Some fragments of my 70 years activity in EM geophysics

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SUMMARY

It is my farewell to EM community. I recall some earlier published half-forgotten results which can be useful today and express my opinion how can be improved some methodological details of EM studies.

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INTRODUCTION

In 1953, I was graduated from the Faculty of Physics of St. Petersburg University (SPbU) with a degree in geophysics and was allocated to Moscow for postgraduate studies at the Institute of Physics of the Earth (IPE). An outstanding mathematician (regularization theory) and geophysicist (magnetotelluric sounding (MTS)) academician Andrei Nikolaevich Tikhonov were appointed as my supervisor. I chose the topic "Induced polarization of ion-conducting rocks" and defended my PhD thesis in 1957 (Rokityansky 1957, 1959). At that time a great event began - the International Geophysical Year (IGY), and I was sent to Alushta, Crimea to equip the observatory and carry out registration and processing of natural variable electric **E** and magnetic **B** fields with a period from 1 s to 1 day. I had unique materials in my hands. I was interested in the relationship between **E** and **B** and its variability along the Earth's surface, that is, in essence, the MTS-MVP (Rokityansky 1961, Rokityansky et al. 1964). In the first decade of the MTS method, the Tikhonov-Cagniard (T-C) model was used in its purest form - a plane wave over a horizontally layered Earth. As a result, depth to the conductive base of the upper mantle was obtained at depths from 100 to 2000 km, even at close observation points. Such a spread did not correspond to the theory of EM induction and the results of other geophysical methods. I analyzed many practical MTS curves, made model calculations and was the first who discovered the existence of static distortions, and formulated simple methods for minimizing them – binding (tying in) to trusted data, static shift to global GDS data, grouping, which made it possible to carry out deep MTS on the real geological structures with local distortions (Rokityansky 1971, 1982, p. 201-209).

In 1957-1965 I worked in IPE department EM fields headed by

Valery Troitskaya.

Valery was outstanding personality, scientist and organizer of international cooperation in the «cold war» times. She was born in 1917. In the years of repressions of 1936-1939, her father was arrested and awaited an execution. To save him Valery, a student of SPbU, decided to ask for an audience with the formidable head of KGB, Lavrenty Beria, and managed to convince him of her father's innocence. Father was released (the rarest case). During IGY and after, Valery decisively for the benefit of cooperation violated the ridiculous KGB restrictions on the behavior of Soviet citizens abroad.

She established a network of electromagnetic observatories across USSR, in Arctic and Antarctica and studied ULF micropulsations with period 1-600 s. She organized the first experiment between magneto-conjugate points Sogra-Kerguelen and measured geomagnetic fluctuations at the depth 2.6 km in the French bathyscaphe «Archimed». She made 2 internationally recognized discovery: micropulsations «Pearls» and «DPO» - decreasing period oscillations indicating contraction of the magnetosphere. Troitskaya was member of the IUGG Bureau (1963-1967), the first woman president of IAGA (1971-1975), since 1985 - Honorary IAGA Member, member of the first Steering Committee of the International Geosphere-Biosphere Program (1986-1990). I participated in some of these studies, as well as in the registration of USA nuclear tests on a Pacific island and Soviet underground tests in Central Asia. I also organized an EM observatory in Cuba.

In 1960 academician M.A.Sadovsky became the Director of IPE. He obliged all departments to

participate in the Earthquakes (EQ) Forecast. This topic also was proposed to me. I refused and in 1965 moved to Institute of Geophysics in Kiev for

Geoelectromagnetic investigation of the Earth's crust and mantle

I organized the EM Research Laboratory and led it 25 years. In the first 5 years I have tested, studied and understood the possibilities of various methods of the deep electrical conductivity study and formulated a methodology for the interconnected use of the three main methods MVP-MTS-GDS (Rokityansky 1970 and in all my consequent monographs). Search and study of the anomalies of geomagnetic variations and associated conductive anomalies was a hobby for me. Every year we carried out field works for 3-4 months. I went out into the field and manually processed and interpreted the photorecords in order to determine where the next observation sites should be placed in order to optimally map the anomaly.

Many anomalies have been found and studied using induction vectors and anomalous field in horizontal magnetic components, that is by MVP method. Large anomalies in Eastern Europe: Kirovograd (1969), Carpathian (1972), Moscow-Tambov (1977), Ladoga (1981, moreover, MTS were carried out there before the MVP, but the anomaly was not discovered), Donbas (1988, but in the data of more than twenty MTS and records of pulses from the Volgograd-Donbas long (487 km) line the anomaly cannot be clearly distinguished).

Physics of the anomalous field formation

Anomalous currents in a high conducting body arise due to local electromagnetic induction inside this body, as well as due to conductive redistribution (and concentration) of currents induced in the host medium on the large territory comparable with the external source size. Quantitative estimates were made in the early 1970s based on analytical solutions for a cylinder and sphere presented as an infinite series which first term is proportional to the applied electric field (it forms the conductive anomaly), the second – to magnetic field – it forms the magnetic eddy type anomaly. Available results of 2D and 3D numerical calculations and physical modeling were also considered.

Analysis of natural situations showed that conductive type anomalies are predominate for elongated conductors, and a corresponding theory was developed for them (Rokityansky 1975-a and -b; 1982 p. 247-277, 290-307). The frequency characteristics of the conductive type anomalous field are equal to the product of the non-decreasing function of the period V ($0 \le V \le 1$, V=1 corresponds DC), which describes the degree of filling of the conductor by anomalous currents and the normal impedance of the given region, apriori studied by the GDS-MTS soundings. The impedance is a decreasing function of the period, so its product with function V has a maximum at some period T_O. The position T_O is closely related to the total longitudinal conductance G [S×m] - of the anomalous body, that is, the scale of the anomaly. On the period T_O, the anomalous fields and the induction vector become real C=Cu, the imaginary induction vector Cv passes through zero changing sign. On shorter periods Cu and Cv are parallel, on longer periods they are anti-parallel for 2D anomaly.

Short specification of the MVP method

Necessary and sufficient condition to make the conclusion on the existence of an electrical conductivity anomaly is the existence of a geomagnetic variations anomaly.

The existence of an anomaly of geomagnetic variations is evident from the stable presence of vertical component and from the difference in horizontal components at moderately spaced sites.

The shape of the profile curves of the anomalous field yields reliable estimation of the maximum possible depth of the anomalous currents **center** *d* and the width 2*L* of the anomaly.

Frequency response of the anomalous field yields estimate of the total longitudinal conductance *G* of the elongated anomalous body.

- It is a simple completely reliable MVP pre-computer results, which (anomaly location, *d*, *L* and *G* with their uncertainties) **should be used as apriori information** for consequent thorough MVP-MTS inverse problem computer modeling.

MTS

MTS can give false results even in relation to such a fundamental category as the existence or absence of an anomaly. For example, on the southern slope of the Ukrainian Shield (US), a dozen MTS curves above the axis of the Kirovograd anomaly, which is confidently identified according to the MVP data, show the absence of this anomaly (the reason is screening by sloping sedimentary layers).

However, MTS can more accurately than MVP determine the depth h of the upper edge of the anomaly although harmful distortions from near-surface inhomogeneities remain. So, a dozen MTS over the axis of Kirovograd anomaly in US made it possible to determine only the average

result of *h*=15±5 km (Rokityansky et al 2018)

Carpathian anomaly.

Let me remind of the Carpathian anomaly. Having data of more than 200 MVP points, the position of its axis was determined with good uncertainty of 5-10 km, and according to 8 profile graphs of the anomalous field in the Western Carpathians, the maximum possible depth of the center of anomalous currents was estimated: 24, 16, 19, 18, 18, 24, 26 and 21 km (Jankowski et al. 1985). The next step should be MTS to clarify the depth of the upper edge of the anomaly. In Ukraine, in the 1970s and 80s, we made about 50 MTS, identified 6 zones and, using 11 curves directly above the axis, determined the depth of the anomaly upper edge of 12±4 km.

At 22EMIW in Murnau I proposed «Project of the Carpathian anomaly depth study by means of detailed MTS over its axis». Project was not supported with a criticism: «for the MTS interpretation 2D profiles across the anomaly are necessary» - I strongly disagree with the latter. When the anomaly axis is known, only longitudinal curves are needed to determine its depth.

The anomaly in the center of Europe should be better studied. It can be, for example, a source of geothermal energy. I recommend to accept and realized «Project of the Carpathian anomaly depth study by means of detailed MTS over its axis» and would be happy to participate in it.

On 2D inversion and regularization

And in general, I think the mandatory 2D inversion is not justified. Exact 2D structures do not exist, the inevitable presence of deviations from 2D creates a systematic error in the 2D inversion results, which cannot be predicted and described using a statistical uncertainty obtained during data processing.

Unlike practical science (electrical prospecting), deep geoelectrics is regarded as a fundamental science, which sets the task of an honest, reliable study of the objective reality — the Earth. Since observation of electromagnetic fields is possible only on/above the Earth in a limited number of sites with limited accuracy, the conclusions of geoelectrics are always ambiguous. Providing only a single solution, in particular resulting from the use of regularization, can lead to false conclusions, and regarded as a manipulation of facts, that can discredits both the authors and the whole science of geoelectrics. So, many products of inversion (in particular 2D) should be regarded not as a well proven geological result but as one of possible transformation of response functions.

Esotericism and related issues

In 1989 I became interested in dowsing considering it as geophysical method but without support in physics which I planned to achieve. In next 5-years laboratory Plan-Project instead of the MT topic (which I led 25 years), I naively proposed a topic on dowsing, which was not accepted in institute. I was left without a Project and was sent to retire.
2 years I worked in a private company on esoterics, in 1994-1998 in «Ukranian Natational Research Center for Defense Technologies» was the only geophysicist and had the task of developing geophysical weapons. There, I tried to improve Kozyrev's theory (Rokityansky II 2008, 2012), studied the locality of thunderstorms and their confinement to geological structures, studied experiments on informational weather control and proposed its explanation (Pokityansky II 2014), studied the tectonic factor of the Chernobyl disaster and so on. After the collapse of the USSR, the economy constantly degraded in independent Ukraine and nobody's developments were used.

Return to geophysics

In 1999, at the EGU Assembly in Nice, I organized a Session on Quasi-spontaneous Variations (Rokityansky 1999). In 1999-2001, I collaborated with the discoverer of seismic electric signals (SES) prof. P.Varotsos (Greece). To explain high SES sensitivity in Ioannina place, Varotsos supposed existing under the place highly conducting channel. ≈40 MTS were made and interpreted, 2 PhD dissertations were defended but channel was not found. I made MVP and joint MVP-MTS data revealed conductor and its parameters.

I returned in Institute of geophysics, but no instruments for field works, no money for business trips to conferences and field works, for purchasing and printing articles. I and 3 PhD students processed worldwide Intermagnet data, Japanese geomagnetic data and obtained some results (Rokityansky en al 2019). Very low salary in academic institutes made my students move from the institute to private IT companies.

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