Impact of France Nuclear Tests on typhoons and Earthquakes in November 1990

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Abstract— *The paper investigates the relationship between the development of typhoons and strong earthquakes after the France nuclear tests (NT) in November 1990. It is shown that after the NT acoustic impact on the tropical disturbance of the Pacific Ocean cloud structures self-organized into a system of three interacting category 5 typhoons. The dependence of the earthquakes M> 4.6 and the intensity of these typhoons as well as Typhoon Mike which passed earlier through the Philippine Islands are considered. Areas were found where the impact of typhoons led to earthquakes M> 5.4 of small lithospheric plates.*

Keywords—* *Pacific, nuclear test, typhoon, earthquake.

I. INTRODUCTION

Three mechanisms of interaction between tropical cyclones (TC) and strong earthquakes are usually considered. The first 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 [1].

The second 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 [2].

The third 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 [3].

Note that nonlinear self-organization of internal gravity waves (IGW) in the form of a separate TC or TC chain can occur due to an inhomogeneous geomagnetic field in the presence of a zonal stratospheric wind as shown in the cycle of theoretical papers [4-5]. This situation was observed after a series of American NTs in 1992 [6].

It seems important to return to observations in November 90 after the Nuclear Tests of France in order to understand the features of earthquakes in small lithospheric plates adjacent to the Indo-Australian and Philippine Plates. This paper is devoted to the study of the features of earthquakes in small lithospheric plates adjacent to the Indo-Australian and Philippine Plates. In this regard it seems important to consider in more detail the relationship between TC and strong earthquakes observed in this region after France Nuclear Tests in November 1990.

II. TYPHOON DEVELOPMENT IN THE EASTERN PACIFIC OCEAN

TC monitoring and forecasting in the Western North Pacific Ocean are in the area of responsibility of the Joint Typhoon Warning Center (JTWC). The results for 1990 are presented in the report [7]. The trajectories and intensity of TC's in November 90 are shown in Fig. 1 according to [7]. Asterisks mark earthquakes M> 5.4 in this region. 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).

Tropical Cyclone 03B was occurred the Bay of Bengal. TC formed on October 31 in the area (7 N 92 E), reached the coast of India on November 3 in the area (18 N 84 E), pick intensity 30 kt, min see-level pressure (SLP) 1000 mb.

Mike, one of the most intense and destructive Super Typhoon (ST) of 1990, caused havoc in the central Philippine islands, pick intensity - 150 kt, min SLP 885 mb – established 10 Nov 18 UT. Mike downgrade to Tropical Storm (TS) based on interaction with Vietnam coast 16 Nov 12 UT.

Page was the part of the three-storm outbreak which included a pair of TC near the date line: Owen in the northern hemisphere and Sina in the southern hemisphere. Persisting as a discrete disturbance for nearly two weeks before the first warning was issued. 26 Nov 06 UT Page upgrade to TS followed the development of a well defined 75 km diameter eye. Pick intensity 140 kt, min SLP 898 mb.

Owen started as a discrete cloud mass southwest of Hawaii 14-15 Nov. It started to rapidly intensify from tropical depression (TD) to typhoon intensity in less than 18 hours 21-22 Nov. Owen weakened and then reintensified to ST 26 Nov. Pick intensity 140 kt, min SLP 898 mb.

Sina was fist noted as a shallow depression within the South Pacific Convergence Zone to the west of Wallis Island. Sina subsequently peaked intensity 230 km/h (124 knot), min SLP 960 hPa during November 26.

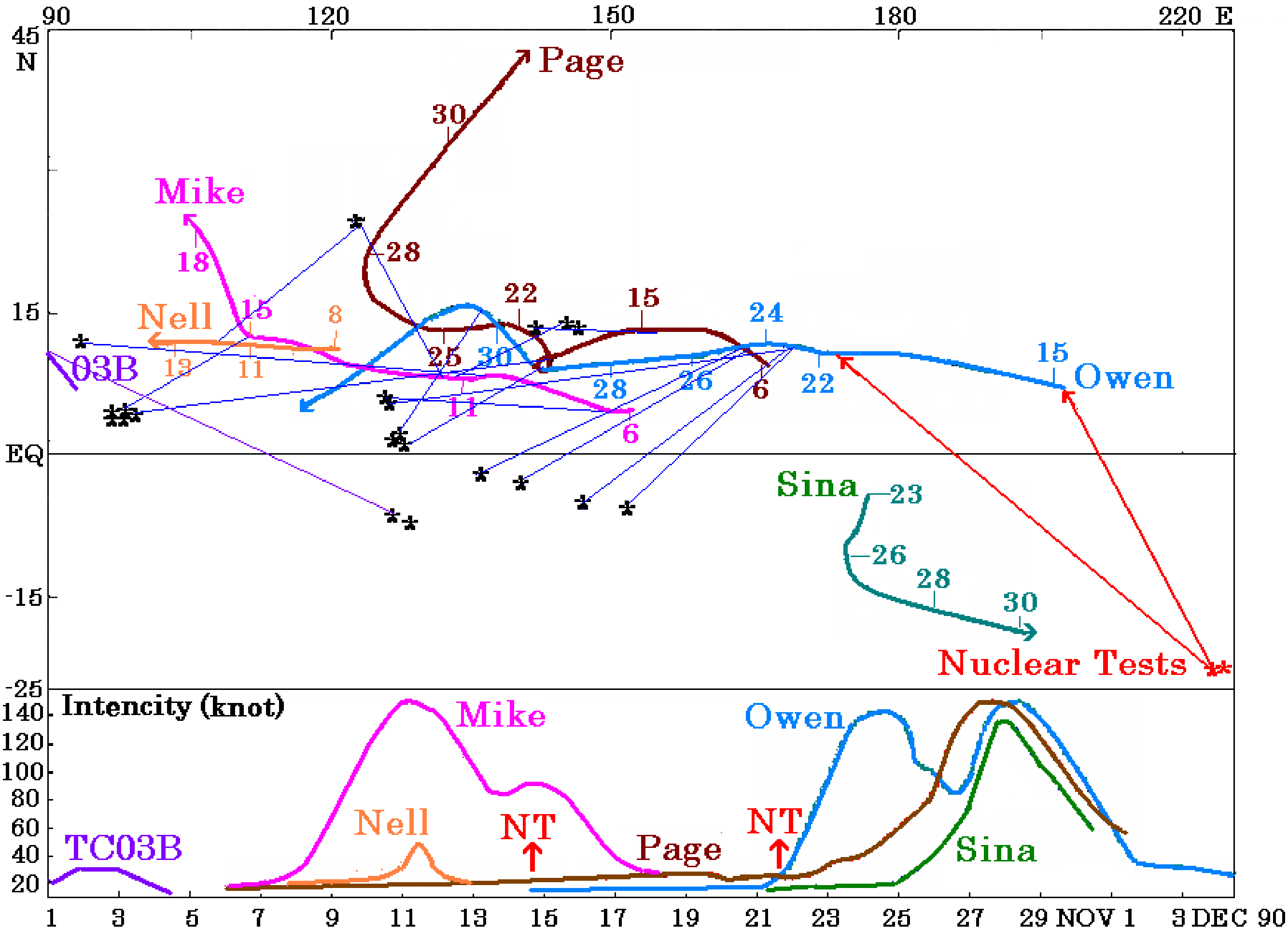

FIGURE 1: Trajectories and intensity of TC. Asterisks mark earthquakes M> 5.4, which are tied to the strongest and nearest TC.

The characteristics of the France underground nuclear test experiments [8] are given in Table 1.

TABLE 1
NUCLEAR TEST EXPERIMETS OF FRANCE

No.	Name	Date time UT	Epicenter S / W	Yield kt	Mw
1	Hyrtacos	14 Nov 1990 18:12	22.23 138.34	118	5.5
2	Thoas	21 Nov 1990 17:00	21.85 138.93	36	5.4

III. LITHOSPHERIC EARTHQUAKES OF INDIA, PHILIPPINES, INDONESIA, NEW GUINEA AND MARIANA ISLANDS

Earthquake data were taken from the United States Geological Survey (USGS) [9]. The region 4 S - 20 N, 92 - 148 E was chosen, 69 earthquakes with a magnitude M> 4.6 were recorded in it in November 1990.

They are concentrated along the main faults of the lithospheric plates. Four areas are highlighted in Tables 2-5 below. Shocks with maximum intensity are highlighted in red and aftershocks are highlighted in blue.

TABLE 2
EARTHQUAKES OF BIRMA MICRO-PLATE

No.	Date Nov 90	Area	UT h : m	Epicenter N / E	Mw	Depth km
13	7	coast of northern Sumatra	20:42	5.88 /92.07	4.6	35
19	10	southern Sumatra, Indonesia	11:07	-1.66 /100.48	4.9	80.1
20	10	Andaman Islands, India	11:30	12.21 /93.75	5.4	33
34	15	northern Sumatra, Indonesia	02:34	3.91 /97.46	6.7	48.4
35	15	northern Sumatra, Indonesia	04:48	3.98 /97.32	5.8	30.4
36	15	northern Sumatra, Indonesia	05:18	3.91 /97.29	5.6	53.5
37	15	northern Sumatra, Indonesia	05:47	3.92 /97.35	5.4	48.5
40	16	Simeulue, Indonesia	10:06	2.88 /95.82	4.9	33
42	17	northern Sumatra, Indonesia	02:13	1.26 /99.06	4.9	127.3
44	18	northern Sumatra, Indonesia	16:06	3.88 /97.36	5.1	61.8
45	18	northern Sumatra, Indonesia	16:23	3.94 /97.34	5.5	67.2
51	22	northern Sumatra, Indonesia	17:31	3.81 /95.26	4.8	57.2
57	27	northern Sumatra, Indonesia	00:28	3.22 /98.4	5.1	144.9

The Birma Micro-Plate earthquakes were most strongly impacted by the interaction of Typhoon Mike with the Vietnamese coast on Nov 15-18 and the intensification of Typhoon Owen on Nov 22 and 27 at the edge of the Pacific Plate.

TABLE 3
EARTHQUAKES OF PHILIPPINE ISLANDS

No.	Date Nov 90	Area	UT h : m	Epicenter N / E	Mw	Depth km
3	3	Sibuyan Sea, Philippines	15:21	12.9 /122.49	4.7	33
5	4	Molucca Sea	18:26	0.81 /125.19	5.3	33
7	6	Luzon, Philippines	00:37	16.34 /121.1	5.0	10
12	7	Mindanao, Philippines	14:36	5.64 /125.25	5.7	77.8
14	8	Molucca Sea	11:37	2.55 /126.65	4.9	33
22	11	Minahasa, Sulawesi, Indonesia	15:10	0.32 /122.23	5.1	130.9
26	13	Mindanao, Philippines	10:25	9.23 /126.3	4.7	33
38	15	Philippine Islands region	09:43	15.02 /122.04	4.9	22.1
39	15	Molucca Sea	17.32	0.43 /125.32	5.0	33
43	17	Mindanao, Philippines	20:00	5.6 /126.25	4.8	33
46	19	Mindanao, Philippines	01:36	9.89 /126	4.7	124
48	20	Halmahera, Indonesia	09:03	0.17 /127.01	5.8	114.1
50	22	Mindanao, Philippines	05:30	5.02 /125.43	4.9	196.5
52	23	Mindanao, Philippines	07:41	5.54 /125.85	5.5	125
55	25	Philippine Islands region	16:57	10.13 /126.17	4.8	34.5
56	26	Molucca Sea	02:05	1.51 /126.38	4.7	75.4
58	27	Mindanao, Philippines	09:34	7.55 /126.87	4.6	63.5
59	27	Luzon, Philippines	22:49	17.1 /120.09	4.7	65.3
64	29	Mindanao, Philippines	08:02	5.57/126.78	4.6	217.6
67	30	Minahasa, Sulawesi, Indonesia	13:19	1.03/123.97	5.8	28.3
68	30	Minahasa, Sulawesi, Indonesia	14:17	1.02/124.0	5.3	55.3

A very difficult situation was observed in the Philippine Islands in November 90 due to the passage of Typhoons Mike and Owen. However the earthquakes (No. 1-6) were most likely associated with the interaction of TC 03B with the coast of India. The resulting vibrations [2] could be transmitted along the Sunda Trench to the Philippine Plate. The stress release occurred along the Philippine Trench (No. 3 and 5) on 3-4 Nov, in Papua (No. 1) on 1 Nov, on the other side of the Philippine Plate near the Mariana Islands (No. 2, 4, 6) on 2 and 4 Nov.

A crustal earthquake occurred in Luzon at a depth of 10 km on November 6. The remaining 69 earthquakes were lithospheric ones with h> 20 km. This could be due to the fact that tropical disturbance began to develop in the western end of the Pacific Plate in the area (7 N 152 E). If in this case low-frequency oscillations arose, similar to observations [2], then they were captured in the Philippine Trench waveguide and caused a quake (No. 7). Most segments of the Philippines including northern Luzon are part of the Philippine Mobile Belt which geologically and tectonically separate from the Philippine Sea Plate [8]. Seismologists' views on earthquakes of the Philippines can be found for example in article [10].

The cloud system was localized (7.5 N 146 E) and transformed in TD (25 knot) on 7 Nov. as noted by JTWC [7]. A strong earthquake (No. 12) has occurred.

The development of Typhoon Mike was accompanied by separate lithospheric earthquakes at h ~ 33 km on 8-17 Nov.

Deep focus earthquakes occurred at h ~ 120 km on Nov 19-23. Before that in the rarefaction area of Typhoon Mike approaching Vietnam the Sanda Plate was uplifted and, accordingly, was subducting of the Philippine Plate. After the dissipation of Typhoon Mike relaxation occurred along the eastern and southern border of the Philippine Plate - earthquakes (No. 46, 48, 50, 52). The earthquakes are related to the intensification of Owen which passed through the Philippine Plate on 25-30 Nov.

TABLE 4
EARTHQUAKES OF MARIANA PLATE

No.	Date Nov 90	Area	UT h : m	Epicenter N / E	Mw	Depth km
2	2	Guam region	11:09	13.78 /143.93	4.8	33
4	4	Northern Mariana Islands	17:57	19.76 /145.32	4.6	171.3
6	4	Guam region	22:23	12.97 /145.2	5.4	51.8
8	6	south of the Mariana Islands	01:54	11.89/143.6	4.8	32.2
9	6	south of the Mariana Islands	10.24	11.83/143.64	4.9	33
10	6	south of the Mariana Islands	14:04	11.87/143.6	4.9	30.8
15	9	south of the Mariana Islands	14:40	11.87 /143.59	4.5	33
16	9	south of the Mariana Islands	15:10	11.92 /143.73	5.0	48.1
17	9	south of the Mariana Islands	23:06	11.83/143.69	4.9	37.9
18	9	south of the Mariana Islands	23:11	11.8 /143.69	4.8	33
21	11	Guam region	11:33	13.84 /144.44	5.4	142.9
24	13	Mariana Islands region	07:15	15.45/147.62	4.8	33
25	13	Mariana Islands region	07:38	15.59/147.8	4.7	33
28	13	Mariana Islands region	12:29	15.57/ 147.81	5.0	31.2
29	13	Mariana Islands region	12:37	15.55/147.73	4.8	33
30	13	Mariana Islands region	22:11	15.64 /147.79	4.7	34.3
32	14	Mariana Islands region	16:30	12.25 /141.14	5.4	126.8
33	14	Mariana Islands region	21:08	15.59 /147.75	4.9	30.2
41	16	Guam region	19:55	12.3 /145	4.5	33
49	21	Mariana Islands region	21:15	15.38 /147.44	4.8	76.4
60	28	Guam region	15:10	13.8 /145.1	4.9	33
62	29	Mariana Islands region	04:29	15.13 /147.48	5.1	31.8
63	29	Mariana Islands region	05:53	15.11 /147.56	4.8	23.3
65	29	Guam region	14:50	13 /143.83	5.1	126.6
66	29	Mariana Islands region	19:12	17.06 /147.24	4.6	69.2
69	30	Northern Mariana Islands	15:24	16.44 /145.74	4.5	543.2

Three quakes (No. 8-10) occurred in an area of ~ 10 km at a distance of 120 km north-east of Challenger Drop on 6 Nov. Typhoon Mike began to form at the western end of the Pacific Plate (7 N 152 E).

Four quakes occurred in the same area (No. 15-18) on 9 Nov. Typhoon Mike intensified to ~ 100 kt and shifted to Caroline Plate (9 N 137 E).

Strong earthquake struck Guam (No. 21) on 11 Nov. Typhoon Mike moved to the southern end of the Philippine Plate (8 N 132 E).

The earthquakes were determined by the movement of Typhoon Mike on 13 - 16 Nov.

Also the earthquakes are associated with the strengthening of Typoone Owen which passed through the Philippine Plate on 28 - 30 Nov.

TABLE 5
EARTHQUAKES OF PAPUA AND NEW GUINEA

No.	Date Nov 90	Area	UT h : m	Epicenter N / E	Mw	Depth km
1	1	Papua, Indonesia	03:39	-3.53 /139.37	5.7	35.3
27	13	coast of Papua, Indonesia	10:30	-2.44 /139.86	5.2	33
31	14	Papua New Guinea	03:14	-3.03 /142.07	5.2	33
47	19	coast of Papua, Indonesia	15:31	-1.77 /134.39	4.9	33
	22	Papua New Guinea	20:49	-5.57 /151	6.3	28.7
	23	Papua New Guinea	00:56	-5.0/145.79	5.7	61.8
53	24	coast of Papua, Indonesia	16:17	-2.03 /135.29	5.3	33
54	24	Papua, Indonesia	18:18	-3.18 /139.55	5.3	36.1
61	28	Papua, Indonesia	19:30	-3.05 /139.53	4.8	33

On 13-14 Nov Earthquakes (No. 27, 31) have struck Woodbark Plate where Caroline Plate and North Bismark Plate abut. Typhoon Mike moved from the Philippine Plate to the area (11 N 122 E) and its impact was transmitted through the Caroline Plate.

On 22-24 Nov after Owen sharp increase a sequence of strong earthquakes due to NT was observed as noted in Fig. 1. Table 5 additionally includes two strongest earthquakes on the South Bismark Plate. The North Bismark Plate separates this plate from the Pacific Plate.

On 28 Nov earthquake (No. 61) struck Woodbark Plate. After Owen crossed the Mariana Trench no earthquakes were recorded in this region until 1 Dec.

IV. DISCUSSION OF THE RESULTS

The analysis of the earthquakes data M> 2.5 [9] in the considered area in November 90 showed that in addition to the original list reflected in Tables 2-5 10 lithospheric earthquakes of magnitude 4.3 - 4.5 occurred. Eight earthquakes were in the Mariana Plate, one was at the Birma Plate and one was at Papua. The magnitude of the earthquakes varied from 4.6 to 6.7. The earthquake energy $\boldsymbol{E}$ in joules will be estimated by the formula (1) which connects it with the magnitude $\boldsymbol{M}$ [8].

$$M = 2/3(\lg E - 4.8) \quad (1)$$

Then we get that $\boldsymbol{E}$ varied in the range from 0.501 TJ to 708 TJ (Tera Joule).

Estimation of NT energy (Table 1) according to formula (1) gives in the first case 11.2 TJ and in the second one 7.94 TJ. Calculation of energy through the trotyl equivalent Y (kt) gives 494 TJ and 151 TJ respectively. This means that in the first case 2.3% of the explosion energy and in the second one 5.3% of it was converted into seismic energy.

The earthquake characteristics indicate that in the cases under consideration the same mechanism of action on the lithospheric plates took place. Let us consider the mechanism in more detail using the example of the South Bismark Plate earthquake on 22 Nov. The initial situation is given in Fig. 2.

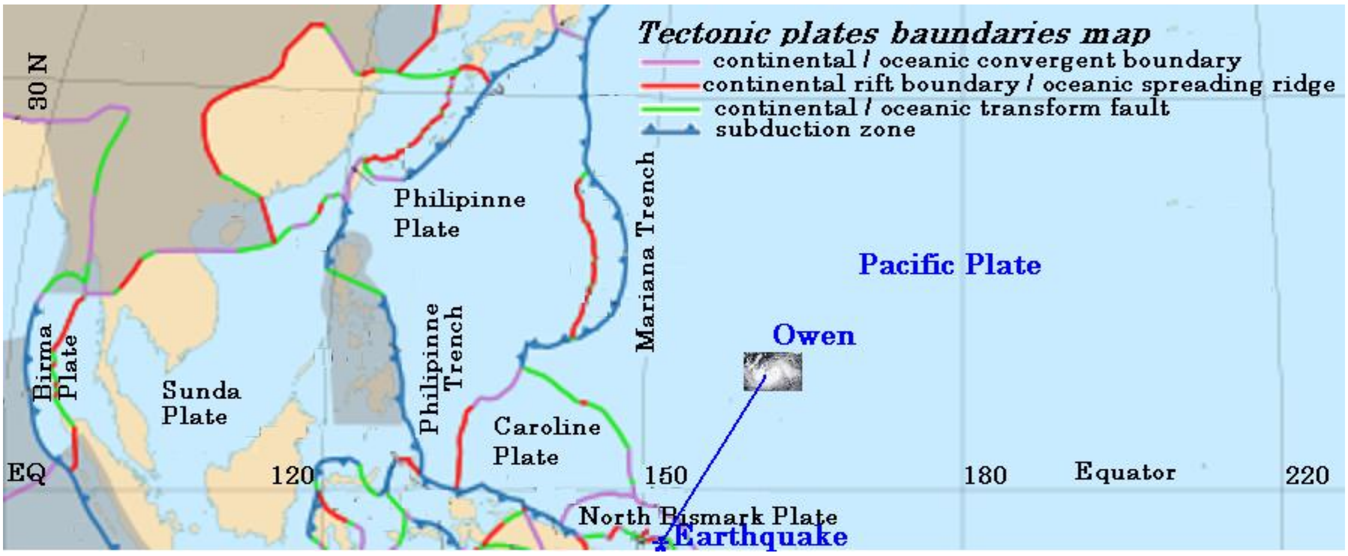

FIGURE 2: The scheme of interaction between Owen and the earthquake of Earth Bismark Plate 22-Nov-90.

Owen commenced explosive intensification as a tropical depression experiencing a drop in central pressure of 62 mb in 24 hours [7] one hour after NT Thoas. An eye 35 km in diameter was formed, the diameter of a compact cloud structure ~ 300 km. Let us estimate the force ***F*** lifting the Pacific Plate as the multiplication of the fall pressure on the eye area. This estimate gives $\boldsymbol{F} = 6\ 10^{12}$ N = 6 TN.

We consider a large lithospheric plate as a solid, rigid plate interacting with the surrounding plates. In this mechanical system the conservation law of moment of forces is being fulfilled. The ends of the Pacific Plate in this situation will put down and pull the small plates under which it is partially offset. In the most stressed place a rupture occurs part of the small slab breaks off and falls. A new equilibrium is being established.

There are three initial equations, a detailed discussion of which is beyond the scope of this article:

1. The conservation law of moment of forces is written relative to a point on the boundary of the cloud structure for a sector whose angle is equal to the ratio of the transverse length of the collapsed block to the distance between Owen and quake. Longitudinal length is estimated as the distance to an adjacent plate. On the one hand we have the lifting force of the typhoon on the other hand we have the breaking force equal to the multiplication of the ultimate strength by the slab area.

2. Incompressibility of magma. Since the lithospheric plate floats, when it tilts, the volume of displaced magma is equal to the raised one. In the case under consideration the distance between Owen and quake is ~ 1500 km which is less than the Earth's radius and the sphericity is not taken into account. This equation includes the drop height of the slab.

3. The energy released during the South Bismark Plate earthquake is estimated by (1) at 178 TJ and it is equated to the work of the forces of rupture or the potential energy of the collapsed slab.

This physical representation is in good agreement with the numerical parameters of plate tectonics [8]. It explains the lithospheric nature of all earthquakes (Tables 2-5). The depth of most earthquakes is ~ 30 km. In more complex cases of deep lithospheric earthquakes the subsidence of the large lithospheric plate must of course be taken into account.

It should be noted that three out of four NTs in the US in June and September 1992 affected TC [6]. The TCs changed their intensity and movement direction. The 7.2-magnitude crustal earthquake Landers 92 occurred when Hurricane Selia reached its maximum. The earthquake mechanism is in good agreement with the concepts of [2].

Analysis of the strongest earthquakes in California over the past 30 years has shown that they can be associated with the development of TC [6]. Moreover the earthquakes east of the San Andreas Fault had foreshocks. An algorithm for analyzing foreshocks is proposed, it gives the place and approximate time of the main quake. Earthquakes west of the San Andreas Fault have no foreshocks. The presentation of the report in Russian 22 pages is attached to the theses [6], which can be opened by clicking on the appropriate index.

Forecasting the development of seismic activity for a number of different geophysical parameters of the environment both on the ground and from satellites is of great practical importance [12].

A preliminary analysis of seismic activity in November 1990 showed that it intensified after strengthening of TC Sina under the influence of NT Thoas on the American continent.

V. CONCLUSION

1. Almost all lithospheric earthquakes in the regions adjacent to the Philippine Plate can be explained in terms of the impact of tropical cyclones in November 90.
2. France Nuclear Tests acoustic impact on tropical disturbance areas led to their self-organization to the intensity of super typhoons in November 90.
3. Preliminary analysis showed that the TC impact on the Pacific Plate in November 90 was transferred to the area of Mid-American Trench and Peru-Chile Trench. A detailed analysis of these events will be presented.

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