the mechanism of the release of lithospheric stresses in areas far from the source of impact.

II. CORRELATION BETWEEN LITHOSPHERIC EARTHQUAKES AND TC INTENSITY

We consider lithospheric earthquakes h> 20 km near the American continent after the Nuclear Test on 14-Nov-90 before the dissipation of super typhoons Page and Owen on December 4. Earthquake data were taken from the United States Geological Survey (USGS) [7], and tropical cyclone data were taken from the Joint Typhoon Warning Center (JTWC). JTWC results for 1990 are presented in the report [8].

During the selected period, 24 earthquakes with magnitude M> 4.5 were recorded, which are presented in Table 1. When constructing a correlation between the energy of earthquakes and the intensity of TC (Fig. 1), earthquakes with M> 4.0 were taken into account, that is, 14 weaker earthquakes were additionally included.

TABLE 1
EARTHQUAKES M_W >4.5 NEAR THE AMERICAN CONTINENT

No.	Date 1990	Area	UT h:m	Epicenter N/W	Mw	Depth km
1	11-15	Coixtlahuaca, Mexico	04:27	17.91 / 97.33	4.7	70.4
2	11-16	South Sandwich Islands region	07:20	-59.71 / 26.24	5.7	33.0
3	11-17	Santiago de Cao, Peru	10:24	-8.68 / 79.88	4.7	35.0
4	11-18	coast of Central America	14:15	2.29 / 84.41	5.0	33.0
5	11-18	Cayarani, Peru	19:46	-14.62 / 71.9	4.8	136.3
6	11-18	Bonaire, Saint Eustatius and Saba	20:28	17.8 / 63.04	5.4	91.8
7	11-20	Tocopilla, Chile	16:28	-22.69 / 69.88	4.7	58.3
8	11-20	Diego de Almagro, Chile	22:33	-26.38 / 70.82	4.6	56.0
9	11-21	Iquique, Chile	07:56	-20.5 / 68.92	4.6	126.0
10	11-21	Las Vegas, Honduras	12:58	14.89 / 87.55	4.5	33.0
11	11-21	Curahuara de Carangas, Bolivia	16:45	-17.53 / 69.1	4.5	169.2
12	11-21	San Pedro de Atacama, Chile	23:23	-22.9 / 68.71	4.6	81.4
13	11-22	Los Andes, Chile	01:17	-32.19 / 69.99	4.6	119.7
14	11-22	Huarmey, Peru	14:25	-10.13 / 78.62	5.1	47.5
15	11-23	Zorritos, Peru	07:27	-3.62 / 80.82	4.9	33.0
16	11-23	Palora, Ecuador	22:15	-1.8 / 78.08	4.7	155.7
17	11-23	Salento, Colombia	22:35	4.71 / 75.57	6.1	144.6
18	11-24	Coro, Venezuela	07:53	10.76 / 69.42	5.1	41.9
19	11-25	Caucasia, Colombia	01:52	8.09 / 75.06	4.7	73.8
20	11-25	Sucúa, Ecuador	12:32	-2.69 / 77.77	5.4	25.4
21	11-26	Calama, Chile	18:50	-21.35 / 68.72	4.5	124.2
22	12-02	Calama, Chile	14:37	-21.82 / 68.33	5.3	120.7
23	12-03	Cepitá, Colombia	00:38	6.77 / 72.97	5.3	159.0
24	12-04	Upala, Costa Rica	08:02	10.91 / 84.85	4.8	159.0

The earthquake energy $\boldsymbol{E}$ in joules will be estimated by the formula (1) which connects it with the magnitude $\boldsymbol{M}$ [9].

$$\boldsymbol{M} = 2/3(\lg \boldsymbol{E} - 4.8) \tag{1}$$

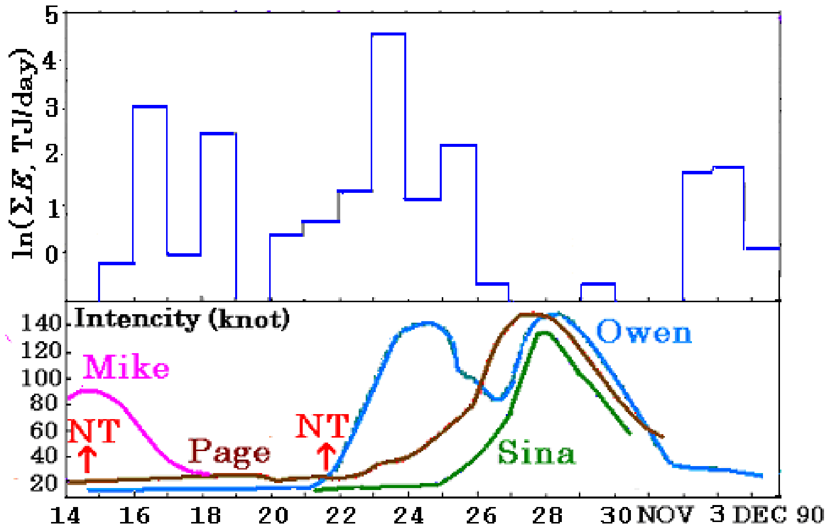

FIGURE 1: TC intensity and energy of lithospheric earthquakes per day

Intensity – the maximum sustained 1- minute mean surface wind speed, typically within one degree of the center of a tropical cyclone (1 knot = 0.51444 m/s).

The histogram values are given in natural logarithms of the sum of earthquake energies per day in terajoules.

In Fig. 1, four time intervals of seismic stress relief are distinguished. The picture becomes clearer if the earthquake sources and the centers of the "Fantom" TC are superimposed on the map of lithospheric faults, i.e. diametrical projections of TC centers to the other hemisphere (Fig.2).

III. LOCALIZATION OF EARTHQUAKES RELATING TO SEISMIC FAULTS AND "FANTOM" TC DISPLACEMENT

The transfer of the impact of typhoons Mike, Page, Owen and TC Sina on the lithospheric plates of the other hemisphere can be explained from the law of conservation of angular momentum. For a rotating closed system of interacting lithospheric plates, the change in angular momentum due to the uplift of the plate in the area of pressure drop in the center of the TC should be compensated by the corresponding movement of other plates. This impact will be considered as the impact of the "Fantom" TC. Fig. 2 shows their dates and the centers of the corresponding TC, enclosed in quotation marks.

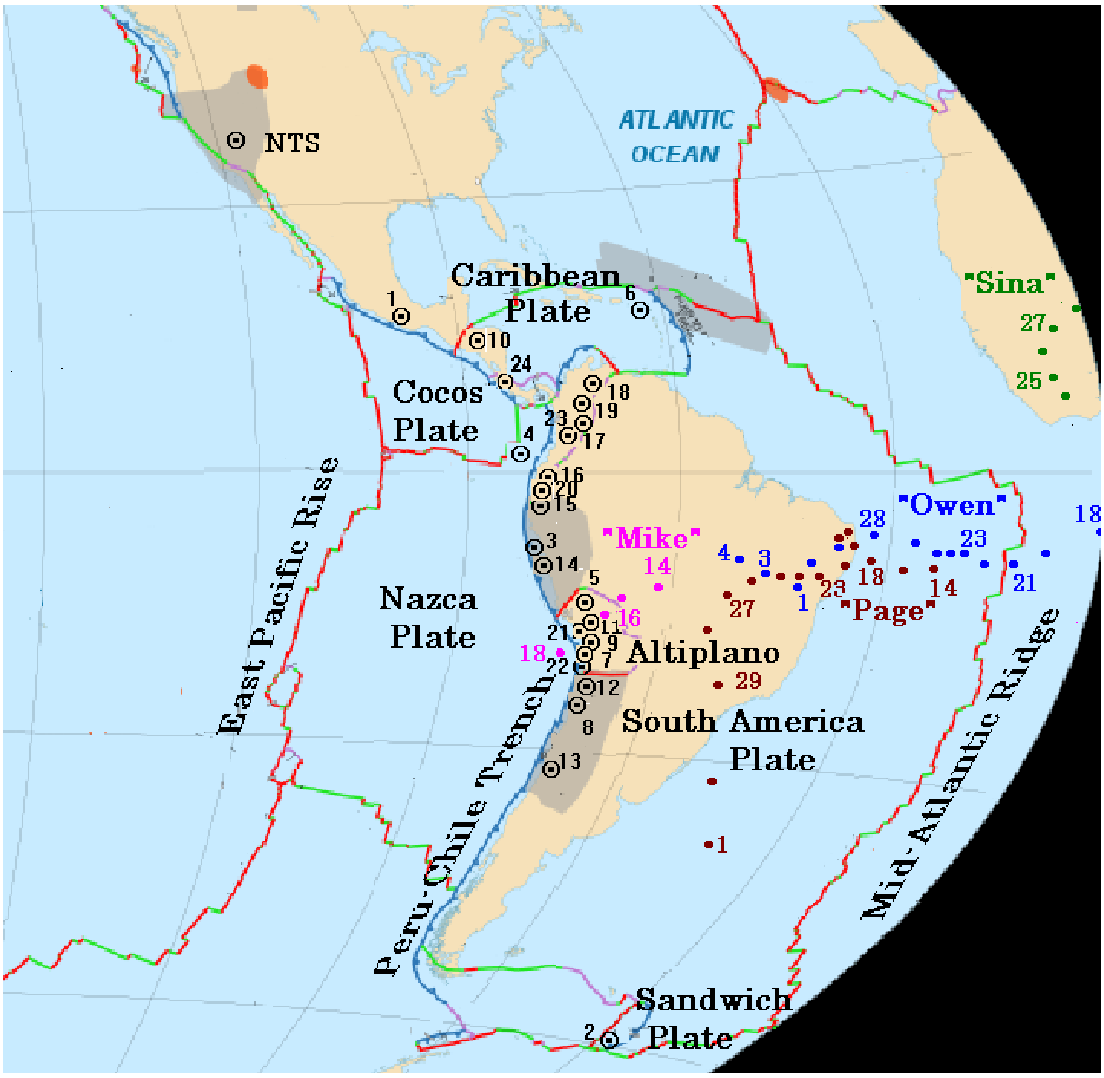

FIGURE 2: Location of earthquakes (Table 1) and diametrical projections of TCs on the map of lithospheric faults

Most of the considered earthquakes have occurred along the Peru-Chile Trench.

IV. THE DISCUSSION OF THE RESULTS

1. Earthquakes No 1-6 (Table 1) occurred on November 15-18 during the phase of falling intensity of Typhoon Mike (Fig. 1). During this time, Mike left the Philippine Islands and approached China. On November 17, it passed through the Hainan Island 270 km long. In a diametrically opposite area, "Fantom" Mike crossed the Altiplano high plateau and crossed the Peru-Chile Trench (Fig. 2). Earthquakes No 1, 5, 6 were deep focus with h ~ 100 km, which

corresponds to the pulling out of the "roots" of lithospheric plates from magma and their rupture in the weakest point [6]. Earthquakes No 2-4 were at a depth of h ~ 30 km, which corresponds to the pattern of uplift in the center of impact and downward movement at the edges of oceanic plates [6].

2. Earthquakes No 7-20 (Table 1) occurred on November 20-25 with the development of the first maximum of Typhoon Owen and an increase in Page intensity (Fig. 1). During this time, Owen approached Mariana Trench. On November 19-21 Page almost stopped, and on 22nd its center shifted to Challenger Deep. In the diametrically opposite area, the “Fantom” Owen crossed the Mid-Atlatic Ridge on 22-Nov (Fig. 2). After that, on 22-24-Nov at the stage of increasing intensity of Owen and Page, the foci of earthquakes No 13-18 began to systematically move to the north. At the phase of decrease in Owen intensity and increase in Page intensity, the foci of earthquakes No 18-20 began to move systematically to the south.
3. From 26 to 30 November, Owen, Page and Sina developed synchronously to the fifth category. Seismic activity on the American continent has dropped sharply. At the stage of their intensity growth, only one earthquake No 21 occurred. At the stage of decreasing intensity on 29-Nov, there are two earthquakes with M = 4.4. One thing happened in Mexico (5:30 UT, 18.3 N 100.6 W) when Owen's “Fantom” entered the mainland. Another happened in Peru (13:28 UT, 18.2 S 69.3 W) when the “Fantom” Page left the mainland. These earthquakes are not included in Table 1, but were taken into account when constructing the histogram.
4. Earthquakes No 22-24 (Table 1) occurred on December 2-4, when only Owen remained. All earthquakes were deep focus and strong enough, which indicates that, apparently, there was a relaxation of the displacements of lithospheric plates, which arose due to the impact of three super typhoons.

The forecast of the occurrence of earthquakes, at present, can be given probabilistically [10], which is shown in other articles of this collection. Satellite methods for monitoring the displacement of lithospheric plates are now widely implemented; see, for example, [11], which can confirm the main conclusions of this work. The development of crustal earthquakes, accompanied by the release of radon, can also be predicted by changes in a number of geophysical parameters [12].

V. CONCLUSION

1. The TC impact on lithospheric plates is one of the triggers for the release of seismic stresses.
2. Lithospheric earthquakes occur at the phases of a sharp increase and decrease in the TC intensity.
3. Critical moments in areas diametrically distant from the TC can be determined by the peculiarities of the movement of the “Fantom” TC relative to seismic faults.

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