Formation and development of seismological research in Russia

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Abstract. The paper is devoted to the first stage in the development of seismic observations in Russia, covering the period from the late 19th century to the 1930s. The study aims to reconstruct the process of organisation of systematic instrumental seismic observations. The objectives of the study included identifying the main organisational forms of seismic observations, methods and equipment used in these observations, as well as analysing the main scientific results. It was established that the leading role in the emergence and development of seismic observations in Russia was played by a prominent physicist, academician B.B. Golitsyn. He had not only organised a network of I and II category seismic stations but also developed a seismograph with galvanometric recording of his own design for these stations. It is shown that a vast and full-rigged seismic network, the world’s only, enabled tackling a number of important scientific problems. As a result of the organisational and scientific works conducted during this period, the basic principles for the well-rounded assessment of seismic hazard were developed that remain relevant to this day.

1. Introduction

The history of seismic observations in Russia is devoted to some publications, dedicated, as a rule, to anniversary dates. Chkhakya A.D. considered the development of seismic services in Georgia [1]. The articles of Sidorin A.YA. and Kozyreva L.I. presented the results of studying historical seismic events [2, 3]. Some authors analyzed the contribution of prominent scientists to the creation and development of seismological observations in Russia and other countries [4, 5].

Our country faced the problem of earthquakes and their catastrophic consequences after the seismically active regions of Transbaikalia, the Far East, the Caucasus and Central Asia incorporated into the Russian Empire. In 1840, a catastrophic earthquake occurred in Shamakha (Azerbaijan), in 1887 – in Verniy (today Almaty, Kazakhstan). The strongest earthquake happened in Krasnovodsk (today Turkmenbashi, Turkmenistan) in 1895, and in 1902 – in Andijan (Uzbekistan) and again in Shamakha. Frequent tremors in these areas led to the destruction and death of people.

2. The beginning of seismological research in Russia

In 1887 after the earthquake in Verniy, on the initiative of famous Russian geologist I.V. Mushketov, a temporary seismic commission was organized in the Russian Geographical Society. The purpose of this commission was to collect and systematize different information about seismic events on the territory of the Russian Empire and bordering countries. For this purpose the special questionnaires were developed. They were filled in according to the results of surveys of earthquake witnesses. Also to study
the effects of devastating earthquakes some expeditions were organized. One of the important results of its activity was the preparation of the “Catalog of the Earthquakes of the Russian Empire” (by I.V. Mushketov and A.P. Orlov), which contained information about more than 2000 earthquakes that occurred in Russia and other countries during the period from the 6th century BC until 1880 [6].

The first regular observation of seismic phenomena with the help of a special pendulum was carried out by the German astronomer E. von Rebeur-Pachwitz (1861–1895) at Strasbourg university observatory in 1892. In Russia, observations of seismic phenomena using the horizontal Rebeur-Pashwitz pendulum were organized at the Nikolayev Marine Observatory (since 1892), at the Observatories of Kharkov (from 1892) and Yuryev (from 1897) universities and at the Tiflis Observatory (from 1899) [7]. Organization of seismic observations at observatories was due to the fact that the observatories were equipped with precision time instruments needed to accurately record the time of aftershocks.

On January 25, 1900, by the decree of Nicholas II, for the systematic study of earthquakes, the Permanent Central Seismic Commission (PCSC) was established under the Imperial Academy of Sciences. The director of the Pulkovo Observatory, O.A. Backlund, became its chairman. The purpose of the commission was a systematic study of earthquakes, collecting and publishing seismic data. To organize permanent seismic observations, it was supposed to create some seismic stations and provide them with the necessary equipment.

3. B.B. Golitsyn and creation of Russian seismic network

In seismology, as in no other science, international cooperation is of great importance. Only by analyzing data related to the same earthquake from different seismic stations, it was possible to determine the position of the earthquake epicenter, the depth of its focus and the intensity of shocks. During this period, horizontal pendulums of various designs with different accuracy of recording earthquakes were used for observations in different countries. The acquisition of the equipment abroad demanded big financial expenses, so the problem of the seismic instruments quality was extremely important. Boris Golitsyn, a famous physicist and head of the Physics Laboratory of the Imperial Academy of Sciences, played a major role in solving this problem.

B.B. Golitsyn was one of the first who suggested using physical and mathematical methods for studying the earthquake mechanism. He understood that strong earthquakes occurred rarely, but in order to catch the shocks from weak earthquakes that occur much more often, it is necessary to increase the sensitivity of seismic instruments and develop a reliable method to record seismic waves. Golitsyn was sure that the modernization of existing seismographs would not give the necessary accuracy of observations. He proposed changing the mechanical principle of seismic devices to electromagnetic one and developed seismograph of his own design. This approach not only increased the sensitivity of the instrument, but also allowed to use galvanometer and photographic paper fixed on a rotating drum for more accurate recording of seismic vibrations. In addition, by means of Golitsyn's seismographs another important task was solved – reducing the influence of the own vibrations of the device on the recording of aftershocks. Golitsyn proposed a new method of damping pendulums – electromagnetic method [8].

On November 26, 1906, the recording of remote earthquake signals using the Golitsyn seismograph began at an experimental seismic station organized at the Pulkovo Astronomical Observatory [9]. In 1909, B.B. Golitsyn and the head of the Pulkovo seismic station I.I. Wilip began researches deal with the construction of a vertical seismograph (with a horizontal pendulum) with galvanometric registration [10]. He believed that equipping each seismic station with a set of two horizontal and one vertical seismograph would be optimal to provide the necessary accuracy of observations.

B. Golitsyn solved another important scientific problem – determining the azimuth of an earthquake epicenter according to data of one seismic station. He could solve it due to the fact that the vertical and horizontal electromagnetic seismographs had the same parameters.

Testing vertical and horizontal seismographs at the Pulkovo seismic station showed the reliability of these instruments, their higher sensitivity, as well as the clarity and legibility of the seismograms. After
that, it was decided to equip all the existing and newly created seismic stations of I and II category with Golitsyn seismographs (Figure 1).

![Golitsyn seismographs](image)

**Figure 1.** Horizontal (a) and vertical (b) seismographs with galvanometric registration, Polytechnical museum.

The I category stations (including the Pulkovo Central Seismic Station) were located in Tiflis, Irkutsk, Tashkent, Yuryev, Yekaterinburg and Vladivostok. Their aim was to record and study remote earthquakes for the exploration of the overall seismicity and internal structure of the Earth. The location of these stations in the direction from west to east ensured that no earthquake would be missed. It was intended to equip stations of the I category with a set of two horizontal and one vertical Golitsyn’s system seismographs.

Seventeen stations of the II category, designed to study and forecast strong earthquakes, were supposed to be located in seismically active areas. These stations were equipped additionally with Golitsyn’s horizontal seismographs with mechanical recording to register strong shocks. All devices were made in the workshops of the Physics Laboratory of the Academy of Sciences.

Boris Golitsyn put a lot of effort to achieve financial support from the Russian state for the implementation of this project. On June 17, 1910, Emperor Nicholas II signed a law on the allocation of 45,440 rubles annually for the maintenance of seismic stations. For the management of all seismic stations, processing and publication of seismic data, as well as training special staff and formation of topics for further researches the Central Bureau of PCSC was elected. It consisted of B.B. Golitsyn, mining engineer A.P. Gerasimov and Lieutenant-General I.I. Pomerantsev [11, p. 196–197]. Financial support for the seismic service organization in Russia was also provided by private individuals. Thus, a seismic station in Makeyevka was organized with the funds allocated by the Congress of Miners of the South of Russia. Famous petroleum industrialist E. Nobel financed the creation of seismic stations in Baku and Balakhani [11, p. 200].

By 1915 Golitsyn seismographs were installed at seismic stations of the I category in Tiflis, Tashkent, Baku, Yekaterinburg, Irkutsk, Vladivostok, Baku, Makeyevka and seismic stations of the II category in Aleksandrovsky (Sakhalin), Petropavlovsk (Kamchatka), Kabansk (Transbaikalia), Barnaul, Verniy, Osh, Samarkand, Kandahar, Zurnabate, Shemakha, Borjomi, Pyatigorsk, Tomsk, Omsk and Nizhne-Olchedayev (Podolsk region). Such an extensive and well-equipped seismic network, the only one in the world, led Russia forward in the field of seismology. Bulletins with data from Russian seismic stations were sent not only to special seismic institutions, but also to leading universities and other scientific organizations in more than 30 countries. As a result, leading seismic stations in England, France, Germany, Italy, Sweden, Japan and other countries were equipped with sets of seismographs of the Golitsyn system. Equipping seismic stations with the same type of devises not only provided high quality analysis of seismic data obtained in different countries and regions, but also allowed to solve some important scientific problems.
A young graduate of St. Petersburg University P.M. Nikiforov (1884–1944) took an active part in organizing seismic stations and supplying them with the necessary equipment. Since 1908, he was invited by B.B. Golitsyn to participate in the scientific research at Physical Laboratory, in 1909 he was elected to the post of PCSC Secretary, and he held this post during the entire time of the commission existence.

In 1911, to provide seismic stations with qualified staff, B.B. Golitsyn gave a special course included 89 lectures. These lectures were of great importance for the development of the national seismological school. Preparing this course Golitsyn summarized and structured extensive theoretical material, which was then published in Russian and German. This book was the first textbook on seismology [12]. The training also included practical exercises at Pulkovo seismic station. In the future, such courses were held annually.

In 1911 B.B. Golitsyn was elected the Chairman of the International Seismological Association, which included 24 countries. It was the evidence of international acknowledgment of Russian seismology successful development. It was decided to hold the next congress of International Seismological Association in August of 1914 in St. Petersburg, but the beginning of the First World War thwarted these plans.

In 1913, B.B. Golitsyn summed up the results of using seismographs with galvanometric registration at Russian seismic stations. He noted that compared with 1911 (when the stations were equipped with another instruments), the number of recorded earthquakes increased from 383 to 576 (Pulkovo), from 219 to 456 (Tiflis), from 243 to 738 (Irkutsk). In the same period, one of the best seismic stations in Germany (in Göttingen) recorded only 134 earthquakes per year, and 139 ones in Strasbourg, and 64 – in Budapest [13, p. 360]. In addition, the number of cases of determining the coordinates or azimuth of earthquake epicenter according to one station data was increased and more than doubled.

In 1913–1915, studying some seismograms of distant earthquakes obtained at Pulkovo station, Golitsyn discovered the boundary of physical properties change in the Earth’s interior – at a depth of 492 km. This boundary characterized by an intense increase of the seismic waves velocity. Later, the upper mantle layer, bounded by this depth, was called The Golitsyn layer.

May 16, 1916 B.B. Golitsyn died suddenly from pneumonia. P.M Nikiforov began leading Russian seismic service.

4. Development of seismological researches in USSR (1920–1930)

During the revolution and civil war, the activities at many of seismic stations were interrupted. However, in the middle of 1920s, thanks to the efforts of P.M. Nikiforov, the work of the seismic service of our country has been restored.

The active construction of industrial enterprises and railways in earthquake-prone regions of Central Asia, the Caucasus and the Far East of Russia increased the importance of seismic observations. On the initiative of P.M. Nikiforov Seismological Institute of Academy of Science (SIAS) was established in March 1928. He became its first director. Under the guidance of P.M. Nikiforov the system of seismic observation was expanded by creating regional networks of seismic stations for the detailed study of earthquake-prone regions of the USSR. For such stations, P.M. Nikiforov invented a new type of seismograph for recording close earthquakes. In 1937 as a result of the regional seismic stations data analysis, a map of the seismic regionalization of the USSR was prepared. It had no analogues in the world [14].

5. Conclusion

The results of the organizational and scientific activity during this period became the base of the main principles of a comprehensive seismic hazard assessment development. They included the study of background seismicity at stationary seismic stations and the creation of temporary local seismic networks for more accurate seismic zoning. On a new instrumental basis, these principles continue to operate presently.
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