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Department of Geophysics

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INTRODUCTION

From the historical point of view the Department of Geophysics, initially the Professor Walery Edward Janczewski's Department of Applied Geophysics, then the Geological Geophysics Chair, was at the very beginning (1946) the most important unit at the Geological and Surveying Faculty, next Faculty of Geological Prospection, at the Academy of Mining and Metallurgy. The unique group of geophysicists presented various geophysical methods for solving applied geology tasks, always pointing out physical basis of each measurement. The historical development and scientific profile of the Department of Geophysics was very similar to its contemporary structure. Geophysical staff at the Academy of Mining and Metallurgy always tried to apply relatively quick and cheap geophysical methods in prospection for oil and gas, water, and other mineral raw materials, i.e. black coal, lignite, sulphur, salts, copper and iron ores. Significant development of heavy industry in Poland after the Second World War and great endeavour undertaken by the Academy of Mining and Metallurgy in development of the country mobilized geophysical team to use all available geophysical methods. Close cooperation with the first geophysical enterprise in Kraków (now Geofizyka Kraków SA) gave an additional motivation and chance to combine industry measurements and scientific interpretation of geophysical results.

Methods which were used and developed in that historical time at the Department of Geophysics, as well scientific activity were the continuation of the long geophysical tradition initiated in Kraków with the first Geophysical Chair of Maurycy Pius Rudzki founded at the Jagiellonian University in 1895 and researches in seismology, geology and glaciology conducted by Walery Edward Janczewski in the first half of the 20th century. Research groups of the Department of Geophysics have started their activity at the very beginning in the following areas: gravity (prof. Zbigniew Fajklewicz), magnetics (prof. Stanisław Małoszewski), geoelectrics (prof. Henryk Orkisz) and seismics (prof. Jerzy Kowalczuk) applied to prospecting and mining of mineral deposits. Since that time the Department of Geophysics at the Faculty of Geological Prospecting has been the important Polish geophysical institution. The Institute of Geophysics of the Polish Academy of Science founded in 1953 closely cooperated with our Department. Here, at the Academy of Mining and Metallurgy, at the Faculty of Geological Prospection in 1955 the famous Polish geophysicist-seismologist, prof. Adam M. Dziewoński presented his Ph.D. thesis on the synthetic seismograms used in seismic prospection in 1965.

At present, the staff of the Department of Geophysics includes 23 researchers and academic teachers, 4 technical workers, and 9 PhD students (Fig. 1). Retired professors still cooperate with the Department taking part in scientific projects.

RESEARCH AREAS/ RESEARCH GROUPS

Research groups at the Department of Geophysics are engaged in solving basic, research-scientific and applied geophysical problems. Generally, the area of interest covers problems of applied geophysics in prospecting, mining, engineering, and environmental applications. The Department of Geophysics carries out projects that are directed towards the prospection of new mineral raw materials with specialized methodology and the improvement of known methods in detailed recognition of geological conditions and determination of petrophysical parameters of exploited deposits.

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Fig. 1. *Staff members of the Department of Geophysics in 2016*

Nowadays, special attention is paid to application of geophysical methods in recognition and monitoring of changes in natural environment caused by anthropogenic activity. In the 1980s, prof. Stanisław Małoszewski, as the Head of the Inter-Departmental Institute of Geophysics at the Faculty of Geological Prospecting, established and developed the mining geophysics, a new branch intended to solve selected mining problems with the use of geophysical methods. Mining geophysics was also oriented towards the geohazard, which appeared to be very important discipline because of increased intensity of raw materials exploitation, especially in the Upper Silesia region.

Now, several research groups work within the Department of Geophysics, which are presented below. The geoelectrical team is working on engineering, environmental and archaeological problems with the use of Electrical Resistivity Tomography, Vertical Electrical Sounding and Penetrometer-Based Resistivity Profiling methods. The measurements are conducted in many areas of Poland. Examples of engineering applications regarding surface damages caused by mining exploitation come from Czernichów near Kraków (ISMOP project), Jaworzno, and Ruda Śląska (Upper Silesia). Environmental applications include some examples, such as: the influence of an industrial waste heap on subsurface zone condition in Kraków, Nowa Huta district, a dump heap impact on electrical properties of a subsurface zone in Czernichów near Kraków, detection of leachates from copper mining tailing pond Żelazny Mostr. Examples of archaeological problems cover a wide range of applications: archaeological remnants identification – in the Czorsztyn castle, detection of medieval graves in Modlnica near Kraków, recognition of near surface sediments nearby the Wawel Hill in Kraków and many other field case studies. Scientific work of that team comprises also numerical and analogue modelling. The Department of Geophysics poses a unique laboratory set-up consisting of a water tank and electrical measurement circuits allowing generate the field study on a laboratory scale.

The seismic team utilizes seismic data in order to recognize broadly defined geological structures in order to improve exploration of conventional and unconventional hydrocarbon reservoirs, to recognize geological structures of exploited deposits such as copper, native sulphur, rock salt as

well as to identify the shallow geological structures and their geotechnical parameters. Hence, the team uses a wide range of processing, interpretation and theoretical wave-field modelling. In terms of geological interpretation, the structural, stratigraphic, sedimentation and litho-facies analyses are carried out. The seismic reservoir characterization includes complex seismic trace attributes calculation, determination of velocity field and extraction of geo-mechanic parameters. The seismic team also works on acquisition, processing and interpretation of seismic data in order to recognize the shallow geological structures, to determine the geotechnical parameters and to monitor the shallow deposits (e.g. native sulphur) during exploitation.

The petrophysics and well-logging group undertakes the projects directed to combine the data from different scale measurements. On the basis of elastic properties of sandy-shaly Miocene formations in the Carpathian Foredeep and carbonate formations of the Main Dolomite in the Fore-Sudetic Monocline the methodology was proposed of joint interpretation of laboratory elastic waves velocity measurements, full waveforms acoustic logging and seismic attributes to upscale the detailed data to 3D seismic scale. The results of sophisticated, new technologies as X-ray micro- and nano-tomography were also included. Other tasks are focused on the effective use of modern technologies, i.e. geochemical logging, NMR logging and dipole source acoustic logging in order to improve the rock models of conventional hydrocarbon and water deposits as well as unconventional shale gas and tight gas formations. Statistical approach to rock type classification and semiautomatic subdivision of continuous rock formation into units of different reservoir and elastic properties is an example of developing and improving the known technologies in new applications. Also, the Monte Carlo modelling techniques are developed by the team in petrophysical applications.

The gravity method has been used and developed since the Department of Geophysics was established. The microgravity investigations were also developed and improved by the gravity team. Recently, the gravity measurements were applied as a basic method in geodynamic investigations in the Western Carpathians. Gravity measurements were also used in recognition of geothermal conditions in the Gorzów Wielkopolski area. Gravity investigations enabled the improvement of geological structures in the Sudetic and Fore-Sudetic Blocks for hydrocarbon prospection. Gravity and microgravity methods were also successfully used in the studies on anthropogenic impact on rock formation due to raw materials exploitation. The methodology for application of gravity and microgravity methods in geohazard problems is still improved and developed. Good example of such application comes from the "Sztolnia Dziedziczna" in Zabrze (Upper Silesia).

The Ground Penetrating Radar (GPR) team in the Department of Geophysics is very active in the area of shallow subsurface measurements applied to environmental, engineering, and archaeological tasks. The team greatly contributes to the popularization of GPR in various applications by publishing the remarkable examples of survey conducted for identification of historical underground items in churches, castles and other buildings.

FACILITIES

In the period 2013–2015, the Department of Geophysics was equipped with the new facilities for laboratory and field geophysical measurement, in the frame of the apparatus grant entitled: "Modernization of the geophysical laboratory to improve abilities to determine physical properties of rocks *in situ* and in laboratory conditions". The equipment was financed by the special Ministry of Science Fund of Science and Polish Technology.

The laboratory set for testing the nuclear properties of rocks comprises scintillator with crystal LaBr3(Ce) (ORTEC Co.) and two-cell spectral alfa Alpha-Duo set with ULTRA-AS ENS-U450 detector, portable radiometer equipped with Ar + CO2 FH 40 G-10 counter with the outer device for pollution measurements – FHZ 742. MCNP-6 software dedicated to Monte Carlo modelling is the complementary purchase for studying nuclear properties. Petrophysical laboratory is equipped with apparatus for thermal parameters measurement – Lasercomp FOX50-190, laboratory dryer – SLW 53 STD, centrifuge – MPW-352/R/RH and scale – PS450 along with the specialist anti-vibrating table – ML 2014094. The next important

purchases are standards for NMR tests (Green Imaging Technologies, Inc.) corresponding to Maran Ultra 27 MHz spectrometer for credible determination of free and bound water in rock samples. The petrophysical laboratory is equipped with ULT-100 (Ultrasonic Velocity Measurement System, GCTS Testing Systems) for measurements of P- and S-waves velocities on rock samples. It enables also determination of dynamic rock elastic moduli under various pressure conditions. The next important set is the advanced system for core samples resistivity measurements ARS 200 (Core Laboratories Instruments). Laboratory is also equipped with Bartington Instruments MS2 apparatus for laboratory and field magnetic susceptibility measurements.

The most important field equipment bought recently is the seismic measurement 48 channels system GEODE 48 (Geometrics) and movable seismic vibration generator GSESS-500-Turbo accelerated by elastometers. The measurement system together with cables, geophones and vibration source is a self-reliant seismic facility that can be used under various field conditions. Other important facility is the field equipment for geoelectric and conductometric measurements consisting of SuperSting R8/IP/SP+112 for ERT, and CMD-Mini Explorer and CMD-Explorer GCM for shallow subsurface conductivity measurements. The field equipment includes also a set of modern magnetometers – Cesium Vapour Magnetic Gradiometer G-858GSX interacting with the GPS integrated with magnetometry base Proton Precession G-856 and non-magnetic construction for vertical and horizontal gradient measurements. Additionally, the field equipment is supplemented with digital tachimeter TOPCON OS-103.

Modern laboratory and field equipment is supported by special software enabling processing, visualization and interpretation of recorded data. Worth mentioning are two programs: MAG3D and GRAV3D for magnetic and gravity data inversion.

Apart from the newest accessories, the georadar team successfully uses two-channel GPR ProEx System (Mala Geoscience) with the set of various unshielded antennas (25, 50, 100, 200 and 400 MHz), shielded antennas (100, 250, 500, 800 MHz) and HF antennas (1.6 GHz). The gravity team uses AutoGRAW CG-5 (SCINTREX) gravimeter.

EDUCATION AND TEACHING OFFERS

The Department of Geophysics is the leading unit responsible for geophysics course and applied geophysics specializations. Studies are run at two levels: undergraduate (BSc) and graduate (MSc). The first level is ended with the professional title of engineer. Students gain basic knowledge on mathematics, physics and applied computer sciences. They have also several geological topics giving them the background of geological processes, stratigraphy, structural geology, mineralogy, petrography and geochemistry, and geology of mineral deposits.

The main courses of geophysical methods are focused on gravity and magnetics, geoelectrics (including resistivity methods, magnetotelluric methods, natural and induced polarization methods and georadar), seismics, and well logging. These courses prepare our students to plan and run simple engineering projects, to run basic field geophysical measurements, to understand rules of acquisition and processing of geophysical data. Students are also taught both the qualitative and quantitative interpretation of geophysical data using various methods.

During the second level studies leading to MSc title, more sophisticated application of mathematical methods in geophysics are presented together with modern physics and theory of geophysical fields. Also, advanced methods of data processing and interpretation of data in all geophysical methods are trained. Students are prepared to plan, launch, carry out and manage the geophysical projects and to solve advanced engineering, environmental and prospecting problems. Additionally, outstanding graduates can take part in the PhD studies in geophysical specialisation offered by the Faculty.

The students at each level of education can use the commercial professional software granted to the Faculty by leading world-wide operating companies: Schlumberger, Halliburton or ABEM. Statistica and MATLAB software, and other professional computer programs like CAD or GIS are also available for students to train applications in the Earth sciences and to develope their professional skills. Some courses are delivered in English

and also some lectures and classes are realized by e-learning.

The staff members of the Department of Geophysics teach topics named "Geophysical methods" or "Geophysics" not only for students of geophysics course, but also for students of other courses and specializations at the parent Faculty, including economic geology specialization realized in English.

The "Mining geophysics" topic is presented to students of the Mining and Geology course at the Faculty. Lectures and classes on geophysics are also realized for students of the Faculty of Mining and Geoengineering at the AGH University of Science and Technology.

The special educational offer is proposed to graduates of various courses and specializations in the Earth sciences as post-graduate studies of applied geophysics in prospecting, mining and environmental specializations. Those post-graduate studies have started in 2005 as the project financed by the European Union and are still continued. Up to now, more than 500 graduates successfully completed this form of studies offered by the Department of Geophysics.

The Department of Geophysics cooperates in teaching of applied geophysics with the Faculty of Earth Sciences at the Silesian University giving lectures and classes on well logging and seismics. Also, lectures and classes on well logging within the post-graduate study organized by the Gdańsk University were prepared and delivered by our staff members.

COOPERATION

Institutional cooperation between the Department of Geophysics and other educational and research institutions is based on personal relationships between the staff members. Below, there is a list of selected institutions: the Institute of Geophysics of the Polish Academy of Sciences (PAS) in Warsaw, the Institute of Geological Sciences of PAS in Warsaw, the Henryk Niewodniczański Institute of Nuclear Physics, PAS in Kraków, the Institute of Economics of Mineral and Energy PAS, the Wroclaw, Silesian, Gdańsk and Warsaw Universities, the Geofizyka Kraków SA and the Geofizyka Toruń SA enterprises, the POGC SA in Warsaw, the PBG sp. in Warsaw, the Polish Geological Institute in Warsaw, the Institute of Oil and Gas in Kraków, the Central Mining Institute (GIG) in Katowice, the Native Sulphur Mine "OSIEK" – Mines and the Sulphur Chemical Plants "Siarkopol" – member of the Azoty Group SA. Selected foreign institutions are as follows: the Vietnam Academy of Sciences and Technology, Hanoi, Vietnam, the Hanoi University of Mining and Geology, Hanoi, Vietnam, the Norwegian University of Science and Technology (NTNU), Trondheim, Norway, the University of Miskolc, Miskolc, Hungary, the Aristotle University of Thessaloniki, Thessaloniki, Greece, the Ecole Centrale de Lille, Lille, France, the Institute of Geology and Geophysics at the Ivano-Frankivsk National Technical University of Oil and Gas, Ivano-Frankivsk, Ukraine.