

A Brief Study on the M 8.7 Earthquake in Kamchatka Peninsula on July 29, 2025

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Abstract:

Based on the theoretical system of the Seismo-Geothermics created by the author, this paper uses the M 4.0+ earthquake catalog of the northwestern Pacific from the California Earthquake Center in the United States to focus on studying the activity background of the Okhotsk Seismic Cone Tectonic (SCT for short), the geographical distribution, three-dimensional spatial distribution characteristics and temporal characteristics of earthquakes and volcanic activities, as well as the variation characteristics of seismic activity ϵ_0 in different sub-crustal strata. It also discusses the causes of sub-crustal earthquakes, disaster chain systems, and strong intra-crustal earthquakes and volcanic eruptions. On this basis, a prediction model and research plan for strong intra-crustal earthquakes and volcanic eruptions in the heat engine belt are formulated, which can serve as a reference for research on prediction methods in regions around the world where the global earthquake catalog meets the basic conditions for research on the Seismo-Geothermics theory.

Keywords: Seismo-Geothermics, seismic cone tectonic (SCT for short), Subshell seismic activity ϵ_0 , disaster chain system, Okhotsk Sea

1 Introduction

The impact area of the global No. 06 Okhotsk Seismic Cone Tectonic (Okhotsk SCT for short) is located between $133^{\circ}\sim 138^{\circ}\text{E}$ and $40^{\circ}\sim 65^{\circ}\text{N}$. The Okhotsk Seismic Cone Tectonic is one of the global deep-source seismic cone tectonics, with a maximum focal depth of 675 km, and it is also one of the most active seismic cone tectonics in terms of intra-crustal strong earthquakes and volcanic eruptions in the world.

A strong intra-crustal earthquake of magnitude 8.7 that occurred on the Kamchatka Peninsula on July 29, 2025, triggered by the Okhotsk Seismic Cone, caused a relatively strong tsunami and was accompanied by multiple volcanic eruptions, attracting great attention worldwide. This is a typical intense activity of the disaster chain involving intra-crustal strong earthquakes and volcanic eruptions, which is worthy of in-depth research.

Based on the author's self-created theoretical system of the Seismo-Geothermics theory [1-8], this paper uses the data of M 4.0+ earthquakes in the northwestern Pacific region from the Northern California Earthquake Center to study the characteristics of relevant seismic sequences, and obtains some new information on the prediction of intra-crustal strong earthquakes, which is beneficial to the research on the prediction methods of global strong earthquakes and volcanoes.

2 Data and Research Background

The data for this study are sourced from the ANSS earthquake catalogue of the California Earthquake Authority in the United States. A total of 93, 140 earthquakes with magnitudes of 4.0 or higher within the Northwest Pacific Research Area ($125^{\circ}\sim 180^{\circ}\text{E}$, $9^{\circ}\sim 65^{\circ}\text{N}$) from 1963 to 31 July 2025 were obtained. The distribution of the crustal layers beneath these earthquakes is shown in Table 1. In Table 1, the proportion of sub-crustal earthquakes is 51.7%, with the maximum depth reaching 686 km. The seismic activities within each layer are generally reasonable and meet the requirements for the research on Seismo-Geothermics theory.

The seismic cone tectonic zoning of the study area is shown in Figure 1, and its three-dimensional distribution is presented in Figure 2. The entire area involves 12 SCTs, among which 06# Okhotsk, 07# Japan, 09# Northern Mariana, and 10# Mariana are all deep-source SCTs with a depth of 600 km or more, which can form multiple systems of strong crustal earthquakes and volcanic eruptions. The remaining 4 SCTs, 05# Bering Sea, 08# Hunchun China, 11# Taiwan and Ryukyu, and 12# Philippines, due to incomplete data, are not included in the research scope of this paper.

The Okhotsk SCT is regarded as a unified disaster chain system. The Kamchatka Peninsula is located within the 06 Okhotsk SCT and is also one of the most active regions within this disaster chain.

Table 1 A hierarchical list of sub-crustal seismic activities in the study area

Area	Total	In-shell	Sub-shell	Sub-shell ratio %	Layered under the shell (km)				depth Km	M max
					35-100	100-300	300-500	500+		
Pacific	93,140	45,006	48,134	51.7	32,126	11,013	4,200	795	-686	9.1

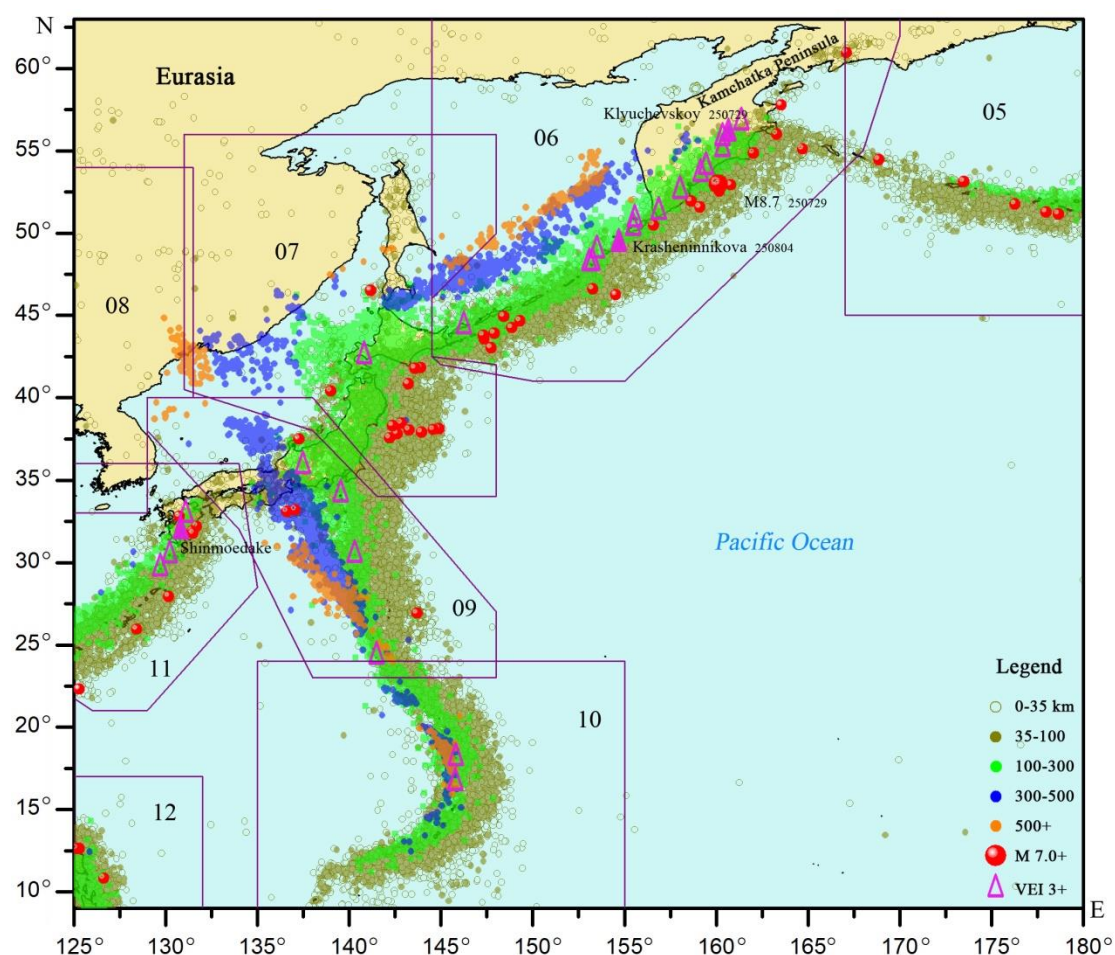


Figure 1 Seismic cone tectonic zoning map in the Northwestern Pacific Ocean

(Data from the US ANSS Earthquake Catalogue, 1963-2025.7.31, M4.0+)

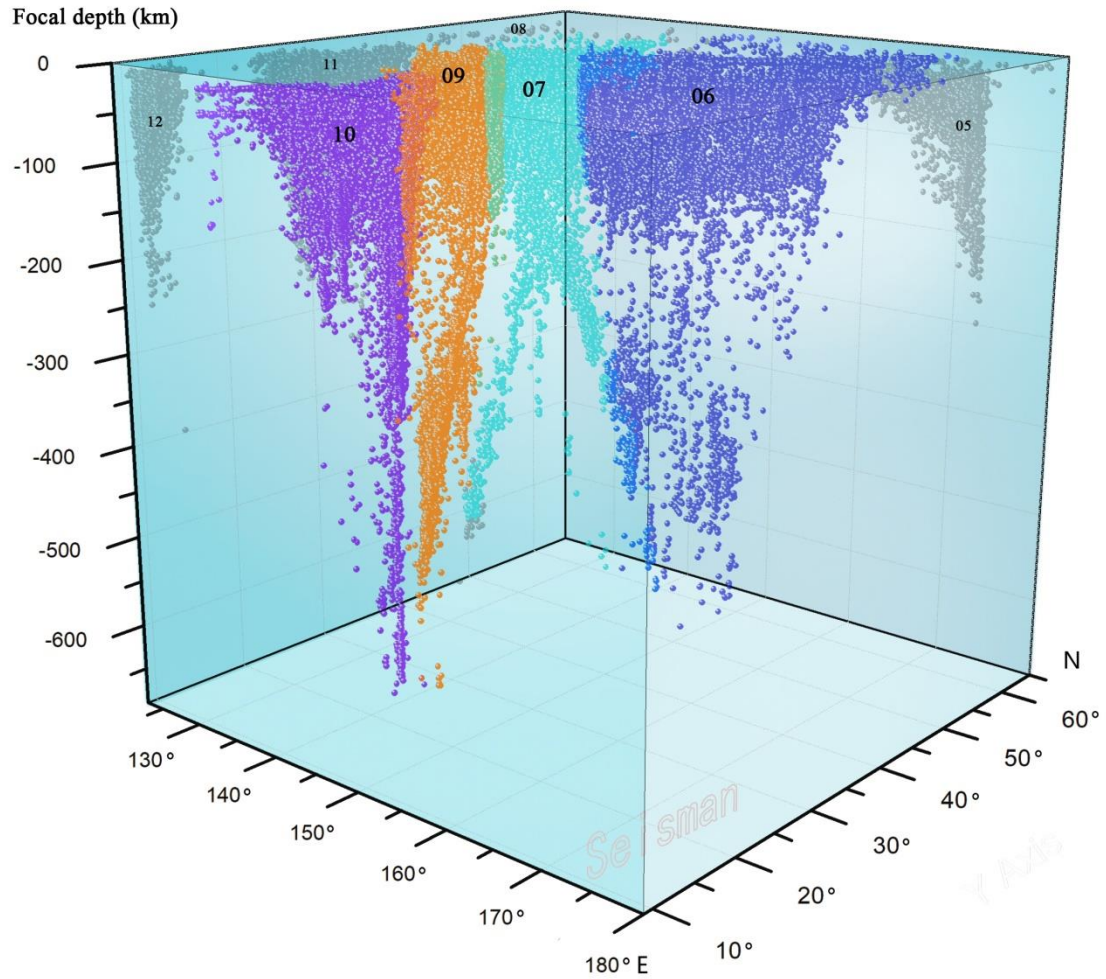


Figure 2 Stereoscopic images of SCT in the northwestern Pacific Ocean

3 The Study on the Activity of the Okhotsk SCT

3.1 Analysis of the Activity Pattern of the Okhotsk SCT

Without considering the specific prediction methods, the Okhotsk SCT can be temporarily regarded as a unified disaster chain system [9], as shown in Figure 3. The maximum depth of the sub-crustal seismic activity is 675 km, and the strong crustal seismic activities are shown in Table 2, and the volcanic eruption activities are shown in Table 3.

From 1963 to 2025, there were a total of 20 M 7.0+ strong intra-crustal earthquakes in Table 2, and 16 active volcanoes in Table 3, with a total of 67 VEI 3+ eruptions. The frequency and intensity of the intra-crustal strong earthquakes and volcanic eruptions are high, making this region one of the most active geological disasters in the world.

The stratified seismic activity image in Figure 3 is a flat cone shape, slightly tilted towards the northwest, and according to the principles of solid geometry, it can be analyzed in the same way as an isosceles cone of the same height.

Most of it is hidden in the sea, with sparse human settlements, and often not attracting much attention. However, this is an important pivot in geology, and the ancient heat flow belt from Kamchatka to Hawaii originated from here, forming an unchanging crustal heat source transfer belt from NW to SE [10]. Some people interpret it as the trace of the penetration of a fixed heat source by the plates, but the author believes that interpreting it as the trend of the crustal heat source transfer is more convenient. The same phenomenon has also manifested in Italy [11].

Table 2 List of Strong Intra-Crustal Earthquakes in the Okhotsk SCT

Date	Latitude	Longitude	Depth(km)	Magnitude	Time sequence coordinates
19690811	43.54	147.35	-28	7.8	1969.610669
19691122	57.76	163.54	-33	7.3	1969.893055
19711215	55.99	163.29	-33	7.8	1971.954395
19730228	50.48	156.58	-27	7.2	1973.159661
19750610	43.02	147.73	-15	7.0	1975.43993
19780323	44.93	148.43	-33	7.5	1978.222289
19780324	44.24	148.86	-33	7.6	1978.226917
19931113	51.93	158.64	-34	7.0	1993.865902
19941004	43.77	147.32	-14	8.1	1994.757692
19941009	43.90	147.91	-33	7.1	1994.770768
19951203	44.66	149.30	-33	7.9	1995.922605
19960621	51.56	159.11	-20	7.0	1996.471534
19971205	54.84	162.03	-33	7.8	1997.927334
20060420	60.949	167.089	-22	7.6	2006.301303
20061115	46.592	153.266	-10	8.3	2006.872516
20070113	46.243	154.524	-10	8.1	2007.033378
20181220	55.0999	164.6993	-16	7.3	2018.969068
20240817	52.9308	160.1331	-29	7.0	2024.627866
20250720	52.9086	160.7868	-10	7.4	2025.548723
20250729	52.53	160.1648	-20	8.8	2025.575276

Table 3 List of VEI 3+ Volcanic Eruptions in the Okhotsk SCT*

Number	Volcano name	Latitude	Longitude	Start date	Stop Date	VEI
290030	Chachadake[Tiatia]	44.353	146.252	1973 Jul 14	1973 Jul 28	4
290240	Sarychev Peak	48.092	153.2	2009 Jun 11	2009 Jul 16 (± 15)	4
290250	Raikoke	48.292	153.25	2019 Jun 22	2019 Jul 1	3
290260	Chirinkotan	48.98	153.48	2016 Nov 29	2017 Apr 7	3
290360	Chikurachki	50.324	155.461	2015 Feb 16	2015 Feb 18	3
290390	Alaid	50.861	155.565	1981 Apr 27	1981 Jun 5	4
300010	Kambalny	51.306	156.875	2017 Mar 24	2017 Apr 23	3
300070	Gorely	52.5549	158.0358	1980 Jun 15 ± 5	1981 Jul 3	3
300120	Zhupanovsky	53.589	159.15	2016 Nov 20	2016 Nov 20	3
300130	Karymsky	54.049	159.443	2024 Jun 20	2024 Nov 12	3
300230	Kizimen	55.131	160.32	2010 Nov 11	2013 Sep 13 (?)	3
300240	Tolbachik	55.832	160.326	2012 Nov 27	2013 Sep 5 ± 10 d	3
300250	Bezymianny	55.972	160.595	2022 Mar 15	2024 Aug 14 ± 2	3
300260	Klyuchevskoy	56.056	160.642	2025 Jul 30		

300270	Sheveluch	56.653	161.36	1998 May 30	1998 Sep 3	3
	Krashenninnikova	49.35	154.7	2025 Aug 4		

*Volcanic eruptions after May 2024 have not been assessed for the Volcanic Explosivity Index (VEI) value.

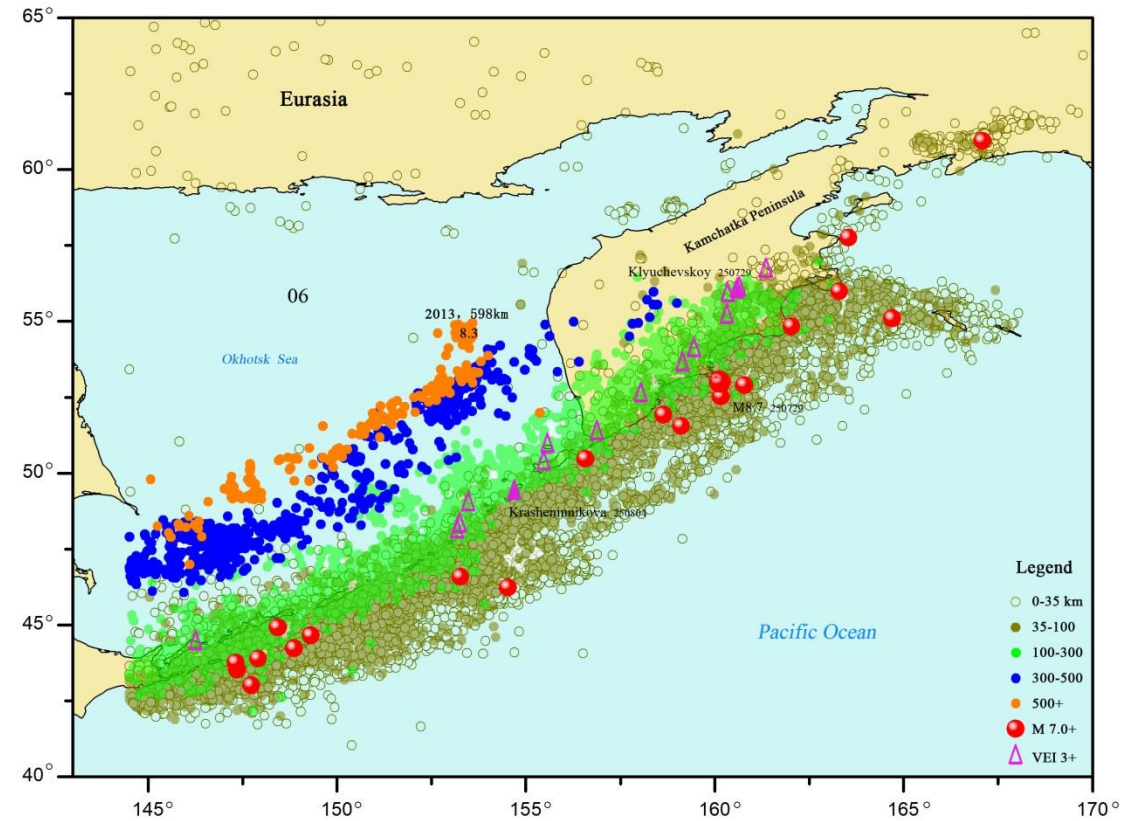


Figure 3 Intra-crustal strong earthquakes and volcanic activities of the Okhotsk SCT

3.2 Three-dimensional stereoscopic image of the Okhotsk SCT

The three-dimensional stereoscopic image of the Okhotsk SCT is shown in Figure 4. As can be seen from Figure 4, the Okhotsk SCT can be divided into multiple sub-cone structures for the prediction research of earthquakes and volcanoes. However, this article only makes a brief examination and does not make a distinction.

The Okhotsk SCT is a flat cone shape, with the apex pointing downward, and it spreads horizontally towards the surface at an equal gradient, which conforms to the ideal model of SCT [9]. Therefore, it can be divided into multiple layers within the crust at a depth of 0-35 km, the sub-crustal energy storage layer at a depth of 35-100 km, the active layer at a depth of 100-300 km, and the upper mantle driving layer with a depth greater than 300 km, etc.

The seismic distribution of each layer is basically reasonable, which is the greatest advantage of the ANSS earthquake catalog. The earthquake catalogs of Japan, the Mediterranean, and Taiwan of China can also meet such basic requirements.

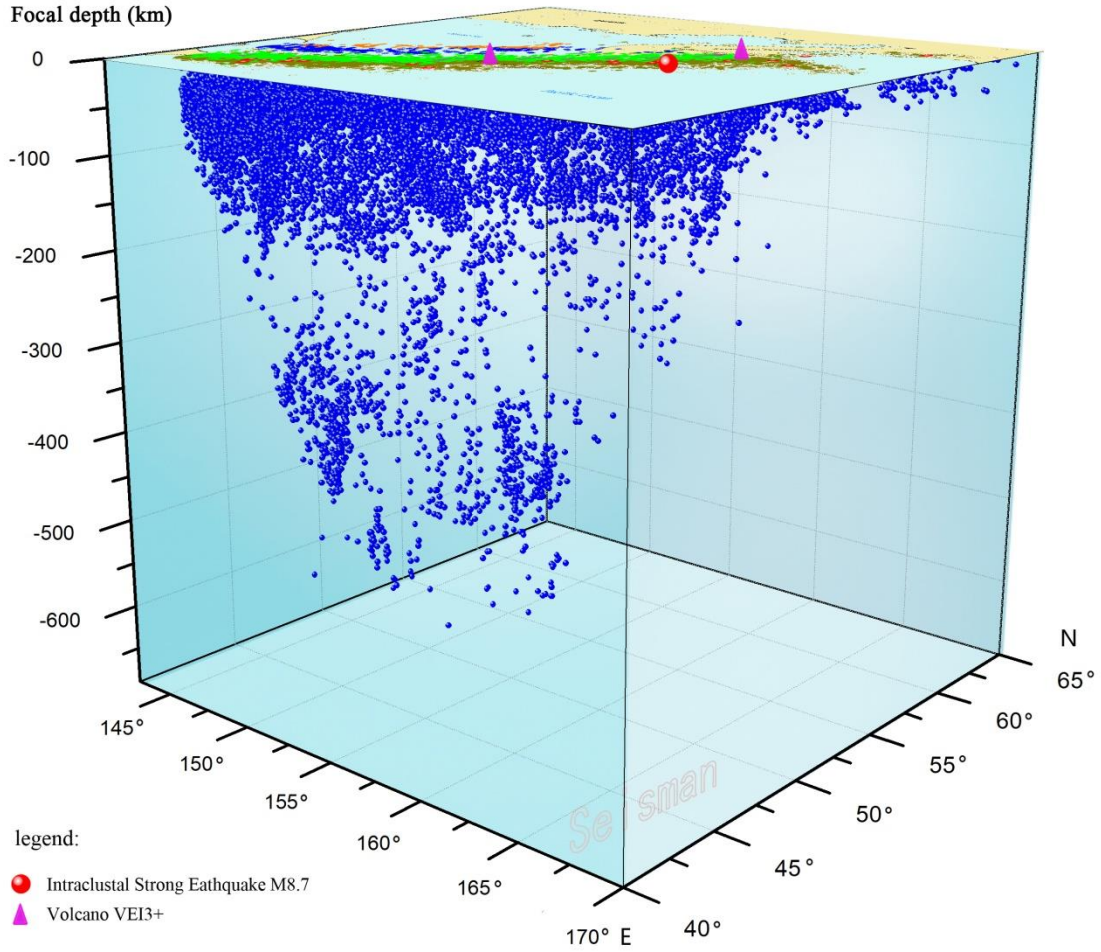


Figure 4 Stereoscopic image of the Okhotsk SCT

3.3 Time-series Image of the Seismic Activity of the Okhotsk SCT

The time-series image of the seismic activity of the Okhotsk Seismic Cone Structure is shown in Figure 5. This image is similar to the planar image of the time flow in an experiment of boiling water, representing the time course of the rolling up and down of the earthquakes beneath the crust, and contains rich information about the causes of the earthquakes.

The seismic activity and volcanoes at a depth of 0-35 km can freely dissipate their energy. The seismic energy at a depth of 35-100 km is partially dissipated and partially stored. The seismic energy below a depth of 100 km is basically unable to dissipate and can only be driven and accumulated layer by layer from bottom to top. The driving layer below 300 km is the energy source of the seismic cone structure. If there is a large adjustment, the earthquakes in the upper strata will follow the trace. As can be seen from Figure 5, after multiple M 6+ seismic activities occurred in the driving layer between 1983 and 1987, multiple M 7.0+ intra-crustal strong earthquakes and volcanic eruptions occurred from 1994 to 1998; when multiple M 7.0+ seismic activities occurred in the driving layer between 2003 and 2013, a peak of M 7+ intra-crustal strong earthquakes and volcanic eruptions began in 2006. As can be seen from Figure 3, the M 8.3 earthquake at a depth of 598 km almost occurred right under the M 8.7 intra-crustal strong earthquake on July 29, 2013.

The process from the driving layer to the intra-crustal activity may be longer, approximately taking several years or even tens of years. Therefore, it can be speculated that the multiple M 6.0+ seismic activities that occurred in the driving layer starting from 2018 may indicate the next round of intra-crustal

strong earthquakes and volcanic eruptions.

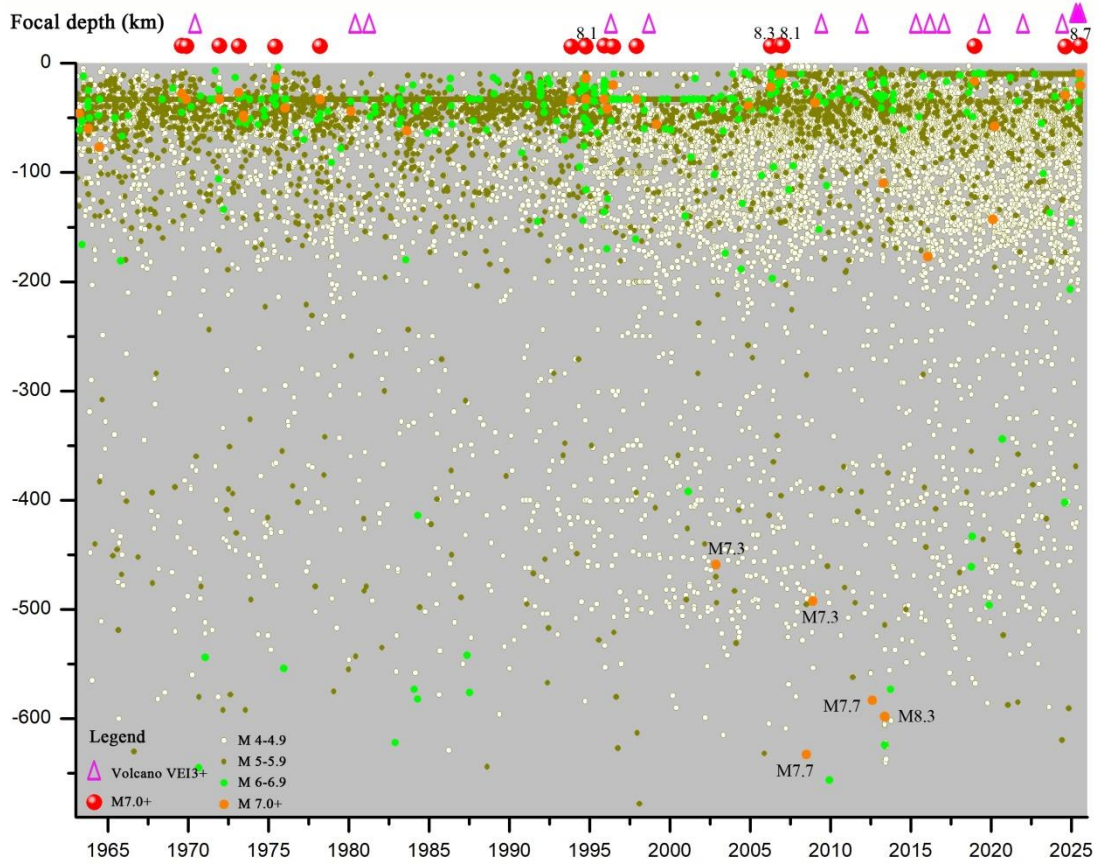


Figure 5 Temporal images in the Okhotsk SCT

3.4 Layered Seismic Activity ε_0 of the Okhotsk SCT

Based on the ideal model of the seismic cone structure and the concept and calculation method of seismic activity ε_0 proposed by Chen Lijun (2025) [9], the layered seismic activity ε_{01} of the storage layer, ε_{02} of active layer and ε_{03} of driving layer in the Okhotsk SCT was obtained, as shown in Figure 6.

As can be seen from Figure 6, the seismic activity ε_{03} of the driving layer has reached its peak during the period from 2004 to 2013, which might be the true cause of the activity on July 29th. An Ms 8.7 earthquake, along with the eruptions of two volcanoes, Klyuchevskoy volcano erupted on July 30th immediately. Since the Ms 8.7 earthquake occurred, the Kamchatka Peninsula has been in a state of vibration. The southern Krasheninnikova volcano had been dormant for over 600 years and erupted for the first time on August 2nd, with a volcanic ash column reaching 6,000 meters. Compared with the M 7.3 Bunin local earthquake and volcanic eruption event in the Miyako region of Japan in 2016, the activity in Kamchatka was tens of times stronger [12].

The most prominent feature in Figure 6 is the seismic activity ε_{02} of the active layer, which is stable and orderly. Almost every rising period of seismic activity (indicated by blue arrows) corresponds one-to-one with the periods of strong crustal earthquakes and volcanic eruptions shown in the time sequence diagram of Figure 5. Thus, it seems that the seismic activity ε_{02} of the active layer is the manifestation of the seismic cone structure activity. However, this is the only example in the world so far.

The seismic activity ε_0 of sub-crustal earthquakes may also affect changes in the global climate [13].

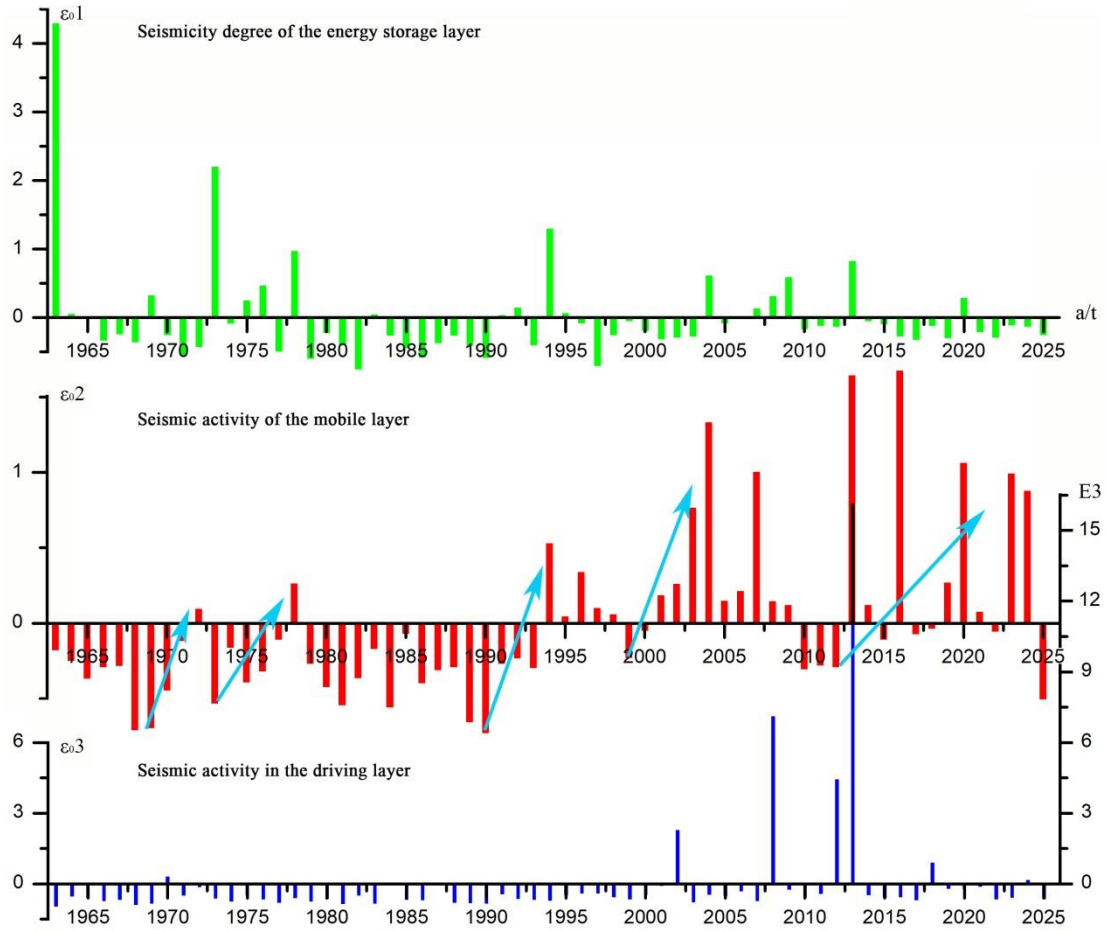


Figure 6 The layered seismic activity ε_0 images of the Okhotsk SCT

4 Discussion

4.1 Regarding Sub-crustal Seismic Activity

The ANSS earthquake catalogue by the United States provides a model for global earthquake catalogues. That is, wherever there are intra-crustal strong earthquakes of magnitude 6.5+ or 7.0+, there must be sub-crustal seismic activity. Strangely, people have never paid attention to this. The foundation of the North American seismic cone structure is very shallow. The maximum depth of the M 4.0+ earthquake catalogue is 96 km, while that of the M 2.0+ earthquake catalogue can reach 600+ km. It is understandable that the United States does not pay much attention to sub-crustal seismic activity.

The national earthquake catalogue of Japan, with initial magnitude can reach 0.5, and the maximum focal depth can reach over 600 km., has a total number of millions of earthquakes, which is basically consistent with the accuracy of the national earthquake catalogue of the United States. However, they always make a fuss about some minor movements in the 3000 m deep sea trench, but never care about how the energy released by the 500 km and 600 km deep sub-crustal earthquakes dissipates? Is there any connection with the intra-crustal strong earthquakes and frequent volcanic eruptions in the region?

Once this point is understood, there is hope for Japan's earthquake and volcano prediction. The energy release of sub-crustal earthquakes can occur spontaneously, but it cannot extinguish by itself. This is an obvious principle.

4.2 On the Disaster Chain System

The earthquake cone structure merely classifies earthquakes, volcanic eruptions and

subsurface earthquakes into one broad category. The prediction methods must identify independent sub-cone structures that are closely connected by intra-crustal strong earthquakes, volcanic eruptions and sub-crustal earthquakes, that is, the disaster chain system.

Disaster chain systems can be easily identified in all deep-source earthquake cone structures worldwide, such as Indonesia, Japan, the Sea of Okhotsk, the Philippines, the Mariana Islands, the Solomon Islands, Tonga, Chile, Ecuador, etc. Another type can be identified using local M2.0+ earthquake catalogues, such as Italy, the Bering Sea, the United States, Guatemala, etc.

The last type is regions without active volcanoes, where the driving layer cannot be found in the M 4.0+ earthquake catalogue and only intra-crustal strong earthquakes and sub-crustal earthquakes exist. In such cases, local high-precision earthquake catalogues should be used flexibly, and the ANSS M 4.0+ earthquake catalogue can only provide rough judgment information. If these places cannot improve the resolution of sub-crustal earthquakes, they can only fuss around with surface seismic data.

4.3 On the Causes of intra-crustal strong earthquakes and Volcanic Eruptions

As can be seen from Figure 5 and Figure 6, the enormous energy required for strong earthquakes and volcanic eruptions within the crust is generated from within the seismic column structure. Specifically, it is driven and accumulated layer by layer from the bottom up by sub-crustal seismic activities under the inherent high-temperature and high-pressure conditions of the disaster chain system. It is not caused by the strain accumulation of active faults on the surface, let alone by the Pacific plate subducts northwest beneath the North America plate [14].

This process takes several years or even more than ten years. The surface faulting may be merely the performer of the energy release in the seismic cone structure, and the volcanic eruptions in the thermal engine zone are also like this.

5 Conclusion

Based on the author's self-developed theoretical system of the Seismo-Geothermal theory, this paper uses the M 4.0+ earthquake catalog of the Northwestern Pacific from the California Earthquake Center, focusing on studying the activity background of the Okhotsk seismic cone Tectonic, the geographical distribution, three-dimensional spatial distribution characteristics and temporal characteristics of earthquakes and volcanic activities, as well as the variation characteristics of seismic activity in different sub-crustal strata. It also discusses the causes of sub-crustal earthquakes, disaster chain systems, and strong intra-crustal earthquakes and volcanic eruptions. On this basis, a prediction model and research plan for strong intra-crustal earthquakes and volcanic eruptions are formulated, which can be used as a reference for research on prediction methods in regions around the world where global earthquake catalogs meet the basic conditions for the study of the Seismo-Geothermics theory.

The research in this paper is only for the study of popular science knowledge and reference for researchers, and does not contain information on earthquake and volcanic prediction.

Conflicts of Interest: The authors declare no conflicts of interest.

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