The Arc-of-Meridian Expedition to the Spitsbergen Archipelago 1899-1901 as an example of international scientific collaboration: tasks and results

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Abstract. As one of the most striking indicators of environmental change,, the Arctic is a region of bifurcated interests of various states. An important role in the process of cognition and development of the Arctic is assigned to the scientific community. The article discusses the experience and scientific tasks of the Swedish-Russian expedition on arc-of-meridian measurement in 1899-1901. The main results of the expedition and its contribution to the further development of research in the Arctic are discussed. The influence on the international scientific community is considered.

1 Introduction

One of the Sustainable Development Goals developed by the UN General Assembly in 2015 is to take urgent action to combat climate change and its consequences. At the end of the last century, discussions on climate change acquired a particular relevance at the global level. The Earth's climate is changing; atmospheric and ocean temperatures have risen, sea levels are rising, and the Arctic is one of the most obvious indicators of climate change. This has opened up new opportunities for consideration of exploration of natural resources that used to be covered by ice or permafrost. Even nowadays, oil plays a dominant role among other energy sources [1]. Climate is a long-term observation of weather that can be evaluated, so the study of these issues requires long-term monitoring. That is why it is necessary to look back at the experience of scientific expeditions studying the environment in the Arctic. One of such expeditions was the Arc-of-Meridian expedition to the Spitsbergen archipelago in 1899-1901, the scientific tasks and results of which are discussed in this article.

Since the middle of the 20th century, scientific and technological revolution began, which contributed to the creation of unique equipment for working on the Arctic shelf [2], improving transport, which made remote areas of the Arctic Ocean accessible, which led to the emergence of the problem of saving ecosystem as one of the key elements of sustainable development. At the present stage, the development of science allows to argue the claims for an increase in the continental shelf, but the issue of expanding the shelf in the Arctic became relevant at the turn of the 19th - 20th centuries. There are also international disputes about the ownership of certain territories in the Arctic. Therefore, the accumulated experience of research and promotion of scientific interests in geopolitically attractive territories should be taken into account at the present stage in order to avoid mistakes in the allocation of zones of influence.

In this regard, it is important to analyze the experience of the Spitsbergen Expedition of 1899-1901 as a scientific international enterprise. Understanding that this event is one of the first experiences of such cooperation, it is necessary to analyze the prehistory of the measurement of the meridian arc, to consider the course of the expedition; to evaluate the results and significance of the expedition for the scientific community.

2 Main body

Before the beginning of the 20th century, there were no permanent residents on the archipelago. Since the 16th century, it was visited by Norwegian and Russian sailors, whalers and hunters. In the 19th century, the era of colonialism was not over, and not all places in the world were developed. Among them were the northern territories and waters of the Arctic. Redistribution, establishment of control over the no-man's land and ownerless territories and sea-fishing in the Arctic began in the 19th century. This led to a number of political, economic and legal international disputes. The attention of the scientific community was drawn to the Spitsbergen since the 1870s, when the Geographical Society in Paris proposed to establish a meteorological observatory on the Spitsbergen archipelago, and the Swedish polar explorer A.E. Nordenskjold proposed to the Swedish government at the same period to consider the status of the archipelago [1]. Moreover, by the beginning of the 20th century, Spitsbergen faced a new global process of industrialization; this way, active exploration and mining of coal began. The availability of valuable raw materials attracted even more attention from various states. The

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uncertain political status made it impossible to carry out industrial activities at the proper level.

The issue of the discovery of the archipelago is still the subject of debate. There are several versions of who pioneered the discovery of Spitsbergen. The Norwegian historian T.B. Arlov highlights the following theories: the "Stone Age" hypothesis; the "Viking hypothesis" (12th century); the expedition of V. Barents (1596–1597); the Pomors hypothesis (16th century) [4]. Researcher I. Baranovsky emphasizes that historically Russia and the archipelago have been linked by a series of events. One example is the wintering of the Pomor Ivan Starostin, who visited Spitsbergen 17 times and stayed for 15 years on the archipelago until his death in 1826 [5]. Thus, despite the fact that until the second half of the 19th century Spitsbergen had been attracting mainly not explorers but those who had trapping and fishing purposes, the accumulation of knowledge about the archipelago begun. Moreover, the experience of sailing in harsh weather conditions gained by the natives and travelers contributed to the subsequent scientific exploration of the archipelago.

More international attention was paid to the archipelago in 1870. The French Geographical Society proposed to establish a meteorological observatory on the archipelago to study the climate indicators in the Arctic. Another proposal was made by the Swedish polar explorer A.E. Nordenskjold to the Swedish Foreign Office of the United Kingdoms. He proposed establishing sovereignty over the Spitsbergen Islands before any foreign power took over them and potentially created difficulties for further exploration [3]. Next year, an attempt was made by the Kingdom of Sweden to claim sovereign rights to the Spitsbergen Archipelago. The government appealed to Russia, Germany, England and Holland to submit objections to the inclusion of Spitsbergen as part of Sweden. However, the Russian government, due to the fact that the issue of historical rights to the archipelago remained disputed, could not agree to such inclusion [6]. The Russian Empire opposed the consolidation of exclusive influence of any European power in Spitsbergen because of the geopolitically significant territory due to its location at the outlet to the Atlantic Ocean.

In 1898, the Imperial Academy of Sciences (St. Petersburg) received a proposal to organize a joint scientific expedition to carry out degree measurements on Spitsbergen submitted by the Swedish Royal Academy of Sciences The Russian side agreed with the Swedish proposal. This would allow polar research to move to a new level. Moreover, the Swedish side undertook part of the funding [6]. The letter from the Minister of Foreign Affairs of the Russian Empire M.N. Muravyov to the Minister of Finance S.Yu. Witte of March 21, 1898, emphasized how important it was to accept the Swedish proposal, otherwise, rejection would mean recognition that Spitsbergen is outside Russian interests. The proposal was positively met by S.Yu. Witte, as this allowed not only to establish positive international relations but also to attract Swedish finances. He emphasized that "Regardless of this, one cannot but recognize it is as extremely desirable for our expedition to join the enterprise of the Stockholm Academy and begin the difficult and complex work with united forces and at half the cost"[7].

Since the geopolitical status of the Spitsbergen archipelago had not been determined by the second half of the 19th century, the issue began to appear more often on the political agenda. This way, international studies were important not only from a scientific but also from a diplomatic point of view. At the same time, the issue of studying the environment in polar regions appeared on the scientific agenda.

The change in the situation with equipment suitable for expeditions in the harsh weather conditions, made it safer and more productive to conduct expeditions in the polar regions. Moreover, scientific research in other parts of our planet, such as measuring the meridian arc or magnetic research, required a logical continuation at high latitudes in order to build up a holistic picture on a planetary scale. One such question that required further disclosure of data from northern latitudes was the question of the shape and size of Earth. A similar expedition was undertaken by the French Academy of Sciences in 1735-1745 sending one expedition closer to the equator, to Peru, and the second one to Lapland, closer to the poles. It had already been recognized that the Earth had some ellipsoidal shape rather than a true sphere, but scientists disagreed on where this ellipsoid was flattened - at the poles or at the equator [8]. In the 19th century the concept of geoid was introduced, which led to the idea that to determine Earth shape and size it is necessary to obtain accurate data on the linear magnitude of the meridian arc at different latitudes.

Technologies such as triangulation, a method of determining the size of Earth by covering its surface with a network of adjacent triangles, have allowed researchers to build an accurate model of the shape of our planet. However, this required measurements to be made in different parts of Earth. This method was based on the idea that the meridians have different curvatures. One successful project focused on degree measurement was conducted by Russian and Scandinavian scientists from the Danube to the Arctic Ocean from 1816 to 1855. However, this enterprise lacked data obtained at high latitudes where the difference in the value of degrees was more drastic. The project of such an expedition was proposed by the Englishman E. Sabin, a polar explorer, who conducted a series of experiments with a pendulum to determine the shape of Earth. He was convinced of the possibility of carrying out a triangulation network on the Spitsbergen islands [9]. Thus, the research carried out at the beginning of the 19th century by determining the length of the meridian arc, predetermined the further line of research in the polar latitudes, namely, taking degree measurements in the northern latitudes.

In 1899, E. Sabin's plan was implemented in high latitudes. The tasks of the expedition were outlined in detail by F.N. Chernyshev in his work "On the course of the expedition for degree measurements on the Spitsbergen islands in 1899-1900". He noted that the program of the expedition was developed at joint meetings of the Russian and Swedish Commissions and included a number of research works, not only geodetic

and astronomical work, but also observations of the northern lights, meteorological and magnetic observations throughout the year. Moreover, a network of triangulation points was developed, consisting of 22 triangles distributed between Ross Island and Mount Keilhau. The joint geodetic work included a meridian measurement , made to measure the size and shape of our planet, "... covering 4 degrees 19 minutes from the southern tip of Spitsbergen, at 76o30' to the northernmost of the Seven Islands, at 80o49'" [9].

As the head of the Swedish commission, which was entrusted with the development of the expedition itself, King Oscar appointed Prince Gustav. Among representatives of the Royal Swedish Academy of Sciences were academician A.E. Nordenskjold, mathematician M.G. Mittag Leffler, professor A.E. Ederin. On the part of the Imperial St. Petersburg Academy of Sciences, a special commission was formed including members of the Academy and representatives of the military and naval departments. His Imperial Highness the Grand Duke Konstantin K. Romanov was appointed chairman of the Russian commission for the preparation of this expedition. The Spitsbergen Commission included the Chief of the Military-Topographic Department of the General Staff Lieutenant General O.E. von-Stubendorf, the Chief of the Main Hydrographic Department of the Naval Ministry Lieutenant General K.I. Mikhailov and the Major General A.R. Bonsdorf. The development of the expedition program was entrusted to O.A. Backlund (chairman), F.B. Schmidt, A.P. Karpinsky, M.A. Rykachev, B.B. Golitsyn and F.N. Chernyshev [6].

The location of the expedition was determined "along the eastern coast of Spitsbergen from the South Cape along Sturfjord Bay and the Hinlopen Strait to the northernmost island in the archipelago of seven islands". The Swedish expedition determined that there were no serious climatic difficulties in the practical implementation of the project. The location of the expedition was not chosen by chance. The large length from south to north made it possible to carry out more complex measurements at a distance of more than 4 ¼ degrees, and the presence of high peaks made it possible to establish signals for astronomical and geodetic observations [6]. For wintering, research programs for magnetic and meteorological observations were developed. It was necessary to set geodetic signals in the south of the island at the selected observation points. The work on physical geography and topography was to be carried out by the reconnaissance party, and the geodetic party was supposed to facilitate this process by surveying the immediate vicinity of the signals. The work in geology was headed by F.N. Chernyshev. Thus, the expedition was entrusted not only with the task of measuring the length of the meridian arc, but also with multifaceted studies, since the selected area had been little studied before, and for some areas there was no data at the time of the study.

The reconnaissance work, the initial survey of the terrain, and the installation of the triangles were distributed between the Swedish and Russian parts of the expedition. The reconnaissance was carried out in order to inspect the territory and select reference points for further observations. During the preparatory expedition in 1898, the Swedes completed work only in the northern part. In 1899, the Russians had to conduct a reconnaissance in Sturfjord Bay, but due to the fact that the bay was later freed from ice and its shores were still poorly studied, these works seemed very complicated, which was difficult to accomplish in one summer [9].

The environment of the archipelago had not been properly studied yet, that is why the Imperial Academy of Sciences (St. Petersburg), despite the degree measurement of the meridian, had astronomical, geodetic, meteorological, physical and geological observations on the agenda. "In particular, to determine the specific gravity of the rocks composing it [the archipelago], which may be presented for studying their influence on the deviation of the plumb line and for understanding the distribution of gravity"[6]. It was planned to conduct familiarization work with the mineral and fish resources of the archipelago, in anticipation of practical results for the development of industries and trade, for raising the welfare of the north of Russia. In the 19th century, the absolute determination of the force of gravity could be made more accurately than before. In 1881, the Austrian scientist R. Sternek invented a pendulum, the measurements of which better corresponded to the necessary parameters [10]. And one of the items on the expedition's agenda was gravity measurements.

As for the financing of the expedition, the situation was as follows. At the beginning, the Russian government planned and allocated 100,000 rubles t for the expedition for one year from 1899 to 1900. The budget of the expedition was estimated at 200,000 rubles, half of which was covered by the Swedish side [6]. However, there were unforeseen expenses associated, first of all, with the weather conditions, because of which it was necessary to extend the expedition, due to which it was necessary to make adjustments to the estimate.

From the letters of the Chairman of the Russian Spitsbergen Commission and President of the Imperial St. Petersburg Academy of Sciences, Grand Duke Konstantin K. Romanov to the Minister of Finance S.Yu. Witte, one can judge about the budget of the expedition. It was already determined before the start of the expedition that the costs would exceed the primary ones. The letters of 1898 mentioned the expenses associated with wintering - the construction of houses and observatories, the purchase of all the necessary tools and food supplies for a year and a half, as well as the sending of reinforced scientific personnel for simultaneous work in the northern and southern parts of East Spitsbergen.

In 1899, Konstantin K.Romanov repeatedly referred to the fact that additional funds were needed for the expedition, as a large amount of work had been completed, but the goal had not been achieved, and to stop the expedition with the results obtained without giving them a logical conclusion would have been considered a failure. Additional funding for the expedition was also necessary to purchase the necessary equipment, the construction of an observatory and houses, covering costs connected with staff. It was not foreseen that a larger number of workers would be needed than initially

determined, or that a special steamer would have to be hired due to the difficulty of delivering all the necessary materials [7]. It should be noted that even projects implemented nowadays in the Arctic require significant funding and remain unprofitable [11].

Despite the lack of funds, archive documents note that the Russian expedition was organized much cheaper and, at the same time, more scientifically complete than the Swedish one. A letter to the Minister of Finance in January 1901 from the Grand Duke Konstantin Romanov notes that, thanks to the good spirits of domestic sailors and scientists, it was possible to perform the most difficult work, but since the work was not completed, it was not worth giving up without completing the tasks, since the completion of the work would be given to the Swedes, thereby the achievements of Russian researchers would fade into the background. At the same time, it is noted that the Swedes were not so successful in fulfilling the assigned tasks, and only completed one-fourth of what the Russians had accomplished [7].

The cost of the expedition went beyond the original budget, however the Russian government was aware of the importance of the research being carried out. Thus, the requests for an increase in funds were considered justified, since the scope of work was expanding as the expedition proceeded, and besides, the approval of the estimate was made at the highest level due to the political importance of this enterprise. It was important for Russia to gain a foothold in the archipelago. Moreover, it was extremely important not to concede all the achievements of Sweden at the final stages due to the only reason - lack of funds. In total, the Russian side spent 160,000 on the expedition, that exceeded the original limit on 60,000 rubles. And for 1903, 1904, 24,000 rubles were allocated to process the collected data. The Swedes also did not meet the limit. According to some researchers, they exceeded the limit by more than 2.5 times [12].

The expedition's results can be traced year by year. In the joint work plan, it was calculated that the end of the expedition would be in 1900. However, F.N. Chernyshev stressed that the ice conditions in which their Swedish colleagues found themselves were especially unfavorable. But the members of the Russian expedition also faced severe hardships due to climatic conditions, therefore he highlighted the selfless courage of the participants of the Russian expedition that allowed them to obtain great results [9]. In the summer of 1899, the work was completed on the placement of the signal network in Sturfjord Bay. In 1899, geodetic and astronomical observations in the most inaccessible research points were completed. Equipment was installed and ready for measurements in the magnetic and meteorological observatory. For the first time, a photographic magnetograph was put into operation, and geological, topographic and hydrographic information about Sturfjord Bay, which had previously been obtained during the Nordenskjöld and Duner expedition in 1864, became more reliable [9].

In 1900 almost the entire research program was fulfilled due to the increase in the volume of work carried out. Three observation points - Cape Agarda, Cape Misunderstanding, and the Helwald plateau - remained outside the scope of observation. However, due to climatic conditions, the Swedish side was unable to fulfill the planned program. The members of the expedition encountered unfavorable ice distribution conditions around the northern shores of the archipelago, which significantly slowed down the progress of research. Therefore, the research continued already in 1901. In the summer of 1901, triangulation work in the southern part of the archipelago was not completed, and the Swedish party was forced to go there during the summer of 1902 to finish its work [3].

A total of 3.5° meridian arc was measured over the three years of the expedition, most of the measurements of which were made by Russian researchers (arc of 2.5°). The Swedes were in charge of the northern part of the triangulation chain in the Spitsbergen archipelago. Their main station was at Cape Crozierpinten in Sorgfjord. There they established a baseline as a reference point for the northern part of the triangulation chain. Most of the research was carried out during the wintering of 1899-1900, which included geodetic work, magnetic and meteorological observations. A zonal survey from Hornsund Bay through the entire Sturfjord Bay to Cape Wallace Point was carried out, that was unique in its geographic location and scope. As a result, the topographic survey covered over 10,000 km2. Hydrographic data were obtained through continuous measurements of the depth of Sturfjord Bay. Crossing the routes of Western Spitsbergen in three places made it possible to obtain hydrological, biological and glaciological information about the inner area of the archipelago, which had not previously been studied [5].

The results of glaciological observations are used nowadays to monitor climate change. For example, researchers A. Pälli, J.C. Moore, J. Jania, and P. Glowacki compared the current state of some glaciers in the south of the archipelago, among them Hornbreen, Hambergbreen, with their state in 1899-1901 during the expedition under consideration. According to their study, the area of the glaciers has decreased by 37-50% [13]. That raises further discussions about climate change.

Observation of aurora borealis during the expedition held by J. Sykora and J. Westman allowed determining the height of the northern lights and its shape and speed. As it was the first study conducted using modern instruments, the obtained data was the beginning of a new era in the understanding the phenomenon [14]. Moreover, the topography of the centre, north, and northeast of Spitsbergen was introduced by G. De Geer and his team during the expedition [15]. Moreover, the data he obtained also allow researchers to analyze the state of glaciers, and the recession of glaciers indicates the ice melting.

For the first time, the results of these studies were presented at the International Congress of Surveyors and Astronomers in Paris in 1900. In October 1903 they were discussed at the 14th General Meeting of the International Geophysical Union and were met with great interest in the scientific community. During the expedition, a tremendous amount of information was obtained in various fields of science, particularly, in geodesy.

Therefore, the question arose of processing data and continuing research, which also required additional funds. During the 1900s, the question of financing the proceeding of the data obtained was on the agenda of the Ministry of Finance several times [6]. The results of the expedition, formalized and compiled in a general way, were eagerly awaited in the international scientific community. But, as D.P. Belyaev noted, having begun in 1904, the publication of the results ended only in 1919 [12].

Despite the fact that the completion of the expedition was delayed, and the research was carried out for three years, not least due to the strong personality of F.N. Chernyshev, the goals of the expedition were fulfilled. The information obtained during the expedition not only contributed to the advancement in the issue of determining the shape of Earth, but also significantly expanded the knowledge of the "terra incognita" – the Spitsbergen archipelago.

3 Conclusion

At the end of the last century discussions about climate change acquired particular urgency at the global level. This opened up new possibilities for consideration of exploration of natural resources that have previously been covered by ice or permafrost. The Arctic is a region with fragile environment but it is also a bifurcation point where the interests of different states intersect. The combination of these factors makes us pay attention to the need to study the Arctic in a historical context. The scientific community has an important role to play in the process of cognition and development of the Arctic, without whose active assistance, if we look back at the historical past, the modern development of the Arctic expanses is impossible.

The Russian-Swedish expedition to the Spitsbergen archipelago to measure the meridian arc was a major international undertaking. It was the first successful research expedition in the Arctic latitudes. In 1899-1901, members of the expedition managed to penetrate into the previously unexplored central regions of the archipelago and obtain material in the field of geodesy, astronomy, hydrography, zoology, botany, geology, meteorology, physics and other areas of natural sciences. The obtained material became of interest to the international scientific community.

The main research task, which the expedition was to solve – the measurement of the meridian arc - was successfully accomplished. Thanks to the persistence of F.N. Chernyshev, the research was brought to its logical conclusion and the Russian side succeeded in fulfilling the task. These studies made it possible to clarify the shape and size of our planet, the magnitude of the compression of Earth's ellipsoid. This logistically and scientifically difficult task was successfully accomplished through the cooperation of the two countries. Both the purely scientific motivation of this expedition, as well as the international cooperation and its successful completion without human casualties make the expedition one of the most successful projects. The expedition participants not only made a contribution to the development of polar science, but also to world science as a whole.

The data obtained during the expedition set new goals for further research. The series of topographic maps made during the expedition were supplemented with data with greater positional accuracy over the next century. New equipment and instruments enabled the research to advance polar science. The results obtained are used to compare the current state of the environment with its state a century ago. The ongoing processes in the environment demand our attention and can be analyzed more properly relying on past experience.

The expedition can rightfully be considered a major scientific enterprise. It is important that decisions on the financing of the expedition were made at the highest level, since in the 19th century, when the states nearest to the archipelago began to claim their rights to Spitsbergen. As a result, Russia's attention also shifted to the Arctic territories, as it gradually realized the importance of polar waters as potential transportation arteries, "storehouses" of natural resources, as well as an access to the Atlantic Ocean. And already in 1900, a Russian polar expedition was sent in search of Sannikov Land with the aim to further develop the region.

Analysing the current situation, the Arctic states include the issue of global climate change in their Arctic strategies. On the one hand, new opportunities appear for the development of natural resources and sea routes, but on the other, new risks of environmental security arise. And these issues already encompass the entire Arctic region, and therefore moving away from the practice of joint decision-making can affect the fragile Arctic environment and, in general, the stability of the Arctic development. It is important that environmental policies contribute to the prevention of man-made disasters and their consequences, as well as to the response to climate change. Even planning the budget of expeditions requires data on the conditions of the areas to avoid unforeseen costs associated with natural conditions, as it happened during the expedition. That is why it is necessary to take the previous experience of scientific research into account.

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