Министерство науки и высшего образования Российской Федерации

Федеральное государственное бюджетное образовательное учреждение высшего образования Санкт-Петербургский горный университет

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ИНОСТРАННЫЙ ЯЗЫК

ГЕОФИЗИЧЕСКИЕ МЕТОДЫ ПОИСКА И РАЗВЕДКИ МЕСТОРОЖДЕНИЙ

Методические указания к самостоятельной работе для студентов специальности 21.05.03

FOREIGN LANGUAGE

GEOPHYSICAL METHODS OF PROSPECTING AND EXPLORATION

САНКТ-ПЕТЕРБУРГ
2020

УДК 811.111 (550.3) (073)

ИНОСТРАННЫЙ ЯЗЫК. Геофизические методы поиска и разведки месторождений: Методические указания к самостоятельной работе / Санкт-Петербургский горный университет. Сост. *Ю.Е. Мурзо*. СПб, 2020. 38 с.

Предлагаемый материал направлен на совершенствование навыков и умений просмотрового и изучающего чтения профессионально-ориентированных текстов с последующим использованием полученной информации в речи, а также на развитие навыков самостоятельной работы с аутентичными текстами. Данные методические указания могут быть использованы как дополнительный материал на занятиях со студентами 2-го курса.

Предназначены для студентов специальности 21.05.03 «Технология геологической разведки» (специализация «Геофизические методы поиска и разведки месторождений») и согласованы с программой по иностранному языку для студентов неязыковых вузов.

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ВВЕДЕНИЕ

Данные методические указания предназначены для учебно-методического сопровождения курса английского языка для студентов специалитета неязыковых вузов, обучающихся по специальности 21.05.03 «Технология геологической разведки» по программе «Геофизические методы поиска и разведки месторождений».

Изучение материала преследует цель развития навыков и умений просмотрового и изучающего чтения текстов по специальности, а также их перевода на русский язык с последующим использованием полученной информации для речевой практики; овладение студентами иноязычной коммуникативно-речевой компетенцией, позволяющей будущему специалисту осуществлять профессиональную коммуникацию; формирование активного словарного запаса, который включает наиболее употребительные английские термины и слова общетехнического характера.

Методические указания состоят из тематических разделов, задания для чтения и перевода составлены на материале аутентичных текстов и сопровождаются упражнениями.

Text 1

EXPLORATION GEOLOGY

Task 1. Read the words and word combinations, translate and memorize them.

Exploration geology, to exploit, orebody, potential area, satellite imagery, density, to drill holes, core, to log, feasibility, to commence, diligence work, predictive targeting, shear zone, lineament.

Task 2. Put the words into three groups (nouns, adjectives, verbs).

Mineral, identify, geological, approximate, fund, data, available, resource, survey, previous, involve, magnetic, technique, correlate, development, approach, stratigraphic, portray, carboniferous, sedimentary, complimentary.

Task 3. Read and translate the text.

Exploration geology is the single most important and very first phase of mining. It begins by identifying what minerals are to be exploited, their geological setting, approximate size of orebody required and potential areas. Once these factors are considered, funds are required to finance the exploration project. Exploration begins by firstly gathering any possible data available on the resource, area, local geology from the geological survey, from satellite imagery as well as previous scientific work.

The next phase usually involves geotechnical prospecting which makes use of either seismic, electrical, magnetic, radioactive or density techniques. Once a suitable area has been found, holes are drilled and the core retrieved is logged and correlated against other logs to form a model of the orebody. Once sufficient holes have been drilled and the ore tested for qualities, feasibility studies and due diligence work can commence.

The development of exploration technology over a century is briefed along with the emerging challenges for the exploration. Exploration approach design and the myriad activities of exploration cycle are described. The adoption of right combination of techniques is warranted to conduct exploration in a cost-effective manner. The Quality Control/Quality Assurance validated exploration data are integrated to generate 3D models for better interpretation and predictive targeting.

Geological exploration for natural resources is expensive with high risk. However, it opens new challenges and opportunities. Governments and multinational companies are key players. The exploration concept looks for a package of unique stratigraphic age, promising favorable rocks, and type structure to host certain groups of minerals.

Mineral deposits portray a surface signature similar to mineral exposed to a surface, weathering effects, remnants of ancient mining, shear zone, and lineaments that can be identified during a field survey. These features guide exploration and may end with new discoveries.

A good quality, precise, surface geological map with various scales plays a significant role in producing an exploration program. Exploration continues at regional, district, belt, and deposit levels with prerequisite activities to achieve specific objectives. Stratigraphic correlation compares and establishes litho- formation to host economic minerals for future searches. Exploration exclusively for coal-lignite, coalbed methane, and oil and gas needs carboniferous and younger sedimentary formation and complementary structures having sufficient plants and algae to form fossil fuels.

Task 4. Give a short description of what geological exploration is, what it deals with and what operations it involves.

Task 5. Use the Internet resources to learn about exploration approaches in different countries.

Text 2
GEOPHYSICAL METHODS OF PROSPECTING

Task 1. Read the words and word combinations, translate and memorize them.

Crust, shaft, to utilize, to employ, alternating fields, emanation, boreholes, well-logging, isotope, facilities, explosive charge, feature, pipe-space cementing, to yield, objective, to distinguish, sea floor, to emit, readings, to transmit.

Task 2. Make adjectives from the nouns as in the example:

gravity – gravitational, biology – biological, science – scientific.

Geophysics, magnet, electricity, geology, mechanics, optics, electronics, radioactivity, seismicity, technique.

Task 3. Read and translate the text:

The study of the structure of the earth's crust by physical methods for the location and surveying of minerals (geophysical prospecting) is an integral part of geophysics.

Geophysical prospecting methods are based on the study of physical fields (gravitational, magnetic, electrical, thermal elastic vibration, radiation, and nuclear radiation). Measurements of the parameters of these fields are made on the surface of the earth (land and water), in the air, and underground (in wells and shafts). The information obtained is used to determine the location of geological structures, ore bodies, and so forth and their fundamental characteristics. This allows the selection of the most proper guidelines for expensive drilling and mining operations, thereby increasing their efficiency.

Geophysical prospecting methods utilize both natural and artificially created physical fields. The resolution, that is, the ability to distinguish specifically the sought-for features of the environment, is significantly higher, as a rule, for artificial field methods. The facilities for research by natural field methods are relatively inexpensive and transportable and yield uniform, readily comparable results for vast territories. In view of this, geophysical prospecting methods utilize natural fields (for example, in magnetic prospecting) primarily in the reconnaissance stage and artificial physical fields mainly for more detailed work, such as seismic surveying.

A series of geophysical prospecting methods is employed in most cases, because each physical field provides specific characteristics for only one aspect of the geological objective. (For example, magnetic prospecting yields data only on the magnetic properties of rock.)

The various geophysical prospecting methods are distinguished according to the nature of the physical fields utilized: gravitational, which is based on the study of the earth's field of gravity; magnetic, which studies the earth's natural magnetic field; electrical, which utilizes induced direct or alternating (current) electromagnetic fields and sometimes measurement of natural earth (telluric) fields; seismic, which studies elastic vibration fields created by the detonation of explosive charges (trotyl or powder) or mechanical shocks and emitted within the earth's core; and geothermal, which is based on temperature measurements in wells, and which utilizes the thermal conductivity differences in rock that account for changes near the earth's surface in the amount of heat coming from the interior of the earth. Nuclear geophysics, a new specialization in geophysical prospecting methods, investigates natural radioactive emanation, mostly gamma radiation, of rocks and ores and their interaction with elementary particles (neutrons, protons, electrons) and radiations whose sources are radioactive isotopes or special accelerators (neutron generators).

All geophysical prospecting methods are based on the use of physicomathematical principles for the development of theory; high-precision instruments with electronic, radio-engineering, precision-mechanical, and optical components for field measurements; and elements of computer technology, including modern electronic computers, for processing the results.

Research in boreholes is conducted by means of all of the geophysical methods. Geophysical measurements in boreholes are performed by instruments whose readings are transmitted by cable to the earth's surface. Electrical, acoustical, and nuclear-geophysical well-logging are the most important techniques. The drilling of deep wells is done with the necessary well-logging, which makes it possible to clearly define the limits of a rock (core) sample and to increase the sinking rate. Geophysical measurements in wells and mine shafts are also used to search for ore bodies in the spaces between them (so-called borehole geophysics). Finally, geophysical methods are used for studying the technical conditions of wells (identification of recesses and projections, control of pipe-space cementing quality, and so forth).

Geophysical prospecting methods are undergoing rapid development and successfully solving the problems of mineral prospecting, exploration, and surveying, particularly in regions covered with layers of soft sediments, at great depths, and under the floors of seas and oceans.

Task 4. Match the words to form collocations/phrases/phrasal verbs used in the text:

1) gamma	a) structure
2) ore	b) conductivity
3) thermal	c) field
4) elementary	d) shaft
5) geological	e) depth
6) mine	f) radiation
7) mechanical	g) particles
8) great	h) shock
9) magnetic	i) body

Task 5. Summarize the information about different geophysical prospecting methods, their characteristics and ways of application.

Text 3

SEISMIC METHOD OF GEOPHYSICAL EXPLORATION

Part I

Task 1. Read the words and word combinations, translate and memorize them. Use dictionaries if necessary.

Seismic refraction, merely, disturbance, to emanate, vibratory wave, ray path, spherical shell, compressional wave, propagating direction, transverse wave, shear strength, traction, isotropic media, to attenuate, boundary, displacement, transverse wave.

Task 2. Translate the adjectives:

Uniform, primary, acoustic, dominant, homogenous, dominant, perpendicular, elastic.

Task 3. Read and translate the text.

Seismic methods are the most commonly conducted geophysical surveys for engineering investigations. Seismic refraction provides engineers and geologists with the most basic of geologic data via simple procedures with common equipment.

Any mechanical vibration is initiated by a source and travels to the location where the vibration is noted. These vibrations are seismic waves. The vibration is merely a change in the stress state due to a disturbance. The vibration emanates in all directions that support displacement. The vibration readily passes from one medium to another and from solids to liquids or gasses and in reverse. A vacuum cannot support mechanical vibratory waves, while electromagnetic waves can be transmitted through a vacuum. The direction of travel is called the ray, ray vector, or ray path. Since a source produces motion in all directions the locus of first disturbances will form a spherical shell or wave front in a uniform material. There are two major classes of seismic waves: body waves, which pass through the volume of a material; and, surface waves, that exist only near a boundary.

Body waves. These are the fastest traveling of all seismic waves and are called compressional or pressure or primary wave (P-wave). The particle motion of P-waves is extension (dilation) and compression along the propagating direction. P-waves travel through all media that support seismic waves; air waves or noise in gases, including the atmosphere. Compressional waves in fluids, e.g., water and air, are commonly referred to as acoustic waves.

The second wave type is the secondary or transverse or shear wave (S□wave). S-waves travel slightly slower than P-waves in solids. S-waves have particle motion perpendicular to the propagating direction, like the obvious movement of a rope as a displacement speeds along its length. These transverse waves can only transit material that has shear strength. S-waves therefore do not exist in liquids and gasses, as these media have no shear strength.

S-waves may be produced by a traction source or by conversion of P-waves at boundaries. The dominant particle displacement is vertical for SV-waves traveling in a horizontal plane. Dominant particle displacements are horizontal for SH-waves traveling in the vertical plane. SH-waves are often generated for S-wave refraction evaluations of engineering sites.

Elastic body waves passing through homogeneous, isotropic media have well-defined equations of motion. Most geophysical texts include displacement potential and wave equations. Utilizing these equations, computations for the wave speed may be uniquely determined.

Surface waves. Two recognized vibrations, which exist only at "surfaces" or interfaces, are Love and Rayleigh waves. Traveling along a surface, these waves attenuate rapidly with distance from the surface. Surface waves travel slower than body waves. Love waves travel along the surfaces of layered media, and are most often faster than Rayleigh waves. Love waves have particle displacement similar to SH-waves. A point in the path of a Rayleigh wave moves back, down, forward, and up repetitively in an ellipse like ocean waves.

Surface waves are produced by surface impacts, explosions, and waveform changes at boundaries. Love and Rayleigh waves are also portions of the surface wave train in earthquakes. These surface waves may carry greater energy content than body waves. These wave types arrive last, following the body waves, but can produce larger displacements in surface structures. Therefore, surface waves may cause more damage from earthquake vibrations.

Task 4. Complete the sentences with phrases from the text.

1) A vacuum cannot support ______________________.
2) The direction of wave travel is called _____________.
3) The fastest travelling of all seismic waves are______________.
4) Compressional waves in fluid are referred to ______________.
5) S-waves do not exist in_________________________________.
6) Surface waves are produced by _________________________.
7) Surface waves can cause ______________________________.
8) The vibration is a change in _____________________________.

Task 5. Write down a brief description of the wave types given in the text.

Text 4

SEISMIC METHOD OF GEOPHYSICAL EXPLORATION

Part II

Task 1. Read the words and word combinations, translate and memorize them. Use dictionaries if necessary.

Source location, locus, propagation, striking, sophistication, elaborate equipment, emplacement, geophone, accelerometer, velocity transducer, voltage, magnitude, single-axis, triaxial, frequency band.

Task 2. Form adjectives from the following nouns.

Seismicity, digit production, environment, distraction, photograph, depth, frequency, wave.

Task 3. Read and translate the text.

Wave theory. A seismic disturbance moves away from a source location; the locus of points defining the expanding disturbance is termed the wavefront. Any point on a wavefront acts as a new source and causes displacements in surrounding positions. The vector normal to the wavefront is the ray path through that point, and is the direction of propagation. Upon striking a boundary between differing material properties, wave energy is transmitted, reflected, and converted. The properties of the two media and the angle at which the incident ray path strikes will determine the amount of energy reflected off the surface, refracted into the adjoining material, lost as heat, and changed to other wave types.

Digital electronics have continued to allow the production of better seismic equipment. Newer equipment is hardier, more productive, and able to store greater amounts of data. The choice of seismograph, sensors(geophones), storage medium, and source of the seismic wave depend on the survey being undertaken. The sophistication of the survey, in part, governs the choice of the equipment and the field crew size necessary to obtain the measurements. Costs rise as more elaborate equipment is used. However, there are efficiencies to be gained in proper choice of source, number of geophone emplacements for each line, crew size, channel capacity of the seismograph, and requirements of the field in terrain type and cultural noise.

Geophones. The sensor receiving seismic energy is the geophone (hydrophone in waterborne surveys) or phone. These sensors are either accelerometers or velocity transducers, and convert ground movement into a voltage. Typically, the amplification of the ground is many orders of magnitude, but accomplished on a relative basis. The absolute value of particle acceleration cannot be determined, unless the geophones are calibrated.

Most geophones have vertical, single-axis response to receive the incoming waveform from beneath the surface. Some geophones have horizontal-axis response for S-wave or surface wave assessments. Tri-axial phones, capable of measuring absolute response, are used in specialized surveys. Geophones are chosen for their frequency band response.

The line, spread, or string of phones may contain one to scores of sensors depending on the type of survey. The individual channel of recording normally will have a single phone. Multiple phones per channel may aid in reducing wind noise or air blast or in amplifying deep reflections.

Seismographs. The equipment that records input geophone voltages in a timed sequence is the seismograph. Current practice uses seismographs that store the channels' signals as digital data at discrete time. Earlier seismographs would record directly to paper or photographic film. Stacking, inputting, and processing the vast volumes of data and archiving the information for the client virtually require digital seismographs. The seismograph system may be an elaborate amalgam of equipment to trigger or sense the source, digitize geophone signals, store multichannel data, and provide some level of processing display. Sophisticated seismograph equipment is not normally required for engineering and environmental surveys. One major exception is the equipment for sub-bottom surveys or nondestructive testing of pavements.

Task 4. Complete the sentences with phrases from the text:

1) The wavefront is the locus ___________________________.
2) The direction of propagation is _______________________.
3) The guidelines are offered for________________________.
4) Optimizing communication depends on_______________.
5) Copyeditor's job is to ______________________________.
6) The choice of a seismograph depends on _______________.
7) Geophones are chosen for ___________________________.
8) The seismograph is the equipment ___________________.

Task 5. Write down a short description of principles and areas of use of geophones and seismographs.

Text 5

SEISMIC REFLECTION AND REFRACTION METHODS

Task 1. Read the words. Can you find the Russian equivalents without using any dictionaries?

Method, principle, seismology, energy, dynamite, geophysics, structure, technique, seismometer, analysis, refractor, topography.

Task 2. Read the words and word combinations, translate and memorize them. Use dictionaries if necessary.

Reflection, air gun, traverse, bedrock microtremor, simplicity, linear array, field data collection, dispersive, shot point, cross-over distance, overburden, receiver, rippability, landfill.

Task 3. Form nouns for the following verbs:

Example: to explore – exploration

To estimate, to require, to reflect, to estimate, to perform, to describe, to specialize, to combine, to measure, to radiate, to apply, to arrive, to consider, to depend, to determine, to produce.

Task 4. Read and translate the text.

We use seismic reflection as a method of geophysical exploration that uses the principles of seismology to estimate the properties of the Earth's subsurface from reflected seismic waves. The method requires a controlled seismic source of energy, such as dynamite, a specialized air gun or a seismic vibrator, commonly known by the trademark name Vibroseis. By noting the time it takes for a reflection to arrive at a receiver, it is possible to estimate the depth of the feature that generated the reflection.

What is Seismic Reflection? Seismic reflection is a geophysical principle governed by Snell's Law. Used in the fields of engineering geology, geotechnical engineering and exploration geophysics, seismic reflection traverses (seismic lines) are performed using a seismograph(s) and/or geophone(s), in an array and an energy source. The seismic reflection method utilizes the reflection of seismic waves on geologic layers and rock/soil units in order to characterize the subsurface geologic conditions and geologic structure.

The methods depend on the fact that seismic waves have differing velocities in different types of soil (or rock): in addition, the waves are reflected when they cross the boundary between different types (or conditions) of soil or rock. The methods enable the general soil types and the approximate depth to strata boundaries, or to bedrock, to be determined.

The reflection microtremor method combines the urban utility and ease of microtremor array techniques with the operational simplicity of the SASW technique, and the shallow accuracy of the MASW technique. By recording urban microtremor on a linear array of a large number of lightweight seismometers, the method achieves fast and easy field data collection without any need for the time-consuming heavy source required for SASW and MASW work. By retaining all the original seismograms and by applying a time-domain velocity analysis technique as is done in MASW, the analysis described here can separate Rayleigh waves from body waves, air waves, and other coherent noise. Transforming the time-domain velocity results into the frequency domain allows combination of many arrivals over a long time period and yields easy recognition of dispersive surface waves.

What is Seismic Refraction? The seismic refraction method is based on the measurement of the travel time of seismic waves refracted at the interfaces between subsurface layers of different velocity. Seismic energy is provided by a source ('shot') located on the surface. For shallow applications this normally comprises a hammer and plate, weight drop or small explosive charge (blank shotgun cartridge). Energy radiates out from the shot point, either travelling directly through the upper layer (direct arrivals), or travelling down to and then laterally along higher velocity layers (refracted arrivals) before returning to the surface. This energy is detected on surface using a linear array (or spread) of geophones spaced at regular intervals. Beyond a certain distance from the shot point, known as the cross-over distance, the refracted signal is observed as a first-arrival signal at the geophones (arriving before the direct arrival). Observation of the travel-times of the direct and refracted signals provides information on the depth profile of the refractor.

Shots are deployed at and beyond both ends of the geophone spread in order to acquire refracted energy as first arrivals at each geophone position.

Data are recorded on a seismograph and later downloaded to computer for analysis of the first-arrival times to the geophones from each shot position. Travel-time versus distance graphs are then constructed and velocities calculated for the overburden and refractor layers through analysis of the direct arrival and T-minus graph gradients. Depth profiles for each refractor are produced by an analytical procedure based on consideration of shot and receiver geometry and the measured travel-times and calculated velocities. The final output comprises a depth profile of the refractor layers and a velocity model of the subsurface.

The primary applications of seismic refraction are for determining depth to bedrock and bedrock structure. Due to the dependence of seismic velocity on the elasticity and density of the material through which the energy is passing, seismic refraction surveys provide a measure of material strengths and can consequently be used as an aid in assessing rippability and rock quality. The technique has been successfully applied to mapping depth to base of backfilled quarries, depth of landfills, thickness of overburden and the topography of groundwater.

Task 5. Match the words in both columns to form collocations:

1) shallow	a) quarries
2) shot	b) interval
3) refracted	c) boundaries
4) regular	d) accuracy
5) coherent	e) point
6) strata	f) waves
7) backfilled	g) noise

Task 6. Make a summary of the text.

Text 6

GEOTHERMAL METHOD OF EXPLORATION

Part I

Task 1. Read the words. Can you find the Russian equivalents without using any dictionaries?

Geothermal, resource, industry, metal, system, modification, geologist, regional, reservoir, kinetic, factor, strategy, adequate, interpretation.

Task 2. Read the words and word combinations, translate and memorize them. Use dictionaries if necessary.

To draw on, flow rate, heat flow, oil seep, fumarole, solubility, equilibrated, spring, permeable structure, injection well, collocated heat, fractured.

Task 3. Read and translate the text.

Geothermal resource exploration, development, and production draw on the techniques of both the mining and oil/gas industries. The geologic setting of geothermal resources is similar to deposits of metal ores, and geothermal systems are thought to be the modern equivalent of metal ore-forming systems. Hence, exploration draws most heavily on the techniques of the mining industry. Development of the resource and its production as hot fluid uses the techniques of the oil/gas industry with modifications because of the high temperatures and the much higher flow rates needed for economic production.

Exploration begins with selection of an appropriate area based on general knowledge of areas with above average heat flow. The best guides for more detailed investigation are the presence of thermal springs (the equivalent of oil seeps). However, to develop undiscovered resources, geologists must rely on other techniques. Because the target is a region of above average temperature, heat flow studies can indicate elevated subsurface temperatures. Among other methods being used and investigated for regional exploration are remote sensing of elevation changes, age of faulting, and geochemical techniques.

Hydrothermal systems suitable for geothermal development must have adequate temperature and sufficient flow for economic production. Because high flow rates are needed for geothermal production, most geothermal production comes from highly fractured reservoirs.

Geochemical studies. The interpretation of the chemistry of hot springs and fumaroles is an important tool used in geothermal exploration. The solubility of minerals strongly depends on temperature, and the kinetic rate of rock-water reactions is relatively slow. Thus, water equilibrated with rocks in a geothermal system can retain their dissolved mineral content as they move to the surface, and the composition of hot springs can be used to determine the temperature of equilibration. The geochemistry of thermal springs is the most widely used geothermal exploration tool for estimating subsurface temperatures prior to drilling wells.

Geophysical methods in geothermal exploration and field operations. Geophysical methods can help locate permeable structures with high-temperature water or steam and estimate the amount of heat that can be withdrawn from the ground in a given time period. Once a field is developed, geophysical measurements can be used to help site additional production and injection wells, to understand the details of the permeability structure, and to provide constraints on reservoir models used in the management of the geothermal field. The primary exploration targets are:

- Collocated heat
- Fluid
- Permeability

Geophysical interpretation in geothermal fields is complicated by two factors. First there are a great variety of rock types in which different geothermal systems might be found.

Second, the geologic structures at geothermal systems are often quite complex, and structure may not determine the location or economic viability of the geothermal field. Consequently, the exploration strategy for geothermal energy differs from that for petroleum fields and is more similar to mineral exploration.

Task 4. Answer the following questions:

a) What industries are geothermal techniques applied to?
b) How does exploration based on thermal technique begin?
c) What other methods are used along with geothermal studies?
d) What systems are suitable for geothermal development?
e) Why is geochemistry helpful for geothermal studies?
f) How can geophysical methods be used in geothermal exploration?
g) What factors complicate the data interpretation?

Task 5. Make a summary of the text.

Text 7

GEOTHERMAL METHOD OF EXPLORATION

Part II

Task 1. Read the words and word combinations, translate and memorize them. Use dictionaries if necessary.

Extrapolation, dramatically, advection, saturation, to intersect, inference, constraint, temperature gradient, injection capability.

Task 2. Read and translate the text.

Temperature at depth can be sensed directly in boreholes or estimated by extrapolation of heat-flow measurements in both shallow and deep holes. Heat-flow measurements combine observed temperature gradients and thermal conductivity measurements to determine the vertical heat transport in areas where conduction is the primary mechanism of heat transport. If the temperature gradient changes dramatically with depth, these measurements indicate areas where heat transfer is dominated by advection. Heat-flow measurements provide evidence both of regions where geothermal systems are more likely and of the extent of localized convecting systems. Because the fluid flow patterns can be complex, the deeper zones of hot fluids are often not directly beneath the shallow high heat-flow anomalies.

Subsurface temperatures can also be inferred from physical properties of rock masses. The information needed to plan and interpret a geophysical campaign can be provided by laboratory measurements of the density, seismic, electrical and mechanical properties of rocks as a function of:

- Temperature
- Pressure
- Porosity
- Matrix material

- Alteration
- Saturation

Locating zones of sufficient permeability for economic production is difficult. Electrical self-potential (SP) provides the only direct signal from subsurface fluid flow; all other methods require the inference of permeability from zones of extension, intersecting faults, state of stress, seismicity, secondary effects, temperature distribution, zones of mineral alteration.

Surface geophysical methods have provided important information for siting early wells at many geothermal fields. For example, the gravity anomalies caused by dense, thermally-altered sediments in the Imperial Valley, California, guided much early drilling. However, surface and borehole geophysics is much more important later in the development of a field, when wells must be sited to provide adequate production or injection capability, or to provide constraints to tune reservoir models.

Task 3. Which words describe physical properties of rock masses? Find examples in the text.

Task 4. Put the missing words in the following combinations:

dramatically heat systems signal measurements tune at electrical

a) primary mechanism of ……..transport
b) ……….self-potential
c) ………reservoir models
d) laboratory ………..of the density
e) localized convecting………..
f) temperature gradient changes …………
g) direct……..from subsurface fluid flow
h) temperature ……depth

Text 8

GRAVITY METHOD OF GEOPHYSICAL EXPLORATION

Task 1. Read the words. Can you find the Russian equivalents without using any dictionaries?

Geology, gravity, effect, instrument, centimeter, topography, optimistic, metamorphic, contrast.

Task 2. Read the words and word combinations, translate and memorize them. Use dictionaries if necessary.

In terms of, causative, unconsolidated, alluvium, igneous rocks, value, void, spatial, specific gravity, required precision.

Task 3. Read and translate the text.

The gravity field on the surface of the Earth is not uniformly the same everywhere. It varies with the distribution of the mass materials below. This lateral change can be measured and interpreted in terms of likely causative geology. A gravity survey is an indirect (surface) means of calculating the density property of subsurface materials. The higher the gravity values, the denser the rock beneath.

Gravitation is the force of attraction between two bodies, your own and the Earth for example. The strength of this attraction depends on the mass of the two bodies and the distance between them. A mass falls to the ground with increasing velocity. The rate of increase is called gravitational acceleration or g for gravity. The unit of gravity is the Gal (in honor of Galileo). One Gal equals 1 cm/sec2.

Various rock types within a study area often contrast enough in density to cause gravity anomalies. The specific gravity of earth materials varies from 1.2-1.5 for unconsolidated alluvium; 2.5-3.5 for hard igneous or metamorphic rocks; to 3-5 for massive metallic minerals. A void has a density of zero, but if filled with water or mud, the density will be about 1-1.5. The specific gravity of water is 1.0.

Specialized gravity meters are used to measure the effects that comprise the Earth's gravity field. For near-surface investigations, the working surface on which the measurement is made is also important. The elevation of the measurement point must be known, or first determined, to better than 2 centimeters.

Crew size is usually small. However, much effort is spent in measuring the elevations to the required precision. Thus, several persons may be required during much of the field work.

The gravity geophysical survey method involves making several mathematical corrections to the measured data to correct for: the elevation of the measurement point, the spatial location of the instrument with respect to the earth, the density of the surface material, the tides, and the surrounding topography, all of which require expertise and specialized processing of the gravity data.

Overly optimistic impressions about the precision of the reading (some manufacturers sell instruments with a one microgal graduation on its dial) and the size of the expected response from the target, are potential misunderstandings in the use of the gravity method.

Task 4. Make up one sentence to express the main idea of each paragraph.

Task 5. Make a summary of the text.

Text 9

MAGNETIC METHODS OF PROSPECTING

Part I

Task 1. Read the words and word combinations, translate and memorize them. Use dictionaries if necessary.

Bar magnet, customarily, roughly, perturbation, ambient field, susceptibility, ordnance, conterminous, auxiliary information, aligned.

Task 2. Read and translate the text.

Basic Concepts. The Earth possesses a magnetic field caused primarily by sources in the core. The form of the field is roughly the same as would be caused by a dipole or bar magnet located near the Earth's center and aligned sub parallel to the geographic axis. The intensity of the Earth's field is customarily expressed in S.I. units as nanoteslas (nT) or in an older unit, gamma (γ): 1 γ = 1 nT = 10-3 µT. Except for local perturbations, the intensity of the Earth's field varies between about 25 and 80 µT over the conterminous United States.

Many rocks and minerals are weakly magnetic or are magnetized by induction in the Earth's field, and cause spatial perturbations or "anomalies" in the Earth's main field. Man-made objects containing iron or steel are often highly magnetized and locally can cause large anomalies up to several thousands of nT. Magnetic methods are generally used to map the location and size of ferrous objects. Determination of the applicability of the magnetics method should be done by an experienced engineering geophysicist. Modeling and incorporation of auxiliary information may be necessary to produce an adequate work plan.

Theory. The Earth's magnetic field dominates most magnetic measurements made at or near the surface of the Earth. The Earth's total field intensity varies considerably by location over the surface of the Earth. Most materials except for permanent magnets, exhibit an induced magnetic field due to the behavior of the material when the material is in a strong field such as the Earth's. Induced magnetization (sometimes called magnetic polarization) refers to the action of the field on the material wherein the ambient field is enhanced causing the material itself to act as a magnet. The field caused by such a material is directly proportional to the intensity of the ambient field and to the ability of the material to enhance the local field--a property called magnetic susceptibility. The induced magnetization is equal to the product of the volume magnetic susceptibility and the inducing field of the Earth.

From a geologic standpoint, magnetite and its distribution determine the magnetic properties of most rocks. There are other important magnetic minerals in mining prospecting, but the amount and form of magnetite within a rock determines how most rocks respond to an inducing field. Iron, steel, and other ferromagnetic alloys have susceptibilities one to several orders of magnitude larger than magnetite. The exception is stainless steel, which has a small susceptibility.

The presence of ferrous materials in ordinary municipal trash and in most industrial waste does allow the magnetometer to be effective in direct detection of landfills. Other ferrous objects, which may be detected, include pipelines, underground storage tanks, and some ordnance.

Task 3. Complete the sentences with the phrases from the text.

a) The Earth's magnetic field is caused by ___________________.
b) The intensity of the Earth's field is expressed in ____________.
c) Rocks and minerals cause _______________________________.
d) Magnetic methods are used to_____________________________.
e) The induced magnetization is equal to _____________________.
f) Magnetite determines_____________________________________
g) ________________________________has a small susceptibility.
h) ____________does not allow the magnetometer to be effective.

Task 4. Find information on the construction of magnetometer, label the scheme.

Text 10

MAGNETIC METHODS OF PROSPECTING

Part II

Task 1. Read the words and word combinations, translate and memorize them. Use dictionaries if necessary.

Cesium vapor, hydrogen rich fluid, inductor, alignment, relaxation rate, photon emitter, absorption chamber, data acquisition, non-volatile memory

Task 2. Read and translate the text.

Instrumentation. There are many different types of magnetometers in use today for various purposes. For environmental and engineering investigations the current standards are generally proton procession and cesium vapor. The magnetometer type reflects the physical process by which the magnetic field is measured. Proton procession instruments have a sensor filled with a hydrogen rich fluid (similar to kerosene). An inductor creates a strong magnetic field in the fluid resulting in the alignment of protons. When the inducted current is suspended, the relaxation rate as the protons return to ambient magnetic conditions is recorded. This rate is directly proportional to the magnetic field. An overhauser magnetometer presents a variation on the proton procession magnetometer by using radio frequency magnetic fields to generate the polarizing signal. This improves the results of a proton procession magnetometer, as the RF field does not interfer with the precession signal.

A cesium vapor magnetometer is usually made up of a photon emitter, an absorption chamber, a buffer gas, and a photon detector. The known properties of a cesium atom allow for the displacement of electrons by applying photons. Cesium can exist at any of nine energy levels; however, it is only affected by the photons at three of the nine energy levels. Therefore, eventually photons will pass through the cesium vapor unhindered, no longer resulting in transfer of electrons. This is essentially the "zeroed" state or baseline, by which relative subsequent measurements are made. Then, when an external AC magnetic field is applied, the difference in energy levels of the electrons is established by the ambient magnetic field. The new field allows photons to transfer electrons once again, which is measured by the amount of light reaching the photon detector resulting in a high performance magnetometer.

Given the requirements for high data density and high acquisition rate, the cesium vapor approach is generally more favorable due to the faster measurement speed. Proton procession magnetometers are frequently incorporated as base stations in these types of investigations.

Data acquisition. Ground magnetic measurements are usually made with portable instruments at regular intervals along more or less straight and parallel lines that cover the survey area. Often the interval between measurement locations (stations) along the lines is less than the spacing between lines.

The magnetometer is a sensitive instrument that is used to map spatial variations in the Earth's magnetic field. In the proton magnetometer, a magnetic field that is not parallel to the Earth's field is applied to a fluid rich in protons causing them to partly align with this artificial field. When the controlled field is removed, the protons tend to return to its original direction in the earth's magnetic field by processing around the Earth's field at a frequency depending on the intensity of the Earth's field. By measuring this precession frequency, the total intensity of the field can be determined. The physical basis for several other magnetometers, such as the cesium or rubidium-vapor magnetometers, is similarly founded in a fundamental physical constant. The optically pumped magnetometers have increased sensitivity and shorter cycle times (as small as 0.04 s), making them particularly useful in airborne applications.

The incorporation of computers and non-volatile memory in magnetometers has greatly increased their ease of use and data handling capability. The instruments typically will keep track of position, prompt for inputs, and internally store the data for an entire day of work. Downloading the information to a personal computer is straightforward, and plots of the day's work can be prepared each night.

Task 3. Match the words in both columns to form collocations:

1) engineering	a) type
2) physical	b) area
3) personal	c) time
4) precession	d) process
5) field	e) investigations
6) cycle	f) signal
7) magnetometer	g) computer
8) survey	h) intensity

Task 4. Find more information on magnetometer types. Make notes about their distinctive features.

Text 11

MAGNETIC METHODS OF PROSPECTING

Part III

Task 1. Read the words and word combinations, translate and memorize them. Use dictionaries if necessary.

In the vicinity of, zipper, boot grommet, rocky terrain, ordnance detection, averaging, ambiguity, amplitude.

Task 2. Read and translate the text.

Distortion. Steel and other ferrous metals in the vicinity of a magnetometer can distort the data. Large belt buckles, etc., must be removed when operating the unit. A compass should be more than 3 m away from the magnetometer when measuring the field. A final test is to immobilize the magnetometer and take readings while the operator moves around the sensor. If the readings do not change by more than 1 or 2 nT, the operator is "magnetically clean." Zippers, watches, eyeglass frames, boot grommets, room keys, and mechanical pencils can all contain steel or iron. On very precise surveys, the operator effect must be held under 1 nT.

To obtain a representative reading, the sensor should be operated well above the ground. This procedure is done because of the probability of collections of soil magnetite disturbing the reading near the ground. In rocky terrain where the rocks have some percentage of magnetite, sensor heights of up to 4 m have been used to remove near-surface effects. One obvious exception to this is some types of ordnance detection where the objective is to detect near-surface objects. Often a rapid-reading magnetometer is used (cycle time less than 1/4 s) and the magnetometer is used to sweep across an area near the ground. Small ferrous objects can be detected, and spurious collections of soil magnetite can be recognized by their lower amplitude and dispersion. Ordnance detection requires not only training in the recognition of dangerous objects, but also experience in separating small, intense, and interesting anomalies from more dispersed geologic noise.

Data recording methods will vary with the purpose of the survey and the amount of noise present. Methods include taking three readings and averaging the results, taking three readings within a meter of the station and either recording each or recording the average. Some magnetometers can apply either of these methods and even do the averaging internally. An experienced field geophysicist will specify which technique is required for a given survey. In either case, the time of the reading is also recorded unless the magnetometer stores the readings and times internally.

Sheet-metal barns, power lines, and other potentially magnetic objects will occasionally be encountered during a magnetic survey. When taking a magnetic reading in the vicinity of such items, describe the interfering object and note the distance from it to the magnetic station in your field book.

Data Processing and Interpretation. Total magnetic disturbances or anomalies are highly variable in shape and amplitude; they are almost always asymmetrical, sometimes appear complex even from simple sources, and usually portray the combined effects of several sources. An infinite number of possible sources can produce a given anomaly, giving rise to the term ambiguity.

One confusing issue is the fact that most magnetometers used measure the total field of the Earth: no oriented system is recorded for the total field amplitude. The consequence of this fact is that only the component of an anomalous field in the direction of Earth's main field is measured. Anomalous fields that are approximately perpendicular to the Earth's field are undetectable.

Task 3. Choose the right words and combinations to fill in the gaps.

Shape ground mechanical pencils magnetic objects field geophysicist

a) Sheet metal barns, power lines, and other potentially ______________will occasionally be encountered during a magnetic survey.

b) The sensor should be operated well above the ______________.

c) Anomalies are highly variable in __________and amplitude.

d) ____________________can all contain steel or iron.

e) An experienced ______________will specify which technique is required for a given survey

Task 4. Summarize the difficulties which occur while data processing and readings.

Text 12

ELECTRICAL AND ELECTROMAGNETIC METHODS OF EXPLORATION

Task 1. Read the words and word combinations, translate and memorize them. Use dictionaries if necessary.

Intrinsic property, resistivity, laterally, lithologic log, salinity, pore space, telluric currents, mise-à-la-masse.

Task 2. Read and translate the text.

Basic Concept. Electrical geophysical prospecting methods detect the surface effects produced by electric current flow in the ground. Using electrical methods, one may measure potentials, currents, and electromagnetic fields that occur naturally or are introduced artificially in the ground. In addition, the measurements can be made in a variety of ways to determine a variety of results. There is a much greater variety of electrical and electromagnetic techniques available than in the other prospecting methods, where only a single field of force or anomalous property is used.

Electrical Properties of Rocks. All materials, including soil and rock, have an intrinsic property, resistivity, that governs the relation between the current density and the gradient of the electrical potential. Variations in the resistivity of earth materials, either vertically or laterally, produce variations in the relations between the applied current and the potential distribution as measured on the surface, and thereby reveal something about the composition, extent, and physical properties of the subsurface materials. The various electrical geophysical techniques distinguish materials through whatever contrast exists in their electrical properties. Materials that differ geologically, such as described in a lithologic log from a drill hole, may or may not differ electrically and, therefore, may or may not be distinguished by an electrical resistivity survey. Properties that affect the resistivity of a soil or rock include porosity, water content, composition (clay mineral and metal content), salinity of the pore water, and grain size distribution.

In most earth materials, the conduction of electric current takes place virtually entirely in the water occupying the pore spaces or joint openings, since most soil- and rock-forming minerals are essentially non-conductive. Clays and a few other minerals, notably magnetite, specular hematite, carbon, pyrite, and other metallic sulfides, may be found in sufficient concentration to contribute measurably to the conductivity of the soil or rock.

Classification of Electrical Methods. The number of electrical methods used since the first application around 1830 is truly large; they include self-potential (SP), telluric currents and magnetotellurics, resistivity, equipotential and mise-à-la-masse, electromagnetic (EM), and induced polarization (IP). Because of the large number of methods, there are many ways of classifying them for discussion. One common method is by the type of energy source involved, that is, natural or artificial.

Task 3. Summarize the key information given in the text.

Text 13

NUCLEAR METHOD OF PROSPECTING

Task 1. Read the words and word combinations, translate and memorize them. Use dictionaries if necessary.

Raw materials exploration, neutron activation analysis, halogens, antimony, thorium, scintillation detector, scattering, backscattering, capture, calorific values

Task 2. Read and translate the text.

Nuclear analytical techniques have great potential to improve the efficiency of raw materials exploration, extraction, and processing, with savings in energy and materials. They can, therefore, contribute to national economies and development programmes. Advantages are that they are rapid, often specific or multi-element, and simple to use. For some applications, they can be used in places where no other techniques can — for example, in hot, dusty, or aggressive environments or where control measurements must be made through the walls of vessels. Also, because they can sample all or most of a process stream they can give more representative results than analyses based on individual samples.

Most importantly, results can be obtained in near real time, thus enabling the measurements to be used for online process control applications.

Basic geological research. All mineral exploration is based on an overall understanding of geological processes and the geology of the particular area investigated. Nuclear techniques are particularly useful for age determination and to obtain knowledge of the distribution of elements in different rock types.

For analysing elements, neutron activation analysis (NAA) has been widely used in basic geological research. It is one of the most sensitive analytical methods for many elements. Even small, very rare samples, such as lunar samples or separated minerals, can be analysed. Overall, NAA is accurate, can be applied without destroying the sample, can be used for multi-element analysis, and is easy to automate.

Through instrumental NAA, more than 40 different elements can be determined in rock samples. (In lunar samples and small mineral samples, it has been commonly used to analyse 40 elements.) In ordinary rock samples, NAA (compared with non-nuclear technique) is most favourably used for analysis of halogens, antimony, rare earth elements, gold, the platinum group elements, uranium, and thorium.

Geophysical exploration for uranium. The uranium element consists of a mixture of radioactive isotopes that decay, forming a series of daughter nuclides. These are radioactive and can be used to trace uranium mineralizations. One is based on direct measurement of the gamma radioactivity of the daughter nuclides of uranium (in particular bismuth-

214). This can be done by simply measuring the total background radiation level above ground, or by measuring the total activity of a rock surface or separate boulders, with a portable gamma survey meter. The measurements also can be done by using gamma ray measurement systems carried in vehicles or aircraft.

Another method is to measure radon isotopes, which are decay products of uranium. Radon is a very mobile inert gas that moves from the rock through fissures up to the ground. It can be measured through its alpha activity.

Borehole logging. In oil and mineral exploration, drilling is required before it is possible to determine if the ore is worth exploiting. Drilling is always expensive, but especially so when several thousands of holes (1-metre deep) are drilled. Therefore, all possible information from the hole must be gathered.

Core samples could be taken to the laboratory for analysis. However, in most cases it is faster to analyse it on the spot. Several X-ray fluorescence analysers that are energy dispersive (either portable or vehicle-borne) have been developed for this purpose. One very convenient technique is to run a probe through the hole and obtain an analysis of the surrounding rock.

A number of nuclear borehole logging devices are in routine use and some others are in the process of development. The most straightforward technique is to log natural radioactivity (gross or gamma spectrometric). This gives information directly about uranium, thorium, and potassium and, indirectly, about mineral composition. Thus, for instance, information about coal can be obtained. The coal seams have a different concentration of radioactive elements than the surrounding rock.

The other nuclear borehole logging probes are based on the interaction of radiation with the surrounding rock. The probes consist of a radiation source and a detector shielded from the source. The radiation from the source undergoes reactions with the surrounding material. In these reactions the properties of the radiation are changed. The new radiation is measured and conclusions about the composition of the rock can be drawn. The advantage of using nuclear radiation is that it is usually very penetrating. Thus, information can be obtained in water-filled boreholes and a large volume of the rock is simultaneously analysed.

Gamma-gamma probes. These consist of a gamma source and one or several instruments — scintillation detectors — suitable for measurement of gamma radiation. The intensity of the gamma radiation scattered back to the detector from the rock depends on the rock's density.

Therefore, the technique is most commonly used in coal and oil exploration. Coal has a much lower density than the surrounding rock and can easily be seen in gamma-gamma logs. The method detects variations in porosity as well, which makes it useful for detecting rock layers bearing oil, gas, or water. High-density metallic ores also can be detected.

Neutron-neutron tools. A number of borehole logging tools based on the interaction of neutron particles with materials are now being used. When fast neutrons interact with matter, the most important reactions are the scattering and capture of neutrons. In processes known as elastic scattering, the initial high velocity of the fast neutrons is gradually slowed down. This process of slowing down is most effective in an environment containing hydrogen. By measuring the thermal neutron flux during irradiation of the rock with fast neutrons, the hydrogen content can be determined. This method also can be used in logging for oil, gas, or water. It is commonly used in oil and gas exploration and several different varieties of neutron-neutron logging tools are in routine use.

Elemental analysis in boreholes can be performed by X-ray fluorescence and a technique called "capture gamma activation analysis". Neither are yet in wide use, but several very promising applications have been identified. The gamma technique would be especially useful in coal exploration. Almost all components of coal can be determined, which means that both the ash content and calorific value can be accurately assessed. The method can also be used to log specific metals, and good results have been obtained for copper and silver.

Mining applications. In the mining process, nuclear techniques are mainly used for recovery of uranium, coal, and oil. In uranium mining, the radioactivity of the rock is used to separate ore and waste rock and to determine the grade of the ore. In coal mining, it is important to know the thickness of the coal layer in tunnels to avoid mining waste rock. One technique successfully used has been absorption of the natural gamma radiation from the rock, but it is not applicable when the host rock has low radioactivity.

Gamma backscatter techniques have been tried instead, but results have not yet been very successful. In oil recovery, radioactive tracers are used to solve different kinds of problems. One example is the investigation of oil recovery through injection of water. When the pressure in an oil reservoir is too low the oil does not come up by its own force. In such cases, it is common to force out the oil by injecting a variety of fluids into the oil field. The efficiency of this process is then studied by injecting a radioactive tracer into one well. Pressure is applied and the transport of the radiotracer to other nearby wells is analysed.

Task 3. Complete the table according to the information in the text:

Method type	**Distinctive features**	**Areas of application**	**Tools**

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СОДЕРЖАНИЕ

ИНОСТРАННЫЙ ЯЗЫК

**ГЕОФИЗИЧЕСКИЕ МЕТОДЫ
ПОИСКА И РАЗВЕДКИ МЕСТОРОЖДЕНИЙ**

***Методические указания к самостоятельной работе
для студентов специальности 21.05.03***

FOREIGN LANGUAGE

**GEOPHYSICAL METHODS
OF PROSPECTING AND EXPLORATION**

Сост. *Ю.Е. Мурзо*

Печатается с оригинал-макета, подготовленного кафедрой
иностранных языков

Ответственный за выпуск *Ю.Е. Мурзо*

Лицензия ИД № 06517 от 09.01.2002

Подписано к печати 31.01.2020. Формат 60×84/16.
Усл. печ. л. 2,2. Усл.кр.-отт. 2,2. Уч.-изд.л. 2,1. Тираж 75 экз. Заказ 55. С 21.

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