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6. *Seismicity of Sakhalin.**

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The Island of Sakhalin belongs to the regions with a relatively high level of seismic activity. The maximum known intensity of its earthquakes is equal to 7–8 according to the 12-degree scale. The maximum established magnitude is equal to $6^1/_2$–$6^3/_4$.

In 1963–1964 all known instrumental and macroseismic data about Sakhalin earthquakes for the years 1909–1963 were gathered and summarized at the Sakhalin Complex Scientific Research Institute under the guidance of the author.

Simultaneously seismicity of the island was correlated with its neotectonic development. Works of such a kind were fulfilled for the first time.

Systematization of seismological data was based mainly on the observations from permanent seismic stations. Regretfully the system of instrumental observations on Sakhalin earthquakes has been in the past and still is very imperfect.

The first seismic station was organized in Korsakov (Otomari) in 1909. Later, new stations were established in Poronaysk (Sikka) in 1928, in Dolinsk (Otiai) in 1934, and in Uglegorsk (Esutoru) in 1939. These stations, equipped with low-magnification seismorgraphs, have worked with many interruptions, yet their bulletins contain important data about Sakhalin earthquakes.

During 1945–1947 no seismic stations were in action on the Island. In 1947 seismographs of Wiechert type were set in operation in Yuzhno-Sakhalinsk. In 1951–1952 sensitive seismographs of Kirnos type were established in addition at Yuzhno-Sakhalinsk and at Uglegorsk. In 1958 the third station with Kirnos instruments was opened in Okha (North Sakhalin). In 1963 both south stations were equipped with more sensitive seismographs (SKM-3).

According to peculiarities of seismic observations the compiling of the catalogue of earthquakes was done in the following way.

* Communicated by R. Takahasi.

For the pre-war period all data relating to the shocks recorded within 300 kilometers from Sakhalin stations were extracted from the station bulletins. These data were compared with annual lists of felt shocks published by the Sakhalin Meteorological Organizations. Only those shocks for which both instrumental and macroseismic data were available were taken into account. When the distance from the station to the shaken point (or to the center of the shaken district) was equal to the epicentral distance of earthquake, this point (center) was taken as the epicenter of the quake. Travel times by Jeffreys-Bullen were used for calculations.

For earthquakes of the post-war period epicenters were found by usual treatment of seismic net data or by using the values of azimuth and $S-P$ time determined on the record of a single station.

In total about 800 underground shocks were so established on Sakhalin the epicenters for 200 shocks being determined. Their time distribution is shown in the Table 1.

Table 1. Time distribution of established earthquakes on Sakhalin

	Years						
	1906—1908	1909—1912	1913—1939	1940—1945	1952—1961	1962	1963
Number of earthquakes	7	21	211	39	280	90	121
Total only with found epicenters	0	2	37	6	60	29	49
Average annual (total)	2.3	5.2	7.8	3.2	28	90	121
Average annual of shocks with found epicenters	0	0.5	1.4	0.5	6	29	49

For all shocks classification of uniform energy was made. It was completed as follows:

For the pre-war records of mechanical instruments[1] correlation between magnitude and total duration of the record was determined on the basis of scarce values of ground displacements given in bulletins.

1) S. A. FEDOTOV, "The Absorption of Transverse Seismic Waves in the Upper Mantle and Energy Classification of Near Earthquakes of Intermediate Focal Depth," *Izvestiya Akademii Nauk SSSR, Ser. Geofisicheskaya,* **6** (1963), 829, (in Russian).

According to E. Bisztricsany's results[2)] the general form of this correlation was taken as

$$\log(F-P)=a+2.25\,M\,. \tag{1}$$

For the following stations values were obtained (Fig. 1):

1) Station Otomari, Omori instrument, 1913–1930, $a\simeq-1.35$;
2) Station Otomari, Wiechert and Omori instruments, 1931–1939, $a\simeq-0.25$;
3) Stations Sikka and Otiai, CMOJ instrument, $a\simeq-1.50$.

For post-war earthquakes energetical class K according to S. Fedotov scale[2)] was found using the maximum amplitudes of S-waves. Transition to magnitude was done with the help of the equation found by the author:

$$M\approx-0.70+0.42\,K\,. \tag{2}$$

In Fig. 2 relations between frequency and magnitude of Sakhalin earthquakes for two described periods are given. Time unit was taken equal to 10 years. One can see that relations for different periods coincide. They can be described by the equation:

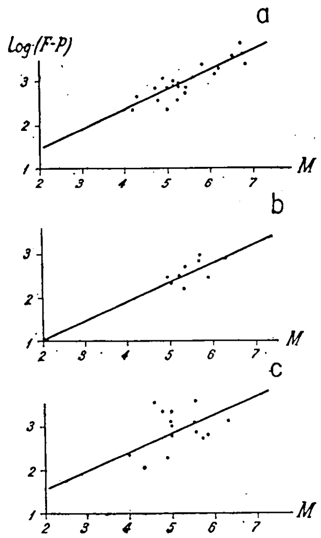

Fig. 1. Correlation between duration of record, in seconds, and magnitude of earthquake. a) Otomari, Omori seismograph, 1913-1930; b) Otomari, Omori and Wiechert seismographs, 1931-1939; c) Otiai and Sikka, CMOJ seismograph, 1928-1939.

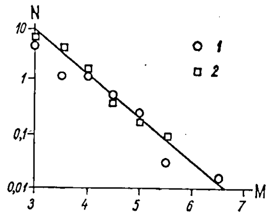

Fig. 2. Magnitude-frequency relation for the earthquakes of Middle and South Sakhalin. 1-according to data of 1913-1939; 2-according to data of 1952-1963.

2) E. A. Bisztricsany, "A New Method for the Determination of the Magnitude of Earthquakes," *Geofiz. Kozl.*, **7**, (1958), No. 2, (in Russian).

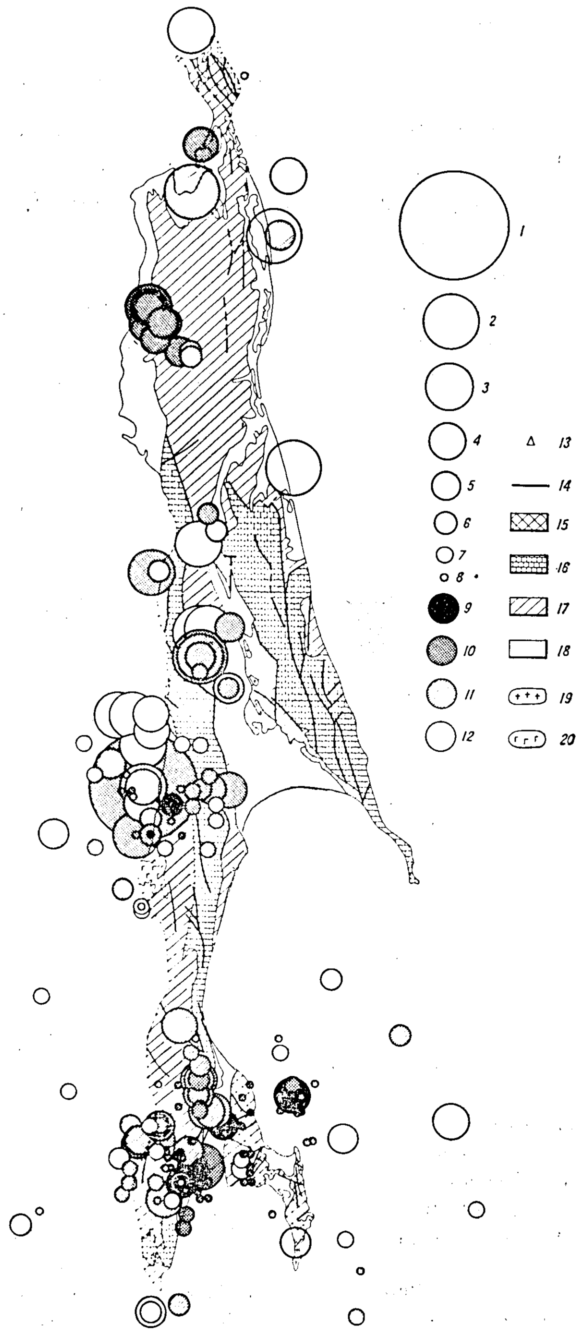

Fig. 3. Map of Sakhalin earthquakes with established position of epicenter for the years 1909-1963. Compiled by L.S. Oskorbin and S.L. Solov'ev with the help of M. D. Ferchev, Go Chan Nam, L. N. Poplavskaya, F. D. Zhuk, and L. F. Volkova. 1~8=magnitude of earthquake: 1–$M \geqq 6$; 2–$M=5^1/_2\sim5^1/_4$; 3–$M=5\sim5^1/_4$; 4–$M=4^1/_2\sim4^3/_4$; 5–$M=4\sim4^1/_4$; 6–$M=3^1/_2\sim3^1/_4$; 7–$M=3\sim3^1/_4$; 8–$M \leqq 3$; 9~12-accuracy of epicenter determination: 9-error does not exceed 15 km; 10-25 km; 11-50 km; 12-error can exceed 50 km, but it is less than 100 km. 13-the margin of the shelf (according to G. B. Udintzev and N. L. Zatonskiy); 14-main faults; 15~18-formations of different age: 15-Paleozoic (?), 16-Mesozoic, 17-Tertiary, 18-Quaternary; 19-blocks of granitoids; 20-Lamanon volcanic massif.

$$\log n \approx 4.3 - 0.8\,M\ (\delta M = 1/2). \quad (3)$$

When passing from magnitude to intensity we can conclude that destructive earthquakes must occur on the island (including the shelf) at an average of once every 5 years. Felt shocks must occur at an average of once every 1–2 months. In Fig. 3 the map indicating known earthquakes which occurred on Sakhalin for the period 1909–1963 is shown. Discussion of space distribution of the epicenters will be proceeded by a sketch of the tectonic and geomorphological structure of the island (Figs. 3, 4).[3]

According to certain peculiarities of this structure Sakhalin can be divided into three latitudinal belts: North, Middle and South with the demarcation lines on 51.3° parallel and on the Isthmus Poyasok.

Middle and South Sakhalin are represented by the system of the longitudinal uplifts and depressions. Close to the west coast of the island is situated the uplift of the West-Sakhalin range. At the end of the Pliocene a levelling plane was situated at this place. The intensity of its post-pliocene elevation was unequal at different points (Fig. 5)[4]. Large-scale falls of the uplift axis took place at the Isthmus Poyasok and in the valley

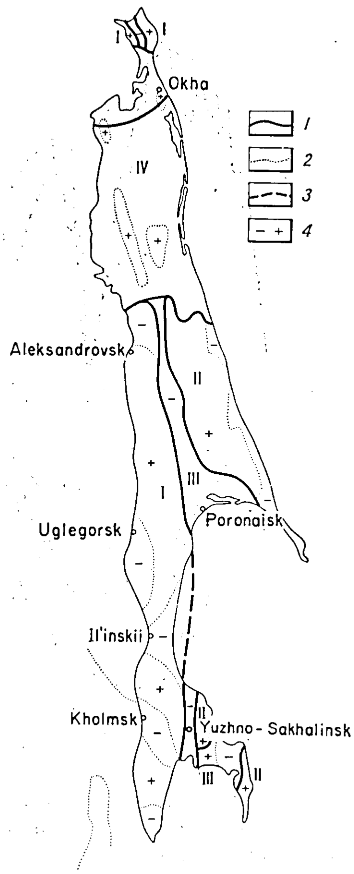

Fig. 4. Geomorphological scheme of Sakhalin (by S. V. Aleksandrov). 1-borders of morphostructures, I, II-morphostructures of intensive recent elevations, which correspond to anticlinoriums; III-morphostructures of recent subsidence in regions of graben-synclinal depressions; IV, V-morphostructures of intermediate type; 2-borders of neotectonic regions; 3-proposed border of morphostructure; 4-sign of relative vertical movement.

3) S. M. Aleksandrov, "Specific Features of the Recent Tectonics and the Sakhalin Morphostructure Development," *Sovetskaya Geologiya*, **2** (1962), 129, (in Russian).

4) E. M. Rudich, "Main Regularities of Tectonic Development of Primorie, Sakhalin and Japan as the Transition Zone from the Continent to the Ocean," *Izdatel'stvo Akademii Nauk SSSR, Moskva*, 1962, (in Russian).

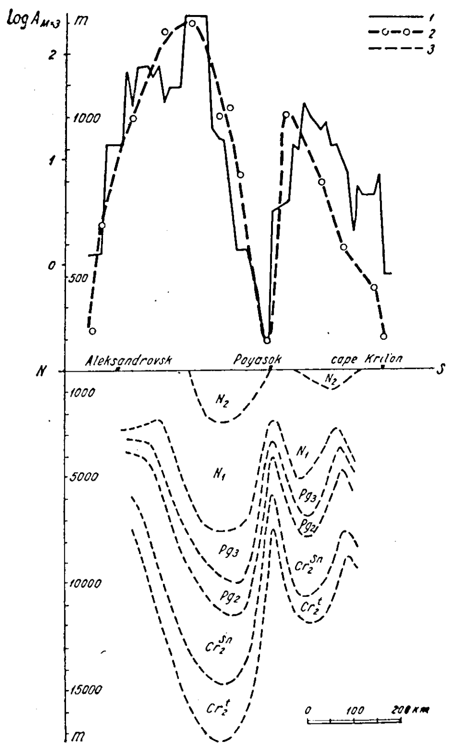

Fig. 5. Correlation between seismic activity (1), generalized height of relief (2) and thickness of Mesozoic-Cainozoic deposits (3) for the West-Sakhalin range.

For finding (1) all epicenters from the anticlinorium are projected to a meridional line, all earthquakes are conditionally transferred to shocks of magnitude $M=3$ with the help of relation $\log n \propto -0.8\,M$; the sums of such conditional shocks are found and smoothed; logarithms of the sums are taken. (2) is built by connecting the highest summits of the range with the help of a smooth line. (3) is given according to E. M. Rudich.

of the Lyutoga river (Aniva–Kholmsk region).

The West-Sakhalin uplift is usually regarded as an anticlinorium. At its core late Cretaceous rocks are exposed. Its sides are composed of Tertiary deposits. According to the structural plan Poyasok is a big squeeze of the West Sakhalin fold and the Lyutoga valley is a superimposed basin.

Adjacent to the east, that is along the central axis of Middle and South Sakhalin, Tym'-Poronay and Susunay depressions are situated. They are filled with late Tertiary and Quaternary deposits.

Between the Tym'-Poronay depression and the east coast of the island the East-Sakhalin range is situated. It consists of pre-Cretaceous (Jurassic?) formations. Consequently it has served as a stable region of denudation during the Tertiary and Quaternary periods.

To the east from the Susunay depression the following submeridional blocks are situated: Paleozoic Susunay range, Tunaicha depression, Paleozoic Tonino-Aniva range.

The relief of North Sakhalin is quite different from the relief of Middle and South Sakhalin. There is a gently undulated plane with prevailing heights of 90–180 meters. The plane is inclined to the north. At this belt of Sakhalin the rocks are covered with a mighty sedimentary mantle consisting of late Tertiary and Quaternary deposits.

The north-east extremity of Sakhalin is represented by the Schmidt peninsula which is composed of three blocks oriented in the south-south-east direction. The middle block is a depression, the two other (outer) blocks being the uplifts.

Comparison of seismological, geological and geomorphological data allow us to draw the following conclusions.

1. The biggest seismic activity is attributed to the margins of the West-Sakhalin anticlinorium which are represented by mighty established or proposed fault systems. Seismicity of its middle-Sakhalin section is more intensive than seismicity of its south section according to relative dimensions of these sections.

There is a very good correlation between intensity of Meso-Cainozoic synclinal bowing, post-Pliocene elevation and contemporary seismic activity

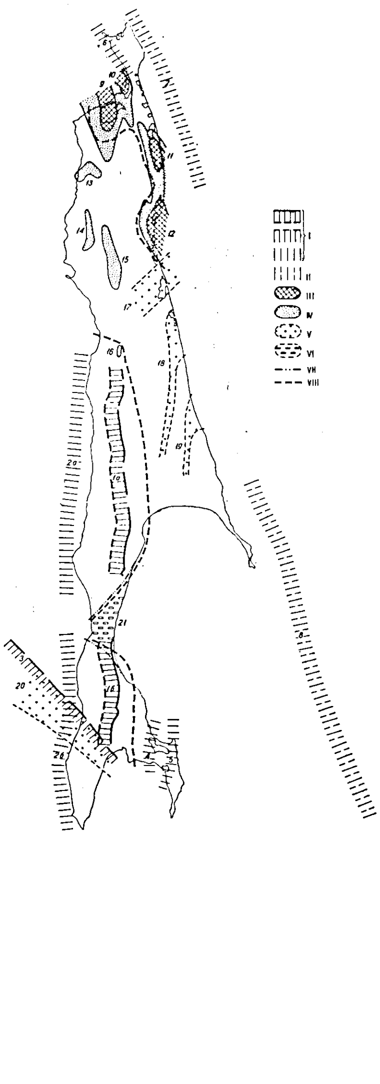

Fig. 6. Seismotectonic elements of Sakhalin. Compiled by S. L. Solov'ev.

I-deep faults more or less explored by geological, geomorphological or geophysical methods and showing seismic activity of different mainly high intensity; II-strips of intensive magnetic anomalies indicating orientation of structures of the shelf of the Sea of Okhotsk, contemporary development of which can produce earthquakes; III-regions where thickness of Tertiary deposits exceeds 7000 meters (according to P.M. Sychev) and which are regarded as regions of the most intensive contemporary sinking accompanied by high seismicity; IV-analogous regions with thickness of deposits exceeding 5000 meters, which show moderate or feeble seismicity; V-blocks of relative lowering inside regions of big recent elevations for which seismicity is established or proposed; VI-analogous blocks for which absence of seismicity is established.

of this block (Fig. 5) that underlines the inherited character of the seismicity of this part of the island.

2. Both intersections of the Aniva-Kholmsk diagonal zone with coast line are marked with very high concentration of seismic foci. It reveals intensive contemporary development of this superimposed basin.

3. The relative movements of such blocks as the Susunay crest, Tunaycha valley, Tonino-Aniva range, their underwater continuations, and underwater Moneron crest explain minor seismicity at other places of South Sakhalin.

4. The seismicity of the Schmidt peninsula has the same tectonic character.

5. The seismicity of all the other parts of North Sakhalin can be explained by a sufficiently quick downwarping of some depressions of its rocky fundament. The most active of them encircle the Okha isthmus, and are parallel to the blocks of the Schmidt peninsula and are expressed on the surface with big lagoons.

6. There are reasonable suppositions that a big seismogenetic fault runs along the east coast of Middle Sakhalin. Available seismological data cannot affirm or refute this supposition. In Fig. 6[5] the general scheme of established or proposed seismogenetic elements of Sakhalin are given. It seems that this scheme sufficiently well represents the real conditions that may exist except in some north and east regions for which more detailed data are necessary.

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6. Sakhalin における地震活動

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Sakhalin における地震活動は比較的活発であるが，最大のマグニチュードは $6\frac{1}{2}$～$6\frac{3}{4}$ 程度である．1909～1963 年間の Sakhalin の地震活動について，綜合科学研究所で観測した地震記録をもとに，頻度とマグニチュードとの関係，震央分布と地形，地震活動と地質構造並に中生代新生代の地層の厚さとの関係などについて検討し，それらの間に密接な関連のあることを示した．

5) P. M. SYCHEV, "On the Thickness of Tertiary Deposits on Sakhalin according to Data of Geophysical Investigations," *Geologiya i Geofisika, Novosibirsk*, **7** (1962), (in Russian).