Publications of the Institute of Geophysics, Polish Academy of Sciences
Geophysical Data Bases, Processing and Instrumentation
vol. 450 (M-38), 2024, pp. 97–112
DOI: 10.25171/InstGeoph_PAS_Publs-2024-019

On the Geodynamics of One Earth

ANDREW KOBOS' INTERVIEW WITH PROFESSOR ALEKSANDER GUTERCH CONDUCTED IN 2009

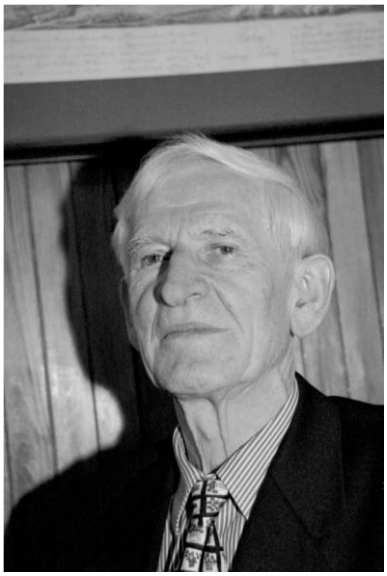
Aleksander GUTERCH[1] and Andrzej M. KOBOS[2]

[1]Institute of Geophysics, Polish Academy of Sciences, Warsaw, Poland
[2]Polish Academy of Art and Science (Polska Akademia Umiejętności)

A word of introduction

It seems that we came across the most valuable material for the present volume while tidying up the Professor's office room. It is an interview of Mr. Andrzej Kobos with Professor Aleksander Guterch, published in the prestigious series "On the Ways of Scholars" by the Polish Academy of Arts and Sciences (Polska Akademia Umiejętności, PAU) in 2009[1]. Thanks to the courtesy of Mr. Andrzej Kobos and the PAU Editors, we were able to post this interview below, in a slightly modified form.

Tomasz Janik



fot. Andrzej M. Kobos

ABOUT YOUNG YEARS

Andrzej Michał Kobos [**AMK**] – *Please tell us about your young years*.

Aleksander Guterch [**AG**] – I was born in 1936 in village Sękowa, Gorlice region of Podkarpacie. It was the site of the oldest center of the oil industry in Poland; Ignacy Łukasiewicz, the pioneer of this industry, was active there in the 19th century. My family, including my grandfather and mother's brother, worked in the oil industry. They were specialist drillers and used to travel to other countries as sought-after professionals. My close family – father and brothers – was involved in the oil industry in Podkarpacie. I remember from my childhood the smell of crude oil lin-

[1] Guterch, A., and A.M. Kobos (2009), O geodynamice jednej Ziemi. **In:** *Po Drogach Uczonych. Z Członkami Polskiej Akademii Umiejętności Rozmawia Andrzej M. Kobos*, Vol. 4, 75–100.

gering in the air, extracted from numerous boreholes located in the Gorlice area. I was the youngest in a family of ten. We spent the German occupation there. Unfortunately, my father died very early, in 1940. Those were very difficult years. I graduated from the High School in Gorlice in 1954, with a one-year break caused by a serious accident, the effects of which I still feel today. I remember my High School studies very fondly because of the teachers. It was still a cadre of pre-war teachers who, in the terrible Stalinist times, were able to conduct lessons, even history, in such a way that they clearly conveyed to young people true information about the history of Poland and the history of the world. I remember the characteristic moment: Professor Stanisław Motyka devoted the last five or ten minutes to what he had to do, starting: "And now the same events in the light of the Marxist theory of history... Remember this, because they will ask you about it". Polish language lessons taught by Professor Elżbieta Dniestrzańska (my class tutor), I remember to this day. And again, in these difficult times, when Polish language textbooks were full of slogans about socialist realism in literature, she was able to instil in us the respect for the great Polish literature of the eras of Romanticism and Positivism, the interwar and war period. It was then that we already learned about Krzysztof Baczyński and other banned authors of literature. Ms. Dniestrzańska was a widow; it was quietly said that her husband died in Katyń – without any doubt who did it. I remember with reverence the extraordinary figure of Professor Jan Sikorski, a soldier of the Polish Legions, a powerful gentleman of stature who used to visit various countries on official delegations before the war. Walking along the desks in the classroom, he used to teach geography, astronomy, and geology, as these subjects were then taught separately. He also used to brilliantly educate us on ancient history. I remember the Battle of Thermopylae and the history of Alexander the Great from his lecture to this day. Decades later, when I found myself in Greece, I travelled to the Thermopylae Gorge. There, in my mind, I saw the powerful figure of Professor Sikorski when, after the story about the death of King Leonidas and his team, he wiped his eyes with a handkerchief out of emotion, and the whole class remained silent for a long time out of impression...

AMK – *However, you went in the direction of mathematics and physics...*

AG – It was also the influence of the school. The same Professor Jan Sikorski, while teaching geography, geology, and astronomy, used to tell us that the basis of all knowledge is mathematics and physics.

AMK – *Which, after all, were created by the ancient Greeks*.

AG – Exactly. In 1954, I entered the Faculty of Mathematics, Physics and Chemistry of the University of Warsaw, majoring in physics with a specialization in geophysics.

AMK – *Who was chairing geophysics at the University of Warsaw at that time?*

AG – These were the beginnings of teaching geophysicists together with physicists, while the Faculty of Geology was operating separately. In the field of lithospheric physics, which was particularly interesting to me, there was Professor Tadeusz Olczak, who began his activity in geophysics before the war as an assistant to Professor Tadeusz Banachiewicz at the Jagiellonian University, in a new branch of knowledge – Earth sciences – based not on observations or comparative analysis, but on strict principles of physics and mathematics. During the first years of our studies, we had a full course in physics and mathematics. Geophysics was located at Hoża 79 Street, a couple of buildings behind the Institute of Physics of the University of Warsaw.

AMK – *You probably did your specialization and master's thesis under Professor Olczak?*

AG – Yes. Unfortunately, I finished my five-year studies with a two-year delay because I had serious orthopedic problems after an accident when I was still at school. I underwent two serious surgeries performed by Professor Adam Gruca in Warsaw.

AMK – *It's unbelievable – later on, you walked in Spitsbergen and Antarctica. About that in a moment.*

AG – I graduated from the University in 1961 and started working as a research assistant to Professor Tadeusz Olczak in the Lithosphere Physics Department, one of the two Departments of Geophysics, University of Warsaw. However, I did not see my future in theoretical research, since I was more interested in exploring the Earth through experimental investigations, which could not have been expected at the University. Professor Olczak accepted my resignation with true regret, but also with understanding, encouraging me to remain in regular contact with him, which I continued, with great benefits, until Professor's death. Following Professor Olczak's advice, I decided to apply for a job at the Department of Geophysics, Polish Academy of Sciences. I was hired by Professor Roman Teisseyre. Being also a theoretician, he initially tried to encourage me to change my interests by presenting relevant problems to be solved in theoretical seismology, but, seeing the lack of enthusiasm on my part, he assigned me to the experimental lithosphere research laboratory. It was not an easy start. Geophysics at PAS, particularly seismology, suffered from a lack of highly qualified personnel. None of the seismology staff, apart from Roman Teisseyre, were PhD holders. So independence and maximum activity were required, but the foreign contacts were very limited. There was, by the standards of the time, a well-supplied library, and this was the basic source of knowledge for young seismologists. Under such conditions, it was only possible to work effectively with the support and friendliness of the management and colleagues. One of my first tasks was to organize, under the patronage of Roman Teisseyre, nationwide geodynamic symposia in Jabłonna near Warsaw, in order to integrate various Earth researchers. These symposia, usually three-day long, were very popular, provided opportunities for formal and informal discussions, and initiated joint research projects. The resulting papers were published in the *Publications of the Institute of Geophysics PAS* (in 1976, 1980, 1984, 1985, 1991). When, after several years of work and having completed my doctorate, I was already well acquainted with the research capabilities of the Department of Geophysics, PAS, and the cooperating institutions, first and foremost the Polish Geological Institute (PGI) and the Geophysical Exploration Company (presently the PBG Geophysical Exploration Ltd.) in Warsaw, and the AGH University of Science and Technology in Kraków, I presented a more detailed program of deep lithosphere research by means of deep seismic soundings in Poland.[2]

ABOUT THE EARLY PERIOD OF YOUR WORK IN GEOPHYSICS

AMK – *What did you begin to deal with?*

AG – I started to deal with a completely new field – the application of active seismic methods to study the structure of the entire Earth's crust. Just before World War II, seismic surveys for exploration purposes began, and in the late 1950s, active seismic methods were developed to study the interior of the Earth's crust; active, that is, based not only on the analysis of the seismic wavefield from natural earthquakes, but primarily on the analysis of seismic waves induced artificially, in a precisely defined place and at a very precisely defined time. The 1950s saw the development of this research, and the first American and Russian papers on the subject appeared. And it was in this field that I began my professional activity, which I continue to this day.

AMK – *For comparison – the geophysical profiles that Professor Marian Mięsowicz used to make in the late 1940s with methods of recording ionizing radiation were shallow, while here*

[2] The editors took the liberty to include an excerpt from the recent publication: Guterch, A. (2023), Remembering Professor Roman Teisseyre, *Publs. Inst. Geoph. PAS* **446 (A-32)**, 53-55, DOI: 10.25171/InstGeoph_PAS_Publs-2023-013, where the author describes his early years in science.

you go deep into the Earth's crust, down to a depth of many tens of kilometers. The quality of the results probably depends on the sensitivity of the measuring instruments.

AG – Here we enter deep into the Earth's lithosphere, currently even to a depth of 100 km or more. At the initial stage, we used seismic instruments that were already functioning in the oil industry – primitive from today's point of view. We adapted this instrumentation and methods to deep seismic soundings. Thanks to this, it was already possible to reach a depth of 40–50 km, using – unfortunately – very powerful explosive charges, since the sensitivity of the recorders was not high. Tube electronics was a "manual" job. Then I also started working closely with the Polish oil industry; we organized these investigations in breaks between their industrial tasks.

AMK – *On their part, it was probably a constant search for hydrocarbons?*

AG – Yes, although it was clear that our methods were not suitable for searching for deposits, they were necessary to explain the fundamental problems of the Earth's geodynamics. Geophysicists and geologists working in the oil industry understood very well that without this type of research, there would be no progress in hydrocarbon exploration. And such a favorable atmosphere persists to this day.

I started working on regular designated seismic profiles in 1964–1965. In the 1970s, the state of recognition of deep structures of the Earth's crust in Poland was already so advanced (for those times) that these works were fully noticed and appreciated on the international forum. They concerned the territory of Poland and adjacent areas because we managed – in these difficult political conditions – to organize cooperation with institutions in neighboring countries, primarily with the Academy of Sciences of the Soviet Union.

AMK – *In 1969, you completed your PhD and organized the Experimental Seismology Laboratory at the Institute of Geophysics*.

AG – In 1969, I defended my doctoral thesis. My work concerned the dynamics of the seismic wave propagation in the Earth's lithosphere, which is the basis for the proper interpretation of the experimentally recorded seismic wavefield. The work was computational; I used the first "main frame" computers in Warsaw for this purpose. I developed this work during a six-month research internship in 1967/1968 at the Institute of Mathematics of the Academy of Sciences of the Soviet Union in Leningrad, with Professor Petrashen and his colleagues.

In 1970, based on my work, I was invited to a three-year contract at the University of Texas at Dallas. Unfortunately, I did not receive a passport – the authorities of the Polish People's Republic decided that I should not be allowed to go out. In 1971, during the period of another thaw related to the "December incidents" of 1970, I was invited to a conversation at the Polish Academy of Sciences with "sad gentlemen" who told me that these were wrong decisions. – "You can leave, try it". I tried. Unfortunately, the seat reserved for me was already occupied. However, I was invited to the same university in Dallas for one semester in 1971/1972. The stay was too short, but I deepened my knowledge about the study of the deep structures of the Earth's lithosphere. This also interested my hosts, and I established friendly relations that brought fruit in the following years.

AMK – *Seismic data is the "input" for mathematical modeling, for huge numerical calculations. This required – and probably still requires – the fastest computers with enormous memory*.

AG – That's right. It comes down to very complicated calculations. But there was a systematic progress. From the late 1960s to the late 1980s, geophysics experienced a very significant instrumental development, closely related (to this day) to the development of electronics. This

has always been close to the oil industry, the driving force behind the search for new solutions. In the late 1970s, we already had decent equipment of our own design.

In 1979, I was invited by Finnish geophysicists to carry out seismic research on the so-called SVEKA profile in central Finland, based on recordings from our seismic stations. The Finns, in turn, prepared all the equipment. I then established very cordial contacts with the Finnish side, which continue to this day. We took part in virtually all experiments performed in Finland, even in the most difficult period of the 1980s. We still maintain very close cooperation.

AMK – *I understand that the measurement instruments were being modernized, but supercomputers were still lacking in Poland, if only because of the embargo*.

AG – Yes, but the first significant computer capabilities appeared. We used them regularly. In the 1980s we also had access to very decent computers in Finland and from our friends in Norway, as I also had cooperation with Norwegians.

AMK – *The Norwegians were already extracting and further exploring for oil in the North Sea. As you emphasize, the driving force was the search for hydrocarbons, but the second issue was the geodynamics of the vast ocean areas, also for the needs related to submarines*.

AG – There were and are three drivers of geophysical research. One was the oil industry on the continents. The second was that geologists and tectonicists understood that there would be no progress in the fundamental problems related to the evolution of the Earth without a thorough understanding of the structure of the Earth's interior; otherwise, everything would remain at the stage of theories and hypotheses. The third driver was the "impact" on the oceans. It was understood that there would be no progress in geodynamics unless geophysical programs were introduced into vast ocean areas. Of course, a number of research projects were carried out for the needs of the navy, primarily the American one.

AMK – *You also "went out to the sea"…*

AG – We started seismic work related to the sea in 1974. I established close contacts with Professor M.A. Sellevoll from the University of Bergen in Norway. Together with him, with the help of the Polish Navy hydrographic ship ORP "Kopernik" and the Norwegian ship "Sverdrup", we proceeded to study the Earth's interior in the zone of transition from the oceanic crust of the North Atlantic to the continental crust of the Svalbard Archipelago in the Arctic.

AMK – *It was a completely new quality. Before, people walked on ice and made geological maps, but here one enters the interior of the Earth.*

AG – Yes. With the greatest respect for geological research, but without geophysical methods, no significant progress in geodynamic research will be achieved.

ABOUT THE "POLONAISE '97", "CELEBRATION 2000", "SUDETES 2003" AND "ALP 2002" EXPERIMENTS AND THE GEODYNAMICS OF CENTRAL EUROPE

AMK – *Let us come back to the research in the Svalbard area in a moment. Your name is associated with several major geophysical projects, the first, being "POLONAISE '97" and "CELEBRATION 2000"*[3]*. Please comment on these projects.*

AG – In 1991, after the political changes in Poland, I was invited by Professor Karl Fuchs, a geophysicist and seismic explorer from Germany, and Professor David Gee, a Briton working at the Uppsala University, to cooperate in the new program called "EUROPROBE" they were developing, which was funded by the European Science Foundation. The idea was to – after

[3] The name of the "CELEBRATION 2000" experiment came from "Central European Lithospheric Experiment Based on Refraction – June 2000".

previous experiments carried out so far in various countries – finally organize a single, joint geodynamic research program that would cover the entire European continent, since this uniform geodynamic "laboratory", i.e., the European continent is, on the surface, divided by dozens of political borders. By the way, Americans ask – "How can you practice geodynamics in Europe?".

The "EUROPROBE" program started in 1992 and lasted until 2001. I was a member of the Scientific Steering Committee of this program, which covered various geological and geophysical issues for the entire continent. Several dozen working meetings were held. Seismic surveys were the key to everything. Could you find a more interesting place for geodynamics in Europe than Poland, where three great geological systems intersect? This was already known from numerous geological works and our seismic surveys. I then started to organize a series of large, modern seismic experiments.

In Poland, we had neither the resources nor the technology. I came across an excellent American geophysicist, Professor G. Randy Keller from the University of Texas at El Paso[4], who after visiting us said: "OK, let's try to do something together". We managed, with his help, to get in touch with the American IRIS Passcal Instrument Center, a national American center with a large number of state-of-the-art seismic stations.

The Americans then provided us with several hundred seismic stations. The seismic apparatus, which had taken up a sizable part of the room in my youth, was now a small, inconspicuous device. We also received a significant number of modern seismic stations from Canada. And so, in 1997, we embarked on the first experiment, called "POLONAISE ′97", in the area of central and western Poland. The main task was to organize drilling and blasting works, very costly and troublesome, but it was achieved with the help of two very good Polish geophysical companies: Geofizyka Toruń S.A. and Geofizyka Kraków S.A. We performed this experiment in June 1997 – it lasted 24 days and nights, about 300 people took part in it, including the American team. Due to the needs arising from geodynamics, there was a slight extension of the seismic profiles to the areas of Germany and Lithuania. It was the first in a series of very modern – on a European scale – experiments.

The Americans then said: "If it went so well, let's do something else". In this situation, we proposed a new seismic experiment, located in the area of Central and Eastern Europe – from western Russia through Belarus, eastern and southern Poland, Slovakia, the Czech Republic, Hungary, Austria, Slovenia, and south-eastern Germany. It was the "CELEBRATION 2000" seismic experiment, carried out in June 2000 over an area of about 500 000 km^2. For this experiment, we managed to gather a record number of instruments: 1 230 state-of-the-art seismic stations from many countries. At that time, we already had 50 of our own Reftek 125 Texan stations manufactured by Refraction Technology Inc., but the vast majority of the stations used in this experiment were provided to us by the American side – so much so that the last batch of stations manufactured by Refraction Technology Inc. was sent directly to Kraków a week before the experiment began. The stations were also loaned to us by the Canadian institutions. Near Kraków, at the base of the Geofizyka Kraków S.A. company, we organized the main center for managing the entire operation, in which a total of about 1 100 geophysicists, engineers, and technical personnel took part. The shipment of pieces of apparatus for the next stages of the experiment across national borders had to be arranged in advance with the relevant customs services. I am pleased to say that we met with full understanding of these services. The

[4] Later at the University of Oklahoma, Norman, OK.

recorders were buried in the ground along the designated seismic profiles. We recovered all of the stations. Nothing was lost, which doesn't even happen in the US.

The whole operation was amazing: it lasted 28 days and 28 nights. It was necessary to hurry because each day generated significant costs. We managed the entire operation together with my closest associate, Professor Marek Grad from the University of Warsaw. Without mobile telephony, the Internet, and GPS, it would not be possible to carry out an experiment of this type in such a short time. The experiment required tremendous discipline in coordinating activities over an area of about 500 000 km^2, accurate locations of the positions of recording stations, and, above all, time discipline with time recording with an accuracy of 10^{-3} s.

Geophysicists from 15 European countries, as well as the United States and Canada, participated in the "CELEBRATION 2000" experiment. A significant benefit to this research endeavor was the opportunity to collaborate with Russian colleagues. Thanks to this cooperation, the Russian side organized a large shot point at the northern end of the longest seismic profile, about 400 km west of Moscow, generating seismic vibrations recorded at the southern end of this profile at a distance of about 1 400 km, making it possible to reach into the Earth's interior to a depth of about 120 km.

In the report of the European Science Foundation for the European Commission in Brussels, entitled "EUROPROBE" 1992–2000, the "CELEBRATION 2000" experiment was described as "the largest seismic refraction experiment ever carried in Europe, involving geoscientists from twelve European countries, Canada, and the USA". In December 2000, Professor Marek Grad and I participated in the Congress of the American Geophysical Union at the Convention Center in San Francisco. At a meeting of the IRIS (Incorporated Research Institutions for Seismology) organization, it was said that "in 2000, IRIS performed several seismic experiments, but none was as good as the CELEBRATION experiment in Central Europe, performed with Polish precision". I then looked questioningly at Mark Grad to see if this was some kind of joke, but it was said with complete seriousness. We were honored in the magazine "EOS" of the American Geophysical Union (with a circulation of 60 000 copies), which publishes a "feature article" in each issue about the currently most important achievement in the field of Earth sciences. The article about the "CELEBRATION 2000" experiment was titled by the editors: Seismologists Celebrate The New Millennium with an Experiment in Central Europe[5]. Meanwhile, The Oxford Guide to Modern Science recognized this experiment as "one of those that bring science into the 21st century".

Later, Austrian geophysicists asked us to extend this experiment (at their expense) to the area of the Eastern Alps. This was the third experiment, called "ALP 2002", and the fourth was "SUDETES 2003" – a smaller one – in the area of southwestern Poland, the Czech Republic, and southeastern Germany – all with the participation of the American side. The seismic profiles determined from these four experiments, with a total length of approximately 20 000 km, cross the broadly understood geotectonic node of the European continent – from the East European Craton, through the Trans-European Suture Zone in Poland, the Bohemian Massif, the Carpathians, the Sudetes and the Eastern Alps, the Basin Pannonia, the Dinaric Alps, to the Adriatic Sea.

AMK – *Could you kindly summarize the most important thing geophysics has learned from these experiments? What is the striking result, and what does it suggest for future research?*

[5] Guterch, A., M. Grad, and G.R. Keller (2002), Seismologists Celebrate The New Millennium with an Experiment in Central Europe, *EOS Trans. Am. Geophys. Union* **82**, 45, 529 & 534–535.

AG – Based on the aforementioned experiments, about 70 publications have already been issued, multi-authored of course, with more than 50 in leading international journals and monographs of the highest rank. The obtained results were presented as invited papers and special sessions at numerous symposia and prestigious scientific congresses. Young people were earning their doctorates and habilitations. I think that even 20 years from now, the results of these experiments will constitute the basis for further scientific investigations, using methods of interpretation that are being constantly refined.

With the help of these experiments, the deep structure of the lithosphere and its physical properties were determined extremely precisely, up to a depth of 50–60 km, sometimes 120 km, over the entire study area, from the geologically old craton of Eastern Europe to the young structures of Central and Southern Europe. New, well-documented geodynamic models have been defined, e.g., for the Carpathians, showing how complex the geodynamic situation related to the development of the Carpathian Arc is. For the first time, we documented the possibility of subduction of the lithospheric plate from south to north in the Eastern Carpathians. This provided new data on the contact zones of lithospheric blocks occurring in this area and new models of lithospheric evolution. These are data suitable for detailed interpretations, including geological ones. We always invite leading geologists from home and abroad to provide geological interpretation of the obtained results of geophysical research. This was also the aim of the international program "EUROPROBE", which I have already mentioned.

TESZ

AMK – *So this is TESZ...*

AG – First, the concept of the Teisseyre–Tornquist line was formulated, which defined the edge of the Precambrian Platform, i.e., the old East European Craton approximately one billion (10^9) years old, and then this concept was extended to the Teisseyre–Tornquist zone. I presented the deep lithospheric background of this zone for the first time in my habilitation thesis in 1974. In the following years, as a result of further seismic work, we presented even more precisely the geometry and physical properties of this zone, with a width of several dozen (70–80) kilometers. Further progress in the recognition of the Teisseyre–Tornquist zone was made as a result of research carried out in 1992–2003, when the international "EUROPROBE" program was in action. Based on precisely defined physical parameters of the lithosphere – seismic wave velocities up to a depth of 60–120 km – we started to make a geodynamic reconstruction and study the history of the geological evolution of the entire area. During the period of operation of the "EUROPROBE" program, a new concept mentioned in your question has just appeared – the Trans-European Suture Zone (TESZ). This zone runs from Great Britain, through Denmark, the Netherlands, Belgium, northern Germany, central Poland, western Ukraine to the Black Sea. In so defined area, there are numerous lithospheric blocks, differing in physical properties and geological history, including the famed Świętokrzyskie Mountains. The boundaries of the Trans-European Suture Zone cannot be precisely defined. From the northwest, the Variscides with a young Earth's crust enter the TESZ area defined in this way, and from the south there are the Alpides – represented in Poland by the Carpathians – characterized by a completely different structure of the Earth's crust. We have already published several summaries of works carried out over the last dozen years in international journals and monographs, which have received a lot of attention at home and abroad, as evidenced by numerous citations and calls for conference lectures and publications.

The next stage in the development of deep seismic studies of the structure of the Earth's tectonosphere in the TESZ area in Poland is the (just completed) two-year international seismic experiment, the so-called passive experiment, known by the acronym "PASSEQ 2006–2008"

("Passive Seismic Experiment in TESZ"). The leader of this project is Dr. Monika Wilde-Piórko from the University of Warsaw, formerly a doctoral student of Professor Marek Grad. In the years 2006–2008, approximately 200 portable seismic stations were installed in the broadly understood TESZ zone (Poland, Lithuania, Czech Republic, and Germany), to record earthquakes, even from remote areas of the Earth. The collected, extremely rich set of seismic data is the basis for interpretation of the entire upper mantle of the Earth, reaching a depth of about 700 km.

We have currently completed the work of summarizing the entire geophysical knowledge about the deep structures of the Earth's crust in the area of the so-called Southern Permian Basin of Europe, reaching from Great Britain through Belgium, Denmark, the Netherlands, northern Germany to central Poland, that is, practically speaking, in the TESZ area. This study will be included as Chapter 2 (of 16) in a large work (also in size) entitled "Southern Permian Basin Atlas". This project is sponsored by the petroleum industries of the aforementioned countries, and the entire work is addressed to the new generation of petroleum geologists.

AMK – *You mentioned the Świętokrzyskie Mountains. This is the cradle, the core of Polish geology...*

AG – Almost every Polish geologist dealt with the Świętokrzyskie Mountains. There are many papers in the geological literature related to this region, papers that sometimes present quite different views. This is a very complicated problem from the point of view of geology. I think that in the near future, there will be an opportunity to resolve the controversial issues based on deep geophysical research.

ABOUT WORK IN THE POLAR REGIONS OF THE EARTH

a) Svalbard Archipelago

AMK – *Let's return to the polar regions, first to the research with your participation in the Svalbard Archipelago in the Arctic.*

AG – As I have already mentioned, after establishing close contacts with the Norwegians in the 1970s, we managed to carry out, together with them, seismic studies of deep structures of the Earth's crust in the area of the Svalbard Archipelago. We organized three expeditions together, the last of which was in cooperation with the Germans and Americans, in the framework of the Maria Curie-Skłodowska Fund.

During the "Cold War", a Warsaw Pact Navy ship, ORP "Kopernik" – then listed in the annals of NATO as a spy ship – with seismic instrumentation on board, was allowed to conduct research there. Only many years later, Professor M.A. Sellevoll from the University of Bergen told me that after numerous meetings he made a solemn declaration to his authorities that he guaranteed that the ship was not engaged in espionage activities. Thanks to this, I was able to organize three expeditions to the Arctic with the help of the hydrographic ship ORP "Kopernik". For the first time, we have determined what the structure of the Earth's crust of the Svalbard Archipelago looks like: its crustal thickness, velocity distributions, seismic boundaries, or, generally speaking, the geophysical parameters of this archipelago, which occupies a key position in the North Atlantic, as it is directly adjacent to one of the Earth's main structures, i.e., the North Atlantic Ridge. I co-organized subsequent expeditions in cooperation with geophysicists from Germany, Norway, and Japan: the fourth in 1999, the fifth in 2005, and the last in 2007–2008.

The last large and significant seismic experiment in the Svalbard Archipelago was carried out in close cooperation with The Alfred Wegener Institute for Polar and Marine Research in

Bremerhaven, with the University of Potsdam, with two Norwegian universities: in Oslo and Bergen, and with the Norwegian geophysical organization NORSAR. The experiment ran from September 2007 to August 2008 and was our significant contribution to the program of the Fourth International Polar Year (IPY) 2007–2009 – a research project of global significance and scope, in which more than 60 countries participated. Our experiment belonged to one of the most important projects of the 4th IPY, called "Plate Tectonics and Polar Gates in Earth History", or, shortly, "Polar Plates and Gates". The participation of the Polish team in this experiment was financed from extra-budgetary funds – from the Norwegian Science Fund and from funds granted to us by the Polish Oil and Gas Company (Polskie Górnictwo i Gazownictwo S.A.).

I would add that it was a continuation of our previous activities – those started already in the 1970s. The research undertaken in the "Polar Plates and Gates" project falls within the framework of the Polish Arctic and Antarctic Research Program 2002–2010, developed in 2002 by the Committee on Polar Research of the Polish Academy of Sciences.[6]

AMK – *I understand that the "Polar Plates and Gates" 4th IPY program was about both tectonic evolution and biological adaptation...*

AG – First, a correction: the "Polar Plates and Gates" 4th IPY project was exclusively about comprehensive geodynamic research.

The Svalbard Archipelago region is a particularly interesting region in which the structure of the entire tectonosphere needs to be studied down to a depth of several hundred kilometers in order to reconstruct the dynamics of Earth's development in this key region. It is also important for reconstructing the Earth's evolution on a global scale. We operated in the North Atlantic Ridge region, which stretches from the southern hemisphere across the entire Atlantic. In the Svalbard region, two plates, the Eurasian and the North American, diverge intensively; the American continent systematically drifts away from the European continent. We made seismic profiles in the zone of close contact between these plates, where there is virtually no Earth's crust – the Earth's upper mantle is almost at the surface: there is only a thin, approximately 3-kilometer-long crustal cover with poorly consolidated sediments. This means that tectonophysical processes related to the evolution of the Earth's upper mantle are still active there. These are exactly the "plates and gates" of the Arctic.

In September 2007, with the help of the Polish ship Horyzont II, we set up 12 broadband seismic stations of German make. And so the so-called passive seismic experiment began. The idea was to record, for as long a period of time as possible – until August 2008 – all deep tectonophysical processes that generate seismic shocks in this area. On the other hand, during the following summer season (2008), a Norwegian geophysical ship performed seismic reflection studies – a technique used in the oil industry. Let me explain here that reflection profiles are used to very precisely determine the structure of the Earth's crust in the first 10–20 km of its depth. We, on the other hand, with the help of a Polish ship, performed seismic refraction studies, which lead to the precise determination of seismic wave velocities and the boundaries in the Earth's crust to a depth of 50–60 km. On the other hand, a passive seismic experiment, based on recordings of seismic tremors that are constantly taking place here, is used to identify the structure of the Earth's upper mantle to a depth of several hundred kilometers.

[6] Guterch, A. (ed.) (2002), *Arctic and Antarctic Research Program of Poland 2002-2010*, Committee on Polar Research, Polish Academy of Science, Warsaw.

We also received from the Norwegians a broadband seismic station, which we set up for a permanent work at the Polish Polar Station in Hornsund in south Spitsbergen. We organized the first work meeting of the entire German Norwegian Polish team, devoted to the interpretation of the collected experimental seismic data, in May 2009 in Zakopane. The first results of seismic modeling are extremely interesting. Interpretive works will last until 2010–2011. The first publications will appear in 2010.

AMK – *I return to my previous question. The program of the 4th International Polar Year also included biological adaptation and even evolution. How can the problems of geophysical or geological evolution and the biological evolution of the Earth be combined qualitatively and in the time scale?*

AG – In the years 1982–1991 I was the coordinator of the entire Polish polar research program, including biological and environmental research. To answer your question, I can only say that everything is treated as one big natural complex. The question you asked is the most difficult one and I am unable to answer it. Geophysics is connected with changes in the environment and ecosystems, even the ones that are very distant in time, as well as with climate change and oceanology. Everything is interconnected, including the evolution of the Earth. Nowhere is this more evident than precisely in the polar regions.

AMK – *Do you have your opinion on climate change, global warming?*

AG – Yes, I have – but for my own use, because I am not a climatologist. I veer towards the opinion of physicists dealing with the physical bases of climatology, who look at climate change not comparatively, but as a great physical process, with full knowledge of what it was like in the Earth's past. This is a cycle that develops and the impact of civilization is limited.

b) Antarctica

AMK – *You also conducted research in Antarctica, on the other, southern side of the Earth…*

AG – I organized the first expedition to West Antarctica in the 1979/1980 season. Later on, there were several geodynamic expeditions, which I already organized with the participation of geologists. Professor Krzysztof Birkenmajer always participated in these expeditions, expressing his appreciation for their achievements. So far, there have been five such expeditions. The fifth, in January 2007, was solely composed of young people who continued seismic research of the Earth's crust in West Antarctica using a Russian ship.

During the next four expeditions, in the years 1979–1991, we carried out an extensive program of seismic studies of deep structures of the Earth's crust in West Antarctica, in a zone that is extremely interesting from a geodynamic point of view, because in the broadly understood contact zone of the Antarctic Plate and the plate of South Pacific. We performed deep seismic refraction studies, using explosives, along profiles with a total length of about 4 000 km, in an area extending over approximately 1 200 km. We also examined the subduction zone of the plate of the South Pacific under the plate of the West Antarctica. I assumed that – instead of sailing by ship and performing seismic profiling in various areas – it would be better to thoroughly study the region of key importance for geodynamics. Thanks to this, there is no other area of Antarctica as thoroughly seismically studied as the area in which we operated.

Then a series of monographs summarizing geodynamic research at the scale of the entire Antarctic was published. These monographs contain chapters with the results of our research. Our works done in the Bransfield Strait, between the Antarctic Peninsula and the South Shetland Arc, deserve particular attention. The results of our works in this extremely important region have challenged the hitherto prevailing views about a thin crust, with a thickness of 10–

12 km, beneath the so-called Bransfield rift structure. We have proven that in this area the Moho boundary – the lower boundary of the Earth's crust with normal physical parameters – occurs much deeper, at a depth of 30–35 km. We have also proven that the crust of West Antarctica is not an anomalously thin crust with thicknesses of 20–25 km, but is a normal crust with thicknesses of 30–40 km. In general, these results are of great importance for the geodynamic reconstruction of the South Pacific.

[…]

ON THE DYNAMICS OF THE EARTH'S INTERIOR

AMK – *Research with your participation shows – as you have already mentioned – that in the area west of the Svalbard Archipelago, the Earth's crust is very thin.*

AG – Yes. During the fourth Norwegian–Polish–German expedition in 1999, we actively entered the ocean floor with very modern equipment, using ocean-bottom seismometers (of Japanese production). As I mentioned before, we made a seismic profile in the northern part of Svalbard, passing through the North Atlantic Ridge, which is one of the most important structures of the Earth, running from the North Pole across the entire Atlantic, along which extremely active processes are still taking place. We have shown that the Earth's upper mantle – what is located at a depth of 40–50 km in Poland – is practically under the ocean floor there, at a depth of about 3 km.

[…]

AMK – *How does geophysical research of the last 30–40 years relate to the studies of tectonic profiles, especially to the maps from geological and tectonic atlases, developed primarily from drillings?*

AG – These are very important facts, without which it is impossible to reconstruct the geological history of the studied area. Geophysics, on the other hand, portrays the modern structure of the Earth. Seismic methods are not perfect yet – I think they are somewhere in the middle of development, just as, for example, elementary particle physics is developing. We have to touch the Earth's structure not directly but through a seismic wave, analyzing and studying the seismic wave field. Our country is located in a special place, where the three great geological systems that make up the European continent intersect.

AMK – *Well, yes, the worst place in every respect! This only reinforces my question, why is the Earth's crust stable here? Maybe some effects cancel each other?*

AG – First of all, let me explain why there are tremors here. Just in 2004, there was a series of quite strong tremors in the Kaliningrad area (5.3 on the Richter scale), felt in the Suwałki region and even in Pomerania. On 16 December 2008, there were tremors in southern Sweden[7]. These are the repercussions of past great processes that took place in the European "object" that is now called the Precambrian Platform of Eastern Europe or the East European Craton. From the south, a young Alpine system enters Poland, represented by the Carpathians, with a completely different structure of the Earth's crust.

AMK – *Can we expect to experience stronger tremors in the future?*

AG – No. These are the death knells of tectonic effects, animated by physical processes. Weak seismic tremors have occurred in the recent past and are also occurring today. These are very

[7] On 16 October 2008, a weak (2.46 on the Richter scale) earthquake occurred near Umeå, in northeastern Sweden; on 23 October 1904, an earthquake with an epicenter near the two Koster islands in Bohuslän, on the west coast of Sweden, was measured at 6.0 on the Richter scale.

important signals, important not only for natural research, but also extremely important for the country's civilization development.

South of this craton there is a large sedimentary basin, reaching – as we have proven in our work – to a depth of up to 20 km. All this rests on a crystalline foundation. However, the fundamental question is: what happened to the material, the sedimentary overburden, that was removed from this craton? How should we recreate the gigantic processes that took place in Earth's history on the old craton 1–1.5 billion years ago?

AMK – *Here, you raised the problem of what happened to the material that was on the East European Craton.*

AG – Yes, this is an extremely important question, it is difficult to answer it for now, but it will be possible to do so, already in the nearest future. Recently, under the supervision of Professor Marek Grad, a large map of the depth of the Moho boundary, that is, the thickness of the Earth's crust, was developed for the entire European lithospheric plate, not just the continent. No such map has been developed before. The work took three years, with a team of over 70 people from Europe and the USA, including our entire group. It was necessary to collect and critically evaluate hundreds of previously published works, sometimes even reinterpreting them, of course in consultation with the authors. I would also like to add that the European lithospheric plate extends from the North Atlantic Ridge in the west to the Urals in the east and from the North Pole in the north to the Mediterranean Sea in the south. In this area, the depth of the Moho boundary, that is, the thickness of the Earth's crust – the outer shell of the Earth in which the history of our planet's evolution is "written" – ranges from about 10 km under the bottom of the Atlantic to 60–65 km under the old East European Craton. The great work was done and published at the end of 2008 under the title The Moho depth map of the European plate[8].

[…]

ABOUT OIL AND ITS EXPLORATION

AMK – *A discussion with a prominent geophysicist cannot leave out one more thing. Oil is still being searched for in Poland, deeper and deeper. I suspect there will be new seismic experiments in 2009 or 2010...*

AG – Hmm... these two voluminous files are just a new project. For the years 2009–2011, we are planning a special seismic experiment – super-deep seismic reflection and tomographic soundings in the area of Southern Podlasie, the Lublin region, and the Polish Eastern Carpathians. The experiment will be very costly, financed exclusively from extra-budgetary funds, i.e., by the National Fund for Environmental Protection and Water Management – at the request of the Minister of the Environment – and by Polish Oil and Gas Company (PGNiG, Polskie Górnictwo Naftowe i Gazownictwo S.A.). To finalize this project, a special scientific and industrial consortium has been established, consisting of: the Institute of Geophysics PAS (consortium leader), PGNiG S.A., and Geofizyka Toruń S.A.. The consortium has already won the international tender for the implementation of this project. The planned experiment will be of great importance not only for the oil industry but also for geodynamic research. This is an exceptionally fortunate example of combining application and research goals. This will be an outstandingly innovative experiment in the full sense of the word. The primary goal of the planned experiment is to solve the fundamental geological problems of the study area and to select an appropriate region for a deep exploratory well. It is expected that the research of this type will be of great importance for new future oil and gas exploration projects at great depths.

[8] Grad, M., T. Tiira, and ESC Working Group (2009), The Moho depth map of the European Plate, *Geophys. J. Int*. **176**, 1, 279–292, DOI: 10.1111/j.1365-246X.2008.03919.x.

ABOUT THE MAGNUM OPUS

AMK – *You have written a number of monographic treatises; you say that a new one will be released soon – that Chapter 2 in the "Southern Permian Basin Atlas". Which of your monographic publications do you consider the most important?*

AG – Under the chief editorship of Professor Gerald Schubert from the University of California, Los Angeles, the Elsevier publishing company issued the 11-volume monograph *Treatise on Geophysics*, which summarized all the most important achievements in geophysics since its beginnings dating back to the late 19th century. We were offered a special chapter in one of the volumes. In it, we included a brief summary of all our experiments, authored by me, Marek Grad, and G. Randy Keller[9]. It was due to Professor Keller that we had free access to American resources of modern seismic stations.

After a special symposium organized in the USA, another American monograph was published: *The Four-Dimensional Earth*. The motto of this symposium and this monograph is "Geological-Geophysical Earth". These disciplines are not separate. There is one Earth. Unfortunately, a division between them is still functioning – which makes no sense, because the Earth is one.

One of the most eminent American geologists, Professor Robert D. Hatcher, said at the beginning of this symposium: "If a geological event occurred 300 or 500 million years ago near Washington, it does not at all mean that it is an event associated only with this area. It was the result of a planetwide process, but we don't yet know what kind of process it was, and in what area and what the interrelationships are". In this monograph, we also have one chapter.

At the most recent The 33rd International Geological Congress Oslo 2008 in August 2008, I was asked to organize a symposium entitled "Reconstruction of the transition zone from the craton of Northern Europe to the Alpine system of Southern Europe". The motto of this symposium was "After all, one geology". There is no geology or geophysics of separate regions or countries, although this scheme still exists. Even the geology of a small area must have its planetary reference. I think our work is a contribution to understanding what the current state looks like, but transposed to the scale of the entire globe.

AMK – *So much happened on this planet... Have you created your own school? You often mention the name of Professor Marek Grad here.*

AG – This is a modest team. Including our colleagues from the University of Warsaw, there are ten of us. What we did was and is in broad international cooperation. There is no division between "those" from the PAS and "those" from the University of Warsaw. Professor Marek Grad started with me as a student on an internship. Later on, he stayed at the University of Warsaw and we have been working closely together ever since. I think it is a very fruitful collaboration.

ABOUT INTERESTS AND COLLECTING

[…]

AMK – *I have heard about your collections of old maps and weapons…*

[9] Guterch, A., M. Grad, and G.R. Keller (2007), Crust and lithospheric structure – long range controlled source seismic experiments in Europe. **In:** G. Schubert (ed.), *Treatise on Geophysics*, B. Romanowicz and A. Dziewoński (eds.), *Seismology and the Structure of the Earth*, Vol. 1, Elsevier, 533–558, DOI: 10.1016/B978-044452748-6.00016-X.

AG – I have a modest collection of maps of Poland and the Grand Duchy of Lithuania. As to military items, it is not a collection but a modest assemblage of some Polish army artefacts from the 18th century to the interwar period. In the early 1970s, I became interested in the weapons and uniforms of Polish soldiers. I then joined the Association of the Lovers of Old Arms and Uniforms. The Association was founded in 1933 as the Association of Friends of the Polish Army Museum in Warsaw. After World War II, there was no possibility to reactivate it, but already in 1957, at the National Museum in Kraków – due to efforts of prominent art historians – it became possible to establish the Society of the Lovers of Old Arms and Uniforms, which in 1960 was transformed into the nationwide Association of the Lovers of Old Arms and Uniforms. Currently, the Association operates in nine cities in Poland and has about 300 members. It included a number of prominent figures associated with World War II and the resistance movement. For many years, the President of the Association was Professor Zdzisław Żygulski Jr., an outstanding art historian from Kraków. For twelve years I had been the president of the Warsaw Branch of the Association. Since 2000, I have had the honor of being elected nationwide president of the Association of the Lovers of Old Arms and Uniforms at the National Museum in Kraków. Since 1972, the Association has been included among the scientific associations affiliated with the Polish Academy of Sciences. The scientific achievements of the Association include hundreds of publications and monographic treatises on the weapons and uniforms of Polish soldiers over the centuries. In 2007, we celebrated the 75th anniversary of the Association – on this occasion, we organized a ceremonial scientific session in Warsaw at the National Museum and the Polish Army Museum. The talks presented at the session were published in the "Commemorative Book". We also celebrated the anniversary by minting a commemorative medal. The Association is funded solely by its membership fees.

To give an example of curiosities of my assemblage – in the 1970s, in an antique shop in Kyiv, I purchased an old Swiss key-wound pocket watch, running perfectly, with a silver chain and a silver coin attached to it – "5 Polish zlotys", and on the reverse of the coin the inscription "Kingdom of Poland" and the coat of arms with the Eagle and the Pogoń and the date "1831"; on the edge of the coin there is the inscription "God Save Poland". What was the journey of this item since the November Uprising? Moving....

ABOUT THE POLISH ACADEMY OF ARTS AND SCIENCES (POLSKA AKADEMIA UMIEJĘTNOŚCI, PAU)

AMK – *How do you perceive the Polish Academy of Arts and Sciences?*

AG – Polish Academy of Arts and Sciences is a unique institution for me. Being elected a PAU corresponding member was one of the most important events in my life. I very much regret that, living in Warsaw, I cannot systematically participate in the extremely interesting lectures organized by the PAU in Kraków. Various actions undertaken by the PAU Executive Board deserve special recognition, such as revising and reviewing school textbooks. I think that PAU could very effectively and objectively influence the shaping of the country's scientific policy if the relevant ministerial authorities were willing to accept such activity. Born in the former Galicia, I also feel a strong emotional bond with the Polish Academy of Arts and Sciences.

Talks in Warsaw on 18 December 2008 and 8 April 2009; text authorized on 30 September 2009.

Aleksander Guterch, Ph.D. in physical sciences; Ph.D. in the field of Earth physics; Prof. at the Institute of Geophysics PAS; head of the Department of Seismic Lithospheric Research at this Institute; president of the Association for Deep Geological Research; ordinary member of the PAS; ordinary member of the Warsaw Scientific Society; member of the Academia Europaea, London; long-time chair-

man and vice-chairman of the Committee on Polar Research of the PAS; chairman of the National Committee on Polar Treaties of the PAS ("Arctic Council" and "Antarctic Treaty"); chairman of the National Committee on the 4th International Polar Year 2007–2009; member and vice-chairman (2006–2009) of the European Polar Board at the European Science Foundation (ESF), Strasbourg; member of the EUROPROBE Scientific Steering Committee (1992–2001) at the European Science Foundation (ESF), Strasbourg; member of the American Geophysical Union; honorary member of the Association of Hungarian Geophysicists; president of the Association of the Lovers of Old Arms and Uniforms at the National Museum in Kraków. Elected to the PAU as a corresponding member on 19 June 1999.

Translated by Bartosz Woźniak

Received 13 May 2024
Accepted 5 July 2024