

# RESEARCH ON THE EARTH'S INTERIOR CONDUCTED BY RUSSIA AFTER IGY: THE GEOTRAVERSE PROJECT AND "INTERMARGINS"

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## ABSTRACT

*Fifty years have passed since the International Geophysical Year (IGY) of 1957–58, one of the most important and noble initiatives in the history of science and in the history of humanity in general. IGY became the model for subsequent international scientific initiatives in various fields of solid Earth research, including the Upper Mantle Project (1961–71), the Geodynamic Project (1971–80), the Geotraverse Project (1987–2003), and the "InterMARGINS" Project (2003). The Russian investigations as part of the Geotraverse Project and "InterMARGINS" were aimed at research into the deep structure of the continental margins of East Eurasia, which are characterized by high seismicity, volcanism, and natural cataclysms hazardous to people living there.*

**Keywords:** International Geophysical Year, Geotraverse Project, "InterMARGINS", Upper Mantle Project, crust, asthenosphere, deep structure, geodynamics, East Eurasia, Sea of Okhotsk, Philippine Sea

## 1 INTRODUCTION

Our planet appears to be big and sturdy with a world ocean, an atmosphere and a magnetosphere, all form an environment where humanity inhabits and on which it entirely depends. Therefore, a fundamental objective of science is to study the laws governing the ways in which the Earth evolves. This objective has led to the emergence of planetary geophysics, a system of sciences, that study the physical processes governing our planet and its separate regions. The mission of planetary geophysics is to perform research that will help us better understand tornados and earthquakes, the deep structure of the Earth and the eruption of volcanoes, polar auroras and earth tides, ice ages and magnetic storms, ocean currents, and crustal movements. Since the objectives of these research efforts are international, scientists studying the Earth join forces and work together. Geophysicists from all nations must actively cooperate because individually they are unable to draw valid conclusions from their separate scientific investigations.

In 1875, Austrian geophysicist Karl Weyprecht came up with an idea of an international scientific investigation of the Earth. **He wrote that knowledge breakthroughs in geophysics were limited because of the absence of simultaneous investigations in various fields, which would enable making comparisons, but such investigations would be possible only when the countries that had advanced views on the sciences decided to work together and completely exclude any national rivalry** (Silkin, Troitskaya & Shebalin, 1962).

Weyprecht's views were instrumental in bringing about the **First International Polar Year (IPY) of 1882–83**. The aim of the First IPY was to study the weather at high northern latitudes, which affects the world's climate, the movement of drifting ice, and geomagnetic phenomena and the aurora. Twelve countries participated, and numerous expeditions were organized, including 12 to the Arctic and 3 to the Antarctic. By 1898, the results of the observations from the expeditions had been analyzed. They included unique data on drifting ice, the weather, geomagnetic phenomena, and polar lights and laid a foundation for further investigations by geophysicists in the coming years (Isaev, 1983).

In the 50 years following the First International Polar Year, scientific knowledge and understanding of the Earth expanded considerably, and a suggestion was made to declare a **Second International Polar Year**. The Second IPY lasted from August 1932 to September 1933. Scientists from 44 countries participated, including ones from the Academy of Sciences and the Arctic Institute of the USSR. More than 100 observation stations were established in the polar regions. As with the First IPY, a wealth of scientific information was gathered. For the first time ever, weather charts for the whole Northern hemisphere were drawn. The depths of the Arctic Ocean and the ice thickness at various points on the Antarctic were measured. A large amount of knowledge was obtained about the nature of polar lights and the close association between auroras and solar activity, and the speed of geomagnetic phenomena was established (Isaev, 1983).

## 2 THE INTERNATIONAL GEOPHYSICAL YEAR (1957–1958)

The advances in science and technology during the 25 years following the Second International Polar Year were remarkable and rapid, driving the need for new data on planetary geophysics. In 1952, the American scientist, Dr. Lloyd Berkner, a member of the International Council of Scientific Unions (ICSU), proposed on behalf of the ICSU conducting new geophysical research in areas of common interest. His suggestion was readily accepted and quickly transformed into the International Geophysical Year (IGY), which became the largest scientific project of the 20th century. Scientists from 67 countries (about two-thirds of the countries that time) took part in the effort (Chapman, 1959; Troitskaya, 1957).

The IGY was originally scheduled to last 18 months, from July 1, 1957, to December 31, 1958. Subsequently, it was extended to the end of 1959. The proposal of an enterprise with a wide scientific scope was welcomed by the leading scientific organizations such as the International Union for Geodesy and Geophysics, the International Union for Astronomy and the World Meteorological Organization. An IGY International Committee was appointed to organize the project. Its officers were a president (S. Chapman, Great Britain), a vice-president (L.V. Berkner, USA), and a general secretary (M. Niccolet, Belgium). At a later date V.V. Belousov from the Academy of Sciences of the USSR became another vice-president (Chapman, 1959; Silkin et al., 1962) (Figure 1).



**Figure 1.** IGY International Committee in Brussels, 1957. The attendees were, from left to right, V.V. Belousov (Vice-President, USSR), L.V. Berkner (Vice-President, USA), M. Niccolet (General Secretary, Belgium), J. Coulomb (member, France), S. Chapman (President, Great Britain) (Silkin et al., 1962).

The committee adopted symbol for the IGY (Figure 2) showing the Earth partly in sunlight and partly in darkness. The viewpoint was the Antarctic to stress the special attention to be given to the Antarctic during the IGY.

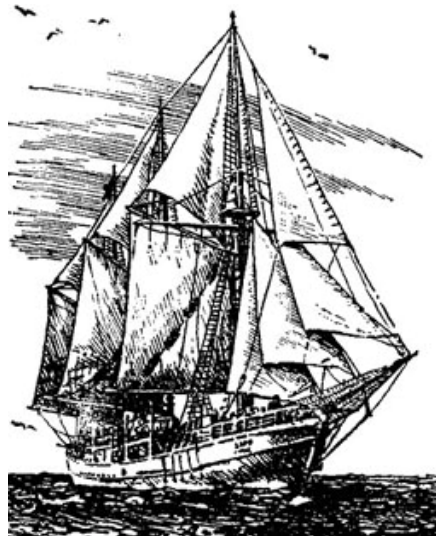


**Figure 2.** Symbol of International Geophysical Year.

The USSR took an active part in this extraordinary event, which coincided with a period of political thaw in the country. Soviet scientists had already been focusing their efforts on international projects. In 1954, the government of the USSR established a special agency for coordinating all research conducted by Soviet scientists related to the IGY. This Soviet Committee of the IGY was responsible for coordinating the IGY research. (Its present day counterpart is the Geophysical Center of the Russian Academy of Sciences.) I.P. Bardin (the Vice-President of the Academy of Sciences, USSR) headed the committee, Prof. V.V. Belousov was the vice-chairman, and Prof. V.A. Troitskaya was the scientific secretary. The committee organized several sections corresponding to various aspects of planetary geophysics: meteorology, geomagnetism, auroras, solar activity, cosmic rays, the ionosphere, meteors, longitudes and latitudes, oceanography, glaciology, seismology, gravity, and rockets and satellites (Hrgian, 1956). A message from Academician I.P. Bardin as an officer of the committee to the IGY International Committee about the plans of Soviet scientists to launch the first IGY satellite signaled the Soviet entry into the IGY program. The launching of the first Soviet IGY satellite was a major event of the IGY (Silkin et al., 1962).

The research program of the International Geophysical Year was many-sided. It included the study of the meteorological phenomena and physics of the atmosphere, the constant and variable magnetic field of the Earth, the polar lights and airglow, the ionosphere and the worldwide pattern of the distribution of radio waves, meteors and cosmic rays, all in an effort to obtain new information about the physical conditions on, near, and far from our planet. The program also included the study of the Earth's interior and its seismic characteristics, of mountain glaciers, of polar ice caps, of physical processes in the world's ocean, of variations in the gravity field on the planet's surface, of the fluctuations in latitudes and longitudes, and of the true form and size of the Earth.

On July 1, 1957, about 30,000 scientists were ready to begin many-sided geophysical observations at 4,000 scientific stations located on all 7 continents. One of the largest groups of geophysicists was the Soviet one. Soviet scientists at almost 500 Soviet stations and observatories, from Franz Josef Land up to Kushka, from the Baltic up to Chukotka, and even in the Antarctic, studied the planetary physical processes along with their foreign colleagues on the agreed upon program.. Research was also conducted on vessels at sea: the Soviet "Vitjaz" and "Michael Lomonosov", the Australian "Diamantina", the American "East Wind", the German "Gauss", the French "Jeanne D'Ark", and the English "Explorer" (Chapman, 1959; Silkin et al., 1962). There was even a non-magnetic vessel, the "Zarja" from the USSR (Figure 3).



**Figure 3.** The Russian non-magnetic oceanographic research vessel, a wooden three-masted schooner called the Zarja, was built in Finland in 1952.

Scientists on the research vessels collected samples of seabed rocks and ocean water, measured the speed of deep-sea currents and the intensity of the magnetic field on the ocean surface, and used shipboard radar to watch for flights of balloons carrying meteorological instruments. They all worked together on the agreed upon program.

During the International Geophysical Year Soviet scientists established a drifting ice station NP-7 to collect the necessary information regarding the ice, meteorology, and hydrology of the Arctic Ocean. (Figures 4) The United States decided to maintain two drifting ice stations, "Alpha" and "Bravo" in the Arctic.



**Figure 4.** A high-latitude IGY observatory, drifting ice station NP-7 located in the Central Arctic region (Silkin et al., 1962).

At the other end of the world, in the Antarctic, twelve countries (the USSR, the USA, Great Britain, France, Belgium, Australia, New Zealand, Japan, Norway, Argentina, Chile and Sweden) established scientific stations for the IGY and carried out geophysical research (Figures 5).



**Figure 5.** Soviet and American scientists in the Antarctic (Silkin et al., 1962).

During the 30-month IGY, the scientists collected a large amount of data and recorded it on sheets of paper, in tables, and on maps and schedules. They also produced seismograms and magnetograms, both on paper and on film. When the IGY came to an end, most of the data were collected at World Data Centers for analysis and interpretation. The preliminary results were most remarkable (Silkin et al., 1962) (Figures 6 & 7).



**Figure 6.** Press conference at Moscow State University in 1963 devoted to IGY results. The man standing is the chairman of the Geophysical Committee under the Presidium of the Academy of Sciences of the USSR,

V.V. Belousov, A.D. Povzner, N.V. Shebalin, N.V. Pushkov and V.A. Magnitsky (from left to right) are sitting at the table. (Belousov, 1986)

It is important to emphasize that at that time the remarkable success of the IGY was due to the cooperation of scientists from many countries. **Therefore, the IGY has gone down in history of science and of nations in general as one of the most important and noble enterprises undertaken by mankind.**



**Figure 7.** Leading geophysicists at final meeting of the IGY International Committee in Berkeley, USA, 1963, including M. Niccolet (Belgium), J. Coulomb (France), L. Berkner (USA), V.V. Belousov (USSR), and S. Chapman (Great Britain) (Povzner & Tjupkin, 1999).

### 3 WORLD DATA CENTERS

In an unprecedented effort, information about the life of our planet was accumulated by thousands of experts from various nations during the thirty-month IGY. The IGY data are unique since the phenomena and processes occurring on the Earth and in the near-earth space are unique. They are invaluable. Even if a small part were lost, the continuity of the observations would be broken.

One of the major IGY aims was to ensure the safekeeping of the results. Another was to provide easy access to the results to anyone wanting to study and compare the observations. An essential feature of the International Geophysical Year was the agreement between the National Committees of two leading countries - the USSR and the USA - that World Data Centers be established. They would collect the data and create equivalent archives of the global observations covering all the geophysical disciplines of the IGY program. The centers willingly exchanged free-of-charge copies of the material that were received from investigators. The information was available to all countries and to all scientists at any WDC. During the three years following the start of the IGY, the WDC's accumulated about 3 million units of storage. This resulted in the creation of the largest scientific archive that had ever been created, one containing information about all areas of the physical life of the planet. It was indeed a "gold mine" of information about the geosciences.

This information was made available to both scientists and the public by publishing reports on the data collected and the results of the analyses in journals, reports, catalogues, and books in many countries. The official organization sponsored the publication of a new scientific journal — the *Annals of the International Geophysical Year*, or the *IGY Annals* for short. The journal was printed for several years in England; the volumes covered not only the programs conducted and the manuals for the devices and techniques, but also the first results of the investigations. In Russia, the results were published in "The IGY Results", a publication sponsored by the Soviet Committee (Soviet Committee ..., 1982; Kharin & Sergeeva, 2007).

### 4 RESEARCH AFTER IGY

#### 4.1 International geophysicist cooperation continues

After the IGY, it became clear that the basic purpose of world science is the common study of our planet by all nations that scientific cooperation is needed during experiment preparation, initiation, and analysis. The scientific scope grew far beyond what was first proposed.

Several solid earth projects and programs were undertaken following the IGY program, and Russian scientists participated in those as well.

- The Upper Mantle Project (1961–71)
- The International Geodynamic Project (1971–80)
- The International Geotraverse Project (1987–2003)
- The International Lithosphere Program (1980–)
- The International Project "InterMARGINS" (2003–)

In 1960, the General Assembly of the International Geodetic and Geophysical Union endorsed the Upper Mantle Project proposed by V.V. Belousov, and 53 countries joined the undertaking. The major aim of the project was to improve geophysical knowledge and understanding of the Earth's interior, of the processes in the asthenosphere (a plastic layer in the upper mantle containing the magma sources feeding volcanoes), and of the formation and development of the Earth's crust. The main result was a new theory of geosciences called "plate tectonics" (Belousov, 1986).

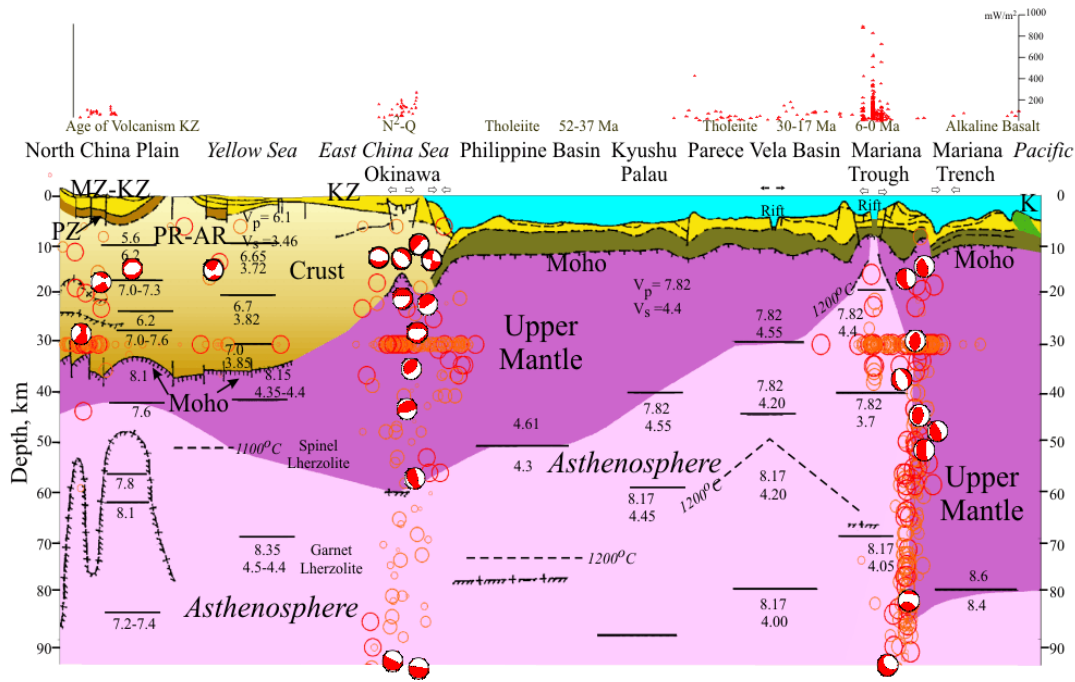
The next project, the **International Geodynamic Project**, focused on the Earth's interior. Particular attention was placed on the physical properties of the Earth's interior, the correlations between the endogenous processes responsible for mineral formation, the slow secular land uplift and the long periodic variations of the sea level, the disposition of oceans and continents in the past, and the development of rift structures in the continents and oceans. The scientific interests of the Soviet geophysicists were extended to include research in other countries. For example, with the assistance of scientific and government organizations in the target countries, Soviet geophysicists mounted two extremely fruitful expeditions: the Soviet East-African geological-geophysical expedition (1967–1969) and the Soviet-Icelandic geological-geophysical expedition (1971–1973) led by V.V. Belousov (head of the Soviet Geophysical Committee, 1961–1990) (Rodnikov, 1974).

## 4.2 The International Geotraverse Project

The International Geotraverse Project led by Dr. A.G. Rodnikov (Russia) was devoted to the study of the deep structure of the transition zone from the Eurasian Continent to the Pacific Ocean and was done in cooperation with Japanese geoscientists (led by Prof. S. Uyeda) and Chinese geoscientists (led by Prof. L. Guodong). The transition zone is an especially large region and is seismically very active. It is particularly important to study the deep structures of such regions, focusing on the areas beneath active volcanoes, the sedimentary basins, and the minerageny areas (Rodnikov, 1986).

The deep structure of the Eurasia-Pacific transition zone was investigated along the deep sections of the tectonosphere, including the lithosphere and asthenosphere. The geotraverse crosses the North China Plain, the Yellow Sea, the East China Sea, the Ryukyu Island Arc, the Philippine Sea, the Mariana Island Arc, and the Pacific Ocean (Figure 8). Deep cross-sections of the crust and upper mantle were constructed on the basis of combined interpretation of the geological and geophysical data.

The correlation between the deep structure of the upper mantle and the structure of the upper geological structures is evident in Figure 8. The higher the asthenosphere, the greater the density of the heat flow and the more recent the formation of the deep sedimentary basins. Under the Mariana Trough, which formed six million years ago, the asthenosphere reaches the crust. In the Parece Vela Basin, which formed in the early Oligocene-Middle Miocene, the asthenosphere lies at depth of 30 km. Under the West-Philippine Basin, which formed mainly in the Eocene, the asthenosphere is at depths of 50–80 km. Under the North China Plain, which experienced tectonic activity in the Cenozoic, the asthenospheric diapir is at depths of 50–70 km (Rodnikov, Uyeda & Liu Guodong, 1991; Rodnikov, Rodkin, Stroeve, Uyeda, Isezaki & Shiki, 1996; Rodnikov, Stroeve, Smirnov, Uyeda, Isezaki, Shiki et al. 2003; Rodnikov, Sergeeva, Zabarinskaya, Rashidov & Rodkin, 2007).



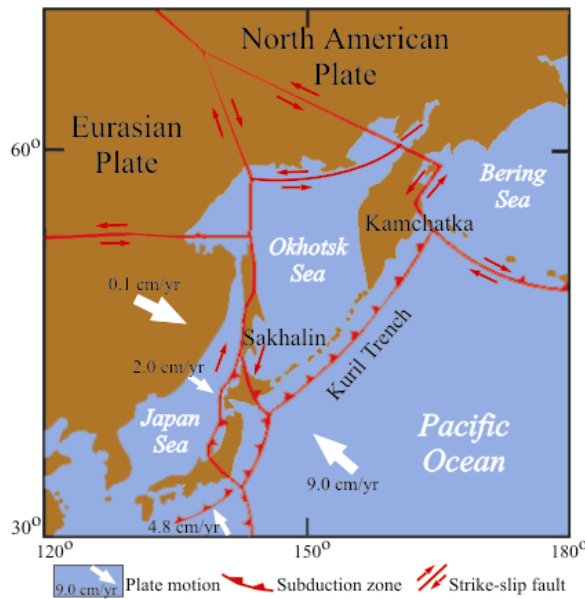
**Figure 8.** The geotraverse crosses the North China Plain, the Yellow Sea, the East China Sea, the Ryukyu Island Arc, the Philippine Sea, the Mariana Island Arc, and the Pacific Ocean (Rodnikov et al., 2007).

### 4.3 “InterMARGINS” Project

The International project “InterMARGINS” began in 2003 and is still underway. Twenty countries are investigating the deep structure of continental margins, which are characterized by high seismicity, volcanism, and natural cataclysms, all hazardous for the people living there (Rodnikov, 2006).

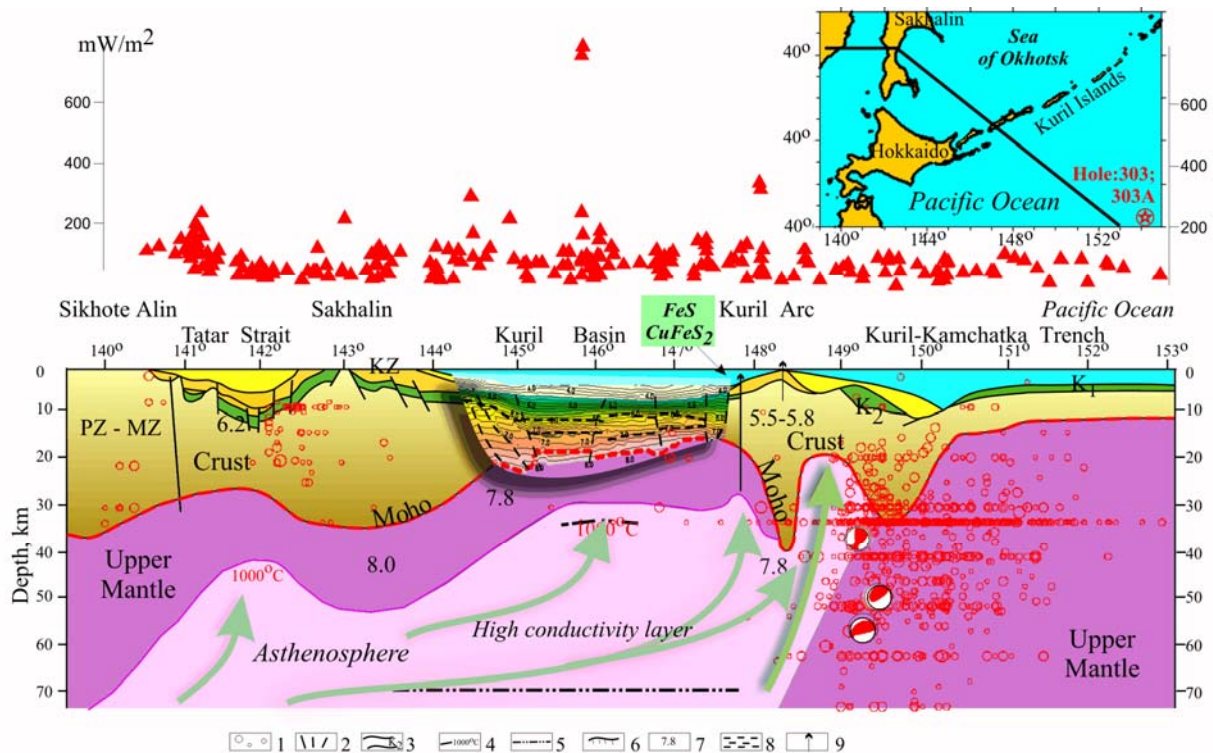
In Russia, the research is focused on the geotraverse running across the Mesozoic structures of the Sikhote Alin mountain range, the rift structure of the Tatar Strait, the Cenozoic formations of Sakhalin Island, the Kuril Basin of the Sea of Okhotsk, the volcanic structures of the Kuril Island Arc, the Kuril Trench, and the Mesozoic plate of the Northwestern Basin of the Pacific Ocean. The geotraverse is about 2000 km long and about 70 km deep.

The Okhotsk Sea region forms a lithosphere plate located between the North American, Eurasian, and Pacific plates (Figure 9). It is bounded by deep faults, mostly strike-slip faults; in the southeast, it is bounded by a recent subduction zone, the Benioff zone (Filatova & Rodnikov, 2006). The contact between the Okhotsk Sea plate and three other lithospheric plates results in high seismicity at its margins. The seismic activity is strongest along the Kuril Island Arc, where the Pacific plate is subducted under the continent, forming a seismofocal zone, traceable to a depth of 700 km. In the west, the Okhotsk Sea plate is bounded by deep faults extending along Sakhalin Island. There the earthquakes are mostly localized in the crust (Yunga & Rogozhin, 2000).



**Figure 9.** Tectonic chart of the Okhotsk Sea region (Kiratzi & Papazachos, 1996; Maruyama, Isozaki, Kimura & Terabayashi, 1997; Biebow, Ludmann, Karp & Kulinich, 2000; Rodnikov, Sergeyeva & Zabarinskaya, 2001).

The deep structure of the lithosphere along the geotraverse was derived from a combined interpretation of geological and geophysical data. The thickness of the crust under the Okhotsk Sea region varies from 35–40 km (beneath Sakhalin and Kuril Islands) to 10–15 km (beneath the Kuril Basin) (Figure 10). The basement ranges in age from the Paleozoic to the Mesozoic. Most sedimentary basins were formed in the Cenozoic (Sergeyev, 2006).

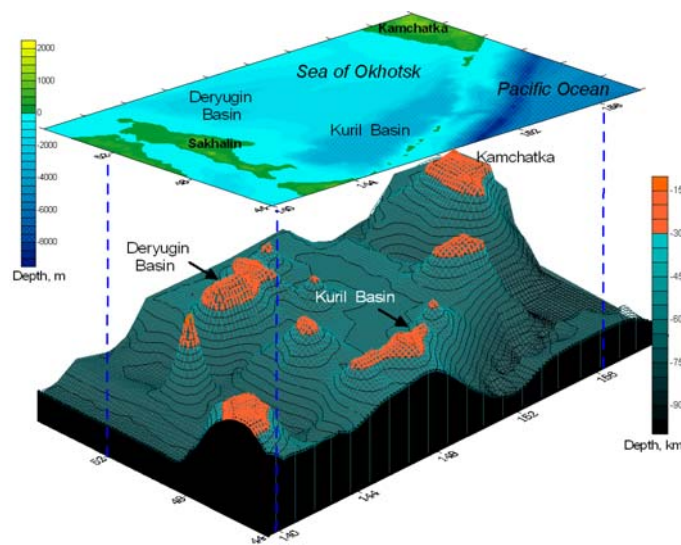


**Figure 10.** Geotraverse of the Okhotsk Sea region (Galperin & Kosminskaya, 1964; Baranov, Dozorova, Karp & Karnaukh, 1999; Emelianova, Lelikov, Siedin & Naryzhnyi, 2003; Zlobin, 2005; Smirnov & Sugrobov, 1980; Rodnikov, Tuezov & Kharakhinov, 1996; Bogdanov & Khain, 2000; Rodnikov et al., 2001; Rodnikov, Sergeyeva, Zabarinskaya, Filatova, Piip, & Rashidov, 2008; Piip & Rodnikov, 2004). The route of the geotraverse is shown at the upper right. The distribution of the measured heat flow ( $mW/m^2$ ) along the profile is



shown above the picture. PZ – Paleozoic, MZ – Mesozoic, KZ – Cenozoic, K<sub>2</sub> – Upper Cretaceous. 1– earthquake source locations; 2 – faults; 3 – geological layers; 4 – isotherm (°C); 5 – boundaries of high electric conductivity layer; 6 – M-discontinuity; 7 – seismic wave velocities (km/s); 8 – water mass; 9 – volcanoes

**The upper mantle** beneath the Sea of Okhotsk region is characterized by both horizontal and vertical heterogeneities (Bijwaard, Spakman & Engdahl, 1998). A layer of specific conductivity (0.3–0.5 S/m) was distinguished in the Kuril Basin on the basis of electromagnetic research focused on the upper mantle at depths of 30–65 km (Liapishev, Sychev & Semenov, 1987). The nature of this layer is related to partial melting, which occurs only in the basin. The asthenosphere in the upper mantle was distinguished for the most part on the basis of geothermal data (Rodnikov, Tuezov & Kharakhinov, 1996). The term “asthenosphere” is used to refer to the layer in the upper mantle where the temperature is high enough to melt the solid rock of the mantle. The asthenosphere is the source of hydrocarbon fluids. The upper boundary of the asthenosphere is assumed to be an isothermal line of 1000–1200°C (Smirnov & Sugrobov, 1980; Rodnikov et al., 1996). Calculations showed that the asthenosphere is in the upper mantle under the Sea of Okhotsk at a depth of 50–70 km and beneath the Northwest Pacific Basin at a depth of approximately 100 km. Diapirs of partially melted matter rise from the asthenosphere and reach a depth of 20–30 km beneath the sedimentary trough of the Tatar Strait, Deryugin Basin, and Kuril Basin. This creates active tectonic conditions that manifest in volcanic, seismic, and hydrothermal activity (Figure 11).



**Figure 11.** 3D model of the lithosphere structure of the Sea of Okhotsk: upper – relief of the Okhotsk Sea floor; lower – relief of the asthenosphere. The asthenosphere in the upper mantle under the Sea of Okhotsk is located at a depth of 50–70 km and under the Northwestern Pacific Basin is located at a depth of 100 km. Diapirs of partially melted matter rise from the asthenosphere and reach a depth of 20–30 km beneath the Tatar Strait Trough, Deryugin Basin, and Kuril Basin, creating an active tectonic regime that manifests in volcanic, seismic, and hydrothermal activity. The regions of the asthenosphere shown in red are areas of magma formation beneath the sedimentary basins (Rodnikov et al., 2008)

Beneath the North Sakhalin sedimentary basin, which contains most of the oil and gas fields of Sakhalin, the asthenosphere is located at a depth of approximately 70 km. Hydrocarbon deposits were also found above the asthenospheric diapirs in the sedimentary basin of the Tatar Strait and Deryugin Basin, and sulfide mineralization was found in the Kuril Basin in submarine volcanic peaks. The mantle fluids of asthenospheric diapirs determine the geodynamic evolution of sedimentary basins and the formation of hydrocarbon deposits in them.

## 5 CONCLUSION

The experience gained during the International Polar Years and particularly during the International Geophysical Year has shown that international cooperation is necessary for a detailed scientific study of the Earth to define a human reasonable existence.

The findings obtained during the International Geophysical Year and from subsequent international endeavors have enabled us to learn more about the deep structure and geophysical fields of the Earth, to solve environmental problems, and to draw up plans for investigating the most dangerous regions, such as the

continental margins, which are characterized by high seismicity, volcanic eruptions, and natural cataclysms hazardous to the people living there.

The Russian investigations conducted as part of the International Geotraverse and “InterMARGINS” Project were aimed at studying the deep structure beneath seismic hazardous zones, volcanic areas, mineragenetic fields and sedimentary basins and at defining the role of the deep processes going on in the upper mantle, specifically in the asthenosphere, during the formation of the major structural units of the active continental margins.

## 6 REFERENCES (Those in Russian are asterisked.)

- Baranov, B.V., Dozorova, K.A., Karp, B.Y. & Karnaukh, V.A. (1999) The geometry of Kuril Basin opening. *DAN* 367(3), 376–379. \*
- Belousov, V.V. (1986) Centenary of the international cooperation in the Earth’s study. In Belousov, V.V., Artemev, M.Y. & Rodnikov, A.G., (Eds.), *The structure and dynamic of the continental margins*, Moscow: Nauka. \*
- Belousov, V.V. & Udintsev, G.B. (Eds.) (1981) *Structure of the Okhotsk Sea floor*, Moscow: Nauka. \*
- Biebow, N., Ludmann, T., Karp, B. & Kulinich, R. (Eds.) (2000) *Cruise Reports: Komex V and VI. Kuril Okhotsk Sea Marine Experiment*, Kiel.
- Bijwaard, H., Spakman, W. & Engdahl, E.R. (1998) Closing the gap between regional and global travel time tomography. *J. Geophys. Res.* 103(B12), 30055–30078.
- Bogdanov, N.A. & Khain, V.E. (Eds.) (2000) *Tectonic map of the Okhotsk Sea region. Scale 1:2500000*, Moscow: Institute of the Lithosphere of Marginal and Inland Seas. \*
- Chapman, S. (1959) *IGY: Year of Discovery*, USA: The University of Michigan.
- Emelianova, T.A., Lelikov, E.P., Siedin, V.T. & Naryzhnyi, V.I. (2003) The geology and volcanism features of the Okhotsk Sea floor. *Tikhookeanskaya geologia* 22(4), 3–18. \*
- Filatova, N.I. & Rodnikov, A.G. (2006) The Sea of Okhotsk geotraverse: tectonomagmatic evolution of Cenozoic extension structures and implication for their deep structure. *Doklady Earth Sciences* 411A(9), 1346–1350.
- Galperin, E.I. & Kosminskaya, I.P. (Eds.) (1964) *Structure of the Crust in the Transition Zone From the Asian Continent to the Pacific Ocean*, Moscow: Nauka.\*
- Hrgian, A.H. (Ed.) (1956) *The International Geophysical Year. Newsletter № 1*, Moscow: Soviet Committee of the Academy of Sciences of the USSR. \*
- Isaev, S.I. (1983) International Polar Years. In Dubov, E.Y. (Ed.), *The modern geophysics: results, problems, prospects (devoted to the centenary of the First IPY)*, Moscow: Znanie. \*
- Kharin, E.P. & Sergeyeva, N.A. (2007) Gold reserves of the geosciences. *Zemlya i Vseennaya* (4), 66–71. \*
- Kiratzis, A. & Papazachos, C. (1996) Moment-tensor summation to derive the active crustal deformation in Japan. *BSSA* 86(3), 821–831.
- Liapishev, A.M., Sychev, P.M. & Semenov, V.Y. (1987) The structure of electrical conduction of the upper mantle of the Kuril Basin of the Sea of Okhotsk. *Tikhookeanskaya geologia* (4), 45–55. \*
- Maruyama, S., Isozaki, Y., Kimura, J. & Terabayashi, M. (1997) Paleogeographic maps of the Japanese Islands: Plate tectonic synthesis from 750 Ma to the present. *The Island Arc* 6(1), 91–120.
- Piip, V.B. & Rodnikov, A.G. (2004) The Sea of Okhotsk crust from deep seismic sounding data. *Russian Journal of Earth Sciences* 6(1), 1–14.
- Povzner, A.D. & Tjupkin, Y.S. (1999) Geophysics is a global science. *Zemlya i Vseennaya* (5). \*

- Rodnikov, A.G. (1974) Geodynamic Project: the recent stage of the international scientific co-operation. In *The Science Today*, Moscow: Znanie. \*
- Rodnikov, A.G. (1986) International project “Geotraverse”: the aims, problems and outlook. *Bulletin of AN SSSR* (2), 101–106. \*
- Rodnikov, A.G. (2006) International project “InterMARGINS”. *Tikhookeanskaya geologia* (5), 107–109. \*
- Rodnikov, A.G., Uyeda, S. & Guodong. L. (1991) *The North China Plain-Philippine Sea-Mariana Trench Geotraverse*, Moscow: Nauka. \*
- Rodnikov, A.G., Tuezov, I.K. & Kharakhinov, V.V. (Eds.) (1996) *Structure and dynamics of the lithosphere and asthenosphere of the Okhotsk Sea region*, Moscow: National Geophysical Committee. \*
- Rodnikov, A.G., Rodkin, M.V., Stroeve, P.A., Uyeda, S., Isezaki, N., & Shiki, T. (1996) Deep structure and geophysical fields along the Philippine Sea Geotraverse. In *Physics of the Solid Earth*, 32(12) 1010–1017.
- Rodnikov, A.G., Sergeyeva, N. A. & Zabarinskaya, L.P. (2001) Deep structure of the Eurasia-Pacific transition zone. *Russian Journal of Earth Sciences* 3(4), 293–310.
- Rodnikov, A.G., Stroeve, P.A., Smirnov, Y.B., Uyeda, S., Isezaki, N., Shiki T. et al. (2003) The Philippine Sea Geotraverse. In Udintsev, G.B. (Ed.), *International Geological-Geophysical Atlas of the Pacific Ocean*, Moscow, Sankt-Petersburg: IOC of UNESCO.
- Rodnikov, A.G., Sergeyeva, N.A., Zabarinskaya, L.P., Rashidov, V.A. & Rodkin, M.V. (2007) The North China Plain Philippine–Sea Geotraverse. *Vestnik “KRAUNTS”. Earth Sciences* 9(1), 79–89. \*
- Rodnikov, A.G., Sergeyeva, N.A., Zabarinskaya, L.P., Filatova, N.I., Piip, V.B. & Rashidov, V.A. (2008) The deep structure of active continental margins of the Far East (Russia). *Russian Journal of Earth Sciences* 10(4), ES 4002.
- Sergeyev, K.F., (Ed.) (2006) *Tectonic zoning and hydrocarbon potential of the Okhotsk Sea*, Moscow: Nauka. \*
- Silkin, B.I., Troitskaja, V.A. & Shebalin, N.V. (1962) *Our unknown planet*. Moscow: AN USSR. \*
- Smirnov, Y.B. & Sugrobov V.M. (1980) Earth heat flow in Kuril-Kamchatka and Aleutian provinces. *Vulkanologia i Seismologia* (2), 3–17. \*
- Soviet Committee of the Academy of Sciences of the USSR (1982). Moscow: VINITI. \*
- Troitskaya, V.A. (1957) *International Geophysical Year*. Moscow: Sovetskaya Rossiya. \*
- Yunga, S.L. & Rogozhin, E.A. (2000) Seismicity, earthquake center mechanisms and seismotectonic deformations within active blocks of the lithosphere. In Grachev, A.F. (Ed.), *Modern tectonics, geodynamics and seismicity of North Eurasia*, Moscow: Probel. \*
- Zlobin, T.K. (2005) Recurrence and regularities in the dynamics of strong earthquakes seismic processes in Sakhalin. *Doklady RAN* 400(4), 524–527. \*