F. N. Krasovsky

His paper
Materials about Him

Selected and Translated by Oscar Sheynin

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I. Saint Fedos

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Abstract

The title of this paper was the nickname of a talented geodesist, Feodosiy Nikolaevich Krasovsky (1878 – 1948) which his students awarded him for his scientific work. He transformed and to a large extent created Soviet geodesy and assisted in the development of this science abroad. Krasovsky created a school and, until his death, remained its recognized leader.

Thus, he developed a harmonious programme and scheme of the main triangulation of a large country and a rigorous method of its mathematical treatment. Together with his former student, the younger great scientist Mikhail Sergeevich Molodensky (1909 – 1991), Krasovsky (just as eminent foreign scholars as well) emphasized the need for applying gravimetry in studies of the figure of the Earth.

And the parameters of the *Krasovsky ellipsoid*,

a = 6 378 245m, $\alpha = (a - b)/a = 1/298.3$

which Aleksandr Aleksandrovich Izotov calculated under Krasovsky's guidance, had been the best possible for that time. During the last years of his life, Krasovsky studied the problems of physical geodesy and its connections with geophysics and geology.

Not a single essential initiative appeared without his active participation and most geodesists who began their work in the second quarter of the 20th century were his direct students and his ideas outlived him for at least several decades. The authority of Feodosiy Nikolaevich was indisputable, not least because of his high moral qualities. He was demanding to others and to himself, but responsive and never thrusted on others his scientific superiority.

Errata (mistakes of irresponsible editor but not in my original text above) are corrected in *Almagest* vol. 10, No. 1, 2019, p. 132.

Abbreviation

AG = Astronomo-geodesicheskie (Astronomical and Geodetic)
GUGK = Glavnoe Upravlenie Geodesii i Kartografii (Main Geodetic and Cartographic Directorate)
KMI = Konstantinovsky Mezhevoi Institut (Constantin Land Surveying Institut), Moscow
KVT = Korpus Voennykh Topografov (Corps of Military Topographers)
MGI = Moskovsky Geodezichesky Institut (Moscow Geodetic Institute)
MIIGAiK = Moskovsky Institut Inzhenerov Geodezii, Aerofotos'emki i Kartografii (Moscow Institute of Geodesy, Air Survey and Cartography)
TZNIIGAiK = Zentral'ny Nauchno-Issledovatel'sky Institut Geodezii, Aeros'emki i Kartografii (Central Research Institute of Geodesy, Air Survey and Cartography)
VGU = Vysshee Geodezicheskoe Upravlenie (Higher Geodetic Directorate)

S, G, n = downloadable document n in my site Sheynin.de which is being copied by Google (Oscar Sheynin, Home)

1. Early years

Krasovsky grew up in strained circumstances, but his uncle, a land surveyor, was able to place him as a student and holder of a grant in the KMI. The boy graduated with a gold medal and was left there *to prepare himself for professorship*. He became an instructor and entered Moscow University as a freelancer and, in addition, spent more than five months at Pulkovo.

Thus Krasovsky extremely broadened his mental outlook which proved very important for his future ebullient activities. In 1904 he already had six published papers in one of which he (1902b) proposed a three-axial ellipsoid as the best approximation of the figure of the Earth. In 1912 Krasovsky became a senior instructor and chair of higher geodesy at KMI and professor in 1917.

The programme of geodesy and astronomy was modest but he essentially widened it and in addition established a laboratory, supplemented the pool of instruments, erected a platform for angle measurements on the building of the Institute and improved the organization of the summer practice.

Krasovsky doubtless understood the need for a serious geodetic coverage of the territory of Russia and, therefore, for well-prepared specialists. The specialists of the KVT deserve praise, but they had not solved that problem; more precisely, were not asked to solve it. In essence, Krasovsky only guided himself by the classical work of Struve (1856 – 1861) and the triangulation of top quality laid out by Pomerantzev in 1910 – 1914. The cartographic description of the country was certainly inadequate as well.

2. Activity under new conditions

On 15 March 1919, as proposed by the brothers Bonch-Bruevich, Vladimir and Mikhail Dmitrievich, the Sovnarkom (Council of People's Commissars, the government) established the VGU, see Sobranie (1919, pp. 139 – 140). In all probability, the brothers had also compiled the text of the pertinent decree. The former brother had been a student of the KMI and a student of the Zurich University and became the business-manager of the Sovnarkom. In this capacity he signed that decree along with Lenin, the chairman of the Sovnarcom, its secretary Fotieva and the future *enemy of the people* Rykov. A later addition to the decree stated: *Published in the* [newspaper] *Izvestia on 23 March*.

The other brother Bonch-Bruevich graduated from the KMI and headed the established VGU until the end of 1923. He invited Krasovsky to fill the position of the chief of the Scientific and Technical Council of the VGU since he was *convinced of his knowledge and persistence* of ensuring a tight connection between science and practical work (Kashin 1979, p. 10). Kashin had only referred to the *archival notes* of Mikhail. Additional information adduced here is extracted from Kusov (2004). On p. 9 Kusov quoted the decree of 1919 with unjustified gaps and listed aims of the future, VGU. In complying with the spirit of his day, he completely excluded the article on the need to establish ties of the VGU with *geodetic organizations of foreign countries*.

Kusov also stated that by the autumn of 1918 Mikhail B.-B began to teach geodesy at the MMI (the new name of KMI) and on 9 February 1921 publicly reported on the desirability of establishing a state geodetic directorate.

Such a directorate, the VGU, was indeed established. Both the aims and authority of the VGU and of its Council were immense. Krasovsky began his new work in 1921, then became the deputy chief of the Directorate and earlier, in 1919, the first elected director of the MMI. There, he established a geodetic, a cartographic and two more faculties. The programmes of geodesy (including gravimetry, theory of the figure of the Earth, photogrammetry and mathematical cartography), astronomy and cartographic disciplines were extended. A new housing for the astronomical observatory was erected.

After beginning work at VGU, Krasovsky left for himself the chair of higher geodesy. The increased demands on the MMI graduates led to the separation of a new institute, the MGI, later, in 1936, renamed MIIGAiK. Already in the MGI an optical-mechanical faculty was established since Krasovsky considered it necessary for developing a national geodetic school.

All these years he actively worked as a pedagogue. He compiled educational programmes, aids and textbooks, read lectures, guided students working on graduate theses and postgraduates, and became the soul of MIIGAiK (Danilov 1953, p. 13). There, he also became chair of higher geodesy and initiated the creation of four faculties.

Krasovsky’s scientific work corresponded to his pedagogic activities and organizational efforts (in the VGU). I specifically mention the pattern of the state triangulation which he (1928/1956, vol. 2, pp. 39 – 69) preliminarily proposed.

3. Arc measurements and the Krasovsky pattern of triangulation

Arc measurements (the determination of the length of one degree of the meridian) had begun in the 17th century. That length corresponded to the latitudinal difference between the end points of the measured arc which was determined astronomically whereas the length was indirectly measured by triangulation.

One such arc measurement was enough for determining the radius of a spherical Earth. Newton however proved that the Earth was a flattened ellipsoid of rotation. To corroborate Newton's theory and at the same time to determine both parameters of the ellipsoid (or to refute that theory) two arc measurements were needed, although actually many more for checking the results and compensating local irregularities in the form of the Earth.

By the end of the 19th century in the simplest case a chain of triangulation consisted of a system of triangles with measured angles. Its linear scale was determined by a base laid out and measured on one end of the chain. That base allowed the trigonometric calculation (by spherical or even spheroidal trigonometry) of the length of the sides of the triangles. An astronomical azimuth measured at an end of the chain allowed the calculation of the azimuths of those sides and the chain became astronomically geodetic.

Base measurements had been very laborious and required a flat surface and therefore the bases were short. By means of a few intermediate angle measurements they were connected with a side of the chain. Base measurement by invar wires 24 *m* long whose length very little changed with the air temperature had only begun by the end of the 19th century.

Actually, bases and azimuths have been measured at both ends of chains and in each triangle all three angles had to be measured to lessen the influence of systematic and random errors. Moreover, for the same reason the azimuths were measured in both directions. Each chain had to be therefore adjusted, or, in other words, the final values of all the measured magnitudes had to be somehow determined, usually by the method of least squares (MLSq). True, it was possible to consider that the azimuths and the bases were sufficiently precise and only to adjust the angles.

Four separate chains formed a polygon, or, roughly speaking, a square 200x200 *km* and the bases and azimuths were placed at the vertices of the polygons. Krasovsky borrowed this harmonious pattern from Pomerantsev and developed it; thus, he halved the lengths of the chains for the net to support the compilation of the state cartographic coverage of the country to the scale of 1:100,000. He also had to determine the necessary precision of the observations of each element of the triangulation which was an immense work.

The polygons thus formed allowed common azimuths and bases for two or even four chains with the chains remaining mutually independent to the highest possible extent. Bomford (1952, § 1.03) showed diagrams of the triangulations of India and the USA: no such harmonious pattern in either case.

The system of the polygons had to be adjusted as a single whole; it was inadmissible to *string* later polygons to those already adjusted since the unavoidable errors will then propagate much more harmfully. And it really was thus adjusted according to Krasovsky's proposals (1932).

First, the chains were preliminarily adjusted. Second, each was temporarily replaced by geodetics. Third, only these geodetics were adjusted as a single whole. Fourth, each adjusted geodesic was replaced by its own chain. Fifth and last, each chain was finally adjusted. Krasovsky remarked that the introduction of geodetics was

Helmert's idea (Helmert 1886, Tl. 1, pp. 1 and 68; Sheynin 1995, pp. 80 – 82) who had to treat an entangled triangulation gradually constructed during a few decades. He was the author of an excellent treatise on the MLSq (1872) and the main follower of Gauss in the treatment of observations, and he is also meritorious in mathematical statistics as well, see my contribution mentioned above.

The Soviet system of polygons was successfully adjusted in 1942 – 1944 and *some countries, for example France, began to reconstruct* their astronomical geodetic net in accordance with the Krasovsky pattern (Danilov 1948/1953, p. 14).

4. Further work at home and abroad

By the end of the 1930s the net of polygons began to extend beyond the Urals and the severe conditions of work required modification of the methods of laying out triangulations and of the measurements themselves. This circumstance became the direct cause for the establishment, in 1928 and on Krasovsky's initiative, of a research geodetic institution, the TZNIIGAiK, now named after him.

He had become its first director (in 1930 – 1937, deputy director). Until 1930 Krasovsky continued his work at VGU (replaced by GUGK) and in 1939 became a member of its board. His deep knowledge and worthy pedagogic and organizational activity helped him to collaborate with that body until the end of his days.

Krasovsky directed the work of TZNIIGAiK and personally participated in the work on many subjects. The Institute compiled instructions for most important types of work and introduced air photography into practice without which the cartographic coverage of the country would have been impossible. Krasovsky's potential additionally revealed itself in the working out of a few new map projections suited for the configuration of a given country. Then, together with geographers he opened up a new direction in the compilation of maps with the participation of geographers and geomorphologists. Accordingly, the teaching of geology, geomorphology and geography at the cartographic faculty of MGI had been essentially strengthened.

In the 1930s Krasovsky began to collaborate with the Baltic Geodetic Commission which coordinated geodetic work of the nations surrounding the Baltic Sea. In 1931 – 1937 he participated in its sessions As the official representative of his country, he was member, and then vice-president and president of the Commission, but early in 1938 the Soviet authorities removed him because of his *bad health* (Bonsdorff 1938). The real reason seems to be that in general almost all the (rare) contacts between Soviet citizens and foreigners had been mercilessly broken off especially since that was the peak of the Big Terror when any information about it was damaging.

Krasovsky himself never asked to be removed and I quote Isotov (1979, p. 50):

Krasovsky frankly expressed his thoughts even when it could have harmed him.

Instead of himself Krasovsky suggested the candidature of Professor (later, academician) A. A. Mikhailov who was indeed voted

President for 1938 – 1939. However, on 14 March 1938 the Soviet diplomatic representative in Helsinki informed the government of Finland that *the geodetic circles* of his country considered its further participation in the Commission pointless since the Soviet Union has entered the International Geodetic and Geophysical Union (whose member was the International Geodetic Association).

A damned lie! First, the Commission had indeed worked in a region but that was still important, and not less for the USSR with Leningrad bordering Baltic. Second, no mysterious circles would have pronounced the opinion described above contrary to Krasovsky. I heard worthy oral statements that the main government geodetic stooge and informer was Virovetz (who later became professor without being a doctor of science). That same Virovetz (1939, end of paper) called Lenin *the genius of mankind* so it was possibly he who personally embodied those *circles*. Third, the Soviet Union only entered that Union in 1955, see the *Great Soviet Enc*., third edition, vol. 6, 1971, p. 287, article *Geodetic and Geophysical Union, International*. This edition was translated, each volume separately, in 1973 – 1983, New York – London.

Mikhailov naturally resigned.

At the sixth session of the Commission Krasovsky's letter was announced: he was unable to come. Geodesy, as Krasovsky added, is a science without borders and he hoped that the joint work of the member nations will be useful for them and that their collaboration will strengthen (Bonsdorff 1938).

T. G. Kuzenova (2004, p. 26), Krasovsky's grand niece, recalled:

In one of his reports [apparently, at a session of the Commision – O. S.] *Krasovsly, as his wife told me, praised the work of German scientists. That was enough for banning him to go abroad. In 1936, being the President of the Commission, he had to remain at home and guided its work in absentia* [by telephone].

5. The Krasovsky ellipsoid

In 1936, Krasovsky derived preliminary values of the parameters of the Earth ellipsoid. In 1937, he left TZNIIGAiK, although continued to direct there the working out of the topics which interested him and turned his main attention to the work of his chair of higher geodesy at MIIGAiK. As stated in § 1, Isotov derived the final values of those parameters and in 1952 Krasovsky (posthumously) and Isotov were awarded the Stalin prize (later renamed after Lenin).

In addition, Krasovsky rigorously solved the reduction problem of geodesy: the transfer of measurements to the surface of the appropriate reference ellipsoid. The generally used *method of development,* as Krasovsky named it, consisted in reducing the measurements to the mean sea level. He himself, however, worked out the *method of projection* (his second term). That is, he reduced those results to the surface of the reference ellipsoid by normals to it since the previous method inadmissibly corrupted geodetic networks. Following Krasovsky, some countries introduced the new method as well.

Krasovsky explicated this subject in a previous edition of his *Rukovodstvo* [manual] (1938 – 1942, two volumes). The first volume was devoted to the field geodetic work. Being original in content and description, it became the reference aid for all geodesists. The second volume consisted of the solution of geodetic problems on the surface of a spheroid and of the application of astronomical geodetic and gravimetric measurements to the study of the figure and size of the Earth. It is there that Krasovsky investigated the method of projection. For this volume, he was awarded, in 1943, his first Stalin prize.

A remarkable scholar, Krasovsky's student M. S. Molodensky, later a Corresponding Member of the Academy of Sciences, specified the method of projection according to Krasovsky's guidance, by introducing gravimetric data. In general, geodesy, which had previously only studied the outer figure of the Earth, certainly by introducing gravimetry, became as well a science of the inner structure of our planet and of its gravitational field. The general gravimetric survey of the country began in 1933. In particular, gravimetry is also applied when searching for minerals.

6. Connections between geodesy and related sciences. The results of the activity

In 1939 Krasovsky was elected Corresponding Member of the Academy of Sciences, class physics and mathematics, and the entire geodetic community unanimously approved his election. Krasovky began to study successfully the connections of higher geodesy, and especially of arc measurements, with geology, geophysics and gravimetry and published two reports (1941; 1947).

Nevertheless, in spite of his efforts, the Academy had not hurried to admit geodesy as a scientific discipline. Krasovsky was unable to carry out all his intentions but Soviet geodesy is still indebted to him for essential achievements and the working out of the programmes and methods of field work and their scientific applications. Not a single essential initiative appeared without his active participation and most geodesists who began their work in the second quarter of the 20th century were his direct students and his ideas outlived him for at least several decades. The authority of Feodosiy Nikolaevich was indisputable, not least because of his high moral qualities. He was demanding to others and to himself, but responsive and never thrusted on others his scientific superiority.

Here is a telling episode. Krasovsky and V. V. Danilov were the joint authors of the first volume of the *Rukovodstvo* (1938), although I think that it would have been more proper to name Krasovsky assisted by Danilov. Indeed, after Krasovsky's death that treatise was included in his *Selected Works* with him indicated as its sole author, and Danilov (1953, p. 16) had not called himself a co-author. Incidentally, this (and other instances) clearly shows the personality of Viktor Vasilievich.

After Krasovsky geodesy attained a previously unimaginable high level, suffice it to mention cosmic geodesy, but his time and his name remain as an essential step in the history of that science.

My previous pertinent publications (2012, **S, G,** 50)

I have privately printed in about fifteen copies the following materials in English translations. **1)** His papers 1936a/[2, pp. 89 – 100]; 1936b/[1, pp. 179 – 183] and indicated two German translations of his studies (1931a; 1931b); 1939a/[1, pp. 9 – 20]; 1939b/1956, pp. 134 – 152, 1942/[2, vol. 4, pp. 550 – 555].

2) His archival letter of 1945 to A. A. Baikov, one of the vice-presidents of the Academy of Sciences about the negative attitude of the class of physical and mathematical sciences to geodesy and on the need to establish an academic commission on theoretical geodesy. Baikov, however, was very ill, soon retired and hardly had time to do anything. Such a commission was not established.

3) Papers about Krasovsky

Bagratuni (1978); Danilov (1953), (Izotov (1979), Pellinen (1979).

II. F. N. Krasovsky: His Paper and Materials about Him

Contents

Introduction

Feodosy Nikolaevich Krasovsky (1878 – 1948) was the leading Soviet geodesist. I am translating one of his papers and three contributions devoted to him. His *Selected Works* (1953 – 1956) are the main source for studying his work; Krasovsky's bibliography, containing many defects, but the only one, is at the end of Bagratuni (1959). Apart from Izotov [iii], twelve reports describing Krasovsky's life and work were read at a special sitting at MIIGAiK (see *Abbreviations* at end of this Introduction) and published in the same source. Three of them were devoted to subjects barely touched by the authors included here: cartography, geodetic instruments, photogrammetry.

Below, I have translated a paper by Krasovsky himself [i], three contributions [ii – iv] published on the occasion of the centenary of his birth and a Bibliography covering all those four pieces.

Here, I only add that he was director, then assistant director, science, of TsNIIGAiK and Vice-President and then President of the Baltic Geodetic Commission. In 1940, Izotov (1950) deduced the parameters of the Krasovsky ellipsoid by issuing from his investigations. Soviet geodesy was based on that ellipsoid from 1946, and the figure of the Earth, now generally accepted, does not differ much from it. Together with his former student, the younger great scientist Molodensky, Krasovsky emphasized the need for applying gravimetry in studies of the figure of the Earth.

I have graduated from MIIGAiK in 1951 as an *astronomer geodesist*, attended the lectures of all the three authors translated below, and V. V. Danilov was in addition the supervisor, or mentor of my diploma. During my student years, F. N. did not read lectures anymore, but his name had been on the lips of our instructors. His nickname, which I also came to know, *Saint Fedos*, only described his scientific prestige.

Krasovsky [i] and especially Danilov [ii] had highly praised the socialist system which hardly reflected their real feelings. Both had compiled their pieces during horrible times; Numerov, about whom F. N. deservedly held a high opinion, was then arrested (and shot in 1941). Incidentally, similar eulogies are in Khinchin's paper (1937).

In particular, I note that Danilov called the Bolshevik coup d'état of 1917 (25 October, old style, or 7 November, new style) by its official name, *Great October Socialist Revolution*; I have written *Revolution*. Then, the authors very often applied the adjective *Soviet*; instead, I have almost always written *our*.

A special point concerns the Decree of 15 March, 1919, which created VGU and became a turning point in the development of geodesy and cartography. Careful authors (Izotov [iii, § 5]) stated that Lenin had [only] signed it, and I came to the same conclusion.

Vol. 38 of Lenin's *Complete Works* (1963) covers the period from March to June 1919, lists the decrees which Lenin had at least partly compiled, or, in a special list, edited. However, the Decree of 15 March is only mentioned in a commentary (pp. 520 – 572) on Lenin's day-to-day work during that period. There, on p. 521, he is named as having participated in a discussion of its *draft* at a sitting of the Council of People's Commisars (= of Ministers, SNK) whose chairman he had been. But who drafted it? Answer: the brothers Bonch-Bruevich, Vladimir and Mikhail Dmitrievich (1873 – 1955 and 1870 – 1956), see vol. 3 of Soviet Encyclopaedia; source described in [i, Note 2].

The former finished a land surveying school, studied in MMI and Zurich University, and was, at the time (1919), managing director of the SNK. Mikhail graduated from MMI, participated in the creation of VGU (no details supplied), and became its first director (1919 – 1923). In 1939 – 1949 Mikhail edited the nine volumes of a geodetic encyclopaedia; I ought to add, however, that authors had barely referred to it. Kashin (1979, p. 10) stated that Mikhail was *one of the main organizers and managers of VGU*. Without documenting his account (a feature regrettably common for Soviet literature of the time), Kashin also quoted Mikhail's archival notes: the Technical Council of VGU was obliged to study the most modern methods of work and secure a tight connection of science and practice. He, Mikhail, invited Krasovsky to head that Council,

Having been sure of his knowledge and persistence in successfully completing each assignment. […] *His appointment was an expression of that connection, because at the time he had been almost the only representative of <u>great geodesy</u> in MMI.*

Here, finally, are two passages from the *Lenin Decree* (*Sobranie* 1919, pp. 139 – 140). The VGU was created

For the topographic study of the territory of RSFSR [see below] *aiming at raising and developing its productive forces and economizing technical efforts and financial means*.

To carry out that aim, VGU

a) Unites and coordinates geodetic activities of all Commisariats and institutions of the Republic;

b) On the national scale, implements and is in charge of main geodetic works (trigonometric, astronomical and precise levelling);

c) Carries out continuous and systematic topographic mapping over all the territory of the Republic;

d) Obviating parallelism, unites and directs surveys of every kind; for compiling and publishing maps of national interest to various scales and for various aims of national economy, it collects and systematizes the results of astronomical, geodetic and topographic works of separate Commisariats and institutions.

e) Works out and approves provisions regulating [geodetic] *activities, and technical instructions and rules establishing unity of the methods of* calculations, *and compilation and publication of maps and plans for various departments;*

f) Organizes cartographic work and publishes maps for separate departments, institutions and individuals, in particular by applying to existing cartographic institutions;

g) Manufactures geodetic instruments and optical apparatuses on the existing factories; supplies them for departments, institutions, and individuals;

h) Organizes scientific work in geodesy, astronomy, optics, cartography, instruments, and surveying in general, and for preparing young scientists; collects, systematizes and keeps maps and other materials of surveys;

i) For internationally harmonizing geodetic activities, contacts geodetic institutions of foreign states.

Signed: Chairman of Council of Peoples' Commisars Ulianov (Lenin); Chairman of Superior Council of National Economy [a future enemy of the people] [A. I.] *Rykov; Managing Director, Council of Peoples' Commisars, V. D. Bonch-Bruevich; Secretary L. Fotieva*

Also mentioned: *Published in Izvestia No. 63, 23 March 1919*

RSFSR (Russian Soviet Federal Socialist Republic) was created in 1918. Federal meant that it included a number of autonomous republics and regions. The Soviet Union was officially established in 1922.

Kashin (1979, p. 9) published allegedly the same two passages (not fully) and, quite in agreement with the contemporary new wave of obscurantism, omitted the last item …

Abbreviation applied here and below

GGK = Main Geodetic Commission of VSNKh (of the Superior Council of National Economy)

GUGK = Main (now, Federal) Directorate of Geodesy and Cartography

KVT = Corps of Military Topographers

MGI = Moscow Geodetic Institute

MIIGAiK = Moscow Institute of Geodesy, Aerial Photography and Cartography; now, Moscow State University of Geodesy and Cartography

MMI = Moscow Land Surveying Institute; now, University

TsNIIGAiK = Central Scientific Research Institute of Geodesy, Aerial Photography and Cartography; now, bears Krasovsky's name

VGU = Superior Geodetic Directorate

I

F. N. Krasovsky

Survey of Soviet scientific work in geodesy during 19 years[1]

Izbrannye Sochinenia (Sel. Works), vol. 2.
Moscow, 1956, pp. 89 – 100
First published 1936

[1] The more extensive is the territory, the higher are the necessary demands on its astronomic-geodetic and spirit levelling networks. The combined action of very small systematic errors about whose essence we are often ignorant, appreciably tells on the results of geodetic work and can make them not really reliable. It is for this reason that purely geodetic networks, however thorough are their results obtained, must be fitted out with some astronomically determined elements and thus to become astronomic-geodetic. In itself, a programme for geodetic work leading to high precision and homogeneity of its results over a vast territory is therefore a scientific achievement. *Organisation scientifique des réseaux géodésiques*, this is how the French properly call a complex of appropriate directions determining the patterns of networks and the programmes and methods of their implementation.

A great and important work on the main problems of the organisation of geodetic work has been carrying on from 1923 to the present day by [several departments and institutions are mentioned]. Only a small number of publications regrettably represent its results.

The size of the polygons of primary triangulation; the frequency of its baselines and the arrangement of Laplace stations; the classification of astronomical stations in primary triangulation, and the ascertaining of methods of their determination; problems of the secondary breakdown; the most advantageous distribution of the weights of measurements in primary baseline networks; checks of azimuth determinations; tolerance in astronomic-geodetic and spirit levelling networks; the size of the polygons of precise levelling; directions for astronomic-geodetic work and levelling of the I and II order; theoretical investigations of the action of errors in triangulation; comparison of quality of the various forms of primary chains of triangulation and the possibility of their implementation in different regions of the Soviet Union, –

this is the list of the main problems which have been tackled from 1923 to the present day.

It is useful to note that rigorous investigations have been partly fulfilled relatively recently, in 1931 – 1935. Until then, the need to offer leading instructions for the rapidly developing geodetic work compelled us to be content with incomplete and non-rigorous studies complemented by the management's experience. Thus [vol. 26][2], the size of the triangulation polygons, the frequency of baselines and the arrangement of Laplace stations was decided on the basis of incomplete studies in Krasovsky's paper (1928), but a rigorous justification of the solution of these problems only appeared in 1935 in [Izotov (1936) and Zakatov (1937) – Editors]. Just the same, the need to have bilateral Laplace stations in baseline networks was established in 1925, although the appropriate data, ascertaining an essential action of lateral refraction on azimuths and confirming the need to have such stations, was only obtained in 1932.

[2] As a consequence of all that scientific work we have, first, those main directions for the implementation of the state triangulation of the I and II orders, which have been followed from 1925 and are ensuring a good precision and homogeneity of geodetic results on our vast territory meeting the most various practical needs and scientific aims; second, a number of thoroughly worked out instructions and aids which in essence are good manuals for students; third, several published scientific works essentially important for theoretically justifying geodetic practice and further developing the construction of geodetic networks. In addition to the above-mentioned papers, Urmaev[3] and Durnev (1937) belong here.

This last-mentioned work definitely ascertains those regions where triangulation chains of the I order consisting of braced quadrilaterals are more beneficial and provides valuable information about the use of local peculiarities of the geomorphological landscape for planning such quadrilaterals. The need to connect and justify geodetic planning with a study of the territory from the viewpoint of physical geography will be practically important.

I will not dwell on the main instructions regulating geodetic works since they are well known. As compared with all other countries, they are characterized by some relaxation of the rigidity of construction in their [the networks'] purely geodetic part, but by more astronomical work than in all large countries, and still more frequent baselines as compared with the USA. As a result, we obtain a construction only less rigid (certainly, to a small extent) than the German triangulation, but allowing us to develop the main AG work at least expenses in the flat regions, very unfavourable for precise geodetic observations.

During the latest years, the rapid development of the national economy and industry has raised the demand for surveying great territories to the large scale of 1:10,000. A tendency for an appreciable enlargement of the scales of the general state mapping had appeared.

This led to a presently going on revision of the adopted pattern of constructing the main geodetic networks for covering a larger area by chains of the highest order[4].

[3] Concerning the implementation of geodetic work, we ought to note the construction and outfitting of comparators [vol. 12] at MGI for invar wires 24 *m* long. They very favourably differ from those constructed in pre-revolutionary Russia for the same aim. However, when discussing base measurements, we also ought to mention the great work which is going on at the All-Union Institute of Standards (the former Board of Measures and Weights).

They obtained very interesting results unknown abroad: calm periods in the changes of the lengths of invar rods, <u>even old ones and even old platinum rods</u>, are replaced by periods of comparatively noticeable changes. This is one of the results of their subtle investigations, essential for geodesy. A frequent comparison of the working rods of the comparator with the VIMS[5] standard measures, being so thoroughly studied, ensured a high precision in reducing the lengths of invar wires to the international prototype metre. We are justified in stating that our baselines are reduced to the same standard measure as those of Finland, Poland, the Baltic republics, Germany, Denmark and England. This is certainly confirmed by comparing our invar wires with Finnish wires which had been used in measuring baselines in all the Baltic republics, Poland and Germany as well as by measurements, in 1935, near Balashov [between Voronezh and Saratov; see Bonsdorff (1935) and Pesonen (1938)] conducted by the Baltic Geodetic Commission. Our own results only differed from theirs by 3 – 4 *mm* per 10 *km*.

Thus, owing to the scientific justification of our baseline measurements, we are sure that there will be no systematic discrepancies in the linear dimensions when our new triangulations will connect with those abroad, and there will be no need to find constant corrections to the lengths of geodetic lines caused by the difference of the standard measures.

Previously, we had to do that, and, therefore, to solve a very important problem by issuing from diverse data, i. e., without being really sure. It is not amiss to note that the excellent coordination between our standard measure of length and those of Germany, England, Poland and all the Baltic republics is appreciably disturbed with respect to France.

[4] On Finland's initiative, the West European countries, when calibrating their 24 *m* invar wires, are beginning, during the latest decade, to apply interference comparators. Here, we are somewhat behind. Only in 1933 did TsNIIGAiK begin investigating and planning the application of the interference of light waves for calibrating invar wires. At present, the equipment for an 8 *m* comparator is made and tested, and working plans for a 24 and 48 *m* interference comparators are developed. All the important parts of the equipment were created according to the strictest demands. From the work done abroad all this is distinguished in that we had, as previously, a *line* main standard measure rather than an end measure[6]. This led to considerable complications which were successfully overcome. Now, this work entered its next stage.

Changes in the lengths of wires essentially influence the results of base measurements. Actually, it is necessary to investigate their lengths during the measurement of each baseline of the I order. Therefore, it is very important to apply the method of the interference of light waves for precise determinations in the field of some control baseline. This problem is successfully studied by our specialists. A practical realization of interference methods of calibration of baseline wires both in laboratory and the field will certainly be an important accomplishment[7].

Next in turn is a construction and equipment of an appropriate comparator in Moscow. We ought to point out that regrettably the scientific work concerning the methods themselves of measuring baselines by invar wires is almost non-existent, and until recently the important question about the causes of the changes in the lengths of the wires was not touched either here, or abroad.

TsNIIGAiK is now investigating wires manufactured from Soviet invar and aims at obtaining indications for making wires meeting the requirements of measurements of the II order. From 1934, TsNIIGAiK together with the Central Radio Laboratory in Leningrad is experimenting on a large scale in the use of the interference of electromagnetic waves for measuring considerable distances of the order of several dozen of kilometres. They issue from Academician L. I. Mandelstam's [vol. 15] scientific directions. Essential difficulties are encountered, but the first stage of work, the determination of distances of the order of 30 *km* with a maximal error of 70 – 80 *m*, is already completed. It is impossible to say now what can be expected from those investigations for geodesy, but we are sure that results, important for mapping uninhabited territories, will be obtained.

The main part of scientific work in these experiments falls on physicists, but the participation of geodesists is absolutely necessary. Only they can correctly formulate a number of technical demands on the equipment; they also, by appropriately combining methods based on the interference of electromagnetic waves with usual geodetic methods of determining distances, will ensure the applicability of the new method in such conditions in which it would not have been successful all by itself.

[5] Going over to scientific work on precise angle measurements, it is necessary to mention investigations of such measurements and of parallactic [trig-] traverses [vol. 20]. An important conclusion is that the results of measurements are corrupted by systematic errors. This inference, warning us against applying large Wild instruments for triangulations of the I order, essentially coincides with the conclusions of the British geodesists made after their recent work in India.

This finding induced firma Wild to start improving the design of its theodolites, and, also, served for us as a cause for discovering such methods of angle measurements which will weaken as much as possible these systematic errors. The importance of these latter attempts is evident since Wild theodolites can play a decisive part in the forthcoming geodetic work above the 60° parallel.

Another essential and rather unexpected conclusion is that under some physical geographic conditions, often occurring in the central strip of the European part of the Soviet Union, the influence of refraction can considerably lower the precision of night observations as compared with those made in the evening. This fact compels us to repeat and widen those studies since their results can considerably alter geodetic practice.

It is not amiss to note either, that our equipment and methods of measurement lead to absolutely negligible influences of instrumental errors and errors of experienced observers on the mean results. The whole business is decided by external conditions which systematically corrupt the results. For precise angle measurements, the urge towards short-term accomplishment of work on a given station is in general at least doubtful.

Not less important is Prof. V. V. Danilov's experimental replacement, in appropriate regions, of triangulation of the II order by parallactic traverses. The geometrical justification of this method of measuring traverses is due to Gast, but to Prof. Danilov certainly belongs its real geodetic learning. The results of his scientific work are considerably important for practice, but for some reason they are not applied in our main geodetic works to the same extent as in the practice of several departments. In a number of regions this method can prove to be very advantageous for constructing networks of the II and III orders.

[6] Our geodesy has formulated a number of demands on practical astronomy as a consequence of the thorough determination of Laplace azimuths. The desired mean error[8] in the determination of the astronomical longitude of a Laplace station should not exceed 0.″2. For securing such a high precision we had to establish an appropriate time service in Moscow. Its exemplary work certainly ought to be counted as a scientific achievement of geodetic practice. In the near future that practice will probably have to take on the investigation of the oscillation of the Earth's pole.

The development of methods of determining the longitude of geodetic stations and the classification of longitude stations attracted special attention of our geodesists. This occurred because until now the application of transit instruments with impersonal micrometers for determining longitudes is still restricted.

A collective of astronomical geodesists compiled new ephemerides of Tsinger pairs of stars which ensure the possibility of selecting the best pairs for determining time according to his method [vol. 28]. This is certainly one of the measures improving the precision of longitudes determined in our conditions.

[7] Other essential problems of scientific geodesy are those of treating, and, chiefly, adjusting trigonometric networks. Here, a substantial step was our transition to the rectangular Gauss – Krüger coordinates [vol. 6, geod. projections] initiated by Prof. N. G. Kell (1930). The main point of the problem was not its methodical development but an expedient application of the Gauss projection which first of all demanded appropriately compiled manuals and tables. Our geodesists had done this.

Then, we have numerous papers in the *Geodesist* periodical on calculating corrections for the curvature [of the projection], the transition back from rectangular to geodetic coordinates, conversion of coordinates, drawing of the kilometre grid, etc. All possible simplicity and convenience are now secured for our entire geodetic and cartographic work.

A mathematical connection of all the systems of rectangular coordinates applied in the Soviet Union and therefore their actual unity; simplicity of adjusting and calculating the main networks; results, expressed in exactly those coordinates which should be used in all applied work, such as land use, mining etc, – all this followed from the thoroughly worked out introduction of the Gauss – Krüger coordinates which had been carried out since 1930.

[8] A great problem about the methods of adjusting triangulation of the I order was formulated for TsNIIGAiK already in 1929 when the polygons of the I order had spread from our Western borders to Volga. For that set of polygons the problem was solved by my method (1929, only an abstract; 1931?) which is a modified version of the Helmert method[9]. Under certain conditions it ensures a considerable speeding-up of work.

An essential difference of my version is an adjustment of the separate chains of triangulation making up the polygons for triangular, azimuth and baseline conditions before the joint adjustment of the polygons [of the geodetic lines replacing the chains]. This preliminary adjustment ought to tell favourably on the establishment of the azimuths of those geodetic lines and therefore to influence essentially the size of the polygonal closures and the possible deformations occurring during the adjustment of the polygons. The adjustment of these first nine polygons had fully corroborated my approach.

Then, according to my estimates, a preliminary determination of geodetic coordinates and azimuths by issuing from the adjusted chains, if only the initial geodetic data in the origin of the triangulation are favourably chosen, relieves us from retaining, during the polygon adjustment, a number of additional unknowns and reduces the polygonal equations to comparatively simple formulas. The drawing up of those equations does not at all demand lengthy eliminations of the additional unknowns which are a feature of the Helmert method.

The further and very speedy development of the triangulation of the I order and especially its reaching Khabarovsk compels us now to look for new methods of adjusting it, and this is actually being done. But the vast size of our network raises a number of other problems: establishment of the initial geodetic data; transition to a new ellipsoid from the Bessel reference ellipsoid; correct reduction of measured triangulation elements to the chosen main surface, etc.

I will return to these problems below, but now I am dwelling on the methods of adjusting triangulations of the II and lower orders. These triangulations have been very considerably extended, so that from 1931 this problem has become extremely urgent. The works of Urmaev are the most important. He (1931b) applied the theory of adjustment in two groups according to L. Krüger and his so-called *transformation*, providing a strict method of adjusting chains and networks without intersecting diagonals and situated between sides of a triangulation of a higher order excellently suiting practical requirements. Then, we ought to mention the work of Krasovsky [1930, 1931] devoted to the assimilation in our country of the adjustment of triangulation networks by the method of variation of coordinates.

Turning to traversing, we have to note that during the latest few years it became here a method ensuring the initial geodetic control over large territories. And we have worked out methods of replacing triangulation of the I order by precise traverses. I bear in mind the method of traverses borrowed from the USA, which, however, we had to change essentially. In our conditions, traverses are laid out along newly cut passages through forests and in primordial taiga rather then railroads and highways.

Precise traverses with its parallactic version along with appropriately laid out chains of triangulation will allow us to construct as successfully as possible the main geodetic control to the North of the 60° latitude. Usual traverses are more beneficial there for obtaining such controls of the lower order required for mapping.

[9] As is seen, during the latest 19 years we have essentially advanced both in the field work, in treating its results and in scientific efforts. To a sufficient extent we have strictly constructed vast main networks on our territory, have met the demands of mapping it as well as the requirements of applied large-scale engineering, land use, mining etc. surveying.

I should dwell now on the scientific application of the results of our AG work and first of all on its application for determining the size and flattening of the Earth ellipsoid and studying the figure of the geoid. I begin, however, by listing our arcs measured along meridians and parallels[10].

Four large meridian arcs are contained between longitudes 27 and 43°.

Three arcs along parallels of 46, 48, 50 and 56°, all of them between longitudes 20 and 25°.

Six short meridian arcs with amplitudes of 4 – 9°.

Vast arcs along parallels 52 and 54°, both beginning at the Polish border. The first one ends in Ust-Kamenogorsk [on the Irtysh river, to the East of Karaganda] with a longitudinal amplitude of 55°. The second one reaches Novosibirsk then lowers until parallel 49° and ends in Khabarovsk with a total amplitude of about 107°.

More than three hundred astronomical stations are already determined in that network with all the three elements (latitude, longitude, azimuth) thoroughly measured at each. This great work is a most prominent achievement. During 19 years we collected perfect data for scientific goals. It exceeds fivefold the European material gathered over 70 years of the 19th century and is almost equal to that collected in the USA during 1860 – 1910.

Our data certainly is of great scientific importance. The four great meridian arcs have a large weight in deducing the equatorial half-axis of the general Earth ellipsoid; our arcs along parallels have a large weight in determining the mean flattening and in addition they provide a unique and sound material for studying the longitudinal changes in the values of that flattening.

A very subtle problem of ascertaining the systematic deviations of the geoid from an ellipsoid of rotation will be studied by essentially issuing from our arc measurements. Its solution is considerably important for geophysicists and geologists and in general for earth sciences which investigate the processes of the Earth’s formation and the life of our planet in the past, present and future.

Thus, we have already contributed vastly and most valuably to Earth studies, and each year our contribution noticeably increases. And we also have to turn attention to our great gravimetric work, a general gravimetric survey of our country, which is going on from 1933[11]. The results of the determination of gravity are applied in geophysics, geology and geodesy. Until 1933, this work was being planned mostly in accord with the demands of geological prospecting and was not compact. The general survey began in 1933. It will provide us in the near future with new and wide possibilities for scientifically treating astronomical geodetic data and in applying new methods of studying the figure of the Earth.

Great arc measurements can be here applied either geometrically or, when using some data, by allowing for the influence of the irregularities of the distribution of masses above and below the surface of the Earth. The latter should issue from gravimetric results obtained in geodesy and its advantages can not be doubted. It is aptly to mention B. V. Numerov's reports of 1929 on the application of gravimetric data for determining deflections of the vertical as well as Mikhailov's most important investigation (1939) of the same subject. These works have played an essential part in the application of gravimetry in geodesy. And Numerov [Numerov & Chramov (1936)] had recently published theoretical investigations on the methods of determining the general figure of the geoid from measurements of gravity[12].

[10] In 1932 – 1934 a wide study of the deflection of the vertical by gravimetric measurements had been carried out near Moscow in the region of the so-called *local Moscow attraction*. Many scientists had been investigating it from the 1860s because of the discovered large anomalies of gravity existing in spite of the absence of any overground relief either in that region itself or nearby.

[11] These are the main interesting results. In a flat country, with an appropriate density of gravimetric stations around and near a certain point, in a circumference with a radius of 20 – 30 *km,* and pendulum observations situated 30 *km* apart in the zone between radii 30 and 100 *km*, the mean error of the determined deflection of the vertical in that point, without allowing for the influence of more distant zones, will not exceed 0.″5. Those zones should certainly be taken into account on the basis of the general gravimetric survey of the country; for the region near Moscow their estimated influence should be around 0.″8.

Upon receiving these results, TsNIIGAiK accomplished a number of studies in establishing the size, the flattening and the orientation of a Soviet ellipsoid by jointly applying AG and gravimetric materials.

It is not out of place to say here a few words about the problem itself of establishing a Soviet ellipsoid. Until now, we are still reducing geodetic results to the Bessel ellipsoid oriented by the astronomical coordinates in Pulkovo. This ellipsoid has an equatorial [half-] axis about 800 *m* shorter than that of the mean Earth ellipsoid. We still do not project strictly our triangulation but somehow develop it onto that unhappily chosen ellipsoid arbitrarily oriented in Pulkovo.

All this is a relic of old times, unscientific, and it is certainly high time to pass on to other procedures. In our conditions, the determination of the size of our Earth ellipsoid is both a purely scientific and practically important problem. On the other hand, bearing in mind the size of our territory, that ellipsoid will certainly approximate the general Earth ellipsoid. The establishment of our ellipsoid can not be solved without investigating the size and the flattening of that general ellipsoid.

A scientific formulation of that problem and the aspiration to be the first in solving it compels us to fulfil the following demands. The size and the flattening of our ellipsoid should coincide with the appropriate parameters of the general Earth ellipsoid reliably determined by issuing from all the contemporary astronomic, geodetic and gravimetric data. It should be oriented by reliably established geodetic coordinates and azimuth and reduced to the general Earth ellipsoid, in the appropriately chosen origin and to the height of the geoid in that place relative to the general Earth ellipsoid.

If and when solving this problem as stated, we will induce other nations as well to put an end to the still existing arbitrariness in the choice and determination of ellipsoids. On the other hand, exactly such a solution leads to correct reductions of all directly measured triangulation elements and the treatment itself of triangulation will become strictly scientific with its results becoming sufficiently precise for the final establishment of the Earth ellipsoid.

We ought to note that, as formulated, the solution of that problem demands a combined use of the results of arc measurements and of the general gravimetric survey. Then, we may note with satisfaction that our scientific geodetic work had already largely established the methods of solving the stated problem.

Finally, we should state that the Soviet Union will be the first nation to treat quite scientifically its arc measurements and to establish an ellipsoid for geodetic work. This is made possible by the material which is being provided by the general gravimetric survey, and, above all, by that attention to Soviet science which will secure the accomplishment of a number of important geodetic and gravimetric projects having purely scientific aims in regions in which life does not yet demand precise work.

Such projects are hardly possible abroad but feasible here and on a large scale in accord with our [geodetic] importance. Only in two or three years we will have stations (for example, near Novosibirsk) with gravimetric coverage extending over a territory of radius 2700 *km*. For such stations, the deflection of the vertical with respect to the general Earth ellipsoid will be determined with an error hardly exceeding 0.″5, and the height of the geoid relative to the normal spheroid with an error less than 10 *m*. Together with the necessary appropriate comparisons with a number of other stations and the results of arc measurements this will properly orient the Soviet ellipsoid.

Then, the programme of our arc measurements is essentially supplemented by the demand, already being taken into account, of a sufficiently detailed gravimetric study of a strip 200 – 250 *km* wide along the meridian or parallel of each arc and appropriately continued in its end points. This new programme of our arc measurements should be adopted abroad as well, but its large-scale implementation is not secured there.

This new programme coupled with the results of our general gravimetric survey will enable us, when treating the arc measurements, to allow for the influence of the overground and underground relief and underground deposits on the direction of the vertical in a given station, without introducing any hypotheses about the structure of the earth's crust. In mountainous regions this work will certainly be somewhat more complicated, but scientific work concerning the Caucasus and Crimea has already begun.

[12] I should add that from 1935 astronomical gravimetric levelling[13] is being made along the arc measurements. It provides profiles of the geoid and allows to reduce all the measured triangulation elements to the surface of some ellipsoid. TsNIIGAiK had worked out the justification and the method of applying such levelling.

AG and gravimetric data already collected and being collected, the scientific methods already having been worked out and applied when those vast and most valuable materials are used, ensure an essential advance in establishing the general Earth ellipsoid. The study of the figure of the geoid is also formulated on a reliable scientific basis and demands an appropriate reorganization of the programmes of collecting necessary data and of the methods of their treatment in all other countries.

The results obtained along with the establishment of the Soviet ellipsoid, – the distribution of the deflections of the vertical and the heights of the geoid above a properly determined ellipsoid, – together with properly established anomalies of gravity will certainly provide most valuable material for geologists and geophysicists. It will indicate underground deposits and prolongations of mountain ridges and give some data on the difference of the densities of those ridges, ascertain the picture of the isostatic compensation for a number of our regions and probably corroborate the existence of systematic deviations of the geoid from a normal ellipsoid.

My preliminary treatment of our arc measurements together with those of the USA and Western Europe already shows that the length of the equatorial half-axis of the general Earth ellipsoid is about 150 *m* shorter than that of the now adopted (and based on the geodetic work in the USA); that the existence of a triaxial Earth ellipsoid is sufficiently well corroborated for the zone between 30 and 60° North latitudes which includes the USA, Western Europe and our territory until the 90° meridian (Krasnoyarsk). My sketchy study of applying our geodetic data for scientific aims is sufficiently convincing for the following conclusion: In the Soviet state, the collection of the vast geodetic data meeting practical requirements is carried out simultaneously with large-scale work ensuring their application for scientific aims in such a way which can not be done now in other countries. We ensure compactness and strictness of the results obtained. Our methods of treating the data and programmes of work are ahead of those of foreign scientists. The system of life of the Soviet state based on science secures further and essential advances in the work of our scientists in geodesy. In the near future Soviet geodesy will naturally play the most important part in international geodesy.

Notes

1. This essay was likely meant to honour the 20th anniversary of the Bolshevik coup d'état [*the Great October socialist revolution*] of 1917.

2. Here and below I am thus referring to the English edition (32 vols, 1973 – 1983) of the third Russian edition of the *Great Soviet Enc*. (1970 – 1978).

3. Urmaev published quite a few pertinent papers.

4. One of our professors at MIIGAiK told us, his students, that Krasovsky had organized a conference for various users of geodesy to voice their requirements about the scales of mapping.

5. The institute of standards was mentioned above; now, the author correctly abbreviated that All-Union Research Institute of Metrology and Standardization.

6. Bomford (first edition, 1952, § 2.06) stated that end standards *for long tended to be obsolete although convenient for comparison with the wave-length of light*.

7. As a student of the Moscow Geodetic Institute (1946 – 1951), I did not hear about interference comparators. I participated in measuring a few baselines in the Ukraine in 1948, when no control measurements were done in the field. I had also worked a few hours calibrating wires on the Moscow comparator in the classical optical mechanic way. However, the National Standards Lab. of the Finnish Geodetic Inst. measures baselines, at least experimentally, by interference methods from 1947, see Google.

8. *Mean error*, here and below, is likely *mean square error of the mean*.

9. Most important was Helmert's introduction of geodesics which, according to the Krasovsky version, replaced chains of triangulation.

They were applied in the adjustment of the polygons after the preliminary adjustment of the separate chains, see also below. On Helmert see Wolf (1968, pp. 324, 378) and Sheynin (1995, pp. 80 – 82). I have studied Helmert's contribution which did not connect the adjustment of networks with the choice of a reference ellipsoid etc. He had to treat a medley of triangulation systems.

10. Zakatov (1950, § 90) stated that the Soviet arc measurements had extended over 45 thousand kilometres.

11. Both Danilov [ii, § 12] and Izotov [iii, § 9] indicated, that that survey had begun in 1932.

12. The next section is not connected with the previous text.

13. That levelling determines the geoidal heights relative to the chosen reference ellipsoid (the *profile*). Deflections of the vertical are needed, and the influence of their non-linear change between stations is allowed for by gravimetric measurements.

II

V. V. Danilov

Feodosy Nikolaevich Krasovsky

F. N. Krasovsky, *Izrbannye Sochinenia* (Sel Works), vol. 1, 1953, pp. 7 – 20

[1] Feodosy Nikolaevich Krasovsky was an outstanding geodesist of our time. He created the Soviet geodetic school and to a large extent contributed to its brilliant successes. For throwing more fully light at the advances of our geodesy and the importance of his work, I briefly describe the state of geodetic activities and results up to the beginning of the 20th century.

Geodetic work in Russia had begun in the first decades of the 18th century when Peter the Great decided to map the country by instrumental surveying and the first geodetic school was established in Moscow. During that century, his idea had never been forgotten and was embodied in the so-called *Descriptions* of the lands of the Empire controlled by a comparatively sparse network of astronomical stations.

However, a real survey of the country by plane table controlled by a network of appropriately compact and precise triangulation was only achieved in the 19th century. In pre-revolutionary Russia, KVT was the most considerable establishment carrying out geodetic work. It was staffed by geodesists of the Military Topographic School in Petersburg which prepared highly qualified topographers who had perfectly well mastered plane table surveying, and topographic triangulators graduating after a year of additional education and specializing in constructing a central geodetic network consisting of triangulation of various orders.

The leading personnel of KVT consisted of a small number of military geodesists, graduates of the geodetic department of the Academy of the General Staff, then being specialized mostly in astronomical observations, and, during the last years before the Revolution, in carrying out precise angle and linear measurements for triangulation of the I order. Military geodesists carried out AG work of that order and headed the organization of topographical geodetic and topographical work of KVT.

Mapping by KVT was based on instrumental surveys to the scales of 1:20,870 – 1:125,220 controlled by triangulation or astronomical stations. At first, K. I. Tenner[1] had begun surveying in 1819 in the Western frontier zone to the scale of 1:20,870 (Vilnius province) and F. F. Schubert, to the scale of 1:16,710. These surveys were partly instrumental and consisted in laying out survey traverses between triangulation stations by astrolabes or compasses with distances measured by chains, contours drawn by eye and relief shown by hatching. However, in 1844 the slow advance of that work compelled a transition to a smaller scale of 1:41,740. Thus 27 provinces in the European part of Russia, all the territory adjacent to Vistula, a large part of Finland and the Caucasus had been surveyed.

From 1848, specialists under general Mende from the Land Survey Department of the Ministry of Justice had been drawn in. Together with KVT they had surveyed eight more provinces and their work served for compiling maps to the scales of 1:146,000 and 1:417,400 for the European part of the country (excepting the regions above the 60° latitude) and the Caucasus.

In 1870, the most necessary state requirements were satisfied, and military topographic surveys began on a more precise level by plane tables to the scale of 1: 20, 820, and, from 1907, to 1:41,740, with plane tables and telescopic alidades and only controlled by stations of triangular network. Relief was shown by contour lines.

These surveys were executed in the Western frontier zone, southern Finland, the Crimea and Caucasus, had a high and quite contemporary precision and served as a perfect material for cartographic purposes. They certainly demanded an extension of the triangular and levelling networks.

The network of triangulation accomplished by KVT in the 19th century was uncoordinated, only covered with large gaps the European part of the country and did not represent [a part of] a single state system. In 1897 – 1907 general Scharnhorst had attempted to put that net in order by adjusting it consecutively, one part after another. KVT, however, finally decided that it was necessary to begin the triangulation of the I order anew, according to the pattern and programme worked out in 1907 – 1909 by a committee under I. I. Pomerantsev. Chains of triangulation consisting of simple triangles along meridians and parallels situated 320 – 370 *km* apart with baselines and astronomically determined azimuths and latitudes (but not Laplace azimuths) measured at their intersections were envisaged, quite contemporary in precision and methods of work.

In 1910 – 1916 chains of triangulation had been laid out along the meridian from Pulkovo to Nikolaev on the Black sea with transversal chains connecting these and the Struve arc. Five polygons were constructed, the southern of which had not been closed because of World War I. Of some importance among the older triangulation, except for that Struve arc, are only the chains of the arc measurement along the 52° parallel and 47°30′ ending at Orsk and Astrakhan respectively; even so, the predominant majority of their stations are lost. Better preserved are only those of the Caucasus, Soviet Middle Asia and Manchuria.

Somewhat better was the state of the vertical control: up to 1916, KVT had carried out precision and *high precision* levelling along railways and river banks, ca. 45 thousand *km* in all, connecting the water-gauge stations at the Baltic and Caspian seas. The preliminarily adjusted altitudes of the benchmarks and the measured differences of their altitudes were published in the S. D. Rielke generally known catalogue[2] and its additions with the altitudes reduced to the mean levels of the Baltic and Black seas.

Up to 1917 KVT had compiled the following maps.

To the scale of 1:417,400: the European part of the country, Western Siberia, Russian Middle Asia

Scale 1:669,600: a considerable part of Siberia

Scale 1:4,174,000: all Siberia

Scale 1:208,700: the Caucasus and a considerable part of Russian Middle Asia

Scale 1:125,220: Western part of European Russia

Scales 1:41, 740 and 1:83,480: Western and Southern frontier zones including the Caucasus, partly Russian Middle Asia and Manchuria

Some of these maps were compiled by instrumental, but mostly by partly instrumental surveying or only taking the measures by eye. The Land Surveying Department also had a considerable number of geodesists. It filled its need in personnel from the graduates of the MMI (the engineers) and land surveying schools with a three-year period of education. That Department had been legalizing the boundaries of landownership. Such work had begun under Empress Ekaterina II and continued until the Revolution. It consisted of carrying out traverses by astrolabes and compasses, later by theodolites and tapes, fixing their turning points by wooden posts and pits, and compiling land surveying plans for each landowner. These plans showed the situation of the boundaries of the owner's, and of the adjacent owners' land, [country] roads, settlements and the main parcels of land (arable land, pastures etc), but not the relief. They covered almost all Russia, but their material was useless for mapping; attempts to compile maps of provinces had been unsuccessful.

Somewhat better was the surveying done by that same department in the Caucasus by angle measurement and plane tables, controlled by triangulation and showing relief by contour lines.

The Forest, Railway, Resettlement , Hydrographical, Geological and other departments had also been carrying out topographical geodetic work, but it was uncoordinated and could have been barely used for mapping the country.

[2] When discussing the scientific geodetic conceptions in Tsarist Russia, two facts ought to be mentioned. In 1816 – 1855 V.Ya. [F. G.

W.] Struve, an astronomer of the Derpt [Tallinn] University, had carried out the famous meridian arc measurement (Struve 1856 – 1861) from a cape in the North extremity of Scandinavia to the mouth of the Danube, about 25° of latitudinal difference, along longitude 27°. Attention to his work was turned by high precision of its angle and linear measurements, but mostly owing to the thoroughly worked out methodical problems. His book became classical, and our geodesists are still deriving benefit from it.

The second fact was the work of F. A. Sludsky, professor at Moscow University, in the 1880s on the theory of the figure of the Earth [see Sludsky (1967)], much ahead of those times. He is known to have been the first to offer the differential equation of the geoid and the idea of jointly applying AG and gravimetric data for determining the form and size of the Earth. He also indicated that on land the geoid was situated below the surface of the normal spheroid, and above, on the seas.

Thus, up to 1917, the [general] state of geodetic work was unsatisfactory. Lacking was a unique system of central geodetic network of sufficient precision, either horizontal or vertical. There was no map of a sufficiently large scale covering all the country; maps to the scale of 1:417,400 only existed for the European part of the country and were dated in many parts; to the scale of 1:208,700 and the topographic maps of larger scales 1:20,870, 1:41,740, 1:83,480 and 1:125,200 were only available for small territories mostly in the frontier zone. Departmental geodetic work was carried out from time to time and absorbed considerable means without providing satisfactory results for mapping. A rapid reform of geodetic activities became urgent and was implemented after the Revolution.

[3] On 15 March 1919 Lenin decreed the creation of VGU liable for arranging geodetic work with the aim of uniting all such activities and organizing them for most fully satisfying the various requirements of the country and mapping it to an acceptable scale in the shortest possible time. The beginning of Professor Krasovsky’s geodetic career occurred during those years.

We know very little about Krasovsky’s earliest years. He was born 26 September 1878 [new style] in Galich, Kostroma province, into a family of an office employee. After losing his father in early childhood, F. N. had to live in strained circumstances. His primary education took place in the district school in his home town.

The teachers paid attention to the boy’s outstanding aptitude and attempted to assist him in every possible way in extending his knowledge. Upon finishing that school, the efforts of his uncle, M. O. Krasovsky, a senior land surveyor, made possible for F. N. to enter the general educational classes of MMI holding a state stipend. There, in that Institute's boarding house, Krasovsky had passed his life until the maturing of his creative power.

The classes provided approximately the same education as the non-classical schools [German, Realschule] but in addition they offered three courses in land surveying and two, in engineering. After successfully finishing them, Krasovsky passed on to the senior special courses [of the Institute] and animatedly began to study higher mathematics, mechanics, geodesy, astronomy and other special disciplines. The lectures read by such brilliant professors as I. A. Iveronov, V. K. Tserassky (astronomy), the future academician S. A. Chaplygin (mechanics), L. K. Lakhtin (mathematics), had been to a large extent conducive to his studies. The students had access to the Institute's unique fundamental library boasting 150,000 volumes and containing classics of general Russian and foreign literature of the 19th century, as well as of geodesy, mathematics and astronomy of the same period in Russian, German and French. There did exist a real source for learning!

Young F. N. gave himself up with ardour to studying the talented works of the founders of geodesy, astronomy and mathematics, Struve, Chebyshev, Grave, Markov, Tsinger, Gauss, Bessel, Lagrange and Laplace[3]. Already then the serious taciturn young man had been enjoying deserved authority among his comrades for his deep knowledge and high ethical quality.

[4] In 1900, Krasovsky graduated with a gold medal and was retained at the Institute to prepare himself for scientific and educational work. The next two years have passed in intensified studies of mathematics, theoretical mechanics, geodesy and practical astronomy. F. N. conducted practical classes for students and at the same time entered the physical mathematical faculty of Moscow University as a lecture-goer permitted to attend lectures without formally becoming a student. He did attend the lectures of best University professors and filled gaps in his education. With gratitude, he later recollected professors Chaplygin, Tserassky and Iveronov who had stirred in him an unquenchable desire for knowledge and a spirit of a researcher.

The studies at the University had left deep traces on the intellect of the young scientist during his maturing and created him as that tireless champion of science and researcher whom he was and, and who is thus left in our memory. For completing his preparation, the Institute sent F. N. to Pulkovo observatory. There he worked in practical astronomy under F. F. Witram and A. P. Sokolov and in geodesy participating in treating the materials of the Spitsbergen meridian arc with Witram and A. S. Vasiliev.

Some attendant circumstances had regrettably curtailed his scientific trip, and he spent in Pulkovo only 51/2 months instead of the scheduled ten. Upon returning to Moscow in 1903, Krasovsky submitted a thorough report (1904) on his work in Pulkovo. From there, we find that, in addition to treating the materials of that arc measurement, F. N. was able to participate in the investigation of the Pulkovo horizontal circle and acquaint himself with the compilation of maps of barely known countries, and with various types of map compilation by KVT. His other activities touched on practical astronomy and mostly consisted in acquainting himself with observing stars and of treating the measurements obtained; working with a portable transit instrument with a registering micrometer; determining the right ascensions of stars; with changes of latitudes, proper motion of stars and reduction of various catalogues to the same epoch.

All this work, as he (1904, p. 110) stated, had widened his scientific horizon and made it possible *to understand the subject in a wider context and clearer to imagine the aims of modern practical astronomy*. The report is very instructive for postgraduates in that it shows how should a scholar regard his work.

[5] The *List of Works of F. N. Krasovsky*[4] shows six writings published up to 1904. In the first one (1901), he turned attention to three of G. N: Shebuev's works. The first two (before 1901; possibly 1892 and 1895) had analytically and rigorously considered the geometric properties of an arbitrary surface, and, in a particular case, the author had studied the distances, azimuths and triangles on the surface of a triaxial ellipsoid little differing from a sphere. Applications of that case in geodesy had especially interested Krasovsky since it was directly connected with examining the figure of the Earth.

The third Shebuev's work also interested F. N. because the author was the first to formulate and solve the problem about the influence of the anomalies of the potential of the terrestrial attraction on the discrepancies (closures) of the polygons of levelling both for any surface and a surface little differing from a sphere. As an example, the author applied the method of models[5] which is now in general use. For a closed polygon he provided a formula for calculating its discrepancy caused by those anomalies.

Shebuev's investigations did not regrettably find any practical application which is quite understandable: a gravimetric survey of the country was lacking, but the very appearance of his work secures the priority of Russian scientists in the region of the so-called *geodetic gravimetry* created nowadays mainly by M. S. Molodensky with some participation of F. N. himself. The problem raised by Shebuev had found its theoretical solution (Molodensky 1948) and is being put into practice.

Krasovsky's first original work (1902b) is as though a candidate dissertation[6]. It testifies to his complete maturity as an engineer and young scientist. Interestingly, F. N. issued from the idea about the triaxial terrestrial ellipsoid as most approximating the body of the Earth. This idea runs through all of Krasovsky's subsequent writings for more than forty years and is most clearly expressed in (1936b). There, he convincingly showed that the introduction of a triaxial ellipsoid leads to a much better agreement between the results of various arc measurements. This means that the so-called large waves of the geoid are best represented by the simplest of all the regular geometrical forms, by the surface of a triaxial ellipsoid[7].

It can be thought that the idea of the stated optimal property of that ellipsoid was widely disseminated among geodesists of those times. This circumstance can explain both the appearance of the above-mentioned works of Shebuev and Krasovsky's choice of the subject for his first scientific writing. Its importance certainly consists not in the results obtained, but in its methodical approach: he introduced a supplementary unknown and solved the equations of arc measurements compiled for a simpler surface of an ellipsoid of rotation rather than for the surface of the triaxial ellipsoid sought. This trick, which essentially simplified his problem, has always been applied in the future by him himself and his students.

[6] Upon returning from Pulkovo and entering the teaching staff of MMI, Krasovsky began to busy himself with problems in geodetic education and organize laboratories. It should be borne in mind that in pre-revolutionary Russia the Institute had not been able to promote higher geodesy as a science. The instruction in it and in astronomy had been modest and restricted to satisfying the needs of the Land Surveying and other departments for constructing networks of triangulation of the III order. Accordingly, these disciplines were only taught for two years with a small number of [weekly] hours and one summer training session.

From 1907, F. N., as a junior instructor, began reading his own course of higher geodesy for third- and fourth-year students alternating year after year with Prof. I. A. Iveronov, but in 1912 he became senior instructor and chair of higher geodesy. In 1917, F. N. was already an ordinary professor of the same chair. From 1907 to 1917, Krasovsky had been teaching geodesy as a pluralist at the Moscow Higher Technical School. At the same time, he had read lectures [at MMI] in the theory of the figure of the Earth and conducted practical classes in astronomy; Iveronov delivered lectures in that discipline.

F. N. personally participated in surveying several cities (Kursk, Kazan, Revel [Tallinn], and Moscow) accomplished by the students on behalf of MMI, in applied investigations of land-melioration in the Middle Volga region, and directed the astronomical work of the Resettlement Department in Siberia which provided valuable material for mapping.

However, during those years Krasovsky turned his main attention to educational problems. First of all, he improved the organization of the winter and summer training sessions; established a geodetic laboratory; enlarged the geodetic room by modern precision theodolites for measuring angles in triangulation of the I order; built a tower with four posts on the Institute's roof for exercises in angle measurement; supplemented the triangular network in [the vicinity of] Pererva[8], the venue of the students' summer training sessions in geodesy, by a few new wooden signals and thus approximated those sessions to actual working conditions.

Being himself interested in the issues of *greater geodesy*, he foresaw the impending essential heightening of the demands from the national economy to higher geodesy after a revolution, whose approach had been clearly felt by the most progressive elements of the society, to whom F. N. also belonged. He specified his aim as preparing his students for accomplishing precise geodetic work on the vast expanses of Russia taking in account its physical geographic conditions; and for securing for them a clear notion of the general problems of geodesy and of the special conditions existing in backward Tsarist Russia.

Krasovsky tackled his aim from two sides. *First*, it was necessary to work out methods of the field work beginning with the construction of the triangulation of the I order. Relevant experience did exist: the Struve arc and the work of KVT during the 19th century, but mostly the knowledge acquired by the lay-out of the chain of the I order from Pulkovo to Nikolaev and of the adjacent five polygons of the same order accomplished in 1910 – 1914 under I. I. Pomerantsev by quite modern methods and instruments. In addition, there existed the experience of constructing departmental triangulation of the lower orders, and of foreign triangulations.

Krasovsky's generally known publication (1916) appeared as the result of developing those problems and reading lectures. There, for the first time ever, he thoroughly described the methods of practically constructing control geodetic networks (building of signals, baseline and angle measurement, precise levelling) with a part devoted to the treatment and adjustment of trigonometric networks.

Second, it was necessary to develop the mathematical part of all the calculations concerning the treatment of AG networks; to study the main problems of Russian higher geodesy; and to trace the main patterns and methods of their solution by issuing from the specific features of Russian territory and the level of development of Russian geodetic work. All that should have widened the students' mental outlook and prepared them for practically solving the problems demanded by life.

Krasovsky's study of these chapters of higher geodesy resulted in a number of lithographed editions of his lectures and monographs devoted to separate issues characteristic for that period of his scientific work. The typical and original features of his school began to manifest themselves: an exhausting completeness and thoroughness of description *with all the conclusions being carried out to practical results*. F. N. never left any puzzling questions; on the contrary, as though foreseeing such cases, he encountered them himself. Not accidentally did all the practitioners and researchers turned only to him when looking for and finding answers to all the occurring questions.

Krasovsky himself considered that the working out of each problem was concluded and indeed concluded it only after obtaining exhausting and clear answers to all questions either formulated by him himself or those which could have been expressed or will be encountered by his readers or listeners. Here, his considerable pedagogic experience and remarkable features as an outstanding specialist in scientific methods had revealed themselves.

[7] After the Revolution, Krasovsky's activities were displayed especially wide. Being concerned about a correct organization of geodetic education, and becoming, in 1919, the first elected rector of MMI, F. N. began separating it into the geodetic, land surveying, cartographic and engineering land-melioration faculties. This measure allowed a considerable strengthening of the instruction in geodetic, astronomical and cartographic disciplines. Courses in gravimetry, theory of the figure of the Earth, photogrammetry and mathematical cartography were included in the curricula of the geodetic faculty, geodetic and gravimetric rooms were established, a new building for the astronomical observatory was built and a 240 *m* baseline arranged in the Institute's yard.

Of decisive importance for the further development of MMI as an institution of higher geodetic education was the creation, in 1919, of VGU decreed by Lenin. It was liable for conducting all the main AG work, surveying and mapping the country, uniting and directing the geodetic activities of all the departments. This novelty changed the aims of the geodetic faculty of MMI. Its graduates were faced with conducting all the AG and gravimetric work over the entire expanses of a vast country in all its diversity. It was necessary not only to assimilate the existing methods of work and the pertaining arsenal, but in addition to solve a number of new and most complicated problems in geodetic theory and practice following from the size of the country's territory and the immensity of the forthcoming aims of socialist construction.

The preparation of highly qualified specialists in geodesy and cartography became the Institute's main goal and led to its further separation in 1930. It broke up into independent Geodetic and Land

Surveying institutes. The land surveying faculty was given over to the latter, and the engineering land-melioration faculty transferred to the Timiriazev Agricultural Academy. The geodetic faculty of MGI was itself separated into the AG and geodetic aerial photography departments with the latter soon becoming an independent faculty. Then, the need to organize national production of instruments compelled the Institute to establish an optical-mechanical faculty, without which, as F. N. thought, the development of the national geodetic school could not have been considered accomplished. Finally, the cartographic faculty was soon separated into the cartographic, polygraphic and cartographical geodetic departments but the latter was then transferred to the geodetic faculty.

Thus, gradually, an institution of education consisting of four faculties had been formed; in 1936, it was renamed MIIGAiK. This evolution occurred first of all as a result of the school's reorganization in connection with the new requirements of life and it testified that the new geodetic institute was full-blooded. Professor Krasovsky was the life and soul of that process. He personally worked out or participated in the development of new curricula, programmes and profiles of courses of the separate faculties and in the compilation of educational aids. He designed new rooms and laboratories; wrote fundamental textbooks in higher geodesy; read lectures; organized and directed practical classes for students; guided the preparation of students' degree theses and led postgraduates; and at the same time actively worked as a scientist.

[8] The created VGU formulated new aims, previously unprecedented in scope and importance, and this occurrence became the turning point in Krasovsky's forming as a geodesist. Until then, he only solved separate particular problems connected with surveying cities, levelling over large areas in Zavolzh'e, with his most considerable practical work being the directing of 1) the astronomical observations of the Resettlement Department in Eastern Siberia (1909 – 1917)[9] and 2) the construction of the Moscow triangulation (1919 – 1921). Now, however, the object of his activities became the vast territory from the country's Western frontier to the Pacific shores in all diversity of its natural features and complications of arranging the main geodetic work.

F. N. was one of the first to become a staff member of VGU, and he forever merged all his intentions and aspirations with its activities. All Krasovsky's previous work may be seen as preparation to his future tireless activities of an outstanding geodetic theoretician and practitioner.

During his work as an educator, he developed the methods of accomplishing the field work involved by constructing control networks; established a mathematical basis for their treatment up to and including calculation of geodetic coordinates on the surface of the adopted reference ellipsoid; fundamentally and methodically solved the issue of the forthcoming determination of the initial geodetic data; traced the approach to scientifically applying the AG work for studying the size and form of the Earth.

The graduates of MMI were therefore theoretically quite prepared for solving the forthcoming great problems of the geodetically opening up of our vast territory and only lacked practical know-how and required scientific guidance (ensured by F. N. with unsurpassed skill).

The year 1921 can be seen as the beginning of Krasovsky's work at VGU; abandoning the rectorship of MMI, he became at first the inspector of works for the Moscow region, then occupied the post of the head of the scientific and technical council of VGU. From 1924 to 1930 F. N. directed geodetic work as assistant head of VGU. During those years, he had to fulfil a great managerial and scientific and technical work of developing, in essence anew, the AG network of the I order; to prepare personnel; acquire instruments and other equipment; work out the pattern and programme of main geodetic works and arrange them in the field, sometimes personally, as when measuring the Riazan baseline of the I order in 1923; to instruct the leading personnel; compile the main instructions for accomplishing the field and computational work, etc. The difficulties involved had been especially great because those had been the most trying first years when the Soviet government was in the making.

[9] Among Krasovsky's scientific works of that period especially important was one (1928) where he, while developing and extending the experience of VGU, suggested and scientifically justified a new pattern for the state triangulation:

1. The size of the chains of I order were almost halved from 370 to 220 *km*.
2. At the intersection of such chains, the astronomical azimuths and latitudes were replaced by bilateral Laplace azimuths. In addition, such azimuths, only unilateral, were envisaged in the middle of each chain; true, this latter suggestion was not put into practice.
3. For securing mapping to the scale of 1:25,000, the polygons of the I order were filled up by a continuous network of triangulation of the II order controlled by two intersecting main chains of the same order with a baseline and bilateral Laplace azimuth at *their* intersection. In 1939, a special commission of GUGK somewhat supplemented that proposed network of the II order by heightening its precision so that it will also control surveys to the scale of 1:10,000.

The merits of this proposal were especially revealed much later, in 1942 – 1944, when the AG network constructed by then (and covering

2/3 of our territory) was jointly and rigorously adjusted according to the method developed by Krasovsky and improved by D. A. Larin. It turned out that only our AG network was thus adjusted; in all other countries, this was at best done approximately. Indeed, only the Krasovsky pattern allowed a joint rigorous adjustment, a feature which manifested his keen foresight. When working it out, he had to a certain extent presciently seen the method of its adjustment but only much later, in 1931, did F.N. directly approach that issue. Taking into account our remarkable success, some other countries (France, for example) began to alter their AG networks after Krasovsky's pattern.

[10] In 1928 – 1929, the main geodetic work had been going on at full speed. Sufficient control was already established over a considerable territory which allowed VGU, and then GGK, 1928 – 1930, to begin a planned mapping of the country. Krasovsky [appropriately] attempted to appraise the necessary scale for the state map of the country. Issuing from the requirements of the departments and national economy, he (1924b)[10] quite justifiably concluded that the scale of 1:100,000 should be aimed at, which had to be ensured by an initial mapping of large tracks to the scale of 1:25,000. However, taking into account the necessity of compiling the map to the desired scale in the shortest possible time, he suggested making use of the rich materials of land and forest surveying by some additional work for connecting the separate wood plots and orienting their boundaries at least by determining astronomical azimuths. For that latter aim F. N. designed a special method[11].

Krasovsky's work in mathematical cartography belongs to the same period. He developed a few new projections best suited to the configuration and latitudinal location of a given country (1925). Another subject under his study was the participation of geographers in the compiling of topographic maps; together with the geographer A. A. Borzov he created a new direction in cartography expressed in the joint compilation of state maps by cartographers, geographers and geomorphologists.

This novelty essentially enriched the contents of maps and heightened their general scientific value which to a large extent explains the success of the very first fundamental cartographic work (maps to the scales of 1:1,000,000 and 1:5,000,000) of our cartographers. Geographers were also drawn in for collating materials already during topographic surveying done by VGU and for compiling geographical descriptions of separate sheets of the map to the scale of 1:1,000,000.

These ideas and suggestions had been reflected in the curricula of the cartographic faculty of MGI, namely, in strengthening the instruction in geology, geomorphology and geography. Accordingly, the value [the usefulness] of the faculty’s graduates was considerably heightened.

[11] By the end of the 1930s the main portion of the polygons of the I order in the European part of the country (to the south of latitude 60°) had already been constructed, and the work extended to the East of the Urals. The severity of the barely populated Siberia and the special conditions of the northern regions of the European part of the country caused new problems and difficulties. It became necessary to review and specify the methods of precise linear and angle measurements and establish the optimal types of centres and benchmarks for differing and extremely diverse physical geographic conditions taking place over a vast territory including regions of deep frozen ground and permafrost. Necessary to review the building of signals; examine the methods of precise levelling; develop methods of terrestrial and aerial photographic surveying without which the mapping of the country was impossible; to work out methods of treating and adjusting AG data; trace the programmes and methods of scientifically applying the appearing rich materials, etc.

[12] An urgent solution of all this complex of complicated scientific problems was required. This compelled Krasovsky to initiate the establishment of a research institute which was indeed done at the end of 1928, and that institute was later called TsNIIGAiK. F. N. became its first director. From 1930, after freeing himself from the duties of assistant head of VGU, he wholly surrendered himself to developing research activities and preparing the personnel needed for that as a director, then the assistant (science) director (1930 – 1937).

In spite of great difficulties (lack of premises, laboratories, sufficient personnel, and transfer from Moscow to Leningrad and back), that institute had developed and by 1937 became a large research institution and acquired a deserved authority both home, in the country as a whole, and abroad. It consisted of geodetic, geodetic aerial photography, cartographic and instrument sections. Its main achievements during the first decade of its existence, were:

Establishing the proper methods of angle measurements in triangulation of the I order; **examining** the influence of vertical refraction on the results of precision levelling and determining its methods; fundamentally working out the supplementing of the main triangular chains of the I order by astronomical observations so that we became the only country where these observations had been most effectively applied in geodesy; **developing** a rigorous method of adjusting large AG networks (the methods of Krasovsky and Urmaev, 1931b); **working out** the methods and arsenal of aerial photographic surveying so that it became the main tool for state surveying up to and including large scales and essentially sped up the compilation of the state topographical map. This circumstance had played a great part in the mapping satisfying the requirements of its socialist economy and the successful accomplishment of the Stalin five-years plans. Then, **instructions** in all the main types of AG work were compiled and provided a robust scientific base for their arrangement.

We should also note that in 1932 the general gravimetric survey of the country had begun. It essentially contributed to the future proper arrangement of all the main geodetic works. [To supplement the previous text, the author adds:] During those same years F. N. established the main approach to the development of arc measurements and derived the first reliable size and form of the Earth ellipsoid (the Krasovsky ellipsoid of 1936)[12].

Those considerable scientific achievements of TsNIIGAiK, having been the fruit of a large collective of talented geodesists, were hardly possible without Krasovsky's directing and often personal participation with his great scope of scientific activities and deep and original thinking. These traits indeed explain his indisputable authority and importance.

The brilliant successes of our cartography were also to a considerable extent indebted to his guiding influence. F. N. engendered that sphere of knowledge by the idea of an geomorphological and geographical approach to cartographic materials which greatly enriched our maps and placed them at the head of world cartography.

[13] When, in the beginning of 1937, TsNIIGAiK became firmly established, F. N. quit carrying out the duties of its assistant director and turned his main attention to MIIGAiK, to its chair of higher geodesy. Nevertheless, in TsNIIGAiK he continued to direct the work that interested him, the establishment of the initial geodetic data and the study of the geoid's figure; his student, A. A. Izotov, was directly engaged in that work. In 1940, by making use of the vast arc measurements extending from our western borders to the Novosibirsk meridian, and the materials of such measurements in Europe and the USA, Izotov, working under Krasovsky's general guidance, derived the most trustworthy elements [parameters] of the general Earth ellipsoid,

$$a = 6{,}378{,}245\ m,\ \varepsilon = 1/298.3,$$

later called after Krasovsky, and selected as the foundation of all our AG work instead of the previously applied Bessel ellipsoid.

Later Izotov obtained the elements for orienting that ellipsoid most agreeing with the surface of the geoid over all our territory with the origin at Pulkovo but taking into account the Laplace stations at all the intersections of our AG network.

Thus the initial data for the forthcoming joint rigorous adjustment of all our network of I order were determined. In those same years F. N. suggested and worked out the *method of projection* for treating that network instead of the earlier universally applied method of development. The new method was greatly important: the treatment of the trigonometric network of I order became mathematically wholly rigorous and clear; excluded was the additional corruption of the network peculiar to the previous method and lowering its precision as compared with what is typical for field work, by a factor of several dozen.

At the same time, following Krasovsky's indications and under his guidance, M. S. Molodensky worked out the method of astronomical gravimetric levelling whose application allowed to obtain the profiles of the geoid along chains of the triangulation of I order and thus enabled to make use of the method of projection in a future adjustment of our AG network. This joint rigorous adjustment was accomplished in 1942 – 1944 by the Central Computation Department of GUGK under Krasovsky's general guidance as though thus completing the first period of constructing the country's AG network. We are now the only country in the world possessing a most precise network of I order thus adjusted (and covering 2/3 of our territory). No other country had been yet able to solve satisfactorily this main problem of geodesy.

[14] During that period F. N. compiled the generally known treatise (1938 – 1939, 1942). Its second part (1942) was awarded the Stalin Prize of the first degree[13]. The treatise has become a fundamental aid for the MIIGAiK students, practitioners and researchers. Its first part was devoted to the methods of field work involved in constructing the horizontal and vertical control networks and made use of the entire experience collated by GUGK up to 1937 as well as that accumulated abroad and the results of our laboratory and theoretical investigations. From its first appearance (1926), the exhausting completeness and clarity of exposition led to its becoming a *Handbuch*, in which geodesists had been finding the solution of all the problems they encountered.

The second part covered the geometry of the spheroid, the solution of all problems considered on its surface and the scientific issues connected with the application of AG and gravimetric measurements for studying the size and form of the Earth and the structure of its upper mantle and crust. Being deeply original in contents and description, it concentrated the results of Krasovsky's entire scientific work. And, going far beyond the boundaries of an aid, its importance is outstanding, it is a *leading* contribution. Especially important were chapters 9 – 11. There, F. N. quite clearly and fully elucidated all the main issues connected with the adjustment of vast AG networks, treatment of arc measurements and application of the results for deriving scientific inferences about the size and form of the Earth, i. e., about problems in which Krasovsky had been mainly interested during the last years of his life.

In chapter 9, he described, with appropriate fullness including additions made during those years, his method of rigorously adjusting vast AG networks. Striving to secure as much as possible the independence of the derived lengths and azimuths of the geodesics temporarily replacing separate chains, and thoroughly analyzing the sources of error, Krasovsky concluded that it was necessary to raise the precision of the Laplace azimuths by introducing the so-called *fundamental* azimuths 1,000 – 1,200 *km* apart, chosen and observed especially careful. A preliminary adjustment of the azimuths situated between them allows to heighten considerably their precision.

Krasovsky deduced rigorous azimuth equations with additional terms, as compared with Helmert's equations, correcting the deformation of the AG network if developed on the surface of the reference ellipsoid. Having analyzed the size of these terms, he concluded that the ensuing corruption of the adjusted Laplace azimuths should not be disregarded since they led to a systematic *twisting* of geodetic chains and thus engendered serious deformations in the AG network as a whole.

[15] Until now, each country usually projected its treated AG networks on the surface of the geoid, then developed them, without correcting the lines or angles, on the surface of the adopted reference ellipsoid. Understandably, this development of the irregular surface of the geoid on the curved surface of an ellipsoid resulted in the deformation of the network. Curiously though, the efforts of West European and especially American geodesists had been directed toward proving that those deformations were insignificant and practically unimportant.

If true for small territories, this is not at all valid for large regions, as Professors' Krasovsky and Danilov appropriate investigations convincingly showed. Suffice it to indicate that, for example, the ensuing error of the mutual location of Khabarovsk and Pulkovo is 30 – 40 times greater than the same magnitude due to errors of the field work and can not be allowed. Then, in chapter 11 F. N. proved that the *method of development* also corrupted the thus derived elements of the reference ellipsoid and its orientation. That method, rather than ensuring from rigorous mathematical treatment, resulted in unknown and considerable errors being introduced in the coordinates of the networks' stations.

Even were it possible to tolerate those errors from the standpoint of the country's mapping, in principle, for deriving correct scientific conclusions, such an *arbitrary* treatment of an AG network is inadmissible. In future, the defects of the method of development will be felt especially acutely when the networks of different countries are joined. The coordinates of common stations will diverge to such an extent, that even a *cartographic* contact is impossible.

Because of those considerations F. N. proposed to replace the method of *development* by *projecting* the elements situated on the surface of the geoid on the surface of the reference ellipsoid by normals to the latter. An absolutely rigorous, mathematically strictly treated network, free from any additional corruption or deformation, will result. The method of projection was first applied in 1942 – 1944 for the joint rigorous adjustment of our entire AG network. This required a preliminary establishment of the mutual position of the surfaces of the geoid and reference ellipsoid.

In chapter 9, Krasovsky thoroughly worked out the method of compiling such geoidal *profiles* and of projecting its elements (lines and angles) on the surface of the reference ellipsoid. Concerning the adjustment of AG networks, we see that the scientific thoughts of our geodesists in the person of F. N. and his students had considerably advanced, and ensured for us the first place.

Krasovsky (1902b) devoted his first scientific writing to the derivation of a triaxial ellipsoid from Russian arc measurements. From then onwards, he had always been interested in the issues of arc measurements and the following derivation of the elements of the Earth ellipsoid and its orientation.

[16] After 1930 F. N. returned to that issue in numerous contributions and thoroughly developed the arrangement of arc measurements and their scientific applications. Carefully analysing the materials and conclusions following from the main measurements, he arrived at a number of essential inferences and proposals:

On the necessity of appropriately **locating** the arcs and their interconnection into a single system with a surface coverage; on many fundamental **defects** and the ensuing weak efficacy of the **isostatic hypothesis** when applied to correct astronomical stations for the deflection of the vertical; on the necessity to allow, when treating arc measurements, for a **triaxial** Earth ellipsoid; on the expediency of abandoning arbitrary presumptions and basing the treatment of arc measurements on data of **gravimetric surveying**.

As a result, F. N. proposed a new programme of arc measurements which advisedly combined AG and gravimetric materials. We had indeed begun to measure our arcs according to this new programme.

Krasovsky's contributions had thus introduced complete clarity into the complicated and subtle methods of arranging and applying arc measurements. In particular, he fully elucidated the part of gravity in arc measurements and worked out methods for applying gravimetric observations. All these issues are described with an exhausting completeness in chapters 9 and 10.

When studying the derivation of the size of the Earth ellipsoid and the elements of its orientation, F. N. provided an original method for solving that problem by issuing from the heights of the surface of the geoid above that of the adopted reference ellipsoid. He described this in his earlier contributions (1936a, b) and chapter 9, pt. 2, of his *Treatise*. This method had not been yet applied, but promises much benefit owing to its simplicity and precision.

The discussion above shows that that *Treatise*, pts 1 and 2, represents an exceptional phenomenon both in our and foreign literature. Being absolutely clear, complete and rich in new ideas, it also provides answers to all questions raised by our practice. This is not at all surprising since F. N. based his writing on experience accumulated during more than 40 years of teaching, almost ten years of direct practical work as an assistant (science) chief of VGU, and, finally, on another decade of guiding scientific work of TsNIIGAiK.

While actively working as a scientist and teacher, Krasovsky participated in a number of conferences (1921 – 1929), collaborated with the Geodetic Board of Gosplan [All-Union State Planning Committee] taking part in three of its conferences, participated in the activities of the Baltic Geodetic Commission (in its sixth conference in Warsaw in 1932 and seventh conference in Moscow [and Leningrad] in 1934)[14]. In 1933, he was elected its vice-president, and president in 1936. He compiled and read many reports on the main issues of astronomical geodesy, delivered lectures at the Kuybyshev Military Engineering Academy and mathematical-mechanical faculty of Moscow State University. In 1939 F. N. was appointed member of the Board of GUGK; in 1922, he was expert in the conferment of scientific degrees, first at Glavprofobr[15], then at the pertinent All-Union Academic Board.

It may be said that he participated, directly or obliquely, in each considerable measure, in arranging a continuous **gravimetric survey** of the country and compiling its programme; reforming the higher and secondary **geodetic education**; **arranging** the geodetic work at GUGK and several departments; and **examining** the research programme and separate investigations at TsNIIGAiK. In January 1939, F. N. was elected Corresponding Member of our Academy of Sciences (physical and mathematical department) and from 1941 had been collaborating with its Institute of Theoretical Geophysics.

We ought to indicate especially Krasovsky's membership of the Board of GUGK. Enjoying considerable authority, he was able to influence essentially its decisions concerning the main issues of the arrangement of geodetic work and its methods and thus to continue successfully keeping to his general guidelines traced when he had been mainly working in VGU. F. N. valued this possibility very much and remained until death one of the Board's most active members.

At the Academy of Sciences, F. N. devoted the last decade of his life (1939 – 1948) to examining the main issues of higher geodesy which connect it with such adjacent disciplines as gravimetry, astronomy, geology and geophysics. He continued to develop programmes and methods of arc measurements by additionally involving geological, geophysical and gravimetric data and formulated the pertinent problem of studying the structure of the Earth's upper mantle. These two directions are well represented in his reports (1941; 1947). The first of these directions connected with the working out of a new chapter of higher geodesy, the so-called *geodetic gravimetry*, is presently continued by the well-known contributions of M. S. Molodensky, a Corresponding Member of the Academy of Sciences; the second direction is similarly represented by his student, Prof. V. A. Magnitsky [later also a Corresponding Member of the Academy].

[17] Summarizing almost half a century of Krasovsky's activities, of the most prominent geodesist of our time, we ought to say that his great contribution to science is even difficult to appraise now. His brilliant achievements in arranging vast geodetic work and scientifically applying it had advanced our socialist country so that it became the leader both in geodetic theory and practice. Indeed, our geodesy is essentially indebted to him who ideologically headed a large collective, consisting mainly of his direct or oblique students.

Even more important was the fact that the entire strong body of geodesists had been soldered together in a single harmonious family by the pathos of Soviet construction […]

It is impossible to separate Krasovsky's name from that of his famous students and companions like the scientists Molodensky, N. A. Urmaev, A. M. Virovets, Izotov, A. S. Chebotarev[16], Magnitsky, A . I. Durnev, O. G. Dietz, K. A. Tsvetkov, D. A. Larin, I. Yu. Pranis-Pranevich, P. S. Zakatov, N. M. Aleksapolsky, B. V. Fefilov, et al, or the names of enthusiastic practitioners like A. N. Baranov, S. G. Sudakov, M. K. Kudriavtsev, A. V. Rytov, V. F. Pavlov, P. I. Povaliaev and many others.

They all, each earnestly working in his place, have contributed to the common aim of our glorious geodesy. F. N. contributed so much […] that, were there no previous renowned culture of the Russian nation, or successes of Russian geodesy in the 19th century[17], no Revolution […], he would have been unable to develop and reveal fully his talent, and we would be lacking that Krasovsky, whom he is for us now. Looking over the main stages of his scientific creative work, we see that all his studied issues were raised by life, dictated by its demands.

A tight connection of our geodesy with life and its demands is peculiar for all our geodesists rather than for him alone. True science can not tear itself from life, otherwise it is separated from that ground which nourishes it by its juices […].

An active connection with life and practice engendered both Krasovsky's scientific work and pedagogic efforts. Exactly for this reason his spoken or printed word is so precise and clear and his work so rich in new ideas and so surprising by the deepness and power of intuition. [A quotation from Stalin follows.]

Now, when F. N. is gone, his contributions acquire an absolutely special importance. Collected in a single edition, they will continue to serve as an inexhaustible source of new thoughts and ideas for contemporary geodesists and future generations.

Krasovsky (1938 – 1939, 1942; 1942, p. 441) perfectly well said about Struve (1856 – 1861):

A conversation through this writing with that man of great intellect, a talented theoretician and practitioner of many years, is really necessary for educating a beginner and useful for an experienced and practically knowledgeable geodesist for verifying himself.

These words are no less applicable to Krasovsky's own contributions.

Notes

1. Danilov mentioned quite a few Russian geodesists of the 19th century. See Belikov & Soloviev (1971) and Zakatov (1950, § 93). I have expressed the scales of the old maps in the metric system.

2. I can indicate Rielke (1894) and *Katalog* (1934).

3. Who compiled this list? Did not Krasovsky study, for instance, Cauchy? On the other hand, although Grave was an eminent scholar, his name hardly belonged there.

4. Where did Danilov find that list? This is an example of an inadmissible faulty documentation, as understood at least nowadays.

5. In the 1960s, I had come across a few publications applying the method of a *corrupted model*, as the workers of TsNIIGAiK called it. Begin with an adjusted chain of triangulation (say), randomly corrupt its elements by errors chosen in accord with an appropriate normal distribution, and adjust the chain anew. The result, as far as I remember, largely meant that 2/3 of the corruptions became smaller, and 1/3, larger, although not exceedingly so. A similarity with the Monte Carlo method suggests itself.

6. The degree of *candidate of science* was conferred on those who successfully defended their candidate dissertation. It corresponds to the doctor of philosophy degree. See [vol. 11, article candidate of science].

7. The simplest regular form is certainly provided by a sphere.

8. Pererva is, or at least was, the name of settlements in several Russian regions.

9. Izotov [iii, § 3] mentioned a slightly different period, 1909 – 1916.

10. The date, 1924, does not agree with the context.

11. Explanation (Krasovsky 1924a). At a station with known geographical coordinates, a certain moment of sidereal time corresponds to any angle between the two stars, and therefore to a certain azimuth of Polaris as well. Krasovsky did not even mention the terrestrial object; apparently, it should have been included in the same set of observations with the stars.

Krasovsky had published four pertinent papers in 1924, 1925, 1928 and 1929, the last one, 33 pages long, appeared as a booklet (Moscow). In my Bibliography, I only mention the first paper.

12. Izotov [iii, § 12] called that *ellipsoid of 1936* provisional.

13. During the Khrushchev *thaw*, those Stalin prizes were renamed *State Prizes*, and thus called by Izotov [iii] and Bagratuni [iv].

14. *Glavprofobr* likely meant an institution of professional education (*obrazovanie*).

15. In a private conversation with a few students including me, Bagratuni remarked that Idelson (1947) naturally did not refer to Chebotarev. Idelson had compiled the first manual in least squares in a modern way whereas Chebotarev (1958) even later published a mammoth textbook on a pre-Helmertian level. He also was a Honoured Scientist of the Russian Federation (actually, a *Honoured Mastodon*). On one occasion he (1951, pp. 8 – 9) stated that it was not sufficient for a mathematical law to *describe* a phenomenon since Marx had argued that it was necessary to *change* the world! Then, he (1958, p. 579) declared that for fourteen centuries Ptolemy had been keeping mankind in ideological bondage …

At the time (1952 – 1953) Chebotarev was extremely influential.

16. In § 3, Danilov also stressed the general unsatisfactory state of Russian geodesy in the 19th century.

III

A. A. Izotov

Krasovsky's contributions to the development of geodesy and cartography.

Izvesiya Vysshykh Uchebnykh Zavedeniy. Geodesiya i Aerofotos'emka, No. 2, 1979, pp. 42 – 51

[1] The scientific, pedagogic and social work of the prominent astronomer-geodesist and cartographer Feodosy Nikolaevich Krasovsky began at the outset of this century and continued for almost fifty years. Especially fruitful was the second half of this period which coincided with the unique years of the formation and development of our geodesy and cartography as a branch of scientific knowledge and national economy. The Soviet geodetic school, whose universally recognized leader he remained for many years, was indeed born to a considerable extent as an original direction in the development of scientific thought under the influence of his powerful ideas and basic scientific work.

Krasovsky's activities extending over the wide field of geodesy and cartography had been surprisingly many-sided, purposeful and fruitful. He was involved with preparing engineers and scientific workers, solving the main geodetic scientific and technical problems, developing the vital scientific and methodical principles of the organization[1] of the main astronomic-geodetic work and topographic mapping, etc. In all of these directions he provided that scientific basis on which our geodesy and cartography had been developing during the second quarter of this century, and whose robustness we are feeling until nowadays.

I had been happy to be one of his closest pupils and, in addition, to collaborate intimately with him during many years. Under his day-to-day guidance I went through a remarkable school of scientific and various practical work. I could have recounted much about him both as an outstanding scientist and an original person, but I have to restrict my paper to only providing the most important information about his life and work.

[2] There are very few documents reflecting Krasovsky's childhood and adolescence. He was born 26 September 1878 [new style] into a family of an office employee in Galich, Kostroma oblast (province). After losing his father in early childhood, he had to live in strained circumstances. His primary education took place in the Galich district school, now the Krasovsky 4th Galich secondary school. Owing to the insistent efforts of his uncle, who noticed Krasovsky's remarkable aptitude, he entered general educational classes of MMI holding a state stipend. This was very important for a young man lacking material security.

After successfully finishing these classes, F. N. passed on to become a student of the same institute and graduated in 1900 with a gold medal. He was left at the institute for preparing himself for scientific and pedagogic work and additionally educated himself at the Pulkovo astronomical observatory and the physical and mathematical faculty of Moscow University. His direct teachers and instructors had been such outstanding scientists as I. A. Iveronov and A. S. Vasiliev (higher geodesy); V. K. Zerassky and A. P. Sokolov (astronomy); L. K. Lakhtin (higher mathematics); and the future academician S. A. Chaplygin (theoretical mechanics). Having been strongly induced by their scientific ideas and views, the young man's thoughts and interests as teacher and scientist had been formed. He was destined to contribute greatly to the development of the science of geodesy and cartography.

[3] In the pre-revolutionary years Krasovsky mainly worked in MMI which is very much obliged to him. From 1907, he was a junior instructor, but read lectures in higher [a word is missing in the text]. In 1911, F. N. became a senior instructor, and in 1917 the academic status of ordinary professor was conferred on him. He continuously held that position until his death on 1 October 1948. From 1907 to 1917 Krasovsky also read lectures on geodesy in its applied direction in the Moscow Higher Technical School.

In the pre-revolutionary years F. N. in addition participated in applied investigation of land-melioration in the Middle Volga region, surveying in towns and astronomical observations in the field. From 1909 to 1916 he directed astronomical expeditions in Eastern Siberia for the Resettlement Department. They provided valuable materials for mapping the studied territory. Krasovsky's published reports show that he introduced many improvements in the methods and organization of field astronomical work. He is also known to have worked out a method of determining the azimuth of a terrestrial object, called after him, by measuring the horizontal angle between the Polaris and a subsidiary star; it had been widely used.

It might be said that F. N. belonged to those prominent scientists who covered their wide section of science and in addition studied adjacent branches of knowledge. Thus, while working mainly in higher geodesy, he studied practical astronomy, gravimetry, the theory of the Earth figure[2] and cartography. His ideas and investigations in each of these disciplines were marked by formulating and solving fundamental problems of great scientific and practical importance.

Krasovsky's first published work indirectly indicated that he had begun scientific studies even during student years. Already then he became deeply interested in determining the figure and the size of the Earth. That problem had been the essence of all his scientific work, and, under the influence of his powerful ideas, its solution became the leading direction in the development of our AG science. One of his first considerable scientific works was indeed devoted to the establishment of the size of a triaxial ellipsoid by applying Russian arc measurements.

[4] After the October revolution Krasovsky's scientific, pedagogic and social activities began to acquire really broad dimensions and to develop in most various directions. In 1919, he was elected rector of MMI which then consisted of two faculties. Together with progressive scientists of those times, F. N. succeeded in establishing quite a few other ones. Greatly important was the formation of the geodetic faculty, later the cradle of our higher geodetic education. MIIGAiK had been gradually developing from that faculty. It prepares engineers and scientific workers in all the contemporary branches of geodesy and cartography.

While working out the curricula and programmes of that faculty, then of the [new] institute, F. N. strengthened the instruction in mathematics, geodesy, higher geodesy and astronomy, and introduced the study of theory of the Earth figure, gravimetry and the fundamentals of geophysics. These curricula and programmes had been repeatedly specified, but their main principles are still valid. Krasovsky also compiled a number of educational manuals and a fundamental treatise on higher geodesy in three [in two] volumes (1938 – 1942). It provided the most complete for that time description of the methods of main geodetic works and mathematical theories of higher geodesy. In 1943, F. N. was awarded the State Prize for its second part.

As a teacher and scientist deeply understanding the main problems of geodetic science and the importance of geodetic theories and methods for solving various scientific and practical problems, Krasovsky powerfully inspired the organization and contents of our higher geodetic education. His views and ideas about that education were partly set forth in some of his published works devoted to that subject, but partly are only kept in the memory of his living closest students and associates.

F. N. had invariably cared that the preparation of geodesists of highest qualification should be based on a deep study of AG theories and physical and mathematical disciplines and oriented to the solution of scientific problems of geodesy itself and of the [geodetic] technical problems encountered in various fields of human activities.

[5] In 1919, Lenin signed a decree setting up VGU whose successor is now GUGK. This setting up was the turning point and the beginning of a new stage in the progress of our geodesy and cartography. From then onward, F. N. closely linked his many-sided activities with the scientific and practical problems of VGU which was responsible for the state geodetic and cartographic service. In 1921, discontinuing his rectorship at MMI but remaining there the chair of higher geodesy and carrying out serious scientific and pedagogic work, he took a job at VGU. From 1923 until 1930 he was there chairman of its scientific-technical council and assistant director being the head of the scientific and technical management of all main geodetic and cartographic work done in the country.

Considerable experience in accomplishing AG work and topographic mapping is known to have been accumulated in pre-revolutionary Russia. And at the same time, advances in geodetic and cartographic science and technique worthy of attention were also attained on the level of that time. However, from the very beginning of its work, VGU had encountered great scientific and practical requirements not tackled previously either here or abroad. They were concerned, first of all, with the construction of a control geodetic network and organization of topographic mapping, in both cases for the entire country.

It was therefore necessary to solve the main scientific problems connected with the establishment of the Earth figure and size. It was evident that these requirements and problems could not be met/solved without appropriate scientific investigations, and at the end of 1928, on Krasovsky's initiative, a State Institute for Geodesy and Cartography was established. It was later renamed TsNIIGAiK, now bearing Krasovsky's name. Until 1930, F. N. was its director, and, until 1937, its assistant director [but see ii, end of § 8]. Very soon the new institute became the main centre of the development of scientific geodetic concepts.

[6] F. N. proved that for a large country the previous principles of constructing geodetic control nets were useless, and revised them. By 1928, issuing from his theoretical investigations on the action and accumulation of the errors of measurement in triangulation, he worked out a harmonious and scientifically justified pattern and programme for the construction of the state triangulation. He solved the problems about the optimal size of the polygons of the I order and the necessary frequency of baselines and Laplace stations (on which the longitude, the latitude and azimuth are determined by astronomical observations). He also set forth the principles of constructing subsequent lower orders of triangulation laid out within those separate polygons.

Krasovsky's proposals envisaged a construction of an AG network satisfying both the requirements of a topographic study of the country and the aims of solving scientific geodetic problems. In spite of repeated revisions and improvements, their main ideas are still valid. Moreover, they had inspired other countries.

By the end of the 1920s, a considerable, for those times, AG network had been constructed in the European part of the country, and it became necessary to treat and adjust it. Helmert had outlined some pertinent methods, but he connected that problem with determining the size of the Earth ellipsoid and establishing the so-called initial geodetic data. F. N. fundamentally revised his method and formulated his own proposals. First of all, he separated the adjustment proper and the determination of the size of the Earth ellipsoid and its orientation in the Earth's body. He also improved the theory and simplified the drawing up of the condition equations taking place in the polygons. Then, he worked out the problems concerning the application of Laplace azimuths during the adjustment of the vast AG network. His deep ideas are still not exhausted and will for a long time retain guiding scientific importance.

[7] The adjustment of such networks encounters the so-called geodetic reduction problem, the choice of a method for reducing measurements to the surface of an Earth ellipsoid which to some extent characterizes the shape and the size of the Earth. Even in the previous century, the Russian mechanician and geodesist F. A. Sludsky [see Sludsky (1967)] had made known, although not clearly enough, his considerations on the two possibilities or methods of solving that problem.

One of them only admitted the reduction to the [mean] sea level, i. e., only to the surface of the geoid, in spite of the further mathematical treatment of the observations being done on the surface of the chosen reference ellipsoid. The second method envisaged a reduction directly to the surface of that ellipsoid by appropriately correcting the observations. However, neither the features of these methods, nor their essence and consequences of their application were studied at all. Krasovsky's deep investigations rather clearly showed that the first one, universally applied, which he called the *method of development*, actually meant the development of the unknown geoidal surface on the surface of the chosen reference ellipsoid. In addition to the corruptions, due to unavoidable errors of measurement, it led to considerable deformations barely yielding to mathematical analysis.

F. N. also showed that the second *method of projection*, as he named it, which had not been previously applied, consisted in projecting geodetic stations and the measurements made there on the surface of the reference ellipsoid along its normals at those stations and therefore lacked any mathematical deficiencies. After his works the strict method of reducing measurements became quite consciously applied both here and abroad.

The new method requires determination of the deviations of the geoid from the adopted reference ellipsoid within the network under adjustment. However, for our vast territory the previously known solution by astronomic levelling, proved useless since it required frequent AG stations which meant much work and heavy expenses.

[8] While desiring to work out more rational methods for determining the geoidal figure, F. N. formulated the idea about applying AG and gravimetric data together. His idea took shape in the works of one of his former students, a Corresponding Member of our Academy of Sciences, M. S. Molodensky, who developed the now widely known method of astronomical gravimetric levelling. Our contemporary school of theoretical geodesy, generally recognized the world over, had been progressing by basing itself on his, Molodensky's, investigations.

In his studies, Krasovsky also worked out methods of adjusting continuous triangulation networks. In particular, he made practically applicable the theory of the now widely used method of adjusting geodetic networks by variation of coordinates (1930, 1931). Now called *parametric*, it proved to be the most convenient for applying computers.

It is very difficult to describe all Krasovsky's ideas and writings concerning the improvement of the methods and programmes of main geodetic works. He also greatly contributed to working out the requirements to, and classification of precise AG and levelling instruments. Then, F. N. had developed many mathematical problems of higher geodesy and methods for solving the direct and reverse geodetic problems on the surface of reference ellipsoids.

We know that in the past it was usual to express the location of control stations in the geographical coordinate system which is not really convenient for topographic mapping and useless for applied surveying. The works of F. N. contributed to the correct and general practical use of plane rectangular coordinates in the Gauss – Krüger projection. He himself and his closest students had so fully ascertained the theory and practice of their application, that no subsequent studies by other authors could have added anything new.

In the 1930s, when civil and industrial building had begun to develop widely, Krasovsky was often asked to consult applied pertinent geodetic work. I am regretfully unable to describe here an episode with his consultations connected with the erection of the planned Palace of the Soviets[3] in Moscow, and therefore to show his exceptional ability to penetrate the essence and the methods of solving complicated engineering problems, remote, as it seems, from his main scientific interests. In general, bearing in mind the application of geodetic methods in various branches of engineering, he urged that the fundamentals of applied geodesy should be developed as a scientific discipline. However, as I imagine, this important problem is still not fully solved.

[9] In 1932, the general gravimetric survey is known to have begun. It was a most important component of our AG work and considerably heightened its scientific importance. Having correctly estimated the value of this scientific enterprise, F. N. first of all had worked out a plan for developing gravimetric work answering the requirements for the solution of geodetic scientific problems. At the same time he set forth the main ideas and considerations on the approach to, and methods of applying the materials of that survey for solving the scientific and practical problems of geodesy and cartography.

When considering and improving the theories and methods of higher geodesy, F. N. had always borne in mind the solution of a wider range of scientific problems of geodesy itself and of other earth sciences. Thus, having worked out a modern organization of spirit levelling, he showed that precise levelling should above all serve for studying the differences between the levels of seas and oceans, vertical movements of the earth’s crust etc. His ideas fostered a correct organization of the work of GUGK on precise levelling and powerfully promoted repeated levelling. Already in the 1950s their results are known to have enabled to compile a chart of modern movements of the earth’s crust within the boundaries of the European part of the Soviet Union and provided most valuable information for understanding the processes taking place in the earth’s entrails.

[10] Strange as it is, Krasovsky’s scientific activities in topography and cartography are still very little studied. However, even what is well known, testifies about his considerable merit in the topographical studying and mapping of our vast country. He worked out the conic equidistant projection, the most suitable for representing our country on geographical maps; at the time, it enjoyed wide application. It is remarkable that even in 1923 F. N. advanced the opinion that the compilation of a precise topographic map of the country to the scale of 1:100,000 was the main goal of the statistical geodetic service. We may note with satisfaction that this important problem was successfully solved long ago. In the 1920s he had proposed a system of scales for topographic mapping and put forward the idea of differentiating our territory from the standpoint of mapping. Later Krasovsky outlined the approaches to, and methods of using the results of land and forest surveys and other applied geodetic work for compiling the state topographic map. In 1938 he returned to problems of mapping, and, drawing on the accumulated scientific and practical experience, offered new solutions concerning the scales and contents of topographic maps.

[11] It is surprising but true, that already by the end of the first decade of the work of VGU either F. N. himself, or [at times] a very small group under his supervision fulfilled a great amount of work on compiling the first directions for the state triangulation, astronomical work, precise levelling, topographic mapping and surveys of towns. All of them were specimens of scientific regulation and unification of programmes, methods and results of AG and topographic works for our territory and had been later repeatedly revised and specified in accord with the new advances of geodetic science and practice.

In the 1920s, F. N. had been a member, then the assistant chairman of the Geodetic Board of Gosplan [ii, § 16], obliged to determine the aims and directions of the progress of our AG and topographic work (see Krasovsky (1931c)). In 1939 he was appointed member of the Board of GUGK and remained in that capacity to the end of his life. It may be said that Krasovsky directly and creatively participated in working and carrying out each scientific, technical and organizational measure in geodesy and cartography.

[12] F. N. had begun his scientific activities by determining the size of an Earth ellipsoid from arc measurements; during all his life, he never forgot this subject. His investigations about constructing geodetic control networks, methods of adjusting AG networks, the programme of gravimetric survey, organization of precision levelling, etc, – had been a continuous development of his ideas about, and approaches to studying the figure of the Earth. However, Krasovsky's broad range of direct work on that subject only dates from the very beginning of the 1930s, when new considerable AG networks satisfying contemporary requirements to arc measurements had already been constructed.

F. N. obtained the first new results simultaneously with the adjustment of the polygons within our European territory. They absolutely clearly showed that the formerly known size of the Earth ellipsoid did not serve as a reliable basis for establishing our system of geodetic coordinates.

Krasovsky above all subordinated the investigations of the shape and size of the Earth to establishing a reference ellipsoid and the initial geodetic data for adjusting the national AG network. In solving this problem, he scientifically justified the requirements for the choice of the size of that ellipsoid and the initial data for astronomic-geodetic networks and cartographic work. At the same time, F. N. improved the theories and methods of determining the size of the Earth ellipsoid from arc measurements and justified the application of both astronomic-geodetic and gravimetric data for solving this problem.

In 1936, making use of our arc measurements together with those of Western Europe and the USA, Krasovsky published his deduced size of the Earth ellipsoid. However, he thought that his conclusion should be specified and entrusted his students in TsNIIGAiK with further investigations leaving to himself their scientific guidance. In the beginning of 1940, by issuing from more extensive data and, again, those foreign materials, new parameters of the *Krasovsky* ellipsoid were obtained. It is now being applied in our geodetic work and in other socialist [at the time] countries. In 1952, the State Prize was awarded for those investigations to Krasovsky (posthumously) and Izotov.

[13] In 1939 F. N. became Corresponding Member of our Academy of Sciences and began to investigate scientific problems of astronomy and geodesy connected with studying the inner structure of the Earth. In these studies, he urged to link the main geodetic scientific problems to investigations in other earth sciences. Considering the progress of geodesy as of one of these sciences, F. N. indicated in his last work that in the past geodetic methods and the results of AG work had enabled to establish that the Earth was an oblate ellipsoid and in addition to ascertain some main regularities in the inner structure of the Earth and its crust. He had justly pointed out that geodesy thus solved many very important geophysical problems in the years *when there yet was no geophysics*. According to his thoughts, the results of AG and gravimetric work, namely the declinations of the vertical and anomalies of gravity, were very valuable numerical data that can help to ascertain problems on the inner structure of the Earth and especially of its crust[4].

Regrettably, his considerations had not yet been duly developed by contemporary geodesists and are awaiting the efforts of future investigators.

[14] In his versatile activities, F. N. attached special importance to pedagogic work which enabled him to prepare engineers and scientists in the main directions of higher geodesy. Holding the chair of that discipline in MIIGAiK[5], he incessantly advised its members about the methods and contents of their work. He himself read lectures on spheroidal geodesy including subjects which now make up the contents of theoretical geodesy. In my view, his lectures had been attractive and interesting not only by their elegant style and for being easily understandable, but above all because he often reached far beyond the known and expounded his own views on the approaches to, and methods of solving the main geodetic problems.

Without exaggerating, we may say that most of our geodesists, who had begun their engineering or scientific work during the second quarter of this century, were Krasovsky's direct students and became the bearers of the ideas of his school possessing great magnetic force. To that school belonged the leading officers of our state geodetic service and many prominent scientists, who have contributed to the progress of geodesy and cartography. To a large extent it were his students who have been tirelessly putting into practice the scientific ideas of their outstanding teacher and mentor and constructed our precise AG network, created continuous networks of triangulation and topographic maps of our country. At present, geodetic and cartographic work continues to develop on a new scientific and technical basis but the influence of Krasovsky's scientific ideas and views on their organization is still felt.

[15] Those, who had met F. N., imagined that he was strict and very demanding. Yes, he was very demanding, above all towards himself and therefore towards all those with whom he had to associate. From students, postgraduates and collaborators he had demanded persistent day-to-day work for acquiring new knowledge and accumulating experience for solving the constantly broadening scientific and technical problems. F. N. had extremely highly valued the ability to work persistently and wished to contribute to the common aim.

In his life and work Krasovsky always kept to the strict demands of moral fibre and especially cared about the professional behaviour of geodesists. Understanding, that considerable engineering problems and important scientific goals were being solved (attained) by issuing from geodetic data, he had demanded professional honesty and awareness. If a geodesist allowed himself sloppy work or showed lack of spirit, and such cases did happen, F. N. achieved his dismissal from geodetic work.

In spite of his apparent severity, Krasovsky was kind and responsive. Anyone finding himself in a difficult situation, could have obtained his good advice and a more substantial support. He was not only strict and demanding, but just in his interrelations with others and honestly served his cause. He openly made known his thoughts and views, even in those tricky circumstances when it could have harmed him.

F. N. had been an indisputable authority for, and enjoyed deep respect of geodesists and cartographers. His scientific, pedagogic and social activities were highly estimated and deservedly recognized. He was awarded the Orders of Lenin and of the Red Banner of Labour, and the International Astronomical Union named a lunar crater after him.

From long ago his name belongs to the history of our AG science, but he is still living in the thankful memories of his living students and associates as a tireless hard worker, outstanding scientist and exacting teacher. Owing to his very large scientific heritage, mainly reproduced in the four volumes of his *Selected Works* (1953 – 1956), he will be living for a long time in the minds of the future generations of our geodesists, as though urging them to solve new scientific and practical problems of geodetic and cartographic science.

Notes

1. According to Krasovsky [i, § 1], in such contexts *organization* meant the choice of the network's pattern and the programme and methods of its construction.

2. The figure of the Earth hardly belongs to an adjacent branch of knowledge.

3. In 1931, the Cathedral of Christ the Saviour was dynamited to free the necessary space for that Palace. However, underground water prevented the building and an open swimming pool had appeared instead. The Cathedral was a masterpiece of architecture for which great many ordinary Russian citizens had donated money. A new Cathedral was erected in 2000 on the same place, for which again money was donated. It was Kirov, a leading Soviet politician, who proposed to erect the Palace which likely made Stalin jealous. Kirov was assassinated under strange circumstances.

4. Isotov did not mention isostasy (and neither did Bagratuni [iv]). Danilov [ii, § 16] referred to Krasovsky: he discovered that the isostatic hypotheses had
many fundamental defects and was barely effective *when applied to correct astronomical stations for the deflection of the vertical.*

5. So was Krasovsky still the chairman of the same chair in MMI, as is stated in § 3? In § 4 the author added that MIIGAiK had been developing from the geodetic faculty of MMI, but after 1930, when MIIGAiK was established, did not MMI retain its chair of higher geodesy? Apparently, it did. Yakovlev (1979, p. 31), similarly to Izotov, mentioned that Krasovsky had retained that chair until his death.

IV

G. V. Bagratuni

F. N. Krasovsky (observing the centenary of his birth).

Izvesiya Vysshykh Uchebnykh Zavedeniy. Geodesiya i Aerofotos'emka, No. 4, 1978, pp. 150 – 155

[1] 26 September 1978 [new style] will be the centenary of Feodosy Nikolaevich Krasovsky's birth. An entire period in the formation and progress of our geodesy is inseparably connected with his name.

The size of our territory, its physical-geographical and climatic conditions, the great problems concerning national economy and defence, have been the decisive factors defining the formation and progress of the main geodetic and cartographic work. Lenin, in his famous Decree of 1919 creating VGU, most fully and thoroughly defined and appraised the pertinent problems. For solving them, it was necessary to work out, scientifically and practically, the arrangement of geodetic work for the entire country taking into account the features of its territory. This problem was exceptional in complexity and dimensions, and new manpower was needed. At that important moment our geodetic school was indeed born and from its very first days Krasovsky became its leader.

F. N. was an outstanding scientist, a talented teacher of higher geodetic education, and a prominent practitioner as well. His importance for geodesy and cartography is not restricted to our country. He belonged to those like Bessel, Struve et al, who had been developing the world geodetic science after Gauss' initial contribution and Helmert's death[1]. He was one of the organizers of periodic geodetic conferences of Baltic countries and participated there; he had been closely connected with eminent German, Finnish and American geodesists O. Eggert, Grossmann, L. Bonsdorf, J. F. Hayford, W. Bowie et al. He was interested in, and studied all the main branches of geodesy, [practical] astronomy and cartography and to each of them he had originally and fundamentally contributed.

Formerly, the main geodetic work in our country had been carried out on a high scientific and technical level and offered [allowed] essentially new solutions for the development of geodesy. Such was the work of Struve (1856 – 1861) and the contributions of *military topographers* K. I. Tenner, I. I. Hodz'ko, I. I. Stebnitskiy as well as many other works of KVT. However, no geodetic or cartographic work had been going on on a national scale and neither did there exist a pertinent department.

[2] Only Lenin's decree formulated problems on a national scale, a topographic study of the entire territory for restoring and developing the country's productive forces. It became therefore necessary to work out a stochastically justified organization[2] of a national AG network. By the mid-1920s Krasovsky solved this great problem. Without exaggerating, we may say that he had stochastically investigated and determined the regularities in the accumulation of observational errors and the pertinent influence of the form of the geodetic figures. F. N. had thus provided a classic; nothing similar is existing in the entire world geodetic literature[3].

Investigations in the same directions have been going on until now, and serious advanced were made. We may note, for instance, Tatevian (1967). However, all work of this kind and the results obtained have their issue in that contribution more or less supplementing and developing its main propositions and conclusions. It was also highly appreciated abroad. Fifty years have passed since it was published, but we are still referring to it in studies and teaching.

In our days, the benefit of Krasovsky's pattern and programme are telling upon their admitting a joint adjustment of the great national AG network by computers. The main features of the present pattern of constructing such networks still largely coincide with Krasovsky's conclusions.

[3] F. N. had begun his scientific work by studying the figure of the Earth, and he concluded his life work by solving that problem. It was no mere chance that in 1953 a State Prize was awarded to him (posthumously) for the deduction of the parameters of the Earth ellipsoid now named after him. In 1946, the Council of Ministers adopted them as the Earth's constants for all geodetic, astronomic etc work.

The determination of the figure of the Earth is remaining an important scientific problem of higher geodesy. It had been carried out for a few thousands years, but its history had qualitatively changed in the work of Krasovsky[4]. Helmert (1880 – 1884) is known to have defined geodesy as a science of that figure. [Even] during Newton's time it became clear that the real figure of the Earth did not coincide with any geometric figure, which was the beginning of a new stage. Many new ideas had been formulated in the 19th century, and the 20th century had solved that problem in the first approximation by establishing that it was connected with the inner structure of the Earth. This is what Belousov (1964), an eminent geophysicist and a Corresponding Member of our Academy of Sciences, wrote:

Geodesy, which up to now had only been the science about the external figure of the Earth, is also becoming the science of its inner structure.

Precise data, obtained by geodetic observations of the movements of the Earth's crust and artificial satellites, provide very valuable information about the distribution of masses in the crust and the upper mantle of the Earth. F. N. was naturally unable to pronounce any opinion about the observations of artificial satellites, but our geodesists are applying them when pursuing the aims coinciding with those which Krasovsky had raised for *physical geodesy*. He it was who coined that term; during the latest decades, its scope has widened to such an extent that it is now considered an independent scientific discipline, *cosmic geodesy*.

That considerable scientific work in physical geodesy, which F. N. had initiated at our Academy of Sciences, is now being successfully continued by his students and associates, Corresponding Members of the Academy M. S. Molodensky, Yu. D. Bulange[5] and V. A. Magnitsky.

The results of satellite observations provide the flattening of the Earth ellipsoid, and such calculations had been accomplished here and in the USA. Their results were very close, and, furthermore, they corroborated the value of the flattening according to Krasovsky, 1/298.3. The error of that value is only expressed in the second decimals of its denominator.

F. N. thus solved one of the fundamental problems of higher geodesy, the determination of the parameters of the Earth ellipsoid, already in the 1940s, and so thoroughly that we still may be applying his results both in practical work and theoretical investigations.

[4] Krasovsky is highly meritorious not only because he had elaborated the patterns and programmes for constructing the state geodetic network and arranged precise geodetic observations in the field, but, in addition, in connection with mathematically treating the results of vast geodetic networks. Above all, he had devised a method for projecting the results of observations onto a reference surface instead of the indefinite *method of development* used by such prominent geodesists as Helmert and O. Eggert. Later, Molodensky worked out Krasovsky's idea and suggested a harmonious system of astronomical gravimetric levelling.

By the beginning of the 1930s, a considerable, for that time, AG network consisting of 10 polygons was constructed in the European part of the country, and a scientific and technical problem of working out methods for strictly treating and adjusting such networks had been encountered. F. N. had created such a method, and, after preliminary trials, published his work (1934)[6]. At the same time he had developed methods for calculating geodetic coordinates on an ellipsoidal surface and paid special attention to the problem of transferring them over large distances.

Again at that time, topical became the problem of selecting the most expedient geodetic projection and coordinate system for treating the results of geodetic observations on a plane. After a profound and thorough theoretical investigations, Krasovsky had chosen a conformal projection and the Gauss – Krüger coordinates. He also devised supplementary aids such as tables, patterns of calculation and various nomograms for treating geodetic networks. He solved the ensuing problems so thoroughly and expediently that we are often applying his created arsenal almost without changing it.

[5] To this period also belong great scientific and technical problems of mapping our vast territory. Investigations were needed for establishing the scales of topographic surveying, plans and maps. F. N. had studied these problems and published a number of papers dealing with them. One of them (1938) as though summarized his work.

As an assistant chief of GUGK for scientific and technical problems, assistant director of TsNIIGAiK for science and a Board member of GUGK, Krasovsky had been systematically engaged in such studies. He also directly participated in organizing cartographic education in MIIGAiK. According to his proposal, a speciality, engineer – field cartographer was established there. These engineers, as he imagined, will be heading field cartographic work.

[6] At the beginning of the 1930s, construction, and especially hydrotechnical projects and town development (for example, the construction of the Moscow underground), had begun on a large scale. New geodetic problems were encountered concerning observations and measurements and Krasovsky had participated in working out the scientific and technical basis for the necessary geodetic work on a large scale.

He was connected with such applications even in the beginning of his career. In the 1920s, he had been teaching geodesy [as a pluralist] at the construction faculty of Moscow Higher Technical School. His lectures, as is seen in an extant manuscript, were clearly directed towards applications, especially construction, and his views are still important. F. N. thought that it was above all necessary to substantiate scientifically the precision of the work, to elaborate the proper methods of measurements and select suitable instruments. He stressed that the preparation of engineers in geodetic institutes should take into account the requirements of the various branches of national economy, and construction in particular.

Incidentally, he had consulted geodesists constructing the Moscow underground; his students A. N. Baranov, A. Sh. Tatevian, M. I. Sinyagina, G. K. Zubakov, M. N. Sokolov, G. D. Onar and others, had been working there. He also consulted the erection of the Palace of the Soviets when its circular foundation began to be laid. Finally, Krasovsky had been supervising the degree work [where?] on orienting mines.

[7] F. N. is greatly meritorious for arranging the higher geodetic education. For more than 25 years he chaired higher geodesy at MIIGAiK; in 1919 – 1921, he was the elected rector of MMI and headed the methodical commission of its geodetic faculty. The rapid flourish of that faculty was connected with his activities.

Geodetic education in pre-revolutionary Russia is known to have remained in difficult circumstances, and F. N. often indicated this fact. This is what he (1934) wrote:

Until 1917, there existed the Land Surveying Institute with no separate faculties. Geodesy and practical astronomy had been treated in a single textbook together with civil law, land surveying laws and other legal subjects destined to preserve private landownership. This curious phenomenon of the Tsarist times, this school called the Land Surveying Institute, should have been utterly reorganized.

Modern higher geodetic education is retaining the features which had been established by the efforts of the professors, geodesists of that institute, under Krasovsky's guidance.

F. N. has great deserts for creating textbooks in higher geodesy. By the mid-1920s, geodetic work had begun to develop rapidly, and the preparation of engineers on a large scale was topical, geodesy was becoming a leading direction in technical education. In 1924 – 1925, widely drawing on his own considerable scientific and technical experience, Krasovsky compiles and publishes, in 1926, the first part of a fundamental *Treatise in Higher Geodesy*. Its second part, written in 1927 – 1929, had only appeared in 1932. A thoroughly revised and supplemented edition of that *Treatise* was published in 1938 – 1939 (its first part) and in 1942, – the second part for which Krasovsky was awarded a State Prize of the first degree. For its time, his work was an exceptional occurrence both in scientific level and completeness of covering its subject.

Krasovsky's main writings including that manual were collected in his *Selected Works*, vols 3 and 4 (1953 – 1956) edited by V. V. Danilov, M. D. Soloviev, A. A. Isotov, P. S. Sakatov, A. I. Durnev and S. G. Sudakov, but regrettably that revised edition was not reissued.

F. N. had been systematically preparing scientists for work in higher education. He selected his candidates by carefully studying their scientific possibilities and the results of their practical work. Most of those chosen had therefore become known scientists and educationists, such as professors Durnev, Sakatov, Isotov, Magnitsky, A. M. Virovets. And such prominent geodesists, astronomers and cartographers as Danilov, N. A. Urmaev, Soloviev, M. K. Tsvetkov,

M. N. Sergeev, F. V. Drobyshev, Molodensky, M. S. Sverev had been his associates and collaborators.

[8] And F. N. had also collaborated with those eminent scientists of his time who had created their own schools and directions of work in geodesy, cartography, photogrammetry as well as astronomy and gravimetry, for instance with A. A. Mikhailov, N. G. Kell, A. S. Chebotarev, V. V. Kavraisky. Being highly cultured both generally and scientifically, Krasovsky had been always able to communicate with them during scientific discussions and conferences on the fundamental problems of higher geodesy and the above-mentioned disciplines. In conversations with his postgraduates F. N. often referred to the works and authority of his colleagues.

It is very important to note that all those scientists greatly respected Krasovsky and reckoned with his authority and writings. In 1939, being unanimously supported by the geodetic scientific community, he was elected Corresponding Member of our Academy of Sciences, and in 1943 the title of Honoured Scientist of the Russian Federation was conferred on him. He certainly was our outstanding scientist, and his name may be ranked among those of Gauss, Bessel[7], Struve, A. R. Clarke, Helmert, W. Jordan, and V. V. Vitkovsky.

Notes

1. Bessel had preceded Helmert.

2. For such contexts, I am borrowing that term from Krasovsky [I, § 1].

3. This is a mistake, see for example Friedrich (1937) and a later contribution written on a high mathematical level, Grafarend & Harland (1973).

4. This statement is not borne out in the sequel.

5. Certainly derived from the French *Boulanger*.

6. I can only refer to Krasovsky (1931a; 1931b).

7. I do not agree with the author: Gauss and Bessel should not have been included.

Appendix
an episode in the history of the Baltic Geodetic Commission

Krasovsky's collaboration with the BGC, about which Bagratuni [iv, § 1] said a few words, ended abruptly. How and why?

I. Bonsdorff
Bericht des Generalsekretärs [of the BGC]

Verh. 10. Tagung Balt. geod. Kommission *1938*.
Helsinki, 1938, pp. 42 – 45

[..] Tratt die Konvention [about the establishment of the BGC] den 20. Januar 1937 in Kraft für eine neue Periode […], d. h. bis ultimo 1948. […] Der Präsident der BGK [of BGC], Prof. Th. Krassovsy, teilte […] mit, daß die Regierung von USSR ihn wegen seines Gesundheitszustandes von dem Posten als stimmberechtigtes Mitglied der Kommission entbunden hat und Prof. [of Moscow University, future academician] A. A. Michailov zu dem Posten ernannt hat.

[The representatives of the seven remaining in BGC countries took a vote on that issue and Michailov was approved by six voices for 1938 – 1939. *Michailov dankte für die Ehre*.]

Am 14. März 1938 übermittelte die Gesandschaft von USSR dem finnischen Auswärtigen Amt folgendes Schreiben:

[…] Le Gouvernement de [Soviet Union] a pris la decision de renoncer à la participation ultérieure [in BGC]. […] A partir du 1 janvier 1937 l'Union des R. S. S. est entrée dans la Ligue Internationale Geophysique et Géodesique. Les cercles géodésiques des Soviéts estiment que la participation dans cette Unification internationale rend inutile la participation […] dans une Unification qui porte un caractère local et poursuit des buts plus restreints.

Am 21. März übermittelte das Finnische Auswärtige Amt dem Gesandten von USSR folgende Note:

[The Convention does not envisage] la dénonciation […] avant la termination de la validite de celle-ci. […] Le Gouvernement de Finlande ne peut pas considerer la dénonciation […] comme conforme aux stipulations […].

[On March 24 A. Michailov informed the General Secretary of the BGC (i. e., Bonsdorff)] daß ich (that he) mein Amt […] niederlege. [A new president was elected instead.]

Here are my comments.

1. Krasovsky himself evidently did not ask to be relieved so that a (patently false) pretext had to be invented. Recall Izotov [iii, § 15]: Krasovsky *openly made known his thoughts and views, even in those tricky circumstances when it could have harmed him*.

2. That some mysterious geodetic circles decided that Soviet participation in BGC became superfluous was a damned lie. First and foremost, Krasovsky would have vigorously objected. But strangest of all is that the Soviet Union had only joined the *Ligue Internationale* in 1955 (*Great Sov. Enc.* [vol. 6, article *Geod. and Geophys. Union*]! Sapienti sat! (For a clever man this is sufficient).

3. Danilov [ii, § 16] stated that Krasovsky was elected President in 1936.

4. Krasovsky was unable to attend the sixth session of the BGC held in 1932. Its *Comptes rendus* were published in Helsinki in 1933 and there, on p. 18, the President, E. Kohlschütter, described the letter he received from F. N. This is what E. K. stated:

Die Geodäsie eine Wissenschaft sei, die keine Grenzen kenne, und spricht [F. N.] *die Überzeugung aus, daß die gemeinsamen Arbeiten der Kommission alles beteiligten Ländern großen Nutzen für ihre eigene Arbeiten bringen werden, auch hofft er, daß die Verbindung zwischen den Teilnehmern der Baltischen Kommission immer kräftigen werden möge.*

So why did the Soviet authorities decide to quit BGC? The cause was certainly political, perhaps connected with the serious deterioration, in 1938 – 1939, of Soviet – Finnish relations (and the ensuing war).

Joint Bibliography

In compiling this Bibliography, I have extensively used the Bibliography included at the end of Bagratuni (1959) which he had published in spite of its many defects. The additions such as [1, pp. …] or [2, pp. …] refer to the first two volumes of Krasovsky's *Selected Works* (1953 – 1956). A few items listed below are not mentioned in the main texts. English titles denote *Russian* contributions.

A special point concerns Krasovsky (1938 – 1939, 1942). As a student, I studied its first part (1938 – 1939) whose authors were Krasovsky and V. V. Danilov, but at least from 1978 Krasovsky somehow became its sole author and Danilov himself [ii, § 13] accordingly mentioned that source. However, both Krasovsky and Danilov are mentioned as authors in [6, article *Geodetic instruments*], in Izotov's article *Geodesy* in vol. 6 of the *Great Sov. Enc.*, in Bomford's (1971) Bibliography and in my translation of Bomford

(1952) in 1958 (after the publication of Krasovsky's *Selected Works*!), in the Editor's Preface.

F. N. Krasovsky

1901, On the works of G. N. Shebuev in higher geodesy. *Trudy Topografo-Geodezicheskoi Komissii*, No. 13, pp. 24 – 28.

1902a, Triangulation in [several mentioned districts] of Zabaikal'e special province. *Pamiatnaya Knizhka Konstantin Mezhevoi Institut* (Memorial Book, Grand Duke Konstantin Moscow Land Surveying Inst.) for 1901 – 1902, pp. 135 – 147.

1902b, Determination of the size of the Earth triaxial ellipsoid from Russian arc measurements. [1, pp. 23 – 49.]

1904, Report on the professional trip to Pulkovo astronomical observatory. [2, pp. 215 – 219.]

1916, *O Trigonometricheskikh Setyakh. Lektsii po Vysshei Geodesii* (On Trigonometric Networks. Lectures in Higher Geodesy). Privately printed.

1924a, Determination of the azimuth of a terrestrial object by measuring the horizontal angle between Polaris and a supplementary star. [2, pp. 201 – 203.]

1924b, *O Masshtabakh Gostopos'emki* (On Scales of the State Surveying). Moscow.

1924c, On applying the materials of land and forest surveying for making a topographical map. *Zemleustroitel*.

1925, Calculation of a conic equidistant projection, the most suitable for representing a given country. [2, pp. 186 – 200.]

1926, *Rukovodstvo po Vysshei Geodesii. Kurs Geodezii etc* (Treatise in Higher Geodesy for Geod. Fac. Moscow Land Surveying Inst.). Moscow. See also Krasovsky (1930; 1932).

1928, *Skhema i Programma Gosudarstvennoi Trianguliatsii* (Pattern and Programme of State Triangulation). Moscow. [2, pp. 39 – 69.]

1930, *Kurs Geodesii* (Course in Geodesy), pts 1 – 2. Moscow – Leningrad. Krasovsky was author of pt. 2 and Editor of pt. 1.

1930, 1931, *Uravnivanie Trigonometricheskoi Seti* etc. (Adjustment of Trigonometric Networks by the Method of *Indirect Observations*, or by Determining Corrections to Coordinates), editions 1 – 2. Leningrad.

1931a, Methoden zur Ausgleichung der staatlichen Triangulation I Ordnung. *Mitt. des Chefs des Kriegs-Karten- und Vermessungswesens,* 1. Jg., No. 3, 1942. In Russian, publ. same year [1, pp. 273 – 337].

1931b, Methoden zur Ausgleichung der staatlichen Triangulation I Ordnung in der UdSSR. Ibidem. In Russian [1, pp. 338 – 350.] See also Krasovsky (1933).

1931c, The work of the Geodetic Board of the All-Union Council of National Economy in 1926. *Trudy Vtorogo Geodesich. Soveshchania*, *Moscow*, pp. 101 – 105.

1931, 1934, *Kurs Geodesii dlya Studentov Vtuzov* (Course in Geodesy for Students of Technical Institutes of Higher Education), pt. 1, pts 2– 3. [Moscow.] Krasovsky was Editor.

1931 – 1937, German, Papers and reports. *Verh. Baltischen geod. Komm.*, Sessions 5 – 9. Helsinki. Eleven contributions including Krasovsky (1933; 1935a; 1936a; 1936b; 1936c; 1937).

1932, *Vysshaya Geodesia* (Higher Geodesy), pt. 2. Leningrad.

1933, Die geodätische Arbeiten in der UdSSR. *Verh. 6. Tagung, Baltischen geod. Komm.*, *1932*. Helsinki, pp. 99 – 109.

1934, On the main astronomical geodetic work in the Soviet Union. [2, pp. 70 – 73.] See also the German publications (1933; 1935a; 1936c).

1935a, Bericht über astronomisch-geodätischen Arbeiten in der UdSSR. *Verh. 7. Tagung, Baltischen geod. Komm*., *1934*. Helsinki, pp. 148 – 161.
1935b, *Kurs Geodesii* (Course in Geodesy), 4th edition. Moscow. Coauthor: A. S. Chebotarev.
1936a, Einige neue Grundlagen für die Aufstellung der Gleichungen und der Programme der Gradmessungen. *Verh. 8. Tagung, Baltischen geod. Komm*., *1935*. Helsinki, pp. 193 – 198. Russian [1, pp. 179 – 183.]
1936b, Übersicht und Untersuchung der Ergebnisse der neuen Gradmessungen. *Verh. 8. Tagung, Baltischen geod. Komm*., *1935*. Helsinki, pp. 176 – 195. Russian [1, pp. 82 – 178].
1936c, Same title as (1935a). *Verh. 8. Tagung, Baltischen geod. Komm*. Helsinki, pp. 88 – 95.
1937, Zur Frage der gemeinsamen Anwendung astron.-geod. und gravimetrischen Materials für die Bestimmung der Gestalt des Geoids. *Verh. 9. Tagung, Baltischen geod. Komm*., *1936*. Helsinki, pp. 199 – 202.
1938, On mapping the entire territory of the Soviet Union. [2, pp. 117 – 122.]
1938 – 1939, 1942, *Rukovodstvo po Vysshei Geodesii* (Treatise in Higher Geodesy), pts 1 – 2.
1941, Contemporary problems and development of arc measurements. [1, pp. 226 – 250.]
1947, On some scientific problems of astronomical geodesy in connection with studying the structure of the Earth mantle. [1, pp. 251 – 272.]
1953 – 1956, *Izbrannye Sochineniya* (Sel. Works), vols 1 – 4. Moscow. Vol. 1, 1953: papers in periodicals on figure of the Earth; adjustment of the triangulation of the Soviet Union; Essay on his life and work (V. V. Danilov [ii]). No information about the first publication of those papers is given.
Vol. 2, 1956: Papers in periodicals without specifying their general subject.
Vol. 3, 1955: Main geodetic work; geodetic control.
Vol. 4, 1955: Geometry of a spheroid with geod. applications; the Gauss – Krüger coordinates; deflection of the vertical and deviations of geoid from reference ellipsoid; arc measurements; treatment of networks.
The last two volumes are reprints of the *Treatise* (1938 – 1939; 1942).

Other Authors

Bagratuni, G. V. (1959, Russian), *F. N. Krasovsky*. Moscow. Contains a bibliography of Krasovsky's writings.
Belikov, E. F. (1961), *Bibliograficheskiy Ukazatel Geodesicheskoi Literatury za 40 Let* (Bibliography of [Russian] Geodetic Literature for 40 Years), *1917 – 1956*. Moscow.
Belikov E. F., Soloviev L. P. (1971), *Bibliografichesky Ukazatel Geodesicheskoi Literaturi s Nachala Knigopechatania do 1917 Goda* (Bibliography of [Russian] Geod. Literature from the Beginning of Book-Printing to 1917). Moscow.
Belousov V. A. (1964, Russian), Revealing the mysteries of the Earth's entrails. Newspaper *Pravda*. [Information certainly incomplete.]
Bomford, G. (1952, 1962, 1971), *Geodesy*. Oxford, 1980. My Russian translation: Moscow, 1958.
Bonsdorff, I. (1935), Messung der Grundlinie in Balaschov 1935. *Verh. 7. Tagung, Baltischen geod. Komm*., *1934*. Helsinki, pp. 61 – 63.
Chebotarev A. S. (1951), On the mathematical treatment of observations. *Trudy MIIGAiK*, No. 9, pp. 3 – 16.
--- (1958), *Sposob Naimen'shikh Kvadratov* … (Method of Least Squares and the Fundamentals of the Theory of Probability). Moscow.

Danilov, V. V., Daniloff V. W. (1935), Methode der Präzisionspolygonometrie im System der geodätischen Grundarbeiten. *Verh. 6. Tagung, Baltischen geod. Komm*., Tl. 2, *1934.* Helsinki, pp. 207 – 223.

--- (1937), On parallactic traverses [on trig-traverses]. *Geodesist*, No. 7 and 10.

--- (1946), *Tochnaya Poligonometriya* (Precise Traverses), 2nd edition. Moscow, 1953.

Durnev, A. I. (1937), Planning chains of triangulation of the I order consisting of braced quadrilaterals. *Trudy TsNIIGAiK*, No. 15.

Friedrich K. (1937), Allgemeine … Lösung f. die Aufgabe der kleinsten Absolutsummen. *Z. f. Vermessungswesen*, Bd. 66, pp. 305 – 320, 337 – 358.

Grafarend E., Harland P. (1973), *Optimale Design geodätischer Netze*. München, *Deutsche geod. Kommission Bayer. Akad. Wiss.*, Bd. A74.

Helmert F. R. (1880 – 1884), *Mathematischen und physikalischen Theorien der höheren Geodäsie*, Bde 1 – 2. Leipzig, 1962.

Idelson N. I. (1947), *Sposob Naimen'shikh Kvadratov* … (Method of Least Squares and the Theory of Mathematical Treatment of Observations). Moscow.

Izotov, A. A. (1936), *Otsenka Tochnosti Triangulyatsii* (Estimation of the Precision of Triangulation). Moscow.

--- (1950), *Forma i Razmer Zemli po Sovremennym Dannym* (The Form and the Size of the Earth according to Contemporary Data). Moscow.

Kashin, L. A. (1979, Russian), F. N. Krasovsky, an outstanding scientist and organizer of state geodetic activities. *Izvesiya Vysshykh Uchebnykh Zavedeniy. Geodesiya i Aerofotos'emka*, No. 2, pp. 8 – 23.

Katalog (1934), *Katalog Vysot Marok i Reperov* etc (Catalogue of Heights of Marks and Benchmarks of the High Precision and Precision Levelling in the European Part of USSR).

Kell, N. G. (1930), *Koordinaty Gaussa – Krügera i Ikh Primenenia* (The Gauss – Krüger Coordinates and their Application). Moscow.

Khinchin, A. Ya. (1937), The theory of probability in pre-revolutionary Russia and in the Soviet Union. *Front Nauki i Tekhniki*, No. 7, pp. 36 – 46. Translation: www.sheynin.de Download No. 7 this being a collection of translations.

Lenin, V. I. (1963), *Polnoe Sobranie Sochineniy* (Complete Works), 5th edition, vol. 38. Moscow.

Mikhailov, A. A. (1939), *Kurs Gravimetrii i Teorii Figury Zemli* (Course in Gravimetry and Theory of the Figure of the Earth). Moscow.

Molodensky, M. S. (1937), Bestimmung der Gestalt des Geoids unter gemeinsamen Anwendung astronomisch-geodätischer Lotabweichungen und Schwerestörungen. *Verh. 9. Tagung, Baltischen geod. Komm.*, *1936.* Helsinki, pp. 203 – 223.

--- (1948), External gravitational field and the figure of the Earth's physical surface. *Izvestia Akad. Nauk SSSR*, ser. Geogr. & Geophys., vol. 12, No. 3.

Numerov, B., Chramov, D. (1936), Über die Bestimmung der Figur der Geoids aus Schweremessungen. *Gerlands Beiträge zur Geophysik*, Bd. 48, pp. 193 – 208. The authors follow each other in the Russian alphabetic order. Numerov published many papers on the Gauss – Krüger coordinates, practical astronomy and instruments.

Pesonen, U. (1938), *Messung der Basis Balaschov in Rußland in Jahre 1935*. Sonderveröff. No.7, Balt. geod. Komm. Helsinki.

Rielke, S. D., Compiler (1894), *Katalog Vysot Russkoi Nivelirnoi Seti* etc. (Cat. of the Heights of the Russian Levelling Network from 1871 to 1893). Petersburg.

Shebuev, G. N. (before 1902, possibly 1892), Geometrical foundation of geodesy on the surface of a triaxial ellipsoid very little differing from a spheroid. *Trudy Topogr.-Geod. Komission*, No. 5.

--- (before 1902, possibly 1895), Distances, azimuths and triangles on the surface of a triaxial ellipsoid little differing from a sphere. Ibidem, No. 8.

Sheynin, O. (1995), Helmert's work in the theory of errors. *Arch. Hist. Ex. Sci.*, vol. 49, pp. 73 – 104.

Sludsky F. A. (1967), *Izbrannye Geodesicheskie Sochinenia* (Sel. Geod. Works). Moscow.

Sobranie (1919), *Sobranie Uzakoneniy Rabochego i Krestianskogo Pravitel'stva* (Coll. Statutes of the Workers' and Peasants' Government). No place [Moscow].

Struve V. Ya. [= Struve F. G. W.] (1865 – 1861), *Duga Meridiana* (A Meridian Arc), vols 1 – 2. Petersburg. Moscow, 1957.

Tatevian A. Sh. (1967), Studies in the construction of control geodetic networks. *Trudy TsNIIGAiK*, No. 181.

Urmaev, N. A. (1930), On consecutive adjustment of triangulation networks. *Geodesist*, No. 5.

--- (1931a), On the distribution of weights in baseline networks. *Trudy TsNIIGAiK*, No. 1.

--- (1931b), Adjustment of polygons in geodetic and rectangular coordinates. Ibidem.

Wolf H. (1968), *Ausgleichung nach der Methode der kleinsten Quadrate*. Hannover – München.

Yakovlev, N. V. (1979), F. N. Krasovsky and the chair of higher geodesy. *Izvesiya Vysshykh Uchebnykh Zavedeniy. Geodesiya i Aerofotos'emka*, No. 2, 1979, pp. 30 – 41.

Zakatov, P. S. (1937), On the precision of triangulation chains of the I order consisting of braced quadrilaterals. *Trudy TsNIIGAiK*, No. 15.

--- (1950, 1964, Russian), *A Course in Higher Geodesy.* Jerusalem, 1962. German edition: Berlin, 1957.